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CONTEMPORANEOUS GEOMORPHOLOGICAL PROCESSES IN LONGYEARDALEN, VESTSPITSBERGEN (SVALBARD)

Abstract

In July 1974 the author undertook geomorphological investigations in Longyearbyen, Isfiord, Spitsbergen, with reference to previous investigations made in 1958. Action of slopewash, solifluction, and mechanical weathering was the object of these new studies. The catastrophic rainstorms in 1972 caused some changes in morphology of local slopes. The effects of this rainstorm lay mainly in altering and accentuating previously existing landforms. In recent years mechanical weathering has shown an increased activity which has promoted a new debris transgression on talus cones. This process is accompanied by slope recession at a mean annual rate of 0.3 mm. For the last 30 years the author estimates he rate of solifluction to be from 2 to 4 cm per year.

INTRODUCTION

The geology and geomorphology of Longyear valley, which issues into Advent fiord (Isfiord), is well known, mainly due to the location here of the administrative and economic center of Svalbard. In 1958 I made some geomorphological investigations at Longyearbyen and at that time I gained the impression that on the slopes intensive gravitational processes were taking place, caused by meltwater and rain. At about the same time, A. RAPP (1957) was conducting investigations in Longyearbyen and neighbouring fiords. In his conclusions, based mainly on comparisons of photos taken at different periods, this author found rather minor activity of geomorphological processes on Spitsbergen slopes.

In 1972, during two days (10 & 11 July) a torrential rainfall occurred with previously unrecorded intensity. The two day rainfall, amounted to 31 mm and for the whole month it was 70 mm which compared to the monthly average of 17 mm (records of the meteorological station at Longyear, cited in the works of F. THIEDIG, U. LEHMANN, 1973) was a catastrophic occurrence. The cause of this heavy rainfall were warm, humid air masses which moved northward from the intensely heated Scandinavian peninsula. The immediate result of this rainfall was the activity of mass wastage processes (downslope flow of debris and mud) as well as erosion (Pls. 1, 2). It must be remembered that periglacial areas are characterized by a vigorous surface flow of water due to impermeability of the ground (permafrost). Almost all the rainwater flows down the slopes and its energy is spent as a force setting in motion the periglacial slope cover or as a powerful agent of erosion.

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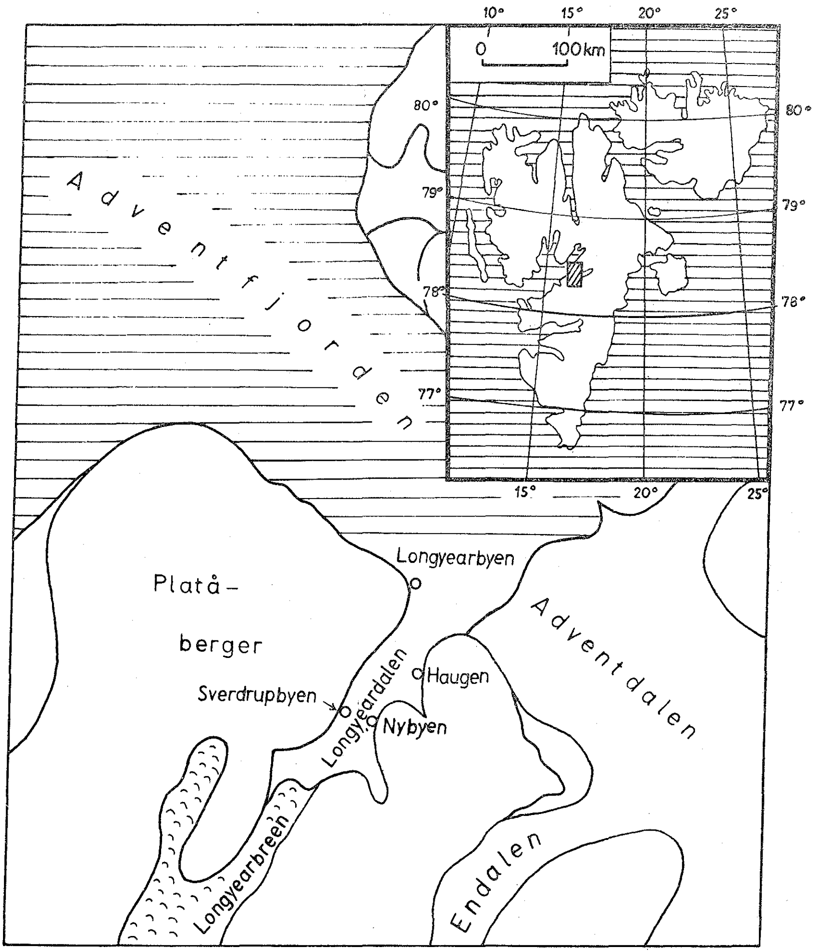

Fig. 1. Location map of Longyearbyen area

Immediately following this catastrophic rainstorm, the Longyear region became the research field for a number of scientists, and the results of their investigations have already appeared in print (Thiedig, Kresling, 1973; Thiedig, Lehmann, 1973; Rapp, Larsson, 1974).

I visited Longyear valley in July of 1974 as a member of the Polish Hornsund Expedition. Investigating the slopes I found, still fresh, traces of the 1972 rainstorm. Compared with the observations of scientists who noted the results of the catastrophe prior to me, I was in a more advantageous situation as I could, with greater accuracy, compare the state of the slopes in 1974 with the state before the rainstorm, using morphological sketches and above all photographs which I had taken during my previous studies in 1958.

Longyear valley, measuring 4 km from the head of the glacier to the fiord, is a typical periglacial valley. It has a flat bottom, covered with gravel, debris and cobbles, and very steep slopes and talus cones. As the valley is situated in a nearly meridional direction (SSW-NNE) we shall discuss its uniform western slopes and its eastern slopes which are dissected by two small lateral valleys. The upper edges of the slopes lie at 450 to 470 m above sea level. The slopes are divided into an upper part covered by regolith, above 200 m of absolute height, which performs

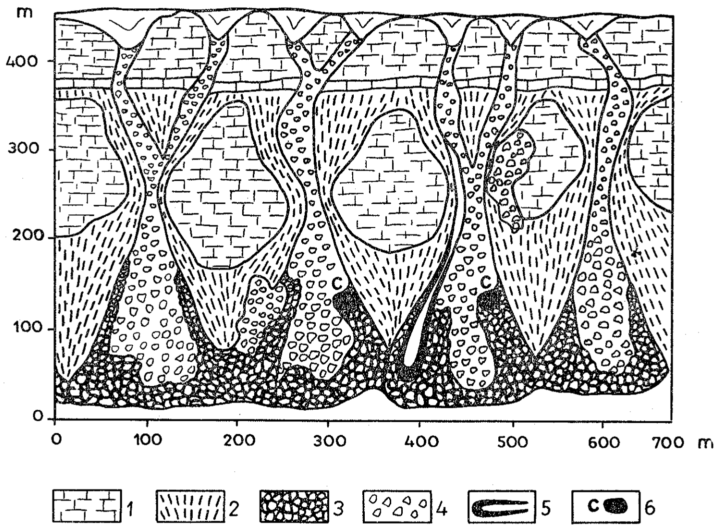

Fig. 2. Talus cones on left slope of Longyear valley, north of Sverdrupbyen

1. bedrock (Cretaceous, Tertiary); 2. old slope covered by vegetation; 3. older cone surface (dark boulders); 4. younger cone surface from last transgression; 5. gully of debris avalanche; 6. coal piles

alimentary function and a lower accumulation part with talus cones, below 200 m of absolute height (Fig. 2, Pl. 3). The upper part is built of Tertiary sandstones, olive-green in colour, and the lower part of grey Cretaceous sandstones. The rocks are fragile, fissured and weather easily.

