CORRELATION OF MARINE SEISMIC AND HIGH RESOLUTION AIRBORNE MAGNETIC DATA

A CASE STUDY IN THE WESTERN OTWAY BASIN, OFFSHORE VICTORIA

BY

D.L. CATHRO

RECORD 1995/52

AGSO

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

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SUMMARY

The acquisition in 1994 of a high resolution aeromagnetic survey in the offshore Otway Basin has allowed the correlation of detailed magnetic data and marine seismic data over the same geological features

Weak lineaments in a vertical gradient image were determined to be the result of real structures. Transfer faults, normal faults, depositional channels and bars and igneous intrusions were identified on magnetic images and verified on seismic sections.

This case study has verified the ability of the magnetic method to map structural, sedimentary and igneous features within a sedimentary basin.

CONTENTS

Appendix has been omitted in the hardcopy of record 1995/52.

LIST OF FIGURES

Figure 18a	Magnetic profile N over barrier bars and faulting illustrated in seismic section.
Figure 18b	Magnetic model of profile N with magnetic response attributed to a combination of barrier bars, channelling and faulting.
Figure 18c	Alternative magnetic model of profile N with magnetic model attributed to very shallow channels and faulting.

1. INTRODUCTION

The integration of seismic and magnetic data in the interpretation of sedimentary basins is becoming more common as a result of improvements in the processing and imaging of the magnetic data. Total - field magnetic images are traditionally used to determine the broad structural geometries of sedimentary basins. The aim of this study is to determine how well the detailed information present in modern - day total field and vertical derivative images correlate with seismic data. For example, are weak lineaments in the vertical gradient real structures, or are they fortuitous alignment of events as a result of image processing techniques performed on the data?

During 1994, 44379 km of high resolution airborne data was acquired in the offshore Otway Basin for the Australian Geological Survey Organisation. Results of this survey were presented by Gunn (1994). The flightline spacing was 500m, at an altitude of 130m above sea level, with sampling interval of 8m and a resolution of 0.01nT. Due to active exploration in this region, seismic data is also available in the same area. Selected lines for correlation were chosen from Survey OP80 shot in 1980 for the Phillips Australian Oil Company. Acquisition parameters include a 25m group interval with a 2 second sample rate. The availability of both the magnetic and seismic data in this region provides an excellent opportunity for correlation of detailed magnetic and seismic responses of the same geological features.

2. IMAGES USED FOR MAGNETIC INTERPRETATION

Magnetic interpretation images used for the correlation consisted of:

- Total magnetic intensity (TMI) colour image (Fig. 1). This image was primarily used to supply data for modelling using the software package Modelvision. It was chosen for this purpose rather than the other images because it is known that the data in this form has not been affected by later processing. Deep regional basin-forming features were interpreted from the reduced to the pole version of this image, which removes the effects of the inclination of the Earth's magnetic field.

- First vertical gradient grey scale and colour images illuminated from various angles to accentuate the visibility of subtle high frequency lineaments produced by shallow sources. It is the high frequency anomalies clearly visible in these images that were investigated for correlation with seismic data. Figure 2 illustrates a colour vertical gradient image illuminated from the northeast at a scale of 1:1 000 000.
- Interpretation of the above mentioned images at 1:250000 scale was performed by Gunn (1994). His interpretation (Fig. 3) illustrates the four main features chosen for possible correlation with seismic data. These are: transfer faults, channels, normal faults and igneous intrusions. The deep basic igneous sheet cannot be correlated with the seismic due to its depth within the section.
- Magnetic profiles of the non illuminated vertical gradient were constructed parallel to, and at the same horizontal scale as, the seismic sections to allow direct comparison of the two datasets.

3. SEISMIC DATA USED IN CORRELATION

- Selected migrated sections at various scales from survey OP80 originally acquired by GSI for Phillips Australian Oil Company were used in the correlation with the magnetic data. The data were not originally migrated but were later reprocessed by BHP and Geco- Prakla. Full details of the seismic lines used in this study, their location and the extent of processing are supplied in Appendix 1.

4. REVIEW OF MAGNETIC INTERPRETATION

The interpretation of Gunn (1994) illustrates several main features within the Western Otway Basin (Figs 1, 2 and 3).

- The magnetic high covering a large proportion of the survey area, which has been interpreted as resulting from either a sill or basalt flow at a depth of 2 to 10 km.
- Transfer faults trending at approximately 210 degrees, evident as weak positively magnetic features, and which are more obvious on the various vertical gradient images than the TMI.

- Normal faults approximately parallel to the current continental margin which appear on the vertical gradient images as very weak lineaments. The magnetic response due to faults is proposed to be derived from either precipitation of magnetic material along the fault plane or due to dislocation of magnetic mineral bearing layers within the sedimentary sequence.
- Depositional features such as channels which tend to focus along the fault zones. The magnetic response of these features may be from detrital material, derived from the erosion of Tertiary igneous bodies.
- Igneous intrusions and lava flows which are well represented on both the TMI and the vertical derivative images as high amplitude anomalies.

5. CORRELATION OF SEISMIC AND MAGNETIC DATASETS

The location of the seismic lines with respect to the various features described above are indicated on all images. Representative examples of all features were chosen for modelling with selected profiles illustrated in this report and annotated on the diagrams.

The software package Modelvision, was used to model profiles from Total - field magnetic data. The profiles were originally obtained in ER Mapper and transferred to Modelvision for modelling. Typical profiles and models are presented in this report along with corresponding seismic sections. Invariably, the modelled profiles are not perpendicular to the contour trends of the anomaly being modelled due to the requirement to be parallel to the seismic lines. Therefore to get an accurate estimation of depth, the modelled depth must be multiplied by the cosine of the angle between the profile and the direction normal to the contour trends.

The main features interpreted from the magnetic images will be discussed in turn with examples from both datasets.

The format of the figures consists of a portion of a seismic section with a corresponding portion of a vertical derivative profile. The vertical scale on the profiles is 0.001nT/m/cm unless otherwise indicated. The vertical scale on the seismic sections is 1msec/cm for the odd numbered sections and 2msec/cm for the even numbered sections. Approximate depths of the features are indicated on the seismic sections for comparison with the magnetic modelling. Accompanying the seismic sections are a variety of profiles and models derived from the total field image of the same region. The ability to model multiple geological scenarios to the one magnetic response indicates the ambiguity involved in interpreting magnetic data. Intensity units are in nanoteslas, distance is measure in metres, with the shot point range also indicated. Susceptibilities are in c.g.s. units.

Prior to determining the subsurface response to the magnetic method it is of interest to note that in the Otway Basin, sea floor features as recognised in the seismic sections do not give an observable magnetic response. One such example is given in Figure 4 which is a portion of line OP80-31 (PROFILE A) in which surficial features and a generally increasing water depth have no observable response on the magnetic profile. This implies that the sea floor relief does not cause magnetic responses.

5.1 Transfer faults and shallow channels

These two features are discussed together because the channel systems have developed preferentially along transfer fault zones in the Otway Basin. Figures 5 and 6 indicate the seismic and magnetic responses along profiles B and C respectively. Several models fit the magnetic anomalies and the ones illustrated are not exhaustive of the combinations possible. Both magnetic profiles can be modelled to represent channel features or a combination of channels and faulting with profile C also modelled to represent faulting only (Fig. 6d). The seismic data indicates that both channelling and faulting are present and the magnetic anomaly is interpreted as being a result of a combination of these two features. The faults are interpreted as being transfer in nature because the geological sections are different on either side of the fault zones. Some of the "fuzziness" associated with the fault zone may be due to ray-path deformation within the channel. The modelling indicates the ambiguity associated with the interpretation of magnetic data with several models of countless combinations possible depicted in the figures.

5.2 Normal faults

Figures 7, 8, 9, 10, 11 and 12 indicate the seismic and magnetic responses along profiles D, F, G, H, O and P respectively. The seismic data for figure 7 depicts the existence of both channels and faulting and the models along this profile indicate that the observed anomaly may be the result of a combination of these features. Similarly, the magnetic responses in figures 8, 9 and 10 can be modelled as being the result of either faults or channels. The channel scenario is not supported by the seismic data in these profiles. Figures 11 and 12 do not include models but illustrate the selective nature of the magnetic response to faulting. This may give more weight to the possibility of the source of the magnetic material in the faults existing along the fault plane rather than the response being the result of dislocation of a magnetic mineral bearing layer in the sedimentary sequence. If the response was due to layer dislocation, the faults would be more consistently represented. The patchy nature of the magnetic response to the faults may be due to the selective migration of fluids containing magnetic minerals along fault planes. The magnitude of the magnetic response is also variable and tends to be higher with shallower faults as indicated in figure 10a.

5.3 Igneous Intrusions

Three seismic lines cross igneous intrusions to the east of the study area. These are illustrated in figures 13, 14, 15 and 16 and indicate the seismic and magnetic responses to profiles J, K, L and M respectively. Figures 13 and 14 are taken over the smaller of the two igneous bodies. Again, more than one magnetic model is viable although only one is supported by the seismic data which indicates a feature between 1000 m and 1300 m (note the difference in vertical scales between the seismic sections). Figures 15 and 16 illustrate the responses over the larger anomaly, and again a flat shallow feature is supported by the seismic data, although a variety of models fit the observed magnetic anomaly. As these profiles are perpendicular to each other (13/14 and 15/16), the features can be defined as circular in plan and may be lopoliths. The feeders for these intrusions are not evident, which may be for a variety of reasons:

- The feeders may be of the plane of the 2-D seismic lines
- If the feeders are present in the plane of the seismic lines, they will not be visible if they are vertical and narrow, except for diffractions, because seismic data handles horizontal features better than vertical features.
- The feeders may not appear on the magnetic images if they no longer contain magnetic materials.

5.4 Other Depositional Features

Recent depositional features such as channelling and barrier bars may derive a magnetic response from detrital material sourced from Tertiary igneous bodies. Figure 17 illustrates the magnetic response to a channel, with the magnetic response in figure 18 modelled as bars, channels and faults in a variety of combinations.

6. CONCLUSIONS

This case study has demonstrated that aeromagnetic data has the ability to map faults, channels and igneous features and can also be of significant use as a primary exploration tool or as an adjunct to the seismic method.

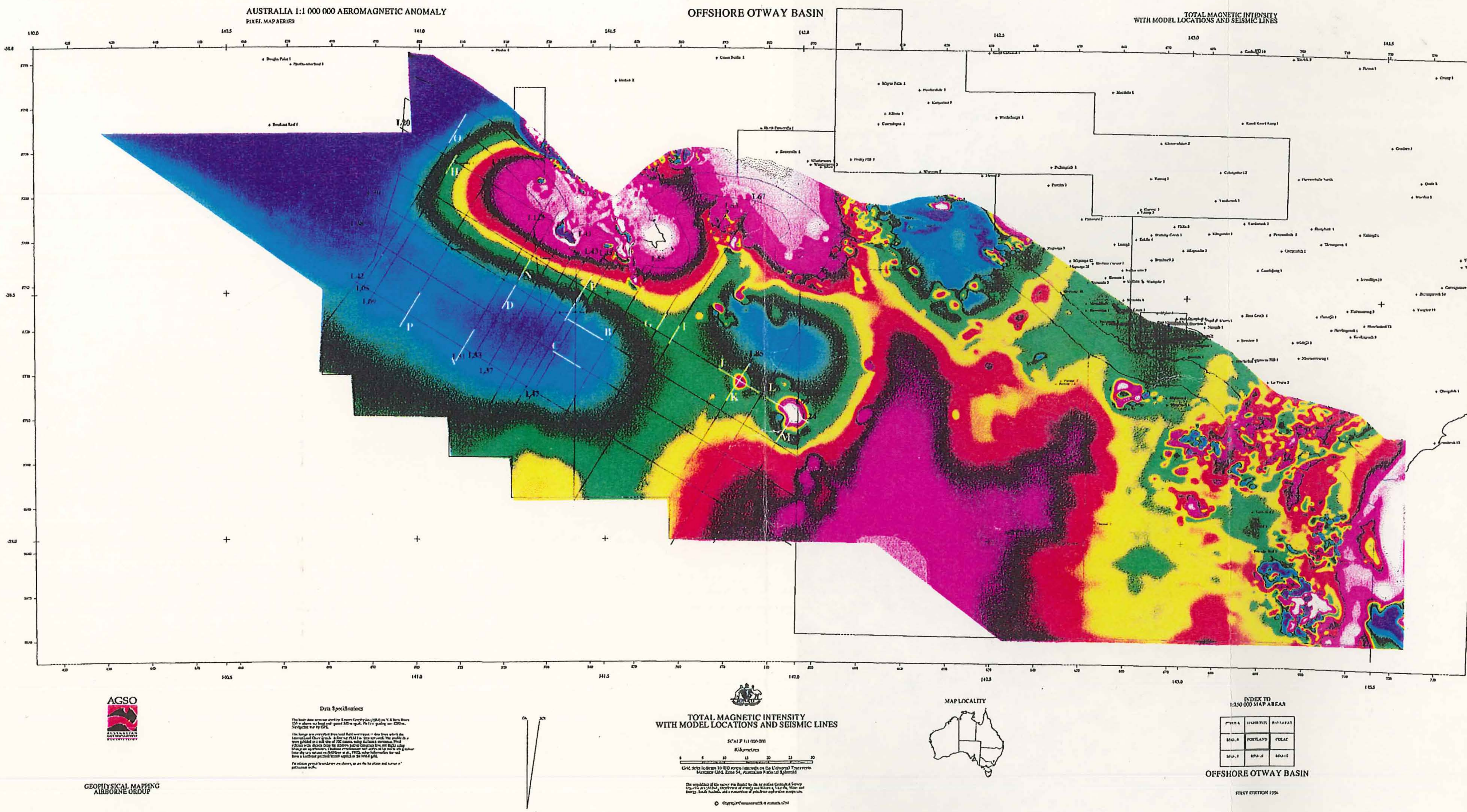
REFERENCES

Gunn P.J. 1994 - Offshore Otway Basin Aeromagnetic Interpretation. *Australian Geological Survey Organisation Record* 1994

ACKNOWLEDGMENTS

The seismic sections illustrated in figures 5, 6, 13 & 15 come from a variety of non-exclusive proprietary surveys owned or marketed by Geco-Prakla (Aust) Pty Ltd. Permission to use this data is gratefully acknowledged.

FIGURE 1



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OFFSHORE OTWAY BASIN
TOTAL MAGNETIC INTENSITY
WITH MODEL LOCATIONS AND SEISMIC LINES
AGSO
GEOPHYSICAL MAPPING
AIRBORNE GROUP
Data Specifications
TOTAL MAGNETIC INTENSITY
WITH MODEL LOCATIONS AND SEISMIC LINES
Kilometres
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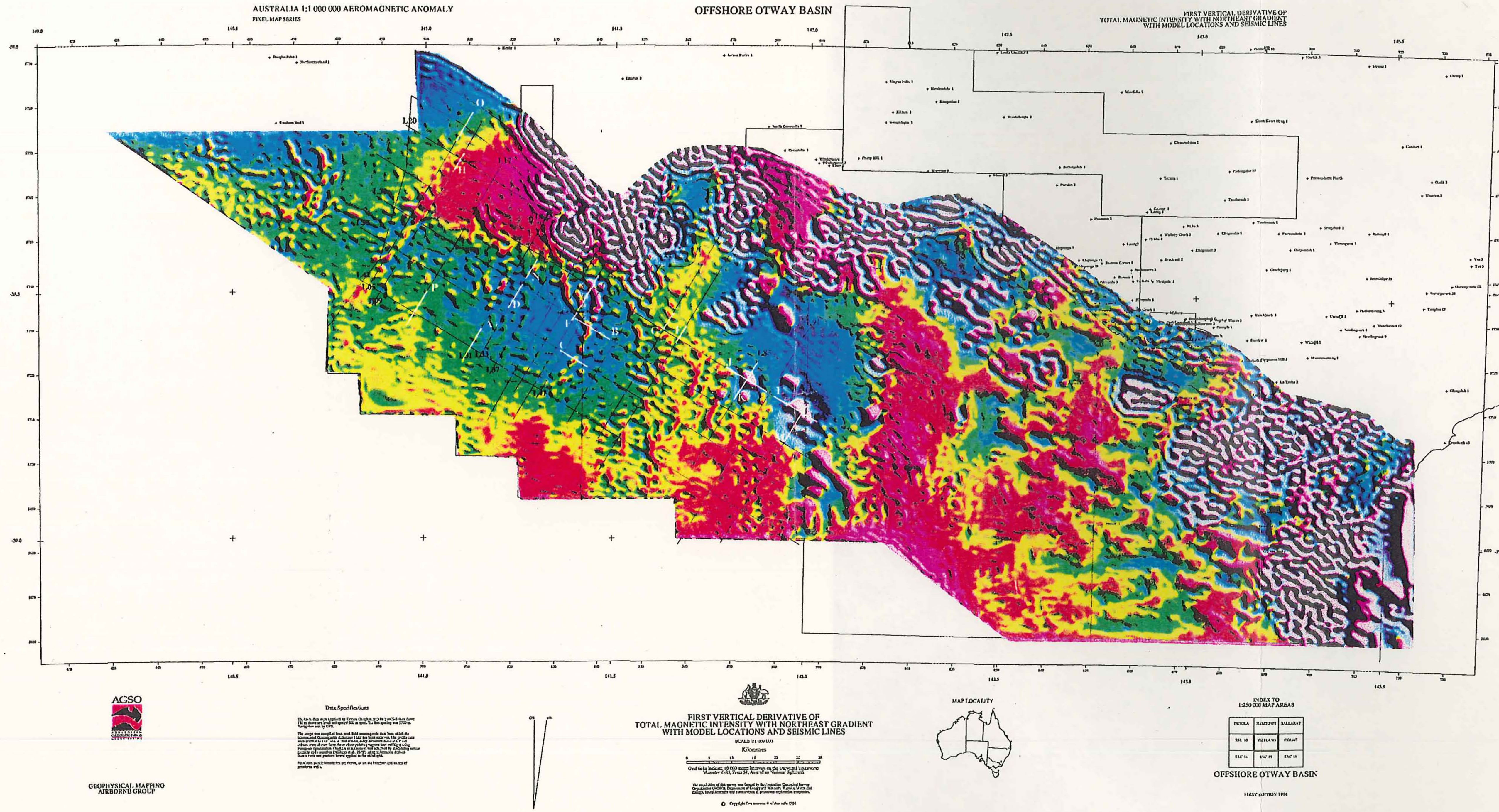
5
10
15
20
25
30
MAP LOCALITY
INDEX TO
1:250 000 MAP AREAS
PORTLAND
OFFSHORE OTWAY BASIN

FIGURE 2



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OFFSHORE OTWAY BASIN
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TOTAL MAGNETIC INTENSITY WITH NORTHEAST GRADIENT
WITH MODEL LOCATIONS AND SEISMIC LINES
AGSO
GEOPHYSICAL MAPPING
AIRBORNE GROUP
Data Specifications
FIRST VERTICAL DERIVATIVE OF
TOTAL MAGNETIC INTENSITY WITH NORTHEAST GRADIENT
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Kilometres
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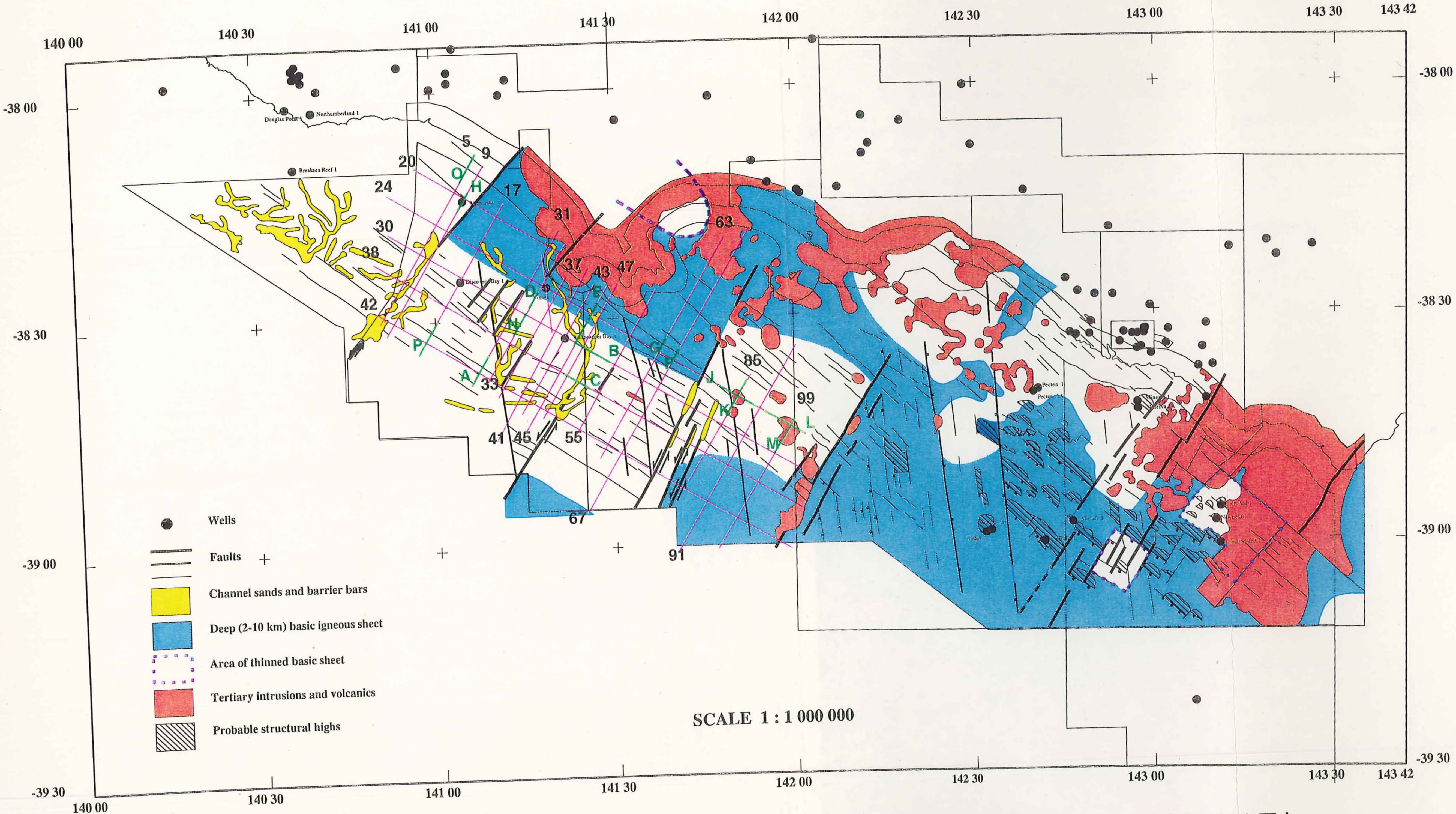
INDEX TO
1:250 000 MAP AREAS
OFFSHORE OTWAY BASIN

