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EXPLORATION LICENCE 9/88

WINTERBROOK

TASMANIA

PROGRESS REPORT FOR THE YEAR

ENDED JULY 8, 1989

MICROFILMED

COMPILED AND WRITTEN BY:

S. W. Rand, Sven Rand
GEOLOGIST.

ISSUED BY:

David Wallace
D. B. Wallace,
REGIONAL MANAGER.

AUGUST 1989

Distribution:

Department of Mines
Aberfoyle - Burnie
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89-3003

TABLE OF CONTENTS

		Page No:
1.0	Summary and Conclusions	1
2.0	Introduction	2
3.0	Previous Exploration	5
4.0	1988/1989 Exploration	7
4.1	Gridding	7
4.2	Geology	7
4.2.1	Rock Chip Petrology	8
4.2.2	Rock Chip Geochemistry	9
4.3	Geophysics	9
5.0	Discussion and Recommendations	10
6.0	References	11

LIST OF APPENDICES

Appendix 1 Rock chip sample locations and field descriptions.

Appendix 2 Petrological description of rock chip samples.

Appendix 3 Geochemical analyses of rock chip samples.

Appendix 4 Interpretation Report, UTEM Survey Dec 88/ Jan. '89. Winterbrook EL 9/88. (Silic, 1989).

LIST OF PLATES

(in order of discussion in text)

WINT 6 (in text) ✓ EL 9/88 Winterbrook Location Plan.

WINT 5 ✓ Summary of Exploration (1:25,000).

WINT 4A ✓ EL 9/88 Winterbrook Location Survey Points (1:10,000).

WINT 4B ✓ EL 9/88 Winterbrook Location Survey Points (1:10,000).

1.0 SUMMARY AND CONCLUSIONS

Exploration by Aberfoyle within the Winterbrook exploration licence (9/88) during 1988/1989 has concentrated on deep search geophysical techniques over outcropping Cambrian volcanics. The volcanic rocks are only exposed in parts of the licence, being dominantly buried beneath younger cover rocks.

A 43 km four loop UTEM survey and limited mapping was conducted over the exposed volcanics. No conductors attributable to massive sulphide accumulations were detected.

Mapping and sampling of the volcanic rocks will be undertaken to determine stratigraphic correlations with other volcanics within the Mt. Read volcanic sequence. Further UTEM surveying is proposed to test for sulphide accumulations beneath the cover rocks. This programme may, however, be subject to a review of the prospectivity compared to other Aberfoyle licences within the area.

2.0 INTRODUCTION

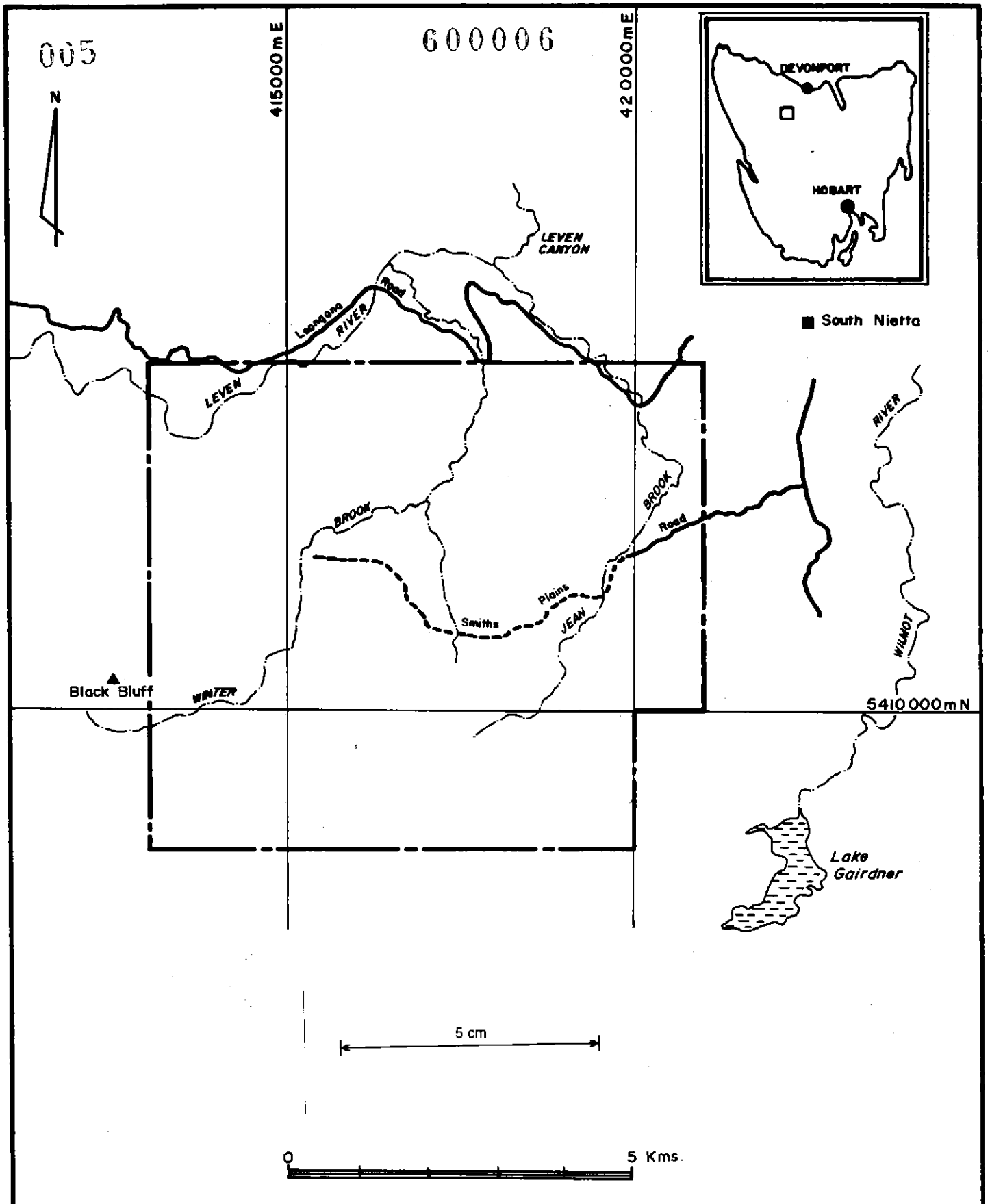
Exploration licence 9/88 Winterbrook was granted to Aberfoyle Resources Ltd. on 9th August, 1988. Previously the ground was part of EL 7/74 Moina, held up to July 1987 by Comalco, The Shell Co. of Australia and CRA Exploration Pty. Ltd.

The Winterbrook licence (EL 9/88) covers an area of 54 square kilometres approximately 10 km from the Wilmot power station. The licence covers ground south of the Leven River and to the west of the Wilmot River (refer to plate WINT 6).

The licence area is dominantly rugged and heavily vegetated by a mix of rain forest species and eucalypts. A small portion in the north is cleared and relatively flat. The area is accessed by minor roads (namely Smiths Plans Road and Loongana Road), along with a network of logging roads.

The geology comprises locally outcropping Cambrian volcanics which dominate beneath younger cover rocks, being Ordovician sediments and Tertiary basalt (refer to plate WINT 5). The Cambrian rocks comprise an inlier of acid and intermediate to basic rocks of the Fossey Mt. Trough. These are dominated by volcaniclastics but include some Hellyer like lavas.

No significant mineral deposits have yet been discovered on the licence. A number of small granite related mineral deposits occur to the south east, in the Mt. Jacob - Moina area.



Aberfoyle Resources Limited

EXPLORATION DIVISION

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Init.	Date	Init.	Date

NORTHERN TASMANIA

E.L. 9/88 WINTERBROOK
LOCATION PLAN

Compiled :	SWR
Drawn :	SWR, RJE
Traced :	RJE
Checked :	SWR
Location Code :	
Scale :	As shown
Date :	July , 1989
Plate No. :	WNT. 6

5111

Previous mineral exploration in the Winterbrook licence has involved predominantly modern exploration methods within the last two decades, there being little evidence of early prospectors. Modern exploration for volcanogenic massive sulphides was undertaken initially by Comalco in 1976, before the licence was taken over by Shell and CRA.

Their exploration programmes employed a variety of techniques; initially stream sediment sampling and airborne geophysics, with follow-up IP, soil geochemistry and UTEM. The programmes resulted in a total of eight drillholes (6 diamond, 2 percussion) to test anomalies on the Winterbrook licence. No mineralisation was intersected.

Aberfoyle's primary target is volcanogenic massive sulphides. Exploration in the area since acquiring the licence involved a gridding programme followed by a four loop 42.8 km UTEM survey. Only limited mapping and sampling has been undertaken on the licence to date.

3.0 PREVIOUS EXPLORATION

No mineralisation was located by prospectors within the current licence boundary. Around the turn of the century, however, a number of granite related tin, tungsten, molybdenum, bismuth, fluorite and gold deposits had been located in the Moina area to the south east.

Modern exploration within the area by Comalco, up until 1976, was aimed primarily at locating fluorite-magnetite skarn mineralisation, though gold and tin deposits were also sought. Their exploration programmes up until 1976 concentrated predominantly on the Moina area.

Comalco explored the area for volcanogenic massive sulphide mineralisation individually from 1976 and in joint venture with Shell from 1980. Their programmes concentrated on the Cambrian volcanic rocks of the Winterbrook inlier in the Winter Brook area (covered by the current licence boundary) and also in the vicinity of Mt. Jacob, to the south east.

Initial work in the area involved a regional stream sediment sampling programme which produced a number of anomalies. Two grids were cut in the current licence area (Lower and Upper Winterbrook grids) with an additional grid established at Mt. Jacob. The grids were designed to cover the outcropping Cambrian volcanic rocks to allow access for follow-up soil sampling and IP surveys. This work produced several anomalies in the Winterbrook and Mt. Jacob areas. Of these, only the anomalies in the Mt. Jacob area were recommended for further testing.

Two holes were drilled at Mt. Jacob aimed at IP and geochemical anomalies. Both holes passed through Ordovician sediments into altered and mineralised volcanic rocks. The best intersection contained 10m of 1.3% Pb and 1% Zn.

CRA joined the joint venture as managers in March, 1985. They extended the grid (shown on plate WINT 5) and undertook further soil sampling and UTEM surveying which produced a number of anomalies. Four of the anomalies were tested in a drilling programme involving two percussion drillholes and six diamond drillholes (one of these was a redrill of a percussion hole), totalling 964.8m. Drillhole collar locations are shown on plate WINT 5.

The drillholes intersected a mixture of sheared volcanic rocks and limestone units. No mineralisation was intersected in any of the holes and the conductive responses detected in the UTEM surveys were considered to have been due to the intersected shear zones (von Strokirch, 1987).

CRA considered that the prospect had been adequately explored, with no results worthy of follow-up. They subsequently relinquished the licence in July, 1987.

For reports of previous exploration in the area refer to Weste (1978), Askins (1980), Smyth (1981, 1982 and 1983), Wright and Smyth (1984), Caithness (1986) and von Strokirch (1987).

4.0 1988/1989 EXPLORATION

Exploration undertaken by Aberfoyle since acquiring the licence (EL 9/88 Winterbrook) has comprised gridding, limited sampling and mapping and a UTEM survey.

4.1 GRIDDING

The gridding programme in the Winterbrook licence involved a number of phases. Initially gridlines were established over outcropping Cambrian rocks in the northeastern, mid western, and southeastern sections. The gridlines were ~ northwest-southeast lines established at 200m spacings, with a base-line at 046° magnetic. The initially surveyed grid lines are shown at 1:10,000 scale on plates WINT 4A and 4B. The complete grid, including areas of future gridding, is shown at 1:25,000 scale on plate WINT 5.

A total of 41.6 line kilometres of line cutting was undertaken.

4.2 GEOLOGY

Only very limited mapping and sampling was undertaken within the licence. Six rock chip samples were collected for petrological and geochemical analysis (sample locations and field descriptions are included as Appendix 1 with petrological descriptions and geochemical analysis included as Appendices 2 and 3 respectively). The sample locations are shown on plate WINT 5.

4.2.1 Rock Chip Petrology

The samples collected comprise a mixture of rock types, summarised as follows (refer to Appendix 2 for detailed descriptions):-

Rhyolite lava or crystal tuff (sample 427275)
This is a light grey-green quartz-phyric lava or tuff which has been completely sericitised. Quartz phenocrysts are rounded and embayed suggesting re-equilibration with the matrix. Common broken phenocrysts within the fine-grained groundmass tend to support a volcaniclastic origin.

Feldspar + quartz phyric rhyolitic ignimbrite (427280)
This dark red-grey sample contains minor resorbed quartz phenocrysts and common albitised plagioclase phenocrysts. Spherulites are common in the matrix.

Andesitic crystal-lithic tuff (427278)
This is a massive dark grey-green volcanic rock containing variably sized feldspar, augite and amphibole (hornblende) phenocrysts. The rock contains minor fragments of formerly glassy lava or tuff.

Andesitic lava (samples 427279 and 427281)
This rock type is typically a massive dark brown-green lava containing plagioclase and augite phenocrysts in a fine-grained matrix. Sample 427281 is from the rim of a pillow lava, with some cherty interpillow material included.

4.2.2 Rock Chip Geochemistry

All of the samples described above were submitted for routine geochemical analysis. Sample 427281, the andesitic pillow lava, was submitted for a broad range of elements.

None of the samples were elevated in base-metals, barium, arsenic, silver or gold. The results for lithogeochemical elements have been included in Aberfoyle's regional geochemical database.

4.3 GEOPHYSICS

A 43 km four loop UTEM survey was conducted over the Winterbrook grid. The loop locations and resultant survey profiles are included here as part of Appendix 4.

The survey failed to detect any conductors attributable to massive sulphide accumulations. A more detailed assessment of the data is included in the survey report, Appendix 4.

5.0 DISCUSSION AND RECOMMENDATIONS

The geology of the area as shown in plate WINT 5 is based predominantly on CRA mapping. No regional mapping has been undertaken in the licence.

The presence of a mixture of basic to acid volcaniclastics and lavas provides a favourable stratigraphic environment for volcanogenic massive sulphide mineralisation. The dominance of basic to intermediate units and relative absence of possible Tyndall correlates (Minnow Keratophyre) suggests that these volcanic rocks are possibly similar to the Que-Hellyer volcanics.

A surface mapping and sampling programme combined with a geochemical and petrographic analysis will be undertaken to determine possible correlations of these rocks within the established Mount Read volcanic sequence and compare the prospectivity with other Aberfoyle tenure.

Cambrian rocks on the licence not yet covered by modern exploration techniques are invariably buried beneath younger cover. Future gridding and UTEM surveying will be aimed at testing the volcanics beneath these cover rocks, in an attempt to detect possible deposits otherwise hidden from normal geological and geochemical exploration methods.

6.0 REFERENCES

Askins, P. W., 1980, EL 7/74 Moina, General Area. Report on all investigations to December, 1980, by Comalco Ltd.

Caithness, S. J., 1986, EL 7/74 Moina. Report on exploration for 12 months to 18 June, 1986 (CRAE internal report No. 14008).

Jennings, I. B., 1979, Sheffield Sheet 37 Geological Survey of Tasmania Explanatory Report.

Smyth, W. D., 1981, EL 7/74 Moina, Tasmania. Progress report on exploration during the period 1.1.80 to 30.7.81. Unpub. Shell report 08.1062.

Smyth, W. D., 1982, EL 7/74 Moina, Tasmania. Progress report on exploration during the period 31.7.81 to 30.6.82. Unpub. Shell report 08.1066.

Smyth, W. D., 1983, EL 7/74 Moina, Tasmania. Progress report on exploration during the period 1.7.82 to 30.6.83. Unpub. Shell report 08.2064.

von Strokirch, T., 1987, EL 7/74 Moina. Report on area relinquished on 18.7.87.

Weste, G., 1978, EL 7/74 Moina, Tasmania. Black Bluff-Smith Plains. Report on all investigations to September, 1978, by Comalco Ltd.

Wright, R. G. and Smyth, W. D., 1984, EL 7/74 Moina, Tasmania. Report on area relinquished on 18.7.84. Unpub. Shell report 08.2269.

APPENDIX 1

Field descriptions and sample locations of rock chip samples submitted for petrological and geochemical analysis.

P indicates sample submitted for petrology

G indicates sample submitted for geochemical analysis

Sample	Location	Field Description
427275 P G	4.1 km from Maxwells house. Winterbrook track.	Grey rhyolite (int?). Same rock as at 3.0 and 3.4 km.
427278 P G	2.4 km from turn-off at Maxwells house. Winterbrook track.	Polymict andesitic ash volcaniclastic. Clusters of pink K-feldspar. Some pyrite with K-feldspar.
427279 P G	3.35 km Winterbrook track.	Bedded andesitic rock with prominent pink K-feldspar.
427280 P G	2.8 km turn off at Maxwells house. Winterbrook track.	Minor intercalation of maroon Minnow Keratophyre.
427281 P (271791 G)	23.2 km from turn off at Maxwells house. Winterbrook track.	Andesitic pillow? lava with chert.
427282 G	2.65 km along Winter-brook track.	Andesitic lava, minor K-feldspar, and traces of pyrite.

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APPENDIX 2

Petrological Descriptions of Rock Chip Samples

(descriptions provided by Dr. A. Crawford,
University of Tasmania)

SAMPLE: 427275

LOCATION: Winterbrook, 4.1 km from Maxwell House (Coffee Plantation (?)) on Winterbrook Track.

SUMMARY: This rock was a quartz-phyric rhyolitic lava or crystal tuff which has been thoroughly sericitized.

HAND SPECIMEN: This is a light grey-green felsic volcanic with quartz phenocryst but lacking any obvious lithic fragments.

THIN SECTION DESCRIPTION:

This rock is a quartz-phyric rhyolitic tuff or lava which has been extensively sericitized. It contains abundant rounded, embayed and fractured quartz phenocrysts to 3mm long, some of which contained devitrified rounded melt inclusions. The quartz phenocrysts have re-equilibrated at their margins with the quartz+albite-rich matrix, so that they are intimately intergrown with the matrix.

The formerly glassy groundmass is a very fine-grained, uniform-textured devitrification product of rhyolitic glass now composed of a mixture of quartz and albite, riddled with flecks of sericite. Angular patches of sericite appear to be fracture fillings, and sericite also occurs as cross-cutting veinlets. It is difficult to determine with certainty whether this rock was originally a rhyolitic lava or a crystal tuff. The abundant broken quartz phenocrysts tend to favour the latter in my opinion.

SAMPLE: 427278

LOCATION: Winterbrook, 2.4 km from turn-off at Maxwell House (Coffee Plantation (?)) on Winterbrook Track.

SUMMARY: This is a well-preserved feldspar+quartz+augite+hornblende -phyric andesitic crystal-lithic tuff. It is likely to be a pyroclastic equivalent of the Crown Hill-type andesites of the area S of the Henty Fault.

HAND SPECIMEN: This is a massive dark grey-green andesitic crystal-lithic tuff with sparse lithic fragments of formerly glassy lava or tuff.

THIN SECTION DESCRIPTION:

This sample is a well-preserved andesitic crystal tuff containing crystal fragments of quartz, dominant feldspar and subordinate clinopyroxene, and sparse lithic fragments. The crystal grains show poor size sorting and are usually angular, and the matrix makes up only about 20 modal% of this rock. Feldspar phenocrysts are albitized plagioclsae and are pinkish, they contain abundant sericite flakes and less abundant small granules of epidote and chlorite flakes. Quartz fragments are angular and geneerally resorbed to various degrees. Augite phenocrysts are subhedral and largely replaced by an intergrowth of actinolite, chlorite, epidote and calcite. Several grains of primary brown-olive green pleochroic amphibole are preserved. Patches of green chlorite containing euhedral golden crystals of epidote are common.

This sample is obviously andesitic, as indicated by the relatively abundant augite phenocrysts, the presence of amphibole phenocrysts and the abundance of epidote and chlorite in the groundmass.

SAMPLE: 427279

LOCATION: Winterbrook, 3.35 km from Maxwell House (Coffee Plantation (?)) on Winterbrook Track.

SUMMARY: This rock is a plagioclase+augite-phyric meta-andesite.

HAND SPECIMEN: This is a ,assive, brown-olive green andesitic lava with some pinkish wispy bands in the groundmass which may be due to K feldspar alteration of glass.

THIN SECTION DESCRIPTION:

This sample is a plagioclase+augite-phyric andesite in which approximately 20 modal% of plagioclase and 2-3% of augite phenocrysts are set in a formerly virophyric groundmass. Plagioclase phenocrysts are sericite-flecked pinkish albite prisms to 2mm long. In hand specimen, the pronounced pink colouring of the feldspar phenocrysts gives the appearance of K feldspar, but staining with sodium cobaltinitrite proved them to be albite, supporting the optical identification. Augite phenocrysts are subhedral and partially altered to actinolite and chlorite. Microphenocrysts of FeTi oxide are relatively unaltered and quite large (to 0.5mm), and a few resorbed phenocrysts of quartz are present. The groundmass is patchy, with areas dominated by quartz and albite proably after glass, and more chlorite- and epidote-rich areas. Epidote also occurs as tiny euhedral crystals in narrow meandering veins.

This relatively unaltered sample is worth analyzing for our Mount Read Volcanics study, if that is OK.

SAMPLE: 427280

LOCATION: Winterbrook, 2.8 km from turn-off on Winterbrook Track.

SUMMARY: This sample was a feldspar+quartz-phyric rhyolitic ignimbrite.

HAND SPECIMEN: This dark red-dark grey felsic volcanic contains visible phenocrysts of quartz and feldspar, and shows red K feldspar (?) alteration of the fluidal former glassy groundmass.

THIN SECTION DESCRIPTION:

This sample is a formerly glassy rhyolite containing around 5-10 modal% of albitized plagioclase phenocrysts and sparse resorbed quartz phenocrysts to a maximum size of 1mm. Apparently fresh FeTi oxide microphenocrysts are not uncommon. The groundmass shows a well-developed fluidal structure; rhyolitic glass has devitrified to quartz and albite, and post-solidification growth of feldspar (albite or K feldspar?) spherulites is a distinctive feature of this rock in thin section. Growth of spherulites has pushed groundmass sericite outwards so that most spherulites have a sericite rim. Patches of dull yellow epidote are present in the groundmass, together with sericite veinlets, minor chlorite and calcite. In places, calcite has crystallized as euhedral rhombs.

SAMPLE: 427281

LOCATION: Winterbrook, 3.2 km from turn-off on Winterbrook Track.

SUMMARY: This is a pillow rim of an augite+plagioclase-phyric meta-andesite

HAND SPECIMEN: This is a massive dark brown relatively fresh andesite with cherty interpillow material.

THIN SECTION DESCRIPTION:

This sample is of a pillow margin of a mafic andesite. It contains around 10 modal% of large euhedral clinopyroxene phenocrysts (to 3mm long), which often contain rounded inclusions of FeTi oxides. Less abundant plagioclase phenocrysts are equidimensional , stout prisms which are slightly rounded and show limited sericite alteration. A number of small gabbroic crystal clots are present, composed of augite, plagioclase (albitized) and subordinate FeTi oxide crystals.

The groundmass is very heterogeneous. Some areas are mottled greenish-yellow and relatively rich in patchy fine-grained epidote and chlorite, whereas lighter coloured areas are dominated by quartz and albite mosaics in which epidote grows as stumpy euhedral prisms. The formerly glassy pillow rim is composed of devitrified glass containing augite and less abundant plagioclase phenocrysts. It is traversed by irregular fractures filled by greenish chlorite and secondary feldspar and quartz; the feldspar forms radiating rosettes which extend into the quartz-dominated veins; it is difficult to determine whether the feldspar is albite or K feldspar.

APPENDIX 3

Geochemical Analyses of Rock Chip Samples
(In approximate order of sample number)

(Analyses performed by ANALABS)

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023

ANALABS

A division of MacDonald Hamilton & Co. Pty. Ltd.

none (09) 458 7999 52 Murray Road, Welshpool, W.A. 6106 Telex AA92560

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STATE OF SAMPLES		PRE-TREATMENT							ANALYSIS		
REFER BELOW	SAMPLE NUMBERS	DRY	CRUSH	SPLIT	PULVERISE	SIEVE	OTHER SEE REMARKS	NONE	REFER TO ANALYSIS SECTION	PREPARATION	METHOD
	271791	RO	Prep: 010,011,012,013,016						Cu,Pb,Zn,Ag,Ni/101,As/114		
	271791	RO							Ba,Cr,Zr,S,Y,Nb,Sn/401,Al2O3,SiO2,TiO2,Fe2O3,Mn		
	271791	RO							Au/309		

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RESULTS TO

REMARKS

WINTERBROOK ROAD

STATE OF SAMPLES		ANALYSIS — PREPARATION				ANALYSIS — METHOD	
whole core	WC	perchloric acid	A1	cold acid	CA	atomic absorbtion	AAS
split core	SC	hydrochloric acid	A2	specific sulphide	SS	x-ray fluorescence	XRF
cutting	CU	nitric acid	A3	other mixed acids	Ma	spectrophotometry	SPEC
rock	Ro	aqua regia	A4	alkaline attack	AA	colorimetry	COL
soil	SO	nitric-perchloric	A5	volatilization	VO	chromatography	CHR
pulp	PU	HF mixture	A6	ignition	IG	titration	TTN
water	WA	HF under pressure	A7	pressed powder (XRF)	PP	other chemicals means	CHEM
tissue	TI	fusion	A8	glass fusion (XRF)	GF	miscellaneous	MISC
stream sediment	SS					fluorescence	FLUOR
heavy mineral	HM					inductively coupled plasma	ICP

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ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No.	PAGE
	23.3.08.05206		3024	1 OF 3

TUBE No.	SAMPLE No.	S	Cr	Ni	Cu	Zn	As	Y	Zr	Nb
1	271791	0.040	35	50	15	80	4	25	200	<3
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23	DETECTION	0.005	5	5	5	5	1	5	5	3
24	UNITS	%	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM
25	METHOD	613	401	101	101	101	114	401	401	401

Results in ppm unless otherwise specified
T = element present; but concentration too low to measure
X = element concentration is below detection limit
— = element not determined

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025 600026

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SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No.	PAGE
	23.3.08.05206		3024	2 OF 3

TUBE No.	SAMPLE No.	Ag	Sn	Ba	Au	Pb	Na2O	Al2O3	CaO	Fe2O3
1	271791	<0.5	<3	740	<0.008	10	5.120	15.2	2.17	6.73
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23	DETECTION	0.5	3	10	0.008	5	0.005	0.1	0.01	0.01
24	UNITS	PPM	PPM	PPM	PPM	PPM	%	%	%	%
25	METHOD	101	401	401	309	101	104	408	408	408

Results in ppm unless otherwise specified
T = element present; but concentration too low to measure
X = element concentration is below detection limit
— = element not determined

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SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No.	PAGE
	23.3.08.05206		3024	3 OF 3

TUBE No.	SAMPLE No.	K2O	MgO	MnO	P2O5	SiO2	TiO2	Ti ppm		
1	271791	1.89	2.820	0.09	0.156	63.6	0.58	3477		
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23	DETECTION	0.01	0.005	0.01	0.007	0.1	0.01			
24	UNITS	%	%	%	%	%	%			
25	METHOD	408	408	408	408	408	408			

Results in ppm unless otherwise specified
T = element present; but concentration too low to measure
X = element concentration is below detection limit
— = element not determined

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	Various	RC	Prep: 009,011,012,013,016							Cu,Pb,Zn,Ag,Ni/101,As/114		
	Various	RC								Ba,Cr,Zr,Ti,Y/401		
	427243,427262/65,427277	RC								Au/309		
	Various	RC								CaO/104		
	427243,427253/54,427256/57	RC								K2O/401		

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REMARKS

600028

STATE OF SAMPLES		ANALYSIS — PREPARATION				ANALYSIS — METHOD	
whole core	WC	perchloric acid	A1	cold acid	CA	atomic absorbtion	AAS
split core	SC	hydrochloric acid	A2	specific sulphide	SS	x-ray fluorescence	XRF
cutting	CU	nitric acid	A3	other mixed acids	Ma	spectrophotometry	SPEC
rock	Ro	aqua regia	A4	alkaline attack	AA	colorimetry	COL
soil	SO	nitric-perchloric	A5	volatilization	VO	chromatography	CHR
pulp	PU	HF mixture	A6	ignition	IG	titration	TTN
water	WA	HF under pressure	A7	pressed powder (XRF)	PP	other chemicals means	CHEM
tissue	TI	fusion	A8	glass fusion (XRF)	GF	miscellaneous	MISC
stream sediment	SS					fluorescence	FLUOR
heavy mineral	HM					inductively coupled plasma	ICP

AUTHORISED OFFICER

028

600029

ANALABS

A Division of Macdonald Hamilton & Co. Pty. Ltd.

ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No.	PAGE
	23.3.08.05282		3048	2 OF 6

TUBE No.	SAMPLE No.	Cu	Pb	Zn	Ag	Au	Ba	As	Ni	Zr
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
18										
19										
20	427275	5	<5	15	<0.5	-	1050	<1	5	180
21										
22										
23	427278	35	<5	75	<0.5	-	380	3	15	140
24	427279	10	<5	60	<0.5	-	1200	2	5	190
25	427280	<5	<5	55	<0.5	-	920	1	25	140

Results in ppm unless otherwise specified
T = element present but concentration too low to measure
K = element concentration is below detection limit
- = element not determined

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600030

029

ANALABS

A Division of Macdonald Hamilton & Co. Pty. Ltd.

ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No.	PAGE
	23.3.08.05282		3048	3 OF 6

TUBE No.	SAMPLE No.	Cu	Pb	Zn	Ag	Au	Ba	As	Ni	Zr
1	427282	<5	<5	80	<0.5	-	1050	1	5	140
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23	DETECTION	5	5	5	0.5	0.008	10	1	5	5
24	UNITS	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM
25	METHOD	101	101	101	101	309	401	114	101	401

Results in ppm unless otherwise specified

- element present; but concentration too low to measure
- element concentration is below detection limit
- element not determined

AUTHORISED OFFICER

030

ANALABS

A Division of Macdonald Hamilton & Co. Pty. Ltd.

ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No.	PAGE
	23.3.08.05282		3048	5 OF 6

TUBE No.	SAMPLE No.	Ti	Y	CaO	K2O					
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20	427275	1050	25	-	-					
21										
22										
23	427278	3900	20	6.000	-					
24	427279	3150	25	-	-					
25	427280	1450	20	-	-					

Results in ppm unless otherwise specified
- element present but concentration too low to measure
- reagent concentration is below detection limit
- element not determined

AUTHORISED OFFICER

031 600032

ANALABS

A Division of Macdonald Hamilton & Co. Pty. Ltd.

ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No.	
	23.3.08.05282		3048	6 OF 6

TUBE No.	SAMPLE No.	Ti	Y	CaO	K2O					
1	427282	3350	40	-	-					
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
[illegible]										
18										
19										
20										
21										
22										
23	DETECTION	50	5	0.005	0.005					
24	UNITS	PPM	PPM	%	%					
[illegible]	METHOD	401	401	104	104					

[illegible] in ppm unless otherwise specified [illegible]

AUTHORISED [illegible]

032

600033

APPENDIX 4

Interpretation Report

UTEM Survey

DEC. 88/JAN. '89

Winterbrook EL 9/88

(Silic, 1989)

LIST OF CONTENTS

INTRODUCTION

SURVEY SPECIFICATIONS

DISCUSSION OF RESULTS

CONCLUSION

REFERENCES

PLATE

WINT 5

APPENDIX I

UTEM DATA SECTIONS

APPENDIX II

INTERPRETATION OF TDEM DATA USING FIRST AND SECOND SPATIAL DERIVATIVES AND TIME DECAY ANALYSIS

INTRODUCTION

Electromagnetic techniques have played important roles in the discoveries of the Que River and Hellyer deposits (Webster and Skey, 1979; Silic et al, 1985; Eadie et al, 1985). Since the Hellyer discovery Aberfoyle Resources has further refined the use of these techniques in the search for Hellyer and Que River type targets (Silic, 1989) and Appendix II.

The purpose of this report is to discuss the results of a UTEM (West et al, 1984) survey over a grid on the Winterbrook licence. (Plate 1)

SURVEY SPECIFICATIONS

A four loop 42.8 km UTEM survey was executed over a part of the Winterbrook grid (Plate 1).

The prospective geology in this grid is invariably covered by tertiary basalts. As such the optimum loop layouts, designed to couple with the most prospective horizons were not possible. Therefore to a large extent, any significant accumulations of sulphides below the tertiary cover would most likely show up as current gathering responses (eg. Hellyer, Silic et al 1985, Silic 1989).

Vertical component data (Hz) was collected on 50 metre station spacing.

DISCUSSION OF RESULTS

No features indicative of sulphide accumulations were detected by this survey. Some formational near surface conductors, which are identified by the second derivative technique from Silic, 1989, exist on some parts of the licence.

However, considering that the possibility exists that the UTEM loops may not have optimally coupled with the "prospective"

horizons (the locations of which is imprecisely known due to the tertiary cover), the effectiveness of the Winterbrook survey will be reviewed on the completion of current Aberfoyle inhouse research on the effectiveness of current gathering in delineating steeply plunging (eg. Hellyer with a much steeper plunge) conductive targets.

CONCLUSION

No conductor which could be attributed to significant sulphide accumulations were detected by this survey. The effectiveness of the survey will be reviewed on the completion current research on current gathering in steeply plunging targets.

000037

REFERENCES

Eadie, E. T., Silic, J. and Jack, D. J. (1985), 'The application of geophysics to the discovery of the Hellyer ore depost, Tasmania', Explor. Geophys. 16, 207-209.

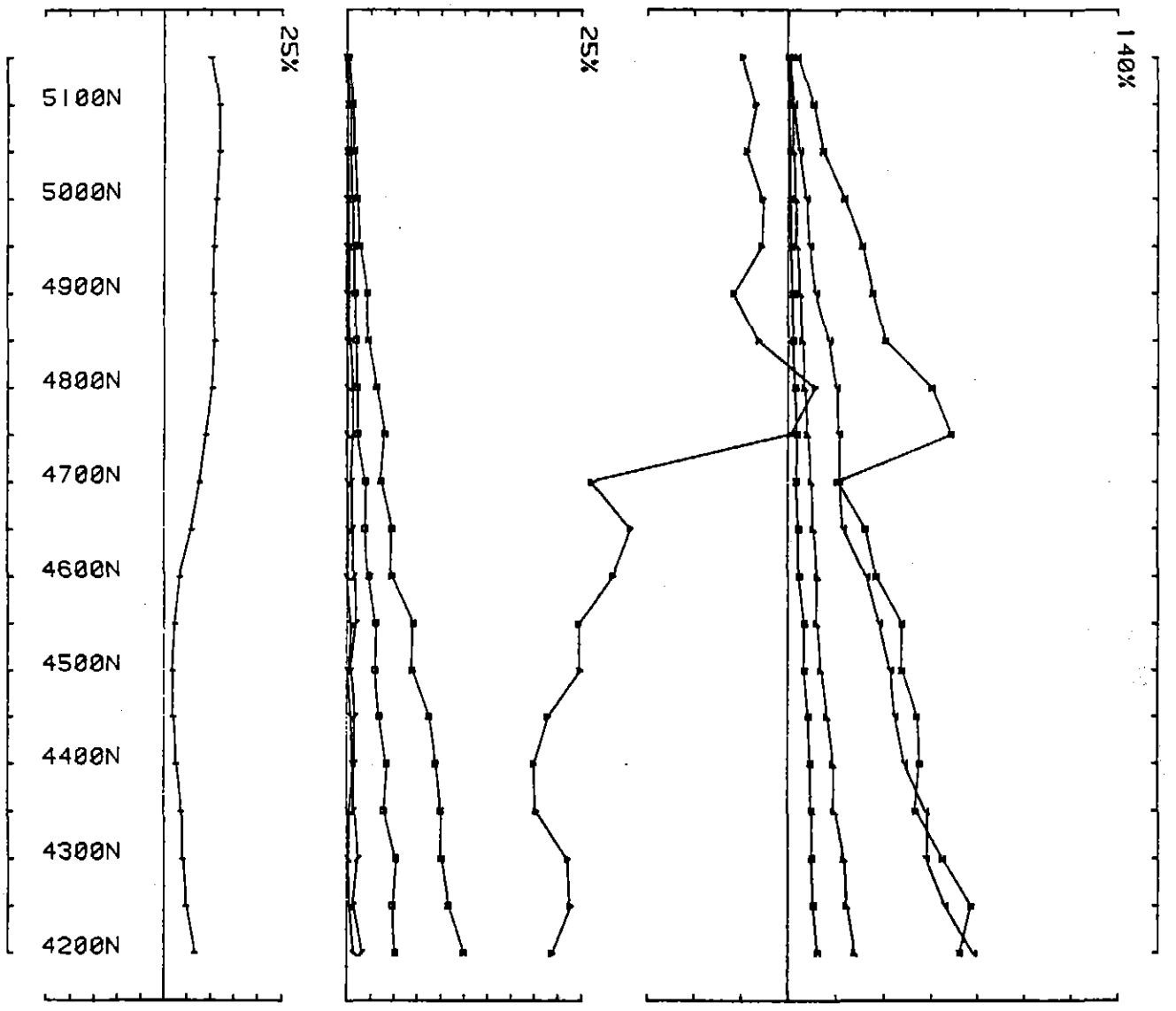
Silic, J. (1989), 'Interpretation of TDEM data using spatial derivatives and decay analysis', Explor. Geophys. 20

Silic, J., Eadie, E. T., and Jack, D. J. (1985), 'Application of time domain electromagnetic methods in the discovery of the Hellyer ore deposit, Tasmania, Australia', in volume of Extended Abstracts of the 55th SEG meeting, Washington, DC.

Webster, S. S. and Skey, E. H. (1979), 'Geophysical and geochemical case history of the Que River deposit, Tasmania', in Geophysics and Geochemistry in the Search for Metallic Ores; Peter J. Hood, editor, Geological Survey of Canada, Economic Geology Report 31, 697-720.

West, G. F., MacNae J. C. and Lamontagne Y. (1984), 'A time domain EM system measuring the step response of the ground', Geophys., 49, 1010-1026.