Typical geomorphological processes, active on Longyear slopes, may be classified in three groups: (1) linear flow processes, including debris and mud-flow tongues and erosional gullies, (2) surficial accumulation processes, including rock fall and dry debris transgression on talus cones, and (3) solifluctional surface processes.

EROSIONAL AND FLOW PROCESSES

Here one finds debris tongues and erosional gullies interlinked. Generally they could be included among the type of phenomena known as *muren* or in Russian *sieley.* As the Tertiary and Cretaceous sandstones weather, they supply a large amounts of fine particles, including even clayey ones. Thus the saturated regolith mass has a considerable degree of fluidity. When favourable conditions occur, such as rapid snowmelt in the spring or heavy summer rains, streams of debris or mud and debris, flow down the slopes. They may be compared to a phenomenon, known in the Arctic and in high mountains of the USSR, as *structural muren*, in which the proportion of debris material to water is over 50%. These are not debris avalanches – as justly points out A. Rapp (1974). If the debris contains a large admixture of clay – as exists on the slopes closer to the valley's mouth – the tongues are flat, spreading out at the slope pediments to widths of a dozen or more

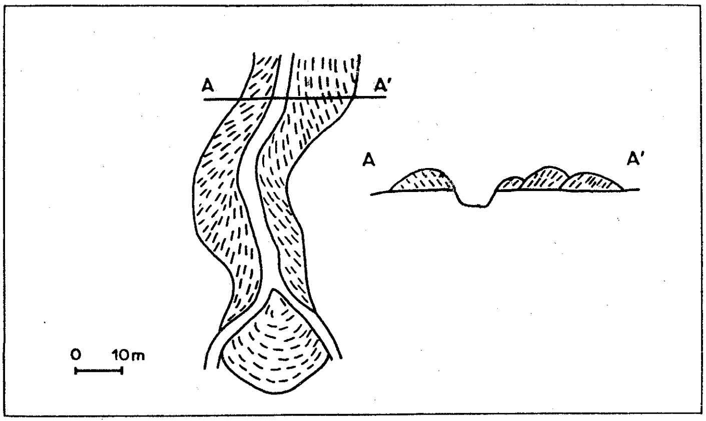

Fig. 3. Debris tongue ("muren") on left valley slope, dissected by gully. Boulder arrangement is shown on the diagram
Section A–A' twice enlarged

meters, forming "colluvial cones" (Pl. 2). Slab like debris pieces arrange themselves according to strengths of downflow forces giving a very regular pattern illustrated, for instance in fig. 3. Along the tongues the slabs are arranged lengthwise, slightly angled downwards, whereas at the head, they form transverse arcs. From the arrangement of the slabs it may be deduced that the motion of the mud-debris streams is concentrated along the tongue axis, and from this axis the spreading debris forms oblique arcs. As a rule, an erosional gully forms the axis which is the line of concentrated water flow.

The first conclusion stems from the above observation. The erosional work of water, utilizing the existing transverse slope depressions, preceeded the mass movement of the debris and mud mixture. This fact is self evident, for water, being a more labile agent than mass of debris carves the gully on the slope first. Such a gully demarcates the track for the downslide of the debris and mud and, when this mass fails to find room in the narrow gully and overflows it sideways, it forms a debris-mud stream. This stream is fed by material loosened on the slope along the initial gully. This explains the streaks of slabs spreading outward, arranged vertically but oriented in line with the particular flow direction (Fig. 2).

The debris-mud tongue under discussion has spread out to some 50 or so metres. But it is one of the smaller examples. Others, which developed after the 1972 rain-

Photo by A. Jahn, July 1974

Pl. 1. Northern slope of Advent fiord, dissected by erosional gullies in which snow still remains

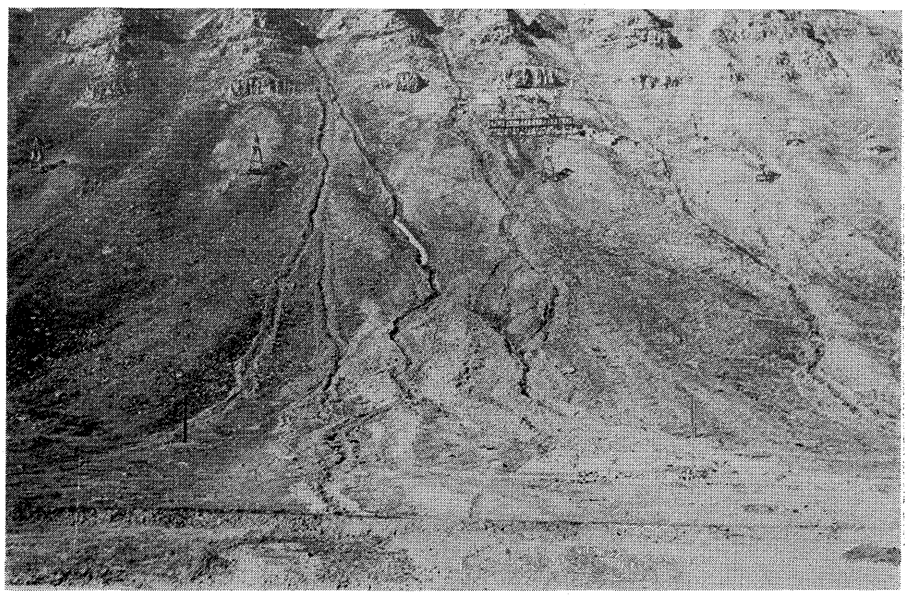

Photo by A. Jahn, July 1974

Pl. 2. Colluvial cones on the left slope of Longyear valley, dissected by erosional gullies. On top of the slope: remnants of the old mine. The cones extend down to the road

Photo by A. Jahn, July 1974

Pl. 3. Talus cones on left slope of Longyear valley shown in fig. 2. On the third cone from the left is a large erosional gully with natural levées. On this cone is the coal heap on which measurements were made of the rate of movement of the youngest debris transgression

Photo by A. Jahn

Pl. 4. Natural levées, tongues and colluvial cones formed in a gravel pit as the result of rain water flow (Mysłów, Sudety Mountains, Poland)

