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D of M | A.O. | C.G. | E.O. | D.S.M.E | Registrar | E & IL
Received 8 SEP 1982
Answered
DEPT. OF MINES
REF. No. 7266/82

MAPPING TERTIARY BASALT THICKNESSES BY FORWARD MODELLING OF GROUND MAGNETIC DATA

HOUSEGO GRID - MT. BISCHOFF

A TO P 5/80

NORTH WEST TASMANIA

CRA Exploration Pty. Limited

15 June, 1982

AMG REFERENCE POINTS ADDED

726002

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NORTH WEST TASMANIA

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1. SUMMARY

Ground magnetic data from the Housego Grid, Mt.Bischoff, Authority to Prospect 5/80, was treated mathematically to allow forward modelling of basalt thicknesses to be undertaken. Magnetic susceptibilities, as measured from drill core, and remanent magnetization data were used as constraints on the bulk susceptibilities assigned to these models. The observed magnetic field was found to be adequately explained by postulated basalt configuration. Recommendations for confirmatory drilling have been made. No sub-basaltic magnetic targets were delineated.

2. INTRODUCTION

The Housego Grid is located less than ½ kilometre ~500m northeast of Waratah, North-West, Tasmania. At the request of Metals Exploration Ltd., a study of basalt configuration and magnetic susceptibilities over the grid was undertaken. This study was to fulfill a recommendation put forward in Metals Exploration Ltd. Report 542 (Jannink, 1981.)

" that susceptibility readings be taken on the core of drill holes MBD 59 to MBD 62 (also FL1 to FL9 if possible). These readings should be related to the ground magnetic survey (and airborne) and a Geophysicist should be engaged to establish whether it is possible to screen out the effects of basalt cover and thus establish magnetic profiles/contours of sub-basaltic rocks."

The problem was approached in two ways - first by measurement of drill core magnetic susceptibility as recommended, and secondly by mathematical manipulation and simulation of the ground magnetic data.

The two were, in the final analysis, amalgamated to allow meaningful conclusions to be drawn.

3. CONCLUSIONS

Drill hole information indicates that basalt thicknesses and magnetic susceptibilities vary significantly and unpredictably over short distances.

If susceptibilities and thicknesses are confined to realistic ranges a model can be constructed to imitate the observed magnetic field. This model is used to show that the field could be explained by basalt alone. Confidence in the model is high on the western half of the grid where drill hole information is dense, but low on the eastern half where no drill hole information exists.

If the model is accepted then there remains no potential for a sub-basaltic, magnetic target to exist - i.e. if the effects of the modelled basalt were removed from the magnetic map no significant magnetic anomalies would remain.

4. RECOMMENDATIONS

Although the magnetic modelling shows that all magnetic responses can be caused by basalt, the solution is not unique and therefore requires confirmation.

It is therefore recommended that:

1. a percussion hole be drilled on line 10840mE at 10000mN to ascertain the source of the magnetic high located here. A relatively thin basalt thickness (0 to 20 metres) is expected,

2. a percussion hole on line 10440mE at 10000mN be drilled to confirm the existence of the graben structure, and

3. field checking of the interpreted fault striking north-north westerly through lines 10240mE to 10400mE and continuing off the grid in that direction into an area not covered by basalt.

This information will allow an appraisal of the methods used here to be made for application to other basalt-covered exploration areas.

In addition, it is recommended that should further sub-basaltic exploration be contemplated then:

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1. the area be covered by an intensive ground magnetic survey. Ideally this should consist of very closely spaced lines (25 metres) with 5 metre station spacing,

2. the survey grid extend well beyond the limits of the basalt unless the flow is sheet-like and extends far beyond the exploration area,

3. the lines are to be of a suitable length to allow regional components to be identified,

4. magnetic data to be upward continued using a three-dimensional algorithm,

5. measurements of the magnetic susceptibility and remanent magnetisation of the basalt should be made on fresh specimens collected from various areas of the grid.

6. forward modelling to be carried out using average bulk susceptibilities obtained by 5 above,

7. updating of the model as drilling information becomes available.

5. GEOLOGY

The majority (around 90%) of the grid is overlain by vesicular Tertiary Basalts. All information on sub-basaltic geology is gained from diamond drilling carried out by the Tasmanian Department of Mine and Metals Exploration Ltd.

A full geological interpretation is included in Jannink, 1981.

Sub-basaltic rocks consist of steeply dipping Precambrian carbonaceous shales, siltstones and quartzites and gently dipping Cambrian sandstones, siltstones, conglomerates (?breccias) and dolomites.

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The contact between Cambrian and Precambrian rocks is usually a fault contact. Prospective zones appear to be dolomitic lithologies associated with this contact.

Mineralisation consists of tin, lead, zinc and minor copper in the form of cassiterite, jamesonite, sphalerite and chalcopyrite respectively. Fluorite and pyrite are common. Sub-basaltic leads do occur and, where exposed, are found to carry tin.

6. INFORMATION AVAILABLE - PREVIOUS GEOPHYSICS

Mt.Bischoff, immediately north of Waratah, was flown for aeromagnetics by Geoex Pty.Ltd. in 1979. The Housego grid area was included in this survey. A ground magnetic survey was carried out over the grid utilising ten metre station intervals on lines spaced 40 metres apart.

Selected lines were surveyed with the time domain Pulse E.M. system and the frequency domain Max-Min II E.M. system.

Diamond drilling, consisting of nine Department of Mines holes (FL-1 to FL-9) and four Metals Exploration holes (MBD 59 to MBD 62) has been completed.

Magnetic susceptibility and remnance studies have been carried out by the C.S.I.R.O. on various lithologies and styles of mineralisation around Mt.Bischoff. Basalt samples from the grid were included.

All of the above data was made available for the study.

7. DISCUSSION

7.1 Magnetic Susceptibility Measurements

Core from select drill holes on the grid was measured for magnetic susceptibility. This was needed to obtain a realistic range of susceptibility values of both basalt and country rocks so as to allow meaningful forward modelling.

Core samples were of two diameters: HQ (61mm) for the basalt sections and NQ (45mm) for the country rock sections. For expediency two different susceptibility instruments were used - a Scintrex SM-5 meter for the HQ core and a Bison 3101 meter for the NQ core.

7.1.1. Comparison of Susceptibility Meters.

A comparison was carried out between the two susceptibility meters to determine the validity of using results from the two meters in the same analysis. The comparison did not include a calibration as no standard was available.

Two specimens were used in the test: a length of serpentinite core (10cm x 2.5 cm dia.) and a length of basalt core (15cm x 6.1cm dia.). Appropriate corrections were applied to both measurements to compensate for the non "infinite slab" configuration of the samples. The basalt sample was crushed to enable measurement by the Bison meter whose receptacle can only accept core of 5.1cm maximum diameter. Volume corrections were applied to this reading.

The results obtained were:

	SM-5	BISON 3101
Serpentinite	0.043 S.I.	0.0495 S.I.
Basalt	0.004 S.I.	0.0035 S.I.
Reading Accuracy	0.001 S.I.	0.0001 S.I.

It is considered that the error between the two instruments is well within the accuracy of the SM-5 and the correction factors applied. The meters were therefore deemed equivalent for the purposes of this study.

7.1.2. Core Magnetic Susceptibilities

Basalt core was measured at a frequency of approximately five samples per metre.

Non-basaltic core was measured at a frequency of approximately two samples per five metres. The values were averaged to produce a 'bulk' value per metre of core in the basalt and per five metres of core in the underlying country rocks. The rationale behind this measuring pattern was the assumption that the basalt was relatively highly magnetic, highly variable, and close to surface. Country rock, on the other hand, was expected to be largely non-magnetic, more monotonous and deep. Thus small fluctuations in basalt susceptibility would have the potential to produce appreciable magnetic responses, whilst large volume changes in susceptibility would be needed in the country rocks to produce similar responses.

Measured magnetic susceptibilities are presented as Appendix I.

7.1.3. Remanence

The susceptibility meters used could not measure the remanent magnetisation of the samples. An investigation into the remanent magnetisation and susceptibility anisotropy of a number of lithologies, including basalt, and various styles of mineralisation from the Mt.Bischoff area was undertaken by the Division of Mineral Physics, C.S.I.R.O. (1979). A portion of the report from that work is included as Appendix II.

The major conclusions are:-

i) barren country rock is non-magnetic and contains little or no remanent magnetisation componant.

ii) massive sulphides are strongly magnetic with remanence dominating induction, but of normal, or near normal polarity.

iii) the Tertiary basalts are strongly magnetic with remanence dominating induction by a factor of about 11 to 1. Polarity is reversed.

The practical ramifications of the last observation is that the effective susceptibility of the basalt will be highly modified due to remanent magnetisation. Hood (1963) shows that for reversed polarity remanence, as in this case, the effective susceptibility, K', will be $K' = -K(Q-1)$ where K is the measured susceptibility and Q is the measured Koenigsberger Ratio (remanent to induced magnetisation). The average value of this ratio was 10.9 in the basalts, therefore actual susceptibilities will be effectively increased by a factor of 9.9. The high effective susceptibility of the basalts would make it unlikely that massive pyrrhotite mineralisation could be detected beneath a moderate, but variable, thickness of basalt. (see Appendix II, Table II). Indeed, the susceptibility measurements on hole FL-1 indicate that whilst a significant intersection in the hole has values greater than that of basalt, the depth of intersection (195 to 210 metres) and the remanent componant of the basalt's magnetisation preclude it from being identified on the magnetic contour map.
(see plans TASh 762 and TASh 772).

7.2 Mathematical Analysis and Simulation

The meaningful simulation of a magnetic field requires that the field being imatated is non-complex, and the model used is geologically plausible and realistic.

The first requirement can only be met by artificial manipulation of the field - e.g. filtering, smoothing or arbitrary removal of anomalies and regional components. The second requirement is met by using a starting model derived from a sound geological concept or factual data - e.g. outcrop, drill holes or supportive "circumstantial" evidence (other geophysical data).

7.2.1. Filtering

As expected from basaltic terrains, the magnetic field mapped by the ground magnetic survey is dominated by high amplitude, high frequency responses. These reflect the variability of basalt susceptibility, configuration and weathering characteristics. This results in a contour map which is misleading - showing only the small scale, near surface variations in the basalt instead of the gross variations from which more useful information can be derived. Plan TASh 760 is a summary of the original magnetic contour map. The contour interval, 500nT, is dictated by the noisy nature of the data. Whilst large, deep seated features are present, the map is nonetheless dominated by noise spikes.

In an endeavour to simplify this map and allow forward modelling the data was upward continued using the method of Tsay (1978). This essentially results in the data being passed through a low-pass filter. Line 10920mE was upward continued to a number of levels to monitor this frequency filtering (Plan TASh 766). From this, continuation of the data to 25 metres above the plane of observation (ground level) was chosen. This level is sufficient to filter out all anomalies having a half wavelength of ten metres (the station spacing) yet at the same time allow maximum definition. The resultant map, Plan TASh 762, is seen to be devoid of much of the noise inherent in the original data. A contour interval of 100nT was used, although this could easily have been smaller. The data is now much more ameniable to modelling.

