Hydrogeographical features of the Upper Tisa river-system

Mihály Andó

Introduction

Along its 964 km length, the River Tisa is environed by a 157,180 sq. km catchment area. The river rises in the north-east of its catchment area and reaches its recipient, River Danube at Titel.

The drainage basins of River Tisa and its tributaries are excessively different from one another not only as far as their shape, situation, size, hydrography and sloping are concerned, but with regards to their soil composition too. With the shape of an arching semi-circle, the towering ridge of the Carpathians is the boundary of the catchment area. The southwestern-western watershed is comparatively low, in some places its surface shape is in fact even. The catchment area is divided in the middle by the Munţii Apuseni, east of which lies the 400-600 m high plateau-like Transylvanian Basin, and to the west lies the Great Plain.

Based on the hydrogeographical data the catchment area of River Tisa is divided into three characteristic sections: the mountainous Upper Tisa, the Middle-Tisa, receiving most of the waters of the drainage basin, and bound by the confluences of the two main tributaries, River Szamos/Someş and River Maros/Mureş, which drain the Transylvanian Basin, and lastly the Lower-Tisa extending from its confluence with River Maros to its confluence with River Danube.

The present study gives a detailed account of the Upper Tisa river-system, the section of River Tisa down to its confluence with River Szamos. However, there will also be a brief account of the drainage basins of River Szamos and River Bodrog, because both may play a major role in shaping the water resources of River Tisa. Therefore this section of the river is extended as far down as the town Tokaj (Figure 1.).

Keywords: hydrogeology, Upper Tisa catchment

The relief, structure and geological features of the catchment area of the Upper Tisa

The river-system of the Upper Tisa in the Northwestern Carpathians can be divided into structurally distinctive and tectonically connected parts. Within these parts isoclinal structure and exfoliation can be detected. The distribution of the reliefs of the

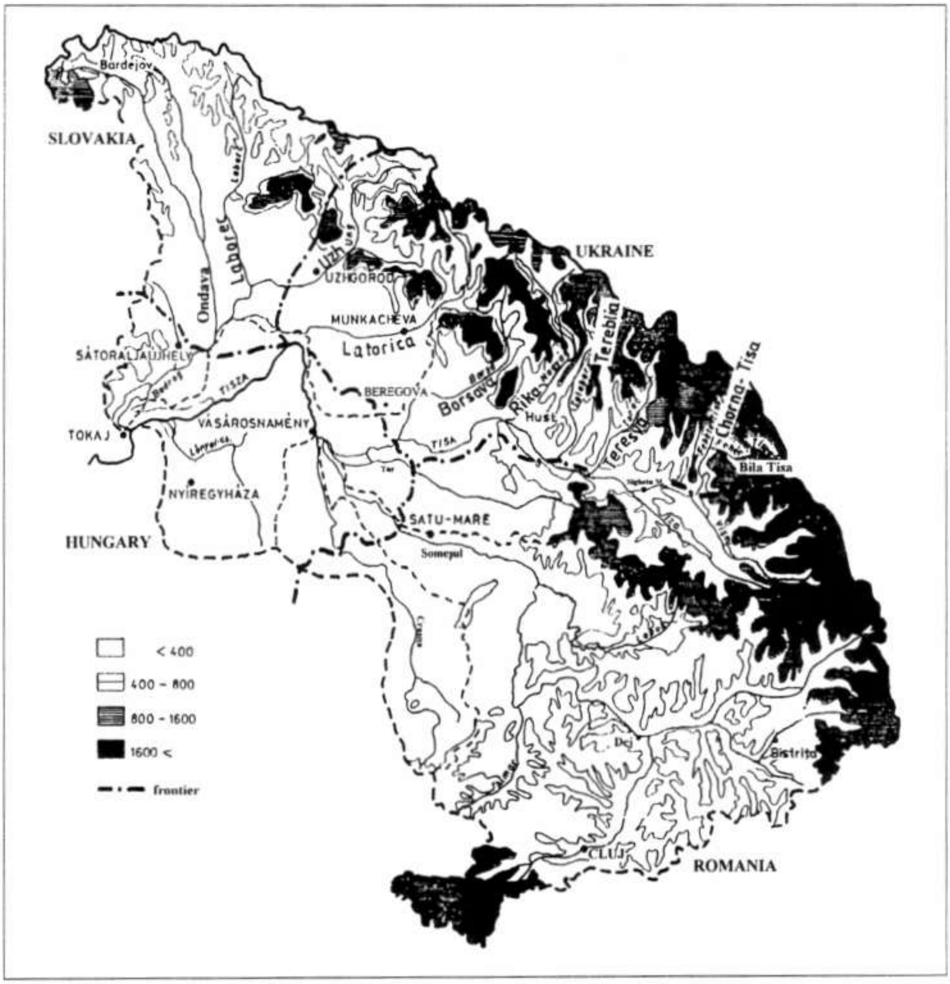

Figure 1. Relief of the Upper Tisa, after VITUKI

river-system is in many respects similar to the structure of the West Carpathian region, because the bulk of these mountains also consist mainly of Eocene and Cretaceous formations. It is similar structurally as well, because on the outer side of the Carpathian arc there is sandstone ('flis'), which is geologically comparable to the fairly narrow sandstone zone lining the Alps. In the Northeastern Carpathian region, regarding the Eastern Beskyds and the Maramureshian Alps, besides sandstone limestone comes to play a minor role as well in the rock composition. Furthermore, crystalline rock, in the form of 'cliffs', can be found in traces in the inner side if the sandstone zone. Crystalline rock does not form a morphological zone in the catchment area, only the environs of Pop-Ivan bear a large stretch of surface crystalline ancient mountain formation.

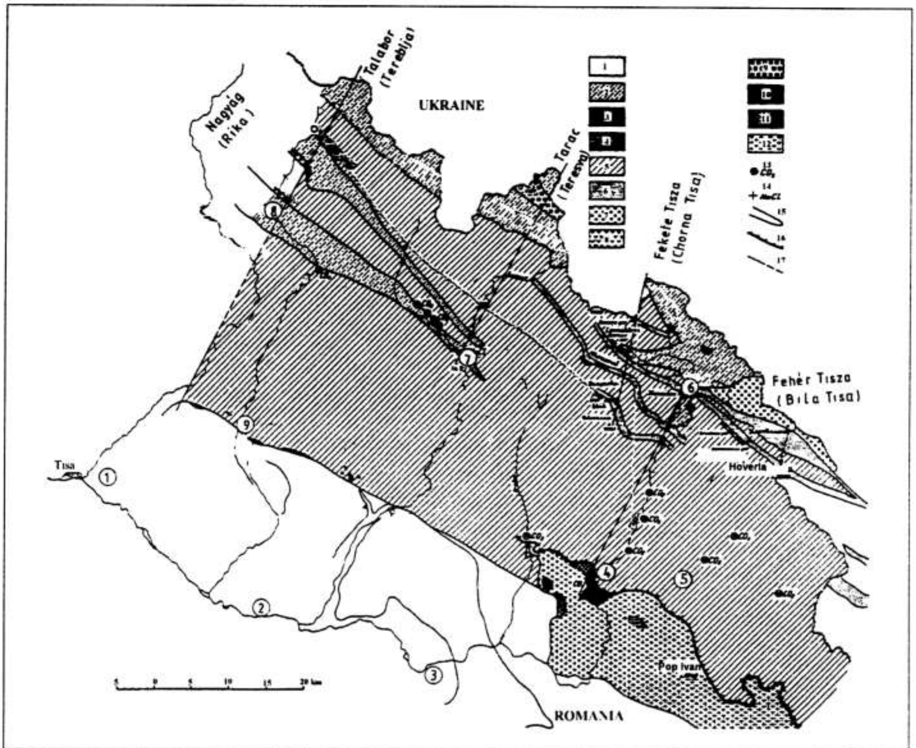

Figure 2. A schematic geological map of the area between River Black Tisa and River Tereblia, after Szalai T.

Legend: 1 Mediterranean; — 2 Middle Oligocene; — 3 Lower Oligocene (shale); 4. Upper Eocene (clay-marl); — 5 Eocene (MAGURA belt); — 6 Upper Cretaceous, Lower Eocene (clay); — 7 Upper Cretaceous, Lower Eocene (sandstone); — 8 Upper Cretaceous, Lower Eocene (shale); — 9 Cretaceous, Eocene; — 10 Cliffs; — 11 Triassic; — 12 Mica schist, gneiss; — 13 Aereated springs; — 14 Salt springs; — 15 Tectonic window; — 16 Overthrustings; — 17 Segments

The high mountains here are crystalline masses emerging in isolation from the significantly folded Permian-Mesozoic strata. They were probably already parts of the structure of the former Variscian mountains. The Mesozoic strata - together with their shell that today encloses them in a common frame - were involved in the Cretaceous folding, but their present mountainous character is still partly due to the faults that took place in the Tertiary (Figure 2.).

In our homeland only few of the 'Tisia'-massif ancient mountain range have stayed on the surface. At other locations the Tisia sank so deep that it has been covered by thick Tertiary formations. The volcanic mountains also belong to Tertiary formations. They are traces left by lava eruptions from the tectonic rift of the western foothills of the sandstone mountain ranges and the fissure marking the subsidence of the Plain (Figure 3.).

