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Ground-penetrating radar profiles across post-glacial faults at Kåfjord, Troms and Fidnajohka, Finnmark

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REPORT

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Title:
Ground-penetrating radar profiles across postglacial faults at Kåfjord, Troms and Fidnajohka, Finnmark

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Summary:
GPR measurements have been carried out across presumed postglacial faults at Kåfjord, Troms and Fidnajohka, Finnmark, Norway. The purpose of the measurements was to map the subsurface extension of the faults, and to clarify whether the Nordmannsvik fault (Kåfjord) is a gravitational fault or a true tectonic, postglacial fault.

At Kåfjord, three GPR profiles have been measured across a linear terrain feature in till expressed as an elevation offset. The GPR records show that the feature is a surface expression of a structure dipping 45-50° towards the north-east. For two of the profiles (P1 and P2), a relatively constant dip of the structure towards the north-east indicates normal tectonic faulting. Profile 3 shows a gentler dipping of the structure towards depth which is in favour of both tectonic and gravitational induced faulting. To try to resolve this ambiguity, further investigations should include prolonging GPR profiles 2 and/or 3 to the valley bottom in the north-eastern direction, to investigate the possibility of a gravitational induced fault. Also, a more extensive structural geological mapping programme should be carried out in the area.

At Fidnajohka, a postglacial, reverse fault has been subject to previous extensive investigations. One GPR profile has been measured across the central part of the structure. The GPR record delineate a structure parallel to the dip of the foliation and postglacial fault, which may represent a fracture associated with faulting.

Keywords: Geofysikk	Georadar	Neotektonikk
Holocen	Forkastning	
		Fagrapport

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1 INTRODUCTION

Ground-penetrating radar (GPR) measurements have been carried out across presumed post-glacial faults at Kåfjord, Troms and Fidnajohka, Finnmark, Norway. The work is a part of the NEONOR (Neotectonics in Norway) project, which is financed by NGU, Amoco, Phillips, Norsk Hydro, Statkraft, Oljedirektoratet, Statens Kartverk, Norges Forskningsråd and NORSAR.

The purpose of the measurements was to map the subsurface extension of the faults, and to clarify whether the Nordmannsvik fault (Kåfjord) is a gravitational induced fault or a true tectonic postglacial fault. The measurements were carried out by Jan Steinar Rønning (Fidnajohka, 7/7-1997) and Jan Fredrik Tønnesen (Kåfjord, 29/9-1997). Processing was carried out by Eirik Mauring. Interpretation of GPR records was done by Odleiv Olesen, Jan Fredrik Tønnesen and Eirik Mauring.

2 INSTRUMENTATION AND DATA ACQUISITION

GPR measurements were carried out along three profiles at Kåfjord and one profile at Fidnajohka. Common mid-point (CMP) records were obtained for velocity analysis and depth conversion of the GPR records. Measurements were carried out using pulseEKKO IV GPR system at Fidnajohka and pulseEKKO 100 GPR system at Kåfjord (both manufactured by Sensors & Software Inc., Canada). Transmitter frequency and voltage were 50 MHz and 1000 V respectively. The antennae separation was 1 m and the station interval was 0.5 m. Profile information and additional acquisition parameters are listed in Table 1.

Table 1: Profile information and acquisition parameters.

Location	Profile #	Profile length (m)	Sampl. Int. (ns)	Recording time (ns)	Stacks
Kåfjord	1	125.5	1.6	1200	16
Kåfjord	2	210.5	1.6	1200	16
Kåfjord	3	200	1.6	1200	16
Fidnajohka	807	175.5	1.6	1000	32

3 PROCESSING

CMP measurements were carried out for velocity analysis. Appendix 1 and 2 show the results from these measurements. At Kåfjord, the correct CMP stacking velocity seems to be c. 0.11 m/ns (appendix 1), while it is 0.10-0.11 at Fidnajohka. A velocity of 0.10 m/ns was selected for depth conversion at the latter locality.

After data acquisition, the GPR records were terrain corrected. At Kåfjord, elevations were read from a map in scale 1:50 000. Small terrain variations were corrected for using elevation information from comments on the GPR records. At Fidnajohka, levelling of the profile has previously been performed. During plotting, a stepwise linear gain was applied to the data in addition to 5-point stacking along traces to reduce high-frequency noise. This report also offer alternative presentations of the records using trace difference. In trace difference, the difference of neighbouring traces are presented in order to enhance dipping reflectors.

4 RESULTS

Locations of the surveyed areas can be found in Map -01 and -02.

4.1 Kåfjord

As mentioned earlier, one of the objectives of the investigations at Kåfjord is to try to determine whether the Nordmannsvik fault is a gravitational induced fault or a true tectonic post-glacial fault. Varnes et al. (1989) suggests that gravity induced sliding is most likely to occur when the elevation difference is greater than 300 m. At Kåfjord, the slope of the terrain is 10-12°, and the elevation difference between the fault scarp and the valley bottom is 150-200 m. Thus, gravitational sliding seems less likely, but still has to be considered.

<u>P1</u>
The record is shown in Map -03. Possible bedrock surface can be seen as a reflector subparallel to the terrain surface at depths of 5-10 m. The reflector is not very distinct, due to small contrasts in permittivity between bedrock and the overburden, which in turn indicates that the water saturated zone lies deeper than the overburden/bedrock interface. There is normally a large permittivity contrast between water saturated overburden and bedrock.

Several dipping reflectors can be seen in bedrock. These could represent foliation or fracturing. The former is less likely, since structural observations in a small stream c. 500 m to the east show that the dip of foliation is c. 10° towards the north-east. This is much gentler that can be observed on the record (see below). An abrupt offset in the terrain surface between position 45 and 50 corresponds with the position of the up-dip extrapolation of the most prominent reflector between position 55 (525 m.a.s.l.) and 115 (471 m.a.s.l.). This could indicate that the dipping reflector represents a structure that has been active during Holocene (i.e. postglacial activation). The dip is fairly constant towards depth (a migrated dip of c. 48° towards the north-east). This is in favour of tectonic faulting, since a gravitational induced slip interface is expected to become more gently dipping towards depth (Varnes et al., 1989). Still, the profile should be extended towards the valley bottom to the north-east to see whether the structure can be followed back up towards the terrain surface. This would be the case of a gravitational induced slip. A preliminary interpretation of the structure is that it represents a normal, listric, postglacial fault.

The trace difference record enhances the dipping reflectors. On this record, several dipping reflectors can be seen. Some of them can be followed across just a few traces and should be considered as artefacts of the trace difference processing. Others could represent fractures/faults that have not been activated after the last deglaciation. An example of these could be a reflector which can be followed from position 25 (530 m.a.s.l.) to position 85 (480 m.a.s.l.).

P2

The 'normal' and trace difference records are shown in Map -03. Top of bedrock can be seen as a reflector at depths of 5-10 m in the upper record ('normal' presentation). Two dipping reflectors are prominent. Both have a migrated dip of c. 50° towards the north-east. The one farthest to the north-east (position 125 to 180) probably has a terrain surface expression in terms of an elevation offset between position 120 and 125 which corresponds to the surface feature discussed for profile 1. In fact, the feature can be followed continuously between the two profiles. The corresponding dipping reflector is interpreted to have a postglacial activation. The dip is fairly constant towards depth, again indicating tectonic faulting. The prominent, dipping reflector to the south-west (position 50 to 105) does not have a surface expression, indicating that this structure has not been activated during Holocene.

A gently dipping reflector can be followed more or less continuously from position 25 (538 m.a.s.l.) to position 180 (505 m.a.s.l.). The reflector seems to cut through steeper dipping events, and the most plausible interpretation is that it represents the groundwater table. The undulating appearance can in some places be due to insufficient topographical correction. A possible hydraulic head drawdown can be seen between position 135 and 145 (514 m.a.s.l.). This could be an effect of a very permeable fault zone.

The trace difference record shows distinctive diffraction patterns from the upper termination of the presumed postglacial fault. This is further evidence for abrupt offset of the bedrock surface due to fault movement.

P3

The 'normal' and trace difference records are shown in Map -04. Possible bedrock can be seen as gently dipping reflectors at depths of 5-10 m. The most prominent dipping reflectors can be seen in the south-western part of the profile. However, these do not seem to have a surface expression. Most likely, they represent fractures/faults that have not been active during Holocene. A fainter, dipping reflector can be seen between position 100 (517 m.a.s.l.) and 115 (502 m.a.s.l.). This reflector probably represents a fault having its surface expression at position 85-90 in terms of an elevation offset which can be traced continuously to profiles 1 and 2. As concluded for these profiles, the fault probably has been active after the last deglaciation. The reflector can be followed further towards depth on the trace difference processed record. Although it is very faint, it can be seen to have a more gentle dip towards depth. This could be in favour of both tectonical and gravitational induced faulting. As mentioned earlier, a prolonging of the profile towards the valley bottom to the north-east could shed some light on the possibility that the fault could be gravitational induced. Gently dipping reflectors can be seen between position 75 (519 m.a.s.l.) and 90 (515 m.a.s.l.), and between position 115 (503 m.a.s.l.) and 175 (491 m.a.s.l.). These resemble the reflector interpreted as the groundwater table in profile 2, but appear at a different elevation level. Also, they are discontinuous and have an offset between position 90 and 115. Another reflector with the same dip can be seen between position 45 (501 m.a.s.l.) and 85 (493 m.a.s.l.). The dip of these reflectors are c. 10°, which corresponds with the observed foliation from surface mapping (Zwaan, in prep.). The reflectors could represent fracturing parallel to the foliation in this area, but this is still far from conclusive.

