Report 92.325

Neotectonic studies in Finnmark 1992

NORGES GEOLOGISKE UNDERSØKELSE

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RAPPORT

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Sammendrag:

The postglacial Stuoragurra Fault (SF) lies within the regional Mierujav'ri-Sværholt Fault Zone which is located in the extensive Proterozoic terrain of inner Finnmark. To explore the SF at depth, 135 m of core-drillling was located between two previous percussion drillholes. More detailed information has been acquired from the core-drilling as compared with the previous drilling. The location of the main fault zones from the core-drilling is consistent with the results from the geophysical measurements. The two uppermost zones are coinciding with 2-3 m wide zones of brecciation. The postglacial fault coincides with the lowermost of these zones and is composed of several thin (a few cm wide) zones of fault gouge within a 1.5 metre wide zone at a depth of 37 metres. We can conclude that the postulated listric shape of the fault is most likely to be the correct model.

The annual average changes in elevation of benchmarks based on precision levelling in 1954 and later in 1975 along the old road from Alta to Kautokeino have shown a significant deviation from the general postglacial upheaval of Fennoscandia. Instead of an increasing uplift from 2 mm/year in Alta to 5 mm/year in Kautokeino as is generally indicated on land upheaval maps of Fennoscandia, a subsidence of the inland area was observed. During Quaternary geological mapping in the Iešjav'ri area one submerged shoreline has been observed at the southern margin of this lake. The shoreline is located roughly a few dm below the present water-level, and we think that this indicates that a vertical crustal movement with a N-S gradient opposite to that of the general postglacial rebound has occurred during the last few hundred years. Relevelling of the profile of 1954 and 1975, however, did not reproduce this pattern. We therefore recommend that a systematic mapping of the shorelines around Iešjav'ri should be carried out to clarify this problem.

Emneord:	Kvartærgeologi	Kjerneboring
Geofysikk	Neotektonikk	
Berggrunnsgeologi	Landheving	Fagrapport

CONTENTS

1 INTRODUCTION

In recent years, geological and geophysical field studies aided by aerial photography and airborne geophysics have shown that, in Finnmark, late- or postglacial faulting has been much more widespread than hitherto believed. As well as major structures, such as the Stuoragurra Fault (Olesen 1988, Olesen et al. 1992a,b), there is also evidence of local, contemporary fault movements (Roberts 1991). In addition, there are data which suggest that recent vertical movements do not accord with the accepted theoretical principles of post-glacial isostatic rebound. Further studies of the Stuoragurra Fault have been undertaken in 1992 as a part of the project 'Seismo- and neo-tectonics in Finnmark, Kola and the southern Barents Sea' which is conducted by NTNF/NORSAR on contract for the three Norwegian oil companies Statoil, Norsk Hydro and Saga Petroleum. The main activities by NGU (subcontractor) have been core-drilling of the fault. Relevelling of part (15 km) of the old road between Alta and Kautokeino has been carried out by the Norwegian Mapping Authority (Appendix).

2 GEOLOGICAL SETTING

The Stuoragurra Fault (SF) is interpreted to be situated within a several hundred metre wide fault zone (Olesen et al. 1992a,b). This zone is part of the Big'gevarri Duplex within the regional Mierujav'ri-Sværholt Fault Zone in the extensive Proterozoic terrain of inner Finnmark. The SF is a SE-dipping reverse fault and a c. 1 metre-thick fault gauge zone, detected in percussion drillholes, was considered to represent the actual fault surface. Magnetic fabric data demonstrate that the postglacial fault parallels the schistosity of the surrounding bedrock. Detailed geophysical studies show that low-resistivity and low-velocity zones occupy a several hundred metre wide belt in both the hanging-wall and the foot-wall blocks and are interpreted to originate from strongly fractured and water-bearing quartzites. It has consequently been shown that the Stuoragurra Fault is controlled by older faulting and foliation, on a local as well as on a regional scale. The earliest detectable displacement along the Mierujav'ri-Sværholt Fault Zone is of Proterozoic age and the latest major movements occurred less than 9000 years ago.

At Skipskjølen on the Varanger Peninsula similar escarpments to the ones occurring along the SF can be observed on aerial photographs within the Trollfjord-Komagelv Fault Zone (Olesen 1991). Since the glacial overburden is missing, it is not possible to date this fault. It is, however, regarded as a potential Late Quaternary postglacial fault because of its similarity in appearance to the SF.

Contemporary reverse-fault movements have been documented from a displaced drillhole in phyllites in a road-cut along the eastern side of Laksefjorden (Roberts 1991). There, an ESE-directed displacement of more than 5 cm has occurred over the last few years along a 40°-dipping, NE-SW-striking, fault surface paralleling the slaty cleavage which is axial planar to Caledonian folds. This offset is ascribed to a release of accumulated strain energy possibly triggered by a seismic event. There is also evidence, in this same area, of recent movement along other cleavage-parallel surfaces, such that the cumulative shear displacement in the region may be far greater than that fortuitously recorded by the drillhole 'marker'.

3 FIELD STUDIES 1992

3.1 Core-drilling

In the Fidnajåkka area (Fig. 2) a dip estimate of 50° to the SE of the Stuoragurra Fault in the upper 10 m of the subsurface can be inferred from the topographical data. Because of the collapse of the scarp and subsequent erosion we consider that the error in this estimate can be about 10°. From the percussion drilling (UTM coord. 597000-7687900), a dip of 30° was interpreted from the intersection with a 1 m thick fault gouge at depths of 37 m and 25 m in drillholes 4 and 5 (Olesen et al. 1992a,b, Figs. 10C and 16). This would indicate that the fault has a listric form. Another possibility is that the fault continues at depth from the surface with a dip of 50-60°. If this model is correct, the drillholes in the hanging-wall block were abandoned prematurely and did not penetrate the fault.