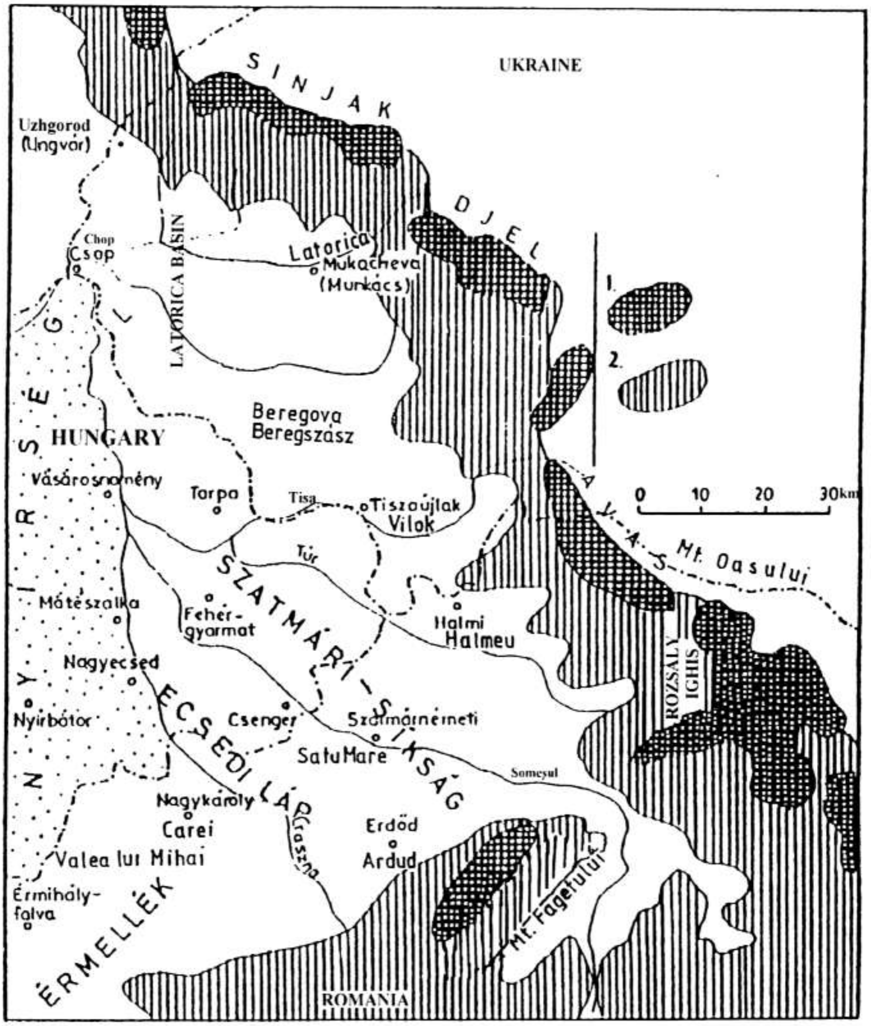

Figure 3. The Szatmári Plain and the Latorcai Basin

Caption: 1 Mountains; — 2 Regions at the foot of mountains

To sum up, what is dealt with here is mountains with very simple structure, because apart from the rudimentary cliff belt they only consist of a volcanic belt within a sandstone belt. Parts of the volcanic belt are the Vihorlat, the Sinjak, the Diel, the Vinovgradiv Mountains and the Oaş-Ighiş-Gutâi Mountains range.

Between the Oaş-Ighiş-Gutâi Mountains volcanic mountains on one side and the sandstone belt of the Maramuresh Alps together with the mountain range in Pop-Ivan consisting of emerging crystalline rocks on the other side, lies the Maramuresh Basin filled with Tertiary layers. Finally, we must also mention that along an imaginary curved line connecting the southern part of the Eperjes-Tokaj Mountains (Zemplén Mt.) with approximately the middle of the Vihorlat-Gutâi (M. Gutâiului) range, there are some individual small mountains emerging from under the Quaternary strata of the northeastern bay of the Great Plain.

Intense volcanic activity in the Tertiary was an outgrowth of the fragmentation of the Tisia. There was significant volcanic activity along the main faults, especially at the edges of the massively subsided large basins along the Great Plain. Volcanic ash cemented into tuff and lava alternately accumulated one layer on top of the other, thus volcanic mountains came into existence. That was a long and resurgent process, so it partially settled on sediments already from the Tertiary. Volcanic masses covered by the youngest Tertiary strata were multiply traversed by faults. The bulk of the eruptions took place in the first part of the Upper Tertiary, the Miocene; their product is mainly andesite, whereas it is chiefly rhyolite in the east.

In some places volcanism created fairly shapely mountains, most of which, however, are now in ruins having been the victims of eroding forces. Only the highest tops reach above 1000 m, the average altitude is about 800-900 m. The forms are subdued and gentle, their mildness or sharpness depends on the rock composition, the alternation of soft tuff and hard lava.

The first member of the range is the 1074 m high Vihorlat between the Uzh Valley and the Laborec Valley. It is separated from the Eperjes-Tokaj volcanic range by the wide valley entrance of the rivers Ondava and Laborc. In the collapsed, therefore caldera-like hollow of the volcanic cone is Szinnai Lake, at an altitude of 619 m. The Uzh Valley and the Latorica Valley embrace the mass of the Sinjak (1014 m); the Latorica Valley and the Borzhava Valley enclose the mass of Veliki-Diel (1068 m). Its tuff slope in the southwest spreads widely towards Beregova. The volcanic range of the Vinovgradiv Mountains (Salanki Mt., 372 m; Chorna Gora 568 m; Tupij Mt. 878 m) extends as far as the valley of River Tisa. With it the volcanic range leaves behind the sandstone belt, and at the southwestern edge of the Maramuresh Basin, on the left of the Tisa valley its next members emerge: the 805 m high Oaş and the 1307 m high Ighiş. Its further extension is the shapely, 1447 m high Gutâi with the final member of the range being the 1842 m high cone of the Ţibles. Its southern slopes dip as far as the Transylvanian Basin.

The present-day mountain range of the Upper Tisa river system also belongs partly to the ancient mountain belt. Its mountainous character is due to Tertiary faults, or more precisely to the circumstance that its environs subsided deeper along the faults.

The parts with greater subsidence - basins of various sizes - were flooded by the Tertiary sea. In some of them we can find sediments of the Lower Tertiary, whereas in the Great Plain only that of the Upper Tertiary, exclusively at the edges and in faults.

In the Northeastern Carpathian system the sandstone belt is the widest, but not the highest. For instance, in the northwest the width of the sandstone belt reaches 50 km and in the northeast it even exceeds 100 km.

Since the multi-stage event of folding, the intensely eroding sandstone belt has experienced crust movements many times: some of its clods broken into large pieces emerged obliquely. The surfaced edges and the main ridges are in the inner side, so the

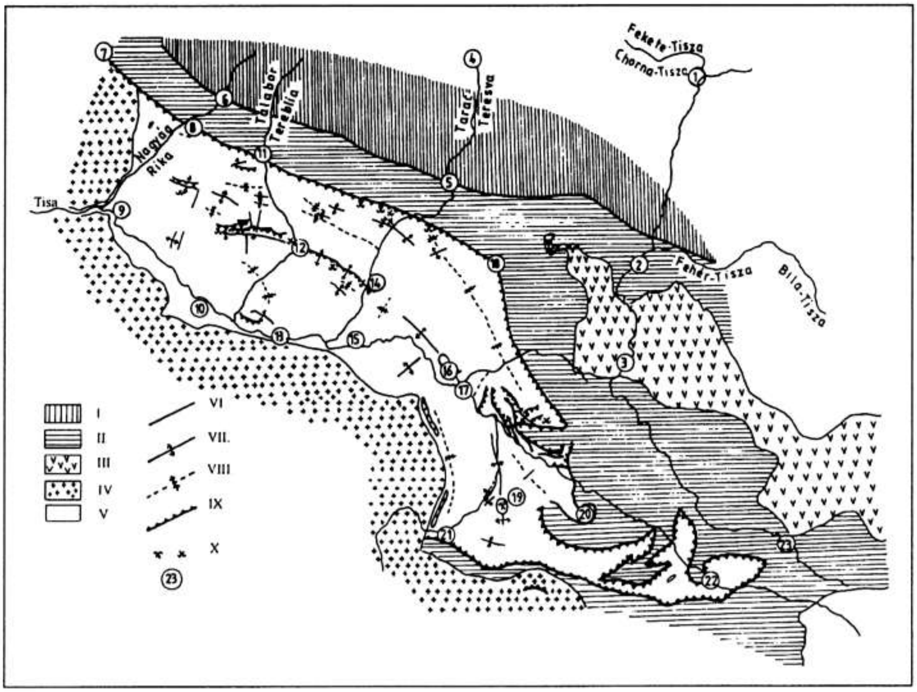

Figure 4. Sketch of the mountain structure at the basin of the Upper Tisa, after Szentes F.

I Outer flis belt; — II Inner flis belt; — III Crystalline shales; — IV Andesites; — V Miocene basin; — VI Structural fault; — VII Anticline; — VIII Syncline; — IX Normal fault; — X Salt mines; — 23 towns/villages

narrower, steeper slopes face the basin. The folded layers are intersected by the present surface: the emersions of the harder layers were formed into the shape of long ridges. The Eastern Beskyds reached significant altitude, second only to that of the Maramuresh Alps. It is also evident in the altitudes of mountain passes. The Uzhecki Pass leading from the Uzh Valley to the San Valley is 889 m, the Serednoverecki Pass leading from the Latorica Valley to the Stryj Valley is 841 m, and the Yasina Pass (also called Jablunicki Pass) leading from the Chorna Tisa Valley to the Prut Valley is 931 m high. Already in the Eastern Beskyds peaks exceeding 1300-1400 m and in the Maramuresh Alps peaks exceeding 1500-1800 m can be found, while Hoverla is exactly 2061 m high.

In the Northeastern Carpathians the main ridge has been etched only to a minor extent by the rivers. That is the reason for the comparatively slight difference between the heights of the passes and the peaks. Here, within the main ridge we are able to identify an inner range which is more intersected by rivers.

Where the sandstone belt is represented by higher mountains, the valleys are apparently deeper, the peaks towering from them are magnificent, but only as far as their mass is concerned, because they, too, have a subdued shape.

Compared with the vast stretch of the sandstone belt, the sequence of limestone cliffs in the inner edge of the belt appears to be merely insignificant patches. Still, they are very conspicuous parts of the landscape: from the environment consisting of softer rocks and - as viewed from the distance - having a mild contour, they emerge steeply, in places with bare faces.