4.2 **Fidnajohka, Masi**

This area has been subject to previous extensive geophysical investigations (Olesen et al., 1990 & 1992). The presence of a postglacial fault is evident in this area. The fault is named the Stuoragurra fault which can be traced in a SW-NE direction for 80 kilometers. The fault is reverse. Previous GPR measurements with a 400 V transmitter (Olesen et al., 1992) failed to delineate the subsurface extension of the postglacial fault. A more powerful transmitter system (1000 V) has now been utilised to try to delineate the fault.

A GPR profile has been measured along profile 807 (see Map -05). From position 160 (level 5 m) to position 235 (level -15 m) a very distinct, gently dipping reflector can be seen. Refraction seismics and percussion drilling (Olesen et al., 1992) show that this reflector represents the bedrock surface. Another (fainter) dipping reflector can be seen from position 151 (level 2 m) to position 177 (level -10 m). This reflector is enhanced on the trace difference record, and it appears shallower towards the terrain surface. Due to limited penetration, it cannot be followed far towards depth. Drillhole 5 cut the postglacial fault at a depth of c. 25 m along the drillhole (see Map -05 for position of drillhole 5), whereas the reflector on the GPR record is shallower (16-17 m). The dip of the foliation and postglacial fault is c. 30° (Olesen et al. 1990 & 1992), which is about the same as the dip of the reflector. Although the reflector doesn't depict the position of the postglacial fault, it probably represents a shallower fracture associated with the faulting. The 'ringy' reflection pattern between position 145 and 150 is probably due to very moist surface conditions.

5 CONCLUSIONS

GPR measurements have been carried out across presumed postglacial faults at Kåfjord, Troms and Fidnajohka, Finnmark, Norway. The purpose of the measurements was to map the subsurface extension of the faults, and to clarify whether the Nordmannsvik fault (Kåfjord) is a gravitational induced fault or a true tectonic, postglacial fault.

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At Fidnajohka, a postglacial, reverse fault has been subject to previous extensive investigations. One GPR profile has been measured across the central part of the structure. The GPR record delineate a structure parallel to the dip of the foliation and postglacial fault, which may represent a fracture associated with faulting.

6 REFERENCES

Olesen, O., Henkel, H., Lile, O.B., Mauring, E. & Rønning, J.S: 1990: Detailed geophysical investigations of the Stuoragurra postglacial fault, Finnmark, northern Norway. *NGU Rapport 90.160,* 24 s.

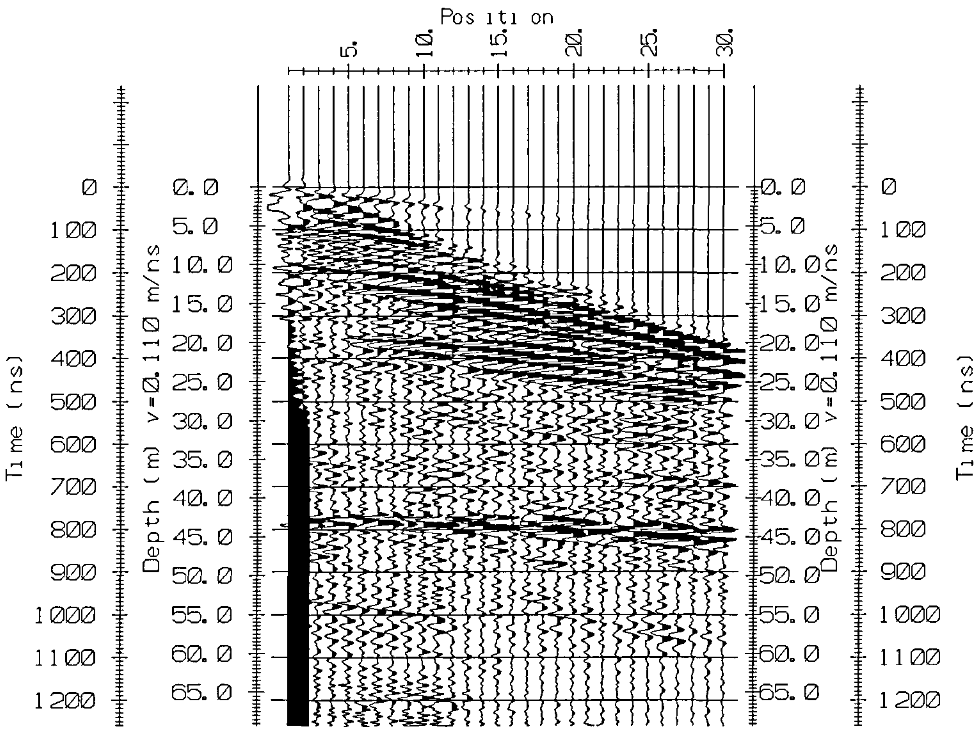
Olesen, O., Henkel, H., Lile, O.B., Mauring, E., & Rønning, J.S. 1992: Geophysical investigations of the Stuoragurra postglacial fault, Finnmark, northern Norway. *Journ. Applied Geophysics 29,* 95-118.

Varnes, D.J., Radbruch-Hall, D.H. & Savage, W.Z. 1989: Topographic and structural conditions in areas of gravitational spreading of ridges in the Western United States. *U.S. Geological Survey professional paper 1496.*

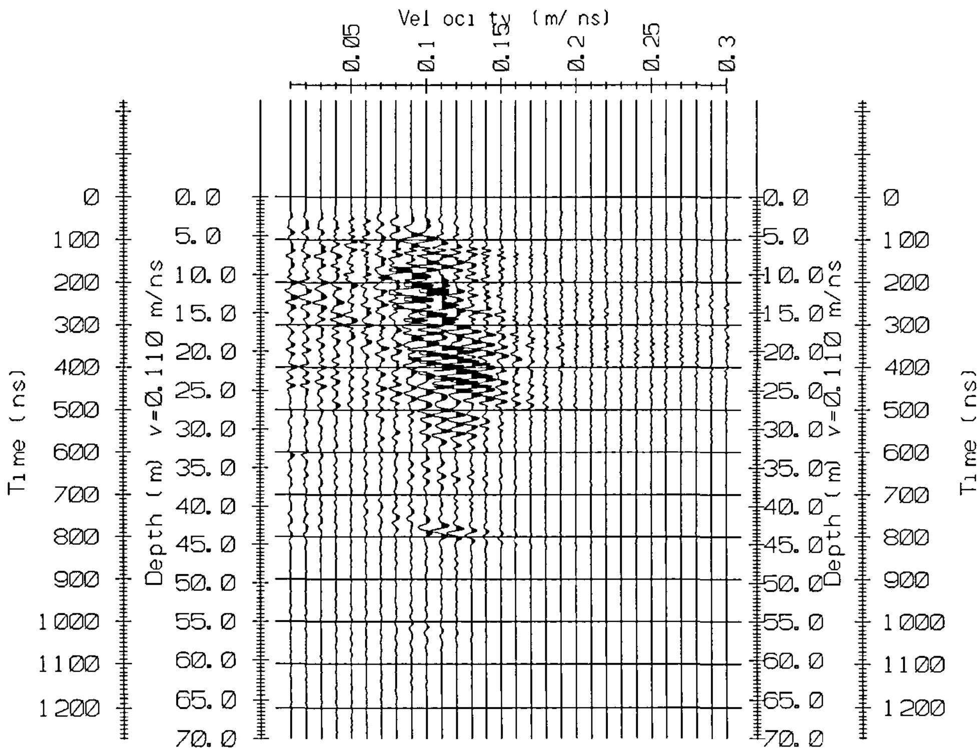
Zwaan, K.B. in prep.: Foreløpig berggrunnsgeologisk kart 1:50 000. 1634 II Kåfjord. *Norges geologiske undersøkelse.*