To explore which of these two models is the correct one or closest to being correct, 135 m of core-drilling was located between the two previous holes (the new hole is located at coordinate 45E along profile 807 (Olesen 1991) and dips at 67° to the NW). The drilling was carried out by Frank Sivertsvik and Geir Viken, both at NGU, during the period August 12th to August 26th 1992 using a Diamec 260 machine. The diameters of the drillhole and the core are 46 mm and 34 mm, respectively. The result from this drilling is shown in Fig. 3. More detailed information has been acquired from the core-drilling as compared with the previous percussion drilling. The one metre thick zone of fault gouge is, for instance, composed of several thinner (a few cm wide) zones of fault gouge within a 1.5 metre wide zone at a depth of 37 metres. The location of the main fault zones from the core-drilling (Figs. 3 and 4) is consistent with the results from the geophysical measurements (Olesen et al. 1992a). The three most intense zones of fracturing are located at 13-18 m depth, which is immediately below the bedrock surface, at 37-45 m and at 117-119 m. One wide zone of less intense fracturing is located at 68-80 m. The two uppermost zones are coinciding with 2-3 m wide zones of brecciation (Fig. 5).

We can conclude from Fig. 4 that the listric shape of the fault is most likely to be the correct model. The dip of the fault is 0-10° between drillholes 4 and 6 (see Fig. 4) which is much gentler than expected. It is difficult to decide if this represents the general dip of the fault at this depth or if it is a local deviation from a generally steeper dip. The existence of a variable dip of the postglacial fault is supported by the observation of an accommodation fault in the hanging-wall block of the fault (Fig. 3C in Olesen et al. 1992b). Interpretation of the aeromagnetic data shows that the dip of the albite diabases in the Fidnajåkka area is 40° to the SE (Olesen 1991) as indicated in Fig. 4. The results from the drilling may indicate that the postglacial fault merges with the fault zone below the albite diabase.

The core from drillhole no. 6 shows that the foliation and bedding are generally perpendicular to the drillhole. This may also indicate that the deviation of the drillhole is small. In five 1-2 m wide zones the banding shows a 20-50° discrepancy from the foliation indicating smaller scale folding than shown by Olesen et al. (1992a), Fig. 16. The existence of this larger scale folding may, however, be correct for the SF in the Masi area 20 km to the north where much of the mapping was carried out by Professor Christopher Talbot.

3.2 Precision levelling

Fig. 1 shows the annual average change in elevation of benchmarks in relation to mean sea level. These data are based on precision levelling in 1954 and later in 1975 along the old road from Alta to Kautokeino (Sørensen et al. 1987, P. Skjøthaug pers. comm. 1991) and show a significant deviation from the general postglacial upheaval of Fennoscandia. We observe a subsidence of the inland area which contradicts the assumed increasing uplift from approximately 2 mm/year in Alta to approximately 5 mm/year in Kautokeino (e.g. Bakkelid 1992). From Fig. 1, one should also note that the Alta-Kautokeino levelling profile approaches the Stuoragurra Fault when moving to the south, and thus indicates that it is the foot-wall block of the Stuoragurra Fault that is being depressed rather than the hanging-wall block being uplifted. Repeated precision levelling across the Stuoragurra Fault 3 km to the north of Masi (Fig. 1) in 1987 and 1991 has revealed a relative depression of the foot-wall block of 2.3 mm (Olesen et al. 1992b). This gives an annual average of 0.6 mm which is in the same order of magnitude as the annual depression of 0.5 mm observed along the Alta-Kautokeino levelling profile at the eastern shore of Biggejav'ri 2 km to the west of the Stuoragurra Fault (Fig. 1).

During Quaternary geological mapping in the Iešjav'ri area, at least one submerged shoreline has been observed at the southern margin of this lake (Fig. 1). The shoreline is located roughly a few dm below the present water-level, and we think that this indicates that a vertical crustal movement with a N-S gradient opposite to that of the general postglacial rebound has occurred during the last few hundred years. This observation is consistent with the previously mentioned precision levelling profile from Alta to Kautokeino (Sørensen et al. 1987).

To study this land uplift pattern further, 15 km of this profile was relevelled during the period 25.08 - 03.09.1992 by the Norwegian Mapping Authority (see Appendix). As a result of these relevelling measurements, it was found that no significant movement (neither uplift nor subsidence) could be detected along the whole of this profile during the last 18 years. There are two possible explanations of these observations:

1) There is a systematic error in the measurements from 1954.

2) The subsidence varies with time.

Changes in the direction of neotectonic movements with time have been reported from Yrkje, southwest Norway (Anundsen 1989) and Vänern, southern Sweden (H. Henkel, pers. comm. 1992). It is also hard to believe that a systematic error in the measurements could have caused the observed consistent pattern of subsidence (Fig. 6) when we take into account that the profile has been levelled in both directions.

Locally, there is a statistically significant movement of 3.4 mm from 1974 to 1992 between the two benchmarks, U07N0002 and U07N0003, which are located in the foot-wall block of the Stuoragurra Fault. The latter benchmark is situated adjacent to the fault escarpment (see Appendix). This location may be a little inaccurate because the benchmark is transferred from a 1:100,000 scale map to the 1:50,000 scale map (L. Grimstveit, pers comm. 1992). The exact location should be checked in the field. A 1 mm inaccuracy of the plotting on the original 1:100,000 scale map could imply that this benchmark is situated in the hanging-wall block of the SF.

4 RECOMMENDATIONS FOR FURTHER WORK

To check if there is a variation in subsidence with time, we recommend that a systematic mapping of the shore-lines around the lake Iešjav'ri is carried out. The size of this lake (approximately 10 x 10 km) should make it possible to check where the subsequent older shore-lines are being drowned or exposed on land. From this pattern we can deduce which way the area is actually being tilted. This work can be carried out by one of the present authors (LO) who has already mapped the area on a regional scale.

Four kilometres to the southwest of Masi (UTM coord. 601800 - 7703650), an approximately 1.0 m high, cone-shaped structure with a 0.8 m deep central depression occurs in a glacial deposit (Fig. 7). The outer diameter of the structure is 11 m and the diameter of the central rim is 5 m (Olesen 1991). This structure may represent disturbances in waterlain sediments (Lagerbäck 1990) induced by seismicity during the formation of the SF. To explore this possibility we recommend to excavate the structure to map the internal structure.

We do also think that the 135 m deep drillhole will be useful for further geological and geophysical studies of the Stuoragurra Fault; for instance mineralogical studies of fault rocks and *in situ* stress measurements (contact is already established with Professors Ellen Roaldseth, Kåre Rokoengen and Arne Myrvang at NTH for discussion of collaboration).

