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On landslides in Finnish Lapland

by Raimo Kujansuu

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ON LANDSLIDES IN FINNISH LAPLAND

BY
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WITH 12 FIGURES IN THE TEXT

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The landslides in Finnish Lapland involve sudden mass movements of till deposits. This paper describes slides varying in morphology and mode of movement, their occurrence and situation on slopes, and the grain size and orientation of the displaced material. By means of pollen stratigraphy and C^{14} dating applied to the peat beds overlying the material, it has been possible to determine the minimum age of the landslides. They have been found to have taken place more than 8 000 years ago. The study traced the landslides back to the exceptional climatic and humidity conditions prevailing during the deglaciation stage of the ancient continental ice sheet. Further, the possibility was recognized that the slides were associated at the same time with recent faults occurring in the region, such occurrences having conceivably triggered the slides.

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INTRODUCTION

The significance of landslides in shaping land forms is great in areas where, as a result of the erosive action of, for example, faults, glaciers or rivers, there have developed excessively steep slopes, which fast mass movements tend to restore to equilibrium. In the countries of northern Europe, the commonest slides involve fine-grained bottom sediments, and in most instances they are the result of disequilibrium of land forms caused by fluvial erosion. Such phenomena have been reported from Finland ever since the early decades of the present century (e.g., Hellaakoski 1920, Tanner 1924, Olander 1934). Rockslides on a large scale are common in regions where there exist young sedimentary or volcanic rocks, whereas only in exceptional conditions (prominent relief, prevalent jointing, weathered rock) have slides of crystalline schists or plutonic rocks occurred.

Less often have slides of coarse, non-sorted mineral deposits been reported, and the majority of such reports deal with movements down fairly steep slopes of thin surficial layers of earth, or so-called debries-slides. Slides of this kind have been described from, for example, the mountainous region of Sweden (Rudberg 1950, Rapp 1960, 1962, 1963), where the surface layer of till has become water-logged, among other things, after unusually heavy rains to the extent of starting to run down the slopes. Nasmith (1964) has described slides of clayey till material in the region of the Meikle river, northern Alberta, and Dishaw (1967) a massive earthflow that occurred on the north shore of Babine Lake, British Columbia.

The landslides of Finnish Lapland involve the movement of till deposits. Rapp (1960, p. 149) uses the term »earthslide»; in this paper the term »landslide» is used, however. The slides here in question occur mainly on fairly gentle slopes, and the circumstances affecting their genesis deviate fundamentally from those previously described. The till masses had been remarkably thick, in many cases over ten meters, and with an elliptical or round ground pattern. In Sharpe's (1938) classical classification, they belong largely to the class of earthflow, where, besides flowage, there also occurs slumping at the upper end of the slide. Rapp (1960, p. 150) has applied to small landslides of this type in the Kärkkevagge area the term »bowl-slide».

In magnitude, the landslides of Lapland are fairly big (0.5 to 1.5 million cu. m) and completely overgrown by vegetation. They did not come to light until aerial photographs could be examined and interpreted; by this method, land forms can be given an exaggerated three-dimensional appearance and extensive tracts visualized at the same time (cf., Nasmith 1964, p. 162). In Finland, the interpretation of aerial

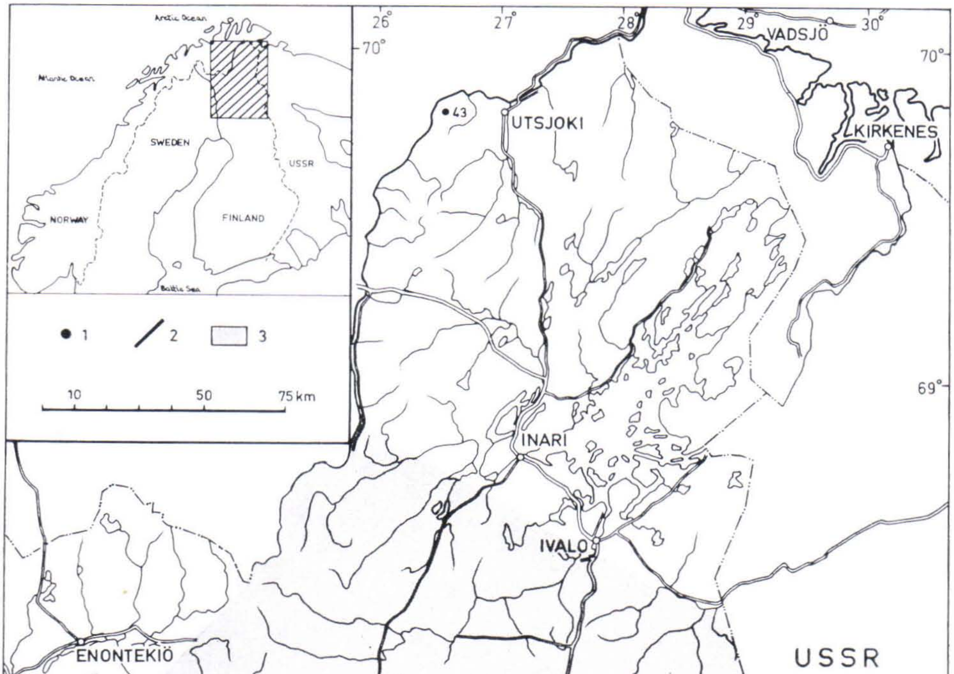

FIG. 1. The situation of the landslide area in northern Europe (ruled), the relation of the landslides (1) to recent faults (2) and to the area of weathered bedrock (3).

photographs has been used for over a decade to facilitate the mapping of Quaternary deposits on a 1: 400 000 scale. In this work, morphological indications have held a central place and landslides have been an excellent example of the special morphological phenomena revealed through the interpretation of photographs. A corresponding special feature is the recent faults in Lapland (Kujansuu 1964).

