CENTRE for FIELD ARCHAEOLOGY

University of Edinburgh

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Commissioned by Historic Scotland

Investigations at North Ballachulish Moss
Stage 2
Report No. 390

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1. SUMMARY

1.1. This report presents results of a surface penetrating radar survey, sediment coring and post-excavation analysis conducted by the Centre for Field Archaeology (CFA) on North Ballachulish Moss. The fieldwork was undertaken in January 1998. From the results of the fieldwork, modifications to the initial post-excavation project design were considered appropriate and authorised by Historic Scotland. The alterations are detailed in the text. This work complements previous research at the site undertaken by CFA in 1996.

1.2. A final report will be produced in 1998 assimilating results from the two stages of investigation.

2. INTRODUCTION

General

2.1. This project is an extension of two previous archaeological assessments of North Ballachulish Moss. The first was carried out by Glasgow University Archaeological Research Division (GUARD) in 1993. The work of GUARD (Pollard 1993) demonstrated the existence of significant peat deposits in the southern portion of North Ballachulish Moss while no significant deposits were noted in the northern portion. It was concluded that the greatest archaeological potential existed in the southern portion. This was followed up by a radar survey, trial trenching, test-pitting and coring of approximately two thirds of the southern portion of the moss by CFA in 1996 (Clarke 1996, 1997). These works enabled an assessment of the archaeological and palaeoenvironmental potential of the area. The present work focuses on the remaining third of the southern portion. This is the area to the north of the 1997 baseline in Fig 2. The research was commissioned by Historic Scotland.

The Site (Fig 1)

2.2. The moss at Ballachulish lies on a raised beach terrace at the mouth of Loch Leven, about 15 kilometres to the southwest of Fort William. Since the nineteenth century Ballachulish Moss has yielded significant archaeological finds, some of international importance. From artefacts already recovered, notably the Ballachulish figurine (see below), it is clear that Ballachulish Moss has provided conditions ideal for the survival of organic archaeological remains. These conditions represent an important property of peat in archaeological terms as such organic materials rarely survive on dryland sites. It is generally considered that the preservative properties depend upon fairly stable waterlogging of the moss, and it is therefore important to not only preserve the area of the moss, but also to manage the site by minimising the risk of peatland deterioration and water loss.

2.3. In 1880 the Inverness Courier reported the recovery from the moss of a five foot high carved wooden figurine now known as the Ballachulish Goddess, in addition reference was made to previous recoveries of flint artefacts, a circular wattled building, ox and deer horns, casks of bog butter, wooden basins, platters and bowls, stone cists and cinerary urns (Christison 1881). Coles (1990) highlights the importance of the Ballachulish figurine in a European context. Records of archaeological recoveries from the moss, in addition to archaeological recoveries from all Scottish raised and intermediate bogs, are stored in the archaeological database of Scottish raised bogs, completed by CFA (Clarke and Finlayson 1995), and the Archaeological database for the Scottish wetlands, completed by CFA in (Clarke 1997) which are currently held by Centre for Field Archaeology (CFA) and Historic Scotland.

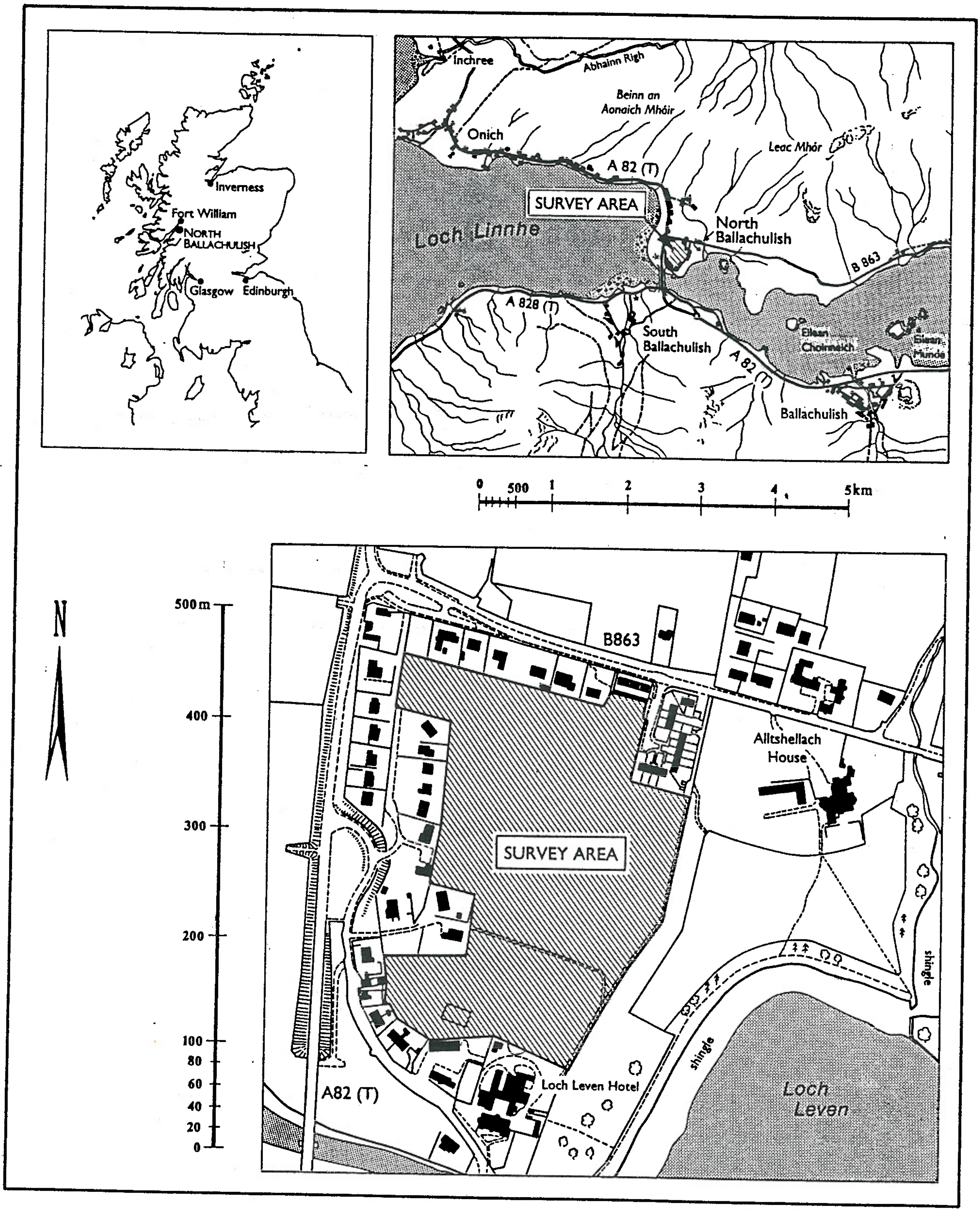

Fig 1. Location map of study area

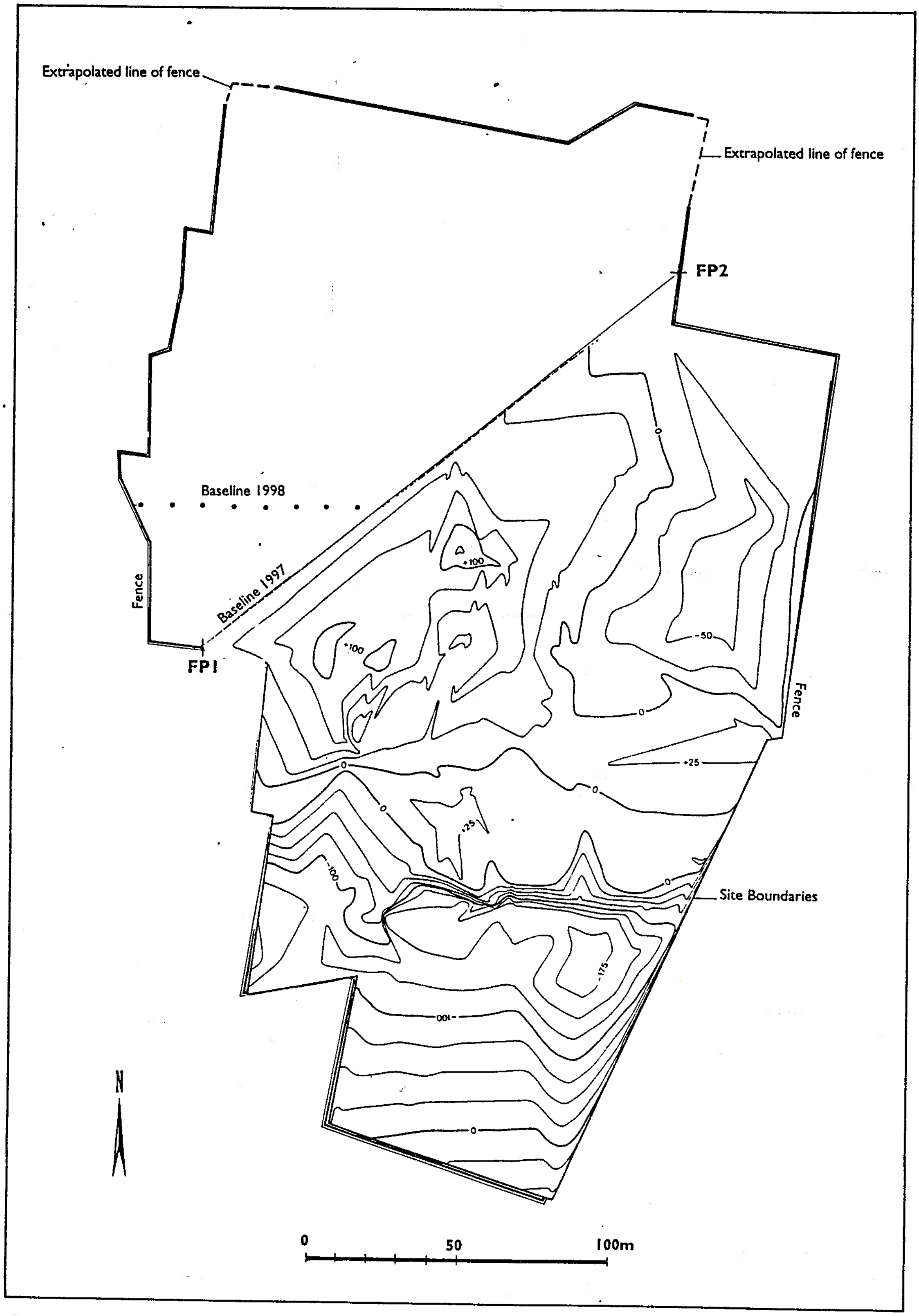

Fig 2. Topographic Survey results and boundary information

Previous work

2.4. An initial probing survey of North Ballachulish moss carried out by Pollard (1993) showed the presence of peat to depths of up to 3.5m, demonstrating the potential for the survival of archaeological remains. The survey also illustrated that the sub-peat topography appeared to undulate possibly indicating the presence of former pools or relict stream beds. Both macrofossil and pollen results indicated that the site was most likely wooded in the initial stages of peat formation, and macrofossil evidence suggested that even when the site was not wooded, woodland existed in the immediate vicinity. Stratigraphic and macrofossil composition across the site were found not to be consistent suggesting that vegetation communities differed across the surface of the bog (Ramsay nd). All indications suggested that important archaeological remains could still be concealed within Ballachulish Moss, particularly in the southern portion.

2.5. Development threat prompted the expansion of the initial survey to a more detailed archaeological and palaeoenvironmental assessment of the southern portion which was carried out by CFA. Land ownership sensitivities at the time meant that only two thirds of the southern portion of the moss were accessible. Using surface penetrating radar it was demonstrated that the study area within the moss comprised three peat-infilled basins. The topography underlying the peat, as defined by the radar, appeared to corroborate the findings of GUARD (Pollard 1993), although the radar produced a higher resolution picture of sub-peat features. Within the deepest of the basins a series of radar anomalies was detected. Excavation and radiocarbon dating demonstrated that these anomalies were indications of a prehistoric platform feature with associated worked wood.

2.6. A core from the deepest of the lake basins facilitated the reconstruction of the past vegetation history of the moss using pollen and macrofossil analysis. Macrofossil analysis also demonstrated that vegetation cover across the moss was variable. Radiocarbon dates indicated the non-synchronous inception of the peat in different areas of the moss. The earliest peat inception dates to ca 6,000BP. It is possible that anthropogenic activity on the moss may have triggered the development of peat in the southern portion of the study area at ca 2000 BC. Removal of peat, probably through peat-cutting, is evident towards the top of the dated profiles. Details of this work can be found in Clarke 1998.

Objectives

2.7. The present study focuses on the remaining third of the southern portion of the moss. The fieldwork was undertaken following the relevant objectives set out in Historic Scotland's Project Outline. The principal objective was to build on the 1995-6 studies conducted by

CFA thereby completing the archaeological and palaeoenvironmental evaluation of the southern portion of the remaining area of the moss.

2.8. In order to address these issues the archaeological and palaeoenvironmental assessments aimed to map both the underlying and surface topography of the moss, to assess the nature and dates of peat formation across the area and to determine vegetation cover both before peat growth commenced and during the development of the moss.

2.9. Other objectives included assessing the potential for the survival of both organic and inorganic archaeological and palaeoecological materials, to provide a detailed consideration of ways in which the administration of this area of wetland could be improved through active management, and to provide a detailed mitigation strategy for those deposits which cannot be preserved as a result of threats to the moss.

Reporting

2.10. A draft summary report of the results will be published in *Discovery and Excavation in Scotland 1998.* A report fit in all respects for publication will be produced on receipt of radiocarbon dates combining the results of stages 1 and 2 and providing a complete archaeological and palaeoenvironmental assessment for the remaining southern portion of North Ballachulish Moss

Archiving and Finds Disposal

2.11. A copy of this report and all site records will be deposited with the National Monuments Record of Scotland at the appropriate time. There were no finds associated with this stage of investigation.

Acknowledgements

2.12. CFA wishes to thank G.J. Mc Intyre for arranging access to the site through Mr Bremner, the landowner. Dr Richard Hingley, the Historic Scotland Project Manager and other Historic Scotland staff provided many useful ideas and advice on previous investigations at the site. Utsi Electronics Ltd advised on aspects of the radar survey. Thanks to Anthony Newton of Department of Geography, University of Edinburgh for instruction, assistance and advice with the percussion corer. Thanks also to the local people of North Ballachulish for their interest and encouragement.

3. RADAR SURVEY

3.1. The fist task was to conduct a radar survey to define the basin morphology of the study area, and identify a location suitable for coring. As demonstrated in Clarke (1998) radar can also detect features within the peat.

3.2. The survey was carried out using Utsi Electronic's ***Groundvue 2B*** system, which has a working range of approximately 10 metres in wet peat. The surveys were carried out using an impulse of 5 nanoseconds, a scan time of 320 nanoseconds and a sampling interval of 20cm. The parallel radar transects were run at 10 m intervals perpendicular to an approximately East-West baseline. A degree of overlap with the stage 1 survey was necessary to match the results from both stages. The baseline was also surveyed using radar.

3.3. Originally the intention was to conduct a closer interval radar survey in areas of deeper peat. However, no areas of deep peat were identified so no further survey was required.

3.4. The survey did identify a series of shallow anomalies, between 0 and ca 50cm, which most likely represents a system of drains. If this is the case then it is possible that they discharge into the largest lake basin, identified in the previous survey, and may contribute to its saturation. To the northwest of the site the peat begins to deepen just beyond 1m, perhaps reflecting the steepening edge of another basin, but a wire fence prevented access to pursue the course of the deepening peat. The fence marks the boundary between the moss and the gardens of adjacent houses.

3.5. Where the radar traversed the large basin, identified during the stage 1 investigations, stratification was visible within the peat. Within the confines of the lake basin a thin layer was detected on the radar trace at ca 1.5m below the surface towards the edge and deepening in the centre to ca 2.5m. This could represent either a stratigraphic change, or the presence of a band of a non-peat material. All radar anomalies within the basin appear to be situated above this stratigraphic feature. This was not detected during stage 1 investigations. However, the radar equipment has been modified to improve resolution since the 1996 survey. The *Groundvue 2* system which was used in the 1996 survey is identical to the *Groundvue 2B,* used in the 1998 survey, apart from the fact that the former uses horn type antennae while the latter uses "bow-tie" antennae. The use of the bow-tie antennae reputedly allows more of the signal to pass into the ground and therefore provides greater clarity and detail in the radar plots (E. Utsi pers. comm.). Further, in the 1996 survey a radar sampling interval of 40cm was employed while the latest survey used a sampling interval of 20cm. The closer sampling interval and modified antennae may explain the greater resolution in the peat profile obtained using the *Groundvue 2B* system. Hence the detection of stratigraphy within the peat, which was not identified in the 1996 survey.

3.6. Full details of the radar survey are included as Annex 1.

4. TOPOGRAPHIC SURVEY

4.1. In addition to mapping the underlying topography of the moss a contour and topographic survey was conducted across the surface area of the site. This survey was conducted using an industry standard EDM with datalogger.

4.2. The EDM survey produced an overall picture of the variable relief of the land in addition to defining the boundaries. Dense vegetation prevented accurately surveying some points along the boundary and these points have been extrapolated on the plan in Fig 2. An area of overlap with the stage one investigations was included in the topographic survey in order that the survey could be aligned with the 1996 topographic survey

4.3. In conjunction the results of the radar and the topographic surveys allow a three-dimensional impression of the peat deposits to be formulated.

5. SEDIMENT CORING

5.1. Radar surveys have the advantage that preliminary results are instantly available although obviously calibration and processing of the data results in a clearer trace of the deposits. From the preliminary results it was apparent during this survey that the study area contained no novel areas of deep peat, other than the edge of the large basin identified and investigated in 1996.

5.2. To satisfy the project design a sediment core was extracted from the area of deep peat just inside the study area and within the confines of the peat-infilled basin. The sediment column was extracted using an Eijkelkamp percussion gouge with a removable internal sample tube. Three 1m cores were extracted from a single bore-hole. A fresh sample tube was used for each core. At the base of the 3m core clays were encountered. No further sediment was sampled. Use of the percussion equipment resulted in some compression of the extracted peat core sequence. It is possible that this layer of clay may represent the thin band of stratification observed in the radar survey. Unfortunately this band was not visible until subsequent data processing and was not noted on site, so the coring did not attempt to test this. (The stratified band could also be interpreted as the platform feature, this is discussed further below.)

