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Neotectonics in northern Sweden – geological investigations

R Lagerbäck
F Witschard

Geological Survey of Sweden
May 1983

SVENSK KÄRNBRÄNSLEFÖRSÖRJNING AB / AVDELNING KBS

POSTADRESS: Box 5864, 102 48 Stockholm, Telefon 08-67 95 40

NEOTECTONICS IN NORTHERN SWEDEN - GEOLOGICAL INVESTIGATIONS

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This report concerns a study which was conducted for PRAV and SKBF/KBS. The conclusions and viewpoints presented in the report are those of the author(s) and do not necessarily coincide with those of the client.

A list of other reports published in this series during 1983 is attached at the end of this report. Information on KBS technical reports from 1977-1978 (TR 121), 1979 (TR 79-28), 1980 (TR 80-26), 1981 (TR 81-17) and 1982 (TR 82-28) is available through SKBF/KBS.

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ABSTRACT

Fairly large areas around the formerly known quaternary faults have been air photo interpreted. The former picture of the faults has thus been complemented in a few significant respects. The fault known as the Pärvie fault has been found to extend somewhat further towards the south, thereby crossing the valley of the Stora Lule river. Furthermore, another fault has been discovered in the Lansjärv region, and thus the faults in this area form a better fit to the regional pattern, with a SSW - NNE trend and a relative uplift of the eastern part.

The fault scarps have been leveled photogrammetrically, and reproduced on maps on the scales of 1:50 000 and 1:100 000, and on overview maps on the scale of 1:250 000. The highest leveled scarps somewhat exceed 30 m. The total length of the faults is roughly 300 km.

During the air photo interpretation, several landslides have been detected, and it seems evident from their location that there is a causal connection between faults and landslides.

As far as possible, the age of the faults relative to the deglaciation has been estimated. The former opinion, that the faults have formed in connection with the deglaciation, has been supported. However, it seems evident that the different faults are not simultaneously formed, but created at separate events. This may also be the case for the different parts of the faults.

Most of the outcrops along the fault zones have been visited in the field, and investigated regarding rock types and tectonic influence. Representative samples have been collected, and thin sections of these investigated under the microscope. Often, the bedrock shows signs of older tectonic influence, and it seems that the faults largely have been released along existing zones of weakness in the bedrock. However, striking exceptions, with fracturing through unaltered rock, have been found in several places.

The faults illustrated in the maps below undoubtedly represent the most important signs of late quaternary fault activity in Norrbotten east of the Caledonian mountains. Further and more exhaustive investigation will hardly change this perception in any essential way. Certainly, minor faults of small scarp height may have escaped detection, but it is unlikely that any major faults have been overlooked.

Neither will the picture of the distribution of the landslides change significantly. The geographic, and very probably also causal connection between faults and landslides seems obvious in both Finland and Sweden.

The matter of the geographic distribution, appearance, and age of the faults may for the time being be regarded as sufficiently illustrated, and it is about time that other aspects of the phenomenon are dealt with. Among these are the connection between the shape of the faults and the qualities of the bedrock, petrographic as well as physical. We need a satisfactory tectonic explanation for the faults. Undoubtedly, the glacial - isostatic forces have a central role, but in what way, and why just in this region? What role do plate-tectonic processes play? The strike of the faults is approximately perpendicular to the direction of plate motion, and compressive forces have acted at the formation of the faults.

To settle these matters, further work is required, including documentation and compilation of the pre-quaternary geology, extended and detailed aeromagnetic interpretation, reconstruction of the process of deglaciation, tectonic analysis, and model computation. The essential work encompasses a wide variety of sciences, and to be successful, the further investigation must be conducted in a truly interdisciplinary spirit.

INTRODUCTION

The present report consists of two separate parts, a quaternary geological, and a pre-quaternary geological documentation of quaternary faults in Norrbotten. The work is part of a documentation program that also includes ground- and aerogeophysical investigation.

State geologist Robert Lagerbäck and ing. Jan-Erik Wahlroos, who has made the photogrammetric measurements and most of the draftwork, answer for the quaternary items. The hard-rock documentation is made by 1.st state geologist Fred Witschard.

In the the report, mainly the results of the documentation are accounted. Attempts at explanation of causes and mechanisms will have to wait until also the geophysical items are completed. It should also be strongly emphasized, that the project, in its present scope, is but a first, probing investigation. More exhaustive explanation of the phenomenon can hardly be expected until after several years of study, including extended quaternary geological, hard-rock geological, and geophysical investigations, and, not least, tectonic analysis. The principal aim of this project is to formulate an outline for the further work.

The quaternary faults in Norrbotten have previously been only roughly investigated, mainly by a very quick air photo interpretation, a limited ground reconnaissance, and a rough aeromagnetic interpretation. The results of these earlier investigations will not be repeated in this report. The reader is referred to Lundquist and Lagerbäck, 1976, Lagerbäck and Henkel, 1977, and Lagerbäck, 1978.

A primary aim of the quaternary documentation has been to investigate whether other faults than those previously known occur in the area. To facilitate a tectonic analysis, the geographic appearance and the scarp heights have been documented better than previously. To make possible an estimation of the age of the faults, a more thorough investigation of their relation to the quaternary deposit and to the deglaciation has been made.

Fairly large areas around the faults have been air photo interpreted in search for possible secondary effects of the fault movements, e.g. landslides of the kind known from Finland. In addition to the original plan, the highest shoreline levels have been estimated within a relatively large area in the Lansjärv region. The purpose was to investigate if the faults can be connected to some anomaly of the total postglacial uplift in the area.

For the work, a lot of data, that was produced for other projects, above all the Nordkalott project and quaternary work connected to different prospecting commissions, have been used. Without the access to this material, the work performed would not have been feasible with the funds available for the project.

The hard-rock geological documentation comprises field inspection of most outcrops in the fault zones, and sampling and microscopic analysis of rocks from these. The aim has been to gather an opinion of the tectonics of the quaternary fault movements, and to investigate to what extent the rock in the fault zones is affected by earlier tectonic influence, i.e. to what extent the quaternary movements have been released along existing zones of weakness.

Very preliminary comparisons with the existing geologic map of the pre-quaternary of the Norrbotten district, with published Af-series maps, and with unpublished map material, show that the faults fairly often seem to coincide with the boundaries between different rocks or rock types, and that they often follow regional geologic structures, e.g. in gneissose rocks. At several places, the faults end at the rock contacts, whereas in other cases they are more or less undisturbed by the crossing of contacts.

However, the economic scope of the project has not allowed documentation of the bedrock outside of the fault zones, and geological maps to a scale greater than 1:400 000 lack for the major part of the area in question. Hence, the matter of in what way the faults are influenced and directed by geologic conditions largely must wait until the bedrock of the district is better mapped out, or until means are set aside for a compilation of existing unpublished map material and for complementary mapping in the vicinity of the faults.

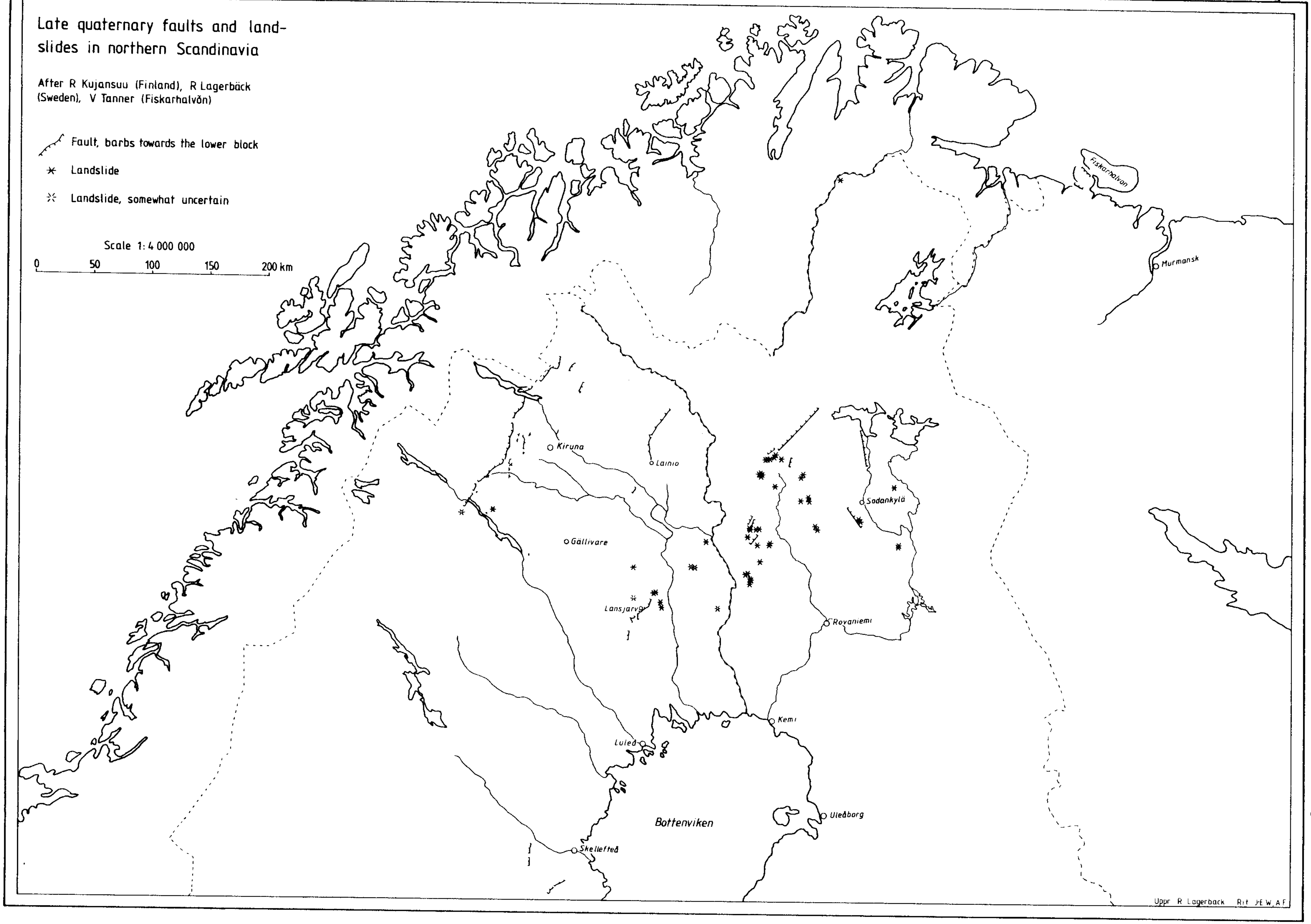
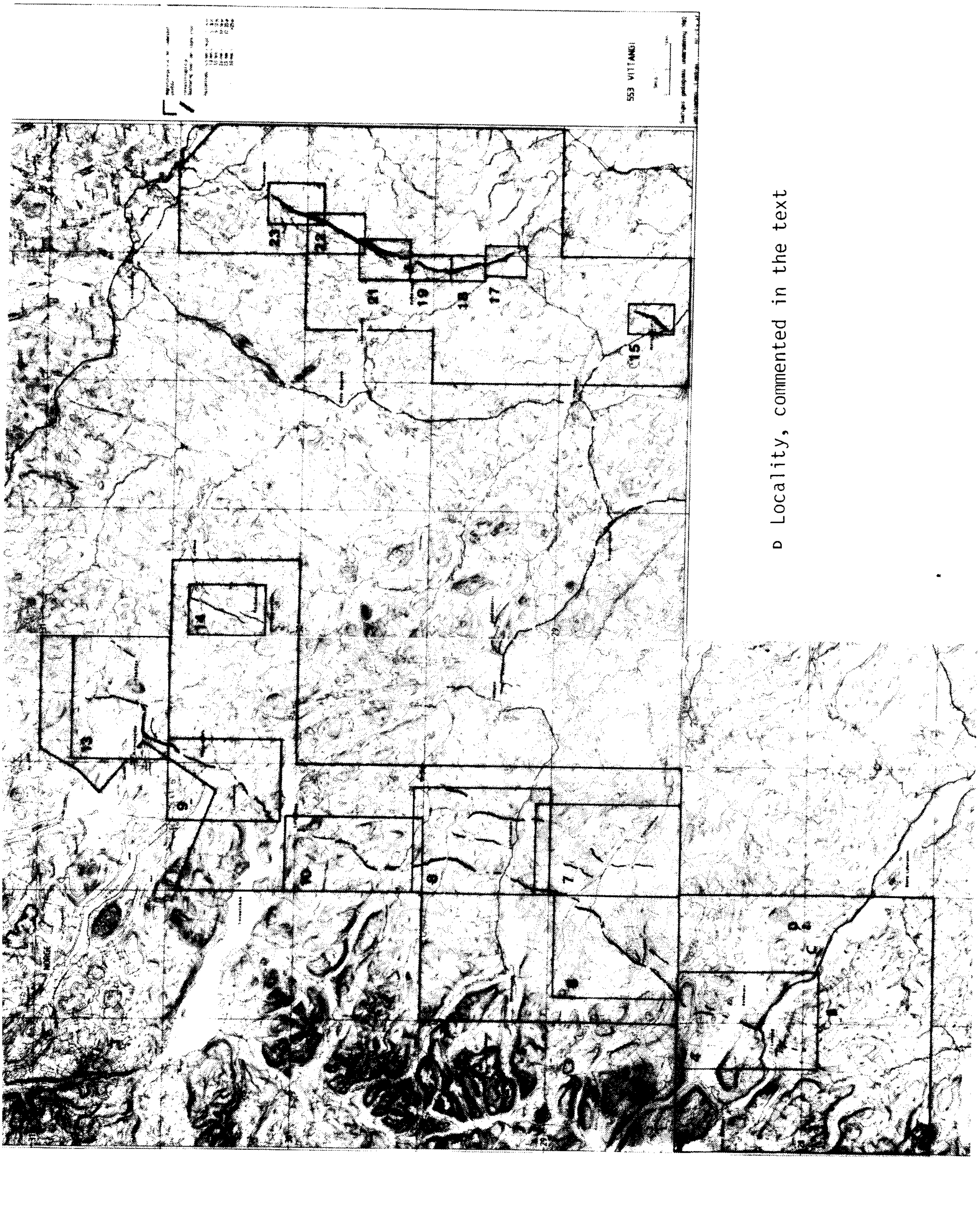

Late quaternary faults and landslides in northern Scandinavia
After R Kujansuu (Finland), R Lagerbäck (Sweden), V Tanner (Fiskarhalvön)
Fault, barbs towards the lower block
Landslide
Landslide, somewhat uncertain
Scale 1: 4 000 000
0
50
100
150
200 km
Fiskarhalvön
Murmansk
Kiruna
Lainio
Sodankylä
Gällivare
Lansjärv
Rovaniemi
Kemi
Luleå
Bottenviken
Uleåborg
Skellefteå
Uppr R Lagerbäck Rit J-E W, A F

Figure 1.

Figure 2. Location of investigated areas.

4 Refer to figure 4.



D Locality, commented in the text

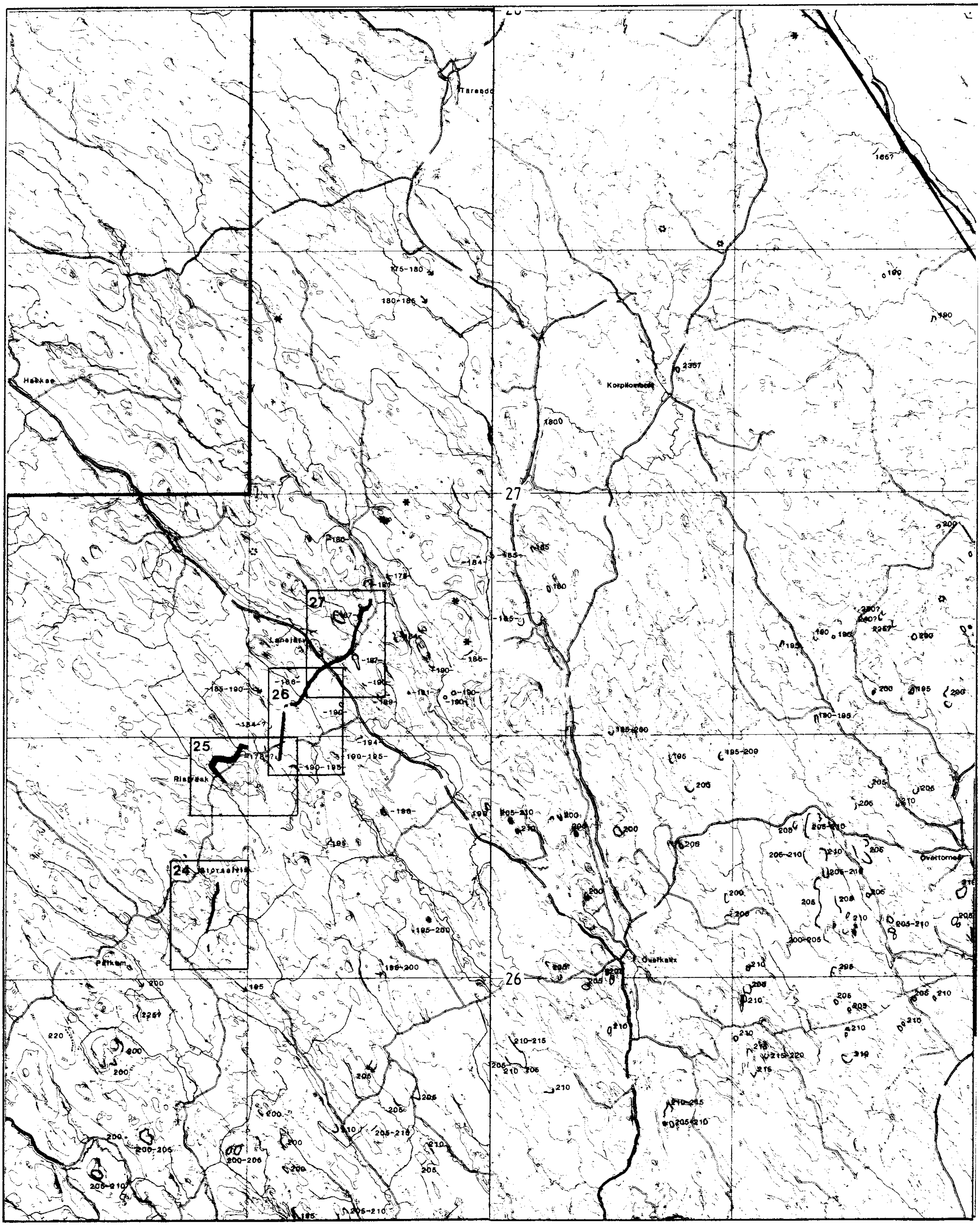


Figure 3. Faults, landslides and shorelines in the Lansjärv region.
Fault * landslide ○ landslide, less certain ⌐210 shoreline level

1. QUATERNARY DOCUMENTATION

1.1 Results from the air photo interpretation

The quaternary faults in Norrbotten have previously been only roughly investigated, by air photo interpretation and by limited field reconnaissance. The air photo interpretation in search for the faults was made very quickly, and partly from a material of very low quality.

For this reason, large areas around known faults have been re-surveyed by air photo interpretation. The area investigated equals about 9 map areas, or 22 500 square kilometers. The extent and the location of these areas are shown in figures 2 and 3.

The air photo interpretation was made by means of a mirror stereoscope, and, mainly, black-and-white prints on the scale of 1.20 000 (from negatives on the scale of 1:30 000) have been used. For some areas, high altitude photograps (scale 1:60 000) in false-colour infrared have been used in parallel with the B & W photos. The material has almost without exception been of high quality.

It should also be mentioned, that during the past few years, vast areas in other parts of Norrbotten have been air photo interpreted in connection with other work and hence the knowledge of the quaternary geology in the district has improved considerably.

The aim of the renewed air photo survey has been to investigate whether any faults have escaped previous detection, and to map out other relevant quaternary geology near the faults more thoroughly. Attempts have been made to date the faults relative to the quaternary deposits and to the deglaciation.

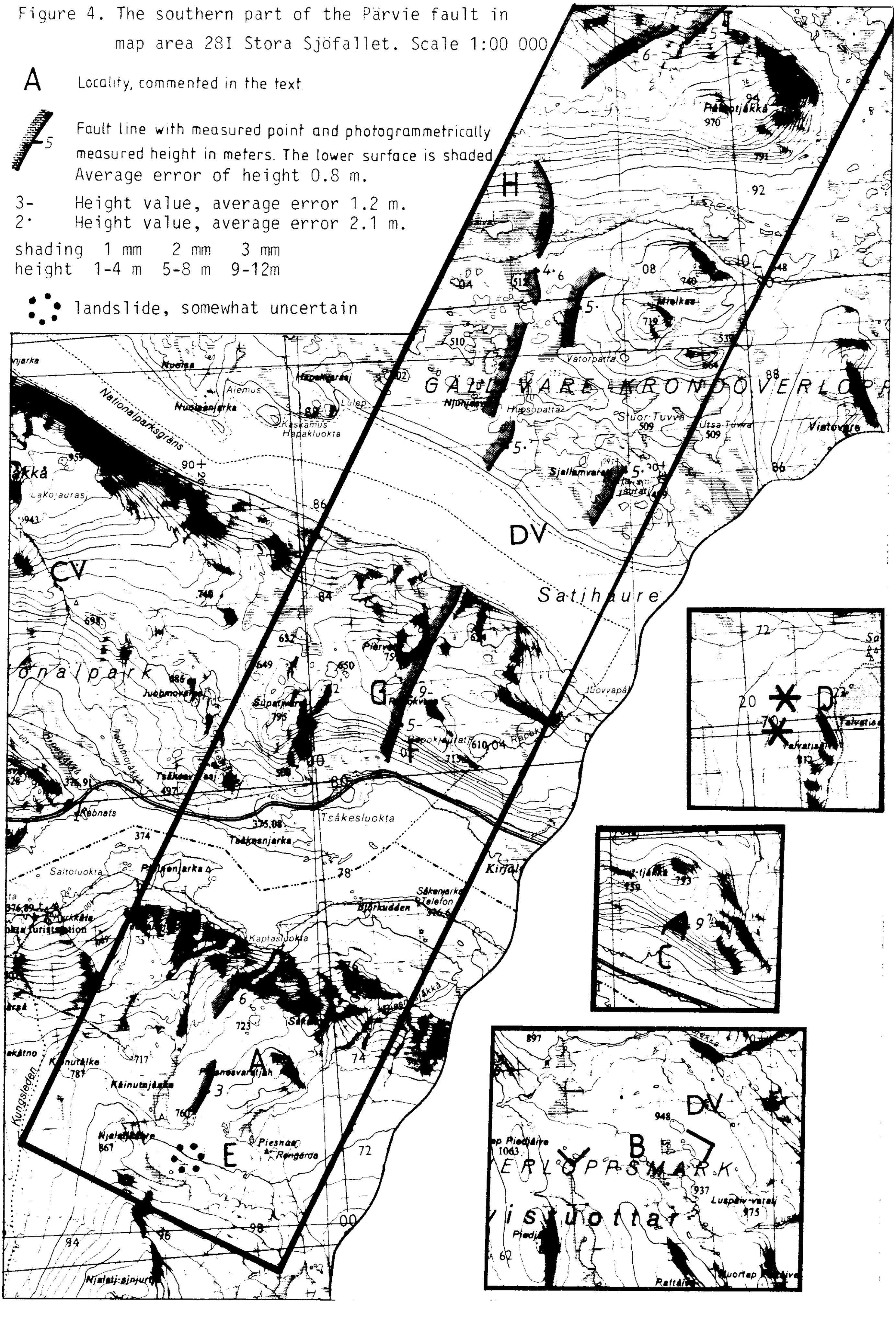
Special attention has been given to possible secondary effects of the fault movements. For instance, it is formerly known that similar faults in Finland very probably have caused a multitude of landslides.

