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ПРИРОДНАЯ СРЕДА ДОЛИНЫ САНТ (ЮЖНЫЙ ХАНГАЙ)

РЕЗУЛЬТАТЫ ИССЛЕДОВАНИЙ МОНГОЛО-ПОЛЬСКОЙ ФИЗИКО-ГЕОГРАФИЧЕСКОЙ ЭКСПЕДИЦИИ

T. II

под редакцией
Л. СТАРКЕЛЯ и А. КОВАЛЬКОВСКОГО

ENVIRONMENT OF THE SANT VALLEY (SOUTHERN KHANGAI MOUNTAINS)

Results of the Polish-Mongolian Physico-Geographical Expedition

VOL. II

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PREFACE

The present volume is the second from the series of monographs and Mongolian dissertations which are issued in the frame of Geographical Studies of the Institute of Geography and Spatial Organization, Polish Academy of Sciences. The first volume was devoted to the problem of vertical differentiation of physico-geographical phenomena in the Khangai Mts. The second one is concerned with the small Sant valley, situated on the southern margin of the Khangai, where in the years 1974—1975 concentrated investigations were carried out dealing with the environment typology and the course of present-day processes.

The Polish-Mongolian expeditions to the Khangai Mts, initiated and led by the Department of Geomorphology and Hydrology of Mountains and Uplands of the Institute of Geography and Spatial Organization of the Polish Academy of Sciences, were being realized in co-operation with the Institute of Geography and Permafrost of the Mongolian Academy of Sciences.

We wish to express our sincere acknowledgements to the expedition leader — associate professor Kazimierz Klimek and to all Polish and Mongolian colleagues who have contributed to the origin of the present work.

The translations into English were done by Miss Elżbieta Chrzanowska, Dr Grace Claire-Dąbrowska, Dr Sylwia Gilewska, Mrs Jadwiga Targosz and Miss Jagoda Sienkiewicz. Miss Anna Łoś translated the Summary into Russian, the drawings have been made by Mrs Maria Klimek and in technical eleboration helped Miss Anna Bęben and Miss Krystyna Rycerz.

To all these persons we wish to express our cordial thanks

Leszek Starkel
Alojzy Kowalkowski

ПРЕДИСЛОВИЕ

Настоящий том является вторым томом из серии монгольских монографий и научных трудов, которые появляются в рамках Географических работ Института географии и территориальной организации Польской академии наук. Первый том был посвящен проблеме вертикальной зональности физико-географических явлений в горах Хангай. Обсуждается небольшая долина Сант, расположенная на южной окраине Хангая, где в 1974—1975 годах проводились концентрированные исследования типологии среды и хода современных процессов.

Инициатором и руководителем польско-монгольских экспедиций был Отдел геоморфологии и гидрологии гор и возвышенностей Института географии и территориальной организации Польской академии наук. Экспедиции были реализованы совместно с Институтом географии и мерзлотоведения Монгольской академии наук.

Мы высказываем нашу благодарность руководителю экспедиции доц. д-р Казимежу Климеку, а также всем монгольским и польским товарищам, за то, что они способствовали созданию настоящего тома.

Текст на английский язык перевели Эльжбета Хжановска, д-р Грей Клер-Домбровска, д-р Сильвия Гилевска, Ядвига Таргош, Ягода Сенкевич. Резюме переведены на русский язык Анной Лось, рисунки выполнила Мария Климек а при технической обработке текста помогали Анна Бембен, Крыстына Рыцеж.

Всем упомянутым лицам высказываем нашу сердечную благодарность.

Лешек Старкель
Алойзы Ковальковски

INTRODUCTION

THE BOUNDARY POSITION OF THE SANT VALLEY

by

Leszek Starkel

The Sant valley lies in the southernmost part of the Khangai. This mountain range stretches 700 km from east to west in the very heart of Mongolia which experiences continentality of climate. This is characterized by severe winters (mean January temperatures of $-26.5°C$ are recorded at the mountain margin, the absolute minimum being $-48°C$), and the summers here can be surprisingly hot. The mean July temperature is $+13°C$, but an absolute maximum of $+32°C$ has been observed at 2000 m asl.

The middle latitudes, from 46° to 48° N, here are a region of strongest thermal and precipitation gradients. These give rise to distinctive changes in the index of dryness being accompanied by changes in hydrological conditions and in vegetation and soil zones. It is for this reason that within this zone dry areas come into contact with the permafrost zone and dry steppes merge with the forest steppe (Starkel 1980) dependent on the local conditions such as climate, ground etc. Variations in water deficit and availability of water for both soil formation and plant growth control the mosaic structure of the geo- and ecosystems within the transitional zones.

In the Khangai range rising to heights of 3500—4000 m asl. the gradient strength is increased by the asymmetry of opposite mountain slopes. At the same time the Khangai has a clear vertical arrangement of natural environmental factors being different from that found in other mountain massifs of Central Asia (Murzayev 1952; Dorzhgotov and Kowalkowski 1979; *vide Geographical Studies* No. 136, 1980). The most spectacular feature is the disappearance of the forest belt on the southern slope of the Khangai. The major cause of this is the convergence of boundaries between the temperature-controlled upper tree line at 2600—2700 m asl. and the moisture-dependent lower tree line about 2000 m asl.
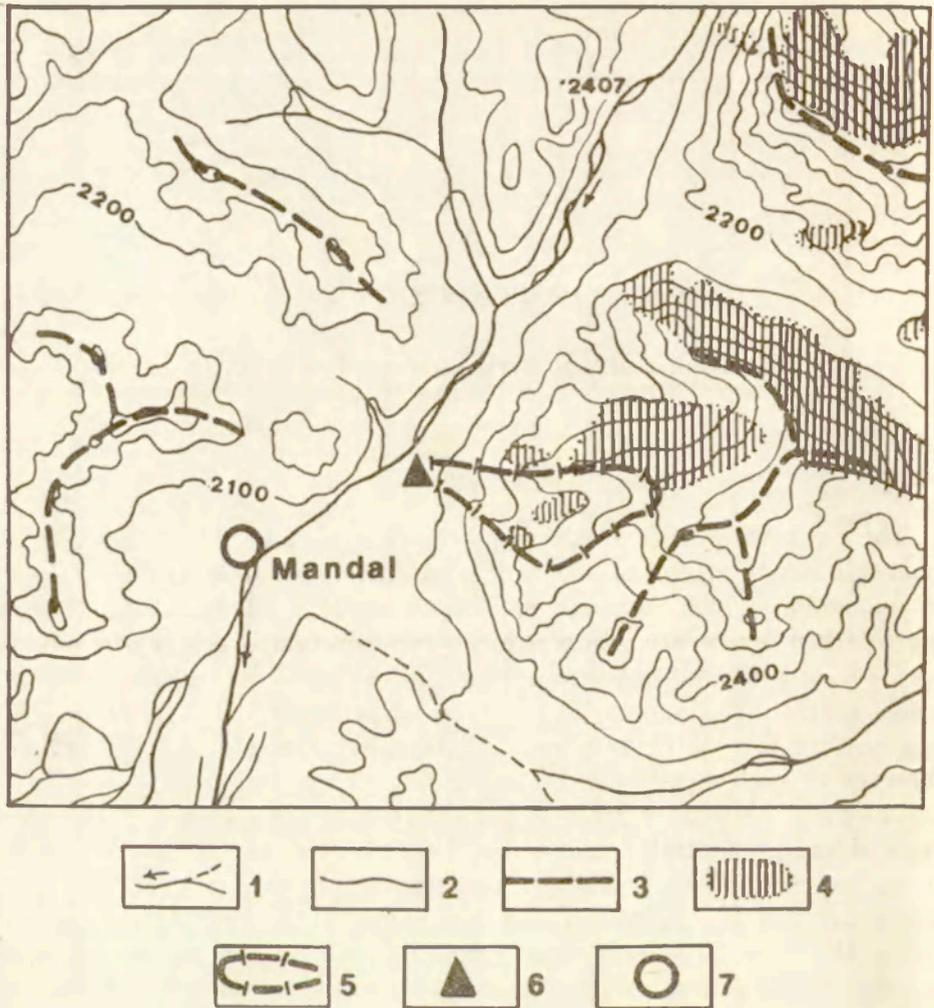
Fig. 1. Location of the Sant valley in the southern Khangai
1 — rivers; *2* — isohypses; *3* — main ridges; *4* — forests; *5* — the Sant catchment; *6* — base camp and meteorological station in summer, 1974—1975; *7* — villages

The Sant valley covers 3 km². It is carved onto the southern margin of the Khangai which rises from the Bayan-Nuurin-khotnor Basin (fig. 1). The Sant valley is part of the Tsagan-Turutuin-gol drainage basin and lies between 2020 m asl. (in the Tsagan-Turutuin-gol valley floor) and 2718 m asl. (on the ridge above the valley head). The area consists of a monotonous series of granite and granodiorite. There are well developed physico-geographical belts (the southernmost extent of the forest-steppe belt at 2100—2650 m asl.), and very strong contrasts in both morphogenetic processes and ecosystems due to slope aspect (phot. 1). These contrasts are determined by wide variations in the radiational balance of the north- and south-facing slopes.

A TOPOGRAPHICAL SURVEY
OF THE SANT VALLEY

R. Zapolski

Fig. 2. Topographical map of the Sant valley elaborated by R. Zapolski (1975). Isohypses at 10 m intervals. Signs indicate forest patches, individual trees, rocky slopes and points of detailed measurements

AIM AND METHOD OF WORK

by

Leszek Starkel

In the summer seasons of 1974—1975 investigations were carried out by the joint Polish-Mongolian Physico-Geographical Expedition to the Tsagan-Turutuin-gol drainage basin in the southern Khangai. This expedition was organized by the Department of Physical Geography, Institute of Geography and Spatial Organization, Polish Academy of Sciences in Kraków acting in co-operation with the Institute of Geography and Geocryology, Mongolian Academy of Sciences in Ulan Bator.

Work has been partially concentrated in the Sant valley. This was selected for the detailed examination of the variations in geo- and ecosystems which are asymmetrically disposed on opposite sides of the valley lying at the boundaries between the forest-steppe and dry steppe zones.

Surveys were undertaken for the purpose of understanding:

1) the typological aspects of the climatically and structurally determined contrasts, together with the mechanism of morphogenetic processes;

2) the evolution of the natural environment under the influence of climatic changes, and

3) the degree of environmental transformations under the impact of man.

It was also the aim of studies to outline the value of habitats for practical purposes.

Survey was undertaken under the direction of L. Starkel (in 1974) and of A. Kowalkowski (in 1975). At first a detailed topographical map of the Sant valley was completed by R. Zapolski, 1975, (fig. 2) on the scale of 1 : 10 000. This was the base map for other detailed special maps including the geomorphological map (Starkel 1975), soil map (Kowalkowski and Lomborinchen 1975), map showing the morphogenetic processes (Pękala 1975), plant communities (Pacyna 1980), habitats (Kowalkowski and Pacyna 1977) etc. Furthermore, the structure of slope sheets, soil catenas and processes have been determined by survey along a line run across the Sant valley — figure 3 * (Kowalkowski *et al.* 1977).

Studies of morphogenetic processes were related to data obtained from a station being situated at 2055 m asl., where the Sant valley joins the Tsagan-Turutuin-gol valley. Measurements here were taken of the

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* Figures 3, 7, 10, 12, 14, 15, 22, 26 are placed at the end of the volume.

radiational balance, air and ground temperatures, precipitation amounts, anemologic conditions etc. (Avirmid and Niedźwiedź 1975; Brzeźniak 1977). In the Sant valley (comp. fig. 3) data have been collected on the microclimate: air and soil temperatures, air humidity, precipitation amounts (Niedźwiedź *et al.* 1975; later studies by Brzeźniak and Sroka); on infiltration and overland flow (Słupik 1975); on morphogenic processes including physical weathering, waste fall, congelifluction and slope wash (Pękala 1975; Pękala and Ziętara 1977); on the production of biomass (Pacyna 1980). Field work has been made by assistance of A. Głodziński, R. Lomborinchen and S. Rychel. The present authors thank them cordially for co-operation.

In April 10—20, 1976, W. Froehlich, J. Słupik and T. Baasan (1977) have collected additional data on temperature, snow and hydrological conditions as well as morphogenetic processes prevailing in the Sant valley during the thaw season (Froehlich, Słupik 1977a, b).

Concentration of special purpose studies in a small area and simultaneous observation of various environmental factors at the same point made it possible to understand the mechanism of various phenomena, to recognize the sequence of catenas and evolutionary systems, and even to reconstruct their developmental tendencies (Kowalkowski and Pacyna 1977; Kowalkowski *et al.* 1977).

Field observations are included in two unpublished volumes of "Reports on the joint Polish-Mongolian Physico-Geographical Expedition to the Khangai" and in a few published papers dealing with both methods employed and results obtained in the Sant valley (comp. References). The present volume, which provides further unpublished data, is a synthesis of studies in the dynamics, typology and evolution of the natural environment of the Sant valley.

COMPONENTS OF NATURAL ENVIRONMENT

CLIMATE

by

Eligiusz Brzeźniak and Tadeusz Niedźwiedź

GENERAL FEATURES OF MICROCLIMATE

The situation of the Sant valley in the marginal zone of the southern Khangai has a bearing on contrasts among phenomena and processes (climate included) which occur on that territory. They find reflection in a clear thermal zone arrangement, differentiation between N- and S-facing slopes and a temporary-spatial changeability of all climatic elements and indices.

The territory of the Sant valley lies in the vicinity of the southern border of the midcontinental Khangai—Khubsugul climatic region with cool and very cool winters (Badarch 1971), where the mean temperatures of January are −15°C to −25°C and the absolute minimum drops even to −50°C. The mean air temperature of July does not exceed 15°C and annual precipitation totals oscillate between 250 and 400 mm (fig. 4). South from the Khangai there occurs transition to the Gobi climatic region — strongly continental with a cool winter. As regards agroclimate, Gungaadash (1971) places the investigated area in the Khangai—Khubsugul mountainous region, with a temperate cool climate (mean annual air temperature lower than −4°C) and a considerable precipitation — up to 400 mm (fig. 4).

The zone differentiation of climatic conditions corresponds to their vertical changeability. This regularity finds expression in thermic zones delimited on the southern slope of the Khangai (Brzeźniak and Niedźwiedź 1980). According to these data, the Sant valley lies within 3 zones, whose upper border is defined by the July isotherm +9°C, being at the same time the upper timberline. The lower part of the valley, up to 2100 m asl., belongs to the steppe belt (the mean of July over 13°C), the area from 2100 to 2400 m asl. lies in the lower forest-steppe belt i.e. the mean of July is 13—11°C), whilst the parts at the altitude 2400—2700 m
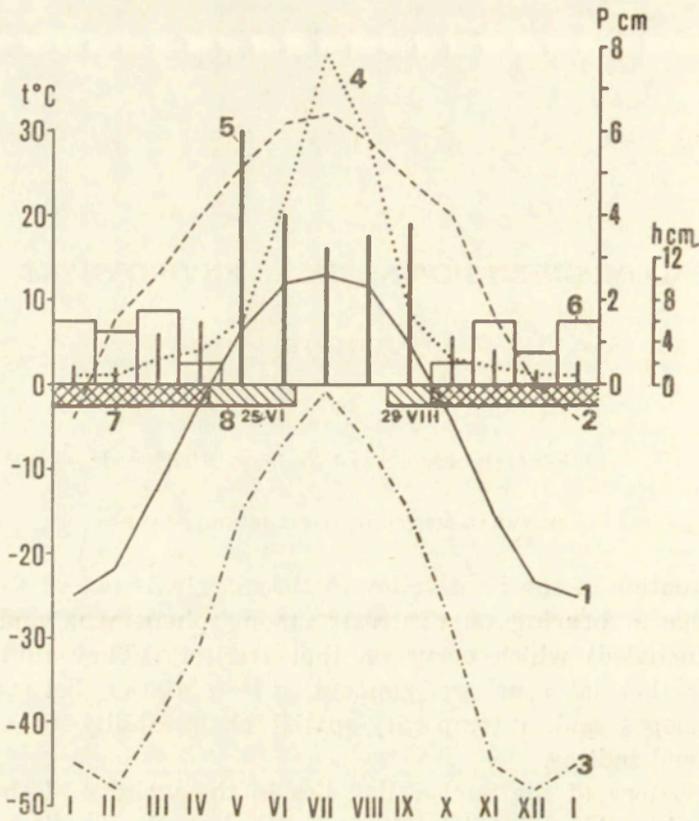
Fig. 4. Climatic diagram for Galuut

1 — mean monthly air temperature; 2 — absolute maximum of air temperature; 3 — absolute minimum of air temperature; 4 — mean monthly totals of precipitation; 5 — diurnal maximum of rainfall; 6 — diurnal maximum depth of snow cover; 7 — duration of the thermal winter; 8 — frost period (average dates of the last and first frost occurrences)

asl. belong to the upper forest-steppe belt (the mean of July within the range of 9—11°C).

A peculiar character of climatic conditions of the described area becomes visible in variability of indices which exemplify a degree of climate dryness. D. I. Shashko's humidity index calculated by Badarch (1971), which represents the relation of precipitation total to air saturation deficit total, assumes the value 0.45 in the southern Khangai, which constitutes a borderline between a sufficiently humid zone and an insufficiently humid zone. The value of this index declines very quickly towards the south. N. I. Ivanov's humidity index (Kalesnik 1964), which expresses the ratio of precipitation to potential evaporation, assumes values under 25%, characteristic of the dry period (April, May, October). The annual value of this index is 47%, which allows us to ascribe this area to weakly humid steppe territories. In the light of

Syelaninov's hydrothermal index (Chromov, Mamotova 1963), in the summer half-year ones does not observe a deficit of humidity so necessary for plant vegetation, on the Khangai territory. Only in May the value of this index drops to 1.2, thus approaching a value typical of after-draught months. To the south of this region the index values fall below 1.0, which is a testimony of an obvious humidity deficit.

Specific conditions of atmospheric circulation influence mostly the formation of climate in the studied area. In the winter half-year the centre of an extensive Siberian anticyclone persists over the western Mongolia. It causes small cloudiness, high air dryness, insignificant atmospheric precipitation, and mostly thin, though long-lasting, snow cover. High radiation from the earth leads to strong cooling of the near-ground air layer, owing to which there arise temperature inversions which cause that the temperature in the Galuut region in January is 4.5°C lower than it would result from geographic parameters of the situation of the station. Absolute minima of temperature in winter reach −48°C (Galuut), whereas in Tsetserleg and Arwajkheer, in more open places, −37 to −38°C.

In the winter period there occur weak winds, predominantly local, and — according to data from the Khuzhirt station — calms constitute over 40% of all measurments. Highest wind velocities, linked to appearance of dust storms, happen in spring (April—May), in connection with a violent vanishing of the Siberian anticyclone and beginnings of activity of cyclones which arrive mainly from the north.

In summer, weather remains predominantly under the influence of thermic low pressure centres travelling from N—W and N. The near-ground winds from these directions are also dominant. They become strongly modified in the Khangai by the local mountain and valley circulation (Avirmid *et al.* 1976). Favourable conditions of thermic convention, especially in the mountain areas, lead to development of big cloudiness and passing showers, and —together with frontal zones — even to longer rainy periods.

INFLUX OF RADIATION

The annual sunshine totals in the Central Asia are c. 3000 h (Chromov 1969). For the mountainous Khangai region these values (based on data from the Khuzhirt and Tsetserleg stations) run from 2680 to 2731 h (*Climatic Annual of Mongolian... 1971*). The annual course is characterized by low variability of monthly totals from March to October, when sunshine values oscillate between 225 and 300 h. (tab. 1). In remaining months, thanks to the Asiatic anticyclone centre persisting over Mongolia, monthly totals do not drop below 100—150 h. In comparison with mean long-run values, the time of sunshine at the

Table 1. The values of the chosen climatic elements in the vicinity of Sant valley

Element	Station	Months												Year
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Sunshine (totals in hours)*	Khuzhirt	210	206	217	297	260	274	250	242	234	236	106	148	2680
Net radiation (totals in kcal/cm²)**	Galuut	−0.9	0.3	0.4	4.4	8.2	8.3	8.5	7.1	4.8	1.7	−0.1	−1.6	41.1
Albedo [%]**	Galuut	70	70	70	35	18	18	18	18	18	25	61	70	—
Mean air temperature* [°C]	Galuut	−26.5	−21.9	−13.2	−1.4	5.0	11.1	12.9	10.8	5.3	−4.4	−17.2	−23.7	−5.3
Mean maximum temperature [°C]*	Galuut	−17.6	−12.2	−3.3	5.4	13.2	18.6	19.3	18.0	13.4	4.5	−8.2	−14.3	3.1
Mean minimum temperature [°C]	Galuut	−32.2	−28.8	−20.1	−10.0	−3.1	3.7	6.5	4.5	−2.4	−12.0	−23.3	−28.8	−12.1
Mean diurnal amplitude of air temperature [°C]*	Galuut	14.6	16.6	16.8	15.4	16.3	14.9	12.8	13.5	15.8	16.5	15.1	14.2	15.2
Absolute maximum temperature [°C]*	Galuut	−4	8	13	20	26	31	32	29	24	20	8	0	32
Absolute minimum temperature [°C]*	Galuut	−45	−48	−40	−31	−15	−7	−1	−7	−15	−28	−45	−48	−48
Mean relative humidity [%]*	Galuut	67	67	57	46	38	50	60	64	56	52	62	66	57
Mean totals of precipitation [mm]*	Galuut	3	3	5	12	19	46	84	55	28	8	8	5	276
Diurnal maximum of precipitation [mm]*	Galuut	5	4	12	15	60	40	32	35	38	11	8	2	60

* after *Climatic Annual... 1971*.
** after Badarch 1972.

outlet of the Sant valley in July 1974 and 1975 was slightly shorter (7—16 h of difference), i.e. 237 and 234 h respectively.

Throughout the year the horizontal surface at Galuut receives c. 136 kcal/cm² of global radiation (Badarch 1972). In particular months this amount changes from 4,2 kcal/cm² in December to 18.2 kcal/cm² in June, these being the highest values for the Mongolian regions outside the Gobi region. The annual total of net radiation on the southern fringe of the Khangai is 40—41 kcal/cm² and drops to 30—38 kcal/cm² on the northern side of the mountain ridge. Negative values of net radiation occur in the period September—February, maximum values (plus) — in July (8.5 kcal/cm²).

THERMIC CONDITIONS

The many-year mean annual air temperature in the Khangai region runs from −5.3° (Galuut) to 0.3° (Arwajkheer) in the southern part and from −2.6 (Khuzhirt) to −0.1° (Tsetserleg) in the north. Differences among its values are conditioned by influence of the mountain range. As the result, temperatures in the Khangai (Galuut) are lower than their counterparts from the stations on the northern slope (Tsetserleg, Khuzhirt) and in the direct vicinity of the mountains (Arwajkhear) over the whole year. Quantitative variations of January (t_I), July (t_{VII}) and annual (t_R) temperatures, dependent on altitude asl. (H), latitude (φ), and longitude (λ), can be defined by empirical formulae, computed on the basis of data from 30 meteorological stations:

$$t_I = 28.3 + 0.0008\ H - 1.368\varphi + 0.118\lambda,$$
$$r = 0.702, \quad B_{es.} = 3.5;$$
$$t_{VII} = 62.2 - 0.0070\ H - 0.648\varphi - 0,042\lambda,$$
$$r = 0.976, \quad B_{es.} = 1.1;$$
$$t_R = 25.0 - 0.0018\ H - 0.666\varphi + 0.076\lambda,$$
$$r = 0.677, \quad B_{es.} = 2.4$$

(r — multiple correlation coefficient, $B_{es.}$ — standard error of estimation). Low values of the correlation coefficient for January and the whole year result from disturbance of thermic relations by strong temperature inversions in winter. Periods of occurrence of extreme values of air temperature are typical of the continental climate of the moderate zone, i.e. mean maximum temperatures occur in July and mean minimum in January (fig. 4, tab. 1).

A different distribution in time and space characterizes mean diurnal amplitudes of air temperature. Highest contrasts among thermic relationships were registered at Khuzhirt (13.3—17.6°C, mean 16.2°C), and, despite a considerable uplifting asl., at Galuut situated in an intermontane basin (12.8—16.8°C, mean 15.2°C).

The feature typical of the investigated area is a long-lasting thermic winter (Galuut — 201 days), on the average from 1 October to 21 April. Spring ($t > 5°C$) — the thermic vegetative period begins in the middle of May. The period with diurnal mean temperatures over $10°C$ (73 days) lasts from 8 June to 19 August. There is a complete lack of thermic summer. The vegetative period lasts 124 days and ends in the mid--September. Sums of temperatures over $10°C$ are only $850°C$, dropping down to 0 at 2500 m asl. (Brzeźniak 1977).

On the fringe of the southern Khangai first frosts happen at the turn of August and September, while the last ones in the first decade of June. Duration of the frostless period (d) is connected with the mean minimum temperature of May ($t_{min.}$ v):

$$d = 9.949 \ t_{min \ v} + 91, \quad B_{es.} = 6 \ \text{days}; \quad r = 0.909$$

($B_{es.}$ — standard error of estimation and r — correlation coefficient).

The southern fringe of the Khangai, with numerous intermontane basins, has the shortest period free of frosts (Galuut — 64 days). In the northern regions this period can be prolonged to 102—109 days (Tsetserleg, Shaamar).

PRECIPITATION AND SNOW COVER

On the southern foreland of the Khangai the annual precipitation totals are 240—280 mm, increasing over 400 mm and probably more in the mountain interior. From September to March monthly precipitation totals do not exceed 10 mm. Precipitation from 3 summer months (June—August) constitutes $67%$ of the annual total. The diurnal precipitation maximum at Galuut is 60 mm as registered in May 1964. In remaining years of the interval 1956—1975 maximum diurnal totals of precipitation ranged from 15 to 40 mm. Yearly there are 78 days with precipitation at Galuut, $45%$ of which constitute days with precipitation in the form of snow (September—May). The snow cover in the Bayankhongor province persists for 7 months (September—April), its average thickness reaching 7 cm in March (BNMAU-YN Uls ... 1977). At Galuut the mean annual total of snow days is 117, but in the mountain areas thickness of snow cover exceeds 15—20 cm (Badarch 1971), and in some places can reach even 1 m, at the same time undergoing quick sublimation on S-facing slopes (Froehlich and Słupik 1977a).

THE DYNAMICS OF CLIMATIC PHENOMENA IN MULTI-YEAR PERIODS

We can demonstrate the characteristics of climatic phenomena variability on the basis of mean temperatures and precipitation totals for July registered in 1957—1975 (Galuut).

Mean annual air temperatures ranged from −6.4°C in 1960 to −2.7°C in 1962 and 1963. 1974 year displayed the temperature higher by 0.1°C, whereas 1975 — 0.4°C lower than the multi-year mean temperature. Temperatures of July ran under the multi-year total (13.1°C) in 1962—1966 and 1971—1973. The highest mean July temperature in the investigated period (15.3°C) occurred in 1970. July 1974 had a slightly lower temperature (14.7°C), but still it was the second warmest July in the described 19 years' period. On the other hand, in July 1975 the mean air temperature was lower than on the average by 0.7°C (fig. 5). In comparison with the Galuut station, the mean temperature of July at the basal station was 0.3°C lower in 1974 and 0.2°C higher in 1975.
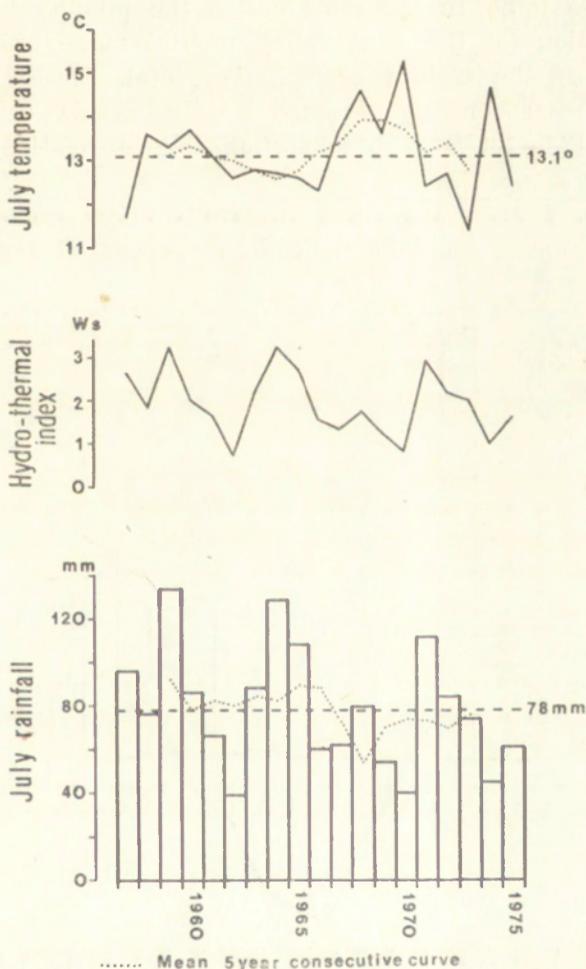
Fig. 5. The march of selected climatic elements in July at Galuut over the period 1957—1975: air temperature (t_{VII}), totals of precipitation (P_{VII}) and hydrothermal index of Selyaninov (W_S)

In the morphometrically diversified Sant valley mean temperatures of July oscillated between 13.6 and 8.6°C at the highest point of the valley.

Annual totals of precipitation ran from 172 mm (1967 and 1969) to 455 mm (1964), the many-year mean equallizing 241 mm. 1974 and 1975 had annual totals lower than on the average, constituting 98 and 95% of its value, respectively. Atmospheric precipitation in July during the last 10 years' period exhibited some tendency to decrease. In 1966—1975 their totals exceeded the many-year mean (78 mm) only 3 times (1968, 1971, 1972). Extreme values ranged from 29 mm (1962) to 134 mm (1959). The precipitation of July 1974 and 1975 clearly departed from the mean long-run totals and constituted 58 and 78% of the average total. In the same period the precipitation of July at the basal station (at the Sant valley mouth) made 229% (1974) and 115% (1975) of the Galuut precipitation total. Inside the valley — according to measurements executed by Niedźwiedź *et al.* (1975 — as much as 123—139% of precipitation fell in relation to the basal station (fig. 6).

In the years 1974 and 1975, despite similar precipitation totals, essential differences could be noticed in the annual course. The 1974
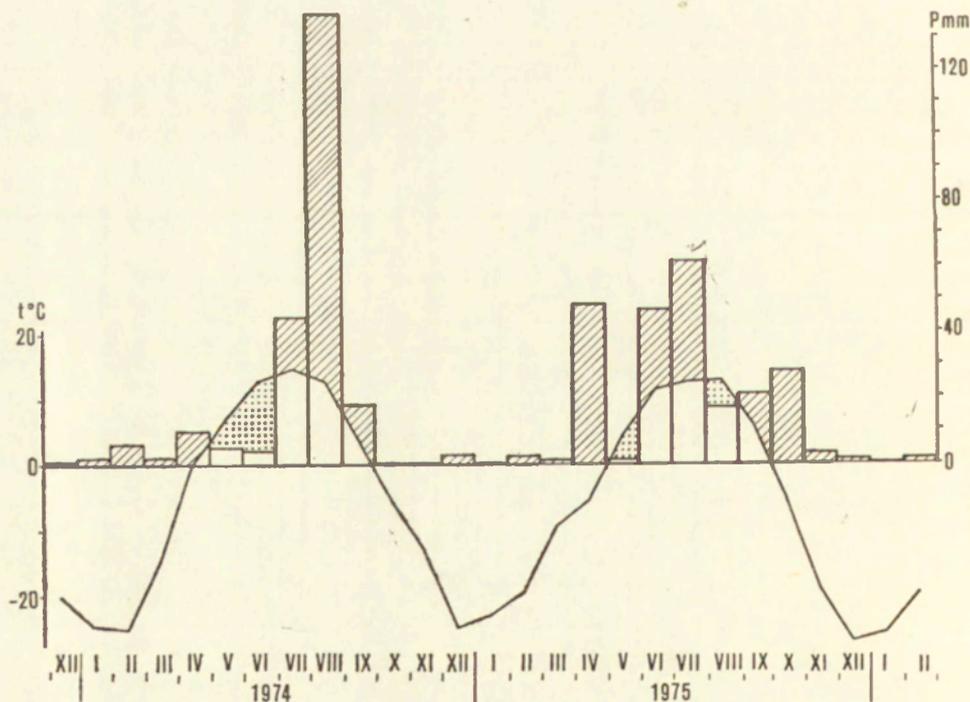
Fig. 6. The march of air temperature (*t*) and monthly totals of precipitation (*P*) at Galuut during the period December 1973—February 1976

summer was preceded by a very strong draught in May and June, and the highest precipitation fell on August. In the 1975 summer monthly precipitation totals were lower than in the analogous season of 1974 and preceded by snowfalls in April, exceptionally abundant for Mongolian conditions. They brought about retention of high amount of humidity in the ground after thaws in the last decade of April (Froehlich and Słupik 1977 a).

