GEOMORPHOLOGICAL ANALYSIS OF PULMANKI-TANA VALLEY IN LAPLAND

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I. PROBLEMS AND ASPECTS

The aim of this paper is to try to explain the factors that have had the greatest effect on the geomorphology of the Pulmanki-Tana Valley (Figs. 1 and 2, the investigated area is bounded by straight lines).

When dealing with this problem, attemps are made to find different dynamic units in the area and also to explain what kind of formations are related to the units in question. The philosophic background of the paper is therefore different from the known «classic« works of DAVIS (1912) and PENCK (1953). In their theories time and landforms are closely correlated. Thus the development of the landforms in the area is followed during the longest possible period and the present forms are explained against the genetic background as parts of certain cycles. In dynamic geomorphology evolving in the latest ten years, on the contrary, the main attention is paid to the events and formations of this day. In other words, one tries to find out the features and the events of the area (e.g. STRAHLER 1952 a and b, HACK 1960).

When using the analogy of thermodynamic systems made by VON BERTALANFFY (1950), the theory by DAVIS is considered to be based on the philosophy of closed system (CHORLEY 1962), whereas e.g. STRAHLER and HACK in their methods of treatment concentrate on studying different processes as dynamic units based on the open system. Thus it is supposed that in each process the factors having an influence in the opposite direction try to gain dynamic equilibrium according to the open system.

The aspect of this paper is related to the latter studies, with the difference being that the aim in this paper is to devise a regional analysis based on the functional features. Classifying more accurately, the aspect is as follows:

1. The object of the study is a certain, definitely bounded area. In contrast, the object in STRAHLER's (1952) so-called pure dynamic geomorphology are the processes irrespective of the area where they are acting. The choice of the area determines what processes are to be the object of the research.

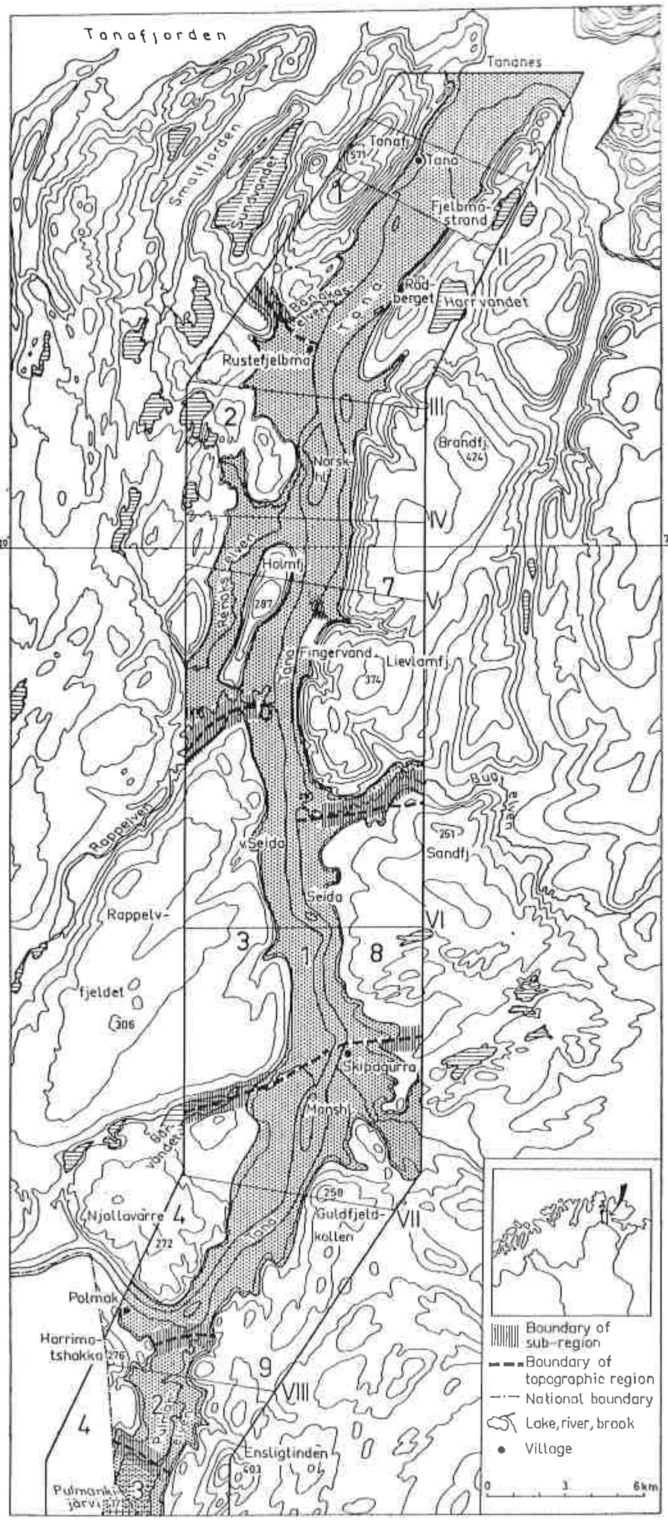

Fig. 1. Northern part of the investigated area. Reduction of the Topographic Map of Norway (1:100 000). Contour interval 60 m. Regions: A. Lower Region (shaded area) 1. Degradative- and aggradative region of Tana, 2. Degradative region of Polmakelven, 3. Region of Pulmankijärvi; B. Upper Region, 1. Barren mountains of Tanafjeldet, 2. Vaara region of Holmfjeldet, 3. Skaidi of West Seida, 4. Vaara region of Njallavarre-Harrimatshokka, 7. Precipice of Lievlamfjeldet, 8. Slope region of Eeast Seida, 9. Vaara region of Ensligtinden. I—VIII-situations of transverse profiles (Fig. 4.).