For comparison with geophysical and geological maps, and for a tectonic analysis, the exact location of the faults is of great importance. For this reason, the geographic appearance of the faults has been more carefully documented than before, in connection with the air photo interpretation. All known faults are now marked on topographic maps on the scales 1:50 000 and 1:100 000 (figures 4,6-10,13-15,17-19,21-27). Over a smaller area within the map area 31J Råstojaure, a more detailed map has been drawn up (fig. 12).

On the above mentioned maps, also the height of the fault scarps has been marked (by shading of different width). One aim of the height measurements is to facilitate a future tectonic analysis. The methods and the accuracy of the measurements are further commented in chapter 1.3.

Below, the results of the interpretation are briefly commented. Mainly, individual sites (marked by letters in the figures) are discussed. The investigated sites are treated by map areas, starting in the southwest, that is, in the southern part of the Pärvie fault. Later in the report, a general account of the results from the interpretation will be given.

Figure 4. The southern part of the Pärvie fault in map area 28I Stora Sjöfallet. Scale 1:00 000



281 Stora Sjöfallet (figs. 2, 4). The Pärvie fault.

The entire map area has been re-interpreted. The earlier perception of the southern part of the Pärvie fault has changed in one significant point, by the discovery of two smaller faults SSW of Kaptasluokta (A 5de). The faults were discovered by geologist Lasse Rodhe in connection with mapping work, and they are undoubtedly of the same type as the other faults within the map area. Formerly, the Pärvie fault was believed to end at the lake Langas, that forms part of the Stora Lule river, but now it stands clear that it continues for some kilometers towards the southwest.

Two short, very low (about 0.5 m) and very angular faults were detected southeast of Arosjaure (B 3f) during the above mentioned mapping work. These faults differ in appearance from other faults in the map area, and it is questionable whether they are part of the Pärvie complex. They are, however, very sharp in spite of their small height, and beyond doubt post-glacially formed. Along one of the faults, a series of craters in the overburden occur. These are probably caused by the moraine sliding down a fracture in the fault zone.

At Anutjåkka (C 4h), a large section of the rock in the slope towards the Lule river has subsided about ten meters (fig. 5). The subsided part is probably located between two crossing fractures, and thus it does not represent a proper fault. The slide may have been initiated by the quake caused by the Pärvie fault. This hypothesis is supported by the proximity to two landslides at Talvatisåive (D 45i). These slides lie in a flat slope and may have been released by seismic influence.

Another slide has been observed at Njalatjkåbre (E 45de), that is, immediately to the south of the southern end of the Pärvie fault. This slide is not quite similar to the above mentioned ones, and may be caused by nivation. At the south of Rapokvare, in the slope downwards Langas (F 6e), the Pärvie fault cuts a series of glacial lake shorelines. According to unpublished research, recently made at the institution of physical geography at the university of Stockholm, it preliminarily seems that the fault has cut all but the lowest of the shorelines (docent Bo Strömberg, verbal communication). If so, this implies that the fault has developed in a probably very short time during the deglaciation of the area. This also agrees with other observations made along the fault.

Immediately to the west of Rapokvare (G 6e), the fault cuts an esker, and this, too, shows that it has formed after the local deglaciation.

2 km to the east of Svalakah (H 9f), it appears that the fault has directed the marginal glacial drainage. The relations are not quite clear, but suggest that the fault at this site may have preceded the local deglaciation.

Close to the north of Pålnotjåkka (I 9g), the fault crosses a number of minor eskers and gullies. The fault seems not to have influenced the shape of these, and hence it developed after the local deglaciation.

To sum up, it may be said that the Pärvie fault is very sharply developed throughout the map area, and its relation to the deglaciation shows that it developed in a short period during the deglaciation of the area.

Figure 5. A subsided section of the bedrock at Anutjåkka to the north of Stora Lule river (map area 28I Stora Sjöfallet). The subsided section is probably situated between two crossing fractures.

Photo: Robert Lagerbäck
The picture is inspected and admitted for publication.

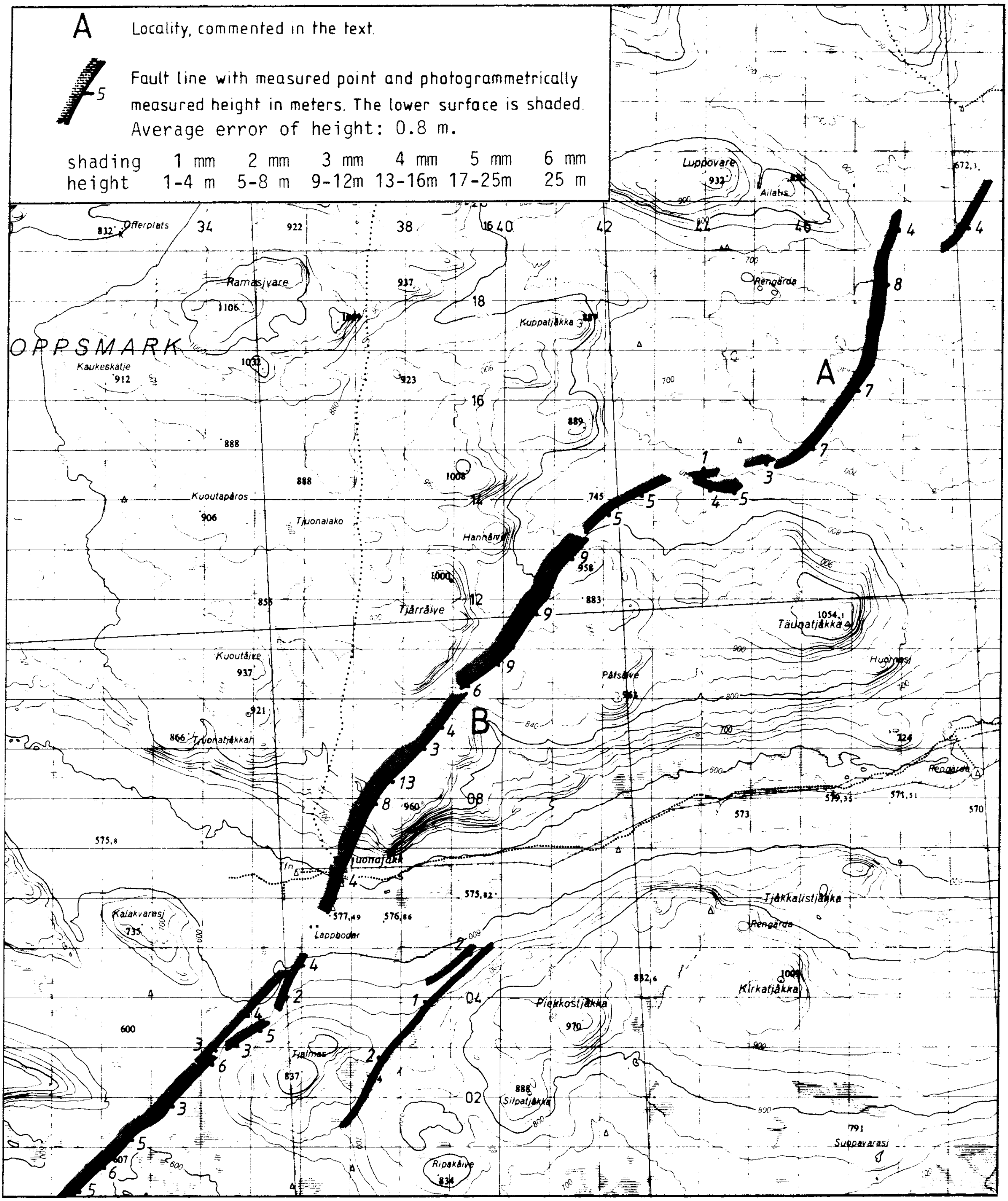
29I Kebnekaise (figs. 2,6). The Pärvie fault.

The eastern part of the map area has been re-interpreted. The former picture has not changed in any significant respect. The faults are very sharp throughout, and cut the small forms of the landscape in a marked manner. The fault east of Tjalmas, running parallel to the Pärvie fault, is very prominent in spite of its small height.

On account of the intense earth flow, the landslides that may exist within the map area are probably very difficult to detect. Small, slide-like scars occur in several places, but these are probably caused by nivation. In one, or possibly two places, the Pärvie fault can be dated relative to the local deglaciation.

4 km to the SE of Luppovare (A 3j) the fault cuts a glacial gully and thus has developed after the ice melted from the locality.

Close to the SE of Tjårråive, (B 1h), the fault is crossed by a melt-water gully, that probably is of glacial origin, in which case the fault has preceded the local deglaciation. It can, however, not be left out that the the gully may be post-glacially formed.



Scale 1:100 000

Figure 6. The Pärvie fault in map area 29I Kebnekaise.

29J Kiruna (figs. 2, 7, 8) The Pärvie fault, the Holmajärvi fault, and other parallel faults.

The western half of the map area has been interpreted. Neither here, the former picture has changed. Above all the proper Pärvie fault, but also several of the eastern parallel faults, are very sharply developed in the quaternary overburden. Particularly in the westernmost part of the map area, the earth flow is extensive, and the traces of possible landslides are probably erased.

At several localities, it has been possible to date the faults relative to the deglaciation. 2 km to the east of Lietekåbba (A 1b, fig. 7), the fault is not developed in the youngest glacifluvial gravel along the Kaitum river, whereas it is very sharp in the moraine to the south. Of course, it is not certain that the fault is developed in the valley beneath the gravel, but if so, it has preceded the final deglaciation of the area.

Five kilometers further to the north, at Tertojåkka (B 2b), the same conditions prevail. The fault cannot be traced in the valley, but is very sharp further to the north, between Hutnjos and Tjåurek. Either the fault is not developed in the valley, in which case it may be younger than the deglaciation, or in case it is covered by the youngest deposit in the valley, it is older than the deglaciation.

At Tjåurek (C 3b), the same fault is cut by a number of minor glacial river furrows, and hence formed before the local deglaciation.

The fault at Kuorpavarto appears in the southern slope of the mountain (D 3a) to be covered by ice front sediments, and is probably older than the deglaciation. The relation is not quite unambiguous, and close to the north of Kuorpavarto (E 3b), the fault clearly cuts a crossing glacial river valley, and thus at this site it is younger than the local deglaciation.

South of Saivorova (F 5c), the fault at Holmajärvi cross-cuts a glacial river valley, and there it clearly is younger than the deglaciation. From the air photos, the fault cannot be traced at the bottom of lake Holmajärvi, but investigation made for prospecting purposes has proved that it is developed there, too.

Immediately north of Holmajärvi, at Aitiniemi (G 6e, fig. 8), the fault crosses another glacial river valley. It markedly cuts the parts of the valley showing signs of erosion, and where the overburden is thin. In the thick eskers, no effect is visible, but these deposits are probably too thick for the fault to appear at the surface. Further northwards, the fault is very sharp throughout, and probably in its entirety formed after the recession of the ice.

The appearance of the two minor faults southwest of Jalkiskätjåive and west of Juovvakätjåive (H 7c, I 8c) is rather blurred. They may be affected by glacial rivers and glacial flow. Probably, they are older than the local deglaciation.

The Pärvie fault is cut by a glacifluvial furrow 5 km to the NW of Kuorpavarto (J 4a). Immediately to the west of the fault scarp, a small esker follows, i.e. erosion is replaced by deposition, and these conditions clearly show that the fault developed before the ice recession.

Also 5 km further to the north, the fault seems to be older than the glacifluvial erosion and deposition.

In the valley of the Kalix river, to the southeast of Årosjåkk (L 6a), the fault generally appears rather vaguely, and not at all in the esker. The reason may be that the soil is thick, or that the fault preceded its deposition, and hence also the deglaciation.

Further to the north, in the northwestern part of Njallåive (M 7a), the fault is crossed by an esker. At the brow of the fault, the esker is replaced by a furrow, which indicates that the fault is older than the deglaciation.

In the southern slope of Salvotjåkka (N 9b), the fault seems to cut the most recent deposits and a furrow, and hence to be younger than the deglaciation. The relations at the locality are, however, somewhat ambiguous, as it appears that undulating deposits, probably sand, may have formed there after the fault. The cause of this impression is probably that the deposits are thick, and that the fault does not quite cut through to the surface. Most likely, the fault is younger than the deglaciation.

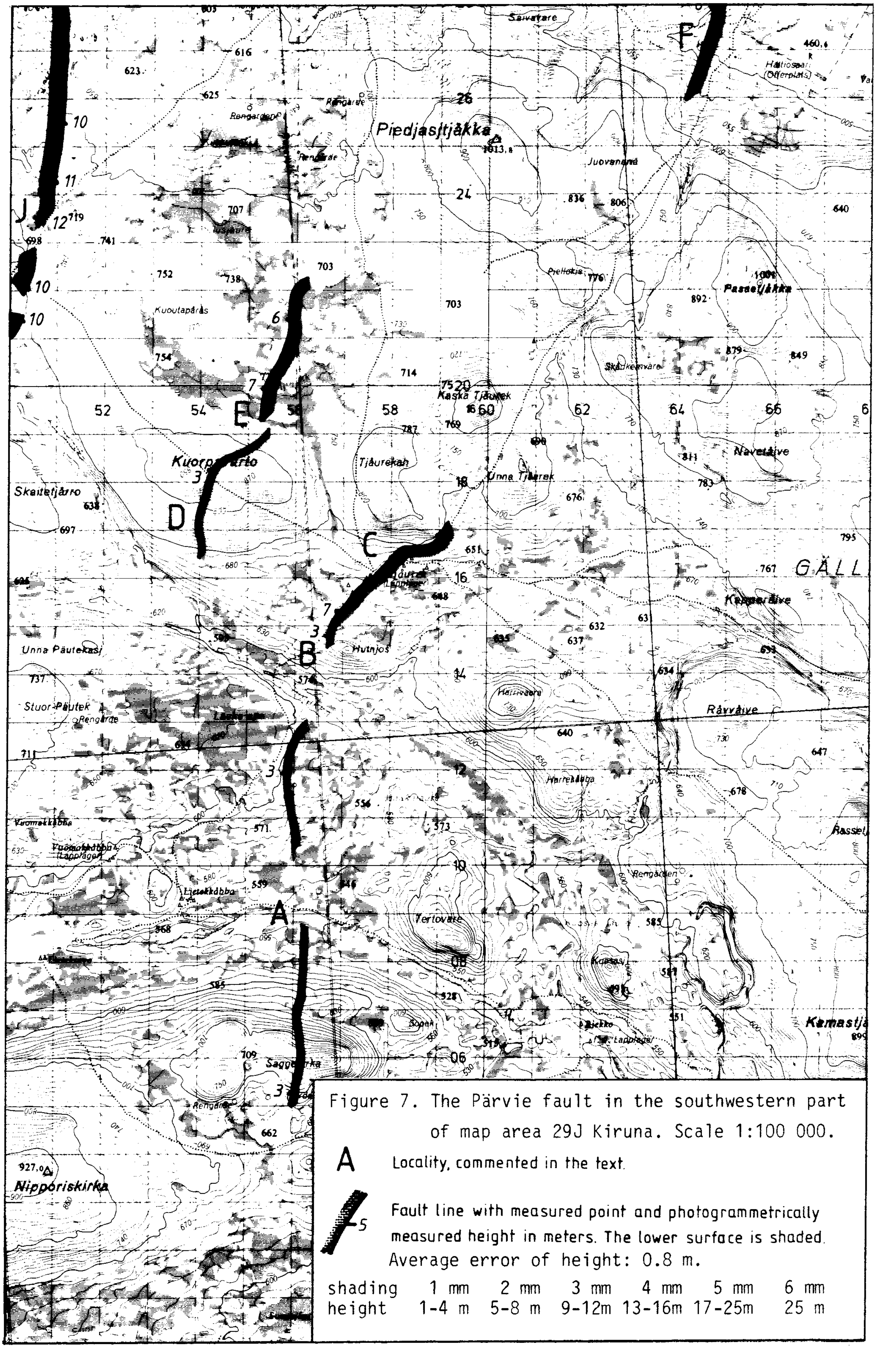


Figure 7. The Pärvie fault in the southwestern part of map area 29J Kiruna. Scale 1:100 000.

A Locality, commented in the text.

Fault line with measured point and photogrammetrically measured height in meters. The lower surface is shaded.

Average error of height: 0.8 m.

shading	1 mm	2 mm	3 mm	4 mm	5 mm	6 mm
height	1-4 m	5-8 m	9-12m	13-16m	17-25m	25 m

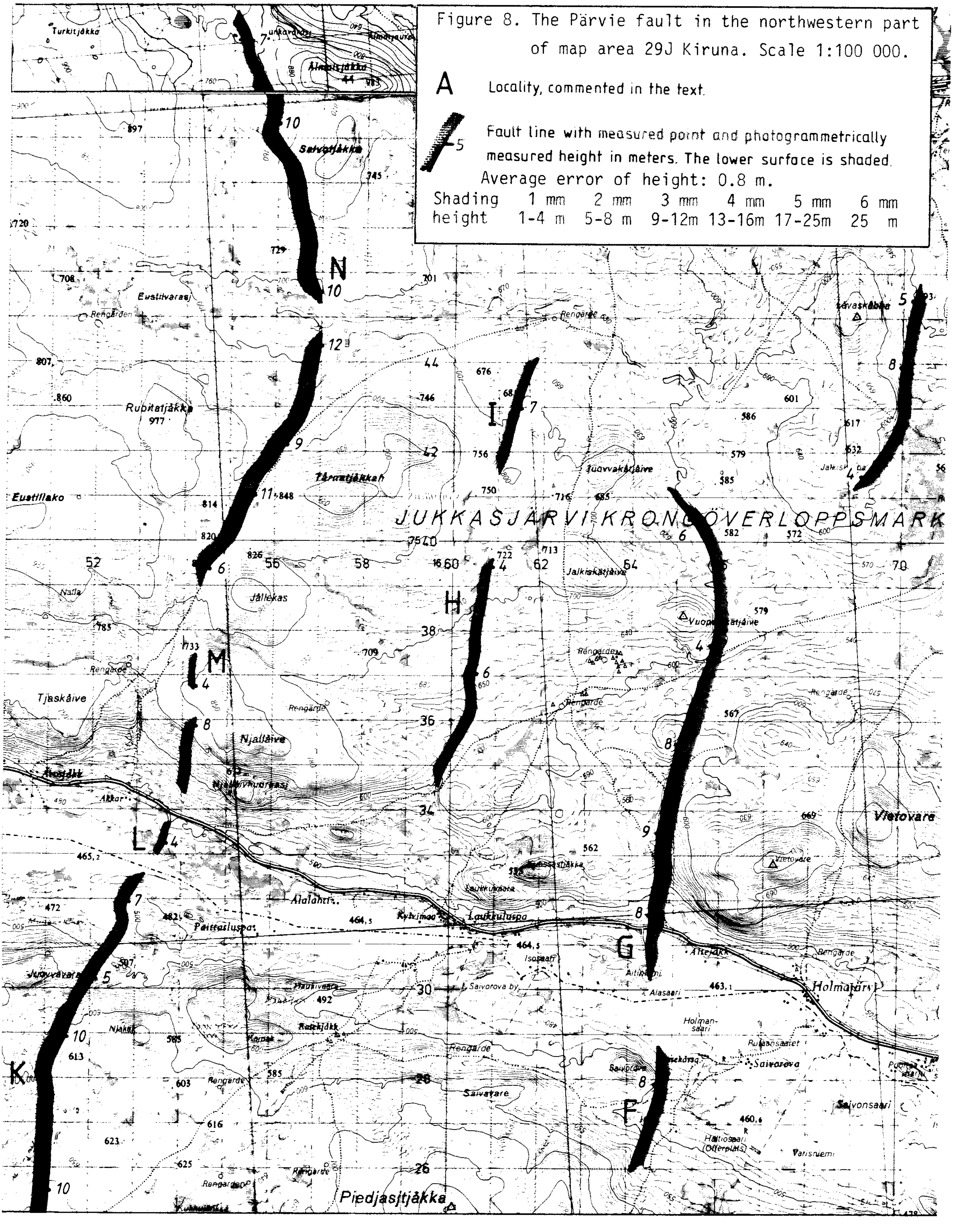


Figure 8. The Pärvie fault in the northwestern part of map area 29J Kiruna. Scale 1:100 000.

30j Rensjön (figs. 2,9,10). The Pärvie fault.

The SW, NW, and NE areas have been interpreted. The former picture remains unchanged. In most places, the Pärvie fault is sharply developed, markedly cutting the quaternary cover and its different forms.

Intense earthflow has occurred in the area, and traces of possible landslides are probably destroyed.

In several places, particularly in the north, it is possible to date the fault relative to the end of the ice age. To the northwest of Njallåive (A 6d, fig.9), the moraine is drumlinized, and the fault markedly cuts these surface forms. Thus it is decidedly younger than the latest active glacial phase, but not necessarily younger than the deglaciation.

Close to the north of Vuoskojaure (B C D 89 ef, fig. 9), the relations are somewhat difficult to interpret. Clearly, a glacial lake shoreline at C has developed in the fault, and hence the fault preceded the melting of the damming ice from the southern area.