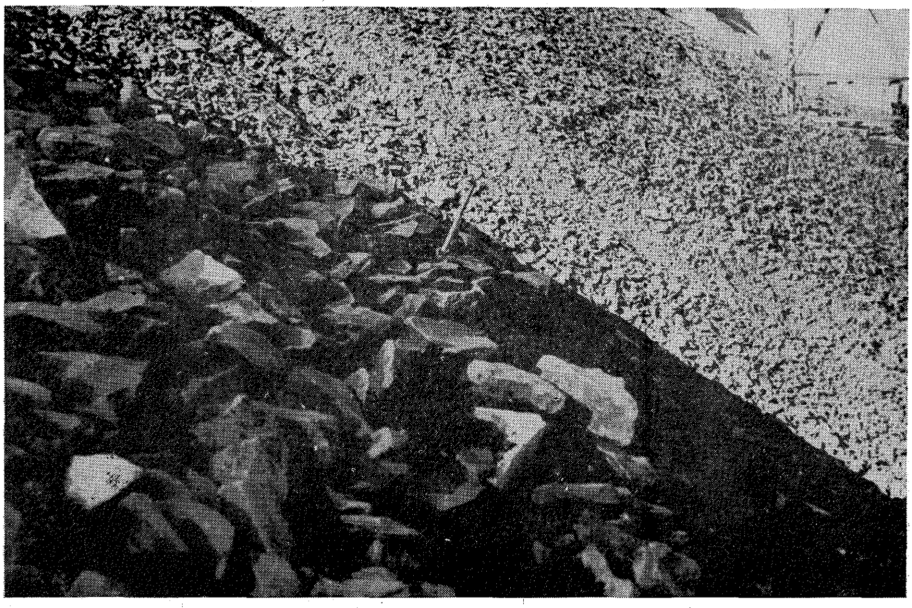

Photo by A. Jahn, July 1974

Pl. 5. Talus transgression obstructed by coal heap. The ice pick marks the boundary between debris and coal

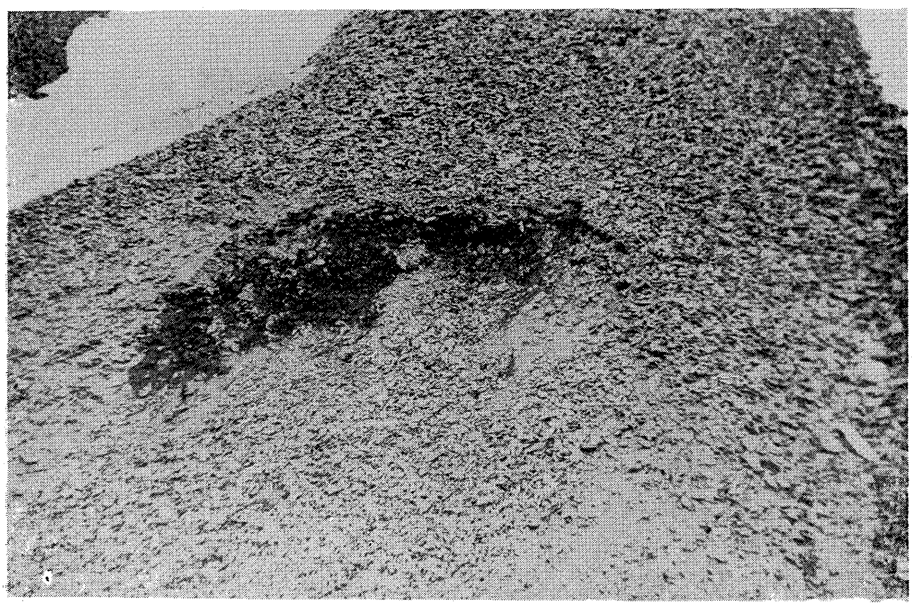

Photo by A. Jahn, July 1974

Pl. 6. Undercut talus cone on right slope of Longyear valley. The cone's core (dark area on photo) is ice-cemented

Photo by A. Jahn, July 1974

Pl. 7. Talus cone in the upper section of Longyear valley. Clearly visible is the pale surface of the youngest debris transgression. The cone is undercut by road builders

Photo by A. Jahn, July 1974

Pl. 8. Arrangement of boulders in talus cone. The large boulders (slabs) at the top lie parallel to the surface gradient of the cone, while in the cone's body they have no definite orientation

Photo by A. Jahn, July 1974

Pl. 9. Effect of solifluction at Longyearbyen in the period from 1943 to 1974. Posts have been tilted 30° from vertical (ice pick)

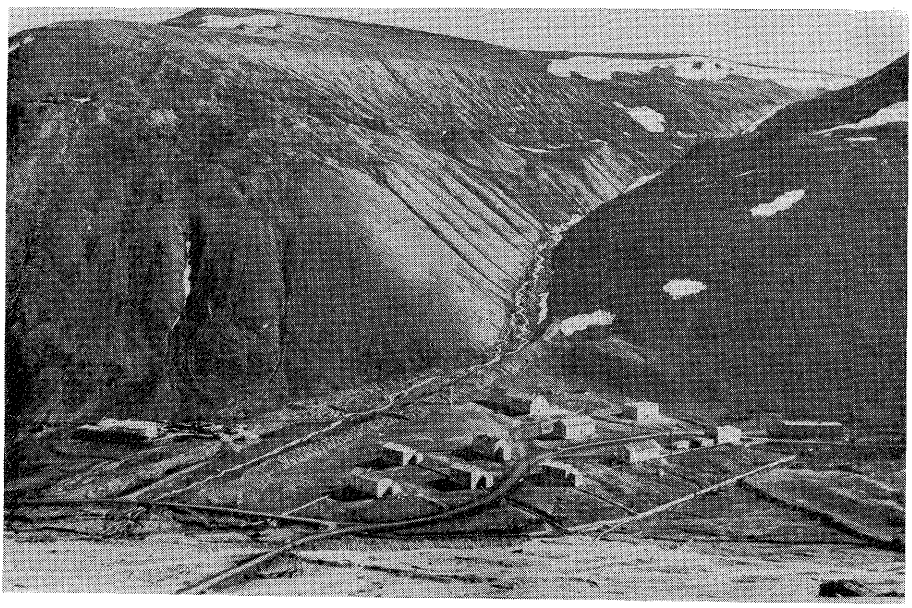

Photo by A. Jahn, July 1974

Pl. 10. Right slope of Longyear valley, above Haugen, densely dissected by erosional gullies

