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The physiography and character of the substratum of the drainage areas of streams of the Polish High Tatra Mts

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Abstract — Within the framework of collective hydrobiological investigations the more important abiotic factors (relief, structure, and physico-chemical properties of the substratum) of the aqueous medium of the principal streams of the Polish High Tatra Mts were determined. It was found that the zonal differentiation of hydrological conditions, of the chemical composition of water, and of the substratum of the bottom of these streams chiefly depend on the quality of the substratum of the drainage area and on climatic conditions. The shift (glacial and contemporaneous) down valleys and beds of streams of fragments of higher-lying crystalline rocks increased the range of their influence on the quality of the water and the settlement of benthic animals. In conclusion, the peculiar character of the factors of this medium was discoussed as well as the possibilities of their action on aqueous biocoenoses.

The present work forms part of collective investigations on biocoenoses of the main streams of the Polish part of the Eastern Tatra Mts, carried out by the Laboratory of Water Biology of the Polish Academy of Sciences in Cracow in the years 1962—1966. Its aim was to determine the more important factors (relief, structure and properties of the substratum) of the aqueous medium of this kind of mountain stream. The knowledge of these data is necessary for a pragmatically carried out analysis of the course of hydrochemical and biological processes occurring in these media. Apart from climatic factors, the relief and physico-chemical properties of the substratum of the drainage areas of mountain streams influence in a high degree the forming of life conditions in these streams. This influence appears not only indirectly through the relation with hydrology and the chemical composition of the water, but also directly. Thus, for example, L a n d f o r d and F r a y (1969) observed that *Plecoptera* inhabit calcareous bottoms more readily than others. According to W e n i n g e r (1968), the dwelling of *Ephemeroptera* and *Plecoptera* larvae at a stand with strong current depends in great measure on the quality and structure of the bottom of mountain streams. C u m m i n s and L a u f f (1969) showed in their investigations that the choice of the place of microsettlement of some animals in the river bottom depends above all on the size of the substrate particles. The present review study was based on materials drawn from the literature and on the author's own complementary investigations (hydrochemical, pedological, and others).

The physiography of the drainage area

The investigated streams drain, through a dense net of permanent and seasonal tributaries, the northern slopes of the Polish High Tatra Mts and part of the Spiš Upland. They form part of the drainage areas of two larger streams, the Białka Tatrzańska and the Sucha Woda. The Białka Tatrzańska in its further course, up to the mouth to the river Dunajec, drains further the eastern part of the vast Nowy Targ Basin.

In the morphological aspect one distinguishes in the Tatra mountain nest the highest rock ridges of its central part called „wierchy", and the lower wooded slopes determined as „regle". This morphological division also corresponds in great measure to the geological structure of the terrain.

The part of the highest ridges in this fragment of the Tatra Mts (1600—2499 m above sea level) shows features of a high-mountain-alpine relief. The elevations usually have sharp and jagged ridges and very steep slopes dissected by long, deep valleys, numerous ravines (with mighty Holocene talus cones), and cirques carved out by glaciers. The two deepest main valley occur in this part of the Tatra Mts: the Biała Woda and the Sucha Woda valleys. To the first of them lateral valleys of the Rybi Potok, of Roztoka, and the Waksmundzka Valley come down in hanging outlets, and to the other the Pańszczyca Valley. The cirques occur in the upper sections of valleys cut off by rock steps in several altitudinal belts (on the site of old firn reservoirs — K l i m a s z e w s k i 1964). In their usually deepened bottoms, of massive rock or covered with mighty banks of moraines and of later rock falls, numerous small lakes have formed (P a s t e r n a k 1965). Below the crags the slopes are at first mosaically overgrown with patches of gramineous vegetation poor in species (alpine zone) and still lower with densely growing dwarf mountain pine (*Pinus montana*).

The montane zone of the Tatra Mts (1100—1600 m above sea level), in which as far as the upper timber line of about 1570 m spruce prevails, has gentler shapes but is still more dissected. It is cut not only by the main valleys beginning above, but also by a number of small, narrow valleys, ravines, and V-shaped valleys with considerable variations of the bottom level, due to the various resistance to weathering of rocks of the substratum. The bottoms of these lateral valleys are largely covered with boulder material of various kind, and in places, within the range of limestones, dolomites, and marls, they are deformed by Karst phenomena (G ł a z e k and W ó j c i k 1963).

The Spiš Upland, forming the central part of the drainage area of the stream Białka Tatrzańska, represents a poorly forested belt with rounded and fairly evened elevations (700—1100 m above sea level). It becomes lower towards the north, passing gradually into the terrain of the mountain foreland basin.

The area of the Nowy Targ basin has a very even surface (500—700 m above sea level) being almost entirely under cultivation. The few small hills are calcareous monadrocks prepared by the erosion from the Pieniny Cliff Belt Zone. The stream Białka flows between two of them (Kramnica and Obłazowa).

On account of the considerable differences in the relative heights of the drainage area, the climate of this region greatly varies in the particular vertical zones. In that part of the drainage area lying above the upper timber line the mean annual temperature from a multiannual period ranges from -2 to $+2$°C, the annual total of precipitation from 1400 to 1800 mm, and the snow cover is maintained on the average 280—305 days in the year. In the forest zone the corresponding figures are from $+2$ to $+4$°C, 1200—1400 mm, and 210—250 days. On the other hand, within the Upland and the Basin the mean annual temperature varies around $+6$°C, the total precipitation amounts to about 1000 mm, and the duration of the snow cover to 165—210 days (O r l i c z 1962, H e s s 1965).