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Fig. 2. Oblique aerial photographs of the drilling site looking NE and SSE, respectively. The location is shown in Fig. 1. A) The SF starts immediately to the north of the road and continues down to the lake where it steps from the left-hand side to the right-hand side of the lake. It continues further across an upheaval in the terrain where the drillholes have been located (indicated by the white arrow). Further to the north the escarpment can be traced on the northern side of a lake. Precision levelling is carried out along the road in the foreground. B) The fault escarpment cuts obliquely across the photograph from left to right. The Fidnajåkka river is located in the background.

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Fig. 6. Difference in elevation (filled squares) along relevelled profile in 1975 relative to levelling in 1954 (provided by P. Skjøthaug, Norwegian Mapping Authority). The profile is located between Masijåkka and Mierujav'ri.

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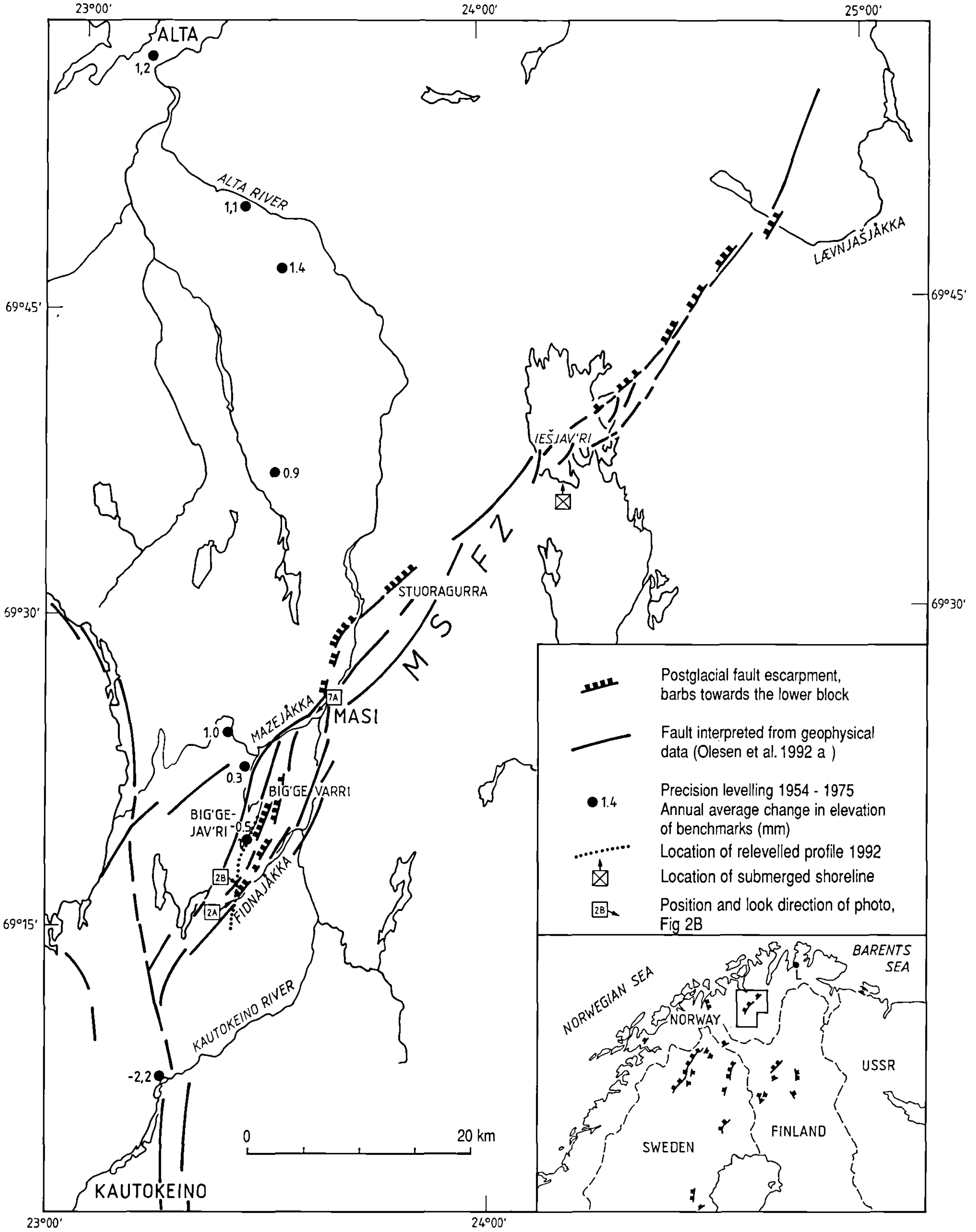

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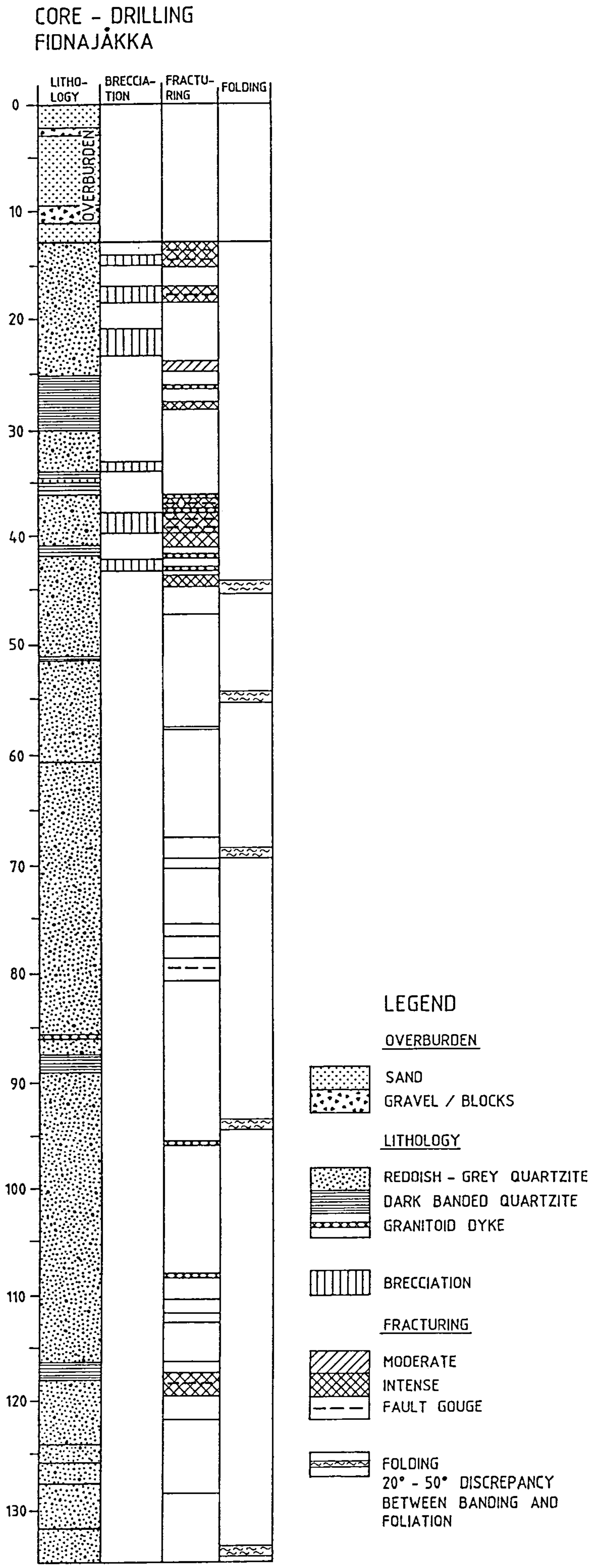
A

