Avalanches of the USSR

G. K. TUSHINSKY, K. V. AKIFYEVA, N. A. VOLODICHEVA
N. L. KONDAKOVA, V. I. KRAVTSOVA, G. S. KONSTANTINOVA
S. A. RAKITA and E. S. TROSHKINA
Г. К. Тушинский, К. В. Акифьева, Н. А. Володичева, Н. Л Кондакова
В. И. Кравцова, Г. С. Константинова, С. А. Ракита и Е. С. Трошкина
Moscow State University, Problem Laboratory of Avalanche, Moscow, USSR

I. Introduction

Considerable difficulties are encountered in the industrial development of the mountainous regions of the USSR (industrial, civil and transport constructions) owing to the widespread avalanche activity. Avalanches cause catastrophes and large material damages. Up to recent times organizations designing the constructions of different types had no data at their disposal on the avalanche danger over the USSR territory.

In 1965–1966 following the task given them by the Gosstroy USSR, the Moscow State University and Hydrometeoservice of the USSR compiled a map of avalanche regions of the USSR (the scale is 1 : 10 000 000). The map depicts regions where special studies are required for the evaluation of avalanche danger with special reference to designing or planning constructions and for other surveys.

In the process of map compilation the materials were generalized based on multi-year avalanche researches carried out in certain regions of the Khibins, in the Caucasus, in the mountains of Middle Asia and in the Transbaikal region. The data provided by the above-mentioned work were used as standards in the compilation of the map, and provided clues to the understanding of the peculiarities of the snow cover formation and of different types of avalanche regimes.

For the compilation of this map of the whole USSR territory, an extensive organizational work was carried out collecting all known data on avalanches which could be expressed as follows:

1. The observational data were collected from snow avalanche stations and regular meteorological stations of the hydrometeoservice system and avalanche defence survice of mining enterprises. These data were of great value due to the systematical continuance of observations without which it was impossible to adjudge the avalanche activity, frequency of their occurrence and weather conditions of avalanching.

2. The materials were generalized from special expedition studies of avalanches carried out during the surveys of different linear constructions and also for the evaluation of a territory to determine its suitability for industrial and civil construction.

In the compilation of the map the scientific workers of Moscow State University carried out field surveys in 1965 in the mountains of Putoran, Kamchatka, Sakhalin and Caucasus.

3. *Questionnaires* were distributed by the territorial boards of the Hydrometeoservice. About 2 000 *questionnaires* were sent to different areas in the USSR for additional data

on avalanching. In addition, the workers of the Moscow State University (MGU) went to Barnaul, Novosibirsk, Krasnoyarsk, Norilsk, Irkutsk, Yakutsk, Vladivostok, Khabarovsk, Petropavlovskna-Kamchatka to obtain information on avalanches from road, forest, geological and other organizations.