THE DISTRIBUTION OF THE LANDSLIDES

The landslides of Finnish Lapland are concentrated in the western parts of the province, where they occur in greatest abundance in the region embracing the districts of Kittilä, Kolari and Pello. In the central region of the province, a few of them are to be met with in the district of Sodankylä, two in the district of Pelkosenniemi and one in the extreme north, in the district of Utsjoki (Fig. 1). With the exception of the last-mentioned, the slides are situated on the southern side of the main watershed, approximately in the zone of the ancient ice divide, or in the area where the ice lingered longest in Finland during the deglaciation stage (Kujansuu 1967, pp. 19, 28). On both sides of the main watershed in Lapland, there occurs in many places in a zone about 150—200 km broad preglacially weathered rock, which has been preserved in the region owing to the weak erosion that has lasted a long time. The area of weathered bedrock is situated for the most part on the north side of the region of distribution of landslides.

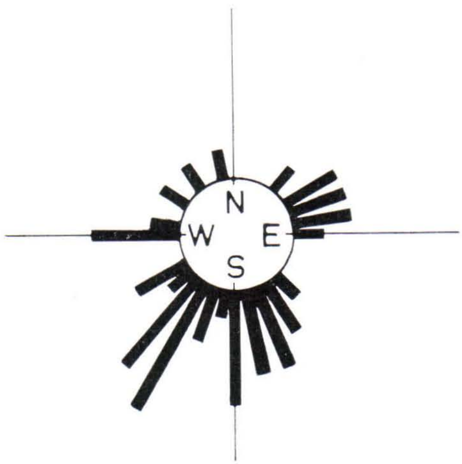

FIG. 2. The frequency diagram representing the directions of movement of the landslides indicates at the same time the situation of the slides on slopes exposed to the sun. The shortest bar represents a single slide.

The majority of the slides are situated in granite or quartzite areas. The reason probably lies purely in the fact that these rocks are responsible for elevated land forms on the flanks of which slides could take place. With the exception of such elevations of bedrock resistant to erosion — monadnocks —, the region over which the slides are distributed constitutes in its main aspects a peneplain.

During the deglaciation stage, the region, having sunk down under the weight of the continental ice sheet, was covered by the Yoldia Sea to an elevation of about 180—220 m. With a few exceptions, the landslides are situated, however, on the supra-marine level, corresponding to between 160 and 360 m above present sea level. Slides occur most abundantly on the southern and southwestern flanks of the hills and fells (Fig. 2). Influencing such a situation, in addition, to the circumstance of their being the sides exposed to the sun most, is the fact that, especially in western Lapland, slopes facing in these directions are most frequent because the great fractures forming the valleys in the bedrock trend NNW—SSE (Kujansuu 1967, p. 17). The slides are situated on the middle and lower slopes of hills and fells, below the timber line, most commonly only from 20 to 150 m above the surrounding peneplain, where the slope profile turns concave and the inclination diminishes. (cf., Iwatsuka 1959, p. 156). The slides took place on slopes whose angle of declivity varies between approximately 3 and 10 degrees. In most cases, however, it is from 5.7 to 7 degrees, corresponding to a difference of from ten to twelve meters in elevation per 100 m.

MORPHOLOGY OF THE SLIDES

In the field, a landslide can be recognized by the steep slide bank (Fig. 3) and by the small, shallow, bowl-shaped depression bordering it on the upslope side. The

FIG. 3. A steep slide scarp, from which the earth masses broke loose to slip down the slope, borders on the side of the upper slope a bowl-shaped hollow (cf., Fig. 6). The photo was taken from the upper edge of slide No. 7 of Aakenustunturi in a northeasterly direction.

inclination of the bottom of the depression is smaller than that of the slope. The material that flowed from the depression forms in most cases ridges at right angles to the direction of the movement with the result that they resemble small end moraines. In some instances, there occur disordered clusters of mounds that bring to mind fields of hymmocky moraine. Usually, the ridges, curving gently outward, have dammed surface waters behind them, causing the basins of the lower part of the slide to turn boggy very rapidly (cf., Nasmith 1964, p. 162). The process of paludification has been also promoted by the circumstance that the slides have in many cases broken through to the ground-water level.

At the boundary between the districts of Kittilä and Kolari, about 35 km to the east-southeast from the parish center of Kolari, there is a slide opening out toward the south-southwest on the southwest flank of the hill known as Otusmaa (Fig. 4; 1, No. 23). The angle of the slope of the hill, which rises some 50 m above the surrounding country, is about 4 degrees, corresponding to a 7-m difference in elevation per 100 m. From the slope, there broke loose a mass of earth 300 × 300 m and less than 10 m in thickness, which slid down a few hundred meters to form a ridge curving distinctly outward at the foot of the slope. The slide was repeated headward and laterally with the result that the displaced mass spread over an area measuring 400 × 750 m. The lateral repetition appears as separate arcs of the outermost ridge formed by the slide, the centermost arc being clearly the oldest. Inside the arcs lies material that has slipped down in the form of ridges and hummocks, which,

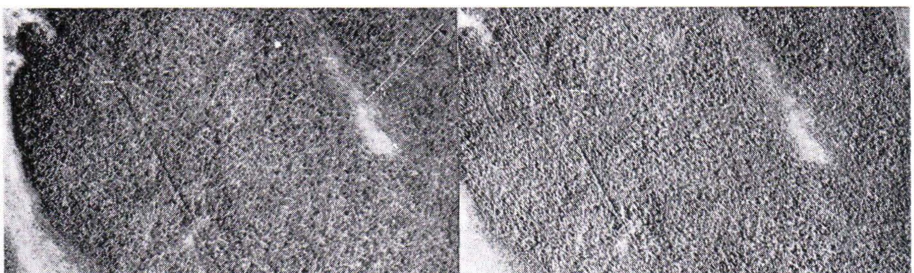

FIG. 4. A stereopair showing the landslide (No. 23) on the southwest flank of the hill known as Otusmaa. The curves of the outermost ridges indicate that the slide took place by lateral repetition. (Reproduced by permission of the Topographic Service).

together with the outermost ridges, bound small bog basins. The discontinuity of the slide scarp and the variety of small topographical features at the base are due to a manifold developmental process and the thinness — less than 10 m — of the displaced mass of earth. Analogous in form and mode of occurrence are the landslides of, for example, Palotiukuvaara (No. 12), Sotkaselkä (Nos. 14 and 15) and Kierinki (Nos. 18 and 19).