KÅFJORD, CMP velocity analysis at P2-0

CMP record

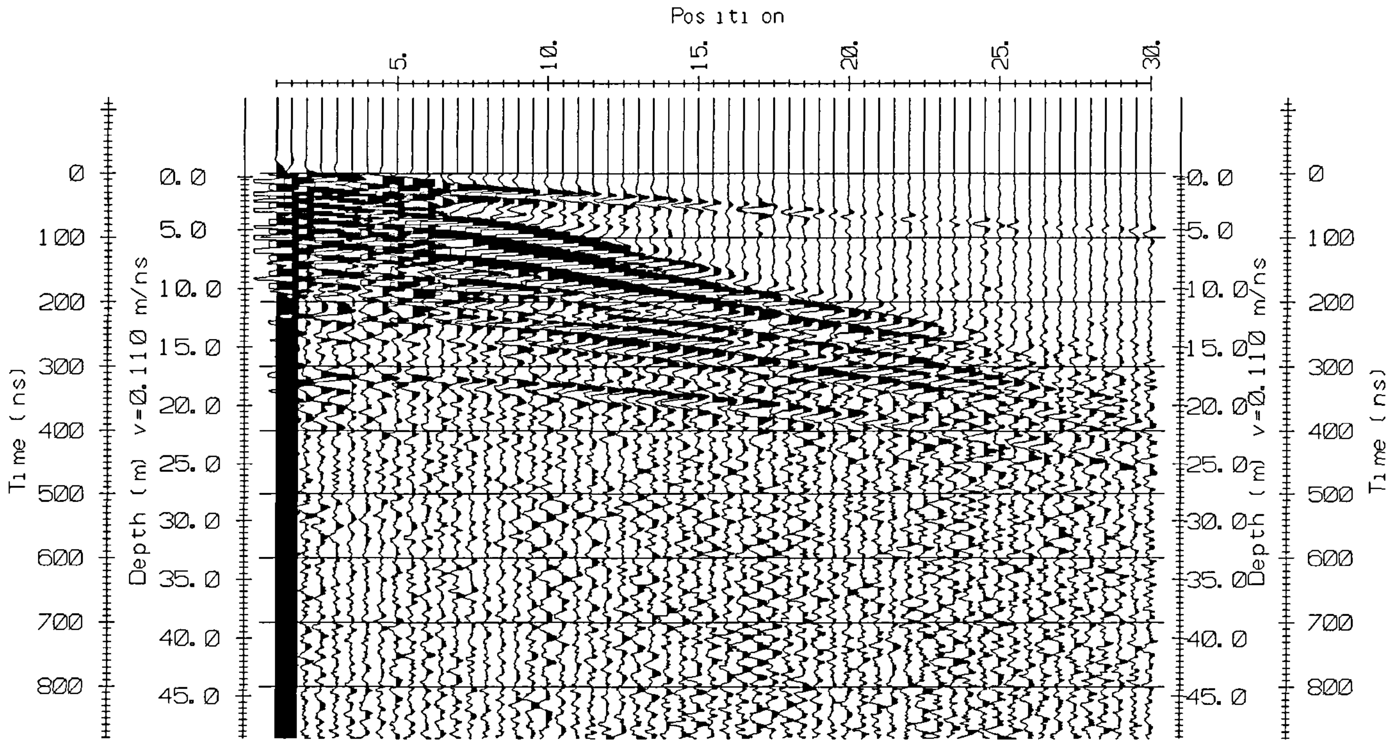


Velocity analysis



FIDNAJOHKA, CMP velocity analysis at position 225

CMP record



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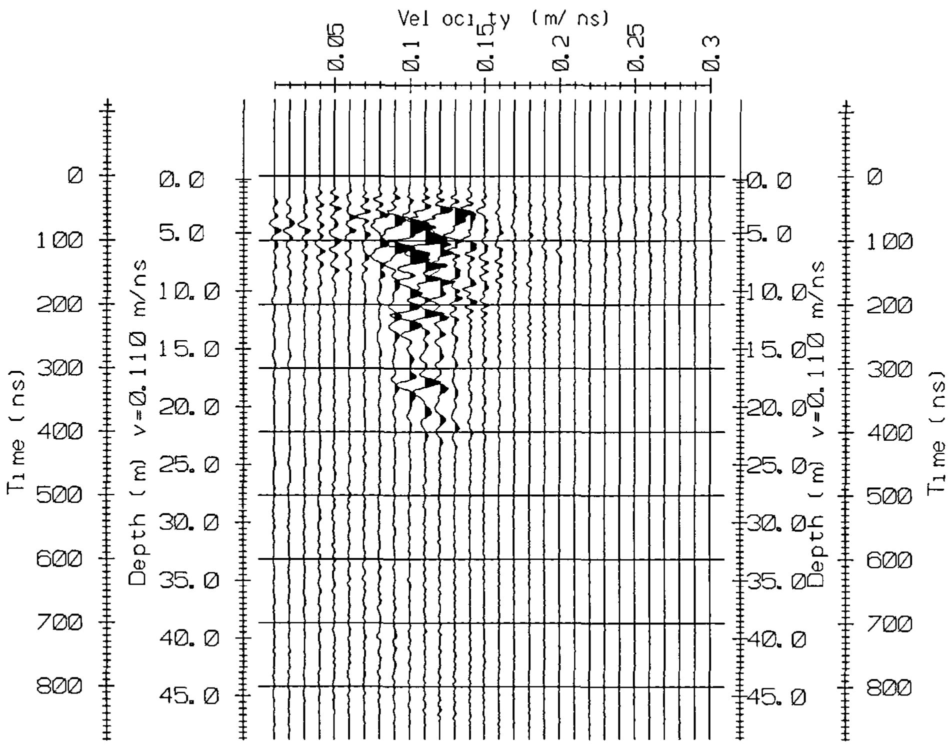
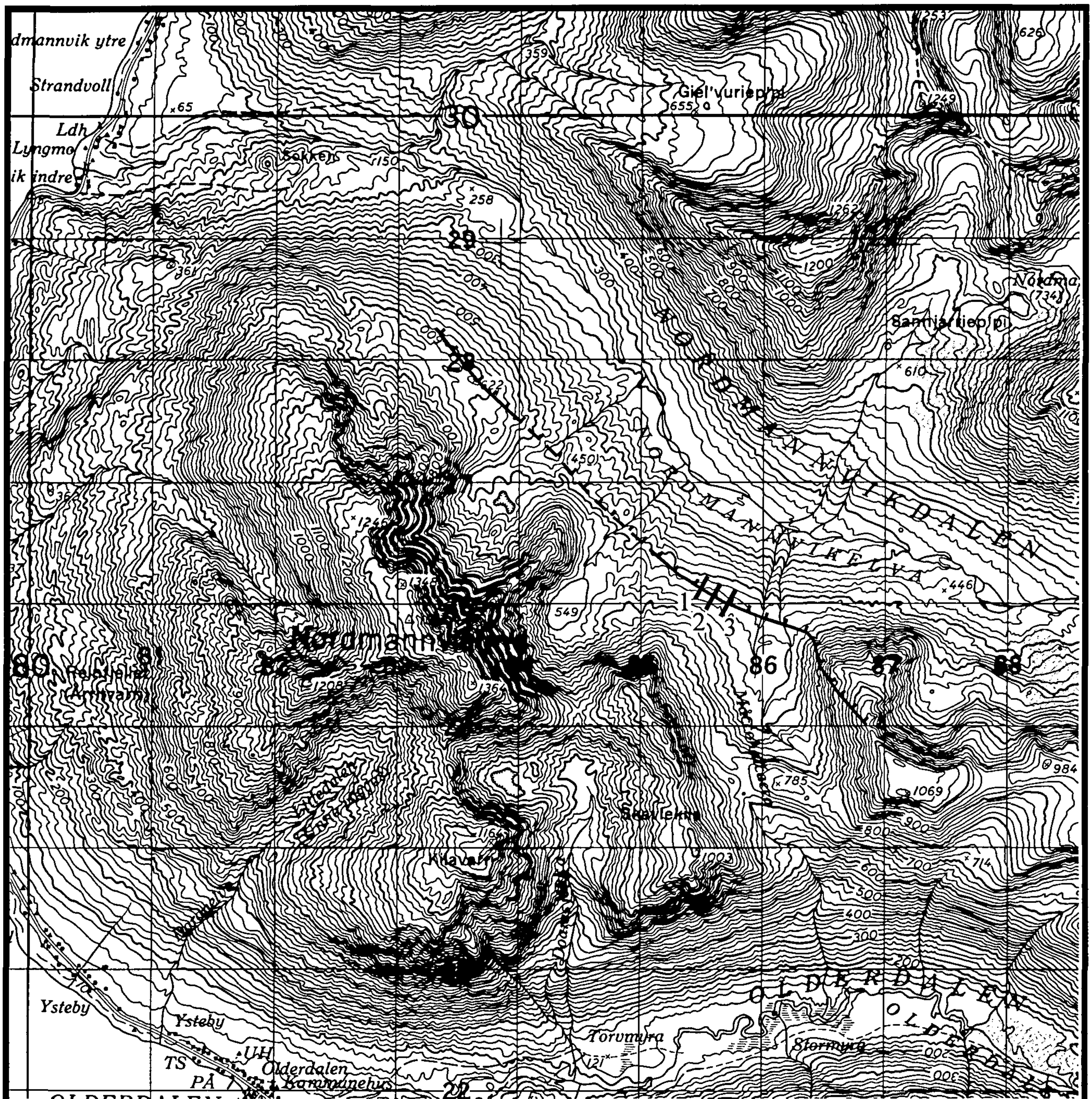
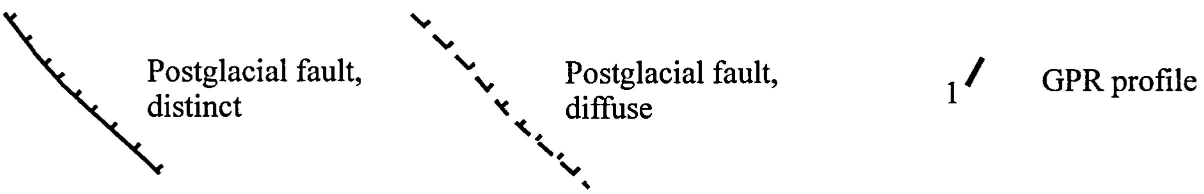
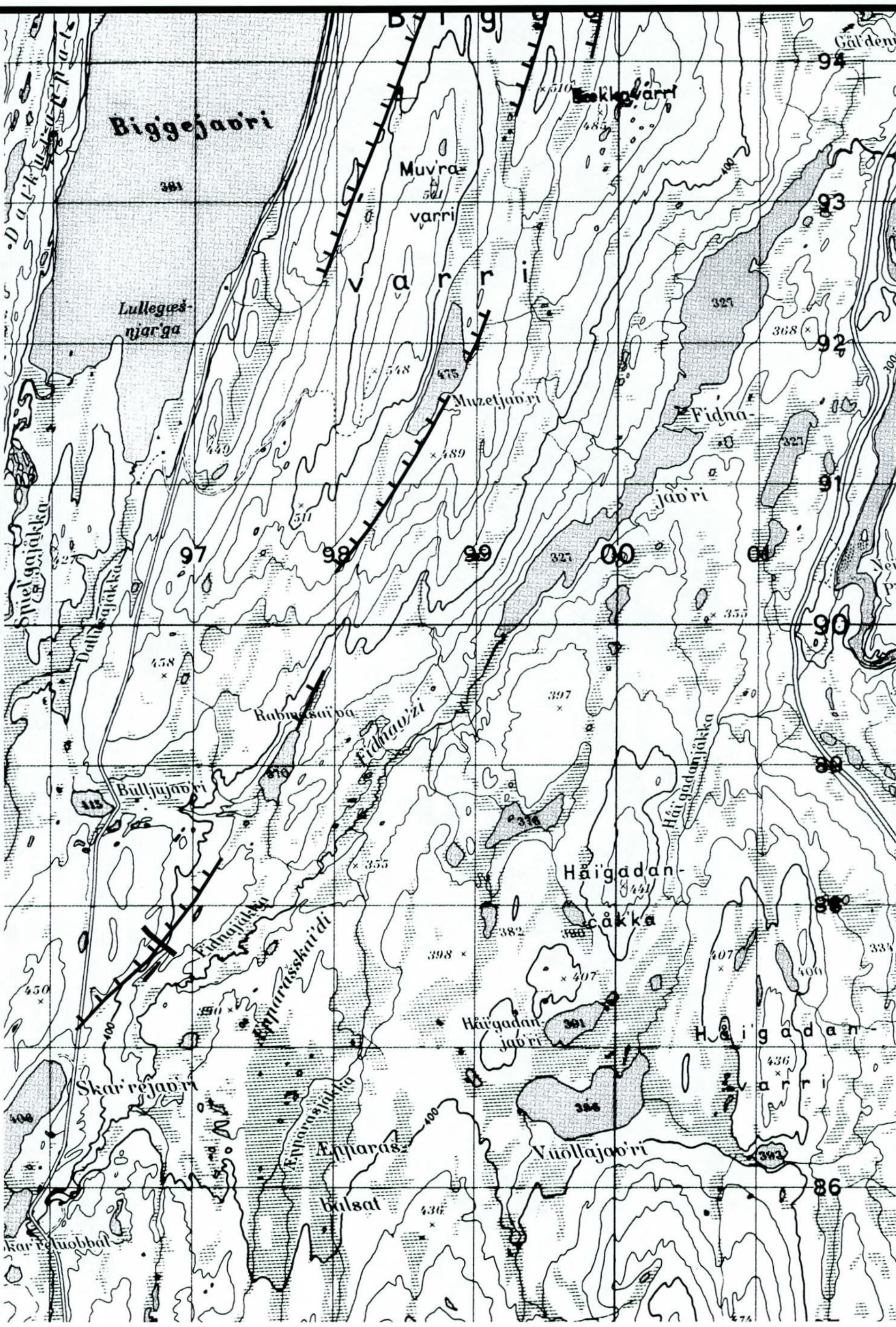