The raised sandstone blocks look monotonous in the landscape. The forest-covered, uninhabited recesses of the ribs line in dull monotony. Even in the high Maramuresh Alps glacial formations do not lessen monotony, because due to mild glaciation even in the 2061 m high Hoverla, there are only a few little 'firn' fields left.

Within the main ridge we can easily distinguish parts of an inner ridge, too, intersected by river valleys. Covered by forests and alpine pastures this is the ridge of the Polonina Runa (1482 m) - Stoj (1679 m), called Verchovina. It is separated from the main ridge by a structural depression, which has sporadically been widened by the upper sections of the rivers Uzh, Latorica, Rika, Tereblia and Teresva running in it, creating basin-like formations in the process. There are steep slopes climbing from the depression up to the main ridge (Chorna Repa 1836, Popadia 1742, Pop Ivan 2022, Petros 2020, Hoverla 2061 m).

Between the sandstone and the volcanic ranges in a NW-SE direction is the wide Tertiary Maramuresh Basin stretching in the valleys of the rivers Tisa, Vişeu and Iza (Figure 4.). The rivers have etched terraced valleys into its surface. It gradually widens and dips toward the 'Gate of Hust', where it joins the Pleistocene depression area of the Great Plain. The basin covers almost unexploitable deposits of rock salt (Solotvina, Coştiui, Ocna Şuhatag). Apart from rock salt there are traces of crude oil in the basin as well (Săcel, Dragomireşti).

Climatic and hydrogeographic features of the drainage basin of the Upper Tisa

The catchment area of the Upper Tisa section down to its confluence with River Szamos is 13,500 sq. km, the section itself is 2,080 km long. The area per unit river length is 6.36 sq. km/km. The greater part of the drainage basin is in Ukrainian territory, a smaller part is in Romanian territory. A very small piece of the catchment area belongs to plain terrain (1444 sq. km).

The drainage basin is bordered by the Maramuresh Alps in the northeast and by the Rodna Alps (Munții Rodnei) in the south.

The catchment area of the Upper Tisa is morphologically rather unfavourable because the region is comparatively short and it stretches wide. Mountain slopes are steep indeed, mountain streams of high dip reach the river valley after covering a relatively short course. Down in the valley pouring waters amass. The mean dip of the surface in the drainage basin reach 550 m/km. On the other hand, dip ranges from 80-200 m/km in the hilly area and 5-60 m/km in the Great Plain. The total dip of the Upper Tisa is 1577 m (Figure 5., 6.)

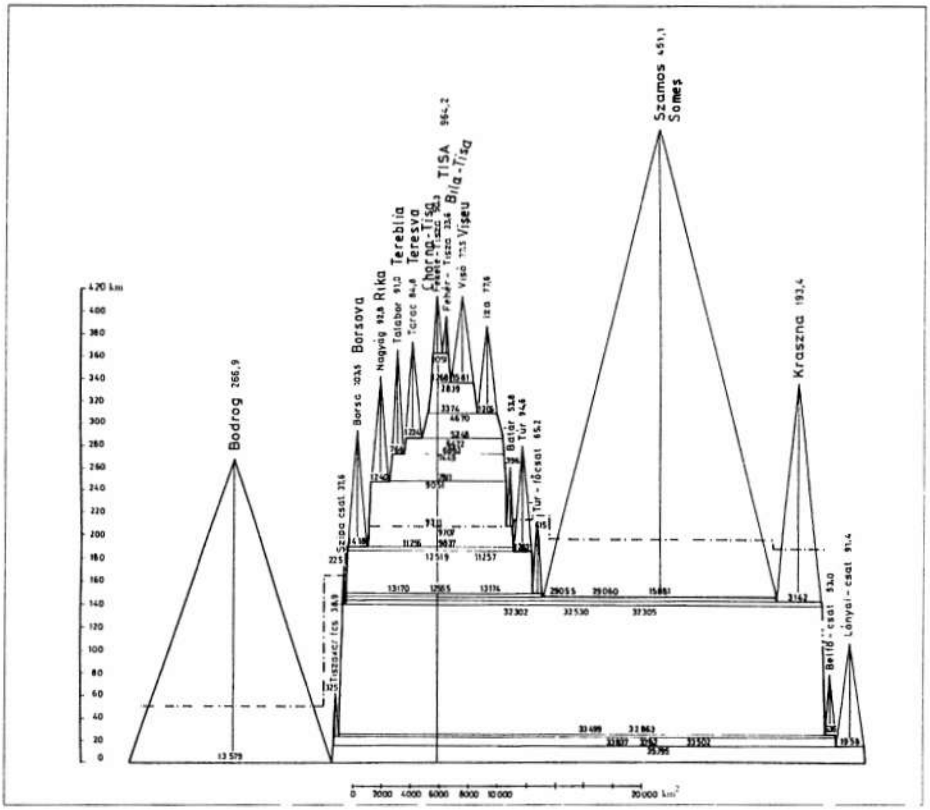

Figure 5. General map of the catchment area of the Upper Tisa, after VITUKI

The relief of the surface determines the distribution of water resources in the region to an extremely great extent, with a considerable proportion of the water resources accumulating in the form of snow. (Table 1.)

Catchment area	Jan.	Feb.	March	Apr.	May	June	July	Aug	Sept.	Oct.	Nov.	Dec.	Year
A./ Regional averages of surface input, mm													
Upper Tisa	22	42	122	124	101	122	118	116	91	94	73	45	1070
River Szamos	21	39	79	72	81	102	91	86	60	64	51	40	786
River Bodrog	27	46	87	70	75	98	95	98	71	75	66	47	855
B./ Regional averages of snow-broth, mm													
Upper Tisa	20	40	10	71	12	0	0	0	2	11	25	29	316
River Szamos	18	34	59	19	2	0	0	0	0	4	14	22	172
River Bodrog	21	40	62	16	1	0	0	0	0	4	15	25	184
C./ Contribution of snow-broth to surface input, %													
Upper Tisa	91	95	87	57	12	0	0	0	2	12	34	65	30
River Szamos	86	88	75	26	2	0	0	0	0	6	28	55	22
River Bodrog	78	87	71	23	1	0	0	0	0	5	23	53	22

Table 1.

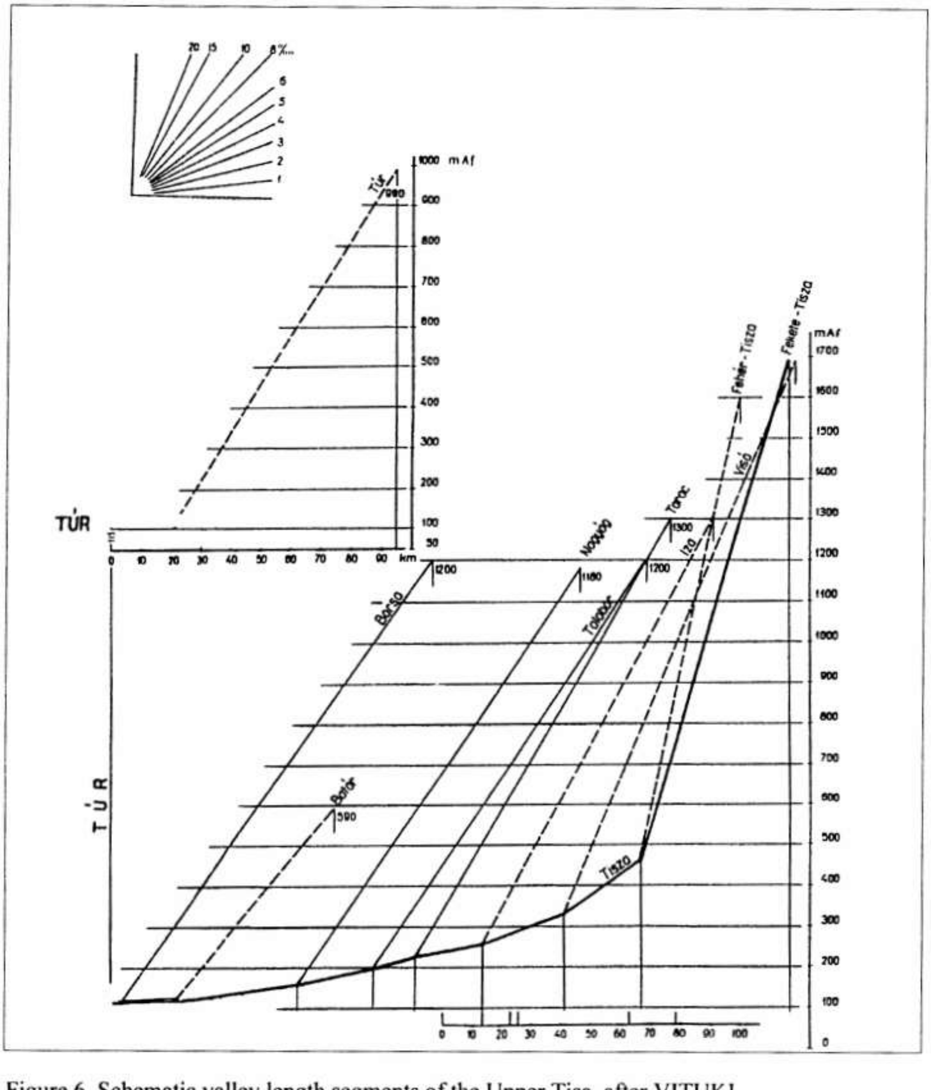

Figure 6. Schematic valley length segments of the Upper Tisa, after VITUKI

(mAf= meter above Adriatic sea level, Tisza/Tisa, Borsa/Borşa, Batár/Batar, Visó/Vişeu, Túr/Tur, Talabor/Tereblia, Tarac/Teresva, Nagyág/Rika, Fehér-Tisza/Bila Tisa, Fekete-Tisza/Chorna Tisa. The first name is Hungarian, the second Ukrainian or Rumanian)

In this respect, triggered by winds and as a result of avalanches, snow may accumulate in large quantities in the glacial valleys of the alpine zones. In the hilly areas and in the plains snow driven by winds accumulates in hollows and concave surface formations (in shower-stream valleys, loess dips and old formations hollowed by erosion). It is these concave surface formations where the most prominent failure of flowage during the melting of snow and the most intense flowage during rainfalls can be observed.