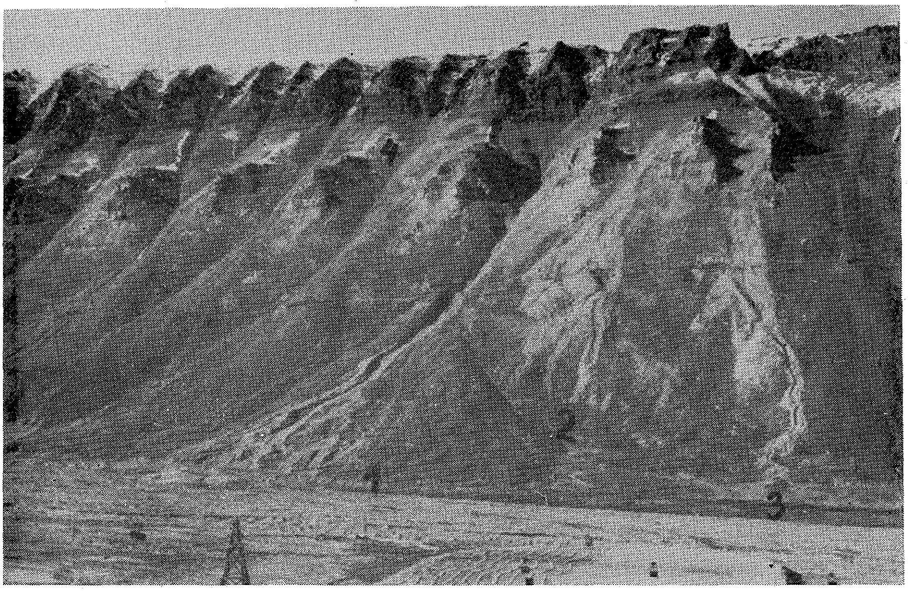

Photo by A. Jahn, July 1958

Pl. 11. Photo of the left slope of Longyear valley in July of 1958

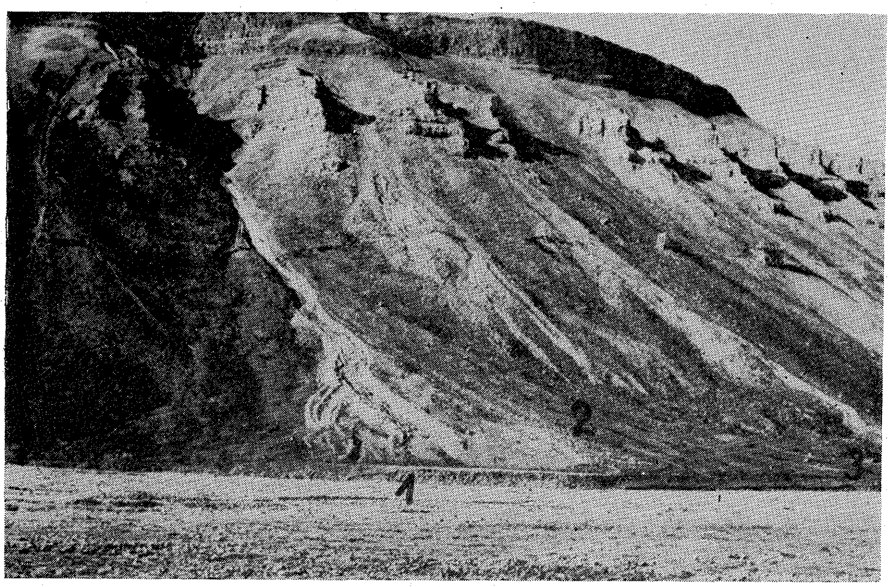

Photo by A. Jahn, July 1974

Pl. 12. The same section of the slope of Longyear valley as shown on Pl. 11, taken after the 1972 catastrophic rainfall. Numerals 1, 2, 3, 4 mark on both photos identical relief details

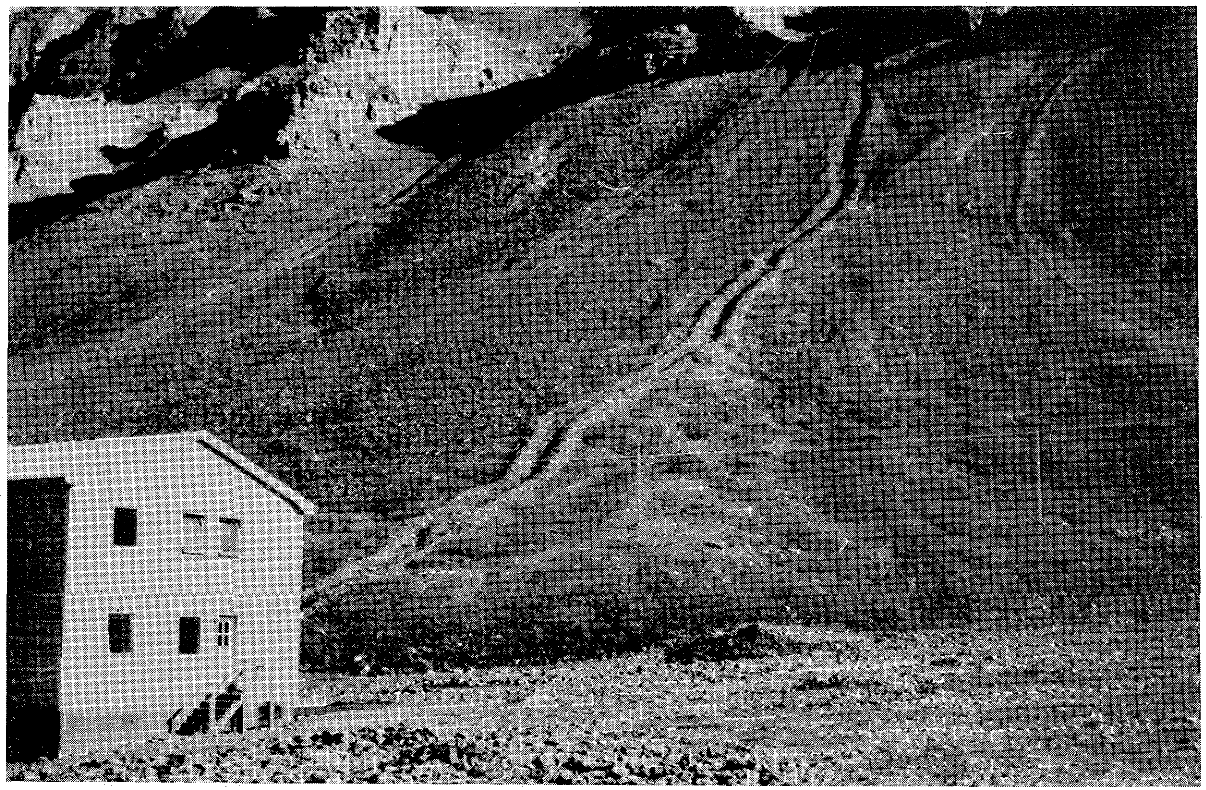

Photo by A. Jahn, July 1958

Pl. 13. Erosional gullies with natural levées on right slope of Longyear valley in 1958

Photo by A. Jahn, July 1974

Pl. 14. The same fragment of the valley slope as shown in Pl. 13, taken in 1974 storm, have overrun the main road at Longyearbyen creating the impression of a heavy catastrophe. This large mass of material originated in niches and depressions which are clearly visible in the middle and upper parts of the slopes. The mass of these colluvial tongues vastly exceeds the cubic content of slope gullies in which these tongues originated. We may therefore conclude that the gullies were mainly tracks for mass transport of the debris material and only partially they were the source of the material.