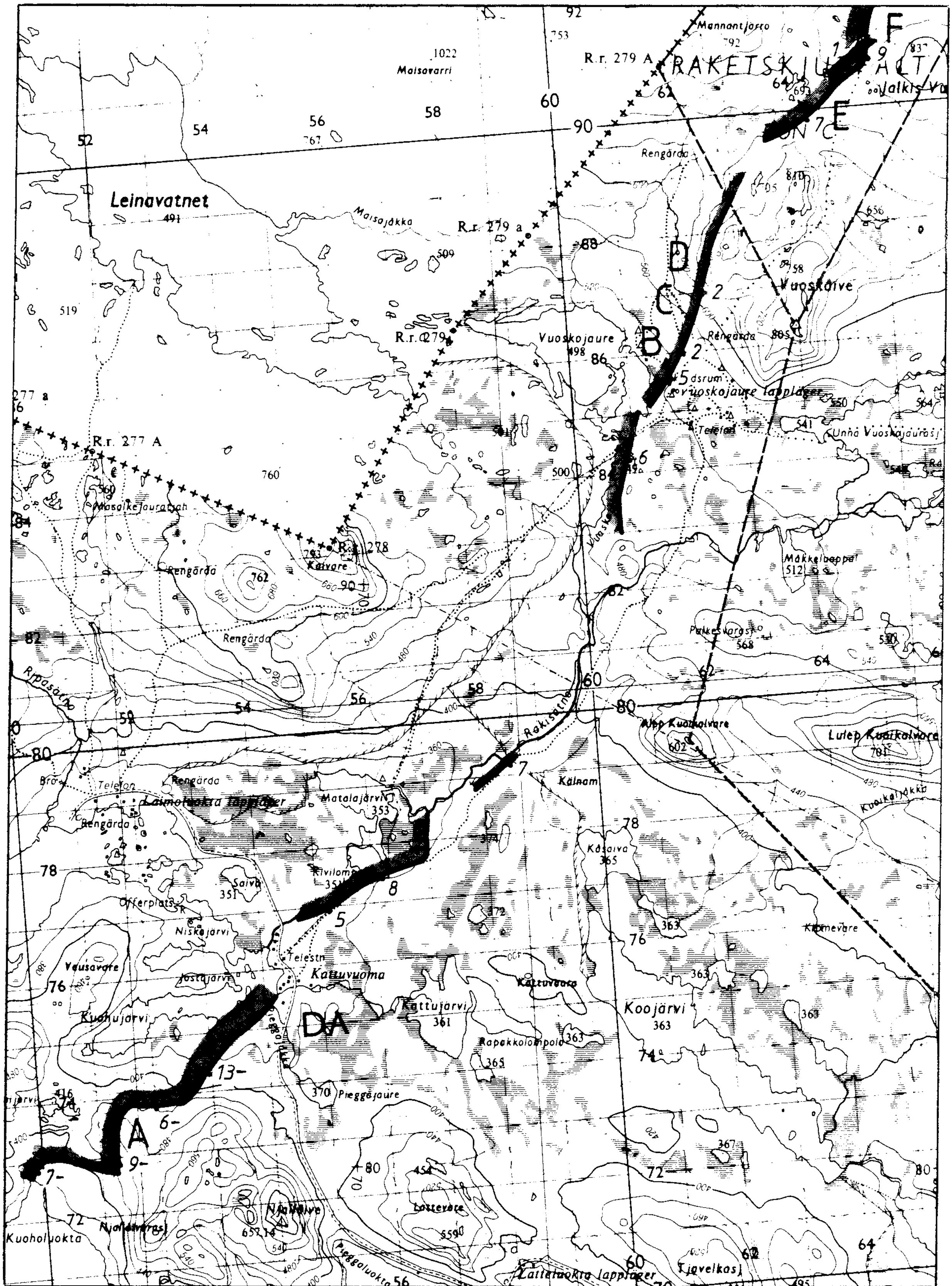
At B, a few glacial river furrows occur in direct connection to the fault, and it looks like the furrows are earlier formed than the fault. However, this is in poor agreement with the conditions at C, unless the damming of the glacial lake was caused by a later change of balance in the ice, with consequent damming and transgression.

A poorly developed and very short glacial river furrow at D appears to have formed after the fault. If this is so, it confirms the relation of the fault to the shore-line at C, i.e. indicates that the fault has preceded the local deglaciation. The conditions may, however, also be interpreted as caused by the transgression of a glacial lake.

To the southwest of Jalkis Vuoskåive (E 9e), the Pärvie fault cuts a glacial river valley, which means that in this place, it is formed after the local deglaciation.

At the border of the map area, to the NW of Jalkis Vuoskåive (F 9f), the fault squarely cuts a glacial river furrow, and hence at this site it is younger than the local deglaciation.

At the far south of the map area, to the northwest of Ålmaitjåkka (G 0b, fig. 10), the fault cuts a moraine hill, that probably formed in direct connection to the deglaciation. Hence, also in this area, the fault probably is younger than the local deglaciation.



A Locality, commented in the text.

Fault line with measured point and photogrammetrically measured height in meters. The lower surface is shaded. Average error of height: 0.8 m.

4- Height value, average error 1.2 m.

3· Height value, average error 2.1 m.

shading	1 mm	2 mm	3 mm	4 mm
height	1-4 m	5-8 m	9-12m	13-16m

Figure 9. The Pärvie fault in the map area 30J Rensjön.

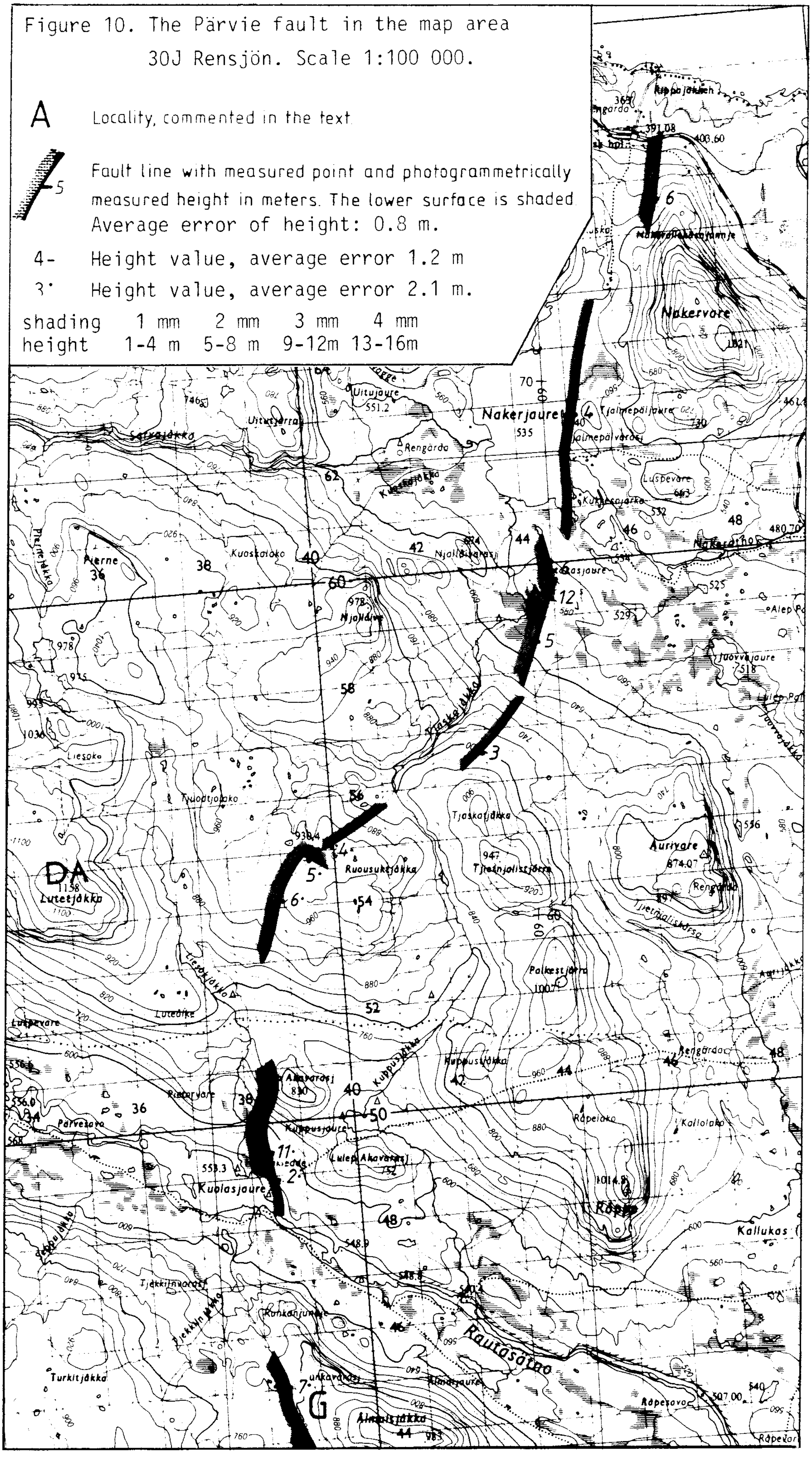


Figure 10. The Pärvie fault in the map area 30J Rensjön. Scale 1:100 000.

31J Råstojaure (figs. 2,12,13). The Pärvie fault.

Interpretation has been made of the Swedish part of the map area. The former picture has been complemented with a rather short and very low fault, scarcely 10 km to the NE from Tsåktso (A 2j, fig. 13). This fault is rather blurred, and in part developed merely as a fracture. However, it apparently cuts the quaternary, and probably should be included in this context (the Pärvie - Pirttimys faults). The Pärvie fault is very sharply developed throughout the map area (cf. fig. 11).

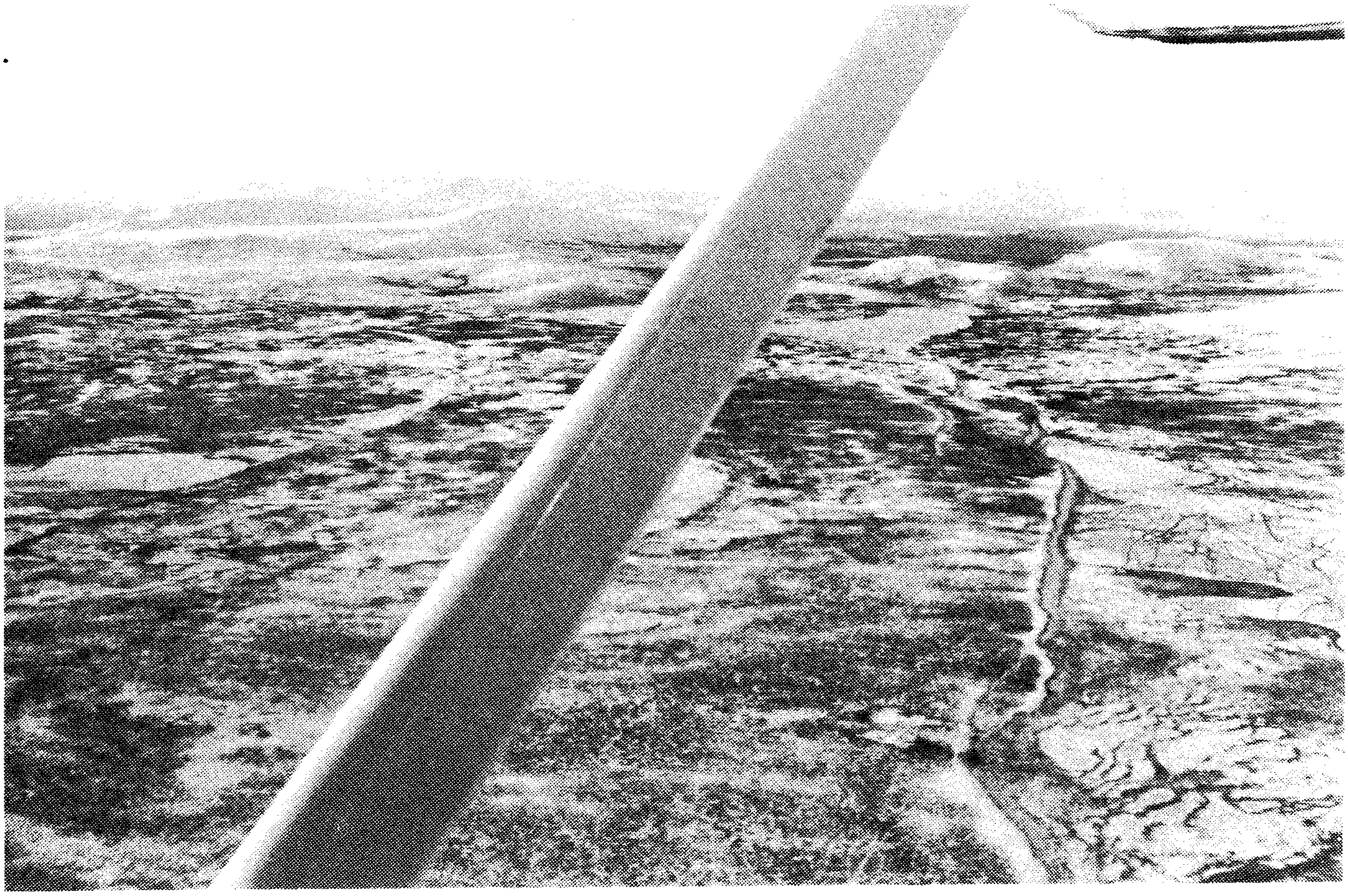


Figure 11. The Pärvie fault at the lake Kamasjaure, visible in the background (map area 31J Råstojaure). The main fault (to the right of the wing strut) is very sharply developed and cuts the drumlinoid moraine forms. A minor fault runs in parallel to the main fault (to the left of the strut). Also this fault is very prominent, though it is only about a meter high. The area between the faults forms a low horst. Cf. also fig. 13. Photo: R. Lagerbäck. The picture is admitted for publication.

At the SE of Mannaktjärro (B 0f, fig. 13), the Pärvie fault cuts both the formerly mentioned (cf. map area 30J, fig. 9) furrow (F) and glaciofluvial sediments. Hence, the fault clearly has preceded the local deglaciation here.

Close to the east of Kamasjaure (C 1g), the northern branch of the fault is very clearly developed, and only thinly covered. The bedrock is largely exposed, and at one site displays beautiful slickensides. In two places below the fault, glacially sculptured and grooved outcrops occur on the lee side of the fault relative to the glacial flow. One of the rounded rocks is only about 10 m away from the 8 - 10 m high fault scarp, and can impossibly have been formed in such a position. Hence, the fault has formed after the latest phase of glacial flow in the area.

2 km further to the east at Pärvejaure (D 0g), the fault squarely cuts a drumlinoid moraine ridge, which as above shows that it developed after the latest phase of glacial flow in the area.

To the north of Tsåktso (E 2h), the fault crosses an area of glaciofluvial sediments. In the thinner parts, the fault is clearly apparent at the surface, and certainly younger than the deglaciation. In the thickest deposits, nothing appears at the surface, which possibly may be explained as that the fault developed during the very deposition of the sediments. However, the most probable explanation is that the sediments are too thick for the comparatively low fault to appear at the surface.

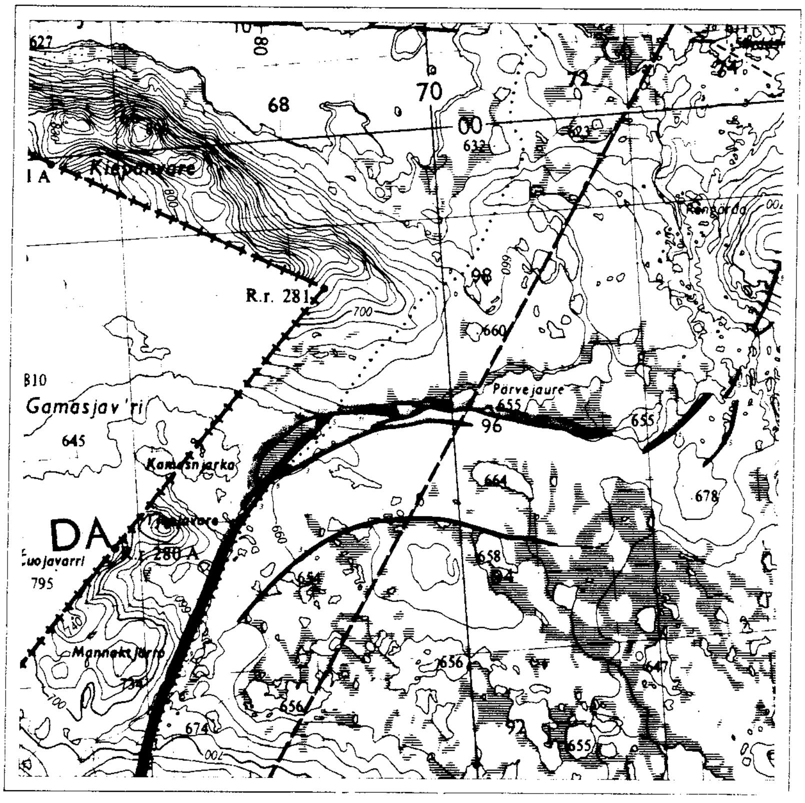


Figure 12. Detail of the Pärvie fault in the map area 31J Råstojaure (0,1 - f,g,h). Scale 1:100 000. Fault line with measured points and photogrammetrically determined altitudes in meters, average error 0.8 m.

Width of shading: 0.4 mm, scarp height 1 - 4 m
0.8 mm, scarp height 5 - 8 m
1.0 mm, scarp height 9 - 12 m

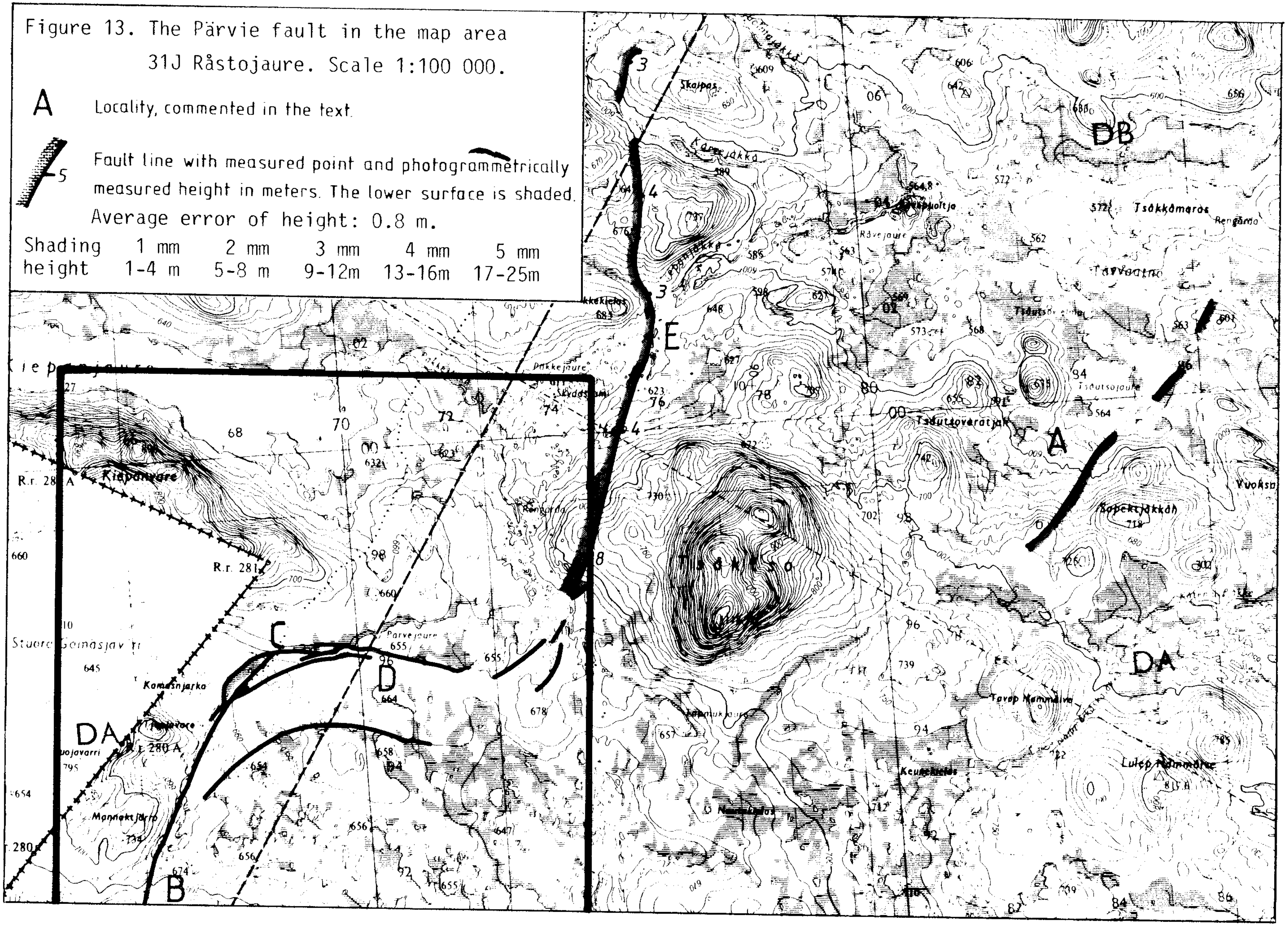


Figure 13. The Pärvie fault in the map area 31J Råstojaure. Scale 1:100 000.