APPENDIX I



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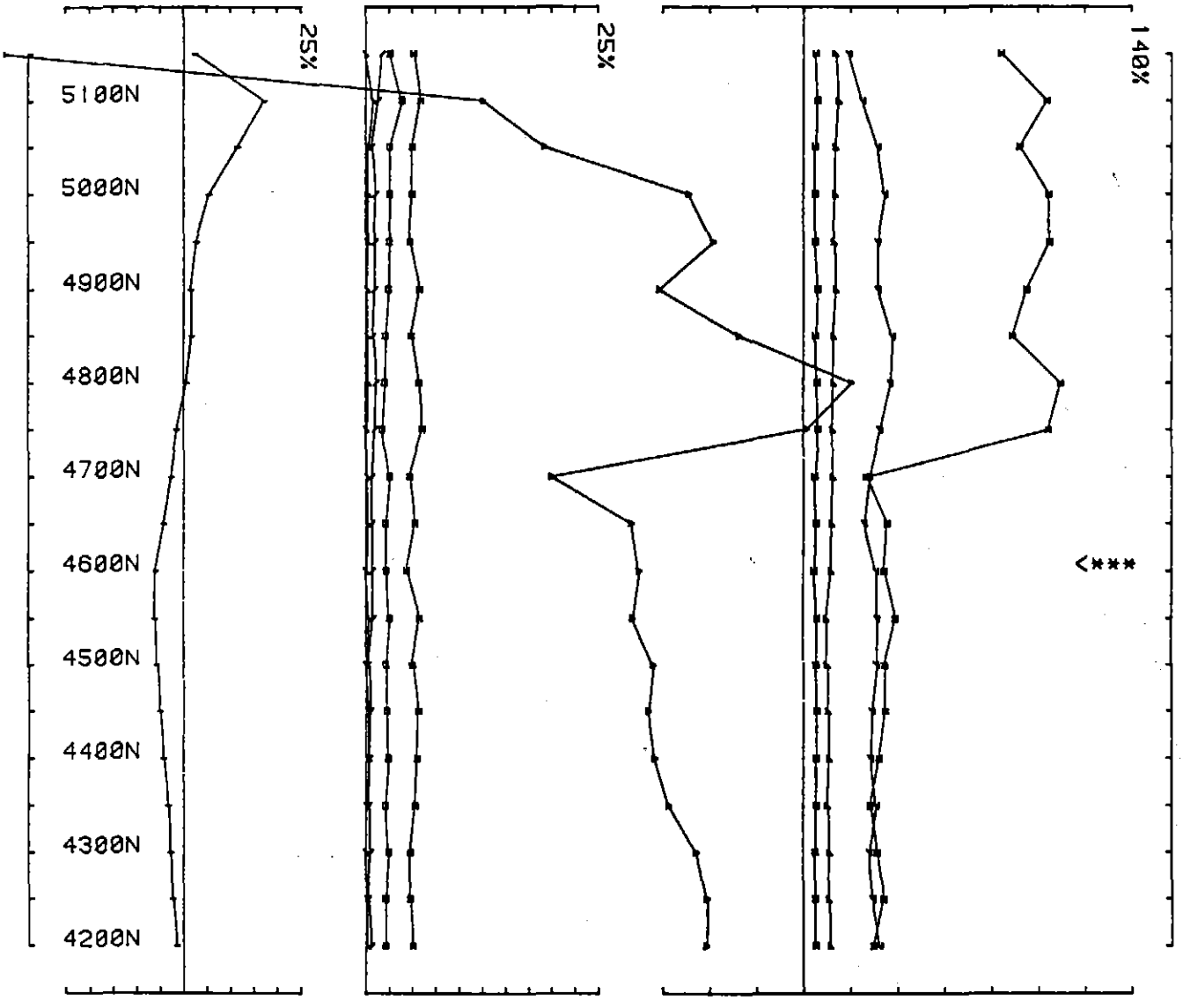

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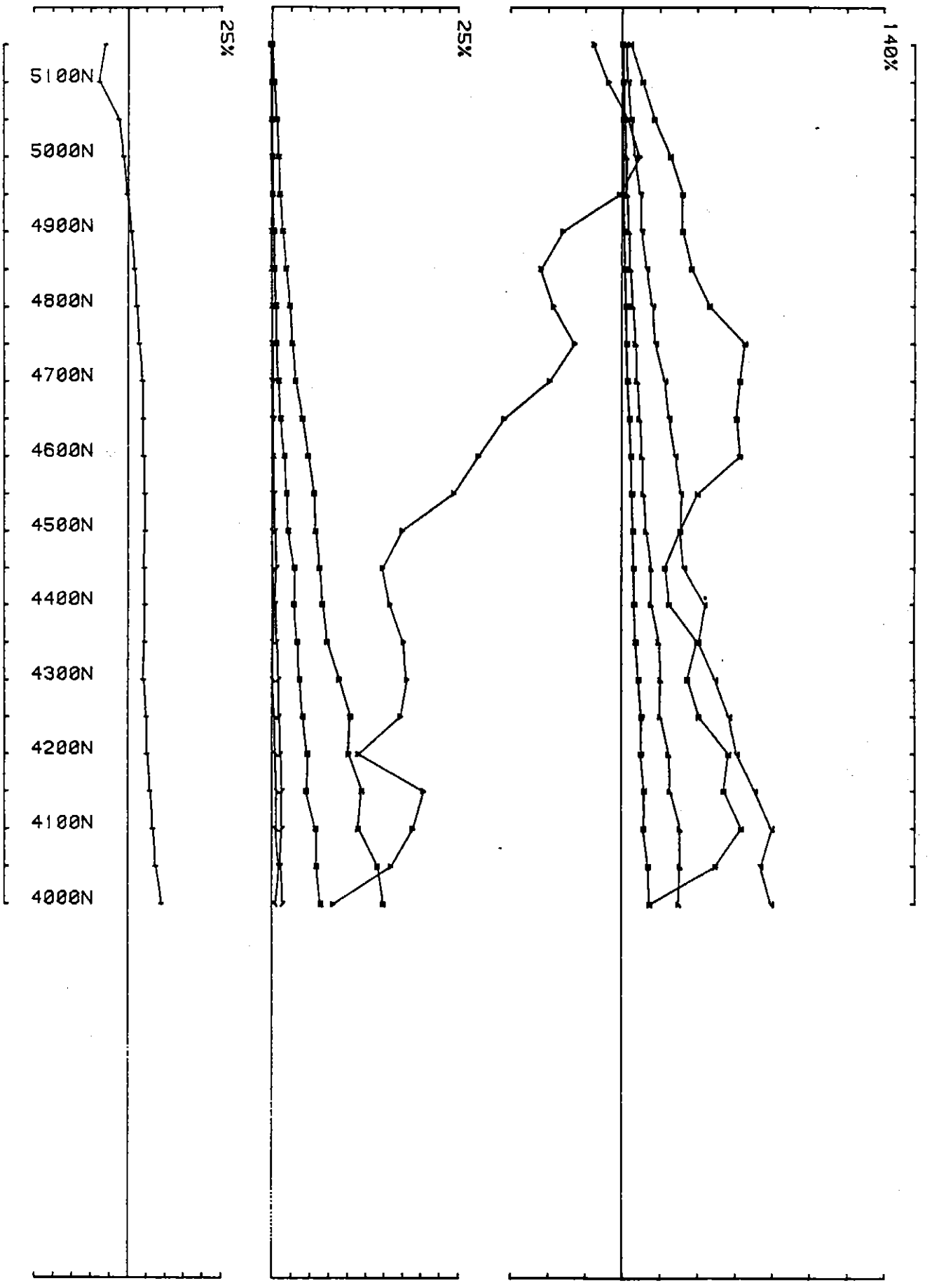

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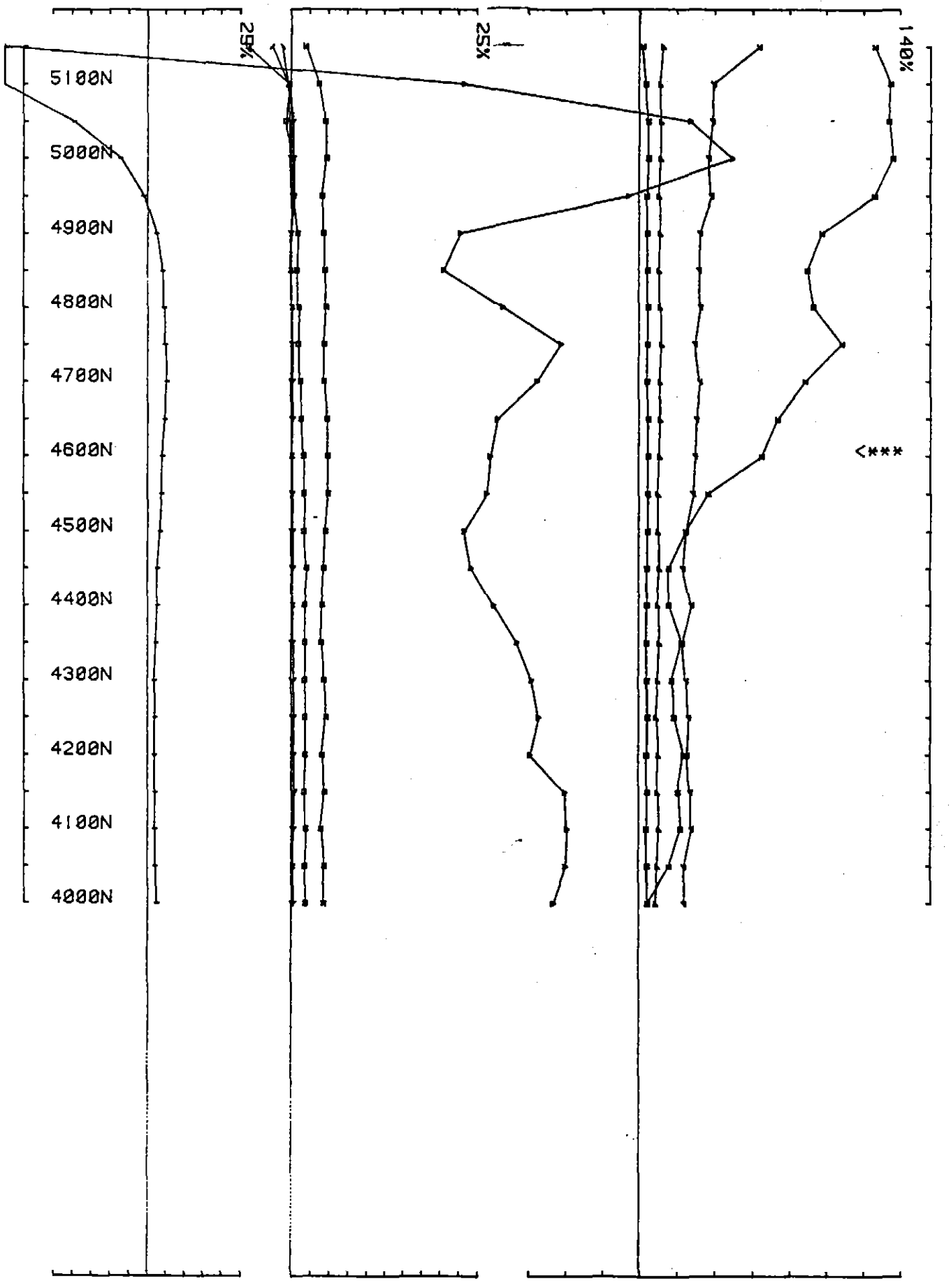

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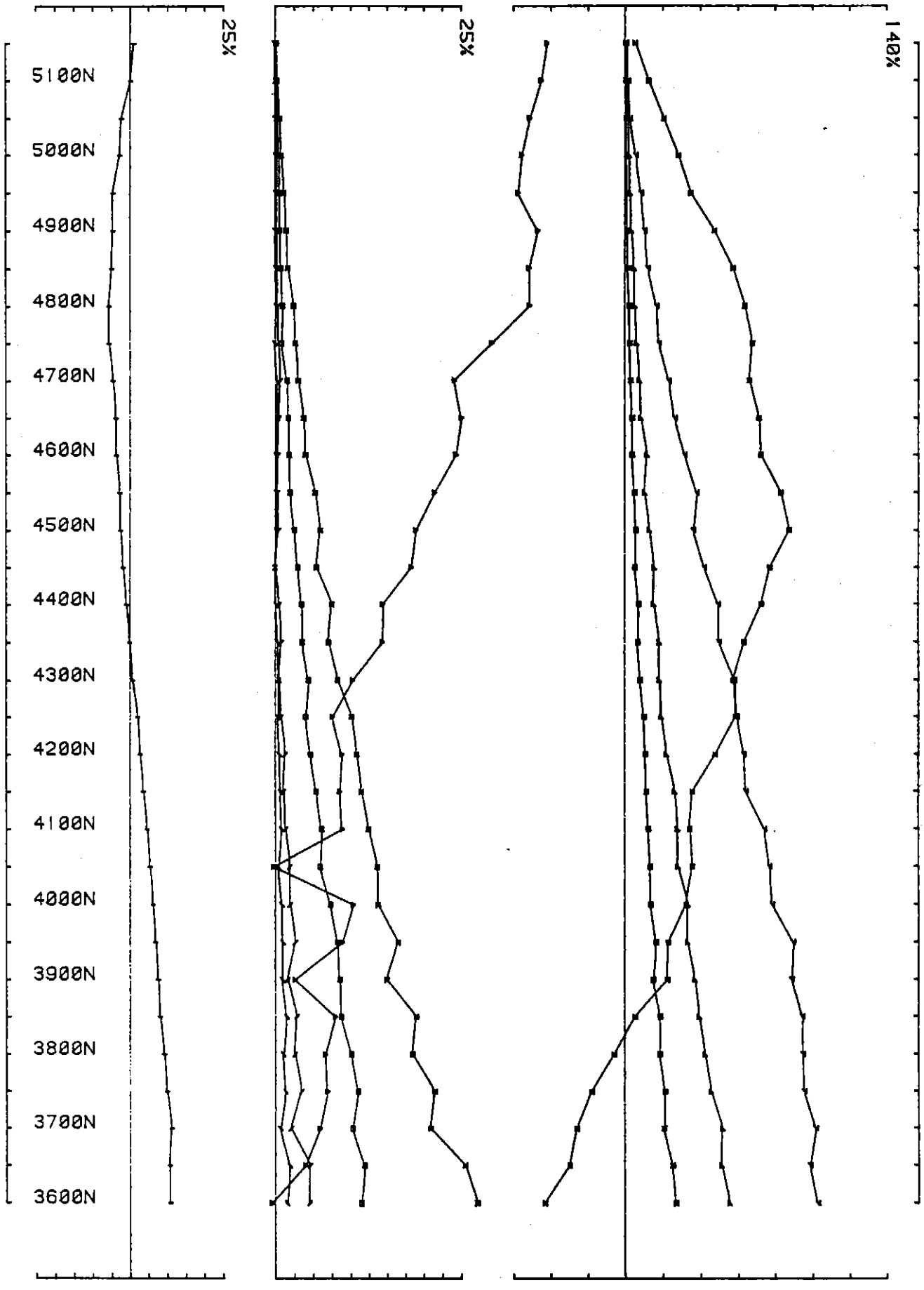

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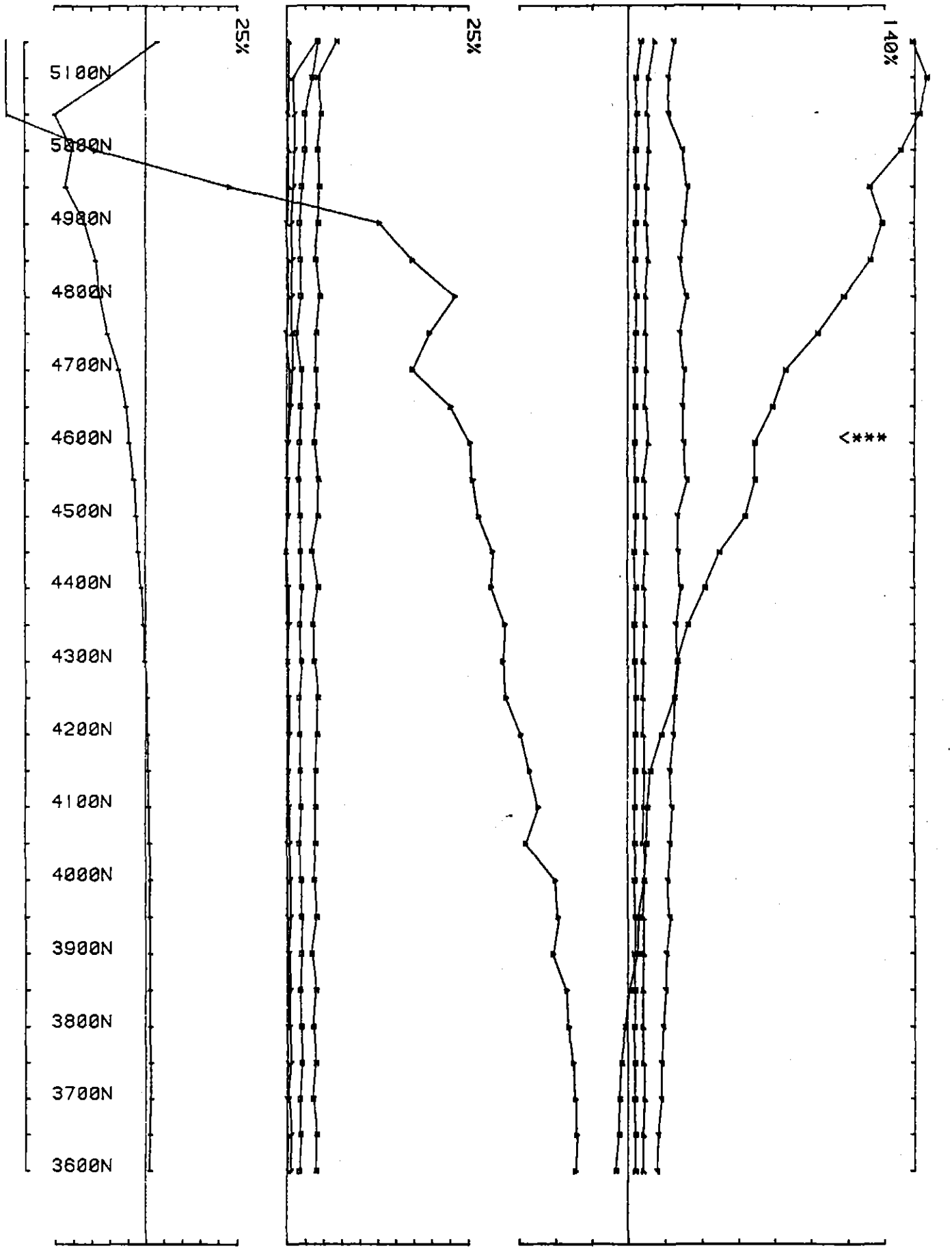

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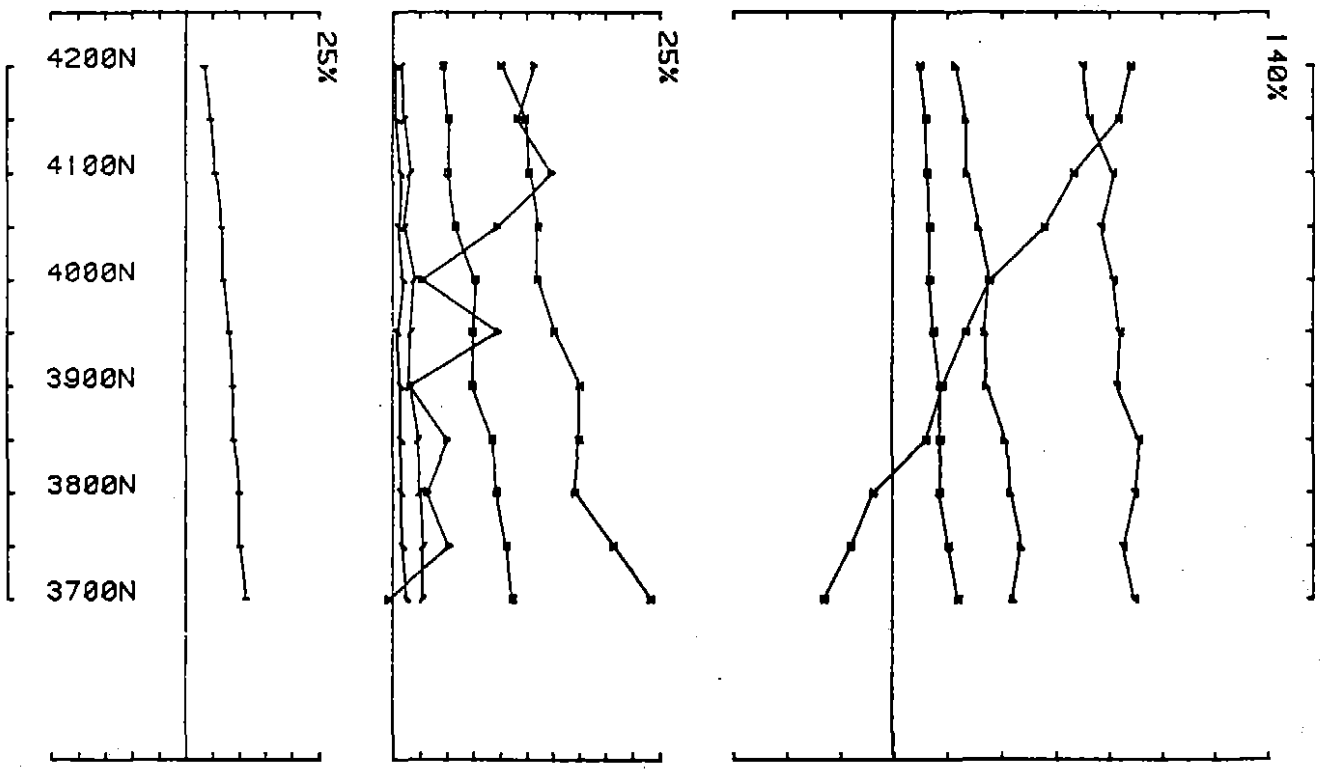

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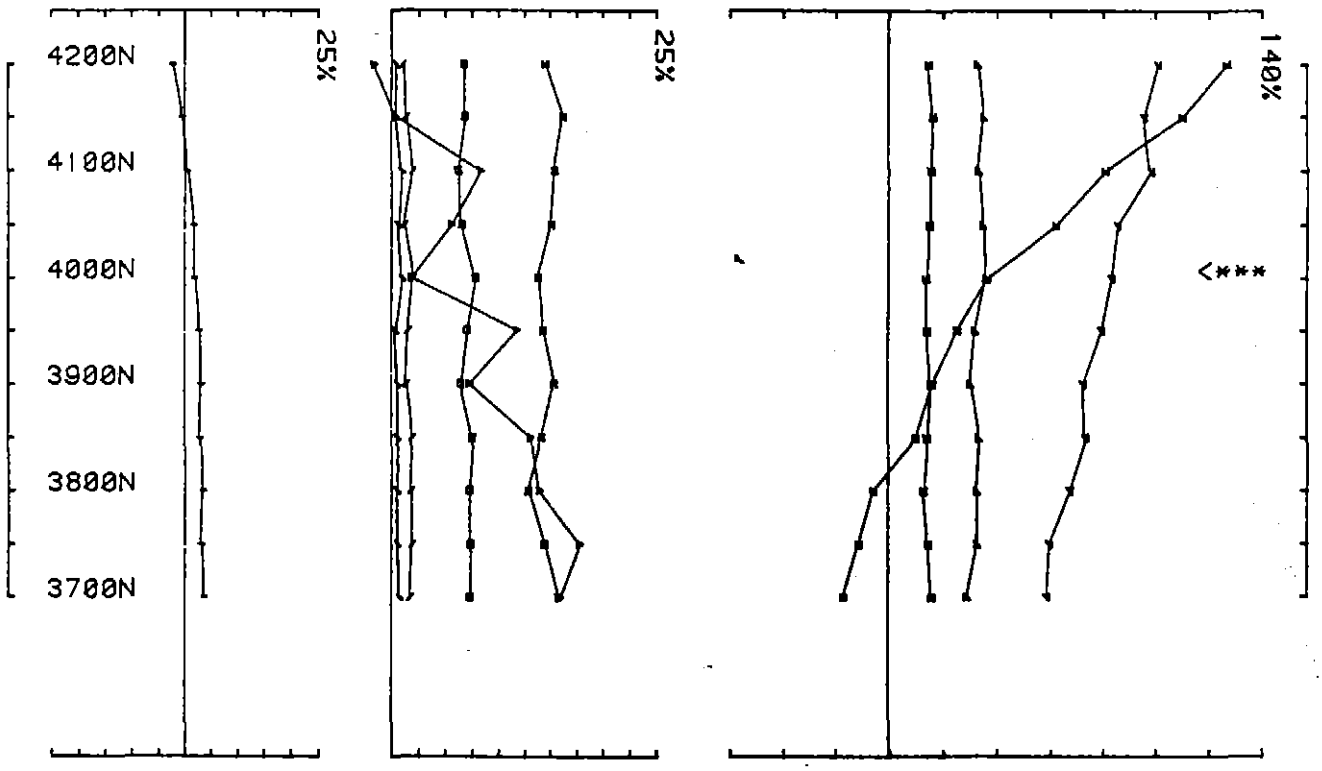

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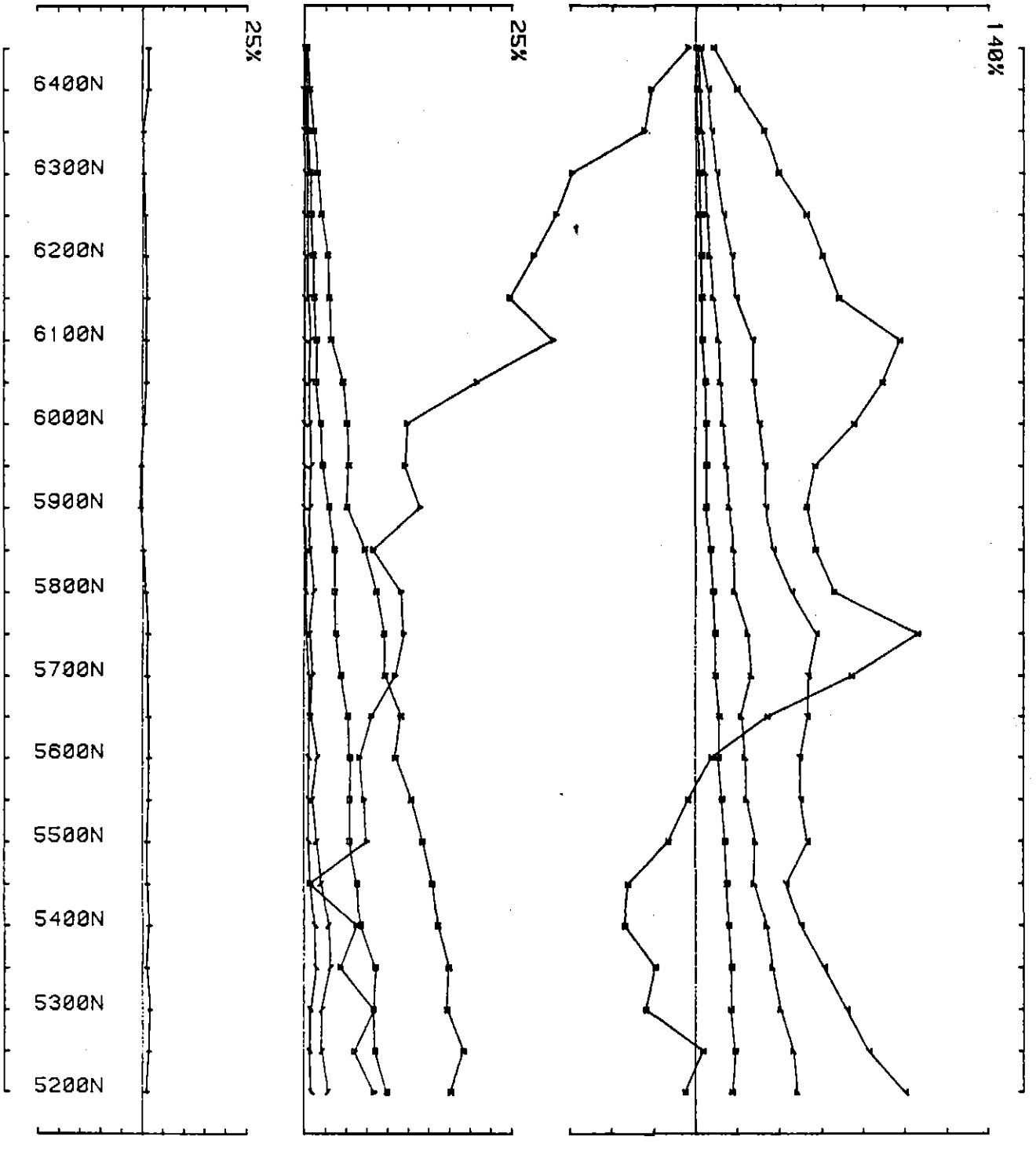

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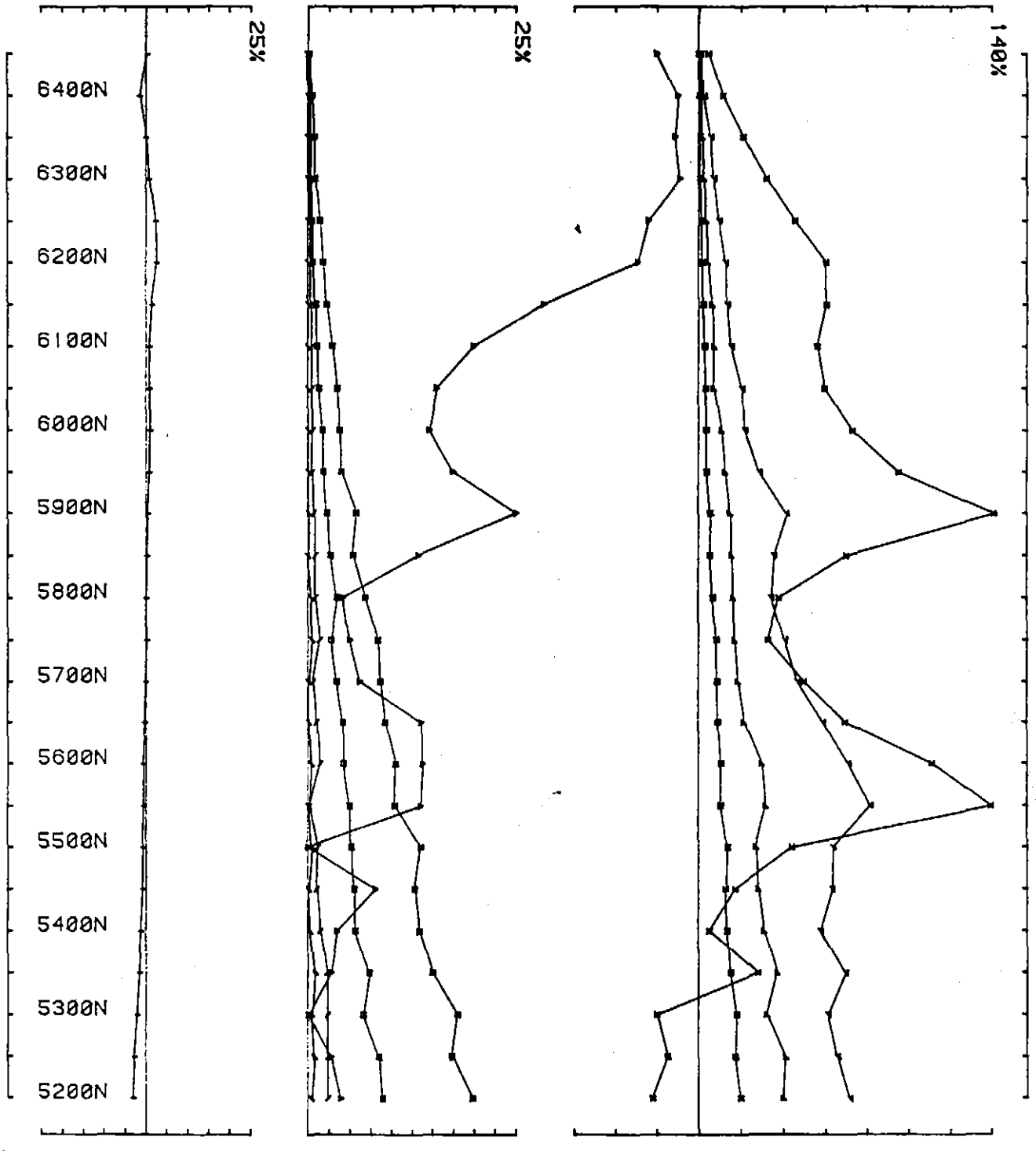

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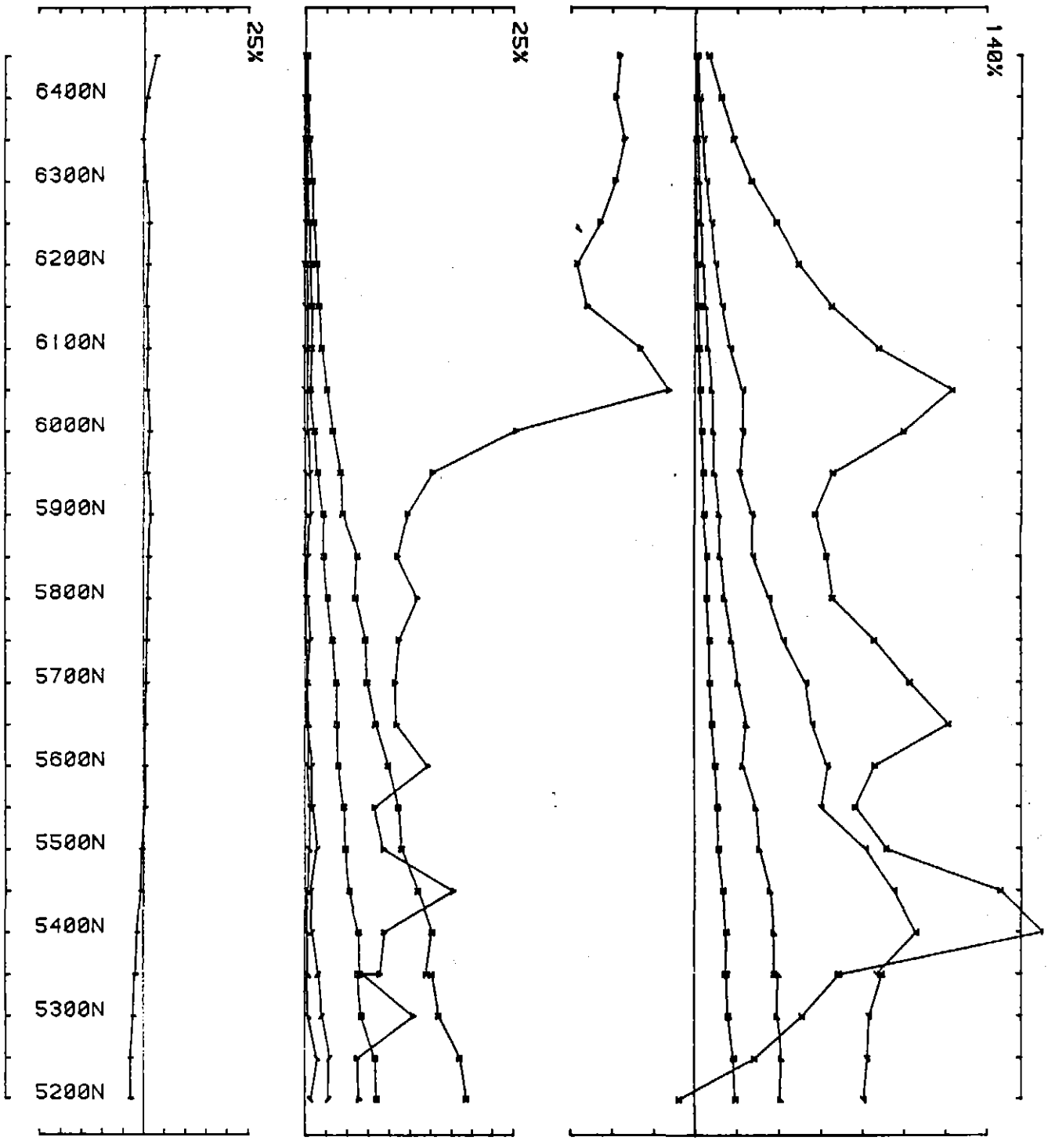

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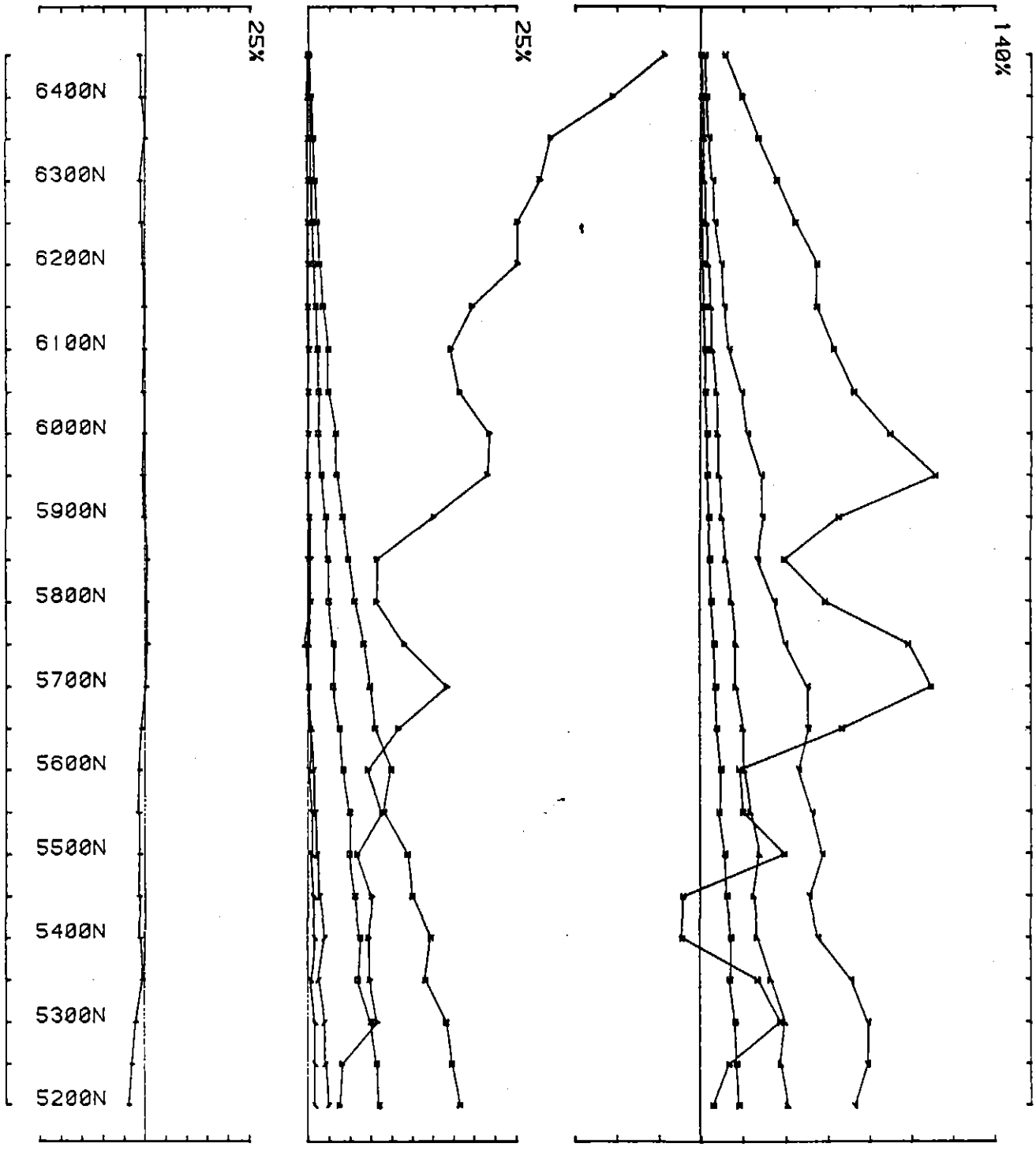

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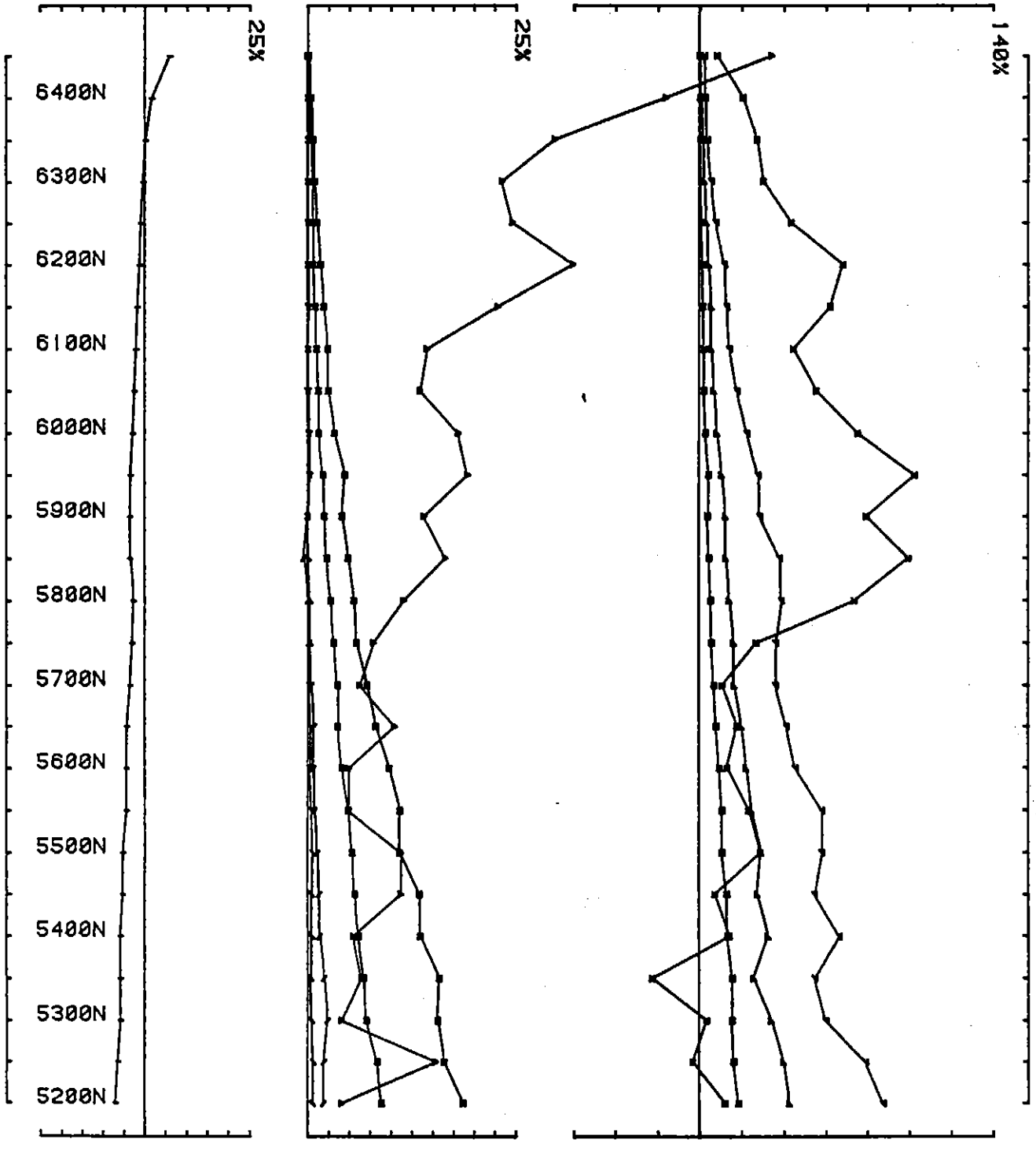

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600052

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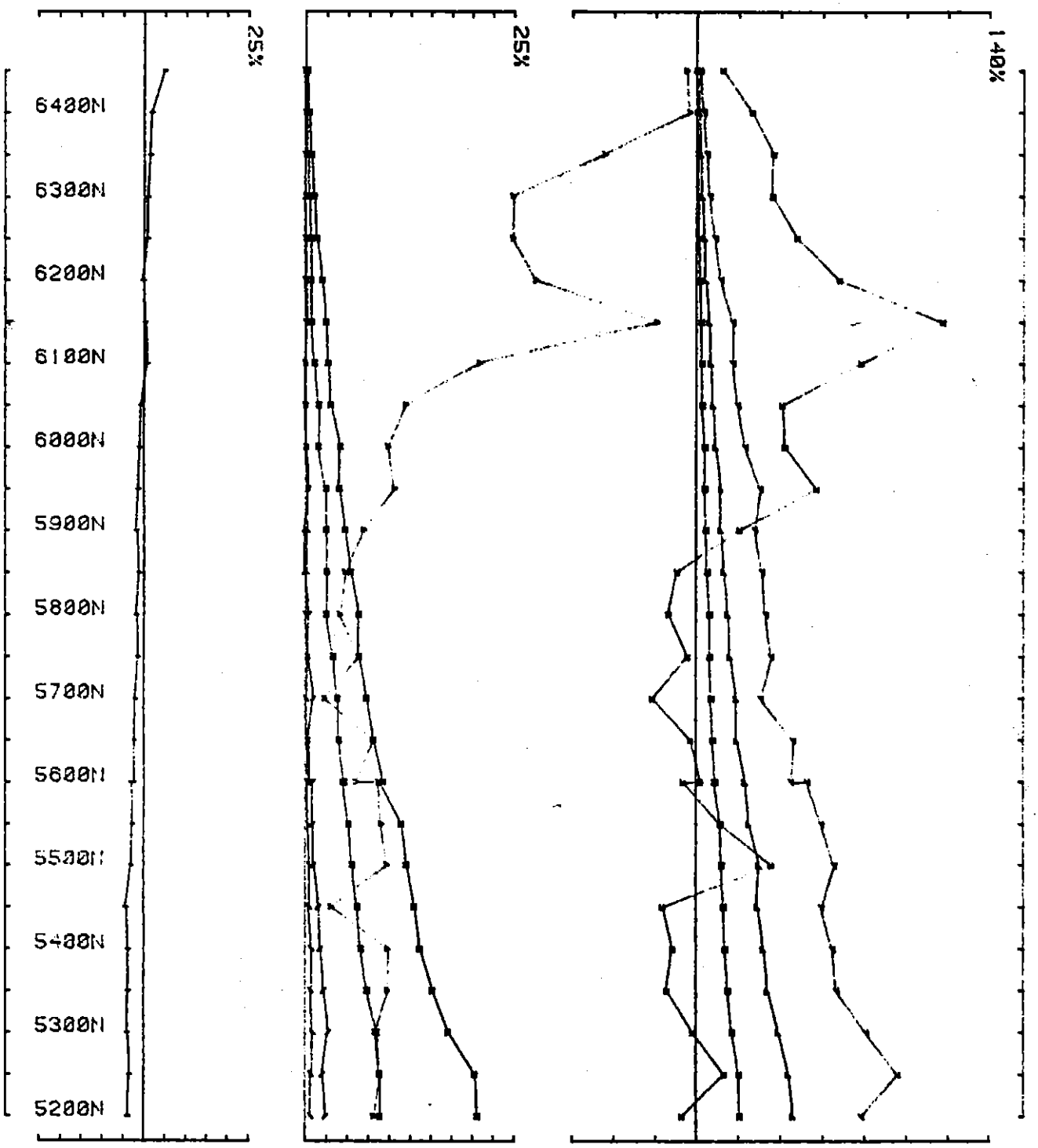