5.3. A sediment core had previously been analysed from this basin as part of the stage one survey and analysis. In consultation with Historic Scotland it was agreed that rather than duplicating the analysis of material from within this basin more useful information could be obtained from the analysis of a column of peat sampled in peat cutting boxes from an exposed section overlying the platform identified during 1996 from trench 2. Here the peat directly overlying the feature was dated to 3730±50 uncalibrated radiocarbon years before present (bp), while two wooden stakes presumed to be associated with the feature were dated to 2870± 50 bp and 3320±80 bp respectively. This suggests an age difference of several hundred years between the feature and the onset of peat formation, but with the peat formation pre-dating the wood associated with the feature. Thus it was concluded that the basal peat may have been contaminated and it was recommended that biostratigraphic correlation be used to test this hypothesis by comparison of the vegetation profile overlying the feature to the vegetation profile of the entire core sequence which had been analysed as part of the stage one programme (Clarke 1998).

5.4. The biostratigraphic analysis recommended above has replaced the analysis of the core sequence from the stage 2 investigations that was initially proposed. Procedures, analysis and results are detailed below.

6. BIOSTRATIGRAPHIC CORRELATION

6.1. In 1996 peat-cutting boxes were used to sample the section of peat exposed above the platform feature encountered during exploratory excavations. The column extended from the top of the feature for 96cm. Two radiocarbon dates were obtained from this section. The basal peat, directly overlying the feature, dated to 3730±50 bp, while 93-96cm above this the peat dated to 2240±50 bp. For reasons outlined previously the basal peat was considered to be contaminated.

6.2. For this stage of analysis contiguous 1cm subsamples of peat were taken for 4cm above the feature and thereafter sampling was at 8cm intervals, except at the overlap of the two sampling tins where the interval was reduced to 4cm for greater accuracy.

6.3. Samples were processed according to the procedures outlined in Moore *et al* 1991 (Potassium Hydroxide/Hydrofluoric acid/Acetolysis). Processed samples were stained with safranin and suspended in silicone fluid (125,000 cst viscosity) prior to strew mounting on glass slides. The slides were sequentially traversed on an Olympus BH2 series transmitted light microscope and pollen and spores were logged. Slide logging was carried out at x400 magnification with critical identifications determined at x1,000 under oil immersion.

6.4. Counts of 250-300 land pollen grains (TLP) were achieved where possible but in ~~six~~ samples, in the centre of the section, only significantly lower pollen counts were attainable. Explanations for this have been proffered in the text. Identifications and nomenclature follow Moore *et al* (1991) and Bennett (1994). Identification was aided by reference material held at the Department of Archaeology, University of Edinburgh and by consultation of Bennett (1994). Preservation of the grains was recorded. Microscopic charcoal fragments greater than 20μm in dimension have been counted as have fungal spores. Concentration of pollen grains at the various sampling points has been calculated.

6.5. A relative pollen diagram through the section is presented in Fig 2. Pollen concentrations are presented in Table 1. Pollen preservation is illustrated in Fig 4.

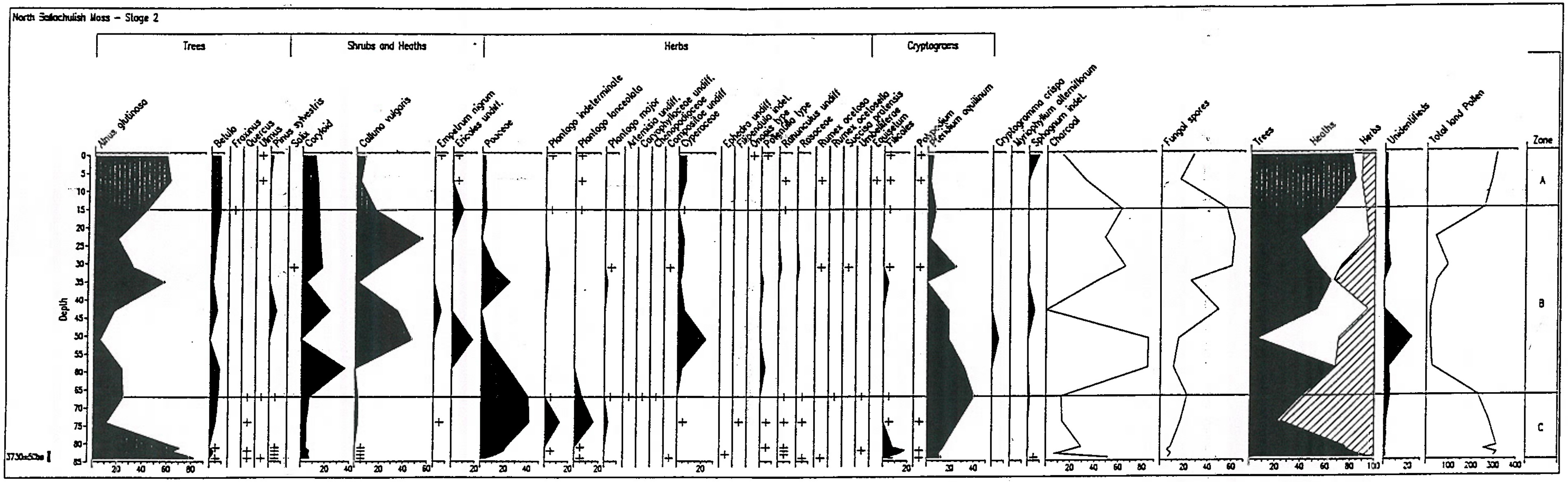

Fig 3 Relative proportions of pollen and spore taxa through the section

Table 1 Land pollen concentrations through the section

Depth cm	Grains/cm^3	ZONE
0	**24606** - *Top of section*	A
7	**20658**	
15	**17194**	
23	**7962**	B
31	**7606**	
35	**7329**	
43	**8252**	
51	**9270**	
59	**6270**	
67	**47450**	C
74	**58716**	
81	**69310**	
82	**61020**	
83	**77218**	
84	**225002** - base of section overlying feature	

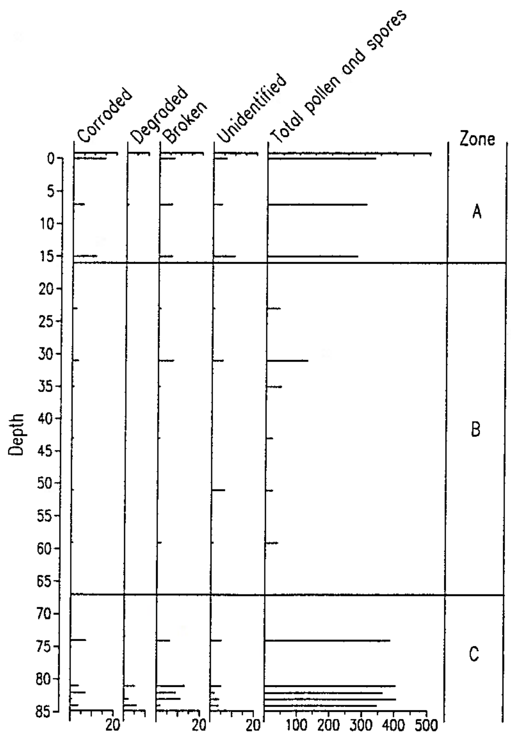

Fig 4. Pollen Preservation Classes

(Corroded, degraded and broken grains calculated as a percentage of Total Pollen and Spores (TPS), Unidentifiables as a percentage of ΣTPS + Unidentifiables)

6.6. The diagram has been subdivided into three zones, A, B and C, based principally on pollen concentration. The composition of the zones is discussed below.

6.7. **Zone C** which extends from 85-67cm, and directly overlies the platform feature, is characterised by the highest pollen concentrations of the section. Pollen counts of at least 250-300 land pollen grains were easily attainable. The basal sample has pollen concentrations of 225,002 pollen grains per cm^3 of sediment while there is a steady decline in the pollen concentration upsection. The top sample in this zone has a pollen concentration of 47,450grains per cm^3.

6.8. The zone is characterised by high alder values peaking at above 80% and falling to ca 20% upsection. Birch rises to ca 10% at the top of this zone. *Plantago* species, including *P. lanceolata* and *P. major* rise to values up to 20%. This gives a combined value of ca 40% for *Plantago* species. Poaceae is present at values up to 40%. Heather (*Calluna vulgaris*) is present at low frequencies. Filicales (undifferentiated ferns) and bracken (*Pteridium aquilinum*) ~~are~~ present. Corroded, degraded and broken grains are present but not in significant numbers to suggest reworked material. Unidentified grains are low. Charcoal and fungal spores are present.

6.9. At the beginning of **Zone B**, which extends from 67 to 23 cm, pollen concentrations plummet to 6270 grains/cm^3 with the highest concentration being 9270 grains/ $cm^{3.}$ Pollen counts are consequently low and not within levels of statistical significance. Data in this zone should be considered qualitatively only. The species represented reflect those from zone C with the notable exceptions of the virtual disappearance of *Plantago* spp and the proliferation of Cyperaceae (sedges). Preservation does not seem to be responsible for the low pollen concentrations, as well-preserved grains are in excess of 90%, and unidentifiables are low. Levels of fungal spores and microscopic charcoal fragments are high in this zone, with charcoal reaching ca 80% of Σcharcoal + TLP and fungal spores reaching up to ca 60% of Σfungal spores + TLP.

6.10. In **Zone A** which extends from 17cm to the top of the sampled section pollen concentrations rise again, initially to 17,194 grains/cm^3 and reaching 24,606 grains/cm^3 by the top of the section. Pollen counts of 250-300 land pollen grains were reached, which are statistically significant. Data here can be considered quantitatively. The assemblage is dominated by alder with birch and Hazel/Myrica as lesser components. Grass is present at low levels, ca 5%, and the plantains are rare. Charcoal values decline to below 20% by the top of the zone and fungal spores decline to ca 30%. Identified grains are generally well-preserved and unidentifieds are low so the assemblage has not been biased through preservation.

Correlation with the profile from stage 1.

6.11. To facilitate comparison between the two pollen profiles a relative pollen diagram from the stage 1 investigations is presented in Fig 5.

6.12. The similarities between Zone 2B from the stage 1 and Zone C from the stage 2 diagrams are striking in their component taxa and in the abundance of key taxa including alder, birch, coryloid, plantains and bracken. The base of zone C has been dated to 3730±50 bp. The base of zone 2B has not been dated but a date of 3180±60 bp has been obtained for a peat sample 10cm into the zone. Thus it is likely that the two zones relate to the same time interval. This suggests that in fact zone 2C has not been contaminated but represents *in situ* peat formation directly above the platform feature.

6.13. The disparity in pollen concentration between zone C and its overlying zone B (stage 2) is difficult to interpret. Preservation does not appear to be responsible as those grains present in zone B were, on the whole, well preserved, and the number of unidentifiable grains is low. However, given the low numbers of counts attained it could be argued that the numbers are not high enough to provide an accurate representation of pollen preservation. The large numbers of plantains, which indicate disturbance, detected from zone C (stage 2) and zone 2B (stage 1), coupled to the presence of substantial amounts of charcoal suggest a significant anthropogenic presence at this time. Stoneman (in Clarke 1997) suggested that on the basis of the macrofossil evidence substantial fires may have been frequent on the moss at these levels. Fire coupled to the clearly disturbed ground conditions may have implications for the preservation of the pollen

6.14. While it is possible to correlate zone C (stage 2) and zone 2B (stage 1) on the basis of the pollen and the dating evidence, above this level the two diagrams do not correspond.

1) To begin with there is a far greater accumulation of peat above zone C (stage 2) (ca 67cm sampled plus an additional 20cm unsampled), than there is above zone 2B (stage 1) (ca 35cm total).

2) Neither pollen concentrations nor vegetation composition between the superseding sections correlate.

6.15. This suggests that peat cutting has most certainly taken place at the top of zone 2B (stage 1), while it is likely that the section investigated in stage 2 is intact. This explains why pollen concentration and vegetation composition differ between the two sections above the level of disturbance.

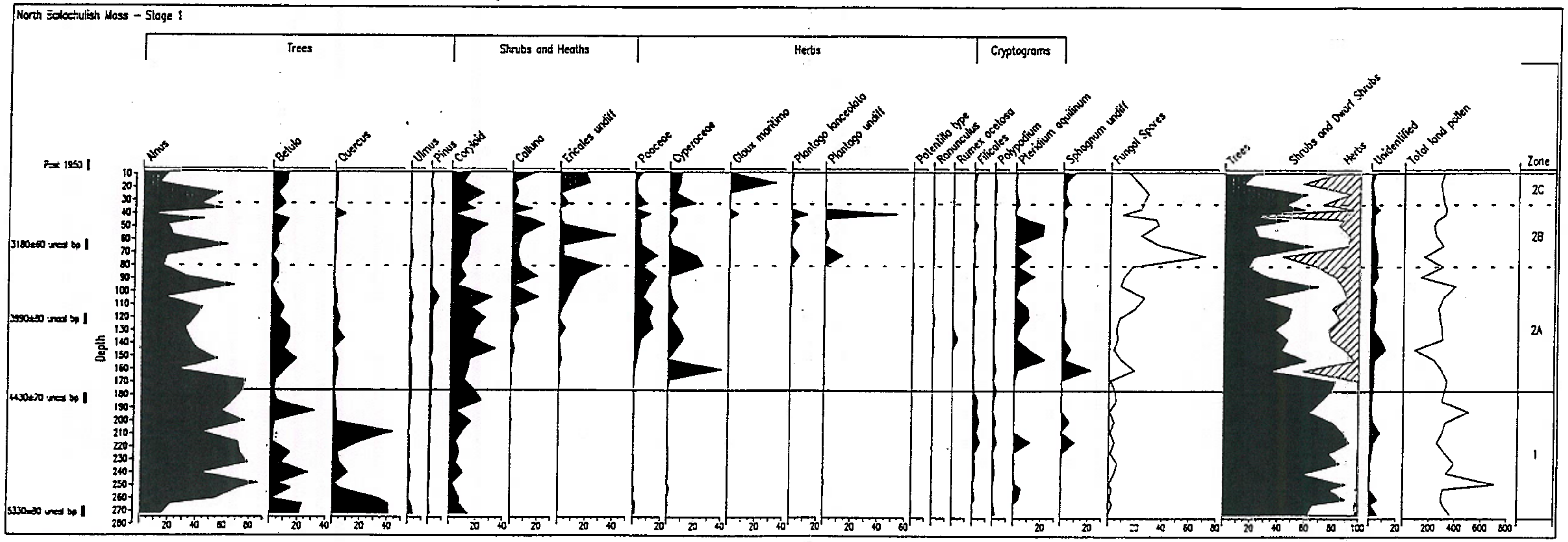

Fig 5 Relative pollen profile from stage 1 investigations

7. ARCHAEOLOGICAL IMPLICATIONS

7.1. In the light of the evidence above it seems that the peat directly overlying the platform feature has not been contaminated as was initially postulated. This suggests that the later dates obtained from the wood initially assumed to be associated with the feature may in fact relate to a separate phase of later anthropogenic activity on the moss.

7.2. The sequence of peat development is not simple. The radar survey notes that most of the potentially significant anomalies appear to lie above the stratified band within the peat. This may imply that the stratified band represents what has previously been identified as a platform feature while the anomalies reflect an overlying later wooden structure(s).

8. CONCLUSIONS

8.1. In summary, during these investigations ground penetrating radar has successfully defined the sub-peat basin morphology of the study area. A topographic survey of the moss was undertaken in order to illustrate the surface contours and features.

8.2. Microfossil analysis was undertaken on a section sampled during a previous phase of fieldwork and analysis of this section suggest that more than one phase of anthropogenic activity is represented in the deposits.

8.3. From these investigations it is clear that Ballachulish Moss remains an important repository of archaeological information. In their present state the remaining peat deposits are capable of preserving organic archaeological and palaeoecological materials. However, monitoring of the site should be considered in future management regimes. There have been significant developments on the fringes of the moss in the latter half of this century, in fact construction was underway on a plot of the moss to the south of the study area at the time of the 1998 field investigations. It is likely that much important information has been obliterated without record. While the remaining peat deposits appear unaffected, without monitoring their stability cannot be gauged. Continued preservation of these deposits depends on stable waterlogging. Criteria for monitoring the condition of peat need to be established.

8.4. The investigations have extended previous surveys carried out on the moss thereby completing the archaeological and palaeoenvironmental assessment of the southern portion of North Ballachulish Moss. A report combining the results of the two phases of investigation will be produced under separate cover.

9. REFERENCES

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10. ANNEX 1

Radar Survey

Utsi Electronics

GROUND RADAR SURVEY OF A SITE WITHIN NORTH BALLACHULISH

FOR

THE CENTRE OF FIELD ARCHAEOLOGY, UNIVERSITY OF EDINBURGH

9TH FEBRUARY 1998

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SURVEY OBJECTIVE

The area shown on the map (Page 6) has been a rich source of archaeological finds. In March 1996 Utsi Electronics was commissioned by the Centre for Field Archaeology to carry out a Ground Probing Radar survey of part of this site in order to

i) delineate the peat basin; and

ii) detect possible archaeological features within the peat.

By agreement with the landowner, the survey was restricted to that part of the site south of fixed points 1 and 2. (See Map, page 6). The results of this survey are contained in Utsi Electronics' report of 26th March 1996 which also forms part of the Centre for Field Archaeology's report No 293 dated 25th October 1996.

The objective of this second Ground Probing Radar survey was to delineate the peat basin and detect possible archaeological features within the peat in the area omitted from the previous survey and to correlate the information derived from the two radar surveys.

SURVEY STRATEGY

Use of Ground Probing Radar

Ground probing radar operates on the same principles as conventional radar except that it uses a wider frequency range; a shorter pulse; and a much shorter range of detection. The radar generates a short pulse which is transmitted into the ground via an antenna. The return signal is received by another antenna. The amplitude and time delay of the returning signal provides information about changing ground characteristics with depth. The use of the radar does not affect the underlying archaeology or geology: it is non-destructive.