In the light of Syelaninov's hydrothermic coefficient for July, which reflects a complex influence of temperature and precipitation on supplying plants with water, it follows that during 19 years this index dropped 3 times below 0.1, i.e. after-drought conditions (1962, 1970, 1974). The humidity excess (index value over 3.0) took place in July 1959 and 1964.

THE RELIEF

by

Leszek Starkel

The Sant valley is the lowermost left-bank side-valley in the mountainous Tsagan-Turutuin-gol drainage basin (fig. 1). Farther downvalley the Khangai Mts are separated from the piedmont basins by a scarp, 300—400 m high.

The Sant valley heads west of the mountain top of 2718 m asl. and attains a length of 3580 m. It ends at 2020 m asl. at the Tsagan--Turutuin-gol valley floor level (fig. 2, phot. 1).

The Sant valley includes three minor parts aligned SEE—NWW and NE—SW changing to SSW—NNE at the valley mouth. The valley is drained episodically. The valley-sides are dissected by one larger valley and a few small chutes of corrasional type. The Sant valley increases in depth from 100 to 250 m and becomes markedly shallower at its end.

The catchment examined is on granite and granodiorite. This is a Permo-Carboniferous synorogenic intrusion (Marinov 1973) which has been tectonically disturbed in Tertiary times. The fine- and medium grained granite contains large amounts of plagioclase and is well jointed. The most important joints run 155° (with a nearly vertical dip), 70° (with southward dips of 50—60°) and 50—60° (with northwestward dips of about 15°). The former directions control the course of valleys, ridges and tors standing above the summit areas. The other direction is reflected in the presence of sloping rock walls of pene--structural type on northwest-facing slopes (fig. 3).

The Sant valley (fig. 7) comprises four contrasting landform assemblages which correspond to the four main relief elements including the summit areas, south-facing slopes, north-facing slopes and the valley-floor (Starkel 1975). Ridges rising to 2720 m asl. above the Sant valley show steps which descend towards the major valley drained by the Tsagan-Turutuin-gol. In the summit area distinct flattenings are found at altitudes of 2550—2500 m and 2440—2360 m asl.

On the ridges there occur flat cryoplanation benches and terraces. The benches with a thin debris cover attain widths of 50 m. Above the platforms rise frost-riven cliffs and joint-controlled tors, 5—10 m high. The now inactive cryoplanation terraces are better developed on the north-facing slopes than on the south-facing ones. The benches are less well developed on the southern ridge where steep and rocky slopes occur in the valley heads (phot. 2, 3, 4). Slope asymmetry is a typical feature of the Sant valley. This asymmetry may be structurally determined (fig. 8; phot. 2, 5, 6, 7).

The short, south-facing slope attains lengths of 300—400 m and is concave in plan. The free face (20—35°) is dissected by chutes of corrasional type, and single tors and blockfields are found there. The gently inclined scree slope (12—15°) has both gravitational—proluvial fans and convex blockstreams. These forms differ by size and degree of preservation in the upper and lower parts of the Sant valley. In its upper part the stepped blockfields are associated with wide chutes less than 1 m deep being occupied by deluvia. These lead down into fans, and single rock-fragments may reach the valley floor. In the lower part of the Sant valley which is marked by increased slope inclination and a greater depth the steep scree slope is dissected by chutes a few metres deep. These contain boulders being seasonally in motion. The chutes lead down to the now inactive blockstreams with strongly marked toes which may lie in the valley floor, or even stretch downvalley for several tens of metres.

In contrast to the south-facing slope, the north-facing slope, 300—750 m long, is slightly convex with gradients rising from 10—18°. It is dissected by wide and shallow chutes which aligned the gravitational transport of masses. The upper slope is often a sloping rock face of pene-structural type.

Downslope the cover sheets increase in thickness independent of gradients. In the lower part of the Sant valley the slope is clearly steeper (20—25°) than in the upper portion.

In general, the valley axis is not aligned with the major joints, although some valley portions are oriented 70° and 155°.

In long profile the valley floor is stepped (fig. 9; phot. 8, 9). The uppermost part which reaches down to 2400 m asl. is irregular, with
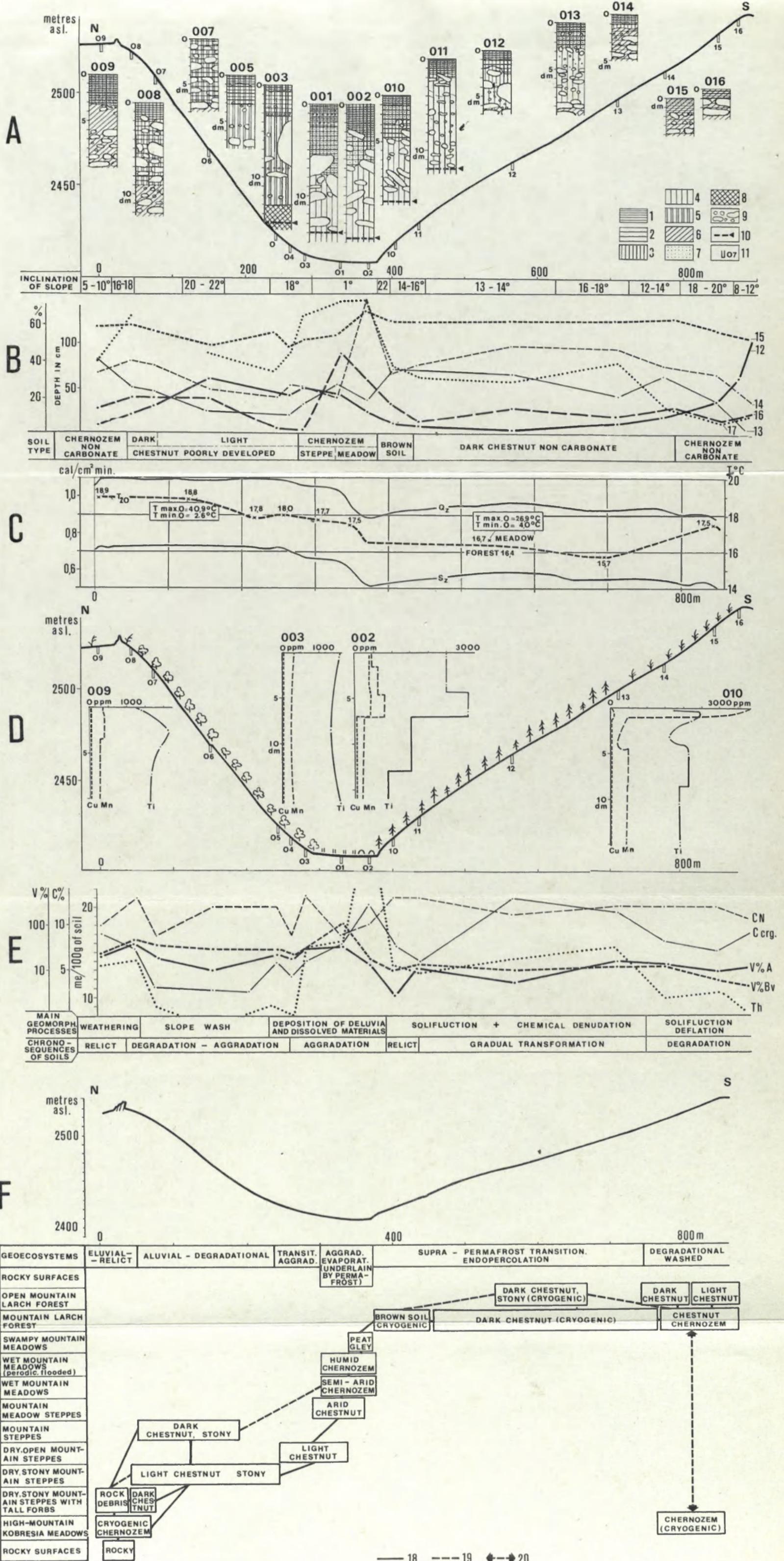
Fig. 8. Typology and dynamic of the environment in the cross-section of the Sant valley

A. Relations between relief, sheets and soils: 1 — residual turfy-humus horizon; 2 — deluvial-humus horizon; 3 — deluvial-proluvial sheet in the valley bottom; 4 — loamy-scree congelifluction sheet; 5 — degraded scree congelifluction sheet; 6 — residual waste mantle; 7 — loamy horizon Bvt; 8 — weathered bedrock; 9 — big block; 10 — base of the active layer in July 1974; 11 — no. of soil profile.

B. Mechanical and other soils properties on the typological background: 12 — fraction ⋅1 mm; 13 — fraction < 0.02 mm; 14 — fraction 0.10—0.02 mm; 15 — total porosity in %; 16 — depth of the horizon of humus accumulation; 17 — depth of the horizon of brown waste BV.

C. Solar radiation and temperature: Qz — total radiation on the slope surface (in July 1971 during mid-day); Sz — direct solar radiation on the slope surface (in July 1974); T_{20} — air temperature at 16^M at the high of 20 cm above ground surface (mean from 12 records in August 1975); T_{max} T_{min} — extremal temperatures at the ground (mean from 21 days in July 1974).

D. Microelements in the different soil profiles (on the cross-section the type of vegetation is schematically shown).

E. Relief and exposure impact on the humus content, sorption capacity and enrichment in the cations.

F. Soil—habitat catenas or geoecosystems in the Sant valley (after Kowalkowski, Pacyna 1977, slightly changed): 18 — main catena; 19 — accessory catena; 20 — exchangeable pedotops

gradients up to 20%. The broad and shallow niche in the valley head passes into a pan-like depression, up to 50 m wide, which contains colluvia. These are overlain by deluvia in the valley axis. Below the pan gradients increase rapidly to 40%, and there occur steps, 20 m high, consisting of rock debris. The material was supplied by blockstreams from the south-facing slope. At altitudes of between 2300 and 2100 m the valley floor is irregular in long profile. The valley has locally a gently inclined (about 8%) floor, which may be as much as 50 m wide and represent a surface of accumulation. Such flat-floored valley widenings alternate with steps. These appear to be pseudo-gaps with shallow
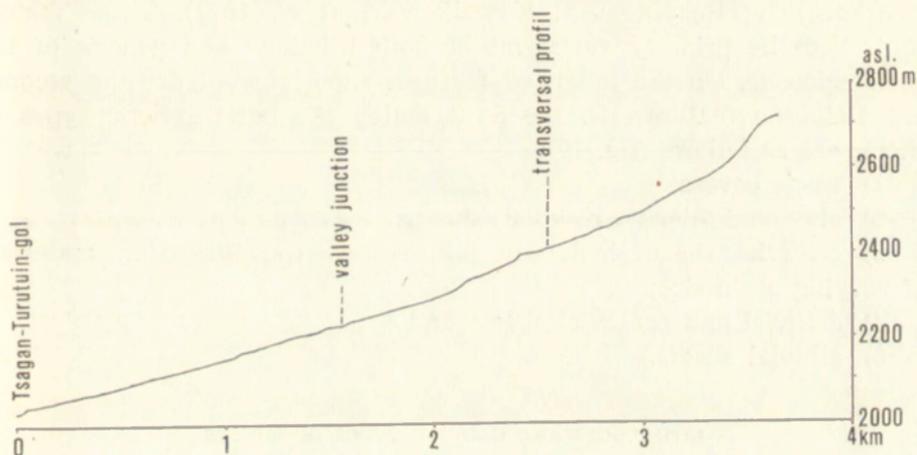
Fig. 9. The geodetic profile along the axis of the Sant valley, elaborated by R. Zapolski

(to 1 m) marginal channels in the toes of blockstreams. In the lowermost part, the valley floor passes into a young gully being eroded in both the cryopediment and rock-cut terraces with a gravel and sand veneer in the major valley. The gully having an irregular long profile with gradients up to 10° reaches the level of the flood plain in the Tsagan--Turutuin-gol valley. It appears that the floor of the Sant valley is clearly hanging at the level of the above cryopediment which passes valleywards into the Pleistocene terraces on the Tsagan-Turutuin-gol (Starkel *et al.* 1975).

The major feature of the Sant valley is the structure-controlled slope asymmetry. The slope aspect contrasts produced contrasting climatic conditions throughout the Quaternary. These in turn produced contrasting assemblages of both past and present-day processes being reflected in the mesolandforms.

SHEETS

by

Alojzy Kowalkowski, Kazimierz Pękala, Leszek Starkel

BASIC FACTORS INFLUENCING SHEET FORMATION

The sheets in the Sant valley are effects of cryogenic weathering of granodiorite under cold continental climatic conditions. The contrasting climates were the major cause of contrasting processes associated with permafrost, of thermal weathering, and of both transportation and deposition in the particular morphogenetic units of the Sant valley (Starkel 1975; Pękala 1975; Kowalkowski *et al.* 1977). These factors controlled the primary variations of both lithology and genesis of the various sheets. On the inherited features superimposed are the secondary Holocene features. In the Sant valley the basic genetic types of sheets are as follows (fig. 10):

1) waste covers;
2) eluviated (blocky, residual) sheets;
3) colluvial sheets including taluses and congelifluction materials of varying grain size;
4) deluvial and proluvial sheets and
5) alluvial sheets.

LITHOLOGIC AND GENETIC TYPES OF SHEETS

O n   t h e   i n t e r f l u v e s . Both waste covers and congelifluction deposits have been formed on the Pleistocene cryoplanation terraces and benches. At the foot of rising tors and terrace scarps rest blocky weathering products and taluses. The cryoplanation terrace flats are made up of cryogenic, twofold, brown clayey with block and clayey with scree sheets being underlain by dry permafrost (Kowalkowski 1975). The periglacial twofold sheets include usually the upper Bvt horizon, 30—40 cm deep, with sorted boulders. This horizon grades rapidly downward into the brown waste Bv, which consists of blocks, scree and abundant skeletal particles (fig. 11, prof. 009). The Bvt horizon with relict humus accumulation is disturbed by patterned ground forms including sorted polygons. These are now being renewed during the wetter seasons.

Granullar and granular-scree weathering products are found on the cryoplanation terraces and benches which developed on the narrow southern ridge rising abruptly form the sub-Khangai basin. In the topmost part these are predominantly Holocene chestnut, arid climate waste covers as well as eluviated sheets and taluses overlying the
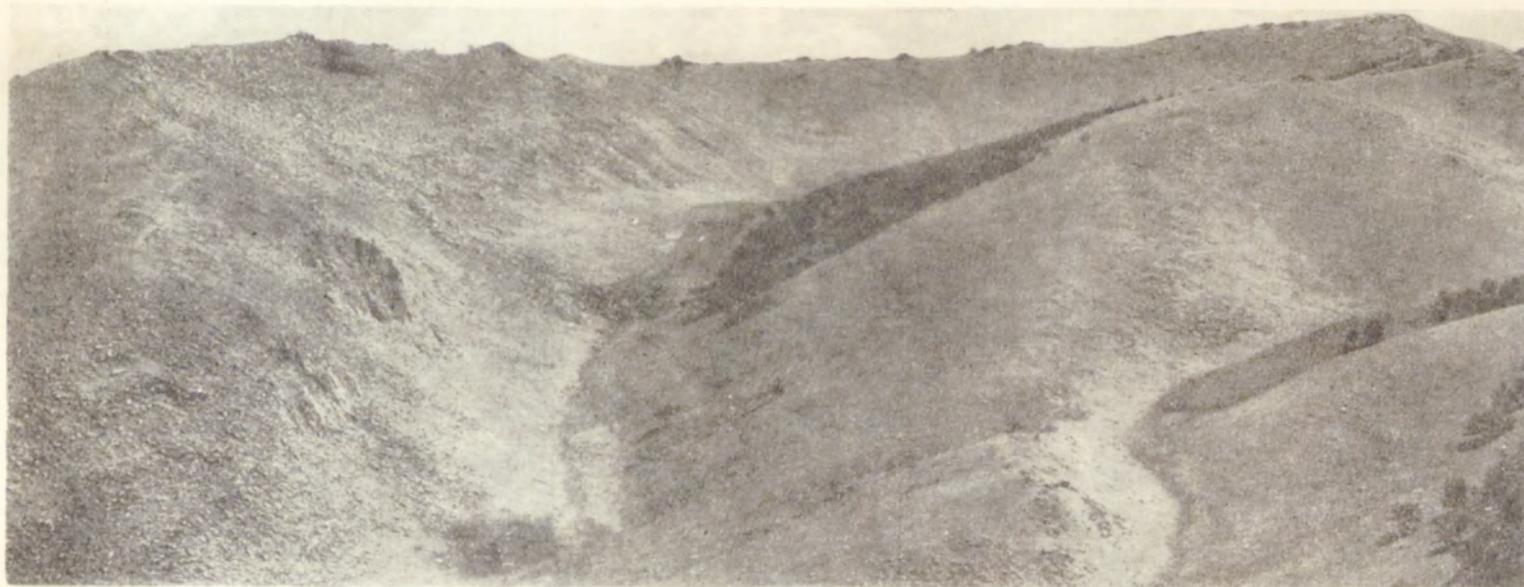
Phot. 1. General view of the Sant valley. Blockfields and scree on the S-facing slope; the forests and meadows on the N-facing ones. In valley bottoms well marked fronts of the active earth-debris flows

Phot. 2. Southern ridge with northern slopes smoothed by solifluction. Cryoplanation benches at the base of rocks

Phot. 3. Residual tors with distinct systems of joints. In the background central Khangai ridge

Phot. 4. Relict tors and cryoplanation bench on the S-facing slope, developed in granitic rocks with nearly vertical jointing. The rich steppe vegetation on the thick chernozem

Phot. 5. Northern slope with patches of permafrost and larch forest in the zone of transversal section, investigated in detail (fig. 8). In the bottom active earth-debris flow

Phot. 6. Southern slope covered by block and scree. At the base covered by deluvia. Near the rocky ridge small patch of the *Populus tremula* woodland
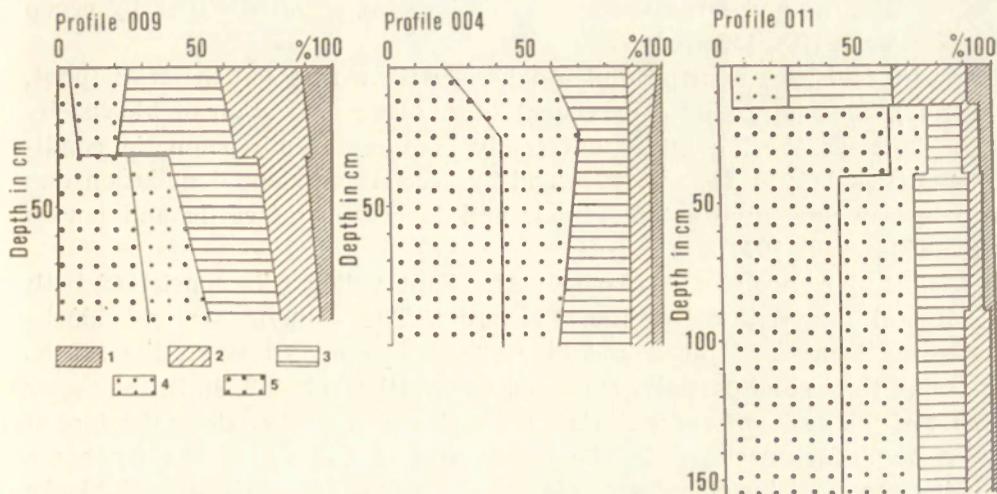
Fig. 11. Mechanical composition of the sheet deposits on the cryoplanation terrace (profile 009), on the S-facing (profile 004) and N-facing (profile 011) slopes

Fractions: *1* — > 1.0 mm; *2* — 1.0—0.1 mm; *3* — 0.1—0.02 mm; *4* — 0.02—0.002 mm; *5* — below 0.002 mm

Pleistocene sheets (phot. 3). Spaces amid the fallen blocks contain fine-grained waste and soil material. The high percentage of silt-size particles (fig. 11) indicates an admixture of brown waste products.

O n   t h e   n o r t h - f a c i n g   s l o p e s. In contrast to the mono-tonous summit areas, the mid- and lower parts of the moist and convex slope carry twofold sheets which differ greatly by range of both thickness and grain size. The Bv series made up of grus and scree is thickest on the lower slope, but it disappears on the upper slope. The older Bvt horizon shows traces of a Holocene chestnut weathering and has been partially altered by denudation. It attains 10—70 cm depths (fig. 11). The upper slope which exhibits locally slabs of rock is covered with contemporary chestnut scree and grus waste covers varying in thickness from a few to several scores of centimetres (fig. 8, prof. 015, 016; phot. 11, 12).

O n   t h e   s o u t h - f a c i n g   s l o p e s. On the opposite dry and concave slope the sheets differ by lithology and genesis because of the greater dynamics of morphogenetic processes. The upper slope including narrow cryoplanation benches is mantled with blocks and residual blocky-scree waste covers. The free face with tors bears a blocky waste and taluses (phot. 3,5). Spaces are filled with modern chestnut waste products and soil materials. These contain silt derived by wind from the cryoplanation terraces. The mid-slope carries blocks and scree grus materials of the relict blockstreams that extend down to the valley floor (Starkel 1975; Pękala 1975). Amidst the blockstreams a thin sheet of

chestnut grus and scree is found. This is being affected either by creep or by wash (fig. 11, prof. 004).

The footslope is on granular deluvia with a fine soil material (phot. 10, 13). This is produced by recent thermal disintegration of blocks, by chestnut weathering under extremely continental microclimatic conditions (Pękala and Ziętara 1977) and by accelerated slope denudation due to burrowing activities of animals and to grazing of cattle and horses (Kowalkowski 1977).

In the valley floor. The Sant valley fills consist of both colluvial and deluvial-proluvial deposits. The colluvia are old block-streams formed of block and clay. These are moved down the south--facing slopes and partially extended downvalley (phot. 8, 9). In the upper part of the valley these materials are actively in motion along the foot of the north-facing slope. In the lower part of the valley the fines are being removed by episodic rainwater. In places accumulations of blocks account for the steps in long profile. They also built up the valley floor. The eluviated fine particles accumulated in depressions between the bulging fronts of blockstreams (Kowalkowski et al. 1977). Towards the top increased coarseness of deluvia is often observed. This is accompanied by a decreased humus content. The twofold composition of the sheets being typical of the periglacial environment indicates long duration of various processes of denudation under changing climatic conditions. In the fine-grained Bvt horizon humus occurs down the whole profile to 80 cm depth. This horizon contains larger amounts of silt particles below the north-facing slope than below the south-facing slope, where larger amounts of skeletal particles tend to occur (fig. 11; phot. 14).

At the valley mouth alluvial fan deposits of differing grain size rest on the 8—10 m terrace of the Tsagan-Turutuin-gol River. This terrace bears coarse gravel and sand over the rock-cut bench (Starkel et al. 1975). The floor of the major valley is made up of both gravel and fine-grained overbank facies.

In the Sant valley there is a certain sequence of Quaternary sheets, which are not identically disposed on opposite sides of the valley. The catenas result from both past processes and modern alterations. The type of sheet controls the mosaics of soil and vegetation covers.

SOILS

by

Alojzy Kowalkowski

The structure of the soil profile, as well as the properties and distribution of the soils in Sant valley, reflect the features of the granite

and granodiorite wastes of different ages (Kowalkowski 1975; Kowalkowski and Lomborinchen 1975; Kowalkowski *et al.* 1977). The mosaic pattern and the soil catenas of this valley are determined by the mosaic pattern of a series of sheets of different origin, granulation and soil thickness, depending upon the exposure and location in the slope profile and the valley bottom, upon the extreme diversities of the local air and soil microclimates (Niedźwiedź *et al.* 1975; Froehlich *et al.* 1977), and upon the influence of local mountain-valley air circulation (Avirmid and Niedźwiedź 1975) resulting in local desiccation of the air and the surface soil layers.

<div align="center">PARENT MATERIAL OF SOIL</div>

In Sant valley, on the cryoplanation terraces and on both north- and west-facing slopes, the bipartial cryogenic brown wastes of granodiorites have been preserved, typical of the cryohumid environment (Kowalkowski 1975). At the top there is a fine-granular Bvt cover 10—40 cm thick, composed of 21.6—49.5% of floatable parts, 33.0—49.0% of very fine sand fraction and 1.4—9.1% of skeletal parts (tab. 2, prof. 009, 010, 011, 012, 013 and 014; phot. 11, 12). This cover grades sharply, though irregularly, to a series of slope cryogenic Bv brown waste of different thickness and differentiated granular structure. This series, in the bedrock over solid rocks, is poor in floatable parts — from 13.7 to 3.4% and silt fraction — from 23.5 to 4.0%, while being rich in sand fraction and boulders of a varying degree of weathering (tab. 2).

The cryogenic waste in the lower and central parts of the north-facing slope has a low sorption capacity (*Th*), ranging from 3.7 to 5.6 me per 100 g of soil, which is linked with a low degree of the parent rock disintegration. The content of organic carbon in the above material varying from 0.24 to 1.09%, on the average 0.59% (tab. 4), is typical of the soil environment in the mountain-continental tundra in Khangai (Kowalkowski 1977).

Young, stony chestnut wastes occur on the upper parts of both north- and west-facing slopes, as well as throughout the south- and east-facing slopes (phot. 15). The wastes in question are of a small thickness and contain a lot of skeletal parts, from 22.5 to 40.7%, less fine sand, from 27.6 to 16.3% and few floatable parts — from 17.1 to 6.7% (tab. 2, prof. 004, 005, 006, 007 and 016). The wastes mentioned above show the features of both thermal-block and granular disintegration (Froehlich *et al.* 1977; Pękala and Ziętara 1977). At present, they undergo degradation resulting in the constant rejuvenation of the soil profile. Relatively high *Th*-value, ranging from 5.8 to 7.8 me per 100 g of soil, encountered in the wastes, is due to the humus admixture, the latter being an indicator of the simultaneously operating soil formation processes.

Table 2. More important indices of grain size

Soils	Pro-file No.	Depth in cm	Genetic horizon	Soil colour	> 1.0 mm	1.0-0.10 mm	0.10-0.02 mm	< 0.02 mm	Mean weighed diameter [mm]
On the cryopla-nation surface	009	0-5	BvtAk	10 YR 3/2	4.8	19.0	41.9	41.9	0.20
		25-30	BvtAk	10 YR 3/2	7.7	14.9	37.3	37.3	0.29
		40-45	Bvt	2.5 Y 5/4	27.2	14.6	25.8	25.8	0.13
		70-75	Bv	2.5 Y 5/4	30.3	21.1	21.5	21.5	2.34
On the N exposition	010	0-5	d BvtA	10 YR 3/3	5.8	25.4	33.0	35.8	0.25
		20-25	d BvtA	10 YR 6/4	26.6	22.0	20.5	30.8	1.39
		35-45	d BvtA	10 YR 6/4	57.5	17.8	14.0	10.6	5.10
		90-100	d Bv	10 YR 5/8	51.8	27.0	11.6	9.7	3.23
		135-140	d BvTjäle	7.5 YR 5/8	56.7	29.9	8.7	4.8	4.48
	011	0-5	d BvtAk	10 YR 4/3	4.7	21.1	38.0	36.3	0.19
		30-35	d BvtA	10 YR 4/4	61.5	14.1	13.2	11.1	3.42
		70-75	d Bv	10 YR 4/8	43.5	26.7	20.2	9.6	1.65
		130-140	d Bv	7.5 YR 5/8	42.2	28.4	22.9	6.3	5.37
	012	0-5	d BvtAk	10 YR 2/2	1.4	16.0	49.0	33.5	0.12
		20-25	d BvtAk	7.5 YR 5/3	4.9	15.3	30.4	49.5	0.17
		50-60	d Bv	7.5 YR 6/3	44.2	19.3	23.7	12.8	1.54
	013	0-5	d BvtAk	10 YR 4/3	6.2	25.3	46.9	21.6	0.24
		10-15	d BvtAk	10 YR 5/4	30.4	20.6	26.0	22.9	0.83
		40-45	d Bv	10 YR 5/3	71.9	12.3	5.9	9.8	4.40
		100-105	Bv	2.5 Y 5/4	22.4	44.1	23.5	10.1	1.44
	014	0-5	BvtAk	10 YR 3/4	9.8	17.7	38.3	32.5	0.31
		25-30	BvA	10 YR 3/4	65.8	10.6	9.9	13.7	3.68
	015	0-5	BvA	7.5 YR 4/2	18.9	28.6	23.8	18.6	0.48
		25-30	BvA	7.5 YR 4/2	78.8	13.6	4.0	3.4	0.69
	016	0-10	BvA	10 YR 2/3	32.6	34.8	25.9	6.7	0.83
On the valley bottom	002	0-5	d BvtA	10 YR 2/1	12.7	13.1	54.9	19.2	0.70
		35-40	d BvtA	10 YR 4/2	23.8	25.5	17.5	40.2	1.12
		60-65	d BvtA		16.7	23.3	18.3	41.7	0.78
		120-130	d Bv	10 YR 4/3	51.0	21.5	16.6	10.8	3.69
		150-155	d BvTjäle	7.5 YR 5/8	54.5	28.6	10.5	6.4	5.31
	001	0-5	d BvtA	10 YR 2/2	23.8	26.7	22.1	27.4	1.22
		20-25	d BvtA	10 YR 2/1	30.5	27.1	20.9	21.5	1.17
		60-70	d BvtA	10 YR 2/1	25.9	24.4	18.5	31.1	0.98
		120-125	d Bv	2.5 Y 5/4	42.7	24.7	20.1	10.6	2.72
		155-160	d BvTjäle	2.5 Y 5/3	40.5	24.3	21.4	13.7	3.05
	003	0-5	d Bv/A/k	10 YR 4/3	25.6	30.5	26.8	17.1	1.34
		80-90	d Bv		49.1	30.0	13.9	9.2	2.38
On the S exposition	004	0-5	d Bv/A/k	10 YR 3/3	22.1	38.6	27.6	11.7	0.95
		20-25	d Bv	10 YR 4/6	36.2	34.2	17.8	12.1	1.12
		80-85	d Bv		40.7	27.7	24.2	11.3	2.12

Soils	Pro-file No.	Depth in cm	Genetic horizon	Soil colour	Fraction [%]				Mean weighed diameter [mm]
					>1.0 mm	1.0-0.10 mm	0.10-0.02 mm	<0.02 mm	
	005	0-5	d BvAk	10 YR 3/4	22.5	44.6	22.0	10.8	0.79
		20-25	d BvAk	10 YR 4/4	26.1	39.2	20.6	14.1	0.84
		60-70	d Bv		30.9	37.6	16.3	14.5	0.95
	006	0-5	d Bv/A/k	10 YR 4/3	31.1	29.9	25.9	13.1	2.18
		80-85	d Bv		40.0	20.3	25.3	14.4	4.68
	007	5-10	d Bvt/A/k	10 YR 4/4	15.1	22.8	38.2	23.8	0.46
	008	0-5	BvtAk	10 YR 3/3	11.6	20.8	41.1	26.5	0.46
		25-30	BvtAk	10 YR 3/4	13.7	17.9	38.3	30.2	0.74
		55-60	BvAk	10 YR 4/6	25.1	14.6	37.1	23.2	1.37
		90-100	Bv	10 YR 4/8	33.5	18.9	33.7	14.0	1.77
		110-120	Bv	10 YR 4/8	33.1	17.0	33.8	16.1	4.77

On the other hand, in the valley bottom, on the older stratified deluvia, the granular structure whereof is similar to that of the multigranular slope series at northern exposure, there occur the thick deluvia containing fine granular soil material (tab. 2; fig. 12, prof. 001 and 002; phot. 13, 14).

