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ANALYSIS OF A SHEEP PASTURE ECOSYSTEM IN THE PIENINY MOUNTAINS (THE CARPATHIANS)

II. THE SOIL-GEOLOGICAL CONDITIONS*

ABSTRACT: The soils of the pastures discussed were formed from flysch rocks (carbonate sandstones, mudstones and marl shales), red globotruncate marls and from the deluvial weathering of flysch rocks overthrust on marl. Brown, leached, pseudogley and typical brown soils were distinguished on the basis of field investigations and physico-chemical properties. All the soils have a very small amount of available mineral components, mainly phosphorus, which has an influence on the low productivity of the pastures.

1. INTRODUCTION

The geobotanical characteristics of the upland pastures of the entire region of the Małe Pieniny mountains was presented in the general study (Czerwinski, Kotowska and Tatur 1974). Complex studies, carried out by the Insitute of Ecology, PAS, were located, however, on a small section of the mountain pastures and therefore arises the necessity for a more detailed description and analysis of the geology and soils of this area, which might be of use in all the microbiological, zoological and botanical investigations, in which the soil conditions play the decisive role as one of the fundamental elements of the habitat.

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Mountainous soils were separated into individual group in the systematics of the Polish Soil Science Society, retaining identical systematical units which are distinguished for lowland terrains (Kowalkowski et al. 1959). That is to say that it involved laying a stress on the specifics of the geomorphic-climatic conditions of the mountains. The elements distinguishing the mountainous terrains from the lowlands are: the more greatly diversified geological structure and the influence of the rocks on the soil-forming process (Dobrzański et al. 1958, Komornicki 1958), favouring the phenomenon of erosion, the deluvial processes and mass movements on the morphology of the terrain and the leaching effect of the rain water flowing from under the surface, the differing climatic conditions (Uziak 1963).

The moment which makes it difficult to elaborate a soil study, especially on the Carpathian Foreland (Przedgórze Karpackie), is the large heterogeneity of the flysch rocks, composed of many series of a diametrically different mineral composition and diverse chemical properties (Dobrzański 1952).

The studies heretofore (Uziak 1963) show that the dominant flysch type throughout the Carpathian terrains are brown soil and an especially isolated subtype of acid brown soils.

2. METHODS AND MATERIALS

Taking advantage of the lithostratigraphic variability, established by Birkenmajer (1958, 1965, 1970) the geological structure of the terrain described was drawn up on the basis of field investigations. The petrographic descriptions of the rocks were carried out on the basis of observations on thin microscopic sections in the specimens taken of the basic types of the rocks. Differential thermal analyses were also carried out for some specimens.

Pedological field investigations were carried out on the basis of 11 soil profiles, which were located by taking into consideration the configuration of the terrain and the changeability of the lithological subsoil. The morphological features described, jointly with the results of the analyses on soil specimens, taken from individual genetic levels, enabled a correct individualization of the basic units of the soils.

There were determined in the soil specimens: the mechanical composition – by Casagrande's areometrical method in Prószyński's modification, pH – electrometrically, the organic C content – by Tyurin's method, the content of the total N – by Kiejdahl's method, the hydrolythic acidity – by the Kappen method, the quantity of metal cations – by the Pallmann method, the K_2O and P_2O_5 available content – by the Egner-Riehm method and a general chemical analysis (SiO_2, Al_2O_3, Fe_2O_3, P_2O_5, CaO, K_2O, MgO) melting off the soil with Na_2CO_3 and determining in feet the individual components by the generally applied physico-chemical methods.

The results only of some soil profiles are presented in the tables and the graphs. The complete documentational material is available at the Insitute of Soil and Agricultural Chemistry of the Warsaw Agricultural University and at the Institute of Ecology of the Polish Academy of Sciences.

3. GEOLOGICAL STRUCTURE

Mountain pastures, where broadly conceived investigations were conducted, are located 1.5 km to the east of the Homole gorge on the slopes of mountains conventionally marked on the sketch as *X* and *Y* and in the erosive valley, occurring between these hills (Fig. 1).