7.2.2. Forward Modelling

A relatively high density of drill hole data exists in the western portion of the grid (lines 9840mE to 10440mE). This data was used to produce a basalt isopach map. Sectioning of this map along the ground magnetic profile lines provided a starting model for a Talwani - type 2-D forward modelling programme. The aim of this modelling was not so much to obtain perfect data fits but to obtain a general profile form, indicating whether or not the observed magnetic field could be explained by basalt distribution alone. (Plan TASh 775 is an example of a modelled line).

Once the area with drill data control had been modelled extension of the model to the east was carried out. In a number of cases, however, no reasonable model could be found to simulate the magnetic profile. Lines which could not be modelled were left out of the final presentation. (See section 7.3 Sources of Errors). A check was carried out to determine the suitability of the along-line models to describe the baseline magnetics. Results indicate the modelling to be quite reasonable (Plan TASh 767). When modelling was completed two contour maps were produced - a simulated magnetic intensity map (Plan TASh 761) and a modelled basalt isopach map (Plan TASh 763).

7.3 Sources of Error

A number of significant assumptions and generalisations have been made in producing the upward continued data and the forward model contour maps. Perhaps the most serious of these is the treatment of the data with two-dimensional algorithms.

7.3.1. Upward Continuation

The upward continuation operator is designed for profile applications and, strictly speaking should not be applied to three dimensional data.

The effect of doing so is to suppress minor trends which run approximately perpendicular to the profile direction and enhance trends running parallel to the profile direction. "Line anomalies" due to levelling difficulties would be enhanced in this way.

The continuation operator requires, in theory, that profiles be infinitely long. Whilst this can never be realized in practice, the longer a profile is the more accurate the continuation will be, particularly at the profile centre. A number of lines on the grid are short (200 metres) and so should be viewed with caution.

A comparison between line-by-line upward continuation and baseline upward continuation is shown on Plan TASh 768. This illustrates the error introduced by using a 2-D, rather than a 3-D, operator.

7.3.2. Forward Modelling

Forward modelling was also carried out with a two dimensional algorithm. The modelling programme used assumes that the cross-section being modelled has a strike length of infinity at right angles to the profile. It is obvious from the magnetic contour map that this is not strictly the case (e.g. line 10040mE and 10560mE). However, if the structure being modelled does not change too drastically from line to line, the lines are close spaced, and only a general profile fit is being sought then the approach is adequate. A number of lines, however, could not be satisfactorily modelled at all due to the complex, strictly three-dimensional nature of the ground. These lines had to be omitted from the final presentation. (Lines 10480mE, 10520mE, 10560mE and 10760mE). In addition, due to the limited length of the profiles, the regional component was difficult to identify making the base level chosen subjective.

7.3.3. Susceptibilities

In carrying out forward modelling the magnetic susceptibility contrast of the model was allowed to vary with the constraints that it had to be negative and constant for any one modelled section. The range of modelled values for the grid was 0.005 S.I. to 0.025 S.I. with a mean of 0.009 S.I. (See Table 1). This is in excellent agreement with the findings of the C.S.I.R.O. which found a range of 0.005 S.I. to 0.012 S.I. with a mean of 0.008 S.I. and in good agreement with actual measured range of 0.001 S.I. to 0.036 S.I. (mean of 0.004 S.I.). This, of course, assumes that host rock susceptibilities are low enough to be neglected.

The assigning of a bulk susceptibility to the section and only allowing a change between sections is a gross over-simplification but one which was necessary to reduce the complexity of the model.

As the magnetic susceptibility-thickness product cannot be uniquely resolved in modelling further uncertainties are introduced by allowing either to vary unchecked. It may be noticed that susceptibilities used in the modelling proceedure are higher in the west than in the east. Modelled basalt "thickness relief" is higher in the east than the west, indicating that perhaps higher susceptibilities should have been used in the east. Without drill hole control, however, there is little reason to attempt remodelling on the eastern side of the grid using higher susceptibilities.

7.4 General Interpretation

Examination of drill core from the grid illustrated that:

1. magnetic susceptibilities of the basalts varies erratically - depending on state of weathering. composition, volume of contained vesicles, and grain size,

2. basalt thickness varies as erratically as susceptibility. Gross thickness changes of very short distances are common, (e.g. holes FL-3 and FL-4 collared at the same location, yet exhibiting a 9.4 metre true thickness difference),

3. individual basalt flows may be recognised in any one hole but could not be confidently correlated from hole to hole, and

4. country rock susceptibilities were, in general, very low compared to basalt values.

It would seem that basalt configuration and susceptibility cannot be reasonably predicted without drill hole control. Forward modelling of the magnetic field by theoretical, locally homogeneous masses can, however, provide a reasonable model; keeping in mind the shortfalls of the proceedures used (Section 7.3 "Sources of Errors"). As can be expected, modelling shows that the magnetic field over the majority of the grid can be effectively explained by a (theoretical) basalt configuration alone. If this model is accepted then no potential exists for a magnetic, sub-basaltic economic target. It should, however, be pointed out that the solution is by no way unique. (See, for example Plan TASh 769). The model for the western half of the grid is well controlled by drill hole information and is therefore expected to be reasonable. The eastern half of the grid, on the other hand, has little or no control so the model must be viewed with open caution.

The modelled basalt isopach map reveals a number of significant basement features. Perhaps the most important of these is the graben-like structure striking in a north-north-westerly direction between lines 10280mE and 10760mE. Due to the fact that a number of lines could not be modelled in this area, the feature is better defined by the magnetic map where the thicker basalt section results in a well defined magnetic low.

The edges of this low are very abrupt suggesting faulting, rather than river-valley type erosion, to be the cause. The magnetic high running parallel to this low on lines 10160mE to 10400mE is interpreted as being caused by the western fault on the graben rather than basalt configuration or a sub-basaltic magnetic source. (See Plan TASh 769). The continuation of this fault to the north is witnessed by a magnetic high in country rocks on the aeromagnetic map (Plan TASh 770).

The basement high defined by hole FL-7 is reflected by a magnetic high - not because country rock is magnetic but because these basalts have reverse polarity remanent magnetisation. A negative magnetic zone, in general, reflects a thick basalt section whereas a positive magnetic zone reflects a thin or no basalt section. The major positive magnetic anomaly on the southern ends of lines 10800mE to 11000mE is thus expected to be a basement high with a major thick basalt section occurring immediately to the northeast.

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TABLE 1

Bulk Magnetic Susceptibilities Used in Line-By-Line Forward Modelling.

LINE mE	EFFECTIVE SUSCEPTIBILITY (inc.Remanence) S.I. Units	ACTUAL SUSCEPTIBILITY (Exc.Remanence) S.I.
9840	-0.25	0.0253
9920	-0.08	0.0081
9960	-0.08	0.0081
10000	-0.05	0.0051
10040	-0.2	0.0202
10080	-0.1	0.0101
10120	-0.125	0.0126
10160	-0.15	0.0152
10200	-0.15	0.0152
10240	-0.1	0.0101
10280	-0.075	0.0076
10320	-0.1	0.0101
10360	-0.075	0.0076
10400	-0.09	0.0091
10440	-0.065	0.0066
10600	-0.08	0.0081
10640	-0.1	0.0101
10680	-0.07	0.0071
10720	-0.065	0.0066
10800	-0.06	0.0061
10840	-0.06	0.0061
10880	-0.05	0.0051
10920	-0.05	0.0051
10960	-0.06	0.0061
11000	-0.06	0.0061
11040	-0.06	0.0061

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8. REFERENCES

Hood, P.	1963	"Remanent Magnetisation - a Neglected Factor in Aeromagnetic Interpretation". Canadian Mining Journal, 1963.
Jannink, A.	1981	"Mt.Bischoff Tin Prospect, Authority to prospect 5/80 Tasmania. Report on Stage 3A Programme". Metals Exploration Ltd. Unpublished Report No.542.
Tsay, L.J.	1978	"A Spatial Analysis of Upward Continuation of Potential Field Data". Geoph. Prosp. Vol.26,No.4 Pp 882-840

9. KEYWORDS

Geophysics - data process, interpret. theory, Tertiary Basalt, ground magnetics.

10. LOCATION

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11. LIST OF PLANS

PLAN NUMBER	TITLE	SCALE
TASh 760	Housego Grid Total Magnetic Intensity Map	1:2000
761	Housego Grid Simulated Magnetic Intensity	1:2000
762	Housego Grid Total Magnetic Intensity Map Upward Continued to 25 metres.	1:2000

TASh 763	Housego Grid Modelled Basalt Isopach Map	1:2000
766	Housego Grid Line 10920mE Continued to 10, 30 and 50 metres	As shown
767	Housego Grid Line 10000mN - Basalt Model derived from cross lines models	As shown
768	Housego Grid Comparison of Baseline Upward Continuation.	As shown
769	Housego Grid Alternate Models for line 10320mE	As shown
770	Portion of Mt.Bischoff Aeromagnetic Survey	1:6000
771	Housego Grid, Mt.Bischoff Locality Plan	1:500 000
772	Magnetic Susceptibilities DD FL-1 Mt.Bischoff	As shown
773	Magnetic Susceptibilities DD FL-5 Mt.Bischoff	As shown
774	Magnetic Susceptibilities DD FL-6 Mt.Bischoff	As shown
775	Housego Grid Line 10080mE Basalt Model	As shown

12. LIST OF APPENDICES

Appendix I — Magnetic Susceptibilities of Core Samples from Diamond Drill Holes on the Housego Grid.

Appendix II — Excerpt from C.S.I.R.O. Report on Magnetic Properties of Rocks and Ore from Mt.Bischoff D.A.Clark - 1979.

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APPENDIX I

MAGNETIC SUSCEPTIBILITIES OF CORE SAMPLES FROM DIAMOND DRILL HOLES ON THE HOUSEGO GRID

HOUSEGO GRID
DIAMOND DRILL HOLE FL1

Magnetic Susceptibilities Measured With 5M-5 (Basalt) and Bison 3101 (Country Rock) Instruments.

DEPTH (METRES)	SUSCEPTIBILITY (S.I.UNITS x 1000)	
1	2.5	(W)*
2	3.3	(W)
3	2.6	(W)
4	2.3	(W)
5	2.6	(W)
6	3.8	
7	2.5	
8	3.5	
9	4.6	
10	5.2	
11	5.0	
12	3.8	
13	5.1	
14	6.7	
15	3.3	
16	3.0	
17	2.4	(W)
18	2.5	(W)
19	3.4	
20	3.8	
21	3.8	
22	3.5	
23	3.0	
Limit of Basalt		
25	0.86	(W) (C)*
30	0.82	
35	0.84	
40	0.47	
45	0.45	

50	0.32
55	0.36
60	0.39
65	0.35
70	0.38
75	0.41
80	0.45
85	0.30
90	0.42
95	0.47
100	0.49
105	0.33
110	0.35
115	0.37
120	0.77
125	0.48
130	0.38
135	0.44
140	0.52
145	0.48
150	0.42
155	0.32
160	1.39
165	1.01
170	0.89
175	0.89
180	1.35
185	1.17
190	0.52
195	3.88
200	7.24
205	9.41
210	1.66
215	1.42
220	1.23
225	0.82
230	0.47
235	0.44

240	0.49
245	0.43

* (W) = badly weathered
  (C) = contaminated?