CHARACTERISTIC OF SOIL TYPES

Contemporary soils show a set of inherited features of the formation phase of the Bvt cover on the surface of the slope Bv series in the cryohumid environment as well as younger, contemporary processes of thermal disintegration and slope denudation of the cryoarid environment.

Contemporary processes of physical and biochemical transformations are associated with the desiccation of climate, which has continued for the last 2—4 thousand years (Kriger 1962; Stepanov 1975; Golubieva 1976; Vipper et al. 1976). During this period, there have formed, in the depressions, frequently on the substrate of fossile chernozems, series of laminated deluvia and proluvia with the content of organic substances diminishing towards the surface. In the lower part dominate alternate coarse- and fine-grained sediments. At the top of the soil, the rhythmic nature of the sediments dwindles away (Kowalkowski et al. 1977).

The soil distribution is depicted in figure 8, while the characteristic of the soils is shown in the tables 2, 3 and 4.

SOILS OF CRYOPLANATION SURFACES AND OF THE NORTH-FACING SLOPE

The soils developed from the bipartial series of the periglacial wastes, outline the range of the relict brown soils, the thick mountain cher-

Table 3. More important water-physical properties of soils

Soils	Profile No.	Depth in cm	Genetic horizon	Specific gravity G/cm³	Bulk density g/ml	Porosity total (P) in per cent	Capillary water capacity maximum (KPW) in per cent	MHy %	KPWmax in per cent of P	Actual humidity in per cent
Cryoplanation surface	009	0-5	BvtAk	2.51	1.01	59.68	47.13	4.97	79.0	2.45
		25-30	BvtAk	2.54	1.11	56.29	47.34	4.68	84.1	10.22
		40-45	Bvt	2.65	1.41	46.79	31.60	4.14	67.5	7.10
		70-75	Bv	2.74	1.48	45.98	23.74	3.83	51.6	5.61
	064	0-5	d BvtAk	2.31	0.87	62.33	45.96	—	73.7	31.20
		15-20	d BvtAk	2.51	1.13	54.98	42.13	—	77.7	34.74
		40-45	Bv	2.57	1.32	48.64	35.37	—	72.7	31.53
		55-60	Bv	2.60	1.51	41.92	15.01	—	35.8	16.22
On the N exposition	010	0-5	d BvtA	2.49	0.93	62.65	58.71	3.99	93.7	7.25
		20-25	d BvtA	2.58	1.26	51.16	43.69	5.17	85.4	5.66
		35-45	d BvA	2.63	1.57	40.30	31.48	5.14	78.1	6.62
		90-100	d Bv	2.64	1.52	42.31	22.49	2.74	53.1	8.85
		135-140	d BvTjäle	2.65	1.66	37.24	24.53	1.67	65.9	14.66
	011	0-5	d BvtAk	2.34	0.89	61.9	56.68	4.01	91.6	3.73
		30-35	d BvA	2.50	1.42	43.2	36.41	2.96	81.3	5.64
		70-75	d Bv	2.52	1.46	42.0	26.15	2.73	62.3	5.59
		130-140	d Bv	2.53	—	—	—	0.92	—	—
	012	0-5	d BvtAk	1.91	0.70	63.30	57.11	5.17	89.8	5.21
		20-25	d BvtAk	2.44	1.17	52.04	50.24	4.95	96.5	8.43
		50-60	d Bv	2.52	1.56	38.04	32.46	3.96	88.2	4.90
	013	0-5	d BvtAk	2.31	0.86	62.77	52.46	5.16	83.6	5.18
		10-15	d BvtAk	2.41	1.32	45.22	30.53	5.12	65.7	4.95
		40-45	d Bv	2.38	—	—	—	3.88	—	—
		100-105	Bv	2.40	—	—	—	1.27	—	—
	014	0-5	BvtAk	2.49	0.89	64.18	40.45	5.06	63.0	6.24
		25-30	BvA	2.40	—	—	—	4.04	—	—
	015	0-5	BvA	2.50	1.06	57.60	56.12	4.29	97.4	3.23

		25-30	BvA	2.54	—	—	—	2.68	—	—
	016	0-5	BvA	2.49	—	—	—	3.86	—	—
On the valley bottom	002	0-5	d BvtA	2.41	0.77	68.64	56.77	6.61	83.4	8.53
		35-40	d BvtA	2.56	1.19	53.35	34.22	8.16	64.1	20.69
		60-65	d BvtA	2.54	1.19	53.14	34.91	9.17	65.7	21.97
		120-130	d Bv	2.67	1.77	33.83	17.52	2.86	51.8	10.49
		150-155	d BvTjäle	2.62	1.62	38.28	11.82	2.89	30.9	7.72
	001	0-5	d BvtA	2.49	1.11	55.42	40.35	3.99	72.8	3.10
		20-25	d BvtA	2.51	1.27	49.30	38.94	4.29	79.0	7.67
		60-70	d BvtA	2.59	1.29	50.19	26.95	4.46	53.7	6.84
		120-125	d Bv	2.68	1.66	38.17	19.09	2.46	50.0	9.14
		155-160	d BvTjäle	2.63	1.69	35.86	21.11	2.46	58.9	11.62
	003	0-5	d Bv/A/k	2.49	1.17	53.01	50.33	3.83	94.9	1.76
		20-25	d Bv	2.66	1.44	47.56	33.45	2.75	70.3	2.97
		80-90	d Bv	—	1.55	—	31.68	—	—	6.29
	060	0-4	d BvA	2.26	0.85	62.39	46.99	—	75.3	32.6
		25-30	d BvA	2.61	1.01	61.30	52.92	—	86.3	38.6
		37-40	d BvA	2.57	1.09	57.59	48.61	—	84.9	34.5
		55-60	d BvtA	2.63	1.24	52.85	48.32	—	82.9	34.8
		60-63	d Bv	2.63	1.38	47.52	33.67	—	70.9	17.4
		80-85	d BvtA	2.69	1.32	50.92	35.10	—	68.9	25.9
On the S exposition	004	0-5	d Bv/A/k	2.72	1.37	49.7	40.41	3.62	81.3	0.60
		20-25	d Bvk	2.81	1.41	50.0	35.62	2.98	71.2	3.74
		80-85	d Bv	2.89	1.51	47.7	32.63	3.08	68.4	5.72
	005	0-5	d BvAk	2.80	1.21	56.7	49.55	2.81	87.4	2.48
		20-25	d BvAk	2.92	—	—	—	2.08	—	—
	006	0-5	d Bv/A/k	2.87	1.44	49.8	41.09	2.77	82.5	1.68
		80-85	d Bv	2.90	1.37	52.7	38.57	3.14	73.2	3.52
	007	5-10	d Bvt/A/k	2.90	1.24	57.2	49.74	3.88	86.9	5.69
	008	0-5	BvtAk	2.77	1.08	61.0	52.61	4.69	86.2	4.96
		25-30	BvtAk	2.30	1.19	48.3	42.61	4.74	88.2	6.25
		55-60	BvAk	2.38	1.34	43.5	31.59	4.07	72.6	8.76
		90-100	Bv	2.77	1.53	31.4	18.16	3.01	57.8	13.03
		110-120	Bv	2.27	—	—	—	—	—	—

Table 4. More important chemical properties of soils

Soils	Profile No.	Depth in cm	Genetic horizon	C [%]	N [%]	C : N	pH$_{KCl}$	CaCO$_3$ [%]	Th [me/100 g]	Vh %
On the cryoplanation surface	009	0-5	BvtAk	5.20	0.504	10.3	5.6	0	13.4	65.6
		25-30	BvtAk	3.90	0.462	8.4	5.5	0	13.0	66.2
		40-45	Bvt	0.89	0.104	8.6	5.4	0	7.1	69.3
		70-75	Bv	0.72	0.089	8.1	5.4	0	7.2	68.2
On the N exposition	010	10-1	L	—	0.686	—	4.2	0	52.5	20.0
		1-0	FH	—	1.638	—	5.2	0	55.7	40.9
		0-5	dBvtA	4.37	0.350	12.4	5.5	0	13.4	58.9
		20-25	d BvtA	1.67	0.115	14.5	4.7	0	9.3	42.9
		35-45	dBvA	1.08	0.078	13.8	4.5	0	8.8	49.8
		90-100	dBv	0.41	0.034	12.0	4.4	0	4.0	52.2
		135-140	d BvTjäle	0.28	—	—	5.0	0	3.7	47.3
	011	0-5	dBvtAk	3.49	0.372	9.4	5.4	0	12.7	50.0
		30-35	dBvA	1.05	0.070	15.0	4.1	0	8.4	43.8
		70-75	dBv	0.63	0.030	21.0	4.5	0	5.5	56.1
		130-140	dBv	0.25	0.020	12.5	4.6	0	5.6	75.2
	012	0-5	dBvtAk	7.46	0.058	12.3	5.0	0	14.1	54.7
		20-25	d BvtAk	1.80	0.147	12.2	5.0	0	11.6	60.0
		50-60	d Bv	—	—	—	4.9	0	—	—
	013	0-5	d BvtAk	6.62	0.567	11.7	5.4	0	15.7	59.6
		10-15	d BvtAk	2.40	0.191	12.6	5.0	0	11.4	52.5
		40-45	d Bv	0.88	0.081	10.9	4.8	0	9.1	52.7
		100-105	Bv	0.29	0.033	8.8	4.7	0	6.0	51.3
	014	0-5	BvtAk	4.70	0.399	11.8	5.6	0	9.9	54.9
		25-30	BvA	1.12	0.128	8.7	5.3	0	9.2	54.3
	015	0-5	BvA	4.12	0.353	11.7	5.3	0	10.3	49.8
		25-30	BvA	2.23	0.252	8.8	4.9	0	7.4	38.7
	016	0-10	BvA	4.84	0.451	10.7	5.5	0	8.9	50.7

Location	Profile	Depth (cm)	Horizon							
On the valley bottom	002	0-5	d BvtA	7.08	0.740	9.6	5.2	0	25.3	54.7
		35-40	d BvtA	2.93	0.399	7.3	5.1	0	18.2	60.3
		60-65	d BvtA	3.49	0.399	8.7	4.9	0	19.7	52.5
		120-130	dBv	0.33	0.045	7.3	4.8	0	—	—
		150-155	d BvTjäle	0.33	0.073	4.5	4.8	0	—	—
	001	0-5	dBvtA	4.56	0.497	9.2	6.0	0	16.1	73.4
		20-25	dBvtA	3.17	0.357	8.9	6.7	0	11.4	78.3
		60-70	dBvtA	2.28	0.238	9.6	8.3	0	17.3	100
		120-125	dBv	0.26	0.031	8.4	7.9	0	9.5	100
		155-160	dBvTjäle	0.14	0.028	5.0	6.2	0	4.6	77.8
	003	0-5	dBv/A/k	3.42	0.273	12.5	5.4	0	15.4	72.5
		80-90	dBv	0.23	0.050	4.6	6.2	0	4.6	71.5
On the S exposition	004	0-5	dBvt/A/k	2.45	0.267	9.2	5.6	0	7.8	61.3
		20-25	dBvk	0.99	0.123	8.0	5.7	0	6.7	69.1
		80-85	dBv	0.45	0.055	8.2	5.9	0	6.0	77.5
	005	0-5	dBvAk	3.37	0.290	11.6	5.8	0	9.0	66.3
		20-25	dBvAk	1.38	0.108	12.8	5.9	0	7.2	68.3
		60-70	dBv	0.73	0.083	8.8	6.1	0	5.8	74.1
	006	0-5	dBvt/A/k	1.65	0.134	12.3	5.2	0	6.5	49.9
		80-85	dBv	1.18	0.118	10.0	5.9	0	7.8	73.6
	007	5-10	dBvt/A/k	1.82	0.207	8.8	5.5	0	9.0	63.3
	008	0-5	BvtAk	4.42	0.350	12.6	6.0	0	14.1	76.8
		25-30	BvtAk	2.96	0.392	7.6	6.4	0	12.4	83.2
		55-60	BvAk	1.13	0.236	4.8	5.4	0	8.9	69.0
		90-100	Bv	0.41	0.043	9.5	5.6	0	5.6	74.8
		110-120	Bv	0.36	0.058	6.2	5.6	0	4.6	69.7

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nozems showing the properties of young chestnut soils as well as of the contemporary dark chestnut noncalcareous soils of different thickness (phot. 10). These soils are characterized, in the A horizon, by a low specific gravity from 1.91 to 2.58, on the average 2.43 G/cm³, as well as by a bulk density from 0.89 to 1.32, on the average 1.02 g/ml, their porosity amounting from 51.2 to 64.7%. They have a high capillary water capacity exceeding 85% of water pores. This is connected with a high humus content, from 7.10 to 12.86%, on the average 8.62%.

The high specific gravity in the wastes, ranges from 2.38 to 2.65 G/cm³, on the average 2.52 G/cm³, while the bulk density — from 1.41 to 1.66 g/ml, on the average 1.50 g/ml. On the other hand, the total porosity is low, despite the occurrence of the permafrost, and amounts from 37.2 to 46.8%, on the average 40.5%, the water capacity being about 60% of total porosity. The sorption capacity of the A horizons is relatively low, from 7.4 to 15.7 me per 100 g of soil. The degree of basic cation saturation at a fairly high acidity is also low and amounts from 42.9 to 65.6%, on the average 56.9%. The sorption capacity in Bv horizons of the substrate decreases to 3.7—9.1 me, on the average — 6.0 me per 100 g of soil, while the degree of the basic cation saturation slightly increases from 38.7 to 75.2%, on the average 56.5% (fig. 13). The humus content diminishes rapidly with the depth below A horizon, attaining on the average 0.93%.

SOILS OF THE S- AND E-FACING SLOPES

The above soils are formed mainly from the denuded Bv wastes as well as the contemporary wastes of a profile corresponding to that of the poorly developed mountain light chestnut soil of a small or medium thickness. In A horizon, having few organic substances — from 2.84 to 7.62, on the average 4.79%, both the specific gravity — from 2.72 to 2.90, on the average 2.84 G/cm³ and the bulk density — from 1.21 to 1.44, on the average 1.32 g/ml, are high. Despite the low total porosity of this horizon, of 49.7—57.7, on the average 53.5%, its capillary water capacity is high and exceeds 86% of the total porosity.

In the shallow Bv wastes, under the A horizon a few centimeters thick, the specific gravity is still higher, on the average 2.90 G/cm³, whereas both the density (on the average 1.43 g/ml) and the total porosity (on the average 50.7%) are low; the capillary water capacity being relatively low — on the average 31.3%, which accounts for the poor capacity of these soils to accumulate water.

The relatively high organic matter content throughout the profile, which in the Bv horizon amounts to 1.41% on the average, constitutes an indicator of the accumulative character of the waste-soil materials.
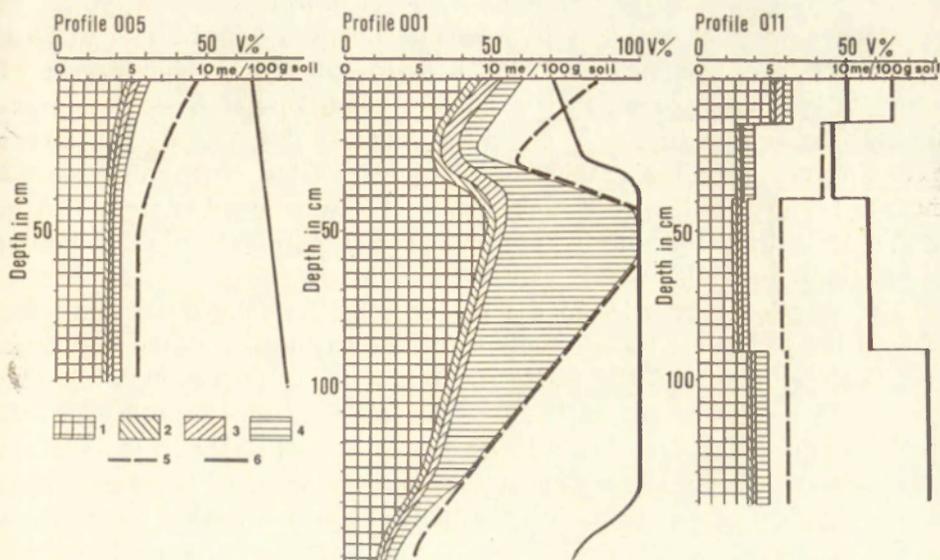
Fig. 13. Exchangeable cation composition and sorption capacity of soils in different soil profiles of S-slope (profile 005), valley bottom (001) and N-slope (011)

$-$ Ca^{+2}; 2 $-$ Mg^{+2}; 3 $-$ K^{+}; 4 $-$ Na^{+}; 5 $-$ sorption capacity *Th* me/100 g of soil; 6   base saturation degree *V*%

The high degree of basic cation saturation — from 49.9 to 77.5%, on the average 67.2% and 73.15% respectively in A and Bv horizons, at the sorption capacity similar to that on the north slope, indicates the xerothermic conditions and the domination of evaporation over precipitation (fig. 13).

VALLEY BOTTOM

There occur mainly thick and very thick mountain deluvial chernozems (phot. 14) developed from the old materials from wetter period, as well as chestnut soils developed from younger slope wash and proluvial sediments (phot. 10, 13), the specific gravity whereof is (in A horizon) 2.26—2.61, on the average 2.49 G/cm³, and the bulk density: 0.77—1.19, on the average 1.09 g/ml. The above values are higher than in the soils on the slope of northern exposure and lower than in the soils of the southern exposure. The total porosity varies from 49.3 to 78.6%, on the average 56.8%. The capillary water capacity, on the other hand is low: from 26.9 to 56.8%, on the average 43.6%. The organic matter content in the A horizon, on the average 8.6%, is similar to that of the soils on the slope of northern exposure; at the 40—60 cm depth, however, it still amounts to 5.2% on the average. Only in the lowest of the Bv layers, partly within the range of the permafrost, the organic

matter content attains its minimum value of 0.49%, which is typical of the tundra weatherings. The high sorption capacity, from 11.4 to 25.3, on the average 17.6 me per 100 g of soil, indicates a high degree of humification of the organic matter under conditions of basic cation saturation from 52.5 to 100%, on the average 70.2%. The deeper layers have Th-values similar to those of cryogenic wastes, on the average 6.2 me per 100 g of soil, with a high degree of base saturation from 71.5 to 100%. It is in these soils where the process of alkalization is taking place (fig. 8 and 13).

The sorption properties in the profile constitute the direct indicator of both the pedogenic transformations of the waste covers inherited from the cooler climate and the waste cover now being formed (tab. 4). The quantitative composition of the exchangeable cations Ca>Na>Mg>K in the waste underground as well as the Ca>Na>K>Mg in the surface soil horizons of both the valley bottom and the slope of northern exposure, is typical of the cryoarid conditions. The quantitative composition of the exchangeable cations on the slope of southern exposure is similar to those mentioned above.

The relict features of the Sant valley soils and of the relatively young cryoarid contemporary phase, is corroborated by the lack in them of carbonate horizon and/or by the presence of its rudiments on the dry, intensely insolated parts of the slopes. It is solely on the small surfaces protected against denudation that there occur soils having a thin $CaCO_3$ horizon. This feature along with the relatively low basic exchangeable cation saturation, testify to the possibility of the leaching type of water régime, on the north slope and cryoplanation terraces in particular. This process is being hindered by a high capillary water capacity, especially after the spring desiccation of soils.

The network of cryogenic polygon structures and the overlaid desiccation crevices in the Bvt cover witness to the periods of higher soil moisturization.

ALTITUDINAL SOIL ZONALITY

The set of Sant valley soils belongs to the southern arid sector of humido-acidic type and remains within the soil zonal structure of the southern Khangai slope (Kowalkowski 1980). In addition, on the north--facing part of the crest that closes the Sant valley from the north, at the altitude of 2420—2710 m, including the near-crest cryoplanation terraces, there occur extensive relict cryogenic chernozems (Haase *et al.* 1964; Kowalkowski and Lomborinchen 1975). In these soils, particularly under forestless conditions, the features of chestnut soil formation can be observed, connected with the contemporary arid climate. The thick deluvia and proluvia of brown chernozems in the lower part of that

slope, at the altitude of 2320—2420 m, have been transformed into non-calcareous dark chestnut soils. It is the dark chestnut soils that dominate on the northern exposure of the Sant valley crest. The islands of the relict brown soils preserved among the above dark chestnut soils and situated in the lower part of that crest, as well as the islands of non-calcareous chernozems situated in the central and upper part of the crest and having the features of chestnut soils are indicative of the southern reach of the influences of cryohumid environment. Contemporary processes of pedogenesis on that slope characterize the dark chestnut soils on the noncalcareous brown cryohumid wastes, and shallow, young dark chestnut soils in the near-crest part.

The southern slope is intensely desiccated. Its inclination of 18 to 22° and the intense processes of thermic rock disintegration favour the formation of poorly developed soils with the features of light chestnut soils of the arid steppe, similar to those of a semi-desert. It is, then, the soil altitudinal zone which constitutes a far-to-the-North reaching element of the arid-type structure of the soil altitudinal zone in South Khangai Highland.

In connection with the transient nature of the types of zonality and the diversity of soil age in Sant valley as well as in the surrounding areas, both the soil type zonation and the altitude zones are not outlined distinctly.

VEGETATION

by

Anna Pacyna

The vegetation of the Sant valley is representative of the lower ridges of the southern aspect of the Central Khangai. The terminal situation of the Sant valley and the proximity of warm dry valleys as well as the desiccating effect of the southerly winds blowing from them (Avirmid *et al.* 1976) influence both the flora and the plant communities.

Detailed botanical studies were made in the Sant-valley for the floristic and phytosociological elaboration of the valley. In this region about 90 phytosociological records were made by the Braun—Blanquet method. Only a selected few of these have been included in the present paper in order to characterize the more important communities.

The distribution of the plant communities in the Sant valley is shown on a map (fig. 14).

The vascular plant flora of the Sant valley includes 270—300 species[1]. As compared with the data for the Khangai Mts as a whole (1455

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[1] Some of the more difficult genera (*Astragalus, Festuca, Salix, Potentilla, Artemisia, Taraxacum*) have not yet been definitively elaborated.

species, Grubov 1955) this number is extremely modest, but the situation and smallness of the region should be borne in mind. A number of steppe species encroaching from the south upon the bottoms of the wide valleys at a small distance into the heart of the mountains do not reach the lateral valleys on account of the change in the microclimate. There are no riverine habitats (willow thicket and gravels) in the valley bottoms, nor any species associated with these. The poverty of the high-mountain flora is caused by the relatively small height of the peak closing the valley and the absence of terrains over 3000 m above sea level in the immediate neighbourhood.

As on the southern aspect of the Khangai, families characteristic of the Eurosiberian region are dominant in the flora of the Sant valley: *Compositae, Gramineae, Cyperaceae, Papilionaceae, Ranunculaceae, Caryophyllaceae* and *Rosaceae*. On the level of the genera, however, the proportions differ. Such genera as *Artemisia, Kobresia, Astralagus, Oxytropis,* as well as *Pedicularis* and *Allium* (less numerously represented in the boreal regions) are of great importance here. According to the latest investigations (Karamysheva, Banzragch 1977) the Sant valley is included in the South Khangai low-moderate mountain district, the southern Khangai steppe sub-province, the Khangai mountain-steppe province and the Euroasiatic steppe region (the Central Asiatic sub--region).

With a difference of c. 700 m in height, three vertical zones of vegetation may be distinguished in the Sant valley, two in only fragmentary form (phot. 1, 2, 5, 6). As in the whole of the Southern Khangai, this is an arid vertical zone system of the Southern Khangai type (Karamysheva, Banzragch 1977; Pacyna 1980).

The Sant valley vegetation system includes three vertical zones:

a) steppe up to 2100 m above sea level;

b) forest-steppe (mountain steppes and woods in the terminology of Yunatov 1950), 2100—2600 (2650) m above sea level;

c) high-mountain vertical zone, over 2600 (2650) m above sea level (fig. 14).

T h e s t e p p e v e r t i c a l z o n e in the Sant valley is fragmentary. It occupies a small area in the valley bottom, near the outlet into the Tsagan-Turutuin-gol valley. It is represented by *Artemisia frigida—Stipa Krylovii* steppe.

T h e f o r e s t - s t e p p e v e r t i c a l z o n e occupies a considerable part of the Sant valley. The general prevalence of mountain steppes, with the exception of small wooded areas on slopes with a northern exposure, is its characteristic feature (phot. 5).

The general data on the forest-steppe vertical zone (and on the steppes) on the southern slope of the Central Khangai have been given in the volume on altitudinal zonality in the Khangai Mts (Pacyna 1980).

The asymmetry of the slope gives rise to separate habitats, involving the differentiation of the plant communities (Kowalkowski, Pacyna 1977). Larch forest and mountain meadow steppe are the natural communities on slopes with a northern exposure.

Mountain larch forest of the pseudo-taiga type (Korotkov 1976, Pacyna 1980) in the Sant valley is restricted to a few small stands (phot. 2, 5; fig. 14). The floristic composition is shown in the phytosociological records (tab. 5). Record 1 shows the natural forest, undisturbed by man, at its upper limit of occurrence; records 2 and 3 the coeval (c. 40 years), rather young, dense woods; records 4 and 5 woods with a canopy cover decreasing until park-like woodland appears (record 6). The larches, the only component of the stand in the Sant valley, do not attain any considerable height, averaging only a few metres (*cf.* tab. 5).

The physiognomical features of the forest depend on the habitat conditions prevailing on the slope. In damp places the stand is dense and the herb layer richer in mesophilous species (*Poa sibirica* Roshev., *Trollius asiaticus* L., *Geranium pseudosibiricum* J. Meyer). On account of the deep shade cast by the trees the herb layer is characterized by its density (steppe species are light-loving) or in extreme cases it is completely absent. The soil is then covered with a thick layer of decaying larch needles and a few mosses or lichens. In drier places, however, the forest is on the whole more open (the canopy cover is 60—70 per cent) and lets more light through, so that the herb layer is richer and denser. In the driest patches, of a park-like character (record 6), the absence of *Poa sibirica* Roshev., a mesophyte which appears in all the other records, is noteworthy.

The species *Pedicularis rubens* Steph., *Potentilla nivea* L. and *Sanguisorba officinalis* L. are decidedly more numerous than in the other stands. A number of species characteristic of the mountain meadow steppes appear only in this stand (e.g. *Helictotrichon Schellianum* (Hack). Kitag.), but are absent in places with a denser canopy cover.

Conforming to the general regularity of occurrence of high mountain species in the more highly situated forest patches (Pacyna 1980), these are also found in the Sant valley at the upper limit of the forest (e.g. *Hedysarum inundatum* Turcz., record 1).

As in the whole of the Southern Khangai, the forest does not reach the bottom of the valley (Yunatov 1950; Pacyna 1980). The lower limit of the forest patch situated lowest in the Sant valley lies at a height of 2300 m above sea level.

The climatic upper forest limit has been preserved fragmentarily only in those parts of the valley under the peak, at an altitude of 2650 m. The concave form of the slope (phot. 2,4) may play a beneficial role here. In other places the upper forest limit is markedly lowered to a height of c. 2500 m and is partly of an anthropogenic character. The

Table 5. Forests

Number of record in table	1	2	3	4	5	6
Field number of record	83	6	15	33	47	7
Date	13.8	26.6	1.7	6.8	21.7	26.6
Altitude above sea level [m]	2620	2425	2470	2320	2340	2460
Exposure	NNW	NNW	NNW	N	N	NNW
Inclination	20	10	5—10	10	15—20	15—20
Canopy cover (A) [%]	80	85	80	70	50	50
Coverage of shrub layer (B) [%]	10	20—30	10	30	10	20—30
Coverage of herb layer (C) [%]	50—60	60	75	75	70	90
Coverage of moss and lichen layer (D) [%]	15	20	30	10	40	50
Height of trees [m]	20	10—15	8	12	10—15	10—15
Area of record [sq. m]	300	500	100	350	250	400

A						
Larix sibirica Ldb.	5.3	5.3	5.3	4.3	3.2	3.2
B						
Larix sibirica Ldb.	+	2.3	+	2.3	1.1	1.2
C						
Larix sibirica Ldb.	.	+	.	+	+	+
Trisetum sibiricum Rupr.	1.2	3.2	.	2.2	1.2	3.2
Festuca ovina L.	1.2	3.3	4.3	2.2	+	4.3
Poa sibirica Roshev.	1.2	+	3.2	2.2	1.2	.
Anemone crinita Juz.	+	1.2	1.2	2.2	2.2	1.2
Pedicularis rubens Steph.	1.2	2.1	2.2	1.2	+	3.2
Potentilla nivea L.	+	1.2	1.2	1.2	+	3.2
Poa relaxa Ovcz.	+	+	.	1.2	1.2	+
Dendranthema Zawadzkii (Herb.) Tzvel.	+	+	.	+	1.1	+
Sanguisorba officinalis L.	+	+	.	+	+	1.2
Galium verum L.	+	+	+	+	+	+
Atragene sibirica L.	.	2.1	.	+	1.1	+
Polygonum viviparum L.	1.2	+	.	.	+	2.2
Rhodiola rosea L.	.	+	+2	+	+	1.1
Myosotis asiatica Schischk. et Serg.	+	+	.	.	+	1.1
Senecio campester (Retz.) DC.	+	+	+	+	.	+
Pedicularis verticillata L.	+	+	+	+	.	+
Androsace septentrionalis L.	.	+	.	+	+	+
Campanula Turczaninovii Fed.	2.2	1.2	3.1	.	2.1	.
Pulsatilla ambigua (Turcz.) Juz.	.	+	2.2	+	.	1.2
Hedysarum inundatum Turcz.	1.2	.	.	+	.	+
Euphorbia discolor Ldb.	.	+	.	+	.	1.1
Gentiana decumbens L. f.	+	+	.	.	.	+
Dasiphora fruticosa (L.) Rydb.	+	+	.	+	.	.
Vicia multicaulis Ldb.	.	+	3.2	.	+	+
Draba lanceolata Royle	.	+	.	+	.	+
Saxifraga sibirica L.	+	.	.	+	.	+
Carex amgunensis Fr. Schmidt.	.	+	.	3.2	.	.
Geranium pseudosibiricum J. Meyer	.	.	.	3.2	+	.
Artemisia tanacetifolia L.	+	.	.	1.2	+	.
Trollius asiaticus L.	+	.	.	+	.	.
Cerastius arvense L.	+	.	.	.	.	+
Scorzonera radiata Fisch.	.	.	+	.	.	+
Androsace incana Lam.	.	+	.	.	.	+

Rosa acicularis Lindl.	.	.	+	+	.	.
Ranunculus pedatifidus Sm.	.	+	.	+	.	.
Chamaenerion angustifolium (L.) Scop.	.	.	+	+	.	.
Oxytropis strobilacea Bge.	.	.	.	+	.	+
D						
Mosses[1]						
Rhytidium rugosum (Hedw.) Kindb.	×	1.3	×	×	×	.
Abietinella histricosa (Mitt.) Broth.	.	1.3	×	.	×	.
Tortella tortuosa (R. Hedw.) Limpr.	×	×	.	×	.	.
Tortella fragilis (Hook. et Wils.) Limpr.	.	×	.	.	.	×
Tortula ruralis var. *hirsuta* (Vent.) Par.	.	×	.	×	.	.
Aulacomnium palustre var. *imbricatum* B.S.G.	.	.	.	×	.	.
Pohlia cruda (Hedw.) Lindb.	×	.	.	.	.	.
Streblotrichum convolutum (Hedw.) P. Beauv.	.	×	.	.	.	.
Lichens[1]						
Peltigera horizontalis (Huds.) Baumg.	+	+3	.	.	.	.
Peltigera canina (L.) Willd.	.	.	×	.	.	.
Peltigera rufescens (Weis.) Humb.	.	.	.	.	.	×
Parmelia vagans Nyl.	.	.	.	.	.	×
Cladonia pyxidata (L.) Fr.	.	.	.	.	.	×
Cladonia coniocraca (Flk.) Vain.	.	.	.	.	.	×

Record 1[2]. *Libanotis condensata* (L.) Crantz., *Dianthus superbus* L., *Draba subamplexicaulis* C.A.M., *Allium strictum* Schrad., *Silene jenisseensis* Willd., *Erigeron* sp., *Umbelliferae* indct. Record 2. *Thlaspi cochleariforme* DC., *Lathyrus humilis* Fisch., *Potentilla* sp. 1.2, *Rheum* sp. Record 4. *Thalictrum foetidum* L., *Polygonum alopecuroides* Turcz., *Galium boreale* L. Record 6. *Polygonum angustifolium* Pall., *Cerastium caespitosum* Gilib., *Thalictrum petaloideum* L., *Gentiana macrophylla* Pall. 1.2, *Carex pediformis* C.A.M., *Dracocephalum grandiflorum* L., *Rumex acetosa* L., *Helictotrichon Schellianum* (Hack.) Kitag., *H. mongolicum* (Roshev.) Henr., *Kobresia capilliformis* Ivanova, *Zerna pumpelliana* (Scribn.) Tzvel. *Oxytropis* sp., *Delphinium* sp.