B

Fig. 2. Oblique aerial photographs of the drilling site looking NE and SSE, respectively. The location is shown in Fig. 1. A) The SF starts immediately to the north of the road and continues down to the lake where it steps from the left-hand side to the right-hand side of the lake. It continues further across an upheaval in the terrain where the drillholes have been located (indicated by the white arrow). Further to the north the escarpment can be traced on the northern side of a lake. Precision levelling is carried out along the road in the foreground. B) The fault escarpment cuts obliquely across the photograph from left to right. The Fidnajåkka river is located in the background.



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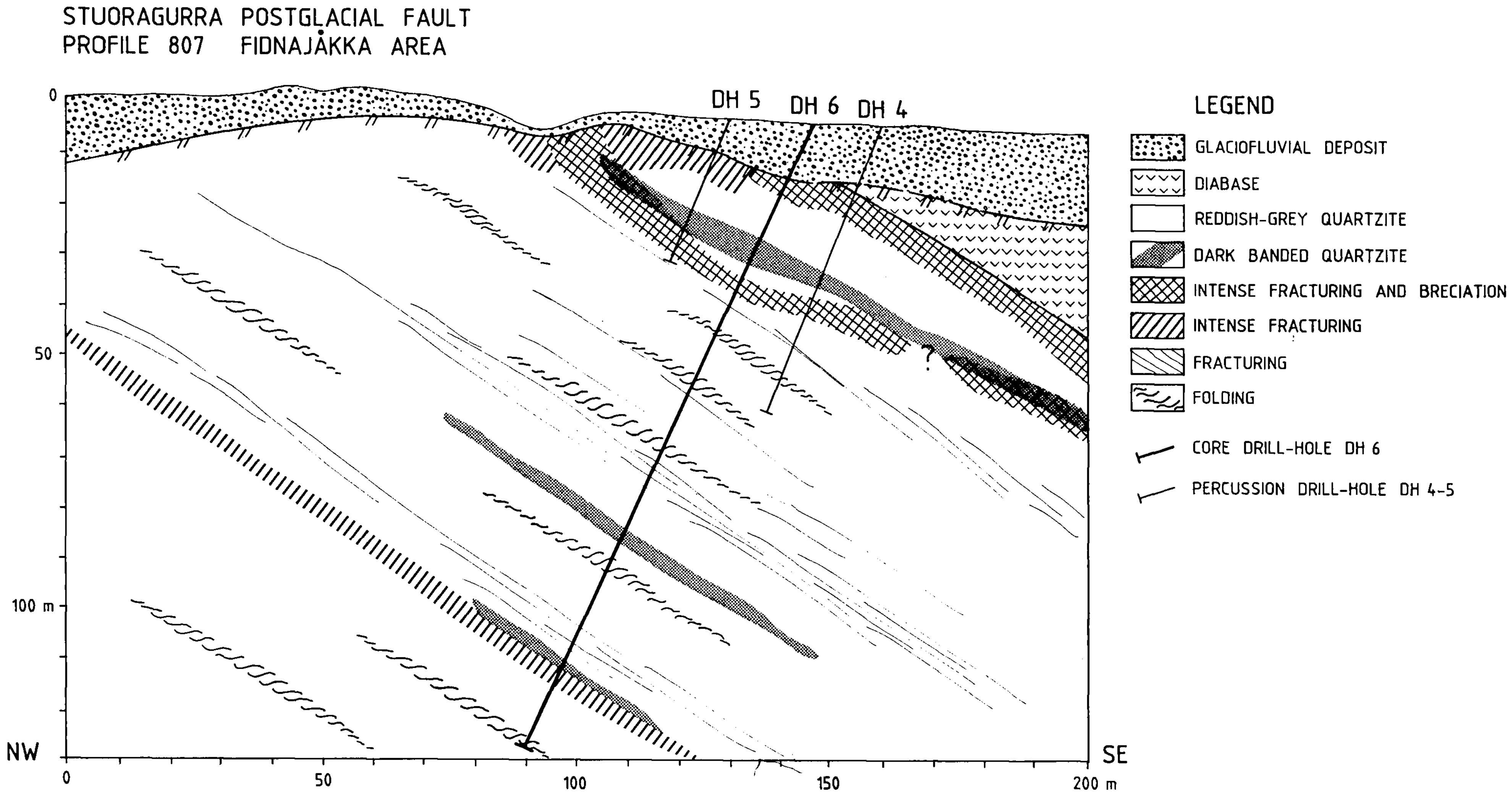