HOUSEGO GRID

DIAMOND DRILL HOLE FL5

Magnetic Susceptibilities measured with SM-5 (Basalt) and Bison 3101 (Country Rock) Instruments

DEPTH (METRES)		SUSCEPTIBILITY (S.I.UNITS x 1000)	
1		0.9	(W)
2		1.2	(W)
3		4.3	
4		5.9	
5		5.4	
6		4.8	
7		4.4	
8		4.2	
9		4.3	
10		4.5	
11		4.0	
12		4.2	
13		1.3	(W)
14		0.3	(W)
15		4.1	
16		4.0	
17		4.4	
18		4.3	
19		1.4	(W)
20		0.9	(W)
21	Line of Basalt	2.8	(W)

25	0.5
30	0.12
35	0.1
40	0.15
45	0.23
50	0.2
55	0.12
60	0.27
65	0.22
70	0.06
75	0.06
80	0.06
85	0.01
90	0.22
95	0.05
100	0.17
105	0.17
110	0.17
115	0.23
120	0.24
125	0.2
130	0.22
135	0.32
140	0.28
145	0.22
150	0.24
155	0.22
160	0.25
165	0.52
170	0.29

*W = badly weathered

HOUSEGO GRID

DIAMOND DRILL HOLE FL6

Magnetic Susceptibilities Measured with SM-5 (Basalt) and Bison 3101 (Country Rock) Instruments.

DEPTH (METRES)	SUSCEPTIBILITY (S.I.UNITS x 1000)	
1	5.8	(W)*
2	5.2	(W)
3	12.3	
4	4.4	
5	2.8	(W)
6	8.9	
7	8.4	
8	16.3	
9	35.8	
10	3.4	
11	3.5	
12	5.3	
13	5.1	
14	4.9	
15	4.2	(V)*
16	4.3	
17	4.9	
18	1.4	(V)
19	0.9	(V)
20	2.8	(V)
21	3.2	(V)
22	1.4	(V)
23	2.9	
24	1.4	(W)
25	0.8	(W)
26	0.3	(V) (W)
27	3.8	

28		1.3	(V)
29		0.9	(V)
30		0.5	(V) (W)
31	Limit of Basalt	0.6	(V) (W)
35		0.81	(W) (C)*
40		0.56	
45		0.38	
50		0.41	
55		0.39	
60		0.33	
65		0.33	
70		0.36	
75		0.36	
80		0.38	
85		0.33	
90		0.26	
95		0.25	
100		0.28	
105		0.28	
110		0.31	
115		0.27	
120		0.26	
125		0.26	
130		0.34	
135		0.28	
140		0.29	
145		0.28	
150		0.36	
155		0.65	
160		0.5	
165		0.6	
170		1.34	
175		0.72	
180		0.95	
185		0.36	
190		0.35	
195		0.4	
200		0.34	

205	0.28
210	1.09
215	0.79
220	0.37
225	0.27
230	0.29

* (W) = badly weathered
  (V) = very vesicular
  (C) = contaminated?

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APPENDIX II

EXCERPT FROM C.S.I.R.O.

REPORT ON MAGNETIC PROPERTIES

OF ROCKS AND ORE FROM

MT.BISCHOFF

D.A.CLARK 1979

DISCUSSION OF RESULTS

Samples considered to be representative of the various lithologies exposed at Mt Bischoff were collected by CSIRO at 10 sites in March 1979. In addition 4 crudely oriented block samples of Tertiary basalt from south of Mt Bischoff were sent later by Mike Porter and are designated MB11A-D (site 11).

Remanence and susceptibility anisotropy were measured on a Digico spinner magnetometer system and bulk susceptibility values were determined on a low frequency (211 Hz) transformer bridge.

The site localities are listed in Table I and the magnetic parameters in Table II and III.

It is clear that of the lithologies sampled only the massive sulphides and the Tertiary basalt are strongly magnetic. All other rock types are non-magnetic (quartzite, quartz-feldspar porphyry) or weakly magnetic (pyrrhotite bearing dolomite). Possible sources of magnetic anomalies appear therefore to be restricted to massive pyrrhotite rocks and basalt. Of these the massive pyrrhotites are more intensely magnetised and overall are probably of normal polarity whereas the basalt is reversely magnetised. This gives rise to the expectation that sulphide mineralization at shallow depth should be detectable underneath the basalt flows in the region.

MASSIVE PYRRHOTITE (SITES 1, 3 and 4)

Koenigsberger ratios greater than unity indicate that remanence dominates induction in the massive sulphides and therefore remanence must be taken into account for interpretation.

To gain an understanding of the remanence components present, alternating field (AF) demagnetisation experiments were carried out on all specimens. These tests gave useful information on the stability of remanence and coercivity spectra.

Thermomagnetic analysis determined the major magnetic mineral present as the ferrimagnetic phase Fe_7S_8 with a Curie temperature of approximately 310°C. A small amount of magnetite was also detected, but this may have been produced by oxidation of the pyrrhotite during the heating process.

Site 1 - The dolomite/massive sulphide contact in the Gossan Face was sampled, MB1A-B being dolomite and MB1C-E being massive pyrrhotite. The susceptibility and remanent intensity increase with the pyrrhotite content of the rock, but the remanence directions (whilst fairly scattered) are consistent for all specimens and are directed roughly west horizontally. Only the dolomite samples

could be oriented with a sun-compass. The average local declination found from these two orientations was 30°W, indicating a 40° declination anomaly at this site, and this value was used to correct magnetic compass orientations of the other samples some two or three metres away. The overall consistency of directions obtained implies that the orientations are not greatly in error.

The magnetisation is fairly soft, most being cleaned out by AF demagnetisation in less than 50 Oersteds, but the directions in general are quite stable to AF cleaning up to several hundred Oersteds. The directions are quite different to the present field, and are therefore ancient, but also differ markedly from the directions at the sites away from the margin of the massive mineralization. This indicates different times of acquisition of magnetisation for the margins and the bulk of the massive pyrrhotite. The large scatter of directions precludes definite conclusions being drawn, but the mean direction obtained from site 1 appears to be more consistent with known Cambrian poles than Devonian pole positions, particularly after correction is made for an interpreted bedding tilt of 30°. There is therefore some support in the data for the hypothesis that the pyrrhotite is primary and the mineralization is a stratabound Cambrian chemical deposit, although the evidence is not strong.

The cleaned remanence directions from the other massive pyrrhotite sites are consistent with a Devonian magnetisation, or remagnetisation, associated with intrusion of the porphyry dykes, although there is probably a substantial present field component at site 4.

Site 3 Sun compass orientations improved the reliability of the results as reflected in the well-grouped directions obtained. Site 3 was well within the massive mineralization and the rocks were quite magnetic with remanence dominant ($Q \gtrsim 3$). The NRMs are somewhat harder than at the other sites with over half the original intensity remaining after AF cleaning to 50 Oersteds, and the directions are fairly stable up to several hundred Oersteds. The magnetisation is ancient but is within 30° of present field which suggests that induction could be assumed as a first approximation in modelling without gross errors.

Site 4 - The rock face at this site was in shadow, precluding sun-compass orientations. This leads to the possibility of a systematic declination error giving erroneous directions. The tight grouping of directions from this site indicates that local declinations are consistent for the different samples.

After AF cleaning, however, the measured directions from site 4 are close to those from site 3, suggesting the magnetic compass orientations are not greatly in error. The problem then arises of the significance of the softer NRM component directed south with shallow negative inclination. This component has an unusual direction which is not consistent with any past dipole field, but is very soft - being mostly demagnetised in less than 10 Oersteds peak alternating field. The low coercive force should be associated with magnetic instability and a tendency both to relax viscously towards the Earth's field direction if undisturbed (acquisition of VRM) and to be readily remagnetised by stray fields of short duration and field strength greater than the coercive force (acquisition of IRM). The divergence of the soft component direction from the present field shows it is not a VRM, and is therefore probably an IRM (isothermal remanent magnetisation). Exposure to laboratory fields of several Oersteds could produce an IRM of coercive force similar to the field strength, but cannot account for the fact that the anomalous component (assumed to be IRM) is not completely cleaned out in 50 Oersted peak AF implying the rocks have been exposed to a field of this order. The most likely cause of the IRM is a nearby lightning strike, although not a direct hit because the relatively low magnetising field and the uniform direction of the IRM component over several metres indicate peripheral influence only. The site is near the top of a small ridge and the rocks are quite conductive, so the lightning strike hypothesis is not unreasonable.

The saturation remanence of a specimen from site 3 is greater than that of a specimen from site 4 indicating a higher pyrrhotite content at site 3. The greater susceptibility at site 4 must then be attributed to larger grain size which is consistent with low coercive force, and would normally be associated with lower Koenigsberger ratio unless the magnetisation was acquired in a higher field at site 4. This evidence supports the IRM interpretation of results from site 4.

The variation of magnetic properties between samples from sites 3 and 4 may be indicative of general heterogeneity of the mineralized zone or may reflect alteration due to the proximity of the porphyry. Further work is needed to establish whether the heterogeneity is compositional or simply due to variation in grain size.

The final cleaned directions from site 4 are close to those from site 3, suggesting the isolated direction may be representative of the remanence of the massive pyrrhotite rocks. Again the cleaned direction from site 4 is close to present field and induction can be assumed in the first instance. The very soft grains are expected to acquire a VRM along the present field direction when undisturbed by surface effects, and should therefore raise the effective susceptibility.

Overall the expected magnetisation vector in the bulk of the rock lies within 20° or 30° of the present field direction and should produce positive anomalies. On the basis of the admittedly limited sampling the average magnetization intensity should be of the order of 30,000 micro-Oersteds (3,000 gammas).

TERTIARY BASALT (SITE 11) - The samples submitted by C.R.A. were somewhat weathered and were thought likely to produce suspect results. However all specimens drilled out from the blocks were found to have downward pointing remanence vectors with declinations determined from the rough orientations supplied mostly being consistent with reversed polarity. Scatter was small within samples despite variation of degree of weathering.

Thus the results indicate reversely polarised NRM with a Koenigsberger ratio of around 11, implying that the basalts should produce negative anomalies.

The high Koenigsberger ratio, which is associated with high stability, is due to the dominance of single domain particles due either to rapid chilling or else weathering of initially larger grains leaving only a small unoxidised core. These single domain grains have very high coercive force and the remanence is extremely stable to AF cleaning, losing only half the NRM intensity in a peak field of 1,000 Oersteds.

Thermal demagnetisation confirms the observation based on AF cleaning that there is only one stable component present up to the maximum blocking temperature of 450°C.

Thermomagnetic analysis indicates the presence of a single magnetic mineral with Curie temperature approximately 570°C corresponding to nearly pure magnetite containing less than 2% ulvospinel in solid solution.

Variations of physical properties from specimen to specimen appear to reflect the degree of weathering, with the freshest specimens being most magnetic. It is believed that the unweathered basalt is fairly homogeneous and bears an average nett magnetisation of around 8,000 micro-Oersteds (800 gammas) with reverse polarity. Because the rocks are relatively young and significant overprinting is unlikely, the expected direction of magnetisation can be derived from the known palaeopole position at the time of formation.

Assuming an age of 20-25 million years B.P., the pole position (75°S, 99°E) gives direction (197°, + 67°) which is within 5° of the present field if reversed.

MAGNETIC FABRIC AND SUSCEPTIBILITY ANISOTROPY - Apart from the massive pyrrhotites, all the other rock types are essentially magnetically isotropic.