FIGURE 3



OFFSHORE OTWAY BASIN: INTERPRETATION OF AEROMAGNETIC DATA

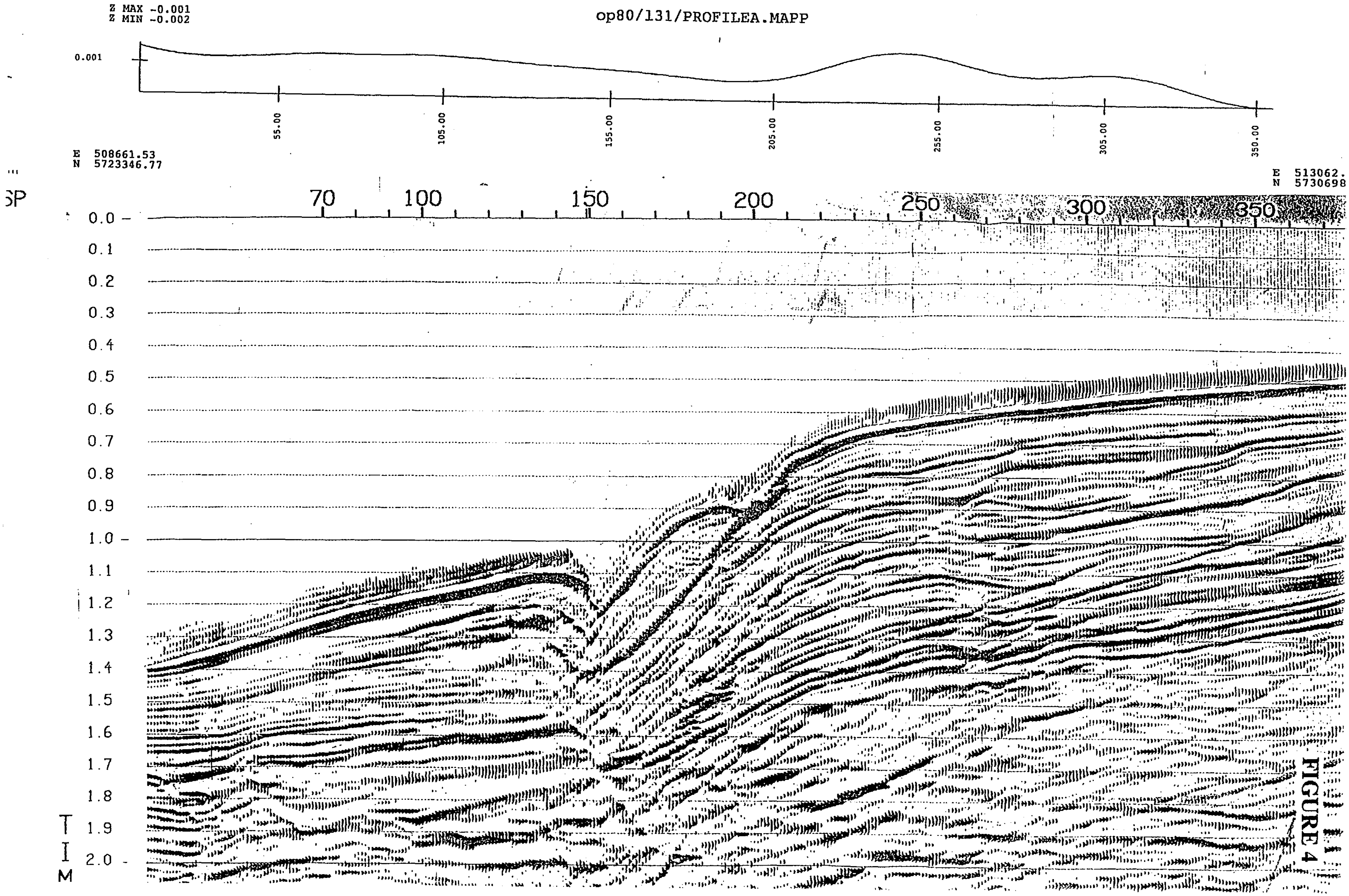


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FIGURE 4

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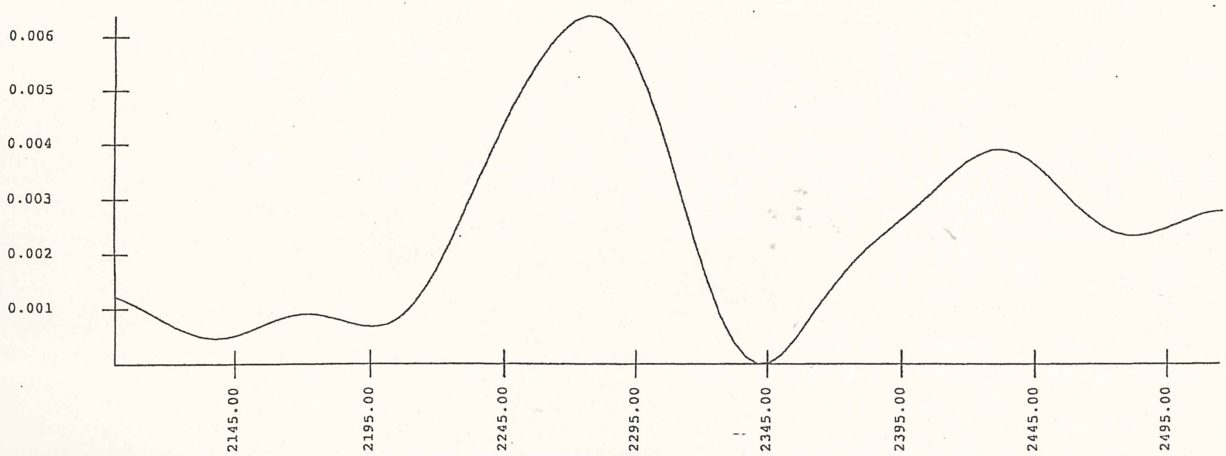
FIGURE 5a



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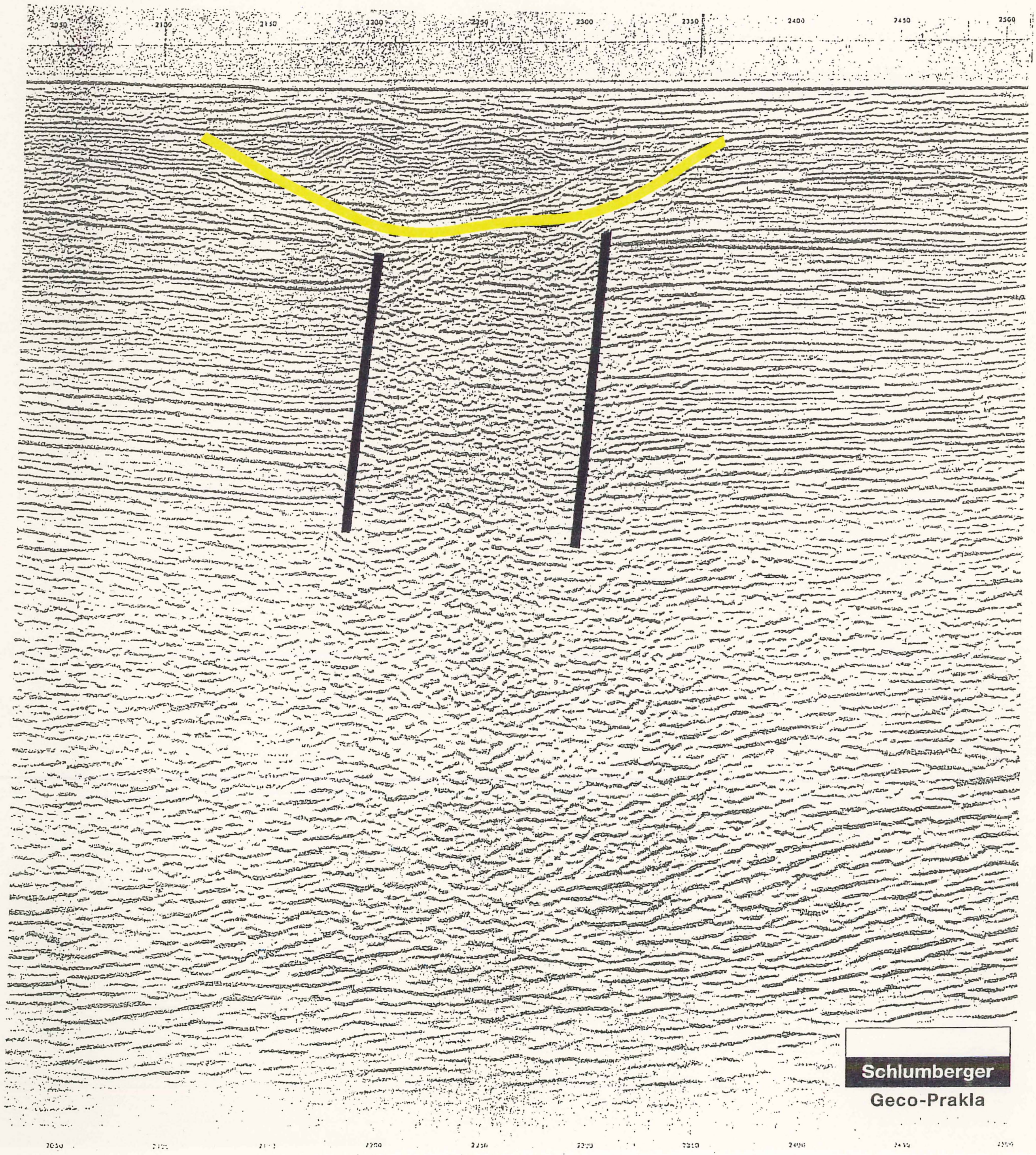

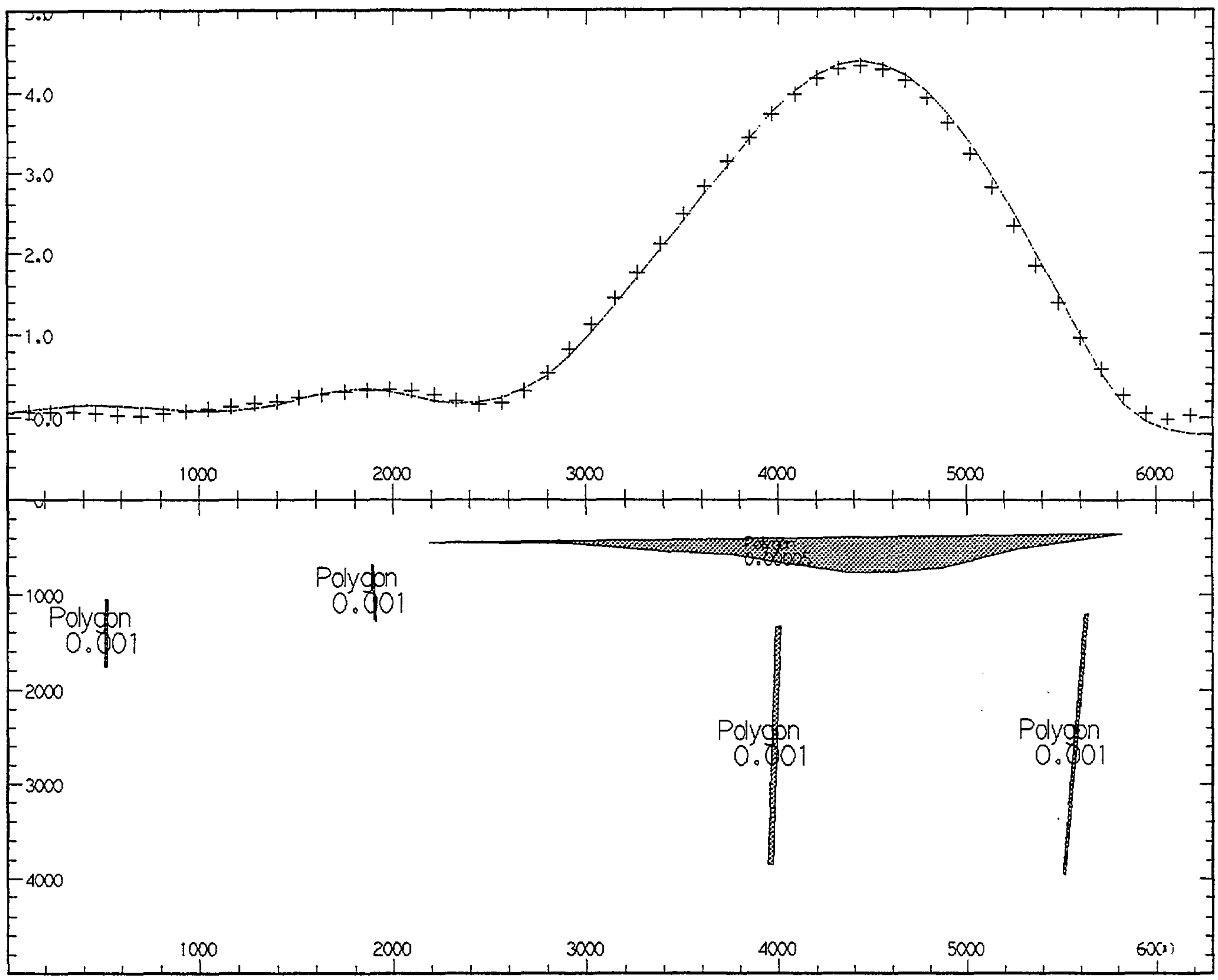

FIGURE 5b

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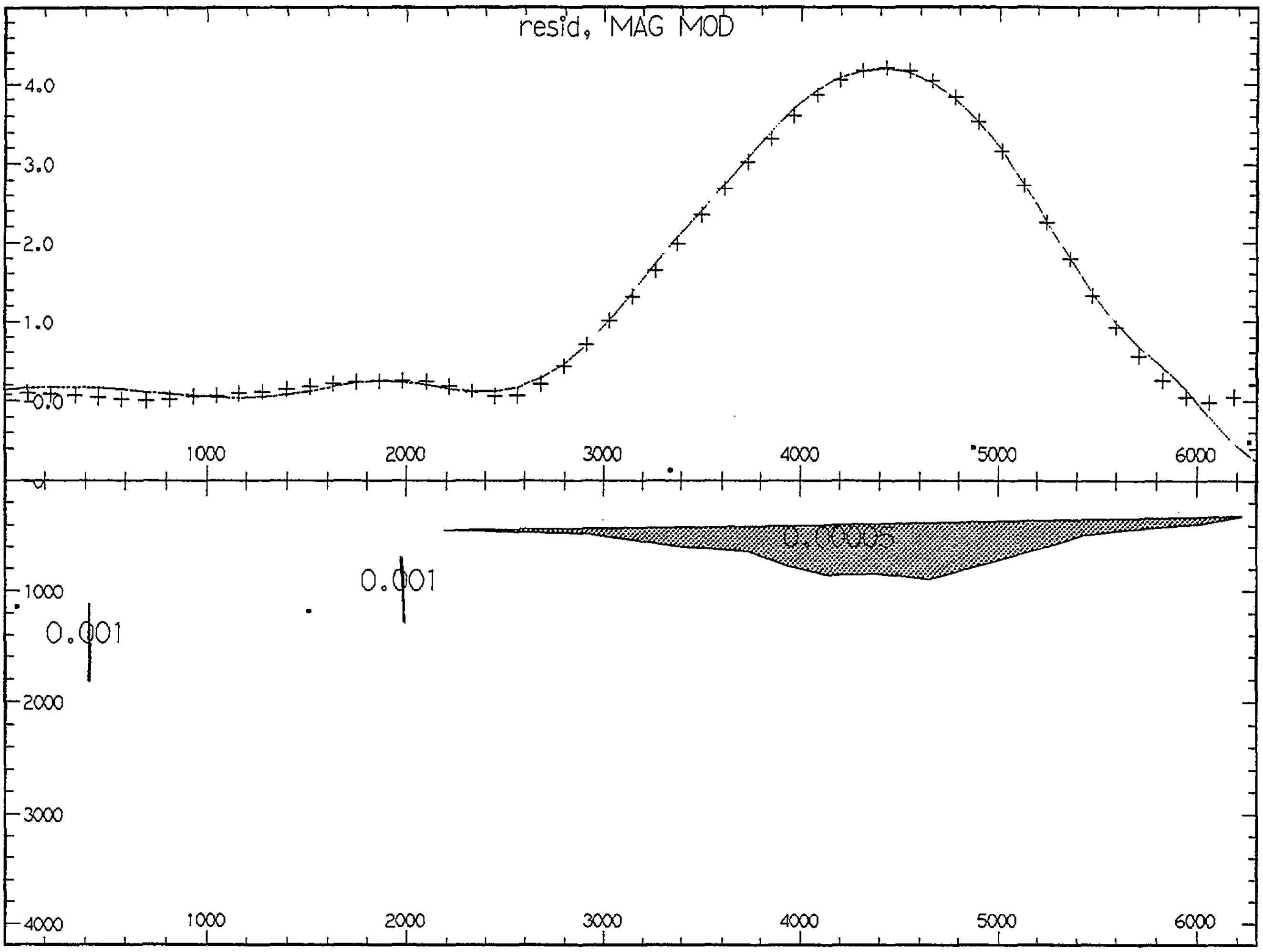
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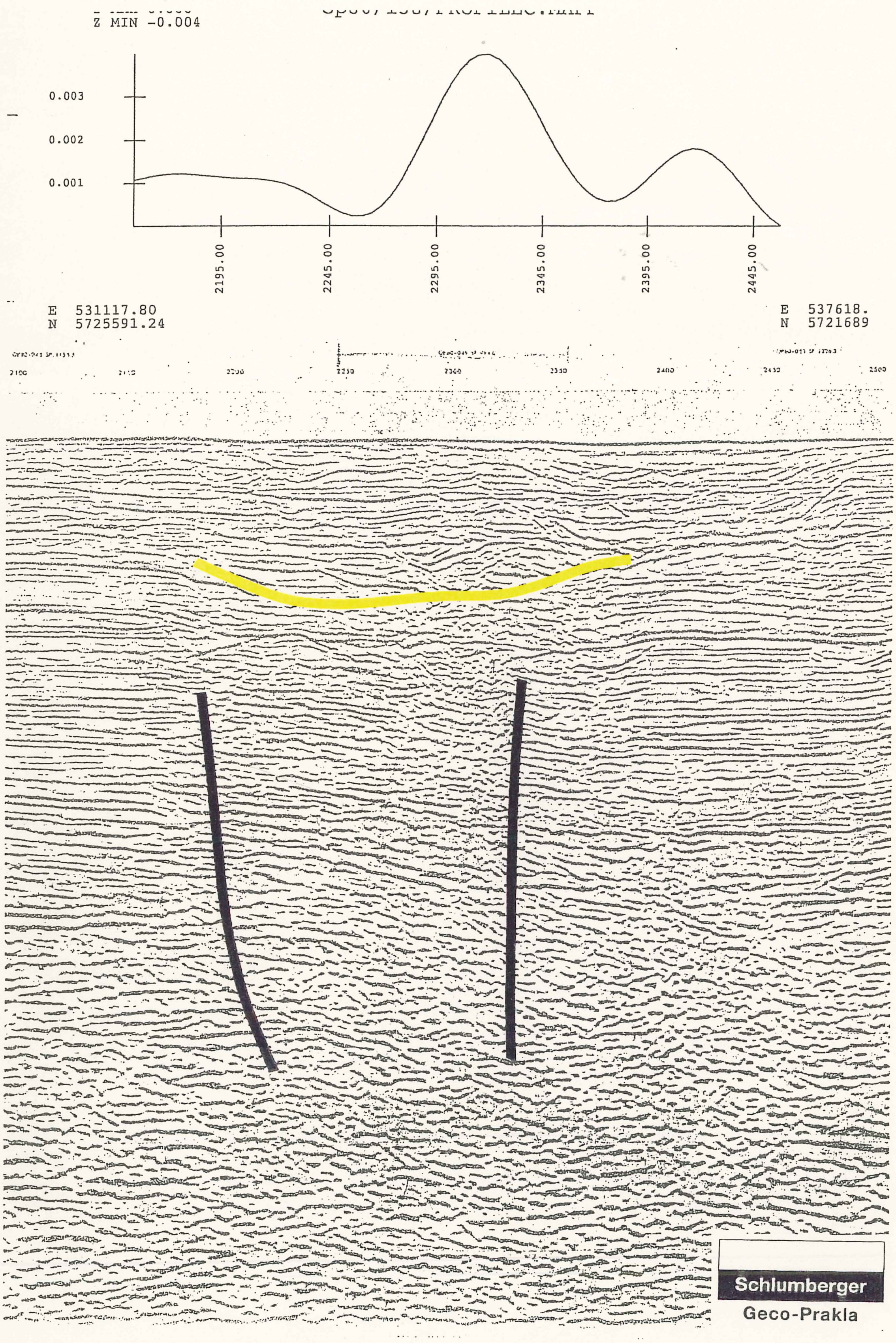
FIGURE 5c