Figure 7. Distribution of annual mean temperatures in the catchment area of the Upper Tisa on the basis of an average over 40 years

As the highest ridge of the Carpathians most often stops the wet air currents coming from the southwest, most of the precipitation occurs here. Its annual average reaches 1400 mm, 80% of which comes from the Atlantic and the Mediterranean, and the remaining 20% is created by local circulation.

The Northeastern Carpathian region has a distinctive distribution of temperature and precipitation as it is situated in a transitional climatic belt. It is by far the continental nature of the climate that is prominent here. Mean temperature in January is between -2 and -4 degrees Celsius, so the figure of average annual fluctuation slightly surpasses the minimum of that of the continental type. Reversed thermal conditions are a common phenomenon in the basins of various sizes and in the deep valleys situated in the mountain ranges (Figure 7.). Annual precipitation is greatly variable, usually at high altitudes it is 1200 mm, at low ones 800-1000 mm; and the lower basins are poor in precipitation (under 600 mm). In the Carpathians, mountain

Figure 8. Distribution of precipitation in mm in the catchment area of the Upper Tisa on the basis of an average over 40 years

slopes predominantly rich in precipitation are the ones that lie in a right angle to the winds carrying precipitation. Such mountain ranges are in NW-SE and N-S directions Figure 8.)

The change in the extent of wetness within a year essentially determines the flow of the rivers. Surface water input determining the flow of the rivers and the seasonal changes occurring in the catchment area cause significant regional differences (Figures 9-12.).

In the Northeastern Carpathians, surface water in the winter months (December, January, February) is mainly from snowfall. Snow accumulation increases with altitude and, regarding the distribution of water input, it causes maximal activity of precipitation in December in the catchment area. Orographical factors exert considerable influence on quantitative changes, as in the above mountainous area

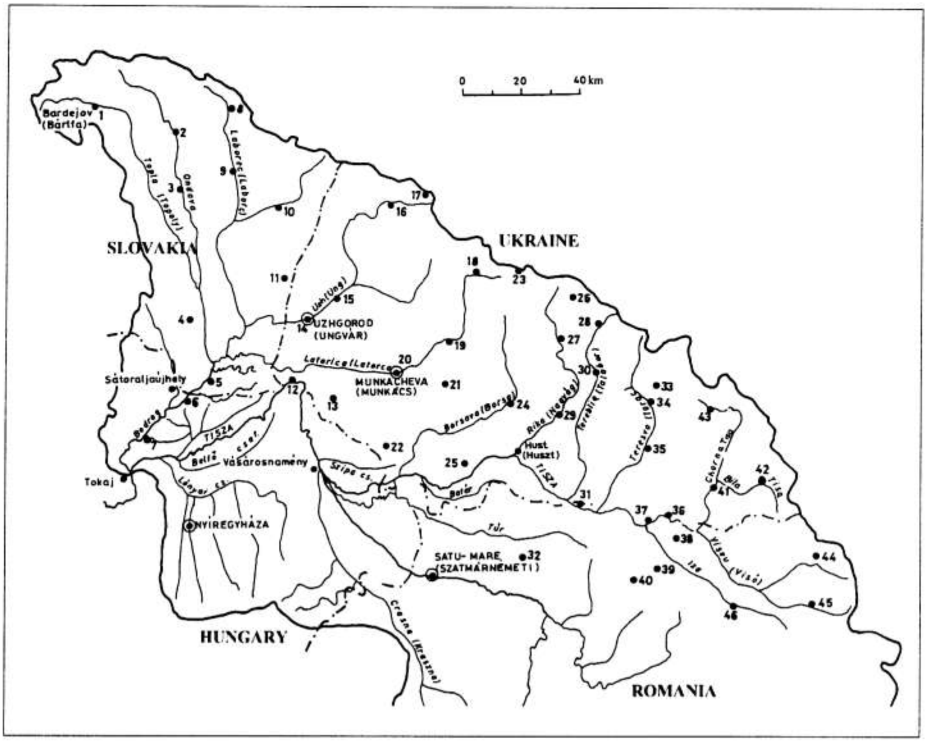

Figure 9. Locations of pluviometric stations in the catchment area of the Upper Tisa and River Bodrog, having data over 20 years

lower than 15 mm of water-input distribution can be observed at altitudes above 1600 m.

In January the regional distribution of precipitation is similar to that of December. At altitudes above 1000-1500 m monthly data show less than 15 mm as well, at altitudes above 2000 m we practically cannot speak of surface water-input due to sub-zero temperatures. In the wetter southwestern slopes of the drainage basin, due to mild winters, we can normally expect monthly figures to be about 30 mm. In the last month of winter (February) frequent melting that causes considerable increase in the flowage of water resources from certain areas is the only change in the monthly averages of surface water. In mountainous regions reaching altitudes higher than 2000 m we can reckon water input mainly at 15 mm, while 30 mm can only be observed in areas at altitudes lower than 1000 m.

Surface water-flow of the spring season (March, April, May) shows a dynamic picture. Snow-melting in spring triggers a significant increase in the surface water input from March to April. In March, for example, in most of the catchment area thaw peaks and the figure of surface water input increase considerably compared with the preceding months. In areas between altitudes of 500 m and 1500 m the average monthly figure can generally be set at about 100 mm. Figures of the leanest water input

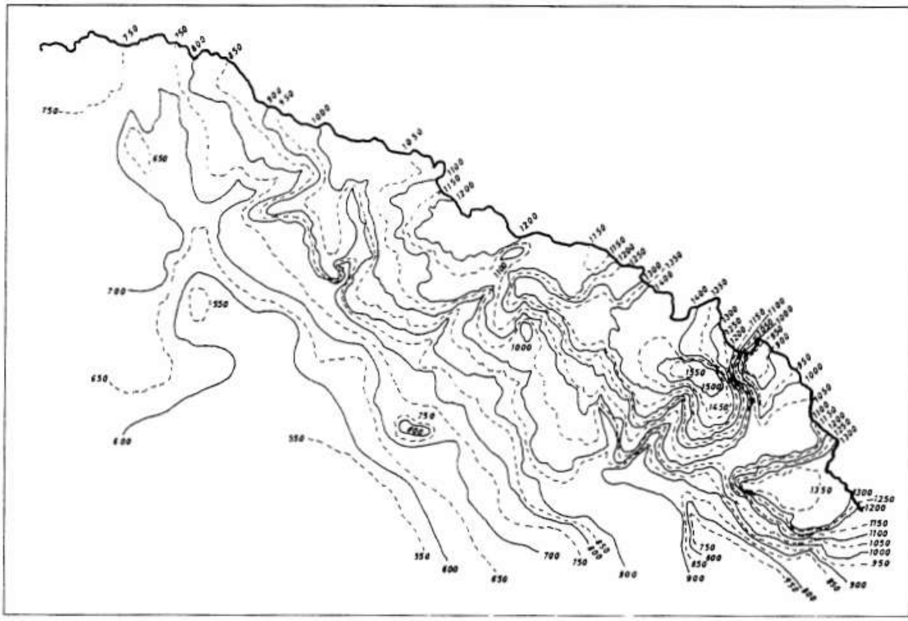

Figure 10. Annual mean values of precipitation in mm in the catchment area of the Upper Tisa and River Bodrog on the basis of 20 years of survey data (see figure 9)

are experienced in the Great Plain and in some regional basins, where monthly averages are merely about 15 mm. Regions situated 2000 m or higher above sea level are considered unfavourable areas, where there is still a process of snow accumulation at this time of year rather than thaw. Intensive increase of surface water-input in the highest regions start only in April. At that time figures of around 100-300 mm are common in the Northwestern Carpathian region. In plain and hilly areas amounting to the bulk of the drainage basin it is rainfall that provides the sole source of surface water input in April. In the catchment area system there are sharp differences between basins, dry valleys and mountainous areas. In May this extreme condition lessens to a great extent: rainfall accounts for the entire surface water input in the region. In higher areas of the mountain ranges the considerable melt and rainfall result in a significant increase in the water input. At altitudes higher than 2000 m, for instance, there are figures exceeding 200 mm.

In the summer months (June, July, August) it is rainfall that provides surface water input everywhere, except in the regions above the snow line. Very high values result (600-700 mm). In the catchment area most of the rainfall is received by the northwestern and northern slopes. In the catchment area system monthly average exceeds even 200 mm, while in the area of the intermediate basins, on the surface of the plain, figures are only about 50 mm. With the comparatively dry weather conditions of July and August, water input of the drainage basin does not decrease here.