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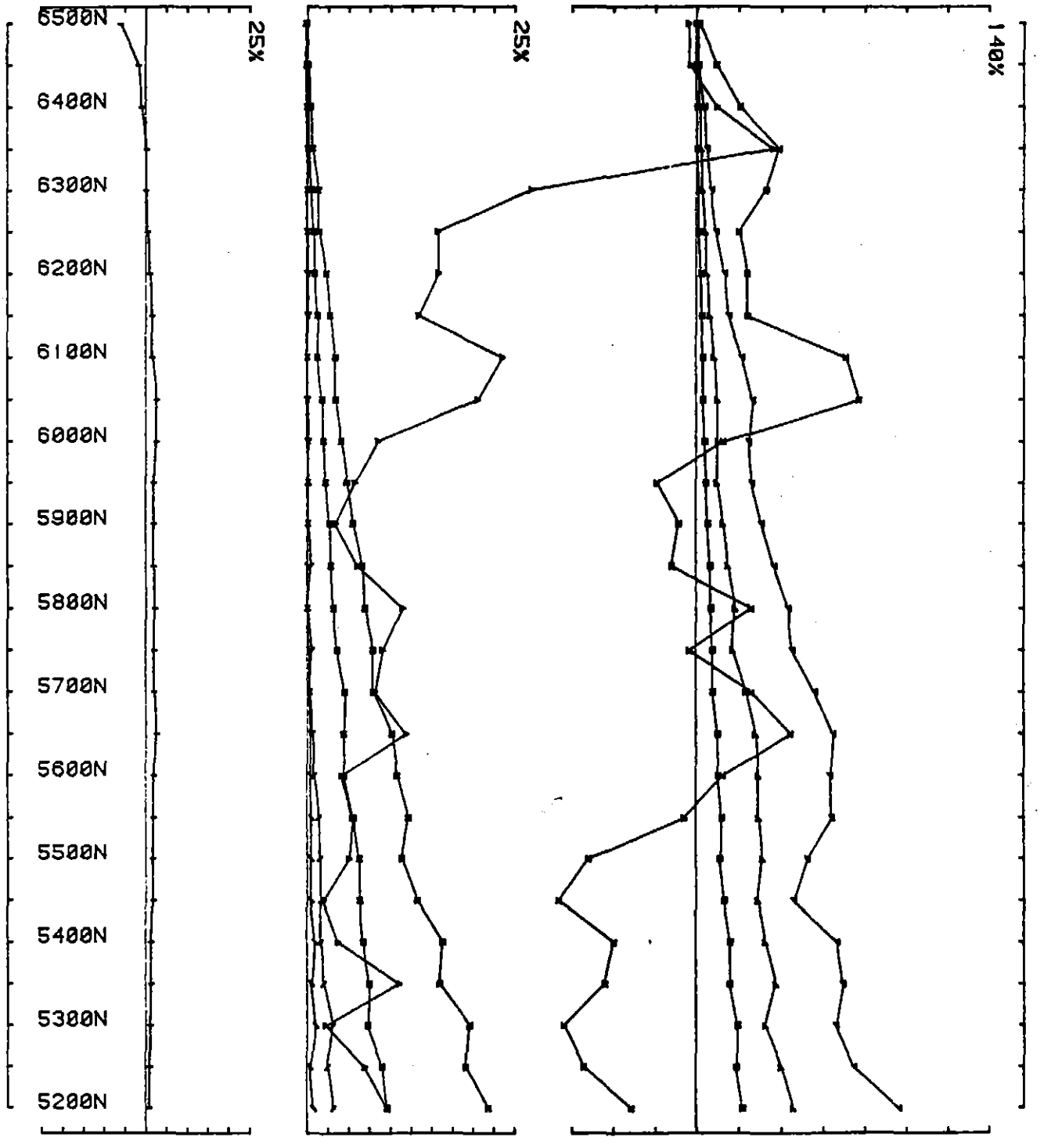

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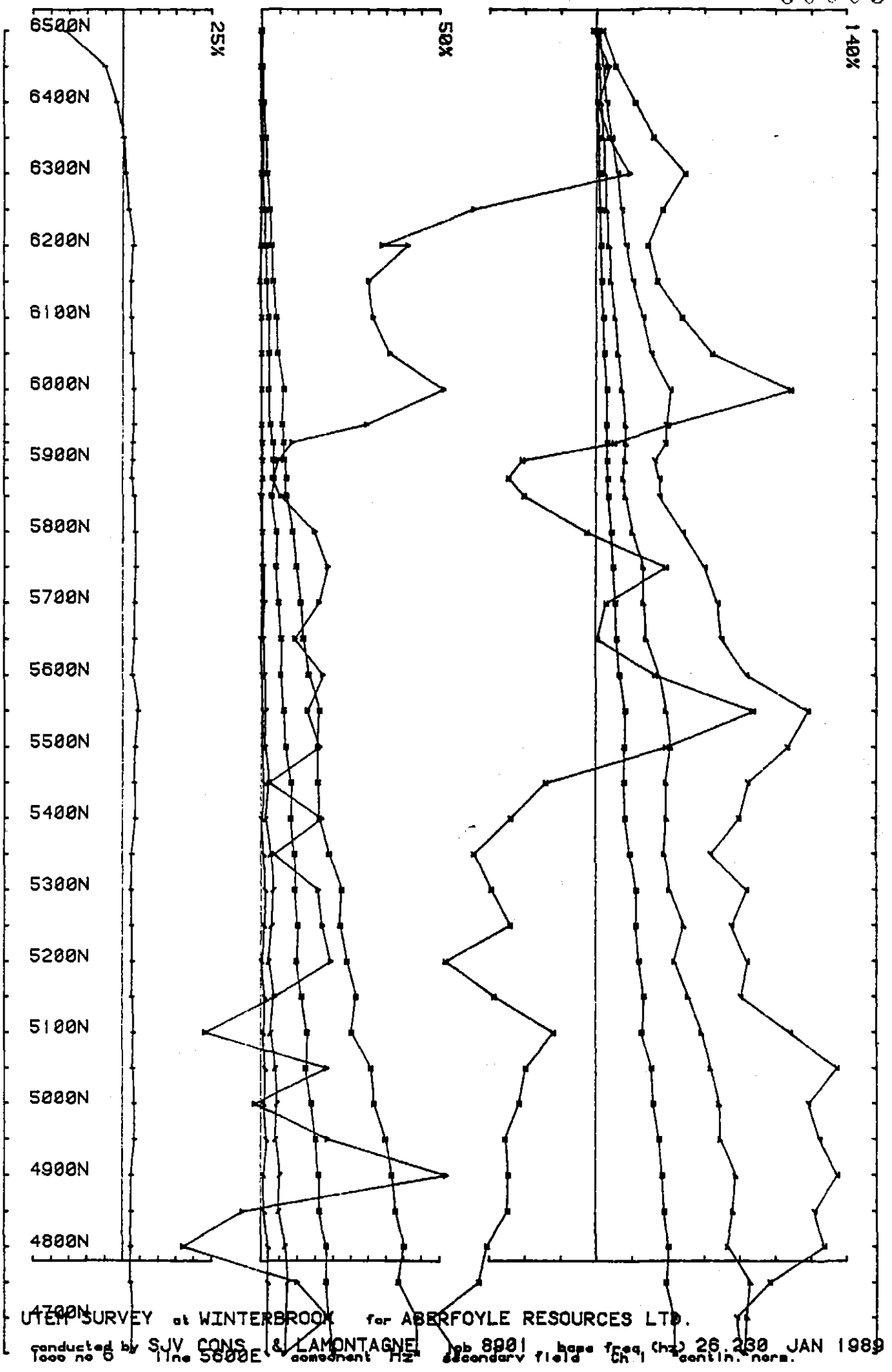

25%
50%
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6500N
6400N
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5400N
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5000N
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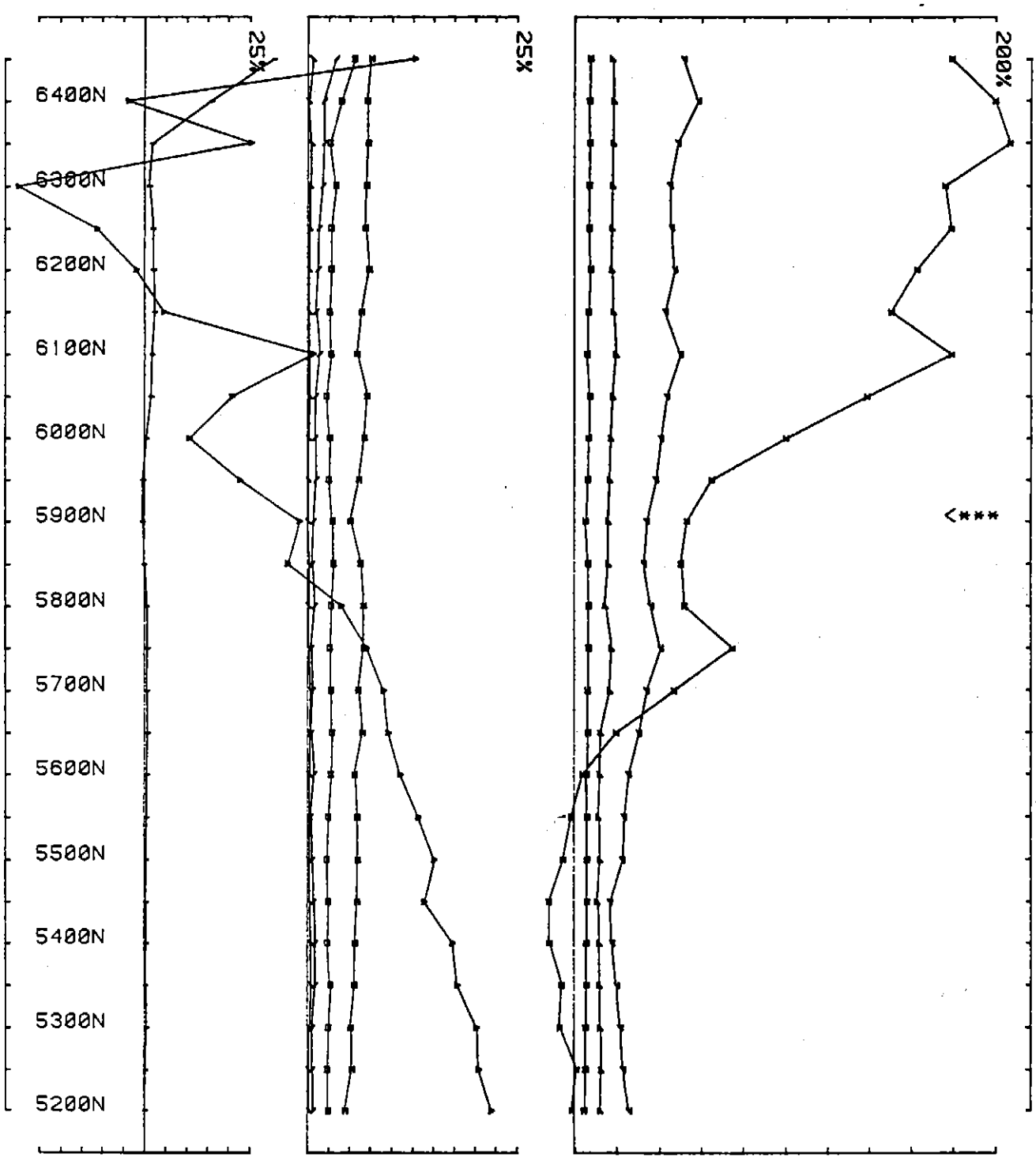

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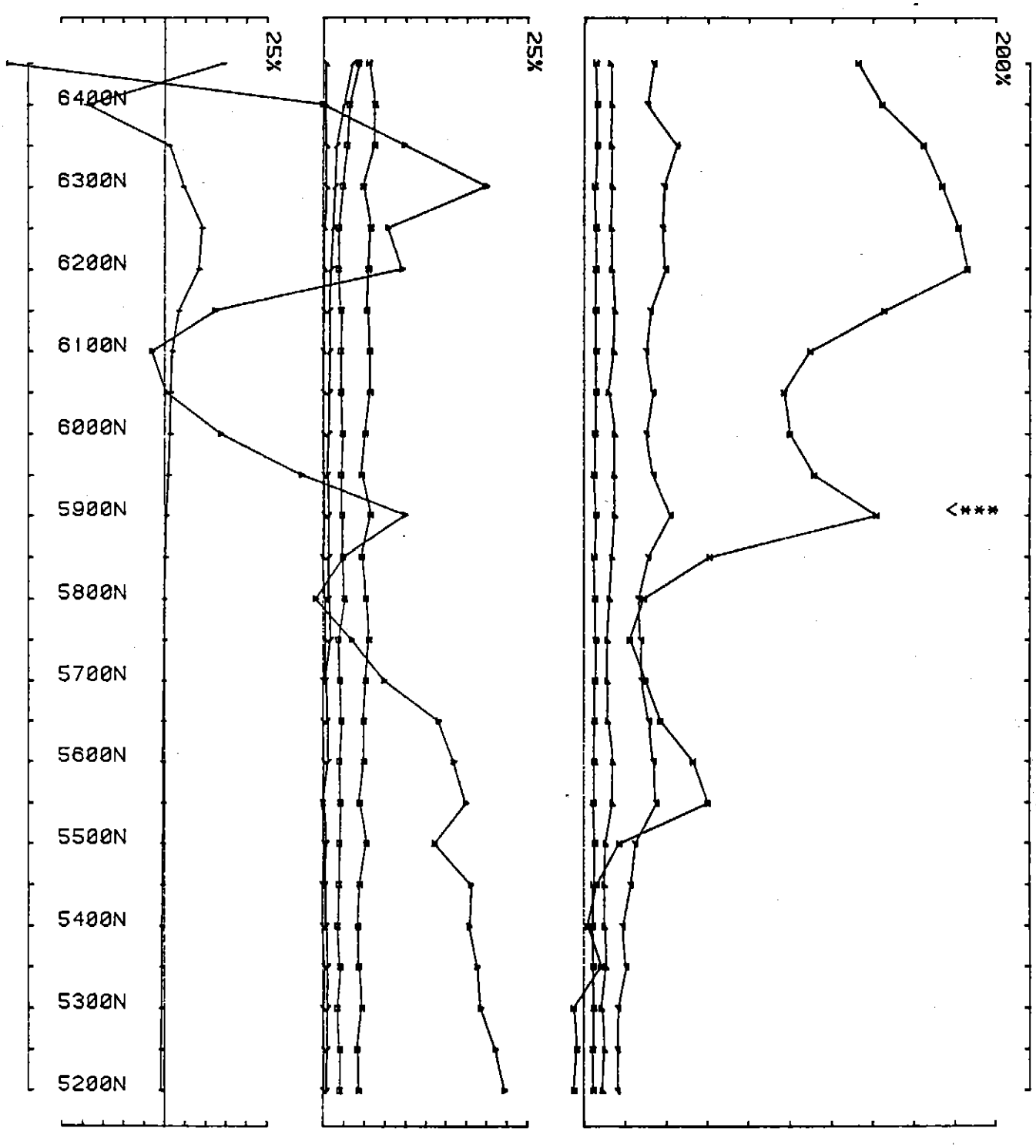

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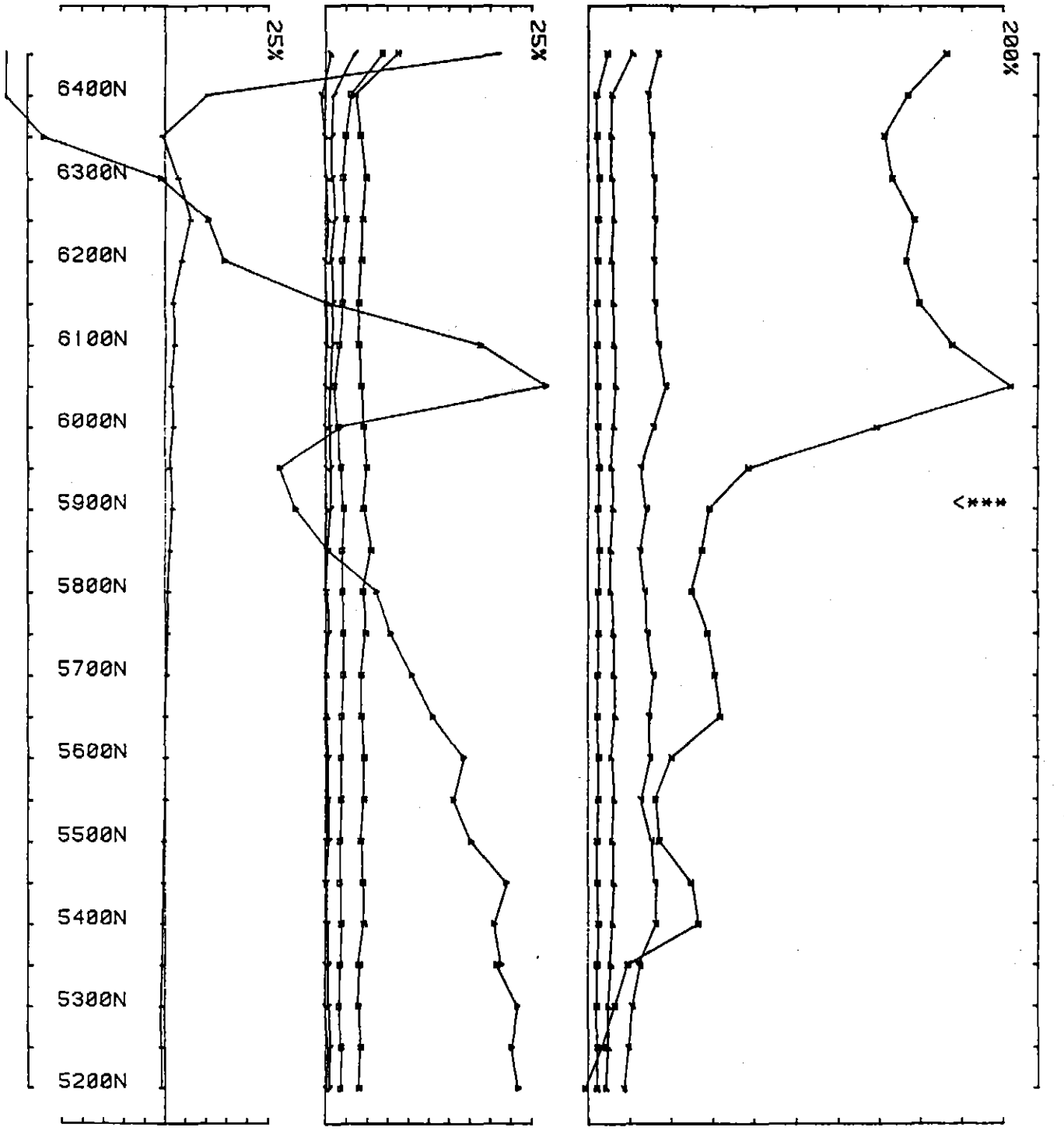

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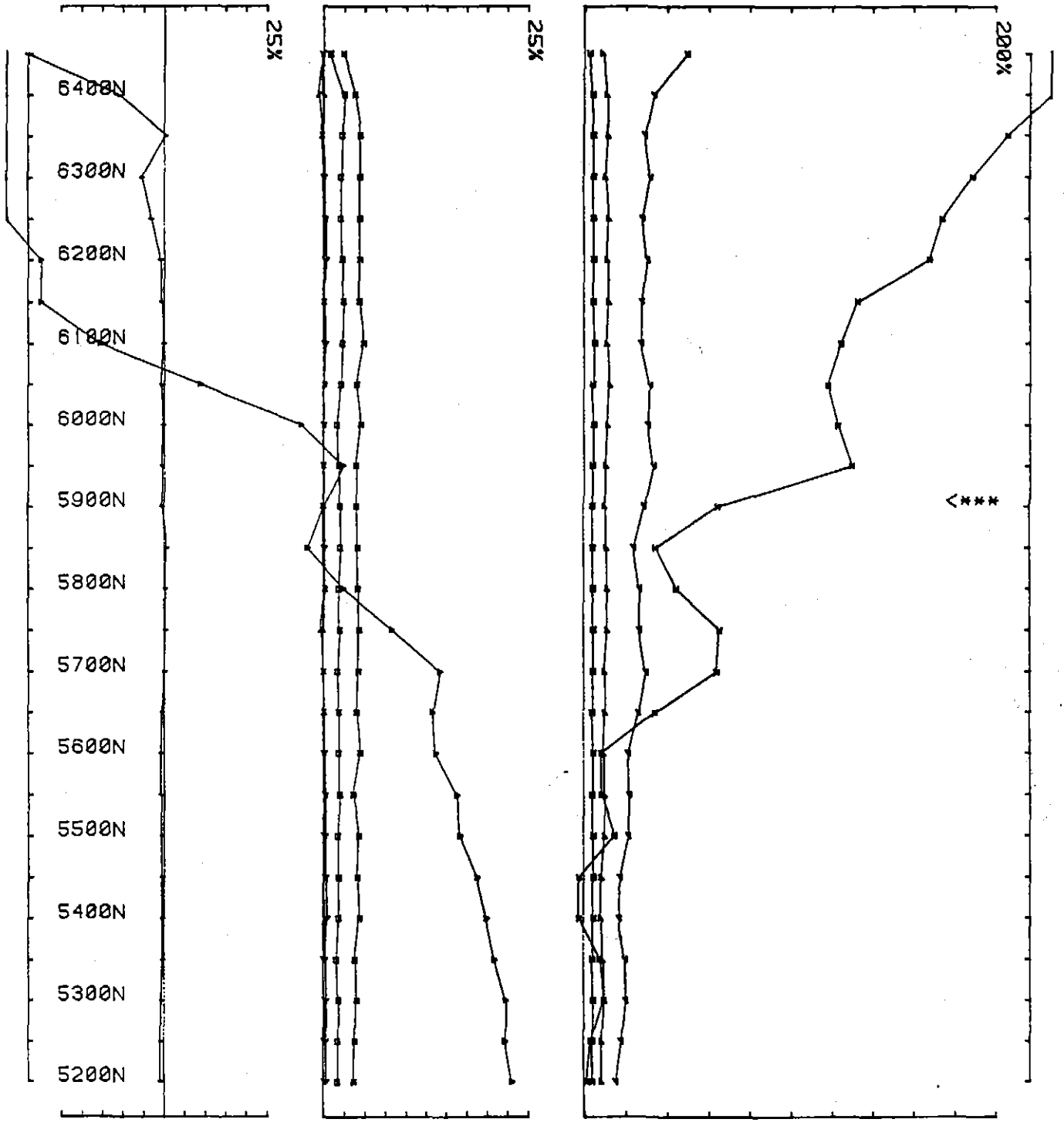

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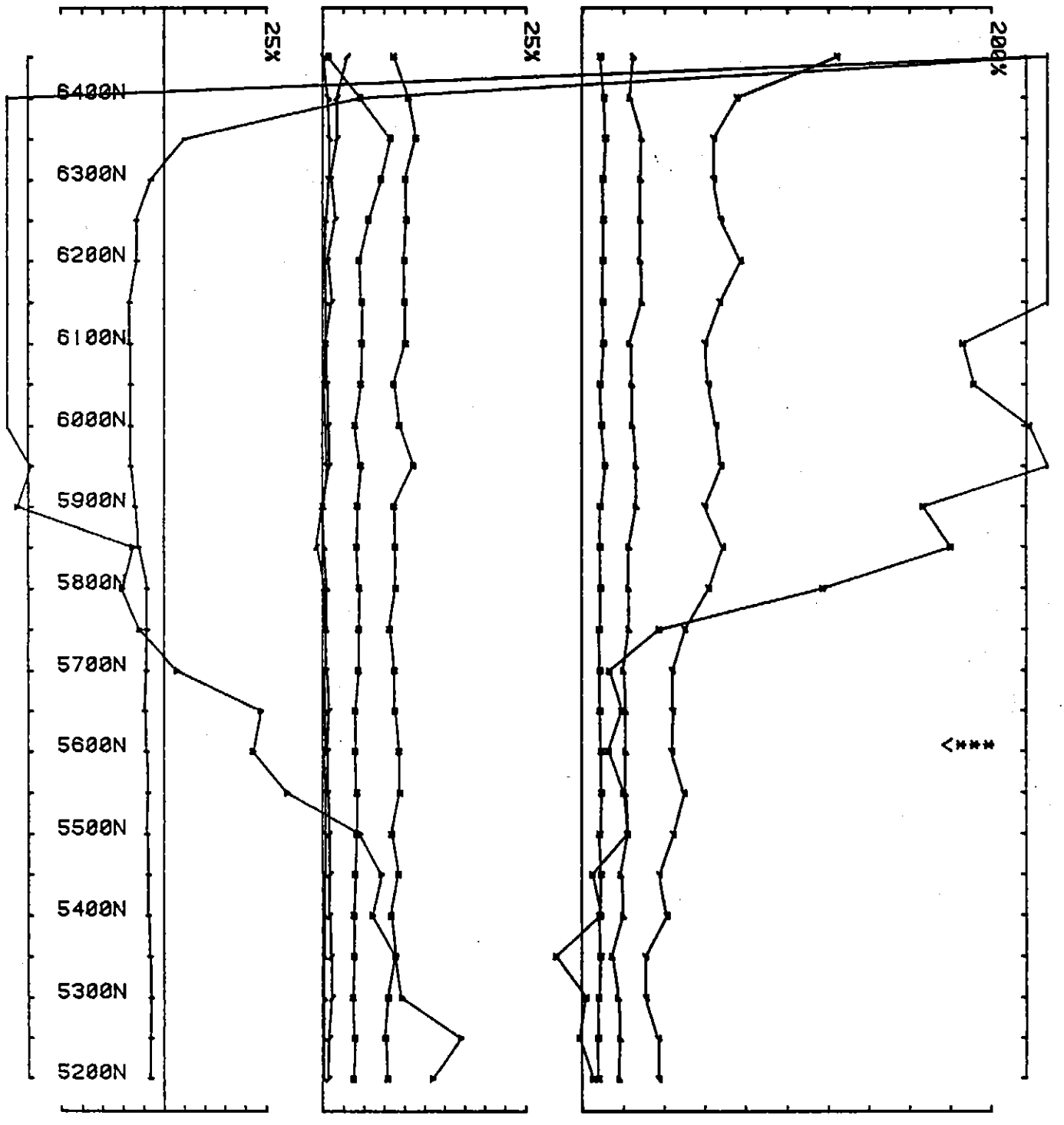
600059



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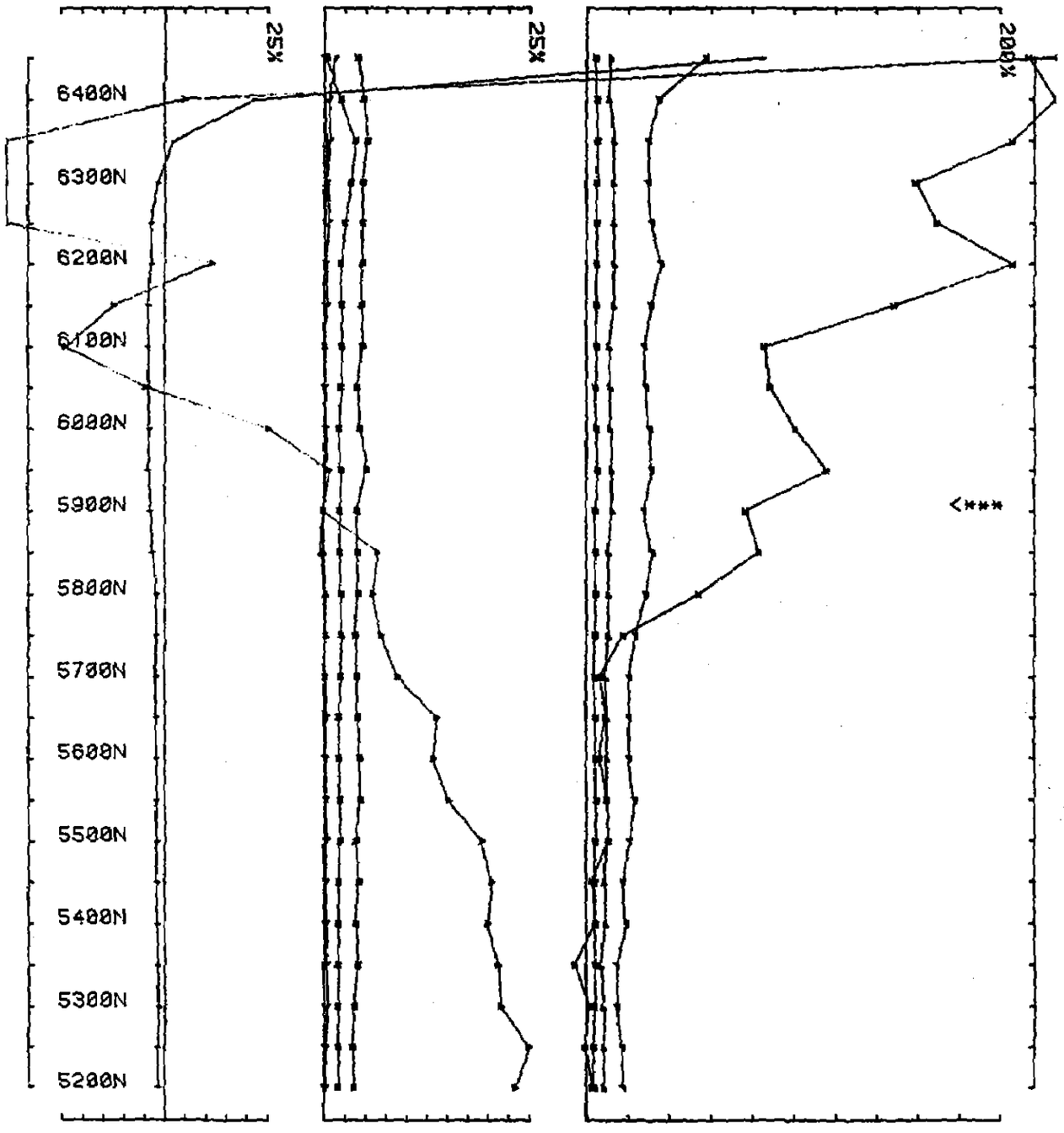

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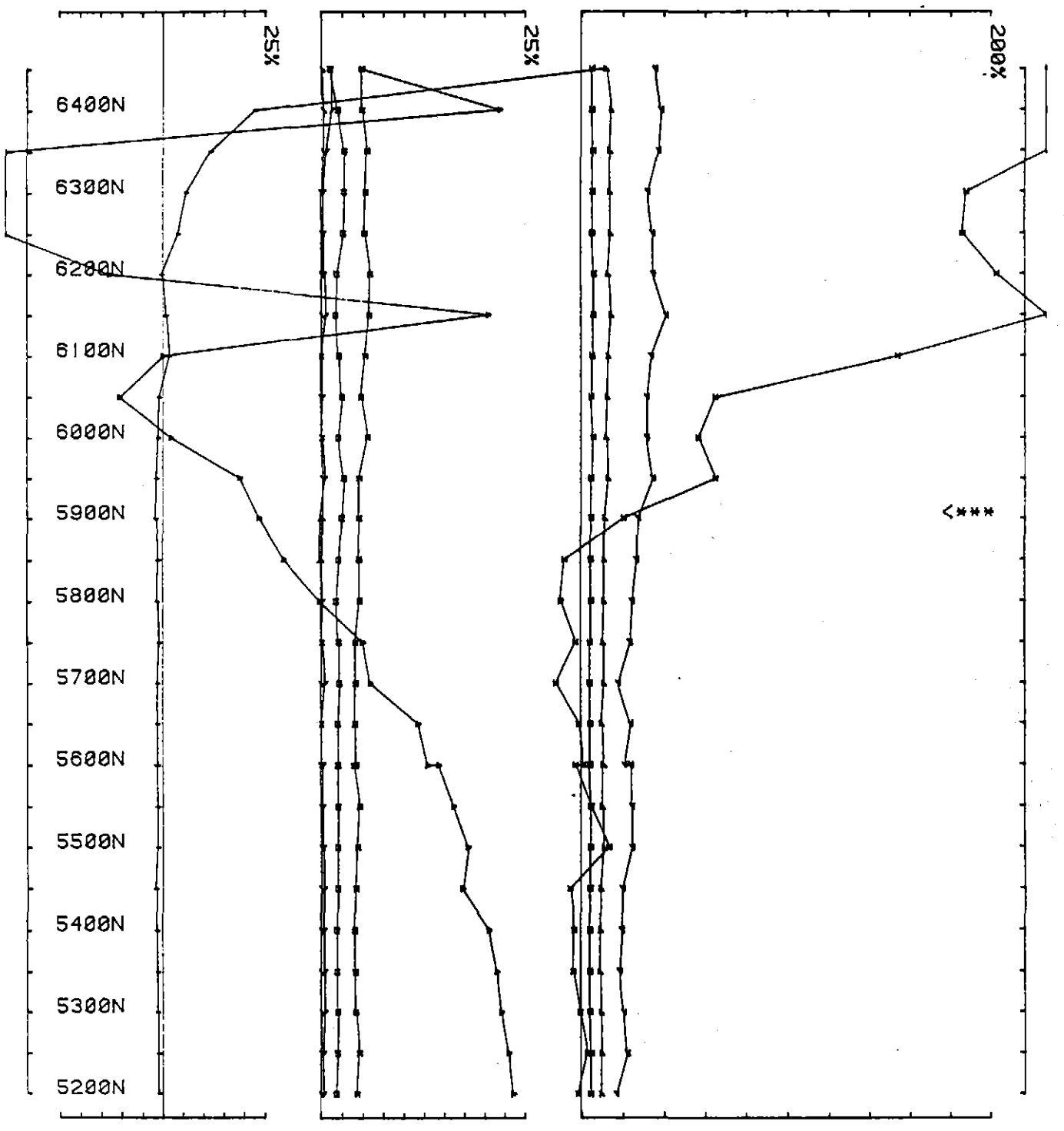

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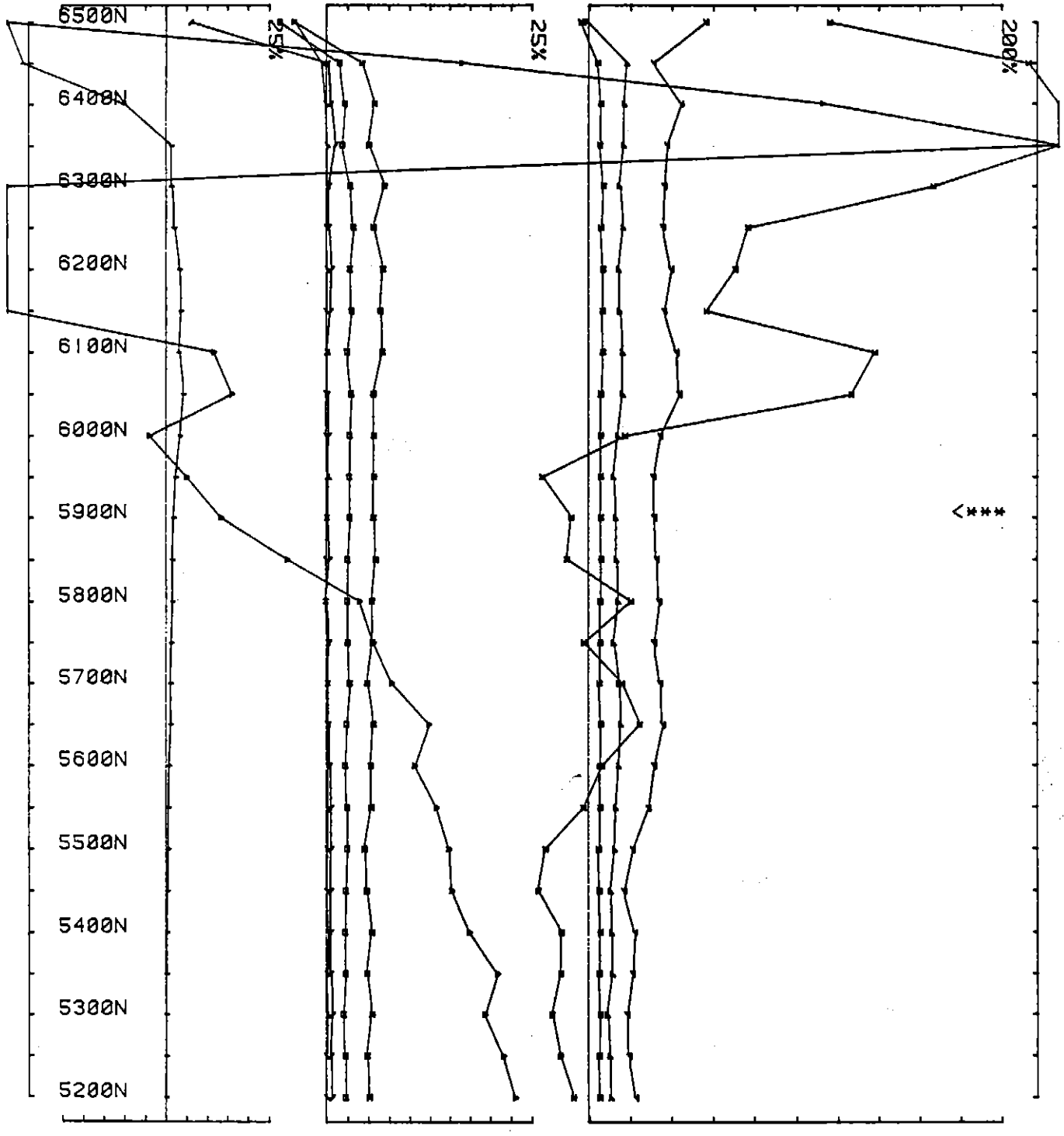

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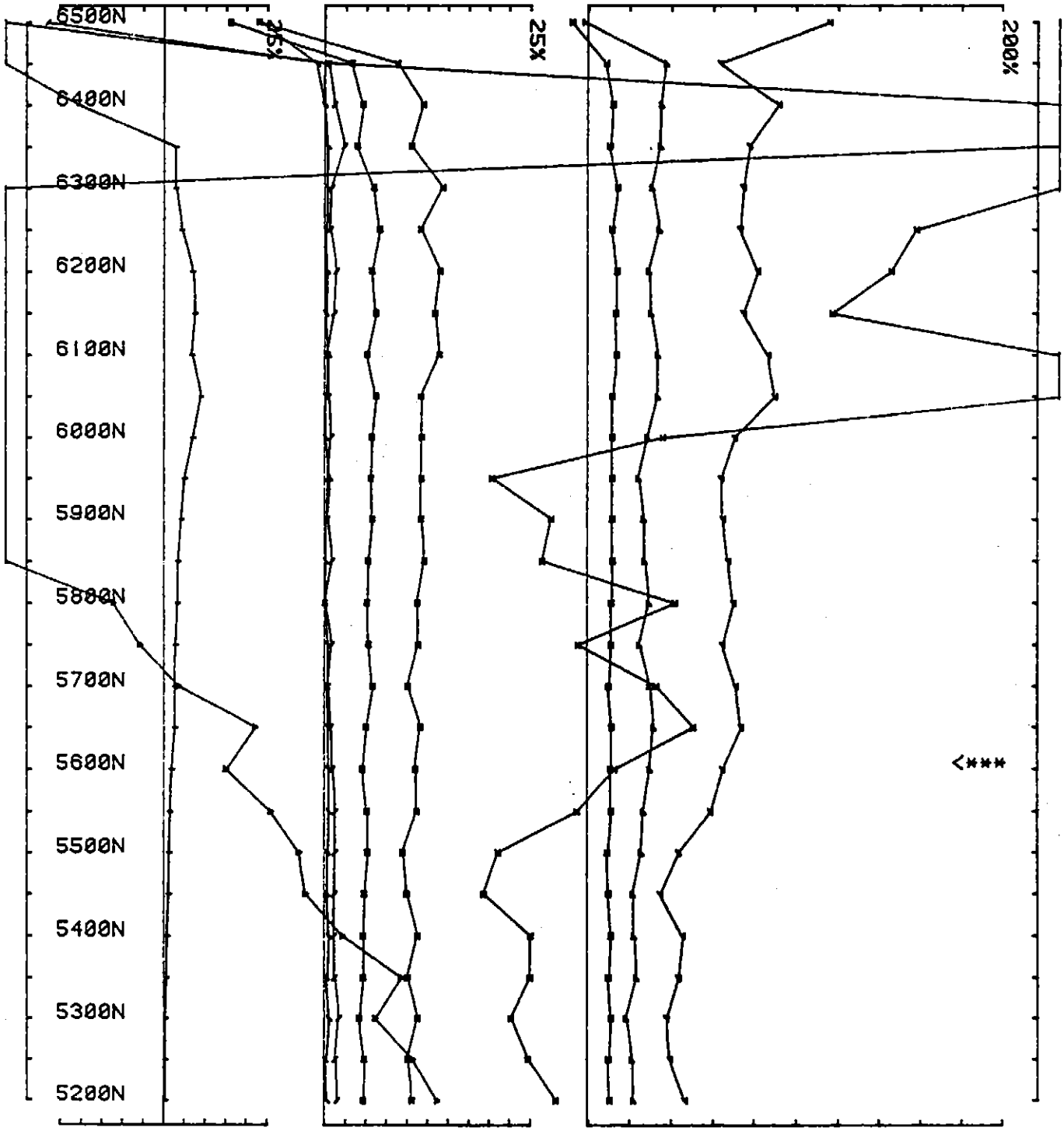