Ground probing radar is therefore a valuable tool in detecting changes in stratigraphy and anomalies within strata. It cannot, however, define the nature of those anomalies nor the geological composition of the strata without additional background information. The radar plots from this survey provide stratigraphic information and a certain number of anomalies within those strata. To determine the nature of the stratigraphic variations and/or the anomalies will require further investigation e.g. by excavation. Obtaining cores from selected points in the site would also amplify the information contained in this report.

Equipment

The survey was carried out using Utsi Electronics' **GROUNDVUE 2B** which has a working range of approximately 10 metres in wet peat. The system is designed to "float" across the ground surface with as little interference as possible in order to obtain clear radar plots. **GROUNDVUE 2B** can be towed by a vehicle but was, in this instance, towed manually. The use of a vehicle would not have been appropriate because of the risk of damage to the surface of the moss and because the site was heavily waterlogged and would not have supported the weight of the vehicle.

The equipment used in the previous survey was **GROUNDVUE 2**. **GROUNDVUE 2B** is identical to **GROUNDVUE 2** except for the shape of the transmitting and receiving antennae which are of "bow-tie" type in **2B** and horn type in **2**. The use of bow-tie antennae allows more of the signal to pass into the ground and therefore provides greater clarity and detail in the radar plots.

GROUNDVUE 2B is optimised for deeper range survey and there is, therefore, a small risk that anomalies within the first 0.5 metres depth might not be detected. In the 1996 survey it was decided to supplement the main survey with a small additional survey using a shorter range, higher resolution radar, **GROUNDVUE 1**. The results of this supplementary survey showed that some of the fine detail of the anomalies within the peat was not being detected by **GROUNDVUE 2** but that the delineation of the peat basin was satisfactory. However the radar plots obtained from **GROUNDVUE 1** were not as clear as those from **GROUNDVUE 2**. This was primarily because the rough surface of the area under investigation was not suited to the smaller antennae of **GROUNDVUE 1** and the excessive movement of transmitter and receiver relative to one another set up strong interference patterns in the radar output. It was therefore decided only to use **GROUNDVUE 2B** in this survey.

It should be noted that an error in depth measurement may arise in areas of very shallow peat. The physical size of **GROUNDVUE 2/2B** (which is necessary to allow the radar to operate at depth) and, in particular, the distance between the receiver and the transmitter reduce its resolution capabilities in the first 50 cm of deposit. When this is combined with surface effects (primarily the changing values of dielectric constant in the first half metre of deposit: see radar plots, page 4) an error in depth measurement may result. This error should not be more than 20cm and applies only to areas of very shallow peat i.e. 50cm and less.

Site Coverage

A base line running approximately west-east was established across the area to be surveyed. Radar readings were taken along a series of parallel runs, in a line approximately south-north, at ten metre intervals along the base line. This gave 18 radar plots. The base line was then itself surveyed by radar.

It was intended to follow this initial survey with a more detailed examination of areas found to contain either deep peat or anomalies which might be reflections of underlying archaeology. However, although a number of anomalies were identified, no additional areas of deep peat nor areas meriting more detailed investigation were identified during the survey.

Survey Parameters

GROUNDVUE 2B surveys were carried out using an impulse of 5 nanoseconds, a scan time of 320 nanoseconds and a sampling interval of 20 cm. A scan time of 320 ns is equivalent to a depth of 5.5 metres in water. Although a sampling interval of 40cm had been used in the previous survey, it was felt that closer examination ought to give better definition while not impeding significantly the speed of operation. This was particularly important since **GROUNDVUE 1** was not being used.

The survey was carried out over two days: 21st and 22nd January 1998.

Radar Plots

ALL RUNS ARE DEPICTED AS RUNNING SOUTH TO NORTH FROM LEFT TO RIGHT ACROSS THE PAGE EXCEPT FOR RUN 29 WHICH IS SHOWN WEST TO EAST FROM LEFT TO RIGHT AND THE CALIBRATION RUN, RUN 21, IN WHICH DIRECTION IS IRRELEVANT.

An accurate measurement of depth depends on knowing the travel time of the radio wave emitted from the transmitter in the ground under examination. This can vary both with ground composition and also degree of waterlogging. All radar plots have been processed using the information derived from the calibration run. Depth information for levels below the peat may not be entirely accurate as the data has been calibrated only for peat levels.

The radar plots produced in the March 1996 report were printed using a length compression factor of 2. As the sampling interval for this survey has been halved from 40cm to 20cm, all radar plots have been printed with a length compression factor of 4 so that they are consistent with the previous report.

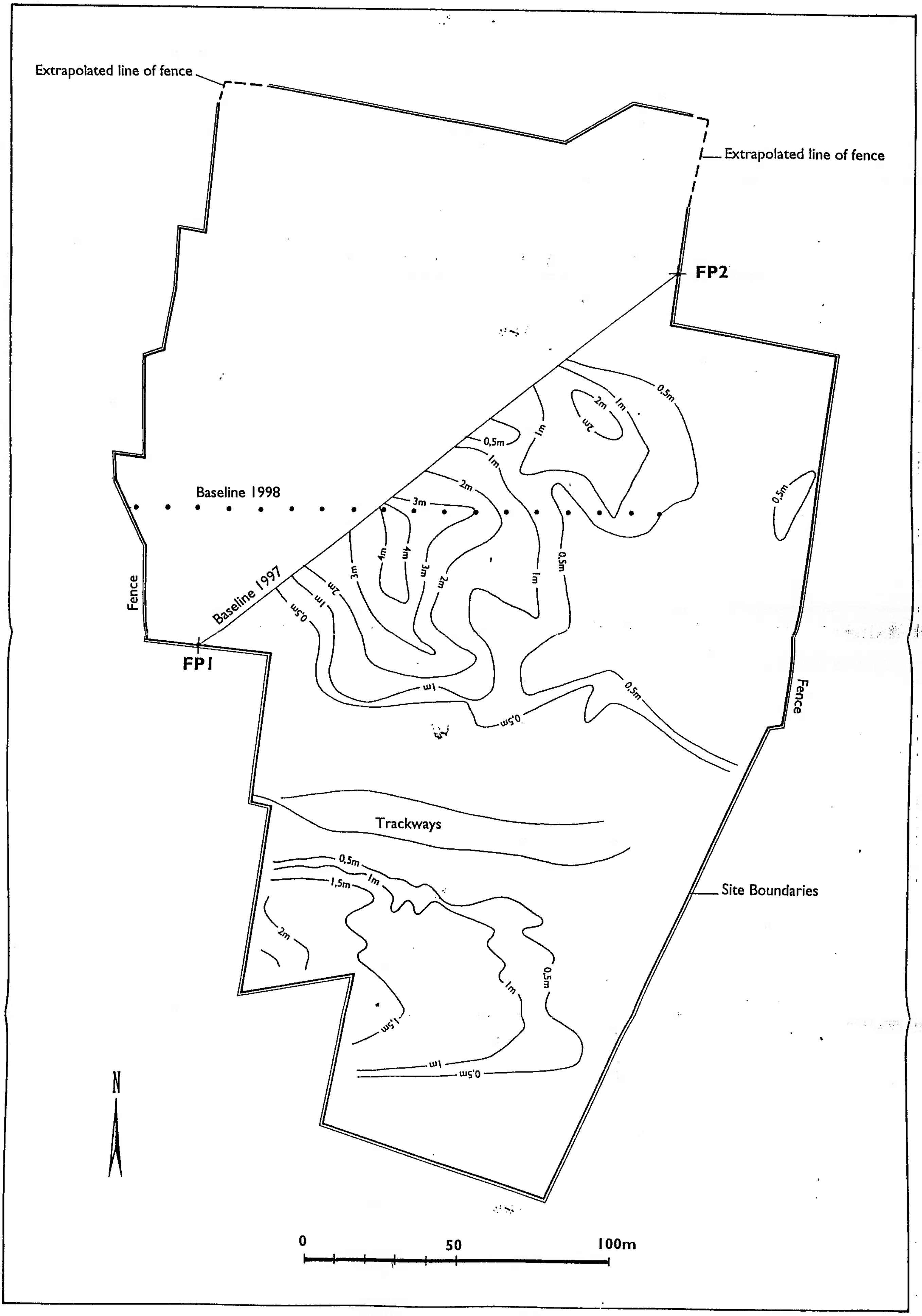
Relative Position of Radar runs

Run 29 defines the base line. (See Map page 6). Other radar runs were carried out at right angles to this line, at 10 metre intervals. Their position may be defined relative to the base line as follows:

Marker (on Run 29)	Run No
18	1
17	2
16	22 & 3
15	23 (4)
14	24 (5)
13	25 (6)
12	26 (7)
11	27 (8/9)
10	28 (10)
9	11
8	12
7	13
6	14
5	15

4	16
3	17
2	18
1 *	19

* marker not registered on survey plot
() runs which correspond partially only: see survey results, page 12.



Extrapolated line of fence
Extrapolated line of fence
FP2
FP1
Baseline 1998
Baseline 1997
Fence
Fence
Trackways
Site Boundaries
0,5m
1m
2m
3m
4m
1,5m
N
0
50
100m

SURVEY RESULTS

Presentation of radar plots

All radar plots exclude the air signal from transmitter to receiver. The horizontal dark/light bands represent the signal from the peat floor; present day land surface being represented by the line across the top of the plot. Depth is shown in 0.5 metre divisions and distance along the surface in metres. The patterning below the peat floor reflects the underlying geology. All depth measurements are relative to the surface so that an apparent rise or fall in a deposit beneath the surface may actually reflect the undulation of the ground at surface level.

The position of the runs is defined relative to the site base line (see Page 4).

Markers, except where otherwise indicated, represent:

1 : Crossing base line

2 : Start of deviation to avoid bramble thicket or other obstacle

3 : End of deviation to avoid bramble thicket or other obstacle

Runs 1, 2, 22 & 23: Commentary

The peat is relatively shallow, not more than 0.5 to 1 metres deep although there is some depth development on run 23 between 90 and 115 metres and beyond 10 metres. The first of these corresponds to the edge of the former lake bed initially identified in the March 1996 survey (cf commentary for Runs 24 & 25).

There are two changes in stratigraphic layers identifiable below the peat deposit. The first of these lies at an approximate depth of 3 metres and the second at 4.5 metres. These are visible in all four plots but particularly clear in runs 22 and 23. In run 23 the upper of these two strata appears to dip towards the lower between 95 and 123 metres distance. Since the line on the plot is not continuous, an alternative explanation could be that this represents a large anomaly lying on the upper surface of the lowest layer at 115 to 122 metres and a depth of 4.3 metres.

There is one anomaly within the peat layer on plot 2, close to the bottom of the peat. This shows as a sharp hyperbola at a distance of 18 metres. Run 22 has a similar anomaly at 38 metres. On run 23 there are a series of sharp hyperbolae near to the bottom of the peat: at marker 1, 70 metres, 62 metres, 42 metres, 33 metres, 23 metres, 15 metres and possibly at 51 metres although this latter is very faint. The narrowness of the hyperbolae indicates closeness to ground surface. It is noticeable that these anomalies co-incide with a "furrowed" pattern in the peat. (See also commentary on runs 24 & 25).

Note that marker 1 on run 2 is approximately 0.5m further south than the grid line.

Runs 24 & 25: Commentary

The peat layer continues to be within 1 metre depth with two exceptions. The northern end of both plots dips just below this level and appears to form the edge of a former lake bed or watercourse. At between 12 and 66 metres on plot 24 and 100 and 150+ metres on plot 25, there is development of the edge of the former lake bed previously identified in the March 1996 report.

Both plots show a regular "furrowed" pattern apparently in the peat floor. This is probably due to the pattern of the present day land surface (since all measurement is relative to that surface) and reflects a series of ridges due to previous use of the moss.

The two stratigraphic interfaces below the peat layer show clearly in both plots with some attenuation of signal in the area directly below the former lake bed. Attenuated signal usually indicates the presence of a heavily mineralised soil under water or could be due to the salt water table.

Anomalies showing as sharp hyperbolae are at 9 metres, 90 metres, 118 metres and 128 metres on run 24 and at 31 metres, 42 metres, 51 metres, and 90 metres on run 25. These anomalies appear to be related to the pattern of ridges referred to above.

Runs 26, 27 & 28: Commentary

The newly surveyed area, most of which lies to the north of marker 1, the base line, contains a very shallow peat layer of between 0.5 and 1 metres depth.

In the southern section of each plot the outline of the former lake bed develops. This steepens rapidly as the runs progress to the east. Within the former lake bed, there are a number of anomalies visible, some quite substantial.

Run	Depth	Distance	
26	1m	22m	Substantial
26	1.2m	27m	Substantial
26	1m	44m (Mkr 1)	Medium
26	0.5m	89m	Small
26	0.6m	106m	Small
26	0.7m	141m	Small
27	0.5m	121m (Mkr 1)	Substantial
27	0.4m	93m	Small
27	0.3m	82m	Small
27	0.6m	75m	Small
27	0.5m	37m	Small
27	0.5m	27m	Small
28	1.7m	20m	Small
28	1.8m	22m	Small
28	1.5m	29m	Small
28	0.5m	81m	Small
28	0.7m	135m	Small
28	0.6m	156m	Small

In addition, the beginning of the peat/sub-peat interface at the southern end of plot 28 may coincide with a signal from a substantial anomaly below the peat layer.

All the substantial anomalies and many of the others fall in the area of deep peat and the former lake bed. Minor anomalies occurring outside of this area coincide with shallow peat (generally within 0.5 metres) and the "furrowed" pattern referred to previously.

There is a faint line running through the peat layer in each of these runs but seen most clearly in run 28 from approximately 2.5 metres depth at the southern end, rising to meet the side of the former lake basin at 50 metres distance and 1.4 metres depth. There may be an additional anomaly at this point. This line represents a stratigraphic change: either layering within the peat or the presence of a thin layer of another deposit, one which does not reflect the signal well. Where layering occurs in peat, it usually shows as a change in content i.e. a number of scattered reflections from woody material in the deeper layers of peat. The presence of a faint line suggests a thin layer of mineralised deposit. All the anomalies in the deeper peat occur above this stratigraphic change.

There is considerable attenuation of the radar signal at the deepest level of peat in run 28. Attenuated signal usually indicates the presence of a heavily mineralised soil under water or could be due to the salt water table.

Sub peat stratigraphy shows clearly in all three plots, especially the lower interface at approximately 4.3 to 4.5 metres depth.

<u>Runs 11, 12 & 13: Commentary</u>

These plots show that most of the new area examined contains a shallow peat deposit. They also show the development of the lake bed profile at the southern end.

There are a number of anomalies within the former lake bed:

Run	Depth	Distance	
11	1.5m	12m	Substantial
11	1.2m	22m	Substantial
11	1.0m	24m	Substantial
11	0.8m	30m	Medium
11	1.2m	56m	Substantial
12	0.5m	128m	Small
12	0.5m	105m	Substantial
12	0.7m	75m	Substantial
12	0.8m	39m	Small
12	0.5m	29m	Small
12	0.5m	2m	Small
13	0.6m	3m	Small
13	0.5m	104m	Small
13	0.6m	122m	Small
13	0.5m	133m	Small

As in the previous plots, the deep layers of peat contain both substantial and other anomalies. All of these lie above the level of the stratigraphic change within the peat bed (see below). The ridged pattern continues in the shallow peat in all three runs. Plot 11 does not show any anomalies in this area but there are three in each of plot 12 and 13, within the first 0.8 metres of deposit.

Beneath the peat, there is evidence of two distinct strata, as previously, with the lower interface (approximate depth of 4.5m) being particularly clear.

There is attenuation of the radar signal along the base of the former lake bed especially in run 11 (see earlier comments for run 28). The evidence for a narrow band of deposit within the peat also shows clearly, particularly in run 11. (Cf discussion in run 28, page 9.)

Marker 1 has not registered in run 11 but its position has been deduced, for contour purposes, from start and end positions. On run 12, marker 4 represents the base line, markers 2 & 3 mark a deviation to avoid trees and shrubs and marker 1 indicates an extra point on the line of sight.

Runs 14, 15, 16 & 17: Commentary

These plots show the shallowing of the former lake bed at the southern end, and the shallow peat deposit to the north.

There are some anomalies in the peat layer:

Run	Depth	Distance	
14	1.0m	23m	Small
15	0.5m	30m	Small
16	0.6m	115m	Small
17	0.7m	33m	Small
17	0.5m	45m	Small

In addition, in runs 16 and 17 and, to some extent in run 15, there is an almost continuous signal from either a series of very large anomalies or a separate layer within the peat. On run 16 it meets the side of former lake bed at a depth of 1.1 metres and a distance of approximately 70 metres. On run 17, the equivalent point is at 0.7 metres depth and 55 metres distance. The anomalies in runs 16 and 17 lie above this level. (Cf comments under run 28).

The "furrowed" pattern referred to previously can be seen again in run 16 and, to an extent, in run 17 but does not appear to contain any anomalies. The sub peat stratigraphy shows clearly as before.

Marker 2 on plot 14 indicates an extra point in the line of sight and not a deviation.

Runs 18 & 19: Commentary

These plots show a shallow peat deposit. Run 18 contains no anomalies. There is one small anomaly in Run 19 at 112 metres distance and a depth of 0.5 metres. Sub peat stratigraphy is consistent with earlier runs. The "furrowed" effect does not occur in this area.

Run 29: Commentary

This plot follows the line of the 1998 base line, from west to east. Markers, at ten metre intervals, show where runs 1, 2, 22 to 28 inclusive and 11 to 19 inclusive cross this line. The exact relation of the runs is listed on page 4. The map on page 6 shows the exact position of this line.

The radar plot presents a profile of part of the former lake bed. There is some attenuation in the radar signal in the deepest peat. (Cf comments on run 28, page 9). There is also the faint trace of a thin deposit within the peat. (Cf comments on run 28, page 9). Just before marker 7, where this apparent deposit meets the side of the former lake basin at a depth of 2.7 metres, the signal shows a sharp dip. This suggests the existence of a channel or watercourse at this point.

Anomalies in the peat layer are visible at:

Depth	Distance	
0.7m	107m	Medium
1m	95m	Medium
1m	91m	Small
2m	88m	Small

All of these anomalies lie above the stratigraphic change within the peat layer.