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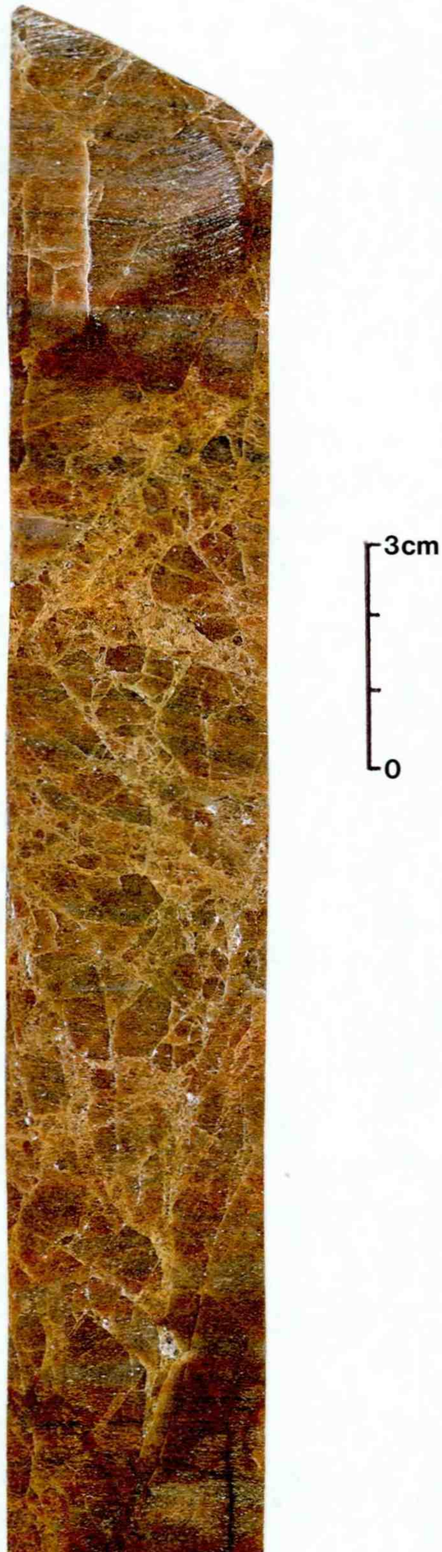

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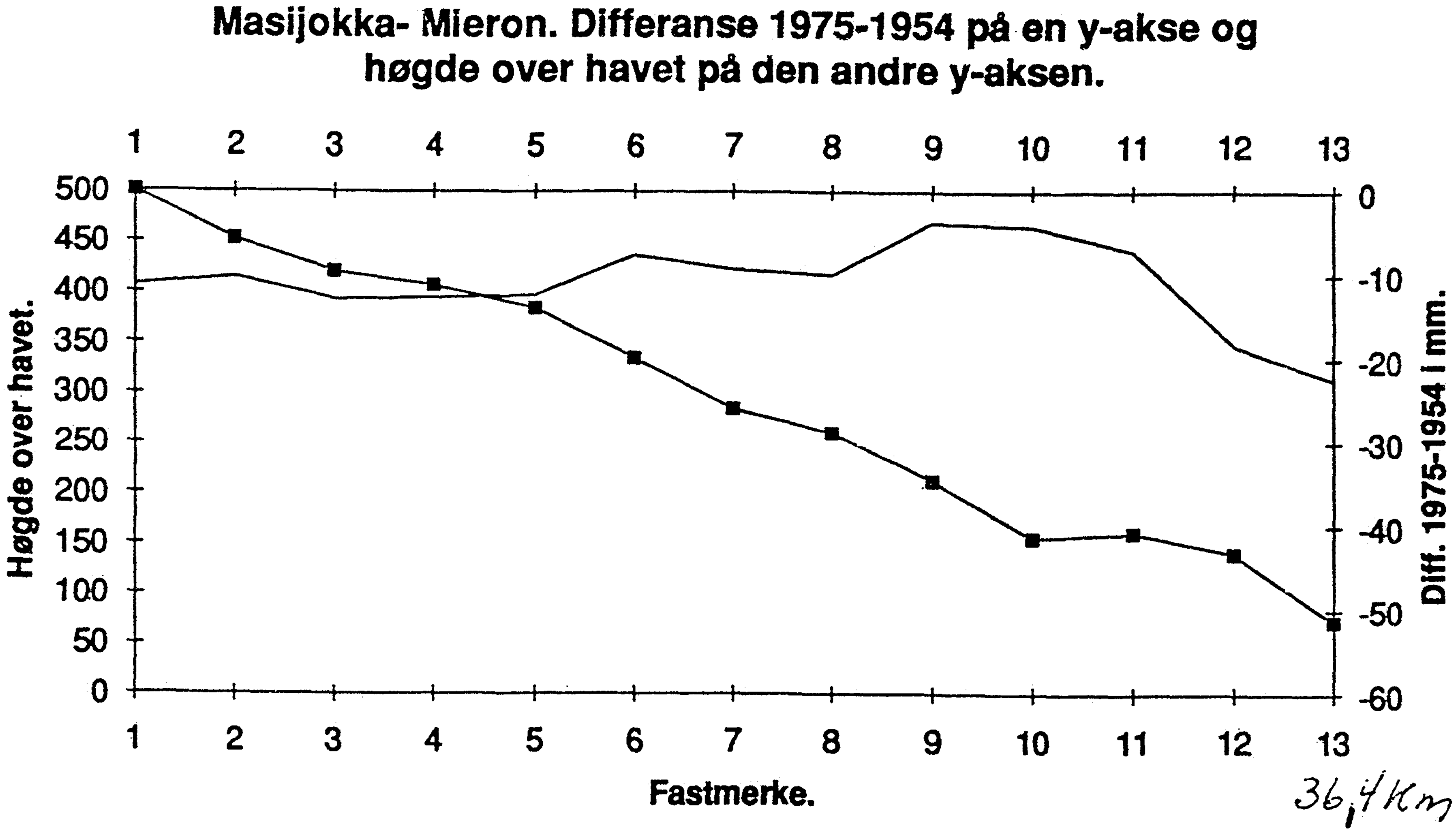

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A

B

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Appendix

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Deres ref.:	Vår ref.:	Dato:
J.nr. 2818/92 Kart HH/OO/ta Ark. 61.2583.11	2524/92 612.6 LG:GG	23.10.92

RENIVELLERING BIGGEJÁVRI - OMRÅDET

Vi har i tiden 25.08. - 03.09.1992 renivellert en strekning på ca. 15 km langs den gamle riksveien mellom Suoluvuobmi og Mieron. Jfr. Deres ref. Det nordligste fastmerket vi målte til, ligger ved nordre del av Biggejávri, det sørligste i veikryss rett vest for Rássegálvárri. (Skrivemåter i samsvar med Det store Norges-atlas, fra Hjemmets Bokforlag/Statens kartverk 1992) Se kartskisse vedlegg 1.