Localities: All records were made in the Sant valley on the left slope
[1] "x" — presence of species in records without giving their abundance and sociability
[2] The symbol "+" has been omitted

absence of permafrost in the shallow stony soils (Kowalkowski, Lomborinchen 1975) may also have an adverse influence on the upper part of the slope, as well as the action of the dry southerly winds sweeping over the peak.

In the Sant valley the woodland region is often disturbed by the activities of man (felling, burning or excessive pasturing). According to the local inhabitants, much larger herds were pastured in this terrain before the revolution of 1921 than later. They also recalled forest fires, of which evidence was found in the form of charcoal in the soil. In places, which are now treeless, many stumps of felled trees are found. Once destroyed, it is very difficult to restore the pseudo-taiga type of forest in a dry climate (Korotkov 1976). This may be seen on the left slope of the valley, near its outlet (phot. 9). In spite of the unchanged aspect and location in relation to the forested area, it is now permanently treeless, except for a few single survivors. As a result of soil erosion it has come to resemble the stony south-facing flank. The de-

Table 6. Mountain steppes

Number of record in the table	1	2	3	4	5	6	7	8
Field number of record	80	78	81	73	64a	71	10	11
Date	13.8	13.8	13.8	6.8	30.7	1.8	25.6	25.6
Altitude above sea level [m]	2480	2420	2560	2450	2410	2420	2450	2470
Exposure	N	NNW	NNW	W	NWW	SSW	SSW	SSW
Inclination	5	30—40	10—15	6—10	2	5—10	30	18—25
Coverage of herb layer (C) [%]	80	80	70—80	85	90	50	50	50
Coverage of moss and lichen layer (D) [%]	...	...	20	...	0	0	0	0
Hight of herbage [cm]	...	20	...	...	10	10	...	...
Hight of inflorescences [cm]	...	50	40	40	40—60	30	30—40	25
Area of record [sq. m]	300	300	500	300	400	300	200	200
1	2	3	4	5	6	7	8	9

C

Festuca lenensis Drob.	.	.	1.2	3.2	2.2	2.2	1.2	2.2
Poa attenuata Trin.	2.2	1.2	+	3.2	3.2	2.2	1.2	2.2
Koeleria cristata (L.) Pers.	3.2	2.2	+	3.2	3.2	2.2	.	.
Pulsatilla sp.	.	+	.	2.2	1.2	2.2	+	1.1
Thalictrum petaloideum L.	.	2.2	.	1.2	2.2	2.2	1.1	1.1
Polygonum angustifolium L.	+	1.1	+	.	.	+	+	+
Oxytropis nitens Turcz.	.	+	+	+2	.	+	1.3	2.2
Pulsatilla ambigua (Turcz.) Juz.	+	.	2.2	3.2	+	+	.	.
Sanguisorba officinalis L.	+	+	3.2	+	+	.	.	.
Agropyron cristatum (L.) Gaertn.	.	1.2	.	.	2.2	+	+	+
Iris flavissima Pall.	.	1.1	.	.	+	+	+	+2
Euphorbia discolor Ldb.	.	+	.	+	2.2	+	+	.
Dasiphora fruticosa (L.) Rydb.	.	+	+	.	+2	.	2.3	+2
Limonium flexuosum (L.) Ktze.	.	+	+	.	+2	+	.	+
Androsace septentrionalis L.	.	+	+	+	+	+	.	.
Potentilla bifurca L.	.	.	.	1.2	1.2	1.1	+	+
Echinops dahuricus Fisch.	.	.	.	+	+	+2	+	+
Helictotrichon Schellianum (Hack.) Kitag.	3.2	1.2	+	1.2	.	.	.	.
Aster alpinus L.	1.2	2.2	+	+	.	.	.	.
Gentiana decumbens L. f.	1.1	+	1.2	.	1.2	.	.	.
Artemisia cfr. monostachya Bge.	.	.	.	.	.	.	.	1.1
Artemisia tanacetifolia L.	+	+	.	1.2	1.2	.	.	.

Species								
Leontopodium ochroleucum Beauv. s. l.	+	+	3.2	2.2	+	.	.	.
Rhodiola rosea L.	.	+	+	.	.	.	1.2	+
Potentilla cfr. *sericea* L.	.	+	.	+	2.2	+	.	.
Pedicularis abrotanifolia M. B.	.	.	.	+	.	1.1	+	1.1
Thermopsis lanceolata R. Br.	.	.	.	+	.	1.1	+	+
Dontostemon integrifolius (L.) C.A.M.	.	.	.	.	+	+	+	+
Rheum sp.	.	.	.	.	+2	+2	+2	+
Galium verum L.	1.1	2.2	+	.	.	.	.	.
Campanula Turczaninovii Fed.	+	+	2.2	.	.	.	.	.
Dianthus versicolor Fisch.	+	+	+	.	.	.	.	.
Silene jenisseensis Willd.	+	+	+	.	.	.	.	.
Orostachys malacophylla (Pall.) Fisch.	+	+	+	.	.	.	.	.
Silene repens Patr.	+	.	+	+	.	.	.	.
Linum baicalense Juz.	.	+	.	+	.	.	+	.
Amblynotus obovatus (Ldb.) I. Johnst.	.	.	.	.	+	1.1	+	.
Peucedanum hystrix Bge.	.	.	.	.	.	2.2	+	+
Thymus gobicus Tscherm.	.	.	.	.	.	+	+2	+2
Umbelliferae indet.	.	.	+	+	+	.	.	.
Festuca Kryloviana Reverd.	2.2	2.2	.	.	.	.	.	.
Potentilla nivea L.	2.2	.	1.2	.	.	.	.	.
Senecio campester (Retz.) DC.	1.2	.	1.2	.	.	.	.	.
Anemone crinita Juz.	+	.	+	.	.	.	.	.
Carex melananthaeformis Litw.	+	.	.	.	+2	.	.	.
Pedicularis rubens Steph.	3.2	.	1.2	.	.	.	.	.
Rumex acetosa L.	+	.	.	.	.	+	.	.
Scorzonera radiata Fisch.	+	+	.	.	.	.	.	.
Delphinium dissectum Huth	.	3.2	1.2	.	.	.	.	.
Androsace incana Lam.	.	+	.	+2	.	.	.	.
Arenaria capillaris Poir.	.	1.2	+	.	.	.	.	.
Carex pediformis C.A.M.	.	+2	+	.	.	.	.	.
Allium prostratum Trev.	.	+	.	.	.	.	.	+
Cotoneaster melanocarpa Lodd.	.	+	.	.	.	.	2.2	.
Gentiana pseudoaquatica Kusn.	.	.	.	+	+	.	.	.
Carex Korshinskyi Kom.	.	.	.	+2	.	1.2	.	.
Artemisia changaica Krasch.	.	.	.	+	.	+	.	.
Veronica ciliata Fisch.	.	.	.	.	+	.	+	.
Artemisia pycnorhiza Ldb.	.	.	.	.	.	1.2	2.2	.

1	2	3	4	5	6	7	8	9
Carex duriuscula C.A.M.	.	.	.	.	1.2	+	.	.
Panzeria lanata (L.) Bge.	.	.	.	.	.	.	+	+
Stellaria dichotoma L.	.	.	.	.	.	.	+	+
Potentilla viscosa G. Don	.	.	.	.	.	.	+	+
Artemisia santolinifolia Turcz.	.	.	.	.	.	.	+	1.1
D								
Mosses[1]								
Hypnum vaucheri Lesq.	.	.	×	.	.	.	.	.
Bryum caespiticium Hedw.	.	.	×	.	.	.	.	.
Didymodon rigidulus Hedw.	.	.	×	.	.	.	.	.
Tortella fragilis (Hook. et Wils.) Limpr.	+	.	.	.	.	.	.	.
Lichens[1]								
Parmelia vagans Nyl.	.	+	×	+	.	.	.	.
Peltigera rufescens (Wies.) Humb.	+	.	×	.	.	.	.	.
Physcia muscigena (Ach.) Nyl.	+	.	.	.	.	.	.	.
Cladonia pyxidata (L.) Fr.	.	.	×	.	.	.	.	.
Cetraria cucullata (Bell.) Ach.	.	.	×	.	.	.	.	.

Record 1[2]. *Carex amgunensis* Fr. Schmidt. 2.2, *Zerna pumpelliana* (Scribn.) Tzvel. 1.2. *Cerastium arvense* L. 1.2, *Aconitum barbatum* Pers., *Allium prostratum* Trev., *Chamaenerion angustifolium* (L.) Scop., *Crepis crocea* (Lam.) Babck., *Dendranthema Zawadzkii* (Herb.) Tzvel., *Dianthus superbus* L., *Gentiana macrophylla* Pall., *Geranium pseudosibiricum* J. Meyer, *Hedysarum inundatum* Turcz., *Larix sibirica* Ldb., *Myosotis asiatica* Schisch k. et Scrg., *Pedicularis verticillata* L., *Poa sibirica* Roshev., *Polygonum viviparum* L., *Rosa acicularis* Lindl., *Vicia multicaulis* Ldb., *Erigeron* sp., *Gentiana* sp., *Compositae indet.* Record 2. *Pedicularis achilleifolia* Steph. 2.2, *Erysimum altaicum* C.A.M., *Schizonepeta multifida* (L.) Briq., *Allium leucocephalum* Turcz., *Serratula marginata* Tausch., *Draba lanceolata* Royle, *Carex* sp. 1.2, *Potentilla* sp. Record 3. *Polygonum alopecuroides* Turcz. 3.2, *Kobresia filifolia* (Turcz.) C.B. Clarke 3.3, *Eritrichium rupestre* Bge., *Gentiana azurea* Bge., *Saxifraga sibirica* L., *Stellaria petraea* Bge., *Oxytropis* sp. Record 4. *Veronica incana* L. 1.2, *Pedicularis myriophylla* Pall., *Linaria acutiloba* Fisch., *Heteropappus altaicus* (Willd.) Novopokr. Record 5. *Leymus secalinus* (Georgi) Tzvel. 1.2, *Artemisia glauca* Pall. 1.2, *Agrostis Trinii* Turcz., *Potentilla* sp., *Oxytropis* sp. Record 6. *Sibbaldianthe adpressa* (Bge.) Juz. 1.2, *Chamaerhodos erecta* (L.) Bge., *Stipa Krylovii* Roshev., *Bupleurum* sp. Record 7. *Chamaerhodos altaica* (Laxm.) Bge., *Androsace Turczaninovii* Freyn., *Thesium longifolium* Turcz., *Potentilla* sp., *Astragalus mongolicus* Bge.

Localities: All records were made in the Sant valley, records 1,2 and 3 on the left slope, records 4 and 5 on the valley bottom, record 6 on the deluvial fan, records 7 and 8 on the right slope

[1] "x" — presence of species in records without giving their abundance and socialibility.

[2] The symbol "+" has been omitted.

forestation of the slope has also caused changes in the microclimatic conditions. All this leads to the degradation of the habitat and renders it difficult for trees to return.

The treeless parts of the slope are occupied by mountain meadow steppe (a mesophilous variant of mountain steppe). This is a very colour-ful community, rich in species with beautiful flowers (table 6, records 1—3). Besides typical steppe grasses such as *Koeleria cristata* (L.) Pers. and *Poa attenuata* Trin., which play a smaller part here than in the dry steppe, *Festuca lenensis* Drob., a species characteristic of the mountain steppes, and *Helictotrichon Schellianum* (Hack.) Kitag., a mesoxerophyte characteristic of mountain meadow steppes, are of importance. The con-tribution of numerous mesophytes and xeromesophytes, which do not appear in any other type of steppe community, is very characteristic. The individual patches of mountain meadow steppe are fairly varied. Their morphology and species composition depend on local humidity conditions and the height above sea level.

The opposite slope of the valley, with the southern aspect, has un-favourable conditions for the development of vegetation on account of the hydrothermal régime and the soil cover (*cf.* chapter „Soils"). It is occupied by dry mountain steppe variants with a cover dropping to under 50 per cent. The deluvial fans at the foot of the slope are the driest habitat in the valley. They are covered by dry mountain steppe with sparse low vegetation dominated by xerophytes (tab. 6, record 6; phot. 10).

The higher reaches of the slope are occupied by stony mountain steppe (Pacyna 1980). This forms a mosaic of stands of various high dry mountain steppe variants, depending on the habitat (phot. 16, 18). A char-acteristic part is played by cushion like and caespitose xerophytes (*Oxytropis nitens* Turcz., *O. tragacanthoides* Fisch., *Chamaerhodos alta-ica* (Laxm.) Bge.). In particularly stony places, where almost half the area is covered with boulders, there occur patches of the predominant shrubs: *Dasiphora fruticosa* (L.) Rydb., *Spiraea flexuosa* Fisch., *Cotonea-ster melanocarpa* Lodd. (tab. 6, records 7 and 8). The more fertile and damper parts of the slope near the summit form better conditions for the development of vegetation (Kowalkowski and Pacyna 1977). A small area is occupied by groves of *Populus tremula*, and a number of meso-philous species (*Anemone crinita* Juz., *Campanula Turczaninovii* Fed.) appear in a narrow strip near the summit (phot. 17).

The asymmetry of the valley slope also results in the formation and distribution of plant community in the valley bottom. The part of the valley bed adjacent to the slope facing north is by nature cooler and damper. Terrains with permafrost are occupied by humid mountain meadow with *Agrostis Trinii* Turcz., *Sanguisorba officinalis* L., and *Po-lygonum alopecuroides* Turcz. This community is characterized by the

very dense herbage as well as by the domination of mesophilous meadow species.

Record no. 63a. 29 VIII 1975. Sant valley, altitude 2410 m above sea level, exposure W, inclination 2°, area of record 100 m², coverage of vascular plants 100%, coverage of mosses 90%, height of the herbage to 15 cm (the inflorescences to 60 cm).

Agrostis Trinii Turcz. 4.2, *Sanguisorba officinalis* L. 2.2, *Polygonum alopecuroides* Turcz. 3.2, *Potentilla anserina* L. 2.2, *Artemisia tanacetifolia* L. 2.2, *Rumex acetosa* L. 1.2, *Dasiphora fruticosa* (L.) Rydb. 1.3, *Carex ensifolia* Turcz. 1.2, *Ranunculus pedatifidus* Sm. 1.2, *Stellaria dahurica* Willd. 1.1, *Euphrasia Syreitschikovii* Govor. 1.1, *Potentilla multifida* L. 1.1, *Carex melananthaeformis* Litw.[2], *C. enervis* C.A.M., *Kobresia filifolia* (Turcz.) C. B. Clarke, *Festuca rubra* L., *Festuca Kryloviana* Reverd., *Koeleria cristata* (L.) Pers., *Hierochloe glabra* Trin., *Hordeum brevisubulatum* (Trin.) Link, *Poa pratensis* L. Mosses: *Bryum pseudotriquetrum* (Hedw.) Gaertn., Meyer et Schreb. 5.5.

A mountain steppe variant with *Veronica incana* L., *Galium verum* L. and *Leontopodium ochroleucum* Beauv. s.l. overgrows those places in which there is no permafrost.

The swampy solifluction lobe with a shallower active layer (Kowalkowski and Lomborinchen 1975), reinforced with water from the northern declivity, is occupied by marshy meadow with *Primula sibirica* Jacq. and *Ligularia sibirica* (L.) Cass. This is a specific community, rare in the Khangai. A dominant role is played by species of wet habitats (*Carex microglochin* Whlbg., *C. ensifolia* Turcz., *C. enervis* C.A.M., *Juncus triglumis* L.), while *Primula sibirica* Jacq. decides the colouring of the community (phot. 5).

Record no. 9. 24 VI 1974. Sant valley, solifluction lobe in the bottom of valley, altitude 2400 m above sea level, exposure SWW, inclination 2°, area of record 500 m², coverage of vascular plants 90%, coverage of mosses 20%.

Carex ensifolia Turcz. 4.3, *C. enervis* C.A.M. 4.3, *C. microglochin* Whlbg. 2.3, *Kobresia Bellardii* (All.) Degl. 2.2, *Juncus triglumis* L. 2.2, *Polygonum viviparum* L. 2.2, *Ranunculus pseudohirculus* Schrenk. 2.2, *Primula sibirica* Jacq. 2.1, *Ligularia sibirica* (L.) Cass. 1.2, *Salix caesia* Vill. 2.2, *Alopecurus brachystachys* M.B.[2], *Kobresia filifolia* (Turcz.) C.B. Clarke., *Cerastium caespitosum* Gilib., *Draba nemorosa* L., *Festuca rubra* L., *Gentiana pseudoaquatica* Kusn., *Pedicularis tristis* L., *Pedicularis* sp., *Poa pruinosa* Korotky, *Potentilla anserina* L., *P. nivea* L., *Potentilla* sp., *Primula farinosa* L., *Ranunculus* sp., *Rumex acetosa* L., *Sanguisorba officinalis* L., *Triglochin palusstris* L. Mosses: *Tortella tortuosa* (R. Hedw.) Limpr., *T. fragilis* (Hook et Wils.) Limpr., *Bryum caespiticium* Hedw., *Camphyliadelphus chrysophyllus* (Bid.) Kanda.

Dry mountain steppe variants overgrow the arid part of the valley bed without permafrost abutting on the right slope. At lower altitudes

[2] The symbol "+" has been omitted.

this is a steppe with *Agropyron cristatum* (L.) Gaertn., *Gentiana decumbens* L. f., *Thalictrum petaloideum* L. (tab. 6, record 5), and higher there is mountain steppe with *Leontopodium ochroleucum* Beauv. s. l. (tab. 6, record 4).

T h e   h i g h   m o u n t a i n   v e r t i c a l   z o n e occupies a small area in that part of the valley near the summit.

Here only a lower high mountain sub-zone has been formed (Pacyna 1980), with *Kobresia* high mountain meadows (record 75).

Record. no. 75. 12 VIII 1975. Sant valley, the slope of the peak 2718 m above sea level, altitude 2635 m above sea level, exposure NW, inclination 30°, area of record 500 m², coverage of vascular plants 85%, coverage of mosses and lichens 20%, height of the herbage to 15 cm, height of the inflorescences to 40 cm.

Kobresia Bellardii (All.) Degl. 3.2, *Carex rupestris* Bell. 2.2, *Helictotrichon Schellianum* (Hack.) Kitag. 2.2, *Festuca lenensis* Drob. 2.2, *Sanguisorba officinalis* L. 2.2, *Polygonum alopecuroides* Turcz. 2.2, *Campanula Turczaninovii* Fed. 2.2, *Androsace Bungeana* Schischk. et Bobr. 2.2, *Ptilagrostis mongolica* (Turcz.) Griseb. 1.2, *Polygonum viviparum* L. 1.2, *Carex pediformis* C.A.M. 1.2, *Gentiana decumbens* L. f. 1.2, *Leontopodium ochroleucum* Beauv. s.l. 1.2, *Aster alpinus* L. 1.2, *Arenaria capillaris* Poir. 1.2, *Poa attenuata* Trin. 1.2, *Koeleria cristata* (L.) Pers. 1.2, *Agrostis Trinii* Turcz. 1.2, *Allium lineare* L.[3], *Androsace incana* Lam., *Anemone crinita* Juz., *Artemisia* cfr. *monostachya* Bge., *A. tanacetifolia* L., *Carex macrogyna* Turcz., *Crepis polytricha* Turcz., *Dasiphora fruticosa* (L.) Rydb., *Dianthus versicolor* Fisch., *Draba lanceolata* Royle, *Eritrichium rupestre* Bge., *Galium verum* L., *Gentiana azurea* Bge., *G. macrophylla* Pall., *Iris flavissima* Pall., *Kobresia capilliformis* Ivanova, *Larix sibrica* Ldb., *Orostachys malacophylla* (Pall.) Fisch., *Oxytropis strobilacea* Bge., *Pachypleurum alpinum* Ldb., *Papaver nudicaule* L., *Pedicularis myriophylla* Pall., *Polygonum anguistifolium* Pall., *Potentilla nivea* L., *Pulsatilla ambigua* (Turcz.) Juz., *Rumex acetosa* L., *Saxifraga sibirica* L., *Scorzonera radiata* Fisch., *Senecio campester* (Retz.) DC., *Silene jenisseensis* Willd. Mosses: *Hypnum cupressiforme* Hedw., *Didymodon rigidulus* Hedw. Lichens: *Cladonia pyxidata* (L.) Fr., *Parmelia vagans* Nyl.

High mountain species dominate in this community: *Kobresia Bellardii* (All.) Degl. and *Carex rupestris* Bell, while *Ptilagrostis mongolica* (Turcz.) Griseb. and *Androsace Bungeana* Schischk. et Bobr. also play a large part. The dry climate causes a numerous group of species characteristic of the mountain steppes to appear (e.g. *Arenaria capillaris* Poir., *Carex pediformis* C.A.M., *Galium verum* L., *Helictotrichon Schellianum* (Hack.) Kitag.). *Poa attenuata* Trin. and *Koeleria cristata* (L.), common species in the flat steppes, also occur here fairly frequently. As compared with the damper high mountain terrains in the vicinity of the main ridge of the Khangai, the high mountain meadows in the Sant valley have a larger proportion of steppe elements (*cf.* Pacyna 1980).

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[3] The symbol "+" has been omitted.

THE DYNAMICS OF ENVIRONMENT

PROCESSES OF ENERGY EXCHANGE

by

Eligiusz Brzeźniak and Tadeusz Niedźwiedź

Investigations of meso- and microclimatic diversifications were carried out in the summer periods: 21 June—31 July 1974 (Avirmid and Niedźwiedź 1975, Niedźwiedź *et al.* 1975) and 14 July—23 August 1975 (Avirmid *et al.* 1976), as well as at the close of the winter period — 10—19 April 1976 (Froehlich and Słupik 1977a).

The base station was located at the mouth of the Sant valley on a flat terrace lifted 29 m over the bottom of the Tsagan-Turutuin-gol valley. The co-ordinates of the station are as follows: $\varphi = 46°\ 50'$ N, $\lambda = 100°\ 05'$ E, $H_s = 2055$ m asl. At this station observations were conducted every 3 h, including all basic meteorological elements and measurements of the radiation balance components: direct, diffused, global and reflected radiation, as well as net radiation of soil surface (fig. 3).

In the transverse profile of the Sant valley, which ran across S- and N-facing slopes, 15 series of patrol measurements of air temperature and humidity of the near-ground layer were executed with the help of an aspiration psychrometer (Assmann's type). At the altitude 2470 m asl. on a S-facing slope, a N-facing afforested slope, and a peak 2719 m asl. extreme temperatures of ground surface were measured. In addition, a diurnal course of temperature 20 cm above the ground was measured during 7 days (17—23 April 1975). At the same points measurement of the near-ground temperature and investigations of snow cover differentiation were carried out from 12 to 18 April 1976 (Froehlich and Słupik 1977a).

A diversified relief of the Sant valley determines occurrence of meso- and microclimatic differences. The vertical extension (2000—2700 m asl.) causes the mean July temperatures to lower from 13.6 to 8.6°C (the mean gradient is 0.71°C/100 m). In winter reign inversion conditions. The lower part of the drainage basin (2000—2300 m asl.) lies in a cold air pool with absolute minimum temperatures dropping down to −48°C.

The warmest zone occurs probably on valley slopes 2500—2600 m asl.

The east-west direction of the valley is responsible for the highest contrasts of the slopes climate. Values of direct radiation for 12 o'clock in July were mathematically computed depending on aspect and inclination, assuming that 1 cm² of horizontal surface receives 1 cal of energy per minute (Stcherban 1968). On the S-facing slope, whose inclination belongs to the interval 17—35°, the global radiation is 1.06—1.09 cal/cm² · min (fig. 8). Values of direct radiation, which oscillate from 0.71 to 0.72 cal/cm² · min, change also on a limited scale (fig. 15).

The global radiation at the Sant valley bottom is 1.04—1.06 cal/cm² · min, whereas the direct radiation is 0.65—0.67 cal/cm² · min. On the N-facing slope the global radiation is considerably lower than the comparative one at the valley bottom, i.e. 0.88—0.97 cal/cm² · min, the inclination being of the order of 11—20°. A similar relationship holds in the case of direct radiation, whose values run from 0.51 to 0.59 cal/cm² · min. An average differentiation of the global radiation in July 1974 (at noon) is represented on the map (fig. 15). It runs from 0.73 cal/cm² · min on steep parts of the N-facing slope (33—35°) to 1.09 cal/cm² · min on the opposite slope. A violent decrease of amount of delivered heat occurs at the foot of the N-facing slope. At noon c. 73% of global radiation consists of diffused radiation. Over the steppe surface 23% of radiation undergoes reflection. However, the lack of data which would concern a spatial differentiation of albedo values in the Sant drainage basin prevents us from making a detailed spatial analysis of net radiation. It follows from measurements carried out at the base station that the net radiation at noon makes c. 58% of global radiation. According to Beresneva's investigations (1976) performed on the north-eastern slope of the Khangai, the global radiation totals in July received by slopes 20° in inclination are from 13.3 kcal/cm² for N to 14.2 kcal/cm² for S exposure. The greatest diversification becomes pronounced in winter. The respective values for December are 0.02—7.4 kcal/cm². Annual totals range from 93 to 154 kcal/cm². According to Soviet studies, monthly totals of net radiation for N- and S-facing slopes (20°) run from 6.2 to 7.3 kcal/cm² in July.

Differences in magnitudes of received solar energy determine a degree of heating and cooling of ground surface. According to data from July 1974 (Niedźwiedź *et al.* 1975), the mean maximum temperature of ground surface on a S-facing slope reached 41°C, whereas it was lower by 14°C (on the average) on an afforested N-facing slope. At night the S-facing slope, devoid of a dense plant cover, was cooled more strongly, so that ground frosts occurred in consequence (down to —1.9°C). The mean diurnal amplitude of temperature at the ground surface was 38 and 23°C, respectively. Interdependencies between the maximum temperature of ground surface on the S-facing slope (t_S) and the N-facing

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slope (t_N) in the summer period on the one hand and the data from the base station at the outlet of the Sant valley (t_B) on the other, can be expressed by the following formulae:

$$t_S = 0.74 \ t_B + 7.4, \qquad B_{es.} = 4.8, \qquad r = 0.84;$$
$$t_N = 0.54 \ t_B + 2.7, \qquad B_{es.} = 3.1, \qquad r = 0.87.$$

The minimum temperatures at the ground surface on the investigated slopes can also be evaluated on the basis of the base station data supported by the equations:

$$t_S = 0.76 \ t_B - 0.9, \qquad B_{es.} = 1.8, \qquad r = 0.70;$$
$$t_N = 0.94 \ t_B - 0.3, \qquad B_{es.} = 1.6, \qquad r = 0.81.$$

where $B_{es.}$ indicates a standard error of estimation and r — correlation coefficient. Apart from aspect, values of temperature at the ground surface in the Sant valley are strongly influenced by altitude asl. With growing altitude, the maximum temperature of ground surface drops down to 1.6°C/100 m. The vertical gradient of minimum temperature is considerably smaller — 0.39°C/100 m. A much greater microclimatic differentiation should be expected in the winter period, as shown by W. Froehlich's and J. Słupik's results (1977a). At the end of the 1976 winter (April) snow cover which occurred on a N-facing slope in the Sant catchment basin was c. 40 cm thick, while a S-facing slope was devoid of snow. Big differences in insolation and a contrastive differentiation of bedrock caused that the ground surface on the S-facing slope was heated to over 30°C, the temperature on the opposite slope being 8°C (fig. 16). Drops of the ground surface temperature attained −23°C at night.

Depending on a weather type, differences in soil temperature at the 5 cm depth on the slopes under investigation ranged from 7 to 15°C in the summer 1974. Such great contrasts are related not only to a lower delivery of heat on the northern slope, but also to a cooling influence of melting permafrost. At the valley bottom and on the N-facing slope one could observe patches of permafrost at the depth below 130—140 cm and in some places already at 90 cm (Kowalkowski *et al.* 1977).

Big thermic differences became marked also in the near-ground air layer. Results of measurements of extreme temperatures 5 cm above the ground have been compared in the table 7. The highest maximum temperatures at this level occurred on a S-facing slope. The Sant valley bottom possesses specific microclimatic conditions, e.g. night drops of temperature in August 1975 attained even −6.0°C. Very big thermic contrasts happened also on an intraforest clearing on a northern slope. Diversification of temperature at the level of 20 cm in the investigated profile is represented by figure 8C. The analysis of the diurnal course of temperature at this height in the period of 17—23 August 1975 points to persistance of differences of the order 1.5—4.0°C during 24 h. The
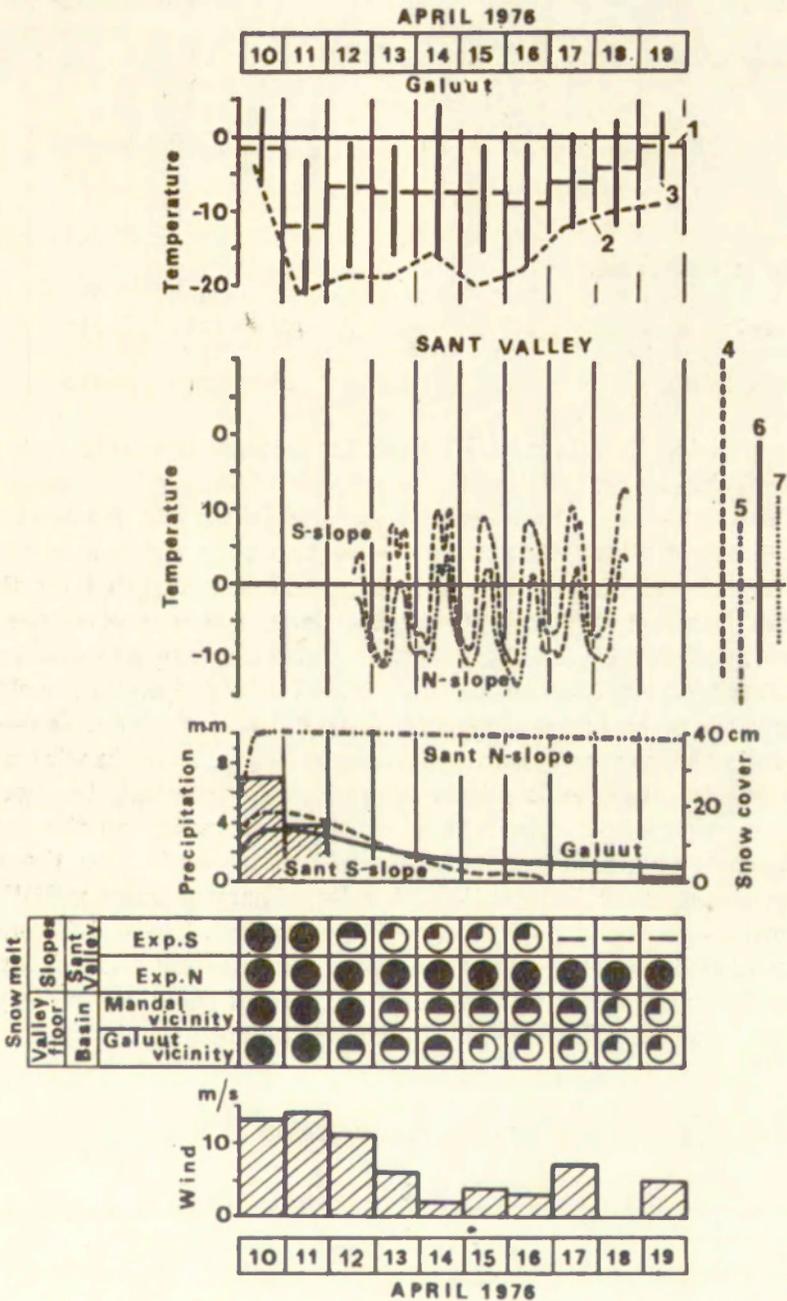
Fig. 16. Weather conditions and snow melt during the period 10—19 April, 1976, in the Sant valley and its vicinity (according to Froehlich *et al.* 1977)

1 — mean air temperature; *2* — minimum temperature at the ground surface; *3* — air temperature amplitude; *4—7* — temperature amplitude at the ground surface; *4* — S-slope in Sant valley, *5* — N-slope in Sant valley, *6* — ground surface in the basin, *7* — ice surface in the basin

Table 7. Extreme values of air temperature (in °C) on the 5 cm level above the soil surface during the period 18—23 VIII 1975

| Measurement point | Height asl. m | Air temperature [°C] | | | Greatest max. | Lowest min. |
| | | Mean | | | | |
		max.	min.	ampli-tude		
Valley bottom	2410	26.2	—0.3	26.5	31.1	—6.0
Lower part of slope exposed to S	2415	27.8	2.2	25.6	33.6	—4.0
Slope exposed to S	2470	28.9	5.0	23.9	34.6	—0.4
Slope exposed to N (forest)	2470	19.1	3.2	15.9	24.1	—1.6
Slope exposed to N (clearing)	2470	27.6	1.6	26.0	33.6	—4.4

sharpest division in values of all climatic elements is visible at the foot of the N-facing slope.