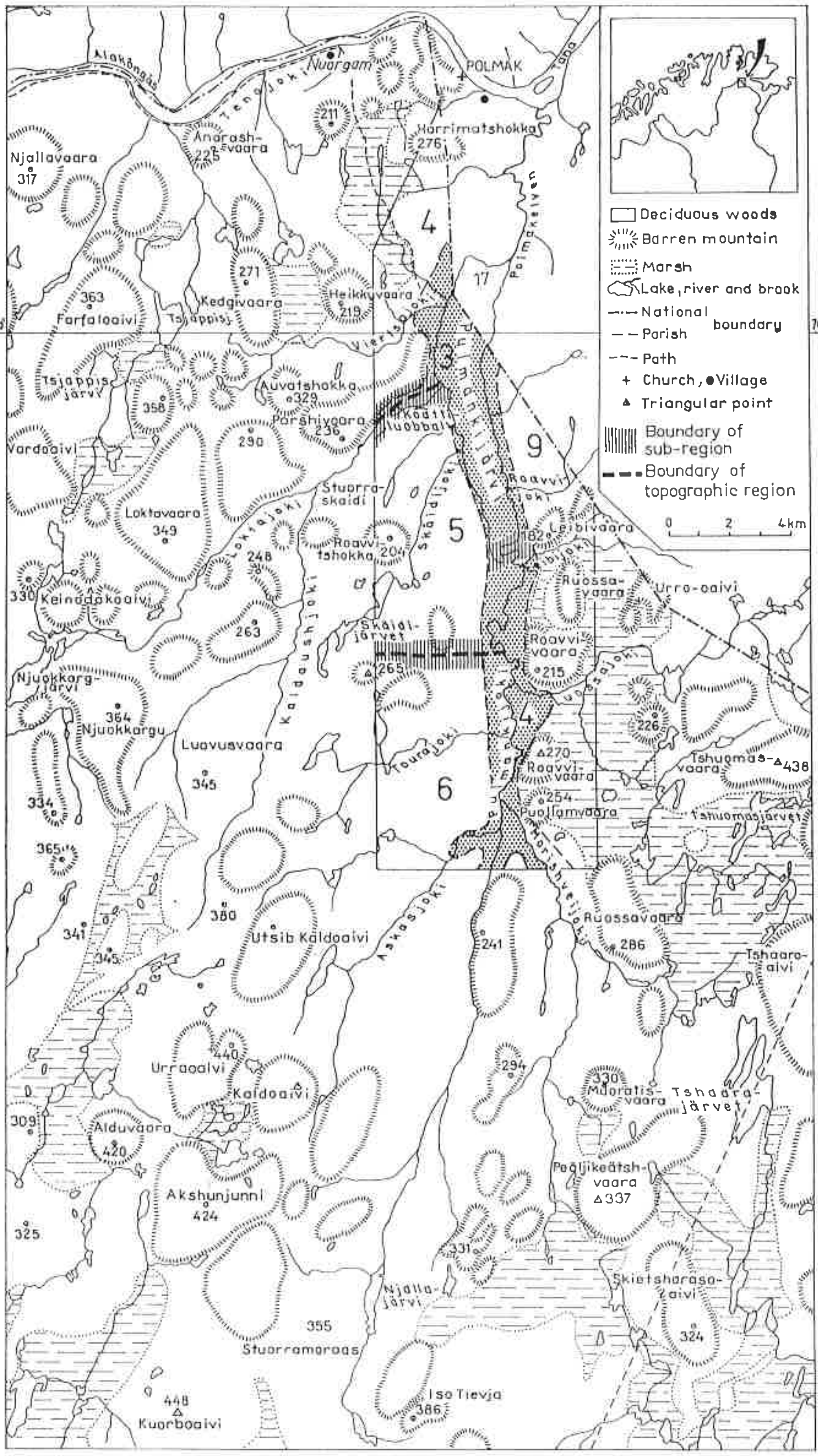

Fig. 2. Southern part of the investigated area. Reduction of the Economic Map of Finland (1:100 000). Regions: A. Lower Region (shaded area), 3. Region of Pulmankijärvi, 4. Degradative region of Pulmankijoki; B. Upper Region, 4. Vaara region of Njallavarre-Harrimatshokka, 5. Region of drumlins of Stuorraskaidi, 6. Region of drumlins and channels of Tourajoki, 9. Vaara region of Ensligtinden.

2. Besides being limited to a certain place, the processes are also confined to a certain time. Time restricts the number of the processes further because the area is studied only during the postglacial period.

3. The area is studied according to the principle of the open system. In other words, the assumption of DAVIS is not made that the area is developing towards a peneplane, but instead it is proved that the area is formed by greatly different processes that try to maintain dynamic equilibrium. However, it is difficult to study the processes during the whole postglacial period. There are two ways to solve this problem: a) by studying the present processes, or b) studying the results of the earlier processes.

4. When analysing the area, attention is paid only to certain process- and phenomenal groups that are called factors. In other words, the factors are composed of either separate processes or phenomena or groups of these. The factors are 1. Size of the area, 2. Relief, 3. Structure of the ground, 4. Climate, 5. Relative changes of sea level, 6. Degradation, 7. Aggradation, 8. Organogenic influence. On the basis of the findings made with the aid of the factors, a regional subdivision is finally made.

II. ANALYSIS

1. Size of the area

In limiting the research area the principle has first been that the area would reach from the bottom of Pulmanki-Tana Valley to only 3—5 km on both sides (Fig. 1 and 2). Secondly, the area was bounded by the sraightest possible lines. The former decision is justified because the features belonging directly to the river valley are included in even such a narrow strip. In addition, it is quite difficult to walk in the area, and the only road goes at the bottom of the valley. Therefore it is possible to do more accurate observations in that narrow strip than e.g. in an area 15—30 km broad. By bounding the area by the straightest possible lines it is easier to determine the total extent of the area and the result is more accurate.

Bounded like this, the research area reaches from the mouth of the Tana River, about 3 km north from the village Tana, to the Pulmanki Valley up to Ruossavaara mountain lying about 10 km south of lake Pulmankijärvi. The total length of the area in N-S direction is 73 km. The width in the Norwegian part varies 7—9 km, but in the Finnish area the width of the strip is 7 km. The total extent of the whole area according to the Topographic Map of Norway (1:50 000) and the Economical Map of Finland (1:100 000) is 594 km^2.

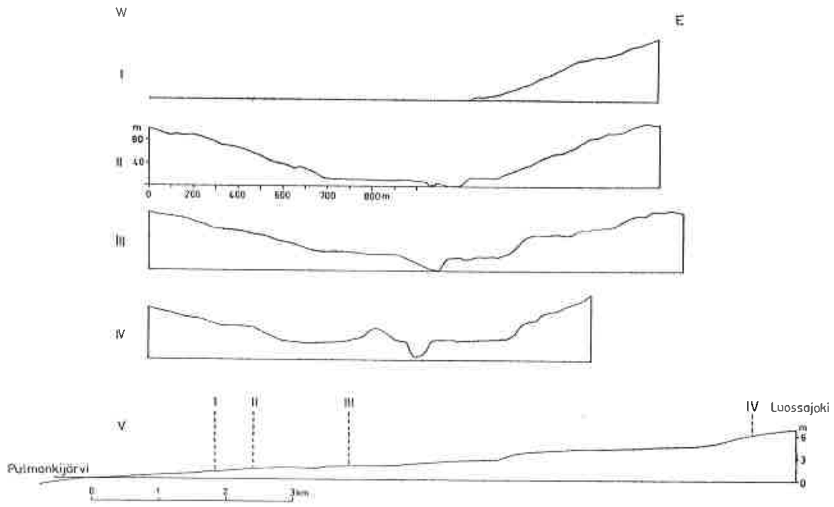

Fig. 3. I—IV=transverse profiles of Pulmankijoki Valley; V=longitudinal profile of Pulmanki River, I—IV=positions of the transverse profiles.