4. Literature sources and fund materials made it possible to generalize the data on

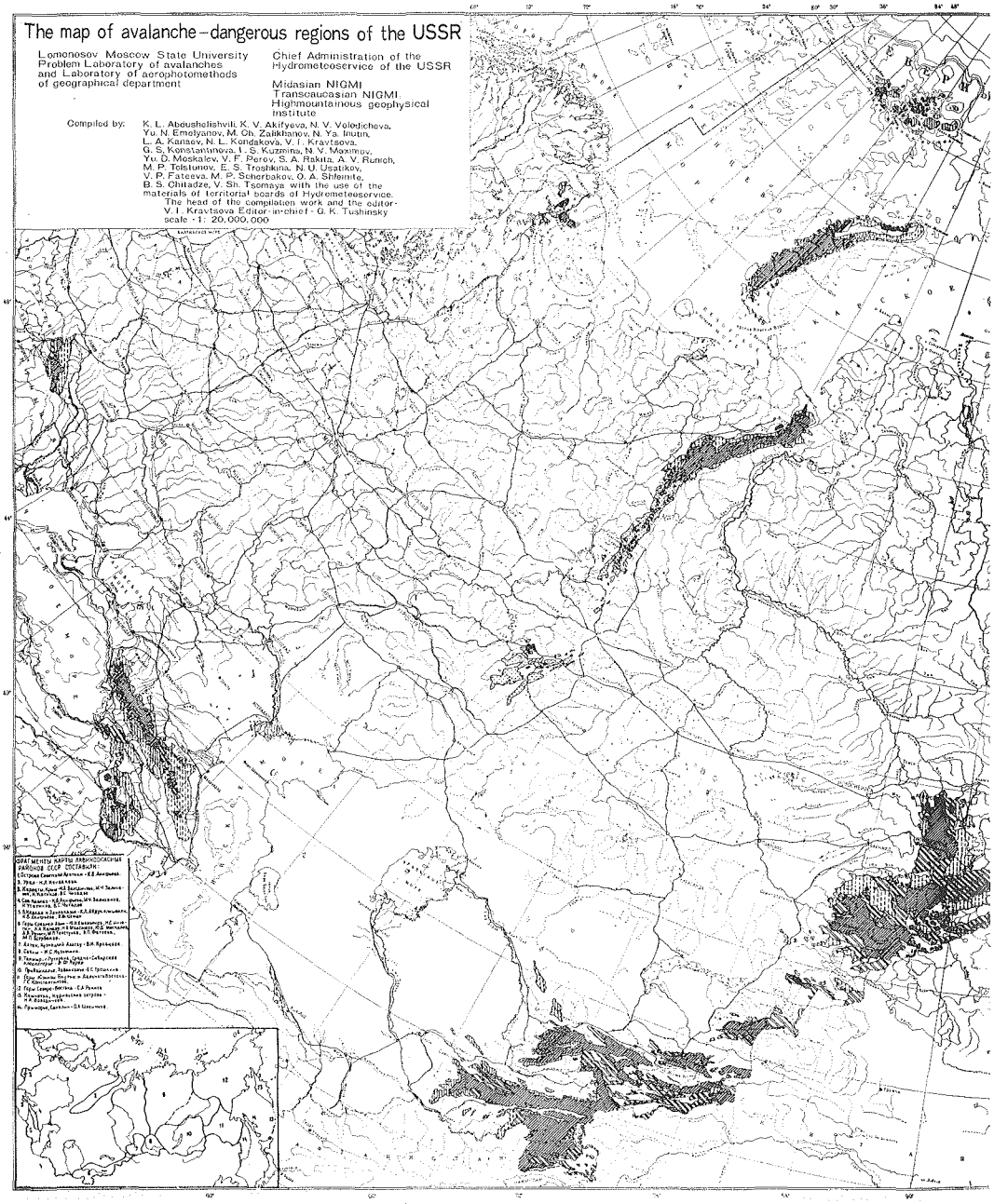
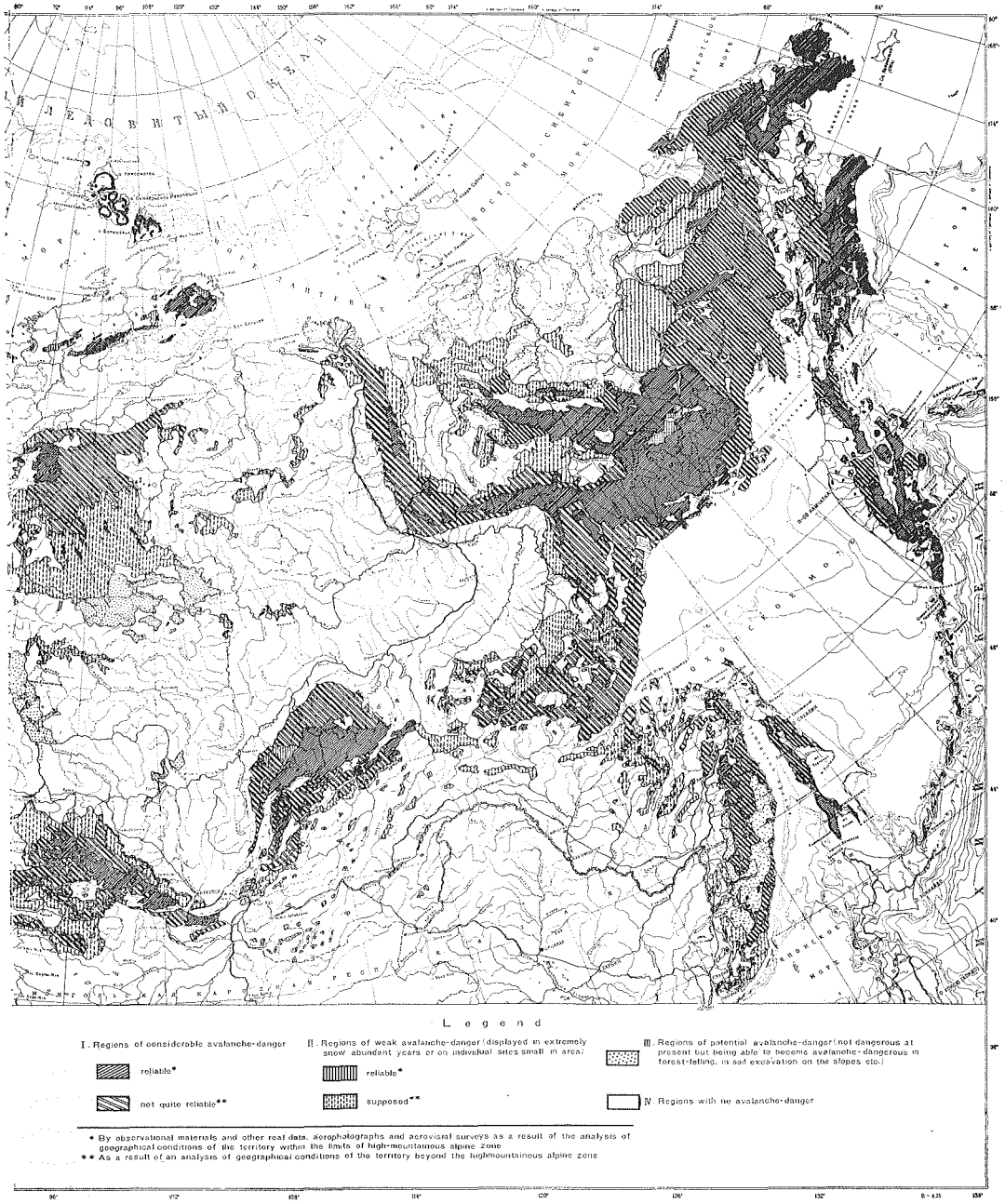


Fig. 1. The map of avalanche dangerous regions of the USSR

avalanches from the beginning of the XIXth century.

Based on this extensive collection of the materials on the facts of avalanching a catalogue was compiled, containing information on avalanches on more than 800 sites —the first review of actual data on avalanches on the USSR territory.