The characteristics of energy and thermic delivery in the Sant valley presented above allow us to state close connections which hold between magnitude of radiation and temperature and are modified by the influence of local conditions. The S-facing slope, which receives the highest amounts of energy (on the analyzed profile), can be characterized by the highest temperatures on all investigated levels. Simultaneously, this is an area with the biggest thermic contrasts in the system day—night. The N-facing slope receives less solar energy, particularly in winter when at noontime it composes less than 30⁰/o of energy reaching the horizontal surface, whereas it constitutes over 200⁰/o of energy on the opposite slope. The factor which limits heating of ground surface on the N-facing slope in summer is retention of a large part of solar radiation by tree crowns and shallow occurrence of permafrost. These differences in quantity of delivered heat determine not only differentiation of air temperature, but also amount of evaporation, rate of snow cover disappearance and — what follows — the soil water balance (phot. 19).

WATER CIRCULATION

by

January Słupik

INTRODUCTION

The investigations carried out in the second half of June and in July 1974 (Słupik 1975; Niedźwiedź et al. 1975) and in April 1976 (Froehlich and Słupik 1977 a; Froehlich et al. 1977) allow us to present the areal pattern of moisture in the asymmetrical Sant valley (fig. 3). Conditions

of infiltration were estimated in 72 points on the soil surface and at the depth of 20 cm. Precipitation totals were recorded in 6 points, and snow thickness and density was measured in the last phase of winter on a N-facing slope. Overland flow was observed in 42 points, while potential evaporation in 2 points on N- and S-facing slopes.

INFILTRATION CONDITIONS

Infiltration capacity, measured with a cylinder infiltrometer, is little differentiated spatially. It amounts to 0.8—0.9 in the Sant valley bottom, 1.5—3.0 on N-facing slopes, 1.5—3.9 on S-facing slopes and 1.1—3.8 mm/min on N—E slopes (Słupik 1975). Permeability of waste covers is, as a rule, higher at the depth of 20 cm. Spatial differentiation of infiltration conditions is reflected in rainy water distribution.

RECEIPTS OF WATER

Areal variability of rainfall is similar over the whole catchment basin (Niedźwiedź et al. 1975). In the 1974 summer, the highest yield of rain amounted to 33 mm/12 h, 11.5 mm/3 h, 7.2 mm/1 h and 0.27 mm/min. In the 1976 winter the highest diurnal snowfall reached 44 mm of water layer (Froehlich et al. 1977). Just after the snowfall the snow becomes distributed evenly over the basin area. Quick snow-melt on the S-facing slope, even in the middle of winter (fig. 16), causes, however, that with incoming of the melt-period the snow cover extent is highly differentiated (Froehlich et al. 1977) and limited by the valley axis parallel to latitude (phot. 19). Snow cover persists only on the N-facing slope. Its thickness in April 1976, i.e. in the last stage of winter, was 40 cm (phot. 20), and the total water equivalent of snow — 107 mm. This thick snow mantle had accumulated since autumn, both from precipitation and deflation (Froehlich et al. 1977).

Continuous accumulation of snow cover on the northern slope and quick snow melt on the southern one in the depth of winter is stimulated by heat radiation balance (cf. fig. 8, 15). This difference in snow cover retention reaches its maximum at the beginning of the melt period. Thus in diversification of water receipts one ought to detect the cause of storage of a bigger amount of moisture in waste covers on the N-facing slope and at the valley floor. This could have created an impulse for permafrost origin and certainly conditions its present existence. Permafrost in turn — being an impermeable layer — facilitates holding of moisture shallow under ground.

WATER DISTRIBUTION

Rain and melt water distribution happens through evapotranspiration, infiltration and surface run-off. Magnitudes of overland flow on

slopes with soil cover in summer are similar, irrespective of the vegetation type (Słupik 1975). In July 1974 it was less than 0.1 mm. Only on bare rock surfaces out of 103 mm of rain 9—23 mm of water layer flowed away, with the max. intensity 0.3 l/s, during a rainfall 0.27 mm/min in yield. Higher frequency and intensity of overland flow can be observed on the S-facing slope, beneath walls and stones. Traces of this concentration flow vanish before reaching the valley floor. In consequence, the distance of overland flow is shorter than the slope length, and the surface concentrated run-off from the Sant basin to the Tsagan-Turutuin-gol river can take place only as a result of a catastrophic event. In summer 1974, even a rainfall exceeding 30 mm did not create any run-off in the valley floor (Słupik 1975).

In the melt-period the overland flow can be higher only on a N-exposed slope, as pointed by high water content in snow, an abrupt course of melting and frozen ground (Froehlich *et al.* 1977). In such a situation one noted an increased overland flow on N-facing slopes, both in the semi-arid zone (Vodogretskyi, Krestovskyi 1975) and in the Canadian arctic (Landals, Don Gill 1972). Part of melt waters soaks into the soil and restores permafrost resources, while its excess forms subsurface flow over the thawing active layer. The flow happens yearly as high moisture of the valley bottom in the part near the N-facing slope, and exceptionally (as was the case in the early summer 1975), creates run-off in the valley bottom, gradually fading away near its mouth.

Potential evaporation was measured with an evaporimeter of Piche type. In July 1974 maximum diurnal values reached 11.2 mm on a S-facing slope and 7.0 mm on a N-facing one. Minima were 0.6 and 0.4 mm, respectively. Losses of water due to the sublimation are 0.1—0.2 mm/24 h on the N slope. On the S-facing slope sublimation intensity is considerably larger, as indicate vanishing of snow cover, without any traces of water flow.

WATER CIRCULATION DURING THE YEAR

The S-facing slope is dry throughout the year and possibilities of transpiration are restricted to a short time after rainfalls, when moisture resources become absorbed by a thin near-surface soil layer, without reaching a ground water level. Blagoobraztsov (1964) confirms conclusions about the lack of ground water recharge from precipitation in the Ala-Tau Mts, and Ming-Ko Woo (1976) about the lack of response of a ground water level on slopes without snow during the melt-period. Despite good permeability of soil, deeper layers remain dry because of shortages of precipitation in relation to evaporation, the more so, because the lack of moisture in winter cannot be compensated by summer precipitation.

The N-facing slope is much more humid, owing mainly to snow cover accumulation during the winter. Melt waters facilitate growth of vegetation before a complete thawing of the active layer, for the rise of capillary water from deeper soil layers is as yet impossible (Froehlich and Slupik 1977 b). According to big changes of precipitation totals from year to year, soil moisture after the melt-time can be very small, as e.g. in 1974, or very big, e.g. in 1975, but usually sufficient for plant growth (fig. 17).
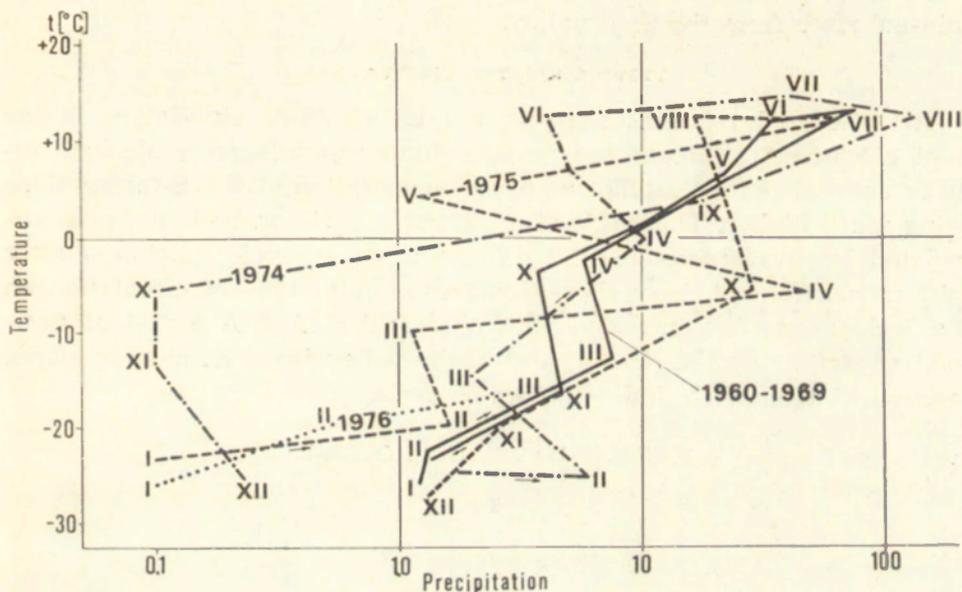
Fig. 17. Mean monthly air temperatures and precipitation totals at Galuut (2160 m asl.) for the period 1960—1969, for the years 1974, 1975 and for January—March 1976 (according to Froehlich and Slupik 1977a)

Presence of permafrost on the N-facing slope and in the Sant valley floor plays an indirect role in water circulation, restricting percolation of rain or melt water into soil and favouring persistance of high soil moisture in the active layer after rainfalls and melt-period. Depth of freezing corresponds at least to depth of thawing in the yearly cycle (Gavrilova 1974). This means that permafrost does not tend to degradation, and water circulates within the active layer. This can be proved by lack of permanent springs and icings in the Sant valley in winter and by a quick response of water circulation to rainfalls and snow-melt, typical of supra-permafrost waters in the active layer (Ming-Ko Woo 1976). A periodical moisture excess on the one hand, and low soil temperature connected with the occurrence of permafrost on the other, do not create optimum conditions for growth of tree roots, because of re-

duction of an absorbed water amount by plant roots. Thus, the over-ground portions of plants may be physiologically dryed. While the active layer is thawing, water becomes gradually passed to the root zone. Roots grow in breadth, as the growth deep into ground is hindered by permafrost (*cf.* Brown and Pewé 1973).

The valley bottom, fed with water from the N-facing slope, is the most humid in segments adjoining this slope. In other spots it is drier and in the mouth section devoid of permanent surface and subsurface run-off. It indicated the lack of alimentation of the Tsagan-Turu-tuin-gol river from the Sant valley.

TYPES OF WATER CIRCULATION

All discussed relations compose a type of water circulation in the Sant catchment basin. Water receipts from rainfalls resemble one another over the entire catchment basin, evaporation of the S-facing slope being much higher. The mechanism of water cycle on both slopes is stimulated by heat radiation and differs in water cycle quickness after rain or snowfalls. A very short (some days only) time of circulation on the S slope can be contrasted with a greatly elongated period of rain--waters storage on the N slope and in the valley floor. Remaining slopes represent intermediate indices of water cycle.

PRESENT-DAY SOIL PROCESSES

by

Alojzy Kowalkowski

Contemporary soil catenas of Sant valley are closely connected with the covers formed by the cryogenic wastes of different ages. The processes of transport, exchange and accumulation, occurring in the respective relief elements, show, however, quite different features. Both the direction and the intensity of the above processes depend upon the exposure, surface gradient as well as the altitude, while their arid character intensifies towards the outlet of Sant valley into Tsagan-Turutuin-gol valley.

CLIMATO-OROGRAPHIC CONDITIONING OF CONTEMPORARY PROCESSES

In the lower part of the drainage basin, up to 2000—2300 m asl., situated within thermal inversions, and particularly on the south-facing slope having poor vegetation (Kowalkowski and Pacyna 1977), as well as wide diurnal temperature extremes, and, at the same time, remaining snowless and extremely dry in winter, there occur at present intense processes of soil profile transformation as a result of both granular thermic disintegration and gravitational transport (Pękala 1975). The elec-

Phot. 7. N-facing slope in the upper portion of valley. The pene-structural rocky slope with intensive processes of creeping, slope-wash and deflation. Isolated trees at the upper margin of the larch forest
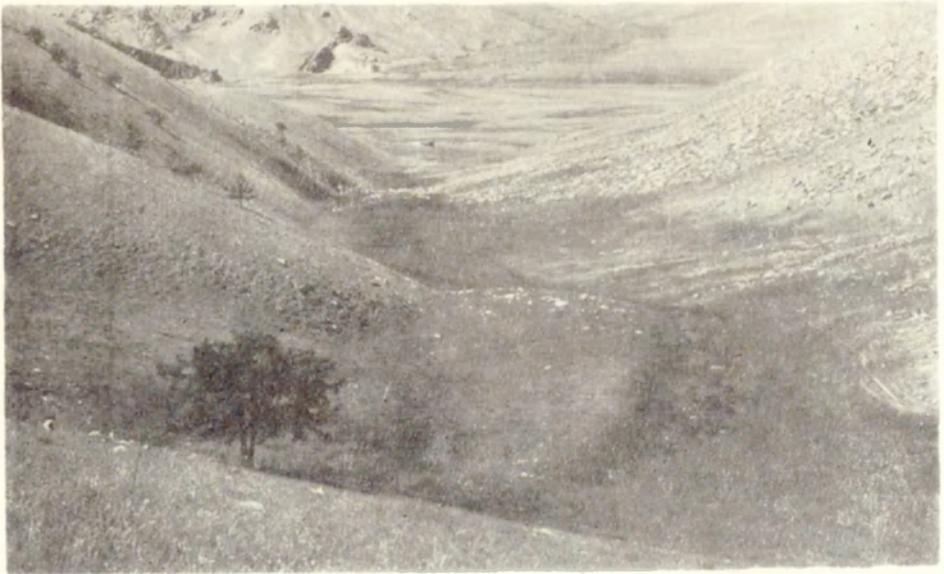
Phot. 8. Lower valley segment with the Pleistocene debris avalanches on the S-facing slope. These blocks create steps in the valley floor. Between them wide plains covered by thick deluvia. In moister furrows dark dense vegetation cover
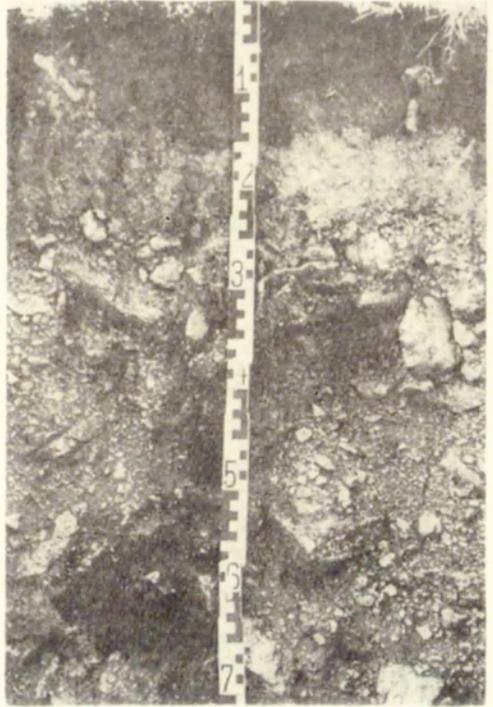
Phot. 9. Lower segment of the Sant valley bottom with fronts of debris avalanches derived from the southern slope, inherited from the cooler climate. At the front steppe meadow with *Iris*

Phot. 10. Dry steppe of the base of southern slope covered by fine granitic scree

Phot. 11. Mountain dark chestnut soil of medium thickness developed on the congelifluctional sheets of the N-facing slope — soil profile 013

Phot. 12. Dark chestnut soil very thick with larch forest patches, developed on the covers of the northern slope — soil profile 011
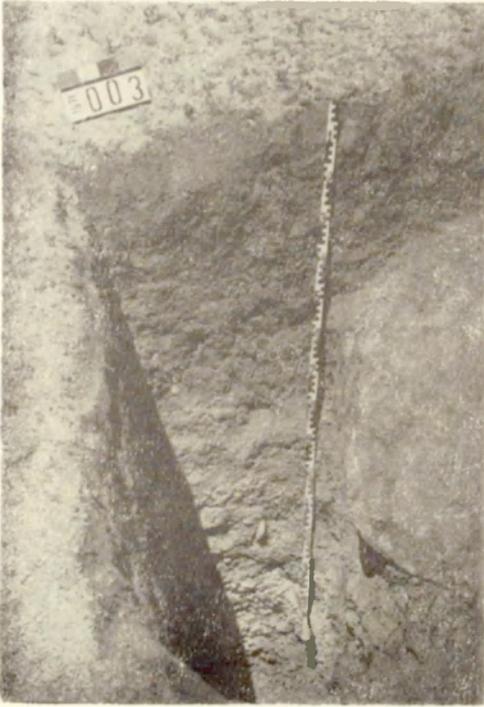
Phot. 13. Light chestnut soil formed in the thick deluvial—proluvial deposits at the base of S-facing slope — soil profile 003

Phot. 14. Mountain chernozem very thick in the valley bottom, developed in the active layer on the solifluctional and deluvial deposits — soil profile 001

tron-microscopic analysis of the quartz grains has corroborated the domination of the thermal disintegration forms with simultaneous low intensity of the processes of chemical weathering accompanied by the occurrence of silica coatings typical of the dry climate (Kowalkowski and Mycielska-Dowgiałło 1980).

The intense washing off, deflation, debris flows combined with the accumulation processes result both in constant rejuvenation of soils as well as in their stony content. As a result of the excess of evaporation over precipitation the bases accumulate in upper horizon in the soil profile, partially in the form of poorly developed carbonate layer, while the dryness of the soil climate favours a rapid mineralization of the organic debris.

The central part of the valley, up to 2600 m asl. is considerably wetter and warmer (Niedźwiedź *et al.* 1975), the northern slope in particular. Large water supplies that accumulate during the winter half-year in the form of snow or frost active layer intensify the physico-struc-
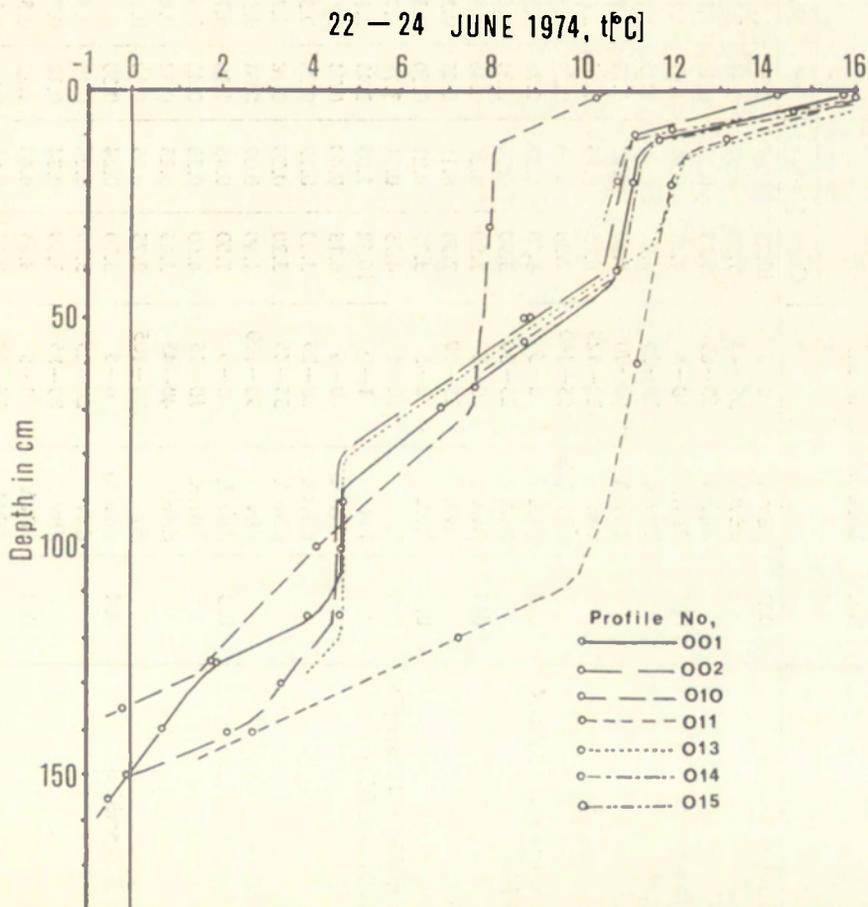
Fig. 18. Soil temperatures in the profiles no. 001, 002, 010, 011, 013, 014, 015

TABLE. Exchangeable cation composition

Soils	Profile No.	Genetic horizon	Depth in cm	Exchangeable cations in me/100 g of soil					Sorption capacity me/100 g of soil Th	in % Th			
				Ca^{+2}	Mg^{+2}	K$^+$	Na$^+$	S	Th	Ca^{+2}	Mg^{+2}	K$^+$	Na$^+$
On the valley bottom	002	dBvtA	0—5	10.25	0.67	0.96	1.96	13.84	25.32	40.5	2.6	3.8	7.7
		dBvtA	35—40	7.50	0.52	0.67	2.26	10.95	18.15	41.3	2.9	3.7	12.5
		dBvtA	60—65	7.75	0.53	0.30	1.74	10.32	19.65	39.4	2.7	1.5	8.8
	001	dBvtA	0—5	8.13	0.51	1.67	1.52	11.83	16.11	50.4	3.2	10.4	9.4
		dBvtA	20—25	6.00	0.40	1.23	1.30	8.93	11.40	52.6	3.5	10.8	11.4
		dBvtA	60—70	8.10	0.52	0.78	7.91	17.31	17.31	46.8	3.0	4.5	45.7
		dBv	120—125	6.75	0.45	0.26	2.00	9.46	9.46	71.3	4.8	2.7	21.1
		dBvTjäle	155—160	2.30	0.16	0.21	0.87	3.54	4.55	50.5	3.5	4.6	14.1
On the upper part of the N exposition	014	BvA	0—5	4.10	0.27	0.76	0.35	5.48	9.98	41.1	2.7	7.6	3.5
		BvA	25—30	3.90	0.26	0.24	0.61	5.01	9.21	42.3	2.8	2.6	6.6
	015	BvA	0—5	3.90	0.25	0.46	0.52	5.13	10.30	37.9	2.4	4.5	5.0
		BvA	25—30	2.30	0.15	0.05	0.35	2.85	7.35	31.3	2.0	0.7	4.8
	016	BvA	0—5	3.35	0.22	0.50	0.35	4.52	8.92	38.7	2.5	5.6	3.9
On the middle and lower part of the N exposition	010	L	10—1	4.75	0.31	3.71	1.74	10.51	52.50	9.0	0.6	7.0	3.3
		FH	1—0	16.62	1.05	2.95	2.17	22.79	55.79	29.8	1.9	5.3	3.9
		dBvtA	0—5	6.15	0.40	0.74	0.61	7.90	13.41	45.9	3.0	5.5	4.5
		dBvtA	20—25	3.00	0.19	0.28	0.52	3.99	9.29	32.3	2.0	3.0	5.6
		dBvtA	35—45	3.20	0.20	0.18	0.78	4.36	8.75	36.6	2.3	2.0	8.9
		dBv	90—100	1.40	0.09	0.08	0.52	2.09	4.00	35.0	2.2	2.0	13.0
	013	dBvtA	0—5	7.00	0.46	1.10	0.78	9.34	15.68	61.6	2.9	7.0	5.0
		dBvtA	10—15	4.60	0.30	0.46	0.61	5.97	11.37	40.5	2.6	4.0	5.2
		dBv	40—45	3.65	0.23	0.32	0.61	4.81	9.12	40.0	2.5	3.5	6.7
		Bv	100—105	2.75	0.05	0.10	0.17	3.07	5.98	46.0	0.8	1.7	2.8
On the S exposition	004	dBv(A)	0—5	3.70	0.24	0.30	0.52	4.76	7.76	47.7	3.1	3.9	6.7
		dBv	20—25	3.70	0.26	0.13	0.52	4.61	6.67	55.5	3.9	1.9	7.8
		dBv	80—85	3.50	0.24	0.12	0.78	4.64	5.99	58.4	4.0	2.0	13.0
	008	dBvA	0—5	8.65	0.40	1.22	0.52	10.79	14.05	46.2	2.8	8.7	3.7
		dBvA	25—30	7.75	0.51	0.94	1.13	10.33	12.41	62.4	4.1	7.6	9.1
		dBvA	55—60	4.60	0.28	0.36	0.87	6.11	8.85	52.0	3.2	4.1	9.8
		dBv	90—100	3.00	0.19	0.15	0.87	4.21	5.63	53.2	3.4	2.7	15.4
		dBv	110—120	2.30	0.15	0.14	0.61	3.20	4.59	50.1	3.2	3.0	13.3

tural and the chemical transformations. The above processes are mo-
derated in spring and summer, under the shelter of the forest-grassland
plant communities that protest the soils against direct insolation as well
as surface denudation.

Rapid freezing of the stony-loamy soil gives rise to the formation of
the so-called dry soil-cryon (Targuljan 1974; Volkovincer 1975) and
does not yield the phenomena of cryoturbation, solifluction and thixo-
tropy.

The permafrost with an active layer down to 60—150 cm (fig. 18)
enhances both the chemical agressiveness of the soil solutions and the
intensity of the translocation of the dissolved mineral compounds and
organic matter. During the dry periods the latter migrates towards the
evaporation surface in the upper warmer part of the profile, while
during the rain periods it is carried by the drainage water towards the
bottom of the valley. Illustrative of the above phenomena is the inverse
relationship between the water content and the temperature found in
the frozen ground and in the surface layer subjected to the insolation
(fig. 19, prof. 001, 002; phot. 14). The maximum moisture content observed
at 40—125 cm depth in the soils, in this part of the valley bottom that
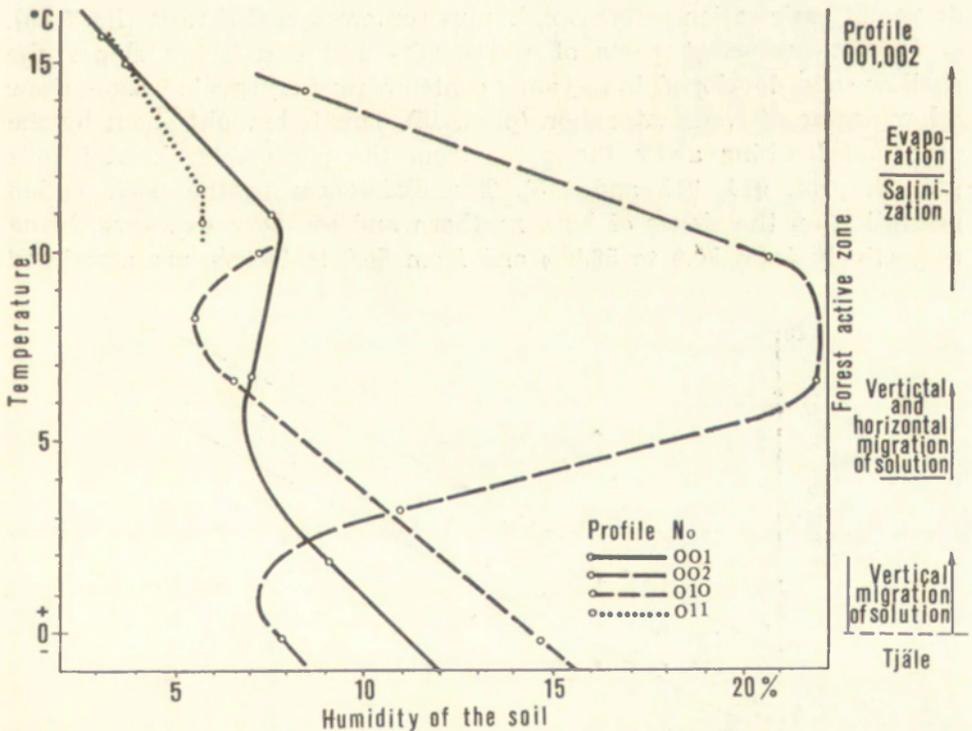
Fig. 19. Relation between soil temperature and water content in the active layer
of permafrost

adjoins to the north-facing slope, can be regarded as a result of the transit draining from this slope. Natrium saturated dBvt and dBv layers in the soil along the axis of the valley bottom result also from this process (prof. 001; tab. 8).

In the soils of the more humid and cool upper part of the valley, over 2600 m asl., there occur the processes of the mechanical and chemical disintegration of rocks and wastes along with the local aggradation of the soil profile or washing out the products of these processes. There prevail here, according to the Stepanov's criteria (Stepanov 1975), the hydrothermal conditions most favourable to the humus accumulation in the shallow soils which frequently are formed immediately on the solid rocks.

EFFECT OF EXPOSURE UPON CONTEMPORARY SOIL PROCESSES

Conditioned by sharp microclimatological contrasts the differences in the processes of exchange, transport and accumulation on the opposite, northern and southern slopes (referred to as zonal slopes by Bykov, 1954), produce in the soils different features of the order of altitudinal zones. The set of soil asymmetry indicators includes: sorption capacity, degree of basic cation saturation, humus content and C/N ratio (fig. 8,20).

In the near-crest parts of the north- and east-facing slopes the shallow soils, developed from young contemporary cryogenic wastes, show a low degree of bases saturation (phot. 15). This is brought about by the continual leaching away the bases from the permeable skeletal soils (tab. 8, prof. 014, 015 and 016). The differences in the basic cation saturation on the slopes of both northern and southern exposure, being respectively from 50.0 to 56.9% and from 50.0 to 76.8%, are associated
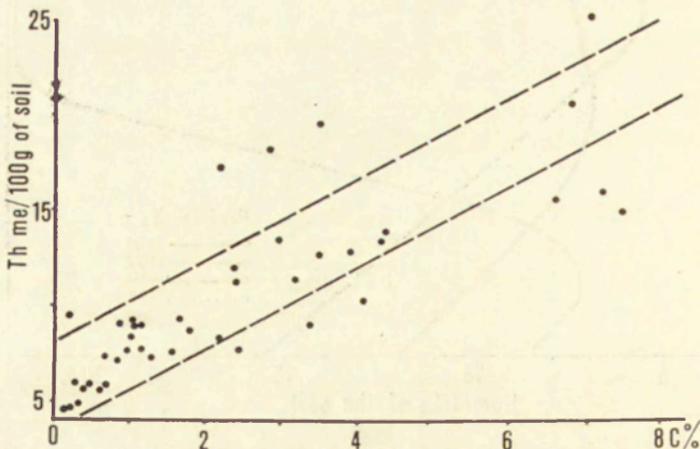
Fig. 20. Relation between organic carbon content C and sorbtion volume Th

with the different types of the water régime (tab. 8). Generally speaking, however, at a relatively low sorption capacity, ranging from 7.76 to 25.3 me per 100 g of soil, there occur, in the soil-sorption complex, very low amounts of magnesium and potassium: respectively from 2.0 to 4.8 and from 0.7 to 10.8% of the sorption capacity, along with considerable biogenic accumulation of the above cations in the upper layers. The scarcity of the above components as well as that of calcium, is probably dependent upon the mineral composition of the granodiorite rocks. The features of biogenic accumulation that overlaps the series of the slope sheets, are found also in the distribution of titanium, copper and lead in the soil profile (fig. 20).