The second type of linear erosional phenomena on the Longyearbyen slopes are gullies bordered on both sides by *natural levées* (the term introduced in 1942 by R. P. SHARP). Such landforms are common on Spitsbergen slopes (as described in 1965 by H. PIASECKI), and fully resemble the erosional gully-like ravines found on talus cones in the Alps and the Tatras.

An example of such a gully, is the landform seen on the third cone of the left valley slope, counting downward from the Sverdrup mine (Fig. 1). The length of this gully is 400 m, its depth 0.5 to 1.0 m, and its maximum width 2.0 m. This gully is fringed by natural levées and ends in a fan-like tongue of loose debris (Pl. 3). A close relationship is noticeable; the levées enter the tongue and join widening

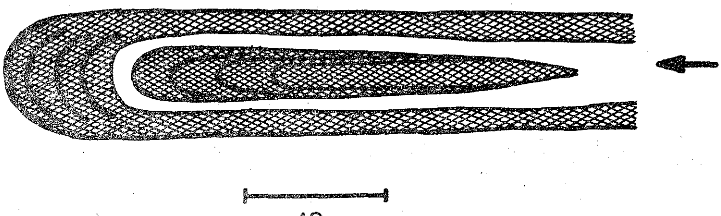

Fig. 4. Talus tongue at gully outlet on left valley slope near Sverdrupbyen. Numerals indicate thickness of debris cover, arrow indicates slope gradient

ridge arcs. The shape and size of the tongue is illustrated in fig. 4. From its size (width up to 10 m, length 40 m, maximum thickness 2 m) the volume of debris brought here from the gully was measured. This volume amounted to 329 m^3 and, including what was contained in the levées alongside the gully, it was approximately 400 m^3. This approximates the volume of the gully itself, and these figures indicate that almost all the material deposited in the tongue and the ridges was derived from the gully alone.

Taking into account the form of the debris flow described above, I maintain that there occur two types of erosional gullies on the slopes of Longyear valley. In the first type, the gully is merely the track of transported material, while in the second type it is the sole and only source of the debris. In the first type, the material which overflows the gully, first forms the natural levées and, as new debris arrives, these levées gradually widen into the form of a tongue-like fan. These tongues consist of many levée-like ridges running parallel to the gully, and are like a union of many levées. In the second type we find only one levée on each side of the gully, and only at the lower end of the gully do these levées combine to form one tongue consisting of several ridges (Pl. 2).

From analysing the lineally oriented forms on Longyeardalen slopes, it appears that erosional gullies are dominant and developed at the initial stage of the action of running water. Because these gullies are a permanent feature, existing on the valley sides for years (only a small number of them have been cut by the rainfall of July 1972 as I shall later point out), it must be concluded that they operate every year, and that the spring meltwaters are the principal erosional agent modelling the slopes. The debris tongues are accompanying features of the gullies, initially as natural levées. Water from seasonal and perennial melting of permafrost also takes part in this action — as has been assumed for this type of phenomena by A. P. Gorbunov and I. V. Severskij (1967) in the Soviet Union and J. Kolasińska (1972).

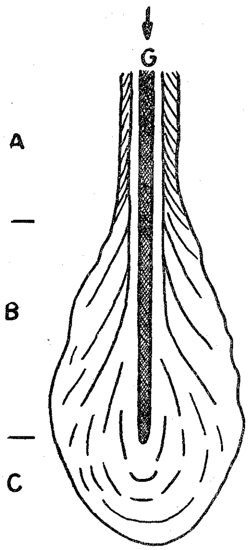

Fig. 5. Diagram explaining pattern of erosional and denudational landforms

A – natural levées; B – tongue; C – colluvial cone; G – gully; arrow indicates slope gradient

A typical development of such forms is diagrammatically shown in fig. 5. The model is composed of three parts with the erosional gully forming its axis. The top part (Fig. 5-A) shows the natural levées, passing downward into a tongue with its characteristic oblique pattern of ridges and debris slabs (Fig. 5-B). However, the structural and morphological elements of the tongue veer more and more towards the gully, run parallel to it, and pass into arcs of a colluvial cone (Fig. 5-C). These three successive sections are the natural consequence of the decrease in slope gradient and of the increasing accumulation of debris material. The powerful and concentrated force of the water stream (section A), downward increasingly dispersed, turns merely into the driving force for the downward flow of the debris tongue (section B). Finally these mass movements cease, and the tongue arcs assume their closed forms (section C). This course of the process is also due to the fact that in time the quantity of water on the slopes (rainfall, snowmelt) decreases. However, should there be a considerable increase of water in the gully its concentrated force will be very powerful, apt to sweep clear the gully, to deepen it and, additionally, to dissect the colluvial cone. This sort of renewed erosion will sometimes happen towards the end of the annual cycle but, usually, it takes place in the spring of the following year, when water from melting snow, channelled in existing gullies, manages to dissect older tongues and cones.

This model of mass flow and erosional processes was based not only on observations made in Spitsbergen but also on field investigations of water flow on steeply inclined (25°) sandy surfaces in Polish gravel pits. Such an example is shown in Pl. 4, where one can see the results of a diminishing flow of sand-loaded water.

TALUS CONES, ROCK FALL, AND PROCESSES OF ACCUMULATION AND SURFACE DEGRADATION

Talus cones occur on the 400 m high Longyeardalen slopes at two levels. In the upper level, among Tertiary rocks, they are small and limited to slope niches. In the lower level, below 200 m, are found the typically shaped cones which are triangular and overlap each other. These cones constitute the main element of the valley's landscape (Pl. 3).

The overall impression an observer gains from looking upon these cones from the valley floor is a distinct division of their surfaces into two parts. An older surface, of darker colour consisting of boulders covered by lichen, and a younger surface lacking vegetation cover (Fig. 2; Pl. 3). From a detailed investigation of

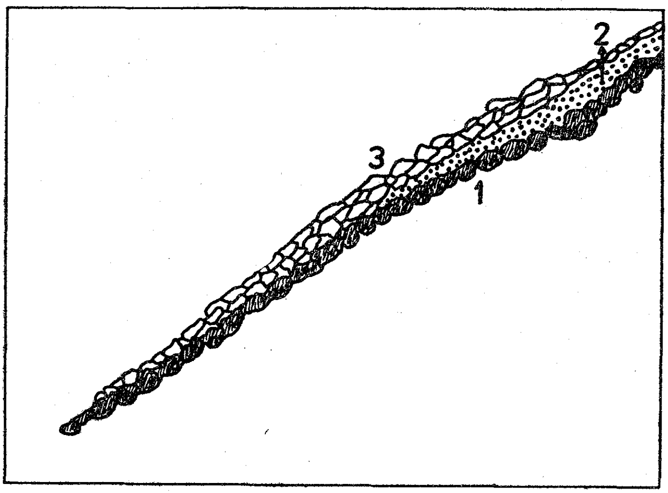

Fig. 6. Relation of youngest debris transgression (3) to old cone surface (1). Both layers are separated by an intermediate transgression of fine grained debris (2) which reaches up to the cone's break of slope

the interrelation between these two covers, made on the third cone below Sverdrupbyen, it appears that the pale cover has been transgressing upon the dark boulder surface. It consists of slab-type rock fragments, larger in size than the dark-coloured boulders (the size of the slabs varies from 10 to 60 cm). In the upper part of the cone, the younger talus cover consists of single slabs, whereas further down they combine into a layer about 0.5 m thick, which becomes gradually thinner and fans out over the cone surface.