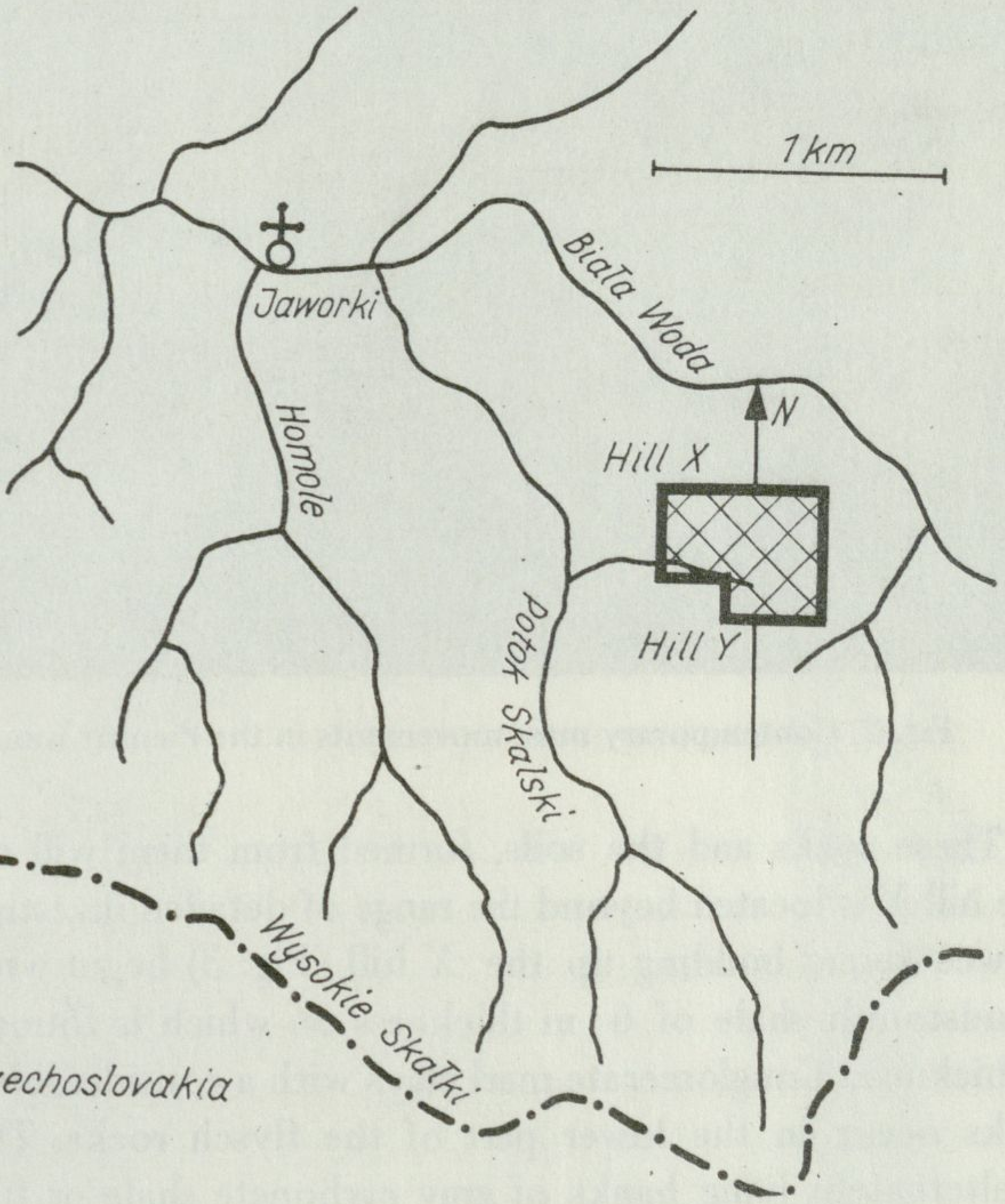

Fig. 1. Experimental area in the Pieniny mountains

The geological structures of this area are a continuation of the tectonic element, marked by Birkenmajer (1970) as a depression of the Potok Skalski (Skalski stream) which is composed of gently folded rocks of the Niedzica Series. The peak and the middle parts of the *X* hill are built up of Sromowce layers of the upper Cretaceous (lower Senon) and consitutes the structural threshold supplying the eluvium transported by mass movements to the red globotruncate (globotruncana) marls of the middle Cretaceous (Cenoman and Cognac) occurring in the erosion valley at the foot of the hill *X*.

Globotruncate marls in the southern part of the valley are covered with a layer of radiolarite and flysch limestone rock eluvium, moved by mass movement from hill *Y* (Fig. 2). The eluvium, overlapping the marls is completely decalcified, its composition containing radiolarite rubbish. The *Y* hill itself is built of flysch rocks and the lower parts of diverse hard limestones and radiolarites of the Jurassic period and the Lower Creta-

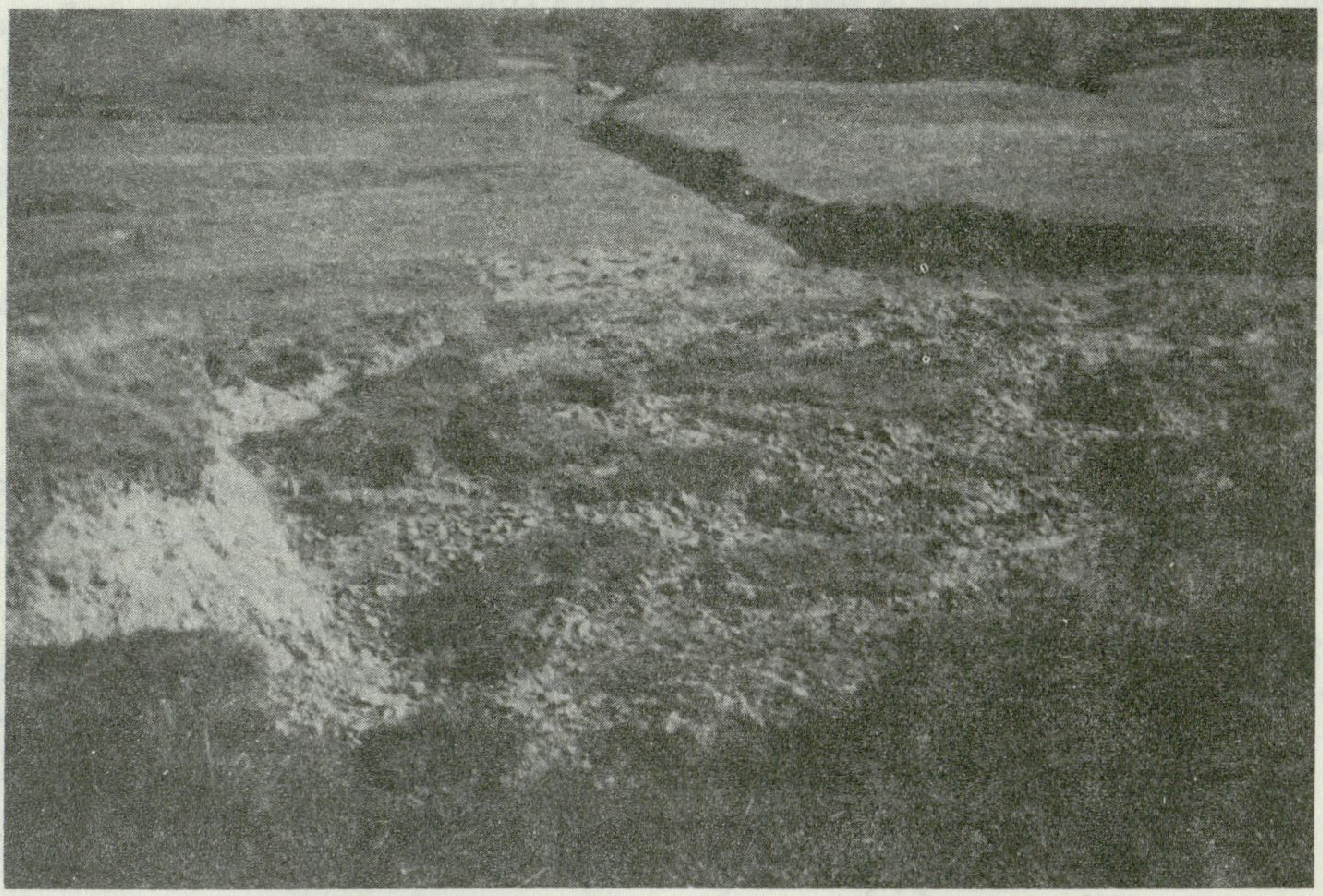

Fig. 2. Contemporary mass movements in the Pieniny mountains

ceous period. These rocks and the soils, formed from them will not be further characterized because hill *Y* is located beyond the range of detailed investigations.

The Sromowce layers building up the *X* hill (Fig. 3) begin with an olive-yellow coloured marl-mudstonish shale of 6 m thickness on which is found a flysch complex of about 100 m thickness. Conglomerate marl clays with a considerable quantity of boulders of diverse rocks occur in the lower part of the flysch rocks. The flysch complex is composed of alternately lying banks of gray carbonate shale or fine-grained sandstones and beds of marl shale or marl-mudstone shale. Sandstones and mudstones occur in beds of varied thickness within several tens of centimeters to 1 m (Fig. 4).

Directional texture, resulting most frequently from the enrichment of some layers in carbonated organic substances and mica minerals, can occur within the banks. The banks can be devoid of directional texture, then the carbonated organic substance is chaotically distributed in the rock. The detritus material of sandstones and mudstones, mainly composed of quartz grains is well sorted into fractions of coarse silt (0.1–0.05 mm), less frequently of fine sand (0.25–0.1 mm) and is most frequently weakly coated. Fine crystallic or pellitic fragments of limestone rocks, fragments of diverse volcanic rocks and feldspars, among which potassium feldspar predominates over oligoclase, occur besides quartz grains. Mica, muscovite and biotite, which is frequently coalesced with chlorite, play a second role as regards quantity. Glauconite, shaped in the form of spherical aggregates is always a characteristic mineral occurring in small quantities but always.