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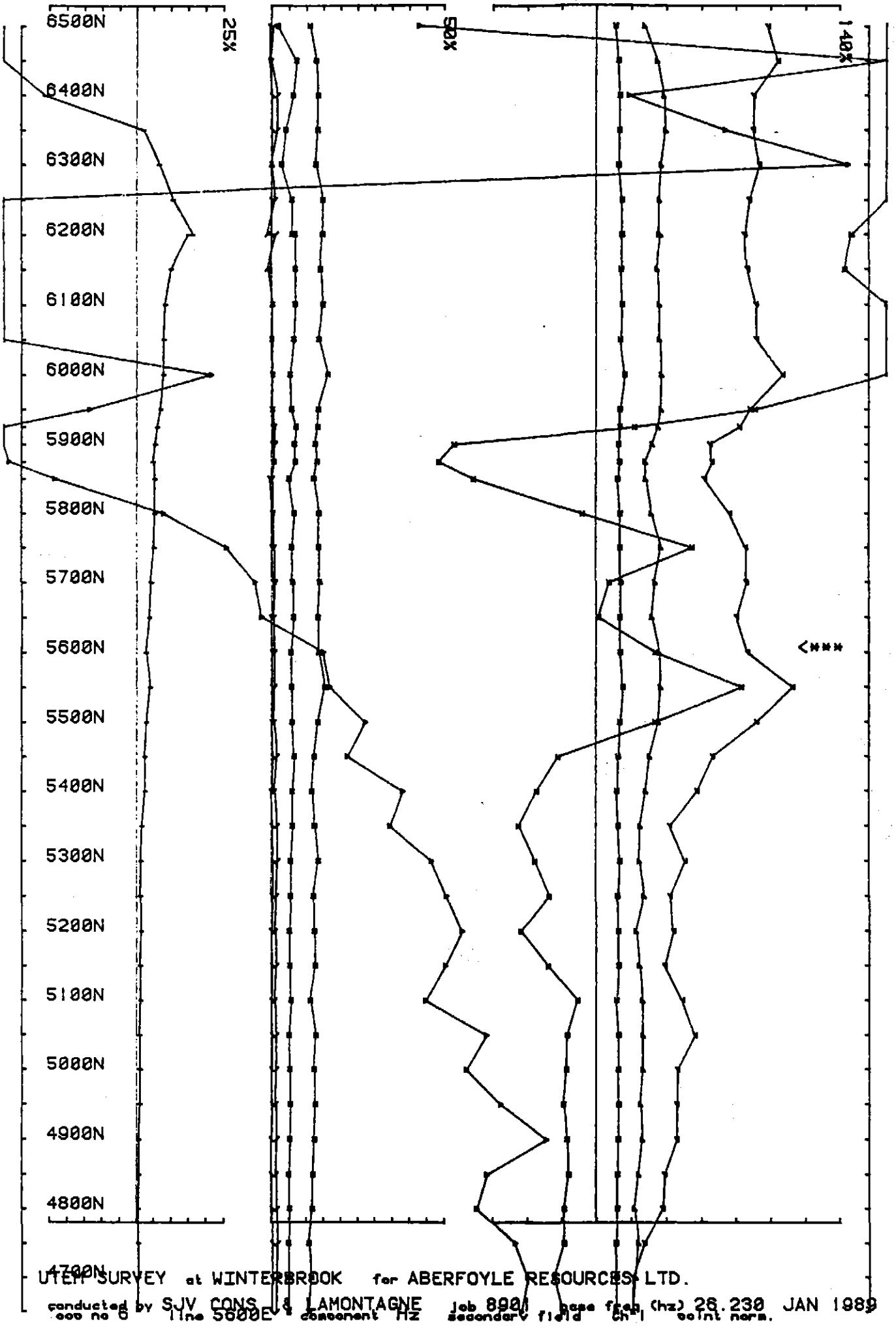

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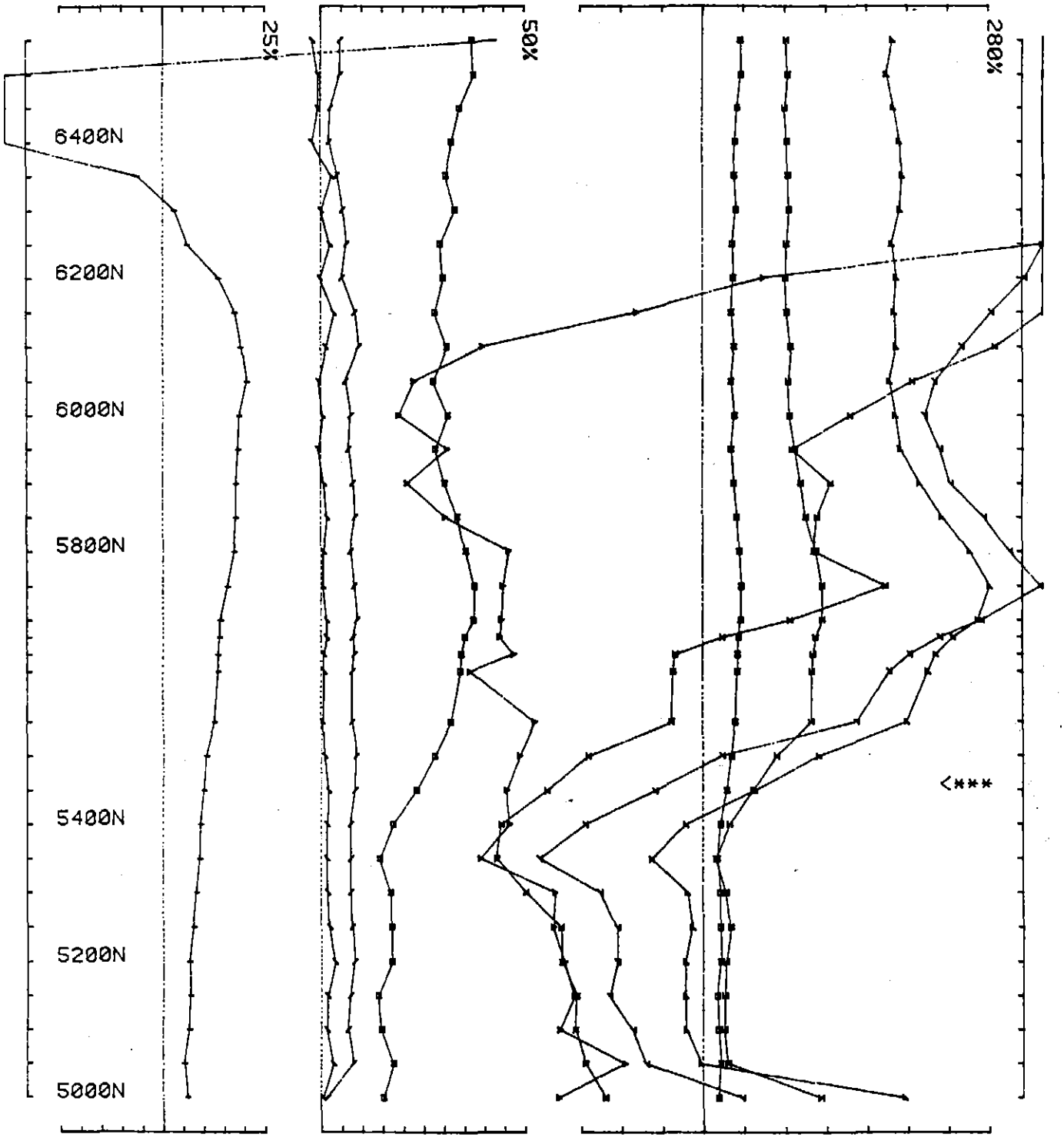
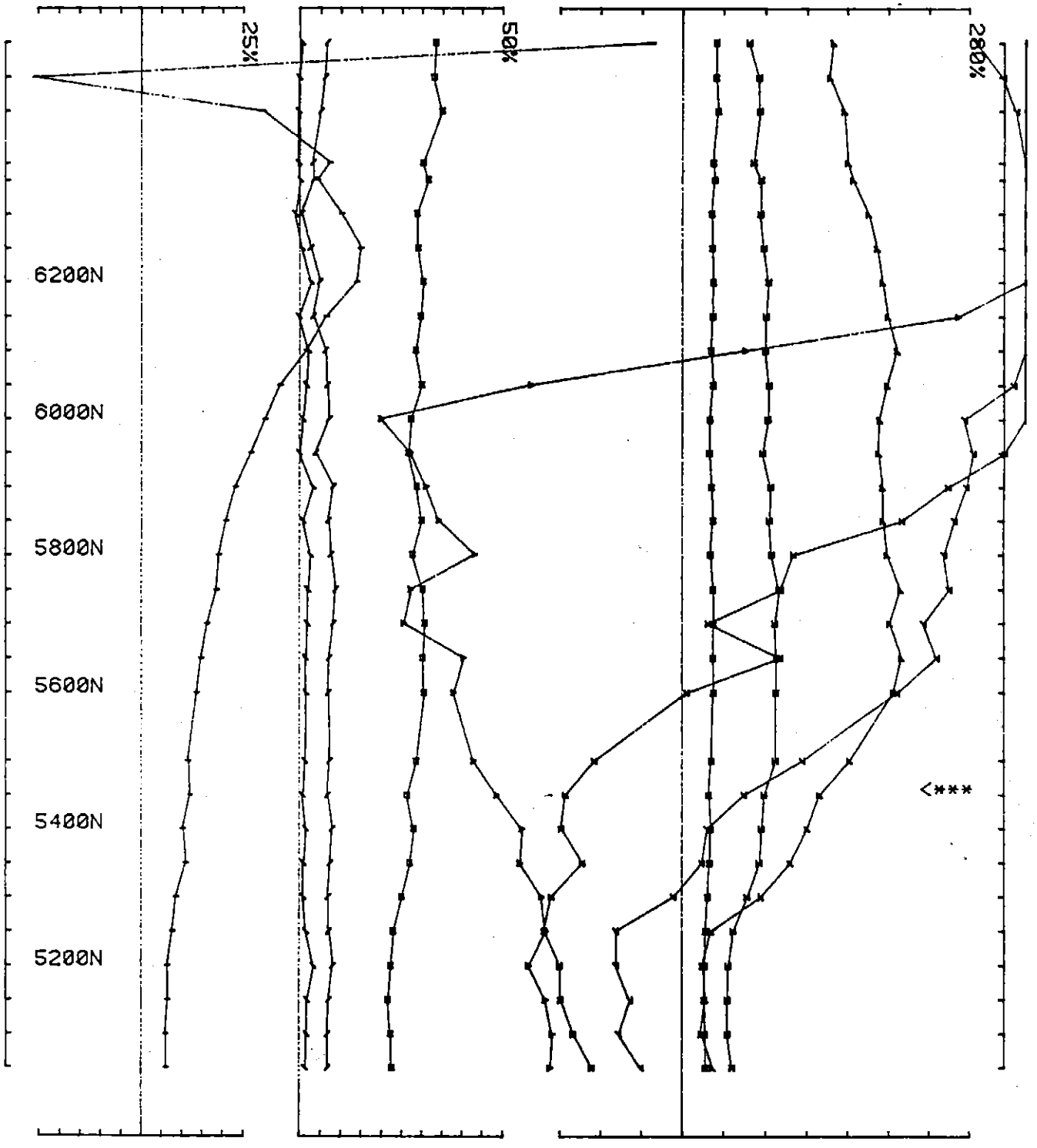
coo no 6 line 5600E component Hz secondary field Ch 1 point norm.



LAMONTAGNE GEOPHYSICS LTD Job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
2200x1800m

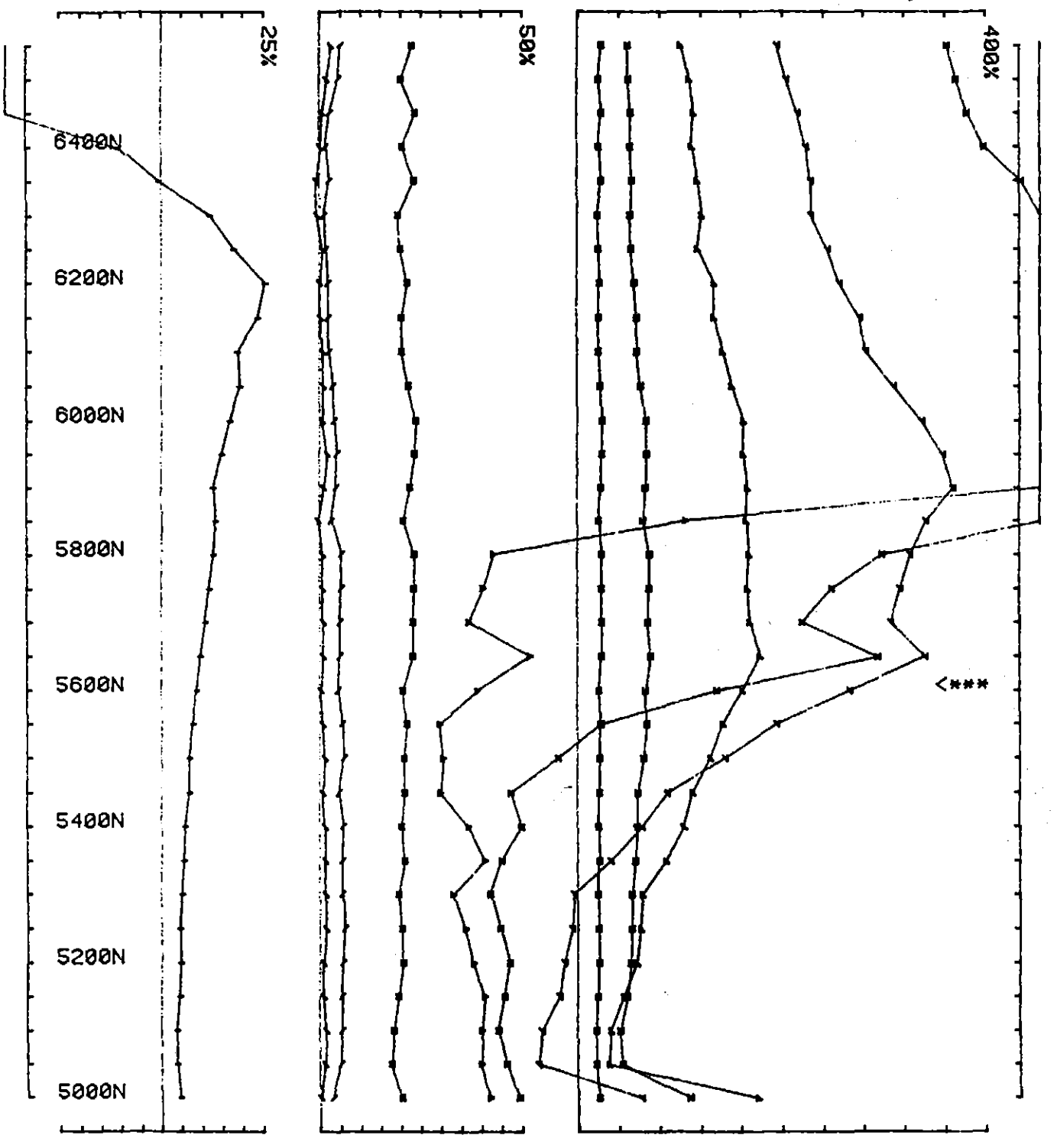
loop no 1
line 7800E
component Hz
secondary field
Ch 1 point norm.
20/11/88



LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
2200x1000m

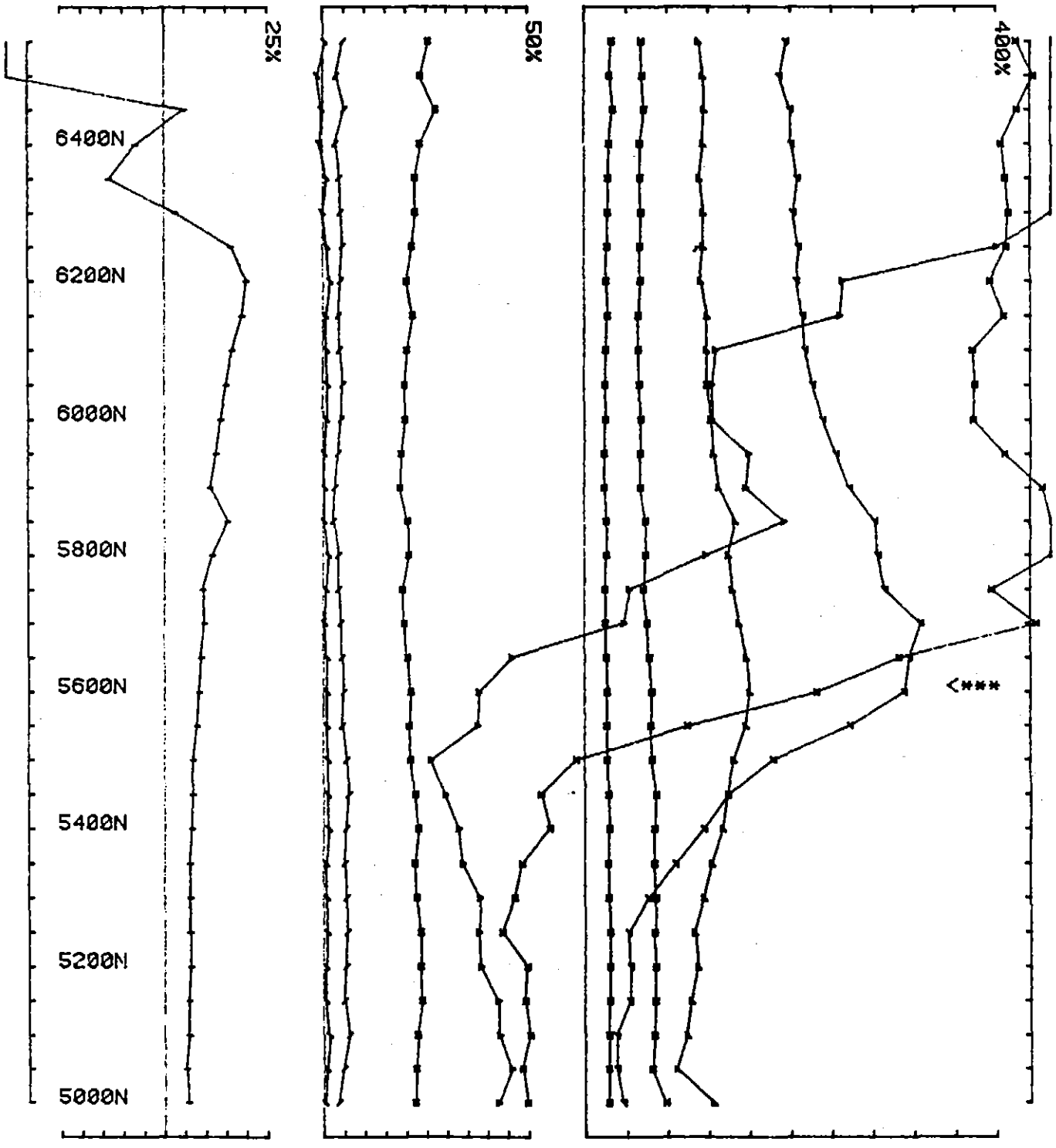
loop no 1
line 8000E
component Hz
secondary field
Ch 1 point norm.
20/11/88



LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
2200x1800m

loop no 1
line 8200E
component Hz
secondary field
Ch 1 point norm.
19/11/88



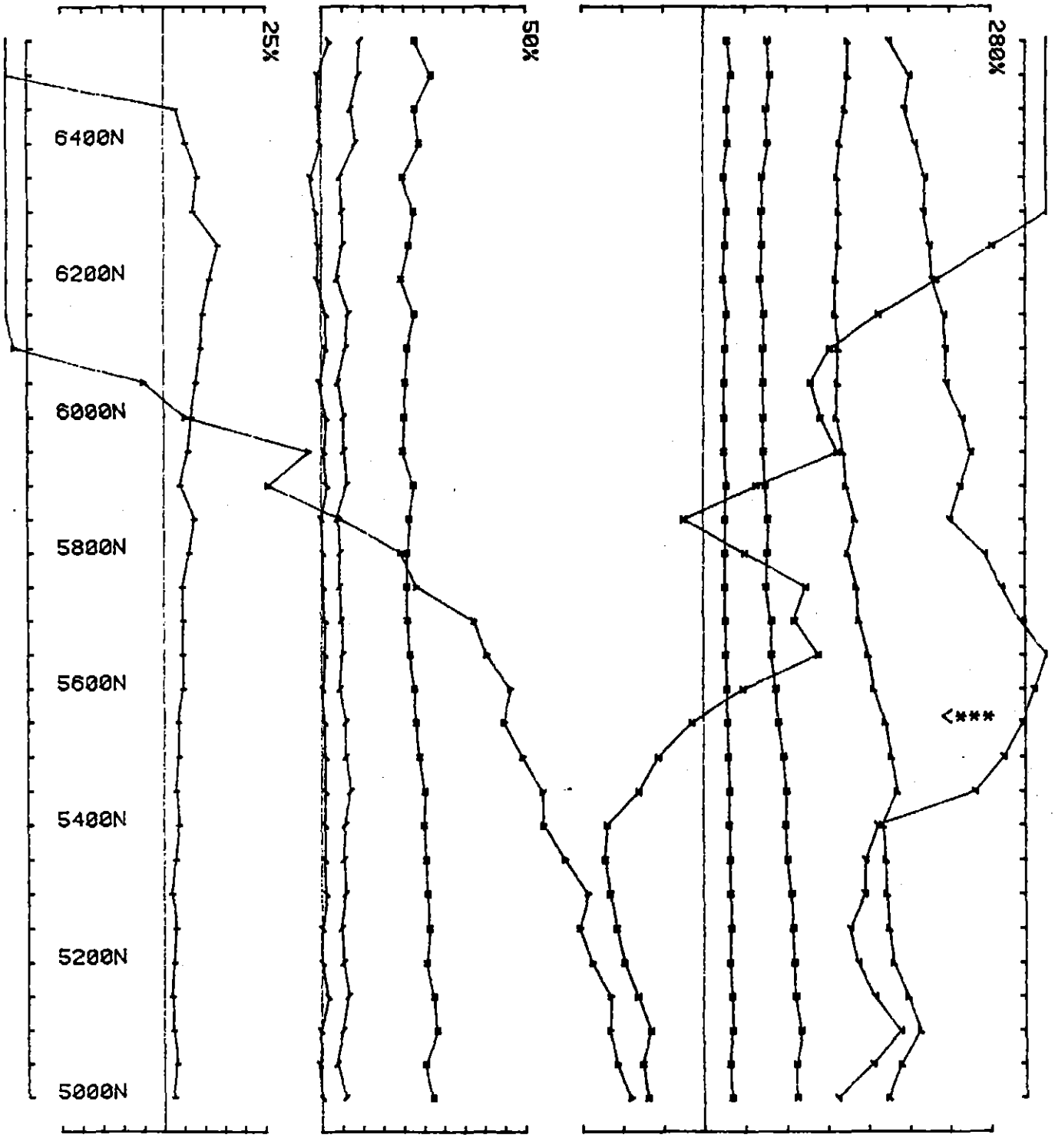
LAMONTAGNE GEOPHYSICS LTD Job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
2200x1800m

loop no 1
line 8400E
component Hz
secondary field
Ch 1 point norm.
19/11/88

600069

0h8

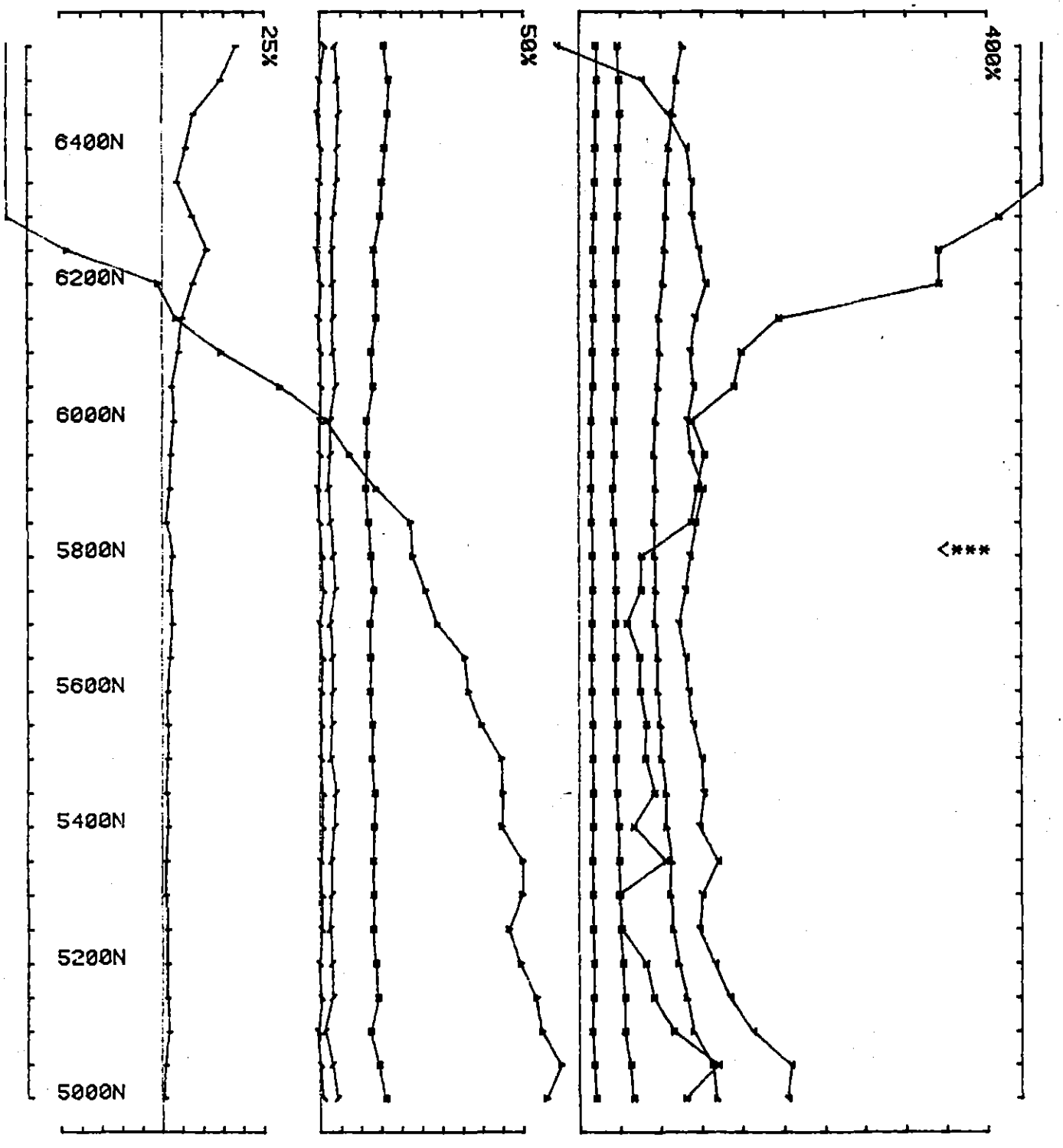


LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
2200x10000m

loop no 1
line 8600E
component Hz
secondary field
Ch 1 point nore.
18/11/88

600070



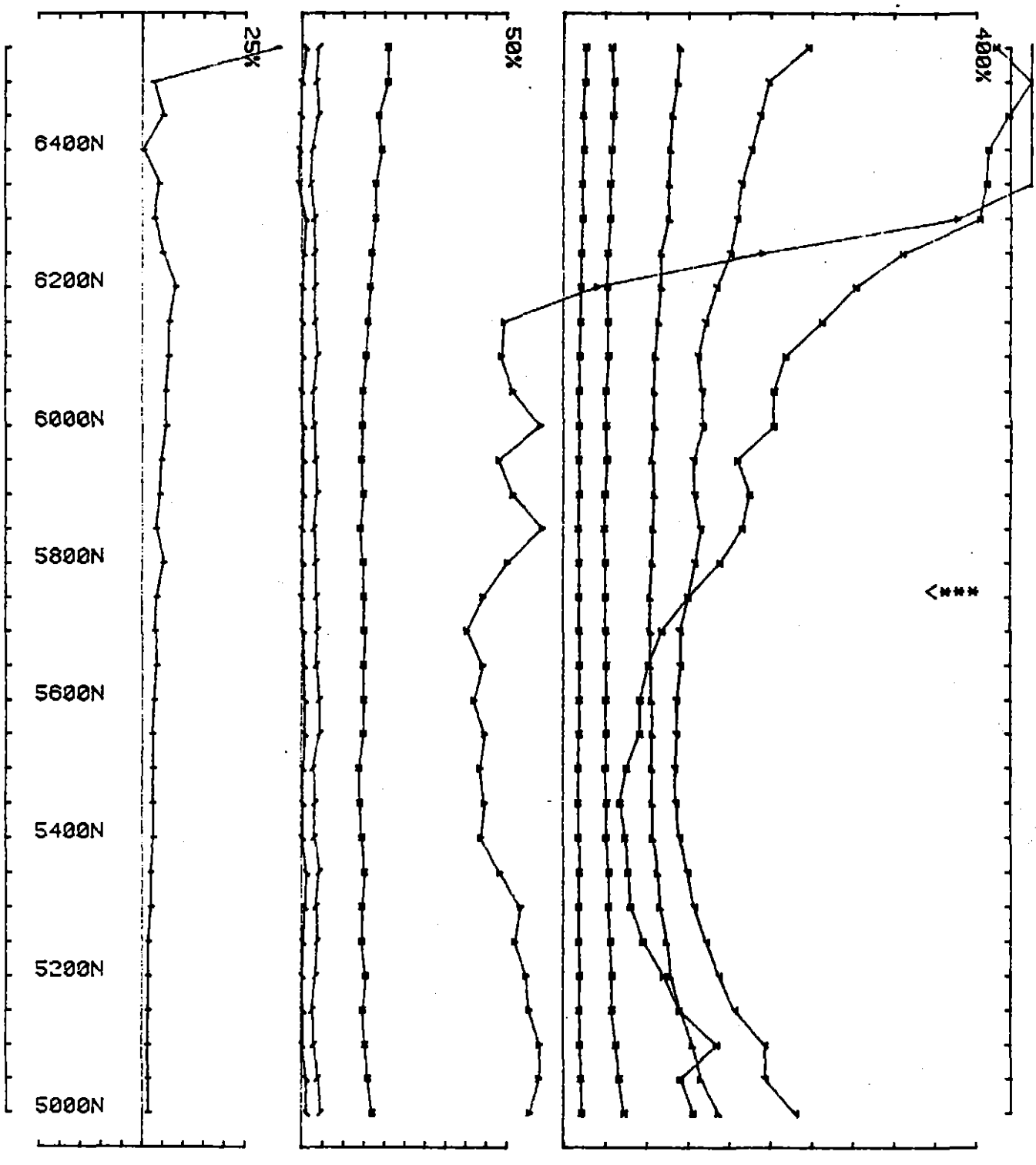
LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
2200x1800m

loop no 1
line 8800E
component Hz
secondary field
ch 1 point nors.
18/11/88

600071

070



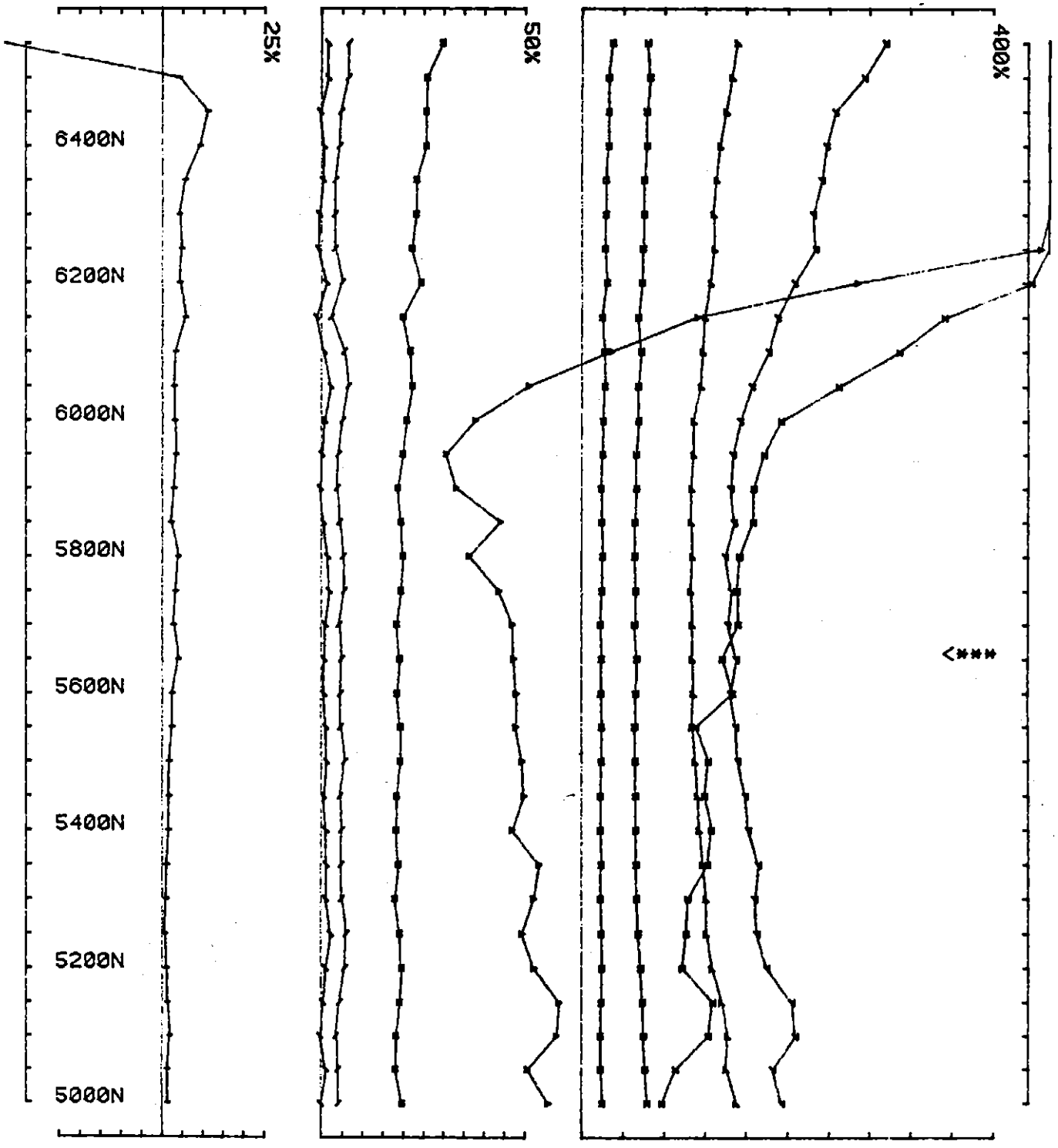
LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
2200x10000m

loop no 1
line 9000E
component Hz
secondary field
Ch 1 point norm.
18/11/88

071

600072



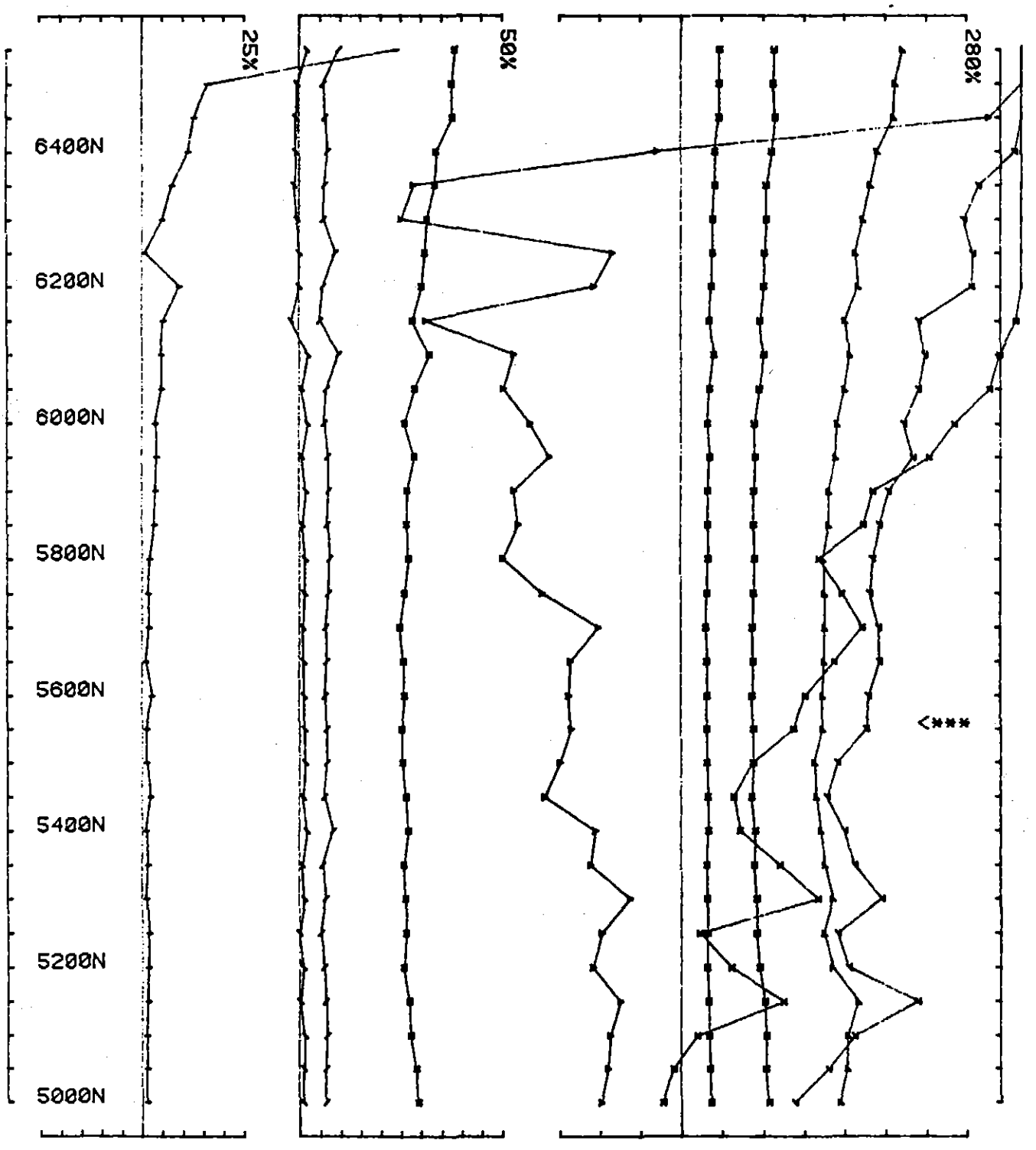
LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 28.230

loop dimensions
2200x1000m

loop no 1
line 9200E
component Hz
secondary field
Ch 1 point nore.
17/11/88

600073

072



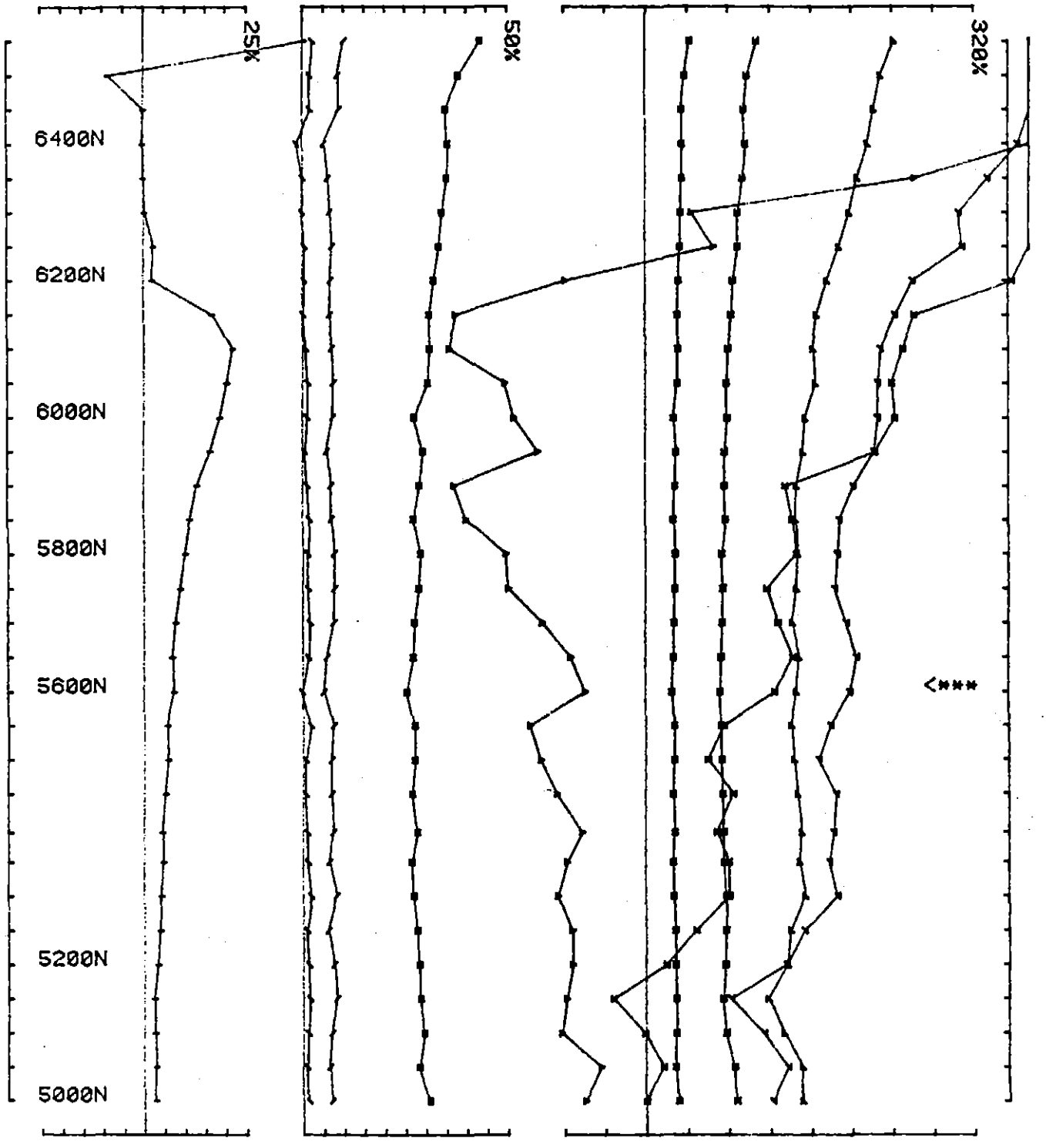
LAMONTAGNE GEOPHYSICS LTD Job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
2200x1900m