The landslide (Fig. 5) that took place in the eastern section of Sodankylä on the south flank of Vittaselkä (No. 17) is situated slightly higher on the slope, the inclination of which is approximately 12/100. Owing to the situation, the slide is elongated in shape in line with the slope. The shallow, oblong gully is bordered on the upslope side by a steep, very sharply delineated and continuous slide scarp, along which the material broke loose and slipped down in a south-southeast direction. The displaced material forms low, outwardly curving ridges, behind which lie small boggy hollows. The maximum length of the slide from the scarp to the outermost ridge is 800 m and its breadth more than 400 m and the quantity of material carried down the slope some 0.5 million cu. m.

In the western part of Kittilä, on the concave side of the arc formed by Aakenustunturi, there are four distinguishable landslides (Fig. 6), which are situated at the lower part of the steep upper slope of the fell, right below the timber line. The inclination of the slope varies here between 10 and 17/100, becoming more gentle at the lower end, or between 2.5 and 7/100. Of the Aakenustunturi landslides, No. 7, which resembles the Vittaselkä slide, is easy to distinguish in aerial photographs.

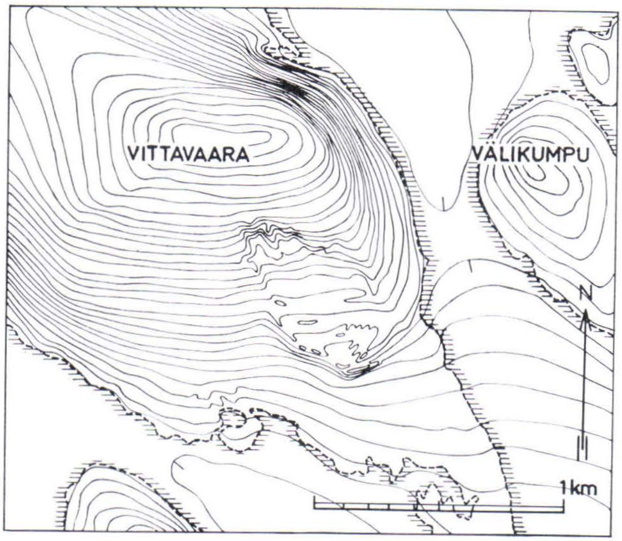

FIG. 5. A sketch map of the slide on the south slope of Vittavaara, where the outward-bulging ridges formed by the displaced material are clearly visible. The contour lines are marked at intervals of about two or three meters.