FIGURE 6a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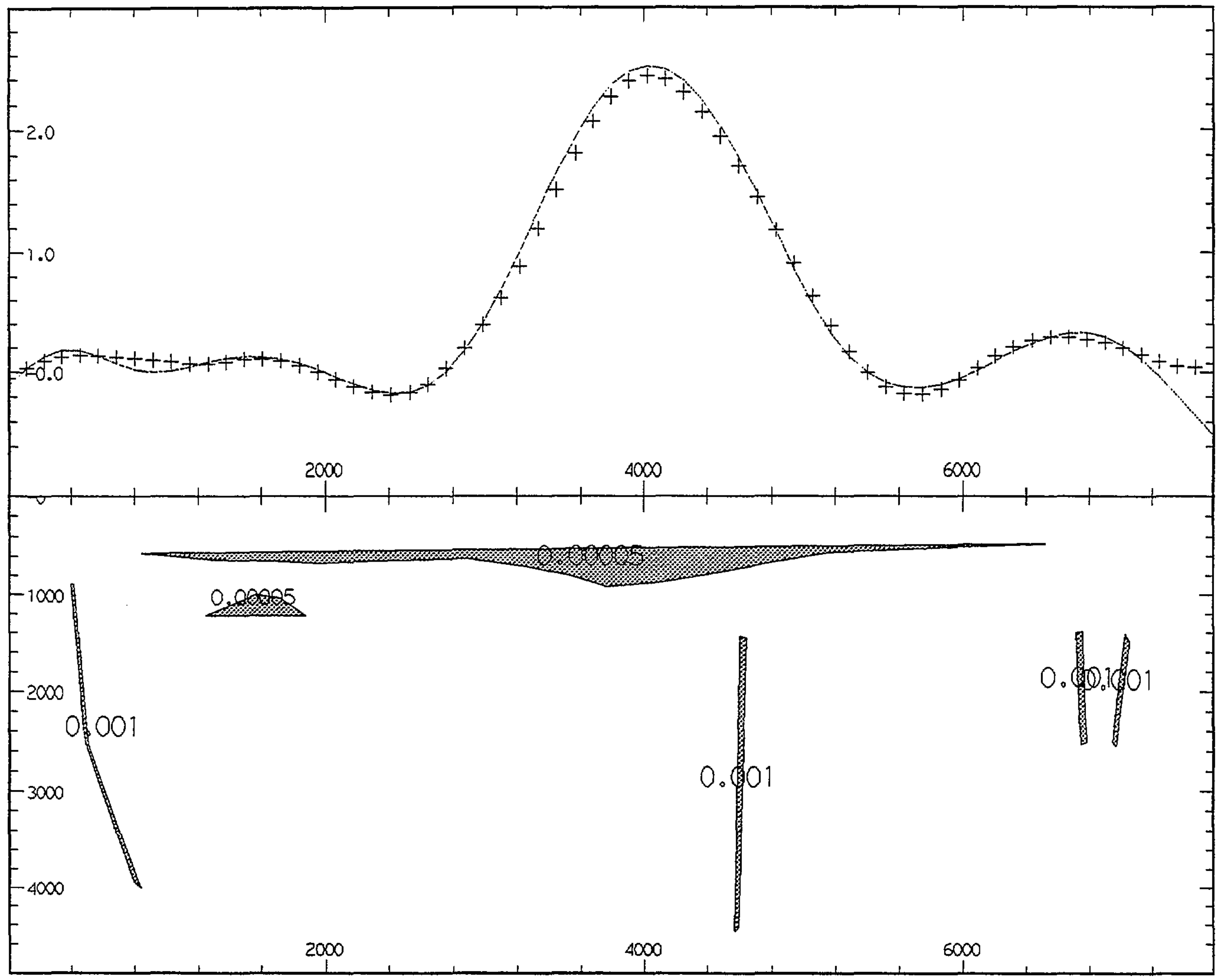
Geco-Prakla



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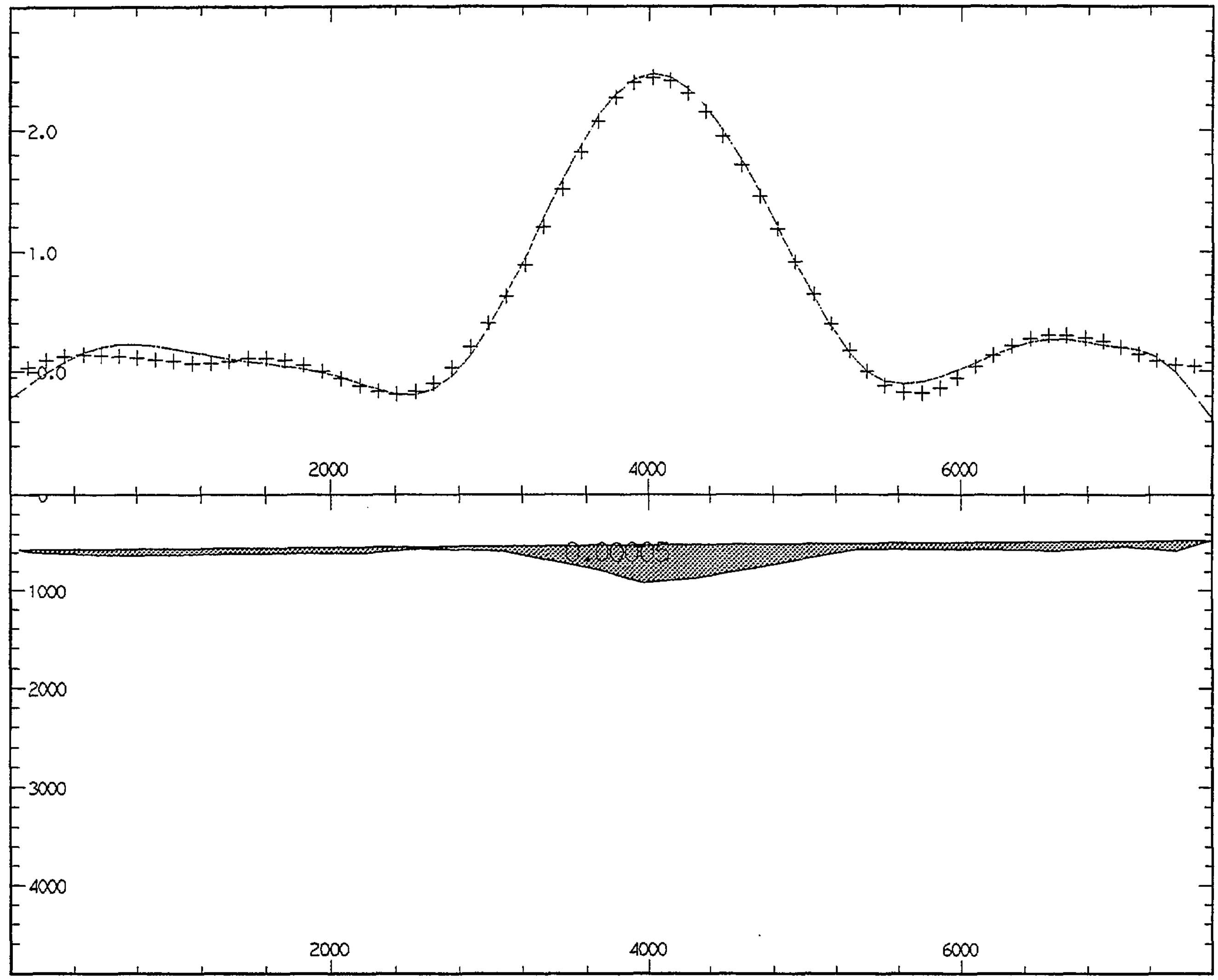

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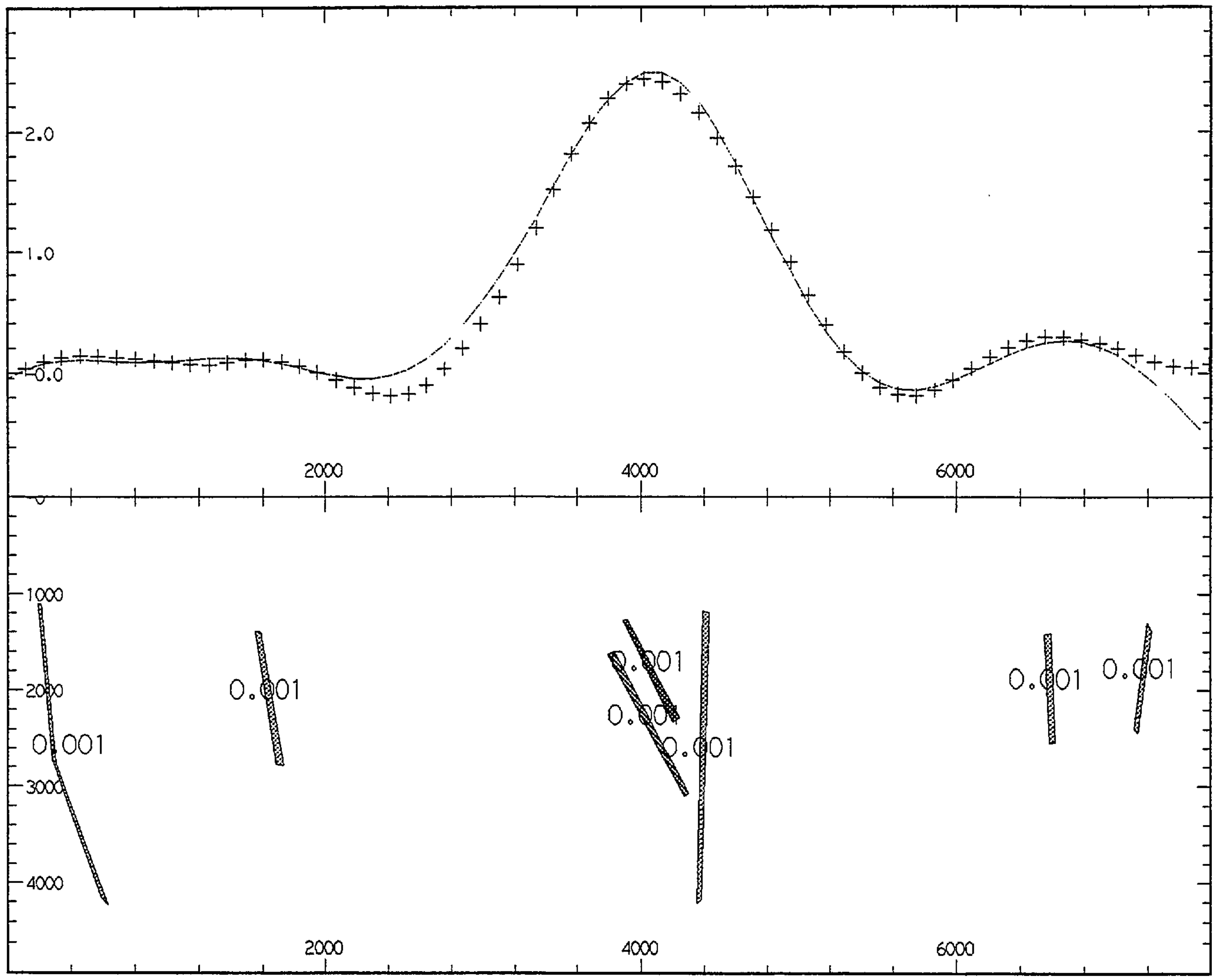
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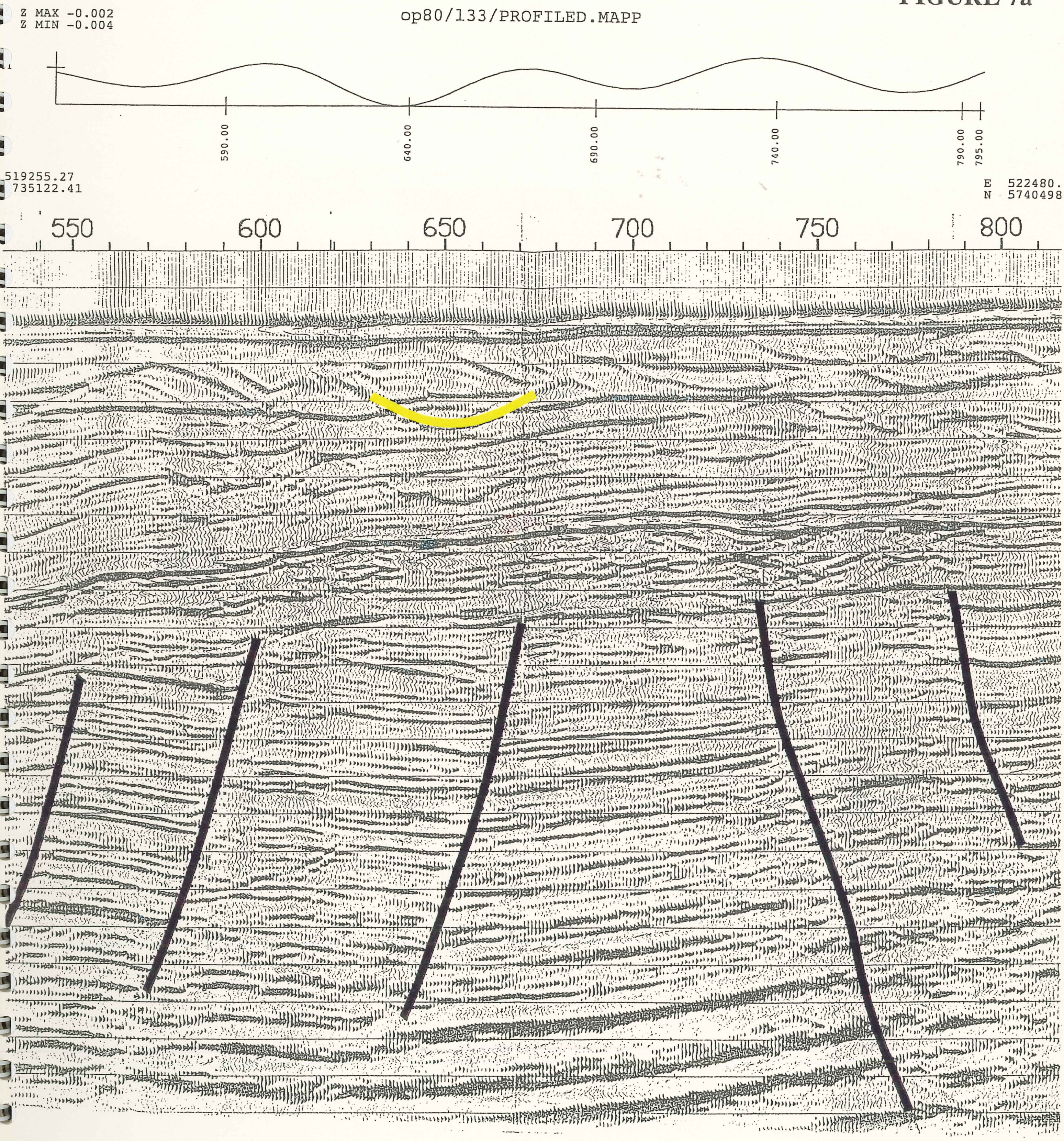
2000
4000
6000

FIGURE 6d

FIGURE 7a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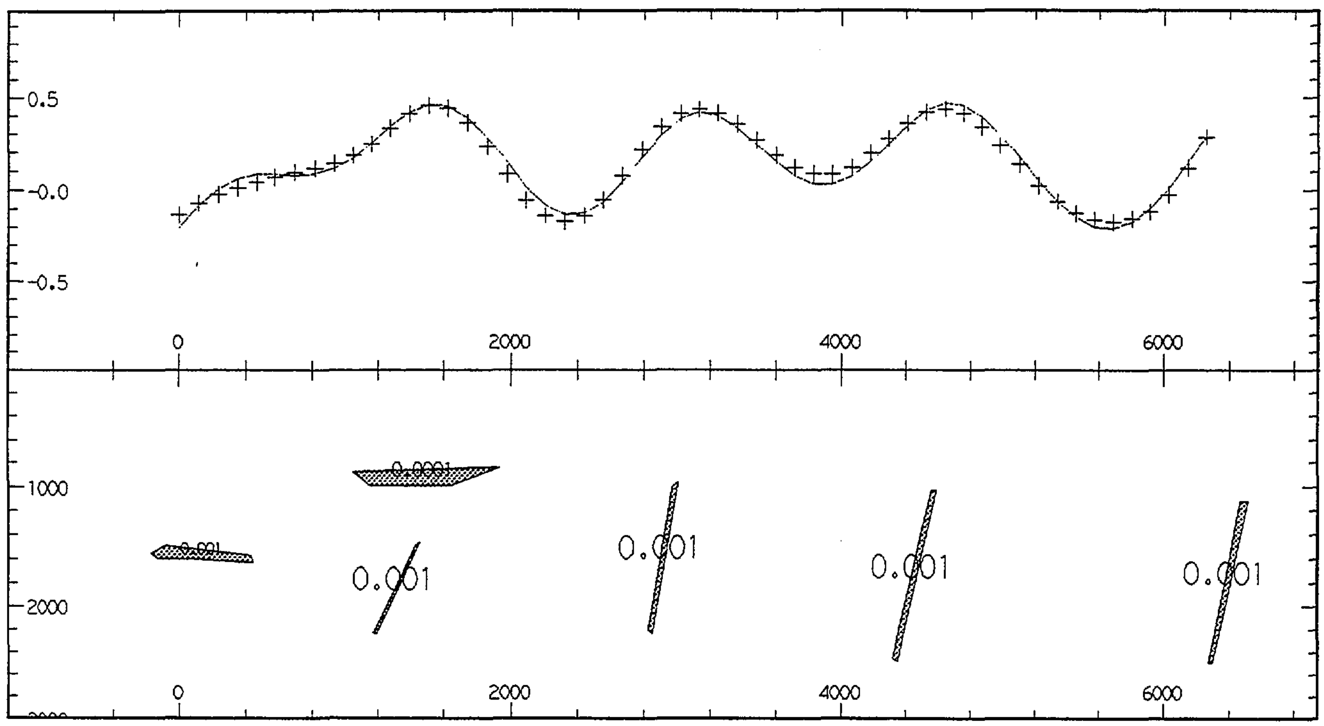

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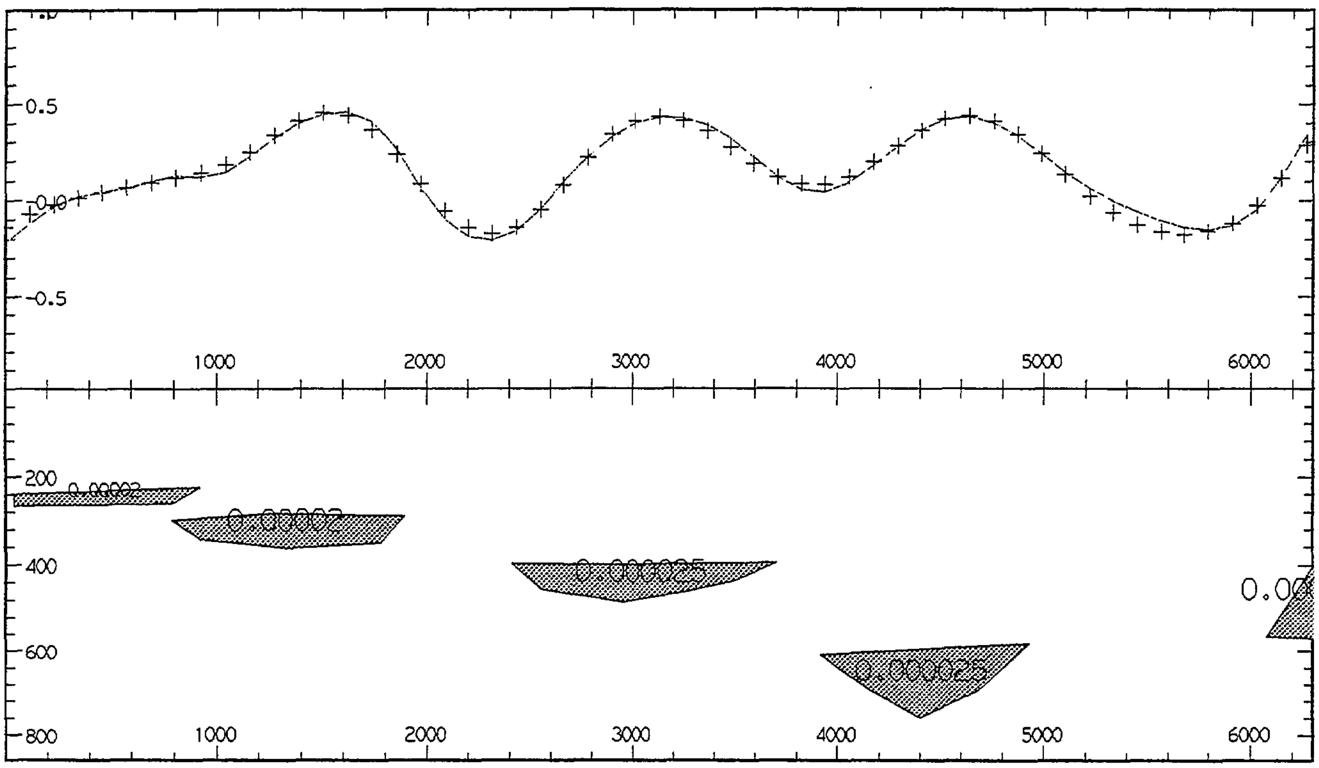
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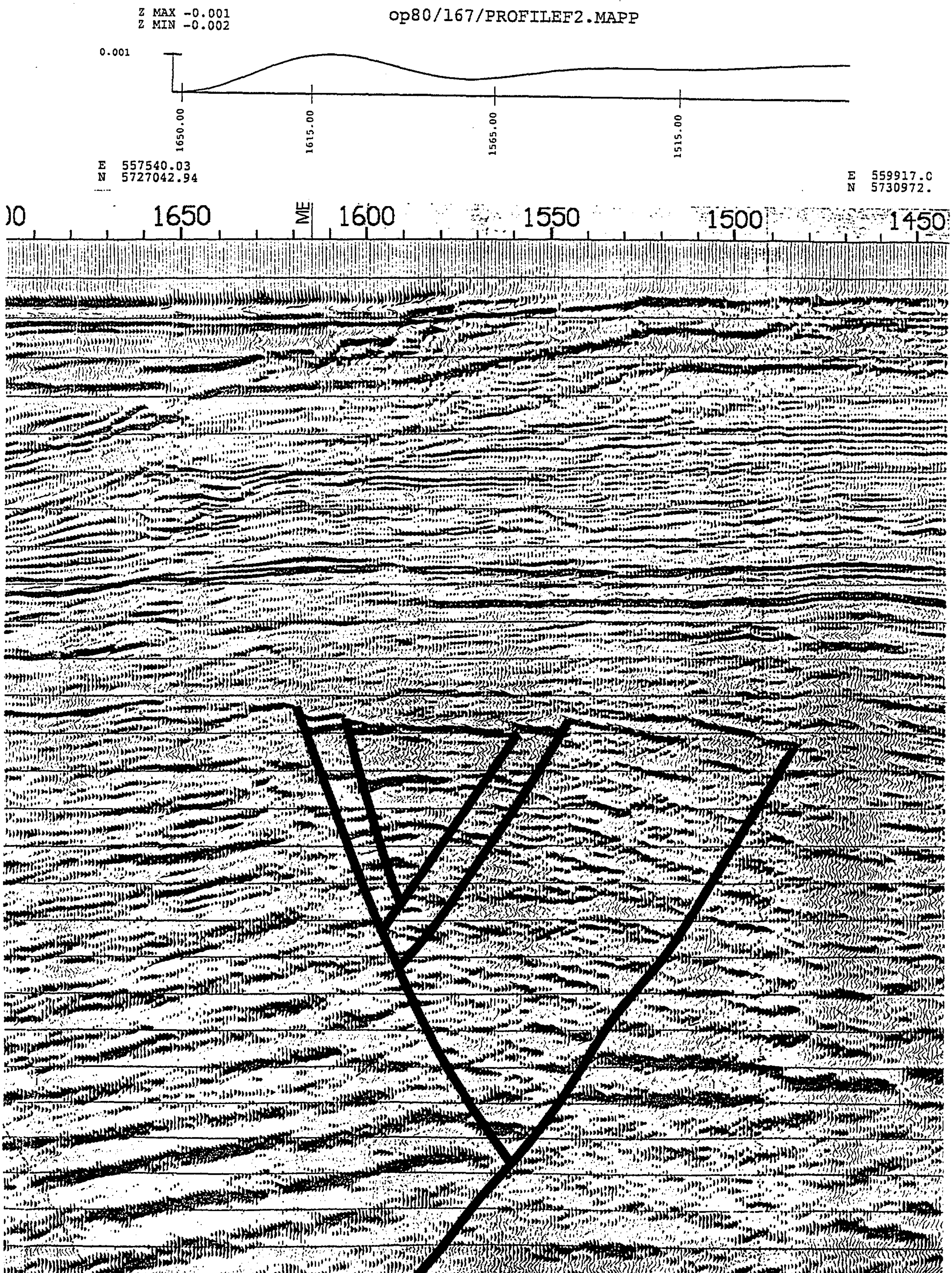
FIGURE 7c