On the western slopes of the Northeastern Carpathians figures reach even 100-150 mm, in most of the Great Plain, however, figures under 50 mm are observed. Due to

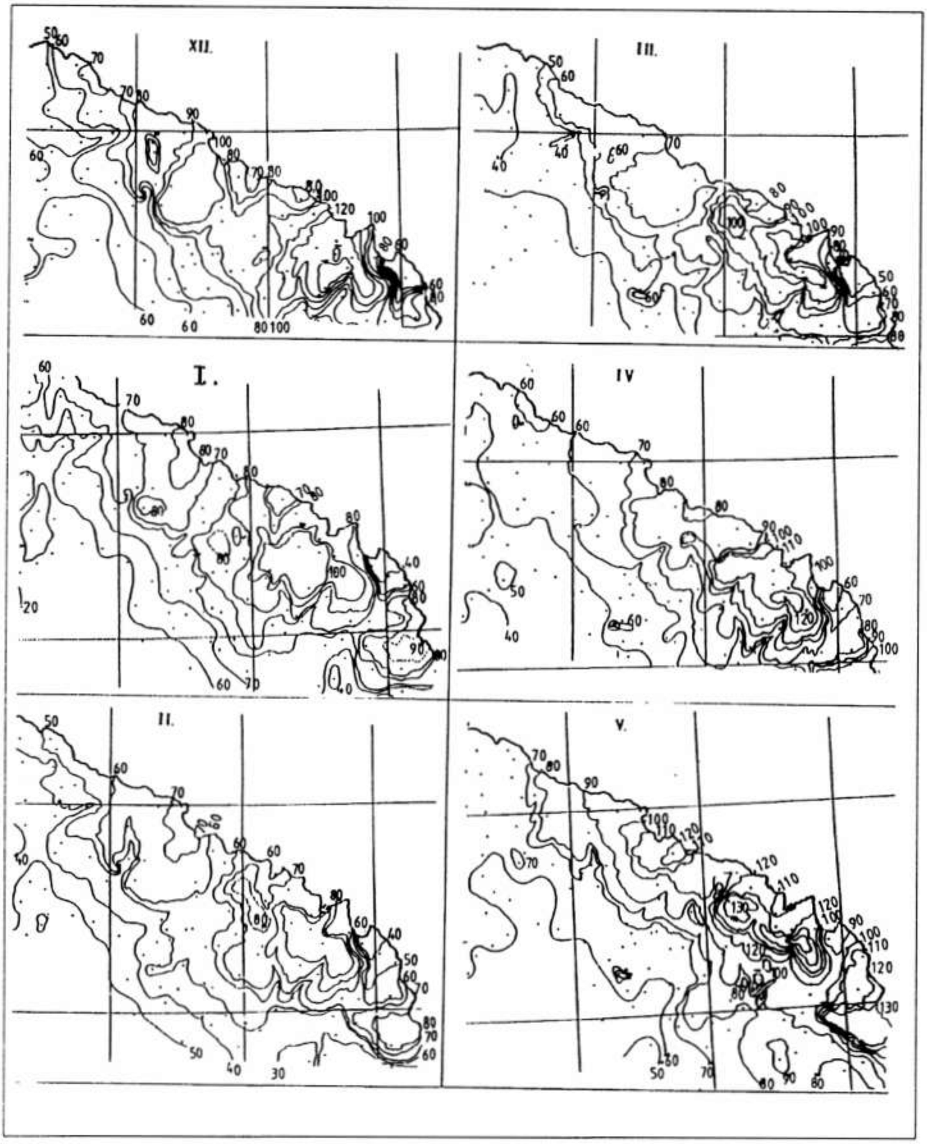

Figure 11. Monthly mean values of precipitation in mm during the winter and the spring months (see figure 9)

the continental effect in August, sources of water input significantly diminish in the whole area.

Regional changes of surface water input in the autumn months (September, October, November) are brought primarily by Mediterranean climate impacts. At this time of the year surface water input decreases significantly in both the drainage basins of the mountain ranges and in plain areas. In October, for example, snow accumulation

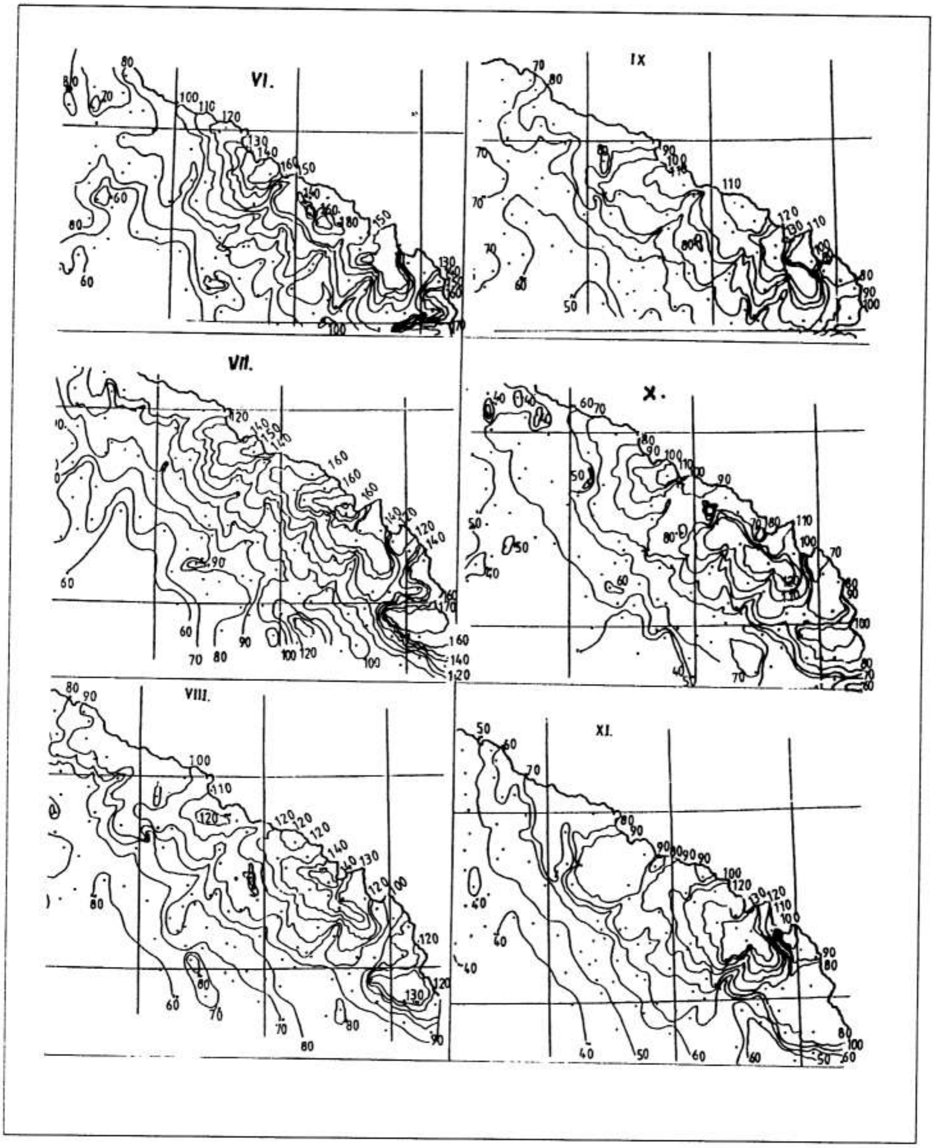

Figure 12. Monthly mean values of precipitation in mm during the summer and the autumn months (see figure 9)

commences at altitudes above 2000 m, and these regions do not count as far as contribution to water flowage is concerned. As early as in November water input mainly show characteristics of winter months. Snow accumulation occurs even at altitudes above 1500 m, while in the Great Plain and in areas of certain basins belonging to the more enclosed ones there are water inputs of about 30 mm. The highest monthly totals - as it has already been mentioned before - are possible in

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
A	16,2	11,4	9,4	7,0	7,8	12,3	18,8	18,8	23,0	15,5	14,0	15,8	14,1
Ac	13,2	13,1	14,5	12,0	10,6	4,3	2,9	6,8	13,0	21,3	22,7	16,8	12,6
Am	10,0	8,8	8,1	8,3	8,4	17,3	25,5	20,0	11,7	8,7	9,0	8,4	12,1
An	9,0	10,0	9,7	8,3	13,2	8,3	5,5	9,7	9,0	10,8	9,3	9,7	9,4
Cm	8,7	9,9	11,6	11,7	8,7	6,3	4,3	5,5	6,3	7,4	10,7	9,0	8,3
AB	4,5	7,5	6,1	6,3	5,5	10,7	8,1	7,7	7,3	4,8	4,3	2,9	6,3
As	6,3	5,3	6,4	5,7	5,2	6,7	6,2	5,5	5,0	6,5	4,0	6,1	5,7
Cmm	9,4	8,2	7,8	9,3	6,1	2,3	1,4	1,3	4,3	6,5	7,3	9,3	6,1
NY	3,8	4,9	4,5	8,3	8,3	6,3	6,4	6,6	5,3	4,0	3,7	4,1	5,5

Table 2. Annual and monthly frequency of macrosynoptic conditions in the Carpathian Basin (in percentage points)

Key to the table:
"A"= The centre of the anticyclone is over the Carpathian Basin. It is a common phenomenon in summer, the direction of wind is indefinite, and prolonged dryness prevails. — "Ac"= The centre of the anticyclone is east of the Carpathian Basin. Southerly and southeasterly winds blow, there is relatively dry weather, a small amount of precipitation is possible. — "Am"= Azorean anticyclone from the west most often with northwesterly winds causing cool, windy and wet summers and mild winters — "An"= The centre of the anticyclone is north of the Carpathian Basin. Northerly and northeasterly winds prevail; chances of precipitation are indeterminable. — m"= There is a cyclonic condition over the Carpathian Basin. This is a common phenomenon most often before a cold frontal passage. It causes wet weather in winter and weather without precipitation in summer with southerly and southwesterly winds. — "AB"= The core of the anticyclone is over either the British Isles or the North Sea. It is variable in the Carpathian Basin. It causes wet weather with northly-northwesterly winds. — "CMm"= It represents strong Mediterranean cyclonic activity with southerly and southeasterly winds. In summer in the southern and western parts of the Carpathian Basin precipitation of more than 50 mm/day may occur. In winter it causes ample precipitation in the north and east of the basin. — "As"= The centre of the anticyclone is south of the Carpathian Basin. Weather with meagre precipitation prevails with southerly and southwesterly winds. — "Ny"= 'Saddle' condition with changing directions of wind; mainly bright and dry weather prevails.

catchment areas under the influence of Adriatic cyclones, as a result of the Mediterranean climate impact.