loop no 1
line 9400E
component Hz
secondary field
Ch 1 point norm.
17/11/88

600074

073



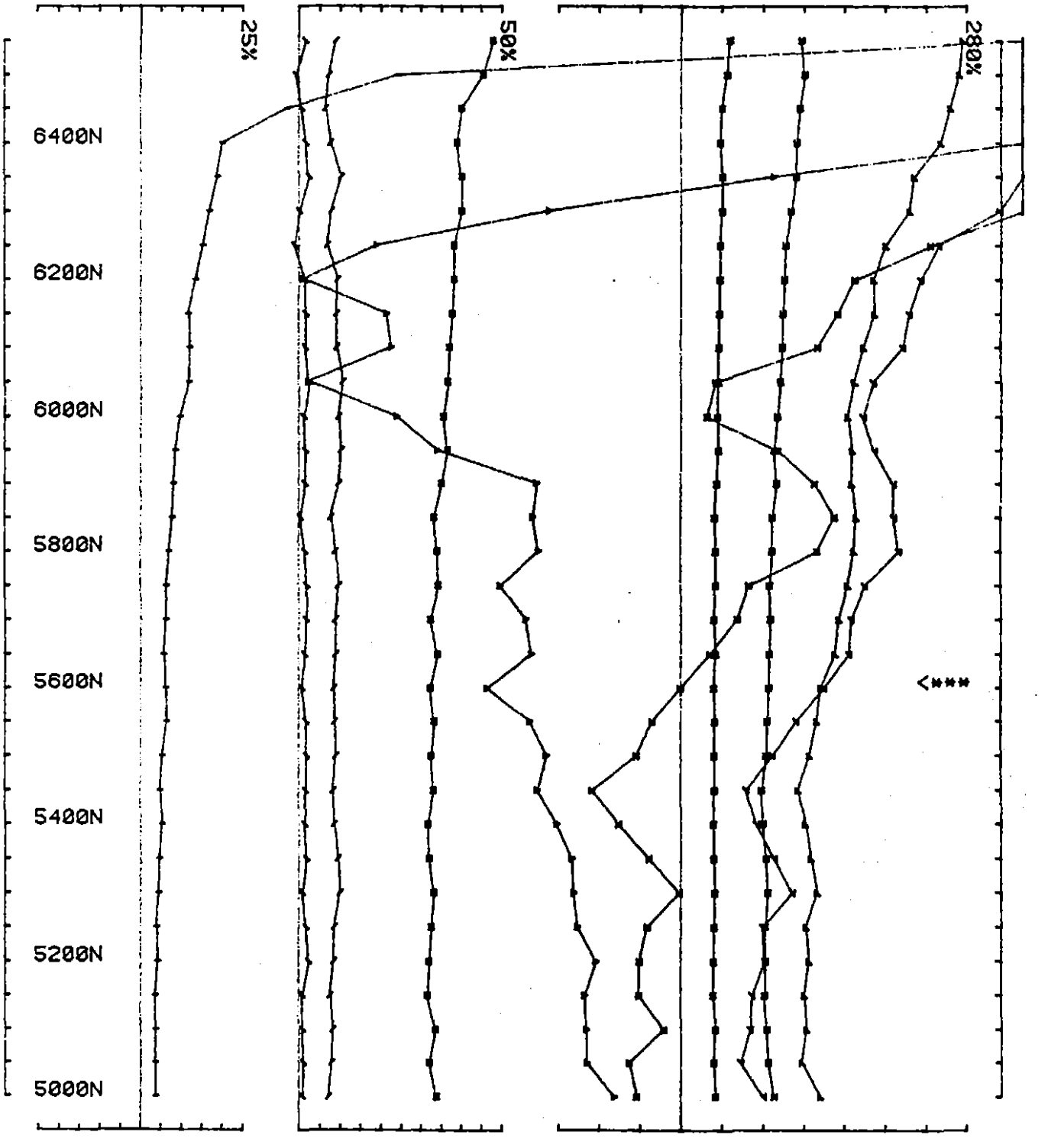
LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
2200x1800m

loop no 1
line 9600E
component Hz
secondary field
Ch 1 point norm.
17/11/88

600075

074



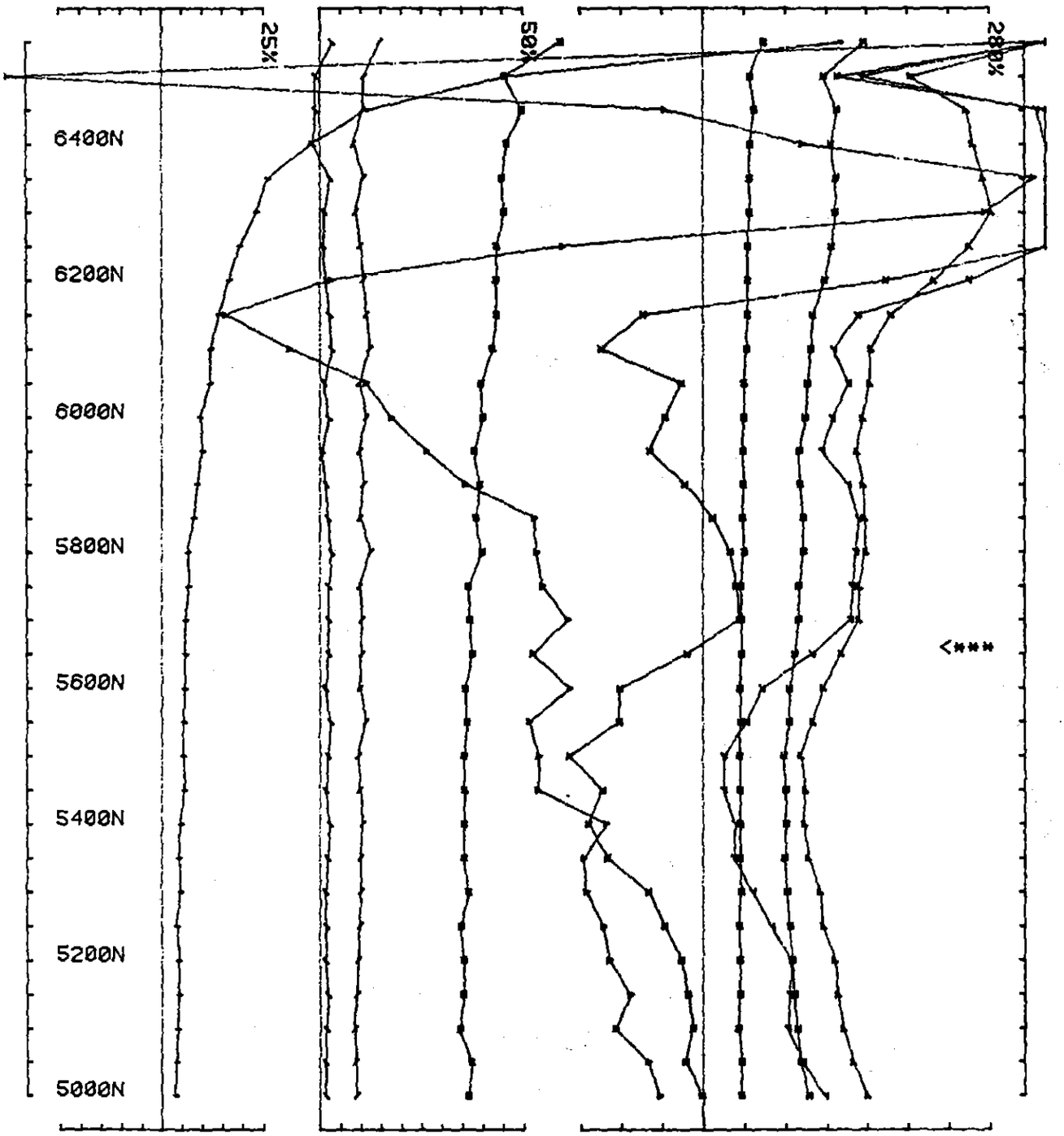
LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
2200x10000m

loop no 1
line 9800E
component Hz
secondary field
Ch 1 point nors.
16/11/88

075

600076



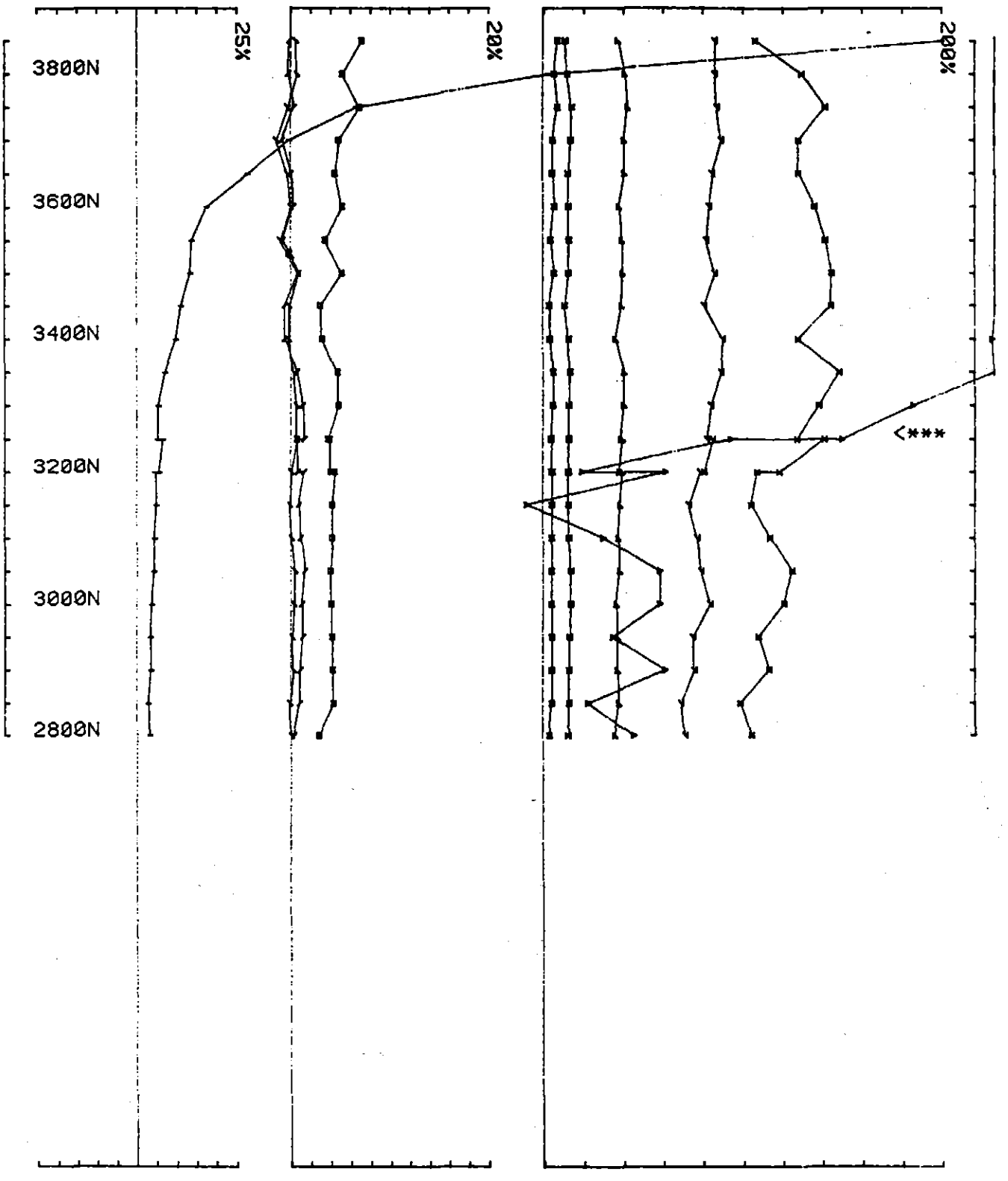
LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions 2200x1800m

loop no 1
line 10000E
component Hz
secondary field
Ch 1 point norm.
16/11/88

076

600077



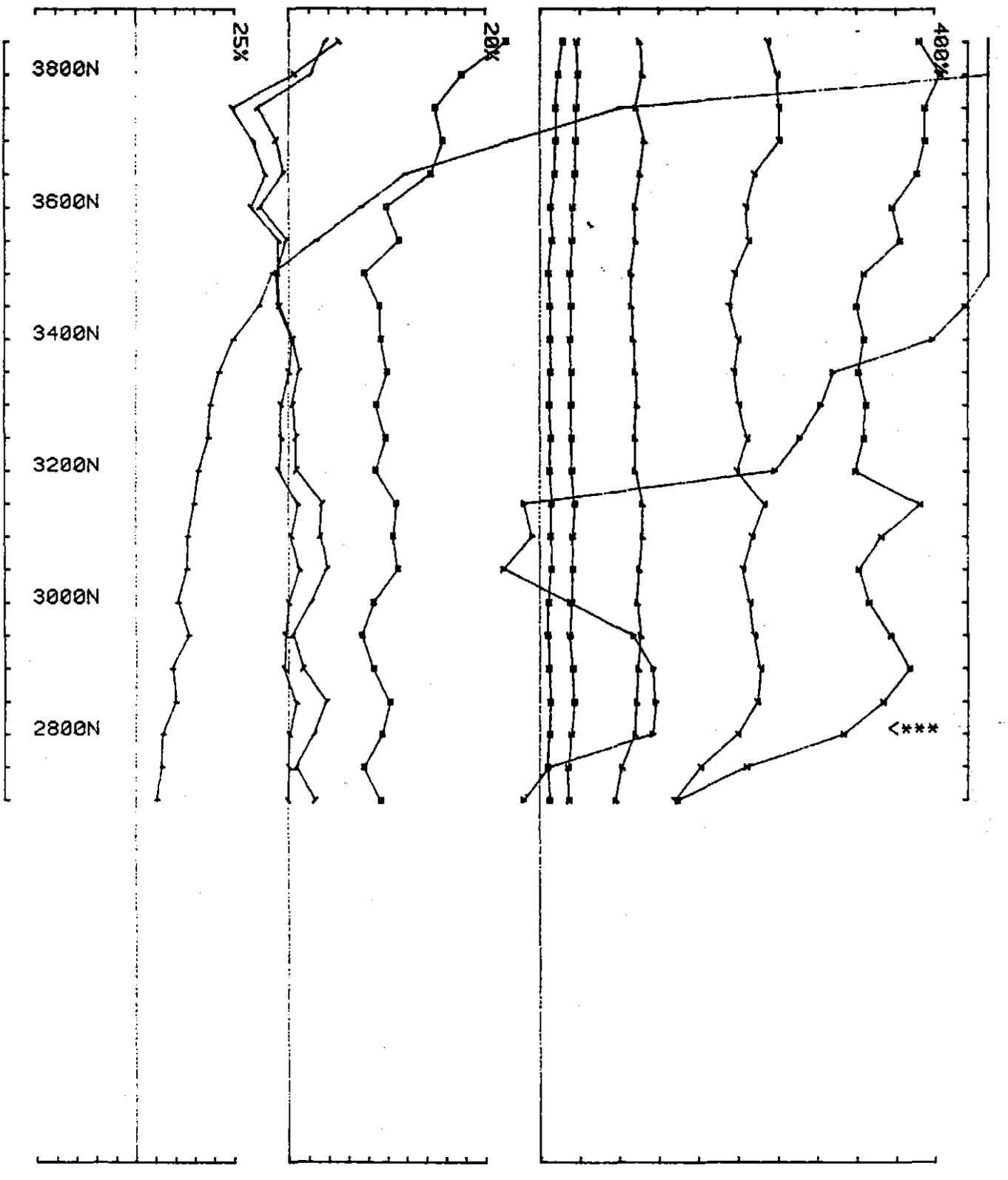
LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
1400x1100m

loop no 2
line 7000E
component Hz
secondary field
Ch 1 point nors.
21/11/88

077

600078



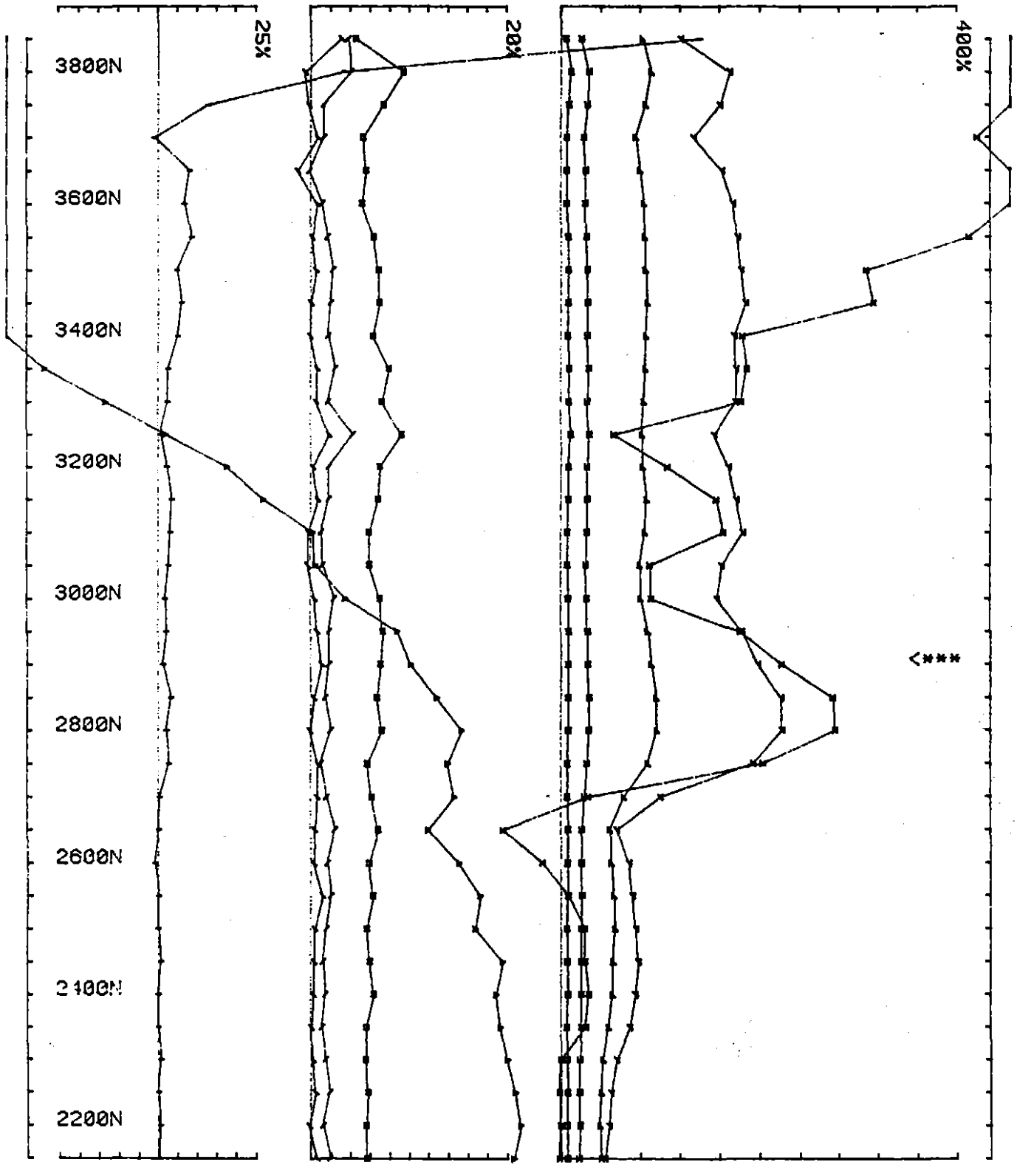
LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
1400x1100m

loop no 2
line 7200E
component Hz
secondary field
Ch 1 point norm.
21/11/88

600079

078



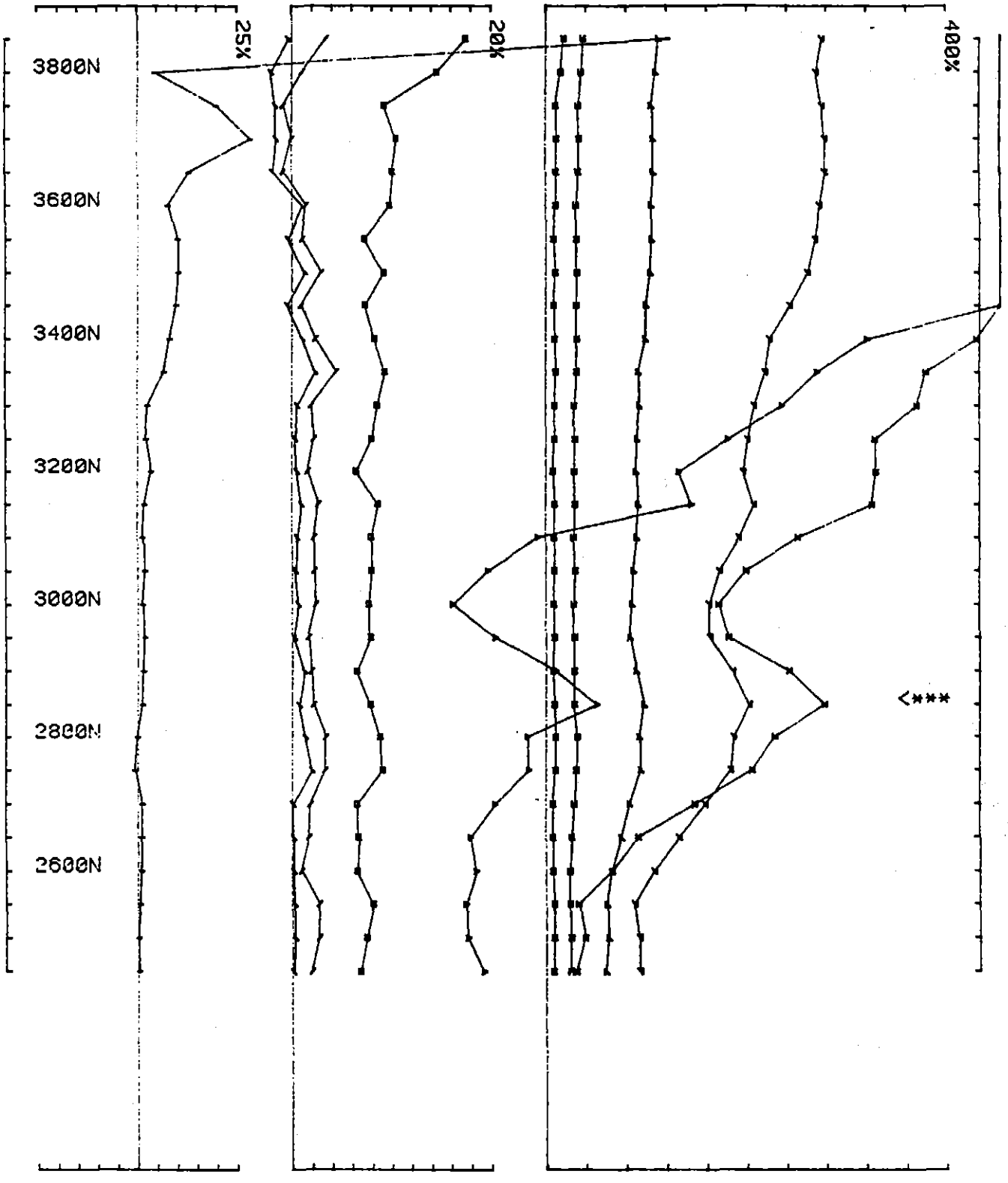
LAMONTAGNE GEOPHYSICS LTD Job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
1400x1100m

loop no 2
line 7400E
component Hz
secondary field
Ch 1 point norm.
24/11/88

600080

079



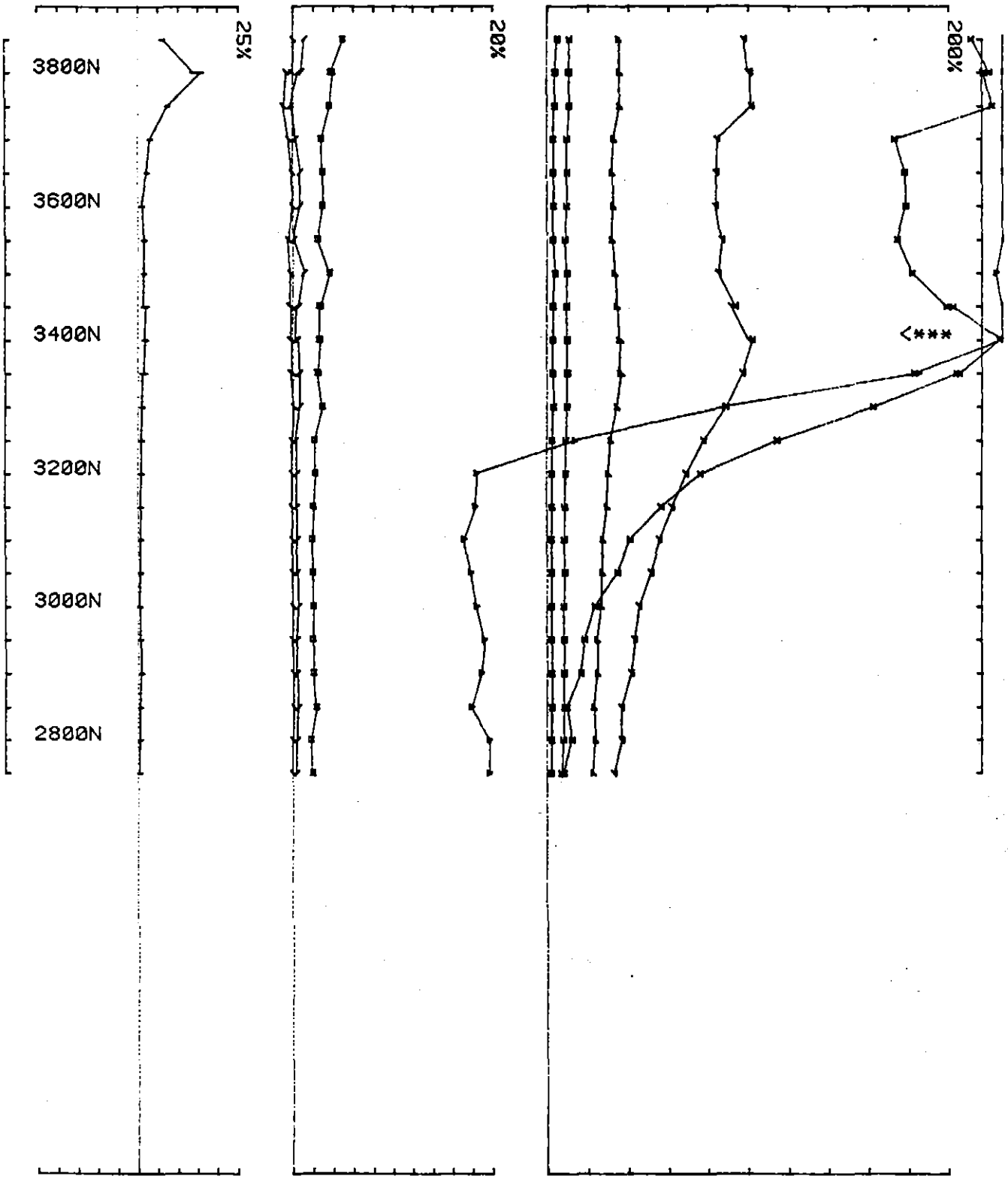
LAMONTAGNE GEOPHYSICS LTD job 8881
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
1400x1100m

loop no 2
line 7600E
component Hz
secondary field
Ch 1 point norm.
24/11/88

600081

030



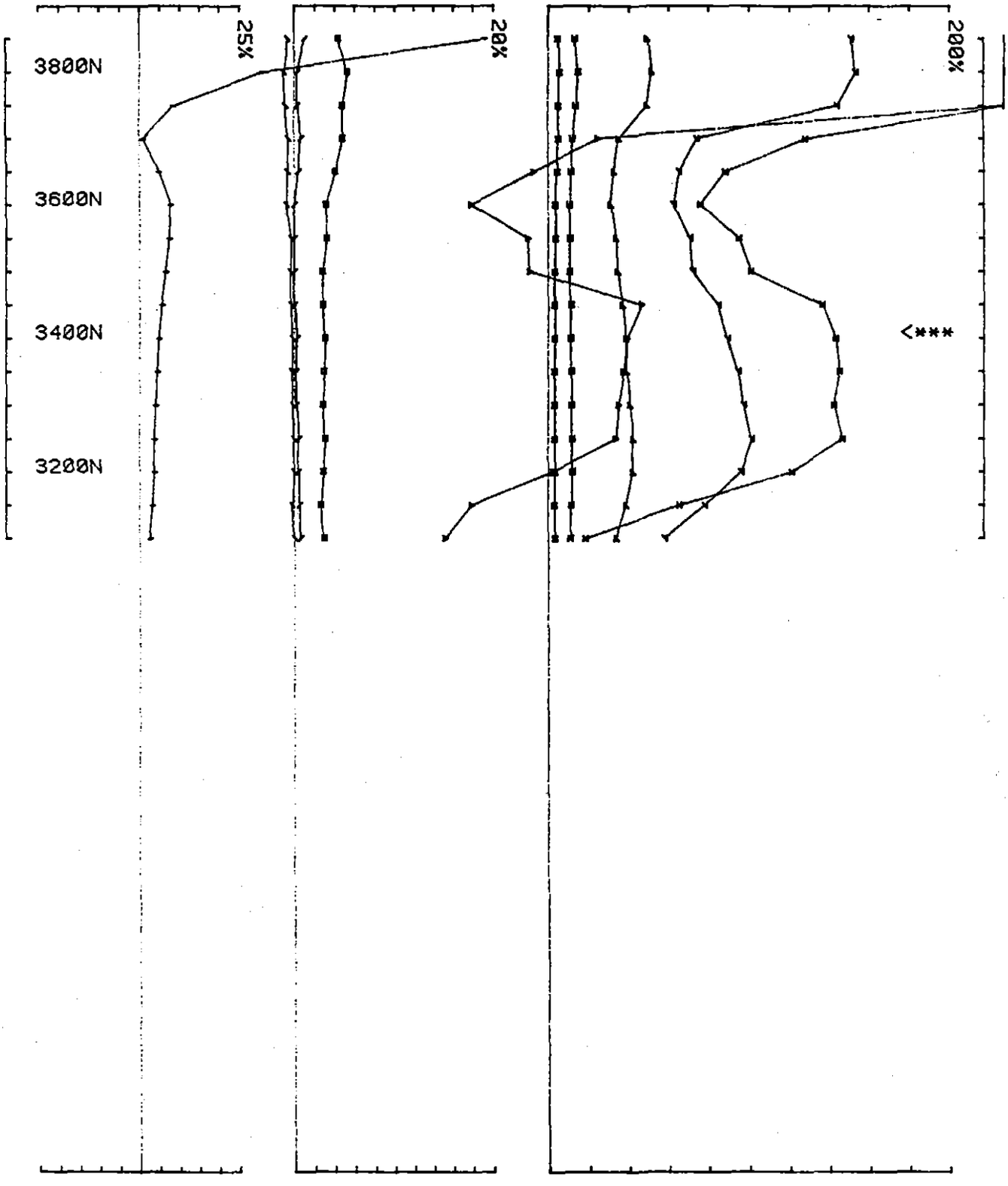
LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
1400x1100m

loop no 2
line 7800E
component Hz
secondary field
Ch 1 point norm.
23/11/88

600082

081



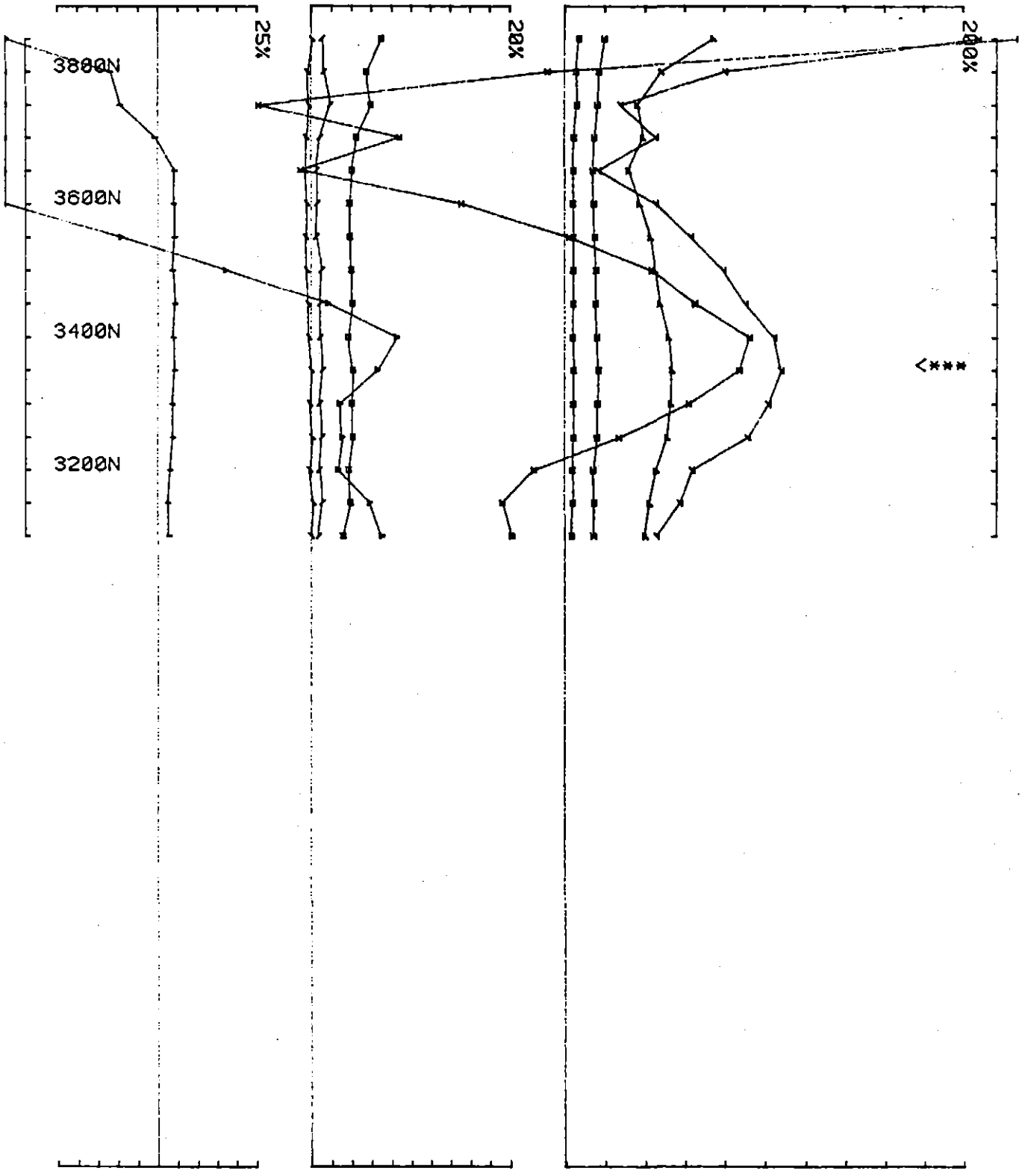
LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
1400x1100m

loop no 2
line 8000E
component Hz
secondary field
Ch 1 point nors.
29/11/88

082

600083



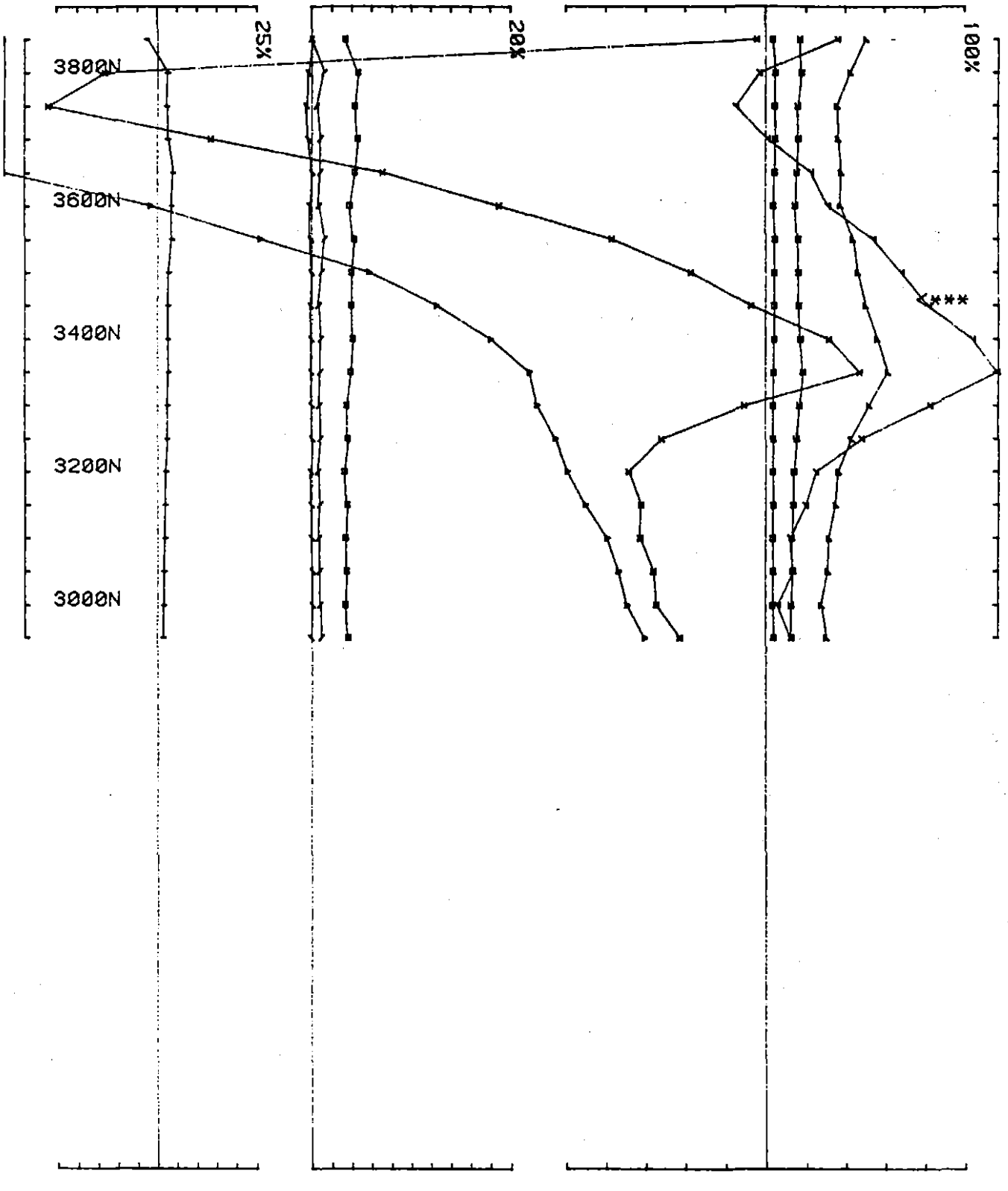
LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
1400x1100m