Principally calcium carbonate with a small additive of clay and ferrous substances is the binder in sandstones. The planimetrical analysis of the sandstones, mudstones of the

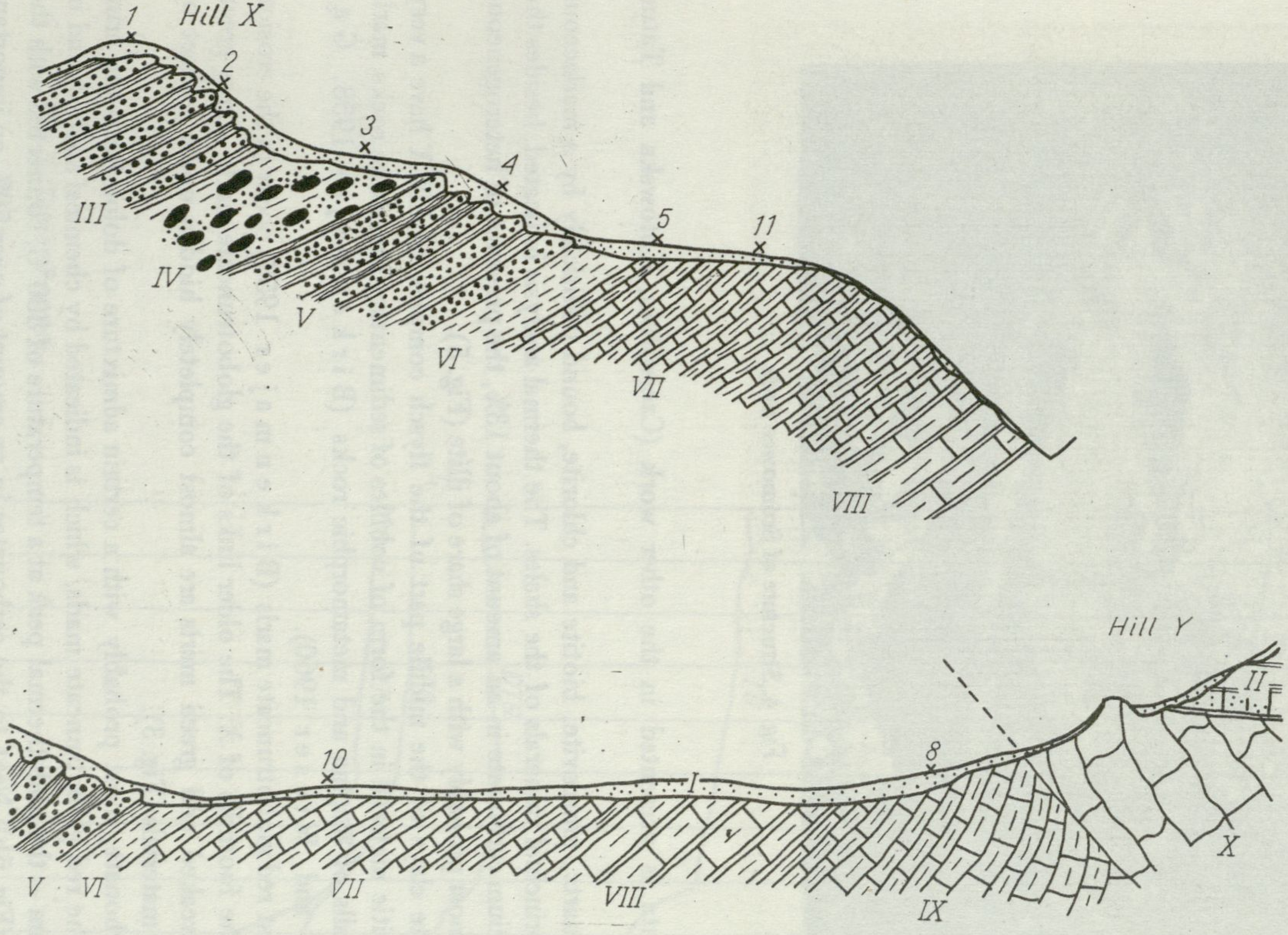

Fig. 3. Geological cross-sections of hills *X* and *Y*

I – Loams and clays (Quaternary), *II* – Złatne Beds; carbonate flysch (Tertiary), *III–VI* – Sromowce Beds (Upper Cretaceous): *III* – flysch; calciferous sandstones and mudstones interbedded with marly shales, *IV* – clays with pebbles of the various rocks, *V* – flysch calciferous sandstones and mudstones interbedded with marly shales, *VI* – marly shales, *VII–IX*: – globotruncate marls (Middle Cretaceous), *VII* – red marls, *VIII* – Śnieżnica Beds, *IX* – variegated marls, *X* – limestones and radiolarities (Jurassic and Lower Cretaceous), *1–11* – soil profiles

Fig. 4. Structure of Sromowce Beds

Sromowce strata is presented in the other work (Czerwiński, Kotowska and Tatur, unpublished).

Grains of quartz, muscovite, biotite and chlorite, bound pellitically by a marlaceous mass, are the principal minerals of the shales. The thermal analysis indicated, besides the presence of calcium carbonate in an amount of about 13%, the presence of heterogeneous clay minerals, most probably with a large share of illite (Fig. 5).

Conglomerate clays of the middle part of the flysch complex of hill *X* have a very diversified detritic material in the form of cobbles of sedimentary limestone rocks, marls and diverse spalls of magma and metamorphic rocks (Birkenmajer 1958, Gąsiorowski and Wieser 1960).

The youngest red globotruncate marls (Birkenmajer 1958) occur in the erosion valley and at the foothills of *X*. The older links of the globotruncate marls – grey-green plate marls, streaked and green marls are almost completely hidden under a sheet of deluvial-eluvial materials (Fig. 3).

Calcium carbonate, most probably with a certain admixture of dolomite is the principal mass of the red globotruncate marls, which is indicated by chemical analysis and in the derivatogram – the endothermal peak at a temperature of 800°C, connected with the loss in weight (Fig. 5b). Next to the carbonates in an amount of over 50%, an important role as to quantity is played by fine detritus, composed of quartz, muscovite, chlorite and carbonized fragments of plants. Unidentified light clayey materials of flaky structure and with a distinctly lower birefringence than in the micas are found in the smallest fractions of the marls. The mineral, giving the rocks described a cherry-red tint, being most probably dispersed throughout the entire rock mass, is hematite, and not ferrum hydroxide,