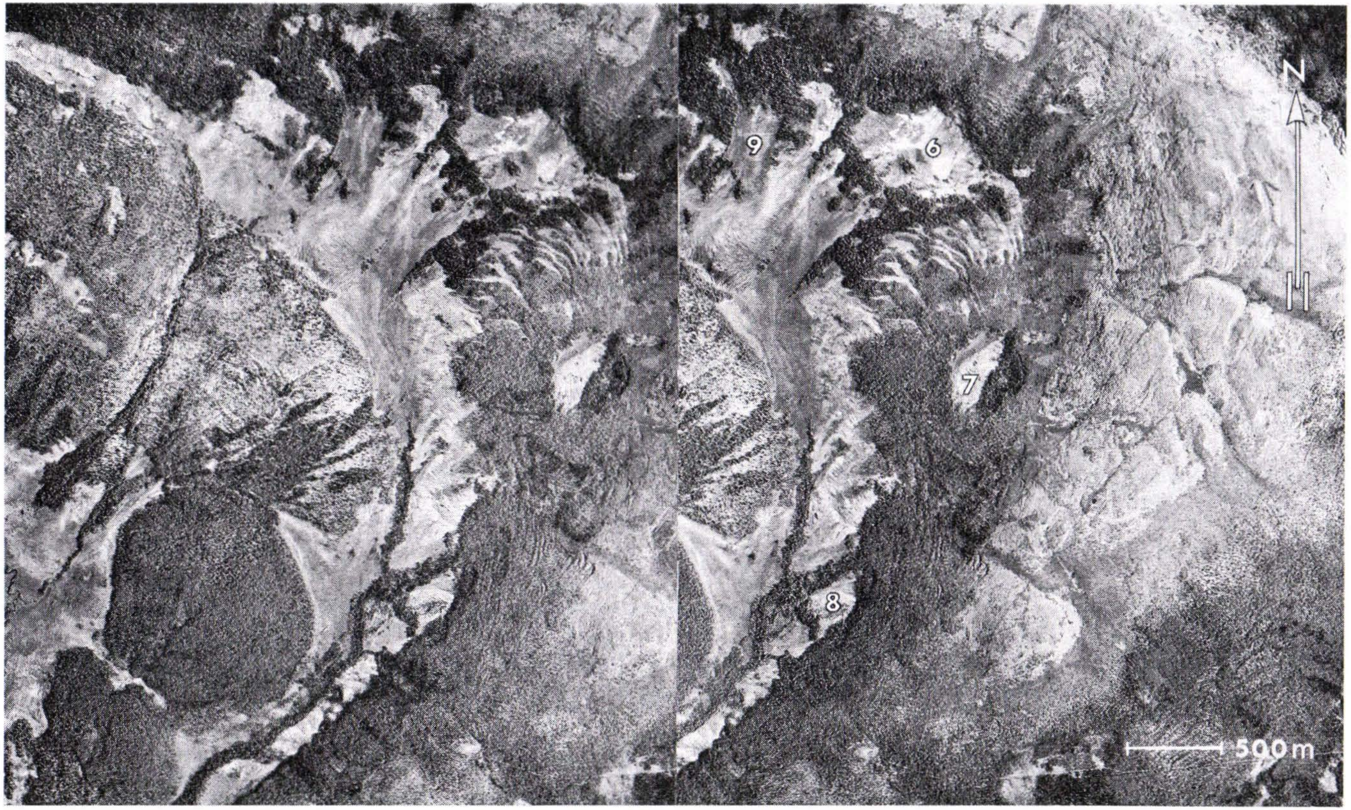

FIG. 6. A stereopair showing the landslides situated in the inner edge of the curve of Aakenustunturi opening up toward the west-southwest. No. 7 is particularly clearly defined because it is situated slightly higher on the slope than the others and the mass of earth involved in the slide had been fairly thick. Nos. 6 and 7 intersect lateral drainage channels that originated during the melting stage of the continental ice sheet. No. 8 is similar in form and position to No. 6, though smaller. In the case of slide No. 9, the thin slab of earth was displaced nearly 1 000 meters, and it formed a small, solitary mound at the foot of a low ridge that halted its movement. (By permission of the Topographic Service).

The steep slide scarp can be observed even in an individual photograph by virtue of its dark shadows; similarly, the light surface of the bog-covered base of the slide stands out from the surrounding area clearly. The material of the slide appears in an aerial photograph as a dark-toned hillocky tract that brings to mind morainal topography. It intersects lateral drainage channels brought about by glacial meltwaters, as does the scar left by the slide. The maximum length of the slide is about 900 m and its breadth 400 m. The amount of material in the slide is roughly 0.5 million cu. m. and the greatest distance traveled between 500 and 600 m. Seven hundred meters farther north is another slide (No. 6), which, situated on a gentler slope, is 500 m long and 750 m wide. Similar in form and position, though smaller in size, is the southernmost one (No. 8); the same remarks might be made of some of the slides on the south flank of Kätkätunturi (Nos. 1—3). In the fourth slide (No. 9) in the area of Aakenustunturi, the amount of earth involved is substantially smaller than in the preceding cases, but the distance covered by the mass was nevertheless considerably longer, or about 1 000 m. The rather thin slab of earth broken loose from the slope slipped across a shallow depression and did not stop until it ran into a low ridge, where it formed a transverse ridge. The inclination of the lower slope is 0—2.5/100. This slide resembles in type the »sheet-slides» described by Rapp (1960, p. 152) from the area of Kärkevagge, although the angle of the slope is appreciably smaller at Aakenustunturi.

The slide on the south slope of Levitunturi (No. 4), 13 km to the north from the parish center of Kittilä, differs from the rest in that it consists of two separate, overlapping landslides of roughly the same kind (Fig. 7), which in form closely resemble the corresponding features at Vittaselkä and Aakenustunturi. Possibly,

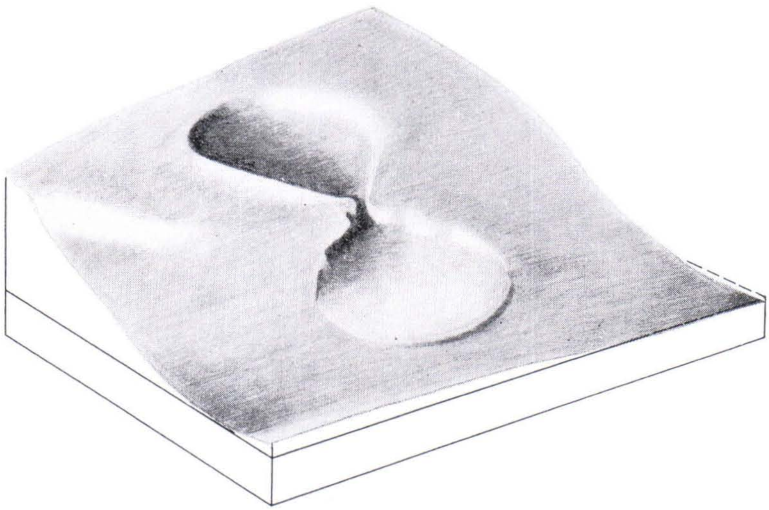

FIG. 7. A block diagram of a bipartite landslide (No. 4) on the south slope of Levitunturi.

the upper slide took place first, adding such an extra load to the lower part of the slope that the lower slide followed the upper one quite rapidly. For the most part, the ridge formed by the upper slide remained, however, in place. The material of the lower slide forms a gently sloping tongue of earth, on the surface of which are low arcuate ridges bulging outward. Behind them have evolved little bogs, as in the case of other slides. The combined valume of material is slightly under a million cu. m. The profile drawn by means of a seismic sounding across the lowest slide in the direction of the slope gave as the thickness of the earth layers at the upper end of the slide approximately 15 m and at the lower and ca. 50 m. Still remaining of the earth layers of the upper part, too, is a thickness of 7 m, and in the 50 m of the lower and there is also slide material to a thickness of between 10 and 15 m. On the basis of the seismic velocity (3 000—3 500 m per sec), it may be concluded that the bedrock underlying the loose deposits is heavily weathered, especially along the foot of the slope. Increasing velocity at higher elevations indicates that the bedrock there is less weathered.