The sub peat stratigraphy shows clearly, except where there is attenuation of the signal i.e. under the deepest peat layer. All the returned signals being attenuated suggests the presence of salt water.

Marker 1 failed to register on the plot but its position is easily deduced from the other markers, distances between markers being 10 metres.

Run 21: Calibration Run

A calibration run is carried out to establish the speed of the radio waves in the deposits under survey and, hence to calibrate actual as opposed to perceived depth. This calibration plot shows three main traces. From the top they are:

- the radar signal through the air directly from the transmitter to the receiver;
- a shallow layer return;
- a deeper layer return from the bottom of the peat.

The term dielectric constant may be understood as providing a measure of the speed of radio waves in a given medium. The dielectric constant for a radio signal from air is 1 (by definition). Curve fitting programs have been applied to the other two returns giving dielectric constants of 55 and 72 respectively. All radar plots have been calibrated to take into account the dielectric constants and antennae geometry.

Runs 3, 4, 5, 6, 7, 8, 9 & 10: Commentary

These radar plots were the initial survey of the area covered by runs 22 to 28 inclusive. It was noticed during survey that the lines being followed were not precisely at right angles to the base line (primarily a line of sight problem in an area of brambles, shrubs and trees). The area was therefore re-surveyed. Comparison of runs 3 and 22 show that the line of this run was accurately positioned.

These plots are included primarily for completeness. Although the information they contain cannot be used because of the uncertainty of their precise position, it should be noted that they show many of the same features referred to in the previous commentary:

- the shallow peat deposit covering most of the area under survey;
- the "furrowed" pattern associated with the west of the site;
- the existence of a number of small anomalies within the "furrowed" area;
- stratigraphic change within the area of deeper peat, represented by an attenuated signal, and
- anomalies within the deep peat lie above this particular layer.

Run 9 is the continuation of run 8, following a change of laptop computer battery.

CONTOUR MAPS

The calibrated peat depths from the radar plots were used to construct contour maps of the area covered by the survey. Three contour maps have been produced:

- 1998 contour map
- 1998 contour map with anomalies
- combined contour map bringing together the results of the 1996 and 1998 surveys.

The 1998 contour map (page 14) plots contours and survey lines. The northern edges of the former lake beds identified in the previous survey (March 1996) show clearly. The remainder of the area is covered by a relatively shallow peat deposit. The ridge or furrow effect referred to in the survey results has also been plotted on to this map. It covers the areas of shallow peat only, primarily to the north and west of the site. The survey area cannot be extended as the land around it has been built on so it is not possible, for example, to establish whether the area to the north-west represents a small inlet channel or not.

The contour map with anomalies (page 15) shows the concentration of major anomalies within the areas of deep peat. An incomplete pattern of smaller anomalies occurs in the shallow peat, mostly but not exclusively within the "furrowed" areas. From the radar plots, the signals from the smaller anomalies within the ridged area are quite distinctive and almost certainly related to each other. Those that fall outside are dissimilar and, hence, probably not related. No attempt has been made to link related signals on the contour map as it is not certain which point links to which other point, 10 metres away. The best indication offered by the map is to follow the edges of the deeper peat which has not been touched by this pattern of anomalies.

The straight lines on the contour map show the travel path of the radar. The sharp hyperbola signal (on the radar plots) indicates that the radar is crossing whatever is producing the returned signal and not following it. As explained previously, it is not reasonable to use the radar to interpret the nature of an anomaly, but it would not be unreasonable to expect that this particular pattern might represent some form of drainage. Whatever the activity it represents, it does not appear to be directly related to the pattern of anomalies within the deeper peat and the other anomalies within unfurrowed areas.

The results of this survey have been combined with the results of the earlier, 1996, survey (by overlaying the two contour maps) to give a combined contour map of the entire area and a proper delineation of the peat basin (page 16). Radar survey lines have been used to combine the two maps and then removed in order to avoid clutter.

Following the 1996 survey, the Centre for Field Archaeology carried out follow up field work, including excavation. In the course of their work, they found a discrepancy in the distance between fixed points 1 and 2 as defined by the first radar run in March 1996 and the distances defined by their fieldwork. This discrepancy, which is approximately 6 metres, occurs again in the combined contour map. Fixed point 1 and the contours defined in the March 1996 survey correspond with the results of the present survey. Fixed point 2, however, does not.

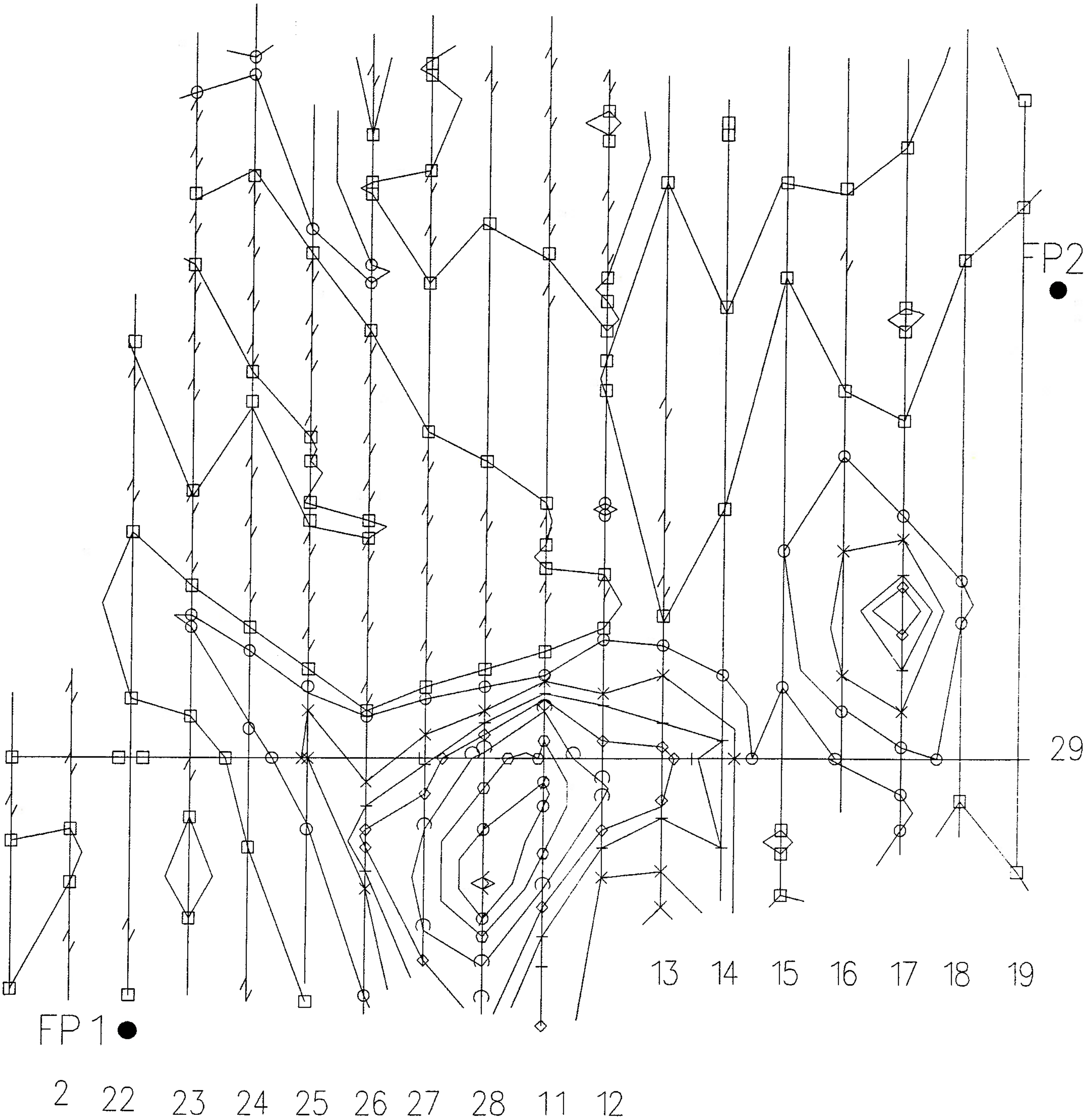
There are two reasons for this. Firstly, due to the physical size of the radar (total length c.2.5 metres), the radar plot begins approximately 1.75 metres from fixed point 1 and ends approximately 1.75 metres before fixed point 2, giving a total difference of approximately 2.5 metres. In addition, from field notes taken in March 1996, the radar had to deviate from the base line because of a large stand of trees and shrubs within the projected travel path. This deviation from projected line of travel is marked on the original survey plot. The distance recorded by the encoder wheel of the radar reflects the actual distance travelled which appears, in this instance, to be shorter.

1998 CONTOUR MAP

Scale: 1cm = 10m

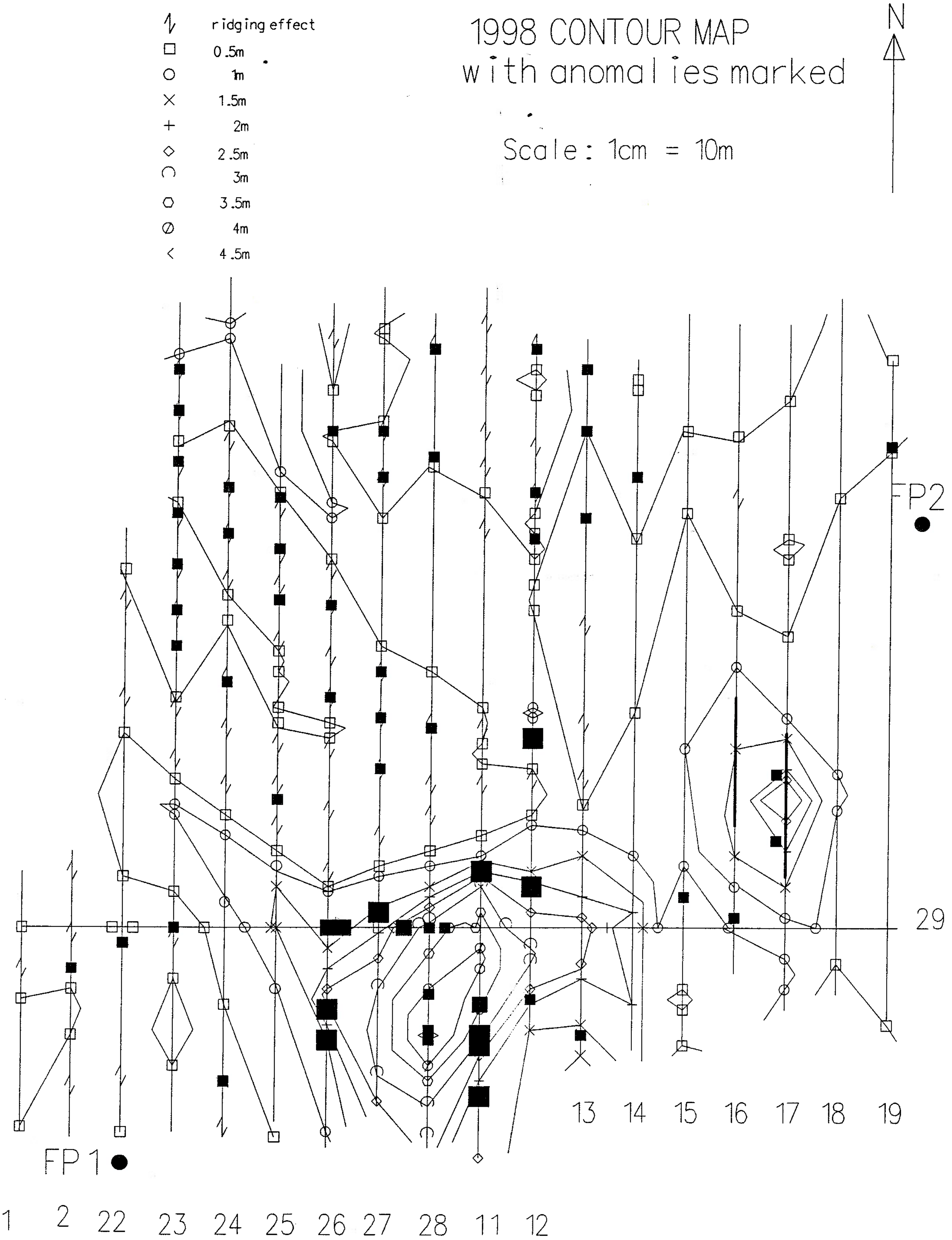
N

- ridging effect
- □ 0.5m
- ○ 1m
- × 1.5m
- + 2m
- ◇ 2.5m
- ∩ 3m
- ⬡ 3.5m
- ∅ 4m
- < 4.5m



1998 CONTOUR MAP
with anomalies marked

Scale: 1cm = 10m

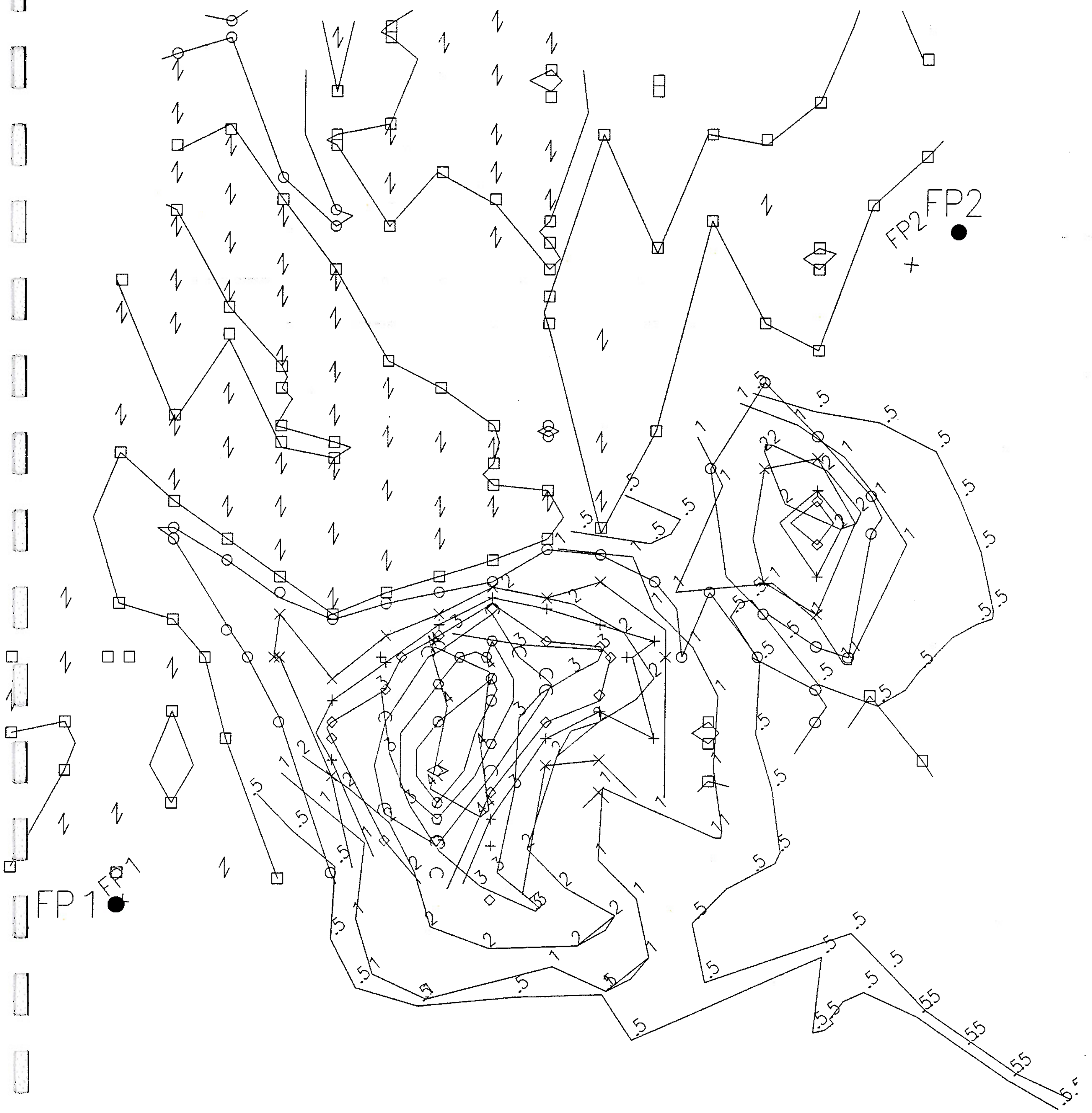


1998 CONTOUR MAP with 1996 contour map overlayed

Scale: 1cm = 10m

N

- ridging effect
- 0.5m
- 1m
- 1.5m
- 2m
- 2.5m
- 3m
- 3.5m
- 4m
- 4.5m



SUMMARY OF FINDINGS & RECOMMENDATIONS

The ground probing radar survey has extended the previous survey undertaken in March 1996 to the remainder of the site in North Ballachulish. The results confirm and correspond with those of the earlier survey, notably in compiling the contour survey of the peat basin.

Substantial anomalies and some more minor ones were found in the area of deepest peat, within the former lake bed. Trial trenching carried out by the Centre for Field Archaeology following the March 1996 survey, showed that a similar pattern of anomalies from this area corresponded to the remains of a wooden platform. (See CFA Report No 293, dated 25 October 1996). It is likely that this is further evidence of the same platform and related remains. It should be noted, however, that this interpretation rests upon the excavation evidence: the radar can only be used to determine the existence of the anomalies and not their precise nature.

The use of bow-tie antennae coupled with the decision to opt for a shorter sampling interval of 20cm has increased the power of the transmitted signal into the ground and doubled the data points in comparison with the March 1996 survey. The resulting radar plots show greater detail than in the previous survey both at depth and within the first metre of deposit.

The first result of this is the appearance of a faint signal within the areas of deeper peat, indicating a stratigraphic change within the peat deposit. It is thought unlikely that this represents a change in peat composition. A peat to peat interface would normally be represented by a more dense pattern of reflections rather than the appearance of a quasi-floor or boundary. The faintness of the signal indicates that the material is not a good reflector of radio waves and that the stratigraphic layer it represents may be thin. Heavily mineralised clays are not good reflectors of radio waves, especially when waterlogged.