FIGURE 8a



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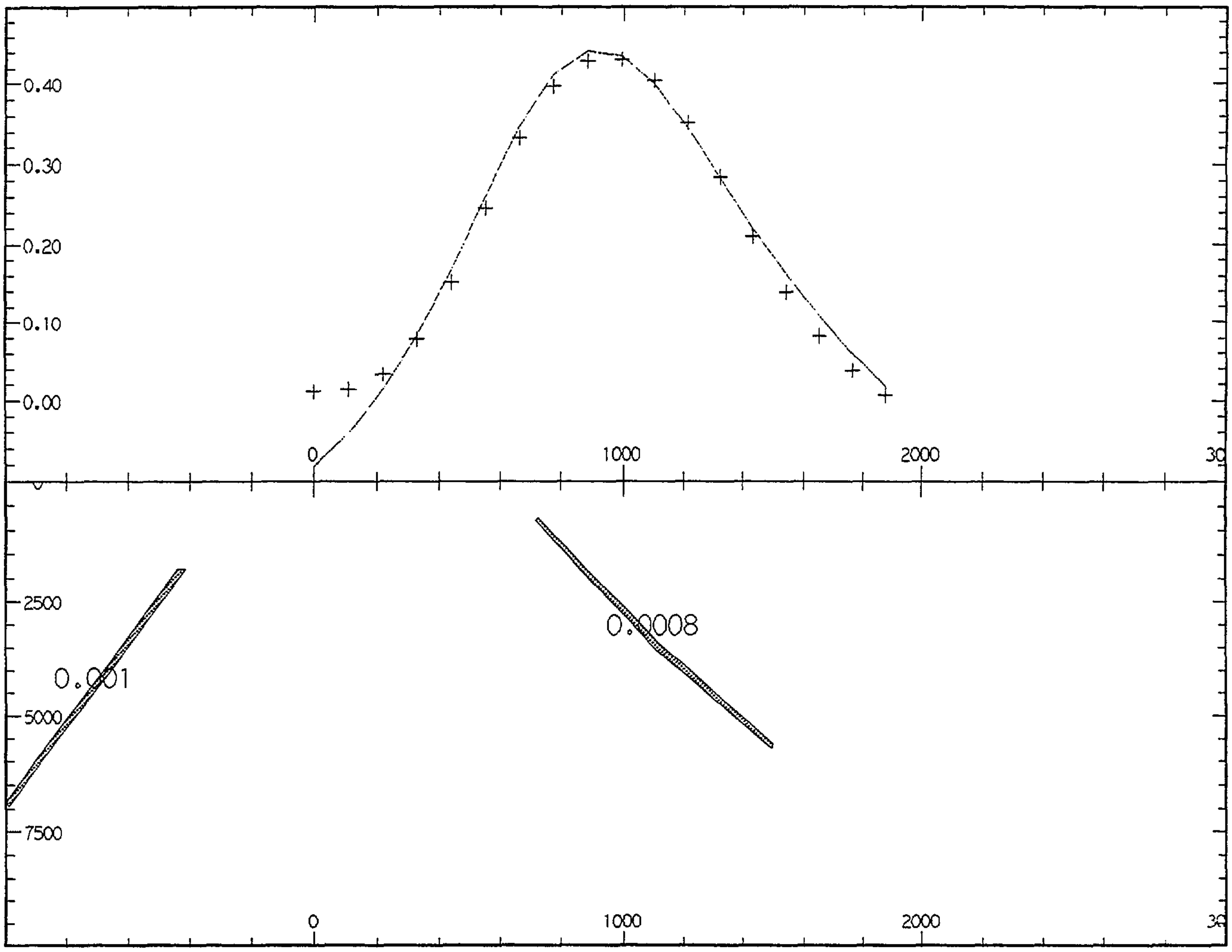

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FIGURE 8b

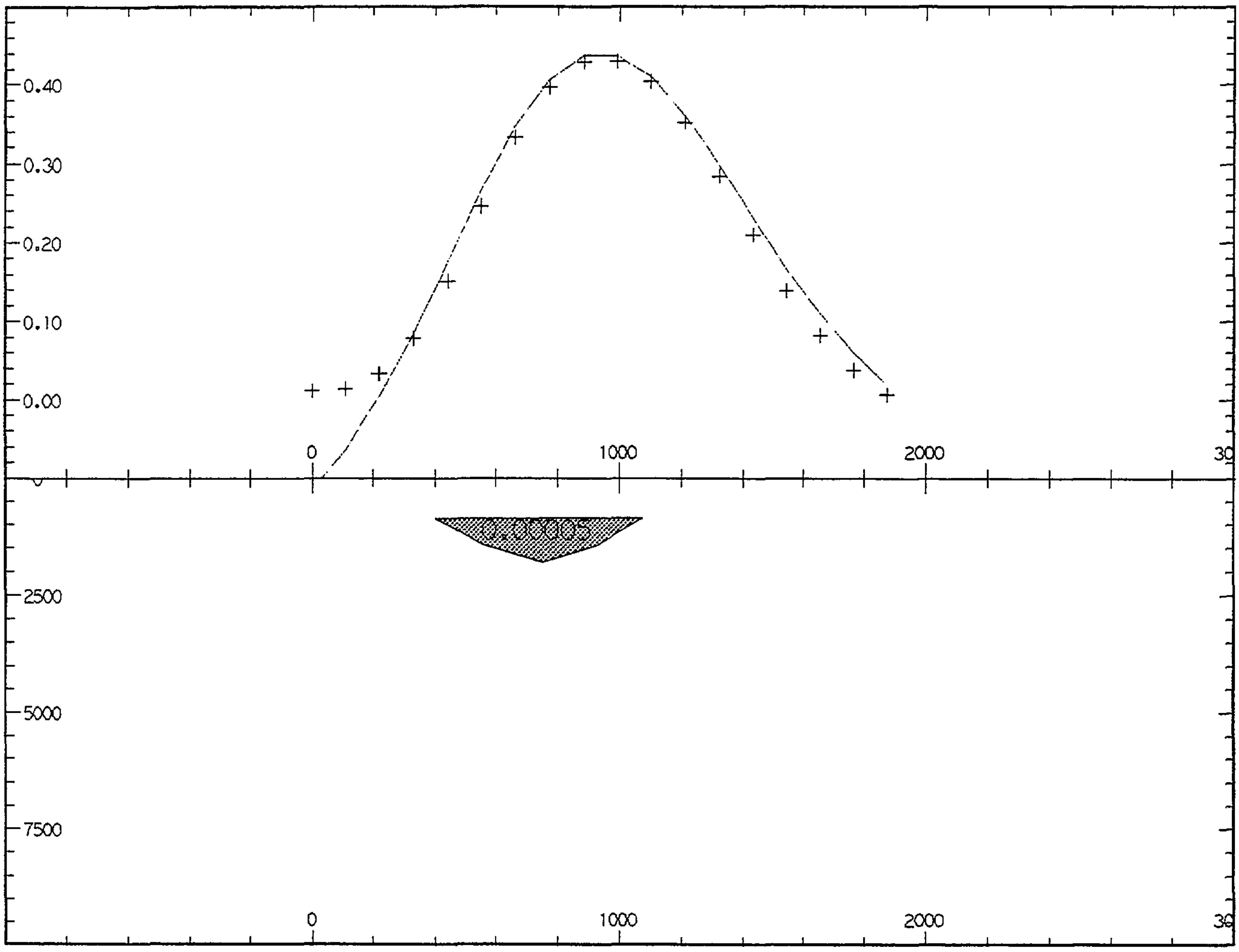
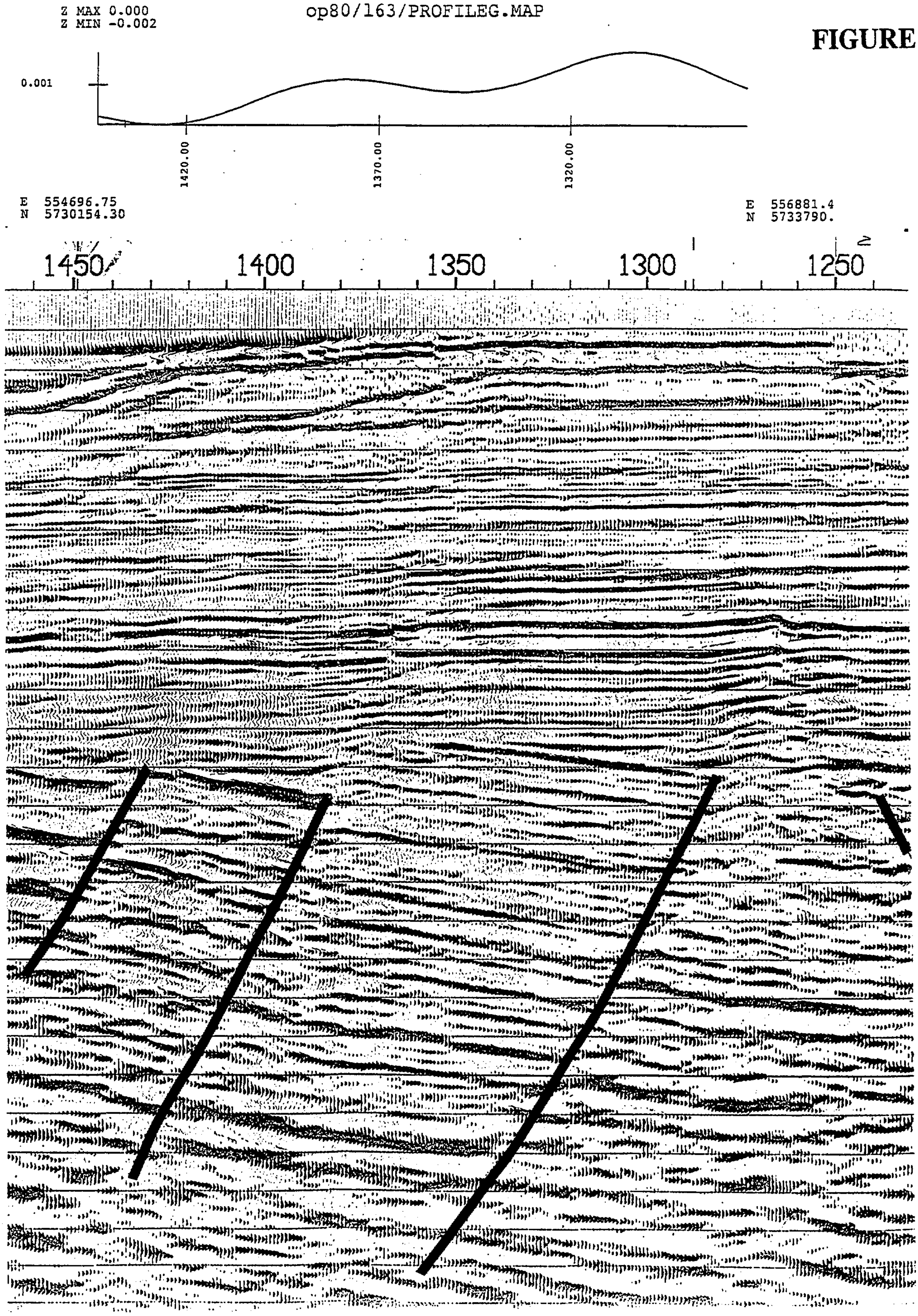


FIGURE 8c

FIGURE 9a



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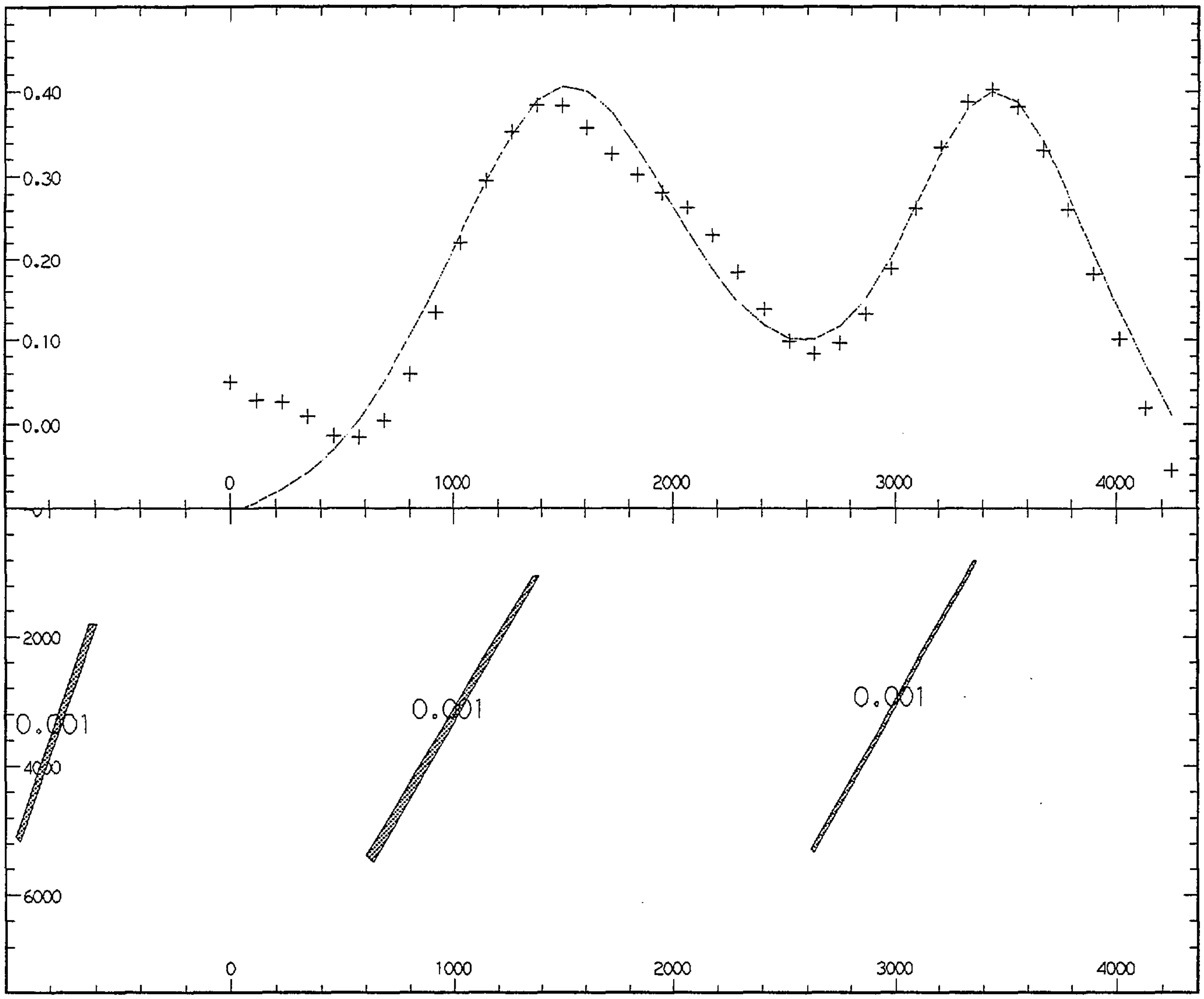

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FIGURE 9b

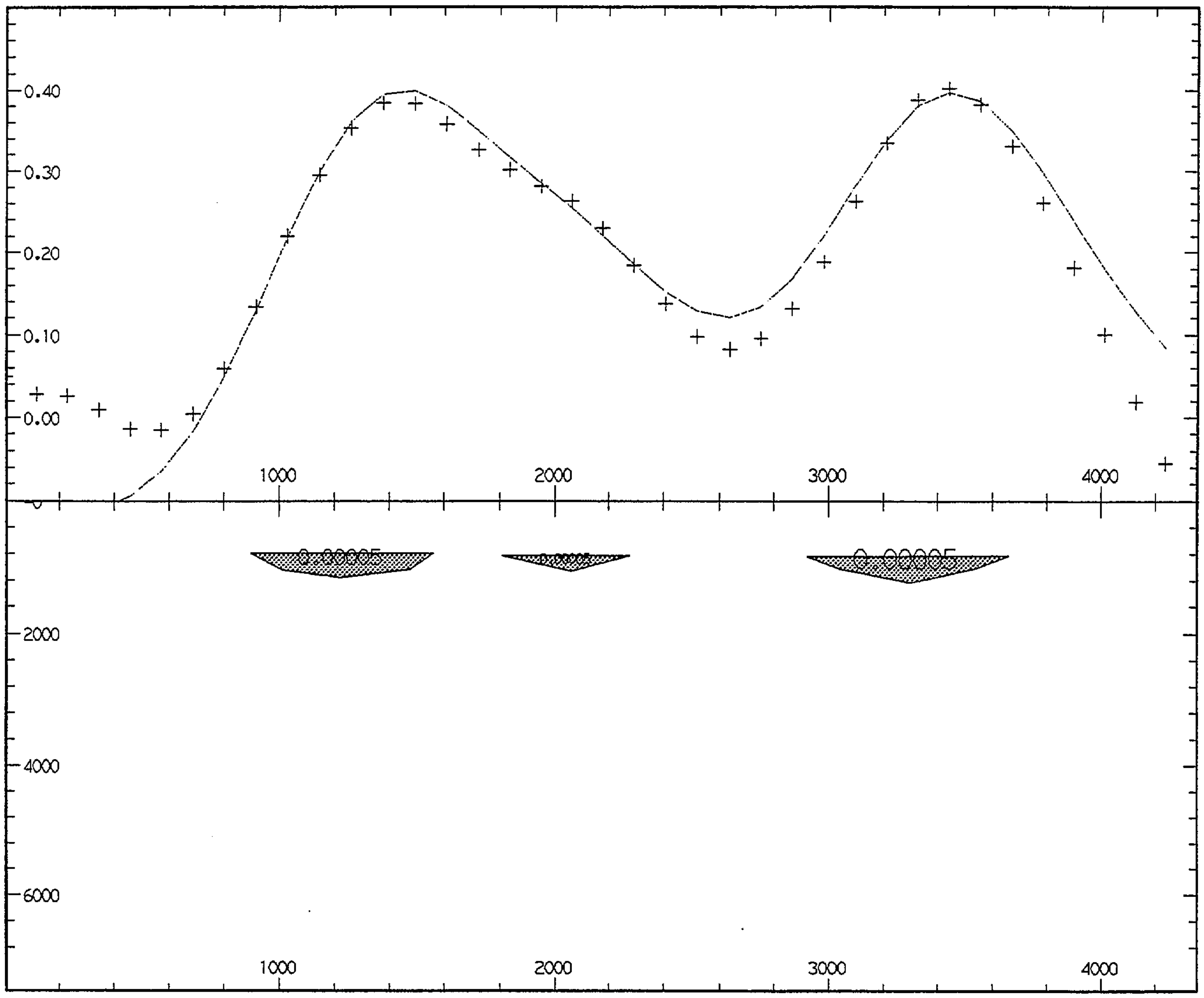
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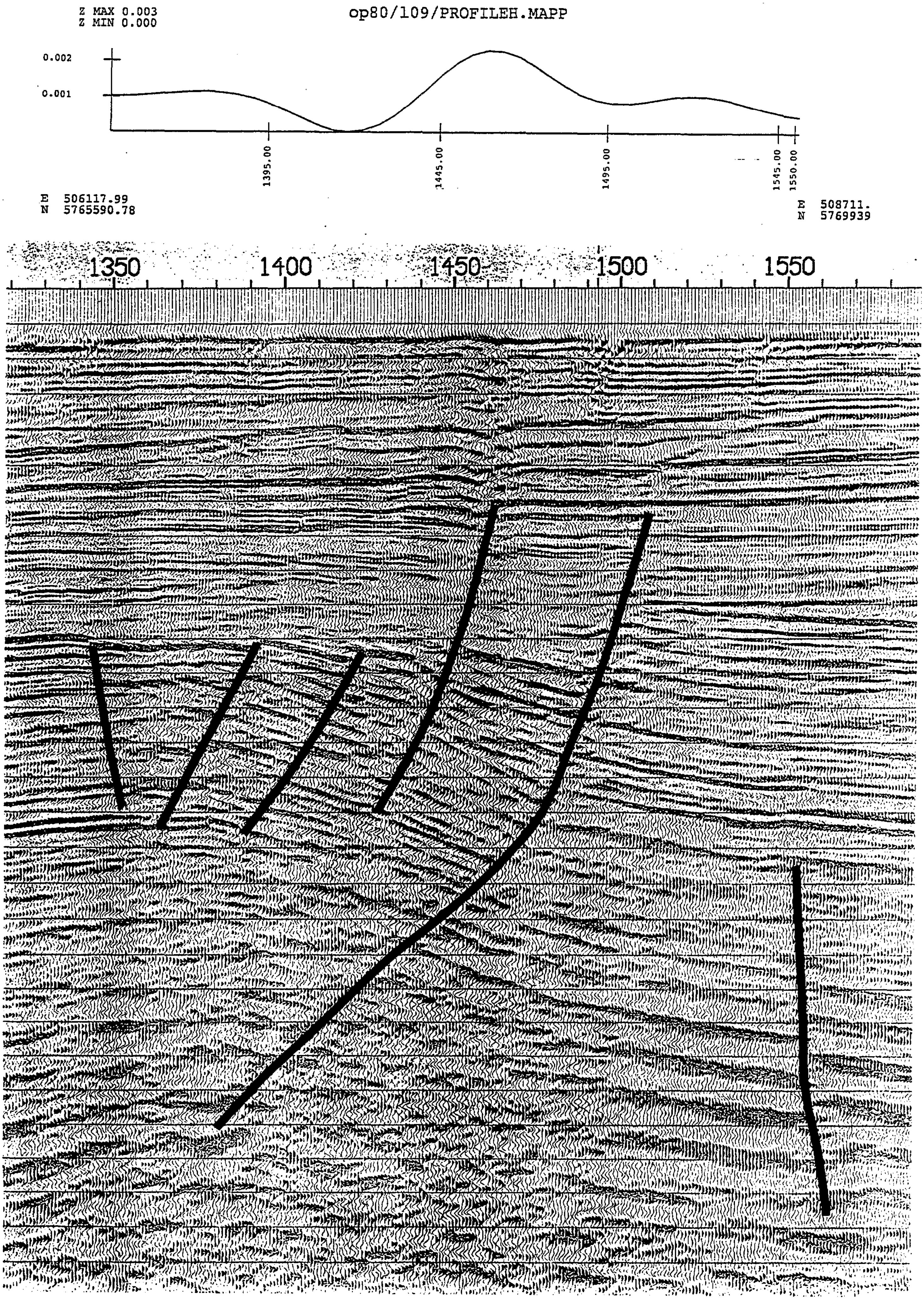
FIGURE 9c