The mountain climate of the Northeastern Carpathians includes characteristics of the climate of enclosed basins, too. Comparatively low precipitation and significant fluctuation of temperature together with its extreme nature are disadvantages of the enclosed basins. Advantages include the fact that the ring of mountains softens the blow of winds and the fact that the proportion of sunshine is much favourable. Annual temperature peaks in July, and the lowest point is in January. Mild winters and cool summers are quite common, and the weather, though not always extreme, is very changeable. Winter is mild when temperate air from the sea penetrates the area, but it is piercingly cold when northeasterly winds carry cold air masses from the middle of the continent. The snow blanket already there may increase the degree of cold. The highest precipitation values are observed here (1300-1400 mm/year).

Precipitation minima and maxima, respectively, occur synchronously in the catchment area system. This phenomenon, when it coincides with regular weather, causes a well-known process of flooding in our rivers. Severe weather conditions often involve excessive differences in the regional distribution of precipitation, which, in turn, may cause inestimable flooding. Considering the possible extremes of precipitation of each month in the region (on the basis of the absolute peaks and lows registered so far) we can come to the conclusion that both the minimum and the maximum figures indicate the rather unbalanced hydro-meteorological nature of the river system. The main reason for this is that the river system is geographically situated in a temperate zone where air masses of different type (continental, oceanic, Mediterranean, Arctic) often interact actively with each other (Table 2).

Atmospheric advection stretching all over the Carpathian Basin usually distributes precipitation unevenly. Yielding and intense precipitative activities are restricted only to smaller areas. Surface relief provides an explanation to this. The most important inner factors of orographical precipitation are the position, shape and height of the mountains, the steepness of their slopes and the vegetation covering the surface. For example, ridges with N-S direction in the Maramuresh Alps serve as "precipitation blocks" when northwesterly, westerly and southwesterly winds blow.

The heaviest rainfalls occur here when intensified activity of the cyclone of the Atlantic Ocean and the centre of its air pressure lows are located over the Polish Plain and Ukraine. In this case a rapid ascent of the air current may result in intense precipitation over the slopes facing the winds. There are similar additional orographic features aside from the above mentioned in several locations in the river system, for the quantity of precipitation increases with altitude. It is therefore evident that both the map of the distribution of precipitation and the map of flowage reflect the relief of the surface. At the highest points of the catchment area of River Tisa mean annual water output exceeds 1000-1200 mm. The flowage factor in the Great Plain decreases below 0.1, in high mountains it exceeds 0.8. Mean annual water output (MQ) depends not only on the size of the drainage basin, but on its altitudinal location, wetness, slopingness, etc. The order of importance of the tributaries, concerning their water output, is fundamentally different from that of the catchment areas according to their size.

Of course, the tributaries of the Upper Tisa are relatively the most important, as, regarding their water output, they are close to their recipient. The water output of River Tisa is nearly doubled by River Vişeu (more precisely it adds 84% to it), even River Szamos increases it 1.5 times (by 57%). Moreover, both River Iza and River Teresva with their relative weight precede River Maros which has a much greater water output.

Annual water output varies extremely, primarily according to the weather. Thus, the annual water discharge of River Tisa may go down as low as half of the annual average, but in a wet year it may exceed even the double of the annual average. Generally speaking, spring months are the most abundant in water in the catchment area of River Tisa.

In drainage basins of relatively great size, accumulation of water from melting is often prolonged, with April taking the lead.

In the Upper Tisa, because of the characteristics of precipitation distribution, the greatest floods occur in the spring and winter months. Winter precipitation, which, compared to other seasons, is less here, too, melts quite quickly, so at the beginning of

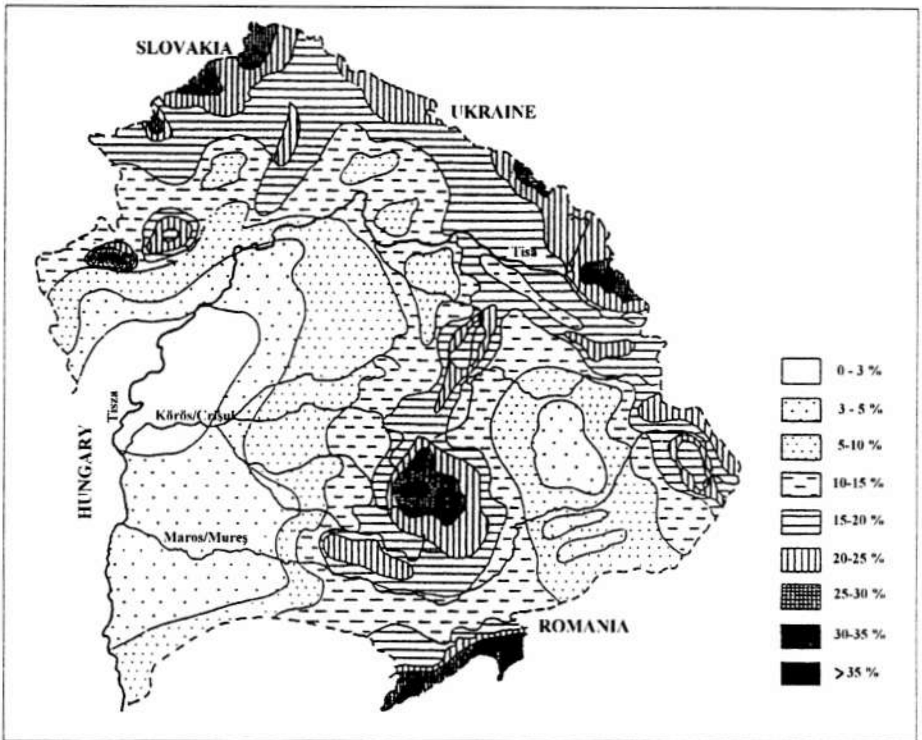

Figure 13. Mosaic map of flowage coefficients of the catchment area of River Tisa

spring warm weather and rainfall cause huge amounts of water to pour on the Middle- and the Lower Tisa region. The melting process usually starts at the beginning of March when snow melts in the plains and is followed by melting in the mountainous areas at the end of March and the beginning of April. In April snow remains only on high peaks and in hollows of cold locations, and only in small amounts. Every year three major flood waves set off from the Upper Tisa. The first is caused by the melting of snow, and it rarely reaches record heights, it is rather a sequence of several smaller flood waves. The second, taking place at the end of spring and at the beginning of summer, is called the "green flood", which is particularly noteworthy if it finds a riverbed already filled by winter floods. The third is the autumn flood wave, which is remarkable only at times of major autumn rainfall, and then mainly in the right tributaries, to the north of River Tisa. The flood waves mentioned do not occur every year, they may often fail to come about.

Out of the three flood waves of the Upper Tisa only the spring and the summer floods are significant in the Middle-River Tisa section. These floods are substantially prolonged because of the floods in the tributaries. The difference between the water mass at low water mark and at high-water mark constantly decreases. At Vásárosnamény, below the confluence with River Szamos the lowest water output (average of many years) is 38 m^3/sec, the highest is 3300 m^3/sec (i.e. 87 times the

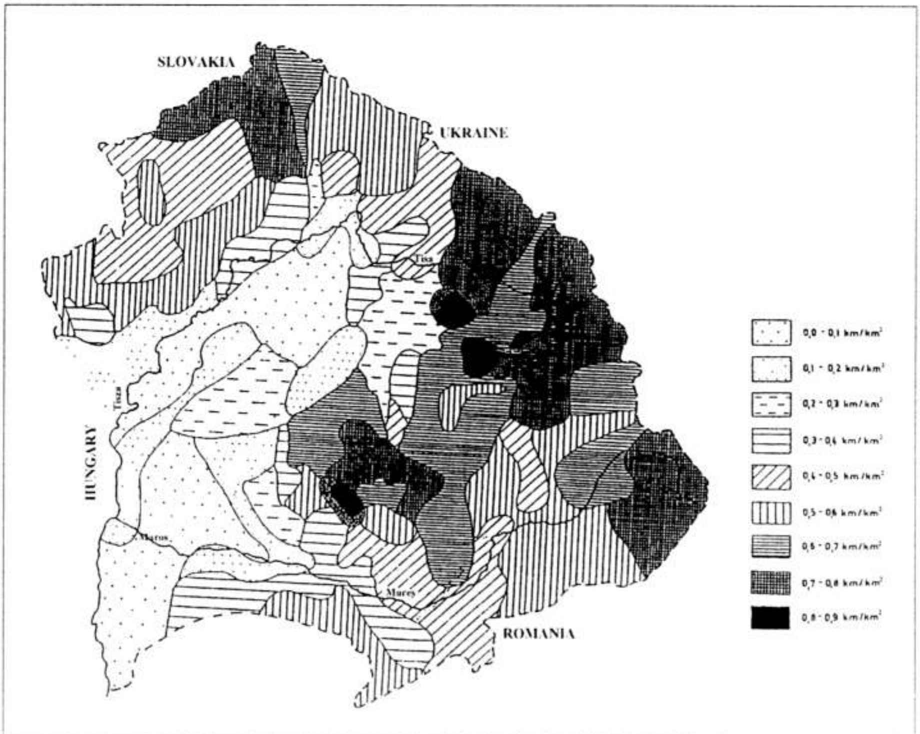

Figure 14. A map of the density of natural watercourses in the catchment area of River Tisa

lowest). The abatement of the flood wave here still cannot be observed because of the joint effect of the rivers Tisa and Szamos, but below Tokaj the lowest water output is 54 m^3/sec, the highest is 4000 m^3/sec, (i.e. 74 times the lowest).

Volumes of flowage in the catchment area hugely depend on the features of the surface relief (angle of slope, exposure, perviousness, proportion of area covered by plants, etc.). One of the most essential factors influencing the density of the watercourses and the dynamics of surface erosion (stage of valley formation) is the relief energy of the region, which primarily exerts its influence in the river system in a way that the higher the figure is, meaning the more marked the features of relief are and the higher the slopingness is, the denser and richer the river system taking shape will be (Figures 13-14.).