A core sample was taken by Centre for Field Archaeology personnel between markers 9 and 10 along the base line (run 29). Coring was halted when a clay layer was reached although this was above the maximum peat level as shown by the radar. The exercise was not continued at the time because the layering within the peat was not apparent when the data was viewed on the laptop computer. This is due to the limitations of the laptop screen display. Processing of the data into hard copy has revealed the stratigraphic variation in the peat. It would be adviseable to repeat the coring exercise to a greater depth in order to establish the precise correspondence with this survey's results.

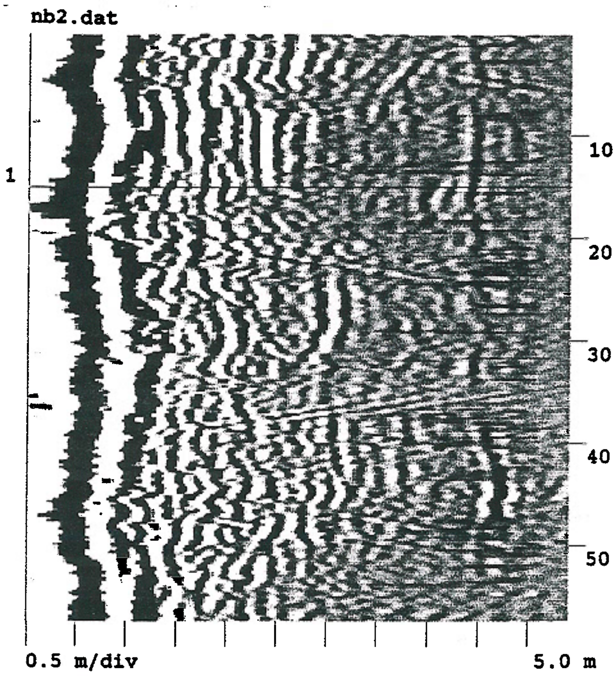
It is interesting to note that all the anomalies within the deeper peat lie on or above this stratigraphic change. The only possible exception to this (in run 28) is more likely to be part of a layer change than an anomaly.

Run 29 (page 11) also suggests that a water channel may have existed along the edge of the former lake bed. Ideally, this suggestion should be verified by referring to the 1996 report to give comparable (west/east) radar plots. This is not possible, however, since that survey did not detect the stratigraphic change. This is due to the lesser signal strength derived from using horn antennae and the larger sampling interval of 40cm (cf above comments above re increased signal power). In compiling this report, the data obtained previously have been re-examined. It is not possible to identify the stratigraphic change on the basis of the 1996 data. However, viewed in conjunction with the present data, the two sets of data are entirely consistent. Consideration should be given to a coring exercise at this point to provide comparative evidence.

This survey provides clearer plots of the sub-peat stratigraphy than the previous one. The radar cannot define the exact nature of these strata. Core samples would need to be taken at suitable points in order to amplify this information.

A pattern of small anomalies, close to the present day ground surface was detected. These anomalies are similar and uniform in nature and all occur within the top 80cm of deposit. Associated with them is a ridged pattern in the peat floor. As all measurements are relative to present day surface, it is likely that this ridging actually reflects the present day surface. There is a possibility that both ridging and the pattern of small anomalies represent a form of drainage system. This interpretation of the radar results would have to be verified by other means, e.g. excavation.

The radar plots in this report have been presented at a length compression of 4 in order to provide consistent information with the previous survey. If measurements are to be taken directly from the plots, it may be necessary to obtain uncompressed data.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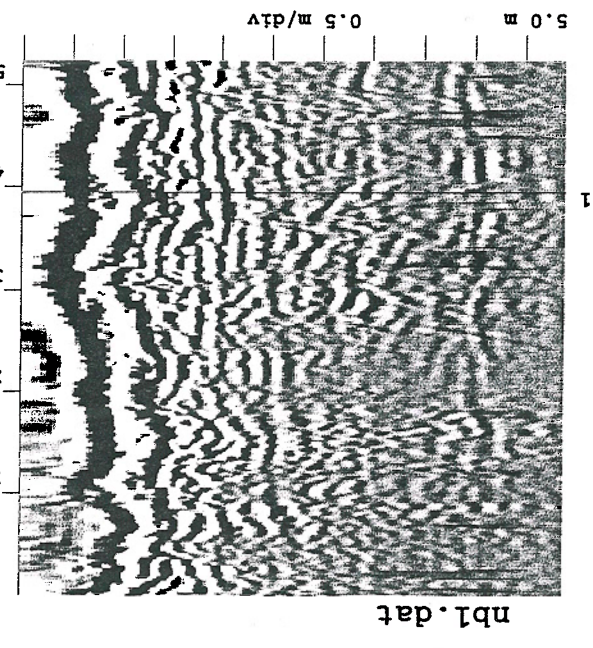
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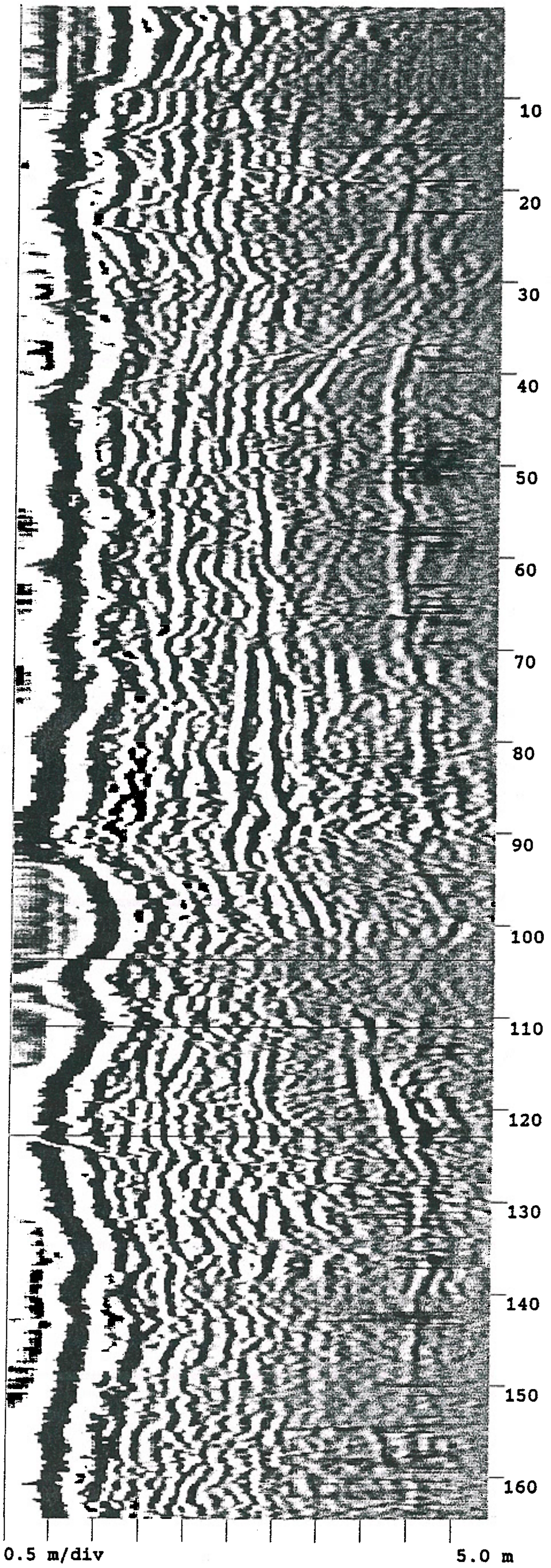

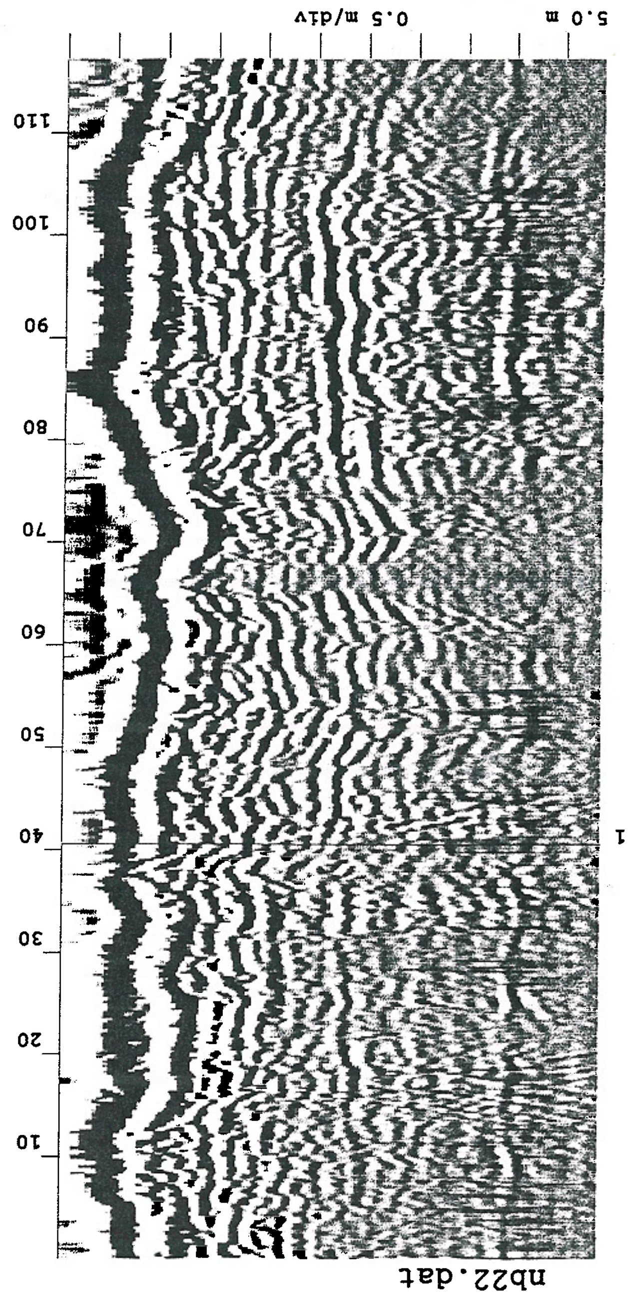

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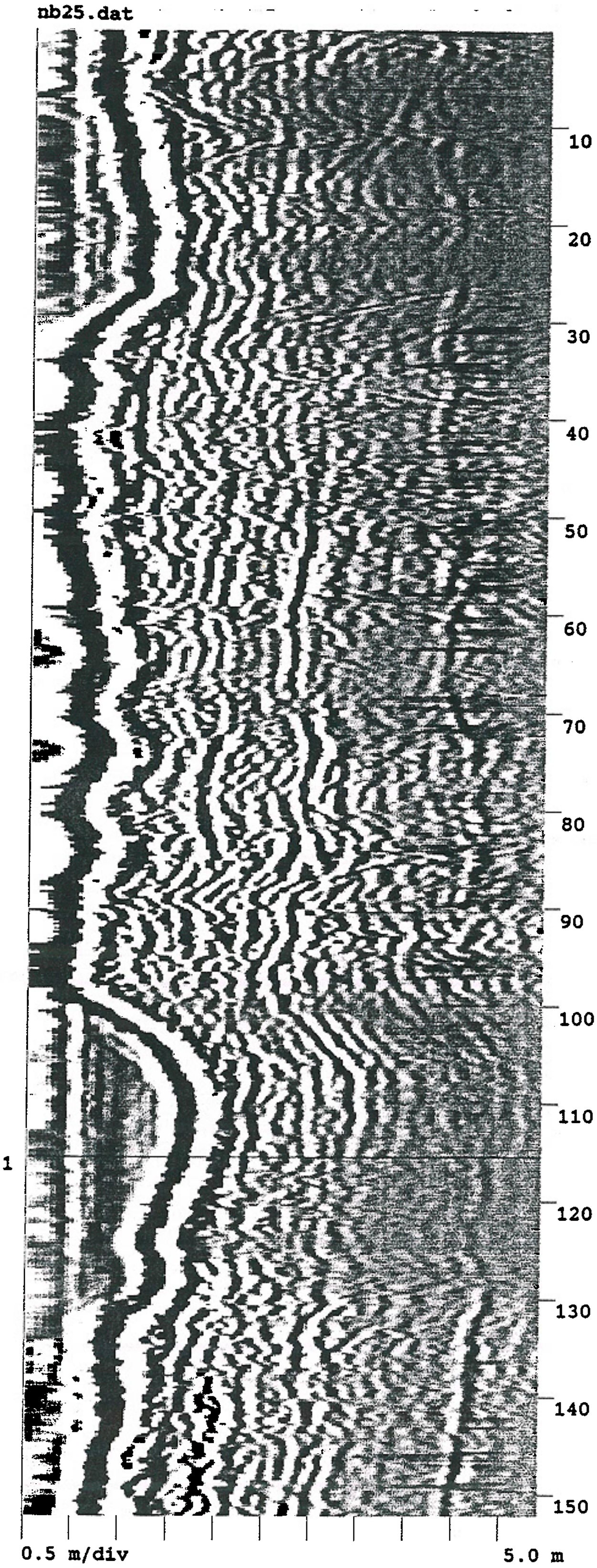
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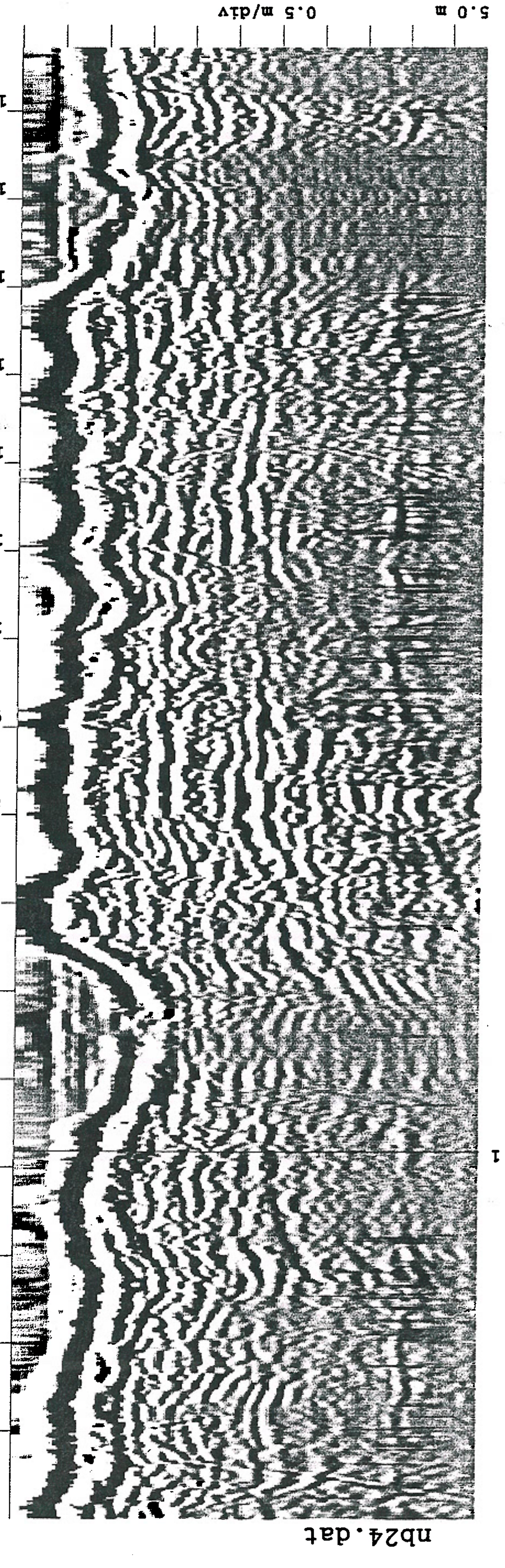
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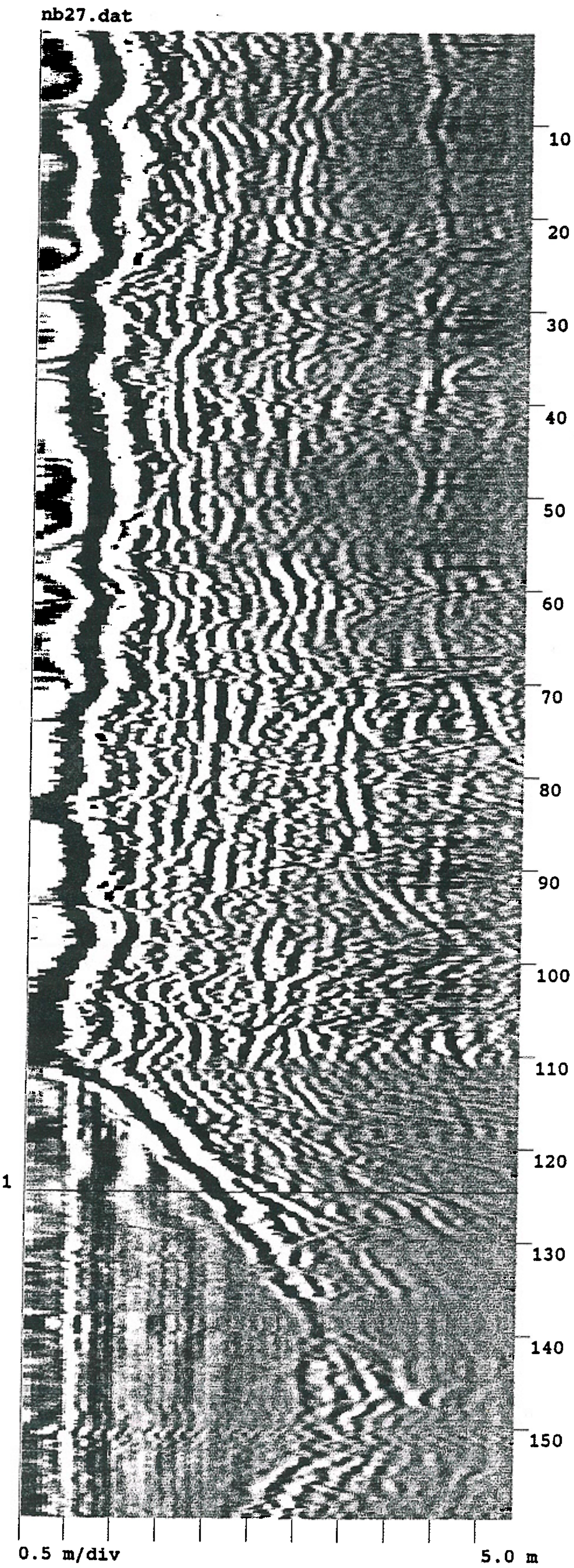
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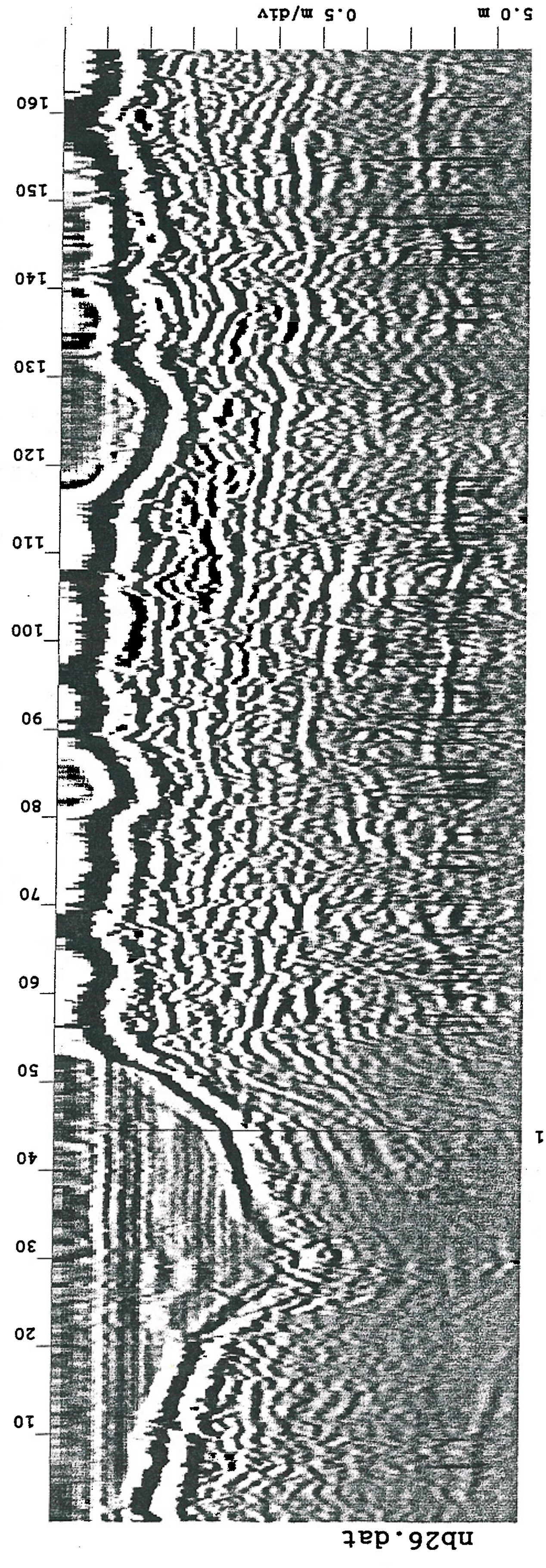
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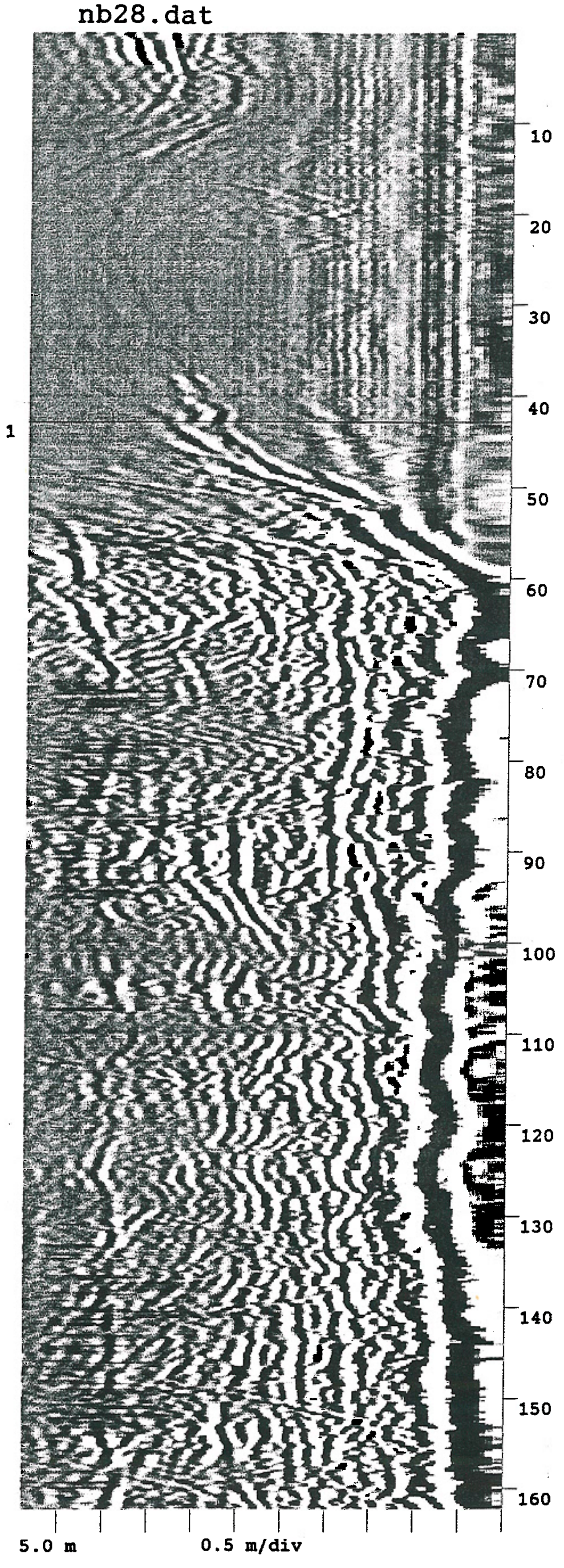