467 km² of this area belongs to Norway and 127 km² to Finland. The 70th parallel passes through the southern part of the area at Pulmankijärvi.

2. *Relief*

The Pulmanki-Tana Valley is an area whose most prominent feature is the continuous valley system. In the Pulmanki Valley, near Roavvivaara and Puollamvaara the greatest relative altitudes determined from the Pulmankijoki River are 200—250 m, near Lake Pulmankijärvi they are about 180 m, but immediately within Norway the heights grow. Ensligtinden Fjeld near the northern part of Pulmankijärvi, 403 m above sea level and 386 m above Pulmankijärvi, is the second highest place in the area. The relative heights of the most prominent mountains bounding the Tana Valley are at firts 200—250 m, but from Bugtelven they increase to 350—400 m. The highest peak of the area, Tanafjeldet 571 m, is at the mounth of the Tana River.

The rivers flowing at the bottom of the valley, the Pulmankijoki, Polmakelven and Tana River, have eroded into the bed to a depth of 20—50 m and revealed numerous old channels and river terraces (MANSIKKANIEMI 1964). The gradients of the rivers mentioned above are very small compared with the rivers in Lapland, the Pulmankijoki River 0.70 m/km (Fig. 3), the Polmakelven River 0.57 m/km and the Tana River (lower course) 0.26 m/km. The elevation of Lake Pulmankijärvi is only 17 m above sea level. It is quite a regular basin when considering its bottom forms (PETÄJÄ 1964). The deepest spot is 34 m, and thus the lake reaches a point about 17 m lower than sea level.

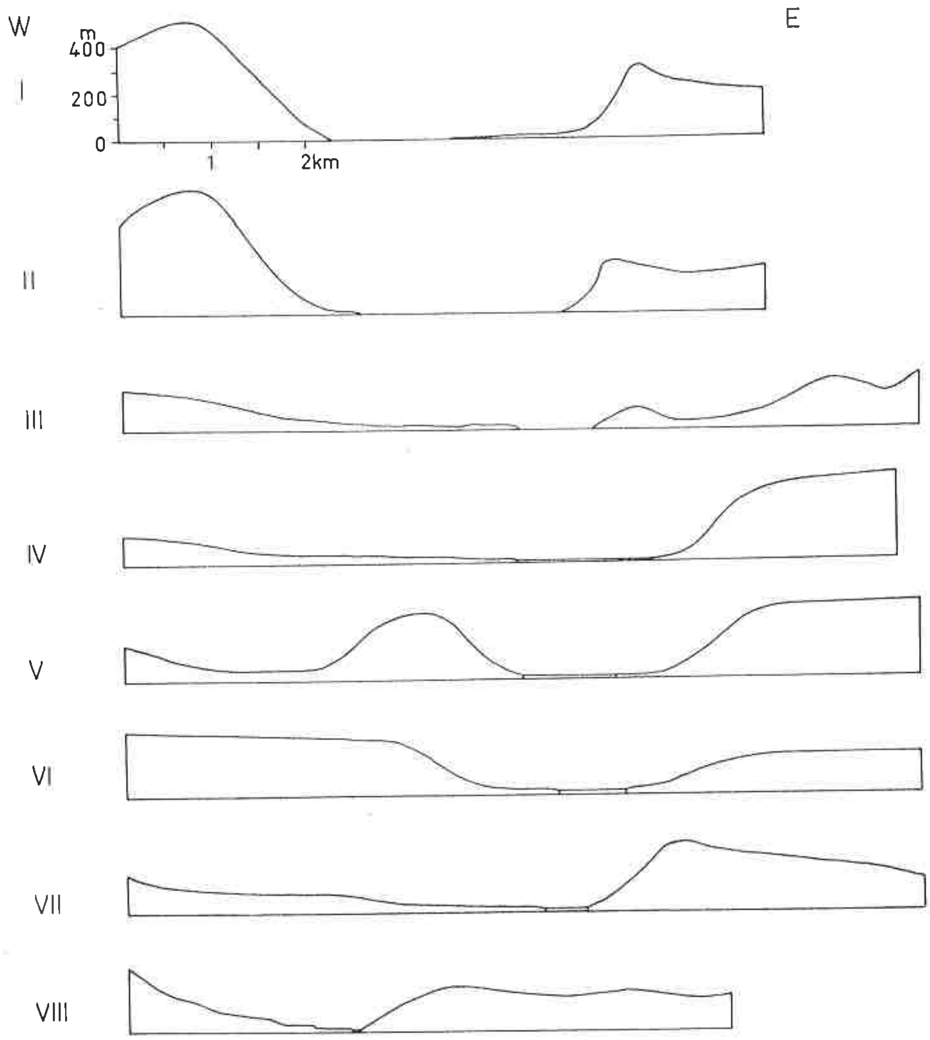

Fig. 4. Transverse profiles of Tana Valley (Fig. 1).

a) Relief of the northern part

By separately analysing each side in the area divided by the Tana River (Fig. 1) one can classify seven homogenous regions as to the relief. For the analysis, each slope of the valley was divided into 2 km-broad transverse strips which reach from the shore of the Tana River to the boundary of the research area. After this, with the aid of a planimeter the area of the strip and the altitude zones were measured on the topographical map and then the percentage of each in the whole strip was calculated. Thus it is clear that in strips narrower than have been chosen, the local minor features would appear more clearly than is necessary. Finally, the parallel strips whose qualities correspon-ded to each other most were joined to the same region.

Considering only the relative altitudes according to the method above and also using the transversal profiles (Fig. 4), the following regions were formed (Fig. 1, broken lines).