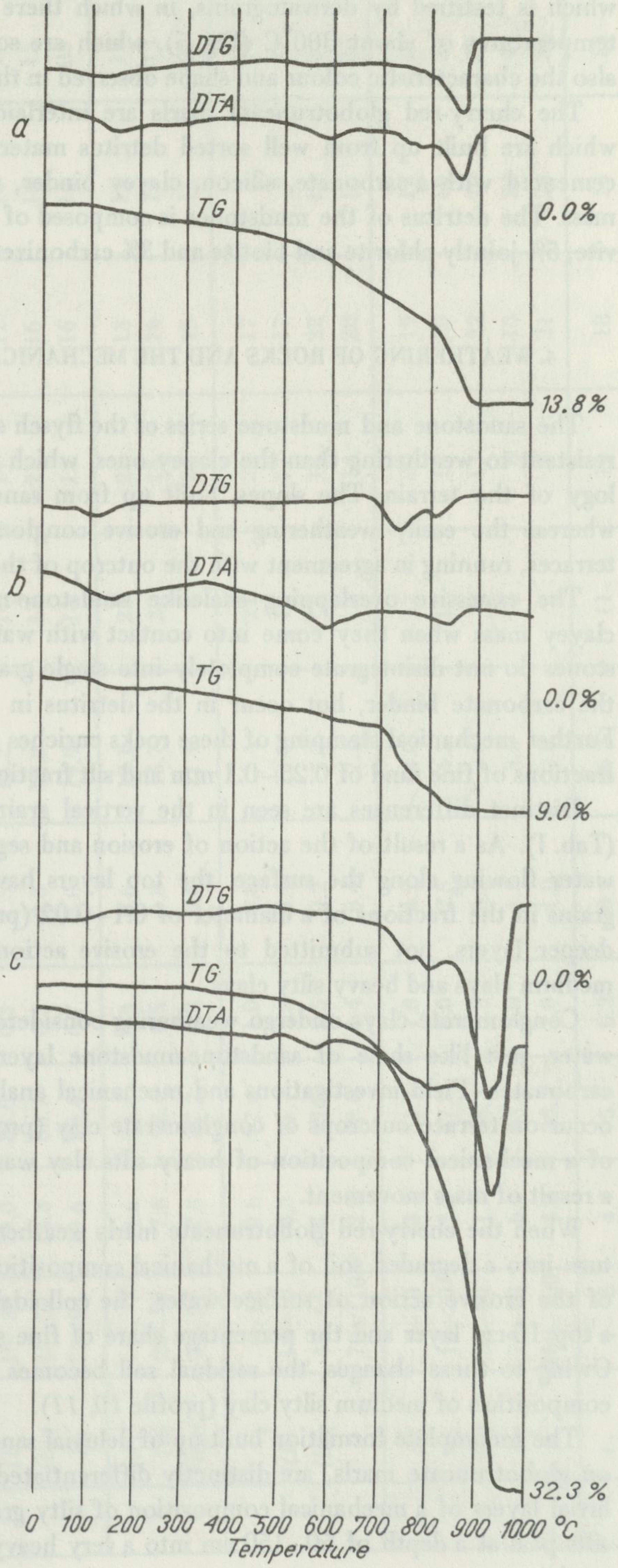

Fig. 5. Thermal curves

a – Sromowce Beds (shales), *b* – decomposed of globotruncate marls; horizon (*B*), *c* – globotruncate marls (red marls), *DTA* – differential thermal analitical curve, *DTG* – differential thermal gravimetric curve, *TG* – thermal gravimetric curve which is testified by derivatograms, in which there are no strong thermal reactions at temperatures of about 300°C (Fig. 5), which are so characteristics for hydroxides, and also the characteristic colour and shape observed in thin microsections.

The cherry-red globotruncate marls are interlaid with green-grey marl mudstones, which are built up from well sorted detritus material of a diameter of 0.05–0.01 mm, cemented with a carbonate, silicon, clayey binder, constituting about 65% of the rock mass. The detritus of the mudstones is composed of 20% quartz, 5% feldspat, 5% muscovite, 5% jointly chlorite and biotite and 3% carbonized remnants of plants.

4. WEATHERING OF ROCKS AND THE MECHANICAL COMPOSITION OF DETRITUS

The sandstone and mudstone series of the flysch series of hill *X* are considerably more resistant to weathering than the clayey ones, which is distinctly marked in the morphology of the terrain. The slopes, built up from sandstones and mudstones, are steeper whereas the easily weathering and erosive conglomerate clays form the characteristic terraces, running in agreement with the outcrop of these rocks (Fig. 3, 6).

The excessive overlapping shalelike sandstone-mudstone strata turn into a plastic clayey mass when they come into contact with water. The marly sandstones and mudstones do not disintegrate completely into single grains even after a complete leaching of the carbonate binder, but occur in the detritus in the form of finely porous boulders. Further mechanical stamping of these rocks enriches the detritus (weathering, eluvium) in fractions of fine sand of 0.25–0.1 mm and silt fractions of 0.1–0.02 mm.

Distinct differences are seen in the vertical graining of the detritus of flysch rocks (Tab. I). As a result of the action of erosion and segregational activities of precipitation water flowing along the surface, the top layers have a mechanical composition of silty grains in the fractions of a diameter of 0.1–0.02 (profiles *1*, *4*). On the other hand, the deeper layers, not submitted to the erosive action of rain water, gradually turn into medium clays and heavy silty clays.

Conglomerate clays undergo weathering considerably more easily and in contact with water, just like shale of sandstone-mudstone layers pass into a silty mass, containing carbonates. Field investigations and mechanical analysis indicated that nonuniform soils occur on terrace outcrops of conglomerate clay (profile *3*) because the residual clay soil of a mechanical composition of heavy silts clay was covered by a flysch residual soil as a result of mass movement.

When the cherry-red globotruncate marls weather, they lose carbonates and gradually turn into a degraded soil of a mechanical composition of actual clays (Tab. I). As a result of the erosive action of surface water, the colloidal fraction is partly washed out from a top 10-cm layer and the percentage share of fine sand and silt becomes larger (Tab. I). Owing to these changes, the residual soil becomes lighter and indicates the mechanical composition of medium silty clay (profile *10*, *11*).

The incomplete formation built up of deluvial sandy-mudstone weathering overlapping on globotruncate marls, are distinctly differentiated as regards granulation. The top deluvial layers of a mechanical composition of silty grains (profile *5*) or medium and heavy silts pass at a depth of 50–150 cm into a very heavy clayey weathering of globotruncate marls.

Tab. I. Mechanical composition of soil

Profile *1* – medium leached brown pseudogley soil, profiles *3*, *4* – strongly leached brown pseudogley soils, profiles *5*, *8* – weakly leached brown pseudogley soils, profile *10* – typical brown soil