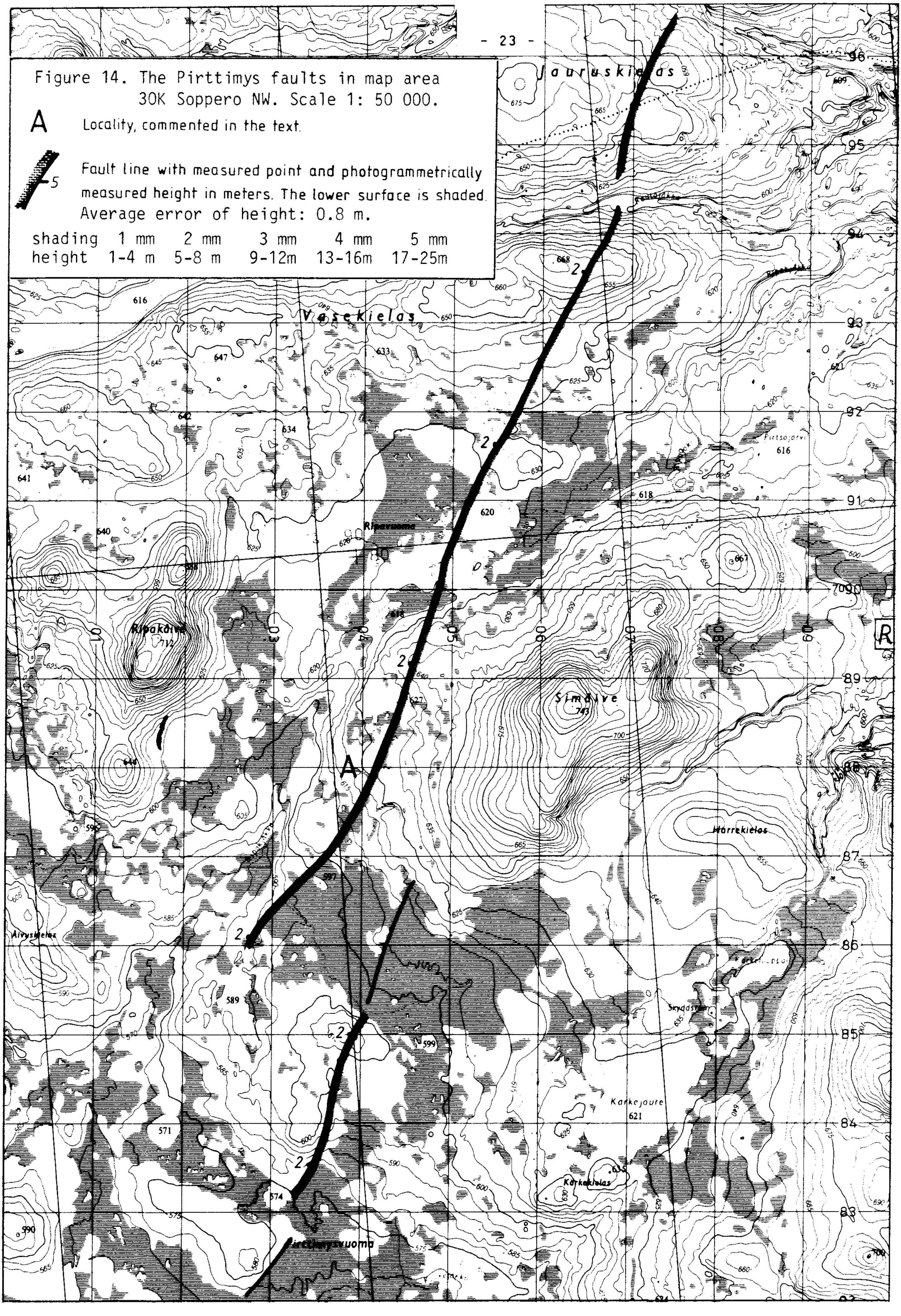


Figure 14. The Pirttimys faults in map area 30K Soppero NW. Scale 1: 50 000.

A Locality, commented in the text.

Fault line with measured point and photogrammetrically measured height in meters. The lower surface is shaded.

Average error of height: 0.8 m.

shading	1 mm	2 mm	3 mm	4 mm	5 mm
height	1-4 m	5-8 m	9-12m	13-16m	17-25m

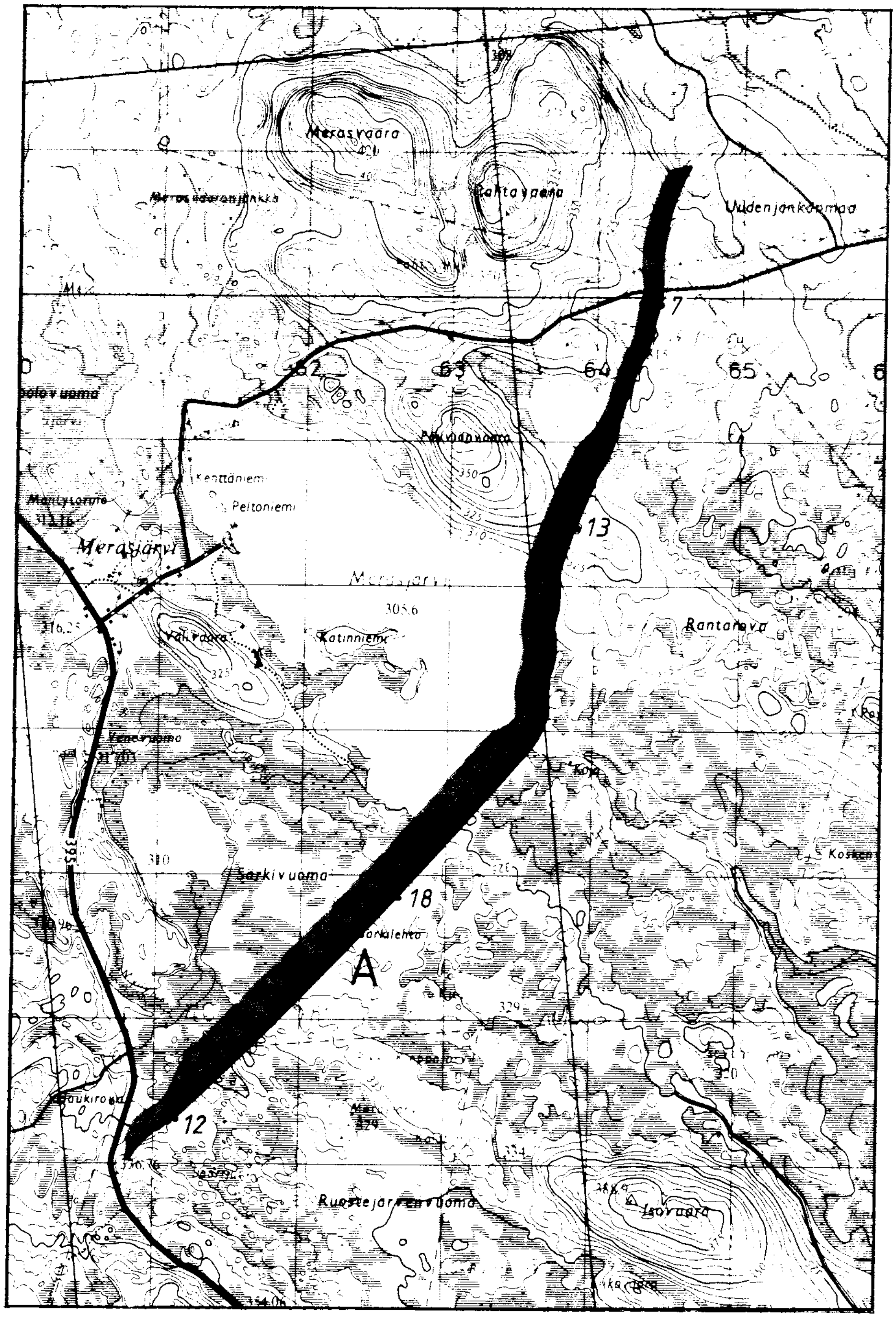


Figure 15. The Merasjärvi fault (part of map area 29L Lainio SW)
Scale 1:50 000. Average error of height: 0.8 m

Width of shading	1 mm	2 mm	3 mm	4 mm	5 mm	6 mm
height of scarp	1-4 m	5-8 m	9-12 m	13-16 m	17-25 m	>25 m

A Locality, commented in the text.

Fault line with measured point and photogrammetrically measured height in meters. The lower surface is shaded.

30k Soppero NW (figs. 2,14). The Pirttimys faults.

The western two-thirds of the map area have been interpreted. Nothing in the former picture has changed. Despite their slight throw, the faults sharply cut the quaternary.

To the west of Simåive (A 7a), the longer of the faults is cut by a small glacial river furrow, which indicates that it developed before the final deglaciation. However, the fault has scarcely been exposed to very active glacial flow, and thus it would have developed in close connection to the deglaciation, after the ice stagnated.

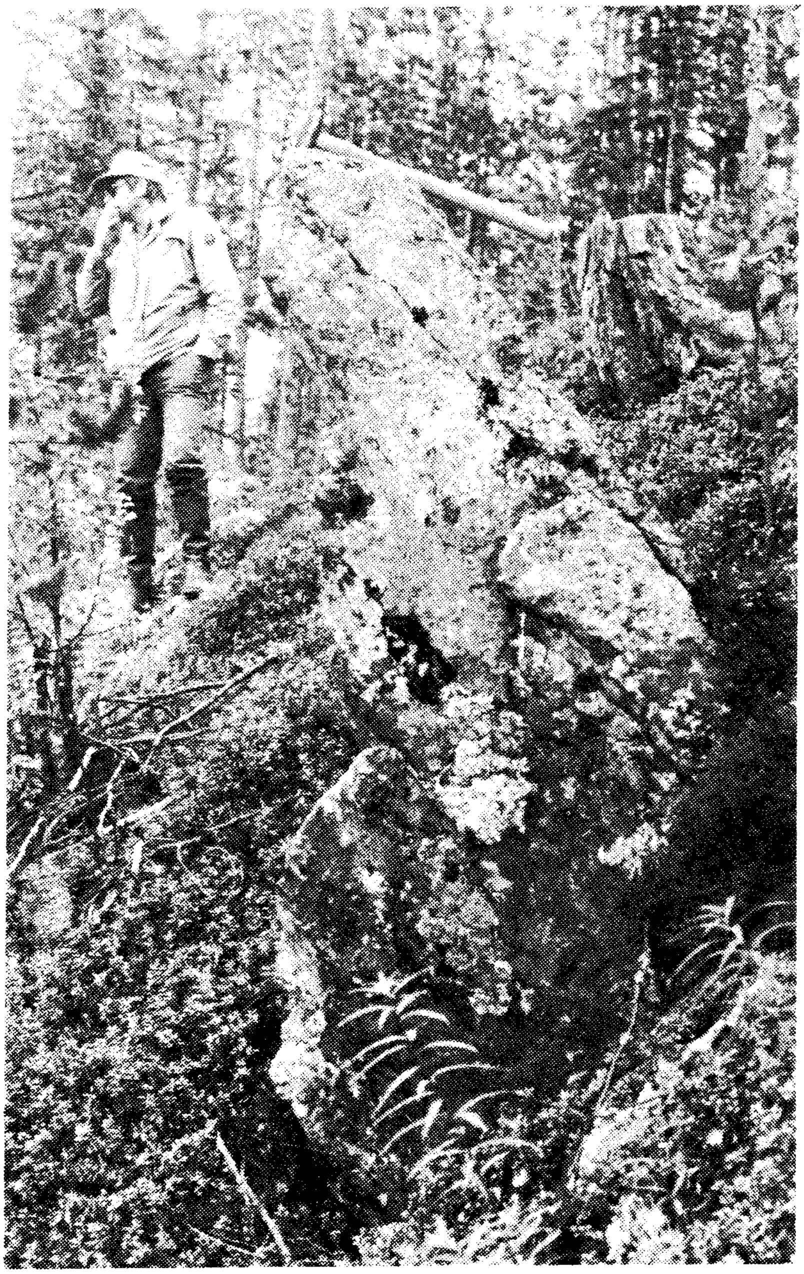


Figure 16.

A sharp rock plinth that protrudes from the moraine slope at the Merasjärvi fault (map area 29L Lainio SW) in a way that shows that the area has not been influenced by active ice after the formation of the fault. In all probability, it is post-glacially formed.

Photo: R. Lagerbäck.

29L Lainio SW (figs. 2,15). The Merasjärvi fault.

The entire map area has been re-interpreted. This has not changed anything in the earlier picture. The fault is very sharp, and cuts the partly thick, unconsolidated soil in a marked manner. Sharp, fractured rock plinths, e.g. at Särkilehto (A 1c, fig.16), protruding from the moraine slope, and the uniform shape of the slope with the material at angle of repose, show that the fault has not been affected by active ice, and that it in all probability formed after the deglaciation.

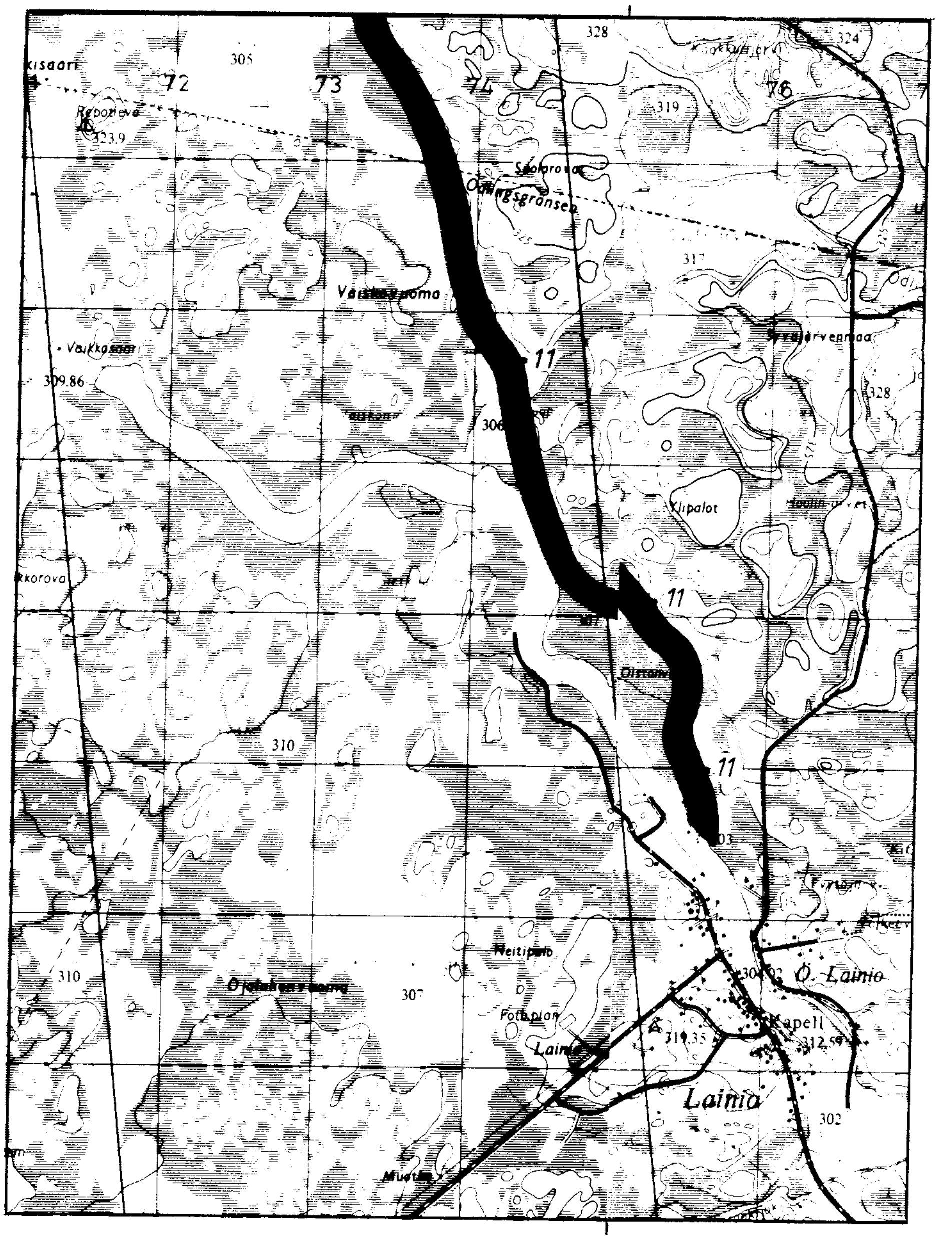


Figure 17.

The southern part of the Lainio fault in the map areas 29L Lainio NE+NW Scale 1:50 000. Average error of height: 0.8 m.

width of shading	scarp height
1 mm	1-4 m
2 mm	5-8 m
3 mm	9-12m
4 mm	13-16m
5 mm	17-25m
6 mm	>25 m

29L Lainio NW, NE (figs. 2,17,18,19). The Lainio-Suijavaara fault.

The entire map areas have been interpreted. Nothing of the former picture has changed. The fault sets out rather abruptly close to the north of Lainio. Its shape is fairly smooth, the smoothness probably due to a thick soil layer. It may, however, also be due to that the fault has been affected by active ice.

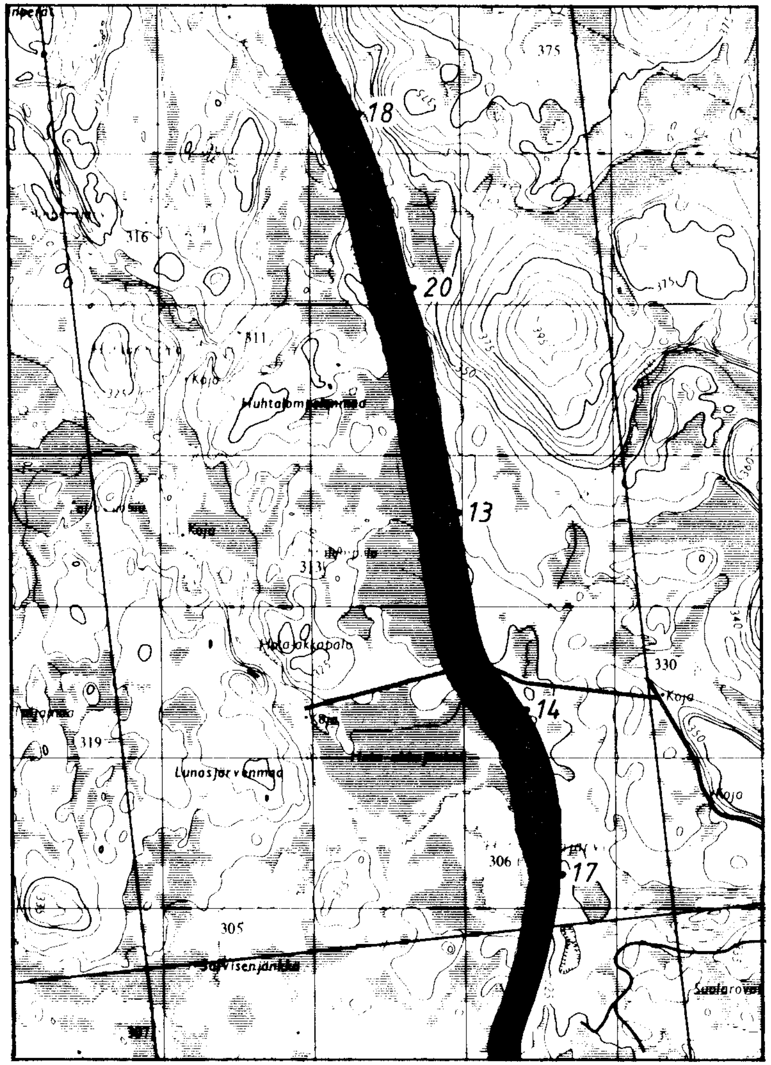


Figure 18. The Lainio fault in map area 29L NW.

A Locality, commented in the text.

Fault line with measured point and photogrammetrically measured height in meters. The lower surface is shaded.

Average height error: 0.8 m.

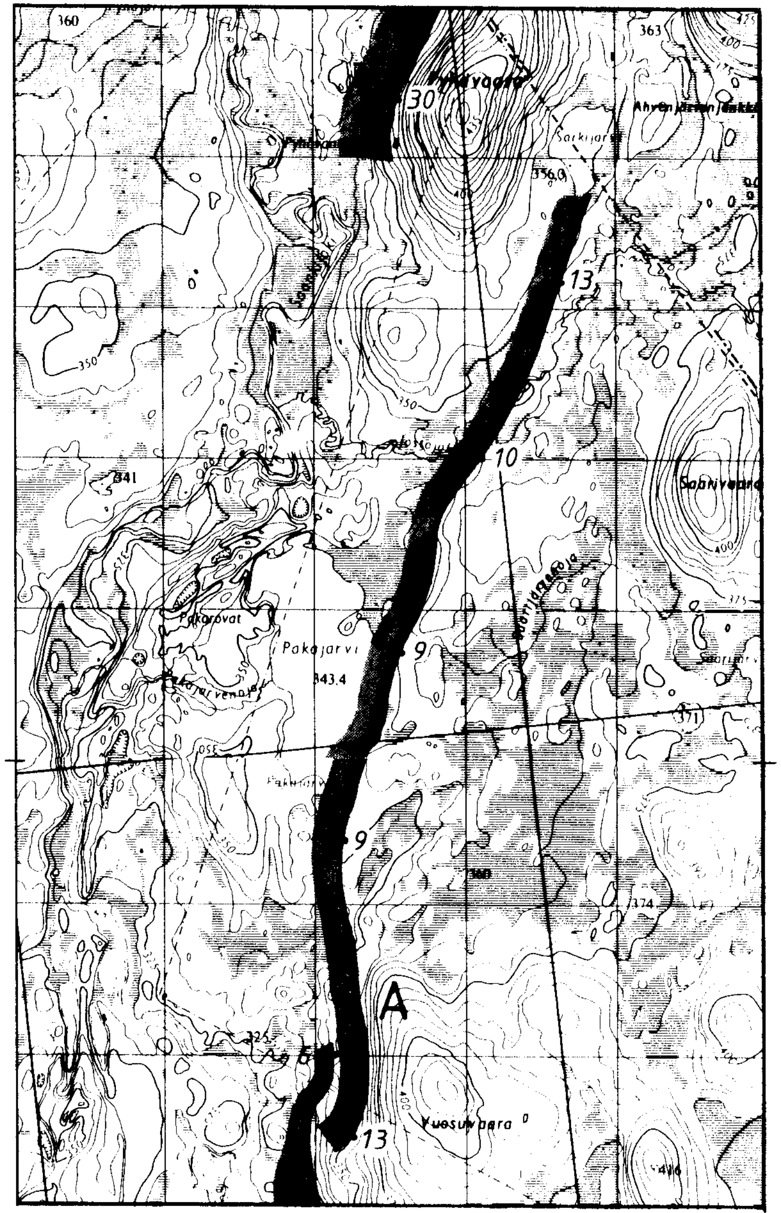


Figure 19. The Lainio fault in map areas 29L NW and 30L SW.

shading	1 mm	2 mm	3 mm	4 mm	5 mm	6 mm
height	1-4 m	5-8 m	9-12m	13-16m	17-25m	25 m

Another cause of the smooth appearance of the fault is that it, at least in some places, e.g. at Vuosovaara (A 9e, fig. 19), is stepwise developed, along several parallel fault planes. At Vuosovaara, where the bedrock is exposed in several places, it is strongly fractured, with sharp and fragmented parts. The erected plinths apparently have tilted outwards, which has resulted in open fractures, even through the soil. It is hard to believe that the fault in this place has been affected by active ice. Hence, it is probably formed after the recession of the ice sheet, or beneath an entirely stagnated ice.

30L Lannavaara SW (figs. 2,19,21). The Lainio-Suijavaara fault.

The eastern two-thirds of the map area have been interpreted. Nothing of the former picture has changed.

An anomalous feature here is the fault to the west of Pyhävaara (A 1e, figs. 20,21), that apparently fills a 'gap' in the main fault at Särkijärvi-Ahvenjärvi. The fault to the west of Pyhävaara is only 2 km long, but very sharp and high, at its highest close to 35 m, which is the highest scarp at any of the faults.