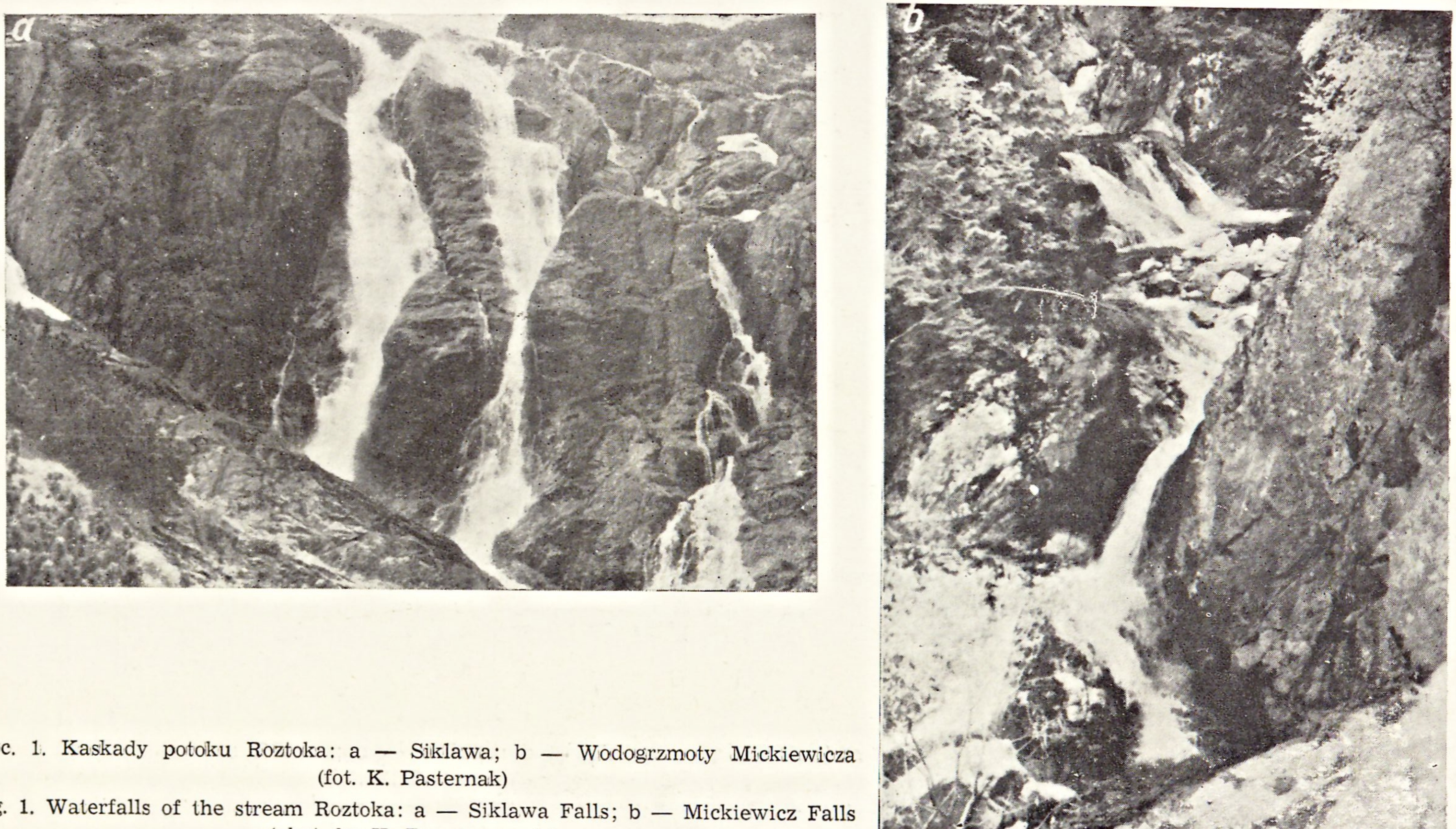
The stream Białka Tatrzańska arises from the junction of three smaller streams: Biała Woda (in Czechoslovakia), Rybi Potok, and Roztoka. These streams drain the easternmost part of the highest ridges of the Tatra Mts. They rise in lakes supplied with water by small, usually seasonal streams, rapidly collecting the flowing rain waters, as well as those retained in fissures and small pools of morainic covers. Of this type of small initial creeks the stream in the Valley Za Mnichem, that in the Mięguszowiecki Cirque, and the stream joining the lake Czarny Staw under the Rysy with the lake Morskie Oko were biologically investigated. These three main source streams of the Białka below the lakes flow in beds covered with large morainic rock boulders or over massive rock. On account of the frequent rock steps and overhangs of the mouths of lateral valleys, numerous waterfalls form in their course. The largest are the waterfall Siklawa (70 m) situated in the source area of the stream Roztoka close to its outflow from the lake Wielki Staw, and the Mickiewicza Falls in the lower course (fig. 1). In the still places near the headcuts, where the velocity of the water flow slightly decreases, some fine gravel and sand, as well as clayey and organic matter, accumulate between the stones. These places are a better environment for the settlement of benthic animals. The mean gradient of the Rybi Potok amounts to about 63.0‰ and that of Roztoka to 99.2‰. The greatest initial gradients often exceed 300‰.

The stream Białka, a little below the mouth of the Roztoka, flows already into the terrain of the forest zone built for the most part of sedimentary rocks. On account of this and owing to the forest density and thicker soil cover, the hydrological conditions in this part of drainage area are different from those on a crystalline, impermeable substratum. Not only is the retention of the latter greater, but also part of the surface waters flow away through Karst swallow-holes to the underground water bodies. In consequence, the stream Białka (a little above the mouth of the Waksmundzki Stream) seasonally loses part of its waters, and in the further section of this zone receives only a very few small tributaries. A larger one supplies it only the initial section of the wooded Upland (after 8 km). This is the Jaworowy Stream, collecting its waters mostly from sedimentary rocks of the terrains of the Bielskie Tatra Mts and the Upland belonging to Czechoslovakia.