Pro-file No.	Horizon	Depth (cm)	Share of fractions		Per cent of fractions in diameter (mm)							
			> 1 mm (%)	< 1 mm (%)	1–0.5	0.5–0.25	0.25–0.1	0.1–0.05	0.05–0.02	0.02–0.006	0.006–0.002	< 0.002
1	A_1	0– 8	4.6	95.4	0.3	1.3	14.4	27	20	14	9	14
	(B)	8–18	8.4	91.6	0.2	1.4	12.3	24	16	14	12	20
	(B)gC	20–55	4.4	95.6	0.2	1.2	6.4	9	26	11	14	31
3	A_1	1–10	5.2	94.8	0.3	1.5	22.2	36	16	8	8	8
	$A_1(B)$	11–14	8.2	91.8	0.4	1.6	18.0	27	18	14	13	8
	(B)	18–35	19.0	81.0	0.3	1.5	15.2	17	19	17	15	15
	(B)g	40–53	14.3	85.7	0.5	2.3	18.2	13	21	16	14	15
	Dg	72–94	19.6	80.4	0.7	4.0	19.9	14	12	16	14	23
4	A_1	1– 7	4.6	95.4	0.3	0.6	18.1	21	23	13	11	13
	(B)	20–40	7.6	92.4	0.5	0.8	15.7	22	18	16	14	13
	(B)gC	54–57	7.8	92.2	0.3	0.6	21.1	8	19	15	15	21
5	A_1	0–12	2.6	97.4	1.0	0.6	17.4	21	22	17	7	14
	(B)	12–40	8.3	91.7	1.5	0.9	19.6	13	17	17	9	22
	(B)g	45–65	4.5	95.5	1.5	0.2	7.3	5	18	22	13	33
	D	70–110	2.0	98.0	1.4	0.4	7.2	1	14	28	13	35
8	A_1	0–10	18.3	81.7	1.8	4.2	4.0	12	29	19	13	17
	A_1	10–20	42.2	57.8	6.0	2.5	4.5	13	19	20	16	20
	(B)	50–60	11.7	88.3	3.3	3.3	3.6	8	13	22	20	30
	Dg	70–80	6.2	93.8	2.0	1.5	3.5	4	8	15	22	44
	D	160–200	4.8	95.2	1.0	1.0	2.0	3	7	21	28	36
10	A_1	1– 8	4.4	95.6	0.3	0.5	26.2	11	16	18	15	13
	(B)	20–37	2.6	97.4	0.6	0.3	7.1	5	11	27	23	26
	(B)C	60–74	16.5	83.5	0.4	0.1	11.4	4	12	27	21	23

Weathering moved from hill *Y* onto older globotruncate marls (profiles *8, 9*) contain a large admixture (10–50%) of radiolarite rubble very resistant to weathering. The granular mass displays the mechanical composition of clayey silts, heavy bulders and clays.

5. SOIL-FORMING PROCESSES AND THE SYSTEMATIC UNITS OF SOILS

The principal soil-forming process on the pasture terrains studied is the weathering of rocks and minerals, connected with the transformation of inflowing organic substances into humus and the formation of an organic-mineral compounds in the presence of colloidal clay. These changes lead to the formation of brown soils leached in various degrees from carbonates and metal cations. The process of reduction of iron compounds may, moreover, superimpose on the process of browning, the result of which is the appearance of green stains of pseudogleying in soils. Pseudogleying takes place when the top layers of a mechanical composition of siltsor silty formations are more permeable for rain water and when a heavy silty weathering occurs in the subsoil in which stagnant rain water periodically creates oxygenless conditions.

Taking into consideration the morphological features and physico-chemical properties of soils throughout the pasture grounds, the following subtypes and kinds were isolated within the framework of brown soil types.

(1) Pseudogley leached brown soils

- (a) formed from the weathering of flysch rocks (profile *1, 2, 4*)
- (b) formed from deluvial weathering of flysch rocks on clays and on conglomerate clays (profile *3*)
- (c) formed from flysch rock deluvium on red-cherry coloured globotruncate marls (profiles *5, 6, 7*)
- (d) formed from flysch rock deluvium and limestones, containing radiolarites on globotruncate marls (profiles *8, 9*)

(2) Typical brown soils formed from globotruncate marls (profiles *10, 11*)

(1a) Leached pseudogley brown soils, formed from flysch rock eluvium, occur in the top part and on the steep sides of hill *X*, partly including within its range part of the pasture regions, called Owcza Droga (Sheep Way). They were formed under the influence of the original vegetation of the formation of coniferous forests highly acidifying the subsoil. The weathering process of rocks and leaching from eluvium of calcium carbonate proceeded intensively under these conditions. Changes followed gradually after complete decalcification in the sorption complex of the soils, consisting in partially supplanting cations of metals by cations of hydrogen (Tab. II). Besides the processes of weathering leading to the characteristic levels of browning, the reduction of iron compounds under conditions of a periodic anaerobiosis caused by the stagnation of water in the deeper not very permeable layers of eluvium is a superimposing process.

Brown pseudogleyed leached soils have the following morphological structure.

A_1 – An accumulational-humus horizon of a grey colour, of several or several-odd centimeters, relatively easy for water to permeate. Crumb structure. A weakly compact system

(*B*) – The browning horizon, brown or light brown in colour of a lumpy structure and a medium compact system. Single decalcified and weathered porous sandstone boulders and boulders of other rocks occur in this horizon

(*B*)*gC* – A transitory horizon of a brown colour with greenish-grey pseudogley spots. The plastic earthy mass in this horizon is constituted of weathered shales, whereas the sandstone and mudstone boulders are weathered only superficially

C – weakly weathered flysch rocks

Brown soils produced from flysch are relatively shallow. The thickness of the eluvium on the top part of the hill *X* amounts to barely 18 cm and it reaches 57 cm on the slopes.

The accumulation horizons of these hills are shallow, but contain considerable amounts (3.71–4.45%) of well humified organic substances of a ratio of C:N 9.5–9.8. The degree to which horizons A_1 and (*B*) are acidified is high; proof of which are the acid and strongly acid reactions (Tab. II). The acidity of the deeper layers of horizons (*B*)*gC* and *C* is smaller and have a neutral reaction in case of an incomplete decalcification (profile *1*).

The percentual share of metal cations in an sorption complex indicates that the configuration of the terrain and the runoff of the surface and subsurface rain water play a large role in the leaching process. The brown soils, found in the peak parts of the hill (profiles *1* and *2*) are leached of metal cations to a lesser degree than the soil of the middle parts of the slope (profile *4*). The more intensive weathering of minerals in an acid medium, connected with the leaching action of the flow of the subsurface water affects the changes in the general content of mineral components. The top horizons A_1 and (*B*) as compared with deeper horizons (*B*)*gC* and *C* are enriched in silica and impoverished especially in calcium and to a lesser degree in iron, magnesium and potassium (Tab. III).

(1b) The pseudogley leached brown soils are produced from deluvial eluvium of flysch rocks on conglomerate clays as regards morphological structure and the physico-chemical properties approach those of soils described in point 1a and differ from them only in being less skeletal and by having a thicker layer of eluvium (over 1 m) and in this connection have a greater capacity for water retention. They are richer in clayey material in the deeper horizons.

(1c) Pseudogley brown soils formed from the slope-wash eluvium of flysch rocks on globotruncate marls occur in the middle parts of hill *X*, on grounds on which the majority of the zoologico-microbiological and botanical investigations are localized. The morphological structure of these soils is as follows.