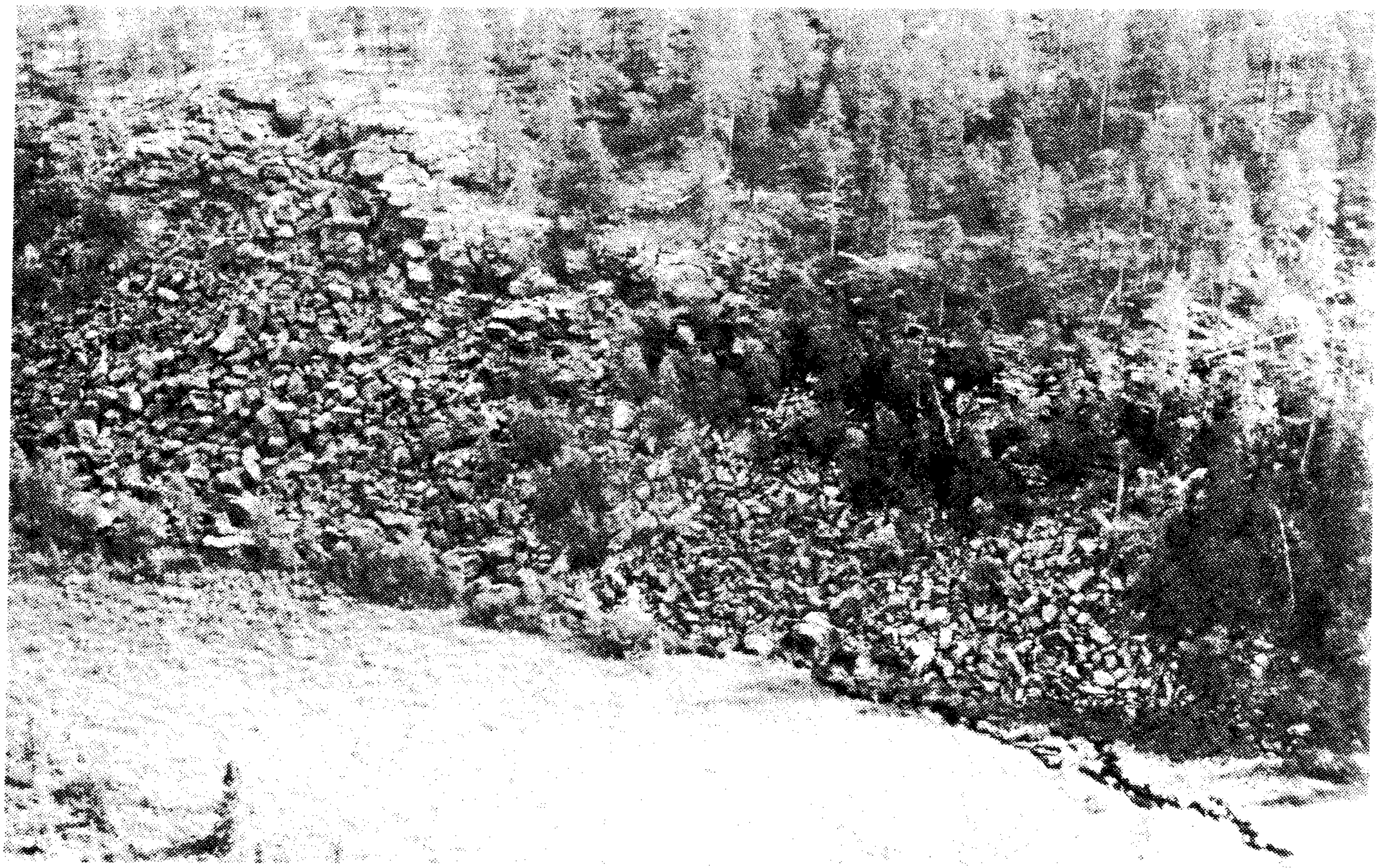


Figure 20. The fault at Pyhävaara (map area 30L Lannavaara SW). The bedrock is intensely, almost explosively fractured. Polygonal prisms in the granite are formed by the fracturing. An abundant source discharges at the foot of the fault scarp, which suggests that extensive open fracture systems exist in the bedrock. The fragmented blocks lie at very unstable positions, and clearly show that the fault has not been affected by active ice. In all probability, the fault has formed after the local deglaciation. Photo: R. Lagerbäck. The picture is inspected and admitted for publication.

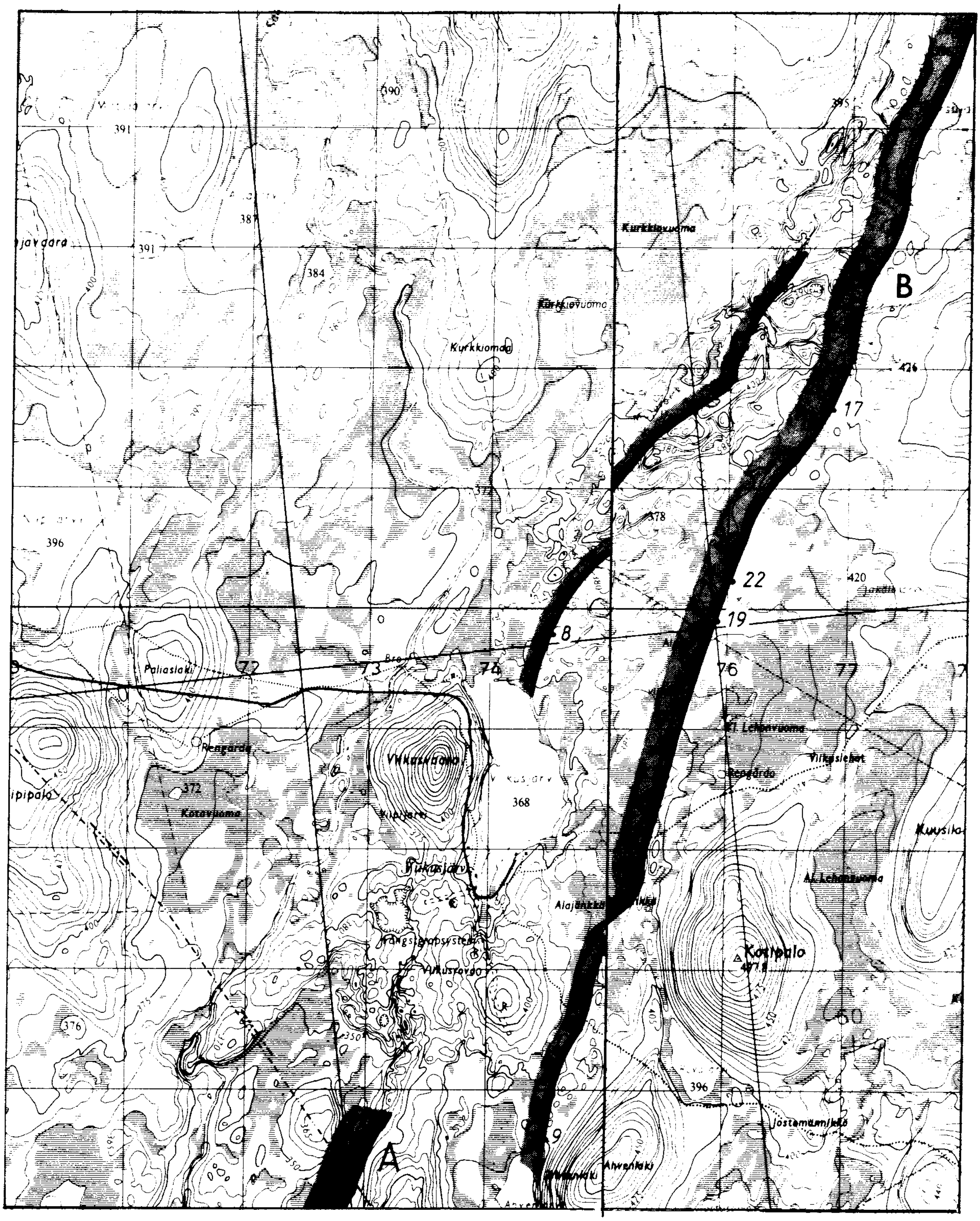


Figure 21. The Lainio-Suijavaara fault at the border of the map areas 30L Lannavaara SE and SW. Scale 1:50000. Average error of height is 0.8 m.

Width of shading	1 mm	2 mm	3 mm	4 mm	5 mm	6 mm
height of scarp	1-4 m	5-8 m	9-12m	13-16m	17-25m	>25m

A Locality, commented in the text.

Fault line with measured point and photogrammetrically measured height in meters. The lower surface is shaded.

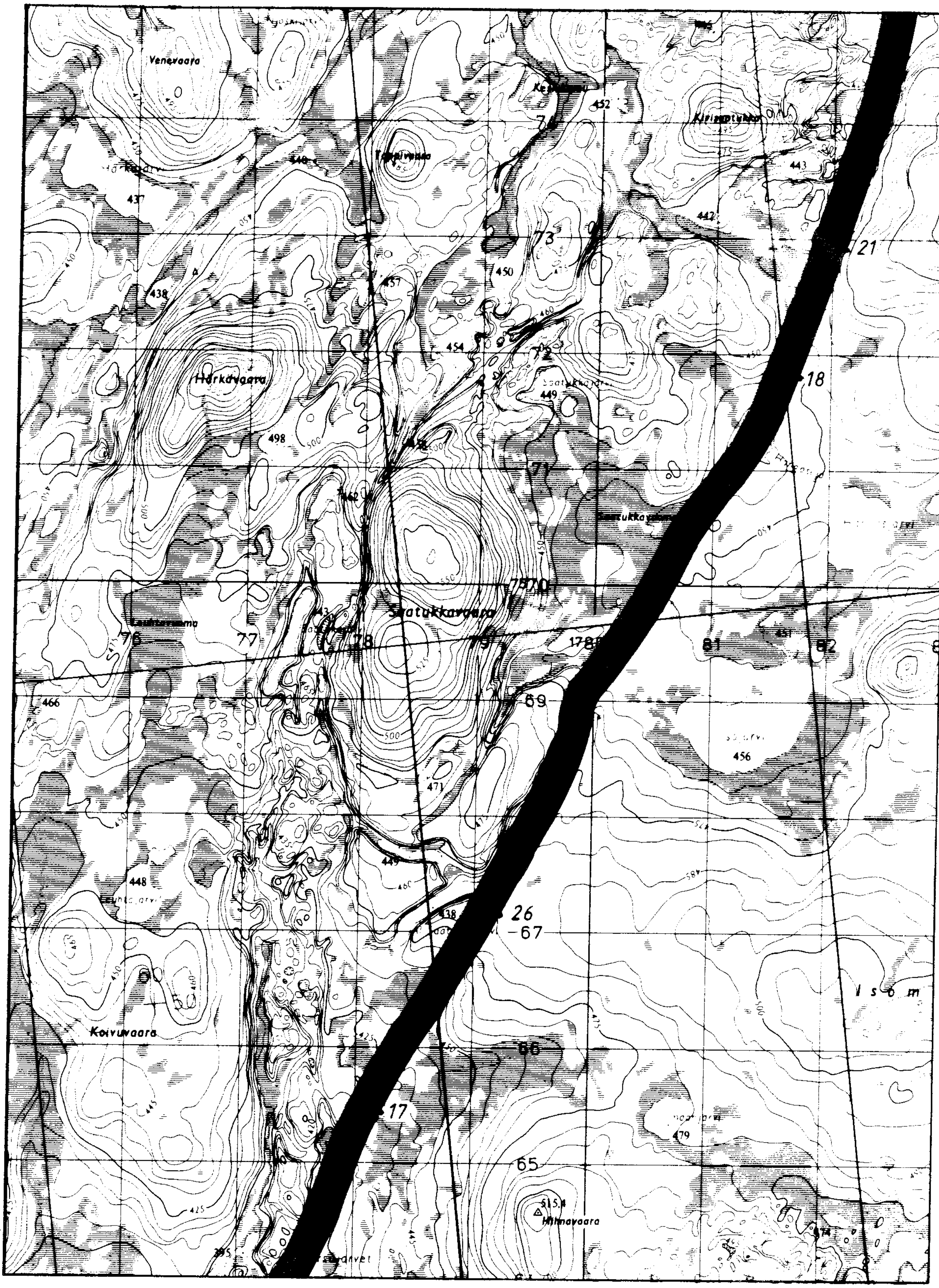
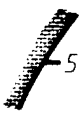


Figure 22. The Lainio-Suijavaara fault, map area 30L Lannavaara SE. Scale 1:50 000. Average error of height is 0.8 m.

Width of shading	1 mm	2 mm	3 mm	4 mm	5 mm	6 mm
height of scarp	1-4 m	5-8 m	9-12m	13-16m	17-25m	>25m

A Locality, commented in the text.



Fault line with measured point and photogrammetrically measured height in meters. The lower surface is shaded.

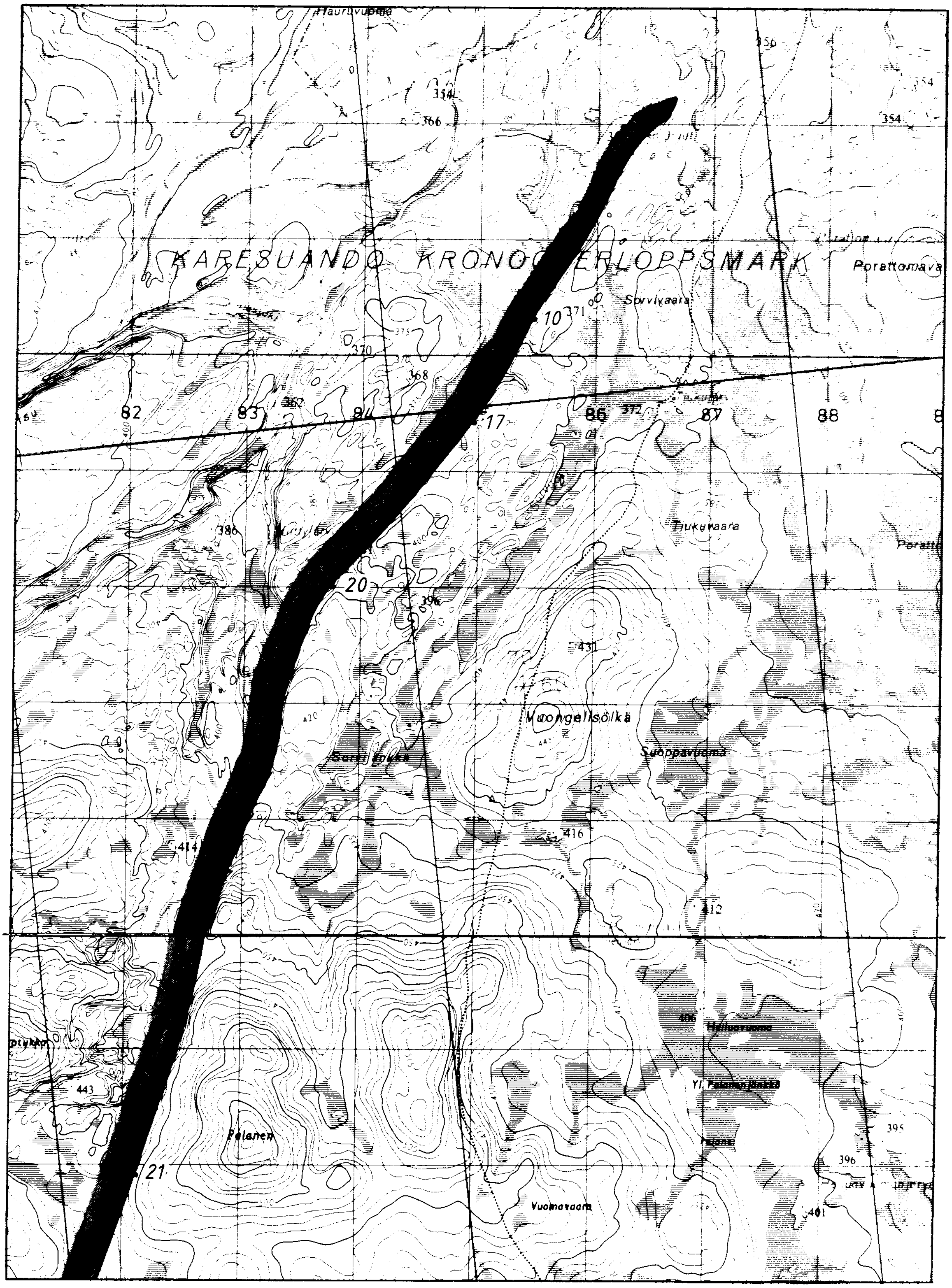


Figure 23. The Lainio-Suijavaara fault at the border of the map areas 30L Lannavaara SE and NE. Scale 1:50000. Average error of height is 0.8 m.

Width of shading	1 mm	2 mm	3 mm	4 mm	5 mm	6 mm
height of scarp	1-4 m	5-8 m	9-12m	13-16m	17-25m	>25m

Fault line with measured point and photogrammetrically measured height in meters. The lower surface is shaded.

The bedrock is largely exposed, and particularly in the northern part (A, fig. 21), it displays a strong tectonic influence, in the form of intense, almost explosive fracturing, partly in the form of polygonal prisms (fig. 20). Large amounts of groundwater well from the foot of the fault. This is a typical feature of most of the late quaternary faults, and indicates an extensive, open fracturing of the bedrock.

Had the fault been exposed to active ice, it would certainly not have retained its present shape, and it is highly improbable that it developed even beneath an entirely dead ice. Thus, the most reasonable assumption is that at least the part at Pyhävaara has formed after the local deglaciation.

30L Lannavaara SE, NE (figs. 2,21,22,23). The Lainio-Suijavaara fault.

The interpretation of these map areas has not resulted in any change in the earlier perception. Throughout, the fault is very high and sharply shaped. To the north, it coincides with a magnificent canyon, the Sattukkakursu.

It is difficult to analyze the relation to the deglaciation. The lower, western parallel fault, (which possibly may be regarded as an extension of the Pyhävaara fault), is covered by rather fine-grained, glaciofluvial sediments. Still it is visible, which may be taken as evidence of that it formed after the sedimentation. On the other hand, it is hard to rid oneself of the impression that both the parallel and, above all, the main fault apparently have canalized the water along the mighty glacial river valley, that in part runs parallel to, and in part coincides with the faults.

Other 'kursu' valleys in northeastern Norrbotten show that the glacial rivers often have a remarkable affinity to zones of weakness in the bedrock, and it cannot be precluded that the Sattukkakursu may have been formed before the fault. Nevertheless, it is probable that at least part of the fault developed before the glacial river valley.

At the northeast of Pessinoivi (B 2f, fig. 21), plenty of sand covers also the eastern, upthrown side of the fault, which might indicate that the deposition of the sand preceded the fault. However, the sand has probably been wind-transported from the thick deposits on the western side of the fault.

The age of the fault relative to the deglaciation can as yet not be assessed. In the south, most of the evidence points to that it developed after the ice recession, whereas in the north, the relation seems to be reversed. Since the deglaciation has proceeded from the north to the south, the conditions cannot be due to that the northern part of the fault was covered with ice while the southern part was ice-free. It is more likely that the fault has developed gradually during the course of deglaciation, or (possibly) that its separate parts have formed at separate occasions. The uniform shape and the continuous course of the fault tell against the latter alternative.

29L Pålkem NW (figs. 3,24,25). The Lansjärv-Risträsk-Storsaivis faults.

The entire map area has been interpreted, but nothing of the earlier picture has changed. The faults are very sharply shaped, especially the northern one, which is considerably higher than the southern one.

At the northern fault scarp at Risträskkölen (A 9e, fig. 25), the bedrock is exposed. The rock plinths are angular and fragmented, protruding from the moraine slope in a way that shows that the area was free of ice when the faults were formed. Also where the fault scarp is covered by soil, its very uniform shape, with the moraine at angle of repose, shows that the ice must have recessed before the faults were released. (Cf. figure 2 in Lagerbäck, 1979).

At Neitaskaite (B 9e, fig. 25), some hundred meters to the east of the fault, is a small, strongly fractured outcrop. The appearance of the rock suggests that it has been seismically or mechanically affected in connection with the fault movement. The fragmented blocks would hardly have resisted an active ice. This further strengthens the perception that the fault is postglacially formed.

In the northern part of Risträskkölen, unusually large amounts of water gush from the fault. The wells have given rise to and nourish the mire Källmyren, located to the north of the fault. The magnitude of the water flow shows that the fault drains a vast area, and suggests the existence of extended, open fracture systems in the bedrock.

29L Pålkem NE (figs.3,25,26). The Lansjärv-Risträsk-Storsaivis faults.

The entire map area has been interpreted, but nothing has been found to change the former picture. The fault in the northwestern part of the map area is sharply shaped, and apparently not affected by glacial flow. As well as the formerly treated fault branches, it probably has developed after the recession of the ice.

27L Lansjärv SE (figs. 3,26,27) The Lansjärv-Risträsk-Storsaivis faults.

The entire map area has been interpreted, and the earlier picture has been changed and complemented in an essential way, above all by the detection of another fault, belonging to the same fault complex. The newly detected fault is about 15 km long and runs between Innerträsket and Telmberget. More or less, it is a direct continuation of the northern of the earlier observed faults. It differs from the latter by having a downthrown western block.

This makes a better fit of the fault complex to the general pattern, which, with the exception of a few of the faults parallel to the Pärvie fault, means that the eastern block is relatively uplifted.

The entire fault is situated below the highest shoreline level, and is largely affected by the destructive forces of the sea. This explains its rather diffuse appearance at the surface. The crest of the fault is often very eroded, and littorial deposits often lie below the fault scarp. Both these phenomena tend to obscure the fault, but in other aspects, it is undoubtedly comparable to the other faults in the area.