It is interesting to note that this younger cover is thickest in the middle part of the cone where there is a noticeable break in the surface gradient, as illustrated in fig. 6. Below this break forming a bulge on the cone surface, the slope reaches its greatest steepness (33°).

The cover of pale rock fragments overlies the darker talus only below the above mentioned break in the slope gradient. Higher up a new layer can be seen consisting of much finer talus particles (8 to 10 cm), which penetrates wedge-like between the pale and the dark talus covers. The relationship of these layers is illustrated in fig. 6.

The age of the darker cone surface is indicated by lichens belonging to the species *Rhisocarpon superficiata, Alectoria pubescens, Umbilicaria arctica* and *Usnea sulphurea* — all of them proving that the slab-shaped rock fragments lie in their present position for at least 50 and, probably, well over 100 years[1].

The intermediate layer of fine talus (layer 2 in Fig. 6) emerges on the surface in the upper part of the cone and joins here the weathered cover consisting of sand and debris partially covered by grass. This indicates that layer 2 (fig. 6) is a flushed--down solifluction cover, originating at the time the cone became stabilized and the processes of talus production had ended.

The cover sheet of pale boulders, i.e. the most recent debris transgression upon the cone surface, is the most interesting feature. This kind of transgression can be observed everywhere in Spitsbergen and is also well known from talus cones on the Scandinavian peninsula (A. Rapp, 1960). As can be concluded from its relation to the dark boulders, this cover sheet has been laid down within the last 50 or so years.

A more detailed study of the age and the rate at which the transgression of the pale boulder cover has been taking place, was made by examining the position

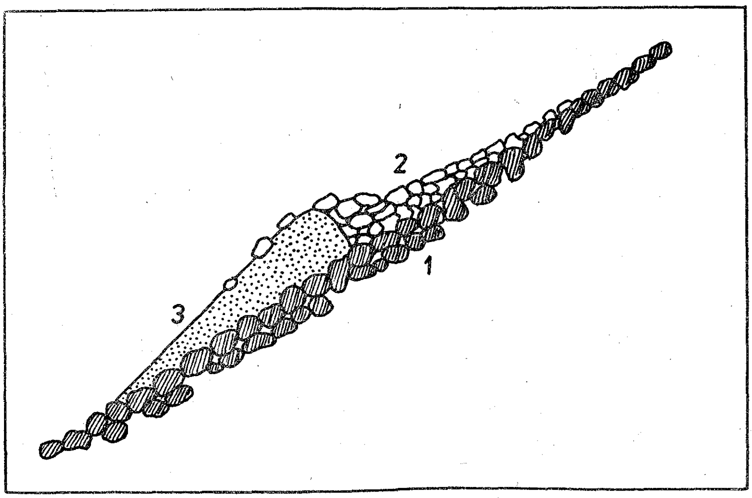

Fig. 7. Effect of youngest debris transgression upon the surfaces of Longyeardalen talus cones

Upon the old cone surface (1) leaning against a 50 cm coal pile (3) a new cone (2) is forming

[1] The identification of these lichens was made by Dr. J. Fabiszewski to whom I am greatly indebted.

of this layer in relation to a string of coal heaps situated on the cone surfaces in Longyeardalen. Coal from the Sverdrupbyen and Nybyen mines used to be transported to Longyearbyen harbour by a suspended cable-railway which runs above the line of the Longyeardalen talus cones (Pl. 3). The coal falling from the cable-cars formed coal heaps on the cones, in a kind of transverse bank, especially next to supporting tresles where the cars are jolted (Fig. 7). These coal banks are obstructing barriers to the boulders rolling down over the cone surfaces. Each such obstacle resembles a sieve, allowing water to seep through but retaining every boulder and every larger rock fragment. The result is that above the coal bank boulders are accumulating in the shape of cones ("small cones") with their bases resting against the coal and their peaks turned upwards (Fig. 3; Pl. 5). Knowing the age of the coal bank and the thickness of debris material accumulated ahead of the coal, one can calculate the rate at which the most recent transgression of the pale boulders has been progressing on the Longyeardalen talus cones. At three examined coal heaps, up to 1 m high, the thickness of the retained debris was 30 to 50 cm. In a concrete example, on the third cone from Sverdrupbyen (Fig. 2), the coal bank is 0.5 m high; the debris has reached the top of the coal heap and part of it even covers the coal slope. The cable-railway had been built some 50 years ago and coal transportation continued intermittently until 1960. Therefore, the talus cones have been rising at the rate of 0.5 to 1.0 cm per year. These figures give some insight into the most recent boulder transgression at Longyeardalen. This transgression is still active; none of the coal heaps have been added to for the last 15 years, and some of them (Pl. 5) have been matched and even overtopped by the boulder streams. In general, however, the obstructing role played by the coal heaps is evident. The pale boulder cover has been stopped in its downslope movement by the coal, and, up the talus cone, this cover extends in a circle on top of the older boulder surface of the dark lichen-covered boulders (Fig. 2).

Obviously the figure for the annual growth (0.5—1.0 cm) of the talus cone reported above, leaning against the coal bank, is by no means the true accretion of the cone surface. Were there no obstruction, the debris moving over the cone surface would have spread in a wide fan, and the accretion on the cone surface would have been much smaller.

In order to establish this value, which would be the actual gauge of cone accretion, the following calculation was made. The volume of the "small" talus cone accumulated during 50 years behind the coal barrier is 6 m^3, and the pertinent segment of the cone, blocked by the barrier, has a surface of 25 m^2. Taking into account the whole cone surface we obtain the value of 90 m^3; this means, that this is the talus volume accumulated on the "old" cone during the 50 year period. Hence we find that the annual accretion of the talus cone is close to 2 m^3. In proportion to the total surface of the upper slope part, from which the talus arrives, we can calculate the rate of slope retreat as corresponding to the amount of talus on the old cone. This slope retreat or degradation stems merely from rock weathering and rock fall, and it amounts to 0.45 mm annually. Yet, this figure is a maximum, referring to the talus cone of greatest accumulation. Where the thickness of the "small" cone is only 20–30 cm, this figure for slope retreat varies between 0.2 to 0.3 mm annually. I am inclined to assume 0.3 mm per year as the average and typical value of retreat of the slope surface caused by weathering and rock fall for the last 50 years, i.e. by the transgression of the pale debris on top of the Longyeardalen talus cones.