The mountain ranges of the Carpathians have a powerful and complex effect on the distribution of atmospheric movements. 1500-2000 m high relief formations constitute real obstacles to air masses coming towards them. Mountain ranges significantly alter the direction of cyclones as well as their natural formation. Passing cyclones moving over the ridges often separate to meet again later in less turbulent zones.

Within air masses forced into an ascending course, intense adiabatic cooling occurs, which, in turn, results in the creation of precipitative activities in the mountainous areas, even in the case of air masses that have proved to be absolutely inactive and dry over the Great Plain.

The ridge of the Carpathians blocks most frequently the humid air masses coming from the west and the southwest, and, as a result, some of the humidity of these clouds falls on the drainage basins of the tributaries flowing into River Tisa from the right, i.e. rivers Teresva, Tereblia, Rika and Borzhava. Although the rain fronts arriving from various directions play a part in the creation of precipitation, the dominant direction of air currents are of crucial importance in the formation of annual precipitation totals. For example, annual average precipitation reaches its peak, 1720 mm, on the southern slopes of the Svidovec Mountains, in the valley of the Sopurka Stream; the maximum figure registered here was 2432 mm. In the area of the river-heads of River Tisa's tributaries flowing from the right, annual precipitation is 1200-1400 mm. Elsewhere, in about 60% of the catchment area of the Upper Tisa, there is more than 1000 mm of precipitation, and in a fairly small area, namely a section of the Iza Valley, there is a figure under 700 mm, while precipitation below 600 mm is recorded at only one station.

Westward the amount of precipitation gradually decreases. Accordingly, the 40-year average still exceeds 1400 mm at the wettest spot of the Teresva Valley, in Usty Chorna; in the Tereblia Valley it is already below that (around 1356 mm), in the Rika Valley it is only about 1250 mm (Berezova 1253 mm) and it is around the same figure in the Borzhava Valley (Rika 1290 mm).

East of the wettest region the figure of precipitation rapidly decreases. Barely 10 km eastward, in the valley of the Chorna Tisa, the annual amount is already below 1100 mm. Moreover, near Yasina the annual total of precipitation does not even reach 900 mm. This region, which is sheltered from rain by the above-mentioned wet Svidovec, is the driest in the Maramuresh Alps. Elsewhere, precipitation as little as here can only be found in the south, in the low-lying areas of the Maramuresh Basin, and in the valleys of the rivers Vişeu and Iza.

West of the 'Gate of Hust' the amount of precipitation decreases evenly and relatively precipitously from 1000 mm to 600 mm, the latter figure being characteristic at the surroundings of the confluence of River Szamos and River Tisa. From other wet regions it is only rivers Borzhava and Túr that carry water of remarkable amount. The upper section of River Borzhava is in the wet area of the Maramuresh Alps, whereas River Túr rises on the southwestern slope of the Oaş Mountains, another area where precipitation exceeds 1000 mm.

The distribution of the annual amount of precipitation can be explained by the orographical structure of the region: the arc of the Carpathian Mountains runs from NW to SE. Arriving in the Carpathian Basin mainly from the southwest or the west, however, air masses carrying precipitation change their course northeastward because the frontier mountains bounding Transylvania in the west constitute an obstacle. As a result, these air masses are forced to bank up, and ascended they precipitate some of their humidity because of dynamic cooling. Precipitation is also enhanced by the channel effect: the area tends to narrow northeastward. Here we deal with the wettest region of not only River Tisa Valley but the whole Carpathian Basin. An increase in precipitation can be detected in our country as close as only 60-80 km from the foot of

Figure 15. The catchment area of River Tisa and its tributaries with the major sub-catchment areas indicated

I The sub-catchment area of the Upper Tisa; — II The sub-catchment area of River Bodrog; — III The sub-catchment area of River Sajó and River Hernád; — IV The sub-catchment area of River Zagyva and River Tarna; — V The sub-catchment area of River Szamos; — VI The sub-catchment area of the Körös rivers; — VII The sub-catchment area of River Maros; — VIII The sub-catchment area of River Bega

the mountains. Obviously, the southeastern slopes of the mountain ranges receive the most precipitation, so there is a great deal of precipitation even on the southwestern slopes of the Oaş-Ighnis. Behind them, in the Maramuresh Alps intense ascent of the air commences because there is no side outlet at lower altitudes. As a result, there is even more precipitation here than in the previous mountain range. Naturally, the Maramuresh Basin sheltered from rain by the Gutâi Mountains is drier, but the river-head area of the Chorna Tisa behind the highest ridge is also rainless (Figure 15.)

The drainage system of River Szamos is at a lower altitude and is much bigger than that of the Upper Tisa. In most of the region there are low and medium height mountains, which are covered by Tertiary argillaceous and marly strata, therefore the sloping of the mountains is not as great as in the water system of River Tisa.

The high-lying areas from where the drainage basin gets water are the southern slopes of the Rodna Alps, the northern side of the Căliman Alps and the eastern half of the Gilău Alps. At its lower section River Szamos drains also the watercourses on the southwestern slopes of the Cibles and Gutâi and the watercourses of the (Szatmári) Bükk. Its catchment area lies lower than that of the Upper Tisa, which already explains partly why the water output of River Szamos lags behind that of the Upper Tisa in spite of the drainage basin of the former being 1.5 times bigger than the latter.

Usually precipitation is also less here than in the Upper Tisa system (6-700 mm). Spring and summer floods of the river generally come along at the same time as those of River Tisa. In autumn, however, heavy rainfall is a rare occurrence in the Transylvanian Basin, so the flood waves of River Tisa in autumn (October) and the high waters of River Szamos do not cause floods. The catchment area is 15,882 sq. km, the length of the river is 1,696 km, the area per unit river length is 7.80 sq. km/km.

The drainage basin of River Bodrog concerning its size is roughly the same as the catchment area of the Upper Tisa (13,579 sq. km). River Bodrog drains the waters of the western parts of the Northeastern Carpathians, and as the amount of precipitation diminishes in the Maramuresh Alps westward, this decrease continues in the drainage basin of River Bodrog, therefore the river carries much less water than the Upper Tisa. The average annual rainfall exceeds 1000 mm only in the region of the eastern source streams Latorica and Uzh. In the river-head area of the Laborec, at the watershed, the figure is about 800 mm, near the springs of the western source streams Topla and Ondava, it reaches only 700 mm. In the region of the streams Latorica and Uzh most of the precipitation does not fall on the main ridge of the Carpathians, but on the area of the Sinjak lying southwest in front of it.

The eastern half of the catchment area of River Bodrog gains its ample precipitation because of the same reasons as the Upper Tisa region, only that the amount of precipitation is slightly lower. What may play a part in this is the fact that the height of the ridge of the Carpathians decreases westward, so cooling off and the precipitation of humidity of the air masses passing over it is also less. Along the upper section of the streams Ondava and Topla the situation is different: this area is out of the way of the air masses advancing from the southwest, hence the comparatively small amount of precipitation, whereas - because of the low ridge - northwestern and northern air currents also play a role in precipitation.

Hydrographic features and the conditions of flowage in the catchment area

Since the Cretaceous period up to the present day some of the high mountains of the river system of the Upper Tisa region have not been covered by sea, other parts surfaced during the Tertiary, or at the end of it as latest. During the long period of time, crust movements and changes in climate have modified the surface-shapings of the

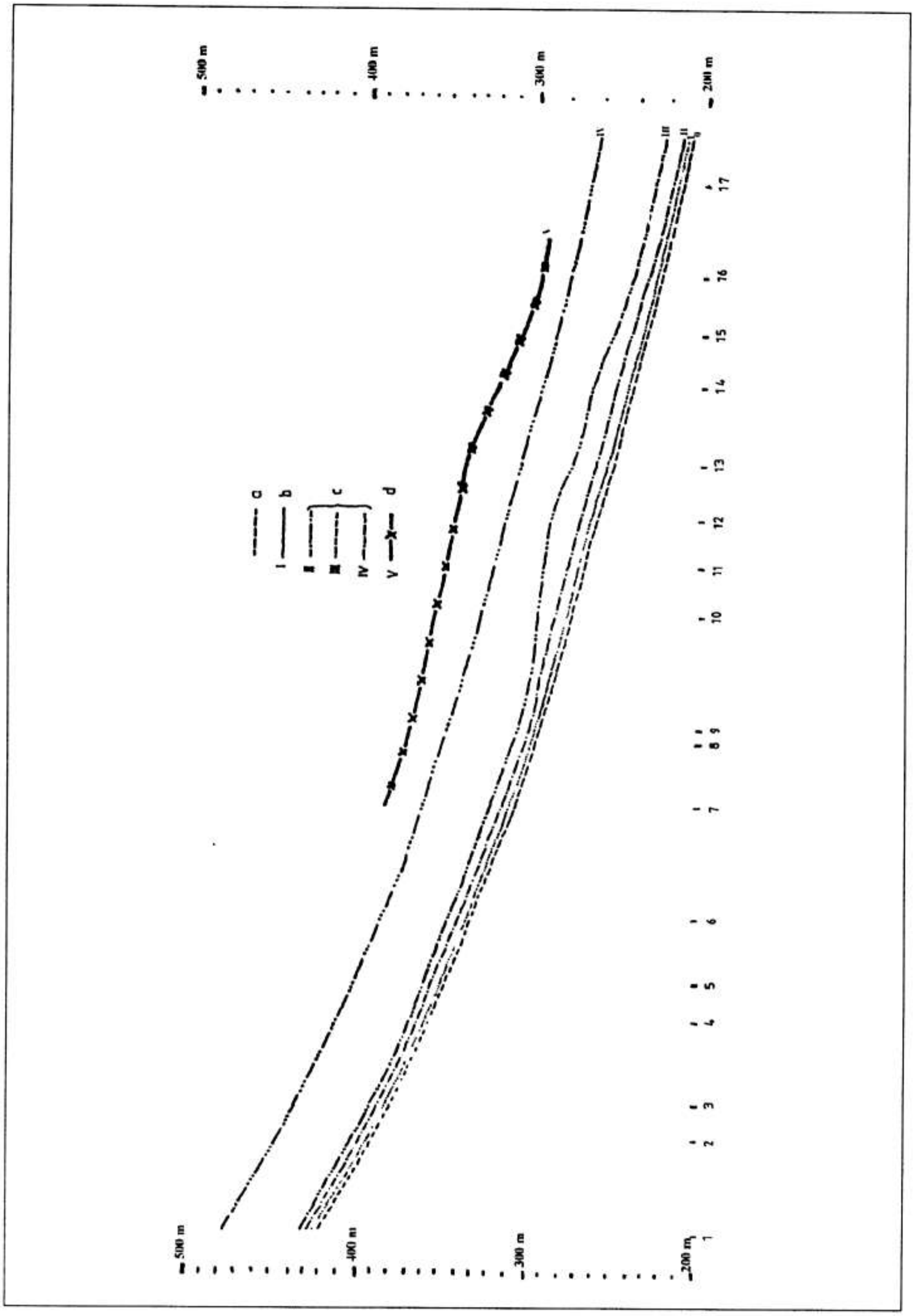

Figure 16. Terraces of the mountain-tract tributaries of the Upper Tisa
Key: a=present level of River Tisa;— b=Holocene (alluvium); — c=Pleistocene; — d=Pliocene