The material that slid down at Akanvalkko (No. 16), 15 km north-northeast of Kittilä, forms a distinctly asymmetrical heap (Fig. 8). The southern edge of the tongue of earth is quite sharply defined, as if there had been some obstruction there to halt the flow of material. The only obstruction that might come into question

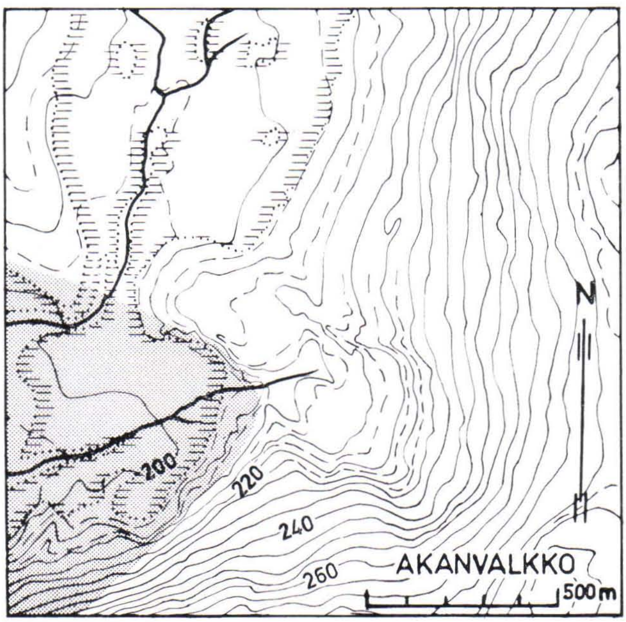

FIG. 8. The landslide situated at Akanvalkko (No. 16) evidently took place right in front of the continental ice sheet as it was retreating toward the south-southwest. The conjectured marginal position of the ice sheet (grey) is marked on the map on the basis of the asymmetric form of the displaced material.

is the margin of the continental ice sheet, which in this region retreated toward the south. In form the steep southern edge resembles a slope developed in an ice contact. In magnitude, the Akanvalkko slide is one of the largest, comprising as it does roughly a million cubic meters. The pitch of the slope is 8.5 per 100 m, and the material slid in a west-southwesterly direction.

According to Sharpe's (1938) classification, certain of the landslides of the Pello and Kolari districts are more of the mudflow type. On the south slope of Vaattovaara (No. 29), 25 km east-southeast of the parish center of Kolari, there is a landslide (Fig. 9) divided into two branches; it came about by a headward repetition. The greatest length of the slide is 1 500 m, the width varies between 200 and 400 m,

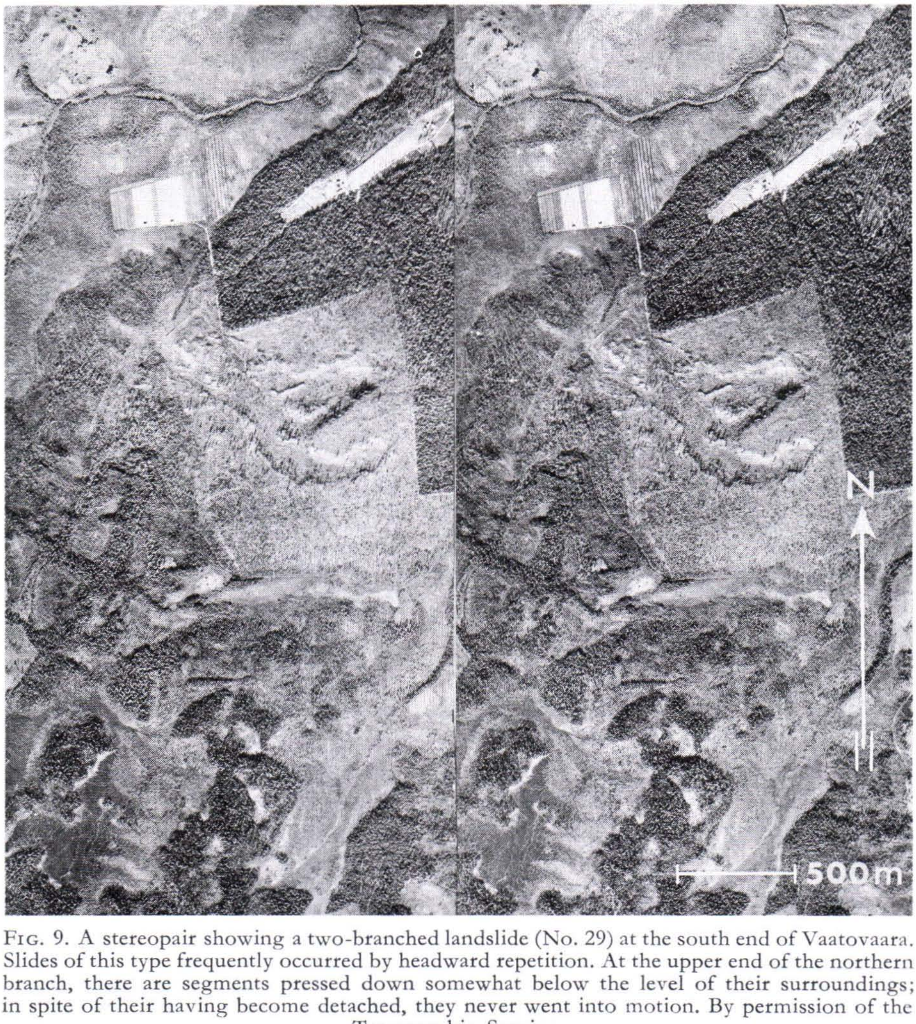

FIG. 9. A stereopair showing a two-branched landslide (No. 29) at the south end of Vaatovaara. Slides of this type frequently occurred by headward repetition. At the upper end of the northern branch, there are segments pressed down somewhat below the level of their surroundings; in spite of their having become detached, they never went into motion. By permission of the Topographic Service.

and the depth is at most about 15 m. The pitch of the south slope of Vaattovaara is between 7 and 9 m per 100 m, that of the base of the slide only 2—4/100. The material of the slide has 1) spread as an extensive, fairly level and thin mantle all the way to the low-lying bogland and 2) composed a thick hummocky formation in a small area on the lower slope of Vaattovaara. From the mode of spread of the material, it may be concluded that at the initial stage the material flowed as a watery soup over a broad area and later, as the amount of water decreased, its viscosity increased and the distance covered by the flow diminished. The curving, branched ground pattern suggests that the slide took place by headward and lateral repetition. The masses of earth that slipped last have come to rest at the bottom of the gully, forming little ridges and hummocks. The development of the final stage of the branch on the northwest side is indicated by small depressions — segments of earth that became detached from the upper end of the slide scar along the curved surfaces and sunk down slightly lower than the surrounding ground without, however, breaking off completely. Evidently, the moisture conditions of the ground changed on the upper slope to the extent of preventing further slides. Landslides similar in type occur on, for example, the south flanks of Aalistunturi (No. 26) and Mustitunturi (No. 33).