In the further sub-montane and plain area of the Nowy Targ Basin the Białka Tatrzańska flows northwards in a already much wider and inhabited valley with large gravel banks near the bed and older alluvial terraces (overgrown in places with small tree concentrations). The stream in this section is joined on both sides by a number of small tributaries, the largest of which flows from the Trybsz region.

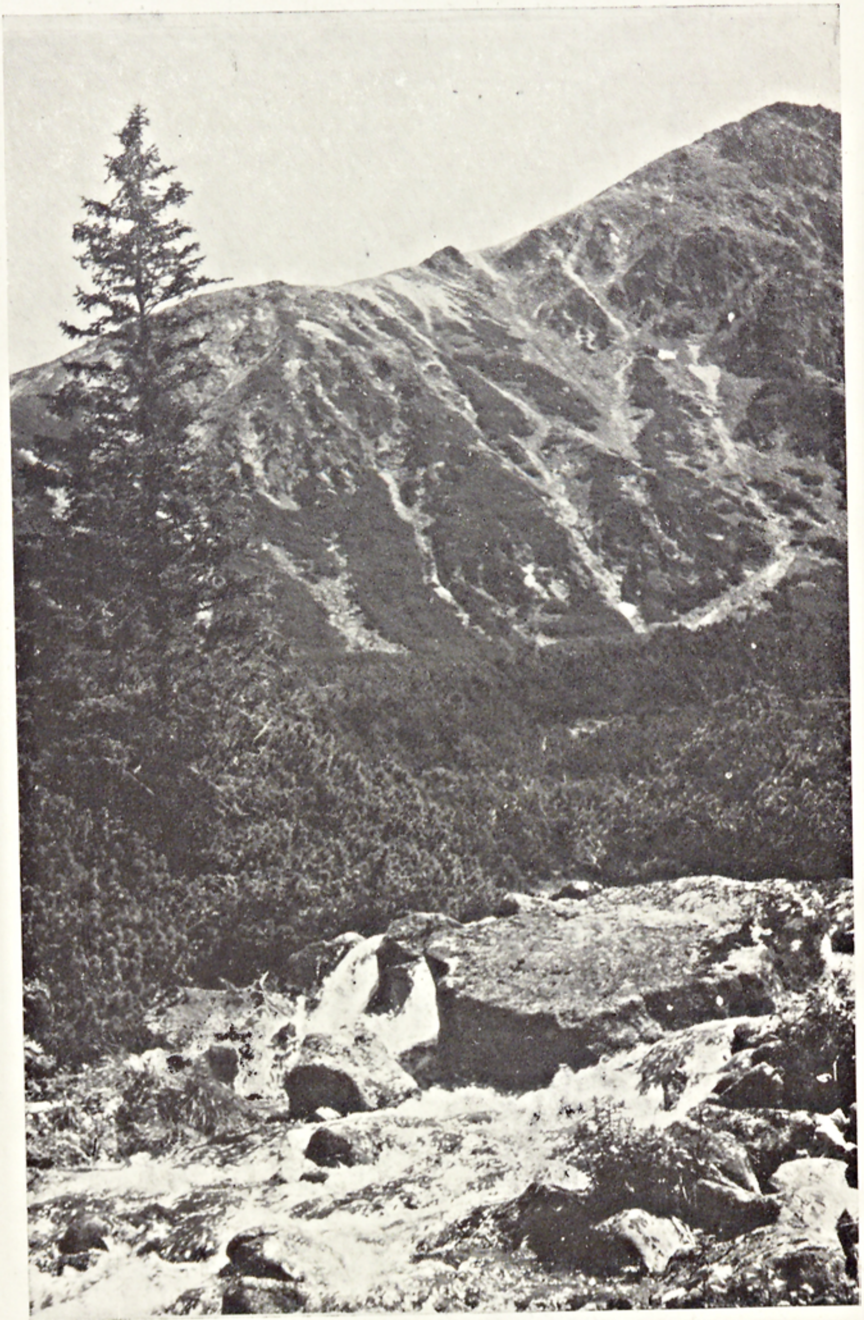
The course of the whole Białka stream is 40.4 km long, its catchment basin occupying an area of 235.4 sq. km. The mean gradient of the stream in its upper course up to the gauging section on the Łysa Polana amounts to about 43.4‰, and in the further course to about 12‰. The lowest river yield occurs in the winter season (snow cover, reduced supply from ground waters).

The stream Sucha Woda collects its waters from the neighbouring more western section of the Tatra Mts, including the valleys Gąsienicowa, Pańszczyca, and Sucha Woda. It is formed by the junction of two small streams draining two bays (cirques) of the Gąsienicowa Valley, separated by the belt of Kościelec (1863—1258 m above sea level). The source of the first stream flowing in a steep stony channel from the western part of the valley are the Zielony and Litworowy Staw. This stream, a little below the Litworowy Staw, disappears in fissures of the stony banks covering the whole bottom of the valley. According to many investigators quoted by Komornicki and Oleksynowa (1969), part of these waters escapes through fissures to the neighbouring Goryczkowa Valley (vauclusian spring of Bystra). In the region of the shelter-house the stream



Ryc. 1. Kaskady potoku Roztoka: a — Siklawa; b — Wodogrzmoty Mickiewicza (fot. K. Pasternak)

Fig. 1. Waterfalls of the stream Roztoka: a — Siklawa Falls; b — Mickiewicz Falls (phot. by K. Pasternak)



Ryc. 2. Kamieniste koryto Czarnego potoku w strefie kosodrzewiny (fot. A. Kownacki)

Fig. 2. Stony bed of the Czarny stream in the mountain-pine zone (phot. by A. Kownacki)

Ryc. 3. Reglowy odcinek koryta Suchej Wody wyżłobiony w kamienistych zwałach morenowych (fot. A. Kownacki)

Fyg. 3. Regle section of the bed of Sucha Woda carved in stony morainic banks (phot. by A. Kownacki) receives a large amount of domestic sewage. The other stream (called Zmarzły in the upper part and Czarny in the lower one) receives its waters at first from the high lying Zmarzły Staw and then from the Czarny Staw and from several large springs. In the initial section (alpine zone) it flows in a very steep bed built partly of massive rock, and later, after flowing over the scarp of the Czarny Staw cirque, in a bed covered with rock banks (fig. 2). On a small section before the inflow of water from the springs the bed of the stream often runs dry.