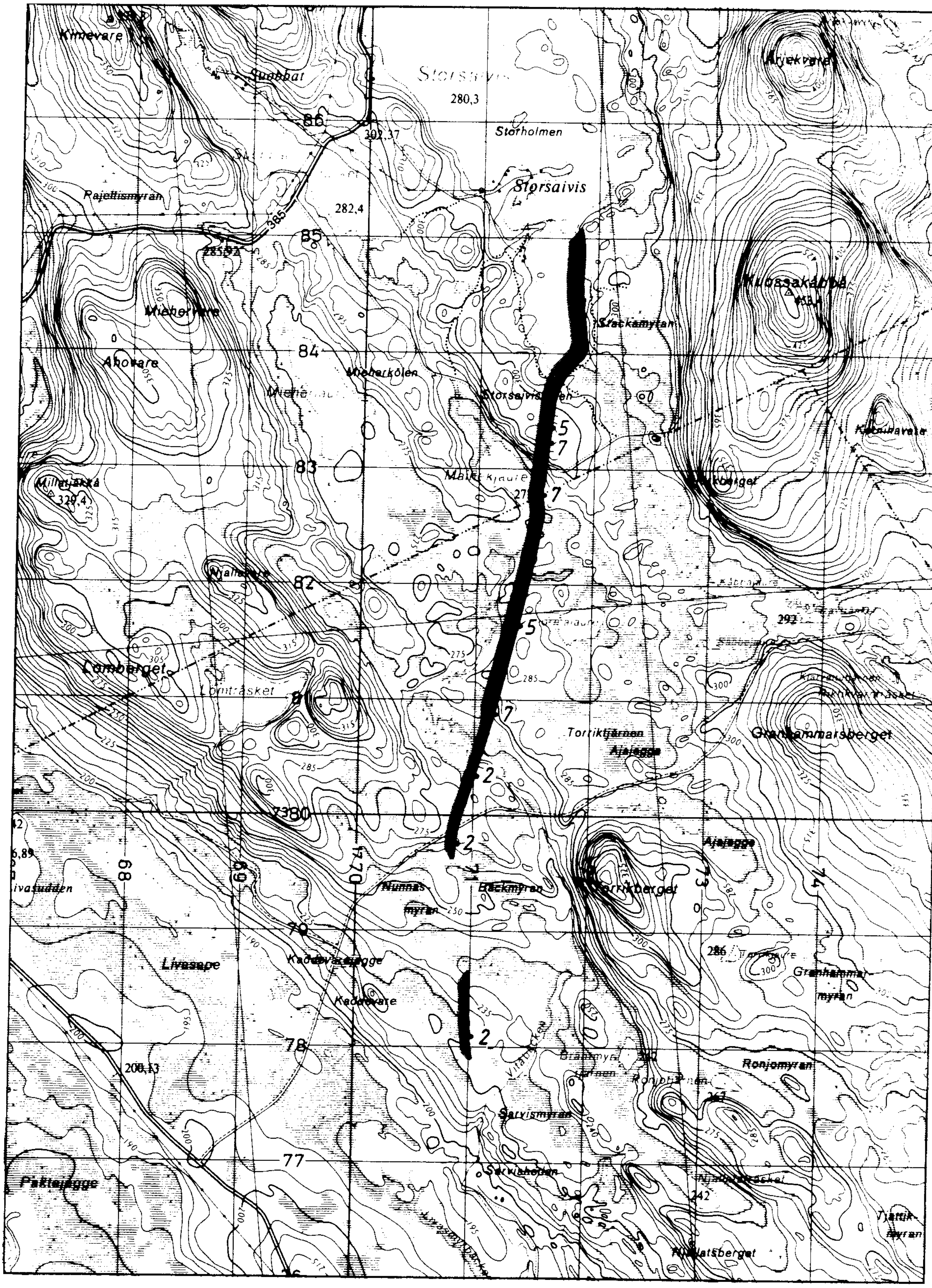


Figure 24. The Storsaivis fault, map area 26L Pålkem NW.
Scale 1:50 000. Average error of height: 0.8 m.

Width of shading	1 mm	2 mm	3 mm	4 mm	5 mm	6 mm
height of scarp	1-4 m	5-8 m	9-12m	13-16m	17-25m	>25m

Fault line with measured point and photogrammetrically measured height in meters. The lower surface is shaded

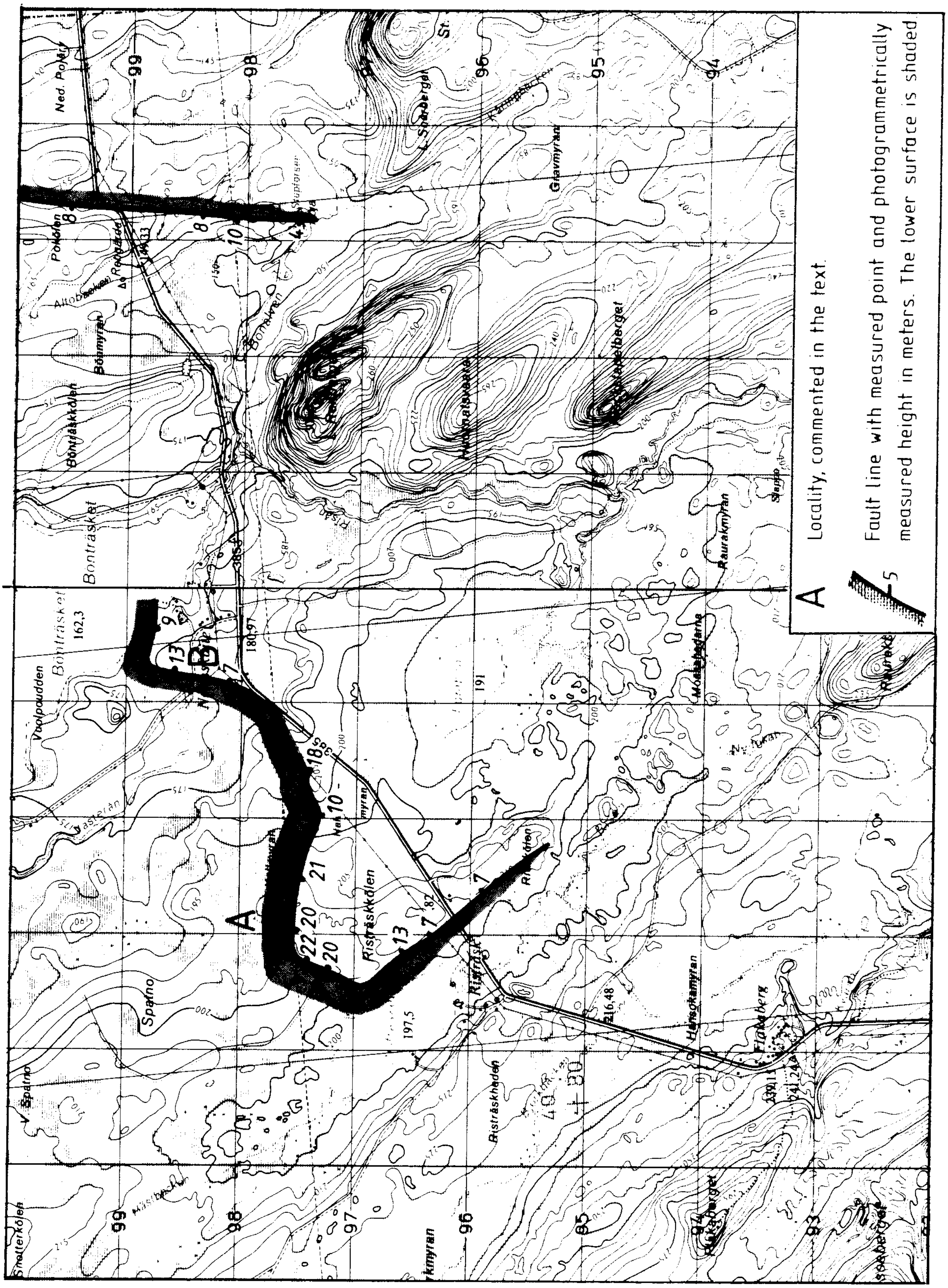


Figure 25. The Risträsk and Lansjärv faults at the border of map areas 26L Pålkem NW and NE. Scale 1:50 000. Av. height error 0.8 m.

Width of shading	1 mm	2 mm	3 mm	4 mm	5 mm	6 mm
height of scarp	1-4 m	5-8 m	9-12m	13-16m	17-25m	>25m

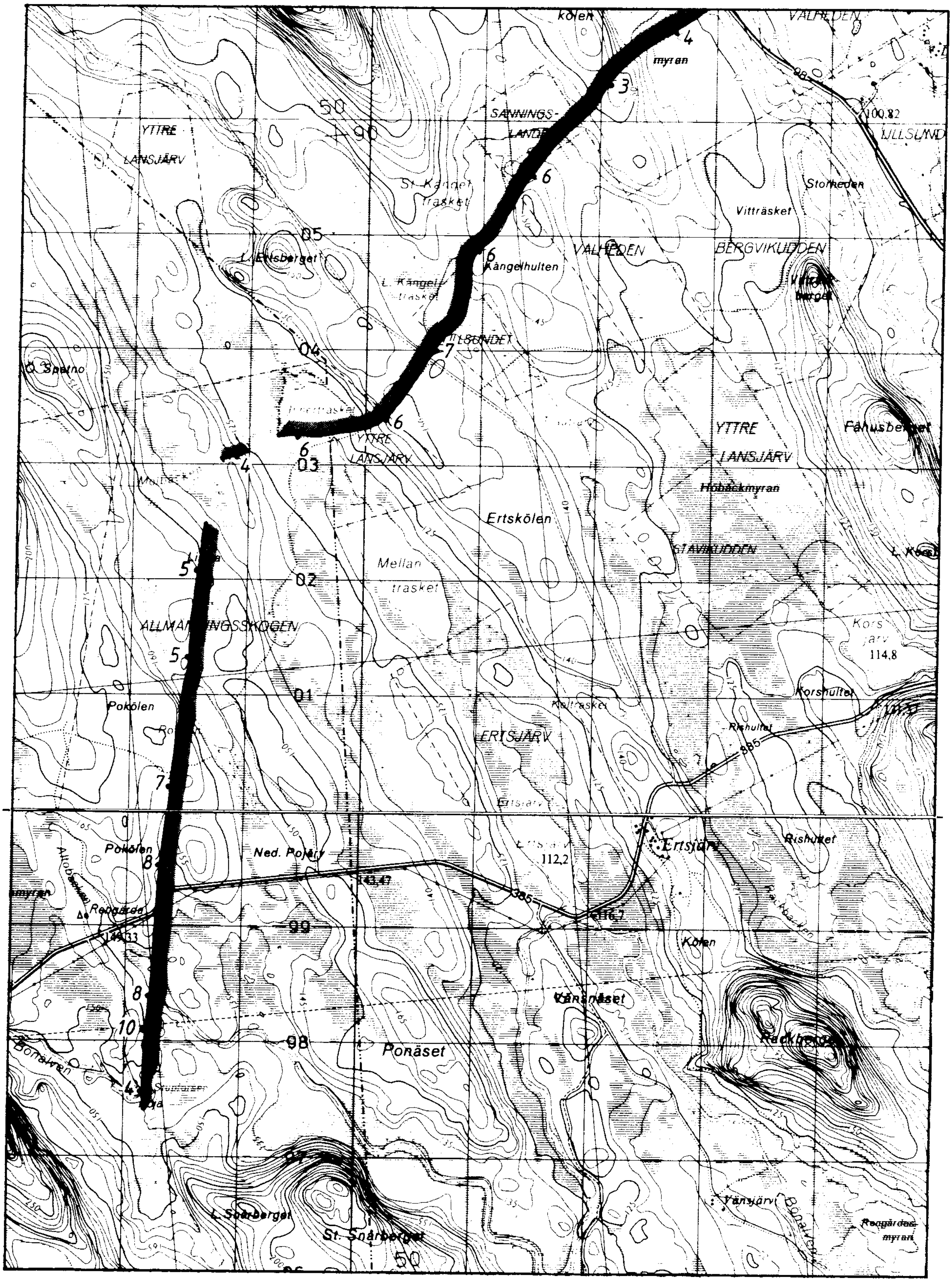


Figure 26. The Lansjärv faults at the border of map areas 26L Pålkem NE and 27L Lansjärv SE. Scale 1:50 000. Av. height error 0.8 m.

Width of shading	1 mm	2 mm	3 mm	4 mm	5 mm	6 mm
height of scarp	1-4 m	5-8 m	9-12m	13-16m	17-25m	>25m

Fault line with measured point and photogrammetrically measured height in meters. The lower surface is shaded.

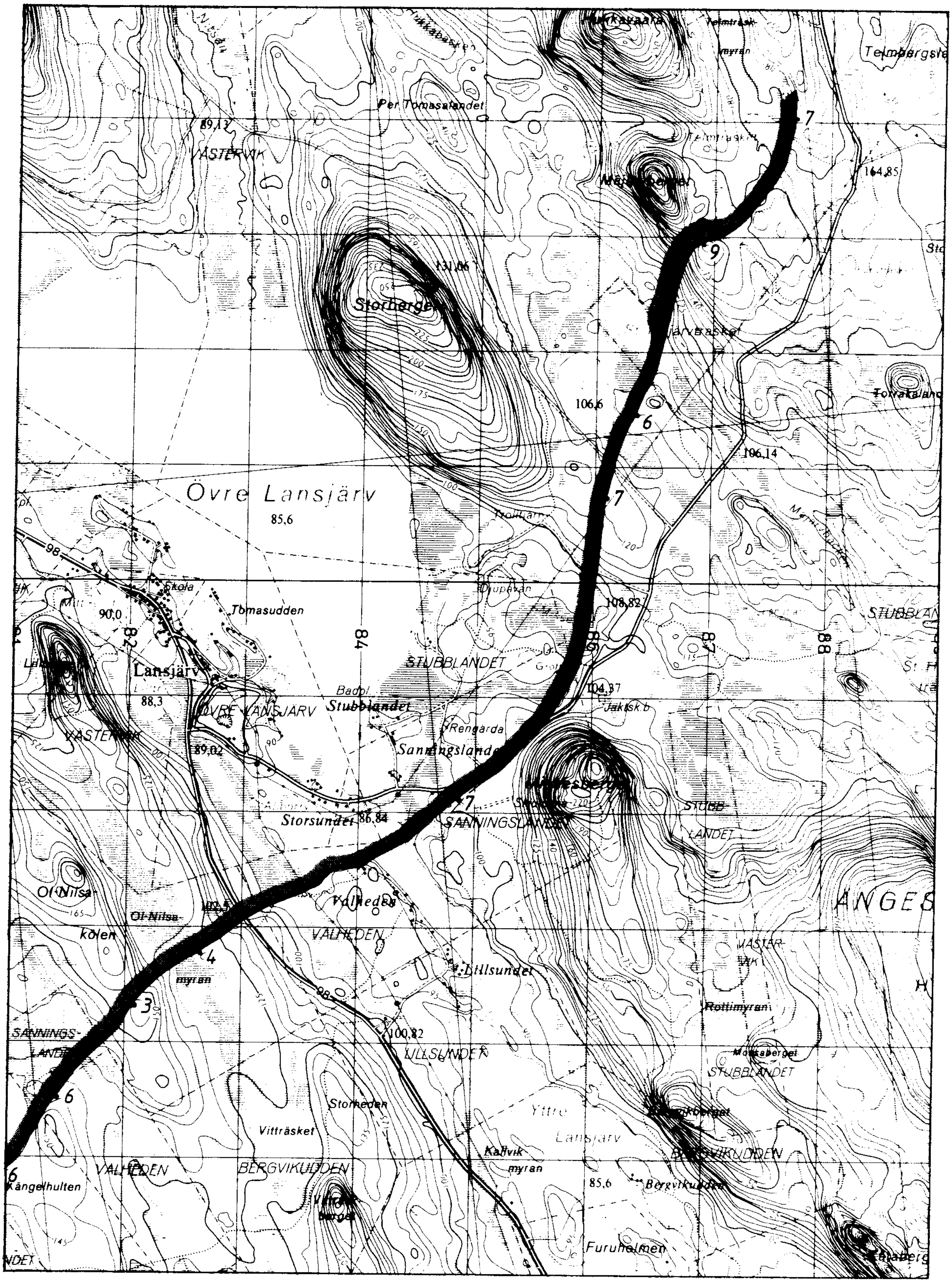
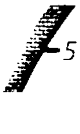


Figure 27. The northernmost part of the Lansjärv fault, map area 27L Lansjärv SE. Scale 1:50 000. Average height error 0.8 m.

Width of shading	1 mm	2 mm	3 mm	4 mm	5 mm	6 mm
height of scarp	1-4 m	5-8 m	9-12m	13-16m	17-25m	>25m



Fault line with measured point and photogrammetrically measured height in meters. The lower surface is shaded.

The fact that the fault is wave-washed all the way up to the highest shoreline level also implies that it formed shortly after, or preceded, the deglaciation. Due to the extensive abrasion, it is hard to decide whether the fault has been formed before the deglaciation, and subsequently been affected by glacial flow. However, a reasonable assumption is that it is contemporary to the other faults, and thus developed during a relatively short period of time after the deglaciation. This perception is also supported by the geographic connection to a number of landslides in the area.

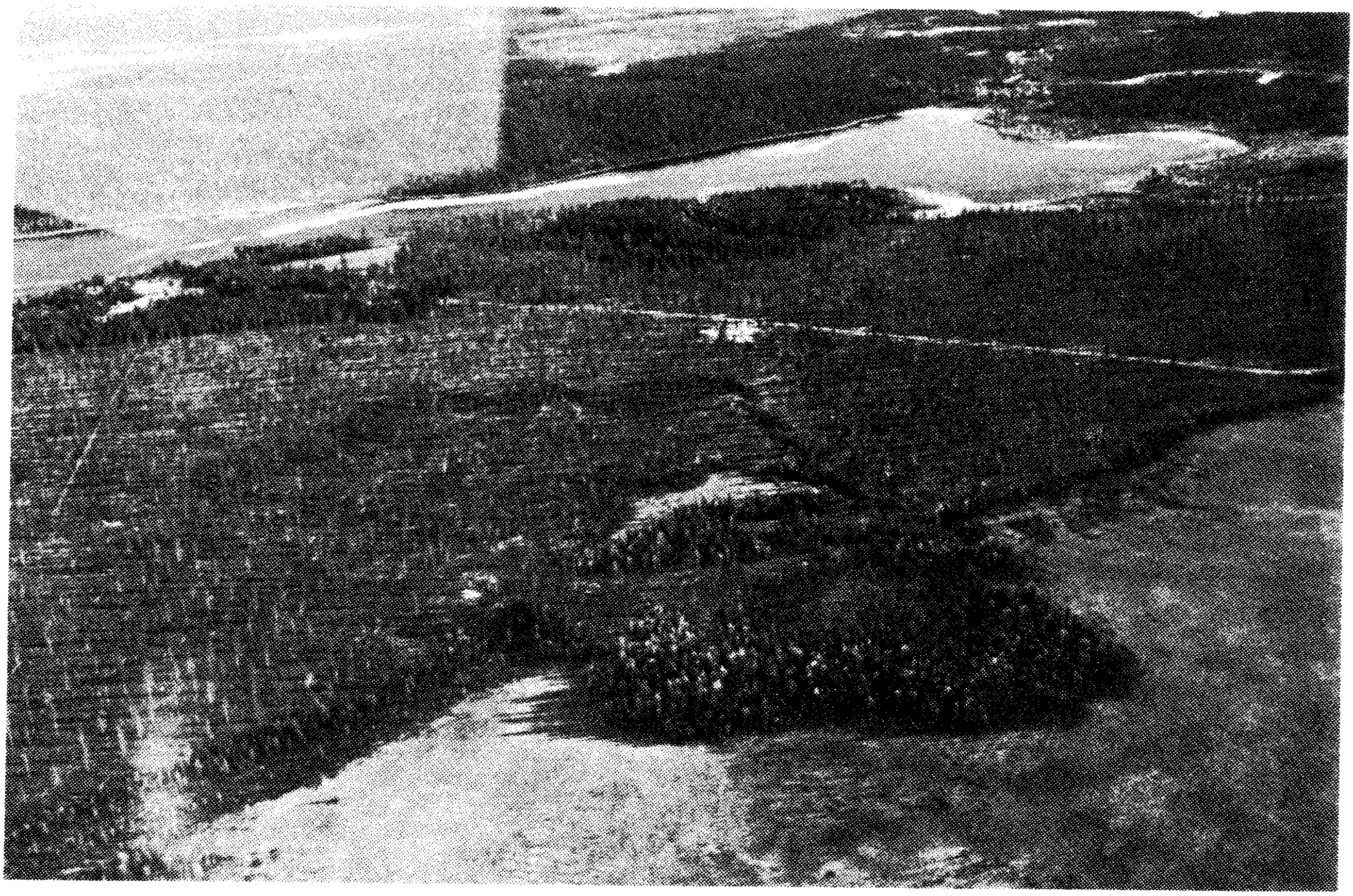


Figure 28. The landslide at Elmaberget (map area 27L Lansjärv SE). The slide has developed in a slope of only 3-4 degrees inclination, and has probably been released by seismic influence. The distance to the Lansjärv fault is only about 12 km.

The picture is inspected and admitted for publication.

Besides the new fault, five or six landslides have been detected within the map area. One of the more distinct occurs at Elmaberget (A 41, fig.3), and is shown in fig. 28. The slides have not been investigated on the ground, but apparently they throughout are developed in moraine.

26L Pålkem SW, SE. 27L Lansjärv SW, NE. 28L Tärendö SE. 26M Överkalix SW, NW, SE, NE. 27M Korpilombolo SW, NW, SE, NE. 27N Svanstein SW, NW. 28M Pajala SW, SE, and other parts of central and eastern Norrbotten. (Cf. figure 3.)

Large areas of central and eastern Norrbotten have been roughly air photo interpreted in connection with other projects, above all the Nordkalott project and different prospecting commissions.

During this work, especially the parts done during the last few years, naturally a certain attention has been given to the possible occurrence of quaternary faults or other features, relevant in this context. Special interest has been given the above enumerated map areas in eastern Norrbotten.

Besides the ones treated in the foregoing, no faults have been observed. It is very unlikely that any important late quaternary faults would have been overlooked. Thus, in all probability, no further major late quaternary faults exist in Norrbotten, at least outside of the Caledonian mountains.

On the other hand, a number of landslides have been observed, and these are marked in figures 1 and 3. The slides occur within the map areas 27L Lansjärv NE, 27M Korpilombolo SE, and 28M Pajala SW and SE. Three of the slides are marked as somewhat uncertain, but are probably of the same nature as the more clear-cut ones. Presumably, their less distinct appearance is due merely to local conditions.

As appears from fig.1, they occur in the same region as the slides in areas 27L SE, and in Finland. Thus, their regional occurrence coincides with that of the quaternary faults.

In figure 3, also the level of the highest shoreline is marked. These estimations rely on air photo interpretation of the highest level of wave-washing and of river deltas, and the altitudes have been read from the topographic map. In order to achieve better precision, the altitude determinations within a smaller area in the vicinity of Lansjärv have been made by photogrammetry.

1.2 The geographic appearance of the faults.

The total length of quaternary faults in Norrbotten is roughly 300 km. The earlier picture of the distribution and shape of the faults has changed in some essential points, namely the southern extension of the Pärvie fault, and the northern extension of the Lansjärv fault.