These materials however only supply information on avalanches at individual sites



while in the vast areas of untrodden mountainous regions of the Altai Mts., the Sayan Mts., the Putoran Mts., the mountainous regions of North-East, Far East, Primorye, Kamchatka, almost no data are available.

The mass survey of a territory could be carried out only by means of aeromethod which have a special role in the compilation of the map.

A deciphering of aerophotographs was carried out on standard sites in all the mountainous regions. By means of aerophotographs a study of the landscape of surveyed territory was carried out to reveal boundaries of avalanche regions and to decipher individual avalanches and a compilation of avalanche maps for certain standard sites was made. The experience of our work with aerophotographs of summer landscape and comparisons of aerosurvey materials obtained in different seasons of the year showed that a deciphering of avalanche can be successfully made by summer aerophotographs based on indirect geomorphological and geobotanical indications.

Deciphering of the aerophotographs of winter landscape made it possible to enlarge the avalanche catalogue with the data on avalanches which occurred during the period of aerophotosurvey.

A great role in the map compilation was played by aerovisual observations carried out by MGU workers in the untrodden eastern regions of the country in the basin of the Upper Kolyma, in the Altai Mts., Kuznetsk Alatau, in the Caucasus, on the Novaya Zemlya, Severnaya Zemlya, on Novosibirskiye Isles, Vrangel Island, Stanovoy Ridge, Burein Ridge, Sikhote-Alin, Sakhalin, the Kurile Isles, Kamchatka, Tchukotka, the Taimir and Aldanskoye Plateau. This work showed an extremely high effectivity of aerovisual observation for revelation of regions of avalanche distribution. In observations from different heights, several hundreds to 8 000 m seasonal traces of avalanching —avalanche snow patches— can be clearly recognized from the air. The success of the work is determined by the selection of the period of aerovisual observations which should be carried out immediately following the melting of the seasonal snow cover.

The whole set of information obtained by aeromethods —by means of observations from the air and deciphering of aerophotographs— yielded nearly 1/3 of the points and sites of avalanching known until the present.

And finally, for most of the regions the principal method of map compilation was the analysis of geographical conditions mainly of the relief and climate and also of the peculiarities of plant cover. Only such an analysis made it possible to show the complete characteristics of avalanche danger of the whole country including the regions where we had no data on avalanches before.

An analysis of the relief was performed by a large scale topographical and review geomorphological maps based on which the working maps for evaluating territory relief (1 : 2 500 000 in scale) were compiled with the account of depths and density of dissection, inclination angles etc. An analysis of climatic conditions was made by climatic maps, reference books and fund materials. Special attention was paid to the depth of the snow cover and its variations from year to year, snow drift transport and also to temperature conditions of the winter period. Avalanche zones were designated as regions with a maximum 10 year average snow depth of more than 30 cm, while the depth of 70 cm was considered to indicate a considerable avalanche danger.

A comparison of maps evaluating relief and climate made it possible to define the territories with different degrees of avalanche danger and to compile the maps of avalanche regions for individual mountainous territories at a scale of 1 : 2 500 000 which was later combined in a review map of the USSR at a scale of 1 : 10 000 000 (Fig. 1).

The regions with considerable and small avalanche danger are revealed on this map will as the regions with potential avalanche danger where a change of natural conditions of human activity will undoubtedly lead to the appearance of avalanches. In addition to this the reliability of marking the boundaries of avalanche regions is characterized.

For the first time the proposed map shows with a considerable degree of detail and reliability how widely the avalanche danger is spread in the mountainous regions of our country. Cartometric works made on it showed that more than 4 500 000 km^2 —which is 20% of the whole territory of the country— are avalanche regions.

The compiled map and an analysis of the conditions of avalanche formation makes it possible to divide the country territory into districts according to the prevailing factors of avalanche formation and in accordance with types of avalanche regime. As a result of this division 50 avalanche regions were defined which were combined into 5 groups (Table 1, Fig. 2).

In dividing the snow avalanche regime of the USSR into districts the difference of snow rocks from the rest of the mountainous rocks was taken into consideration which was the dependence of snow cover on climate and consequently on geographical zones. One must bear in mind that the diagenesis of a snow layer is most closely connected also with geographical conditions which makes it possible to show the geographical types of avalanche regimes.

The importance of ice and snow for the biosphere was emphasized by the outstanding soviet scientist academician V. I. Vernadsky. He pointed to the zonality of water

Table 1. Types of avalanche formation and avalanche dangerous regions of the Soviet Union

Climatic provinces	*Avalanche dangerous region*
I. Arctic regions with snow drift and insolation avalanches	
Atlantic-Arctic province	1. Glaciers and arctic deserts of the Franz-Joseph Land
"	2. Glacial mid-mountain relief of the Novaya Zemlya
"	3. Arctic deserts and glaciers of the Severnaya Zemlya
Eastern-Siberian Arctic province	4. Arctic deserts of the Novosibirskiye Isles
Pacific-Arctic province	5. Arctic deserts of the Vrangel Island
II. Northern regions with avalanches of snow drift and newly fallen snow	
Atlantic-Subarctic province	6. The Kolskiy tundra-northern-taiga peninsula
"	7. Mountain-tundra and forest-tundra in Polar and Prepolar Urals
Atlantic-Arctic province	8. Arctic deserts and tundras of the Byrranga Mts.
Siberian Subarctic province	9. Tundra and Northern taiga of Putoran Mts.
Continental Eastern Siberian province	10. Northern-taiga and tundra of Okhotsko-Kolymskoye Plateau
"	11. Anuysko-Chukotskiye tundra mountains
Pacific Subarctic province	12. Tundra and forest-tundra of Western-Koryak Plateau