FIGURE 10a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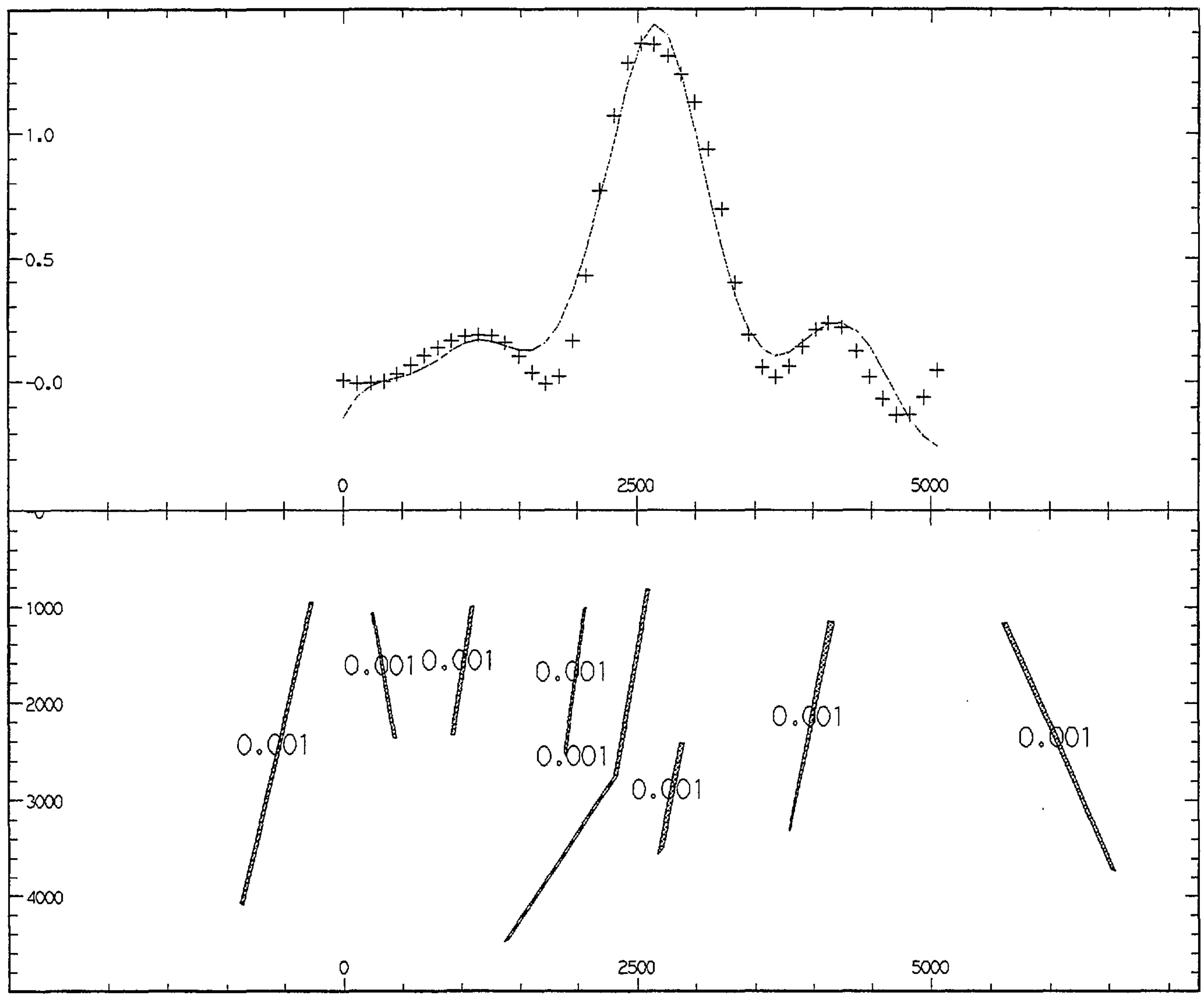
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FIGURE 10b

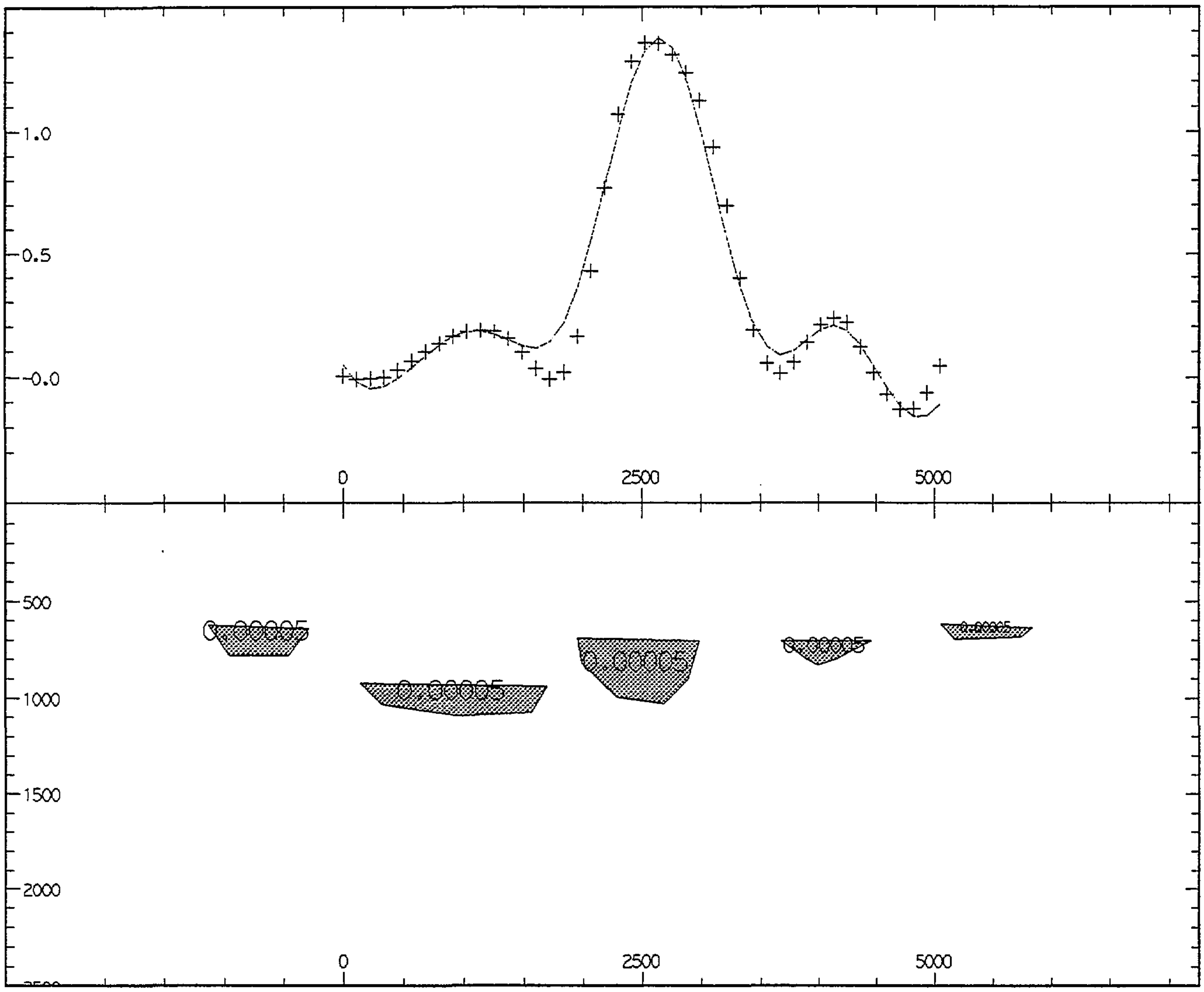

FIGURE 10c

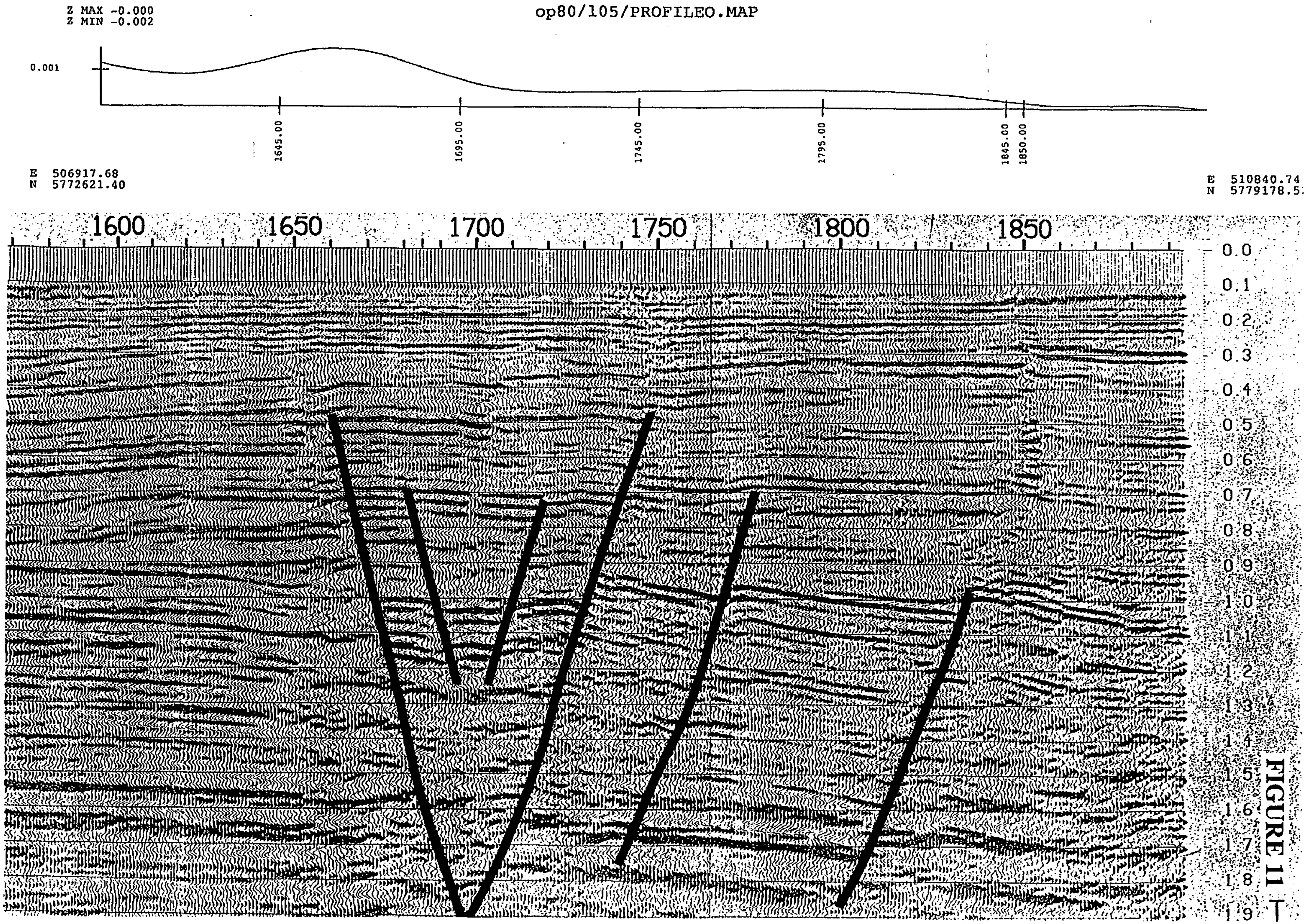
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FIGURE 11

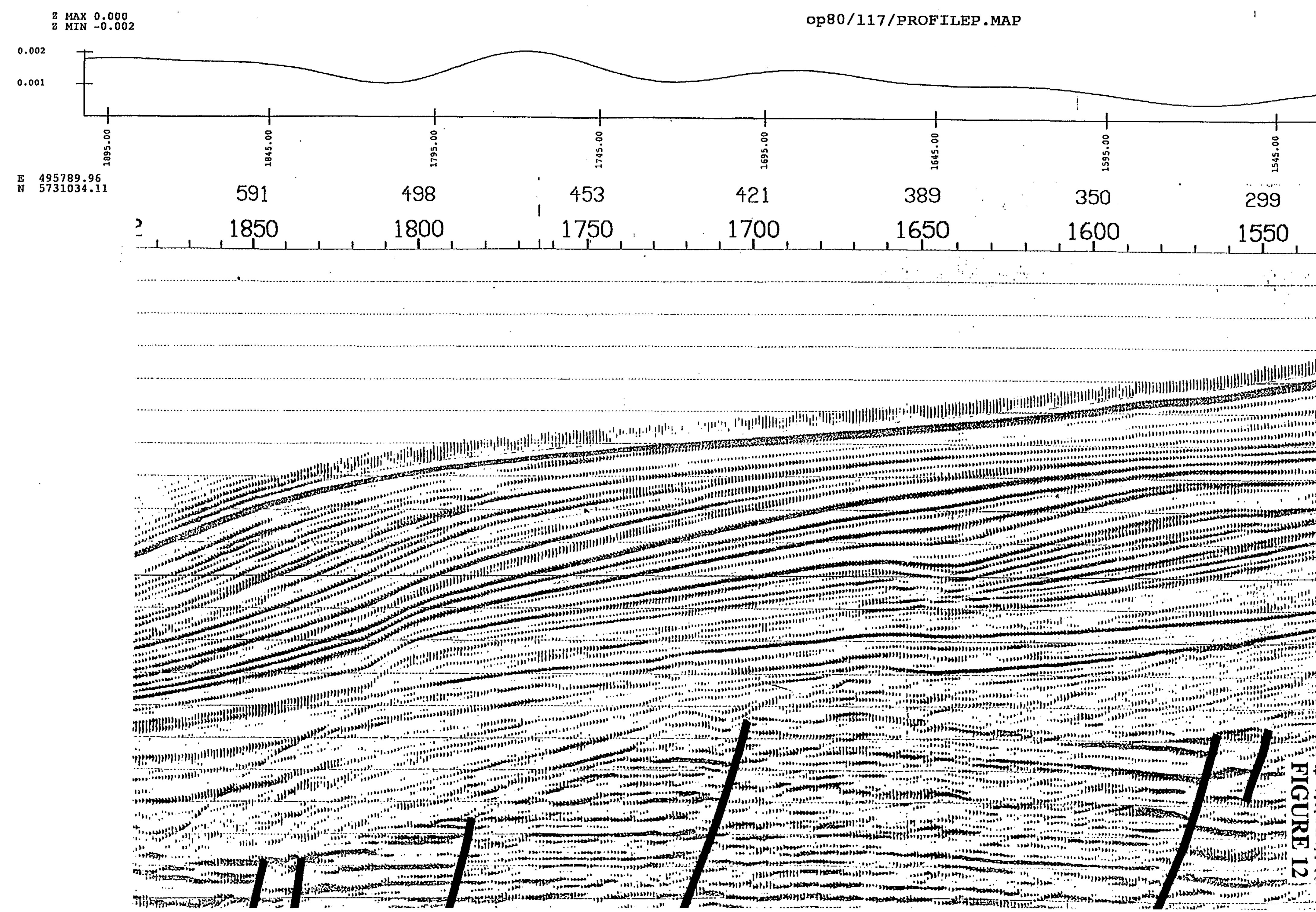

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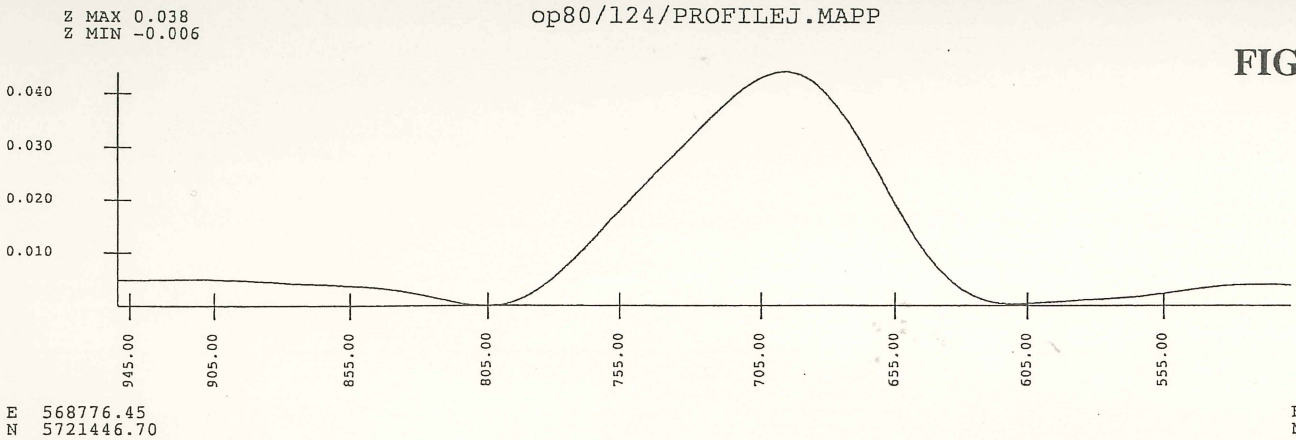
FIGURE 12

FIGURE 13a



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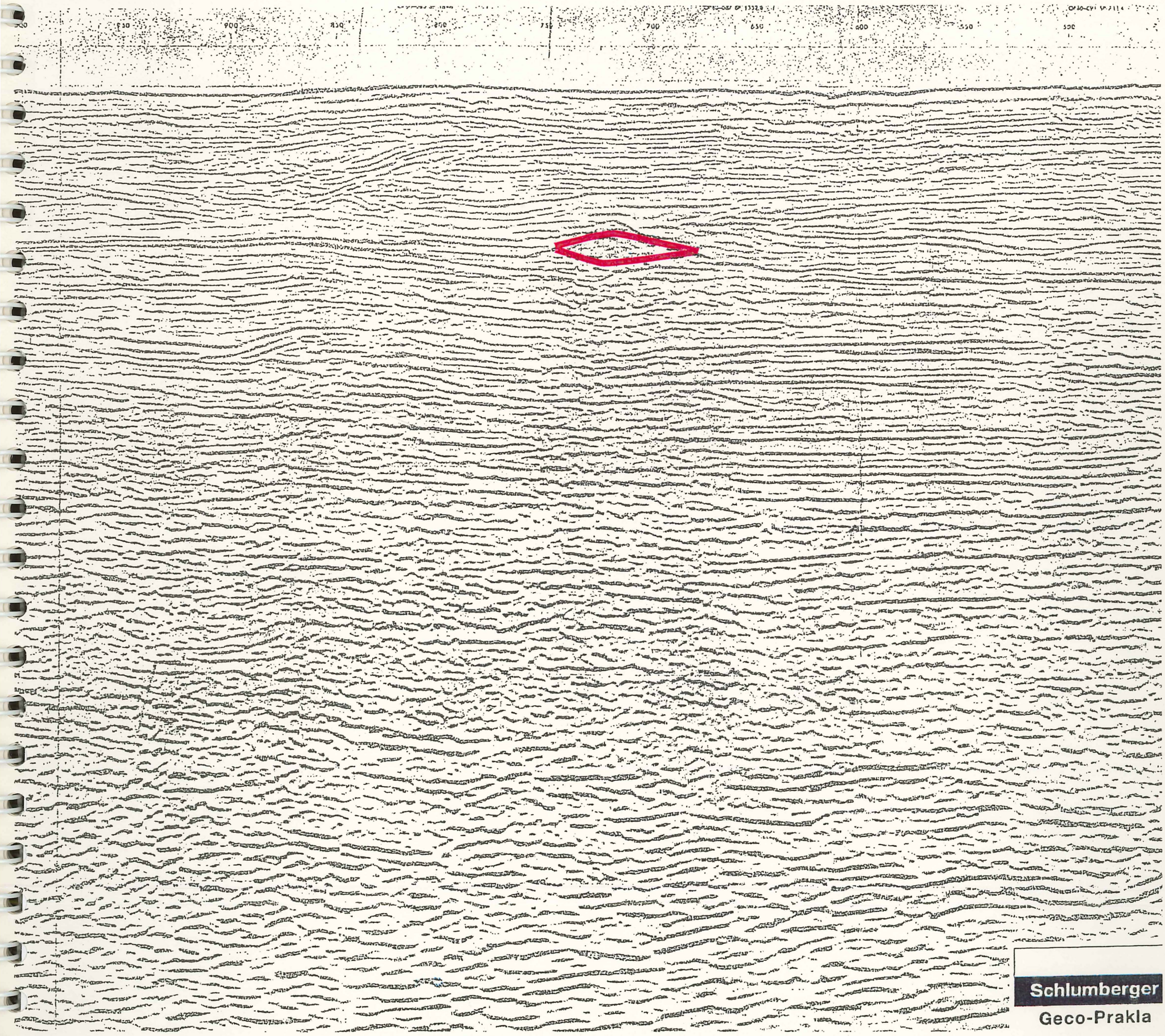