NGU/Amoco/Phillips/Norsk Hydro/ Statkraft/OD/SK/NFR/NORSAR LOCATION MAP **KÅFJORD** TROMS, NORWAY	SCALE 1:50 000	OPER JFT	1997
		DRAW EM	Nov. -1997
		TRAC	
GEOLOGICAL SURVEY OF NORWAY TRONDHEIM	MAP NO. 97.174-01	MAP 1:50 000 1634 II	

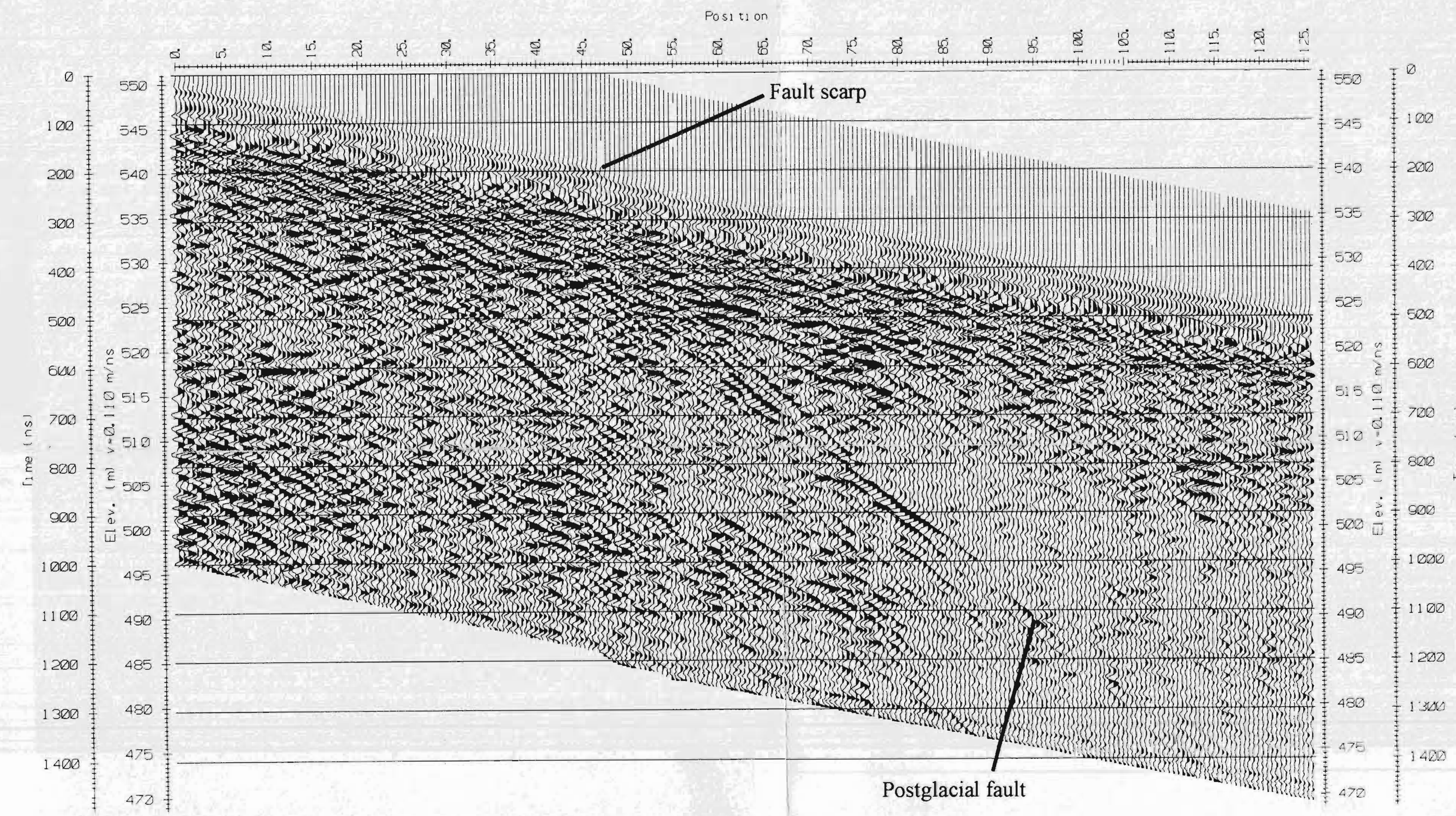


Postglacial fault (Olesen, 1984)