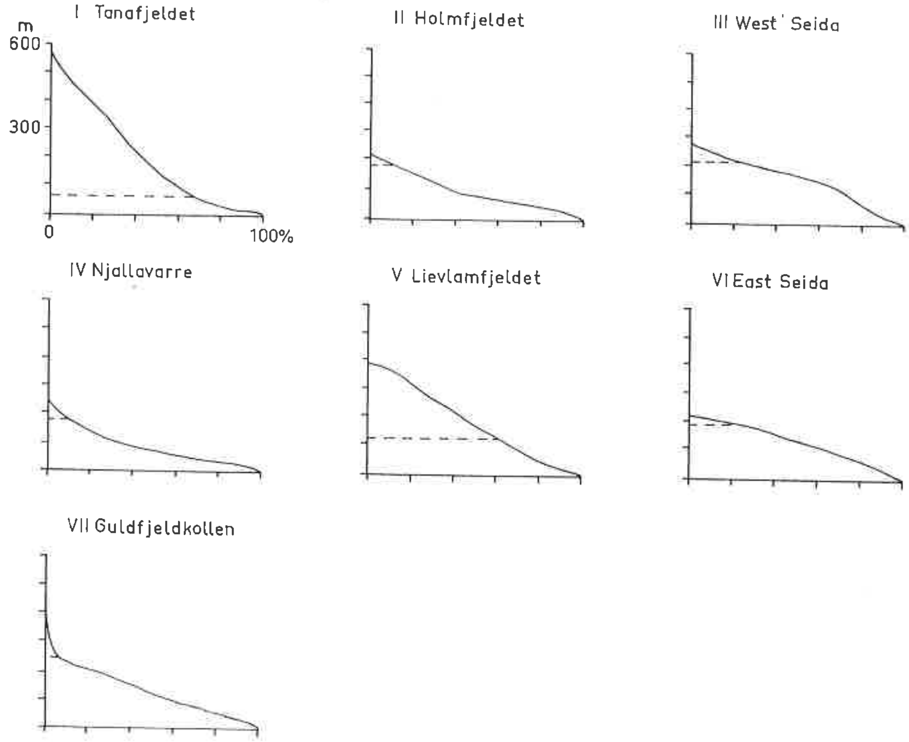

Fig. 5. Hypsographic curves of topographic regions in Tana Valley. Broken line = the upper limit of deciduous woods.

1. Tanafjeldet

The hypsographic curve of the region (Fig. 5, I) rises evenly and clearly reaches higher than any other. The above-mentioned Tanafjeldet rises steeply from the shore of Tana River to 570 m and dominates the whole region with its «wild« forms. Close to the shore of the river are many low areas because 24 % of the region is below the level of 30 m. Yet, it is typical of the highness of the region that 44 % is above 180 m and about a quarter above 360 m. The average altitude of the region is 150 m.

2. Holmfjeldet

This region is the lowest of all the sub-regions. This is clearly seen first in the fact that the altitude of the highest peak is only 287 m. Secondly, as the hypsographic curve shows (Fig. 5, II), 22 % from the region is below 30 m and 60 % below 90 m. In general, the peaks reach only a little above 180 m. The average altitude of the region is only 80 m. The valleys and mountains in NNE-SSW direction appear very clearly in the relief.

3. West-Seida

The region of West-Seida has a clear-cut relief. The level of the Tana River here is 7—10 m. The area of low shoreland, below 30 m, makes up only 15 % of the whole region. After the wide river terrace, the terrain rises about 150 m for a distance of 400—700 m. The tops of the fjelds form a plane where the terrain goes up only 30—50 m/km. It is easy to see the width of the plane in the hypsographic curve (Fig. 5, III), because 71 % of the region is above 120 m and 44 % above 180 m. The average altitude is rather great, 180 m. This region resembles Lievlamfjeldet in its main features with the even tops of its fjelds, but in the latter region the altitudes are about 100 m higher.

4. Njallavarre

The whole region is low (Fig. 5, IV) with 21 % of it below 30 m, and the level of the Tana River is only 10—13 m. 74 % of the region lies below 120 m, and not even the highest peak reaches 300 m. The average altitude is only 80 m. Because of the few hill-like formations called vaara that are over 200 m high, the uppermost end of the hypsographic curve is steeper than in any other parts. The concave curve is thus much like the one in the region of Holmfjeldet.

5. Lievlamfjeldet

The eastern parts of the valley in the lower course of the Tana River form a topographically homogeneous region that reaches from the Bugtelven to the Arctic Ocean. One of the most characteristic features of this nearly 30 km long region are cliffs that are 250 m high and in many places rise immediately from the level of the river (Fig. 6). The wide river terraces found frequently along the western side of the Tana River are much narrower on this side or are missing altogether. Only at the mouth of the river is there such a terrace having an average altitude of 6 m.

Fig. 6. Tana Valley, Rödberget. In the background there is a wide and low (6 m) terrace of the river.

b) Relief of the southern part

Due to the lack of topographic maps on the Finnish side of the research area (Fig. 2), the study of the relief here is more general than above. Aerial photos, the writer's field studies and the Finnish Economical Map 1:100 000 are used as references.

1. The western side of the valley

The northernmost part in the western side of the valley has a variable topography up to the Kaldaushjoki River. The relative altitudes are usually only 40—70 m excluding the shore areas of Lake Pulmankijärvi. The highest peaks rise a little above 250 m.

The region between the Kaldaushjoki River and Skäidijärvi lakes is more even in its relief than the former region, but has a higher average altitude. Nearly the whole region is made up of a uniform mountain («skaidi« in Finnish), with a steep edge facing Lake Pulmankijärvi. The altitude of the top of the skaidi varies from 130 to 150 m above the surface of Pulmankijärvi.

South from Skäidijärvi lakes the western side of the Pulmankijoki Valley varies in its minor features. Yet, irrespective of the relative altitudes caused by the main valley, the region can be considered plane (Fig. 8). Heterogenity

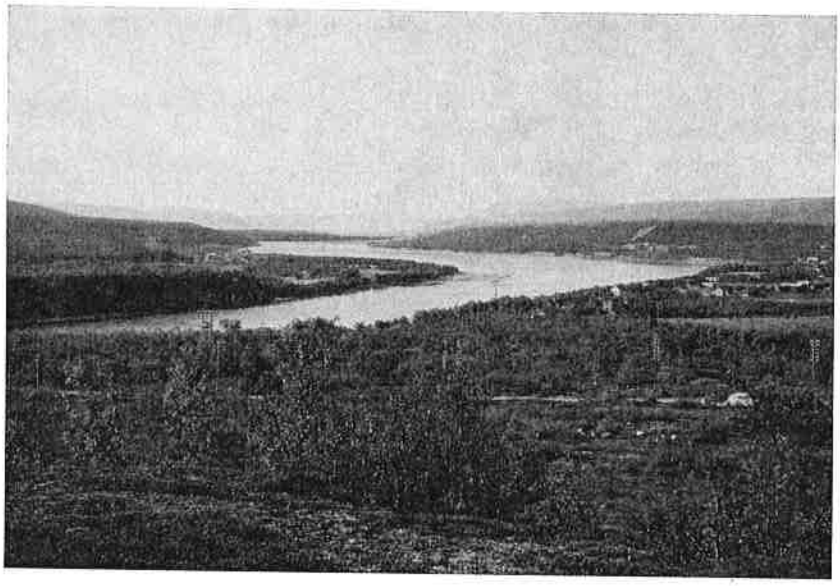

Fig. 7. Skipagurra. Behind the village at the level of 70 m there is a plane eroded by water into loose material.