Schlumberger
Geco-Prakla

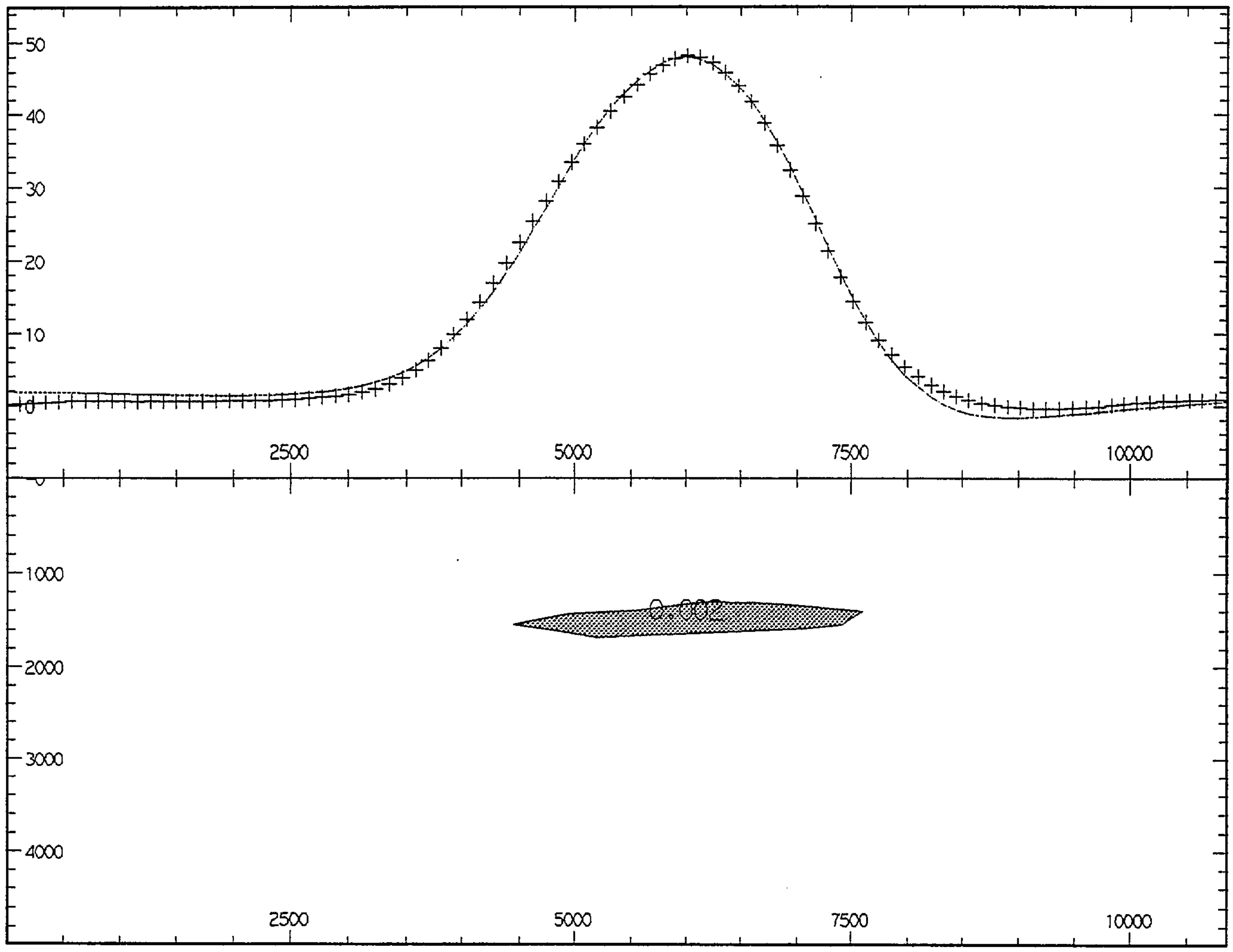

50
40
30
20
10
2500
5000
7500
10000
1000
2000
3000
4000
0.002
2500
5000
7500
10000

FIGURE 13b

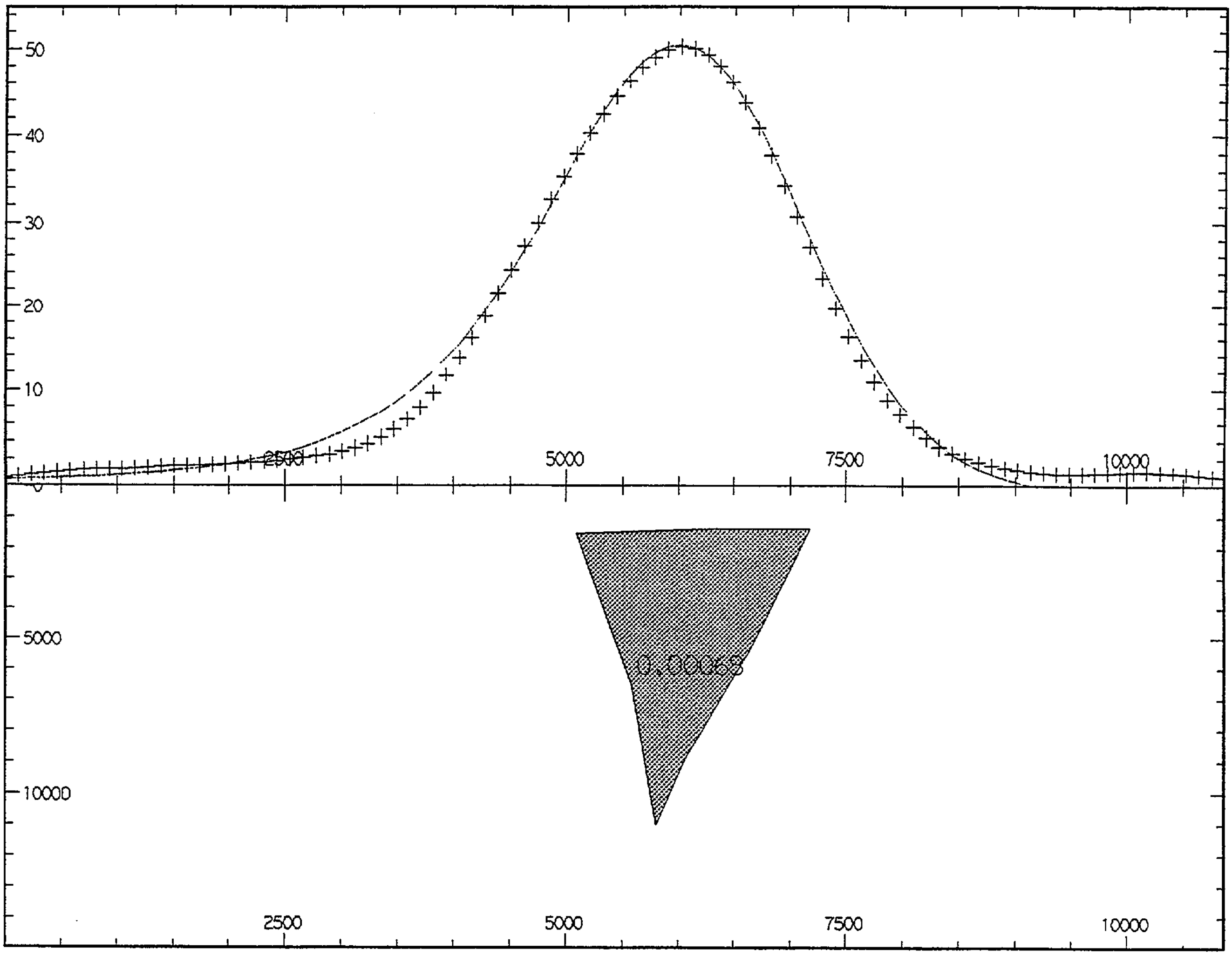

50
40
30
20
10
0
2500
5000
7500
10000
5000
10000
0,00065
2500
5000
7500
10000

FIGURE 13c

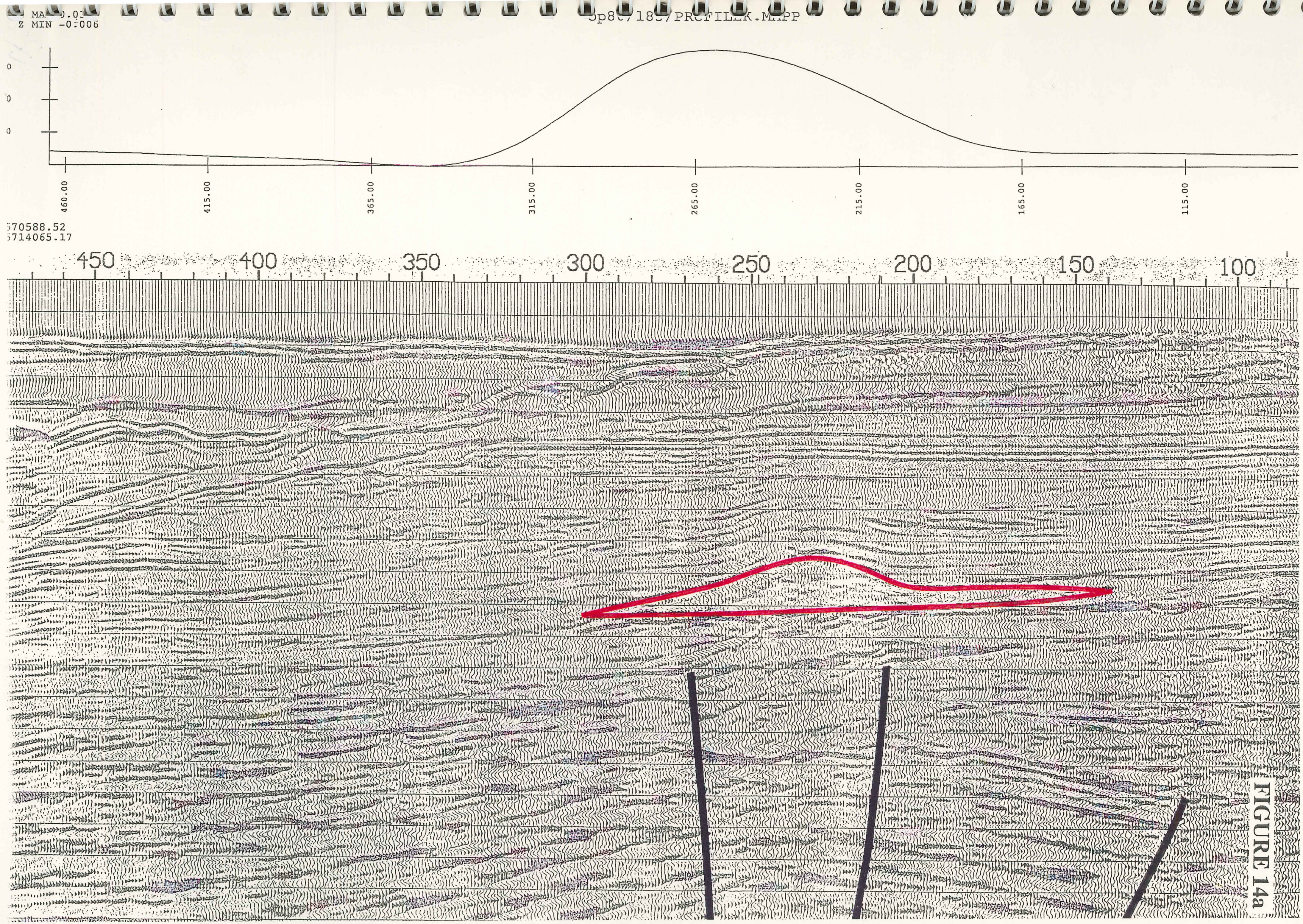

Z MIN -0.006
PROFILEK.MAPP
460.00
415.00
365.00
315.00
265.00
215.00
165.00
115.00
570588.52
5714065.17
450
400
350
300
250
200
150
100

FIGURE 14a

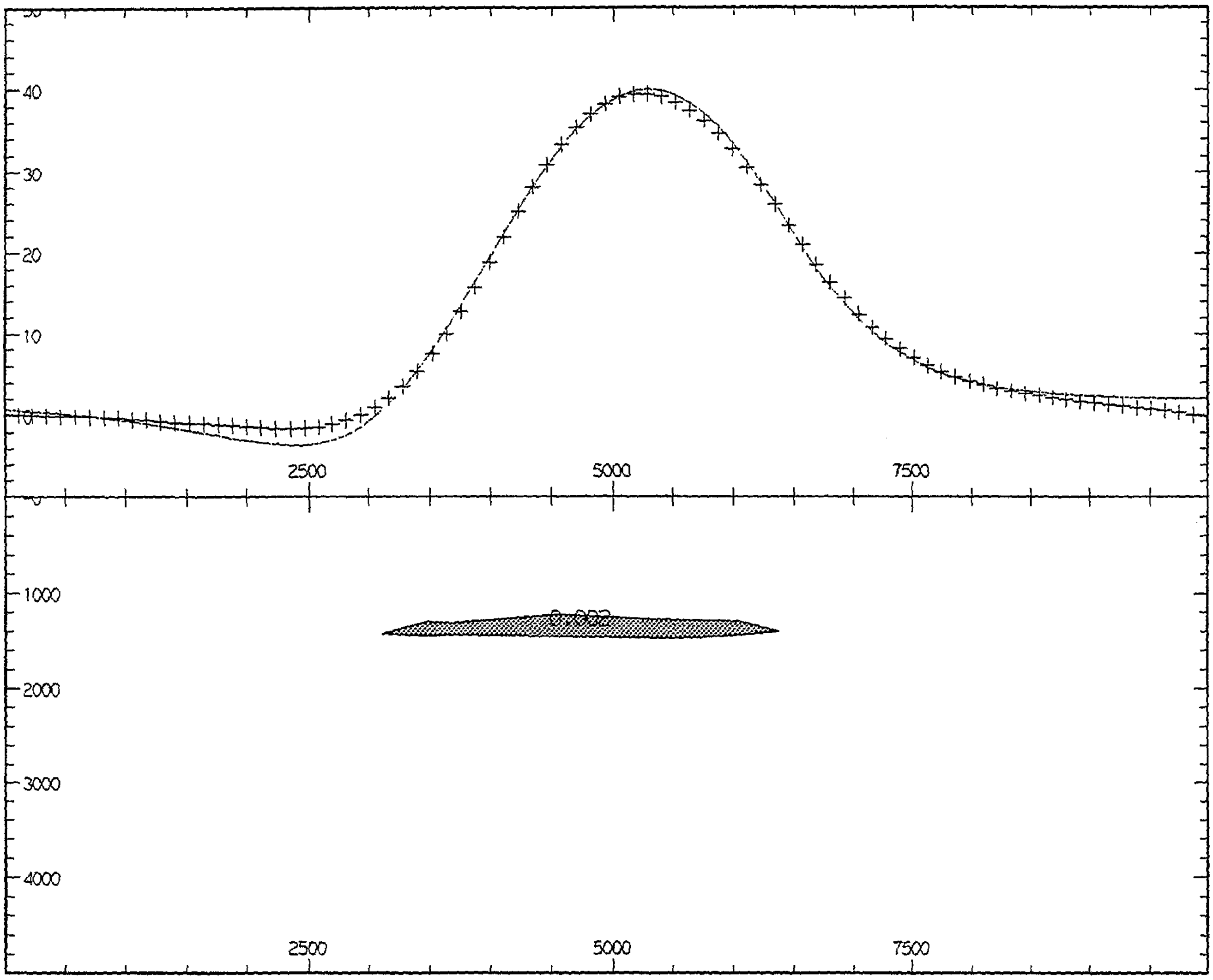


FIGURE 14b

R9505215

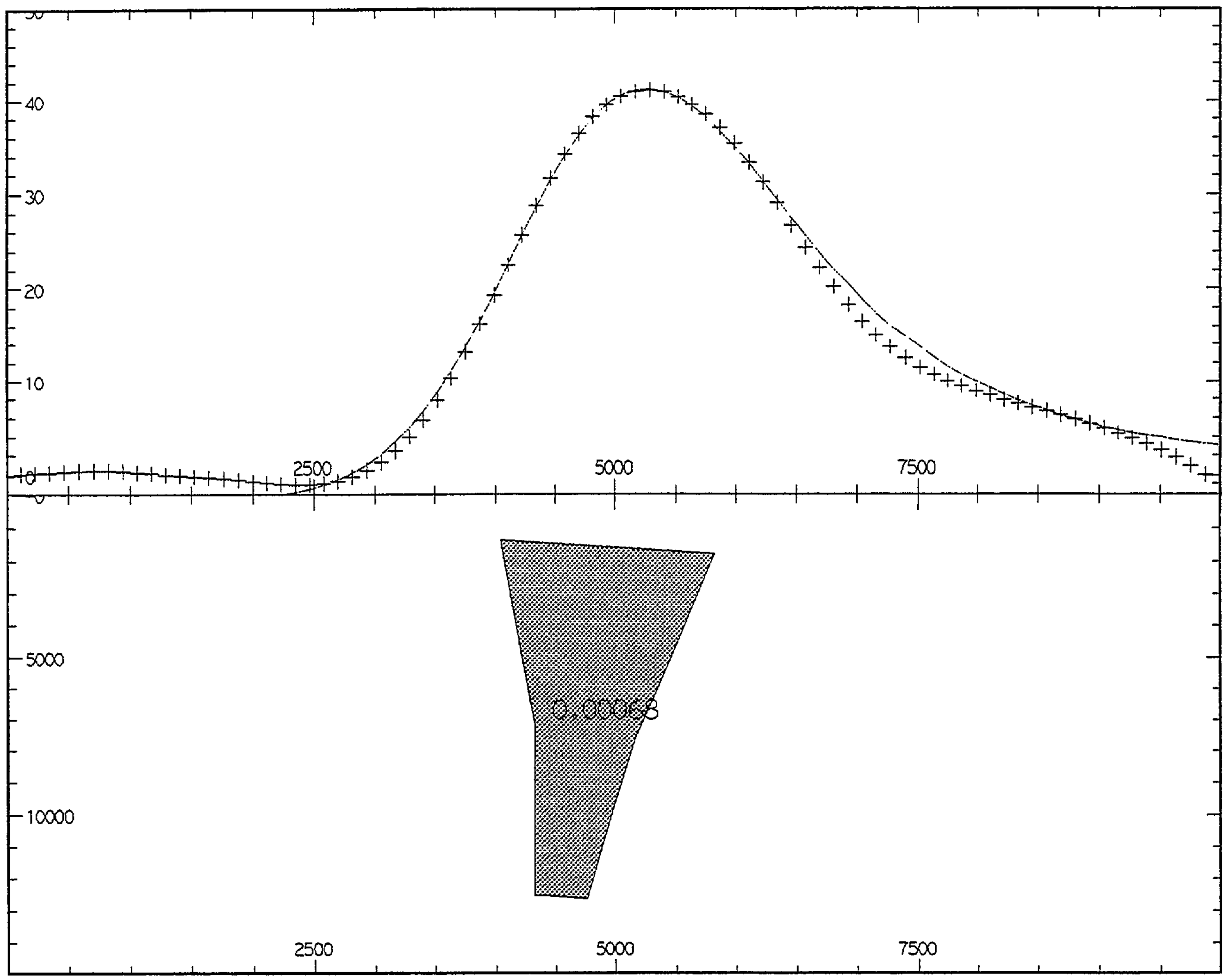
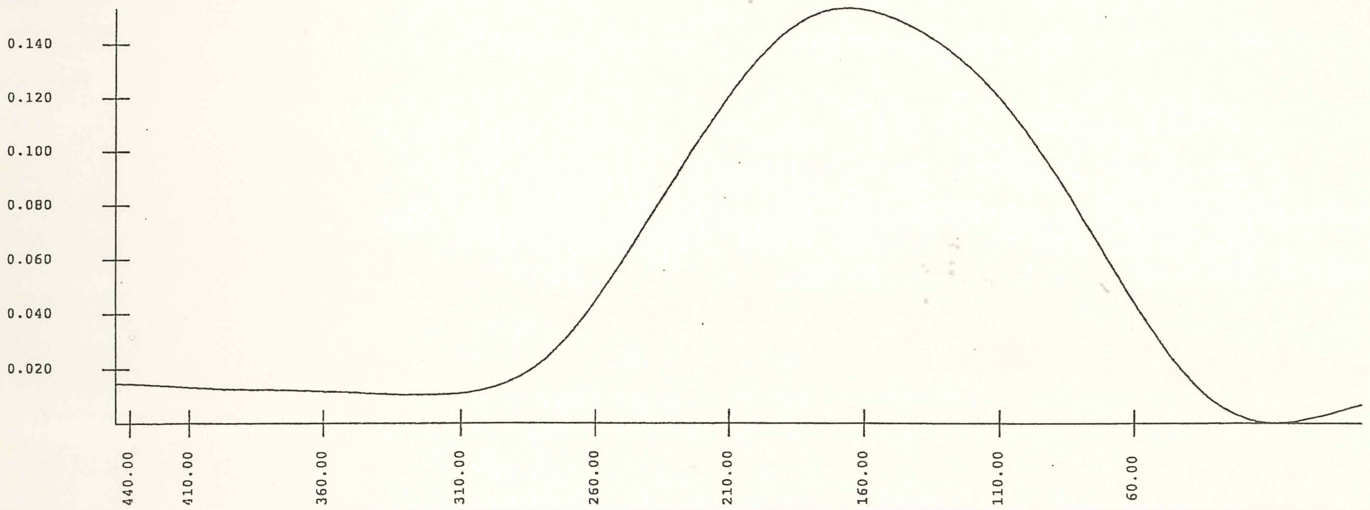