III. Innercontinental regions with avalanches of sublimation diaphthoresis

Climatic provinces	*Avalanche dangerous region*
Atlantic continental province	13. Forest and mountainous-tundra of Northern Urals
"	14. Mountainous-tundra of Southern Urals
"	15. Taiga mountains of the East-Tuva Plateau and Tannu-Ola
Continental Eastern Siberian province	16. Enisey taiga ridge
"	17. Cherskiy Ridge and Verkhoyan-skiye north-taiga and tundra mts.
"	18. Yano-Oimyakonskoye and Yukagiro-Alazeiskoy and north-taiga uplands and plateaux
"	19. Northern-Baikal and Patomskoye taiga plateaux
"	20. Taiga and tundra of Stanovoye Plateau and Stanovoy Ridge
"	21. Transbaikal taiga and forest-steppe mid-and low-mountain relief
"	22. Stanovoy Ridge and Stanovoye Plateau
Pacific Forest province	23. Inner regions of Kamchatka (mountainous-tundra-forest Median Ridge)

IV. Southern mountainous belt with avalanches of newly fallen snow, wind slabs and advective avalanches

Atlantic-continental forest province	24. Eastern Carpathians
Atlantic-continental steppe province	25. Mountainous Crimea
Highmountainous western province	26. Great Caucasus
Western-Transcaucasian province	27. Minor Caucasus
Eastern-Transcaucasian province	28. Djavakhetsko-Armenian volcanic steppe plateau
Mountainous Kopet-Dag province	29. Kopet-Dag
Mountainous Pamirs-Alay province	30. Gissaro-Alayskaya system
"	31. Western Pamirs
"	32. Eastern Pamirs
Highmountainous Tien Shan province	33. Western Tien Shan
"	34. Northern Tien Shan
"	35. Central Tein Shan
Continental Mid-Asian province	36. Djungarian Alatau
"	37. Tarbagatai
Mountainous Altai rnd Sayan province	38. Northern Altai
"	39. South-western and north-eastern Altai
"	40. Central Altai
"	41. Kuznetsk Alatau and Mountainous Shoriya
"	42. Western and Eastern Sayan
Monsoon forest province	43. Khingano-Bureinskiye Mountains

V. pacific and seaside regions with avalanches of wet snow drift and sharply stratified snow

Pacific subarctic province	44. Mountains of Chukotskiy Peninsula
"	45. Eastern part of the Koryakskoye Plateau
Monsoon forest province	46. Northern and north-eastern shore of the Sea of Okhotsk
Pacific forest province	47. Kamchatka-Eastern ridge southern volcanic region
"	48. Volcanic regions of the Kurile Isles
Monsoon forest province	49. Sakhalin Western-Sakhalin and Eastern-Sakhalin Mountains
"	50. Djugdjur Ridge (eastern slopes)
"	51. Sikhote-Alin and Primorye