This transgression is not a local phenomenon limited to Longyeardalen only. Nor is it an anthropogenic event – although some disturbances of the natural environment by man can be observed in this valley – it is a natural phenomenon,

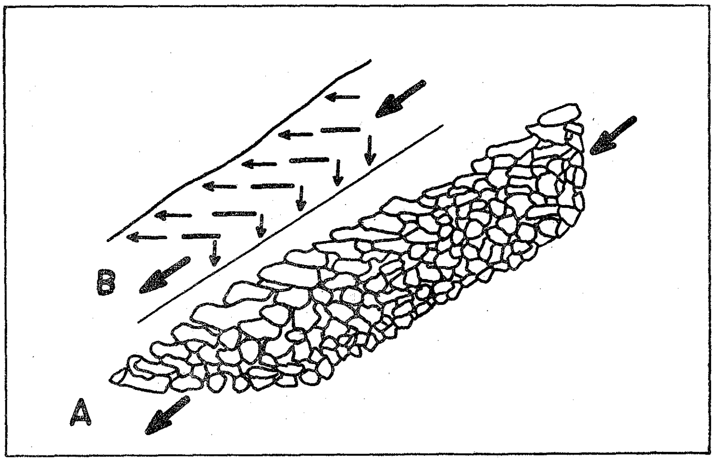

Fig. 8. Arrangement of boulders in the cone when surface layer is slipping

traces of which I also noticed in the northern part of Spitsbergen (Magdalena fiord) and in its southern part (Hornsund). Moreover, the pale "aprons" of the most recent debris transgression are visible on the classical cones of Mt. Templet in Sassen fiord. I also noticed them very distinctly on cones of Varanger peninsula in northern Norway. Present climatic conditions in the Arctic and Subarctic promote mechanical weathering. The Longyeardalen talus cones bear the features of typical periglacial cones, differing, for instance, from the cones seen in the European Alps, by their interiors which contain permafrost ice. Starting from 1 meter deep, the space between particular boulders is filled with ice – a fact which causes specific conditions (Pl. 6). Only the surface layer of a cone is subject to gravity movements. But if this layer consists of slabs, they arrange themselves nearly parallel to the slope – which is evidence of motion (Pl. 8). More precisely, these slabs lie slightly obliquely to the cone surface, that is – as defined by A. CAILLEUX (1947) – in a "relevant" pattern.

The distribution of the forces, leading to this particular slab arrangement is presented in fig. 8. Most probably it is the slide plane along the permafrost boundary that led to this "relevant" position of the slabs. If T. KLATKA (1962) asserts that the classical block fields (Blockmeer) in the Holy Cross Mountains (Central Poland) show for the most part this slab arrangement, the conclusion is — apart from further arguments — that these slabs must have moved under permafrost conditions, much like those slab movements which are taking place on contemporary Spitsbergen cones.

We have seen that the Longyeardalen talus cones consist of two layers: a surface layer with its slabs arranged parallel to the slope, and a deeper layer which the boulders are packed tight. In the second layer the boulders are usually of smaller size than in the surface layer, and are much more tightly packed. I do not know the cause of such structure, but perhaps it is the successive freezing and thawing process, operating during fluctuations in the permafrost surface, that has caused both a breaking up of larger boulders and a closer packing of the rock mass on top of the cone.

From the facts presented, it appears that the material of the Longyeardalen talus cones has been undergoing and continues to undergo a twofold movement. The initial, rapid movement is a falling of rock fragments from weathering slope niches. This process formed what might be called a "transgression apron", a layer spread over the surface of an existing cone. The second movement is continuous and slow, rather a creep, and it is this slow movement which is instrumental in forming the layer of pale slabs arranged with their long axes parallel to the slope gradient. The first movement coincides with stages of increased weathering and finds its expression in the growth of the talus cone. The second movement occurs in periods in which the cones attain stability, and is evidence of a lowering (a smoothing-down) of that cone. Under the present conditions the Longyeardalen talus cones embody the processes of spilling material in their upper sections, and of talus creep in their lower sections.

SOLIFLUCTION

Mass wastage of the rock-fall type, debris spilling and talus creep, dominate on Longyeardalen slopes to such extent that so far the classical periglacial slope process of solifluction (gelifluction) has passed unnoticed. Certain observations I managed to make in 1974 enable me to supply some approximate quantitative data on this topic.

In 1943 part of the Longyearbyen dwellings were destroyed by military action — at the time when vessels of the German navy entered the fiord and shelled the coal mine and its surroundings. Of the destroyed buildings only timber posts, driven into the permafrost, on which the houses had been built remained standing (Pl. 9). Originally these posts were standing upright; but when after the destruction of the buildings the ground surface became exposed to sunshine, causing, in the summers some deeper thawing of the ground, the position of these posts changed. There occurred an upfreezing of the posts, raising them up to 30 cm, as well as tilting them in conformity to the inclination of the ground surface (Pl. 9). This change disclosed the effect of solifluction. Today the angle of divergence from the vertical is practically identical for all posts, ranging from 30° to as much as 34°, while the slope inclination is limited to 11°. Assuming that this divergence of the posts occurred within the active permafrost zone, which reaches here about 1 m in depth, the shifting of the posts (the tangent of the angle of divergence) on the slope surface amounts to about 60 cm. This movement was due to the force of the ground mass that has been translocated on the slope by solifluction. Most probably the ground motion has exceeded the distance through which the posts have moved, because they must have resisted the pressure exerted by the ground. To simplify matters, let us assume that the ground movement has been twice as great as the distance covered by the posts; then the solifluction ground displacement would amount to 120 cm. This indicates that in the lower parts of the Longyearbyen slopes, rather gently inclined and covered by compact vegetation, the ground movement for the period of 31 years, from 1943 to 1974, has been from 60 to 120 cm, i.e. 2 to 4 cm per year. This figure is consistent with estimates made of the rate of solifluction on Spitsbergen, based on detailed measurements performed at Hornsund (A. JAHN, 1961) and is consistent with what is known today from investigations of solifluction undertaken in other areas of the Arctic and Subarctic (A. L. WASHBURN, 1967; A. RAPP, 1961).

MORPHOLOGICAL CHANGES ON LONGYEARDALEN SLOPES DURING THE PERIOD 1958–1974

To a geomorphologist visiting Longyeardalen after the catastrophic rainfall of 1972, most of the erosion slope forms must have seemed so recent that it would have been difficult to avoid ascribing them to anything else but a recent torrential rain and to debris flow.

However, comparing photographs of the slopes taken in 1958 and in 1974, hence before and after the catastrophic rainfall, I maintain that the majority of these slope features, i.e. debris flows and erosional gullies, already existed here before 1972 (Pls. 11, 12, 13, 14). On the left valley slope I notice that practically all the talus tongues had already been active in 1958, including the previously described gully and tongue on the third alluvial cone north of Sverdrupbyen. Most of the mud flow tracks active in 1972 which S. LARSSON shows on his map (*cf.* A. RAPP, 1974) can be identified in my 1958 photos. The successive photographs of the left valley slope which I took from the valley bottom first in 1958 and later in 1974 may serve as an example (Pl. 11, 12). Both pictures show the same outlines of debris flow. Particularly striking is the three-fingered tongue in the centre of the picture (no. 2) which is identical in both photos. In both cases the talus cone is dissected by erosional gullies, whose position has not changed. In the 1974 photo the gullies are clearer and reach greater heights on the slopes. Talus cones nos. 1 and 2, on both photographs showing the same outlines, extend lower than in the 1958 photo. Here, following the 1972 rains, the talus stream has covered the highway visible on the photo. Below a point marked on photo 4 (in the upper righthand corner of Pl. 12), in 1958 there had been a bridged-over gully, smoothed by solifluction and overgrown by grass. In 1972 this gully was revived and cut by a ravine. It is remarkable that no debris movement took place here, no new talus tongue developed, but only very clearly marked far-upward reaching erosional gully, fringed from its very top by natural levées. This gully can be seen distinctly only in its upper part; downward it disappears on the slope and fails to reach the slope pediment.