When measured on the Digico spinner anisotropy magnetometer the massive pyrrhotite specimens exhibit a distinct foliation with near-equal maximum and intermediate susceptibility axes forming a foliation plane with a significantly smaller minimum susceptibility axis normal to the plane.

The minimum susceptibility axis directions from different specimens within a site are clustered about a mean direction which is taken as the magnetic foliation pole. At site 1 bedding planes could be observed which correspond with the magnetic foliation plane within the estimated error (see Table III).

On this basis the magnetic foliation planes at sites 3 and 4 were interpreted as corresponding to the palaeohorizontal. Overall the massive pyrrhotite formation in this area (near the Slaughteryard Face) appears to be dipping roughly 45° to the south-east. This interpretation assumes the fabric to be primary and not tectonic.

Pyrrhotite exhibits very high magnetocrystalline anisotropy, being easy to magnetise in the basal plane and very difficult to magnetise along the C-axis. This anisotropy swamps grain shape effects and therefore implies that anisotropy in most pyrrhotite bearing rocks is due to alignment of crystal axes rather than preferred orientation of non-equidimensional grains. The marked anisotropy of the Mt Bischoff massive pyrrhotite may however be a textural feature caused by concentration of randomly oriented pyrrhotite crystals into thin bands with consequent lowered apparent susceptibility normal to the banding (foliation planes).

Due to the high operating frequency of the Digico instrument (10 kHz) and the high conductivity of the massive pyrrhotite specimens, the magnitudes of the susceptibility ellipsoid axes were grossly in error. As an illustration, the Digico bulk susceptibility unit gave negative apparent susceptibilities for pyrrhotite specimens. The effect of conductivity on the anisotropy unit is to exaggerate the oblateness of the susceptibility ellipsoid. However the directions of the axes should not be affected if the conductive and magnetic minerals occur in parallel foliation planes (in this case, pyrrhotite is responsible both for the conductivity and susceptibility). This is because the minimum susceptibility axis is normal to the foliation plane, as is the back field set up by induced eddy currents in the foliation plane. The hypothesis was put to the test by measuring the apparent susceptibility anisotropy of a copper disc in the spinner. The result was effectively zero susceptibility in the plane of the disc and a large negative apparent susceptibility normal to

the disc, corresponding to the minimum apparent susceptibility axis.

Confirmation of the susceptibility axis directions obtained from the Digico instrument was obtained by measuring susceptibility of several specimens in different orientations with the accurate, low frequency transformer bridge. From these measurements the anisotropy magnitude could be estimated and was found to be considerably less than the values obtained from the Digico.

The values obtained for susceptibility anisotropy (defined as major axis/ minor axis) ranged from 1.3 to 2.3, whereas the values obtained from the Digico went from 1.4 to 5.9. Anisotropy of 2.0 corresponds to a maximum deflection of induced magnetisation of 19.5^{o}. Given the dominance of remanent magnetisation ($Q \gtrsim 3$), the effects of anisotropy on modelling should be negligible.

CONCLUSIONS:

(i) The likely sources of magnetic anomalies in the Mt Bischoff area are restricted to two lithologies: massive pyrrhotite with normal magnetisation, and basalt with reversed magnetisation. The intense magnetisation borne by the mineralised rock gives rise to the expectation that a band of moderate thickness could be followed in the aeromagnetics beneath a shallow basalt layer.

(ii) Remanence is clearly dominant in producing anomalies and must be considered in interpretation. Palaeomagnetic cleaning techniques have allowed the isolation of a remanence direction considered to be representative of the magnetisation component carried by the bulk of the massive pyrrhotite.

(iii) Evidence is presented that massive pyrrhotite rocks at Mt Bischoff carry an ancient magnetisation that has been stable over geological time. Thus it is not safe to assume magnetisation by inducation in massive sulphide ore bodies, although in the case of Mt Bischoff the remanence direction is close enough to present field for magnetic interpretation purposes.

(iv) It is highly desirable that drill core samples of massive pyrrhotite and basalt (if available) are submitted to C.S.I.R.O. in order to test the conclusions based on surface sampling regarding magnetic parameters thought to be representative of the rock types. Since it is unlikely there will be any oriented drill core, it is preferable to obtain samples from two or more drill holes of different known attitude with the top of the samples marked.

TABLE I

	Locality	Grid Co-Ordinates	Rock Type
Site 1	Gossan Face	1980 N, 960 E	Dolomite/Massive sulphide contact
Site 2	Track to Slaughter-yard Face	2050 N, 860 E	Quartzite
Site 3	Slaughteryard Face	2110 N, 1040 E	Massive pyrrhotite
Site 4	Slaughteryard Face adjacent to porphyry	2120 N, 1070 E	Massive pyrrhotite partly enclosed by porphyry
Site 5	Western dyke, Slaughter-yard Face	2060 N, 1100 E	Quartz-feldspar porphyry
Site 6	Western dyke, Slaughter-yard Face	2060 N, 1115 E	Quartz-feldspar prophyry
Site 7	Stanhope dyke	2040 N, 1300 E	Quartz-feldspar porphyry
Site 8	Adjacent to Desert Face and Brown Face	2120 N, 1260 E	Quartzite
Site 9	Between Pig Flat and Happy Valley	1840 N, 1160 E	Dolomite
Site 10	Allen's workings	1775 N, 1015 E	Dolomite
Site 11	South of Mt Bischoff	-	Tertiary basalt

TABLE 11

Samples	Rock type	No. of specimens	Average susceptibility (emu x 10^{-6})	Susceptibility range (emu x 10^{-6})	Average NRM intensity (Oe x 10^{-6})	NRM intensity range (Oe x 10^{-6})	Average Koenigsberger ratio (H = 0.63 Oe)	Koenigsberger ratio range
MB1A-B	Mineralized dolomite	3	490	290-890	5,010	390-14,070	10.1	2.1-25.
MB1C-D	Massive pyrrhotite	4	5,900	2,990-8,040	5,390	4,420-6,450	1.7	1.2-2.9
MB2A-B	Quartzite	2	5.5	3-8	2	1-3	0.8	0.2-1.4
MB3A-D	Massive pyrrhotite	8	8,730	6,640-9,930	17,480	14,140-20,950	3.2	2.9-35.
MB4A-D	Massive pyrrhotite	8	23,070	12,950-30,120	41,160	16,670-64,220	2.8	1.9-3.6
MB5A-B	Quartz-feldspar porphyry	4	2	0-3	2	1-3	-	-
MB6A-B	Quartz-feldspar porphyry	3	0	0	2	2-3	-	-
MB7A-F	Quartz-feldspar porphyry	12	0	0	10	1-32	-	-
MB8A-E	Quartzite	9	2	0-4	1	0-2	-	-
MB9A-B	Dolomite	3	194	193-195	3	2-6	0	0
MB10A-E	Dolomite	6	9	7-11	2	0-6	0.3	0-1.3
MB11A-D	Basalt	12	600	380-990	3,740	2,890-7,030	10.9	5.3-18

726037

Notes:

(i) Susceptibility and remanent intensity values have been corrected for demagnetisation assuming emu demagnetising factors $N_x = N_y = N_z = 4\pi/3$ for the pseudo-spherical specimens.

(ii) Koenigsberger ratio = Remanent magnetisation/Induced magnetisation = NRM/(Susceptibility x Earth's field)

TABLE III

Locality	Site 1	Site 3	Site 4
Sun-compass orientation	MB1A-B Yes MB1C-D No	Yes	No
Mean NRM Direction α_{95}	(265^o, -12^o) 44^o	(36^o, -41^o) 7^o	(176^o, -23^o) 11^o
Mean AF Cleaned Direction α_{95}	(249^o, -13^o) 55^o	(31^o, -49^o) 11^o	(18^o, -61^o) 14^o
Bedding Pole	(290^o, $+45^o$)	-	-
Magnetic Foliation Pole α_{95}	(301^o, $+31^o$) 35^o	(339^o, $+67^o$) 15^o	(285^o, $+60^o$) 38^o
Mean NRM Direction Corrected to Palaeohorizontal	(265^o, $+13^o$)	(19^o, $+7^o$)	(207^o, -27^o)
Mean AF Cleaned Direction corrected to Palaeohorizontal	(250^o, $+7^o$)	(10^o, $+4^o$)	(318^o, -27^o)

Notes:

(i) Directions are expressed (declination, inclination) with inclination defined positive downwards.

(ii) α_{95} is the half-angle of the 95% cone of confidence i.e. the true mean direction has 95% probability of lying closer than α_{95} to the sample mean direction.

(iii) The bedding and magnetic foliation poles are defined as the downward directed normals to the bedding and magnetic foliation planes respectively. For the purpose of correcting remanence directions for post-acquisition tilting or folding, the magnetic foliation plane is interpreted as corresponding to the palaeohorizontal.

(iv) Present Earth's field direction is (13°, -72°). Dipole field direction is (0°, -60.4°).

Scale 1 : 2000

Metres 100 80 60 40 20 0 100 200 Metres

MEL GN

MN

9600 E 9720 E 9840 E 9920 E 9960 E 10000 E 10040 E 10080 E 10120 E 10160 E 10200 E 10240 E 10280 E 10320 E 10360 E 10400 E 10440 E 10480 E 10520 E 10560 E 10640 E 10720 E 10760 E 10840 E 10880 E 10920 E 10980 E 11000 E 11040 E

10800 N 10700 N 10600 N 10500 N 10400 N 10300 N 10200 N 10100 N 10000 N 9900 N 9800 N

62000 62500 63000 64000

726040

Contour Interval : 500 nT
Station Spacing : 10 m
Magnetometer : G-816
All values in nanoTeslas

5 cm

CRA EXPLORATION PTY. LIMITED

82-1815

HOUSEGO GRID
Mt. Bischoff J.V. N.W.Tasmania

TOTAL MAGNETIC INTENSITY

Ref: SKSS - 3	
Scale: 1 : 2000	Report N°:
Author: M F. F.	Date: 20 - 5 - 1982
Drawn: R. T	Plan N°: TASh 760

CRA EXPLORATION Pty. LIMITED

HOUSEGO GRID

Mt. Bischoff I.V. N.W.Tasmania

SIMULATED TOTAL MAG. INTENSITY.