of the minor topography is caused by the old 2—5 m deep channels made by flowing water. When examining the transverse profiles of the valley (Fig. 3, II, III and IV), it is seen that the average bottom altitude of the valley in the upper course obviously increases more than the altitude of the river itself.

2. The eastern side of the valley

The region has a homogeneous relief. The relative changes here are clearly greater than in the western side. The whole area is covered with a row of five mountains («vaara« in Finnish), whose summits vary in elevation from 180 to 270 m. In the longitudinal direction of the vaara range, the relative altitudes are 100—200 m. Measured from the surface of Pulmankijärvi, the corresponding heights are 150—250 m.

3. Structure of the ground

In this connection the quality of the ground is examined as to its resistance against erosion. Thus the aim is to determine the species of rocks in the main features and also the amount and quality of the loose deposits.

Fig. 8. Aerial photo of the Pulmanki River. Near the Tourajoki River some drumlins are seen. By permission of the Maanmittaushallitus.

a) Bedrock

On the basis of its bedrock, the Pulmanki-Tana Valley can be divided into two clearly different parts, the northern eocambrian and the southern precambrian area.

The rocks in the eocambrian part belong to a great extent to the earlier eocambrian group (Føyn 1960, Pl 12, Holtedahl 1960 a). Most common of these are sandstones with a low degree of metamorphism. In addition, shales are found in many places. According to Rudberg (1961) the whole eocambrian area mentioned above belongs to a certain marginal zone formed against archean rocks. In the eocambrian area of Finnmark the landforms are located in the direction SW-NE, a phenomenon caused by many parallel fault lines.

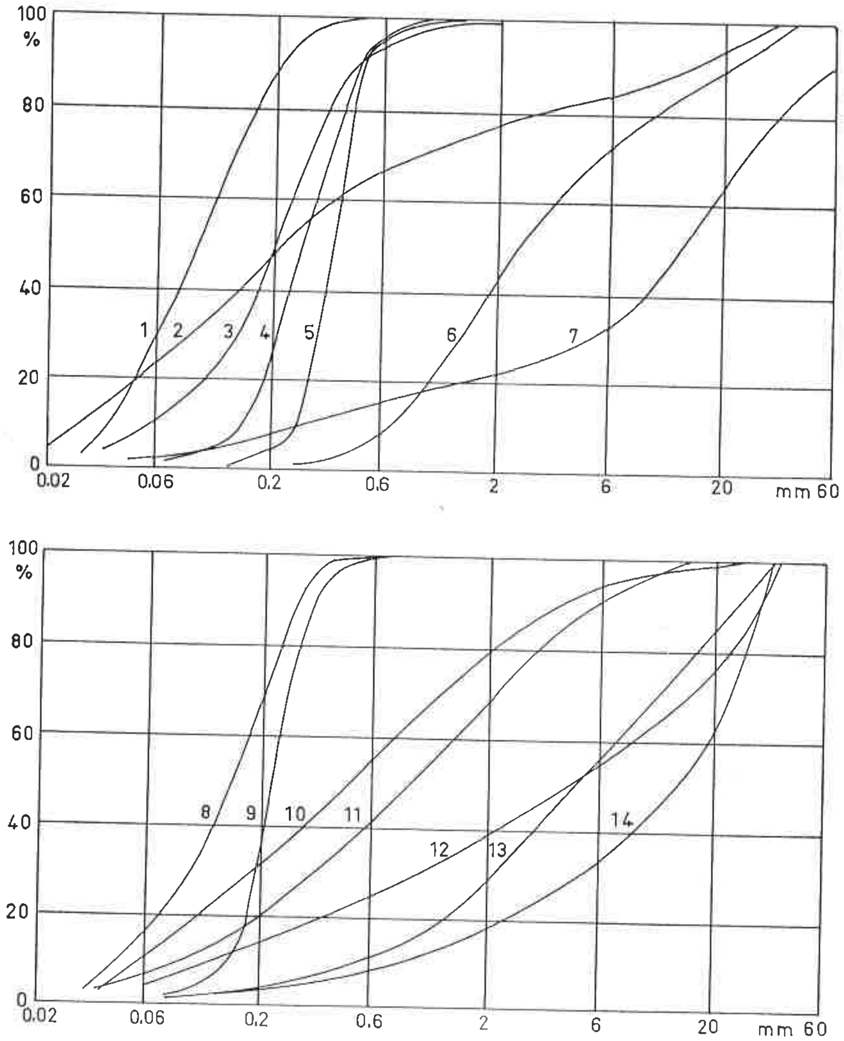

Fig. 9. Cumulative curves of grain size in Pulmanki-Tana Valley. (Compare the text: Structure of the ground).

According to HOLTEDAHL (1960 b) the fjords have been formed in zones of structural weakness, which originated in periods older than the tertiary.

The rocks of the precambrian area are quite homogeneous. Immediately south of the boundary of the eocambrian, there is an area of gneissose granite (migmatized) that extends to the Finnish side (BUGGE 1960, REITAN 1960, SIMONEN 1960, MERILÄINEN 1965). According to MERILÄINEN an amphibolite area is found in the northern and eastern side of Roavvitshokka Fjeld and extends to the northern point of Finland. According to BUGGE, amphibolite occurs in the vicinity of Allikvarre Fjeld on the Norwegian side. MERILÄINEN reports that the eastern parts of the Pulmankijoki Valley consist of gabbros and diorites.

b) Loose deposits

Besides the bedrock, the loose material also determines the resistance of the ground. Thus consideration should be given to the thickness of the strata and also the grain size and hardness of the material. Due to the lack of soil maps, one has to be satisfied with the observations and analyses of material made by the writer.