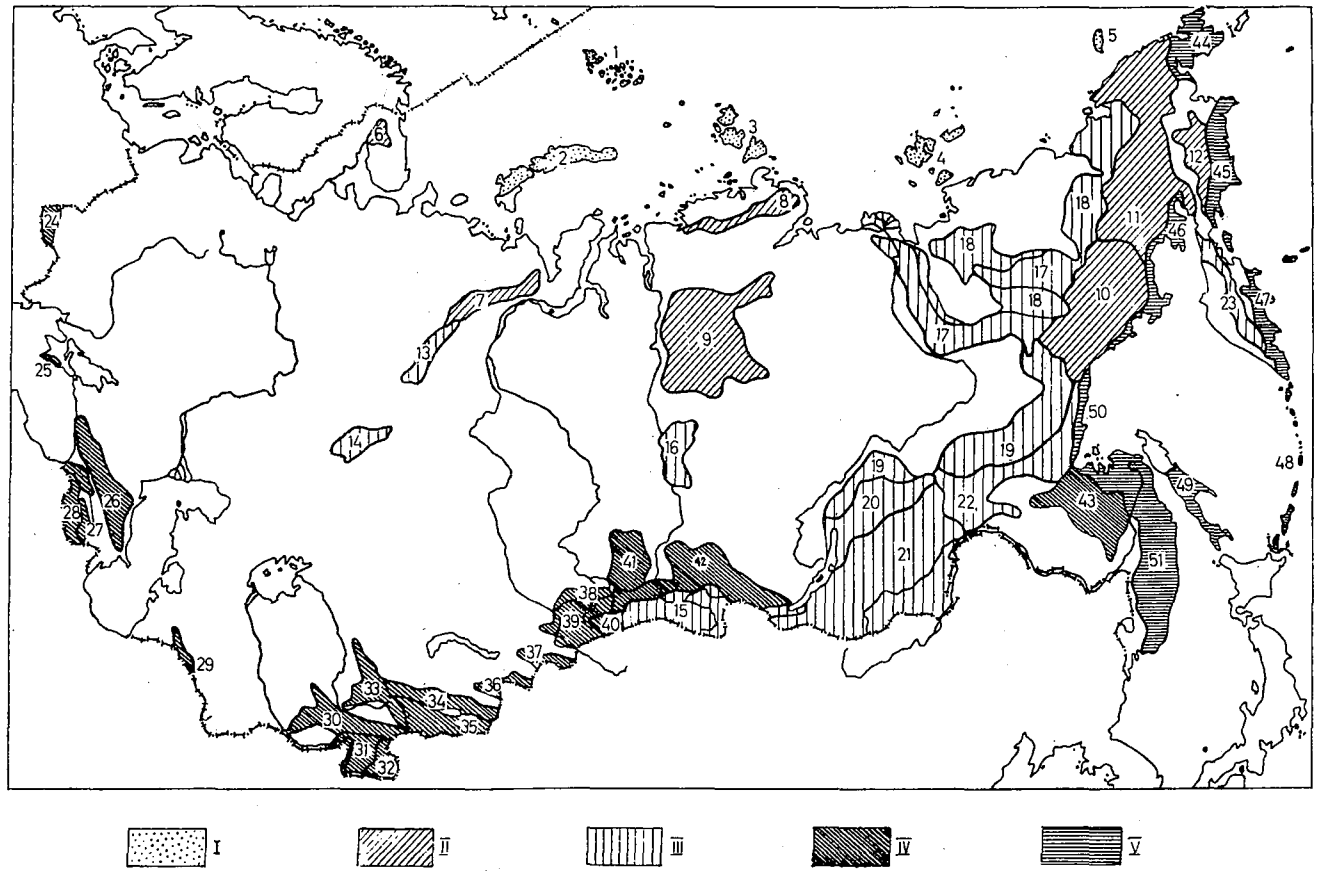


Fig. 2. The scheme of the USSR division in accordance with prevalent types of avalanche formation. I. Arctic regions with snow drift and insolation avalanches. II. Northern regions with avalanches of snow drift and newly fallen snow. III. Innercontinental regions with avalanches of sublimation diaphthoresis. IV. Southern mountainous belt with avalanches of newly fallen snow, wind slabs and advective avalanches. V. Pacific and seaside regions with avalanches of wet snow drift and sharply stratified snow

display on our planet. He wrote: "Similar to fauna and flora distribution and in contrast to a great number of minerals, water displays on the surface of our planet subjected to geographical conditions. They depend on the geographical location on the surface of the globe on the planet position with respect to the sun.

Therefore the basis of our scheme is the physicogeogrophical division of the USSR into districts.

In this division account was taken on the opposite types of development of snow cover in the direction of compression (with prevailing settlement) and the development directed towards loosening (with prevailing sublimation recrystallization) leading to sublimation diaphoresis.

Predetermination of the two types of recrystallization into the stage of early diagenesis is connected with the fact that there is no place for sublimation increase of grains in the snow compressed by wind. In snow with great porosity and air permeability the process of accumulating recrystallization is under way, leading to a rapid increase of large crystals, deep hoar frost. Geographical conditions are quite distinctly reflected in the types of stratigraphic cross sections.

1) *Snow-drift avalanches** occur during strong snow drifts when much snow is accumulated on the leeward slopes. An overburdening of snow leads to a loss of balance of the snow layer on the slope and to avalanching. In a stratigraphic cross section of snow layer a powerful layer of drifted snow, deposited on the surface of old snow is observed which contributes to the occurrence of snow drift avalanche.

2) *Insolation avalanches** occur under the effect of solar rays heating a friable snow layer, which overlies wind packed snow or an ice crust. Thawing leads to the appearance of water in the foundation of a 10~15 cm snow layer. In case of a thin ice crust existing on the snow surface there often occurs a greenhouse effect leading to a melting away of 10 cm snow layer and also producing an insolation avalanche. Insolation avalanches occur on the slopes of southern exposition.

In a stratigraphic cross section of the snow cover a thin transparent crust may be usually observed on the snow surface or buried ice or a thin firn crust which serves as a base for the insolation avalanche of snow layer.

3) *Avalanches of newly fallen snow**. The depth of snow cover rapidly increases during abundant snow falls. The new snow, falling on the surface of old snow does not remain there and slides away forming an avalanche. Especially a fast increase of the height of snow cover is observed in the mountainous regions with a Mediterranean Sea type of climate.

In a stratigraphic cross section of snow layer newly fallen cohesionless snow of considerable thickness is observed overlying the old snow.

4) *Avalanches of sublimation diaphthoresis** occur with high temperature gradients within a snow cover of large porosity and air permeability. In these conditions an intensive process of accumulative recrystallization takes place leading to the occurrence of powerful —0.5 m and over— horizons of deep hoar frost along which avalanching occurs.

* Terms introduced by V. N. Akkuratov.

In a stratigraphic cross section a loose horizon is distinctly observable consisting of large ampullaceous crystals of deep hoar frost.

5) *Advective avalanches** occur under conditions of advection of warm and humid air. An active melt of snow cover takes place irrespective of the slope exposition but with respect to cardinal points. These avalanches show a rapid appearance especially if within the snow layer there are ice crusts where thawed water accumulates and forms a water layer there.

6) *Wind slab avalanches* consist of highly compacted snow which is in a state of strong stress. The stress of wind slab is so high that one can hear a rumbling noise sometimes while walking on it. First this avalanche slides as a monolithic platform but afterwards it is broken into a number of acute angled platforms. The thickness of wind slabs reaches 2~3 m.

In the upper part of the stratigraphic profile a powerful wind slab is observed under which there is a weak horizon of deep hoar frost.