FIGURE 14c

Z MAX 0.137
Z MIN -0.017

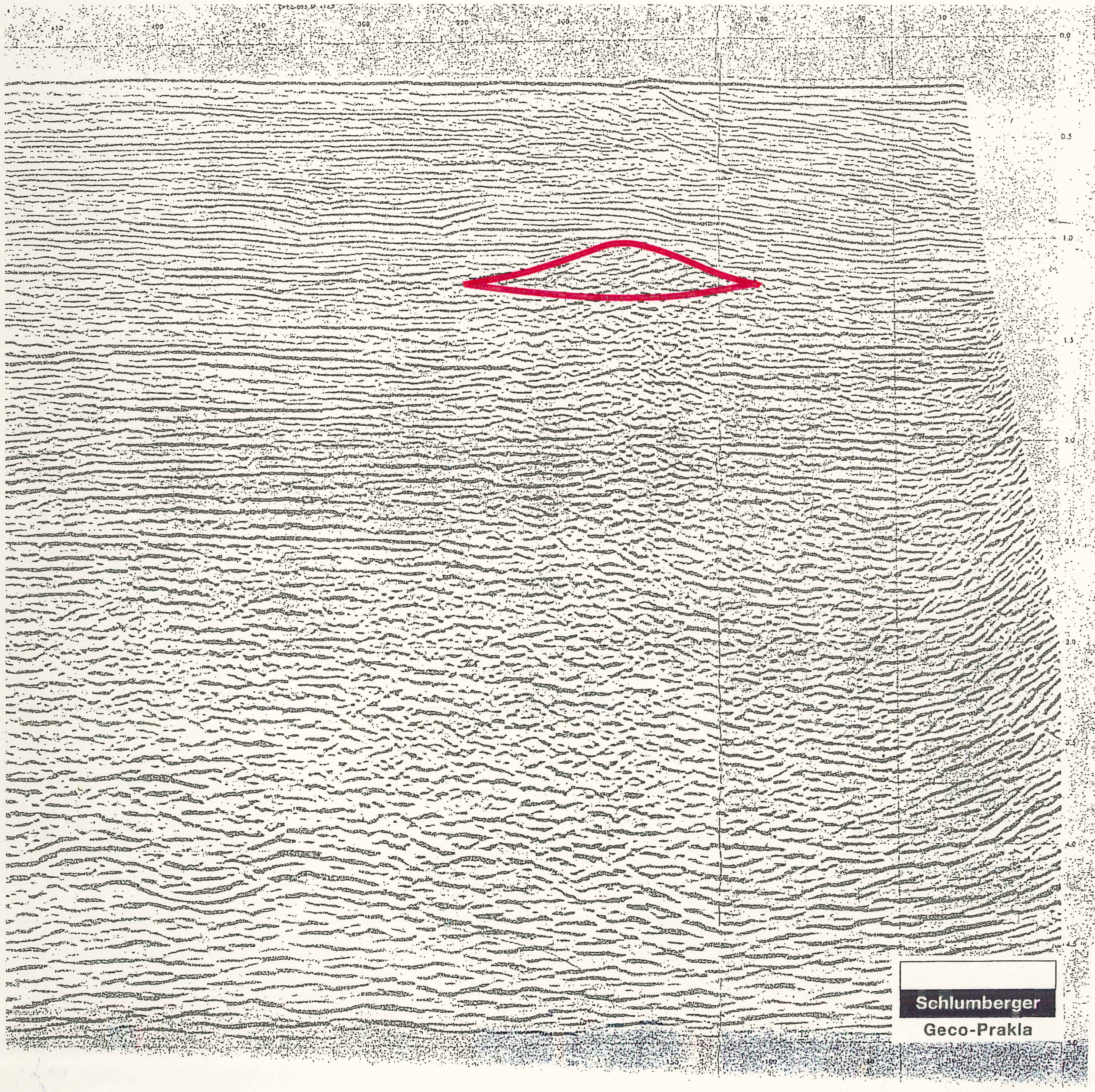
op80/124/PROFILEL.MAPP

FIGURE 15a



E 579546.08
N 5714903.92

E 589415.85
N 5709025.75



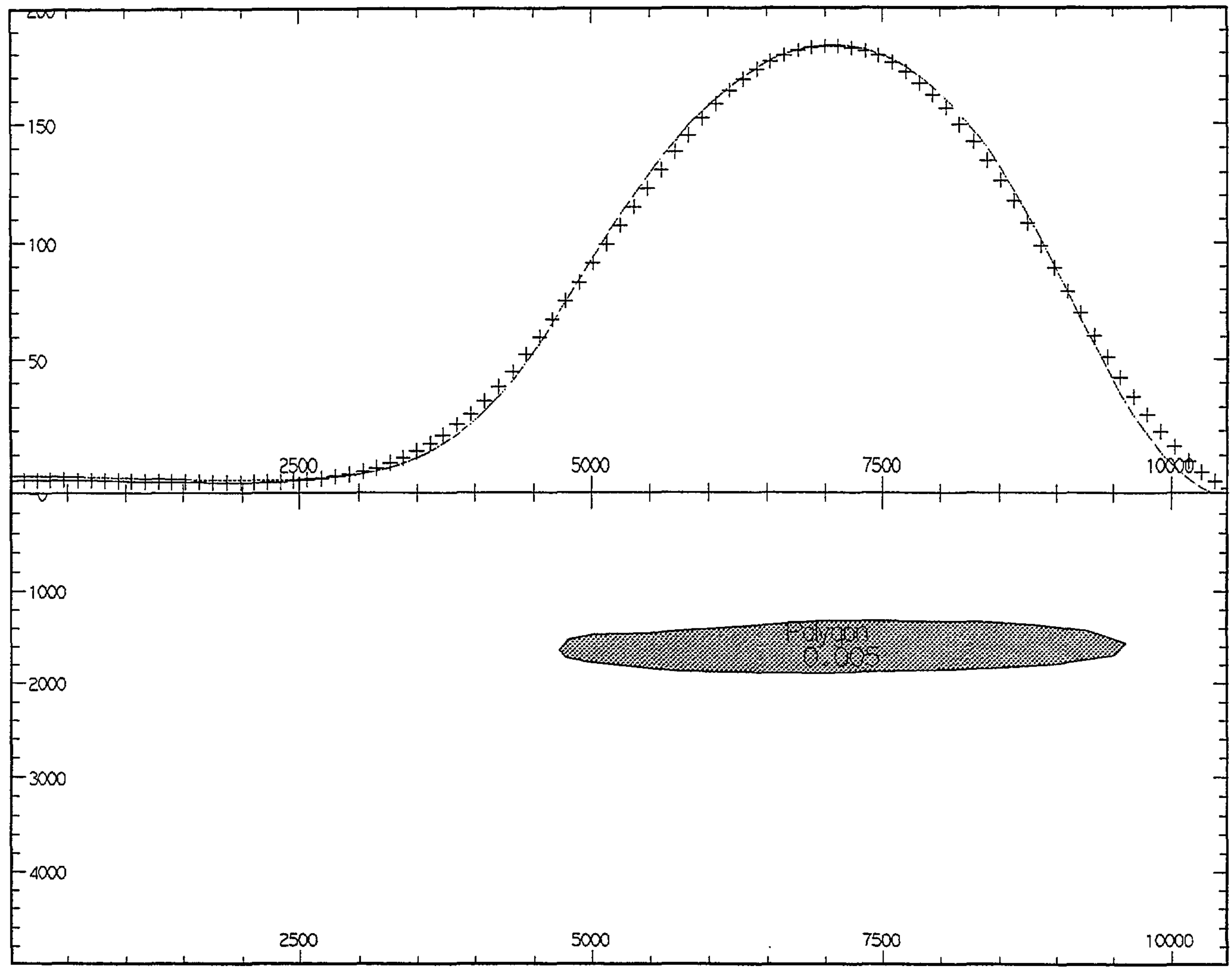


FIGURE 15b

R9505217

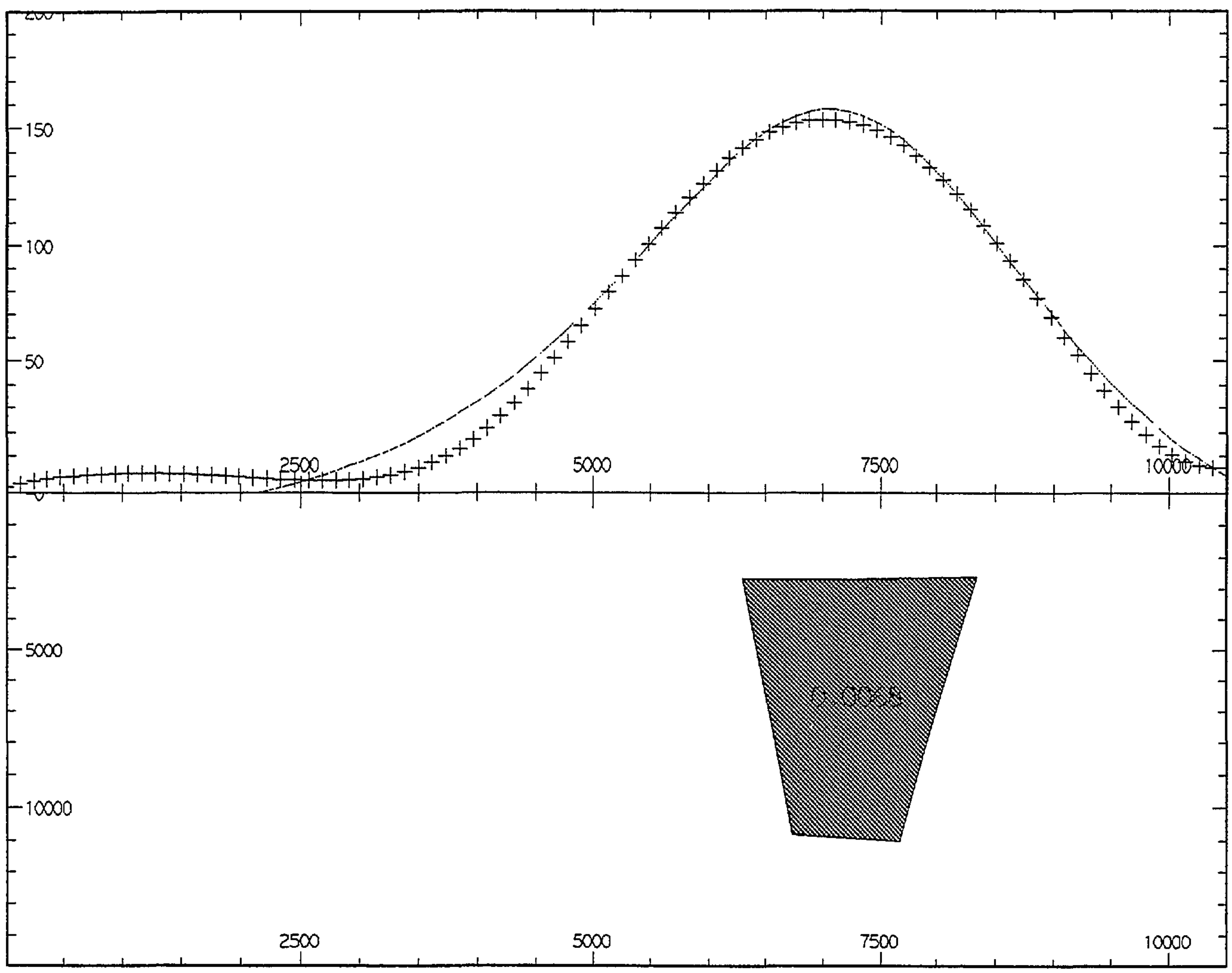
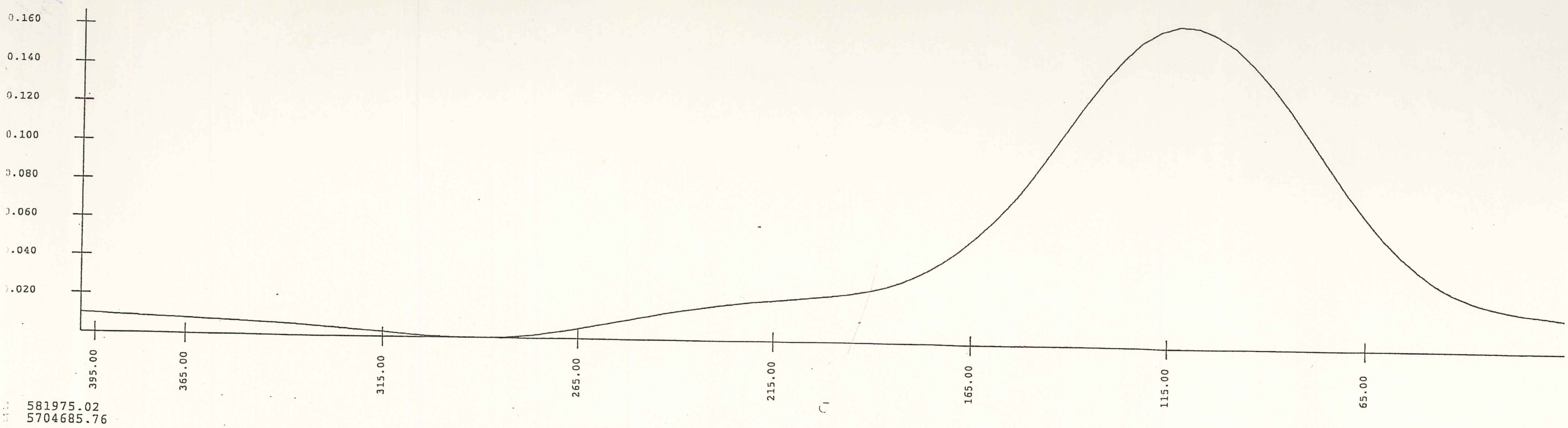
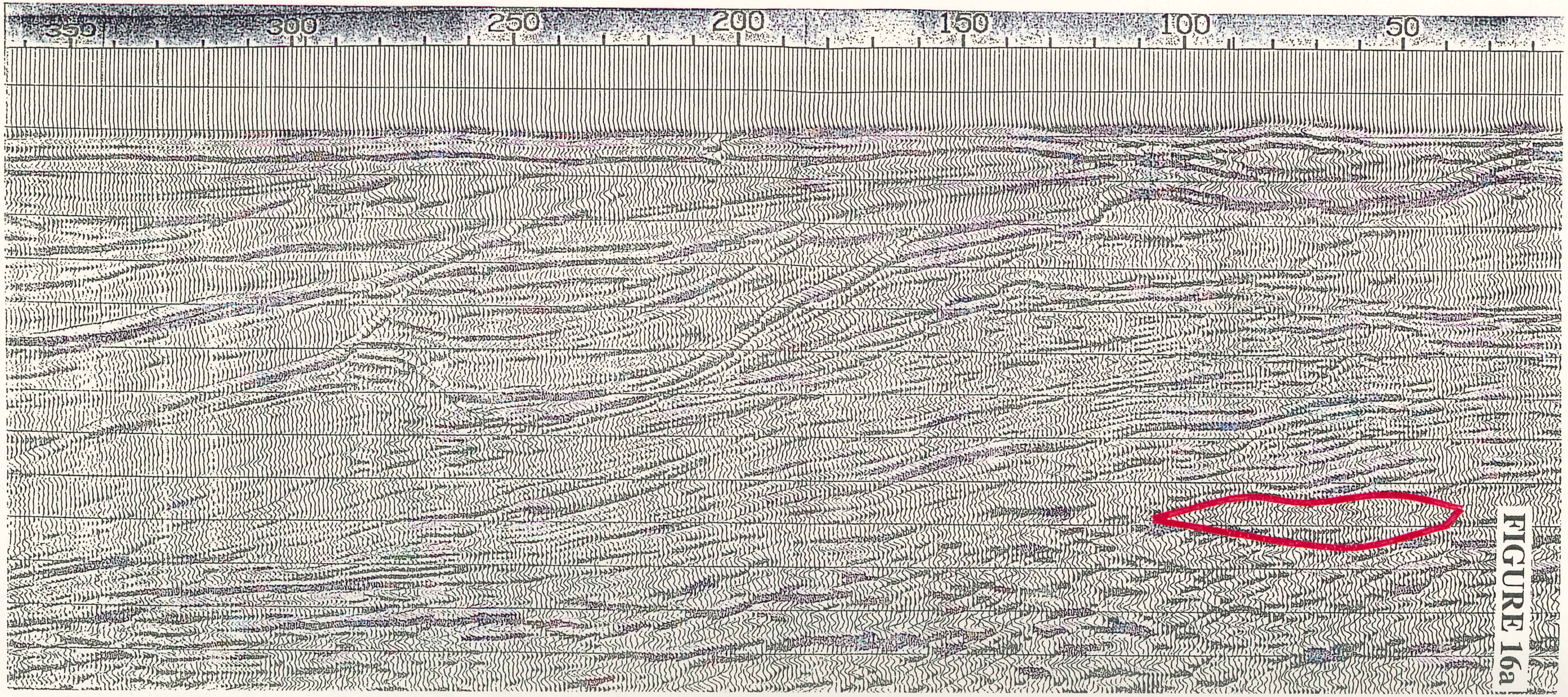

200
150
100
50
0
2500
5000
7500
10000
5000
10000
2500
5000
7500
10000

FIGURE 15c



Z MIN -0.012
Cp80,199,PROFILEM.MAPP
0.160
0.140
0.120
0.100
.080
.060
.040
.020
395.00
365.00
315.00
265.00
215.00
165.00
115.00
65.00
581975.02
5704685.76



350
300
250
200
150
100
50

FIGURE 16a

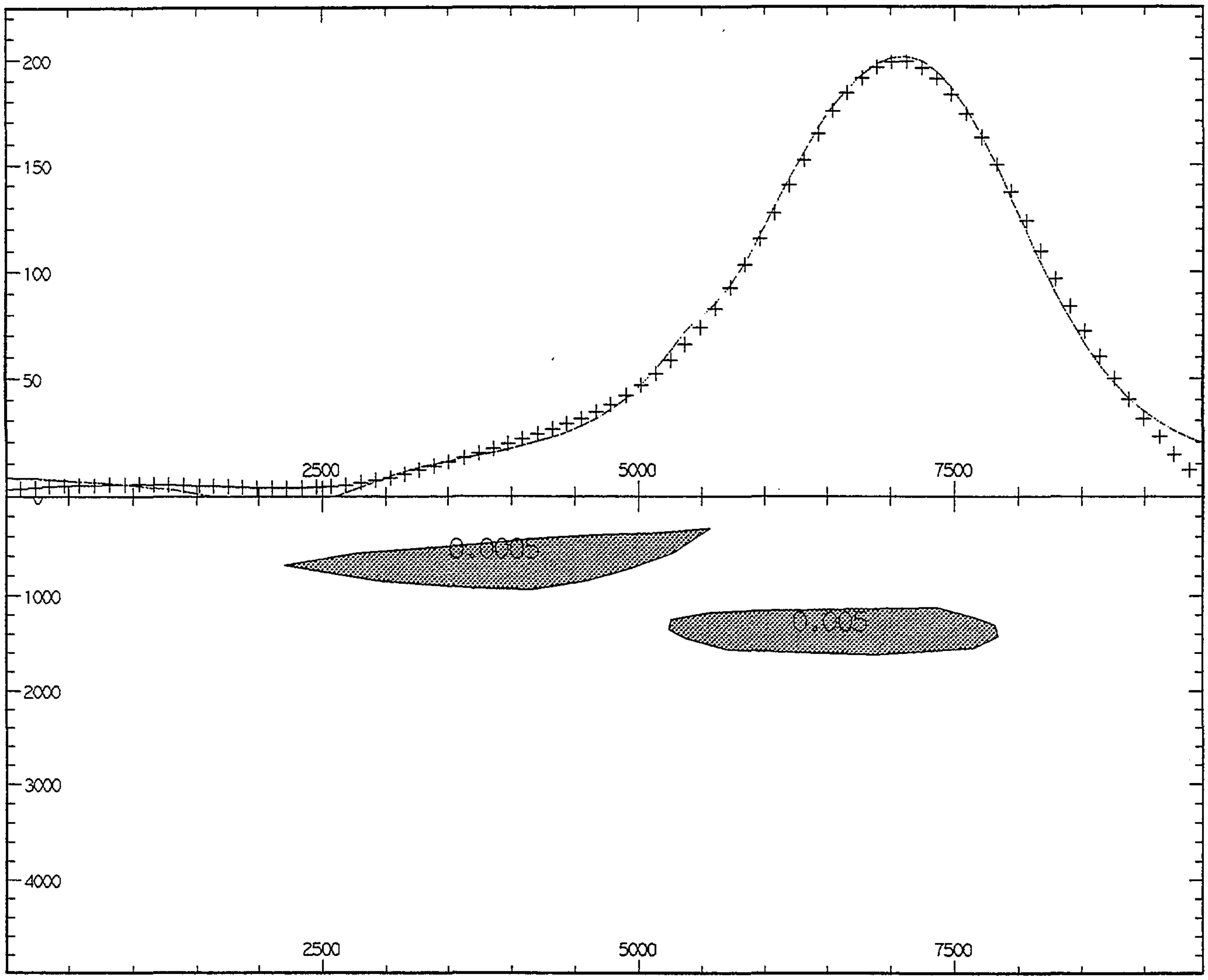
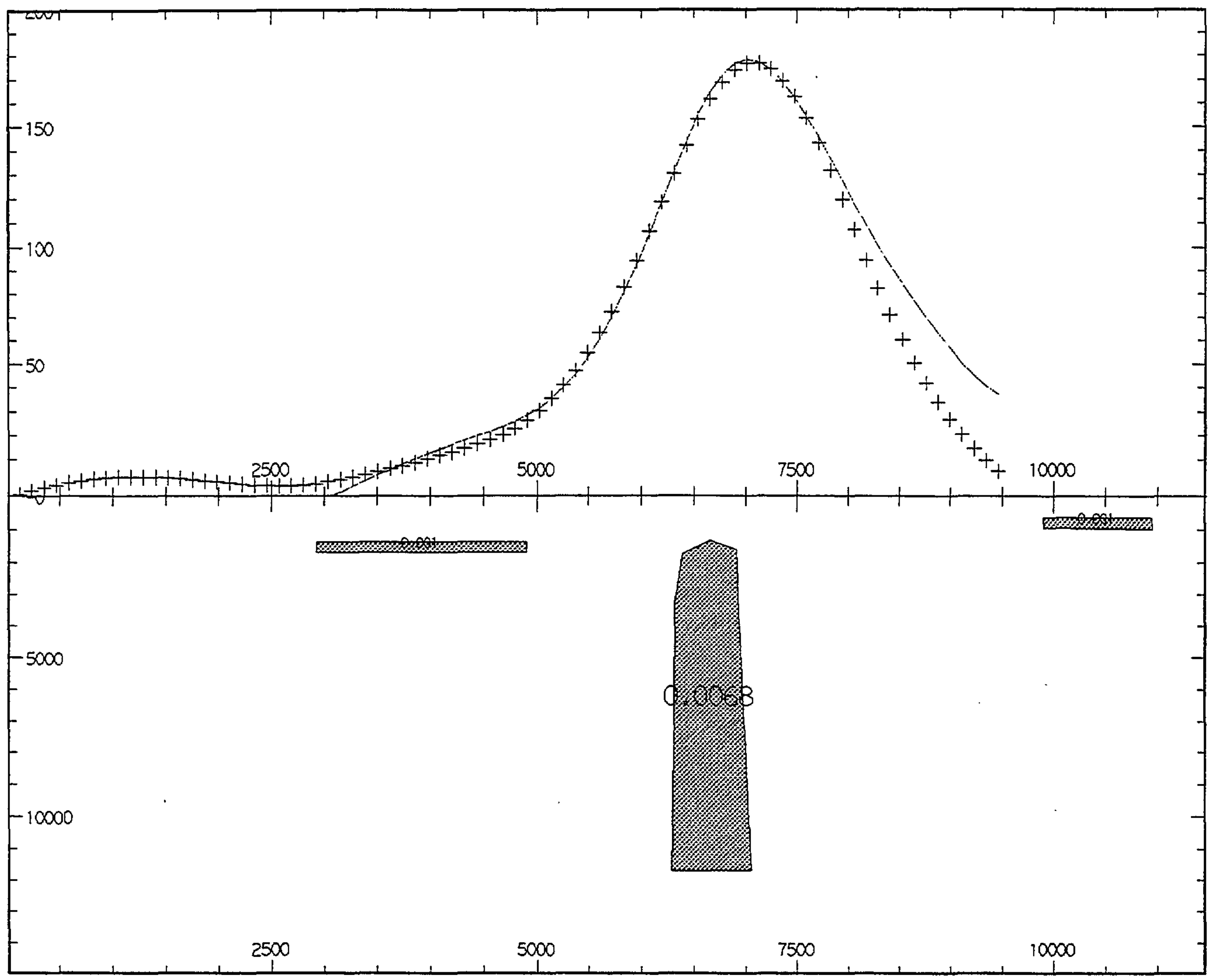