Ref. SK55 - 3	
Scale 1 : 2000	Report Nº.
Author: M. F. F	Date: 20 - 5 - 1982
Drawn: R. T	Plan Nº. TASM 761

S2-1615

72C041

CONTOUR INTERVAL : 100 nT

5 cm

Effective modelled magnetic susceptibility contrast in S.I. units

-0.25 -0.1 -0.2 -0.55 -0.08 -0.09 -0.25 -0.1 -0.075 -0.15 -0.125 -0.1 -0.075 -0.09 -0.07 -0.09 -0.05 -0.05 -0.09 -0.09 -0.09 -0.09

Not modelled Not modelled Not modelled

9800 N 9900 N 10000 N 10100 N 10200 N 10300 N 10400 N 10500 N 10600 N 10700 N 10800 N

9200 E 9360 E 9520 E 9680 E 9840 E 10000 E 10160 E 10320 E 10480 E 10640 E 10800 E 10960 E 11120 E 11280 E 11440 E 11600 E

MN

MEL GN

Scale 1 : 2000

Metres 100 80 60 40 20 0 100 200 Metres

Field simulated by two dimentional Talwan forward models of basalt thickness
Effects of the observed reversed remanent magnetization in basalt hand specimens have been included in computation.
Induced magnetization field values used are. Magnetic field strength 62 500 nT
Magnetic field inclination -72°
Magnetic field declination 12°

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HOUSEGO GRID

Mt. Bischoff J.V. N.W.Tasmania

TOTAL MAGNETIC INTENSITY

UPWARD CONTINUED TO 25m

82-181S

726012

Ref. SX55 - 3	
Scale 1 : 2000	Report N°.
Author: M. F. F.	Date 20 - 5 - 1982
Drawn R. T	Plan N°. TASM 762

5 cm

N 9800 N
N 9900 N
N 10000 N
N 10100 N
N 10200 N
N 10300 N
N 10400 N
N 10500 N
N 10600 N
N 10700 N
N 10800 N

E 9600 E
E 9720 E
E 9760 E
E 9840 E
E 9880 E
E 9920 E
E 9960 E
E 10000 E
E 10040 E
E 10080 E
E 10120 E
E 10160 E
E 10200 E
E 10240 E
E 10280 E
E 10320 E
E 10360 E
E 10400 E
E 10440 E
E 10480 E
E 10520 E
E 10560 E
E 10600 E
E 10640 E
E 10680 E
E 10720 E
E 10760 E
E 10800 E
E 10840 E
E 10880 E
E 10920 E

MN

MEL GN

Scale 1 : 2000

Metres 100 80 60 40 20 0 100 200 Metres

** NOTE **

Upward continuation operator used was that of Tsay
The operator is Two dimensional only, and used an
integration envelope of 40 data points.

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HOUSEGO GRID

Mt. Bischoff J.V. N.W.Tasmania

MODELLED BASALT ISOPACH MAP

Ref.- SX55 - 3

Scale 1 2000

Author. M. F. F.

Date. 20 - 5 - 1982

Drawn. R. T.

Report N°

Plan N° TA5N 763

5 cm

72C043

S2-18J5

*** ' NOTE ' ***

Basalt isopachs derived from Talwani - type two dimensional forward modelling of upward continued ground magnetic data

FLO 18-S Vertical basalt thicknesses derived from diamond drill holes Basalt thickness and hole number indicated

Scale 1 : 2000

Metres 100 80 60 40 20 0 100 200 Metres

MAN

MEL ON

MBD59 27

MBD60 25

MBD61 26

MBD62 83

FL6 29

FL8 22

FL9 10

FL5 19

FL7 0

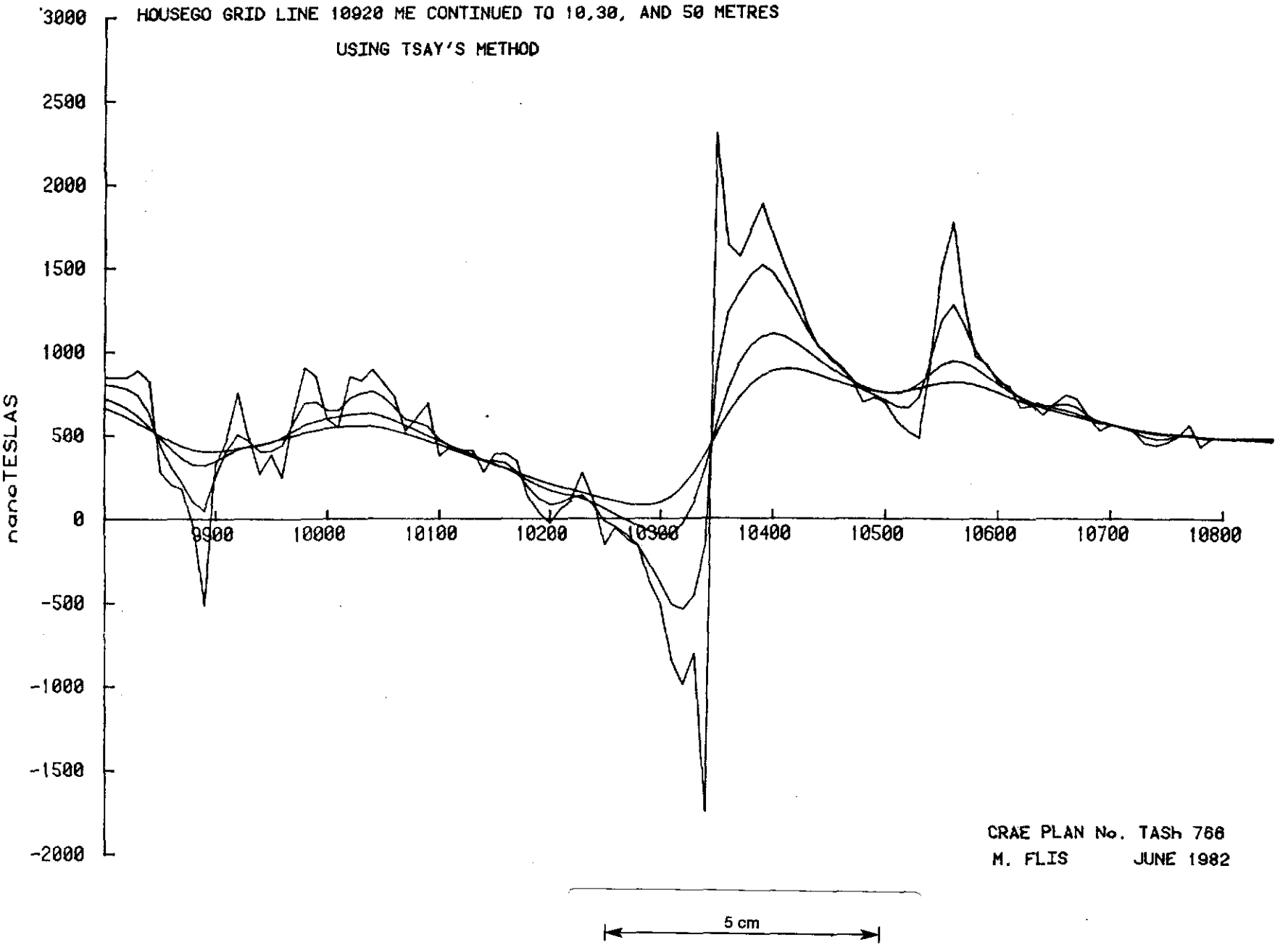
FL4 14

FL3 23

FL2 18 S

FL1 18

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170


HOUSEGO GRID LINE 10920 ME CONTINUED TO 10,30, AND 50 METRES
USING TSAY'S METHOD
nanoTESLAS
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
9900
10000
10100
10200
10300
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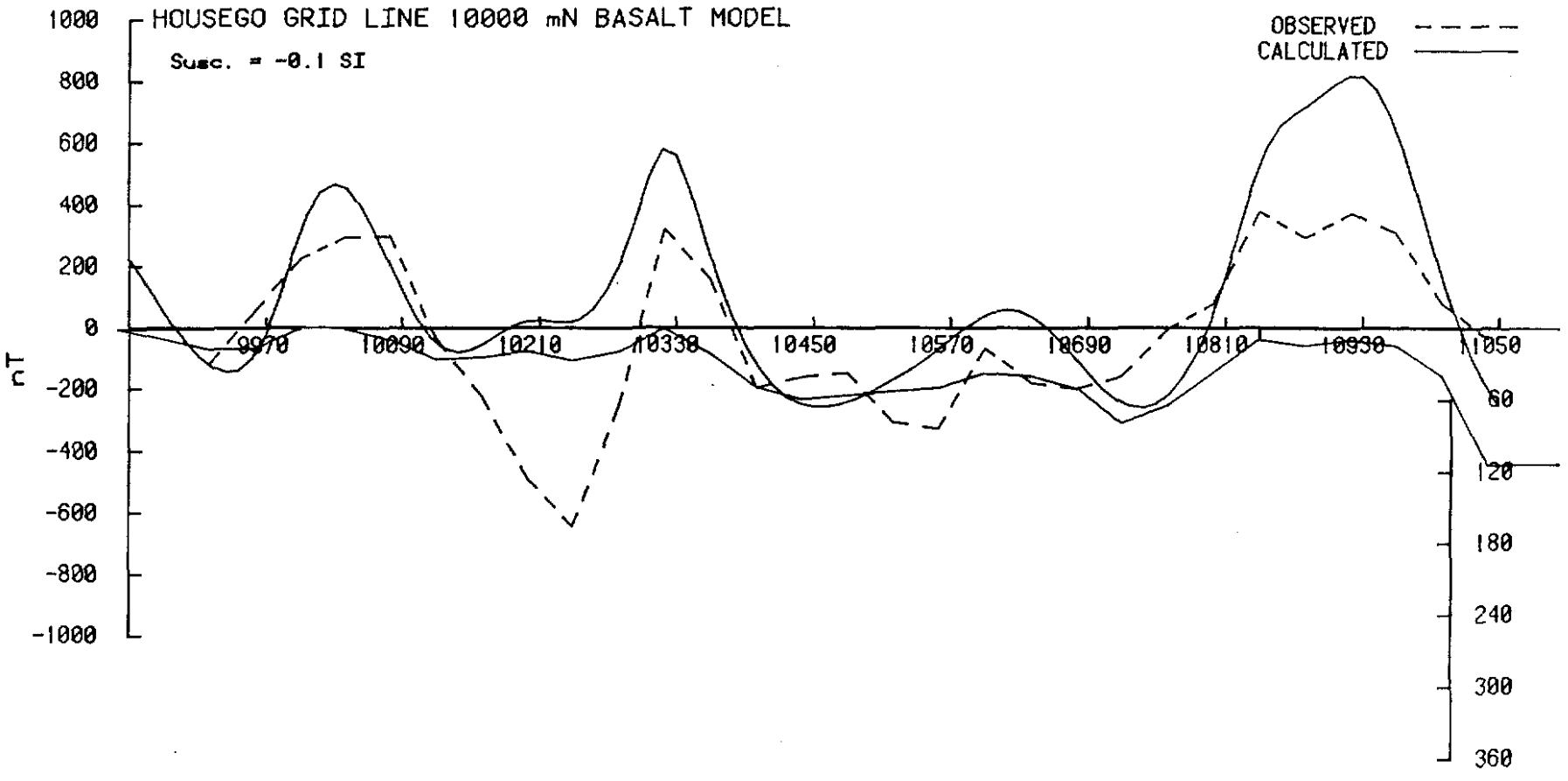
10600
10700
10800
CRAE PLAN No. TASh 768
M. FLIS JUNE 1982
5 cm