29/8/88
Ch 1 point norm
secondary field
component Hz
line 8200E
loop no 2

600084

083



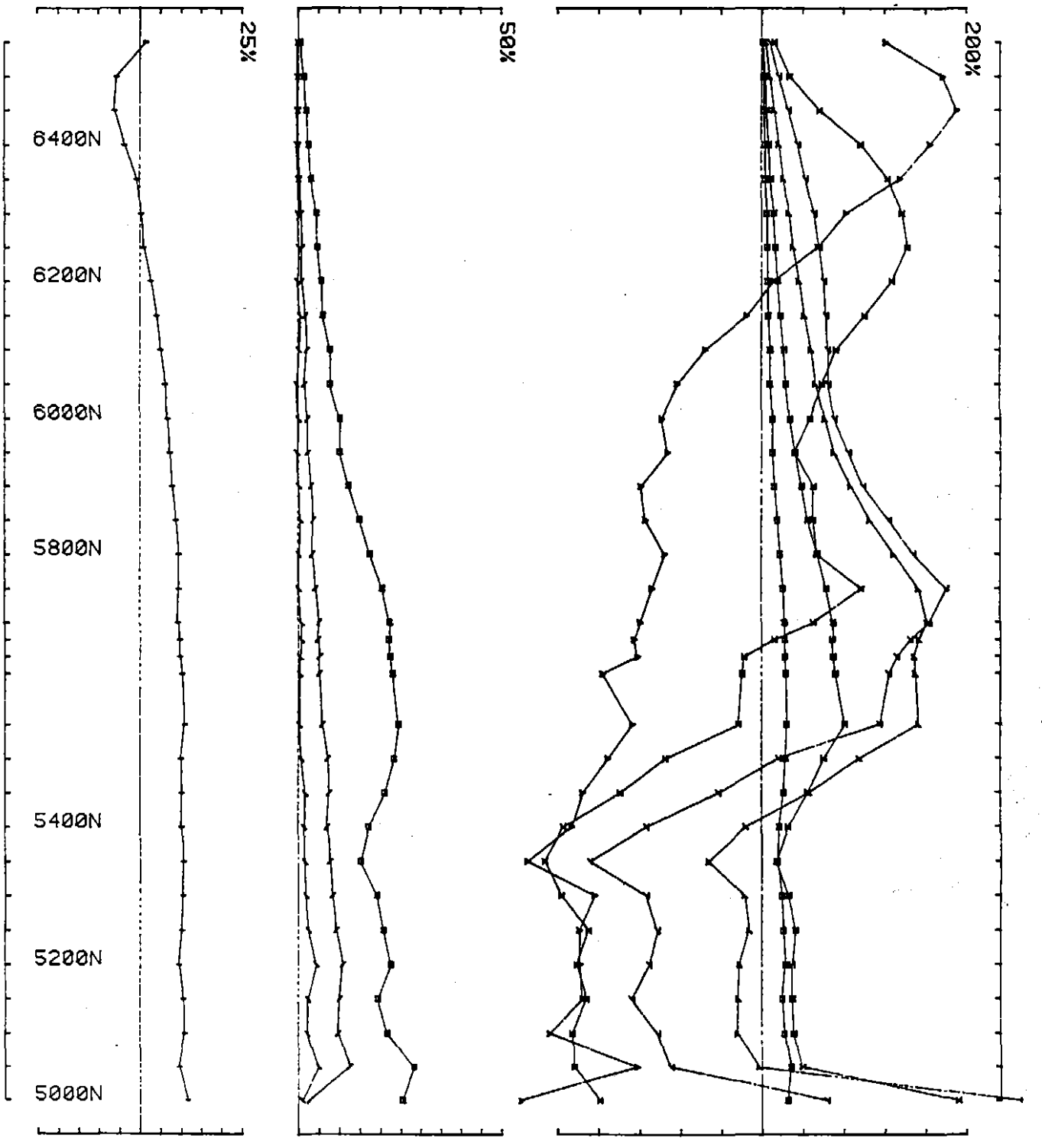
LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
1400x1100m

loop no 2
line 8400E
component Hz
secondary field
Ch 1 point norm.
23/11/88

600085

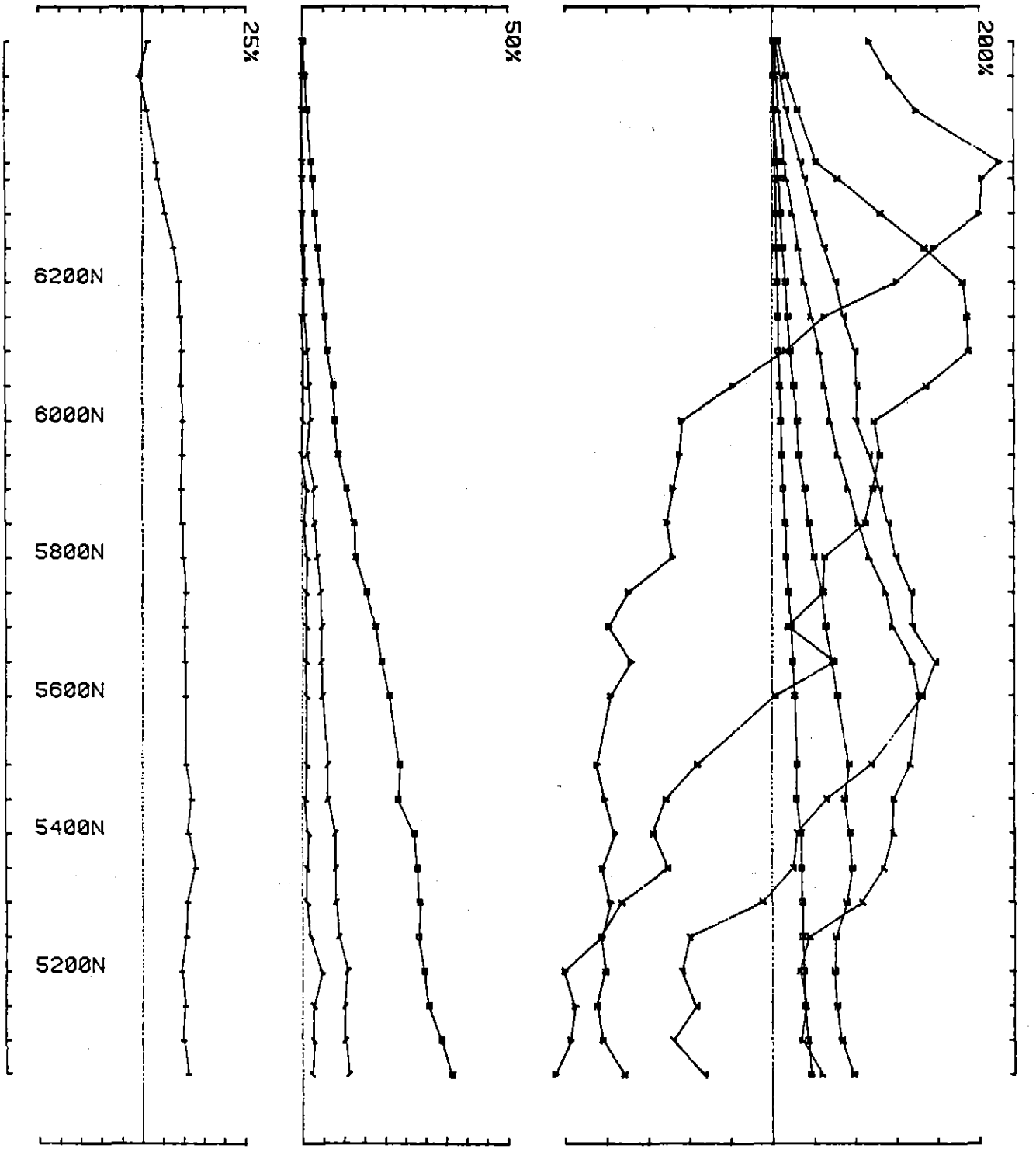
084



LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions 2200x1800m

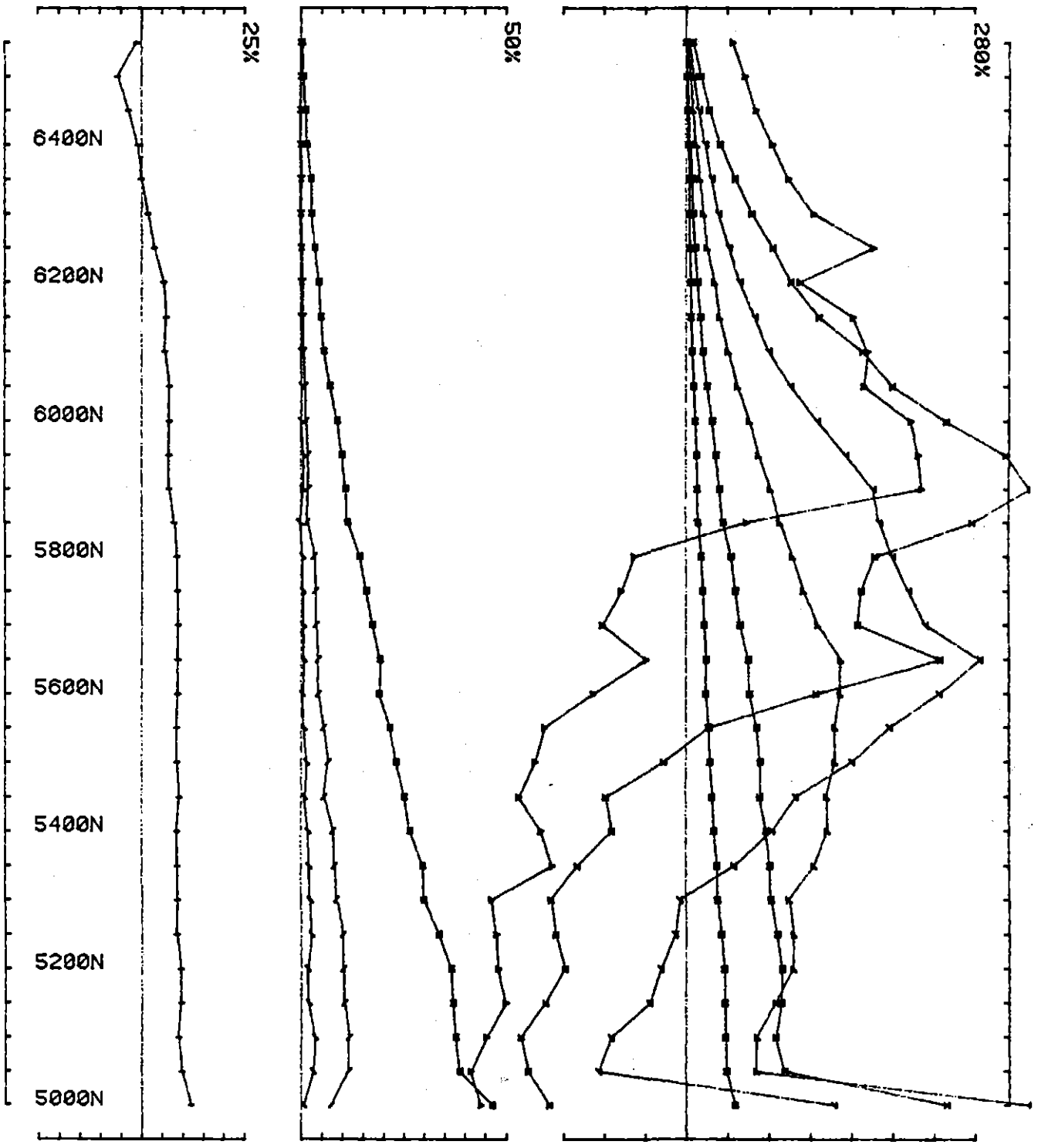
loop no 1
line 7800E
component Hz
secondary field
Chl contin nors
20/11/88



LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
2200x1800m

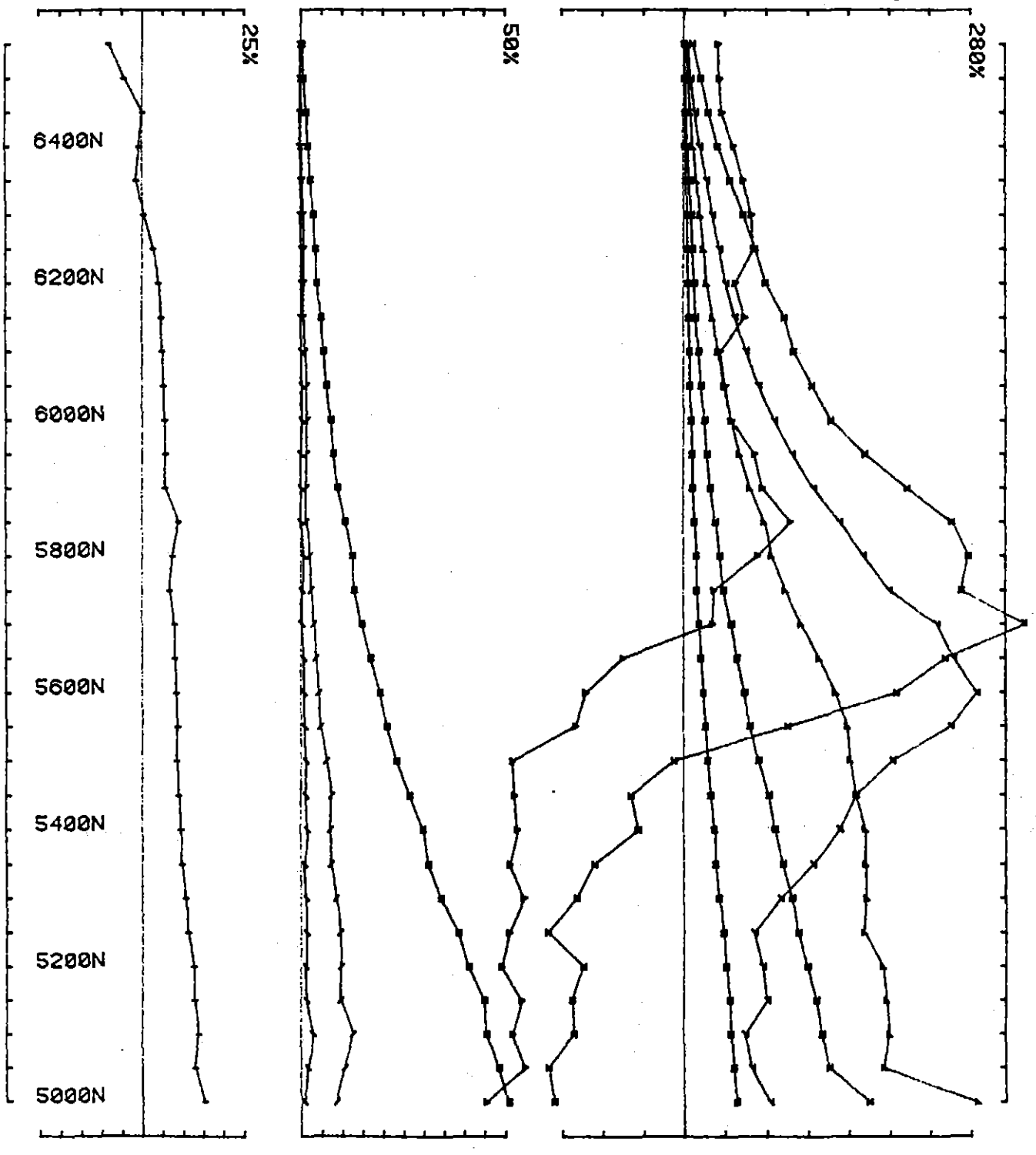
loop no 1
line 8000E
component Hz
secondary field
Chl contin norm
28/11/88



LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
2200x1800m

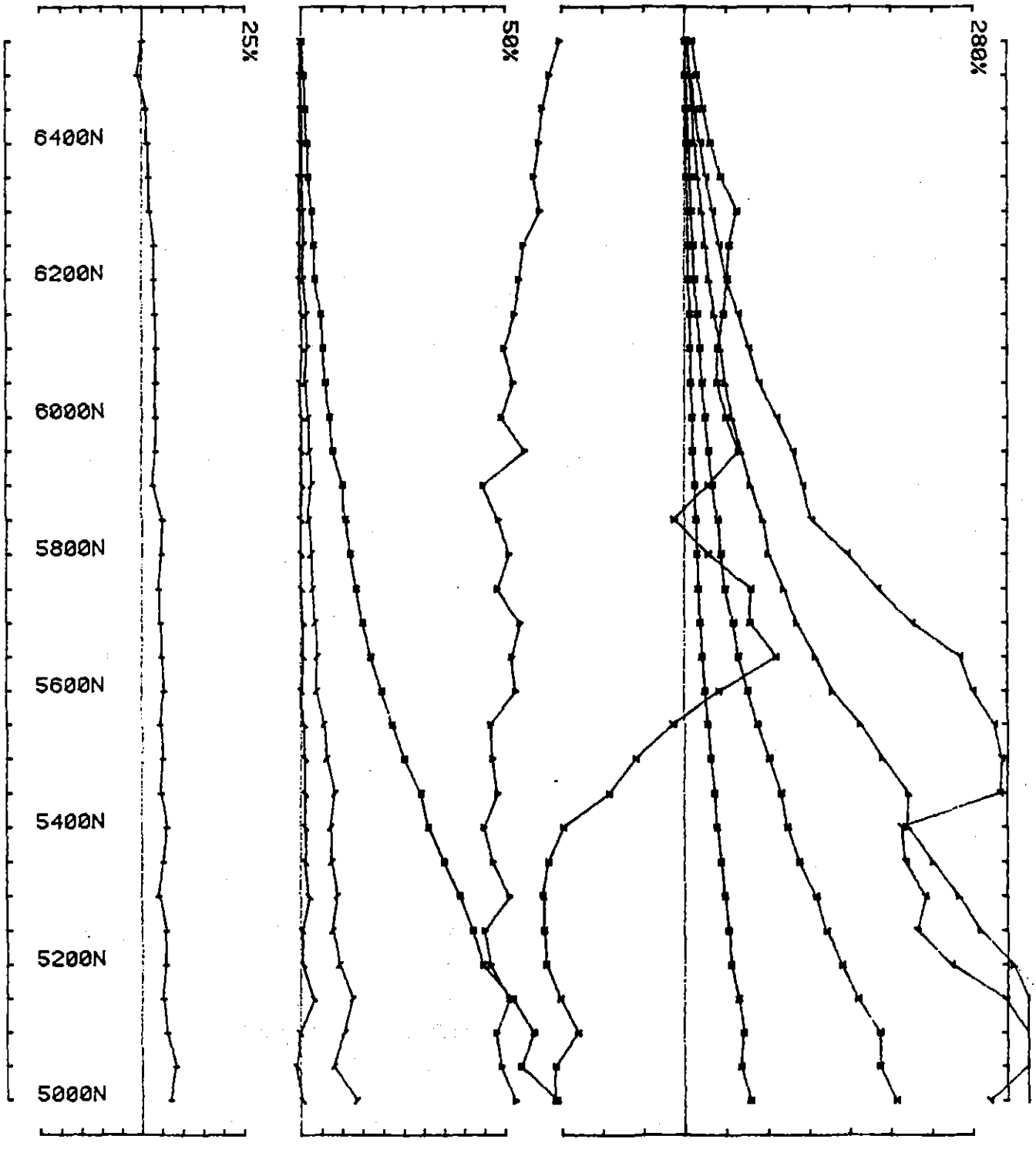
loop no 1
line 8200E
component Hz
secondary field
Chl contin norm
18/11/88



LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
2200x1000m

loop no 1
line 8400E
component Hz
secondary field
Chl contin norm
18/11/88



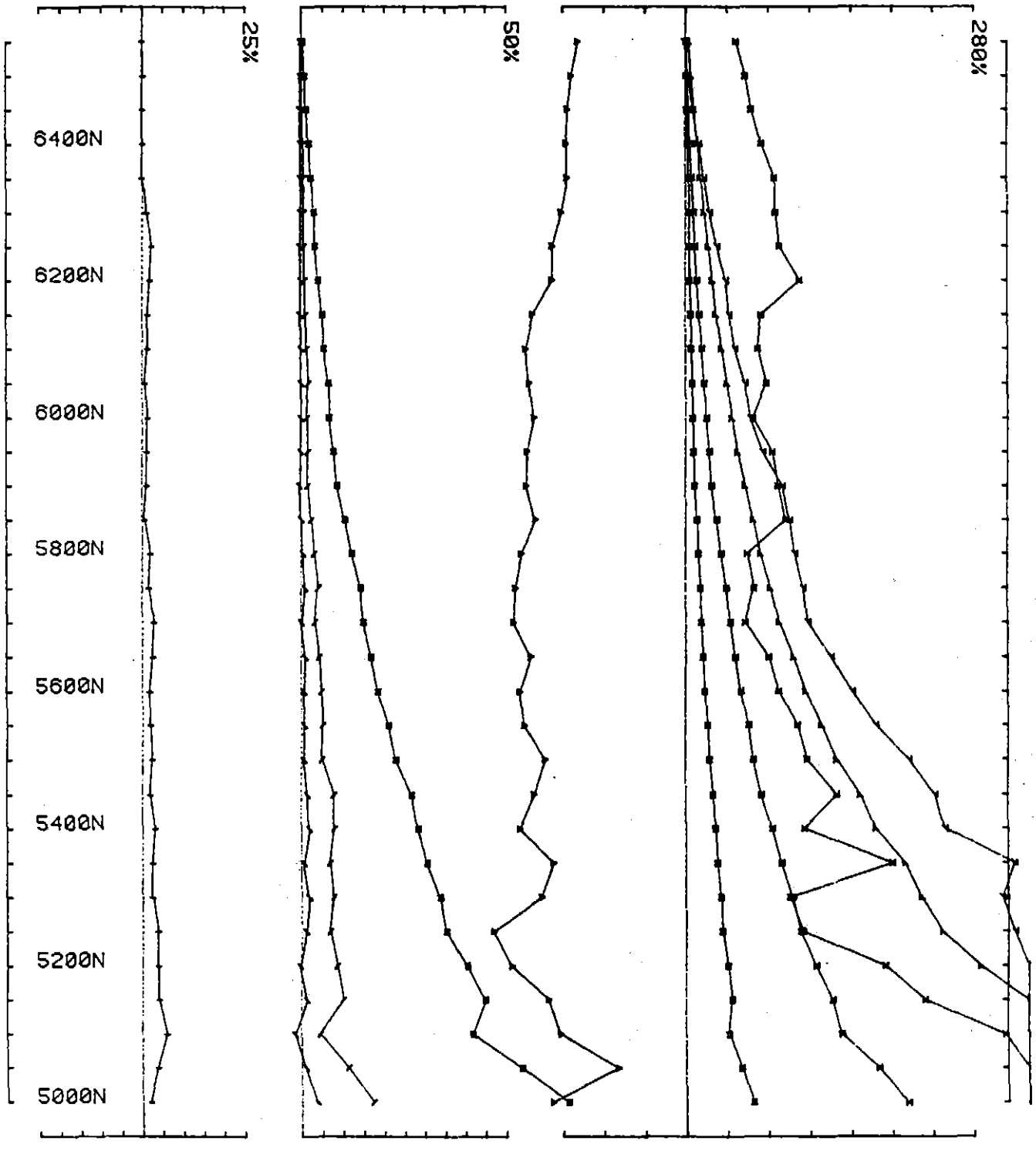
LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
2200x1800m

loop no 1
line 8600E
component Hz
secondary field
Chl contin nors
18/11/88

600090

089



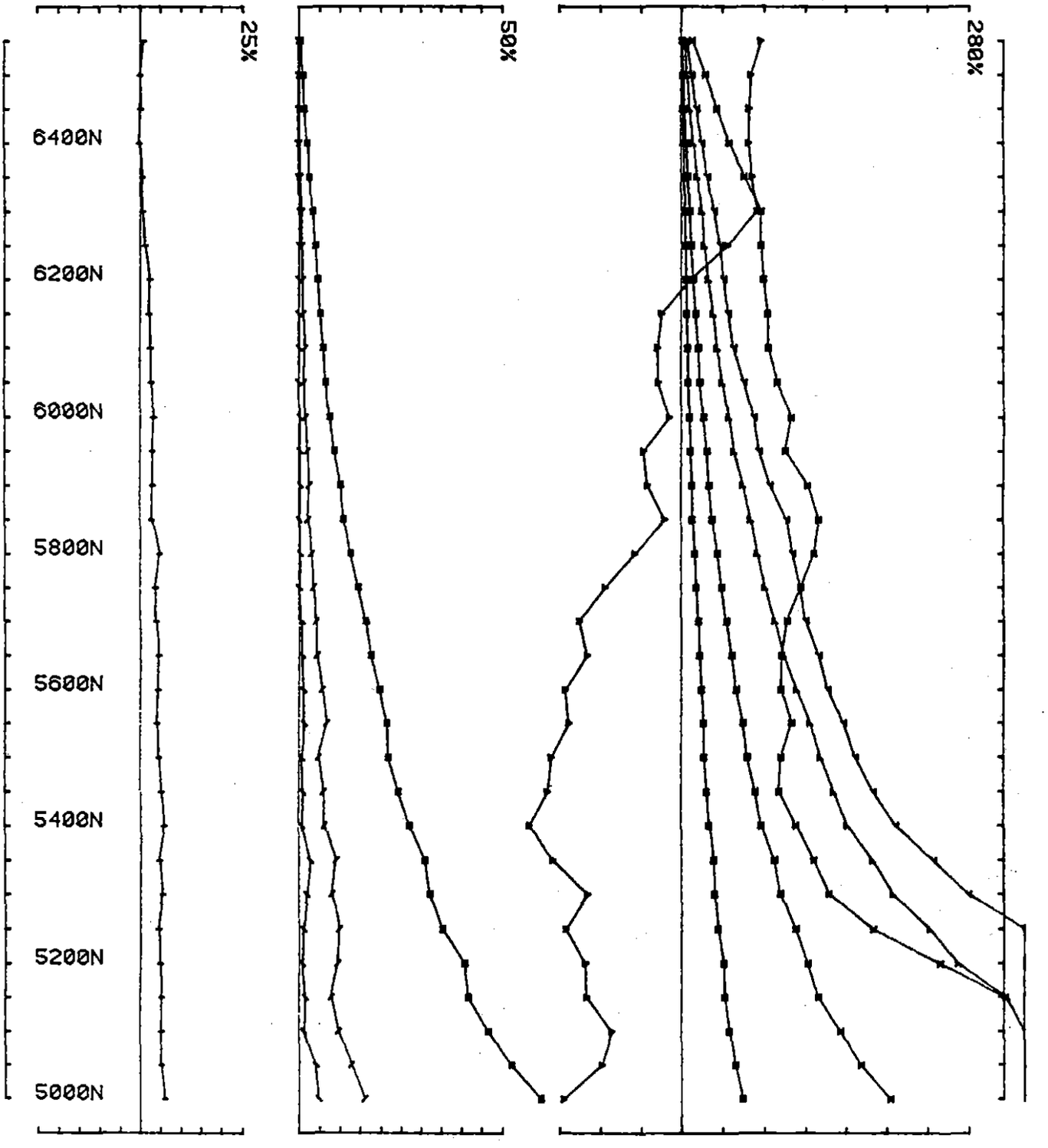
LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
2200m x 1800m

loop no 1
line 8800E
component Hz
secondary field
Chl contin norm
16/11/88

090

600091



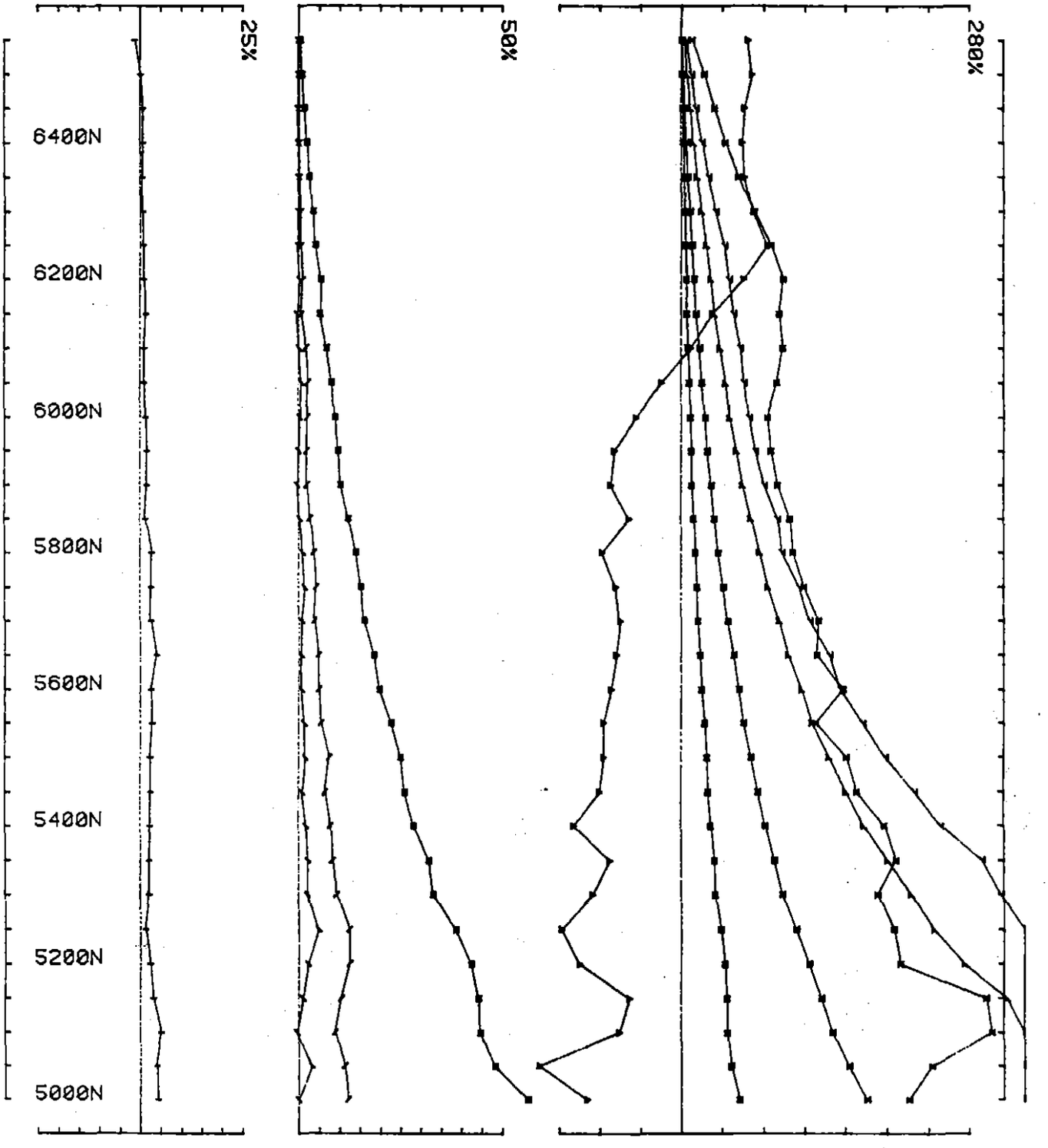
LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions 2200x1000m

loop no 1
line 9000E
component Hz
secondary field
Chl contin norm
18/11/88

600092

091



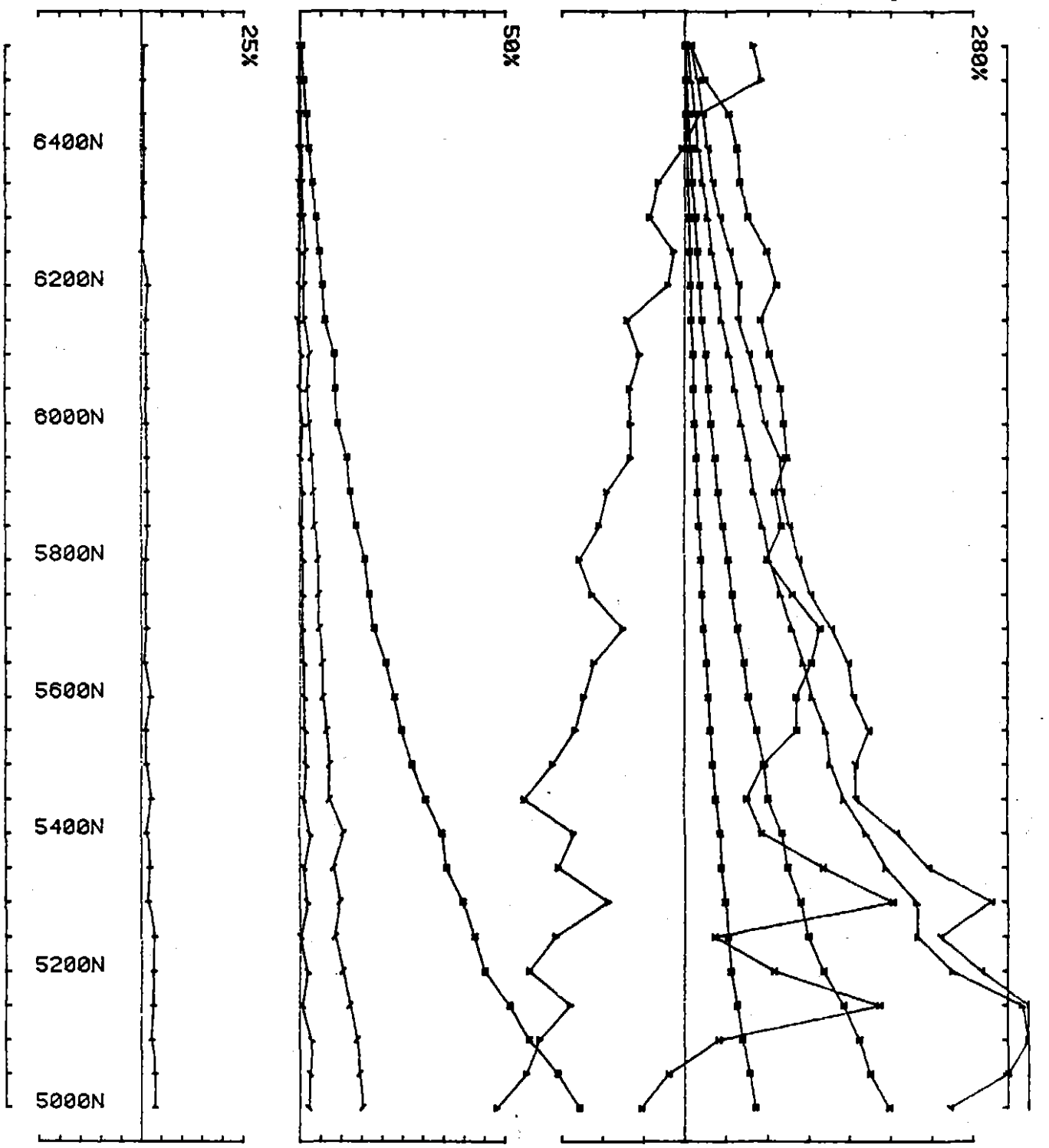
LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
2200m x 1800m

loop no 1
line 9200E
component Hz
secondary field
Chl contin norm
17/11/88

092

600093



LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
2200x1800m

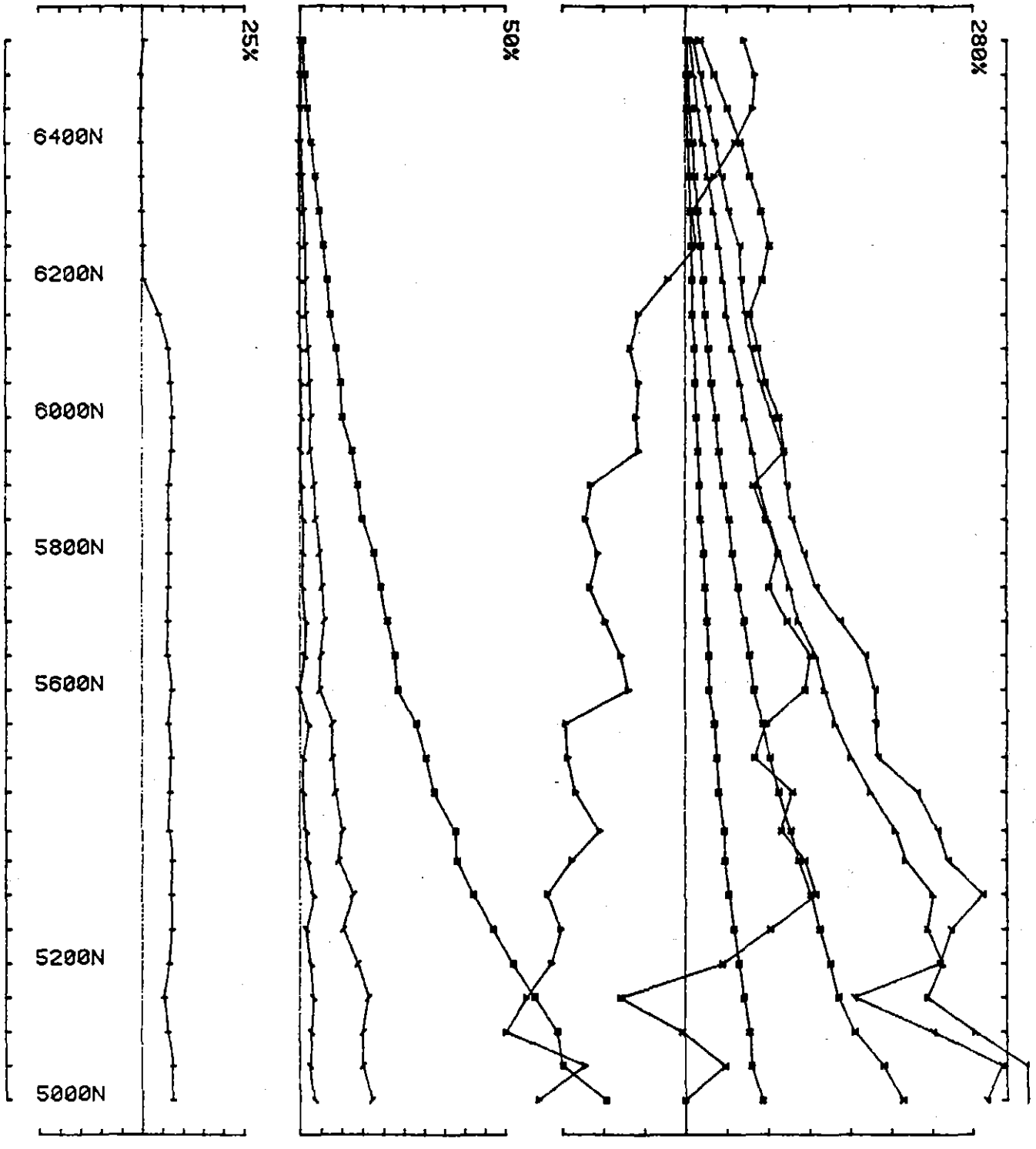
N

17/11/88
Chl contin norm

loop no 1
line 9400E
component Hz
secondary field

600094

093

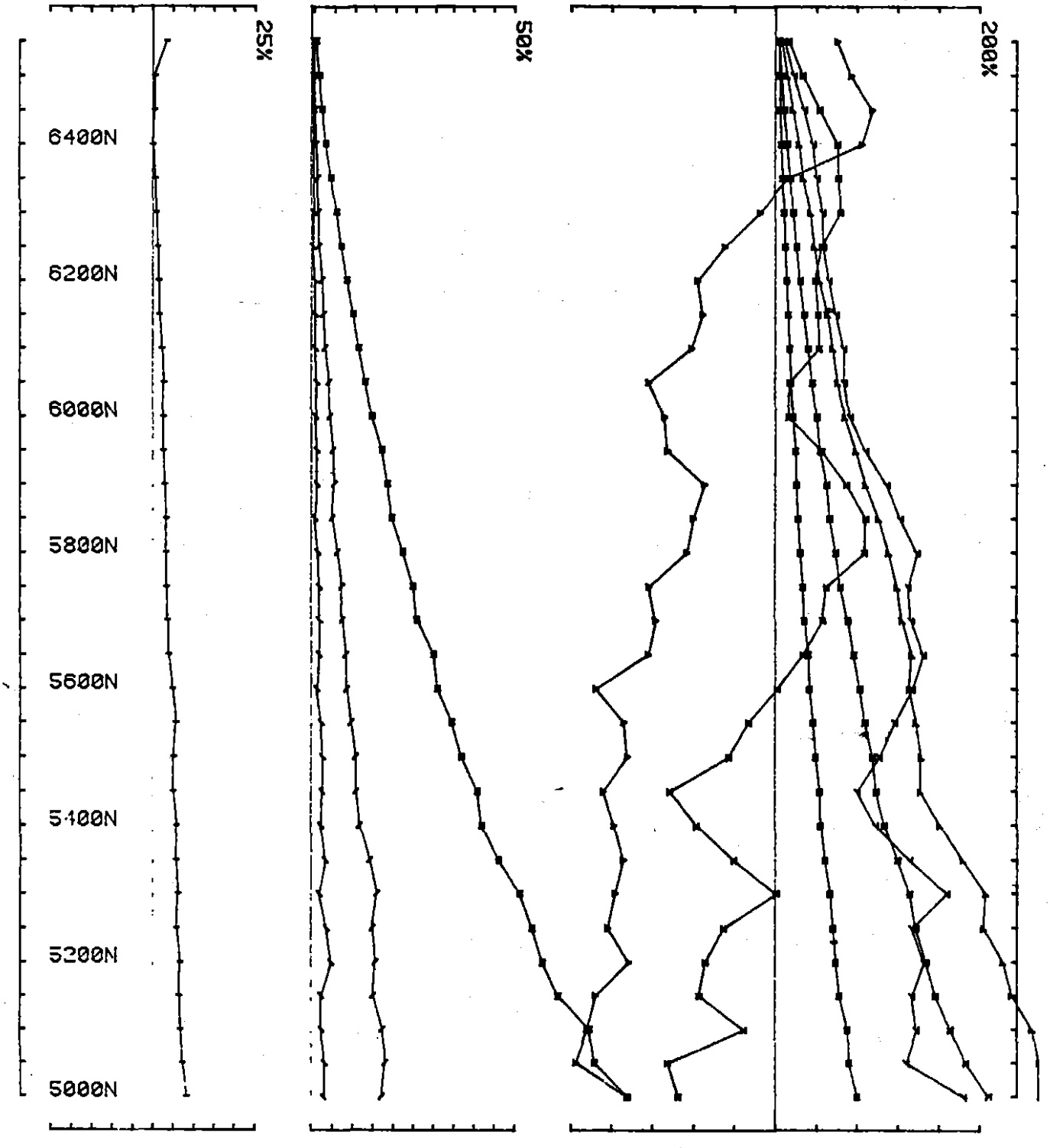


LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions 2200x1000m

N

loop no 1
line 9600E
component Hz
secondary field
Ch1 contin norm
17/11/88



LAMONTAGNE GEOPHYSICS LTD Job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

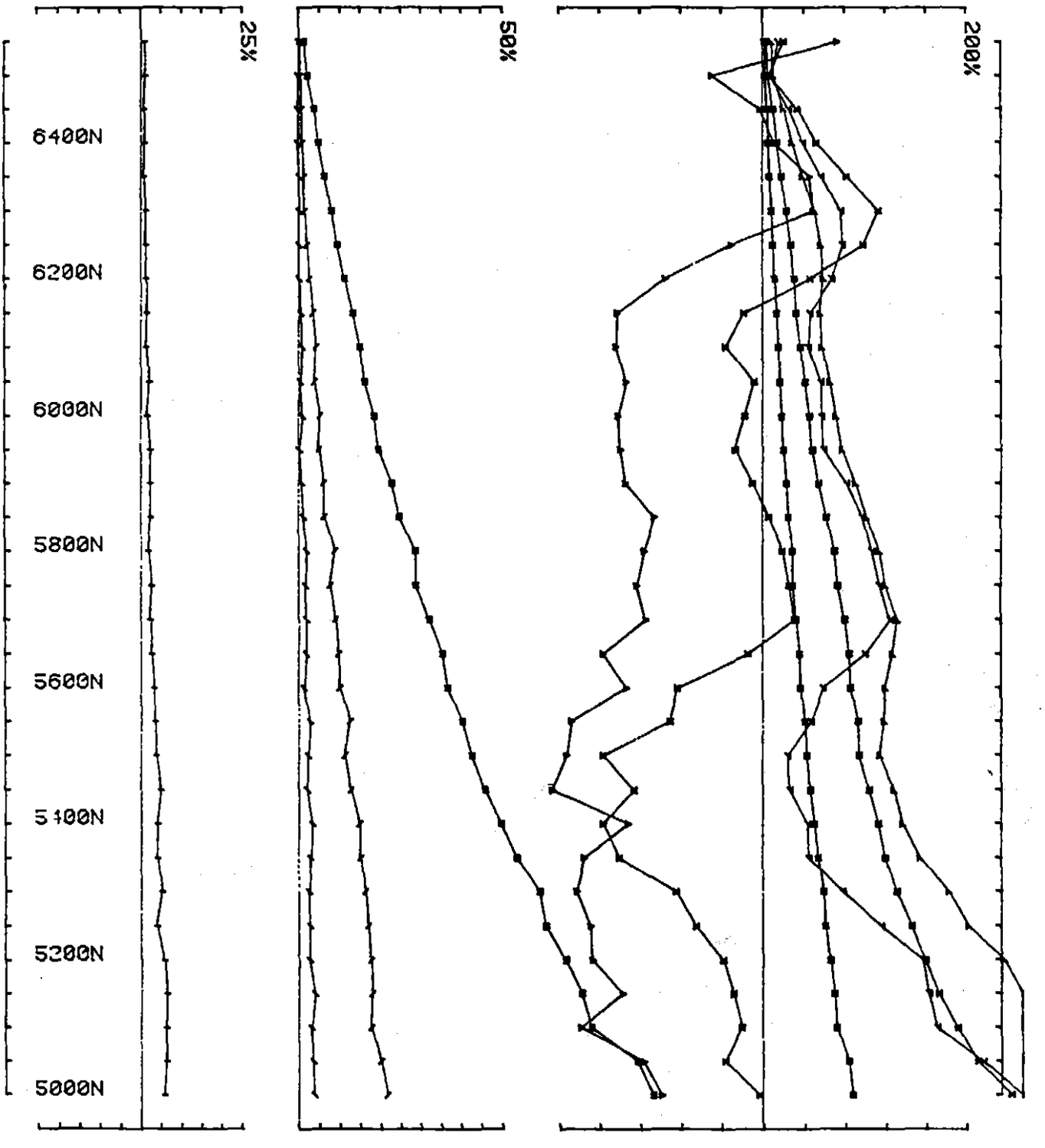
loop dimensions 2200x1800m

N

loop no 1
line 9800E
component Hz
secondary field
Chi contin nors
18/11/88

600096

095



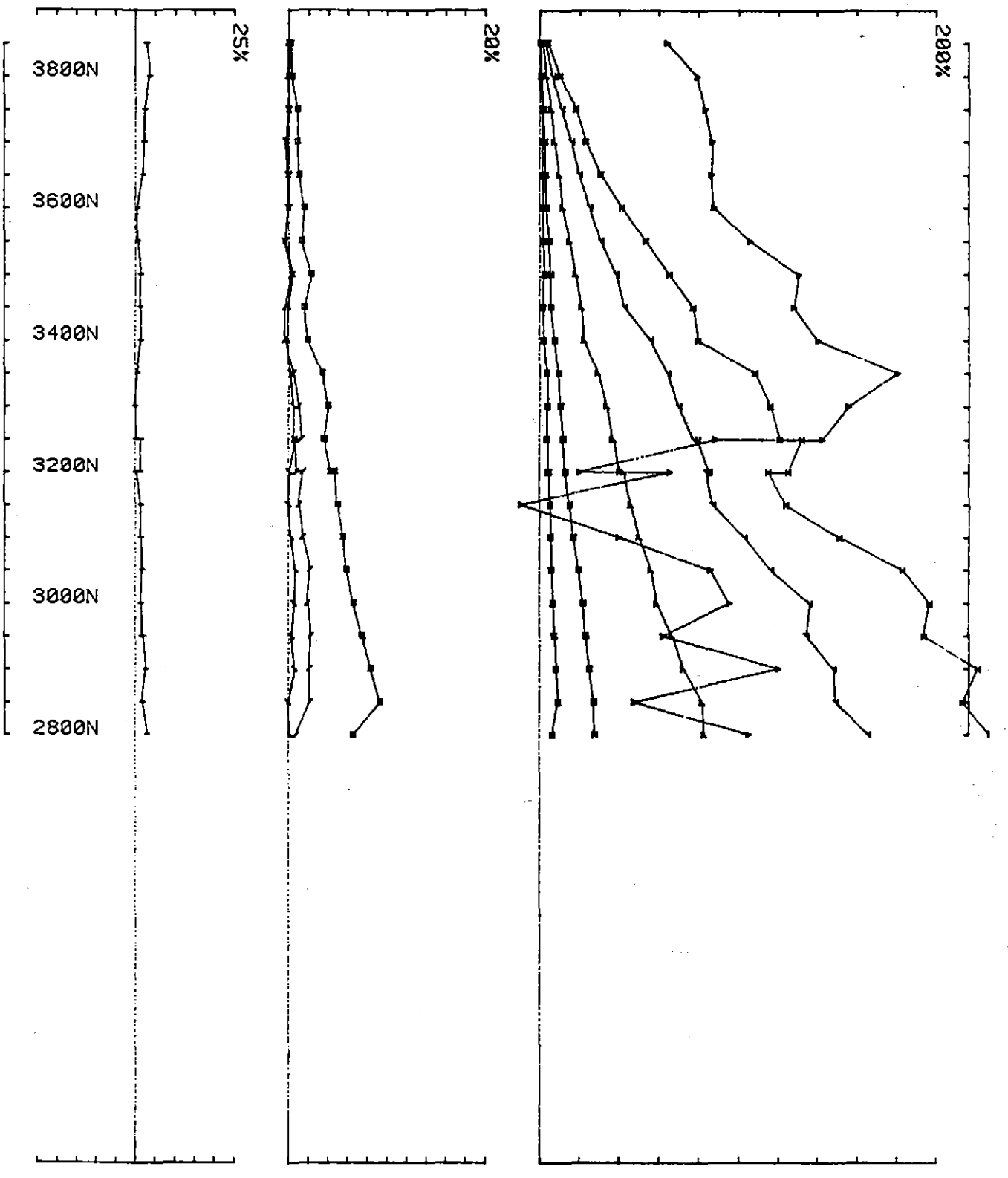
LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions 2200x1800m