FIGURE 16b

R9505219



150
100
50
2500
5000
7500
10000
0.0068
5000
10000
2500
5000
7500
10000

FIGURE 16c

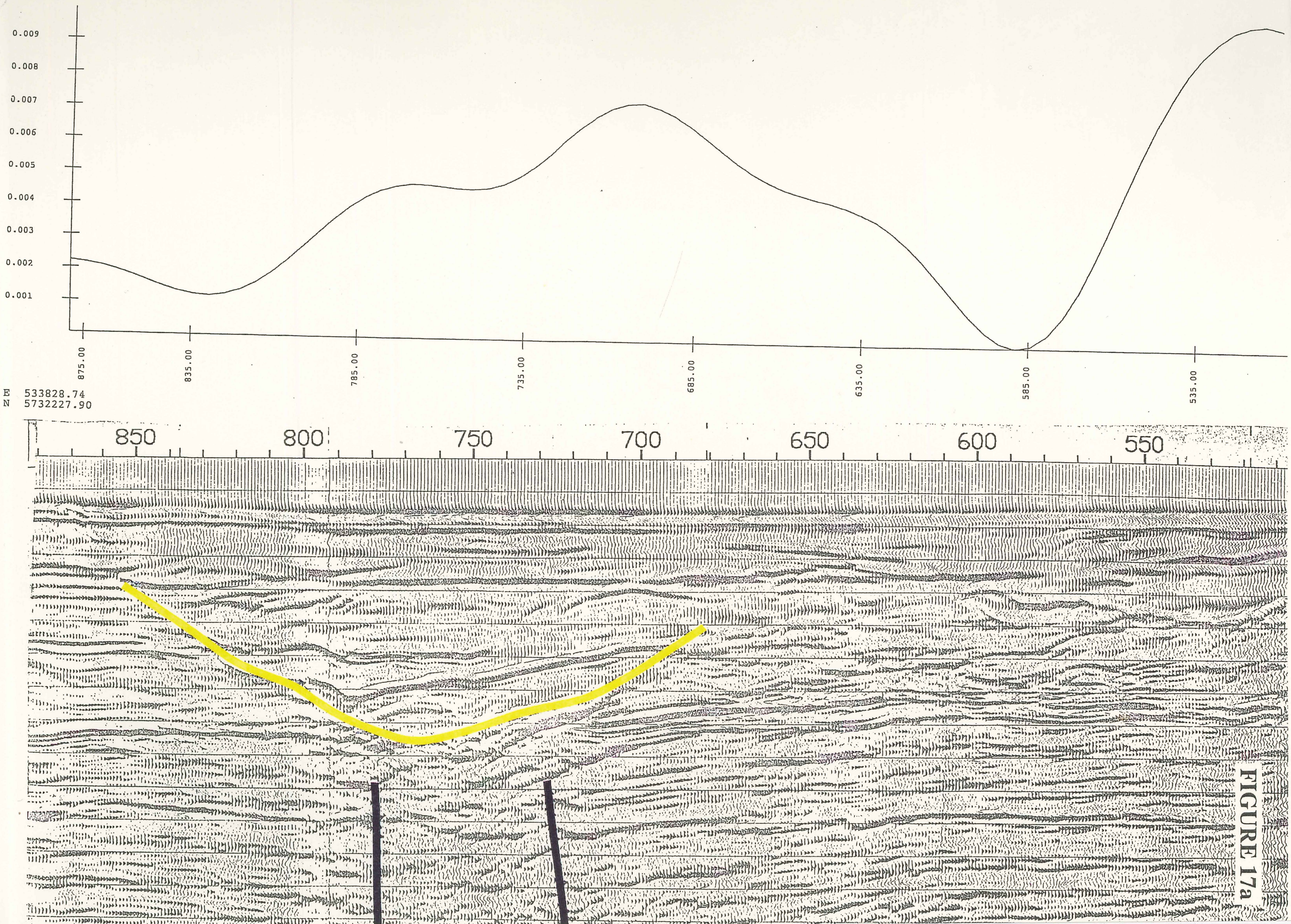

0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
875.00
835.00
785.00
735.00
685.00
635.00
585.00
535.00
E 533828.74
N 5732227.90
850
800
750
700
650
600
550

FIGURE 17a

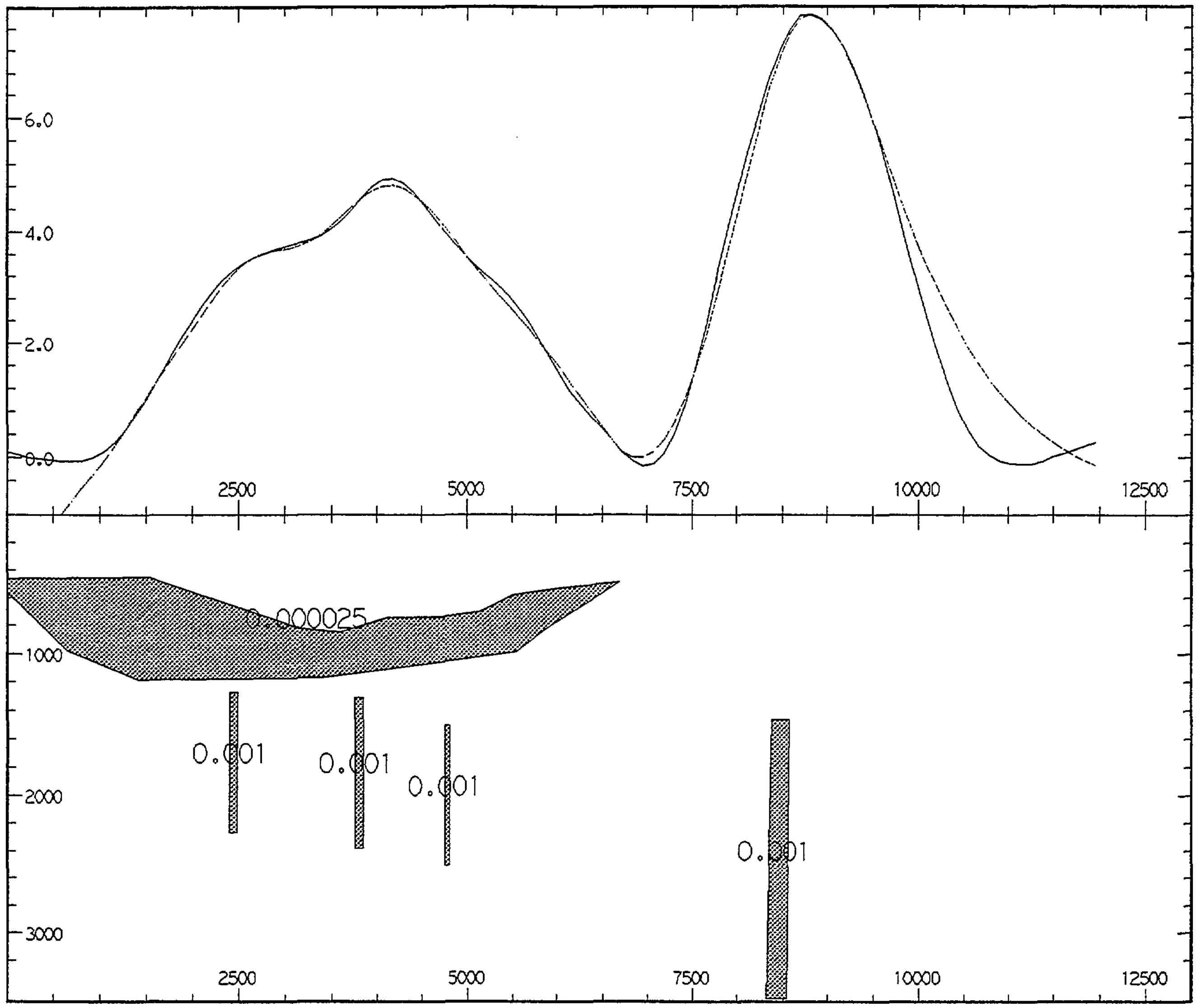
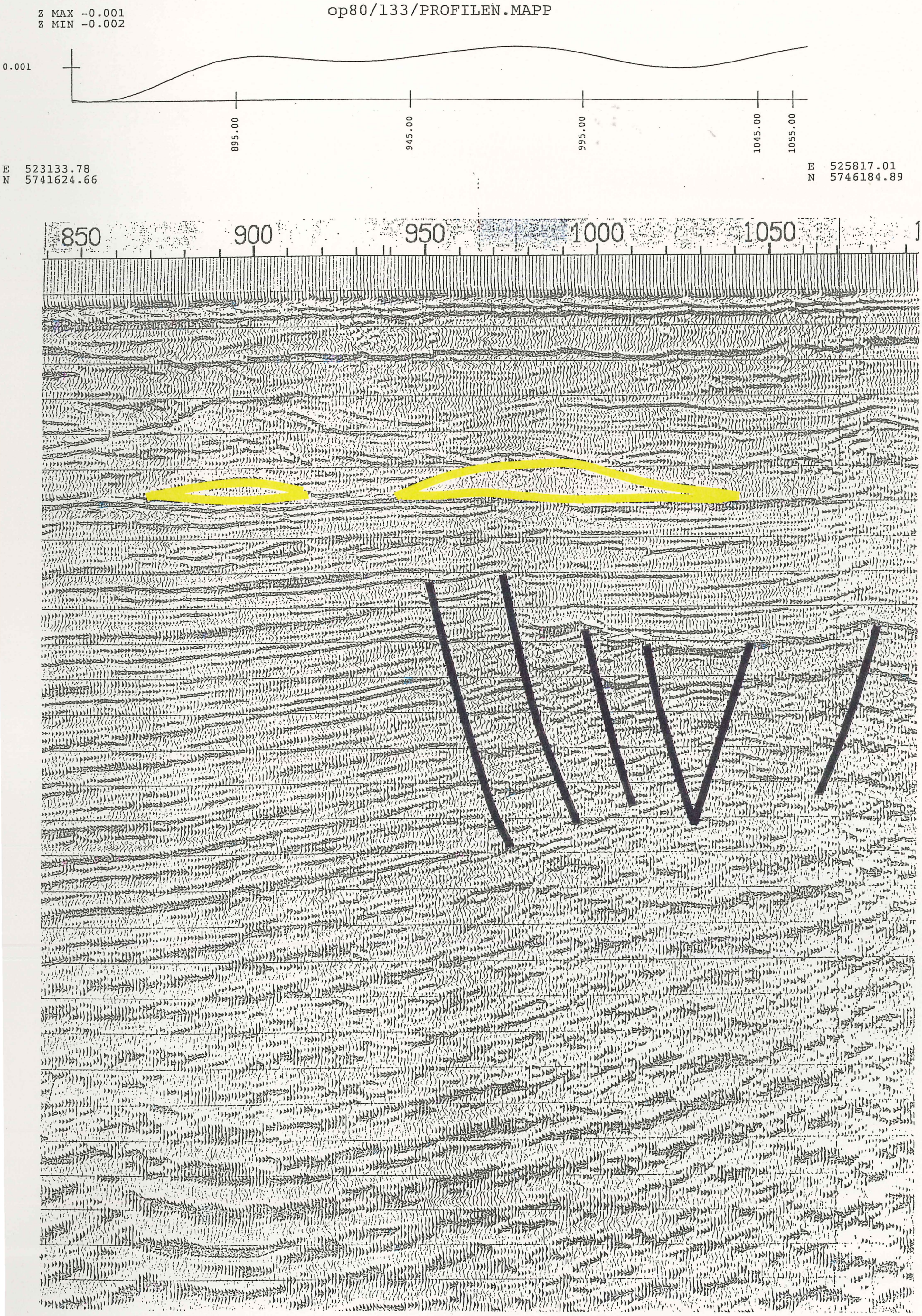


FIGURE 17b

R9505221


Z MAX -0.001
Z MIN -0.002
op80/133/PROFILEN.MAPP
0.001
895.00
945.00
995.00
1045.00
1055.00
E 523133.78
N 5741624.66
E 525817.01
N 5746184.89
850
900
950
1000
1050

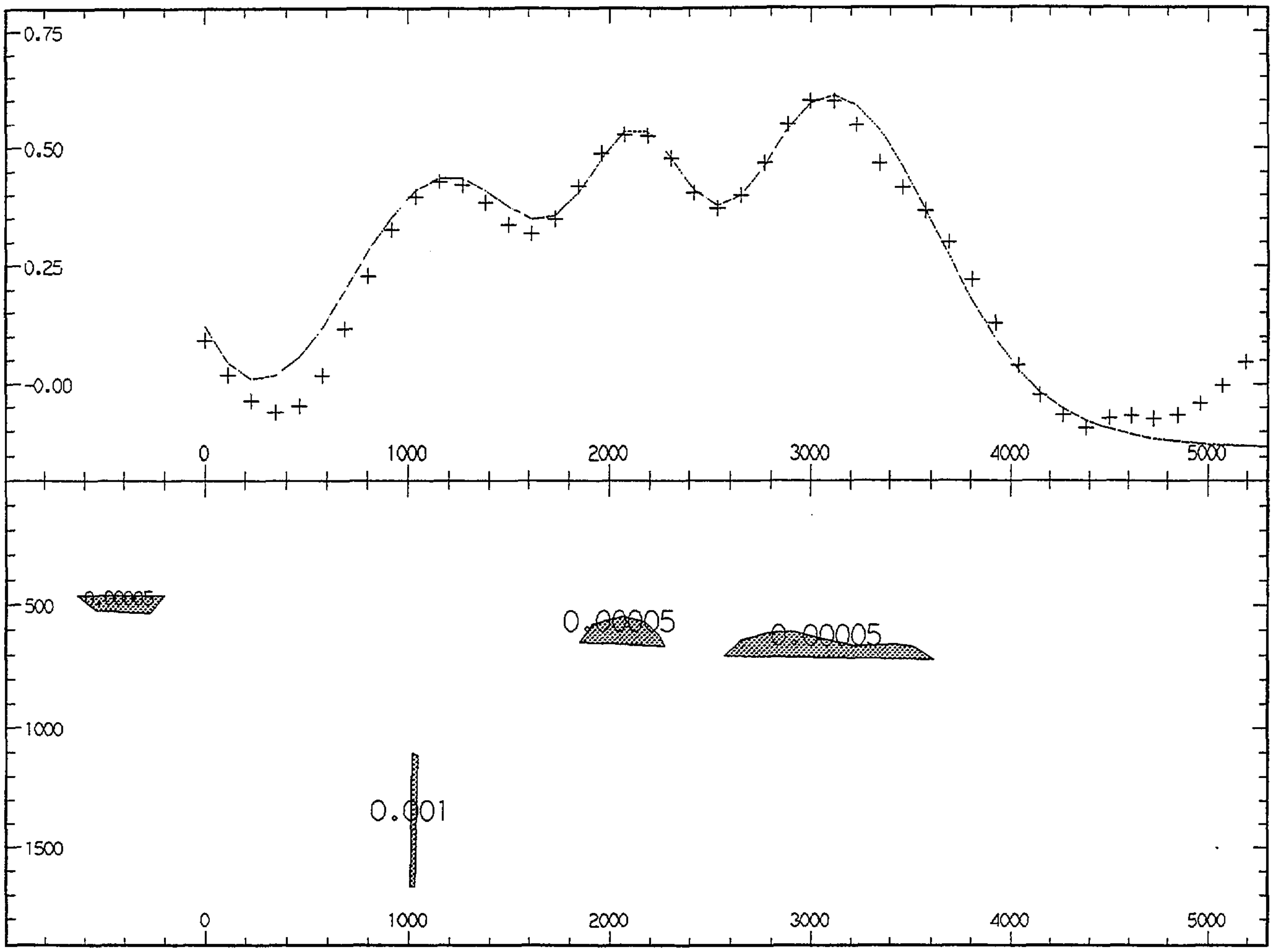

0.75
0.50
0.25
-0.00
0
1000
2000
3000
4000
5000
500
1000
1500
0.00005
0.00005
0.00005
0.001
0
1000
2000
3000
4000
5000

FIGURE 18b

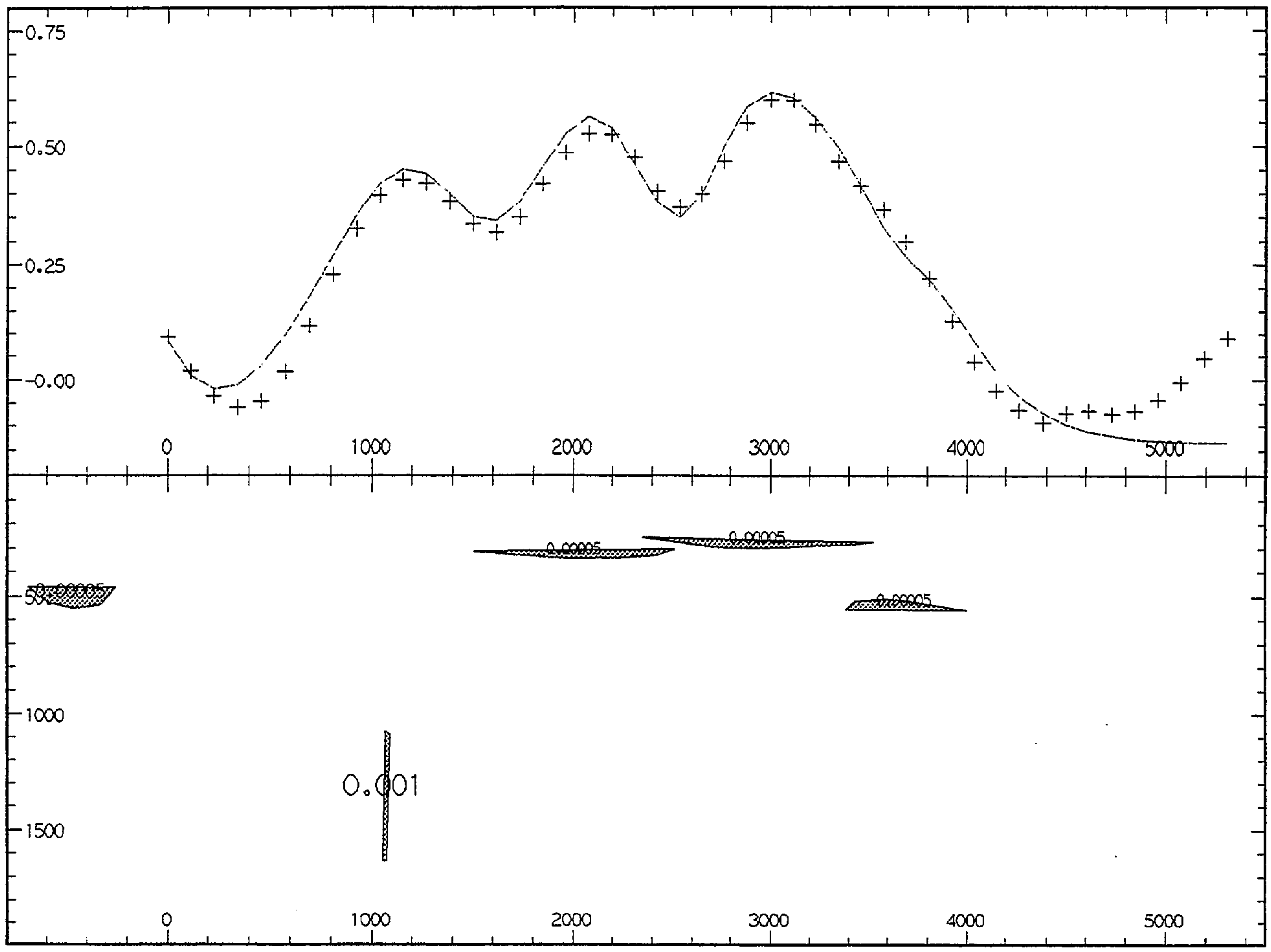

0.75
0.50
0.25
-0.00
0
1000
2000
3000
4000
5000
0.00005
0.00005
0.00005
0.00005
500
1000
1500
0.001
0
1000
2000
3000
4000
5000

FIGURE 18c