The stream Sucha Woda, formed by the junction of these two streams, flows northwards in an already wooded valley, whose fairly flat bottom is covered with thick stony morainic banks (fig. 3). Among them the waters of the stream disappear in swallow-holes and dry up in the bed over large sections; they then reappear at the surface and flow normally. At the beginning of this section the stream Sucha Woda is supplied by a brook from under the Żółta Turnia (2087 m), and further, in the region of the Psia Trawka glade, by the stream Pańszczyca draining the valley of the same name. According to Głazek (1964), part of the waters of the stream Pańszczyca flow into the Sucha Woda subterraneously. In its further section the stream Sucha Woda disappears once more in swallowholes (1100 m above sea level). It reappears for good only on the little permeable Flysch substratum of the Upland (900 m) in the region of its junction with a small right-bank stream flowing from the gorge Skalnite beside the belt Kopy Sołtysie (1334—1420 m). The stream Sucha Woda in this region is supplied by several large vauclusian springs. In the dried up sections of the stream a regular flow of water is noted only from April to the end of July or at the most till August. In the further sub-montane section the stream Sucha Woda, after receiving on its right bank the tributary stream called Filipka (770 m), joins the large stream Poroniec. The stream Sucha Woda is 15.5 km long, the area of its catchment basin amounting to 68 sq. km, and the mean gradient to 68‰.

As can be seen from the above, the water regime is different in the two streams, being particularly complicated in the Sucha Woda (the underground inflow and outflow of waters is not in conformity with the topographic drainage area). This is related above all with the lithological structure of the substratum. A detailed picture of hydrological differences in the Tatra streams is presented in Gieysztor's (1966) work.

Rocks

The structure of the substratum of the drainage area will be presented here chiefly in the lithological aspect, account being taken of the chemical and physical properties of the occurring rocks and soils. For the content of dissolved mineral salts in surface waters depends not only on the chemical features of the substratum but also on the physical ones, such as, among others, the permeability or resistance to weathering (Pasternak 1968).

In the investigated fragment of the Tatra Mts two structural units can be distinguished: the zone of the highest ridges („wierchy"), occupying the interior parts of the massif, and the forest zone („regle") forming its lower northern part.

In the zone of the highest ridges crystalline and sedimentary rocks occur. The former build the highest main bulk of the mountains. They chiefly occur in the form of granitoids of two varieties: normal and white granite. The normal granite, occupying the greater part of the area of the High Tatra Mts, is an oligoclase-biotite (calc-sodium) rock approximate to tonalite. Northwards, the content of biotite increases in this granite, which becomes more basic. These rocks are characterised by a predominance of plagioclase (Na, Ca) over potash feldspars which are often not present at all, by a high content of quartz, and a low one in the sum total of dark minerals (Mg, Fe), chiefly represented by biotite. The white granite is a fine-grained microcline-albite rock with muscovite (richer in potassium), slightly more acidified. A belt of Triassic quartzites and quartzite sandstones, widening within the drainage area of Sucha Woda, starts from above the sedimentary cover of the crystalline main bulk of the Tatra Mts. The quartzite sandstones in the course of weathering from characteristic barren block fields, usually overgrown with yellowish lichens of the genus *Acarospora*. Lower, dolomites, limestones, and clay shales of varying age (Triassic-Cretaceous) occur, with intercalations of sandstones, often quartzitic, or of marls. The forest zone („regle") unit, covering the lowest part of the Tatra Mts, is represented by a series of rocks of the lower nappe, i. e. Triassic fairly fractured cellular and sugarlike dolomites with intercalations of bedded limestones and clay shales with dolomites and limestones, hard Jurassic limestones rich in silica, with intercalations of marls and calcareous sandstones, as well as Cretaceous marls and limestones (right bank of the stream Jaworowy, upper section of the stream Filipka). The carbonate rocks of this series generally have finer grains than those of the highest ridges, showing a complicated folding (Sokołowski 1959, Kotański 1959, Książkiewicz, Samsonowicz, and Rühle 1965).