Thus, the Pärvie fault does not end at an older fault zone along the valley of the Lule river, but continues southwards for some additional distance. The southern part of the Pärvie fault coincides with an older dislocation zone, which continues for about 70 km towards the SSW, and in beneath the Caledonian bedrock (Lagerbäck and Henkel, 1977)

Therefore, it is speculative, but not impossible, that the quaternary deformation of the crust continues southwards in beneath the rocks of the Snavva-Sjöfall series and the Caledonian bedrock, but does not show as distinctly at the surface of these rocks, as it does in the more brittle Precambrian bedrock.

The horst-forming tendency of the Pärvie fault and its parallel faults is somewhat amplified by the newly detected, very low fault in the northernmost part of the map area 31J Råstojaure.

The newly detected fault belonging to the Lansjärv complex makes these faults fit the general pattern (i.e. with an upthrown eastern block) better than before. The fact that the northernmost but one of the fault branches is 'reversed' does not take away the general impression, and the anomaly can probably be explained in the light of the local geology.

The other changes of the previous picture are marginal, and do not alter the overall impression. The fault system in Norrbotten is clearly oriented in a NNE - SSW direction, which by the way also holds for the faults in Västerbotten, and for the greater part of the faults in Finland (cf. fig. 1). Thus, the system coincides by trend with one of the principal older dislocation systems in Norrbotten, and is oriented perpendicularly to the stresses in the bedrock caused by the motion of the earths' crust.

However, the impression that the faults are connected to the general stress field is somewhat disturbed by the easternmost two of the faults in Finland, and by the faults at Fiskarhalvön. At least for the Finnish faults, a connection to the assumed maximal glacial-isostatic depression is more convincing, as the ice sheet is generally believed to have culminated over the central parts of Finnish Lapland.

1.3 The height of the fault scarps - altitude measurements.

It has been regarded to be important to estimate the throw of the faults, one purpose being to facilitate a tectonic analysis. Such altitude measurements can be made in two ways: either by leveling in the field, or by photogrammetry. Field measurements would have been unduly costly, and are out of the question except possibly for special cases. Photogrammetric leveling does not yield the same precision, but is comparatively inexpensive.

The estimations have been made by means of an image interpretation instrument of the brand Zeiss Jena Interpretoskop B, with built-in micrometer gauge. The pictures used are contact prints and enlargements to the scale of 1:20 000 from LMV's standard images. The scale of the negatives is 1:30 000. For a smaller area in the map area 30J Rensjön, special-purpose photograps on the scale of 1:12 000 have been employed. All these pictures have been paper prints. Over the Lansjärv region, high-altitude false colour infrared images have been used in parallel with the B & W material. The IR negatives are on the scale of 1:60 000.

On the average, the scarp height of the faults has been measured at 7 sites for each 10 km of length of the fault, and mainly at places where the height of the scarp changes. The scarp height is marked on the maps by a shading of the lower side, the width of the shading varying with the scarp height. Furthermore, the measured height is given at the measured points. At each measured site, three readings have been taken, both of the foot and of the crest of the fault scarp.

In areas where erosion, sediments, mires or lakes prohibit the measurements, adjacent values from moraine or rock have been interpolated, so as not to give a false impression of varying throw.

Such an impression can, however, not be completely avoided. The faults have not been drawn across lakes and valleys with thick sediments, where we have no positive evidence of their existence. As the faults almost throughout are covered with soil, their scarp height at the surface probably varies with the thickness of the soil layer.

Method of calculation:

Excerpt from measurement record:

px = x - parallax

$\overline{px}$ = average x - parallax

Δpx = difference in px from crest to foot

	px_1	px_2	px_3	$\overline{px}$	Δpx
Foot	97	96	97	97	5
Crest	91	92	93	92	

The value of Δpx has been used in the parallax formula:

$$\Delta h = \frac{h * \Delta px}{b' + \Delta px}$$

where Δh = difference in height
h = flight altitude
b' = base distance of the images.

Δpx in the denominator has been disregarded, since it is of negligible importance with the ratios of Δh to h in question.

Accuracy of the measurements.

The images are not compensated for optical distortion, refraction, or curvature of the earth. Furthermore, the paper is liable to shrink. (However, these sources of error are of little importance for relative level estimations.) Neither are the images rectified, and hence, scale errors must be watched. The limit of angle error of the air photos from LMV is 5 gon. This error causes an altitude error of 270 m at the edge of the image, at a flight altitude of 4600 m. However, in the stereo model, where the estimations are made, the angle error of the two images must be equal to produce this maximal error. 90 % of the standard images from LMV are better than 1.5 gon of angle error, which causes an altitude error of about 80 m at the image edge, the flight altitude being 4600 m. The error decreases linearly towards the center of the image.

The flight altitude has been determined by scale measurements in the central parts of the images and by comparison with the readings of the camera altimeter. In the first image of each line, the altitude has been determined by scale measurement, and in the following, the altitude reading has been compared to that of the first image. Within each line, an additional scale measurement has been made as a checkup.

The standard enlargements (1:20 000) are without altimeter value, but in most cases the corresponding 1:30 000 images have been available. In other cases, scale determinations have been made for each stereo model. The topography has been included in the altitude values. The average error of the altitude determination is estimated at 150 m.

The Δpx - determinations have the largest sources of error. Control measurements were made at a representative fault. Fifteen px readings gave an average error of 0.0193 mm, which is a rather high value.* This is due mainly to two kinds of play in the instrument. The visibility has been very good.
The image sharpness has in several cases been somewhat doubtful, which has made the adjustments to the measuring point difficult.

The base distance, b', of the images causes errors due to the image tilt. At a tilt of 1 gon, the error is less than 7.2 mm at 1:30 000, 10.8 mm at 1:20 000, and 6.6 mm at 1:12 000.

*All these estimations of average error are on the high side.

The average error of h. The average error is calculated according to 'the special law of propagation', which concerns propagation of standard deviations and average errors in linear functions of independent measurements. The values vary slightly for different scarp heights.

Image scale	Image overlap	average error	% of total fault length
1:30 000	60%	1.2 m	53
1:20 000	60%	0.8 m	37
1:30 000	80%	2.1 m	5
1:20 000	80%	1.6 m	3
1:12 000	60%	0.8 m	2

The average error in question is given in the legends of the figures. The accuracy is not checked in situ, but comparable measurements have been made of known heights, and this has shown that the method is useful. Furthermore, the faults in the Lansjärv region have been measured by means of a Wild B8 from high altitude IR photos, and the heights thus obtained have shown very good agreement with the Interpretoskop measurements.

The heights measured vary from zero to about 30 m. The fault at Pyhävaara (30L Lannavaara SW, fig.XX), is at its highest close to 35 m. The height of the Pärvie fault normally varies from 5 to 10 meters, which means that the surface displacement is of the same order as that of the Lainio-Suijavaara fault, though the latter is but a third of the length of the Pärvie fault.

Most often, the scarp height is constant over long distances. The abrupt changes that occur are probably connected to rock changes, or to older zones of weakness. The causes of these throw changes are not known, but this is one of the topics that need closer investigation during the years to come.

Only vertical displacement has occurred, horizontal component is totally absent. This is indicated by the irregular course of the faults and the detail appearance of the shear planes. Vertical slickensides have been observed in several places. The dip of the fault planes seems most often to be 70 - 85 degrees from the horizontal plane of the upthrown block, and throughout it is evident that compressional forces have acted at the formation of the faults.

In most cases, the faults seem to be developed along one single plane, but in some places, a distinct 'staircase' shape appears, which makes the visual impression less pregnant. From the air photos, this might be mistaken for glacial influence.

1.4. <u>The age of the faults</u>

Attempts have been made to assess the age of the faults from their relations to the quaternary deposits and to the traces of drainage, formed at the deglaciation. In many cases, this has been possible. The topic has been treated more closely in the preceding paragraph 1.1, where the faults are commented by map areas.

A summary clearly shows that the Pärvie fault has formed in direct connection to the deglaciation of the area. In some places it has developed before the local deglaciation, and in other places after it. Since the process of the deglaciation cannot be reconstructed in detail, it is difficult to decide whether the fault has formed simultaneously along its entire length, or if it has developed by stages.

It seems most probable that separate parts of the Pärvie fault complex have formed at separate occasions. The most plausible course of deglaciation, with an ice front recessing towards the south and towards the west, implies that the northern part of the fault preceded the southern one by some hundred or hundreds of years.

In some areas, it also seems that adjacent parts of the fault complex have formed at different times. As has been pointed out earlier (the Pärvie fault close to the north of Langas 28I), there are, however, indications that the individual fault may have formed during a very short time, probably in less than a year. However, the relation is not quite clear, and until further notice this statement should be regarded as very preliminary.

Also the conditions to the south of Torneträsk do, however, suggest that the fault has developed during a comparatively short time, maybe at the most a few decades. It should, however, be strongly emphasized that the circumstances of the deglaciation are very difficult to investigate, and that it probably never will be possible to make a detailed dating of the faults from the quaternary relations alone.

However, the Pirttimys fault (30K NW) has certainly formed before the Pärvie fault. How long before is hard to say, but probably at least some hundred or hundreds of years.

The Lainio-Suijavaara fault is very difficult to date. There are indications that the northern part has preceded the deglaciation, whereas the relation seems to be reversed for the southern part.

Possibly or probably, also this fault has developed by stages, since the deglaciation of the area probably has proceeded from the northeast towards the southwest. In all probability, the fault has preceded the Pärvie fault.

All indications point to that the Merasjärvi fault (29L SW) has formed after the local deglaciation. Together with the course of deglaciation, this also implies that it formed after at least the northern part of the Lainio-Suijavaara fault. Its age relation to the Pärvie fault cannot be decided from the course of the deglaciation.

Probably, all of the Lansjärv faults have developed after the recession of the ice from the area. However, the fact that the northern fault branch is wave-washed high up to the highest shoreline level shows that at least this fault branch was developed in early postglacial time. If it is contemporary to the one at Risträsk, this implies that the faults have formed more or less in direct connection to the deglaciation, which means that they are considerably older than the Pärvie fault, as the ice remained for several hundred years longer in the Pärvie area.

The geologic connection to the landslides in the area supports the perception that the faults have formed after the recession of the ice, since no such landslides would have developed in a glaciated area.

To sum up, it seems clear that the faults are not quite of the same age. Instead, there is much evidence that they have formed in connection to the deglaciation of the area in question, which by the way supports the view that the glacial-isostatic forces have released the faults.

Probably, the deglaciation was crucial for the formation of the faults. The total depression, and with that probably also the intensity of the postglacial uplift, was, as far as is known, greatest in the east. Furthermore, ice remained in the west and prevented the uplift of this area. These circumstances would reasonably have brought about a strong tendency to unequal uplift, and thus created the conditions for breakage of the crust.

It should also be borne in mind, that from a geological point of view, the glacial-isostatic movements are very rapid, and that as a tectonic phenomenon they have to be regarded as dramatic. As compared to e.g. plate movements and orogeny, the speed of the postglacial uplift was of a far greater magnitude, and thus an important tectonic factor. Hence, it is not unexpected that the postglacial uplift was accompanied by fault movements and strong seismic activity.

1.5. Landslides

The fault movements during the deglaciation would have had strong seismic effects. These, in turn, may have had secondary effects, e.g. earth- and rockslides, which are common in connection to contemporary earthquakes.

In Finnish Lapland, there is a manifest geographic connection between quaternary faults and landslides (Kujansuu, 1972). Over forty landslides have been observed in Finland, and all but one lie in the same region as the faults. As is apparent from figure 1, the landslides observed in eastern Norrbotten, which are of just the same type as the Finnish slides, constitute an extension of the Finnish area of distribution, and the geographic connection to the faults is further confirmed. Also, the slides and the subsided bedrock section in map area 28I (fig. 5), not far from the Pärvie fault, suggest that there is a causal connection between the faults and the slides.

Kujansuu has dated a few of the Finnish slides by C^{14}-analysis of the bottom stratum in the mires that have formed inside of the slide masses. The analyses give ages that show that the slides have formed in direct connection to the deglaciation or shortly afterwards. Furthermore, the shape of one of the slides shows that it probably has formed in contact with the ice front.

Perhaps it should be pointed out that the observed slides not necessarily are the only occurring within the area. However, as has been said before, virtually all of the central and eastern parts of the district have been roughly interpreted in other contexts, and it is not very likely that any large number of slides would have escaped detection. Thus it seems that also in Sweden, there is a definite regional connection between faults and slides.

Throughout, the slides lie in flat terrain (the slope varies between about 3 and 12 degrees), and hence it is unlikely that they have been released by gravity alone. Instead, it seems plausible, both from their timing and from their location, that the slides have been initiated by the seismic effects of the fault movements.

If this is so, why have not more slides been formed or detected in connection to the Pärvie fault, but concentrated in Finland and in the eastern part of Norrbotten, and to some extent in the southern part of the Pärvie fault? There may be several reasons.

Firstly, the necessary topographic and soil-geologic conditions must, naturally, be at hand. The soil layer must be of a certain minimal thickness and extension, and lie in a slope that is not steep enough for the soil to flow away already in connection with the deposition, but still steep enough to support the formation of a slide. These conditions do not exist in all areas. For instance, in many places the soil layer on the mountain slopes is too thin for proper slides to form.

Another prerequisite is that the area must have been free of ice. As has earlier been stated, there are indications that some faults have developed prior to the deglaciation, while others have formed in connection to the local deglaciation. Thus, large parts of the presumptive slide areas have been covered with ice.

Other parts of the possible slide areas lie below the highest coastline level. The submarine slides that may have formed are probably very different from and more diffuse than the terrestrial ones. Furthermore, any submarine slides will have been abraded in connection to the post-glacial uplift, which further hampers or prevents their detection. In this context, it may be pointed out that at least the upper parts, i.e. the slide scars, of all the Swedish slides occur above the highest coastline level. With a few exceptions, also the Finnish slides lie above the highest coastline level.

The postglacial earth flow, especially in the mountain areas, decreases the possibilities of identifying landslides. In some areas, it has been very extensive and may well have erased the traces of further slides that may have formed in the region of the Pärvie fault.The original morphology of the reasonably steep mountain slopes is often completely destroyed.

Despite the above explanations, the concentration of slides in the eastern area remains peculiar unless other aspects are considered. Under the presumption that there is an actual causal relationship between faults and slides, one such aspect is the magnitude of the quakes that have released the slides.

However, it is difficult to point out any factors that would have caused greater seismic activity in the eastern areas than in the northern and western ones. Rather, the opposite relation would have been expected, since the total fault movement, with respect both to the throw and to the length of the faults, has been far greater at the Pärvie fault than it has been at the Lansjärv faults.

One possible explanation is that the fault movements have been more abrupt in the eastern area, but there is no proof for such an hypothesis. One circumstance that may speak in this direction is that it appears as that the Pärvie complex, and possibly also the Lainio-Suijavaara fault, have developed gradually, rather than at a single event. However, as yet there is no proof that this should not be the case also at Lansjärv and in Finland. On the other hand, the released seismic energy may have been greater in the eastern area, despite that the effects at the surface are not as monumental as in the north and in the west.

However, this highly complex matter is far beyond the purely quaternary geologic documentation, and will hardly be satisfactorily illustrated until after extensive tectonic, seismologic, quaternary-geological, and hard-rock geological investigation.

1.6 The relation of the Lansjärv fault to the highest coastline level

The highest shoreline levels are compiled in figure 3. The purpose of this is to investigate whether there is any anomaly of the total postglacial uplift at the Lansjärv faults. As a hypothesis, the faults might have been caused by a particularly large uplift within this area.

However, this seems not to be the case. The altitudes of highest shorelines are greatest in the southeastern part of the area, and decrease in a systematic way towards the north and towards the northwest. Single, abnormally high values occur, but these can hardly be connected to the faults. Probably, either these shorelines are misinterpreted, or they are the shorelines from local glacial lake damming.

Another aim of the highest coastline determination in the Lansjärv area was to find out whether there is any systematic difference between the levels of the highest coastlines across the fault complex. In order to attain a better precision, the altitude determinations in this area were made from high altitude false-colour infrared images, by means of an instrument of the brand Wild B8. The number of measurements is not sufficient for any positive conclusions to be drawn, but neither in this respect there seems to be any obvious connection between the faults and the total postglacial uplift.

However, it is worth pointing out that the highest coastline level reflects the total uplift at a certain site since the deglaciation of that area. There is nothing speaking against that the uplift during the postglacial epoch might have proceeded irregularly, despite that the final result is a fairly even postglacial uplift.

One should also bear in mind that the ice has recessed gradually from the area, and hence that different areas have become free of ice at different times. Within the area in question, the ice has recessed towards the northwest, which probably accounts for the generally lower highest coastline levels there. Thus it is not impossible that the total uplift since the beginning of the deglaciation has been as large in the northwest as in the southeast, despite that the highest coastline levels differ by about 30 m.

All the same, there is at present no definite reason to regard the Lansjärv faults as the result of a drastic difference in postglacial uplift between different parts of the area. However, the great length extension of the faults does imply that they reflect a profound deformation of the earth's crust. Also, after the discovery of the northernmost fault branch, the fault complex appears more regular, with a relative uplift of the eastern area, just as the other faults with the exception of the parallel faults of Pärvie.

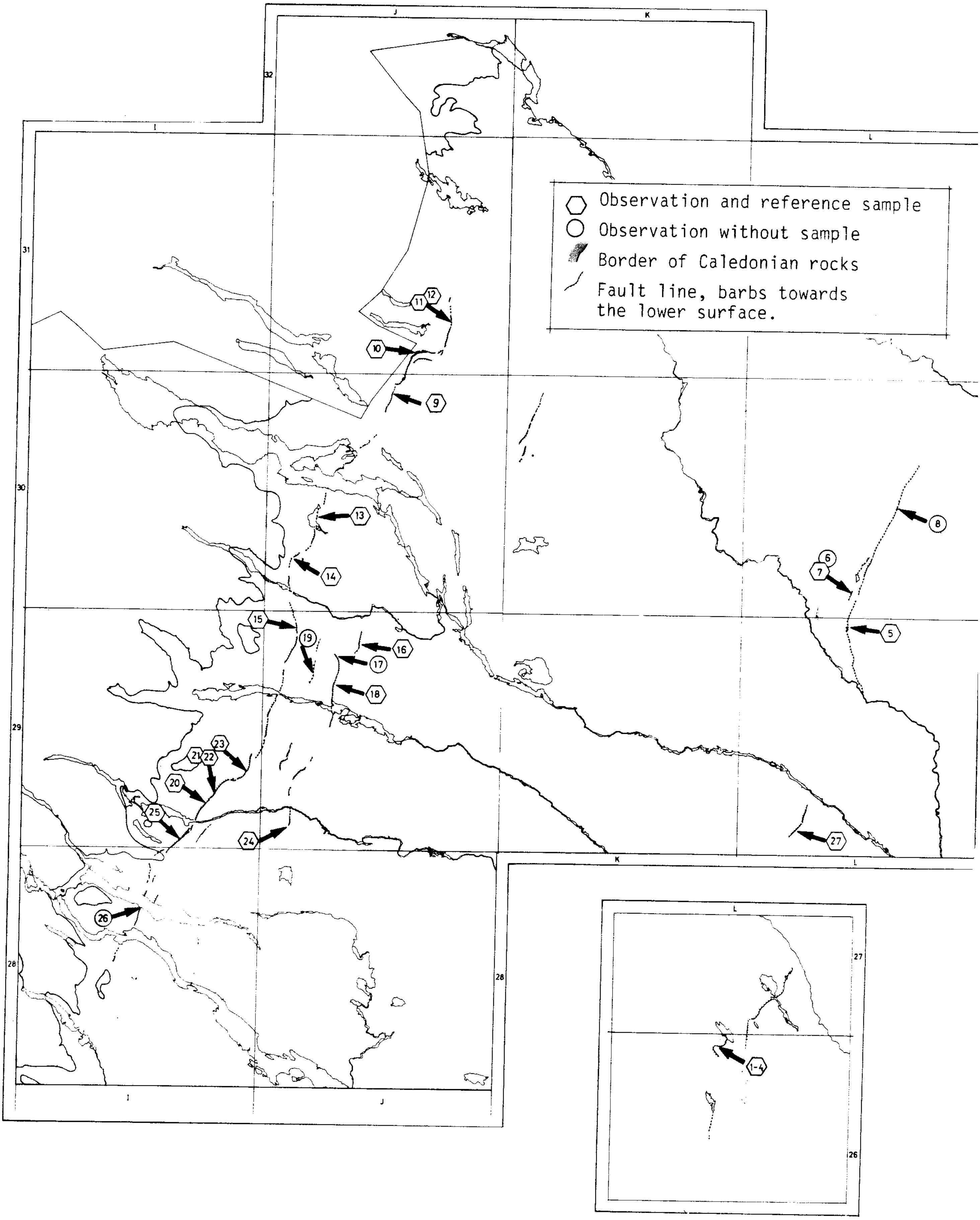


Figure 29. Observation localities at the quaternary faults in Norrbotten

2. PRE-QUATERNARY GEOLOGIC DOCUMENTATION

2.1 Neotectonic deformations

See map 1:1000 000 (figure 29) for location of observation localities.

Observations 1 - 4, Risträskkölen, 26L Pålkem NV.
The area is characterized by hybrid granite, gneiss granite or granodiorite containing strongly assimilated rests of probable volcanic (basic to intermediate - composition) origin. These rocks show strong shear deformation, mainly subvertical, and in the three following principal directions: NW, N30 E and N-S. Mica schists, also present in the hybrid granite, strike to the NW and dip 45 towards the SW. This indicates that the neotectonic phenomenon is oblique to the pre-existing schistosity.

Observation 5, 29L Lainio NV

Predominating Lina-type granite displaying weak schlierer of gneissgranite. The neotectonic phenomenon is materialized in the granite exposures as a succession of elongated blocks, striking N27 W, making up a "staircase" landscape descending towards the west.

Observations 6, 7, 30L Lannavaara SV

This exposure is the most characteristic for demonstrating the effects of neotectonic deformation. The host rock to the deformation consists of acid gneisses and Lina-type granite which are strongly fractured in a very disorderly manner along the neotectonic fault direction. A large number of blocks are still lying in strong disequilibrium, thereby showing the post-glacial timing of the deformation. Fig. 20 shows the effects of this violent cataclastic episode during which, under the effect of quasi-instantaneous tensional stress, the granite has been partly fractured along an irregular hexagonal (beehive) pattern. To the west of this observation (about 100m) a small exposure (No 7) shows rupturing and "staircase" topography towards the East, indicating that the fracture zone is rather wide and has probably locally resulted in small horstgraben tectonics.

Observation 8 30L Lannavaara SE

The neotectonic zone follows and has made up a deep canyon in Lina-type granites, gneiss-granites and banded gneisses with oblique schistosity (N5W, 30 degrees dip) to the canyon.