Analyse av høydeforskjeller som er målt tre eller flere ganger, kan gjøres ved å sammenlikne hvert nivellement med det som ligger nærmest foran i tid, eller ved å sammenlikne hvert av de senere nivellementene med det første. Resultatene av disse to analysemåtene kan bli motstridende, men med bare tre måleomganger tillater vi oss å betrakte endringene "etappevis". Se vedlegg 2 og 3. Mer avansert analyse vil kreve både separate og samlete utjevninger, vi får så overbevisende resultater ved enkel analyse at finere metoder synes overflødige.

I vedlegg 2 og 3 har vi gitt foreløpige analyser. Mulige forbedringer vil ikke bestå i utjevninger, som nettopp nevnt, men hensyn til stangkorreksjoner for målingene 1992, som ennå ikke foreligger. Videre er det mulig å granske målingene enda nøyere, ved å undersøke hver enkelt stangoppstilling, i tillegg til strekningene mellom fastmerkene.

Faktura kr 50.000,- sendes separat. Vi regner ikke moms på beløpet.

Med hilsen

John Sundsby — Leif Grimstveit

John Sundsby — Leif Grimstveit

Vedlegg	1:	Kart over målt strekning 1992
"	2:	Forandringer 1954-1974
"	3:	Forandringer 1974-1992

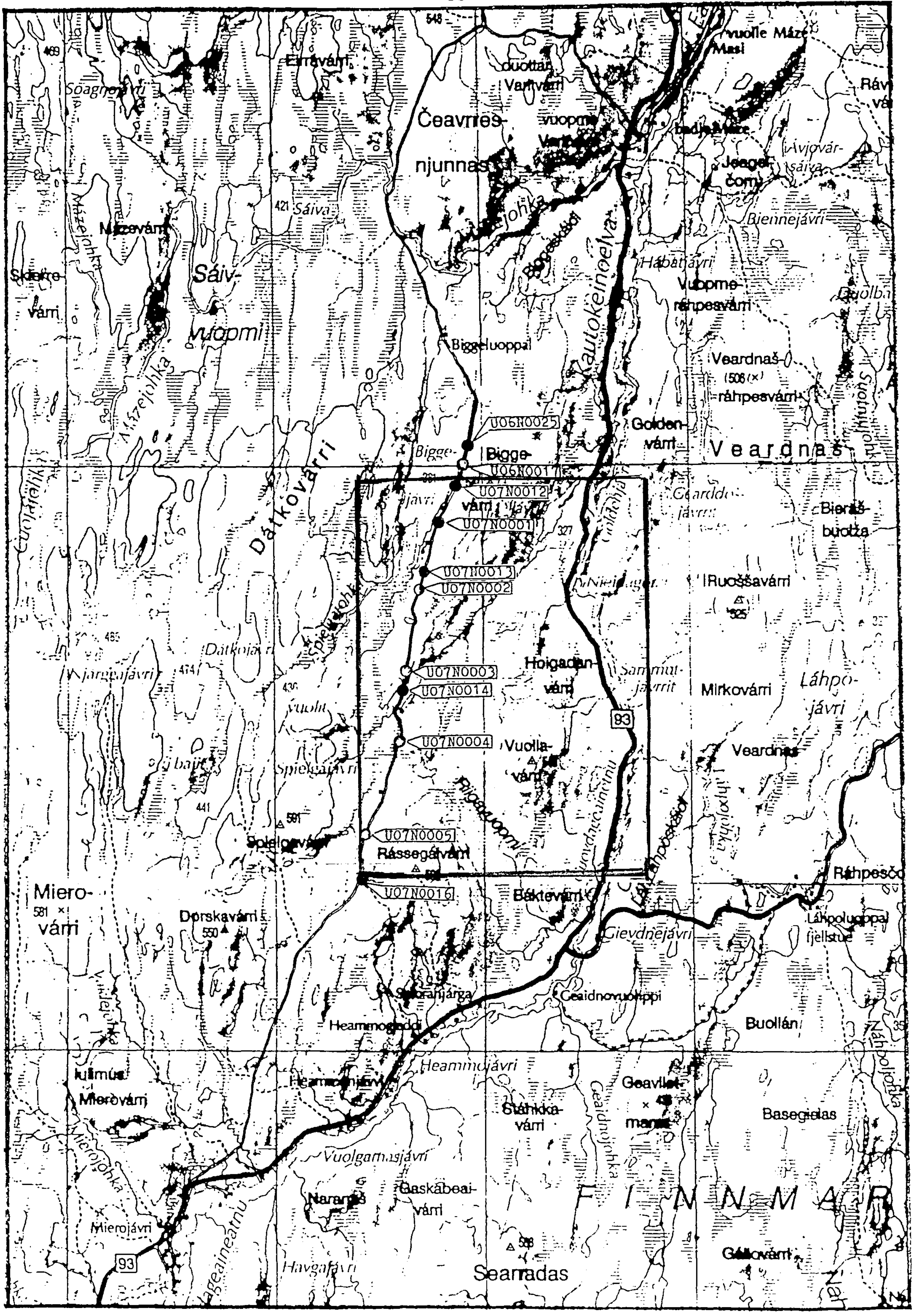
er da altfor stor i tallverdi til å kunne forklares ved tilfeldige variasjoner i målingene. Konklusjonen blir at vi har hatt systematiske innflytelser.

Presisjonsnivellementet kontrolleres ved sammenlikning mellom målinger fram og tilbake mellom fastmerkene, og disse kontrollene stemmer utmerket. Det ser dermed ut til at det har vært en nedsynkning av terrenget sørover fra Biggejavri mot Miron fra 1954 til 1974, sterkere jo lenger sør en kommer.

Vi hadde vært mer overbevist dersom alle fastmerkene hadde stått i fjell. Men en utvikling der store steiner synker stadig dypere i forhold til omliggende terreng jo lenger sør en kommer, er lite sannsynlig.