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140
150
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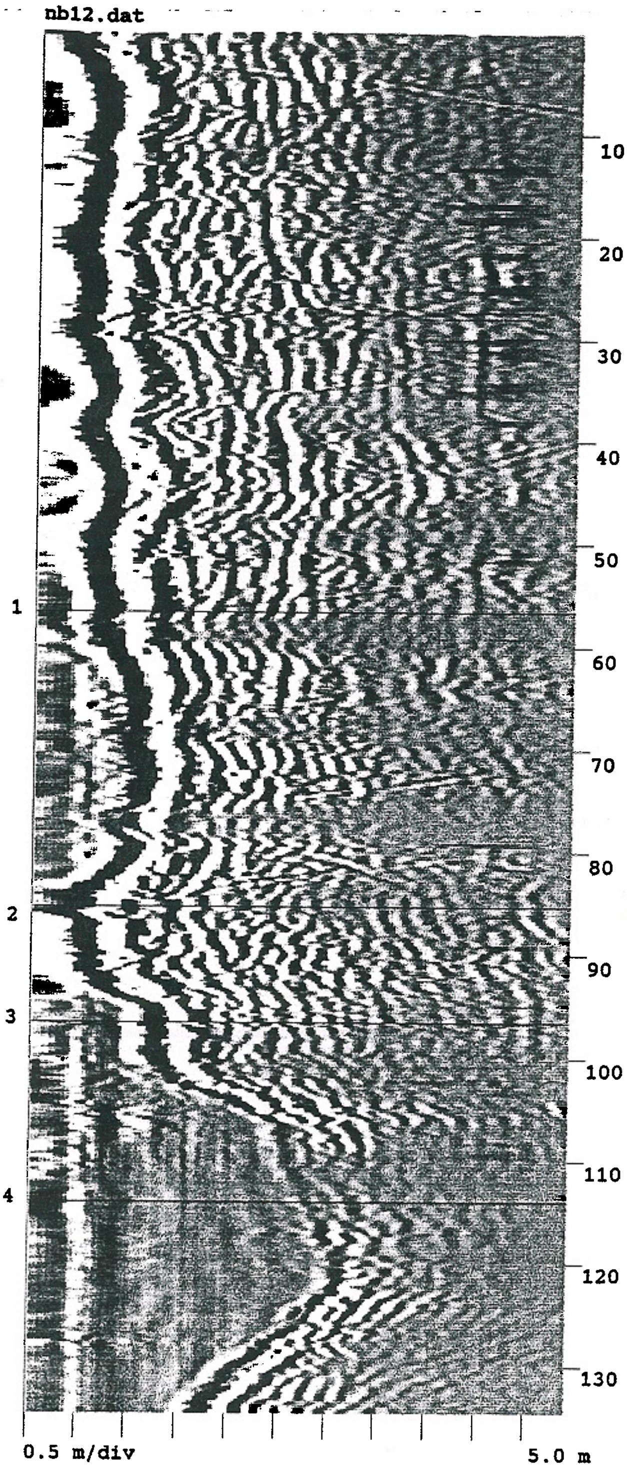
0.5 m/div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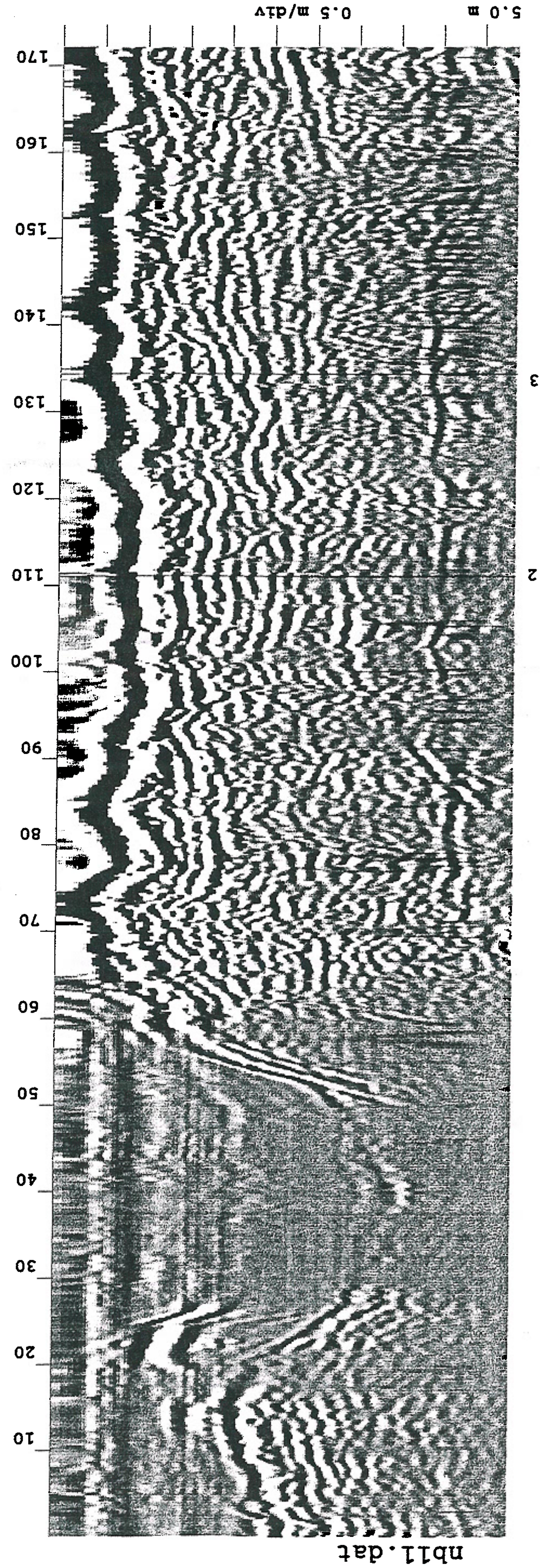
5.0 m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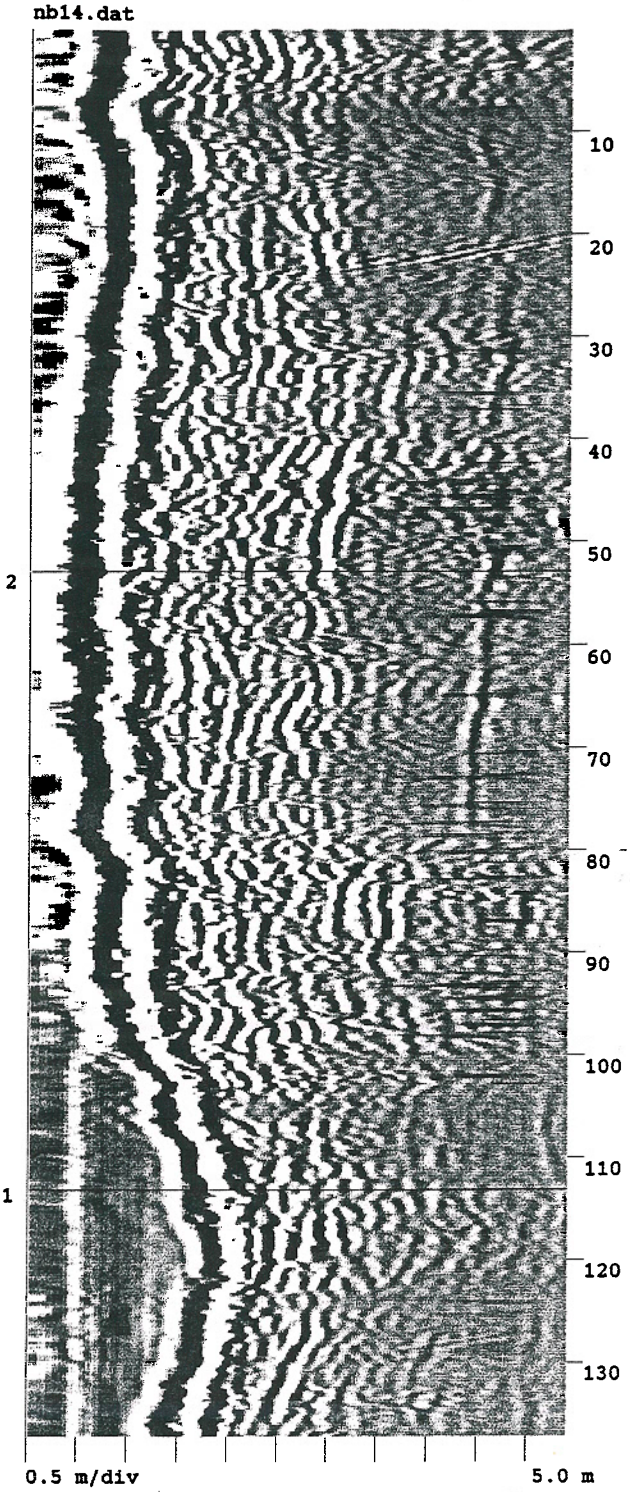
5.0 m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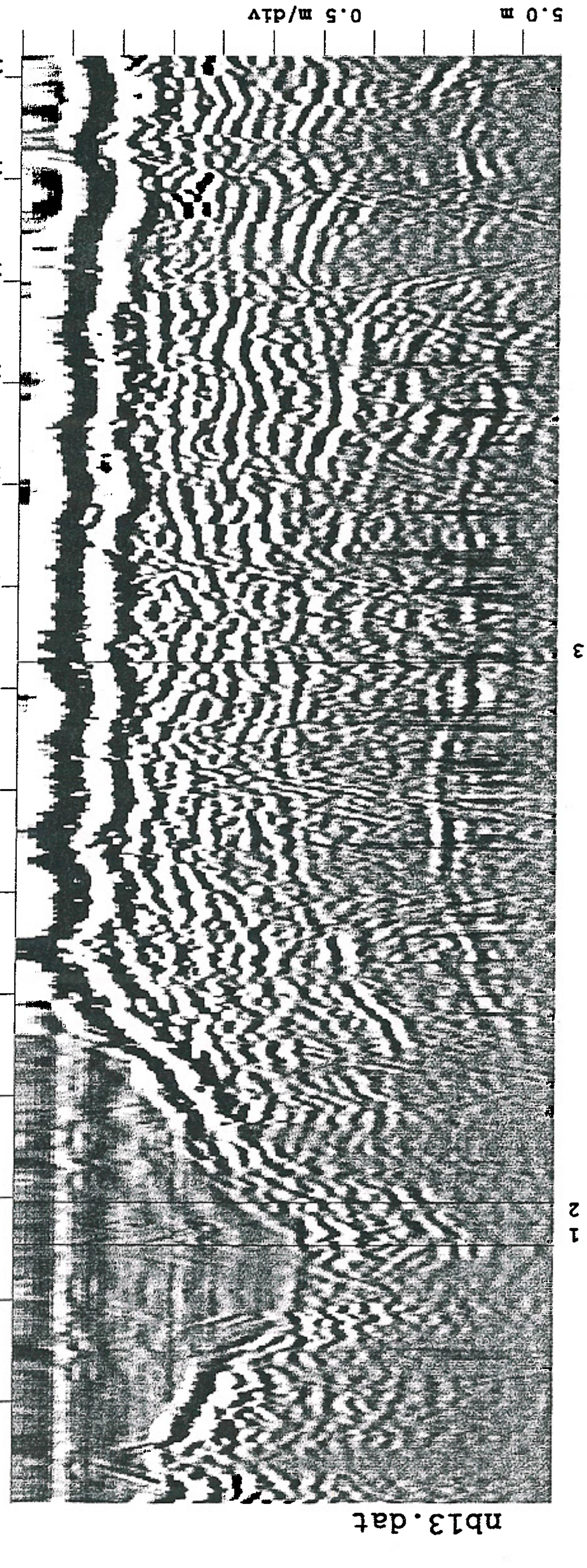