72004



NOTE 'OBSERVED' UPWARD CONTINUED TO 25 METRES
MODEL DERIVED FROM FORWARD MODELLING OF CROSS LINES

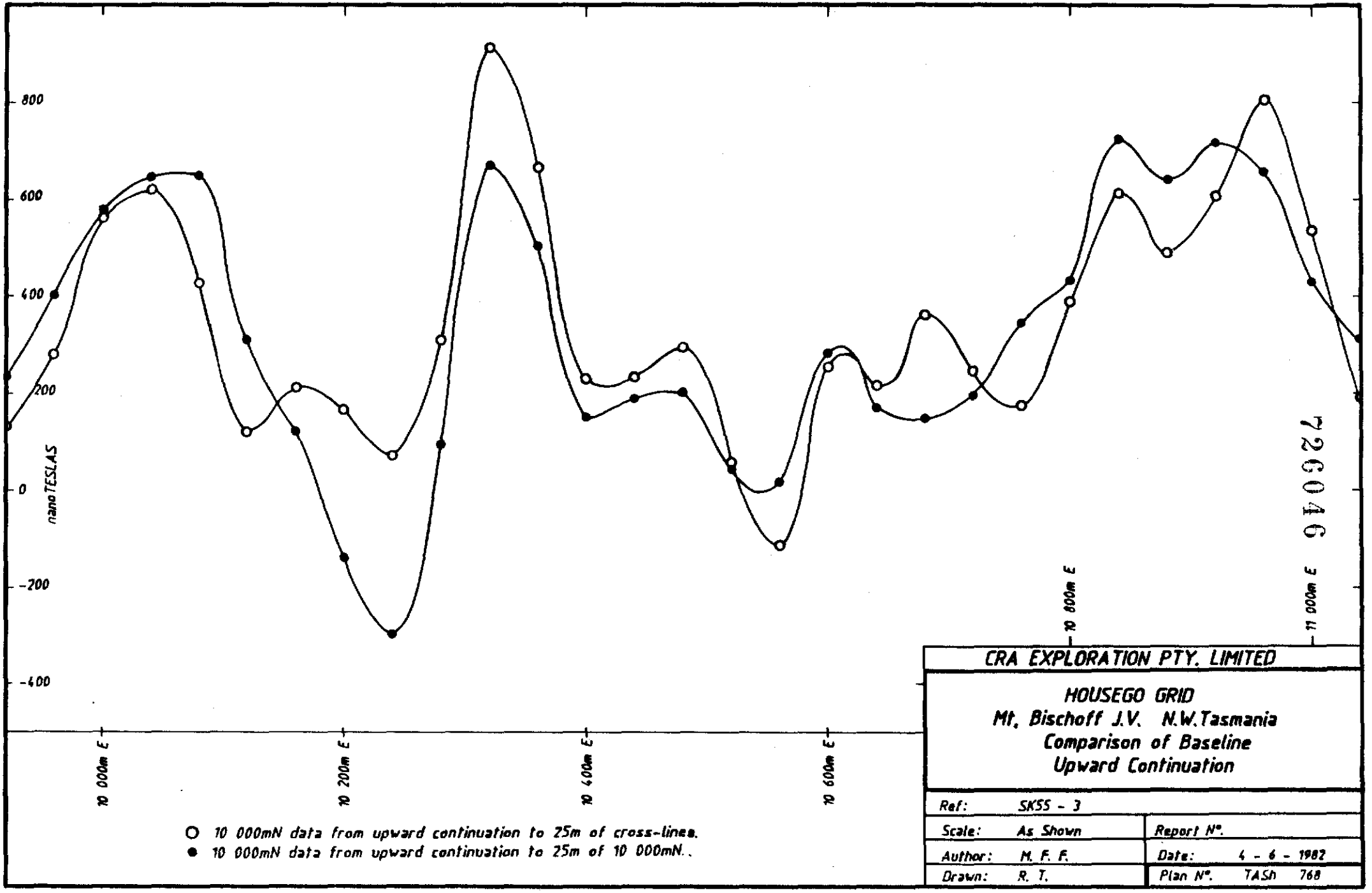
CRAE PLAN No. TASh 767

M. FLIS JUNE 1982

5 cm

726015

5 cm



726046

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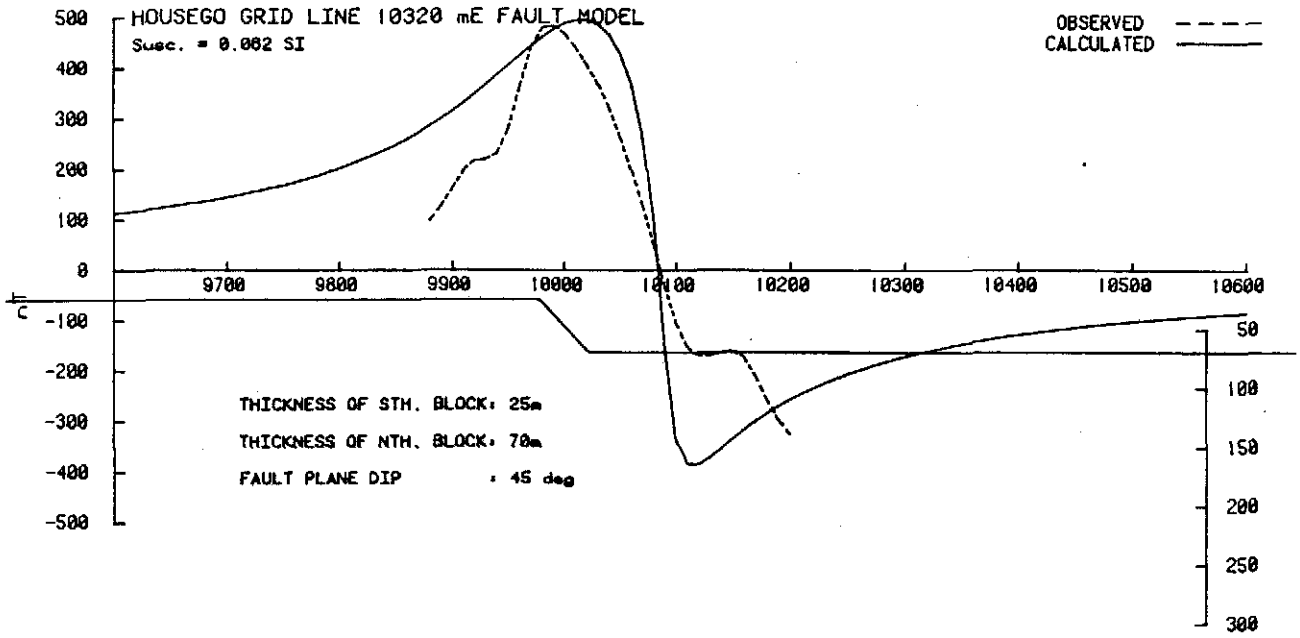
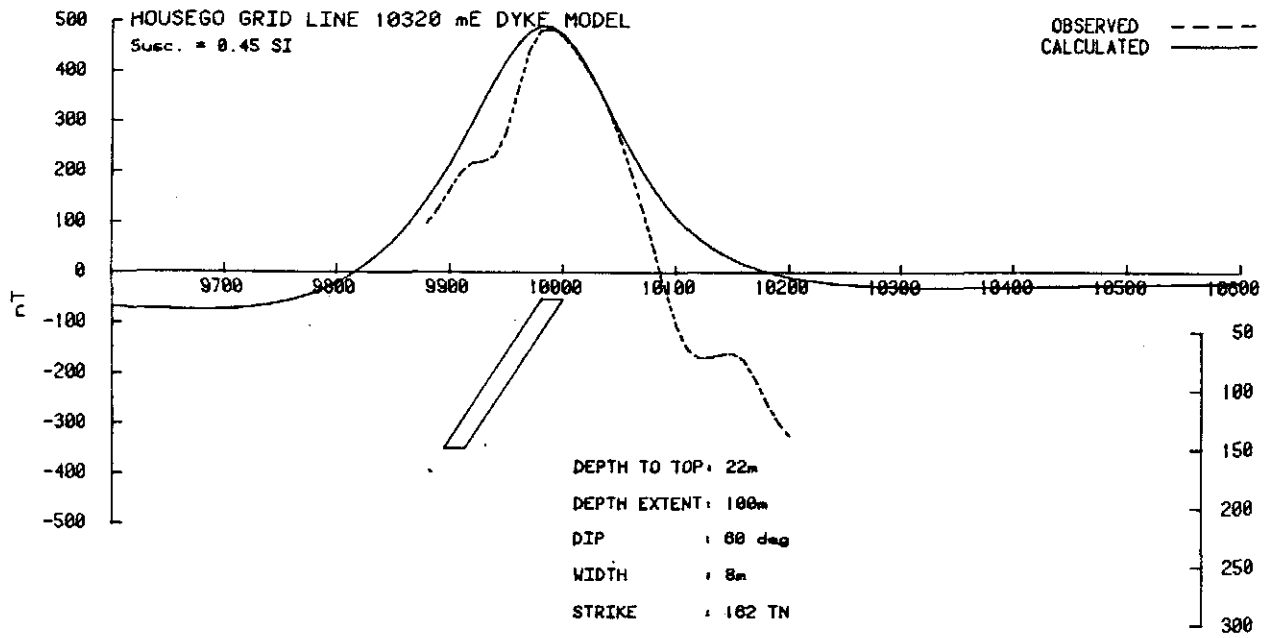
HOUSEGO GRID
Mt. Bischoff J.V. N.W.Tasmania
Comparison of Baseline
Upward Continuation

Ref:	SKSS - 3		
Scale:	As Shown	Report N°.	
Author:	M. F. F.	Date:	4 - 6 - 1982
Drawn:	R. T.	Plan N°.	TASh 768





NOTE 'OBSERVED' UPWARD CONTINUED BY 25 METRES

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M. FLIS JUNE 1982

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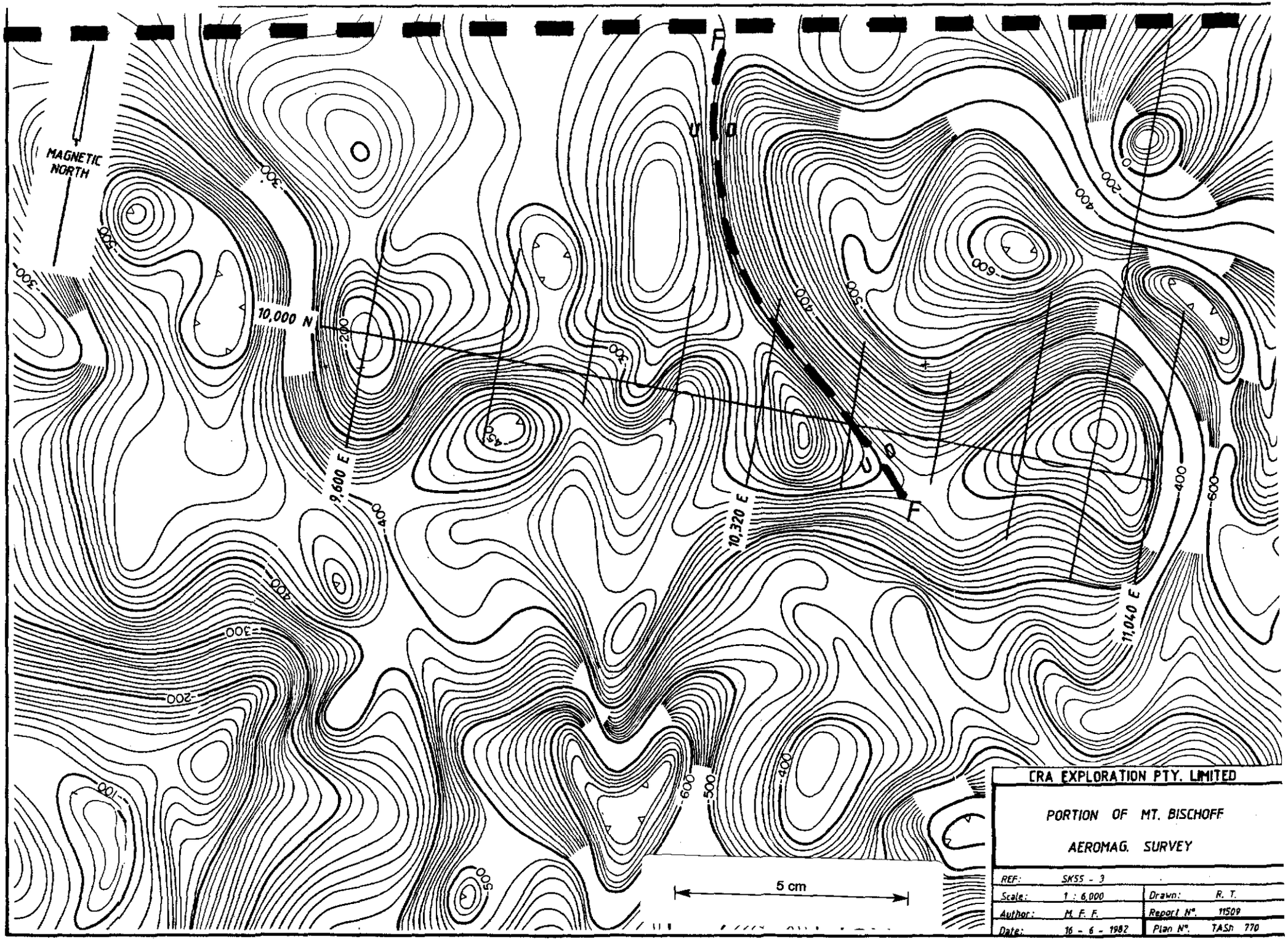