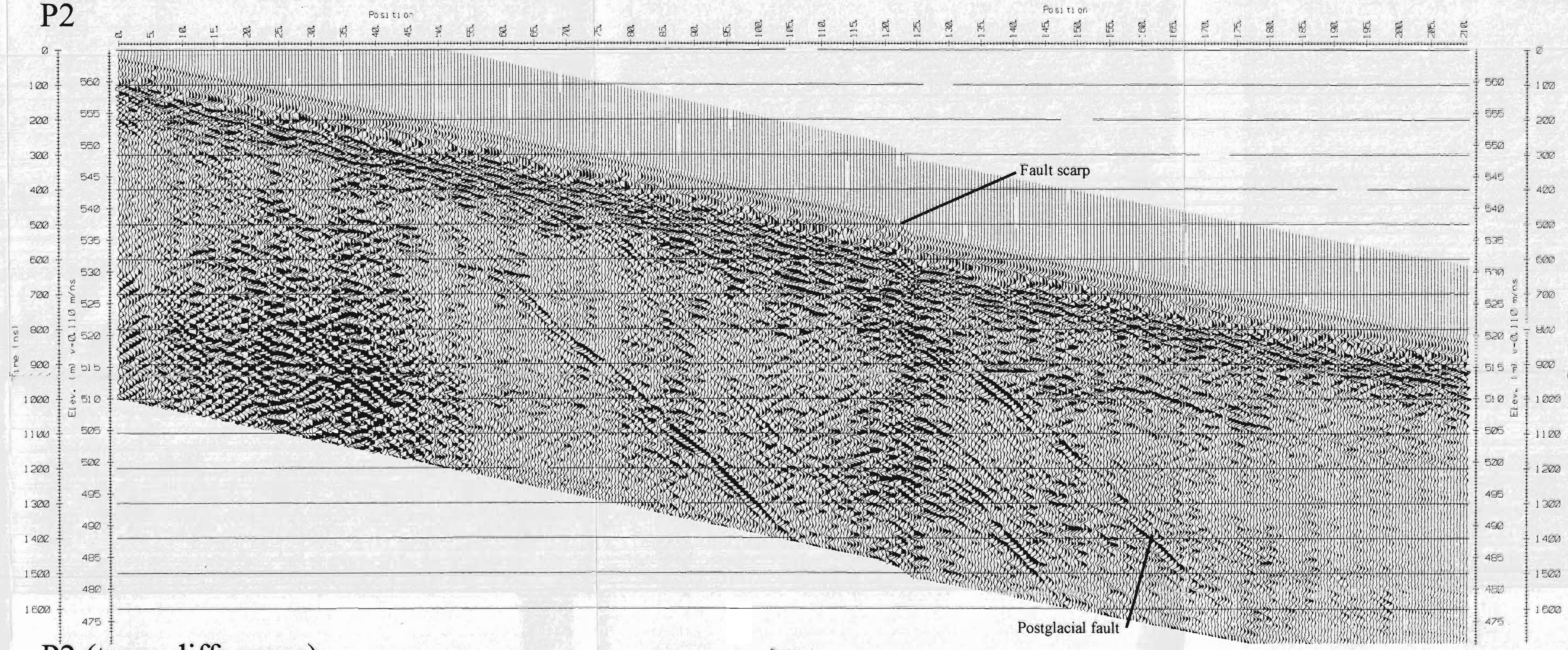
GPR profile

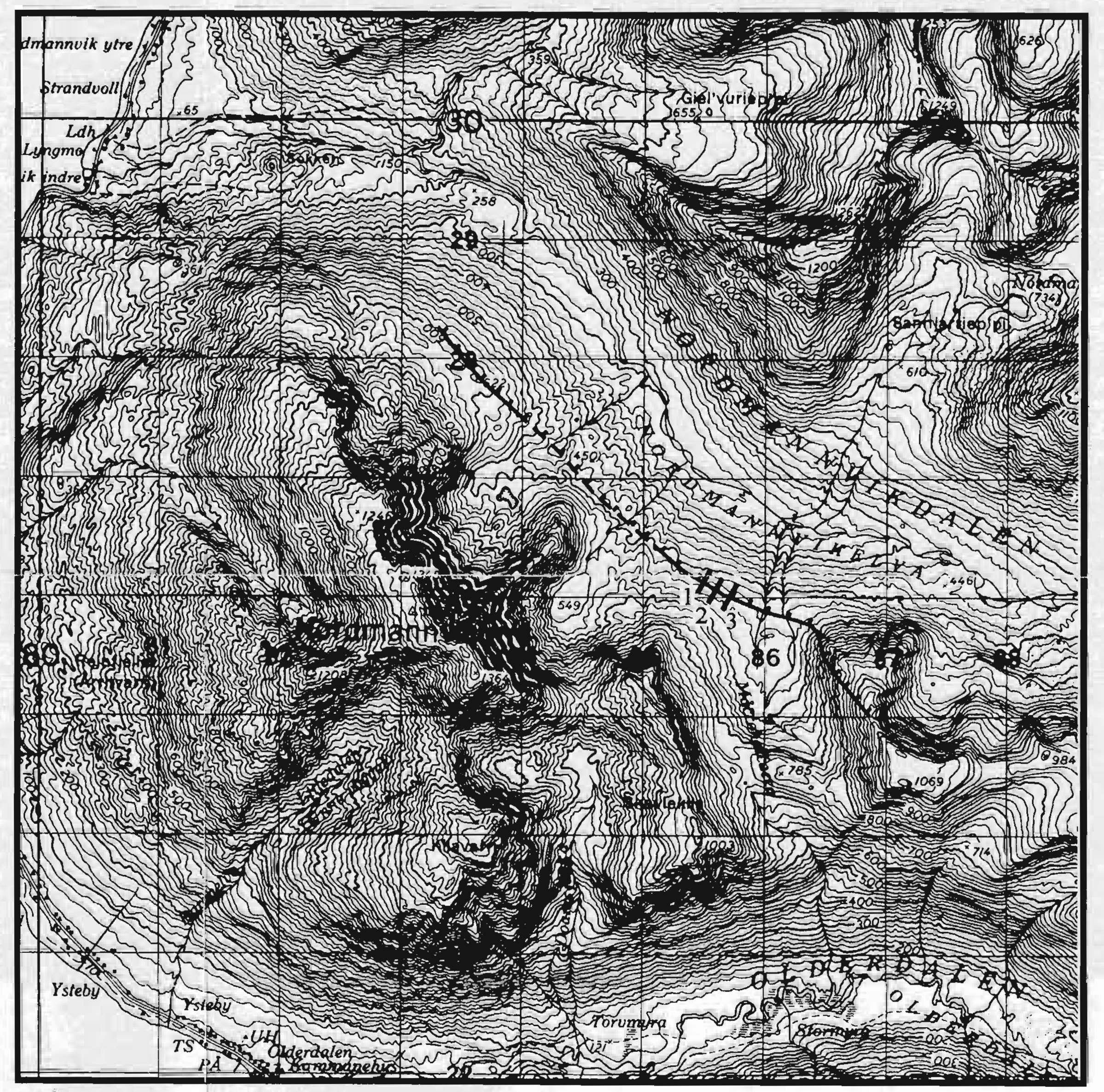
NGU/Amoco/Phillips/Norsk Hydro/ Statkraft/OD/SK/NFR/NORSAR LOCATION MAP **FIDNAJOHKA** FINNMARK, NORWAY	SCALE 1:50 000	OPER JFT	1997
		DRAW EM	Nov. -1997
		TRAC	
GEOLOGICAL SURVEY OF NORWAY TRONDHEIM	MAP NO. 97.174-02	MAP 1:50 000 1933 IV	