A_1 – An accumulation-humus horizon, several or several tens of centimeters in thickness, grey in colour. Of crumb structure. A weakly compact system

B_1 – The browning horizon of a brown or light brown in colour. Grey-green spots of pseudogleying frequently appear in the bottom parts of the horizon $(B)_1g$. A crumb structure. System – moderately compact

B_2 – clayey carbonate weathering of globotruncate marls. Brownish-cherry in colour with green spots. The upper part of this horizon has a greenish-grey colour as a result of a stronger pseudogleying – $(B)_2g$. A rather solid or prismatic structure. Compact system

D – Cherry-red globotruncate marls interlayed with green marly mudstones. Single decalcified sandstones, boulders and cobbles of other rocks, derived from conglomerate clays are to be found in horizon A_1 and (*B*)*g*

Tabl. II. Chemical properties

Profile *1* – medium leached brown pseudogley soil, profiles *3*, *4* – strongly

profile *10* –

Profile No.	Depth (cm)	pH		Content in mg/100 g soil by Egners' method		Exchangeable cations in		
		H_2O	KCl	K_2O	P_2O_5	Ca	Mg	K
1	0– 8	4.5	3.8	10.2	0.9	7.40	1.60	0.20
	8–18	5.2	4.6	7.2	0.7	11.30	1.32	0.14
	20–55	7.9	6.7	6.7	1.3	20.90	1.62	0.20
3	1–10	4.9	4.2	8.2	1.2	5.10	0.61	0.19
	11–14	4.7	3.8	9.9	0.3	3.25	0.36	0.23
	18–35	4.7	3.7	6.1	0.3	3.15	0.36	0.13
	40–53	5.0	4.0	1.5	0.3	4.05	0.67	0.14
	72–94	7.0	6.4	6.0	0.3	14.75	2.30	0.15
4	1– 7	4.7	3.8	15.8	0.2	4.70	0.99	0.23
	20–40	4.6	3.6	6.0	0.1	3.45	0.83	0.13
	54–57	5.4	4.3	5.8	0.1	7.90	1.60	0.14
5	0–12	5.8	5.0	8.5	0.8	8.90	1.22	0.18
	12–40	6.7	5.6	8.5	0.3	10.80	2.09	0.16
	45–65	7.1	6.0	9.8	9.3	13.20	2.46	0.21
	70–110	7.9	6.9	9.8	5.2	28.30	4.44	0.51
8	0–10	6.0	5.5	83.0	1.3	9.4	1.31	1.87
	10–20	6.2	5.5	–	–	12.4	0.82	0.82
	50–60	6.7	5.7	–	–	14.0	0.57	0.57
	70–80	7.0	5.9	–	–	19.2	0.66	0.66
	160–200	8.0	6.8	–	–	16.0	0.24	0.24
10	1– 8	6.3	5.8	19.0	0.2	12.75	1.22	0.35
	20–37	7.7	6.8	7.5	0.1	13.60	1.22	0.15
	60–74	7.7	7.0	5.6	0.2	15.80	1.68	0.14

The thickness of the deluvial weathering amounts to 50–70 cm and still deeper there is a plastic mass of weathered marls and for that reason the soils decsribed show a greater retention capacity of water than others. The accumulation horizons of these soils have, in comparison with the soils described in points 1a and 1b, a somewhat lower (3.28–3.60) amount of well humified humus. These soils are acidified to a lesser degree (Tab. II) and are more weakly leached of metal cations in spite of the complete decalcification of the top layers (Tab. III). The deluvial weathering overthrust contains, in comparison to the

of soil
leached brown pseudogley soils, profiles *5, 8* – weakly leached brown pseudogley soils, typical brown soil

mv/100 g soil		mv/100 g soil						
Na	Sum S_1	hydrolitic acidity H_h	$T = S_1 + H_h$	$V = \frac{S_1}{T} \cdot 100$ (%)	C (%)	Organic matter (%)	N (%)	C:N
0.16	9.36	4.91	14.26	65.6	2.41	4.15	0.254	9.5
0.15	12.91	1.93	14.84	86.9	1.58	2.72	0.174	9.1
0.18	22.90	0.91	23.81	96.2	0.65	1.12	0.087	7.5
0.09	5.99	5.67	11.66	51.4	2.73	4.71	0.221	12.4
0.07	3.91	4.91	8.82	44.3	1.37	2.36	0.154	8.9
0.07	3.71	4.99	8.70	42.6	0.59	1.02	0.073	8.1
0.08	4.94	3.16	8.10	61.0	0.48	0.83	0.053	9.1
0.13	17.33	1.06	18.39	94.2	0.56	0.96	0.058	9.7
0.10	6.07	5.70	11.77	51.6	2.15	3.71	0.219	9.8
0.08	4.49	5.59	10.08	44.5	1.13	1.95	0.114	9.9
0.15	9.79	1.97	11.76	83.2	0.63	1.09	0.064	9.8
0.21	10.42	3.25	13.67	76.2	2.09	3.60	0.232	9.0
0.12	13.17	1.44	14.61	90.1	0.67	1.16	0.070	9.6
0.11	15.98	1.13	17.11	93.4	0.53	0.91	0.056	9.5
0.14	33.39	0.91	34.30	97.3	0.27	0.47	0.060	7.5
trace	12.58	1.66	14.14	89.4	3.17	5.46	0.354	9.0
,,	13.41	1.40	14.81	90.5	1.67	2.84	–	–
,,	14.68	0.93	15.61	94.1	0.77	1.32	–	–
,,	20.00	0.47	20.47	97.9	0.53	0.91	–	–
,,	16.30	0.12	16.42	99.2	0.18	0.31	–	–
0.11	14.43	2.12	16.55	87.1	2.99	5.15	0.330	9.1
0.09	15.06	0.60	15.66	96.1	0.31	0.53	0.073	4.2
0.10	17.72	0.56	18.28	96.9	0.17	0.29	0.039	4.4

marly subsoil, more silica and fewer limestones, magnesium and total potassium (Tab. III).

(1d) Leached brown pseudogley soils, formed from deluvial detritus of flysch rocks and limestones with radiolarites on globotruncate marls occur in the southern part of the erosion valley (Fig. 6). The thickness of the coating of the completely decalcified deluvial detritus of a high content of radiolarite skeleton does not exceed 1.5 m and it becomes smaller from the foot of the hill *Y* toward the north. The soils described are located in

Tab. III. Total chemical analysis of particles < 1 mm and contents of calcium carbonate

Profile *1* – medium leached brown pseudogley soil, profiles *3*, *4* – strongly leached brown pseudogley soils, profile *5* – weakly leached brown pseudogley soil, profile *10* – typical brown soil

Profile No.	Depth (cm)	Content in per cent							$CaCO_3$ (%)
		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	P_2O_5	
1	0– 8	72.0	10.40	3.74	0.28	1.61	2.87	0.10	–
	8–18	72.6	12.83	3.98	0.36	1.21	2.85	0.10	–
	20–55	59.1	14.52	5.22	4.56	2.85	4.84	0.15	6.29
3	1–10	76.4	8.18	2.26	0.35	1.16	2.23	0.14	–
	11–14	78.2	9.56	2.13	0.35	1.03	2.44	0.07	–
	18–35	77.8	11.28	2.60	0.28	1.29	2.70	0.09	–
	40–53	78.4	11.40	2.42	0.42	1.47	2.93	0.07	–
	72–94	67.8	10.53	4.30	1.56	4.36	4.10	0.06	–
4	1– 7	73.6	11.25	2.70	0.28	1.63	2.51	0.09	–
	20–40	76.4	10.21	2.32	0.49	1.69	2.74	0.08	–
	54–57	72.4	11.56	4.20	1.22	2.37	3.25	0.08	–
5	0–12	73.2	9.38	3.29	0.42	1.99	2.90	0.14	–
	12–40	70.1	14.05	4.73	0.56	2.66	3.28	0.09	–
	45–65	63.4	16.00	5.73	0.85	3.81	5.24	0.15	–
	70–110	56.1	13.56	4.91	4.57	4.00	4.37	0.15	8.11
10	1 –8	57.9	18.05	5.66	0.49	3.57	4.61	0.15	–
	20–37	54.0	18.28	6.20	4.21	4.10	5.28	0.14	6.74
	60–74	49.2	15.22	5.46	7.92	5.78	4.96	0.11	12.80