The increased quantity of natrium, in relation to Mg^{+2} and K^+, in the sorption complex in the soils of both slopes, testifies to the arid character of the mesoclimate. The intra-soil water circulates, for a period towards the evaporation surface and for another towards the frozen bottom part which results in the increased amount of natrium in the lower part of the soil profile.

Differentiated hydrothermal conditions as well as migration of mineral compounds result from the differences in both quality and quantity of the humus. As a rule, there is a simple relationship between the humus content and the sorption capacity, the latter being one of the soil quality indicators (Fig. 21). However, the acid humus in wetter, leached soils in the near-crest part of the north slope, as well as the humus base-saturated in the soils in the valley bottom do not comply with the above pattern. More pronounced, however, are the relations between the humus quantity and quality, expressed as the C/N ratio, and the same applies to the relations between the sorption capacity and the age of both the parent rock and the soil (fig. 21). The relict mountain cryogenic chernozems on the cryoplanation terraces, the younger mountain dark chestnut soils developed from the brown, cryogenic weathered materials, as well as the poligenetic mountain dark chestnut chernozems on the slope of northern exposure are rich in humus, the latter being to a high degree saturated with basic cations and having high sorption capacity. The deluvial chernozems in the bottom of the valley show the distinct connection with the soils mentioned above, though their sorption capacity is much higher.

Along the lower edge of the northern slope there extend brown soils having low humus content and low sorption capacity. The above cold--climate soil has been preserved and exists in the valley zone receiving the least amount of thermal energy (cf. chapter "Processes of energy exchange") under hydrothermal conditions unfavourable for the development of chestnut soils.

The denuded and relatively young dark chestnut soils in the upper part of both northern and eastern slopes, as well as soils in the central
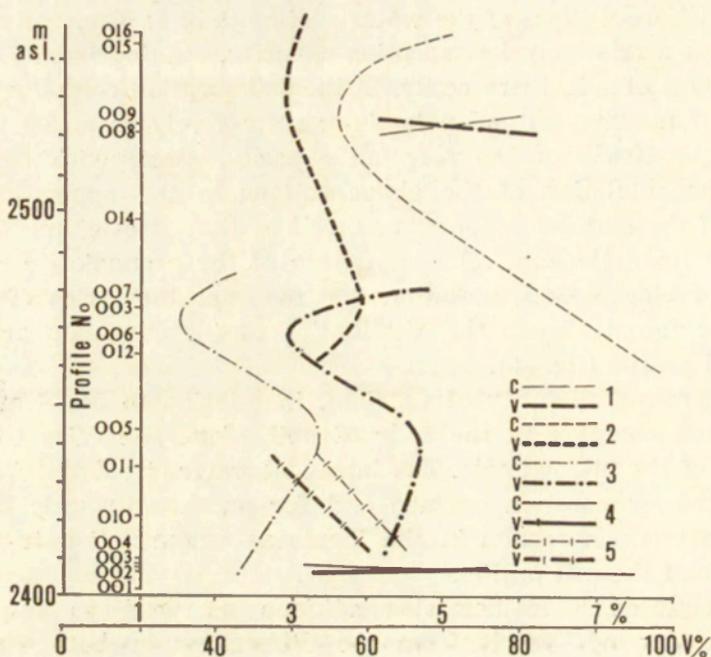
Fig. 21. Soil complexes of the Sant valley in the evolutionary sequence based on the relationship between organic carbon, the degree of basic cation saturation and altitude above sea level

Evolutionary · soil sequence: *1* — mountain chernozems and dark chestnut soil; *2* — mountain dark chestnut cryohumid soils; *3* — mountain light chestnut cryo-arid soils, poorly developed; *4* — mountain chernozems; *5* — mountain brown soils

part of the slope, contain different amounts of humus. The above soils, however, appear to have low sorption capacity that approximates the *Th* value characteristic of the thermic waste of granodiorite.

The degree of basic cation saturation in the BvtA and Bv horizons in the soil catenas of a cross-section of the Sant valley, increases from the relatively wet and leached soils in the near-crest part of the northern slope across the valley bottom to the dry soils of the near-crest part of the southern slope (fig. 20). The above saturation degree constitutes an indicator adequately illustrating the contemporary diversity of water relations in the soils, from the permafrost-evaporative ones on the slopes of northern and eastern exposure to the evaporative soils on the slopes of southern and western exposure.

The set of soil-forming factors operating in the individual topographical units have brought about the development of the mosaics of soils with retardive, regressive or transgressive features.

The Sant valley soils could be arranged in 5 sequences on definite morphological units, which depend upon the altitude, humus content and degree of cation saturation (fig. 8), and this confirms the validity of

the assumed classification (Kowalkowski and Lomborinchen 1975). Against the background of the distinct soil groups the possibility arises of their chrono-historical classification that takes account of the cycles of the soil cover changes (Vreeken 1975).

GEOMORPHIC PROCESSES AND THE PRESENT-DAY RELIEF TRANSFORMATION

by

Kazimierz Pękala and Tadeusz Ziętara

A type of covers, together with morphology and climatic conditions of slopes differentiated as to exposition and height, determines the dynamics of areal variability of geomorphological processes (fig. 22; phot. 1—10).

Processes of physical weathering on dry S-facing slopes take the form of exfoliation and microgelivation. Macrogelivation, influenced by frost, becomes visible over 2500 m and in zones of occurrence of permafrost patches. Changes of weather conditions, and especially of intensity and distribution of atmospheric precipitation, influence the course and dynamics of weathering. Snowless winters and relatively arid summers lead to formation of fine regolith under the influence of exfoliation and grainy falls. Falling of weathering mantle was observed during violent summer hailstorms (Pękala and Ziętara 1977). During snowy winters, on S-facing slopes (where snow melts a couple of hours after snowfalls), physical weathering is also intense (Froehlich *et al.* 1977). Snow-melt water freezes in fissures, thus producing grain and block decomposition of rocks.

Table 9. Physical weathering (accumulation at the feet of rocky walls)

Period	From	To	Average	mm
	g/m²		g/m²	
25 VI—26 VII 74	3.6	53.5	14.5	0.012
25 VI—27 VII 75	24.0	246.0	68.4	0.027
1974/75	42.6	329.8	334.0	0.134

Yearly average for 1000 years*   0.1

* Calculated from the volume of a talus cone covering fossil flora.

Falling in the wet 1975 summer, measured at the foot of rockwalls, was twice as big as in the 1974 summer characterized by low precipitation (tab. 9). The measurements made during the 1974 and 1975 expeditions demonstrated that rock surfaces can retreat with the velocity over 0.1 mm/yr, which corresponds to the amount of grain talus accumulation over 1000 yrs (Kowalkowski *et al.* 1977).

Relict terraces and cryoplanation shelves on the watershed are presently modelled mainly by frost heaving, niveoeolian processes, and physical weathering. These forms are nowadays transformed by weathering, slope wash, deflation, and eolian accumulation (phot. 2, 3, 4). Microgelivation and eolian corrasion cut off large stones (Pękala 1975; Kowalkowski *et al.* 1977).

Relict block streams in upper sections of S-facing slopes have undergone stabilization due to permafrost vanishing and drying. Yet, considering temperature, precipitation variability and high steepness of slopes, these streams are in an unstable balance.

On the S-exposed slopes the dominant phenomena are: weathering of block covers and creeping caused by needle ice, mechanical piping, and strong water saturation of fine material during winter thaws and spring snow-melt (Froehlich and Slupik 1977a). Grainy weathering mantles become degraded as a result of slope wash and deflation. Deluvial accumulation predominates in lower sections. Herds of farm animals as well as marmots (*Marmota marmota*) have a considerable share in degradation of S-facing slopes (Kowalkowski *et al.* 1977; phot. 21).

N-facing slopes, due to higher water content and occurrence of permafrost patches, have loamy-debris covers which undergo creeping (tab. 10). It is creeping of the salifluctional type which affects soil covers with sod (phot. 7), even on interforest clearings. Upper sections of N-facing slopes are covered with a thin regolith and modelled by slope wash and deflation (Pękala and Ziętara 1977).

Table 10. Soil creep on the N-facing slope

Soil cover, m asl.	Soil creep [cm]		
	27 VI—27 VII 1974	27 VII 1974 — 27 VII 1975	average
Meadow in the open woodland, 2480	1—2	12.0—49.0	20.4
Meadow above the forest, 2640	1—3	1.5—28.0	12.1
Meadow above the forest, 2660	2—12	1.0—65.0	7.5

The Sant valley floor is shaped by a complex of processes which lead to constant filling with deluvial-colluvial material, delivered mainly from S-facing slopes and partly from lower sections of opposite slopes. Periodically, covers in the valley floor are set in motion locally by solifluction and washing out by water erosion following heavy summer downpours (Starkel 1975; Kowalkowski *et al.* 1977). A peculiar form of creeping at the valley bottom are active earth-flows with changeable dynamics of motion (fig. 23; phot. 1, 3). Under favourable humidity conditions brought about by heavy snowfalls and summer precipitation,

movements of earth-flows reach 4—7 cm/yr (Pękala and Ziętara 1977).
Those active loamy debris lobes are washed or dissected by shallow
erosional furrows with surfacial waters. Simultaneously, wet depressions
and niche hollows at the base of lobes are infilled with fine material
washed down mostly from S-facing slopes. Solifluction flows situated
down valley at the valley floor (under 2300 m asl.) are now non-active,
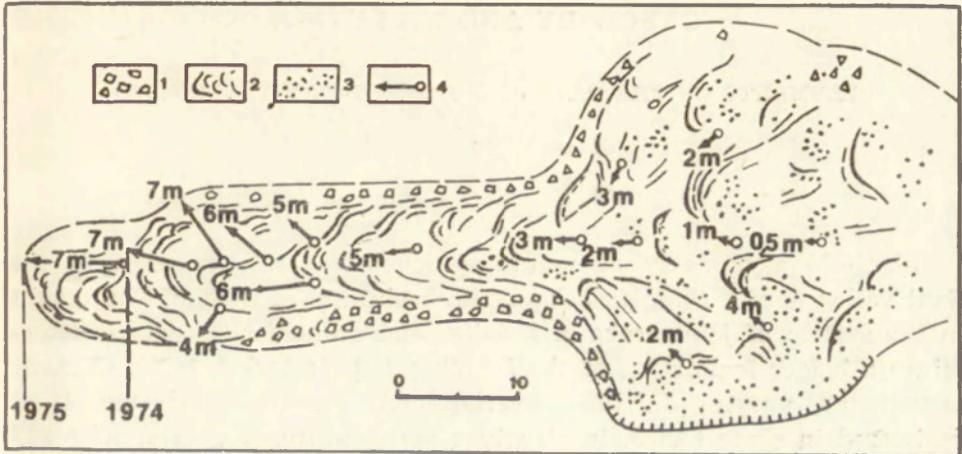but can become activated in favourable humidity conditions.

Fig. 23. Earth flow over the frozen ground down valley of the basic cross-section,
in the valley bottom

1 — older debris at the margin of flow; 2 — individual lobes; 3 — thufurs; 4 — total rate
and direction of movement in meters between 27 VI 1974 and 27 VII 1975

A clear asymmetry of processes transforming land-relief and older
covers becomes pronounced in the Sant valley (Kowalkowski *et al.* 1977).
Shelves and cryoplanation terraces are relicts of a more humid climate.
Weathering-solifluctional block covers which mantle steeper concave
S-facing slopes, suffer exfoliation and microgelivation and are washed
by surfacial and in-soil waters. The foot and lower sections of these
slopes are accreted mainly with deluvial material.

Gentler, convex N-facing slopes in lower deforested sections are
modified by creeping, with the participation of permafrost. In forest
communities one did not observe any more intense processes. The upper
sections, however, are shaped by slope wash and deflation.

Episodic accumulation of deluvia and colluvia takes place at the
valley bottom, whereas solifluction and frost-heaving — in zones with
a higher water content.

Natural processes, particularly gravitational translocations of covers,
are hastened by man's economic activity, i.e. mainly through forest-
-clearance and overgrazing. Herds of farm animals provoke a mechanical
removal of soil covers.

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TYPOLOGY AND EVOLUTION

ELEMENTS OF THE PAST AND PRESENT-DAY TENDENCIES

by

Alojzy Kowalkowski, Kazimierz Pękala and Leszek Starkel

Manifold asymmetry of natural phenomena and processes in the Sant valley is of a complex origin. The beginning of it should be sought in the system of joint craks in granites and granodiorites, which determines a bigger inclination of the S-facing slope (Starkel 1975). Climatic asymmetry, varying in time, overlaps with a structural one. It is registered in slope forms, in structure and texture of covers, soils and present-day processes (Kowalkowski *et al.* 1977). It is not a simple asymmetry, known to us from territories of Europe, Siberia or Canada (*cf.* Kennedy 1976). Richter *et al.* (1963) assume as typical of a cold and dry climate the so-called warm asymmetry, i.e. presence of a gentler and more active N-exposed slope (with permafrost) and a steeper, undercut opposite slope.

Yet, the Sant valley's slopes, though apparently compatible with this arrangement, have at the same time a concave profile of a steep southern slope and a slightly convex one of a gentle slope (phot. 1,5).

EVOLUTION IN A COOLER (MORE HUMID) CLIMATE

At the threshold of the last cold period, the Sant valley displayed already a structurally outlined asymmetry of slopes and a stable contrast of the energetic balance of the opposing slopes. From that time originate principal relief elements on interfluves and slopes, as well as parts of forms at the valley bottom. Cryoplanation terraces and shelves under ridge rocks, now crumbling to pieces, bear witness to descent of the cryoplanation "belt" down to ca 2400 m asl. (Pękala 1975; Starkel 1975). Soils rich in humus (the type of mountain cryogenic chernozem) have been preserved on them. The southern slope, probably reacher in water content and with considerable temperature oscillations in summer, was a place of block-fields and talus debris creation. The latter slide down

periodically as debris avalanches as far as the valley floor, damming it along several reaches (fig. 7; phot. 8, 9). Soils rich in humus were formed in depressions among blocks on this slope (Kowalkowski *et al.* 1977). On the other hand, the N-facing slope melted rarely and was comparatively little active, which is marked in preservation of its concave-convex profile with the cryogenic brown waste series. This nearbottom convexity was linked up to shifts of the valley floor axis under the overshaded slope by episodic block streams from the S slope. Relict brown soils, preserved in lower parts of the N slope, reveal a character of climate in the cold period.

TRANSFORMATION OF RELIEF AND SOILS IN THE HOLOCENE

Warming in the Holocene led to permafrost retreat and checking of gravitational processes on warm S slopes. The chestnut process over-lapped on older soils under conditions of constant removal of fine material and intensification of thermic weathering. Cryoplanation terraces also ceased to evolve and their degradation was set in motion (under 2700 m asl.). Material, washed away from slopes, was gathered at their foot, filling also irregularities in the longitudinal profile of the Sant bottom. The N-exposed slope proved to be more active in congelif-luctional movements above the frozen bedrock. Intensity of those processes must have been low, since it enabled larch forests to encircle slopes and chestnut soils to develop in the loamy-debris solifluction
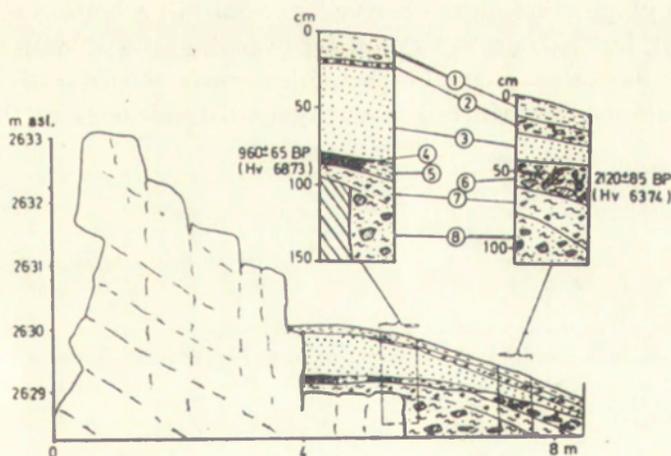
Fig. 24. Profile of cover deposits at the foot of a relict tor on the nothern slope of the Sant valley (by K. Pękala after Kowalkowski *et al.* 1977)

1 — present-day soil (parachernozem); 2 — charcoal horizon; 3 — granite granular horizon (grit); 4 — dated peat in a silty layer with an admixture of granite grit; 5 — soil; 6 — loam with debris with dated charcoal; 7 — clayey loam with fine debris; 8 — clayey blocky cover

deposits. Higher water content made leaching processes possible in the active layer, which — with time — led to a clearly distinct physico--chemical character of soils in the valley floor beneath both slopes.

The upper Holocene had a marked tendency to increased aridity of climate, which found reflection in accumulation of grain regolith under rock walls (fig. 24). This tendency has been going on at least throughout the last millennium. It was parallelled by accelerated soil erosion connected with overgrazing and forest clearance. This can be proved by a discovery of primitive iron-blast furnaces, covered with deluvia, 1 km from the valley mouth. Their charcoal was dated on 1670 ± 35 yrs BP in Hannover (Kowalkowski *et al.* 1977). Man's activity also explains presence of 2—3 m thick deluvia at the foot of slopes and in valley bottoms, superimposed on well-developed soils of chernozem and chestnut type. The deluvia profiles show also increase of a material fraction (and humus decrease) in the uppermost parts, which indicate an advancing degradation of soils in upper parts of slopes.

<center>TENDENCIES OF RELIEF DEVELOPMENT</center>

The present-day processes of water and mineral-organic matter circulation are highly unstable. Thus, one can talk, similarly to other semi-arid territories, about "unstable equilibrium". In the condition of water deficit, to which ecosystems adapted themselves, minor oscillations of energy or water delivery cause disturbances, registered as intensity of different processes (varying yearly). That is why for example in 1975 activization of processes was observed not only in a bottom rich in water (solifluction), but also on a "dry" slope (washing). Oscillations of permafrost limit may also occur in particular years (Gravis 1974). Despite those oscillations, one can talk about general tendencies of the present-
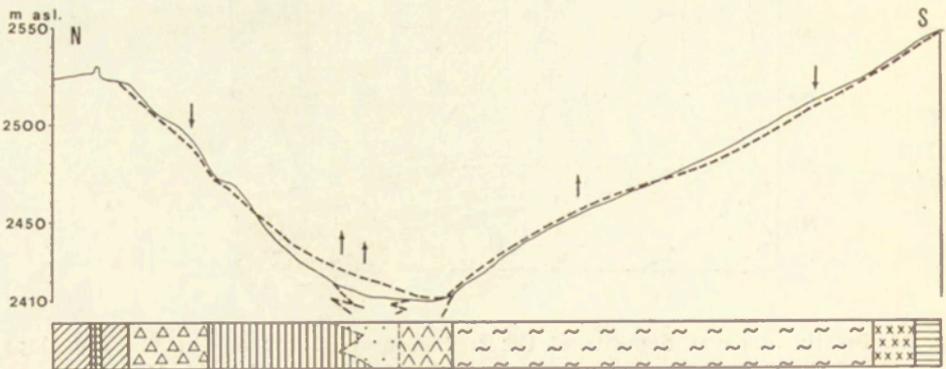

Fig. 25. Tendencies of morphological changes of valley sides (with the sheets as the background) types of sheet; the broken line shows the tendency of relief transformation (explanations see figure 10)

-day relief evolution. It is based on the lack of ridge forms' transformation in the forest-steppe vertical belt, growing of a concave profile of warm slopes, downworn in lower sections by deluvial covers, and levelling of all irregularities in valley floors. Northern slopes are slightly lowered in upper sections; beneath accumulates material (fig. 25). Rockwalls do not retreat, on the contrary they are mantled with microgelivation products. Applying the traditional geomorphological and pedological terminology, as proposed by Ollier (1976), we can state that the S slope catena displays a presently weakened tendency to slope backwearing, whilst the N slope catena — to downwearing.

<center>EVOLUTIONAL TYPES OF SOILS' SEQUENCE</center>

Tendencies present in climatic changes from the close of the Pleistocene up till now have been clearly registered in the soils' sequence on slopes. Relict and fossil features of cold environment, together with overlying features of younger, warmer and drier phases, allow us to distinguish 5 basic evolutional sequences of soils in the Sant valley, related to some definite forms of relief:

1. The relict type. Soils of an old climate, preserved uninterruptedly, functioning in changed conditions. Mountain chernozems of the periglacial environment can be found on non-active cryoplanation surfaces and in rock fissures, and cryogenic brown soils in the lower part of the N-facing slope. Permafrost in the bedrock of these soils is a factor preserving features of the soils and buffering all activity of the present-day arid climate;

2. The relict-transformation type. Features of a changing environment overlap with a full soil profile. On the N-facing slope features of the chestnut process related to a dry continental climate overlie the upper part of the profile of inherited cryogenic brown soils developed from solifluction 2-part covers. Permafrost slows down a rate of the chestnut soils evolution;

3. The aggradation type. The primary soil profile changes into a fossil state due to accumulation of soil and waste deluvial on them, successively transformed into soils with features corresponding to the recent local climatic conditions. In the valley floor there are: a) mountain chernozems — very thick, salty with permafrost, developed from soil deluvia; b) bog-gley soils-cryohumid (with permafrost) overlying solifluction series of brown waste covers and humus-rich soils developed from them in the periglacial environment;

4. The degradation type. Periodical processes of denudation or continuous ones with a very low intensity produce an essential shortening of the soil profile with a simultaneous overlapping of specific soil features typical of a given environment. In the near-ridge part of the

N slope the soils are: a) dark chestnut — low thick, stony and rich in acidic organic substance, or b) light chestnut — low or moderately thick, stony, constantly denuded and related to the present-day environment. Weathering mantle of the former Pleistocene environment have been completely denuded;

5. The degradation—accumulation type. The most complex, embracing middle reaches of the S-facing slope. Relict degraded brown and chernozem soils from the cold period underlie younger microgelivation products displaced along the slope, with the chestnut process developing on them.

TYPOLOGY AND ASYMMETRY OF GEOECOSYSTEMS

by

Alojzy Kowalkowski, Anna Pacyna and Leszek Starkel

EXPOSURE AND ASYMMETRY

Neither rocks of granite-granodiorite intrusion, nor the macroclimate determine an internal differentiation of functionally related geo- and ecosystems in the Sant valley, since the dominant environmental factors are here: exposure, inclination and altitude (both above sea and valley floor level), which jointly determine diversification of the energy and matter circulation balance. Present-day processes add new elements to features of relief, covers and soils inherited from the past. What results are mosaic arrangements of geoecosystems (fig. 26), which — in connection with a different radiation and water balance of N- and S-exposed slopes — form sharply diversified systems of catenas on the valley slopes and floor (Kowalkowski and Pacyna 1977).

Whereas on the S-exposed slope has developed water deficit (high insolation), reflected in soil aridity increasing down the slope, xerophylisation of mountain steppes and in increasing transport of regolith, the leaching processes predominate on the N-facing slope, where the water régime favours development of forest and meadow mountain steppe. Both catenas of the opposing slopes meet at the valley bottom, which is supplied with deluvia from S slopes and with dissolved salts and water from N slopes (fig. 27). At the same time in the system of slope catenas one can notice reflection of complexity of habitats, i.e. vertical zonality and intervalley transformation of belts. The upper timber-line is visible on the N slope, over 2600 m asl. Yet, the inversional valley bottom is devoid of forest, and a stretch of the *Artemisia frigida— Stipa krylovii* steppe (related to the dry steppe belt) encroaches into the valley outlet (phot. 8, 9).

The intravalley transformation finds reflection in drying of near-
-ridge parts of slopes (exposed to south winds) and in thermic inversion
at the valley bottom. This hinders development of forest communities,
and also stimulates appearance of permafrost that transgresses over to
an adjoining part of the N-facing slope.

THE CATENA OF THE N-FACING SLOPE

The gentle northern slope, where thickness of covers and soils,
humidity, and also density of plant communities increase downwards,
is an example of a slope with a mild theramic régime, without drastic
water deficits. Two sections can be distinguished on the slope — the
upper and the middle-lower — with different tendencies of physico-
-chemical transformations related inseparably to water circulation.

The upper section can be defined as the degradation—washed geoeco-
system with a continuous slow degradation of the meadow mountain
steppe. Carrying away of mineral regolith and organic soil material
occurs through surfacial run-off and throughflow. As a result, shallow
chestnut soils, rich in acidic humus substances, have evolved on shallow
debris covers (phot. 15).

The middle-lower section of the northern slope is the suprapermafrost
transitic endopercolation geoecosystem of the forest—steppe. Water
flowing through solifluction covers carries mineral and organic com-
ponents down the slope, under conditions a simultaneous transformation
of upper layers of relict brown regolith into chestnut soils. Water is
partly stored in permafrost, which constitutes a screen for waters
flowing to the valley floor and a source of humidity in dry seasons for
the larch forest and meadow mountain steppe. The forest, here connected
with permafrost, protects the slope against insolation, checks melting
of snow cover, diminishes denudation and favours alluvial processes
(phot. 5, 20).

The accumulative geoecosystem of an adjoining narrow zone of the
valey floor is linked up to the N slope catena. This zone is rich in
water, partially from permafrost, which—in turn—conditions creation
of active solifluction and development of wet mountain meadows
favourable to the evolution of soils rich in organic substance.

THE CATENA OF THE S-FACING SLOPES

The concave southern slopes characteristic features are extreme
thermic conditions and a sharp water deficit. Only on the ridge cryo-
planation shelves sheltered by occur water conditions more favourable
to evolution of soils enriched in organic substance and of more abundant
vegetation, including mesophilous species and even patches of the

Populus tremula woodland. In the profile of this slope one can also distinguish 2 sections — the upper and the lower one — with distinct features. Here water conditions act also as a differentiating criterion, but — considering the lack of permafrost — they depend mostly on physico-water features of weathering mantles and soils (phot. 6, 16, 17).

The upper, steep slope section exemplifies the eluvial—degradation geoecosystem with vegetation of the stony mountain steppe (tab. 6, record 7, 8). If the xerophilous vegetation is not too dense, coarsegrained regolith favours denudation both as slope wash or creeping and a periodical washing of soil regolith covers. Also, weakly developed chestnut soils come here into existence.

Only on under-ridge shelves and in depressions among blocks relict brown regolith and chernozems from the cold period have been preserved, overlain by features of the arid chestnut process. Higher soil fertility and overshadowing are conductive to development of bushy vegetation clusters (*Cotoneaster melanocarpa* Lodd. and others, tab. 6, record 7).

The lower slope section, which forms foothills covered with deluvia filling depressions among older debris lobes, is the aggradation ecosystem of dry mountain steppe. In this zone the highest registered maximum temperatures and lack of water, which washes grainy regolith only episodically during rainstorms, promotes development of poor vegetation of dry mountain steppes (tab. 6, record 6). Despite a considerable thickness of deluvial covers, chestnut soils are shallow, with weakly marked features of salinity in the lower part of the profile.

Towards the valley bottom occure transition to the aggradation—evaporation geoecosystem, where waters enriched in easily migrating mineral compounds, among others from the N slope, bring about soil salinity and development of an abundant mountain steppe (tab. 6, record 5). Thus, the dry part of the bottom is supplied both with coarsegrained material from the dry slope and water containing salts from the opposite slope.

In the longitudinal valley profile the catena of habitats has also been formed. It consists of alternating reaches with bigger inclinations, composed of blocky step (fig. 9, 26) — relicts of the Pleistocene debris avalanches and flat sections, slightly inclined and filled with thick soil deluvia. The mosaics of plant communities develop on them, diversified in the transverse and longitudinal valley profiles. Depending on humidity, the mountain steppes intertwine with wet mountain meadows (phot. 8), and even with marshy mountain meadows (phot. 5) on active solifluction lobes. An additional variation of plant communities can be observed with a growing altitude above sea level.

The contrast between catenas of mountain slopes in the Sant valley is an example of a climatic asymmetry known from many mountain
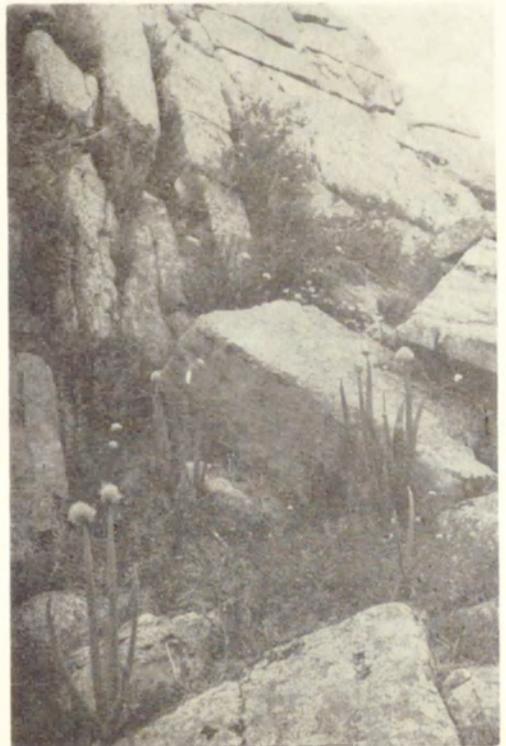
Phot. 15. Thin chestnut soil developed on the weathered bedrock in the uppermost part of the northern slope — soil profile 016
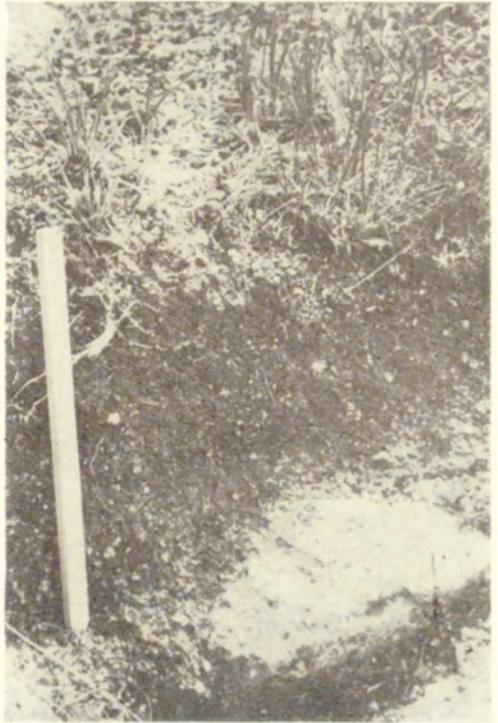
Phot. 16. Dense vegetation in the humid rocky joints in the uppermost part of the dry southern slope

Phot. 17. Small *Populus tremula* forest on the block fields of the southern slope

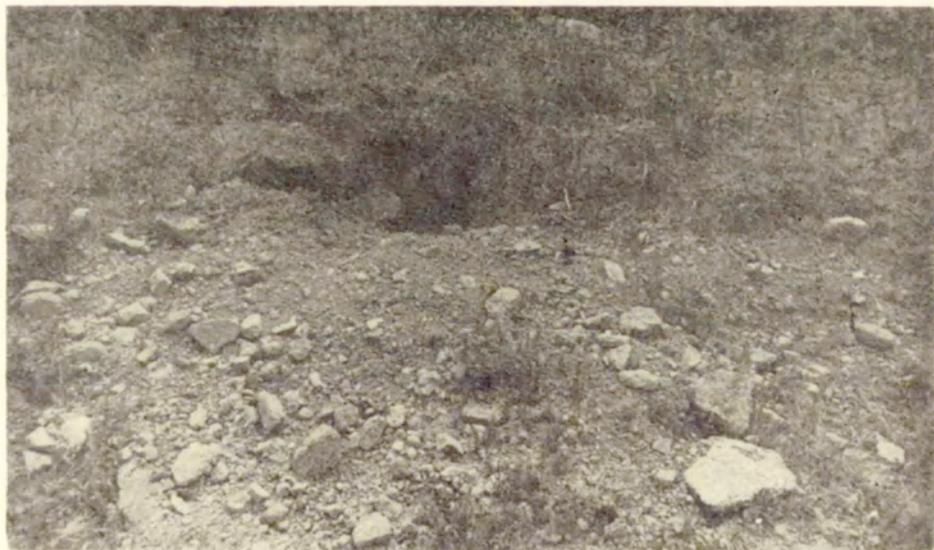Phot. 18. Upper part of the southern slope with rich vegetation following fillings with deep soils

Phot. 19. Role of exposition in the snow cover pattern day after heavy snowfall in April 1976

Phot. 20. The firn-like snow cover deposited in the winter 1975/76 on the northern slope is overlying by 22 cm thick layer of new snow — *cf.* photo 10

Phot. 21. Hollow made by *Marmota marmota* and the removed debris up to 20 cm in diameter. Lower part of the southern slope
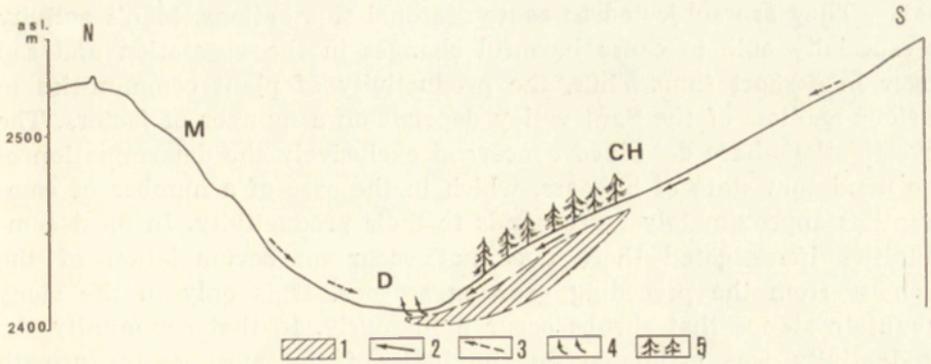
Fig. 27. Physical explanation of the catenas of opposite valley sides

1 — permafrost; 2 — subsurface runoff with predominance of chemical denudation (CH); 3 — overland flow with prevailing slope wash and gravitation (M), at the base deposition of deluvia (D); 4 — evaporation of the soil water and tendency to formation of saline soils; 5 — larch forest

massifs located in continental climates (e.g. Haase *et al.* 1964; Hollermann 1973; Starkel 1980). The Sant valley represents, however, an area with particular extremes of topoclimate where dry and snowless slopes with high evapotranspiration contrast with slopes with permafrost and snow in winter (fig. 27). They condition the formation of definite mosaics of plant communities and intensity of biochemical processes (Kowalkowski and Pacyna 1977).