P1



P2



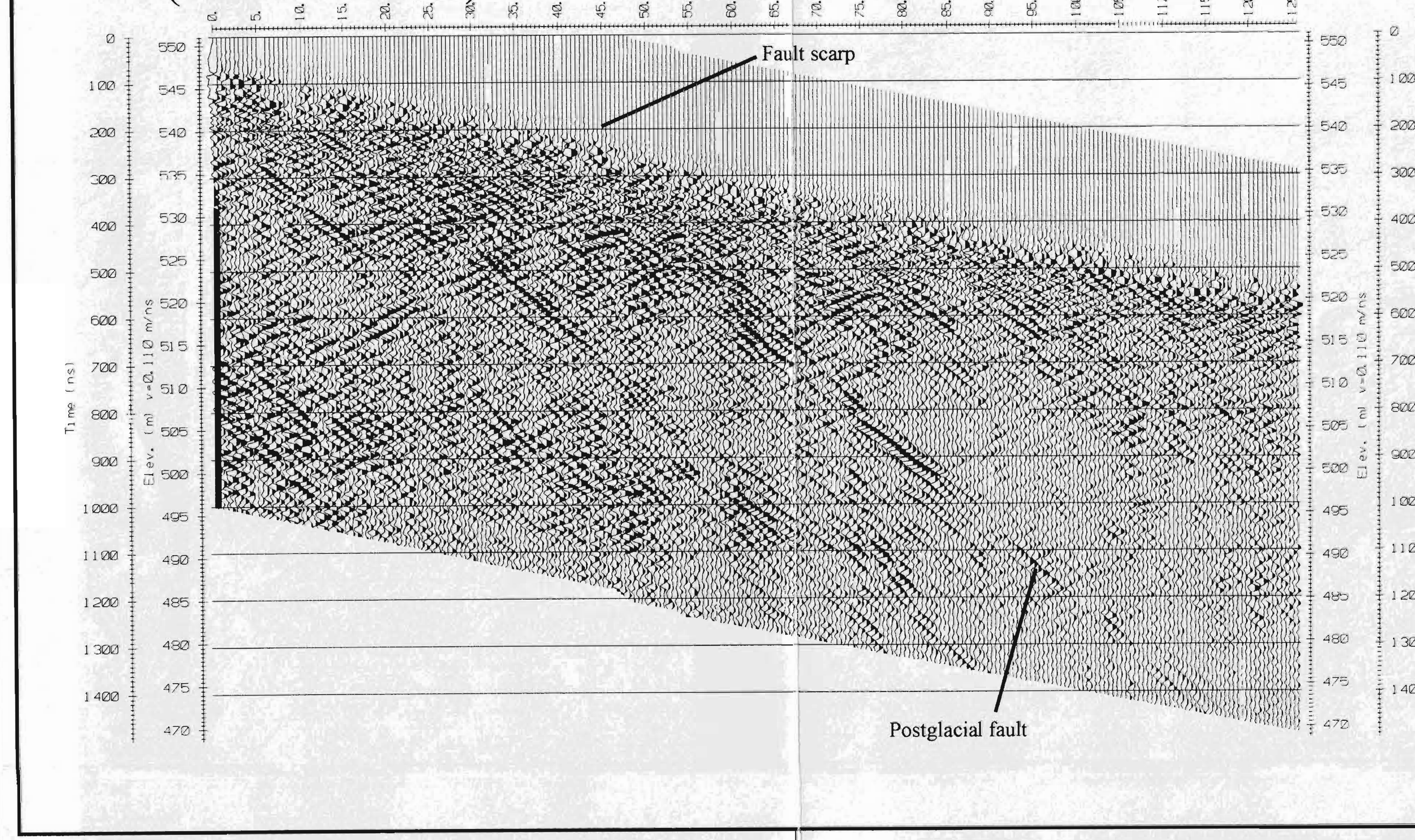


Postglacial fault, distinct

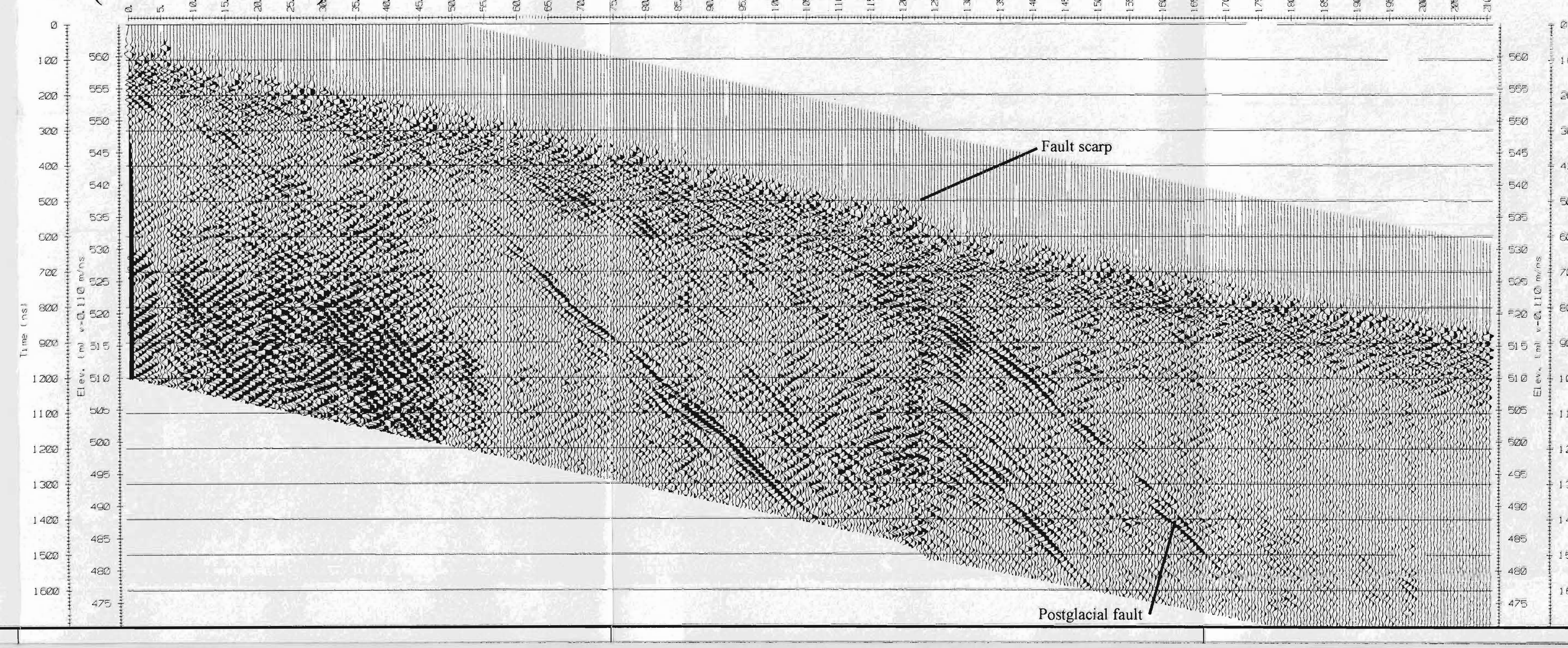
Postglacial fault, diffuse

1 GPR profile

P1 (trace difference)

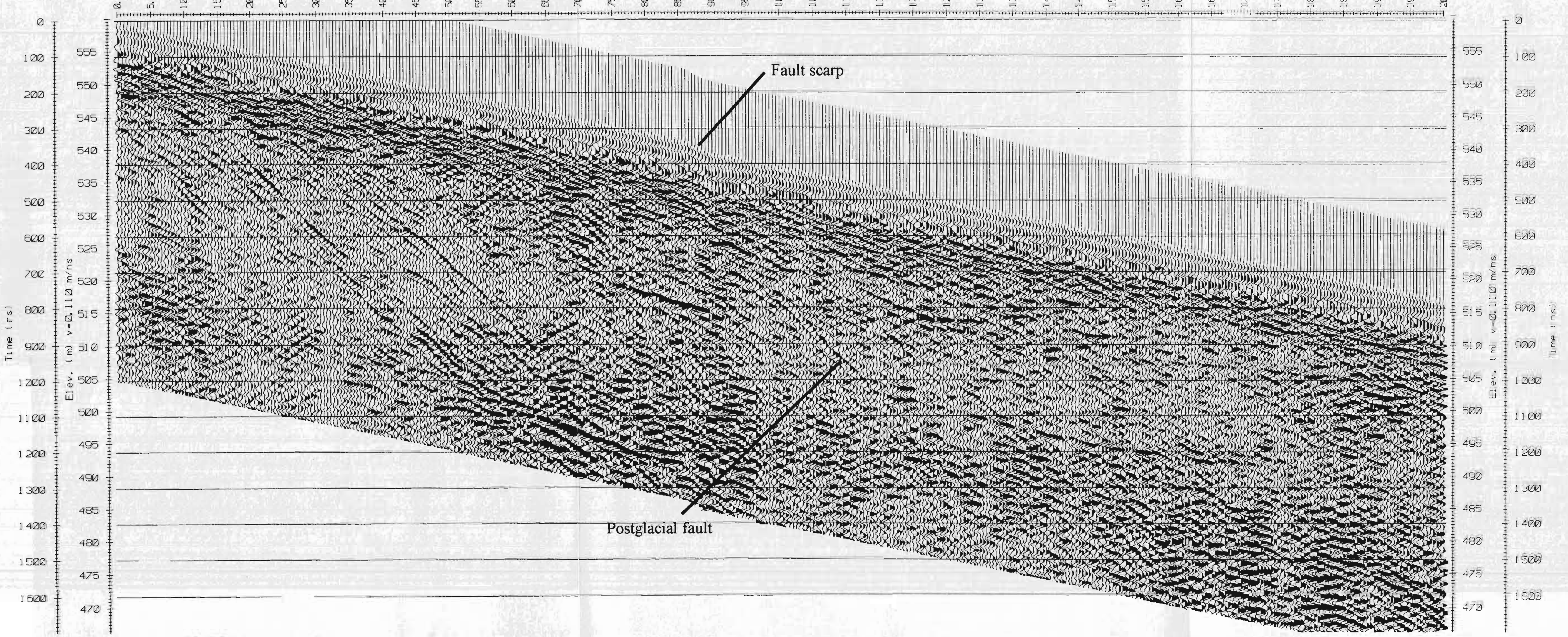


P2 (trace difference)