CRA EXPLORATION PTY. LIMITED

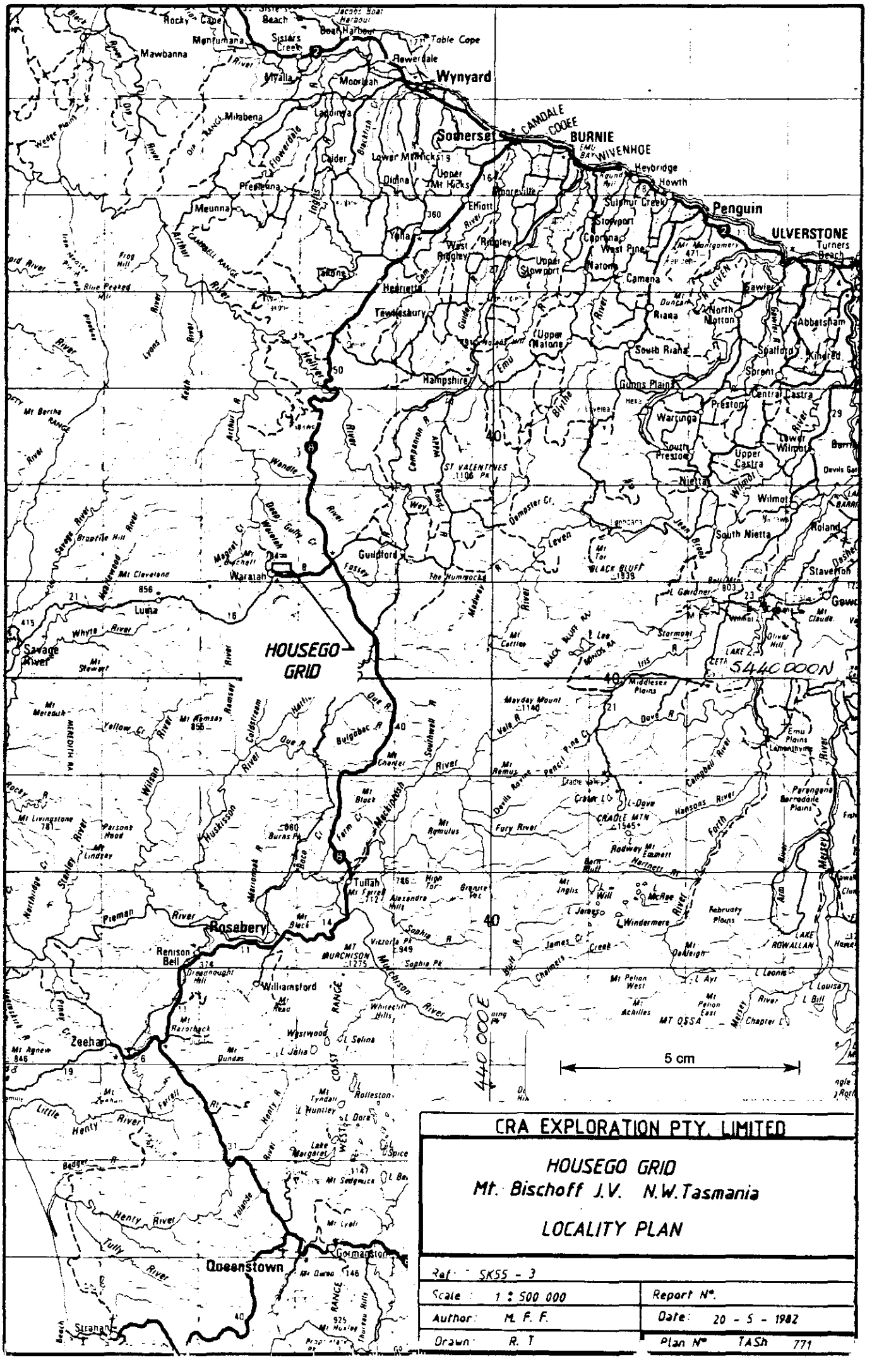
PORTION OF MT. BISCHOFF

AEROMAG. SURVEY

REF:	SK55 - 3		
Scale:	1 : 6,000	Drawn:	R. T.
Author:	M. F. F.	Report N°.	11509
Date:	16 - 6 - 1982	Plan N°.	TASh 770

726048

726049



AMG REFERENCE POINTS ADDED

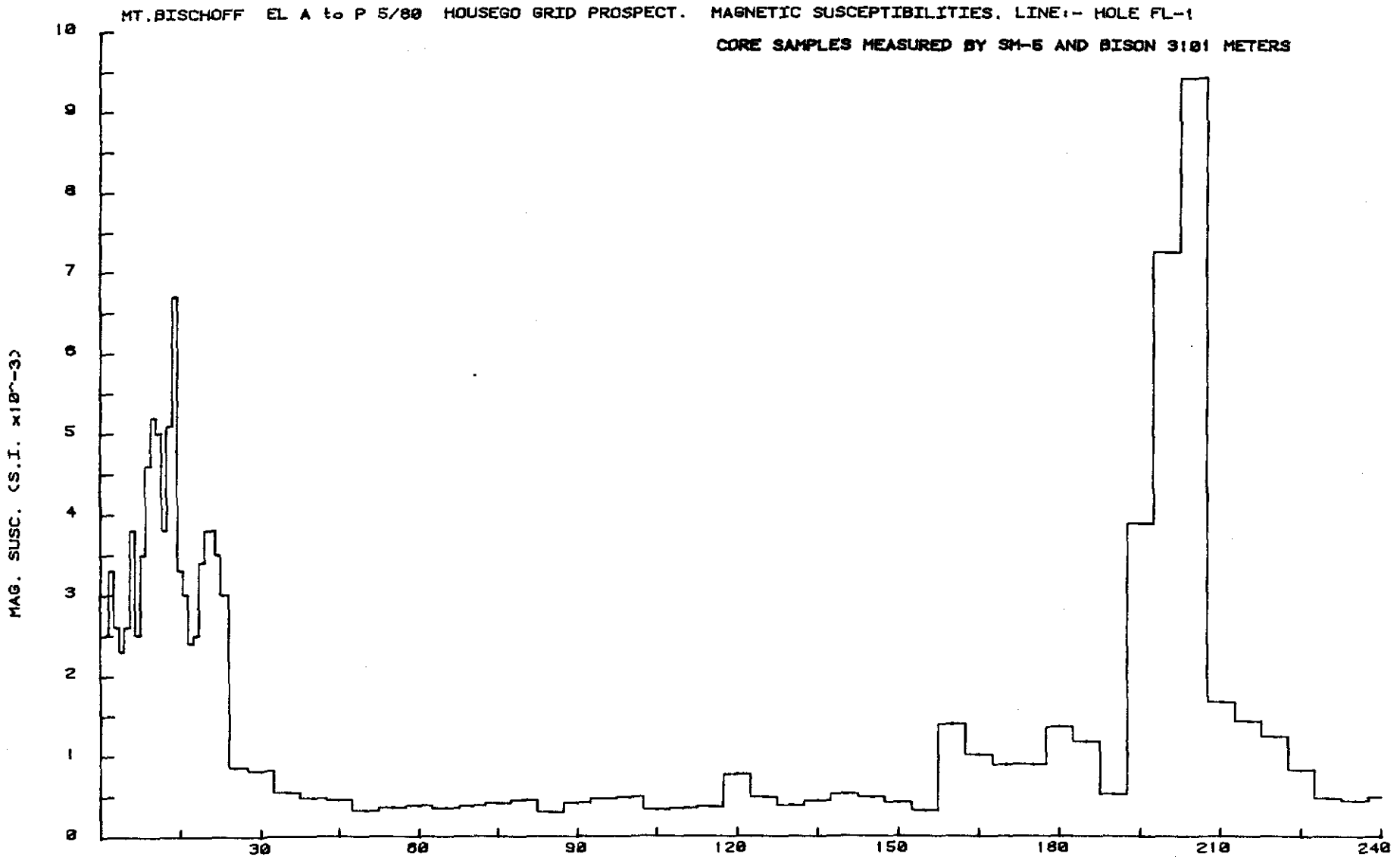
CRA EXPLORATION PTY. LIMITED

HOUSEGO GRID
Mt. Bischoff J.V. N.W. Tasmania

LOCALITY PLAN

Ref: SK55 - 3	
Scale: 1 : 500 000	Report N°.
Author: M. F. F.	Date: 20 - 5 - 1982
Drawn: R. T	Plan N° TASh 771