Conditions are much the same on the right slope of the valley (Pl. 13, 14). Near the Nybyen mine I found only two new erosional gullies which developed in 1972 in the same way as gully no. 4 on the left-hand slope. On the slope near Haugen after 1972 I counted as many as some 50 small erosional gullies (Pl. 10), but traces of their existence are visible on my 1958 photos.

The differences between the pictures taken in 1958 and 1974, which I am inclined to interpret as the consequences of the 1972 rainfall can be summed up in the following points:

1. The debris flows, tongues and colluvial cones were subjected to some extension. These changes occurred mainly at the slope pediments, and this is why the road following this line of pediments has been burried at several places.

2. A general sweeping-out of existing erosional gullies and their extension up the slope has taken place. New natural levées were produced.

3. There are few new erosional gullies; I estimate their number at less than 10%. They have developed at places where former gullies had been smoothed out by solifluction and covered by grass.

I wish to emphasize once more that the July 1972 torrential rains did not produce any new landforms, but their action lay mainly in rejuvenating existing debris flows and sweeping out former erosional landforms. Here we may mention the "triggering" action as did A. Rapp (1974) "...The mass movement were triggered by heavy rainfall". I consider the principal factor in sculpturing the Longyeardalen slopes to be the annually repeated springtime meltwaters. Their perennial action led to the formation of talus tongues, colluvial cones, erosional gullies with their natural levées, and of ravines and small valleys — hence to producing the same landforms which existed here before 1972 and were already fully developed in 1958. Apart from these fluvial processes, solifluction comes here into play as the most persistent, stable and rhythmically repeated factor. Solifluction together with vegetation smoothes out slopes, fills and levels gullies, whereas the impact action of water, sweeps out former gullies and stimulates the motion of debris tongues, creating acute and sharply outlined landforms. Here lies the controversiality of effects of these two factors. From time to time the smoothing work of solifluction is interrupted by the abrupt action of slopewash. This happens when the effect of springtime meltwaters is augmented by summer showers. This sort of situation occurred in 1972. The solifluction surface was dissected by an upward elongation of the gullies and by the revival of former gullies in filled-in valleys and, finally, these surfaces were overlain by debris flow tongues in the lower sections of the slope.

GENERAL EVALUATION OF CONTEMPORANEOUS GEOMORPHOLOGICAL PROCESSES OBSERVED IN LONGYEARDALEN

I am classifying the processes operating on the slopes of the Longyear valley into three groups:

1. the action of meltwater and rainwater on the slopes, direct — erosional (gullies) and indirect (debris flow),
2. the action of mechanical weathering, rock fall, and debris accumulation on cones,
3. solifluction.

The first of these processes aroused the greatest interest, mainly due to the effects caused by the rainstorm in July 1972. Taking into account the result as given by S. LARSSON (*cf.* A. RAPP, 1974), these rains caused erosion and mass movement equalling 1 mm of denudation. It seems to me that this figure is somewhat too high because, as I have pointed out above, part of the debris ascribed to the 1972 rainstorm had already been moved down the Longyeardalen slopes. Nevertheless, we must admit that the 1972 rainstorm catastrophe was a most important event, which to some degree has changed our opinion about the part played by water, as a direct and as well as an indirect factor in the arctic climate. A change of opinion of this kind was adopted first of all by A. RAPP whose conclusions expressed in 1974 differ from what he believed in 1957. A climatic event, the result of which would be a denudation of 1 mm of surface during a single year, is totally abnormal. Were this denudation spread over many years, its annual value would probably be some fraction of 1 mm. For the Hornsund area of South Spitsbergen I have delimited (A. JAHN, 1961) the maximum slopewash (by erosional gullies) as being 1 mm of denudation for a period of 150 to 170 years. Hence, the investigations made in Longyeardalen tend to confirm the belief in the importance of fluvial erosion. They also revealed that closely associated with this erosion is debris flow — even, though it would be difficult to separate these two processes from each other. In my opinion, in Longyeardalen the mean annual denudation is much higher than 0.015 mm — the figure I assigned to Hornsund, though lower than what has been calculated by A. RAPP and S. LARSSON for Longyeardalen in 1972. Weathering and rock fall in the fragile Longyeardalen rocks result in a very high index of denudation — say, of 0.3 mm annually. This figure is much higher than that given by A. RAPP (1960) for these processes as co-agents in the denudation at Kärkevagge (0.04—0.15 mm annually) and by J. T. GREY (1972) for the Ogilvie and Wernecke Mountains in the Canadian Cordillera. I therefore am inclined to suggest that the youngest debris transgression on the talus cones of Spitsbergen (perhaps of the Arctic and Subarctic also) may have lasted at least for 50 years. The formation of new covers ("aprons") is a process commonly observed and probably caused by climatic conditions. These aprons show an excellent gravitational sorting; therefore they cannot be classified under avalanche boulder tongues to which B. H. LUCKMAN (1971—1972) attached such a high importance. I am not, however, dismissing the fact that to some degree snow avalanches may have contributed to this process of debris accumulation. It became possible to determine fairly accurately the rate at which talus cones have been growing, thanks to the fortuitous occurrence of coal piles on top of these cones in Longyearbyen.

As stated before, solifluction in Longyear valley is a process following a certain "standard" routine, and the indices of this force comply with the indices computed for other Arctic areas. Solifluction operates on grass covered, stabilized slopes; and it also acts on talus cones in the form of slab creep over permafrost-affected surfaces.

The interrelation between each other of these three groups of processes is interesting. The former two, fluvial action and rock fall, represent a certain combination which may be expressed broadly as the joint effect of erosion and weathering. In the curve illustrating the course of geomorphological processes they form peaks of rather extreme values, while solifluction is mostly represented by intermediate values. Weathering and erosion are agents which disturb the equilibrium of the slope, its denudational balance while solifluction restores this balance. In the debris stratification on the Longyeardalen talus cones one finds a layer of fine debris and sand underlying the pale slabs of the last boulder transgression. These talus cones had been stabilized before the debris transgression began which is consistent with the phase of the solifluction processes acting at that time. The increased impact of slopewash happened to coincide with an increase in mechanical (frost) weathering. At this time erosional gullies and debris flows developed on the cones as well as a simultaneous growth of the cones due to the last transgression of pale boulders.

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