Of the slides on the east flank of Vaattovaara, the southernmost one (No. 28) has remained almost entirely at the slumping stage.

MATERIAL OF THE SLIDES

The soil of Finnish Lapland consists mainly of glacial minerogenic deposits and postglacial organogenic deposits. The deposits of sorted material are concentrated in the valleys, and they are generally coarse and by origin glaciofluvial or fluvial. Fine-grained bottom sediments are not to be found in the supra-marine area. There are great differences in the thickness of the till mantle. In the fells and hills, the thickness of the till deposits is only 0—2 m, but in the valleys considerably more in many instances even dozens of meters. The thickening of the soil cover begins in the middle and lower parts of the slopes, and it explains the concentration of the slides at these levels, wherever the angle of the slope and the amount of material suffice.

The material of the slides is the same kind of sandy and fine-sandy till as the till generally occurring in the area of western Lapland (Fig. 10). In the area of Levitunturi (No. 4), silt and finer grades account for 35—40 per cent of the total material, the content of clay being only between 2 and 5 per cent. The material of the slide is of the same sort as the undisturbed till in the vicinity. Compared to the former, the material in the area of Aakenustunturi (No. 6) is slightly coarser, with from 23 to 32 per cent consisting of silt and finer grades and clay accounting for between 2 and 3 per cent. At Taapaselkä (No. 25), silt and clay together amount to between

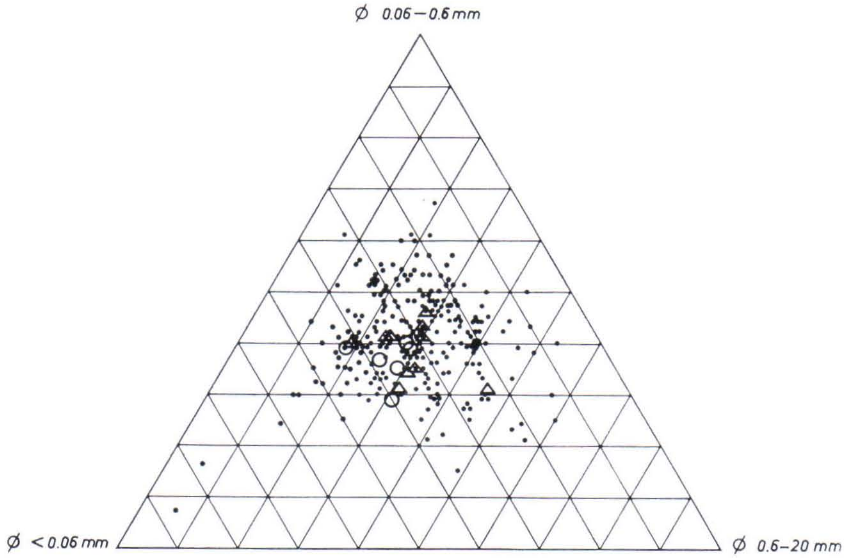

FIG. 10. The granularite of the displaced material (triangles) and the stationary material next to the slides (circles) marked in a triangular diagram, in which the dots represent the granularity of the tills in western Finnish Lapland, according to Kujansuu (1967, p. 20).

35 and 41 per cent of the total (clay fraction = 2—4 %), no difference appearing there, either, between the material of the slide and the surrounding deposits. In the area of Vaattovaara (No. 19), the corresponding figures are 29—45 per cent and 2—3 per cent.

Although the grain size is about the same in the slides and in the surrounding deposits, distinct differences nevertheless appear in the consistence of the material. The material of the slides is looser than that of the undisturbed till of the vicinity.

The movement of the material down the slopes has affected the orientation of the grains. In the undisturbed till, the orientation caused by the flow of the ancient glacier continues to prevail, whereas the orientation of the stones contained in the displaced material varies greatly (Fig. 11). The fabric analyses made from the small ridges situated at right angles to the flow reveal that the orientation of the material of the slides runs either perpendicular or parallel to the ridges (Fig. 11). The differential movement within the mass of earth caused a reorientation of the till fabric. This is but natural because not only the displacement by sliding or slipping of segments of earth was involved but in most cases also a distinct flow. The sliding of segments took place only at the initial stage of the movement. The orientation of stones in a line parallel to the movement or the slope has been observed also in instances of slow movement of masses (e.g., Rudberg 1950).

In their mode of occurrence, material and, above all, form, the landslides of Finnish Lapland are so much alike that their mode of origin was probably quite