Observation 9 30J Rensjön

The neotectonic structure strikes N12E and is subvertical. Slickensides indicate an uplift of the eastern side. The host rock is a rather massive, coarse grained granite of the Perthite series. A certain 'staircase' topography, descending towards the west is visible in the fault zone (about 200 m wide).

Observation 10 31J Råstojaure

Presence of very red, somewhat altered (epidote, zoisite and quartz veinlets) medium-grained perthite granite. This apparently indicates that we are dealing with an old fault zone which has been reactivated. The main fault plane shows a reverse dip of about 78 degrees. The vertical displacement is estimated at about 4.5 meters.

Observation 11 31J Råstojaure

Same type as 10, however with presence of finer-grained rock of the 'leptite' type. Presence of highly crushed and recrystallized rock in the fault zone (mylonite).

Observation 12 31J Råstojaure

Medium-to-fine-grained granite (transition to 'leptite' type with some xenoliths of grey gneiss). Strong indication of rock deformation in the direct vicinity of the small lake. This has resulted in a tight, brittle shearing without recrystallization.

Observation 13 30J Rensjön

Beside the lake Nakerjaure, south of Torneträsk. Presence of a fine-grained, pink quartzite displaying a few small stringers of epidote from a previous weak cataclastic episode.
On the side of the lake, presence of a well-banded volcanic to volcano-sedimentary series, ranging in composition from acidic to intermediate. Some minor faults and brittle deformation follow the neotectonic structure. Most minor fractures are parallel to its plane.

Observation 14 30j Rensjön

A somewhat massive granodiorite is cut by veins and stringers of finergrained material. A thin section (fig. 31) from one of the these zones indicates that it is a mylonite with irregular quartzfeldspar bands alternating with chlorite-sericite rich bands also containing saussurite and epidote. Iron oxides make up some "spotty" coatings around some minerals. Quartz is often found as small angular crystals in a finer-grained matrix. Larger quartz shows interpenetrative relationships, typical of strained rocks. A discordant, rigid deformation, in the form of chlorite-sericite filled fractures cuts across the older cataclastic direction, pointing to at least two phases of rigid deformation.

Observation 15 29J Kiruna

Very red perthite granite and perthite monzonite (c.a. 5% quartz) of the "röd oscar" type. Many young, brittle faults coincide with the direction of the major neotectonic structure. The average dip of the fault plane is 30 degrees towards W22 N. A thin section (fig. 32) taken within the fault zone shows a coarse-grained perthite granite, displaying a very intricate texture with irregular crystal intergrowths between perthite and quartz. Presence of a few, very distinct, cataclastic veinlets with a fine-grained matrix, and containing angular fragments of quartz and feldspar. These veinlets cross-cut the section in many directions. This type of fracturation may be due to the neotectonic event.

<u>Observation 16</u> 29J Kiruna

Strongly tectonized rock of possible volcanic origin. A thin section (fig. 33) shows a very advanced stage of cataclasis resulting in a banded, very fined grained rock cut by stringers of chlorite-saussurite. The boundaries quartz-feldspar are very sutured. A network of rigid fractures is post-mylonitization and could have resulted from the neotectonic event.

<u>Observation 17</u> 29J Kiruna

Coarse grained perthite monzonite with brittle fractures running along the main neotectonic structure. The vertical displacement between the two sides of the structure is here estimated at 1.5 m.

<u>Observation 18</u> 29J Kiruna

Basaltic greenstone, in general rather massive, intensively fractured in the direct vicinity of the neotectonic structure.

<u>Observation 19</u> 29J Kiruna

Mylonite probably belonging to the perthite granite series, in the direct vicinity of the main fault zone. Outcrops outside of the main structure show the presence of medium-to-fine-grained rocks of probable volcanic origin, associated with rather massive perthite granite.

<u>Observation 20</u> 29I Kebnekaise

Strongly fractured and altered greenstone rich in epidote, saussurite and chlorite, still showing in places a ghost of an ophitic texture. A thin section (fig. 34) of this rock shows mylonitic stringers, outlined by dark iron oxides, enclosing a fine-grained matrix with only a few crystals of epidote and magnetite which have been preserved.

<u>Observation 21</u> 29I Kebnekaise

Same rock-type as 20 cross cut by many stringers of epidote-zoisite. Many of these stringers and small faults are mainly perpendicular to the main neotectonic structure. In other places, there occurs a strong fracturation of the rock parallel to the direction of the main structure. The volcanic rock is banded vertically in a N30 E direction, while the main fault runs N-S with a steep dip towards the E.

<u>Observation 22</u> 29I Kebnekaise

Acidic volcanic rocks, well fractured parallel to the direction of the neotectonic fault. Presence of actinolite stringers in some of the volcanics.

<u>Observation 23</u> 29I Kebnekaise

Very tectonized rock of acidic origin (volcanic, granite?). The fractures are mainly parallel with the main fault zone.

Observation 24 29J Kebnekaise

Greenstone, somewhat tectonized and fractured along the direction of the neotectonic fault.

Observation 25 29I Kebnekaise

Rather massive perthite monzonite with a very red colour ("Röd Oscar"). A thin section (fig. 35a) of this rock shows a perthite granite with a typical very complex texture around the perthite crystals. This type of texture is quite common for the perthite series but we have here such a quantity of finely recrystallized zones, that we are probably in or very near an old tectonic zone. One bent microcline (fig. 35b) indicates the particularly intense strain to which this rock has been subjected. A fine powder of hematite in the feldspar accounts for its very bright red colour.

Observation 26 28I Stora Sjöfallet

Exposures on the southern bank of Satihaure (fig. 30). An acidic porphyry to agglomerate displays beautiful crush zones and even ultramylonite zones (non consolidated) which mainly run parallel to the neotectonic fault zone, as well as to the banding in the volcanics. The main fault is here reversed and dips about 25 degrees towards the east.

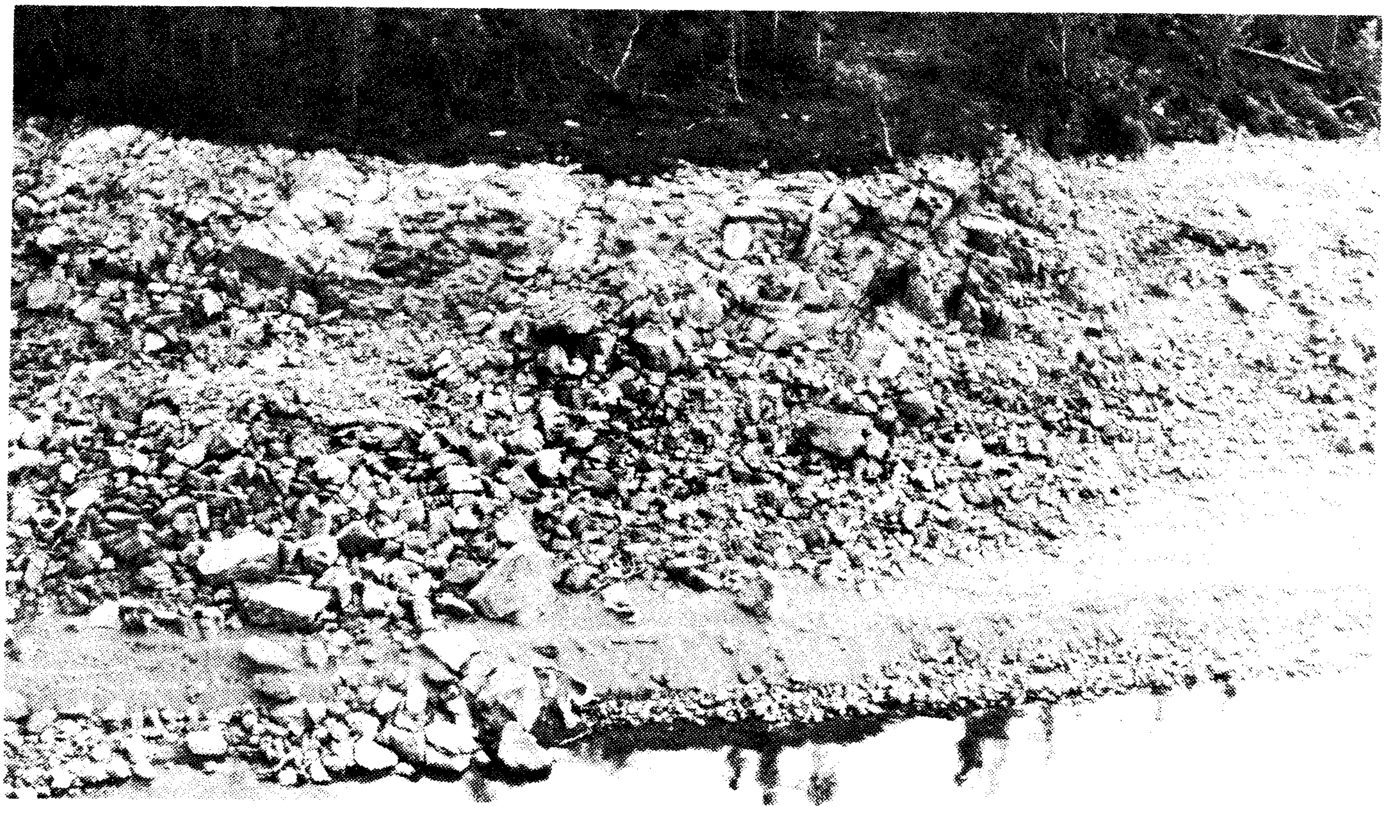


Figure 30. Bedrock observation locality 26. The photo shows the Pärvie fault at the southern bank of lake Satihaure (28I Stora Sjöfallet). The bedrock, consisting of acid volcanics, is heavily fractured in several zones more or less parallel to the main fault zone (to the right). Photo R. Lagerbäck.
The picture is inspected and admitted for publication.

Observation 27 29L Lainio SW

Near to the lake Merasjärvi. The rocks present belong to the Lina granite series, which have been fractured in a staircase manner (see obs. 5) towards the west. Many blocks are sticking out of the ground in a manner which precludes later ice movement (fig. 16).

2.2. Petrography

Five samples have been selected for thin section: Nos 14, 15, 16,20 and 25 (see map 1:1000 000 for location). These rocks have been taken within the fault or crush zone of the respective neotectonic lineaments. All of these samples show various cataclastic influence, ranging from mild (crush veinlets) to very intense (recrystallized mylonite). Some of these samples indicate clearly at least two stages of cataclasis, the oldest showing strong signs of recrystallization (quartz, feldspar, epidote, saussurite, magnetite and chlorite), mainly into more or less fine-grained aggregates. The second deformation can be characterized as a product of "rigid" deformation with very little recrystallization, sharp angles of fragments and in places, concentrations of chlorite, saussurite and iron oxides. This later deformation could be directly related to the neotectonic lineaments studied here. In any case the petrographic study of these rocks indicate that they have been deformed more than one time and that we probably are in presence of old fault zones which have been reactivated many times and represent weakness-zones of the crust.

Observation 14 (fig. 31).

Rock: Strongly cataclastic and recrystallized fine-grained rock of possible volcanic or volcano-sedimentary origin.

Texture: Irregular quartz-feld, bands alternate with chlorite-sericite rich bands. Saussurite - epidote and titanite are also concentrated in the darker bands.

Magnetite and apatite are disseminated throughout the section. Iron oxide makes up spotty coatings around some minerals.

Quartz makes up small $\pm$ angular grains in the matrix. It is also found as larger crystals or cryst. aggregates with interpenetrative relationships.

Abundance of microcline in the matrix.

A discordant, rigid fracturation with some chlorite - sericite concentration cuts across the older cataclasis (recrystallized bands) in many directions.

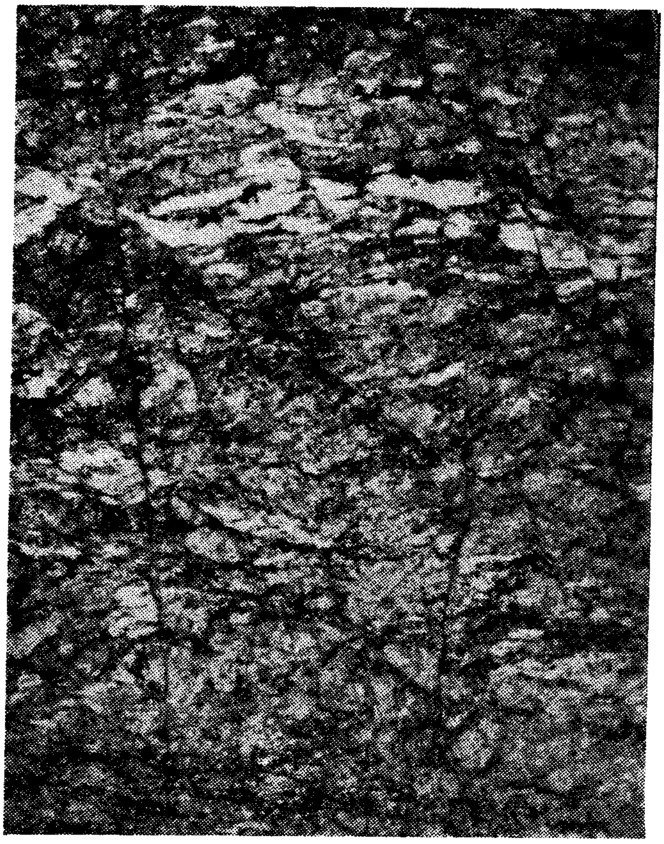


Fig. 31. Thin section from the bedrock at observation locality 14. Magnification 5.5 x.

Photo C. Ålinder.

Observation 15b (fig.32)

Rock: Perthite granite (coarse grained).

Texture: Coarse grained, very intricate with crystal intergrowth and irregular boundaries of both perthites and quartz.

Presence of a few very distinct, cataclastic veinlets with a fine-grained matrix containing angular quartz and feldspar fragments (sub-mylonitic texture). These veinlets run in many directions and cross-cut the entire section.

Fig. 32. Thin section from the bedrock at observation locality 15b. Crossed nicols. Magnification 25x. Photo C. Ålinder.

<u>Observation 16 (Fig.33)</u>

Rock: Mylonite

Totally recrystallized rock in bands (fine-grained to medium-grained) with chlorite-saussurite along fracture zones. Network of rigid fracture (post recryst.).

-Subrounded Q aggregates (medium grained)

-Only Q is medium-grained

-Matrix = (fine grained): $Qn\ mic^{++}\ Al6^{-}$

-Biot.⟶chl

-Very sutured relations between feld + q.

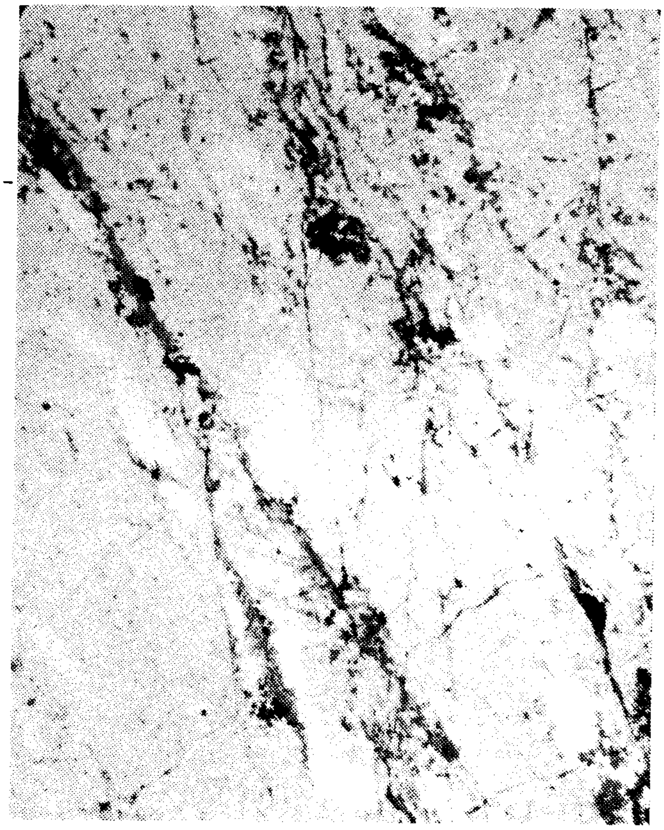


Fig. 33. Thin section from the bedrock at observation locality 16. Magnification 5.5x. Photo C. Ålinder.

Observation 20 (Fig. 34)

Rock: Strongly altered greenstone with much epidote, saussurite, chlorite but in places still showing traces of an ophitic-type texture.

Texture: There runs through the section a darker grey (oxides, saussurite and magnetite), fine to very fine-grained, mylonitic veinlet. All of the minerals have been ground down to a fine powder with only a few epidote and magnetite crystals which have been spared. The fissure varies greatly in width and has somewhat sinuous contours.

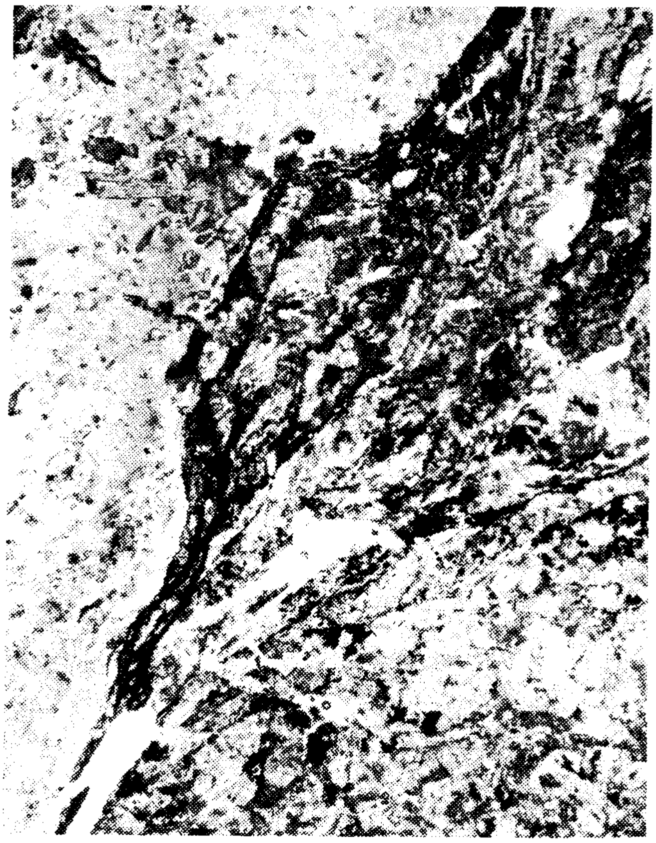


Fig. 34. Thin section from the bedrock at observation locality 20. Magnification 15x. Photo C. Ålinder.

Observation 25 (fig. 35 ab)

Rock: Perthite granite (coarse-grained)

Texture: Typical complex texture of this type of rock with some very fine-grained zones, often around or at the boundary of perthite crystals. This texture is quite common for the perthite series, but we have such a density of these recrystallized zones that we are possibly in presence of an old tectonic zone. One bent microcline shows particularly intense signs of strain. A fine powder of hematite in the feldspar accounts for the 'red oscar' aspect of the rock.

Fig. 35a (left) and b (right). Thin sections from the bedrock at observation locality 25. Crossed nicols. Magnification 40x (a) and 100x (b). Photo C. Ålinder.

REFERENCES

Kujansuu, R., 1964: Nuorista siirroksista Lapissa.
Summary: Recent faults in Lapland.
Geologi 16, 30 - 36.

Kujansuu, R., 1972: On landslides in Finnish Lapland.
Geol. Surv. Finl. Bull. 256, 1 - 22.

Lagerbäck, R. & Henkel, H, 1977: Studier av neotektonisk aktivitet i mellersta och norra Sverige, flygbildsgenomgång och geofysisk tolkning av recenta förkastningar.
KBS Tekn. Rapp. 19, 1 - 22.

Lagerbäck, R., 1979: Neotectonic structures in northern Sweden.
Geol. Fören. Stockh. Förh. 100, 263 - 269.

Lundqvist, J. & Lagerbäck, R., 1976: The Pärve fault: A late-glacial fault in the Precambrian of Swedish Lapland.
Geol. Fören. Stockh. Förh. 98, 45 - 51.

Tanner, V., 1930: Studier över kvartärsystemet i Fennoskandias nordliga delar IV.
Bull. Comm. Geol. Finl. 88, 594 pp.

LIST OF KBS's TECHNICAL REPORTS

<u>1977-78</u>

TR 121 KBS Technical Reports 1 - 120.
Summaries. Stockholm, May 1979.

<u>1979</u>

TR 79-28 The KBS Annual Report 1979.
KBS Technical Reports 79-01--79-27.
Summaries. Stockholm, March 1980.

<u>1980</u>

TR 80-26 The KBS Annual Report 1980.
KBS Technical Reports 80-01--80-25.
Summaries. Stockholm, March 1981.

<u>1981</u>

TR 81-17 The KBS Annual Report 1981.
KBS Technical Reports 81-01--81-16
Summaries. Stockholm, April 1982.

<u>1983</u>

TR 83-01 Radionuclide transport in a single fissure
A laboratory study
Trygve E Eriksen
Department of Nuclear Chemistry
The Royal Institute of Technology
Stockholm, Sweden 1983-01-19

TR 83-02 The possible effects of alfa and beta radiolysis on the matrix dissolution of spent nuclear fuel
I Grenthe
I Puigdomènech
J Bruno
Department of Inorganic Chemistry
Royal Institute of Technology
Stockholm, Sweden January 1983

TR 83-03 Smectite alteration
Proceedings of a colloquium at State University of New York at Buffalo, May 26-27, 1982
Compiled by Duwayne M Anderson
State University of New York at Buffalo
February 15, 1983

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Roland Pusch
Division Soil Mechanics, University of Luleå
Luleå, Sweden, 1983-02-20

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Åke Bresle
Jozef Saers
Birgit Arrhenius
Archaeological Research Laboratory
University of Stockholm
Stockholm, Sweden 1983-01-02

TR 83-06 Investigation of the stress corrosion cracking of pure copper
L A Benjamin
D Hardie
R N Parkins
University of Newcastle upon Tyne
Department of Metallurgy and Engineering Materials
Newcastle upon Tyne, Great Britain, April 1983

TR 83-07 Sorption of radionuclides on geologic media - A literature survey. I: Fission Products
K Andersson
B Allard
Department of Nuclear Chemistry
Chalmers University of Technology
Göteborg, Sweden 1983-01-31

TR 83-08 Formation and properties of actinide colloids
U Olofsson
B Allard
M Bengtsson
B Torstenfelt
K Andersson
Department of Nuclear Chemistry
Chalmers University of Technology
Göteborg, Sweden 1983-01-30

TR 83-09 Complexes of actinides with naturally occurring organic substances - Literature survey
U Olofsson
B Allard
Department of Nucluear Chemistry
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