The stability of discussed habitats is variegated. The most stable are the forest and meadow mountain steppe ecosystems on the gentle, shady N slope. The least stabile and vulnerable to high oscillations of water content and to degradation are lower reaches of S-facing slopes, poorly fixed by vegetation of the dry mountain steppe. One can observe here as well the greatest transformation due to man's activity, and especially overgrazing. It activates a longitudinal transportation of grainy regolith within the S slope catena. On the other hand, forest communities on the N slope suffered a considerable restriction caused by clearings, which can be proved — among others — by stumps of cut trees which occupy an area larger than the present-day forest patches.

PRODUCTIVITY AND UTILIZATION OF HABITATS

by

Alojzy Kowalkowski and Anna Pacyna

The habitats of the Sant valley are distinguished by a variegated stability depending on hydrothermal conditions. Their composition, structure, productivity and other bio-geo-cenotic characteristics are not

stable. They are subjected to acute seasonal fluctuations. Man's activity is especially able to cause harmful changes in the vegetation and soil cover in a short time. Thus, the productivity of plant communities in various habitats of the Sant valley depends on a number of factors. The investigations here described concerned exclusively the determination of the maximum state of biomass, which in the case of a number of communities approximately corresponds to their productivity. In most communities investigated there does not occur an accumulation of the biomass from the preceding growing seasons. It is only in the stony mountain steppe that shrubs occur numerously. In that community the productivity was estimated on the basis of the most recent growth which was separated from the perennial parts. The results of the studies performed in 1975 which was a favourable, humid year should be ana-

Table 11. Humus content in the soils of particular habitats

Locality	Number of soil profile	Plant community	Type of soil	Sampling depth [cm]	Content of humus [kg/m²]	
					0—40 cm	total
N slope	016	meadow mountain steppe	denuded dark chestnut	20	35.36	17.68
	015			40	22.73	22.73
	014			40	17.16	17.16
	013	park-like larch forest	dark chestnut with permafrost	90	19.29	22.59
	012			60	19.89	27.13
	011			140	14.47	19.41
	010	pseudo-taiga larch forest	brown soil with permafrost	120	17.46	25.80
Valley bottom	002	humid mountain meadow	deluvial chernozem with permafrost	140	25.74	51.94
	001	mountain steppe with *Agropyron cristatum* and *Gentiana decumbens*	deluvial soddy chernozem	140	29.51	38.91
S slope	003	dry mountain steppe	deluvial light chestnut	70	9.45	12.00
	004	stony mountain steppe	denuded light chestnut	90	11.36	20.61
	005	stony dry mountain steppe		80	15.67	22.79
	006	stony mountain steppe		70	16.36	24.70
	007		light chestnut	40	15.52	15.52
	008		dark chestnut	140	26.44	41.48
Cryoplanation terrace	009	meadow mountain steppe	relict cryogenic chestnut chernozem	100	31.43	43.40

lysed with adequate carefulness, because the value of the biomass produced in the particular habitats in dry years may be still more differentiated.

The mass of humus accumulated in soils (tab. 11) is an important indicator of the intensity of the biological circulation of substance and productivity of the habitat. The pronounced asymmetry and the influence of altitude on the amount of the content of humus in soil is also marked here. On a south-facing slope the amount of humus accumulated in the 0—40 cm layer increases from 9,5 kg/m² (in the lower, dry part of the slope) to over 26 kg/m² (in its upper, more humid part). Similar tendencies are shown by the total content of humus amounting from 12 to 41 kg/m², which is connected with the accumulation of humus in the lower part of the profile below 40 cm increasing with the height above sea level.

On the other hand, the amount of humus is higher on the slope exposed to the north. In the 0—40 cm layer it grows with the increase of height above sea level from 17.5 kg/m² to 35.4 kg/m². The total content of humus amounting from 17.5 to 25.8 kg/m² is greater in the lower part of that slope, and also points to its accumulation especially in the 0—40 cm layer. The soils occurring there are distinguished by a moderate biological thickness which is connected with the presence of the permafrost in the substratum. The real content of humus in the upper denuded part of the slope exposed northwards (prof. 014, 015, 016) is small. A similar, but more pronouncedly marked phenomenon occurs in degraded and rejuvenated soils of the south-facing slope (e.g. profile 007).

At the valley bottom and on the cryoplanation shelves there are chernozems containing from 25.7 to 29.5 kg/m² of humus in the 0—40 cm layer, as well as in the upper, more moist parts of the slopes. The total content of humus in the soil profile is high, from 39 to 52 kg/m².

The presence of the permafrost at the bottom of the valley as well as in the lower part of the slope exposed to the north entails a greater accumulation of humus (prof. 002, 010 and 013). The stimulating influence of the waters of permafrost origin on the growth of plants finds a corroboration here.

Besides humidity it is the biological factor which exercises an essential influence on the amount of plant biomass, i.e. the activity of fungi and bacteria manifested in the creation of fairy rings in the community of the mountain steppe with *Leontopodium ochroleucum*. Kowalkowski *et al.* (1980) established in the year 1975 an essential differentiation of the chemical composition of the above-ground parts of *Festuca lenensis*. Within a fairy ring there is 1.9-times more nitrogen, 1.8-times more iron, and 1.5-times more potassium and phosphorus than outside the ring.

Because of their numerous occurrence, fairy rings exercise a deciding influence upon the dynamics of the development of plant communities and soils of the dry mountain steppe.

The production of the above-ground phytomass is comparatively small in the Sant valley. The maximum amount of the biomass (tab. 12) in July and August of the year 1975 varies from 153.3 g/m^2 in the driest habitats to 293 g/m^2 in the wettest habitats. This is 2 to 3.8-times more than in the desert plant communities at the Bulgan station (Gordeyeva and Kazantseva 1977). The least biomass occurs in the dry steppe community, which develops on the south-facing slope, and the greatest at the bottom of the valley in the habitats of a wet mountain meadow and mountain steppe with *Agropyron cristatum* and *Gentiana decumbens*.

Table 12. Maximal standing crop of various plants communities in the Sant valley in 1975

Plant community	Phytosocio-logical record	Locality	Altitude above sea level	Maximal stand-ing crop [g/m²]	Ash content [%]
1. Humid mountain meadow	63a (page 50)	valley bottom	2410	292.96 ± 16.16	7.22
2. Mountain steppe with *Agropyron cristatum* and *Gentiana decum-bens*	5 (Table 6)	valley bottom	2410	291.68 ± 14.19	8.65
3. Dry mountain steppe on the deluvial fan	6 (Table 6)	S lope	2420	153.30 ± 11.13	12.09
4. Stony mountain steppe	—	S slope	2450	250.80 ± 29.46	10.56
5. Meadow mountain steppe	1 (Table 5)	N slope	2480	218.80 ± 19.59	11.63
6. *Artemisia frigida — Stipa Krylovii* steppe	—	pediment*	2050	177.38 ± 13.24	12.89

* In Tsagan-Turutuin-gol valley.

The ash content of the phytomass is high, and oscillates from 7.2 to 12.9%. According to Kovda (1971) these values are typical of dry steppes and saline soils. With the increasing aridity they grow in extreme cases to exceed 78% in relation to the wettest habitat in the Sant valley. The differentiated chemical composition of the phytomass (tab. 13) testifies to the highly mosaic-like type of the plant communities. It has no pronounced relations with habitat conditions. It results from the uniformity of the parent rocks of soils all over the area of the valley, and from the varying degree of their weathering and denudation depending on the exposure, age of the weathered material, rainfall waters and their accumulation and migration. The considerable content of potassium in the phytomass and the low concentration of calcium and magnesium are doubtless results of these factors.

The amount of mineral components contained in the plant cover

Table 13. Chemical composition of above-ground parts of plants

Plant community*	% absolute dry mass					ppm absolute dry mass				
	N	P	K	Ca	Mg	Fe	Al	Cu	Zn	Mn
1	1.83	0.15	1.27	0.45	0.20	600	230	5.5	21.0	140.0
2	1.87	0.24	1.66	0.36	0.15	3600	150	6.2	62.0	34.5
3	1.72	0.15	1.22	0.73	0.20	1180	380	8.0	62.0	42.0
4	1.92	0.14	1.43	0.85	0.24	940	380	8.0	40.8	49.0
5	1.72	0.21	1.16	0.88	0.25	3100	760	9.1	62.0	65.5
6	1.80	0.15	1.13	0.94	0.29	2000	980	6.2	50.0	140.0

* As in table 12

Table 14. Mineral components of above-ground parts of plants

Plant community*	kg/sq m area of soil										Ash [%]
	N	P	K	Ca	Mg	Fe	Cu	Mn	Zn	Al	
1	5.36	0.44	3.72	1.32	0.59	0.176	0.00016	0.0410	0.0062	0.0674	21.15
2	5.45	0.70	4.86	1.05	0.44	1.050	0.00018	0.0101	0.0181	0.0437	25.23
3	2.64	0.23	1.87	1.12	0.31	0.181	0.00012	0.0064	0.0095	0.0582	18.53
4	4.81	0.35	3.59	2.13	0.60	0.236	0.00020	0.0123	0.0102	0.0953	26.48
5	3.94	0.33	2.47	2.06	0.63	0.438	0.00014	0.0306	0.0109	0.2144	25.45
6	3.05	0.37	2.06	1.56	0.44	0.550	0.00016	0.0116	0.0110	0.1348	22.86

* As in table 12.

and calculated per area unit (tab. 14) is of major importance as an indicator. In the dry habitats of the mountain steppe the quantities of mineral components in the phytomass are the least. As the moisture of habitats grows, the more alimentary components available in soils are taken from them; consequently, the intensity of their circulation in the soil-plant system grows. It is only aluminium which shows a reverse tendency.

In the Sant valley, the habitats of the highest productivity occupy small areas at its bottom. The stony mountainous south-facing steppe with deep soils is also distinguished by a high productivity. The status of the biomass, in spite of the great looseness of vegetation, is decided upon by the percentage of the particular large perennial plants (*Rheum* sp., *Valeriana officinalis, Sanguisorba officinalis, Potentilla viscosa*). The major part of the valley is occupied by dry habitats of a much lesser productivity.

The habitats of the Sant valley are limited in their economic utility because of overgrazing and the exploitation of wood from forested areas. Their low natural stability is differentiated: it is the least on slopes exposed to solar radiation and covered with sparse vegetation. Their weak resistance to pressure on the side of man, and their great susceptibility to changes caused by soil erosion, are the main factors limiting the chances to steer the exploitation of these habitats.

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ПРИРОДНАЯ СРЕДА ДОЛИНЫ САНТ (ЮЖНЫЙ ХАНГАЙ)

Резюме

ВВЕДЕНИЕ

Второй том, заключающий результаты исследований Монголопольской физико-географической экспедиции, является физико-географической монографией небольшой сухой долины Сант на южном крае Хангая, впадающей в долину Тсаган-Турутуин-гол (рис. 1). Долина Сант поверхностью в 3 км² лежит на высоте 2020 – 2718 м н. у. м., в зоне, где чередуются безводные территории и территории многолетней мерзлоты, сухой степи и лесостепи, а одновременно приближаются друг к другу 2 границы зоны лесостепи: верхняя, обусловленная термически и нижняя — влажная. В долине резко обозначается асимметрия склонов, обусловленная различным радиационным балансом (рис. 8).

Летом в 1974 и 1975 годах проводились подробные исследования Монголо-польской физико-географической экспедицией, организованной в рамках сотрудничества между Институтом географии и территориальной организации Польской академии наук, Отделом геоморфологии и гидрографии в Кракове и Институтом географии и геокриологии (мерзлотоведения) Монгольской академии наук в Улан-Баторе. Долина Сант была объектом подробных исследований асимметрии и вертикальной зональности физико-географических явлений как в типологическом и эволюционном аспекте, так и в отношении механизма процессов. Старались одновременно изучить роль изменений климата и деятельности человека, а также оценить эксплуатационную пригодность местообитаний.

На основе топографических съемок бассейна в масштабе 1:10000 (рис. 2) составлены карты ряда элементов. Проводились климатические и гидрологические измерения, а также измерения почвенных и геоморфологических процессов вдоль поперечного профиля (рис. 3, 8). Они были пополнены наблюдениями в весенний период (апрель 1976 г.).

ЭЛЕМЕНТЫ ПРИРОДНОЙ СРЕДЫ

Климат

На южном склоне Хангая наблюдаются большие контрасты показателей сухости и континентализма климата. Одновременно здесь величина притока солнечной энергии высока и достигает 135 килокалорий/см²/год. Величина годового радиационного баланса составляет 41 килокалорий/см². Средняя годовая температуры воздуха в межгорных котловинах ниже −5°C (рис. 4). Термическая зима продолжается 201 день, а период без заморозков только 64 дня. Годовые суммы осадков составляют 240 – 280 мм, суточный максимум — 60 мм. 67% годовой суммы осадков составляют осадки трех летних месяцев (июнь – август).

Мощность снежного покрова невелика, в среднем доходит до 7 см, причём число дней со снежным покровом превышает 117. Были проведены характеристики температуры и осадков в июле в 1957 – 1975 годах (рис. 5).

Рельеф местности

Территория водосбора построена гранитами и гранодиоритами пермокарбонской интрузии. Система трещин с направлением 155°, 70° и 50−60° отражается в расположении долин и асимметрии склонов (северный более пологий пенеструктурный склон). Отдельно изучались хребты с криопланационными террасами, склоны и дно долинки (рис. 7, 8). Южный склон — более крутой (20−35°), вогнутый, покрыт частично каменной россыпью, а в нижней части замершими каменными потоками. Склон с северной экспозицией с возрастающим уклоном (10−18°) одет солифлюкционными покровами. Ось дна долины обладает ступенчатым профилем. Дно долины состоит из ступеней, сложенных из обломочного материала, разделенных понижениями, заполненными делювием (рис. 9). Особенностью долины является её асимметрия, обусловленная её структурными и климатическими чертами (плэистоценовые мезо- и микроформы, а также формы, развивающиеся в настоящее время).

Покровные образования

Покровные образования являются результатом выветривания и склоновых процессов, проходящих в условиях холодного континентального климата (рис. 10, 11). На вершинах преобладают покровы, сложенные продуктами выветривания (на криопланационных террасах) и резидуальные покровы — осыпи на склонах скальных останцов. Иногда они состоят из двух горизонтов с разделяющими их реликтовыми бурыми почвами. Склоны с северной экспозицией в верхней части покрыты тонким деградированным покровом, сложенным продуктами выветривания, ниже наблюдается двуслойность глинисто-обломочных солифлюкционных покровов. Склоны с южной экспозицией покрыты в более высокой части крупнообломочными покровами, только в котловинах находятся резидуальные продукты выветривания горных пород. Ниже, возле замерших потоков обломочного материала залегает зернистый делювий значительной мощности (рис. 8). На дне возле коллювия, в нижней части деградированного, в верхней части — молодого, лежит песчанисто-пылевой делювий,

Почвы

Мозаичность и катены почв обусловлены минеральными покровами разного генезисх механического состава и мощности, а также контрастностью микроклиматов и водных условий (рис. 15). Материнским материалом являются криогенные коры выветривания (табл. 2, 3). На криопланационных выравниваниях и на северном склоне наблюдаются реликтовые бурые почвы и черноземы с наложенными на них признаками современных процессов образования каштановых почв. На склонах с южной экспозицией преобладают светло-каштановые почвы, часто деградированные, ниже ко дну долины переходящие в каштановые делювиальные. На дне долины преобладают делювиальные черноземы, часто покрытые каштановыми почвами, развитыми на более молодых делювиях.

На приложенных таблицах и рисунках подробно представлен механический состав, физические свойства почв и сорбционные свойства (табл. 2−4). В долине Сант заметна высотная зональность почв. В верхней части наблюдаются реликтовые криогенные чернозёмы, превращающиеся в каштановые почвы, преобладающие ниже 2500 м н. у. м. На южных сухих склонах светло-каштановые почвы принадлежат уже к почвам сухой степи.

Растительный покров

На основе флористических и фитосоциологических исследований (проведены ок. 90 фитосоциологических съёмок) были выделены 3 растительные зоны (рис. 14): степей, лесо-

степей и высокогорной зоны. Представителем зоны степей является полынно-ковальная степь. Зона степей наблюдается у выхода долины. Большая часть долины лежит в зоне лесостепи (*sensu* Юнатов 1950).

Асимметрия склонов долины обусловливает контраст в образовании растительных сообществ на противоположных склонах. На склонах с северной экспозицией наблюдается мозаичность пятен горного псевдотаёжного лиственничного леса (табл. 5) и луговых горных степей (табл. 6). На склоне с южной экспозицией развивается каменистая горная степь (табл. 6). Асимметрия склонов обусловливает также разнообразие сообществ на дне долины — влажные луга (съёмка 63а) и луговые горные степи вблизи склона с северной экспозицией и сухие степи вблизи склона с южной экспозицией. Высокогорная зона на склонах пика 2718 м занята кобрезовыми лугами.

ДИНАМИКА СРЕДЫ

Процессы энергообмена

На основании результатов стационарных и патрульных измерений дана характеристика притока солнечной энергии (рис. 15), а также термики приземного слоя (рис. 16, табл. 7). При анализе приняты во внимание те факторы, которые в значительной степени предопределяют контрастность климата, являются результатом местных условий, т. е. экспозиция, наклон, вид растительного покрова, а при измерениях температуры, дополнительно высота над уровнем моря. Установлена тесная связь между величиной излучения и температурой. Поверхность южного склона получает на 200% больше солнечной энергии, чем горизонтальная, и на ней были отмечены температуры самые высокие из наблюдённых на всей исследуемой территории. Северные же склоны получают меньше 30% солнечной энергии получаемой горизонтальной поверхностью. Такая большая разница в количестве полученного тепла обусловливает значительные колебания температуры как в годовом, так и в суточном ходе. Резкое изменение величины перечисленных елементов климата наблюдается вдоль нижней части залесенного северного склона.

ВЛАГООБОРОТ В БАССЕЙНЕ РЕКИ САНТ

Характеристика влагооборота основана на исследованиях дождевых осадков, снежного покрова, испарения, инфильтрации воды и поверхностного стока в июне и июле 1974 года, а также в апреле 1976 года. Сумма осадков мало изменяется на территории всего бассейна, но резко меняется из года в год (рис. 17). Механизм влагооборота на склонах стимулируется балансом излучения (рис. 15). Поверхностный сток носит местный характер. Выделены два типа влагооборота: очень короткий, продолжающийся только несколько дней на южных склонах, и более длительный период ретенции атмосферных вод, соединённой с питанием многолетней мерзлоты, а также значительной ролью транспирации на склонах с северной экспозицией и на дне долины.

Современные почвенные процессы

Почвообразовательные процессы обусловливает климат и орография. В нижней части бассейна (до 2300 м н. у. м.) преобладает зернистая термическая дезинтеграция и поверхностный транспорт, а также подсачивание и аккумуляция щелочей в верхней части профиля. Выше 2300 м н. у. м. (рис. 18) наличие мерзлоты на северном склоне и на дне долины (слой активной мерзлоты до 150 см) способствует вымыванию растворимых минеральных суб-

станций вниз склона и засолению более сухой части дна. На склоне с южной экспозицией изменение почв зависит от поверхностного смыва. Показателями асимметрии почв являются их сорбционная ёмкость, степень насыщения щелочными катионами, содержание гумуса и отношения C:N (рис. 20; табл. 8). Они являются отражением различного типа водного баланса почв. В связи с этим образуются мозаики почв с реликтовыми, регрессивными и трансгрессивными свойствами.

Рельефообразующие процессы и современное преобразование форм

Вид покровов, местный климат и рельеф склонов определяют динамику, а также локальные различия процессов (рис. 22). Физическое выветривание на южных склонах носит характер эксфолиации и микрогеливации. Микрогеливация наблюдается выше 2500 м. Измерения отпадания свидетельствуют об темпе отступания стен порядка 0,1 мм/год (табл. 9). Горные вершины формируются в настоящее время смывом и дефляцией. На южных склонах преобладают процессы сползания и суффозии, а также результаты деятельности сурков. На северном склоне медленное сползание и химическая денудация, а при отсутствии растительности также смыв и дефляция (табл. 10). На дне долины наряду с аккумуляцией продуктов делювиального смыва происходит течение материала по поверхности мёрзлого грунта (рис. 23). Естественные процессы ускорены хозяйственной деятельностью человека (чрезмерный выпас скота и вырубка леса).

ТИПОЛОГИЯ И ЭВОЛЮЦИЯ

Элементы прошлого и современная тенденция изменений

Долина Санг на границе последнего холодного периода отличалась структурно обусловленной асимметрией склонов и постоянным контактом в их энергетическом балансе. Недействующие уже плейстоценовые криопланационные террасы спускаются до около 2400 м н. у. м. На них сохранились остатки криогенных чернозёмов. Плейстоценовые потоки обломочного материала на южном склоне загромождали дно и подрезали противоположный склон с вогнуто-выпуклым профилем. В голоцене мерзлота сохранилась только на северном склоне с пятнами леса, замедлились гравитационные процессы. Более активным был северный склон. Наблюдается общая тенденция к образованию каштановых почв. Осушение климата в последнем тысячелетии проявляется в образовании мелкообломочных покровов (рис. 24). Одновременное выпасание скота и корчевание леса увеличили эрозию почв (делювий 2—3 м мощности). Процессы происходящие в настоящее время ведут к наибольшим изменениям на вершинах, к слабому понижению северных склонов и увеличению мощности покровов у подножия южных склонов (рис. 25). В секвенции эволюции почв можно выделить 5 типов: реликтовый, реликтово-трансформационный, аггградационный, деградационный, а также деградационно-аггградационный.

Типология и асимметрия геоэкосистем

На южном склоне образовался при высокой инсоляции дефицит воды, отражающийся в возрастающей вниз по склону аридности горных степей и почв, а также в увеличивающемся переносе продуктов выветривания горных пород. На северном же склоне при наличии мерзлоты и водного хозяйства, создающего возможность развития леса и луговой горной степи, преобладают процессы выщелачивания. Обе склоновые катены встречаются на дне долины, покрываемом делювием с южного склона, а также питаемом солями и водой с северных

склонов (рис. 26,27). Одновременно в расположении катен наблюдается зависимость от высотной зональности местообитаний и внутридолинной её трансформации (рис. 8). Поэтому происходит наложение границ сухой степи и верхней границы леса на систему склоновых катен. Контраст катен долины Сант является примером климатической асимметрии с особыми экстремальными величинами. Экосистемы отличаются разной стабильностью и податливостью к преображению их человеком. Наиболее податливыми к изменениям являются местообитания сухой степи в нижних участках южных склонов.

Продуктивность и эксплуатационная пригодность местообитаний

Продуктивность местообитаний долины Сант непостоянная, она подвергается колебаниям, потому результаты исследований, проведенных летом влажного 1975 года, нужно рассматривать с осторожностью. Запас гумуса в почве южного склона колеблется в 40 см слое от 9,5 до 26 кг/м², на северном склоне от 17,5 до 35,4 кг/м² (табл. 11) при высокой пепельности 7—13%. О пестроте сообществ свидетельствует также разнообразный химический состав растительной массы (табл. 13). Количество минеральных компонентов, содержащихся в растениях сухой степи, показано на таблице 14. Самой высокой продуктивностью обладают местообитания на дне долины, а также богатые водой понижения на южном склоне. Небольшое сопротивление прессии человека и податливость к изменениям под влиянием эрозии почв являются главными факторами, ограничивающими руководство эксплуатацией местообитаний.

Fig. 3. Sites of detailed studies and measurements in the Sant valley

1 — basic meteorological station; 2 — microclimatic and rainfall measurement sites; 3 — other rain gauge stations; 4 — measurements of surfacial run-off and snow cover along a line run across; 5 — soil profiles for the cross section along which studies of soil properties, permafrost temperature, air temperature and humidity, water infiltration and a phytosociological survey were made; 6 — other slopes with measurements of infiltration and slope wash by use of plastic bags; 7 — experiments with slope wash measurements; 8 — profiles for measuring congelifluction and soil creep rates; 9 — plastic nets for measuring the rates of scree transport on talus cones; 10 — plastic nets for measuring the rate of weathering at the base of rock walls; 11 — measurement of texture of rock debris; 12 — phytosociological survey; 13 — dip and strike of granitic rocks.
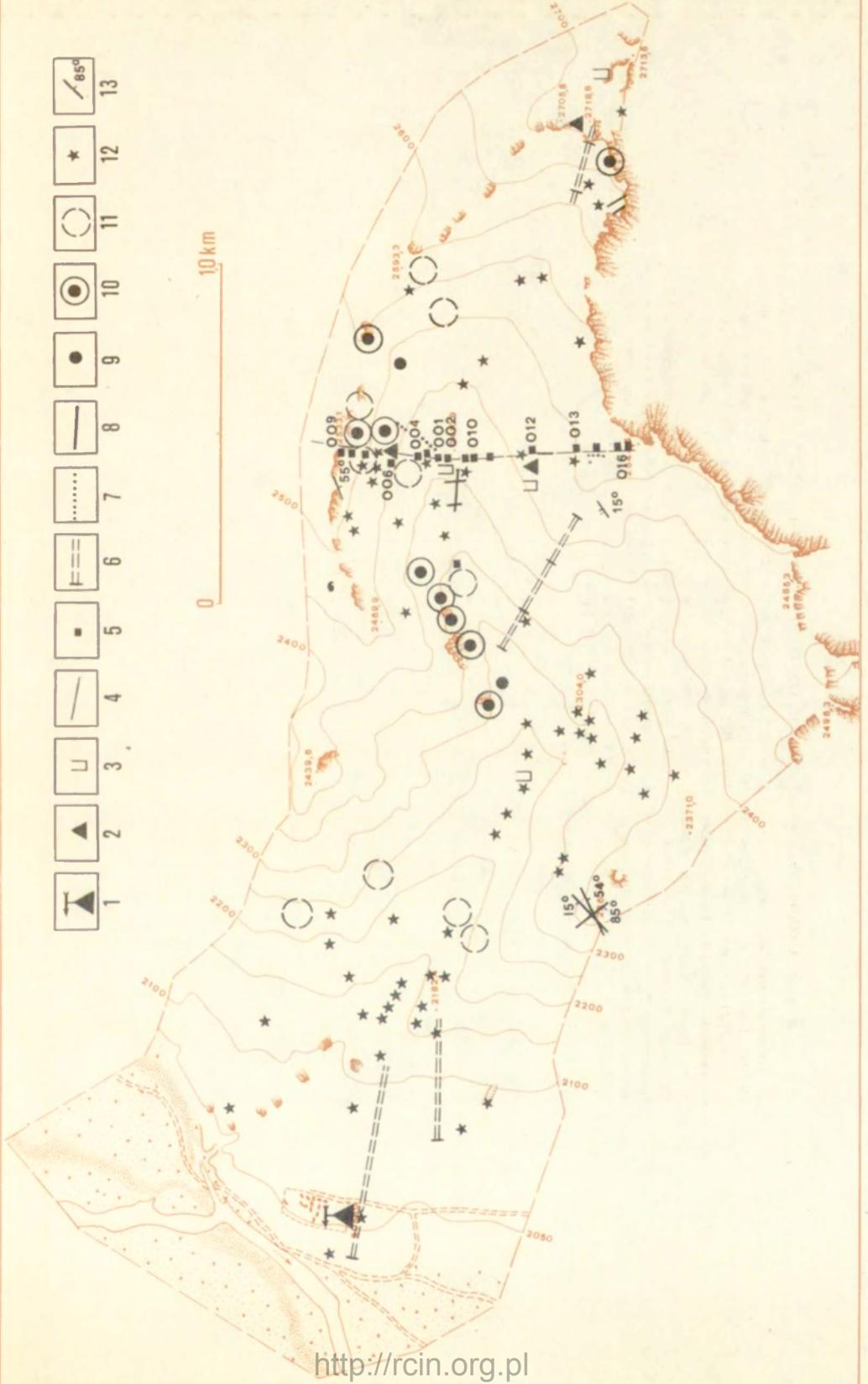
Fig. 7. Geomorphological map of the Sant valley (by. Starkel 1975)