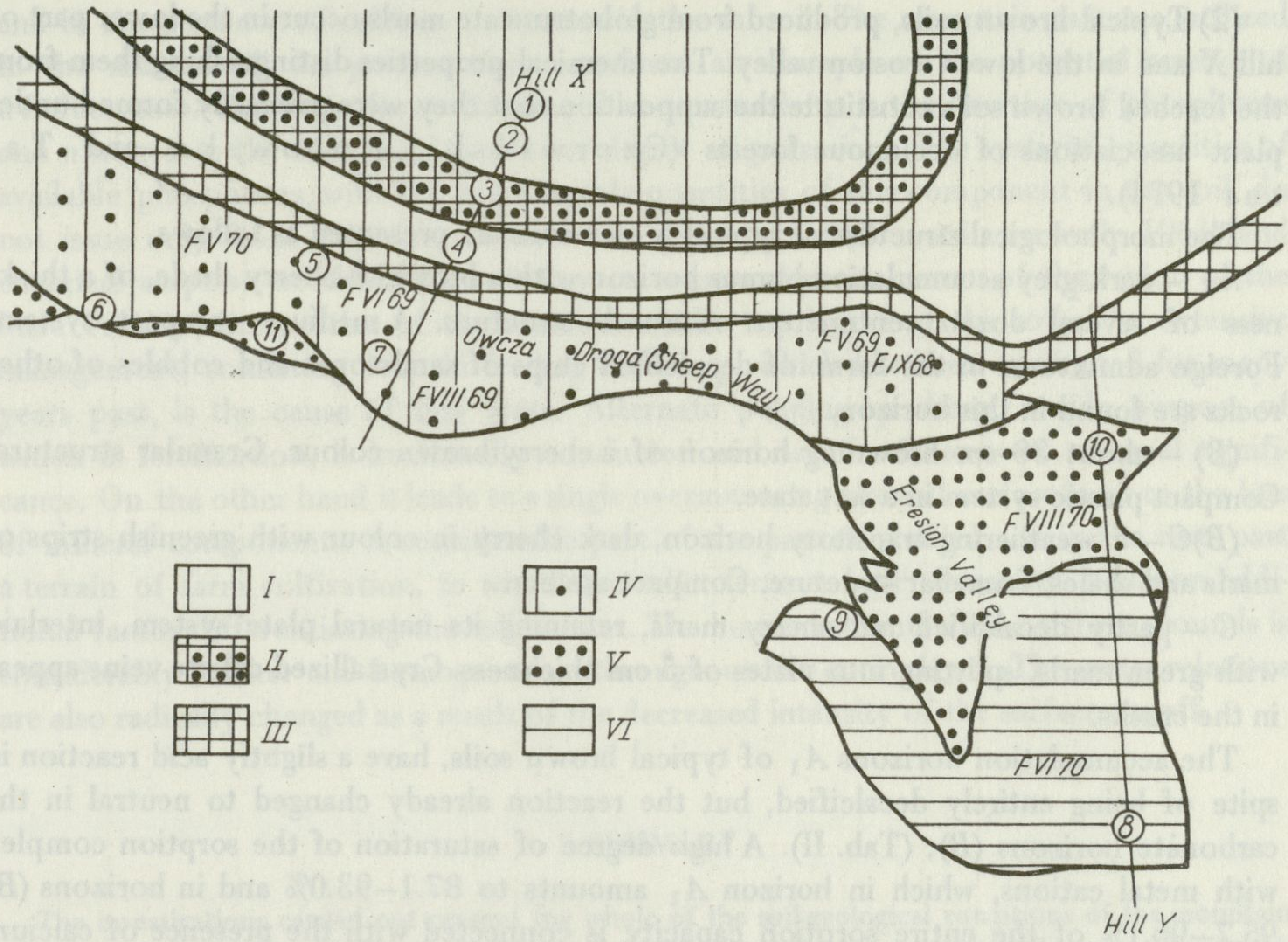

Fig. 6. Geological and soil sketch map. Penning-up sheep dates have been given at the microbiological and zoological research centers (e.g. *F VIII 70), 1–11* – numbers of the soil profiles

I – leached brown pseudogley soils developed from carbonate flysch, *II* – leached brown pseudogley soils developed from flysch deluvial weathering on marly clays with pebbles, *III* – leached brown pseudogley soils developed from flysch deluvial weathering on marly clay, *IV* – leached brown pseudogley soils developed from flysch deluvial weathering on red globotruncate marls, *V* – typical brown soils developed from globotruncate marls, *VI* – leached brown pseudogley soils developed from flysch rock weathering and carbonates with radiolarites on the globotruncate marls

a particular place. There is a flockmaster's hut there, in the vicinity of which a barrack is very frequently put up. This fact certainly has its effect on a number of chemical features of these soils. They stand out by a well formed accumulation horizon, rich in humus (5.46%) and, in spite of the acid reaction of the top layers by a high degree of the sorption complex, by metal cations (Tab. II). Therefore, profile *8* had to be necessarily located on the grounds of the sheep enclosure. The content of exchangeable K and Mg became considerably higher under the influence of penning-up sheep on the grounds where the top sorption layers were. The amount of available potassium, designated by the Egner-Rhiem method reached 83 mg/100 g of soil.

The system of the genetic horizons of brown leached soils in the profile is similar to that of soils described in point 1c, but horizons A_1 and *(B)* have a darker deeper brown colour and show a high content of radiolarite skeleton. Soils of this type are very characteristic for the Pieniny mountains; they occur at the foot of the majority of calciferous rocks.

(2) Typical brown soils, produced from globotruncate marls occur in the lower part of hill *X* and in the lower erosion valley. The chemical properties distinguishing them from the leached brown soils constitute the supposition that they were primarily formed under plant associations of deciduous forests (Czerwiński, Kotowska and Tatur 1974).

The morphological structure of typical brown soils are presented as follows.

A_1 – dark grey accumulation-humus horizon with a brownish-cherry shade, of a thickness of several dozen centimeters. A crumb structure. A medium compact system. Foreign admixtures in the form of decalcified chips of sandstones and cobbles of other rocks are found in this horizon.

(*B*) – about 30 cm browning horizon of a cherry-brown colour. Granular structure. Compact plastic system in a wet state.

(*B*)*C* – a weathering transitory horizon, dark cherry in colour with greenish strips of marls and shales. Lamellar structure. Compact system.