0.5 m/div
5.0 m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60
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80
90
100
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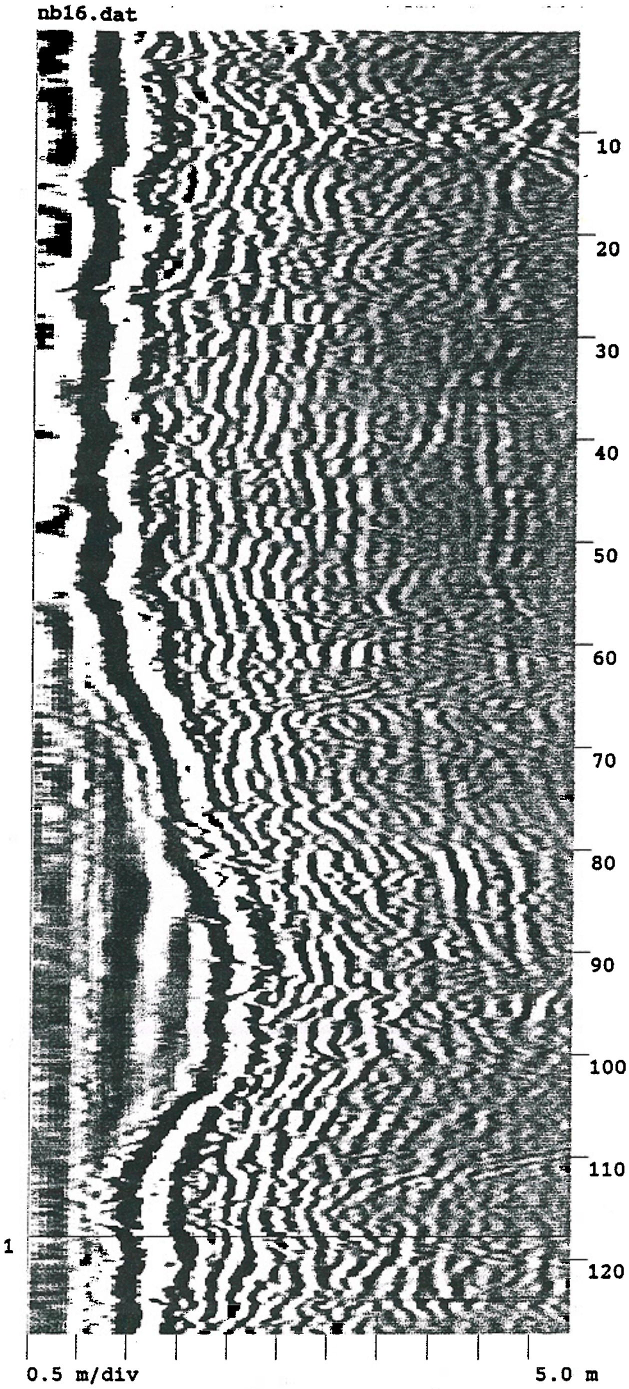
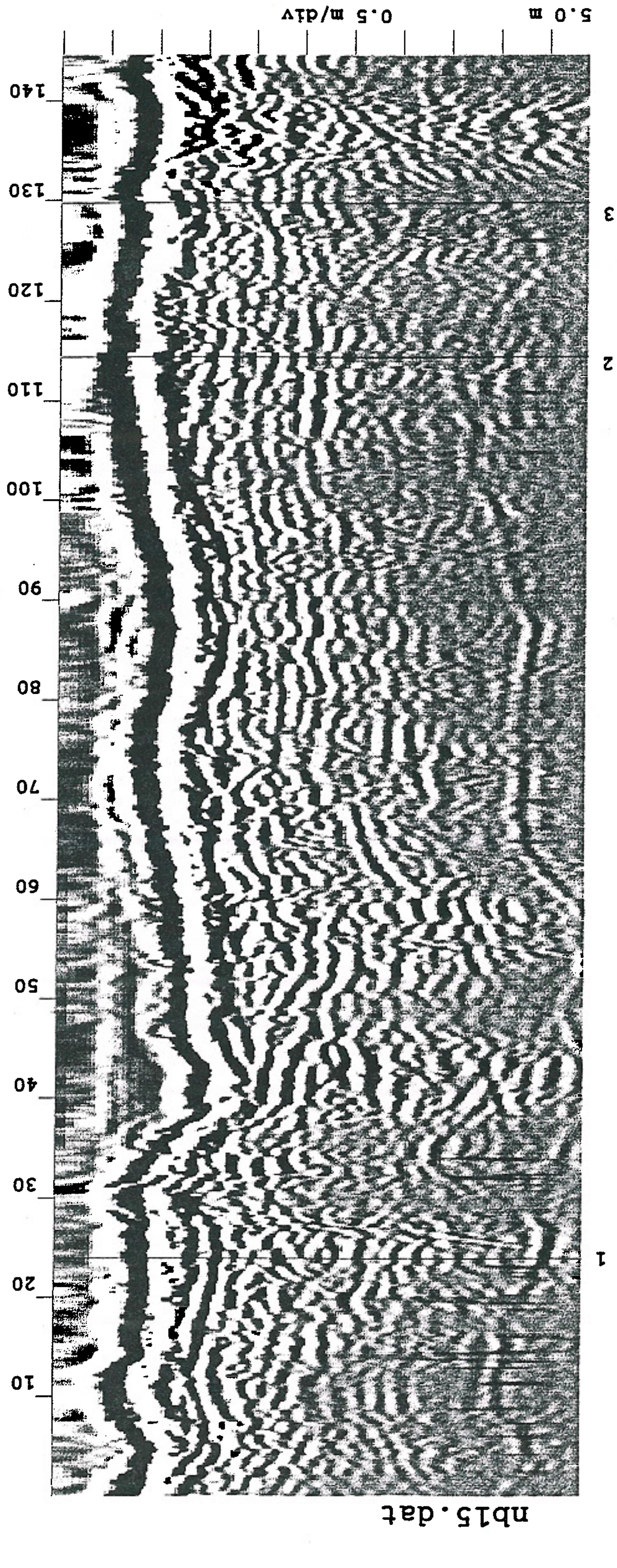
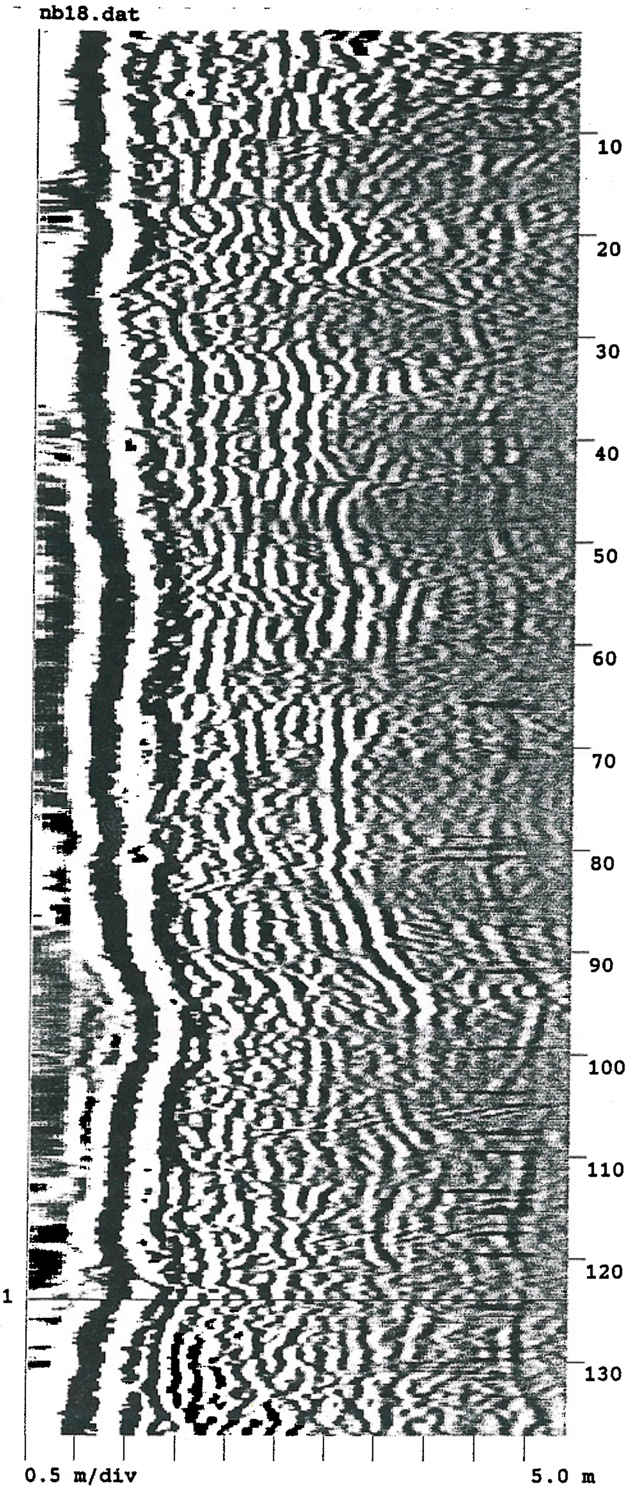
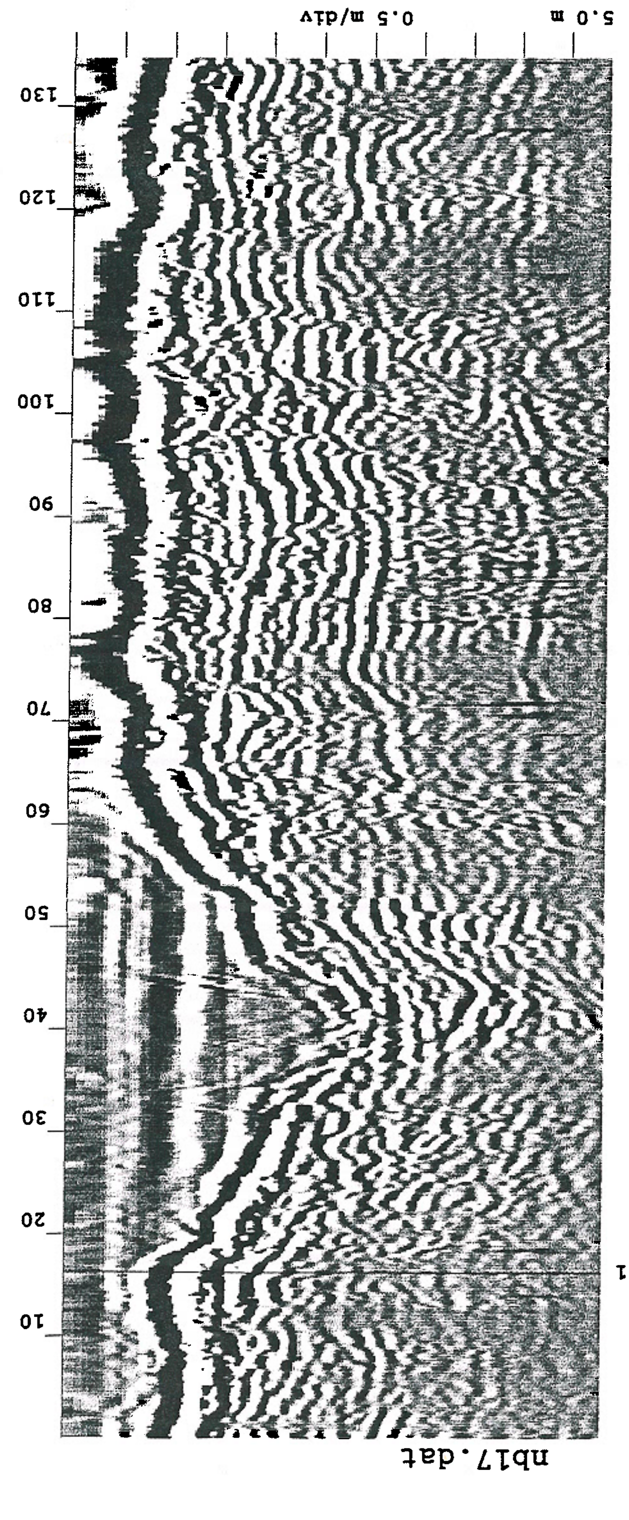
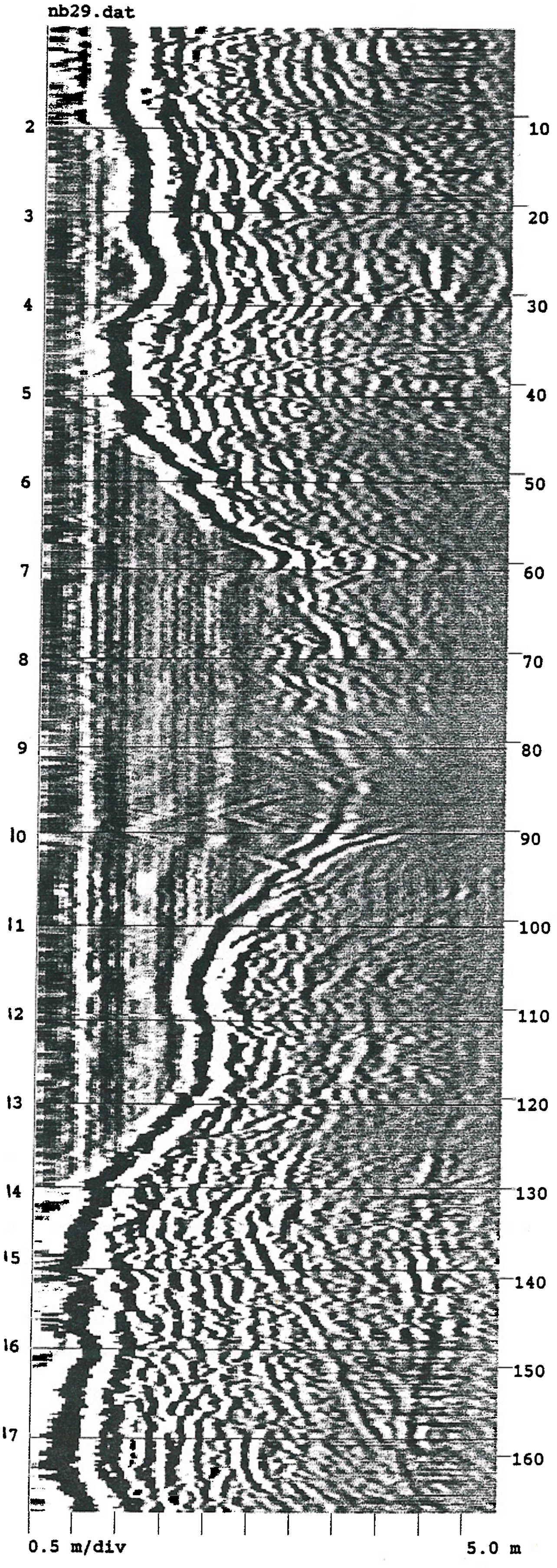
120
130
140
3
2
1