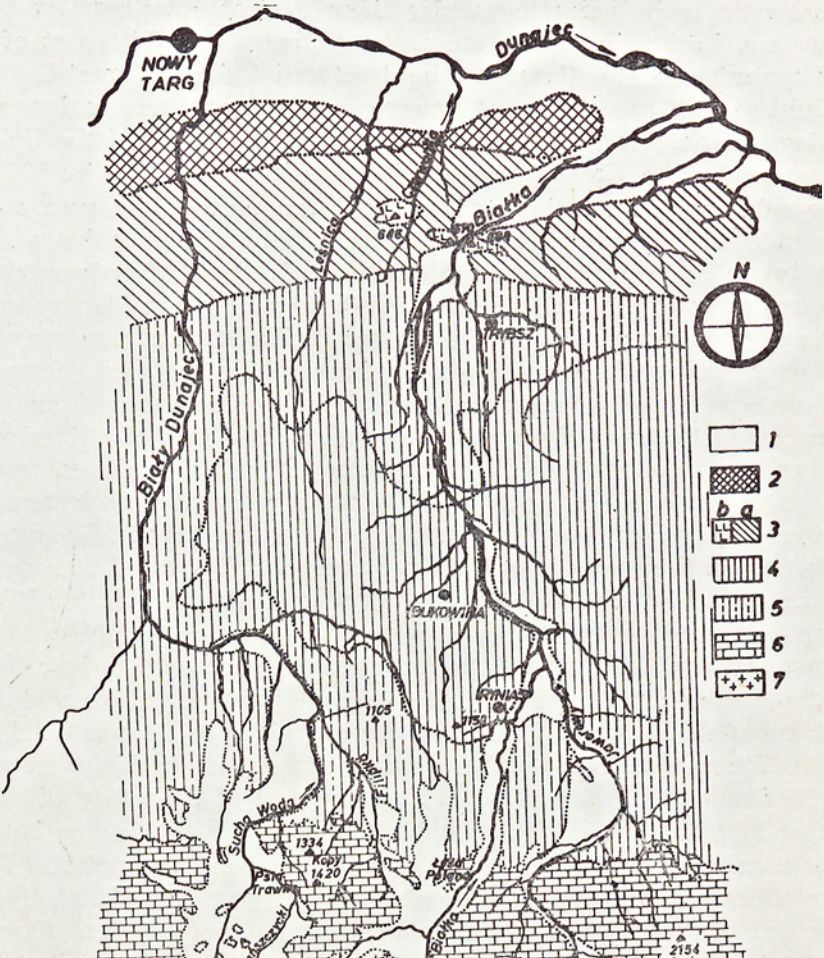
As was already mentioned above, all these rocks in the bottoms of valleys of the two investigated streams are covered in the whole mountain section with morainic and fluvioglacial stony deposits of a fairly great thickness. In the area of the catchment basin of Sucha Woda only small fragments of them are exposed on the surface. The morainic banks are mostly composed of granite and quartzite. According to the author's investigations, they contain very little silt-clay matter (4—15 per cent). Owing to this, they are strongly permeable for waters and poorly safeguard the carbonate rocks occurring under them against Karsting. Rain and melt waters, infiltrating deep into such a substratum, shift part of the clayey material to the fissures. The fractured Triassic limestones and dolomites, as well as the Eocene limestones and numulitic conglomerates occurring in a narrow belt at the contact with Flysch rocks of the Upland, are most subject to Karst processes (G ł a z e k and W ó j c i k 1963).

The sub-montane terrains and the southern part of the area of the Nowy Targ Basin, representing the lower sections of the drainage areas of the investigated streams, are built successively of Tertiary shaly--sandstone rocks of the Podhale Flysch and of rocks of the Pieniny series, occurring in the drainage area of the river Białka in a narrow transverse belt. The Flysch rock deposits are represented by the Chochołów and Zakopane beds. The Chochołów beds, mostly built of sandstone (sometimes with beds and lenticles of dolomite), occur on the ridges of hills. On the other hand, the Zakopane beds, chiefly composed of clay shales, usually build the depressions. The rocks of both these beds have a calcareous or calcareous-clayey cement and a large admixture of muscovite. The content of carbonate in the shales is so high in places that they could be regarded as marls (R a d o m s k i 1958). The Pieniny series is built of hard crinoidean and nodulous limestones (elevations), marls, and shales (B i r-k e n m a j e r 1958). In the section of the drainage area of the river Białka near the mouth Flysch rocks of the Magura beds occur, covered with a thick mantle of loam and stony quaternary deposits (fluvioglacial and alluvial). These deposits cover the Flysch rocks also in the higher sections of the Białka valley and in the sub-montane part of the valley of Sucha Woda.

The lithological outline of the differentiation of the structure of the substratum of the investigated drainage areas is shown on a sketch (fig. 4). On account of the similar action on the chemical composition of water all rocks of the summit and regle series rich in carbonate, as well as quartzites with crystalline rocks, were represented on the sketch as one group.

The little permeable and water dissoluble crystalline rocks in the substratum of the catchment basin of the river Białka occupy vast areas. They build the whole of the catchment basin of its three large component streams, i.e. Biała Woda, Rybi Potok, and Roztoka, as well as the upper part of the further tributary, the stream Waksmundzki. The sedimentary rocks rich in carbonates occur in the montane drainage area of the Białka on only a small section of about 4 km, between the mouth of the Waksmundzka valley and the Flysch Upland (on the right Czechoslovak bank they occur on a much larger section). These rocks occupy a vast area only in the catchment basin of the stream Jaworowy, joining the Białka already on the terrain of the Upland (S o k o ł o w s k i 1948).

In the montane catchment basin of Sucha Woda the relation of the



Ryc. 4. Szkic geologiczny zlewni potoków Białka Tatrzańska i Sucha Woda (wg Sokołowskiego): 1 — utwory czwartorzędowe, 2 — łupki i piaskowce podmagurskie (pod cienką pokrywą czwartorzędową), 3 — margle, łupki i piaskowce (a) oraz wapienie (b) pienińskiego pasa skałkowego, 4 — piaskowce i łupki chochołowskie, 5 — łupki i piaskowce zakopiańskie, 6 — wapienie, dolomity, margle, łupki i piaskowce (serii reglowej i wierchowej), 7 — granity i kwarcyty

areas occupied by these two groups of rocks is different. Crystalline rocks build there a relatively small source area of the catchment basin, whereas the area occupied by sedimentary rocks is fairly large (from the mouth of the Czarny Potok up to the Flysch sub-montane terrains). However, it should be stressed that the zone of the action of crystalline rocks on the aqueous medium (in the drainage area of the Białka as well) shifts considerably downwards. This is due to the glacial and contemporaneous displacement down steep valleys and beds of stream of a huge mass of fragments of crystalline rocks covering other rock deposits of the substratum. Owing to the steep slopes of the beds of streams and to the considerable abrasion resistance of crystalline rocks, granites and quartzites still prevail in the lower sections of the beds of the two streams, especially of the Białka stream.