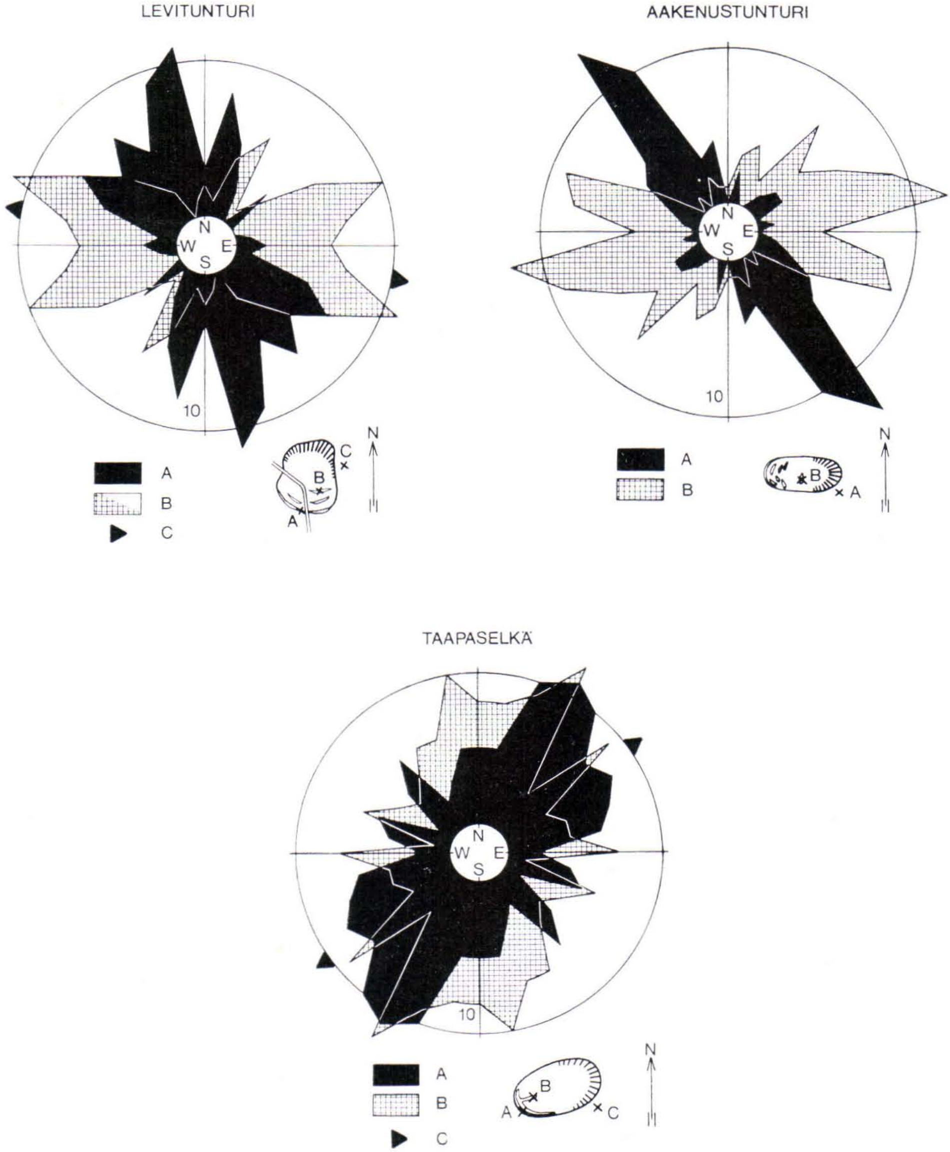

FIG. 11. The rose diagrams show the orientation of the slide material to deviate from the undisturbed till of the surroundings; similarly, there occurs considerable variation in the orientation of the stones in the slide material, too. The direction varies from parallel to perpendicular in relation to the ridges.

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similar. Under the prevailing conditions, the bearing capacity of the soil did not suffice to resist the weight of the deposits with the result that along the curving section surface there broke loose a block of earth, which only at the initial stage slipped down the slope. The sequence of events underwent headward and/or lateral repetition. The main part of the movement consisted of flow, the nature of which was determined by the thickness and water content of the mass of earth and the angle of the slope.

AGE OF THE LANDSLIDES

The landslides of Lapland are fossil; in other words, so much time has passed since their origin that they have become covered by vegetation and substantial peat beds have accumulated on the sites. Evidently, under present climatic conditions, major mass movements of this type are not possible at all.

To determine the minimum age of the slides, peat series were taken from the bogs that had formed behind the ridges for pollen analyses and C^{14} datings. Three

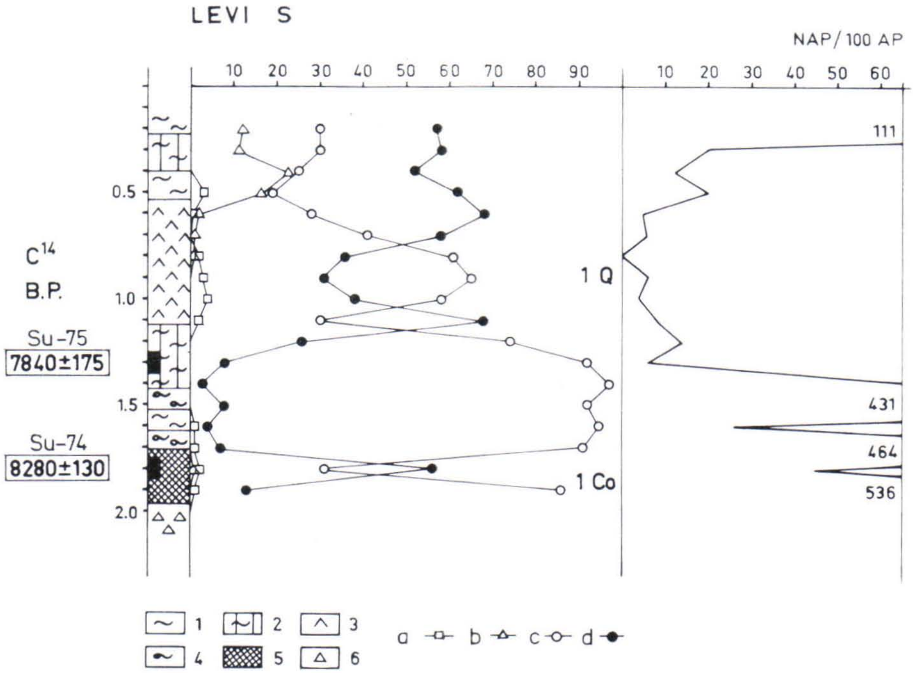

FIG. 12. The pollen diagram constructed from the peat bed overlying the Levitunturi landslide indicates that the deposition of the peat began during the time of the strong Betula maximum, or at about the same time as elsewhere in western and central Lapland. The C^{14} datings carried out from the series probably given too low an age to this Betula-dominated horizon. Key to the symbols: 1) Sphagnum peat, 2) Sphagnum-Carex peat, 3) wood peat, 4) Bryales peat, 5) coarse detritus, 6) till, a) Alnus, b) Picea, c) Betula, d) Pinus.