C – partly decalcified red cherry marls, retaining its natural plate system, interlaid with green marls, splitting into plates of 5 cm thickness. Crystallized calcite veins appear in the cracks.

The accumulation horizons A_1 of typical brown soils, have a slightly acid reaction in spite of being entirely decalcified, but the reaction already changed to neutral in the carbonate horizons (*B*); (Tab. II). A high degree of saturation of the sorption complex with metal cations, which in horizon A_1 amounts to 87.1–93.0% and in horizons (*B*) 95.7–96.1% of the entire sorption capacity is connected with the presence of calcium carbonate, lying not very deeply under the surface. The accumulation horizons are rich in well humified substances (5.15%) even though this cannot be seen by eye. The weathering process of marls, consisting in the first place of their decalcification leads to an enrichment of the top layers in silica (Tab. III).

A characteristic feature of typical brown soils, formed from marls is – in spite of the clayey eluvium – the almost complete absence of pseudogleying, which can be explained by the very slow percolation of rain water into the soil and the flowing off of the surface water into the soil and the flowing off of the excess water over the surface.

All the analysed soils of the investigated pastures are, in spite of the relatively large quantity of total phosphorus, very poor in the available forms of this element. The amount of available phosphorus determined by the Egner-Riehm method does not exceed 1.2 mg/100 g of soil. The deficiency of phosphorus in these conditions is one of the factors, limiting the productivity of mountain pastures. In the brown leached soil (pt. 1a, 1b) – apart from the deficiency of phosphorus – the factor limiting productibility and exerting an unfavourable influence on the botanical composition of the ground cover of the pasture field is the strong acidification.

6. FINAL REMARKS

All the brown leached soils of the pastures studied most frequently, differ from the flysch brown acid soils, assigned throughout the Carpathian terrains (Dobrzański et al. 1958, Uziak 1963) in reaction and sorption properties of the deeper horizons and in the presence of calcium carbonate in the subsoil. The mountain pastures, utilized in the manner till the present time constitute an example of the potential reserve of a fodder base. The basic factor limiting their productivity is the shortage of phosphorus and nitrogen in the soils and, to a lower degree of potassium. The vestigial quantities of available phosphorus, with the considerable quantities of this component in the soil, do not issue only from the high acidity of mountain soils (Wondrausch 1961) and chemical sorption of the PO_4^{--}, but they are a general phenomenon of the region of the Małe Pieniny, irrespective of the reaction of the top layers of the soil. The extensive management, consisting only in feeding the sheep, which has been conducted for many years past, is the cause of this state. Alternate penning-up sheep, a side purpose of which is fertilization, is irrationally conducted and as a fertilizer is of minimal significance. On the other hand it leads to a single overmanuring of small surfaces and to the loss of mineral components. A considerable part of the pasture studied was in the near past a terrain of farm cultivation, to which the relict terraces bear testimony, being an additional factor differentiating the soil habitat. The humus accumulation on these grounds is considerably thicker and homogeneous throughout the entire layer. The water relations are also radically changed as a result of the decreased intensity of the surface runoff.

7. SUMMARY

The investigations carried out present the whole of the soil-geological conditions of the mountain pasture in Jaworki (Fig. 1). The pasture is located within the tectonic depression element of the Potok Skalski (Skalski stream), which is composed of a gentle undulating rock of Niedzica Series (Fig. 3):(1) various limestones and radiolarites – Jurassic and Lower Cretaceous, (2) globotruncate marls – Middle Cretaceous, (3) the Sromowce layers (carbonate flysch, with the characteristic horizon of clays with cobbles) – Upper Cretaceous. Soil variability occurring on the pasture lands (Tab. I, II, III, Fig. 6) is conditioned both by abiotic factors (lithological and geomorphological changeability), diverse primary vegetation,different history of the utilization of the soil. The following soil units were differentiated on the terrains investigated: (1) brown, leached, pseudogley soils – (a) formed from flysch rocks, (b) formed from deluvial eluvium of flysch rocks on clay conglomerates, (c) formed from deluvial eluvium of flysch rocks on globotruncate marls, (d) formed from deluvial eluvium of flysch rocks and limestones from radiolarites on globotruncate marls and typical brown soils formed from globotruncate marls.

Taking into consideration the degree of acidity, the content of metal cations in the sorption complex and the presence of carbonates in the subsoil, the following were distinguished among the brown, leached pseudogleyed soils: strongly, moderately and slightly leached. The process of leaching, apart from acidity, decalcification and unfavourable changes in the sorption complex lead to the impoverishment of horizons A_1 and (B) in calcium, iron, potassium, and enrichment in silica. All the soils of the pastures lands investigated have traces of the quantity of available phosphorus, which jointly with the lack of an inflow of major amounts of mineral nitrogen limits in a large degree their production possibilities.

8. POLISH SUMMARY (STRESZCZENIE)

Przeprowadzone badania dają całokształt glebowo-geologicznych warunków pastwiska górskiego w Jaworkach (fig. 1). Pastwisko to znajduje się w obrębie elementu tektonicznego – depresji Potoku Skalskiego, w skład którego wchodzą łagodnie sfałdowane skały serii niedzickiej (fig. 3): (1) różnorod-

ne wapienie i radiolaryty – jura i dolna kreda, (2) margle globotrunkanowe – środkowa kreda, (3) warstwy sromowieckie (węglanowy flisz z charakterystycznym poziomem iłów z otoczakami) – górna kreda. Występująca na terenie pastwiska różnorodność gleb (tab. I, II, III, fig. 6) uwarunkowana jest zarówno czynnikami abiotycznymi (zmienność litologiczna i geomorfologiczna) jak i czynnikami biotycznymi (różnorodna roślinność pierwotna, odmienna historia użytkowania gleby). Na badanym terenie wyróżniono następujące jednostki glebowe: (1) gleby brunatne wyługowane pseudooglejone – (a) wytworzone za skał fliszowych, (b) wytworzone ze zwietrzeliny deluwialnej skał fliszowych na iłach zlepieńcowatych, (c) wytworzone ze zwietrzeliny deluwialnej skał fliszowych na marglach globotrunkanowych, (d) wytworzone ze zwietrzeliny deluwialnej skał fliszowych i wapieni z radiolarytami na marglach globotrunkanowych oraz (2) gleby brunatne właściwie wytworzone z margli globotrunkanowych.

Biorąc pod uwagę stopień zakwaszenia, zawartość kationów metali w kompleksie sorpcyjnym oraz obecność węglanów w podłożu, wśród gleb brunatnych wyługowanych pseudooglejonych wyróżniono gleby silnie, średnio i słabo wyługowane. Proces ługowania poza zakwaszeniem, odwapnieniem i niekorzystnymi zmianami w kompleksie sorpcyjnym doprowadził do zubożenia poziomów A_1 i (B) w wapń, żelazo i potas, a wzbogacenia w krzemionkę. Wszystkie gleby badanych pastwisk mają śladowe ilości fosforu przyswajalnego, co z brakiem dopływu większej ilości azotu mineralnego ogranicza w dużym stopniu ich możliwości produkcyjne.

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