Soils

In the highest source areas of the catchment basins on a crystalline substratum clastic rock covers (screes) and initial rock soils occur, among which strongly acid (pH 4.0—5.0) alpine boggy and humus soils, as well as eyelets of peat occur mosaically in the alpine zone and in the mountain-pine zone covered the longest with old snows. It seems that the considerable accumulation of organic matter in soils of this region and the less intense chemical weathering of rocks partly results from the reduction of biochemical processes by the low temperatures prevailing in this zone for the greater part of the year.

Under spruce forests of the regle series poor in phosphorus brown loam and rock rubble (skeletal), mostly acid (pH 4.5—6.5) soils were formed on this kind of rock substratum. In their deeper layers a characteristic quartz grit constitutes a large percentage of the skeleton. The colouring of these soils under a layer of forest rot (litter of conifer needles) does not indicate that they are subjected in a high degree to processes of podsolization and leaching. This is probably due to the fact that the strongly acid organic (fulvic) compounds disengaged from the litter of spruce needles are at such a steep inclination of the terrain rapidly washed away by the abundant rain waters and decomposed in the waters of the stream well saturated with oxygen. These compounds accumulate only in small blind marshy depressions of the terrain, or in dystrophic lakes (Toporowe Stawy).

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Fig. 4. Diagrammatic geological map of the streams Białka Tatrzańska and Sucha Woda (according to Sokołowski): 1 — quaternary rocks, 2 — sub-Magura shales and sandstones (overlain by a thin cover of Quaternary), 3 — rocks of the Pieniny Klippen Belt (a — marls, shales, sandstones, b — limestones), 4 — Chochołów sandstones and shales, 5 — Zakopane shales and sandstones, 6 — limestones, dolomites, marls, shales and sandstones (Regle and summit series), 7 — granites and quartzites

The earthy part of these soils ($<$ 1.0 mm) usually has a grain composition of medium loam or of strongly loamy sands. On carbonate rocks cropping out at the surface in this zone rendzinas with a greatly varying content of organic matter formed on small areas (Strzemski 1956). Larger series of them are distributed only in the upper part of the drainage area of the streams Filipka and Jaworowy and on the watershed between the stream Sucha Woda and its tributary the stream Pańszczyca. Shallow rendzinas with a predominance of skeleton are few (the ridge of Gęsia Szyja). The greyish-brown waste mantle occuring among the skeleton usually has the composition of medium loam. Typical rendzinas of a neutral reaction of the humus layer are also encountered sporadically in this part of the Tatra Mts. Rendzinas with an acidified humus layer (pH 5.0—7.3), and especially those formed under spruce forests on hard dolomites, constitute the largest percentage of these soils. On morainic or fluvioglacial rock deposits of the forest zone sections of the bottom of the Sucha Woda and Białka valleys (neighbourhood of Łysa Polana) shallow silt skeletal soils were formed which are highly acidified (pH 5.0—6.0). Their content of stones and gravel sometimes amounts to 85 per cent. Their fine parts usually have the grain composition of a silty clayey deposit (Table I), being therefore fairly permeable and readily washed away. For this reason on the more even parts of the bottom of the Sucha Woda valley traces of an increased leaching can be observed. Mountain alluvial soils occurring in this zone are of a similar character. Skeletal silt and alluvial soils also cover the further sub-montane left-bank part of the drainage area of the stream Sucha Woda.

The right-bank terrains of the catchment basin of Sucha Woda and the areas of the catchment basin of Białka Tatrzańska lying on both sides of it within the Upland, about up to the border of the lower part of the village of the same name, are covered with acid (pH 4.2—6.0) loam soils, mostly decalcified in the upper layers and formed on Flysch. These soils usually have the composition of heavy or medium silty loam (Table I). The relatively high content of silt parts increases their permeability and susceptibility to leaching. On some higher elevations they pass into skeletal soils and generally grow more skeletal towards the interior of the profile. On the other hand, within the bottom of the Białka valley silt or stony alluvial soils were formed (from fluvioglacial, deluvial, or alluvial sediments).

The lowest part of the Białka drainage area near the mouth representing a section of the Nowy Targ Basin, is chiefly covered with silt soils formed for the most part on shaly rocks of the Pieniny Clipp Belt Zone and of the Podhale Flysch. In the valley, very wide in this region, loam and stony alluvial soils (ancient alluvial cones) occur in large, flat terraces. The acidification of soils in this section is very variable, the pH ranging from 5.0 to 7.2.

Tabela I. Skład granulometryczny powierzchniowej warstwy niektórych typowych gleb zlewni potoków Białka Tatrzańska i Sucha Woda w %

Table I. Grain composition of the surface layer of some typical soils in the basin of the streams Białka Tatrzańska and Sucha Woda in %