7) *Avalanches of sharply stratified snow* occur in the process of formation of snow layers under the condition of cold winters combined with deep thaws, ice-crusted ground and even liquid precipitation.

In the stratigraphic snow cover profile there are numerous ice and wind crusts along the surface of which avalanching takes place. Such stratification of snow occurs under the conditions of intensive cyclonic activity.

The relationship between the geographical situation and the mode of snow cover development (in accordance with the compacting or loosening type) made it possible to distinguish five types of avalanche systems.

II. Arctic Regions with Snow Drift and Insolation Avalanches

The Arctic regions are located northward of 70°N. Such a locality defines the physico-geographical and climatic peculiarities. The isles of the Arctic Ocean are in the Arctic climatic zone characterized by a specific radiation pattern (replacement of polar night by polar day), by peculiarities of atmospheric circulation (in winter, western and eastern sectors are regions of frequent cyclonic invasions; central sector, the region of anticyclonic development). The main features of the cold period are as follows: its duration (8–9 months), moderately severe winter (temperature in January is from −13 to −32°C, low quantity of winter precipitates (the highest 10 day average snow depth in April-May reaches 30 cm in eastern and 80 cm in western regions). Strong winds associated with cyclonic activity carry warmth and precipitates. The winds of southern and eastern points in the Atlantic sector and those of northern points in the Pacific sector are very stable and reach high velocities often transforming into air turbulences of gale force. With low temperatures and a thin snow cover occurring irregularly the snow is strongly compacted (up to 0.4 g/cm^3) or retransported under the effect of strong winds. Snow drift transport in the Arctics reaches enormous quantities since the ground wind begins with a wind velocity of 5~7 m/sec. Cyclonic invasions in the western and eastern sectors lead to a sharp increase of temperature up to 25°C per day. Thaws

however seldom occur here, whereas on the Severnaya Zemlya and on Novosibirskiye Isles no thawing is seen.

Being within the limits of the European-Asian shelf the arctic isles are of a different geomorphological appearance owing to different geological structure and age. The common features in the relief are the small absolute heights (the highest point is 1 590 m, the Novaya Zemlya) and a wide development of glaciation, comprising 78% of the entire glaciation area in the USSR. An alpine type of relief is observed only on the Novaya Zemlya; a highly rugged mid-mountainous relief occurs on the Novaya Zemlya and on the Vrangel Island; elevated platform-like surfaces with steep precipitous edges, covered with ice domes, as well as skerries and nunatakes are characteristic of the Franz-Joseph Land and Novosibirskiye Isles. Separate table mountains rising over the flat planes are typical of the Novosibirskiye Isles.

The period of avalanche danger in the Arctics starts after continuous snowfalls which is typical only for the Atlantic and the Pacific sectors; it is also the result of intensive wind transport which is a characteristic limited to these regions as well; the most powerful avalanches fall during the spring thawing; wet avalanches from glaciers reach maximum sizes. In the Siberian sector (Novosibirskiye Isles) avalanching is possible in the middle of winter when snow masses slide on the surface of weak horizons of snow metamorphosed by sublimation recrystallization.

III. Northern Regions with Avalanche of Snow Drift and Newly Fallen Snow

Regions with avalanches of snow drift and newly fallen snow are located in the mountainous massifs of tundra, forest-tundra and northern taiga zone of the Extreme North of the USSR These are mountain masses of the Kolsky Peninsula, (Khibins, Monchetundra, Chunatundra, Lavozerskiye tundras), Polar and Prepolar Urals, Byrranga Mountains on the Taimir Peninsula, the Putoran Mountains in the North of the Middle Siberia, Mountains of the North-East of the USSR (Okhotsko-Kolymskoye Plateau, Anuysko-Chukotskiye Mountains and the western part of Koryakshiye Mountains).

The Extreme North of the USSR owing to its geographical position in high latitudes and its closeness to the Arctic Ocean is characterized by the utmost severity of climate with very long, cold, snowy and windy winter, which causes a long duration of avalanche danger period (from 7 to 10 months) and a high intensity of snow drift processes which are one of the main reasons of formation and fall of avalanches here. The climate of the northern regions of the USSR is mainly subarctic, but due to the enormous continental extension of North from West to East, the climates of its western, central and eastern regions have their essential differences.

The climate of the northern regions of the European part of the USSR is essentially influenced by air masses brought from the Atlantics which is first of all displayed in an increase of the air humidity and in a rise of cyclonic activity which guarantees a considerable amount of precipitation during the whole year especially in the mountainous regions.

The climate of Middle Siberia is formed under the influence of arctic air masses

and the Asian maximum which makes the climate of these regions strictly continental and more severe.

The climate of the North-East of Siberia has the features of a sea side climate due to its being formed under the effect of Pacific air masses. The position of the region on the boundary of the zones with strictly pronounced climate of continental and seaside types defines an increased cyclonicity here accompanied by frequent and strong snow drifts and abundant snowfalls in winter.

During the winter time the thickness of the snow cover in the northern regions reaches 60~90 cm on an average while in the Byrranga Mountains it reaches about 30 cm.

Snow drift formation processes lead to a redistribution of the snow cover causing a concentration of enormous snow masses in avalanches on the leeward slopes and a formation of powerful snow benches on plateau brows. In the Polar Urals there are 100 days with snow drifts in winter, while in the Putoran Mountains there is snow drifting for about 20~45% of the winter period. The mean velocity of winter winds is 6~7 m/sec, the maximum velocity exceeds 40 m/sec.