of the five peat series investigated revealed that the process of paludification had started during the time of the strong Betula maximum. A comparison of the series from Levi (Fig. 12, No. 4), Juppuravaara (No. 20) and Taapaselkä (No. 25) with the pollen diagrams made from nearby areas (e.g., Lappalainen 1970, Beilage II and IV) shows that, in the light of the pollen stratigraphy, the peat beds overlying the material of the slides are just as old as the corresponding beds situated beyond the limits of the slides. At Aakenustunturi (No. 6) and Lylymaa (No. 13), the deposition of the peat started, according to the pollen stratigraphy, only after the period of dominance of the birch, which would indicate that the process of paludification started in these localities somewhat later than at Levi, Juppuravaara and Taapaselkä. This need not necessarily mean that the slides might be younger; in the same proportion, than the overlying peat beds.

Two C^{14} datings have been made from the level of the Betula maximum of the Levitunturi series. They yielded the following result: the lower = 8 280 ± 130 y.B.P. (Su-74), and the upper = 7 840 ± 175 y. B.P. (Su-75). The age of the corresponding horizon of the lower part of the Taapaselkä series was determined to be 7 390 ± 195 y. B.P. (Su-77), and the age of the lower part of the Aakenustunturi series 6 610 ± 175 y. B.P. (Su-78). The last-mentioned is, as already pointed out, younger, according to the pollen stratigraphy, than the preceding ones. The ages obtained from the level of the Betula maximum are lower that those arrived at by Lappalainen (1970) in dating the corresponding pollenstratigraphic horizon in central and western Lapland (range from 8 410 ± 150 y. B.P. to 11 000 ± 130 y. B.P.). On the sites of the slides, the formation of peat has been a slow process, and therefore the effect of matter tending to give a lower age, like that contributed by, for example, the roots of plants, is likely to be considerable in the lower part of the deposit.

The deposits overlying a landslide yield only a minimum age, and they prove that the slides are quite ancient. The likelihood is that approximately the same length of time has elapsed since the landslides took place as the continental ice sheet retreated from the region; conceivably, the slides are connected with the deglaciation process in the sense that the conditions prevailing in the foreland of the ancient ice sheet had favored the occurrence of landslides. This view is encouraged by the observations made on the site of the Akanvalkko slide (No. 16), where the morphological features indicate that it took place right in front of the ice margin.

ON THE FACTORS INFLUENCING THE GENESIS OF LANDSLIDES

Under the periglacial conditions prevailing during the deglaciation of the continental ice sheet, a highly watery layer formed on the surface of the ground as the permafrost thawed out. The still frozen layer of soil underneath prevented the percolation of the water down into the ground water, whereupon the structure of the ground loosened and the properties maintaining its bearing capacity deteriorated to a fundamental extent (cf., Williams 1959, p. 489). The fast melting of the ground frost in warm sunshine played its part, for a large proportion (ca. 70 %) of the slides are situated on southern slopes. The significance of drastic soaking of the ground has already been demonstrated in the origin of various landslides (e.g., Rudberg 1950, Rapp 1960, 1963). According to Helenelund (1964, p. 96), the bearing capacity of silt-rich till decreases sharply from the effect of even a slight excess of moisture. It is thus obvious that under certain conditions till deposits are likely to move easily. Similarly, in the genesis of certain hummocky moraines it is assumed that water-logged till could press into cracks and crevasses in the lower surface of the glacier under the pressure of the overlying ice load (e.g., Hoppe 1952).

The slip plane of the landslides was apparently the boundary between the frozen and the thawed-out ground, the surface of the bedrock or some horizon rich in silt and clay. The seismic soundings carried out at Levitunturi indicate that at least there the slipping did not take place over the bedrock surface, and no observations have brought to light the existence of fine-grained intercalations. There the first alternative looks like the most likely one. The »air-layer lubrication» proposed by Shreve (1965) and Kent (1966) does not seem possible even in the case of the minor slide of Aakenustunturi (No. 9), where the distance covered was the longest. On gentle, $< 10/100$, slopes, earth masses probably could not generate sufficient speed.

Aerial photographs have disclosed the existence in the same region of recent faults in the bedrock (Kujansuu 1964), which are synchronous with the landslides. The earth tremors attending the faults could have triggered the landslides, just as frequently happens at the present time (cf., e.g., Maton and Streitz 1967, p. 127). At least the regional connection in Lapland is obvious. With three exceptions, all the landslides are located close to the larger faults (Fig. 1).

The significance of landslides as factors levelling out slopes has been slight in western and central Lapland, for climatic conditions favoring their occurrence have been of short duration. In the strong relief of the Fennoscandian mountain regions, some of the material slides down the slopes in rapid mass movements (e.g., Rapp 1960, Maps I and II). When fabric analysis is used in the determination of the directions of movement of the continential ice sheet, the effect of both rapid and slow mass movements in re-orienting the material should always be taken into account (cf., Rudberg 1958). The till deposits of central and western Finnish Lapland are highly stabile under the conditions prevailing nowadays and landslides are unlikely, but extremely violent and sudden rainstorms are liable to cause small, rapid mass movements on the steeper slopes of the fells. Changes in the present natural groundwater conditions resulting from the effects on surrounding country of the great man-made lakes of Lapland, for example, and changes in the plant cover of clear-cut areas and the consequences of such changes, or comparable occurrences, are likely to increase the possibilities of small landslides taking place in certain areas.

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