On the both sides of the Tana River there is much fluvial material. Most of these deposits are situated under a level of 20 m in Tananes, about 70 m in Seida and nearly 80 m in Polmak. The material is mainly well-sorted fine sand (Fig. 9, curves: 3 Fingervand, 4 Polmak, 5 Tananes).

In addition to the above fine material, there is coarse and poorly-sorted gravel (Fig. 9, curve 7) in the vicinity of Skipagurra, with 40 % of the material consisting of rounded stones and boulders. According to MARTHINUSSEN (1960) these are glacial-marine deposits whose upper level is situated at 70 m (Fig. 7) according to the P 12 seaphase (the main line).

There are much thinner deposits of loose material above the fluvial level than below. Usually this material has not been sorted at all (Fig. 9, curve 2, Polmak 80 m). Heaps of gravel, stones and boulders have accumulated as a result of weathering and are common especially in the eocambrian area. An analysis made of a talus cone of shale (Fig. 9, curve 6) shows that there are practically no fractions finer than sand.

Also in the vicinity of Polmakelven, Pulmankijärvi and Pulmankijoki, the loose deposits can be divided into two groups, fluvial and non-fluvial. Material belonging to the former group is virtually not found at all above a level of 80 m at the northern end of Lake Pulmankijärvi, 84 m at the southern end and 88 m at the mouth of the Luossajoki River.

The fluvial deposits to the north of Lake Pulmankijärvi are very homogeneous. The material is well-sorted silt or fine sand (Fig. 9, curves: 1, 48 m and 9, 18 m). On the shores of the lake and in the area south of it the deposits are far more heterogeneous. Between the silt deposits (Fig. 9, curve 8, Pulmankijoki 35 m) there are sand and gravel wedges. The proportion of sand and gravel obviously increases above the level of 40 m. The material is gravel with stones (Fig. 9, curves 13 and 14) on the edges of the valley at the level of 70—88 m. An exceptional abundance of this coarse fluvial material occurs at the mouth of Kaldaushjoki and Roavvijoki (MANSIKKANIEMI 1964). The material is similar to that in the coarse deposits of Skipagurra.

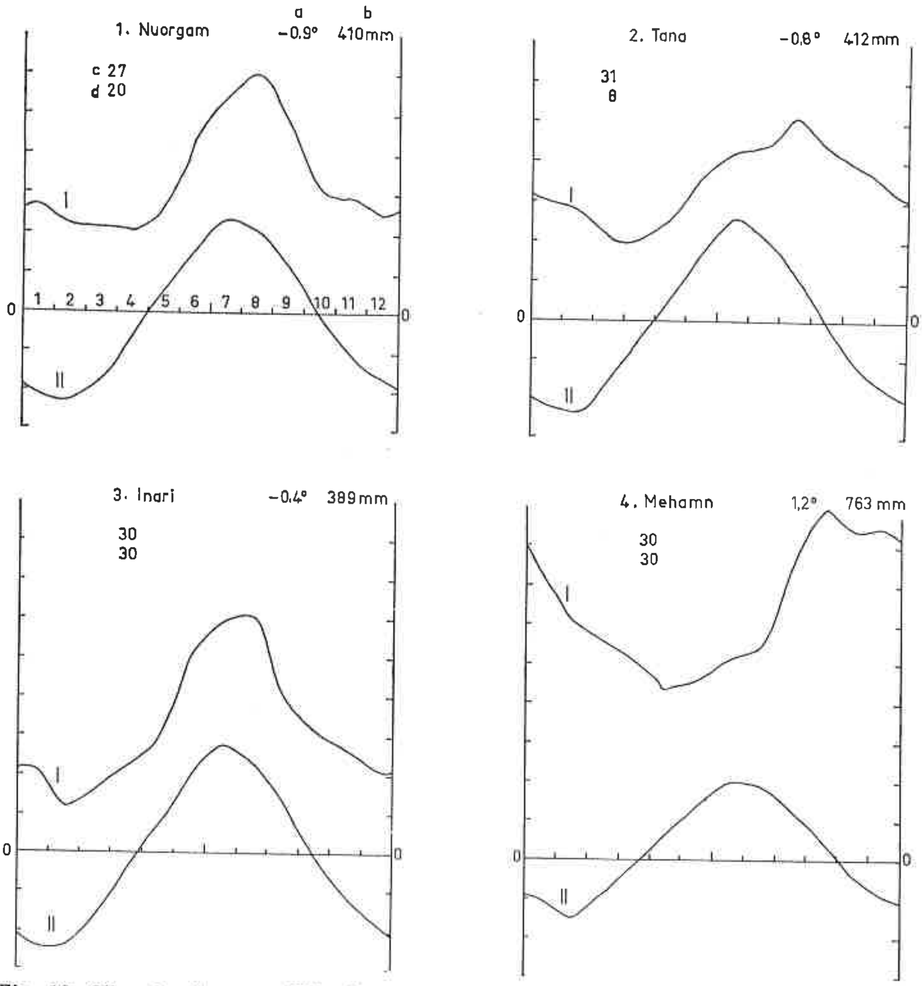

Fig. 10. Climatic diagrams (The form according to Walter 1960). I = monthly means of precipitation, II = monthly means of temperature, five degrees Centigrade corresponds to a precipitation of ten mm; a = mean annual temperature in degrees Centigrade; b = mean annual sum-total precipitation; number of years of observation c = precipitation, d = temperature.

The material obove the fluvial level is mainly till. Not including the peaks, the area is covered by a thin deposit of till (under 1 m). More till occurs west and south-west of Lake Pulmankijärvi. In this area there are many drumlins with an average height of 4—8 m, width 200—300 m and length 600—900 m. The curves 10 (104 m), 11 (85 m) and 12 (98 m, Fig. 9) are examples of the kind of till above the fluvial level.

4. *Climate*

The values from only two meteorological stations, Nuorgam and Tana, are available regarding the area. However, these data are adequate and satisfactory so far as this paper is concerned. For comparison the observations from Inari and Mehamn are also used. The former of these is situated about 100 km to the south and the latter about 50 km to the north of the investigated area. The most important values of the stations are seen in the diagrams made using WALTHER's (1960) method (Fig. 10).

Studies of the climate of the postglacial period are closely related to organogenic influence since the knowledge of earlier climatic conditions comes mainly from different plant fossils.