N

loop no 1
line 10000E
component Hz
secondary field
Chl contin norm
16/11/88

600097



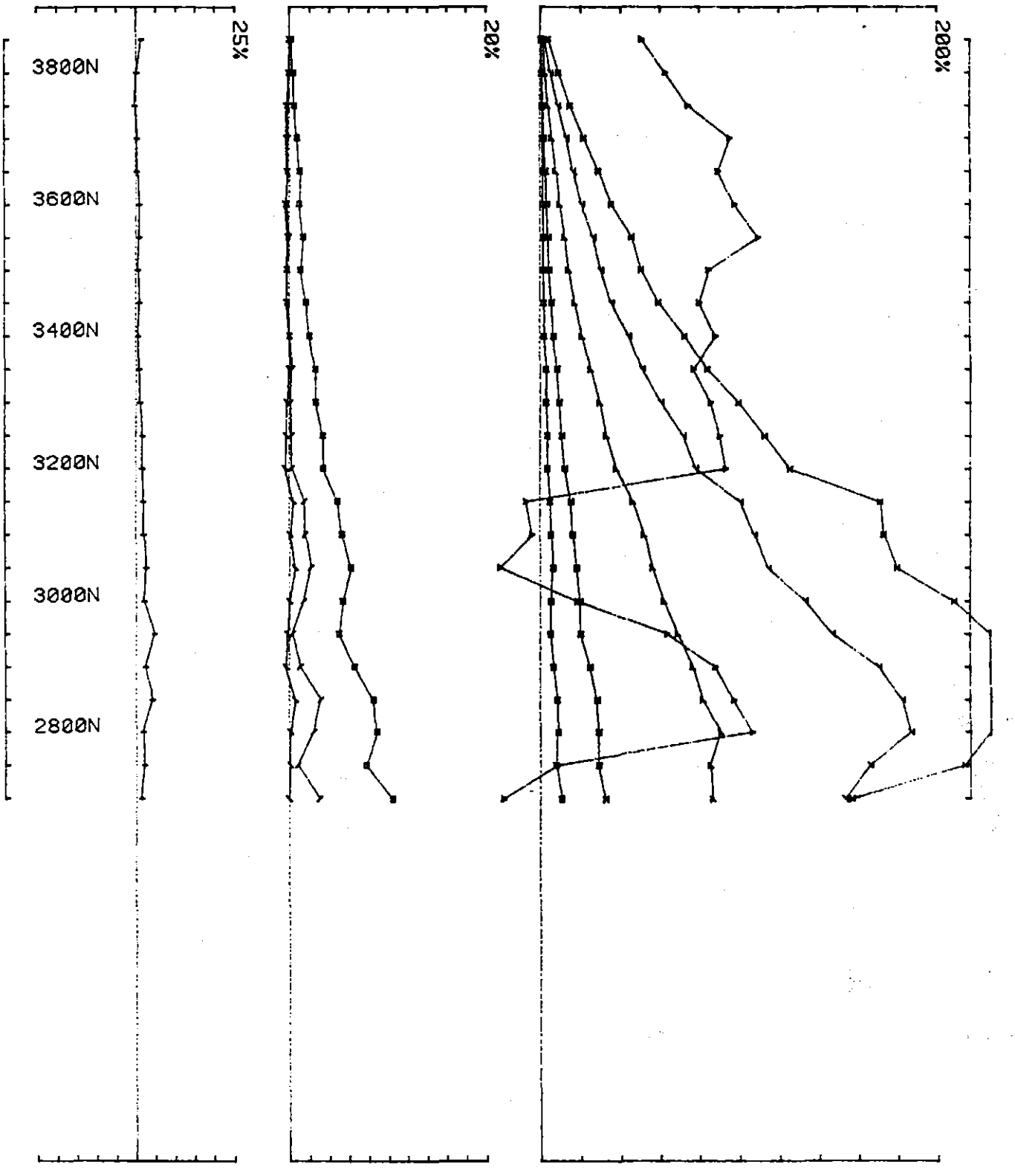
LAMONTAGNE GEOPHYSICS LTD job 8861
client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
1400x1100m

loop no 2
line 7000E
component Hz
secondary field
Chl contin norm
21/11/88

600098

097



LAMONTAGNE GEOPHYSICS LTD job 8861
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area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

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loop no 2
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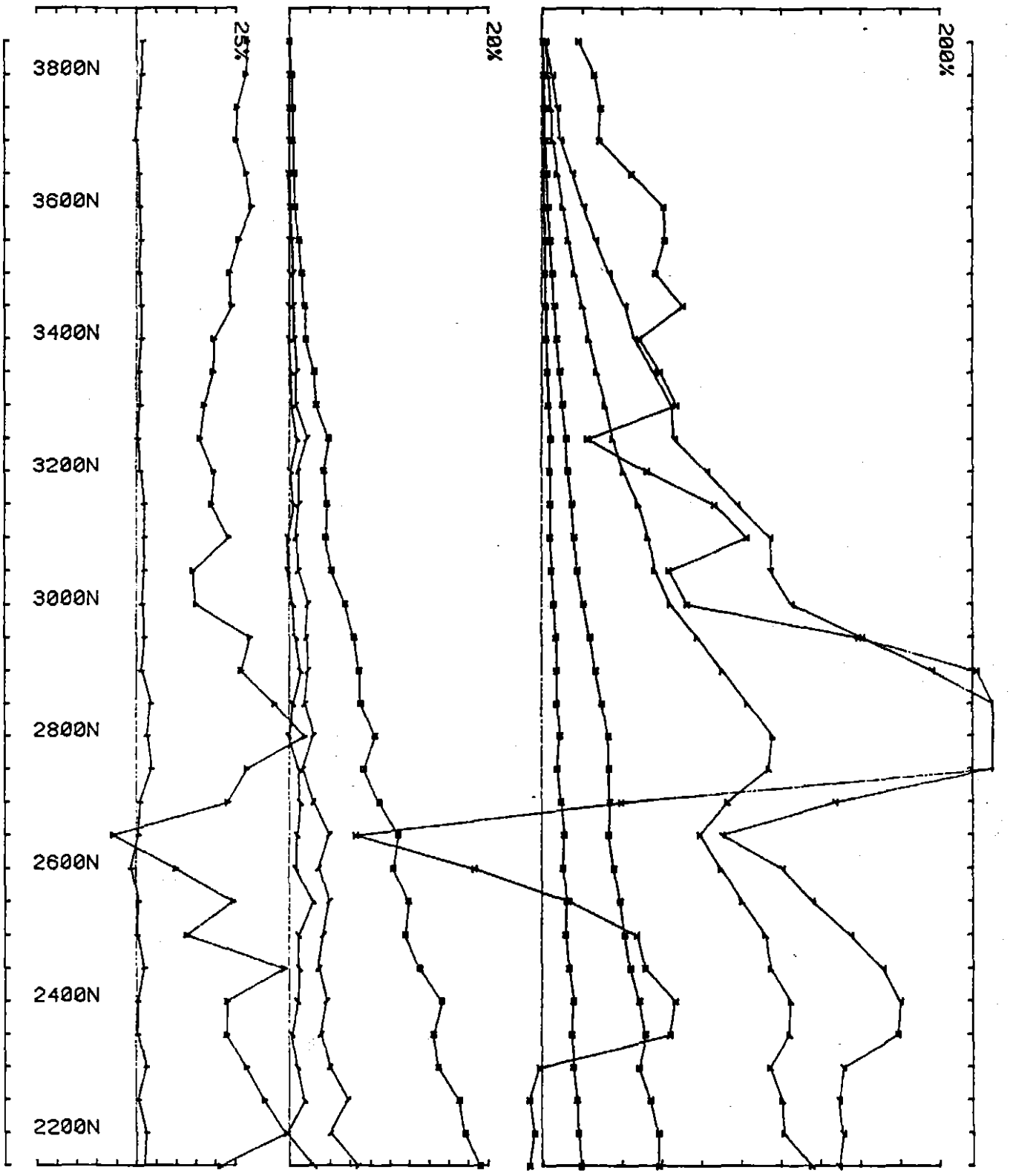
component Hz
secondary field
Chl contin norm
21/11/88

098

600099



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area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
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loop no 2
line 7400E
component Hz
secondary field
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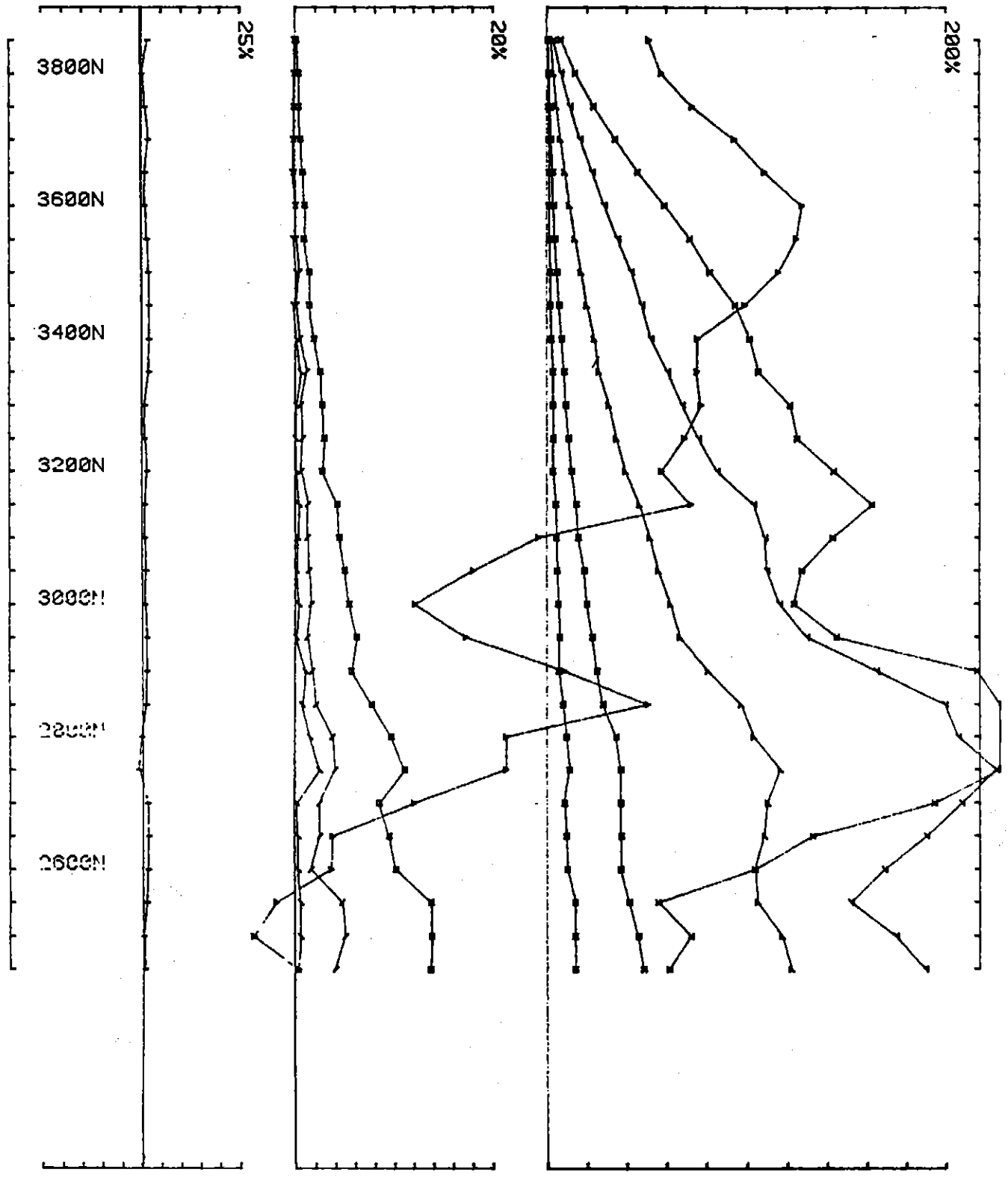
24/11/88

600100



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UTEM SURVEY at base freq (hz) 26.230

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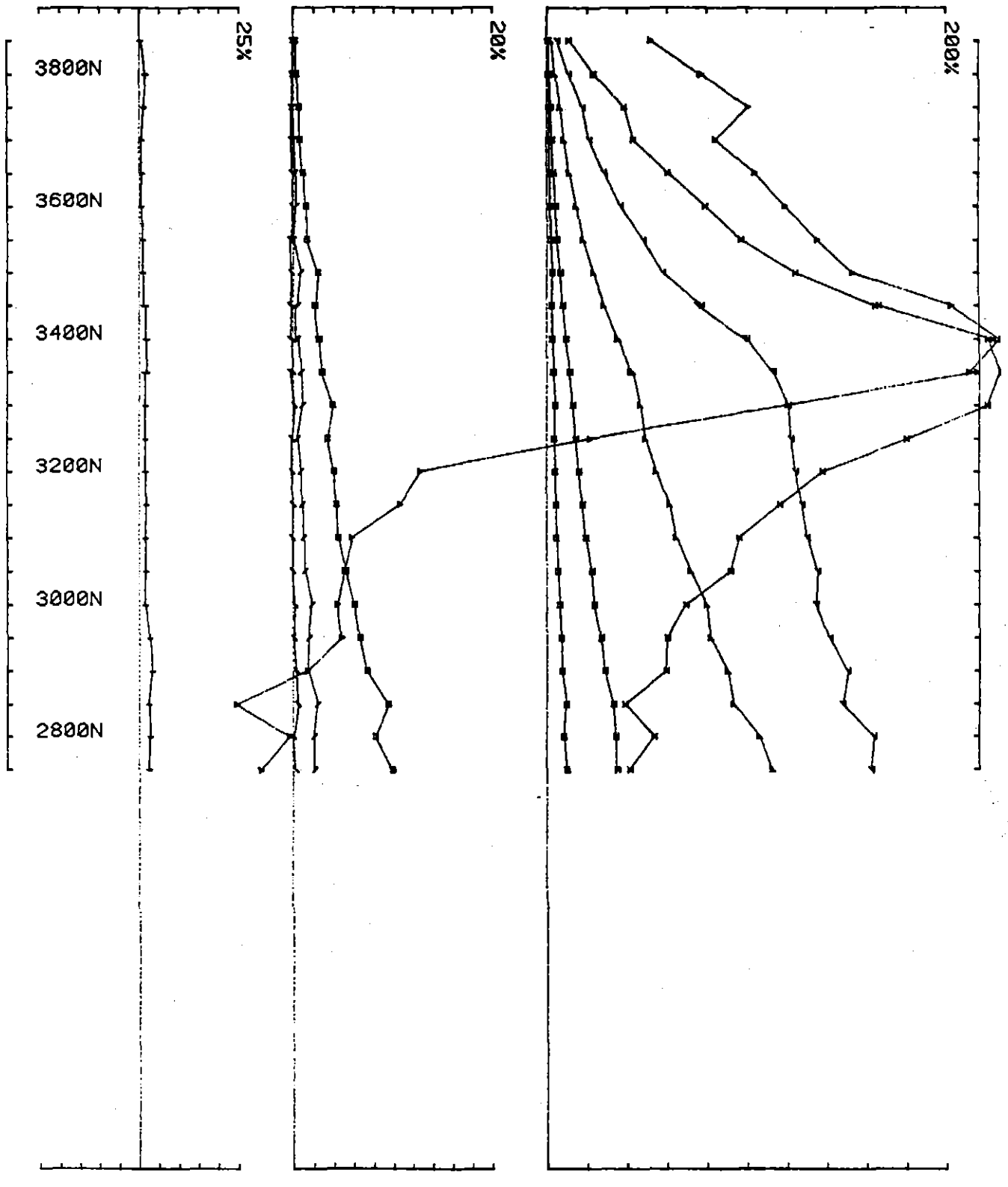

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UTEM SURVEY at base freq (hz) 26.230

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23/11/88

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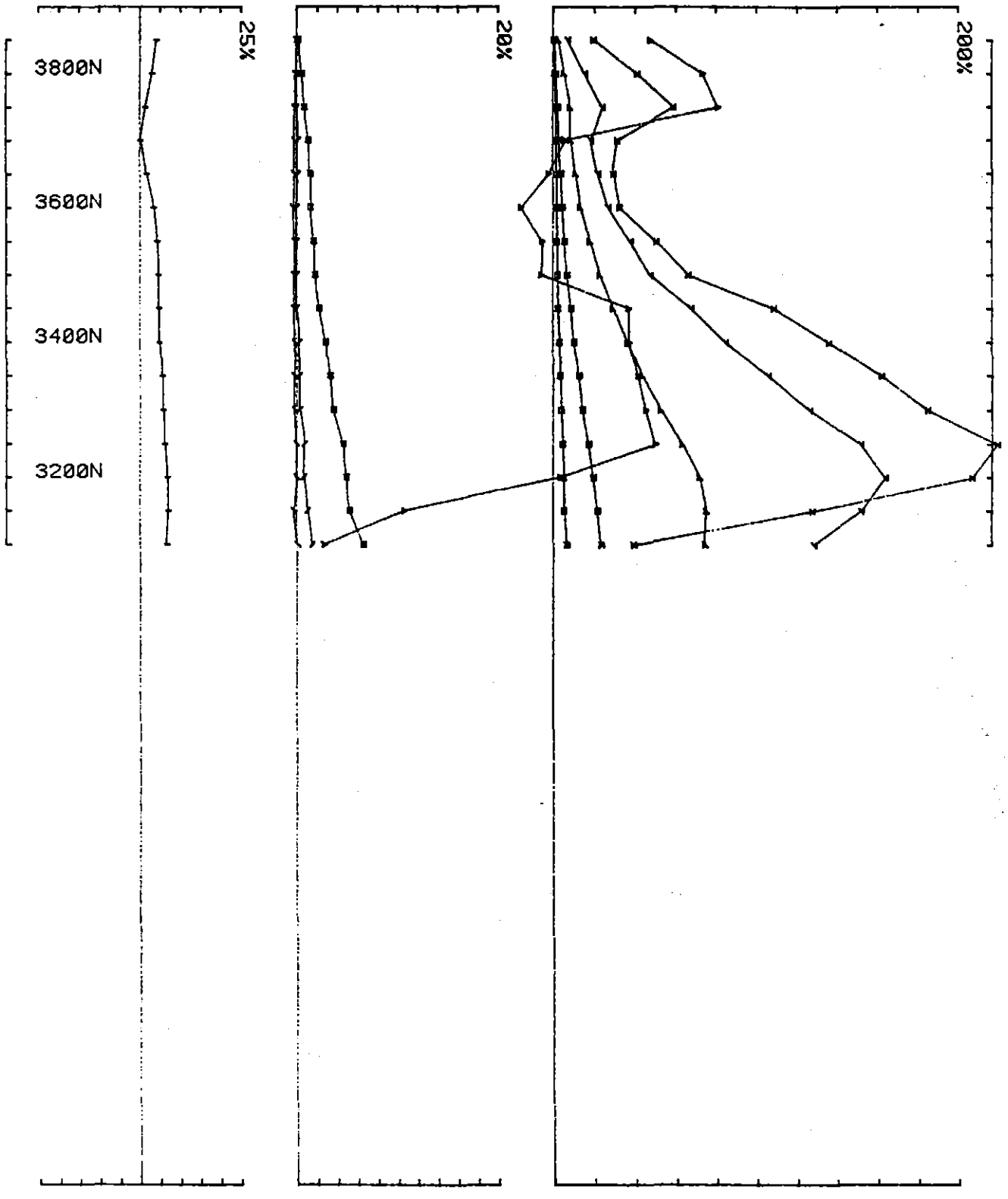

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client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

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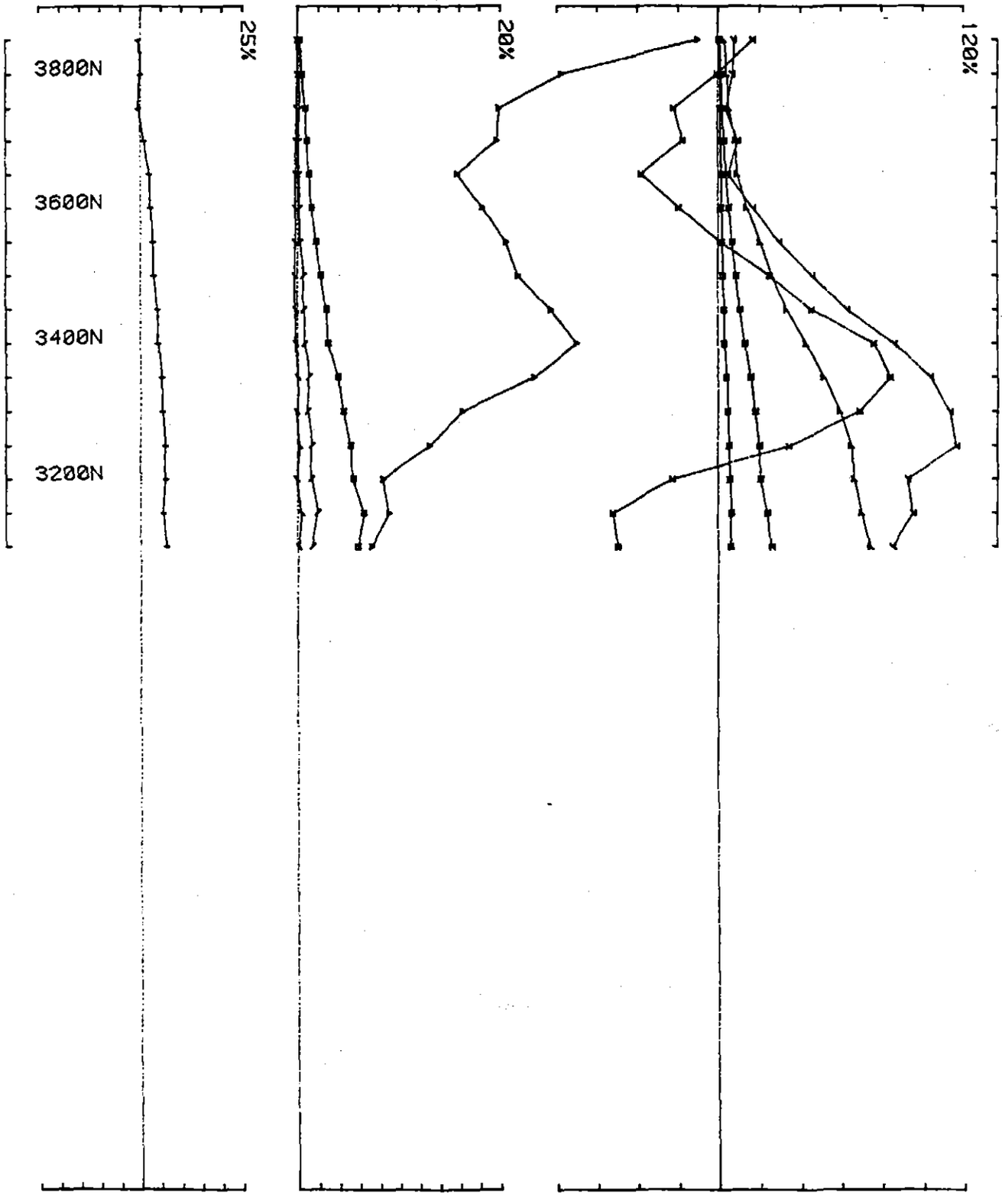

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client ABERFOYLE RESOURCES LTD
area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

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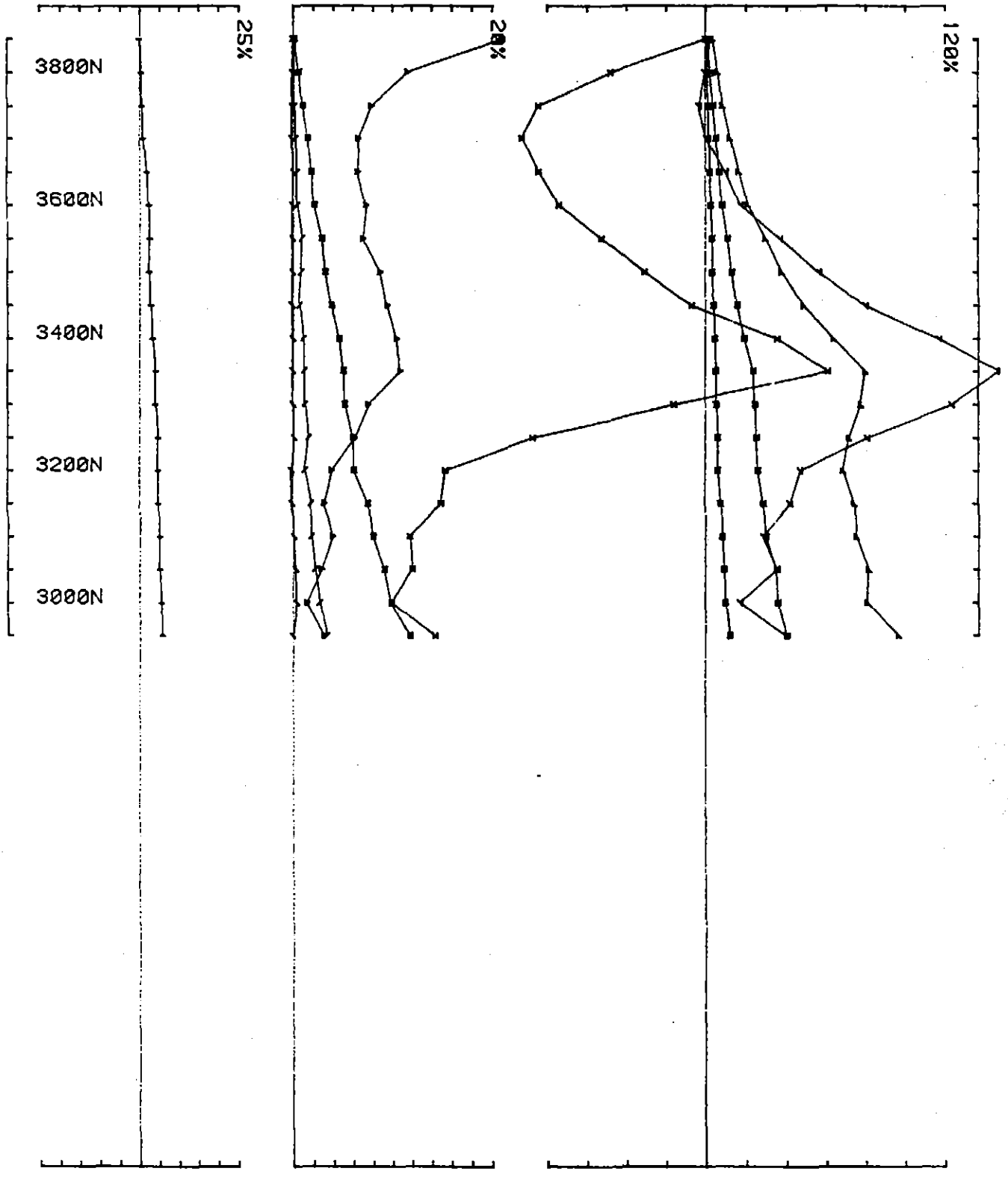

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area WINTERBROOK
UTEM SURVEY at base freq (hz) 26.230

loop dimensions
1400x1100m

loop no 2
line 8400E
component Hz
secondary field
Chl contin norm
23/11/86

APPENDIX II

600106

7th ASEG Conference

Paper No

Interpretation of TDEM Data Using First and Second Spatial Derivatives and Time Decay Analysis

J Silic
Aberfoyle Resources Limited
1st Floor
123 Camberwell Road
Hawthorn East Vic 3123

Keywords

Time Domain electromagnetics, spatial derivatives, decay analysis, current gathering, deposits, formational conductors

Short title

Spatial Derivatives in TDEM

Contact Jovan Silic on phone (03) 882 2226
fax (03) 813 1086

ABSTRACT

Current gathering in fixed loop electromagnetic data often dominates responses from large high-grade ore bodies as well as responses from less desirable features such as fault zones, weathering troughs and regional conductors. Through decay curve analysis, current gathering can now be unambiguously recognised. Many widely used EM interpretation techniques are not applicable to current gathering (channelling) responses. An effective method of deriving the location and shape of the causative source is to study the second spatial derivative, as is shown in several examples.

INTRODUCTION

The discovery of the Hellyer orebody in Tasmania by Aberfoyle Resources (Silic et al, 1985), has shown that important economic discoveries need not be characterised by long time constant, time domain electromagnetic (TDEM) responses. At the time of the discovery it was recognized that the Hellyer response was largely dominated by current gathering effects, and that other non-economic features such as lithologies or weathering troughs which have a resistivity contrast with their surroundings, may produce responses lasting to similar times. Some authors have reported on some of these problems from case histories as difficulties or limitations of TDEM (Spies and Parker, 1984; Irvine and Staltari 1984).

The purpose of this paper is to show that these problems can be

overcome; to discuss decay analysis techniques for recognising responses which are largely dominated by the "static" interaction between the half spaces electric field and the target, commonly known as current gathering (West and Edwards, 1985), and to illustrate the use of the spatial derivative of fixed loop TDEM data in recognizing the geometry of the conductive targets. Only the 2-D solution for the geometry of the targets will be presented; however, the concept can be extended to 3-D bodies.

APPLICATION OF THE INTEGRAL EQUATION METHOD

Numerous authors have discussed the generalized frequency domain integral equation for the total vector electric field that is composed of a primary field $\underline{E}^P$ within a half space perturbed by a secondary field $\underline{E}^S$ from a local conductivity variation within the earth (Hohmann, 1975; Raiche, 1974; Weidelt, 1975). Similar formulations apply to the solutions for the magnetic field (eg. West and Edwards, 1985). San Filipo and Hohmann (1985), and Oristaglio and Hohmann (1984) have successfully obtained solutions for the time domain.

The purpose of this section however is not to discuss the solutions for the "scattering" or "anomalous" current $\underline{J}^S(\underline{r}',t)$ within the inhomogeneity, but rather to determine the effect of a conductive half space on the problem of determining the secondary magnetic field from the scattering current. The equation relevant to the problem expresses the secondary magnetic field as

$$\underline{H}^S(\underline{r},t) = \iint_{vo}^{t} \underline{Gh}(\underline{r},\underline{r}',t-\bar{t})\ \underline{J}^S(\underline{r}',\bar{t})\ d\bar{t}d\underline{r}' \quad -(1)$$

and only the convolution integral

$$\int_{o}^{t} \underline{Gh}(\underline{r},\underline{r}',t-\bar{t})\ \underline{J}^S(\underline{r}',\bar{t})d\bar{t} \quad -(1a)$$

needs to be considered. To study this effect the Green's tensor solutions for a line source in a half space were evaluated (Silic, 1989). By assuming that current density with an arbitrary time dependence can be synthesised as a discreet or continuous sum of exponential decay functions $I_n e^{-t/\tau_n}$ it was concluded by evaluating equation 1a for a number of time constants τ_n, that for $\frac{t}{\sigma\mu r^2} \geq 1.0$ (r being the distance to the source, σ the halfspace conductivity) and measuring times up to about $4\tau_n$, free space approximations may be used to relate the magnetic field components to the current source, although in some instances a time delay which is largely a function of $\sigma\mu r^2$ may have to be incorporated into the calculation (Silic, 1989). Identical results are obtained for a current dipole which is relevant to the 3-D problem. As an example, for a 200 Ωm half space, and a distance r of 200 m, $\frac{t}{\sigma\mu r^2} = 1.0$ gives a time of 252 microseconds, a very early time for most TDEM responses. However the preceding conclusions are not suggesting that the half space is not affecting the current distribution within the inhomogeneity at these "late" times since the two effects can scale differently in time. It is only suggested that free space approximations may be used to relate the magnetic field to a current source. This concept is vital to the following sections.

RECOGNITION OF CURRENT GATHERING RESPONSES:

West and Edwards (1985) have shown by studying the response of a disk inhomogeneity in a conductive half space that to calculate the scattering current, direct interaction between the scattering current and the eddy currents they induce in the host medium may

be neglected to a first order approximation. These static or DC solutions suggest that in the case where the body is reasonably compact, and the primary electric field has the same general direction throughout, then as long as the target's "skin effect" does not dominate, current gathering "anomalous" current density $\underline{J}g^s(r',t)$ may be written from magneto metric response solutions (eg. Edwards, 1974) as,

$$\underline{J}g^s(\underline{r}',t) = C\ \underline{E}^p(\underline{r}',t) \quad -(2)$$

where C is a conductivity contrast/geometrical (body shape) function.

The current gathering "anomalous" current density will then essentially have the time dependence of the primary electric field in the vicinity of the body. Therefore, as long as the "late" time free space approximation from the previous section is valid, the magnetic field will have the same time dependence. To study this time dependence, electric field in a half space solutions from Lewis and Lee (1978) and Silic (1987) are used. It is shown that for step TDEM systems (eg. UTEM, West et al, 1984) at "late" times when $(a^2+r^2+z^2)\frac{\sigma\mu}{4t} \ll 1$, where a is the loop radius, τ is the distance from the loop centre and z is the depth,

$$\underline{E}^p(r,z,t) = \frac{a^2 r}{40\sigma\sqrt{\pi}}\left(\frac{\sigma\mu}{t}\right)^{5/2} + \frac{5a^2 rz\Gamma(5/2)}{48\sigma\sqrt{\pi}}\sqrt{\frac{\sigma\mu}{4t}}\left(\frac{\sigma\mu}{t}\right)^{5/2} \quad -(3)$$

while for the impulse systems (Buselli and O'Neill, 1977; McNeill, 1982)

$$\underline{E}^p(r,z,t) = \frac{a^2 r}{16\sigma^2\sqrt{\pi}}\left(\frac{\sigma\mu}{t}\right)^{7/2} + \frac{a^2 rz\Gamma(5/2)}{32\sigma^2\sqrt{\pi}}\left(\frac{\sigma\mu}{t}\right)^{4} \quad -(4)$$

Essentially at "late" times the step system electrical field is characterized by a $t^{-5/2}$ power-law decay, while the impulse

system's electric fields will have a $t^{-7/2}$ time dependence. To determine whether current gathering effects are dominating the response, a power law decay is fitted with care to the latest anomalous times. If this power law then dominates the response for most of the anomalous time, and its exponent depending on the system is close to -5/2 or -7/2, then current gathering effects may be inferred.

It is also recognized from Kaufman and Keller (1985), that the "very late" time inductive effect, when the vortex currents in the conductive target are following the decay of the half space magnetic field, will also have a $t^{-5/2}$ or $t^{-7/2}$ power law decay. However, this effect may only be important for thick or relatively flat lying targets since the direction of the half space primary magnetic field is relatively vertical at the "late" times. However, unlike the current gathering effect, it begins as a "very late" time phenomena. As such it is not expected to dominate the response for most of the anomalous time.

INTERPRETING SPATIAL DERIVATIVES OF FIXED LOOP TDEM DATA

Different interpretation methods must be used for current gathering anomalies than for eddy current induction responses. The strength of a current gathering effect is a function of conductivity contrast between the anomalous body and the host medium, the body's geometry and the conductivity of the half space, whereas the time dependence of the response is largely a function of the host medium's primary electric field. The latest time at which the anomalous response will be detected, will

therefore be largely a function of the maximum amplitude of the magnetic field at early time, this also being a function of depth or distance to the conductor. Therefore, discriminating techniques which rely on conductivity-thickness estimates from decay analysis, or the latest time affected by a conductor, are not valid for current gathering responses.

This section looks at the problem of attempting to obtain the shape of the conductive source from spatial derivative data, and its implementation as a discriminating technique. It is reasoned that if the shape of the target can be estimated from the profile data, then we may discriminate between the conductive bodies on the basis of their interpreted geometry.

Theoretical Considerations

By using the approximation discussed in the previous section that at "late" times free space Green's tensors may be used in equation 1, considerable simplication results in evaluating the potential field problem which links the magnetic field components to a current distribution. In this section, only results for 2-D bodies will be discussed. Formal solutions have been obtained for arbitrary current distributions within dipping sheets and blocks; however only some of the formal solutions for a dipping current sheet will be presented, as they have a similar, but simpler form to block conductor formulations (Silic, 1989). More complex shapes can be modelled by a superposition of a number of blocks and sheets. By assuming that a current density distribution can be expressed as a polynomial, then analytical solutions for the vertical (Hz) and horizontal (Hx) field components are obtained using Gradshteyn and Ryzhik (1980). Furthermore by manipulating the integral equation which links the

magnetic field components to a current density it is shown (Silic, 1989) that the first and second horizontal spatial derivatives of the magnetic field components are related through a set of geometric functions to the current density and its first spatial derivative at the edges of the conductor. As a result a number of simple relationships between the first and second derivatives of the magnetic field components and the edges of the conductive units are obtained. For example, for relatively uniform current flow in a current sheet

$$\left(\frac{\partial Hz}{\partial x}\right)^2 + \left(\frac{\partial Hx}{\partial x}\right)^2 = \frac{J(o)^2}{(x^2+h^2)} + \frac{J(L)^2}{(x_L^2+h_L^2)} \qquad -(5)$$

where J(O) and J(L) are the current densities at the respective edges of the sheet, while x, h and x_L, h_L, are the horizontal and vertical distances to the edges. This function is completely independent of dip, and is a sum of two bell shaped functions which peak over the edges of the sheet with halfwidths 2h and $2h_L$.

Similarly it is shown that over a current sheet that is flat lying and has uniform current (eg. current gathering weathering trough), the second horizontal derivative of the vertical magnetic field peaks over the edges of a sheet with halfwidths equal to the depth to top of the sheet. The peak to peak distance in the vertical magnetic field however, is always greater than or equal to the width of the sheet. In cases where the width of the sheet is large in comparison to its depth to top, the peaks in the second derivative and the vertical magnetic field are in close proximity to each other. Similar conclusions apply for non-uniform current flow (Silic, 1989).

Figure 1 illustrates these important points. Some responses are

superficially similar. For example the magnetic field over a vertical sheet at depth may approximate the vertical magnetic field over a wide sheet. However, the second derivative method will highlight the short halfwidths in the derivative over the "shallow" edges of a flat lying sheet and allow the discrimination between the two responses as will the "proximity' of the second derivative maxima with respect to the peaks in the vertical magnetic field. Over vertical conductors the peaks in the second derivative for Hz are at least a half depth unit closer to the cross-over point than the peaks in the magnetic field (Silic, 1989). By considering block conductors, similar conclusions apply; second derivatives peak over the edges of relatively steeply dipping blocks, with halfwidths equal to twice the depth to top. Also, in comparison with sheets, the inflection points of the vertical magnetic field are further out from the edges. Discrimination between block conductors, simulating broad lithological units, and relatively steeply dipping sheets then depends on the identification of block edges through the second derivative technique.

ANALYSIS OF FIELD DATA

All three techniques, the forward modelling of the magnetic field components and first and second derivatives have the capacity to recognise the shape and location of conductive bodies. The spatial derivatives however, are preferred as they have a set of simple relationships with the edges of an arbitrary shaped conductor as discussed previously.

Four field examples, all of which have a dominant current gathering $t^{-5/2}$ "late" time decay and a scale model data set will be used to illustrate interpretation techniques which are based on the insights from previous sections. Of the four field examples, two are over world class orebodies, one is over a lithological conductor which shows superficial similarities with responses over the two orebodies and a fourth is a complex response which may contain a worthwhile exploration target. No second derivatives are actually calculated for reasons discussd in the following section. However to follow the logic of the arguments it is sufficient to know that the locations of the peaks in the second derivative can be estimated as points corresponding to the maximum change in the slope of the raw data, and that zeroes occur where the slope of the raw data does not change over some profile length. The examples are used not so much to give a recipe for the interpretation technique but rather to demonstrate the general principles on which an interpretation can be based so that a plausible explanation for the EM processes for the shape of conductive bodies can be obtained. Both the qualitative technique and the present limitations to the quantitative approach will be discussed.

(a) <u>Qualitative Approach</u>

By visually estimating the variation in the slope of the Hz profiles, we can determine the location of the second derivative maxima and its wavelength. We can use this information in conjunction with Hz data, to estimate the shape of the source and its depth to top. In particular any sudden changes in the slope are to be understood as indicating a shallow edge to a conductive unit, or an abrupt variation within a wider conductor.

conductor became a primary target because the visual estimate of the second derivative of the profile shows a smooth continuous variation not indicative of any obvious edge effects which may be related to a broad shallow formational conductor.

The response over the very large Red Dog deposit (Van Blaricon and O'Connor, 1986), is dominated by a current gathering effect, due to its bulk resistivity of 125 Ω m (Figure 4). Any attempt to explain these results in terms of a free space model fails. However the maximum changes in the profile slope uniquely correspond with the edges of the mineralization, with the smoother slope variation corresponding to deeper terminations. The response between edges 2 and 3 is not diagnostic of any particular source and interpreting it by conventional techniques would result in identification of a shallow conductor. However connecting edges 2 and 3, with the deeper edges at 1 and 4, results in a unique interpretation of a substantial, mostly buried flat-lying target. As a comparison, the response marked by edge 5 is interpreted to be a very broad and outcropping source, and surface inspection downgraded it as a prospect.

Superficially, the current gathering response in Figure 5 is similar to the Hellyer anomaly. However, analysis of the very sudden changes in the slope of the profile identifies very shallow edges (less than 10 m from surface) from a broad conductive unit. In this area, this was not considered to be an orebody target.