Vedlegg 1: Kart over målt strekning 1992

(Fellespunkter med tidligere nivellementer)
Innrammet område er vist i vedlegg 4.



Vedlegg 2: Forandringer av nivellerte høydeforskjeller mellom Biggejávri og Mieron, fra 1954 til 1974

Symbol ● = fastmerke i fjell

Symbol o = fastmerke i jordfast stein

Symbol ◐ = fastmerke i fjell eller jordfast stein

Fastmerke	Nivellert høydeforskjell 1954	Nivellert høydeforskjell 1974	Tilsynelatende endring 1954-1974	Avstand
● U07N0001				
	+39.4332 m	+39.4273 m	-5.9 mm	2.20 km
◐ U07N0002				
	-13.4755	-13.4811	-5.6	2.72
o U07N0003				
	-5.1645	-5.1678	-3.3	2.62
o U07N0004				
	+51.2952	+51.2895	-5.7	3.37
o U07N0005				
	-3.3061	-3.3128	-6.7	3.30
o U07N0006				
	-24.7015	-24.7009	+0.6	2.53
o U07N0007				
	-93.2557	-93.2583	-2.6	5.27
o U07N0009				
	-34.5166	-34.5247	(-8.1)	3.06
o U07N0010				
	+33.2109	+33.2188	(+7.9)	3.09
o U07N0011				

Foreløpig analyse

Vi er mest interessert i strekningen mellom fastmerkene 1 og 5, fordi bare denne ble nivellert også i 1992. Men pga. den tydelige tendensen i endringene, og fordi fastmerkene står i steiner, fortsetter vi sammenlikningen sørover så langt nivellementene går med felles fastmerker.

De to nederste endringene har vi satt i parentes, fordi de er nær like store og har motsatt fortegn. Dette indikerer at fastmerke 10 har sunket lokalt, dvs. i forhold til fastmerkene 9 og 11.

De 7 endringene som da står igjen, viser en markert systematisk tendens idet bare en av dem er positiv, og den er i tillegg liten. Hadde målingene vært tilfeldig fordelt, skulle vi ventet noenlunde like mange + som -. Videre er summen av de 7 endringene -29,2 mm, over en strekning på 22 km. Forventet standardavvik for summen av endringene er $1 \text{ mm} \cdot \sqrt{22} = 4.7$ mm. Summen av endringene

Vedlegg 3: **Forandringer av nivellerte høydeforskjeller mellom Biggejávri og Rássegálvárri, fra 1974 til 1992.**

Symbol ● = fastmerke i fjell

Symbol o = fastmerke i jordfast stein

Symbol ◐ = fastmerke i fjell eller jordfast stein

Fastmerke	Nivellert høydeforskjell 1974	Nivellert høydeforskjell 1992	Tilsynelatende endring 1974-1992	Avstand
●U06N0025				
	+11.6332 m	+11.6362 m	+3.0 mm	1.41 km
●U07N0012				
	-1.2676	-1.2710	-3.4	1.56
●U07N0001				
	+28.2427	+28.2438	+1.1	1.69
●U07N0013				
	+11.1846	+11.1847	+0.1	0.58
oU07N0002				
	-13.4811	-13.4777	+3.4	2.71
oU07N0003				
	+2.2904	+2.2908	+0.4	0.81
●U07N0014				
	+59.2896	+59.2905	+0.9	6.0
●U07N0016				

Foreløpig analyse

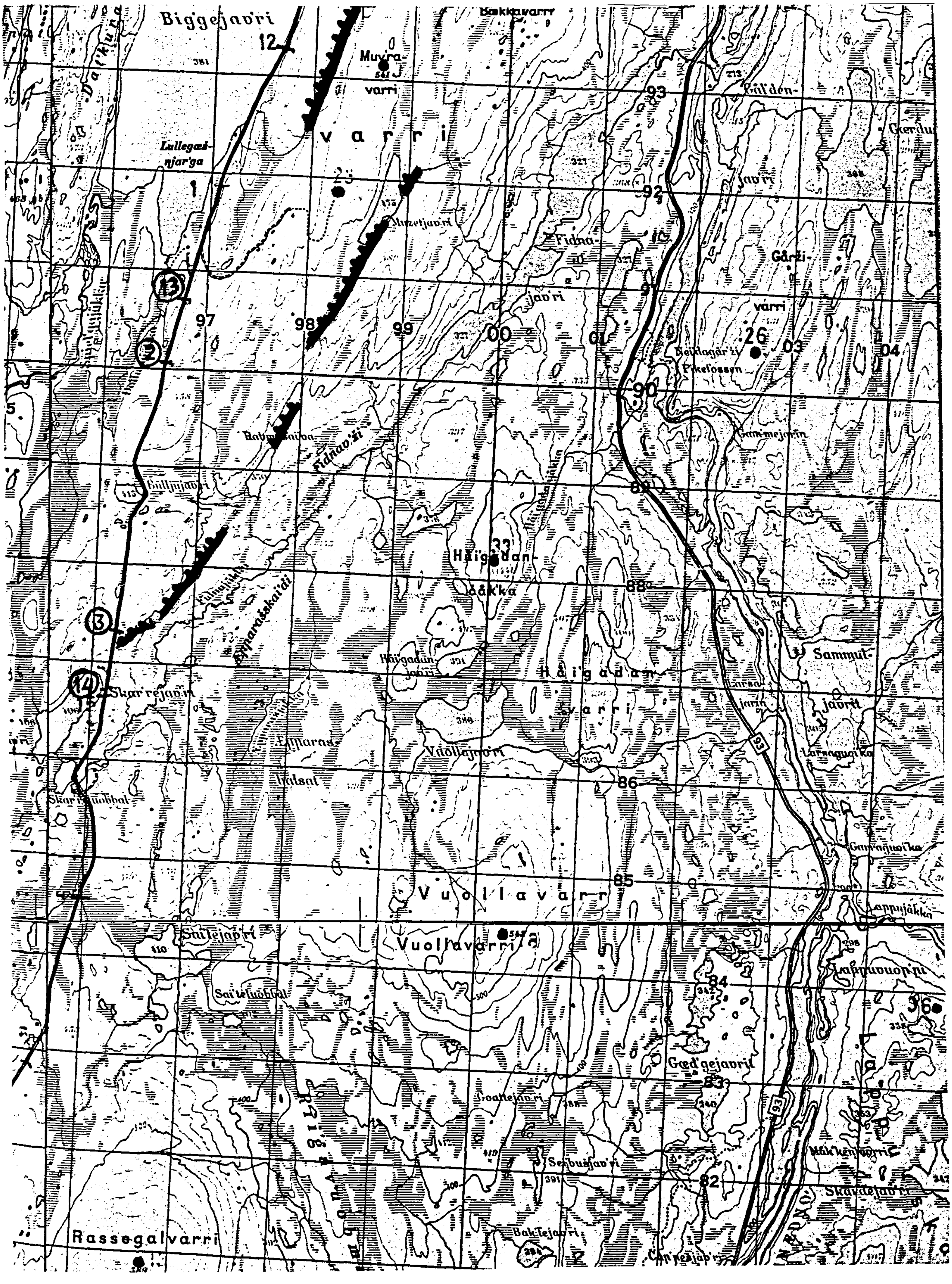
Summen av endringene er +5.5 mm, over en strekning på 14.8 km. Standardavviket for summen er $1\ \text{mm} \cdot \sqrt{14.8} = 3.85$ mm. Konklusjonen blir at summen av endringene ikke er signifikant på 95% - eller 97.5%-nivå. Annerledes uttrykt: Det er mindre enn 5% hhv. 2,5% sannsynlighet for at en konklusjon om ingen høydeendring er feil.