Because the study of climatic phases in Lapland is still unfinished, there is not yet any unified conception. This matter has been treated by e. g. AUER (1927), HYYPPÄ (1936), SAURAMO (1940), AARIO (1943), KANERVA (1956), VASARI (1962), HYYPPÄ, HOFFRÉN, ISOLA (1962) and DONNER (1963, 1965). Most of these studies deal with coniferous Lapland, so that the results cannot be directly applied to the Pulmanki-Tana Valley. Among other things the schematical pollen diagram about North Finland made by DONNER (1963, p. 7) is not applicable in the investigated area. The climatic postglacial phases in the Pulmanki-Tana Valley are probably similar to those in the birch zone in the northern parts of Petsamo (AARIO 1934). According to SIRÉN (1961) in the northern parts of Fennoskandia there have been eight periods of decline of climate and also eight periods of temperature increase since 5000 B. C. SIRÉN also reports that the climatic maxima have regularly recurred at intervals of 900±50 years.

Since the Boreal Age, the investigated area has obviously been covered by Betula-woods as it is nowadays (compare the organogenic influence.) Pinus probably occurred to some extent in the Pulmanki Valley during the periods of earlier Litorina and younger Limnaea.

5. *Relative changes of sea level*

The eustatic changes in the postglacial period have been closely related to climatic events (FAIRBRIDGE 1961, ZEUNER 1959). According to many scientists, warming of the climate starting 14000—15000 years ago continued up to the year 6000 B. P. except for a few short interruptions (SHEPARD & SUESS 1956, GODWIN, SUGGATE & WILLIS 1958, GURRAY 1961). At the same time the surface of the ocean was continuously rising as a result of the melting of the glaciers. Differing somewhat from the foregoing scientists, ANTEVS (1955), EMILIANI

(1955), GRAUL (1959), BROECKER, EWING & HEEZEN (1960) and WOLDSTEDT (1960) report that a decisive warming of the climate took place 11 000 — 10 000 years ago. According to them, it was this change that caused the rapid melting of the continental glaciers. At the same time the sea level markedly rose beginning with the so-called Flandrian transgression that lasted up to the year 6000 B. P. During this transgression the sea level rose from 30 m to its present level, thus on an average 9 mm a year (FAIRBRIDGE 1961).

According to SHEPARD (1964) the sea level probably rose about 6 m during the last 6000 years, but FAIRBRIDGE maintains that it has remained at its present level with variations of at most 3 m during the same time. At present the sea level rises eustatically 1.3 mm a year (CAILLEUX 1952).

In the northern parts of Fennoskandia the relative changes of sea level have varied in the postglacial time in quite a different way as one could conclude from the eustatic levels (TANNER 1915, 1930, UNDÅS 1938, GRØNLIE 1940, MARTHINUSSEN 1960, ANDERSEN 1965). The differences are caused merely by pronounced lifting of the land.

The most evident marks of the uppermost postglacial shoreline in the investigated area are to be seen in the deltas of the Pulmankijoki, Roavvijoki and Kaldaushjoki Rivers and in Seida, too. According to the writer the following relative altitudes are obtained: Seida 68 m, Kaldaushjoki 80 m, Roavvijoki 81 m, Ruossavaara 83 m and Roavvivaara 87 m. These values corresponds to the isophases in MARTHINUSSEN's P 12 line (1960). He maintains that the age of the sea phase in question is about 10 000 years as determined by the C_{14}-method. The above shore formations in the investigated area have probably risen during the latter half of Dryas. Farther south, the Salpausselkä phases were still taking place (OKKO 1957, DONNER 1958, OKKO 1962, HYYPPÄ 1963). Reliable marks of the earlier sea phases have not been found in the investigated area.

In spite of the eustatic rise of sea level in postglacial time, about 30 m in 10 000 years, the sea level has gone down as a result of the rise of the land, e.g. about 80 m in Polmak. Thus the land mass has risen a total of about 115 m in the area. The southern part of the investigated area has risen more than the northern part. According to the writer, the rate of the subsequent inclination is 0.58 m/km, a value similar to that estimated from the isophases in MARTHINUSSEN's P 12 line (0.60 m/km).

6. Degradation

Degradation and aggradation are factors more difficult to interpret than any others. This is due to the fact that in nature they take place simultaneously.

Fig. 11. Polmakelven. Troughs made by wind.

In those places where the bedrock is visible or covered by only thin (under 1 m thick) loose material, degradation has been so little during the latest 10 000 years that it is not important considering the aspect of this paper. The resistance of the bedrock is especially true in the precambrian area (compare OHLSON 1964), but with a few additions it can be adapted even to the eocambrian area. It is probable that the withdrawal of the slope in the precambrian area generally remained under 1 m during 10 000 years (RAPP 1959, 1960). Lowering of the tops of the fjelds was even less. Local weathering can be apparently greater in almost vertical walls of the eocamrian area.

Above the level of 90 m, there has been little degradation in the postglacial period. Many channels that have been eroded into loose material (e.g. in the area of Tourajoki, fig. 8) have arisen already in the glacial period. Under the above-mentioned level, various erosive formations dominate. This is caused by thick loose deposits in which the effect of exogenic forces occurred already in the postglacial time.

At the distance of 25 km, the river has eroded 40—50 m into the glaciofluvial material in the area of Pulmankijoki. In the vicinity of Lake Pulmankijärvi degradation took place mainly in the deltas of the rivers that empty to the lake. The biggest erosive forms are to bee seen at the mouth of the Kaldaushjoki where the river has eaten its way to a depth of 55 m (MANSIKKANIEMI 1964, figs. 4, 10, 11, 12). In the area of Polmakelven the main degradative event has been the erosion of the river to a depth of 40—50 m in the fine-grained deposits. The material is so fine that wind has made troughs in the middle of the valley 3—7 m deep, 50—100 m broad and about 300 m long (Fig. 11).

According to the observations of the writer, the Tana River in Polmak has vertically eroded at least 50 m and at the outlet about 20 m. A good idea of the immense amount of moved material is obtained when it is proved that erosion has taken place in a strip 1 km broad in Polmak and 2.5 km broad near the village of Tana. The activity of the river has been so strong in the Tana Valley that it has destroyed most marks of other degradation forms.

7. *Aggradation*

There has been little aggradation above the level of 90 m. The postglacial deposits of fjeld areas are mainly small accumulations made by weathering on the lower parts of the slopes. There are no deposits in the rivers or lakes considering the aspect of this paper.

On the other hand, the aggradation is very strong under 90 m. Lake Pulmankijärvi is such a good basin of sedimentation that none of the material emptying to the lake continues through it except some of the clays and dissolved material. The rivers in the area have thus eroded the ground and deposited nearly all of the sediment in the lower course and in Lake Pulmankijärvi, and after the glacial period in the beginning in the sea, too. After the lowering of the level of the lake (the sea) the river, however, again caused erosion in the deposited material and sedimentation continued a little lower. The same phenomenon is going on now in the area.