UTEM scale model data in Figure 2 adapted from Macnae et al (1983), shows that every edge within a conductor, (in this case representing variations within the overburden), corresponds to one of the maximum changes in the slope of the profile. Away from these second derivative peaks the slopes are relatively constant, indicating a "narrow" second derivative and therefore that the source is shallow. This is supported by the fact that the peaks in the second derivative are also close to the minima and/or maxima of the anomaly due to the variations in the overburden as discussed in the previous section. Other maximum changes in the slope are due to normal thin layer, early to late time moveouts. This simple analysis could have led Spies and Parker (1984) and Irvine and Staltari (1984) to recognise their responses as being due to variations in overburden and not from a conductor at depth.

The response over the Hellyer deposit in Tasmania shown in Figure 3 is dominated by a "late" time $t^{-2.7}$ power law decay and hence current gathering effects may be inferred. The reason that current gathering dominates is that in this cross section ~~of~~ the dimension of the deposit is small in comparison to its depth. Therefore, at the surface, inductive flow effect is small compared to the magnetic field from unidirectional current gathering flow. This is not to say that the body is a poor conductor. The time constant obtained from down hole EM measurements is about 3-4 milliseconds (Eadie, 1987). In spite of the fact that current gathering was known to dominate this response, the

A more complex profile (Figure 6) can be evaluated as a superposition of a number of responses, some of which show obvious near surface edge effects as sharp changes in the slope of the curve. Their locations have been confirmed by a conventional resistivity survey. These anomalous responses all have an approximate $t^{-5/2}$ "late" time power law decay lasting until about 4 ms, and have no separation in time. However, since the objective on this property is to find a deeply buried deposit, the smooth continuous variation in the profile's slope, indicating a "broad" second derivative gave evidence of a primary target. In this case the smooth part of the profile is outlining only a part of a normal cross-over type anomaly making quantitative interpretation difficult.

(b) Quantitative Approach

The problem posed in the quantitative approach is to remove or identify responses from sources which are not considered to be of economic importance, and to quantitatively interpret the second derivative.

As an example the profile data from Figure 6 is splined and the subsequently splined second derivatives is produced (Figure 7). This highlights the "broad" non-zero second derivative and the near surface edge effects. Since, as discussed earlier, the halfwidth of the second derivative data due to broad conductors is approximately equal to its depth to top, a problem is encountered. Fifty metre sampling of the data, as was done in this case, seriously undersamples the field data for very shallow sources. The splined second derivative data in this case has minimum

halfwidths of about 50 metres. As a result, any attempt to quantitatively remove the shallow "edge" effects is inaccurate. More closely spaced profile data is needed to accomplish this.

The quantitative approach to this type of interpretation is still being developed. A simple filter has been formulated to remove shallow edge effects from data, and a full inversion technique is the next step.

CONCLUSION

We in the exploration industry who have worked on interpretation problems have been frustrated over the difficulty of 3D-EM generalized modelling techniques to provide answers and inversion algorithms that are usable over a complex set of conductivity structures. As a result the historical tendency has been to discriminate between responses on the basis of their time constants or latest anomalous times. Our experience has however shown that this can be a very dangerous practice, if current gathering effects dominate, as the examples over the Hellyer and Red Dog deposits illustrate. As a result a new discrimination technique had to be found. Current gathering effects can now be recognised through decay analysis, and information about the shape and location of the source can be derived through analysis of the spatial derivatives. Although only some aspects of the spatial derivative and these new modelling techniques have been discussed in this paper and examples have been restricted to understanding current gathering responses, the technique can be applied to a completely general current flow.

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LIST OF FIGURES

Figure 1 Normalized vertical (Hz) magnetic fields (bottom) and second horizontal derivatives (top) over a current sheet with a constant current. The profiles are normalized by their peak values, with the magnetic field showing cross-over type responses over the sheet, and the second derivative peaking over the edges of the sheet. The halfwidth of the second derivative over the edges is equal to depth to top. Peak to peak distances in the vertical magnetic field are greater than or equal to the width of the sheet. Second derivative maxima are close to the minima and the maxima in the vertical magnetic field.

Figure 2 UTEM (Hz) scale models over disruptions in a thin layer adapted from MacNae et al. (1983). Every disruption within the layer corresponds to one of the maximum changes in the slope of the profile. Additional maximum changes in the slope are due to normal thin layer moveout.

Figure 3 UTEM (Hz) data from Hellyer ore body. The variation in the slope of the profile is continuous and smooth indicating a broad second derivative. No obvious edge effects are evident. The decay between the two arrows is dominated by a $t^{-2.7}$ power law decay, and so a current gathering effect is inferred.

Figure 4 UTEM (Hz) data from Red Dog deposit, Alaska. Maximum changes in the slope of the profile correspond to the edges of the orebody. Smoother changes correspond to the deeper terminations. Edge 5 outlines a nonprospective outcropping conductor. The decay analysis for the data between the two arrows, shows that a $t^{-2.33}$ "late" time asymptote dominates.

Figure 5 Current gathering response from a prospect near Marysville, B C, Canada shows superficial similarities to the Hellyer response in Figure 3. Sudden changes in slope identify this response to be from a broad near-surface source.

Figure 6 UTEM (Hz) data showing superposition of a number of responses, some of which show obvious edge effects from near surface broad conductors. All responses asymptote to a $t^{-5/2}$ power law. No separation between responses in time is evident. The response marked with the shaded line has a broad second derivative as indicated by a continuous variation in the profile slope, and could represent a buried target at a depth of 200-250 metres. The shaded line represents only a part of a normal Hz cross-over anomaly.

Figure 7 Cubic splined second derivative of the 2 ms UTEM data from Figure 6, highlighting the broadness of one of the responses. The data is not good enough for a quantitative analysis, without the removal of the near surface effects.

124

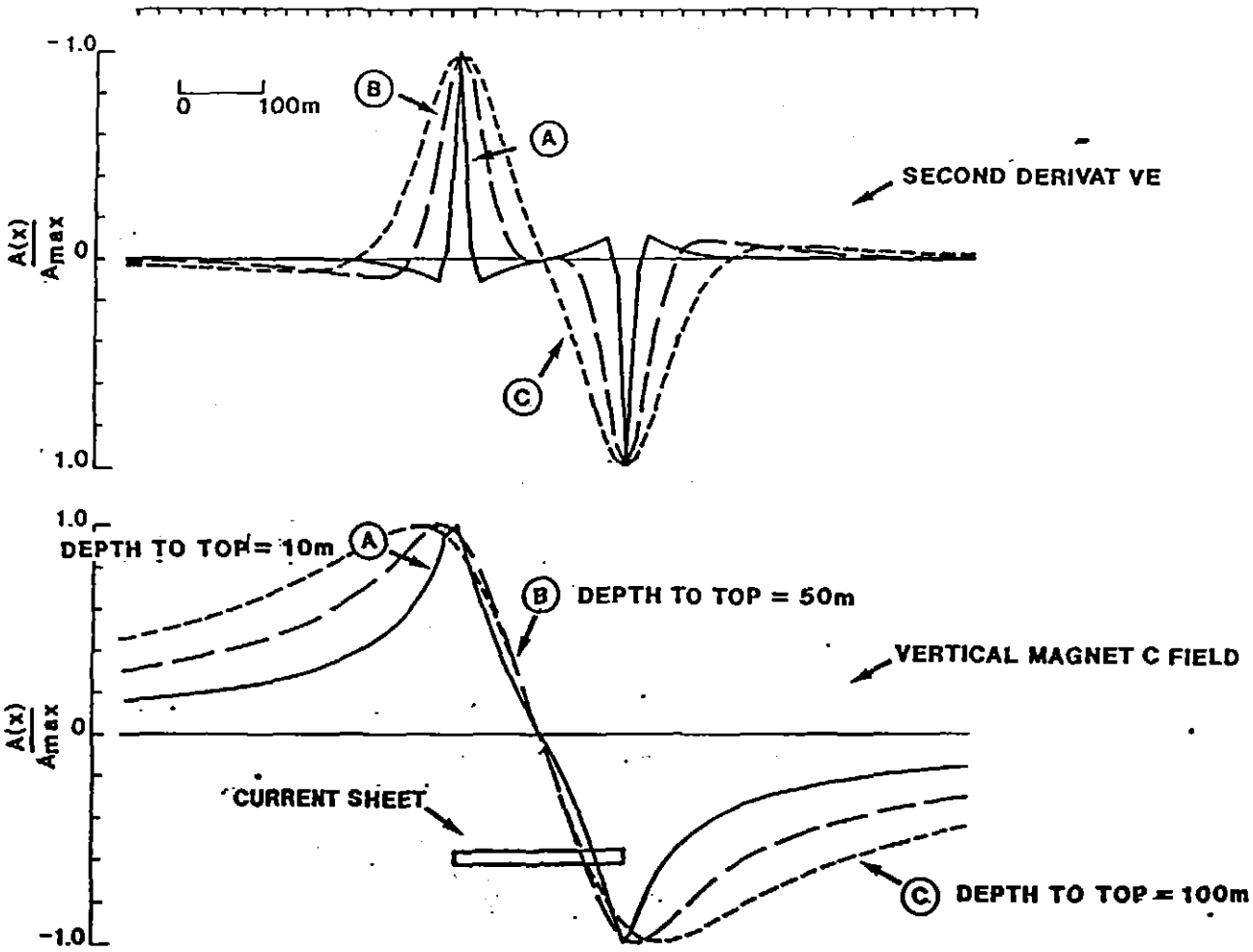

Fig 1

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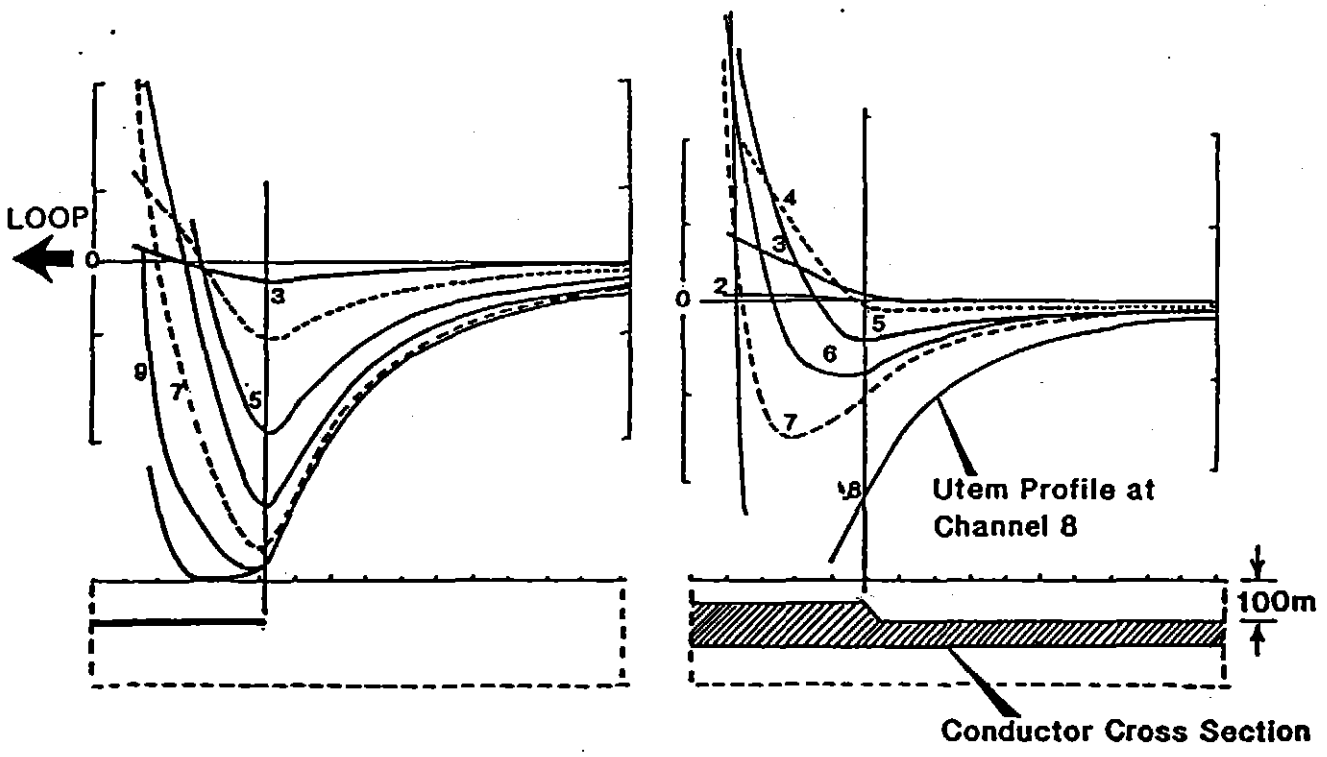
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2
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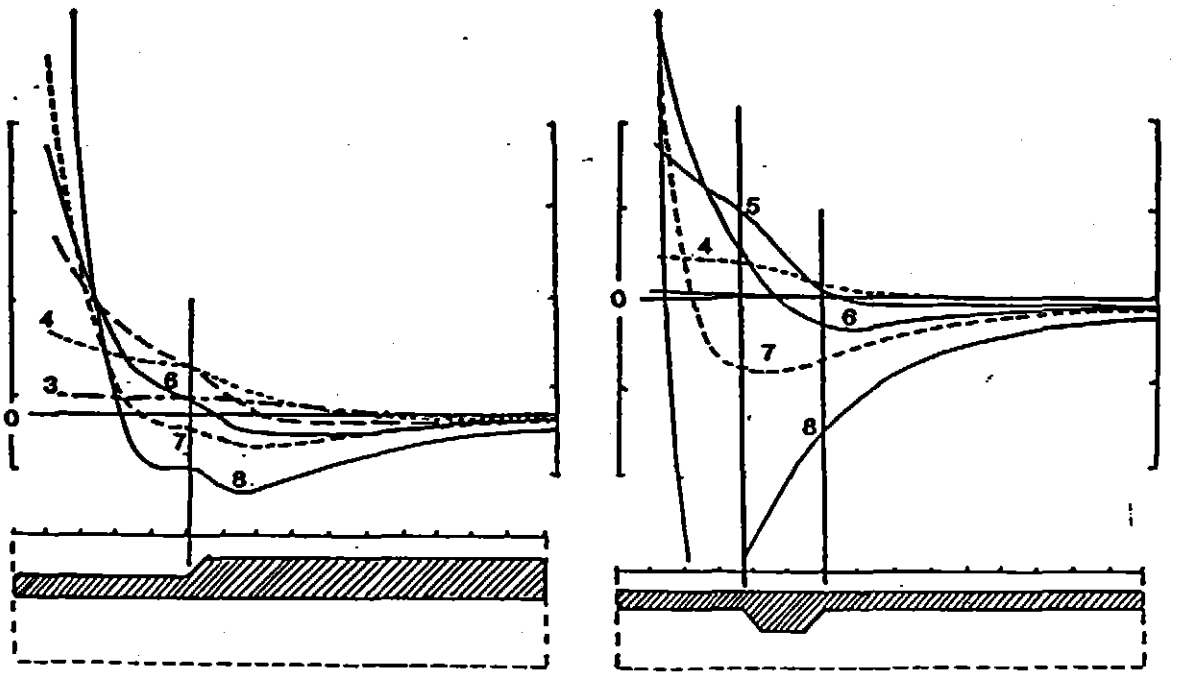
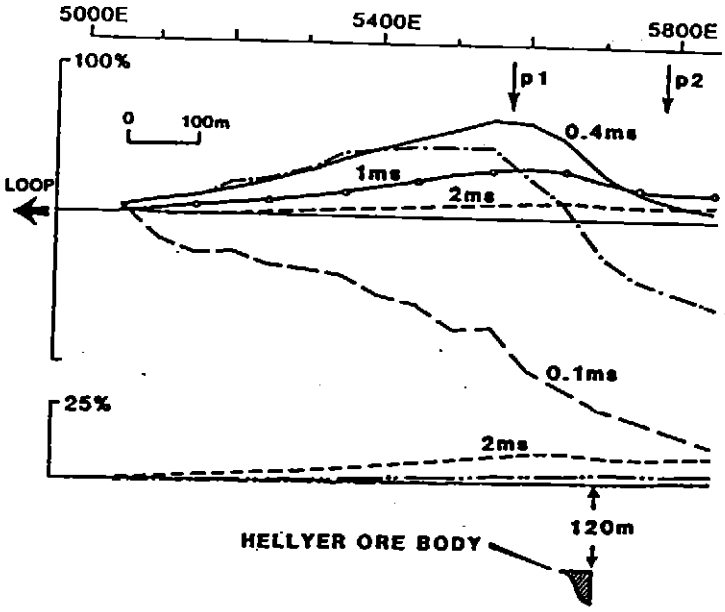
Utem Profile at
Channel 8
100m
Conductor Cross Section


0
3
4
5
6
7
8


5000E
5400E
5800E
100%
p1
p2
0
100m
0.4ms
1ms
2ms
LOOP
0.1ms
25%
2ms
120m
HELLYER ORE BODY

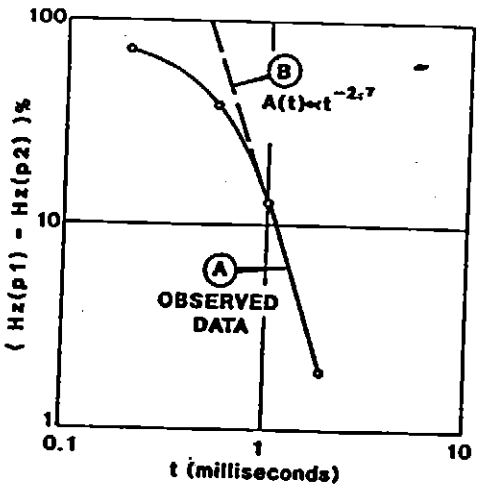

100
10
1
0.1
1
10
(Hz(p1) - Hz(p2))%
t (milliseconds)
B
A(t)∝t^-2.7
A
OBSERVED
DATA

Fig 3

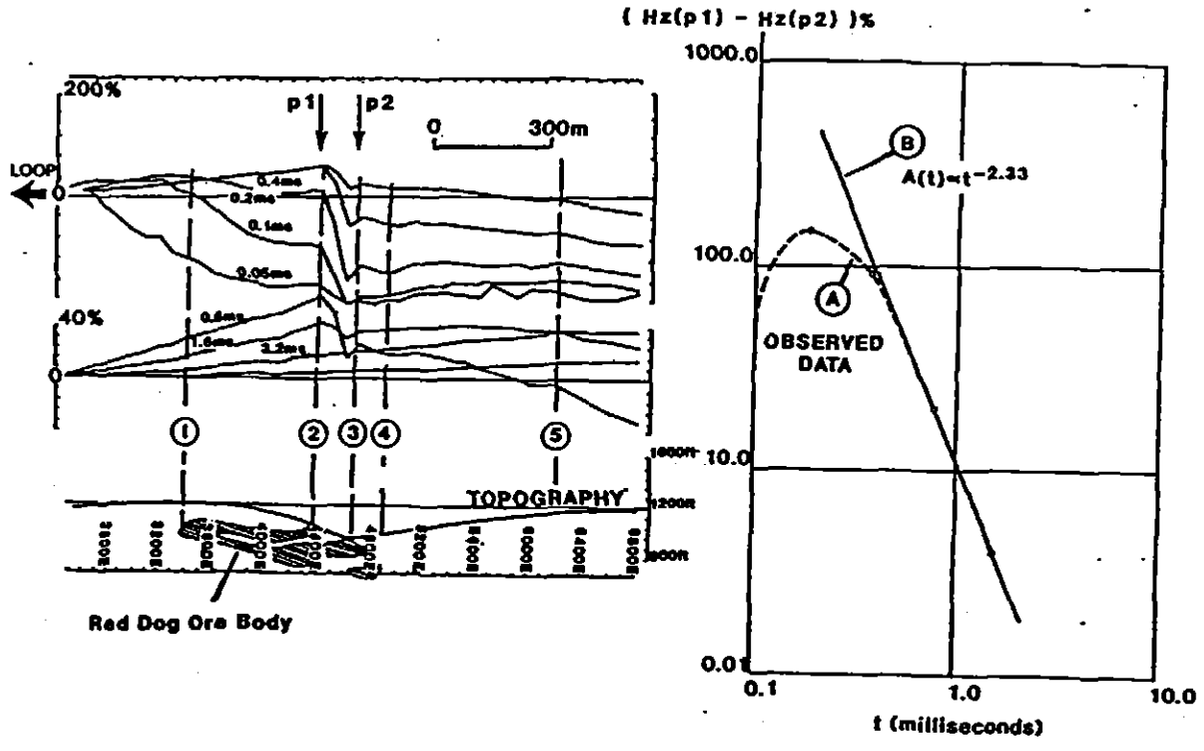

200%
p1
p2
0
300m
LOOP
0.4ms
0.2ms
0.1ms
0.05ms
40%
0.8ms
1.6ms
3.2ms
1
2
3
4
5
TOPOGRAPHY
Red Dog Ore Body
(Hz(p1) - Hz(p2))%
1000.0
100.0
10.0
0.01
0.1
1.0
10.0
B
A(t)∝t^-2.33
A
OBSERVED DATA
t (milliseconds)

Fig 4

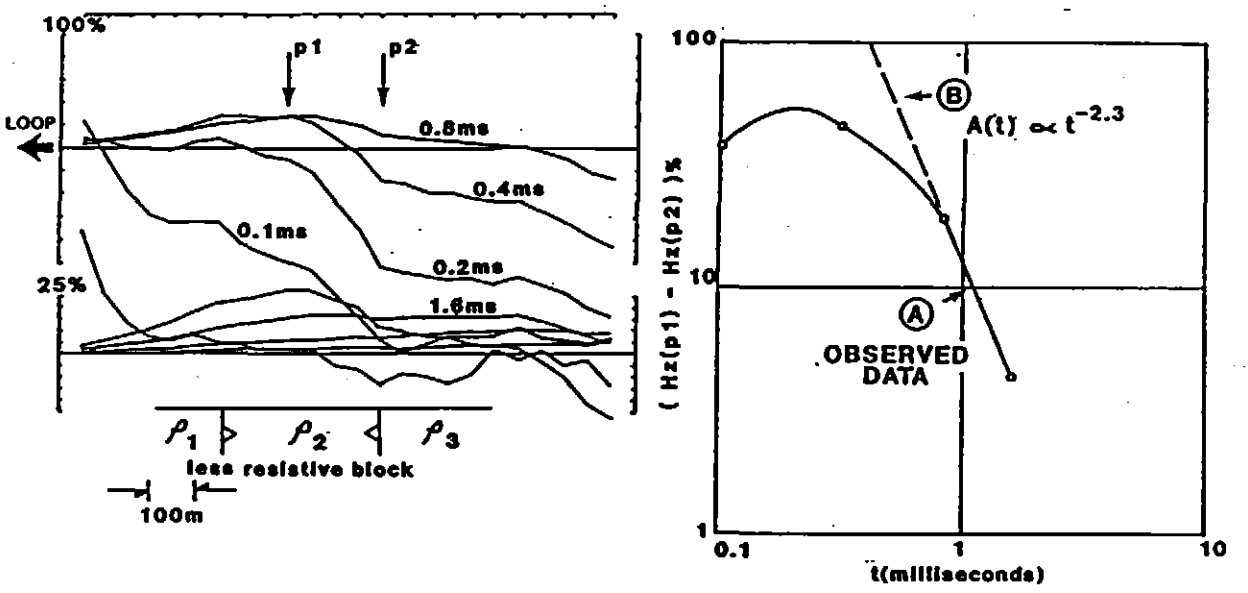
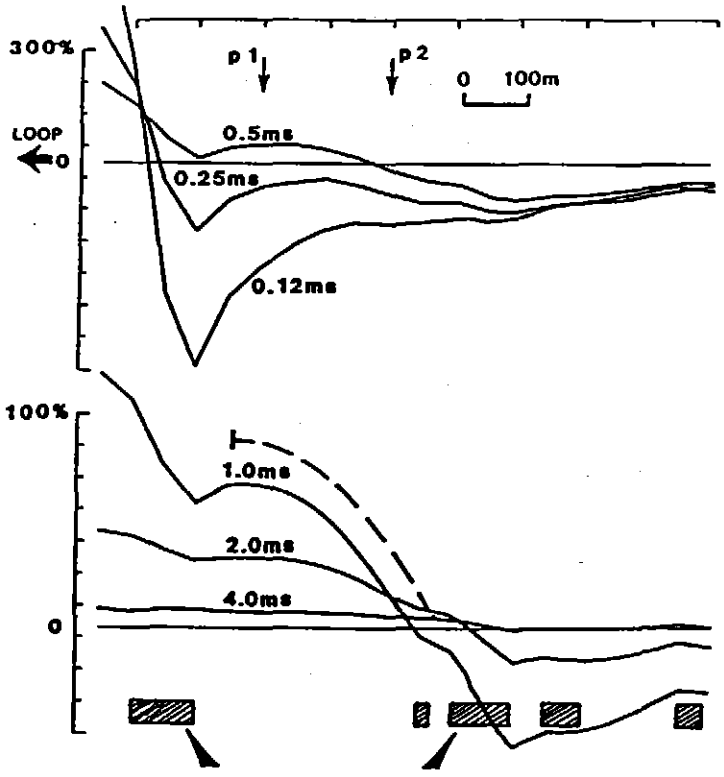

100%
p1
p2
LOOP
0.8ms
0.4ms
0.1ms
0.2ms
25%
1.6ms
ρ1
ρ2
ρ3
less resistive block
100m
100
10
1
0.1
1
10
(Hz(p1) - Hz(p2))%
B
A(t) ∝ t^-2.3
A
OBSERVED DATA
t(milliseconds)

Fig 5


300%
p1
p2
0
100m
LOOP
0
0.5ms
0.25ms
0.12ms
100%
1.0ms
2.0ms
4.0ms
0
LATERAL EXTENT OF WEATHERING CONDUCTORS

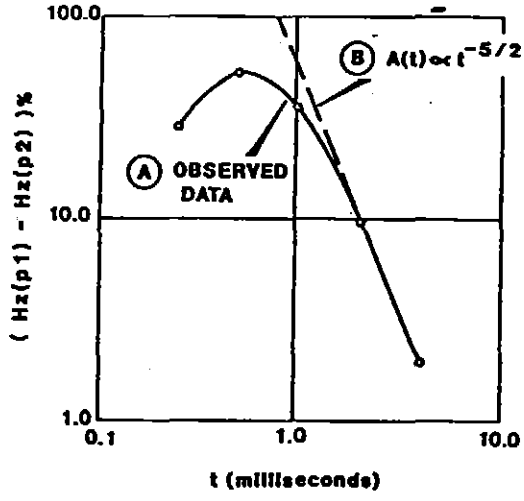

100.0
10.0
1.0
0.1
1.0
10.0
(Hz(p1) - Hz(p2))%
A OBSERVED DATA
B A(t)∝t^-5/2
t (milliseconds)

Fig 6

130

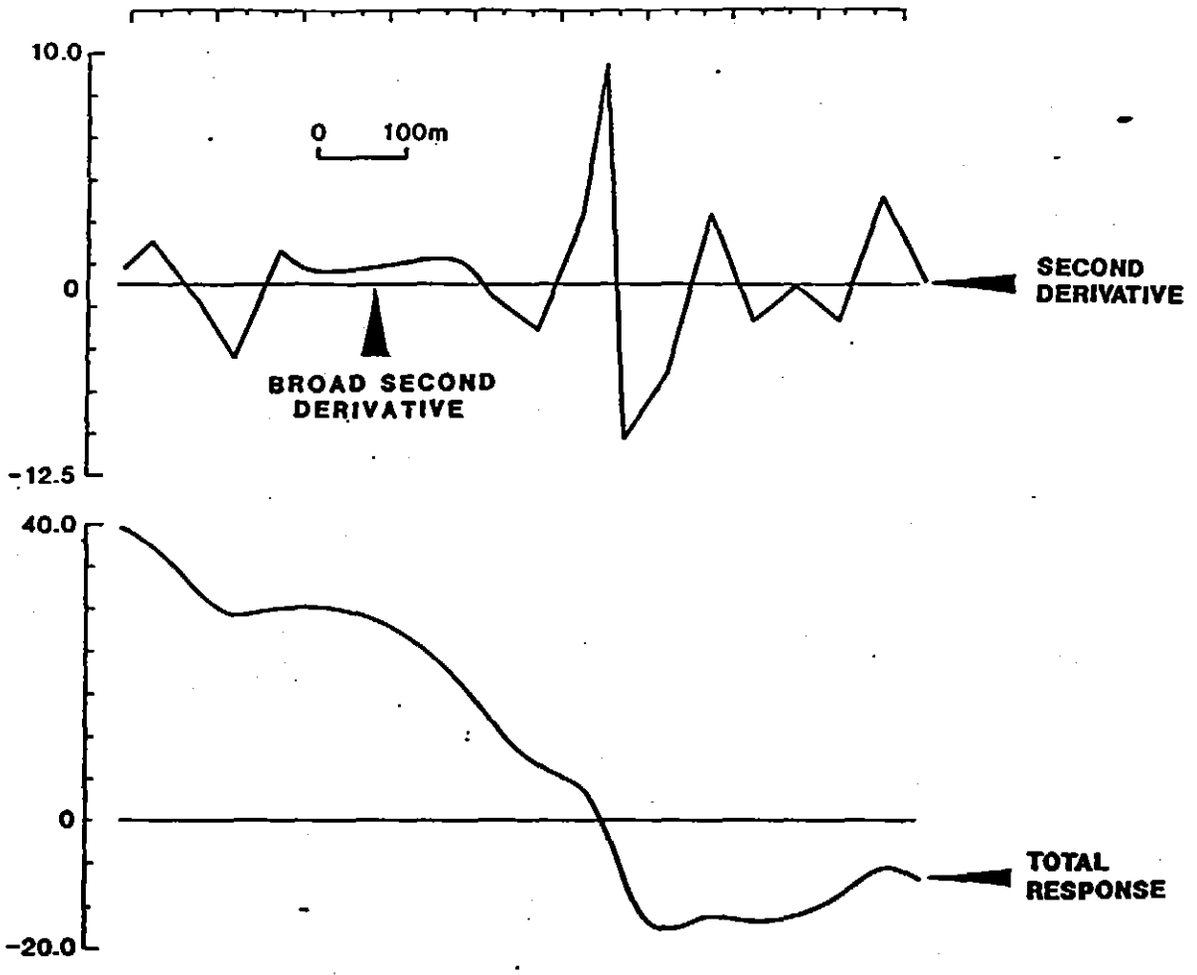
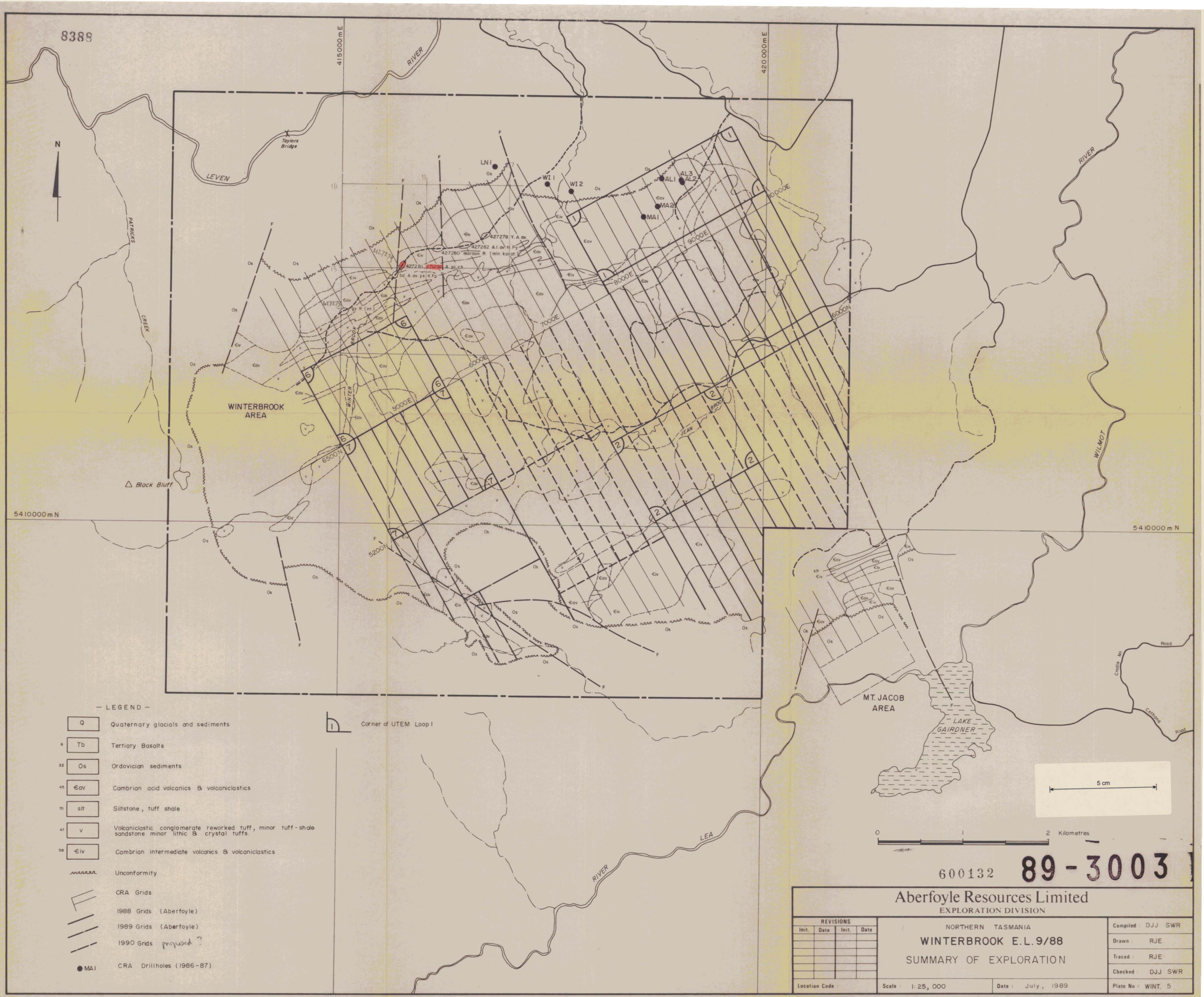

10.0
0
-12.5
0 100m
SECOND DERIVATIVE
BROAD SECOND DERIVATIVE
40.0
0
-20.0
TOTAL RESPONSE

Fig 7


8388
415000 m E
420000 m E
5410000 m N
N
LEVEN
RIVER
Taylors Bridge
PATRICKS
CREEK
WINTERBROOK AREA
Black Bluff
WINTER
BROOK
JEAN
BROOK
LN1
WI1
WI2
AL1
AL2
AL3
MA1
MA2
427278 Y.A.av.
427282 A.I.av.tr.Py
427280 maroon R. (min.karat.)
427281, 271791 A.pl.ch.
bd.A.av.pk.K.Fp
5000E
6000E
7000E
8000E
9000E
10000E
6500N
5200N
6000N
WILMOT
RIVER
MT. JACOB AREA
LAKE GAIRDNER
Road
Cradle Mt.
Cethana
Road
LEA
RIVER
5 cm
0
1
2 Kilometres
— LEGEND —
Q Quaternary glacials and sediments
6 Tb Tertiary Basalts
32 Os Ordovician sediments
45 €av Cambrian acid volcanics & volcaniclastics
70 slt Siltstone, tuff shale
47 v Volcaniclastic conglomerate reworked tuff, minor tuff-shale sandstone minor lithic & crystal tuffs.
58 €iv Cambrian intermediate volcanics & volcaniclastics
Unconformity
CRA Grids
1988 Grids (Aberfoyle)
1989 Grids (Aberfoyle)
1990 Grids proposed ?
MA1 CRA Drillholes (1986-87)
Corner of UTEM Loop 1
600132
89-3003
Aberfoyle Resources Limited
EXPLORATION DIVISION
REVISIONS
Init. Date Init. Date
NORTHERN TASMANIA
WINTERBROOK E.L. 9/88
SUMMARY OF EXPLORATION
Compiled: DJJ SWR
Drawn: RJE
Traced: RJE
Checked: DJJ SWR
Location Code:
Scale: 1:25,000
Date: July, 1989
Plate No: WINT. 5

8386

N

5415 000m N

14

13

12

11

10

09

5408 000 m N

413 000 m E

14 15 16 17

Mountain Valley Lodge

400

RIVER

LEVEN

Track

Brookes

12/10

12/9

Smiths Plains Road 23/23

23/22

04/27

23/27

BROOK

21/16

21/17

WINTER

Track

5600E

Walking

23/10

23/14

Paddys Lake

Winterbrook Falls

4200E

5200N BASE LINE

104/88

4225E

1074

600133

N

TASMANIA

BURNIE

DEVONPORT

LAUNCESTON

Winterbrook E.L 9/88

QUEENSTOWN

HOBART

0 100 Km

Index to Sheets

A B

0 500 1000metres

5 cm

Aberfoyle Resources Limited
EXPLORATION DIVISION

89-3003.

REVISIONS			
Init.	Date	Init.	Date

NORTHERN TASMANIA

WINTERBROOK E.L. 9/88

LOCATION SURVEY POINTS

Compiled :

Drawn :

Traced : JLR

Checked :

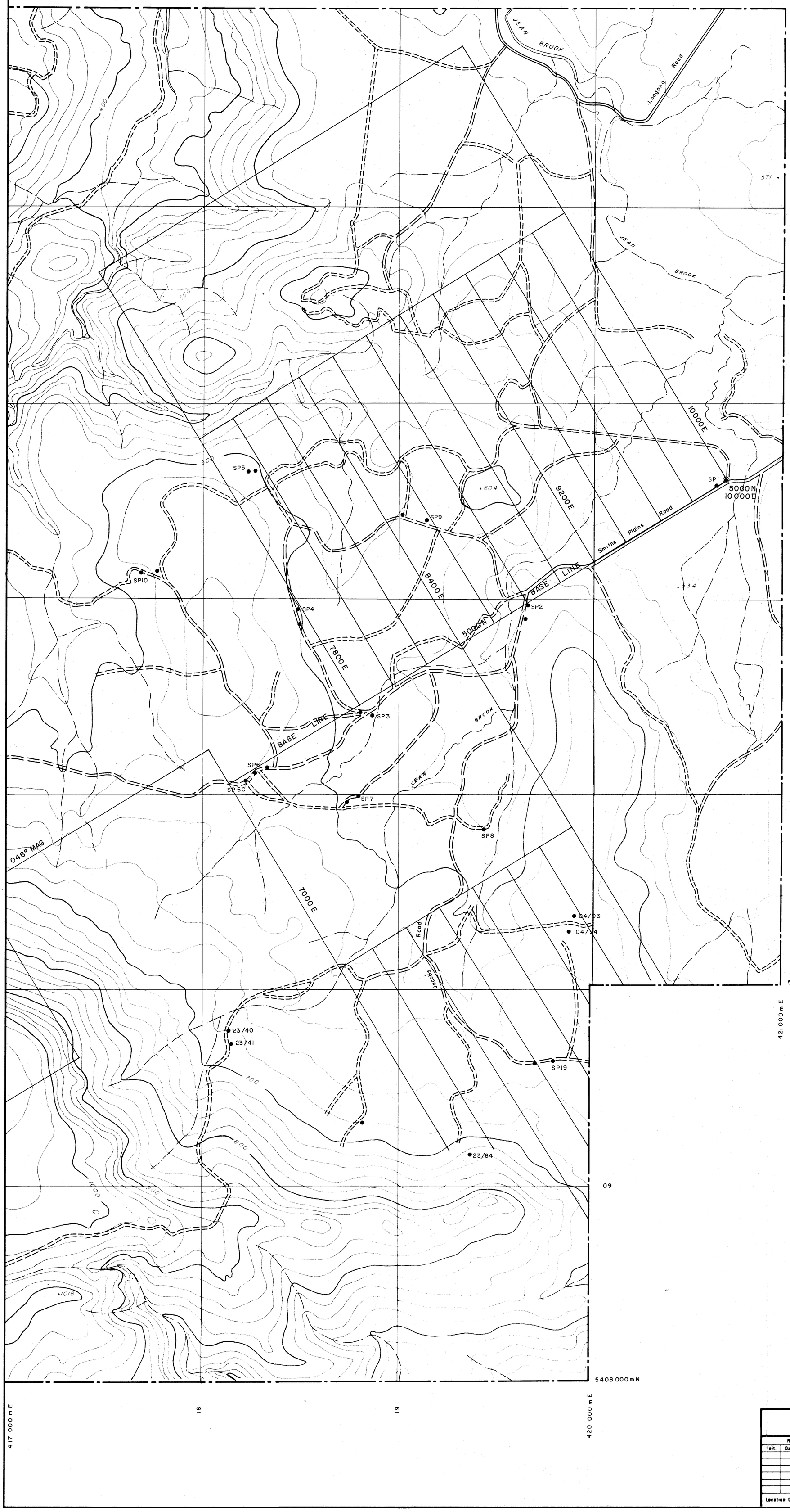
Location Code : K55/3

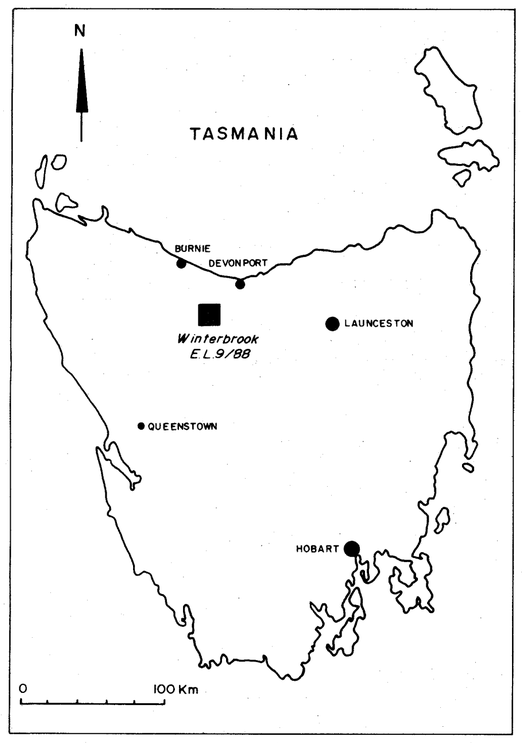
Scale : 1:10 000

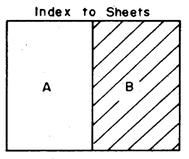
Date : July, 1988

Plate No : WINT 4 A

8387







5 cm

0 500 1000metres

600134

Aberfoyle Resources Limited
EXPLORATION DIVISION

89-3003

REVISIONS			
Init.	Date	Init.	Date

NORTHERN TASMANIA

WINTERBROOK E.L.9/88

LOCATION SURVEY POINTS

Compiled :
Drawn :
Traced : JLR
Checked :

Location Code : K55/3
Scale : 1:10000
Date : July, 1988
Plate No : WINT 4 B