The relief of the mountainous regions of the North of the USSR is characterized by small absolute and relative heights and by a prevalence of mid-mountainous and low mountainous types of relief with a wide distribution of plateau-formation and dome-like elevations. Absolute heights reach 1 000~1 200 m on the average and only small massifs of the Polar and Prepolar Urals, the Putorans, Anuyskiye and Koryakskiye Mountains, rise up to 170~2 000 m. The depth of ruggedness of low mountains is 100~300 m on the average with mean mountains up to 500~700 mand the maximum up to 1 000 m. The slopes of plateaus and especially of river valleys are often covered by a dense net of ravines contributing to the formation and fall of small chute avalanches after abundant snowfalls. Extensive plateau surface favouring the intensive development of snow drifts, supplies enormous masses of snow, transported to the leeward slopes based on which most powerful snow drift avalanches and snow slopes are formed.

IV. Inner Continental Regions with Avalanche of Sublimation Diaphthoresis

Mountainous rigions of moderate latitudes, located in the central part of Eurasia, are far from ocean shores, which explains remarkably pronounced continental climatic conditions. The regions begin with the Northern and Southern Urals, the mountains of North-East and Southern Siberia including Stanovoye and Aldanskoye Plateaux up to the inner regions of Kamchatka belong to this group (the Median Ridge and Ganal Ridge). A large extension from West to East is one of the reasons of continentality of different degrees. On the whole, however, climatic conditions are characterized by homogeneity which determines the general type of avalanche processes.

In winter a larger part of the territory is occupied by an area of high atmospheric pressure, the central part of which is located above Mongolia and the Transbaikal Region. During the entire winter cold continental air is prevalent, formed mainly as a result of transformation of arctic air masses. Therefore for winter months low air temperatures and the absence of thaws are typical. During the cold period a small quantity of

precipitation is seen, amounting to about 20~25% of the annual amount. The principal mass of precipitation (60~80%) is supplied by western air masses during an enhancement of the process of the atlantic air transport in the summer period. The distribution of atmospheric precipitation within the territory is strongly influenced by the mountainous relief. The largest amout of precipitation in the mountains of the Urals and Southern Siberia falls on the western slopes of the mountainous ridges which capture the air masses of the Atlantic Ocean as well. In the mountains of the North-East the wettest is the mountain slopes turned to the wet air masses of the Pacific. The height of the snow cover varies from 10 to 150 cm.

The essential redistribution of solid precipitates is preformed by wind whose velocity markedly increases with the increase of absolute height. At the peaks and passes strong winds (up to 35~40 m/sec) and snow storms often occur. Retransported by strong mountainous winds snow fills canyons and accumulates indepressions. The depth in such places sometimes reaches several meters. In the winter period precipitated snow is characterized by great looseness and mobility. Snow benches and peaks up to 10~12 m of thickness and about 100 m of strike are formed along the crests of valley slopes and in avalanches. With low winter temperatures in the snow cover powerful horizons of deep hoar frost occur leading to an unstable state of snow on the slopes.

The relief of innercontinental regions of the mountainous belt is different to a large extent. Several main types may be distinguished which predetermine avalanching;

1. High-mountainous alpine relief in the regions of intensive elevations at heights of more than 2 000~2 200 m where steeply sloped narrow crests are widely spread. The steepness of slopes is more than 30°.

2. Mid-mountainous type of the relief occupying more than 60% of the area, was formed as a result of erosive dissection of old smoothed surfaces. The height of mid-mountainous massifs is from 800~1 000 to 2 000 m. The relative height is from 200 to 600 m. The slope steepness is from 10° to 25°. Avalanching takes place along eroded and denuded trenches.

3. Highly elevated plateaus and massive uplands, dissected by river valleys along the steep slopes on which avalanching occurs.

Large seismicity (from 8 to 10 units) of certain mountainous regions (Baikal mountainous chains, the mountains of North-East) is one of the principal reasons of mass avalanching.

V. Regions of the Southern Mountainous Belt with Avalanches of Newly Fallen Snow, Wind Slabs and Advective Avalanches

Mountainous regions, bordering the USSR territory along its southern boundaries and including the Eastern Carpathians, the mountainous Crimea, the Caucasus, the mountains of Middle Asia and Altai Sayan mountainous area, are located southward of 55°N within the limits of moderate and subtropical climatic zones. The climate of mountainous areas of moderate zone —the Carpathians, Northern Caucasus, Tien Shan, Altai and Sayan— is formed under the effect of circulation processes, developing in the South of the Russian plain, over the Western Siberia and Kazakhstan. Cyclonic activity

and precipitation under the influence of the relief increase and the influence of the Atlantic Ocean lessening from west to east, which is the main moisture supply, flames up in the mountains ascending above the surrounding plains with a new force. The climate of mountainous regions of the subtropical zone —of the southern slope of the B. Caucasus and Trans-Caucasus, Kopet-Dag and Pamirs-Alay— is formed under the influence of cyclonic activity of Minor Asian and Iranian fronts.