On the contrary, degradation in the postglacial period has obviously been stronger than aggradation in the area of Polmakelven. The river has discharged the material into the Tana River where a strong current has carried everything along. Therefore there is no delta at the mouth of Polmakelven.

The above described re-erosion and re-sedimentation of the delta has also occurred to a great extent at the mouth of the Tana River. Much of the material coming from the upper course of the Tana has deposited at the mouth, too. At the mouths of the rivers that empty into the Tana River there has been aggradation only at the beginning, during the sea phase. After the lowering of sea level below the mouth area, erosion came to prevail in the tributary valleys.

8. Organogenic influence

The whole area belongs to the subarctic deciduous zone (e.g. HUSTICH 1961). Only the tops of highest fjelds are barren, regio alpina areas. In the vicinity of the Arctic Ocean, Betula woods reach only the level of 30—50 m. About 10 km farther to the south the limit rises to 200—230 m. The birch woods reach even the level of 300 m in some places in the Pulmanki Valley. (Fig. 5 shows how many per cent of each region is covered by birch.) There are only few marshes in the area.

The activity of man is of little importance in the Pulmanki-Tana Valley. The Finnish parts of the area are nearly untouched. In the Tana Valley there are in addition to isolated residences four villages: Polmak, Skipagurra, Rustefjelbma and Tana, each with about 10—20 residences. Meadows and fields cleared on the terraces of the river are the most evident signs of man's activity. There is also a road on each side of the Tana River. The activity of man is concentrated only on the 0.5 km broad strip on each side of the Tana River. The rest of the area is nearly untouched.

III. CONCLUSIONS

1. Dynamics of the area

The forces that have an influence on the area can be divided into three main groups: a) degradative forces, b) aggradative forces, c) factors which have both aggradative and degradative influence or none of these. Such factors as temperature, potential energy, relief and gravitation belong to the latter group.

When examining with the help of the above factors the object of this study, the area 600 km^2 in extent, the following events and phenomena are proved to be significant to the dynamics of the area:

1. The main relief features of the area are the same as after the glacial period, because above the level of 90 m degradation and aggradation have been of minor importance.

2. The humid subarctic climate in the Pulmanki-Tana Valley has led to the consequence that the land has been strongly degraded in the areas that contain fluvial material. Those areas where the bedrock has been visible have not degraded at all.

3. The relative changes of sea level have changed the whole area quite distinctly. «The Pulmanki-Tana Fjord« has become an inland feature occupied by rivers in the postglacial time.

4. Degradation and aggradation have had an influence only in the areas below the uppermost sea level. As a consequence of degradation are e.g. the numerous meanders of the Pulmankijoki River and the Polmakelven River and also the 40—50 m high river terraces. In the Tana Valley the river has eroded 20—50 m into loose material along a distance of 50 km.

5. The main importance of the organogenic factor is that excluding the highest peaks the area at present is covered by deciduous woods.

2. *Regions*

The investigated area is first divided into two main parts comprising the area below the uppermost sea level and the area above this level. The former is called Lower Region (Figs. 1 and 2, shaded area) and the latter Upper Region. The boundary between the areas lies so that it is on the level of nearly 90 m in the middle course of the Pulmankijoki, 80 m in Polmak, 70 m in Seida and about 50 m in Tana. The two regions clearly differ from each other in their dynamics. The following main differences are seen:

Lower Region (210 km²)	Upper Region (380 km²)
1. Relative altitudes 50—60 m, even areas on the riversides	150—500 m, broken, uneven areas
2. Abundant water in the basins (Pulmankijärvi, Pulmankijoki, Tana)	Basins are dry to a great extent or amount of water is little
3. The ground is composed of easily degraded loose material	The ground is composed of hard bedrock; only thin loose deposits
4. The region has emerged from the sea, sea forces + sedimentation	Supra-aquatic region
5. Degradation strong, deep river channels	Only few forms of degradation (compare the ground)
6. Aggradation strong	Aggradation weak
7. Betula woods, meadows, activity of man	Betula woods, no activity of man

On the basis of the findings made in the treatment of the factors, the Upper Region and Lower Region are divided into the following sub-regions. The typical qualities of each region are also briefly mentioned.

A. Lower Region

1. Degradative- and aggradative region of Tana
   - degradation and aggradation are strongest in the investigated area
   - the region receives abundant material from outside
   - the material of the ground varies in the size of its grains
   - the activity of man is strongest in the investigated area

2. Degradative region of Polmakelven
   — the region is much eroded; the meandering channel of Polmakelven
   — the material resulting from degradation is carried outside the region
   — the material of the ground is homogeneous and fine
3. Region of Pulmankijärvi
   — little loose material, in its «place« a lake
   — degradation has concentrated at the mouth of the rivers
   — no material has been carried away from the region
   — the material of the ground varies in its grain size
4. Degradative Region of Pulmankijoki
   — the channel, 40—50 m deep, has arisen as a result of degradation
   — much degradation and aggradation has taken place at the same time at the mouth of the river
   — relief variable
   — the material of the ground is heterogeneous in its grain size

B. Upper Region
1. Barren mountains of Tanafjeldet
   — the greatest relative changes in the investigated area 100—500 m
   — the whole region barren mountains
2. Vaara Region of Holmfjeldet
   — low region, the greatest relative changes 200 m
   — topography variable in its minor features
   — many lakes and marshes in basins
3. Skaidi of West Seida
   — clearly featured skaidi area
   — the greatest relative changes about 200 m
4. Vaara Region of Njallavarre-Harrimatshokka
   — low, relative changes under 200 m
   — minor topography variable
   — small pools and marshes in the basins of the bedrock
5. Region of drumlins of Stuorraskaidi
   — quite an even skaidi in its general features
   — many low drumlins on the skaidi
   — relative changes 50—100 m
6. Region of drumlins and channels of Tourajoki
   — an even skaidi in its general features
   — many drumlins broken by meltwater channels
7. Precipice of Lievlamfjeldet
   — the slope towards the Tana River very steep in the area
   — from the precipice to the inland even tops of the fjelds

— relative changes 200—300 m
— nearly the whole region barren mountains

8. Slope Region of East Seida
   — the whole region homogeneous, gradually rising slope from the Tana River
   — only little variability even in minor topography
9. Vaara Region of Ensligtinden
   — relief very variable
   — relative changes 150—350 m
   — many steep forms

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