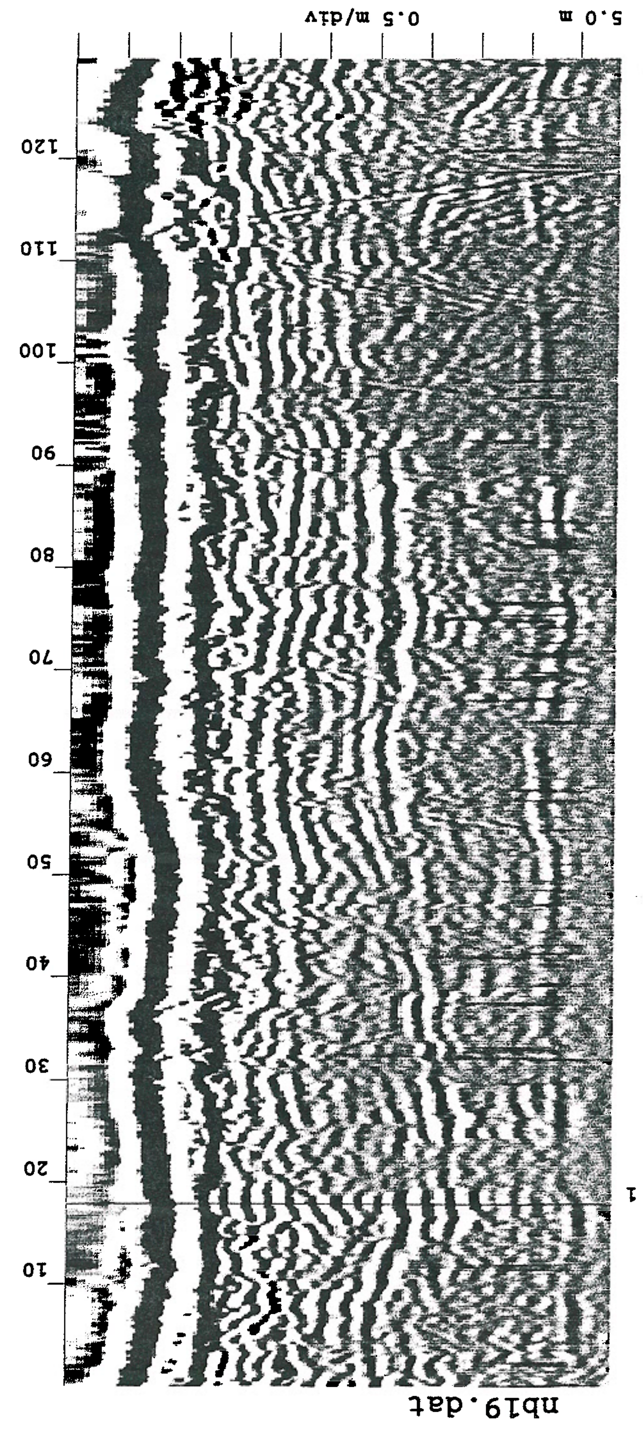

nb16.dat
10
20
30
40
50
60
70
80
90
100
110
120
1
0.5 m/div
5.0 m

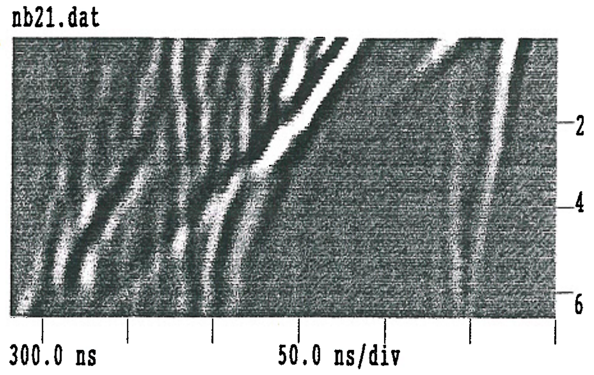

nb15.dat
5.0 m
0.5 m/div
10
20
30
40
50
60
70
80
90
100
110
120
130
140
1
2
3

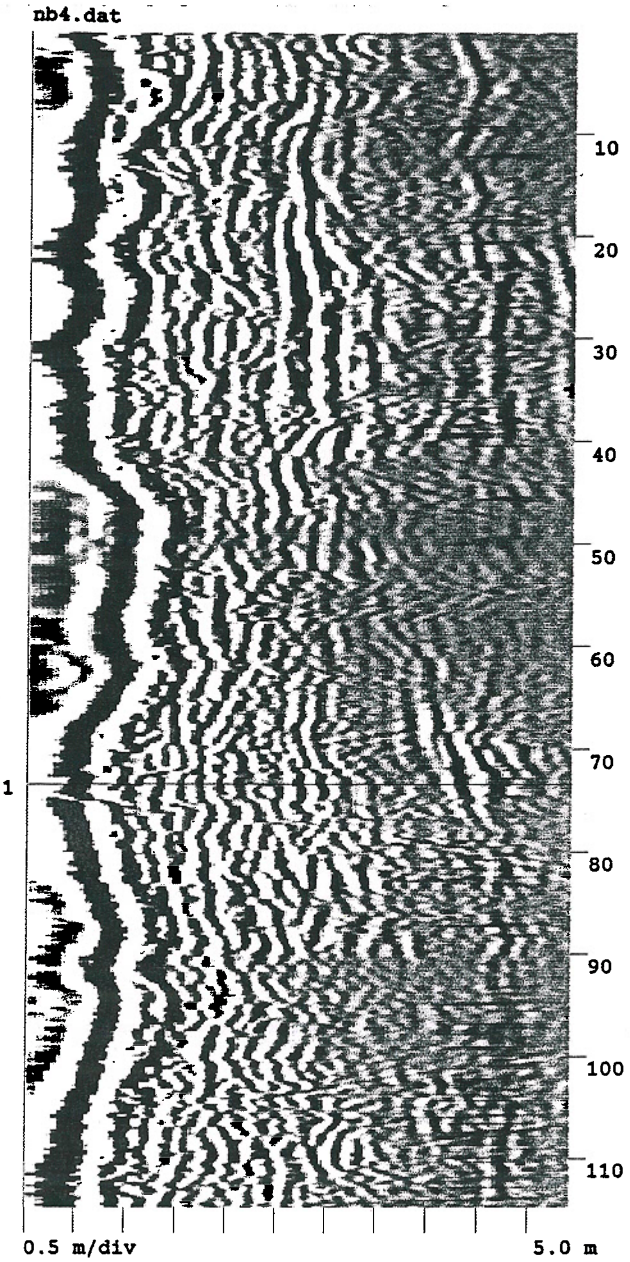

nb18.dat
10
20
30
40
50
60
70
80
90
100
110
120
130
1
0.5 m/div
5.0 m

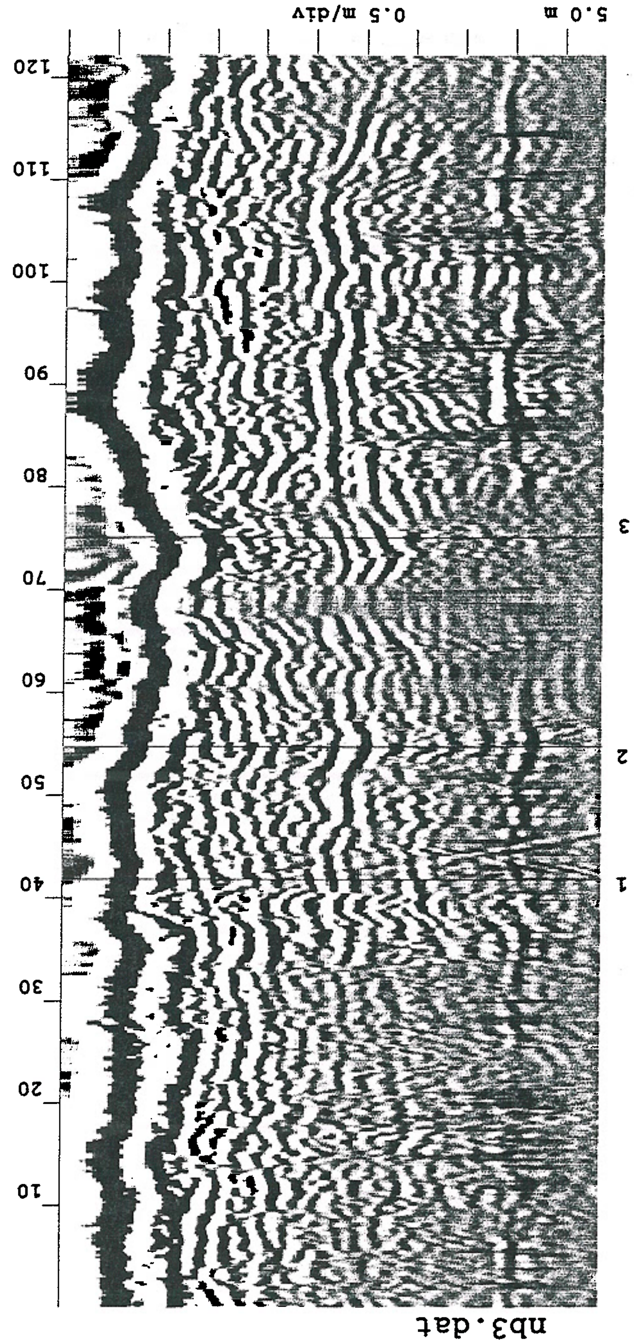

nb17.dat
0.5 m/div
5.0 m
1

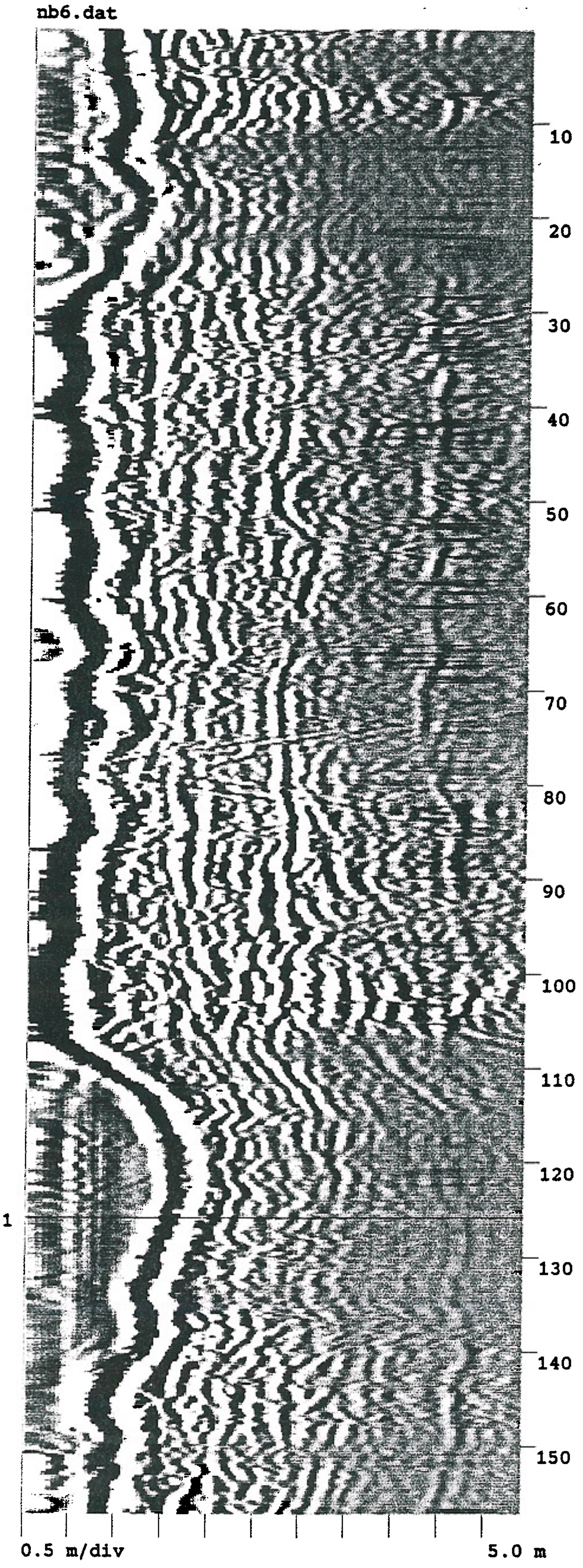

nb29.dat
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
0.5 m/div
5.0 m


nb19.dat
0.5 m/div
5.0 m
10
20
30
40
50
60
70
80
90
100
110
120
1

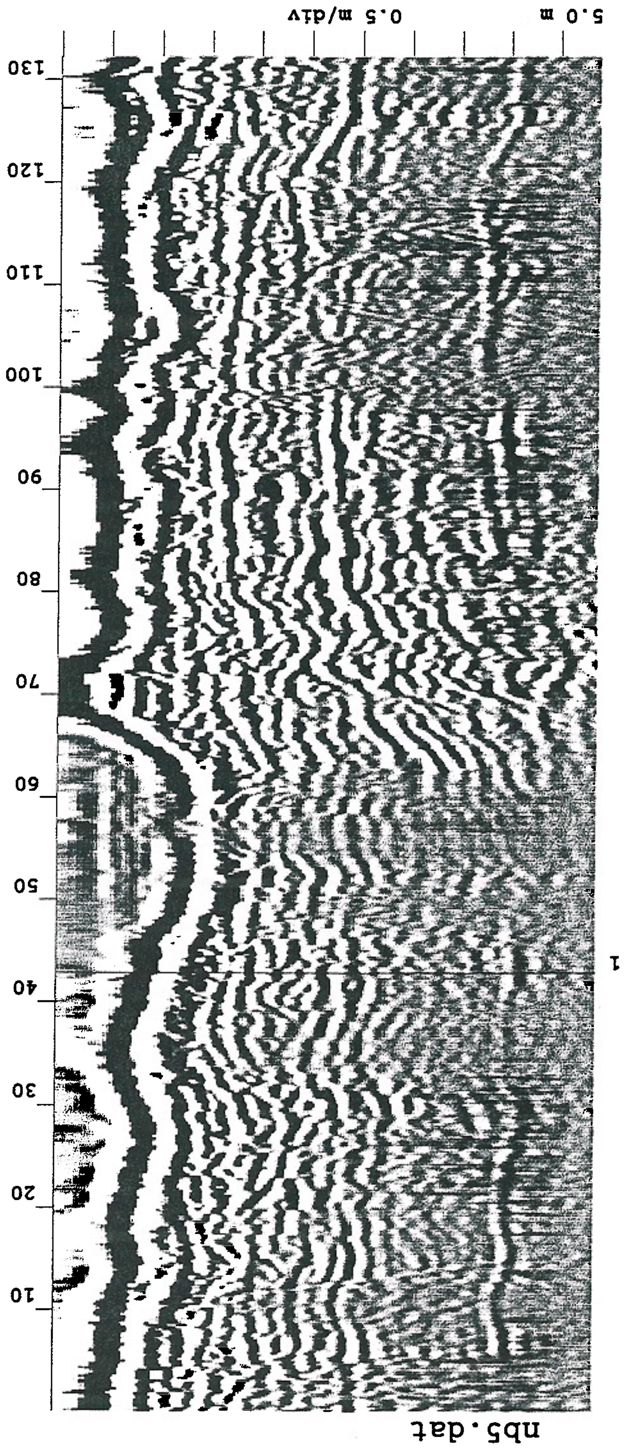

nb21.dat
2
4
6
300.0 ns
50.0 ns/div


nb4.dat
10
20
30
40
50
60
70
1
80
90
100
110
0.5 m/div
5.0 m


nb3.dat
0.5 m/div
5.0 m
10
20
30
40
1
50
2
60
70
3
80
90
100
110
120

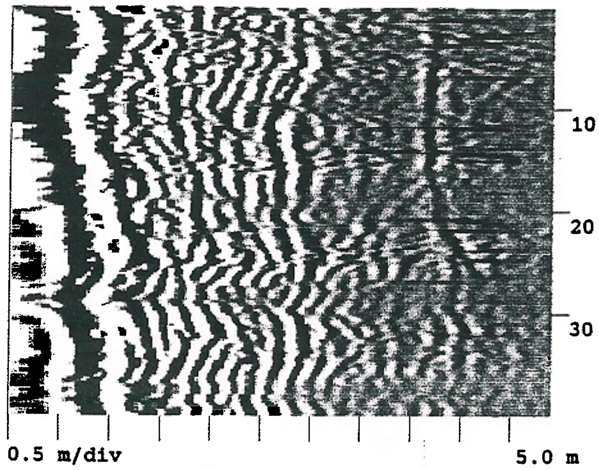


nb6.dat
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
1
0.5 m/div
5.0 m

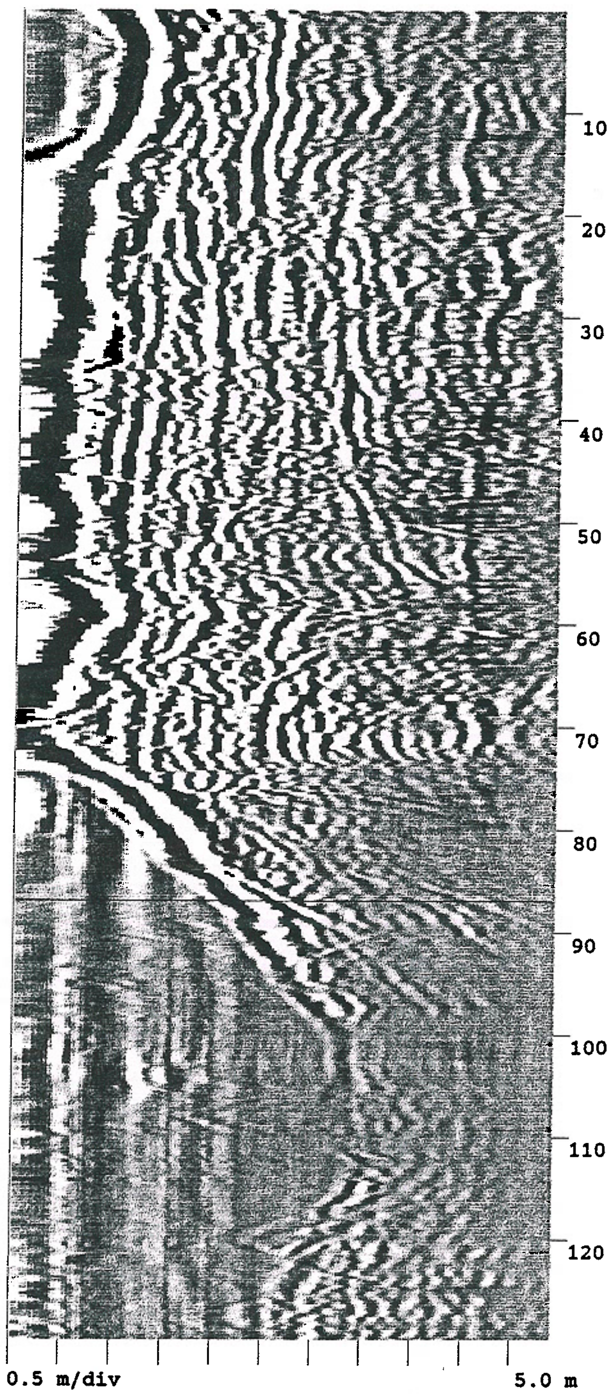


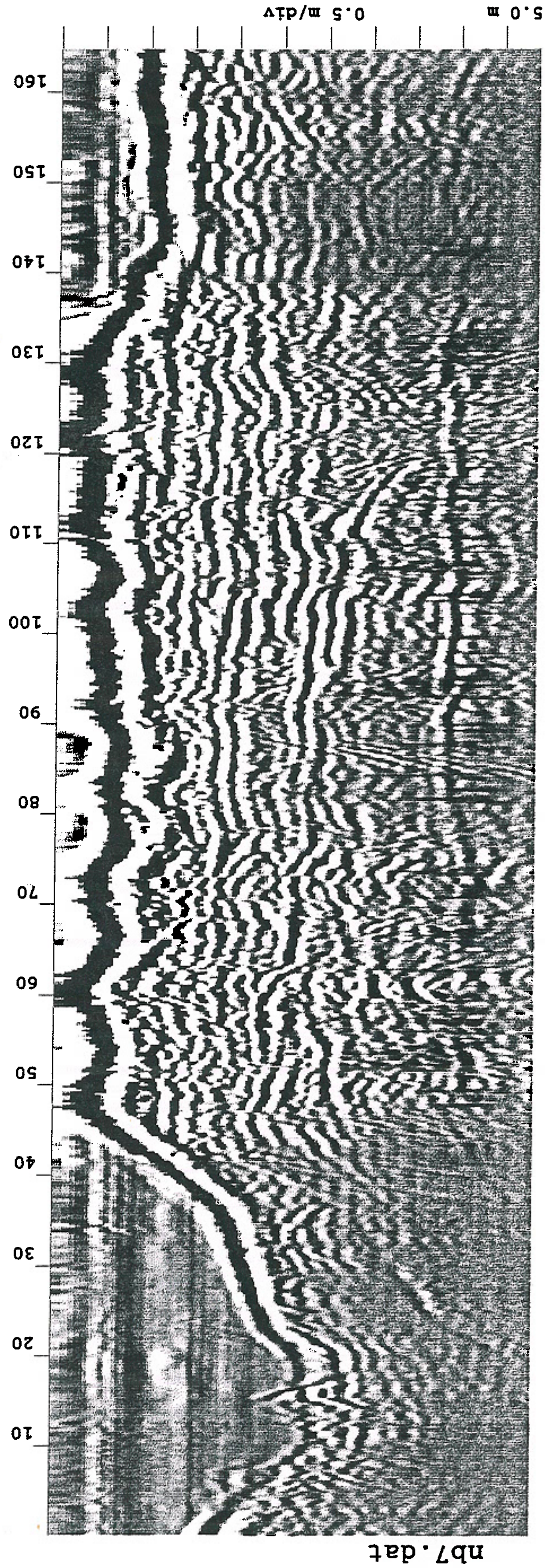
nb5.dat
5.0 m
0.5 m/div
130
120
110
100
90
80
70
60
50
40
30
20
10
1

nb8.dat



nb9.dat





nb7.dat

nb10.dat