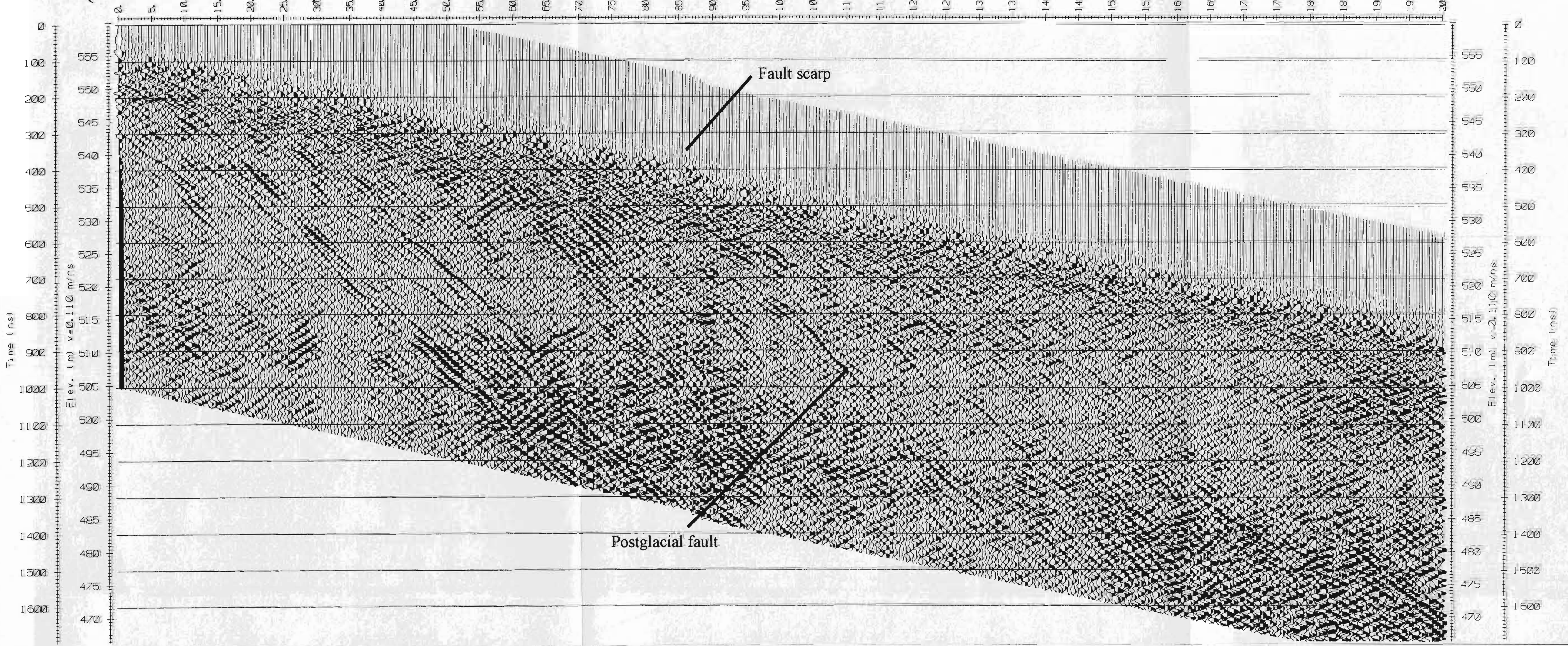


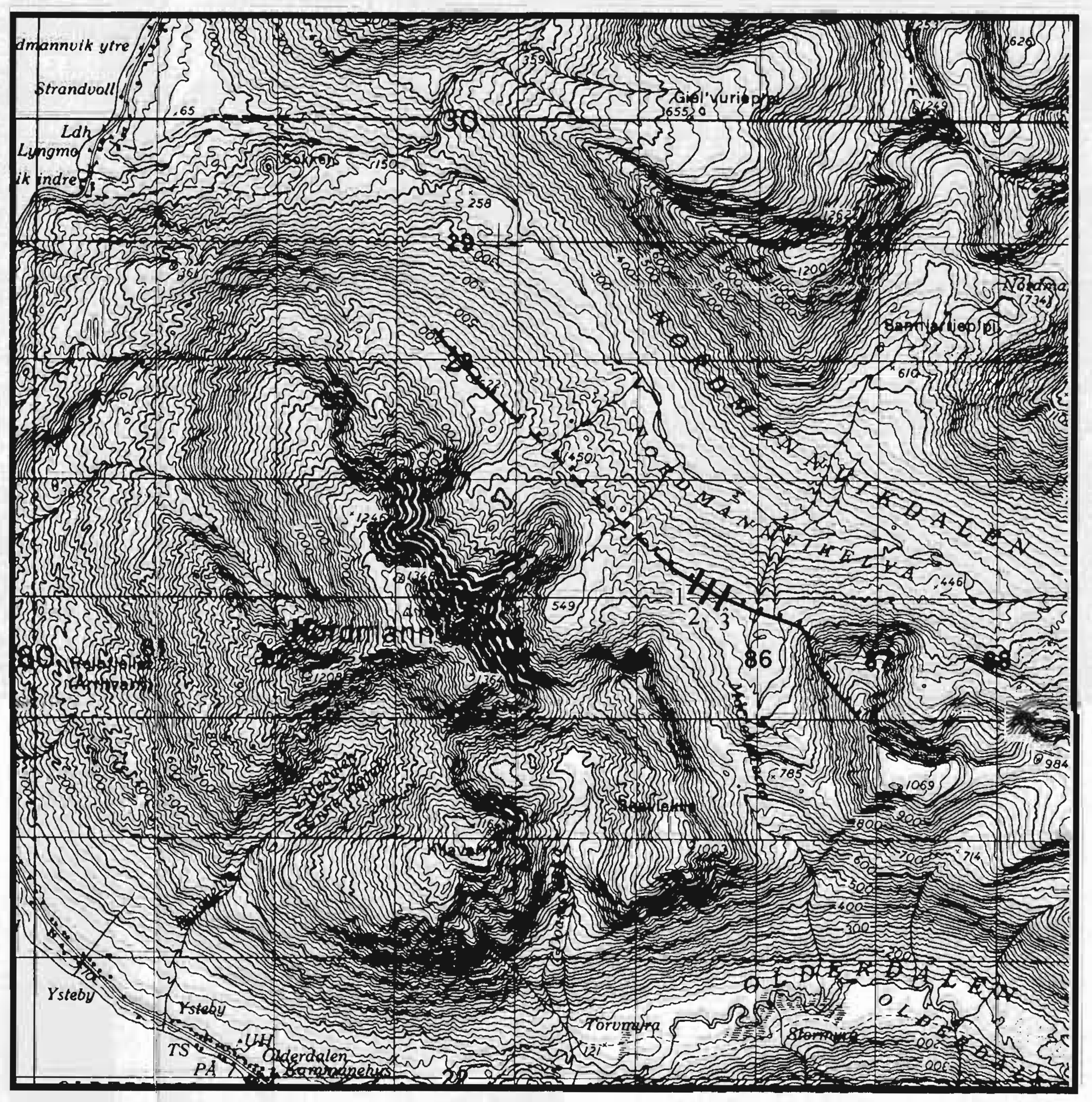
NGU/Amoco/Phillips/Norsk Hydro/ Statkraft/OD/SK/NFR/NORSAR GROUND-PENETRATING RADAR RECORDS 1 & 2 KÅFJORD TROMS, NORWAY	SCALE (Map) 1:50 000	OBS JFT DRAW EM TRAC	1997 Nov. 1997
GEOLOGICAL SURVEY OF NORWAY TRONDHEIM	MAP NO. 97.174-03	MAP SHEET. 1634 II	

P3



P3 (trace difference)