Mellom fastmerkene 2 og 3 er endringen signifikant på 95%-nivå, men ingen av dem står med sikkerhet i fast fjell.

Når vi trekker inn konfidensnivåer, forutsetter vi strengt tatt at målingene er normalfordelte. Dette er ikke testet, fordi antall målinger er lite.

Vedlegg 4: Kart over fastmerker.

Utsnitt av 1:50.000 kartbladene 1933 IV Masi og 1933 III Lappuluobbal. Stuoragurraforkastningen er vist med tykk linje. Tagger peker mot den nedforkastete blokken. Beliggenheten av kartet er vist i vedlegg 1.

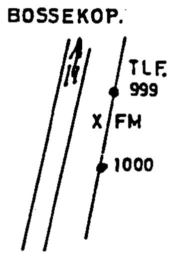


Vedlegg 5: Beskrivelse av fastpunkter.

Norges geografiske oppmåling — Presisjon

Beskrivelse:

I fjellnase (eller stor stein) 13 m ö. ö. veikant og 3 m over veibanen. Mellom tlf.st. 999 og 1000. Ca. 60 m nord topp av bakken i veien 1,1 km nord större tjern.



Fylke: Finnmark
Herred: Kautokeino
Kart:
Fastmerkemodell:
Nivellert år: bok III/
Nivellementsprotokoll nr. 4 side 168
Funnet igjen år:
Ødelagt år:
Nytt merke innsatt år: av

Merknad:

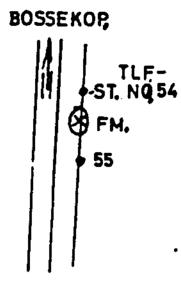
N.G.O. Akse VII
X = 1234083,345
Y = -69016,368.

U 7 N 2	Foreløbig høyde: 436.084	Endelig høyde:

Norges geografiske oppmåling — Presisjon

Beskrivelse:

I mellomstor nokså jordfast stein 12 m ö. ö. veikant og omtrent i höyde med denne. Mellom tlf.st. 54 og 55. 400 m n. n. ende av det nordl. av to vann.



Fylke: Finnmark
Herred: Kautokeino
Kart:
Fastmerkemodell:
Nivellert år: bok III/
Nivellementsprotokoll nr. 4 side 168
Funnet igjen år:
Ødelagt år:
Nytt merke innsatt år: av

Merknad:

U 7 N 3	Foreløbig høyde: 422.609	Endelig høyde:

Norges geografiske oppmåling — Presisjo

Beskrivelse:

F.M. står i fjell 35 m öst for veien og 2 m over veien. F.M. står ca. 60 m sör for förste bakketopp, sör for Biggajavve. F.M. står ca. 30m öst for tlf.stolpe 989.

Fylke: Finnmark
Herred: Kautokeino
Kart:
Fastmerkemodell: F
Nivellert år: 1974-75 bok III/
Nivellementsprotokoll nr. side 74
Funnet igjen år:
Ikke funnet igjen år:
Ødelagt år:
Nytt merke innsatt år: av

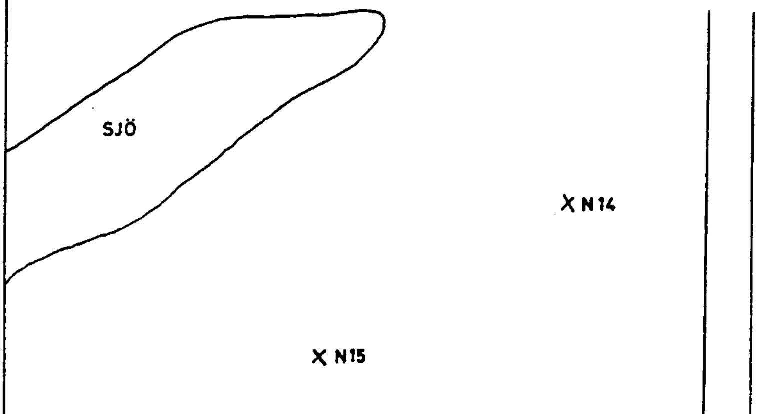
Merknad:

U7 N13	Foreløpig høyde:	Endelig høyde: 424

Norges geografiske oppmåling — Presisjo

Beskrivelse:

F.M. står i fjell 5 m vest for kanten og ? m over veien. På toppen av bakke like sör for der veien heller nordover. F.M. står ca. 200 m sör for nordenden av vatn vest for veien.



Fylke: Finnmark
Herred: Kautokeino
Kart:
Fastmerkemodell: G
Nivellert år: 1974-75 bok III/
Nivellementsprotokoll nr. 7 side 76
Funnet igjen år:
Ikke funnet igjen år:
Ødelagt år:
Nytt merke innsatt år: av

Merknad:

U7 N14	Foreløpig høyde:	Endelig høyde: 424.