A. Denudational landforms: *1* — rock walls; *2* — rock steps; *3* — rocky crests; *4* — tors and similar features; *5* — rounded ridges; *6* — cryoplanation terrace plains; *7* — terrace edges; *8* — cryopediments; *9* — small shallow flat-foored valleys dissecting the valley-sides; *10* — corrasional valleys; *11* — chutes containing deluvia; *12* — steep slopes with block fields; *13* — steep slopes bearing granular eluvia with some blocks; *14* — gentle slope modelled by congelifluction; *15* — zones of deflation; *16* — small erosional channels. B. Aggradational landforms: *17* — blockstreams; *18* — fine debris lobes; *19* — front of debris ramparts; *20* — active congelifluction lobes with thufurs; *21* — granular sheets of deluvial and proluvial origin; *22* — older terrace surfaces; *23* — older alluvial fans; *24* — proluvial plains; *25* — active proluvial fans
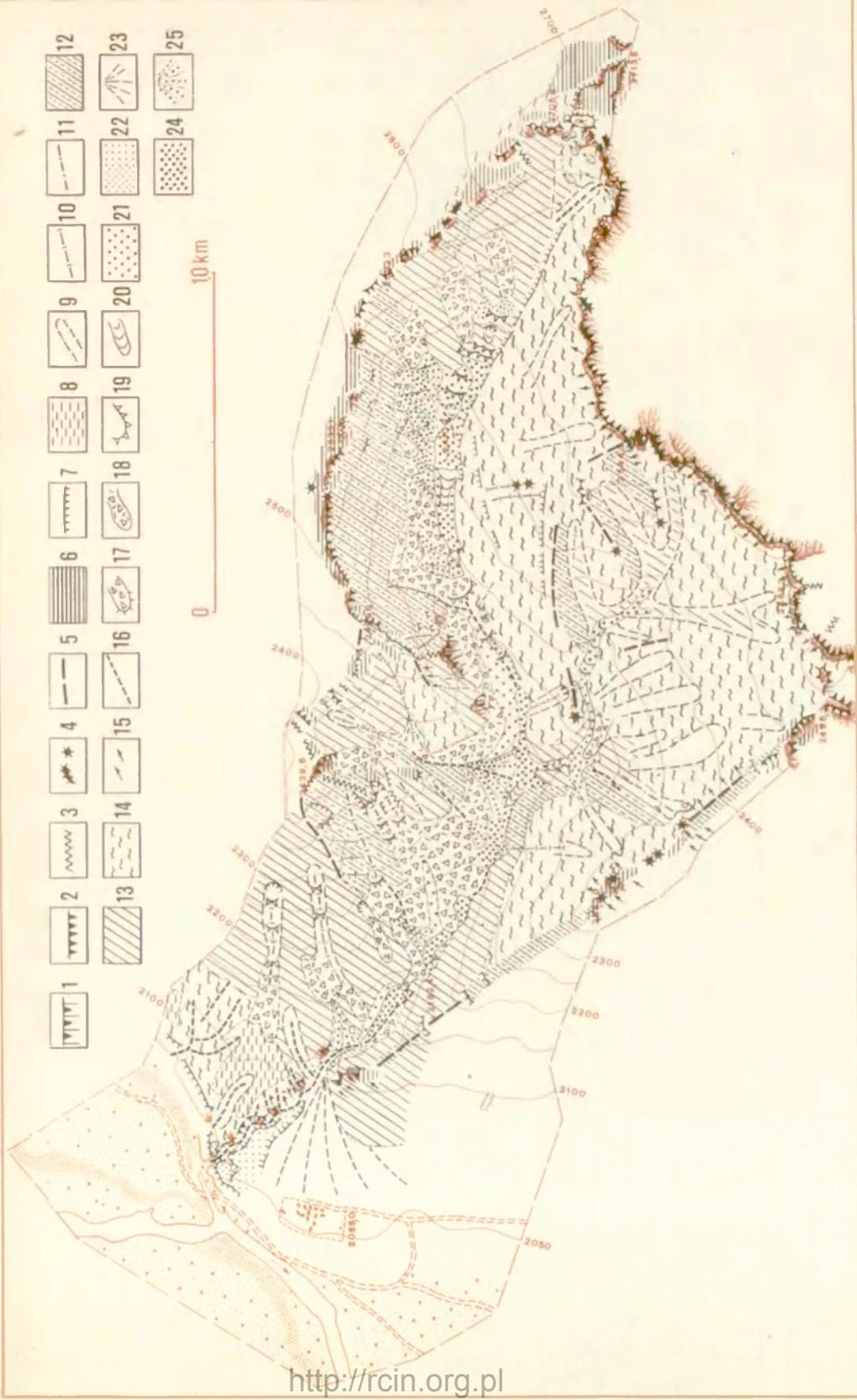
Fig. 10. Sheets of the Sant valley (by K. Pękala)

1 — bedrock (walls and rocky floors); *2* — loamy-blocky and loamy-scree sheets with relict, mountain chernozems; *3* — granular and granular-scree residual covers; *4* — blocky and scree residual covers; *5* — blocky and scree-granular congelifluction sheets; *6* — scree and granular talus sheets; *7* — loamy-scree congelifluction sheets; *8* — scree-granular residual covers; *9* — loamy-scree colluvia of active earth-debris streams; *10* — loamy and granular deluvia and proluvia; *11* — loamy-scree and granular deluvial sheets overlying the Pleistocene alluvia; *12* — fluvial gravels and sands
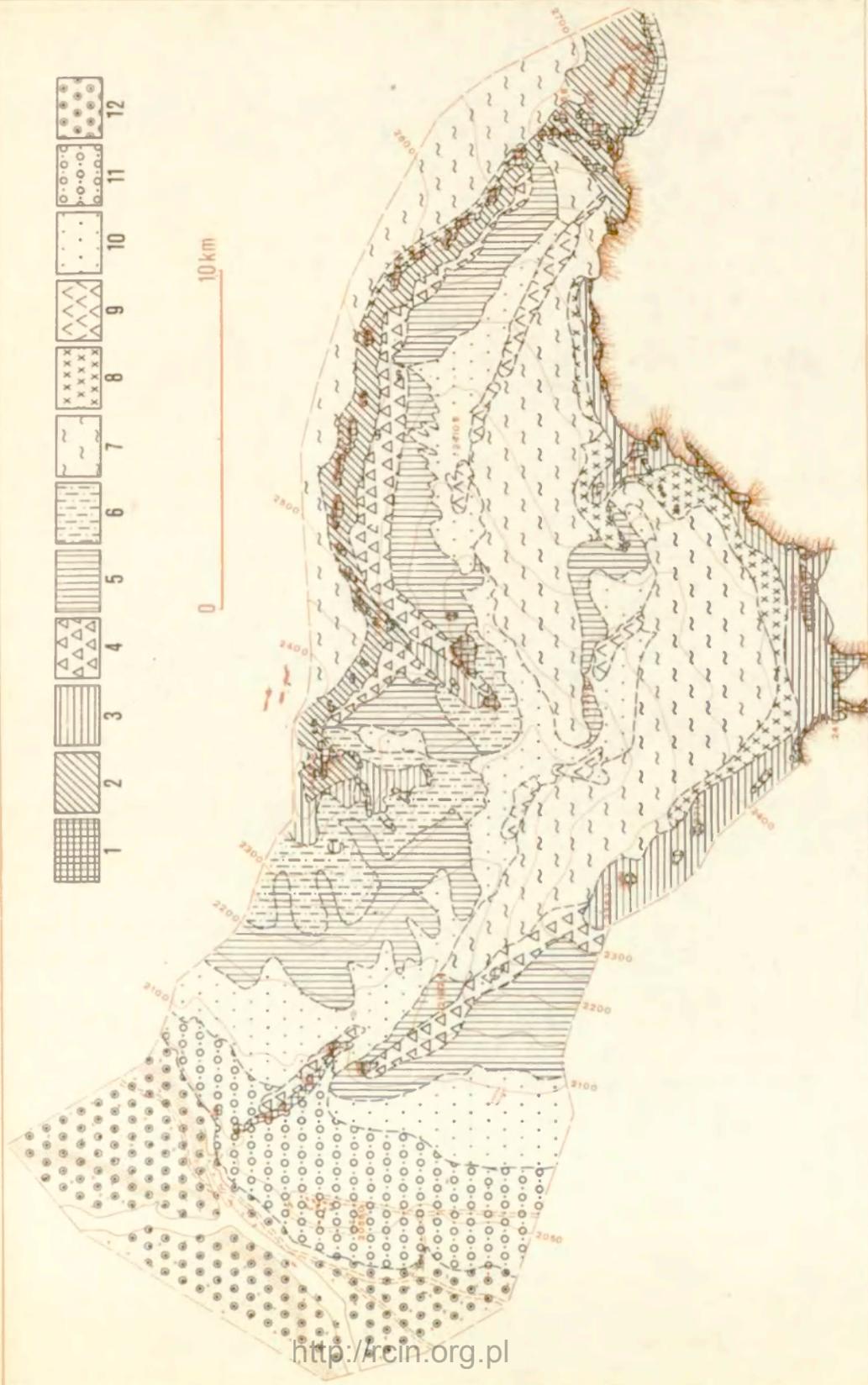
Fig. 12. Soil map of the Sant valley (after Kowalkowski, Lomborinchen 1975, slightly changed)

1 — hydromorphic and stony light chestnut alluvial soils on the permafrost; 2 — lithogenic and automorphic soils of pediment, 2.1. — scree soils of residual hills, 2.2. — light chestnut calcareous and stony soils of different thickness; 3 — montaneous litho- and automorphic soils, 3.1. — automorphic and cryogenic soils of the valley bottom, 3.1.1. — dark chestnut deluvial soils, 3.1.2. — arid deluvial chernozems very thick, 3.1.3. — semiarid and cryohumid very thick chernozems and peaty gley soils; 3.2. — automorphic and cryogenic mountain soils of N-facing slopes, 3.2.1. — brown soils on the permafrost, 3.2.2. — thick dark chestnut stony soils on the permafrost, 3.2.3. — thick dark chestnut stony soils, 3.2.4. — thick chernozems, 3.2.5. — thin light chestnut stony soils; 3.3. — automorphic and lithogenic mountain soils of S-facing slopes, 3.3.1. — thick dark chestnut stony, 3.3.2. — denuded thin light chestnut stony, 3.3.3. — deluvial and proluvial thick stony; 3.4 — lithogenic and cryogenic mountain soil of interfluves, 3.4.1. — thick stony chernozems, 3.4.2. — thick dark chestnut stony, 3.4.3. — thin light chestnut stony and rocky (denuded)

3.4.1. 3.4.2. 3.4.3.

3.3.1. 3.3.2. 3.3.3.

3.2.4. 3.2.5.

3.2.1. 3.2.2. 3.2.3.
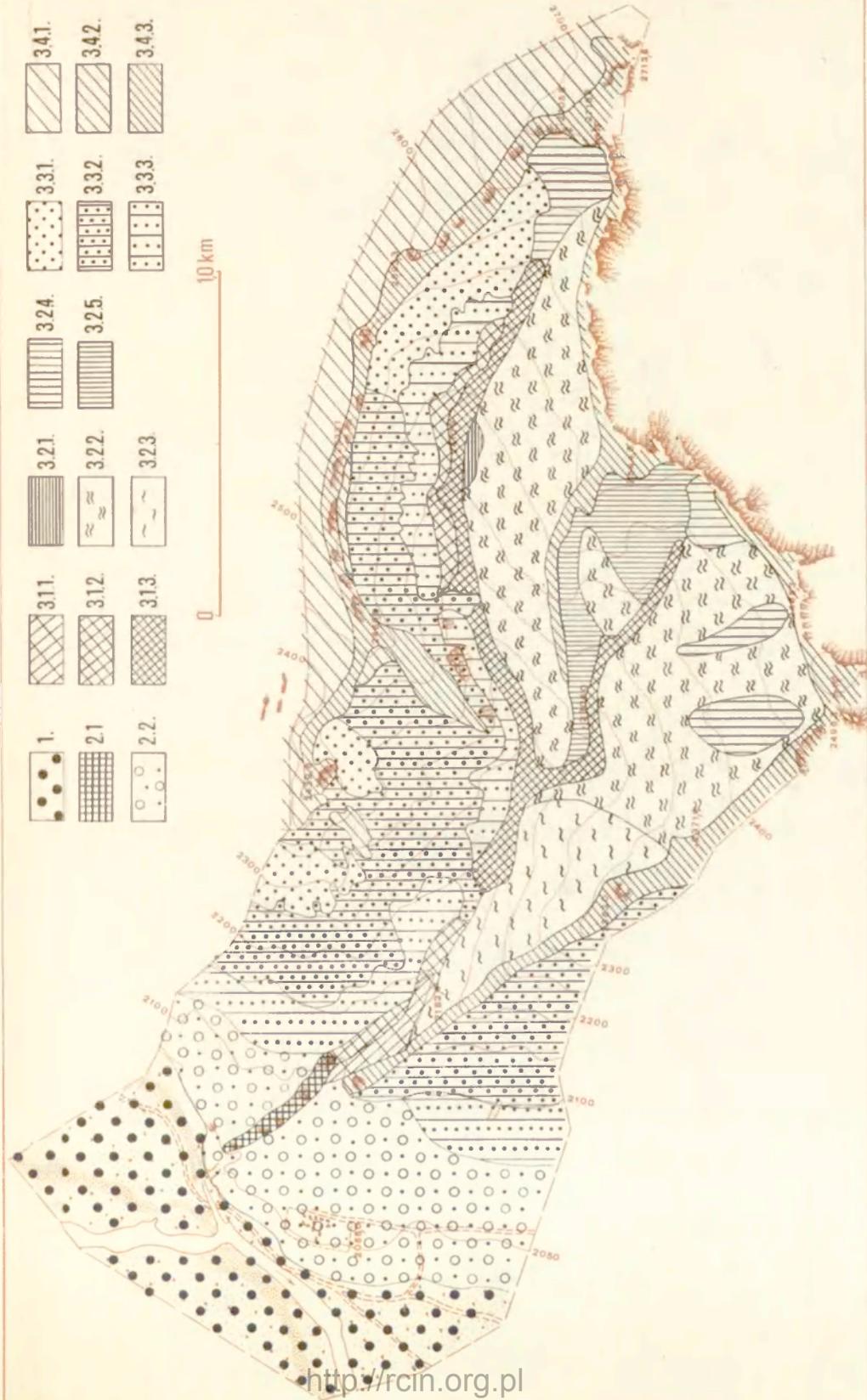
3.1.1. 3.1.2. 3.1.3.

1. 2.1. 2.2.

10 km

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Fig. 14. Vegetation map (by A. Pacyna)

1 — larch forest; *2* — larch forest margin with high mountain species (*Gentiana algida* and *Ptilagrostis mongolica*); *3* — *Populus tremula* woodland; *4* — *Artemisia frigida* — *Stipa Krylovii* steppe; *5* — meadow mountain steppe; *6* — meadow mountain steppe variant with *Polygonum alopecurioides, Sanguisorba officinalis, Leontopodium ochroleucum* s.l. and *Kobresia* sp.; *7* — meadow mountain steppe variant with *Veronica incana, Galium verum* and *Leontopodium ochroleucum* s.l.; *8* — dry mountain steppe with *Agropyron cristatum* and *Gentiana decumbens*; *9* — dry mountain steppe with *Leontopodium ochroleucum* s.l.; *10* — transitional community between stony mountain steppe and meadow mountain steppe; *11* — stony mountain steppe; *12* — stony mountain steppe, variant with tall forbs; *13* — stony mountain steppe, variant with *Pulsatilla* sp.; *14* — open mountain steppe on the deluvial fans; *15* — mountain steppe, variant of the valley terrace edges; *16* — humid mountain meadow; *17* — marshy mountain meadow; *18* — high mountain meadows; *19* — community with *Iris biglumis*; *20* — anthropogenically changed patches of steppe and mountain steppe (places of permanent encampment); *21* — patches of steppe and meadow markedly changed by pasturing; *22* — secondary communities of stony moutain steppe on a stony slope (originating from erosion of the slope after forest devastation)
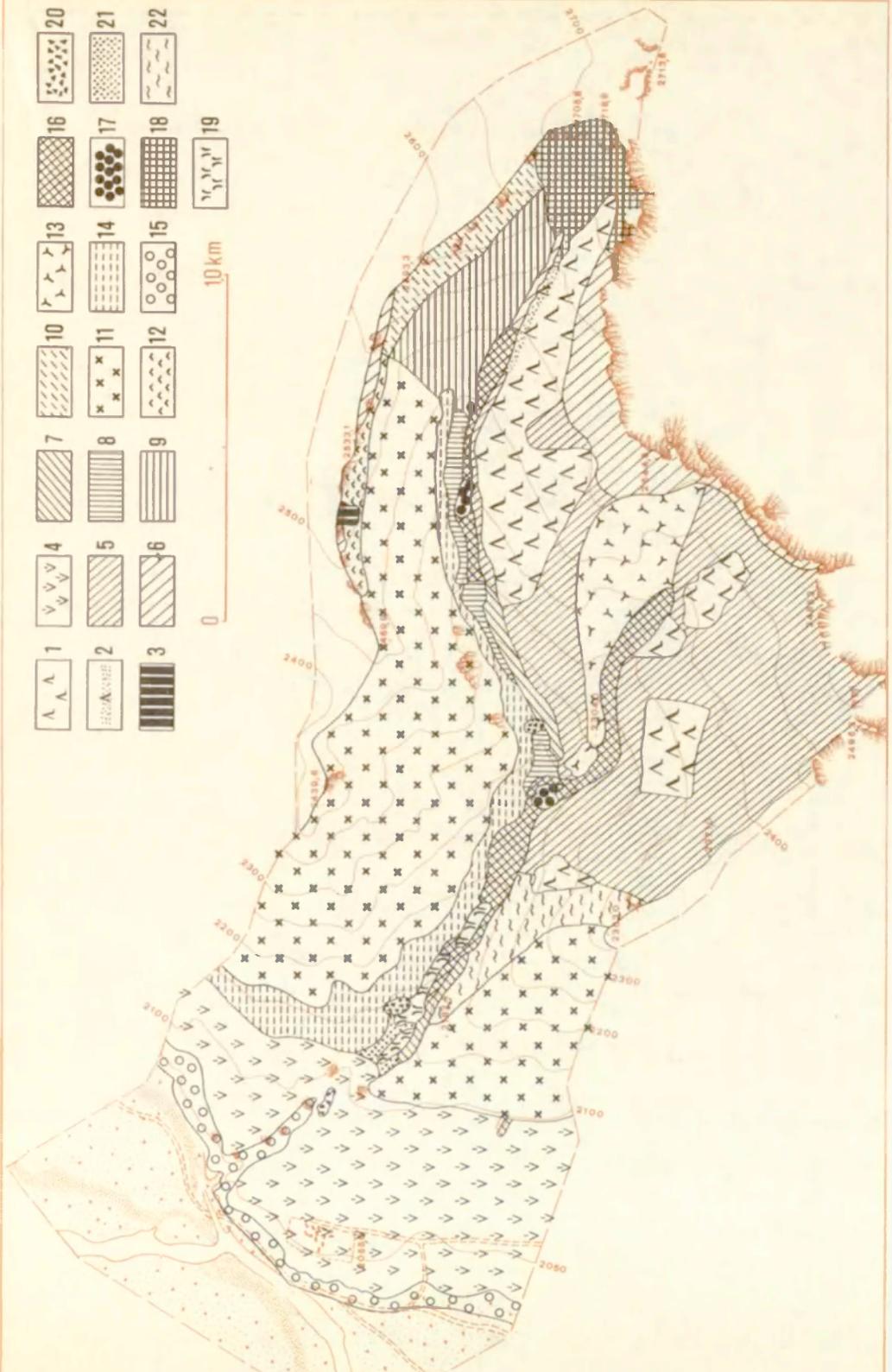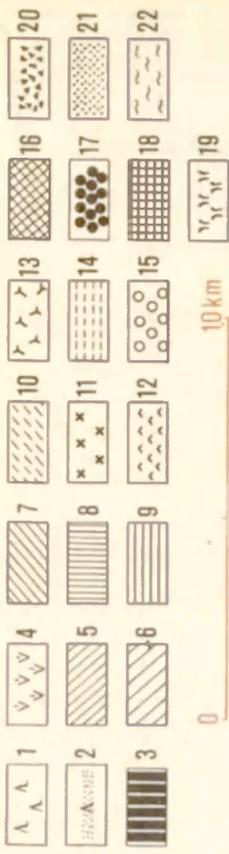
Fig. 15. Map showing global radiation (cal/cm² · min) in July, 1974, at 12°° in the Sant valley

1 — microclimatic station; *2* — measurement points with permanent microclimatic observations; *3* — points of measurements *en route*; *4* — radiation above 1.08 cal/cm². min; *5* — radiation below 0.90 cal/cm². min

Fig. 22. Map of contemporary morphogenetic processes (according to Pękala 1975)

I. Ridges and cryoplanation terrace flats: *1* — Belt of higher ridges. Processes: micro- and macrogelivation, aeolian processes, washing, congelliturbation, frost segregation, congelifluetion; *2* — belt of lower ridges. Processes: physical weathering, washing, aeolian processes;

II. North-facing slopes: *3* — steep rocky slopes extending above the forest limit (2500—2700 m asl.), cryogenic processes (creep, congelifluction), physical weathering, washing; *4* — steep slopes with clayey-debris sheets. Processes: congelifluction, creep of sheets, washing; *5* — slopes with a meadow vegetation. Processes: washing, congelliturbation, influence of cattle breeding; *6* — steep scree slopes. Processes: frost weathering, slow congelifluction creep, washing; *7* — forested slopes with relict congelifluction lobes locally active, leaching; *8* — forested slopes with a dense vegetation — only leaching;

III. South-facing slopes: *9* — slopes with block fields. Processes: exfoliation, subcutaneous erosion, slumping of blocks, washing; *10* — slopes with block streams in the corrasional chutes. Processes: physical weathering, creep, corrasion, subcutaneous erosion; *11* — older generation of block sheets. Processes: subcutaneous erosion, washing, microgelivation; *12* — slopes with prevalence of granular weathering residues. Processes: washing, rock sliding, aeolian processes; *13* — upper sections of the corrasional chutes. Processes: corrasion, washing; *14* — deluvial glacis. Processes: washing, aeolian and zoogenic processes;

IV. The Sant valley bottom: *15* — accumulation of deluvia and proluvia; *16* — denuded congelifluction lobes. Processes: physical weathering, corrasion;

V. Terraces in the Tsagan-Turutuin-gol valley: *17* — terrace, 30—40 m high. Processes: aeolian, washing or accumulation of proluvia; *18* — flat surfaces of terrace, 30—40 m high and sub-slope zones. Processes: aeolian processes, washing, accumulation of cones; *19* — terrace edges, 30—40 m high. Processes: gravitational (zoogenic and anthropogenic), aeolian, slope wash; *20* — low terraces. Processes: linear and lateral erosion, frost heaving; *21* — ravins with linear erosion; *22* — occurrence of animal burrows in granular debris
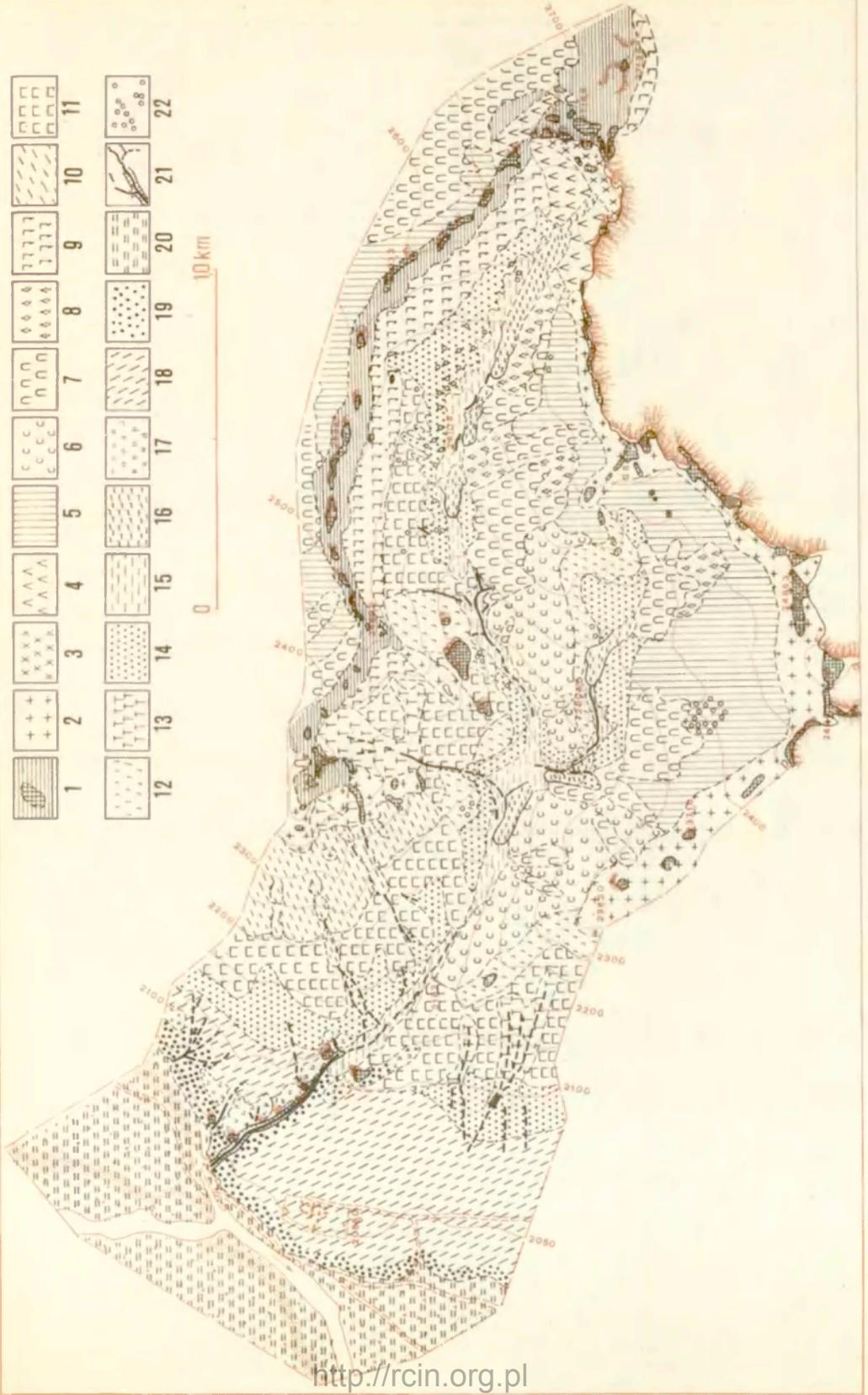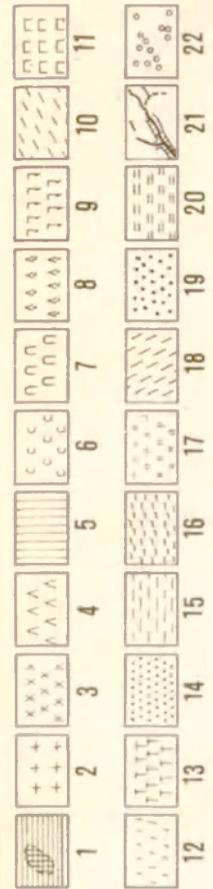
Fig. 26. Map of habitats in the Sant valley (according to Kowalkowski and Pacyna 1977)

1 — habitat of a *Stipa—Artemisia* steppe on light-chestnut, deluvial and stony soils that developed on pediments up o 2100 m asl.; *2* — habitat of mountain dry steppe on primitive stony and rocky, denuded, mountain light chestnut soils and accumulation fans occurring on S- and SW-facing slopes up to 2500 m asl.; *3* — habitat of mountain steppe on rocky, denuded, dark chestnut soils and primitive light chestnut soils of accumulation fans occurring on SW- and S-facing slopes at 2540 m asl.; *4* — habitat of luxuriant mountain steppe on deluvial mountain chernozems which developed in the valley bottom nearby the S-facing slope; *5* — habitat of mountain larch forest on thicker brown, dark chestnut soils and chernozem, denuded, cryogenic mountain soils, partly underlain by permafrost and stone, on N-facing slopes at between 2100 and 2620 m asl.; *6* — habitat of mountain larch-sod forest on shallow dark-chestnut soils and denuded stony chernozems underlain by permafrost along the crest line of the northern slopes extending up to 2500 m asl. and exposed to dry southern winds; *7* — habitat of moist mountain meadows on deluvial permafrost free mountain chernozems occurring in the valley bottom which is overshadowed by the N-facing slope; *8* — habitat of moist mountain being flooded periodically, on deluvial mountain chernozems underlain by permafrost in the valley bottom nearby the N-facing slope; *9* — habitat of marshy mountain meadows in the valley bottoms in sites of subsurface and surface run-off, on swampy-gley soils underlain by permafrost; *10* — habitat of subalpine grasslands on mountain dark chestnut parachernozems and alpine cryogenic chernozems, on landslides and cryoplanation surfaces terrace flats occurring from 2400 to 2700 m asl.; *11* — habitat of the variant of subalpine grasslands on mountain primitive dark chestnut parachernozems and on shallow cryogenic parachernozems developed in sheltered SW-facing slopes and on cryoplanation terrace flats at altitudes of 2600—2700 m asl.
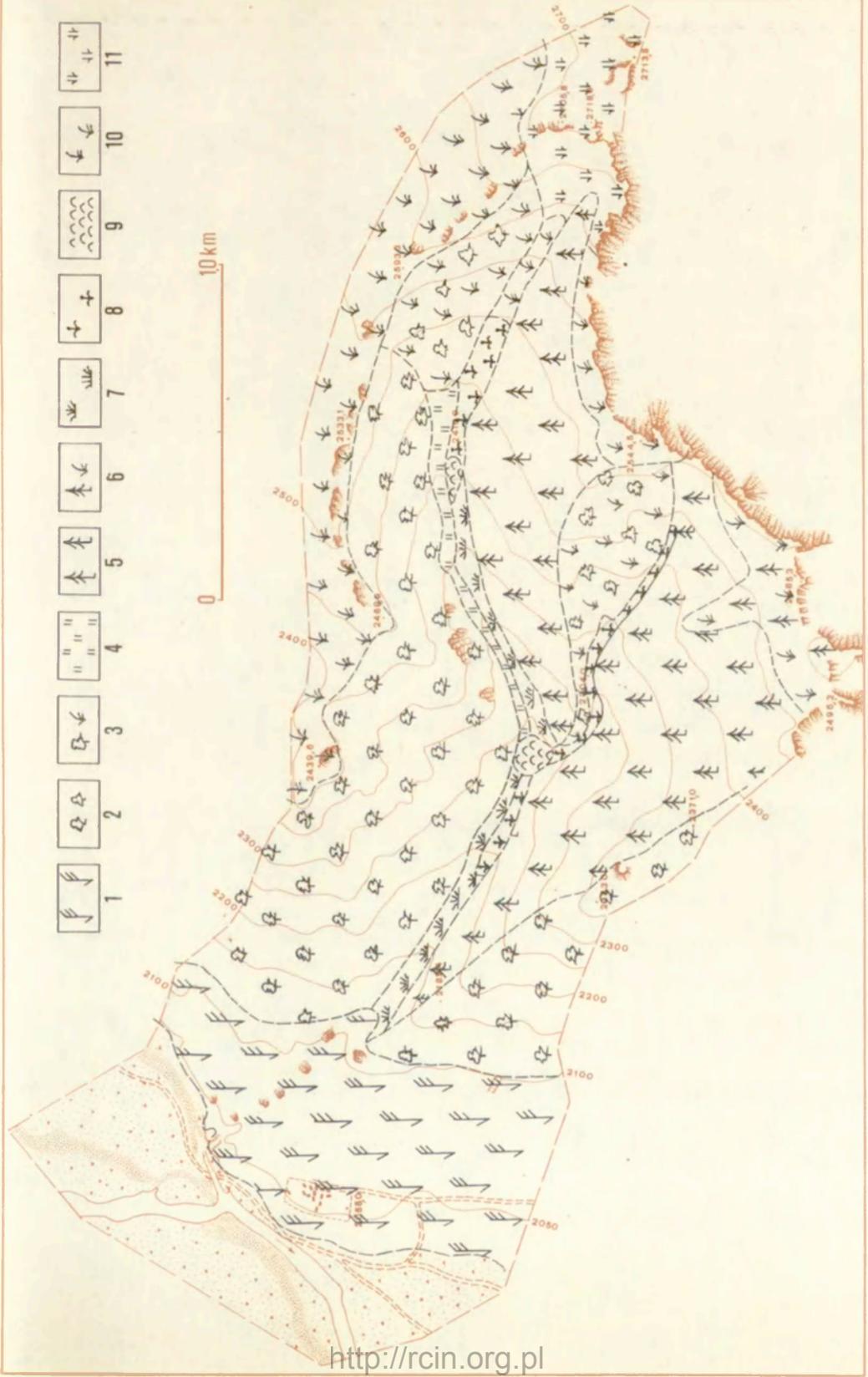
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