The most essential (from the standpoint of avalanche formation) common features of the climate of the southern mountainous belt are as follows:

a) A large amount of precipitation and considerable depth of snow cover (100~300 cm) in connection with capturing the western airstream moisture;

b) Considerable differentiation in precipitation distribution, increasing eastwards where a small depth (10~20 cm) and sometimes the absence of snow cover is typical for the leeward slopes, inner-mountainous plateaus and inter-mountainous basis;

c) Comparatively mild temperature conditions of the winter period connected with the location of territories. This is especially characteristic of the western and central part of the zone —the Carpathians, the Crimea, the Caucasus, the Pamirs-Alay and the western Tien Shan— where in winther frequent are oscillations of temperature about 0°C and deep thaws contributing to moisturing of snow cover and wet avalanching;

d) Foehns, favouring the occurrence of thaws and avalanche danger make their appearance while in eastern regions foehns cause the termination of the snow cover in the valleys;

e) Snow drift transport whose role weakens in the eastern regions.

An enormous extension of a southern mountainous belt from the west towards the east and an associated decrease of the influence of western Atlantic air masses and an increase of other effects —continental air masses of Central Asia and arctic invasions— creates differences in climatic conditions of mountainous countries. For the European part of the belt, the mediterranean sea type of the climate is typical with maximal winter precipitation and mild temperature, while the eastern regions are subjected to significant continental influences of Central Asia and also are under the influence of invading arctic masses. Therefore, Tien Shan, Zailiysky Alatau, Altai and Sayans show a slight approach to the inner continental situation with respect to avalanches. They differ from western regions by the decrease of the role of snow drift transport of which zone is limited only by the upper belt of mountains. Quiet abundant snowfalls, greater looseness of snow than in the western regions and, in connection with lower winter temperatures, the appearance of the horizons of deep rime are typical.

For mountains of the southern belt a wide development of the alpine type of the relief is typical and a strongly dissected mid-mountainous relief extremely favourable for the development of a dense network of powerful avalanches is present. Owing to a combination of such a relief with deep snow, mountains of the southern belt are one of the most avalanche dangerous regions of the USSR.

Essential differences in avalanche danger within mountainous regions are connected with the presence of the removed plateaus and inter-mountainous basins —the high mountainous plateau of the Pamirs, elevated watersheds of the Central Tien Shan, Chulishmanskoye Plateau, Ukok highland in the Altai— which are remarkable not only

in their relief but also in the sharp continentality of the climate as well. They are characterized by a less degree of avalanche danger and show a still closer approach to the avalanche type of the inner continental regions.

The most peculiar types of avalanches in all the regions of the southern mountainous belt are the wet chute avalanches and snow slips, the largest part of which is connected with spring warming, thaws and abundant snow falls as well as avalanches of wind slabs formed during snow compaction by wind.

VI. Pacific and Seaside Regions with Avalanches of Wet Snow Drift and Multiple Stratified Snow

The Far East regions of the USSR which include mountainous regions with a peculiar type of avalanches of wet snow drift and multiple stratified snow are located along the shores of the Pacific and the Sea of Okhotsk and extend to a great distance from the polar circle to 43°N. Large differences between the northern regions (Chukotsk tundra mountains, the Eastern part of Koryak Plateau, taiga and tundra mountains of the shores of the Sea of Okhotsk) and southern regions (Kamchatka, Djugdjur, Primorye and Sikhote-Alin and the Kurile isles) are predetermined not only by geographical latitude but by the climate as well. The northern regions are located in the subarctic while the southern ones are in moderate zones.

In the moderate zone the climate is of a monsoon character which is most vividly defined in the Primorye, on Sakhalin, on the Sea of Okhotsk shore. Within the limits of the Djugdjur Ridge, but toward the North-East, monsoon features of the climate gradually weaken and in Eastern Kamchatka only the features of summer monsoon are preserved.

The period of avalanching (January-April) is characterized by decreased temperatures (−10, −15 to −25°C). Direct closeness of sea softens the severity of the winter period. In contrast to the anticyclonic character of circulation of continental regions in the near sea regions of the Sea of Okhotsk and the Pacific, winter is rather windy. In the Primorye the wind velocity is 5 m/sec on the average; on the Sakhalin 10 m/sec; in Kamchatka and Kurile Isles from 14 to 40 m/sec.

In association with the great differences of the regions described the snow cover distributes irregularly. In the southern half of the Primorye and on the eastern slopes of Sikhote-Alin and the Djugdjur Ridges the depth of the snow cover reaches 30∼40 and 70∼80 cm respectively and the maximum accumulation falls well into the spring months. On Sakhalin, at the North of the Kurile Isles, in the eastern and south-eastern parts of the Kamchatka, in the eastern half of the Koryak Plateau and in the Chukotsk Mountains the depth of the snow cover reaches 150 cm and more than 200 cm in the lee and the snow remains there not less than 200 days per year. In these regions winters are characterized by abundant snow falls, great cloudiness and strong winds, connected with cyclonic activity, developed on the Sea of Okhotsk and the Berring Sea and on the Pacific shore of the Kurile isles and of Kamchatka. Frequent cyclones are accompanied by thaws, sometimes rains and snow drifts, which cause the formation of a multiple stratified structure of snow layers. Mass avalanching is observed in January-

February in the cyclonic zones (Kamchatka, Kurile Isles, Koryakskiye Mountains) and in March-April in the regions with a monsoon climate (Primorye, Sakhalin and others). In the regions described, mainly wet avalanches occur.

A quite complicated relief of the mountainous regions on the shores of the Sea of Okhotsk and of the Bering Sea is created by tectonic paleovolcanic processes, ancient glaciation and subsequent erosion. It is characterized by deep dissection (from 200~300 to 1 000 m), dense erosion network, considerable steepness plopes (from 10°~12° to 30°). The relief character defines the morphological types of avalanches among which chute avalanches and snow slips are widely developed.