Miejsce pobrania gleby Soil sampling points	pH (H_2O)	Szkielet Grains >1mm %	Średnica cząstek gleby w mm Soil particle diameter in mm						Suma Total	Grupa gleb Soil texture group
			1-0,1	0,1-0,05	0,05-0,02	0,02-0,006	0,006-0,002	<0,002	<0,02	
Łysa Polana	5,55	11,5	17	12	29	21	9	12	42	gleby pyłowe szkieletowe skeletal silt soils
Psia Trawka	5,95	14,5	20	18	22	18	9	13	40	
Małe Ciche	4,75	1,5	17	8	24	25	11	15	51	gleby gliniaste loam soils
Głodówka	4,20	-	13	16	18	16	15	22	53	
Rynias	4,90	4,0	20	7	25	15	13	16	44	
Jurgów	4,85	2,5	27	14	16	14	16	20	50	
Bukowina	5,95	-	15	9	22	19	15	18	52	
Czarna Góra	5,85	-	12	9	20	20	20	19	59	
Trybsz	5,50	-	14	10	22	21	16	17	54	
Groń	5,40	-	21	15	28	18	9	9	36	gleby pyłowe silt soils
Krempachy	5,35	-	22	11	30	19	10	8	37	
Nowa Biała	6,40	-	25	15	26	15	11	8	34	

Final observations

The differentiation of the properties and morphology of the drainage areas of the investigated streams is best reflected in the chemical composition of their waters. On account of the crystalline rocks occurring in the upper part of the drainage areas of these streams being little permeable and not greatly subject to chemical weathering (which has a bearing on the total area of the contact of water), and of the steep slopes and poor retention of soils (time of contact with water), the waters flowing down from this part of the drainage area have a slightly acid or neutral reaction (pH 6.2—7.0) and an extremely low content of electrolytes. The content of calcium, as chief dissolved mineral component of the water, does not generally exceed 5.0 mg Ca/l. The content of magnesium is also very low, amounting to 0.5—1.0 mg Mg/l (Komornicki and Oleksynowa 1961, 1969, Bombówna 1968, 1971, Pasternak 1968, 1968a). Potassium occurs in extremely small quantities (0.10—0.25 mg K/l) and so does iron. On the other hand, silica has a fairly large share in these waters. Its raised level, in spite of the acid reaction of the water and the presence of a large number of diatoms (Kawecka, Kownacka and Kownacki 1971) which, as was observed by Wang and Evans (1969), are its important sorbents, is probably related with the mineral composition of the Tatra granites (few potash feldspars and much SiO_2). This assumption seems to be corroborated by the fact that waters flowing on crystalline rocks of a slightly different mineral composition (Vosges, Western Tatra Mts) contain relatively less of this component and more potassium and magnesium (Frecaut and Strauss 1968, Pasternak 1968a). An important source of free silica may be (apart from potash feldspars) soda plagioclases which occur in great quantity in the Tatra granites. During the process of weathering silica disengages itself from them in excess. Apart from the quality of the rocks of the substratum, the generally low mineralization of the water of the upper sections of streams may also be related in some degree with their being for a fairly long time supplied with waters proceeding from the melting of old snows, with the freezing up of the substratum, or with the more abundant precipitation in these zones, bringing about the dilution of soil solutions. Owing to the constant outwash of skeletal soils and the lack of possibility of stagnation of water in the soil on account of the steep slopes, the soil solutions are regularly low in biogenic chemical components. For this reason within the crystalline area of the catchment basins the variability of the chemical composition of waters along the course of streams, resulting from the soils growing thicker and more loamy, as well as from the enrichment of the plant cover, is relatively small.

A considerable increase in mineral components of the waters of the Tatra streams is marked only in the lower zone where sedimentary rocks rich in carbonates occur (the content of Ca in the water ranges most often from 10.0 to 23.0 mg/l, and that of Mg from 3.0 to 6.0 mg/l). However, it should be strongly emphasized that the intensity of this increase in the initial section of this zone does not fully correspond either to the chemical character of these rocks or to their upper range. For it is not so significant as might be presumed from the amount of calcium and magnesium in the rocks and the place of occurrence considerably shifted downward with the course of the streams. This is indubitably related with the above-mentioned shift down the valleys and beds of streams of banks of clastic crystalline rocks covering sedimentary rocks, with the considerable velocity of the surface and underground runoff, and with the relation of the mixing of very poorly mineralized waters from the higher lying crystalline deposits or quartzite beds with waters collecting on the surface or at the bottom of calcareous rocks. This particularly refers to the water of the stream Sucha Woda, whose mountain drainage area is in a much higher percentage covered with carbonate rocks than that of the stream Białka. Karst waters appear in a larger mass only in the lowest mountain zones of valley sections. The none too high solubility in water of hard limestones and dolomites, especially with quartzite beds, as compared with other more permeable carbonate rocks (loess, Flysch rocks) is also of some significance in this respect. The considerable intra-and submorainic (Karstic) run-off of waters brings about in the lower part of the valley of Sucha Woda and in its branching, the Pańszczyca valley, a decrease in surface erosion. In the regle part of these valleys the underground movement of waters may be limited in some degree only by intercalations of shales and sandstones.

A further increase in mineral components of the water of the two investigated streams occurs only on the terrain of the Upland (23.0—33.0 mg Ca/l and 6.0—8.4 mg Mg/l) built of more permeable and more readily weathering Flysch rocks, although they contain less calcium and magnesium carbonates than limestones. In the drainage area of the Białka the inflow of waters of the stream Jaworowy, flowing down mostly from calcareous rocks of the Bielskie Tatra Mts, also contributes to this increase, and in the drainage area of Sucha Woda the inflow of waters of numerous vauclusian springs situated at the contact of calcareous rocks with Flysch, as well as of waters of the stream draining the calcareous Filipka valley. Within the Upland and basin, mostly covered with cultivated, more readily washing out, dusty, and silt loam soils, there is already a greater possibility of an inflow to the surface waters of potassium, magnesium, and other biogenic components.

The considerable erosion of soils occurring in these parts of the drainage areas, usually caused by torrential rain, is not distinctly marked in the degree of silting up of the beds of the investigated streams, especially of that of the Białka. The silting up of the lower sections of the beds of these streams is relatively small. The strong water current (0.7—1.0 m/sec) connected with the considerable longitudinal fall of the streams and the mostly rounded shape of rock boulders does not favour the sedimentation of fine material in their bottom.