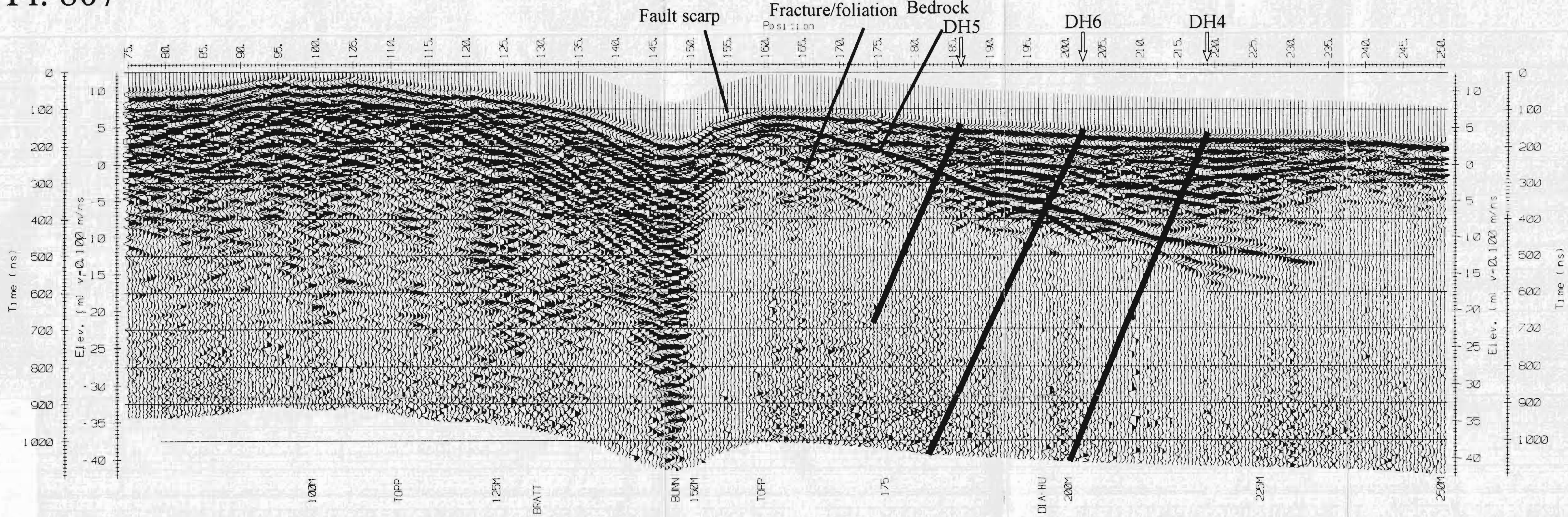
Postglacial fault, distinct

Postglacial fault, diffuse

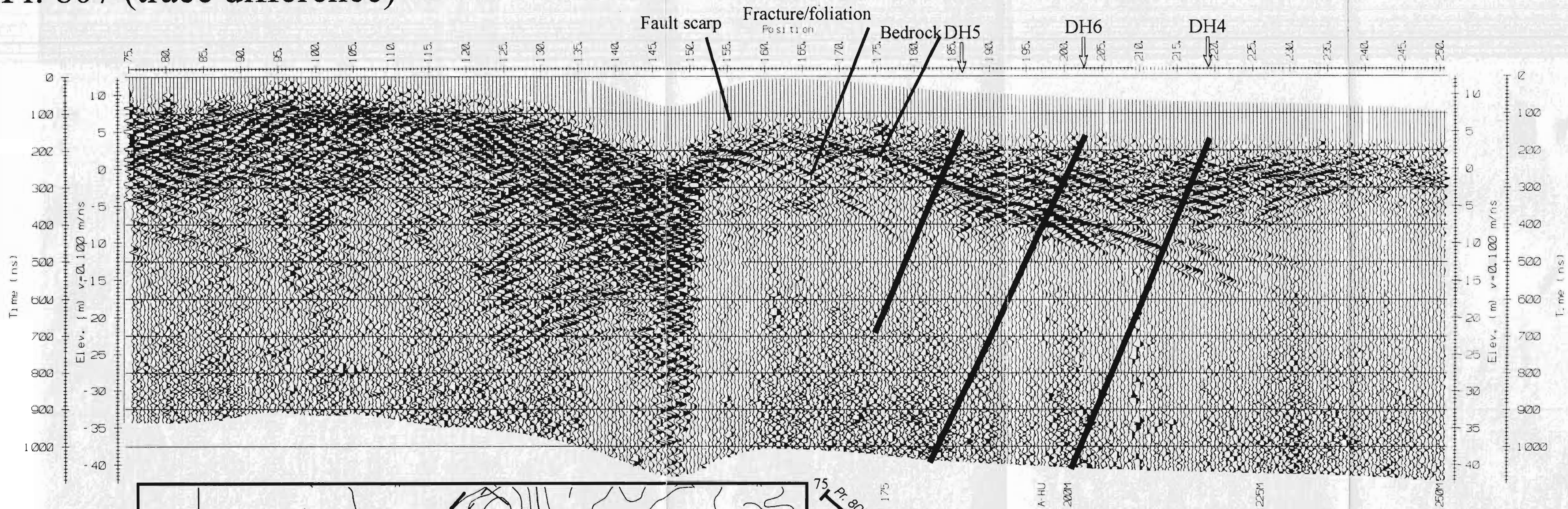
1 GPR profile

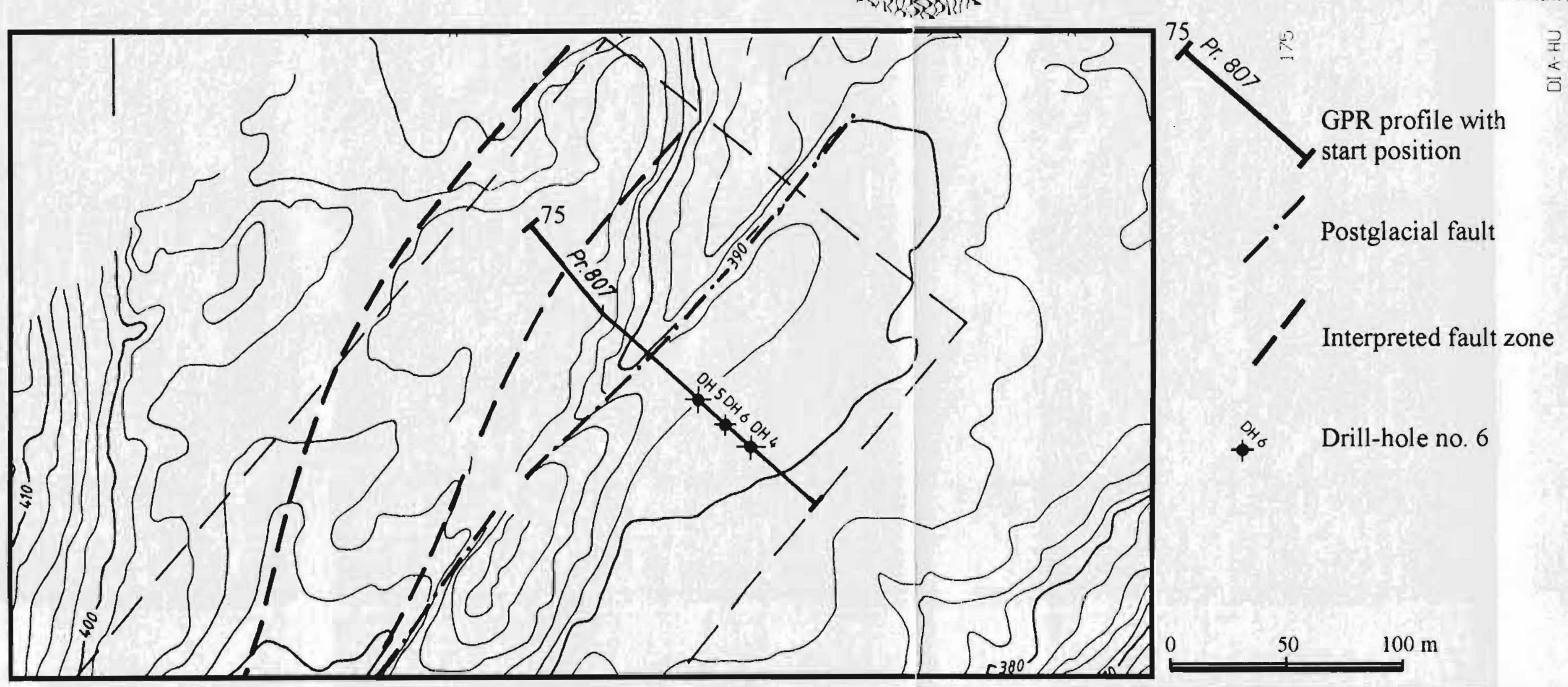
NGU/Amoco/Phillips/Norsk Hydro/ Statkraft/OD/SK/NFR/NORSAR GROUND-PENETRATING RADAR RECORD 3 **KÅFJORD** TROMS, NORWAY	SCALE (Map) 1:50 000	OBS JFT DRAW EM TRAC	1997 Nov. 1997
GEOLOGICAL SURVEY OF NORWAY TRONDHEIM	MAP NO. 97.174-04	MAP SHEET 1634 II	

Pr. 807



Pr. 807 (trace difference)





NGU/Amoco/Phillips/Norsk Hydro/ Statkraft/OD/SK/NFR/NORSAR GROUND-PENETRATING RADAR PROFILE 807 **FIDNAJOHKA** FINNMARK, NORWAY	SCALE 1:2800 (Map)	OBS JSR DRAW EM TRAC	1997 Nov. -1997
GEOLOGICAL SURVEY OF NORWAY TRONDHEIM	MAP NO. 97.174-05	MAP SHEET 1933 IV	