5 cm

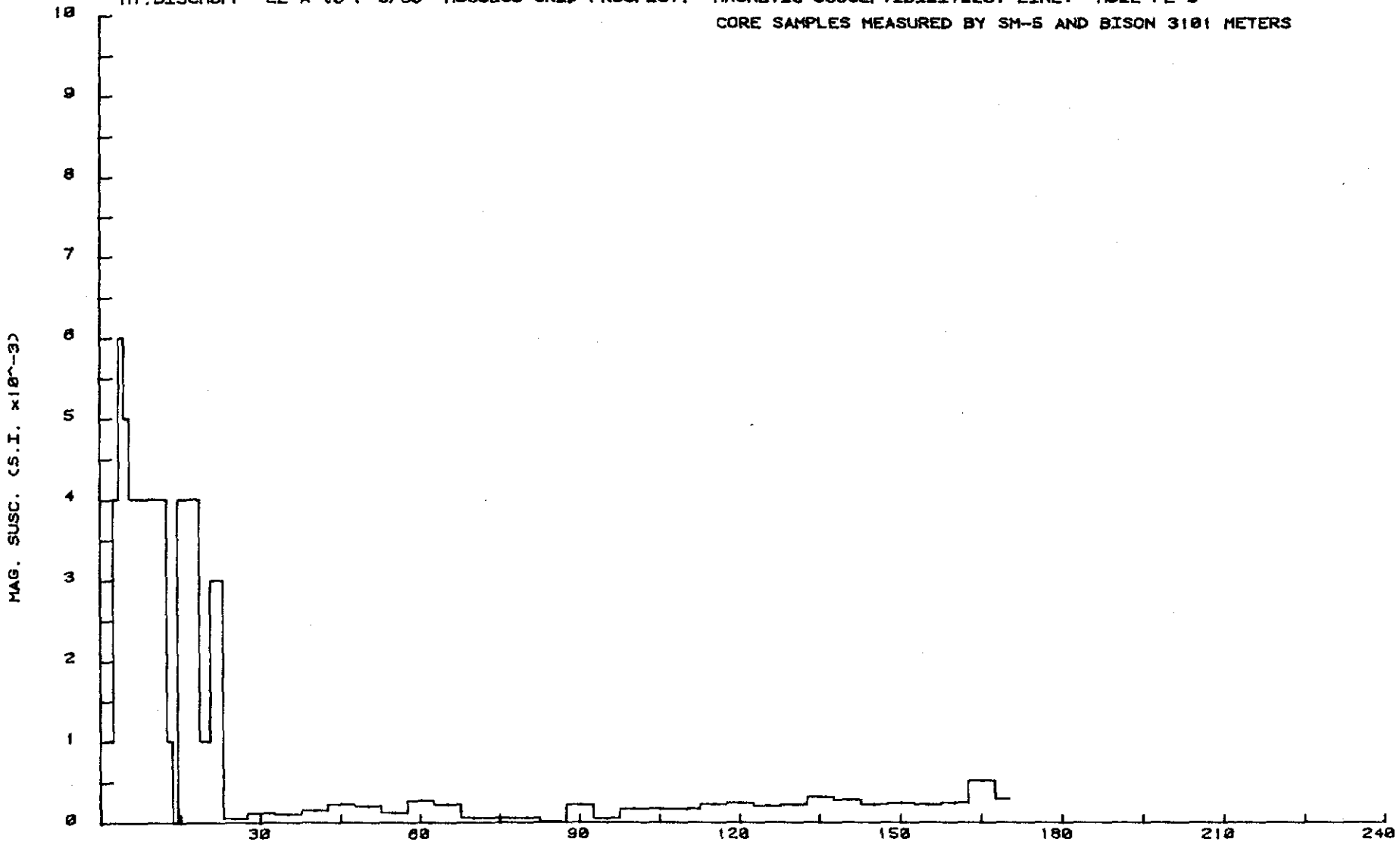


CRAE PLAN N°. TASh 772
M. FLIS JUNE 1982

726050

5 cm

MT.BISCHOFF EL A to P 5/80 HOUSEGO GRID PROSPECT. MAGNETIC SUSCEPTIBILITIES. LINE:- HOLE FL-5
CORE SAMPLES MEASURED BY SM-5 AND BISON 3101 METERS

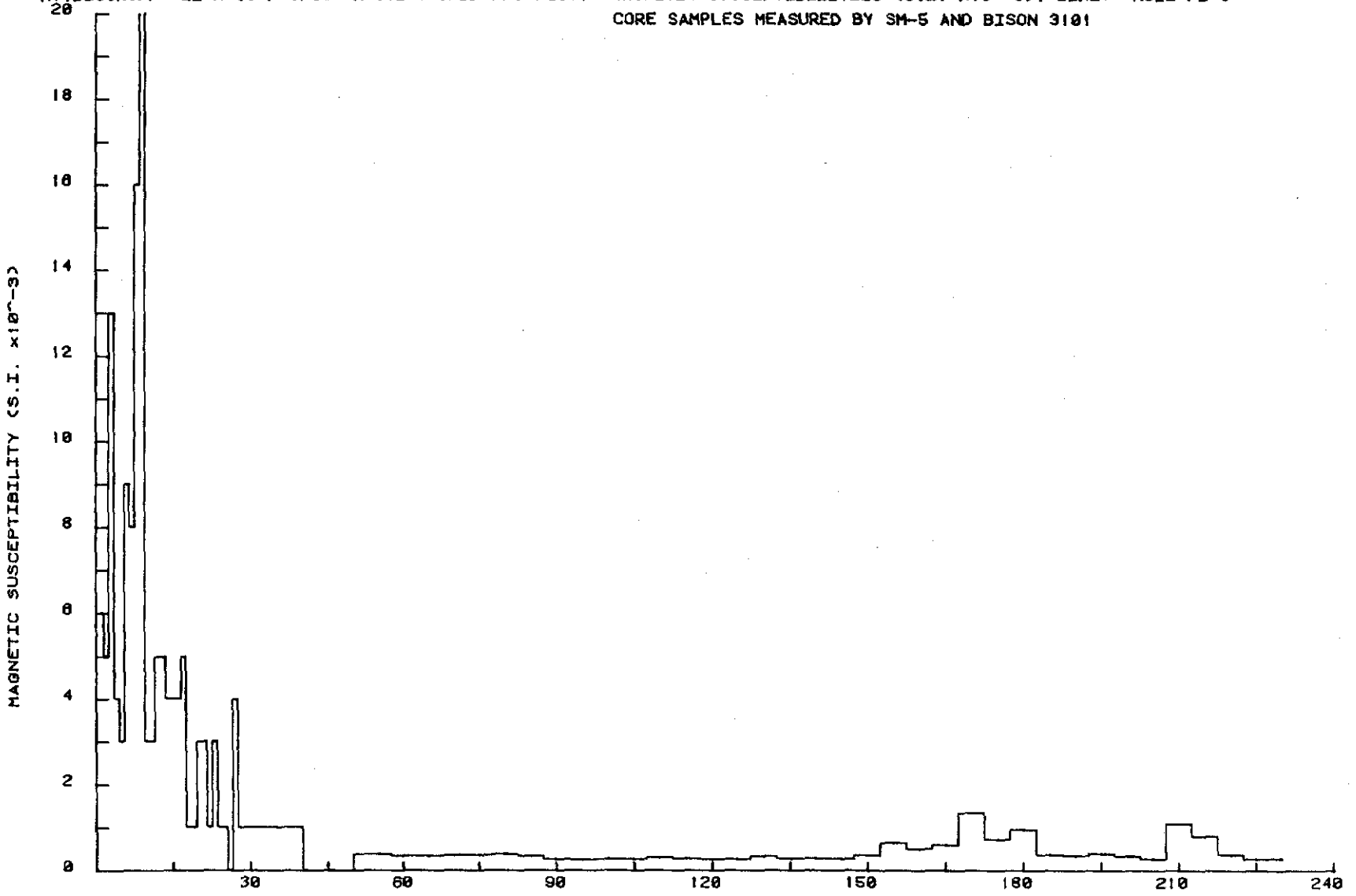


CRAE PLAN N°. TASh 773
M.FLIS JUNE 1982

726051

5 cm

MT.BISCHOFF EL A to P 5/80 HOUSEGO GRID PROSPECT. MAGNETIC SUSCEPTIBILITIES (S.I. x10^-3). LINE:- HOLE FL-6
CORE SAMPLES MEASURED BY SM-5 AND BISON 3101



(RAE PLAN N°. TASh 774
M.FLIS JUNE 1982

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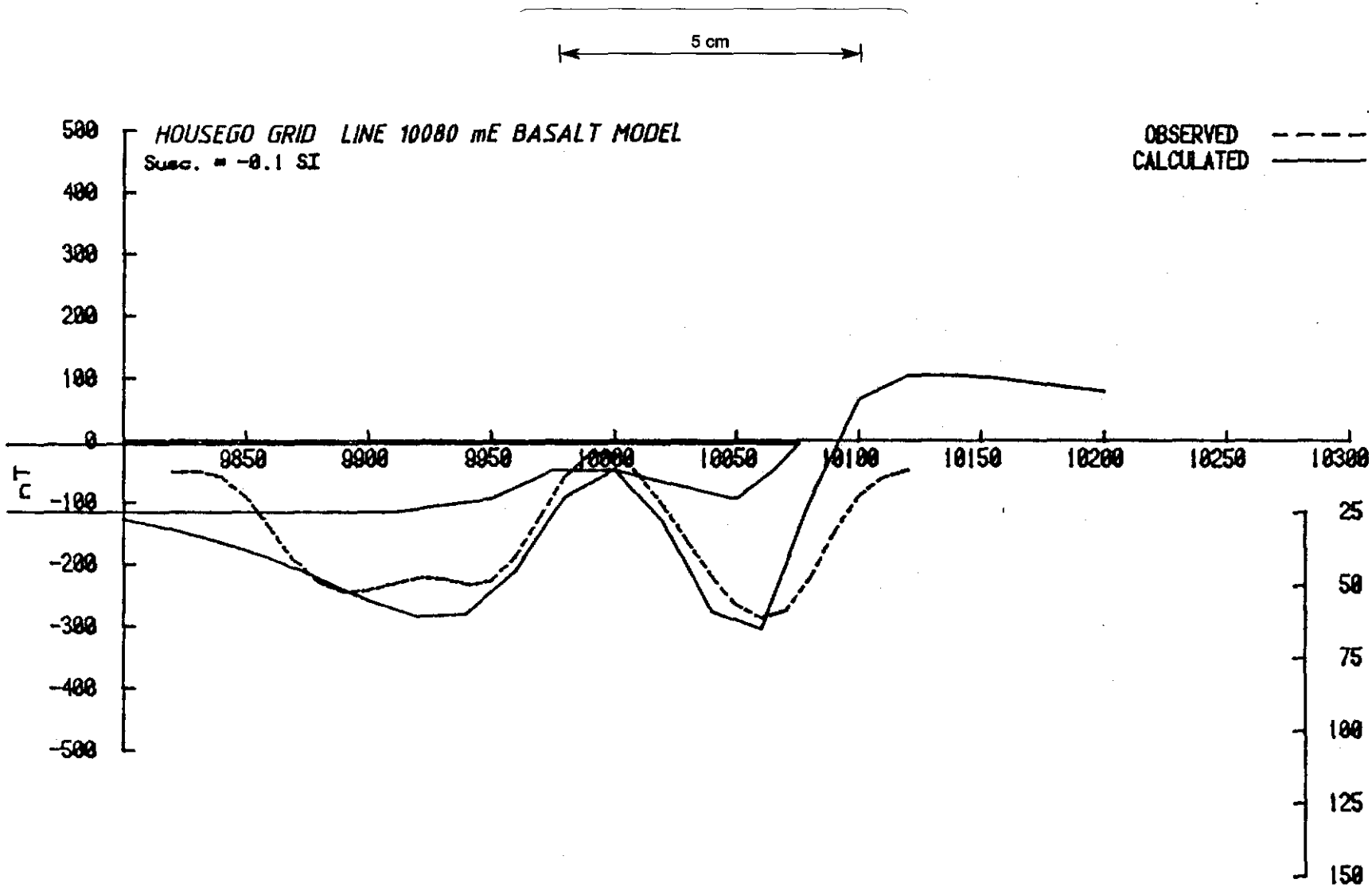

CRAE PLAN N°. TASh 775

M. FLIS JUNE 1982

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