STRESZCZENIE

W pracy scharakteryzowano ważniejsze abiotyczne czynniki (rzeźba, budowa i właściwości podłoża) środowiska wodnego dwóch głównych potoków polskich Tatr Wschodnich, tj. Białki Tatrzańskiej i Suchej Wody. Dane te są potrzebne do pragmatycznego przeprowadzenia rozważań nad przebiegiem w tych środowiskach hydrochemicznych i biologicznych zjawisk, które zostały zbadane przez zespół pracowników Zakładu Biologii Wód PAN.

Objęte badaniami potoki odwadniają poprzez gęstą sieć stałych i okresowych dopływów północne stoki Tatr (2449—1100 m) oraz część Pogórza Spiskiego (1100—700 m). Białka Tatrzańska w swym dalszym biegu zbiera swe wody jeszcze z prawie bezleśnych wschodnich terenów Kotliny Nowotarskiej (700—500 m). Spadki tych cieków oraz różnice w klimacie są bardzo duże. Większość ich początkowych dopływów bierze swój początek w polodowcowych jeziorach, położonych powyżej górnej granicy lasu (strefa hal i kosodrzewiny). Jeziora zasilane są przez liczne, małe strumyki, najczęściej okresowe, zbierające szybko spływające wody opadowe i roztopowe (starośniegi) oraz zatrzymywane w szczelinach i zastoiskach pokryw morenowych.

Większość górskiego obszaru zlewni potoku Białka, odwadnianego przez trzy duże początkowe dopływy (Białą Wodę, Rybi Potok i Roztokę), budują skały granitowe (ryc. 4). Na dalszym odcinku Białki występują niezbyt szerokim pasem różnowiekowe wapienie, dolomity i margle z ławicami łupków i piaskowców, często kwarcytowych (serii wierchowej i reglowej). Większy kompleks kwarcytów znajduje się zwłaszcza w strefie kontaktu osadowych skał z krystalicznymi (na ryc. 4 połączony ze skałami krystalicznymi). W górskiej części zlewni Suchej Wody stosunek powierzchni zajmowanych przez te dwie grupy skał kształtuje się odmiennie. Krystaliczne skały zajmują tylko niewielki źródłowy obszar zlewni, a skały osadowe, zasobne w węglany, dość znaczny. Na odcinku wapiennych skał, na skutek krasowego podziemnego zanikania wód, hydrologia omawianych cieków, zwłaszcza Suchej Wody, bardzo się komplikuje. Strefa oddziaływania na wodę krystalicznych skał znacznie się przesuwa w dół biegu potoków. Wiąże się to z glacjalnym i współczesnym przemieszczeniem w dół stromych dolin oraz koryt cieków ogromnej masy odłamów skał krystalicznych i pokryciem przez nie innych utworów skalnych.

W pogórskiej części zlewni omawianych cieków występują już łatwiej przesiąkliwe i wietrzejące piaskowcowo-łupkowe skały fliszu podhalańskiego o spoiwie ilasto-wapnistym (warstwy chochołowskie i zakopiańskie). Na dalszych terenach zlewni Białki, należących do Kotliny, dominują margle, łupki i wapienie pienińskiego pasa skałkowego.

W zależności od wysokości na krystalicznych skałach wytworzyły się rozmaite gleby. W szczytowych partiach gór powstały inicjalne gleby skaliste, w strefie hal i kosodrzewiny gleby skaliste i murszowo-próchniczne, a pod reglowymi lasami charakterystyczne, silnie kwaśne, ubogie w fosfor gleby gliniasto-szkieletowe. W tej ostatniej strefie, na węglanowych skałach, występują także przeważnie kwaśne rędziny, a na morenowych utworach pokrywających dna dolin (głównie Suchej Wody) gleby pyłowo-szkieletowe. Pogórskie i przedgórskie (Kotlina) tereny zlewni pokrywają przeważnie kwaśne gleby gliniaste i pyłowe, wytworzone na fliszu i skałach serii

pienińskiej. Gliniaste gleby są dość rozmywne, zawierają bowiem spory odsetek części pyłowych (tabela I). Znaczne spadki i zaokrąglone kształty otoczaków w korytach cieków powodują, że znaczna erozja gleb w dolnej części zlewni nie znajduje pełnego odbicia w stopniu ich zamulenia.

Zróżnicowanie fizyko-chemicznych właściwości i morfologii podłoża zlewni bardziej wiernie zaznacza się natomiast w składzie chemicznym wody. Pewne zatarcie tego obrazu w odniesieniu do stopnia nasilenia wzrostu elektrolitów w wodzie i miejsca jego występowania zachodzi tylko w początkowych rejonach wapiennej części zlewni, szczególnie Suchej Wody. Składa się na to przypuszczalnie, poza wspomnianym powyżej przesunięciem w dół okruchów krystalicznych skał, szybki spływ wody ze stromych zboczy (krótki kontakt wody z podłożem) oraz większy dopływ do omawianych cieków wód krasowych i potoków odwadniających reglowe tereny wapienne (potok Jaworowy, Filipka) dopiero na terenie Pogórza. Ekstremalnie mała zawartość potasu i żelaza, a stosunkowo znaczna krzemionki w wodach spływających z terenów krystalicznych wiąże się prawdopodobnie w dużej mierze z osobliwym składem mineralnym tatrzańskich granitów. Poważnym źródłem wolnej krzemionki mogą być występujące w nich w dużej ilości sodowe plagioklazy. Większy zasób w wodach na terenie podgórskim soli mineralnych jest — jak się wydaje — skutkiem lepszej przesiąkliwości i wietrzenia fliszowych skał.

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