elemental forces many times. Vertical crust movements are common in the mountainous area. With their dip heightened, the rivers, or certain sections of them may have repeatedly etched their valley plain, so in their valleys terraces cut into one another recur in a stepped way. It is mainly the valleys of the major rivers that are terraced. Climate changes of the Pleistocene period as well as the alternation of cool-and-dry ice ages and wet-and-warm interglacial periods led to similar results via the changes in the amount of water or the rubble.

Universal elevation was one of the reasons why the sea covering the Tertiary basins was isolated, freshened and then disappeared. Faulting, and through that, relative differences in altitude altered the dip of the rivers, their potential energy and their surface-forming activity, of all of which visible indications are the terraces.

Since the Pliocene up to the present day rivers of the Northeastern Carpathians have formed six terraces in the process of etching. Terraces in the river valley are not parts of a uniform group, what is more, the eroding force of the rivers made the older terraces disappear. Where there is a gorge along the riverbed only fragments of the youngest terraces remained. Appendix I gives useful information of the etching of the rivers, though determining the exact age of the terraces is very difficult. Where the valley of River Tisa widens, more remains of the terraces survived. So there was a unique terrace formation in the Maramuresh Basin, too. This section of the basin played the role of a filter indeed. River Tisa and its tributaries running down from the high mountainous areas have their first sudden slowdown here. As a result, River Tisa becomes shoaly and a pre-plain-tract river, with its alluvial deposit settling in the past and in the present (Figure 16.).

Terrace 1 is 2.25 m above the level of River Tisa. This is the youngest terrace, its facies is often shapely. The gravel composition is completely the same as the one belonging to 'flis'.

Terrace 2 is the youngest among the glacial terraces, it is a prominent, well-developed terrace, it belongs to the most common terraces of the upper section. It is situated 6-10 m above the level of River Tisa. Its composition is gravel, which is always loose because of the lack of cementing substance. Conglomeration cannot be observed anywhere.

Terrace 3 is one of the commonest among terraces of medium level. It is 14-16 m above the level of River Tisa. Regarding its morphology it is cohesive and its gravel content is also quite fresh, there are no decayed parts in it. Gravel accumulation may have happened in the middle of the ice-age.

Fragments of terrace 4 are quite rare, but still enough to form a cohesive terrace system. It is 50-55 m above the level of River Tisa. This being the oldest glacial terrace is relatively intact, decayed pieces can hardly be found.

Terrace 5 belongs to the older, Pliocene terraces that still remain. It is 75-80 m above the level of River Tisa. This is the last terrace that can be traced back to a cohesive terrace level with the help of its remains. Its gravelly rock composition reflects the erosion through time. Certain compounds of the pebbles are greatly decayed.

Terrace 6: They are very conspicuous levels above terrace 5, but it is risky to establish a connection between them. Resembling the terraces of River Tisa there are terraces of the above mentioned types along its tributaries, too. They can primarily be found in isolated pieces in the valley of River Teresva.

Anyhow, terraces are important components of the landscape, and they are also important from the people's point of view: on the lower ones, protected from floods and having a plain surface, there are a number of villages with their arable lands, and the roads are also here. Some patches of the higher, therefore older and, as a result, more eroded terraces proved to be suitable for building castles.

V-section valleys created by rivers are the prevailing formations in the Northeastern Carpathians. There is a great deal of variety in the details. The density of the valley network and characteristics of minor surface formations depend on the size and height of the mountainous area on the one hand, and on its composition and the qualities of rocks in its structure on the other.

Minor rivers and streams rising in the inner side of the mountain ranges of the sandstone belt flow together in groups before they break through the volcanic belt in the relatively narrow valley. To the central trough of River Tisa in the Maramuresh Basin six torrent river valleys are attached, stretching from Sighetu Marmației to Hust: rivers Rika, Tereblia, Teresva, Chorna Tisa, Bila Tisa, Vişeu and Iza. (Table 3.)

Watercourse	Name of section	Location	Catchment area	Water output, m^3/sec		
		rkm	sq. km	low eater	average	high water
Vişeu	Petrova	8,5	1586	3,6	29,2	1020
Túr	Turulung	56,1	723	0,14	8,8	300
Teresva	Dubove	34,2	240	3,57	8,4	663
Tereblia	Kolotsava	57,7	149	141,8	4,05	356
Rika	Hust	1	781	4,14	27	1667
Iza	Vadu Izei	9,7	1130	0,58	15,9	660
Borzhava	Dovge	69	407	0,66	10,1	399

Table 3. Regime data referring to some sections of the tributaries of the Upper Tisa

If the surfacial unity of this huge region is seen, which takes shape in a 100 km long trough and its narrow southern as well as its 40 km wide northern mountainous slope, including the perfect enclosure of these two slopes by the Rodna Alps (Munții Rodnei), then what we see here is a big indivisible hydrographical unit whose water supplies constitute the water bases of River Tisa.

The huge trough of the Maramuresh dominates so much over the mountain tributaries that their independence is overcome by its attraction. The fact that the valleys of Maramuresh are formations by simple slope rivers also contribute to that. As a result they do not furcate, do not branch. They are narrow ditches on which human settlement spreads, and each joins the big trough of River Tisa separately.

The dip of the rivers already in the basin or just reaching the bays of the plains is much lower. Their potential energy may be only as much as or just less than what is needed to carry their sediments. In the former case the river is a valley-tract, meandering river; with its prominent bends it creates a wide valley plain. In the latter case it is a mountain-tract, branching, shoaly river filling its valley with its sediment.

Evaluating the hydrogeographical features in detail, on the basis of the valley structure and the characteristics of the surface morphology, the catchment area can be divided into three parts: mountainous, hilly, and plain areas. River Chorna Tisa rising north, about 50 m under the ridge of the Okula-Aklos and later joined by River Bila Tisa flowing from the east, flows mainly southward, then at its confluence with River Vişeu, takes its course westward and keeps this direction as far as Tjachiv. The drainage area of the Upper Tisa above Tjachiv is about 7000 sq. km, which can hydrogeographically be divided into two characteristic sections. From the spring of River Tisa the real mountain-tract section spreads roughly from Rahiv to Luh. Here River Tisa is a real mountain river, a real "wild river"; its speed reaches 3-4 m/sec at several places. In the narrow valley it runs deep in a bed interspersed by big, in places 1 m^3 large cuestas, races and faults, roughly as far as the confluence with the stream Kasovska.

The hilly section spreads from the village of Luh, from the confluence with the stream Kasovska, to the village near Tjachiv. Below Luh the "embrace" of the mountains suddenly ends and River Tisa flows out into the hilly region. However, because of the sloping of the terrain, it does not lose much of its speed. 3-4 km below the village V. Bochkiv, there is a fall at the bend between the La Ciube Mountain and the village of Tisa (Romania). Further down as far as Sighetu Marmației there is an alternation of small and big islands. It is here, approximately between Sighetu Marmației and Solotvina that River Tisa first pours out its "bundle", its mass of water, to which River Iza contributes to a great extent. The first big levee beginning here impairs the flowage conditions throughout a 25 km length or so with a number of branches, bends, falls and shallows. Below the confluence with River Teresva, River Tisa runs down at such a speed that along an approximately 7 km stretch as far as Tjachiv no considerable island is formed. We first encounter major islands and falls only near the Tjachiv bridge. Another major levee begins only below the ravine between Tjachiv and the Papasztag Mountain. The section of the river ends at the edge of the Maramuresh Basin, where the mountain pass of Hust (or the 'Hust Gate') can be found. The following section of River Tisa is between Hust and Vinogradiv in a region of low hills consisting of volcanic rocks.

The mountainous area surrounding the Great Plain elevated differently in the Quaternary, and the basin of the plain did not subside uniformly either: sub-basins of different size were formed, so different kinds of rock from the mountains filled up the different parts of the basin. From Vinogradiv to Vilok River Tisa is a mountain-tract river. From its spring it travels 200 km with an average dip of 8 m/km and arrives at the edge of the Great Plain carrying an enormous amount of gravel. From that point to the confluence with River Szamos and River Kraszna its dip decreases fortyfold, the average barely reaching 20 cm/km. Because of the abrupt loss of dip it deposits most of the large pieces of its sediment here, at the edge of the Great Plain, it branches and wanders around the 40-50 km wide plain covering it with multiple layers of gravel. Keeping west near Vásárosnamény it runs into the elevated "island" of Nyírség, and it takes a sharp turn north from here. Below the turn it receives River Szamos and River Kraszna flowing from Transylvania, from the south. River Szamos is a longer river: by the confluence it has covered 370 km as against the 200 km of River Tisa (Figure 17.).

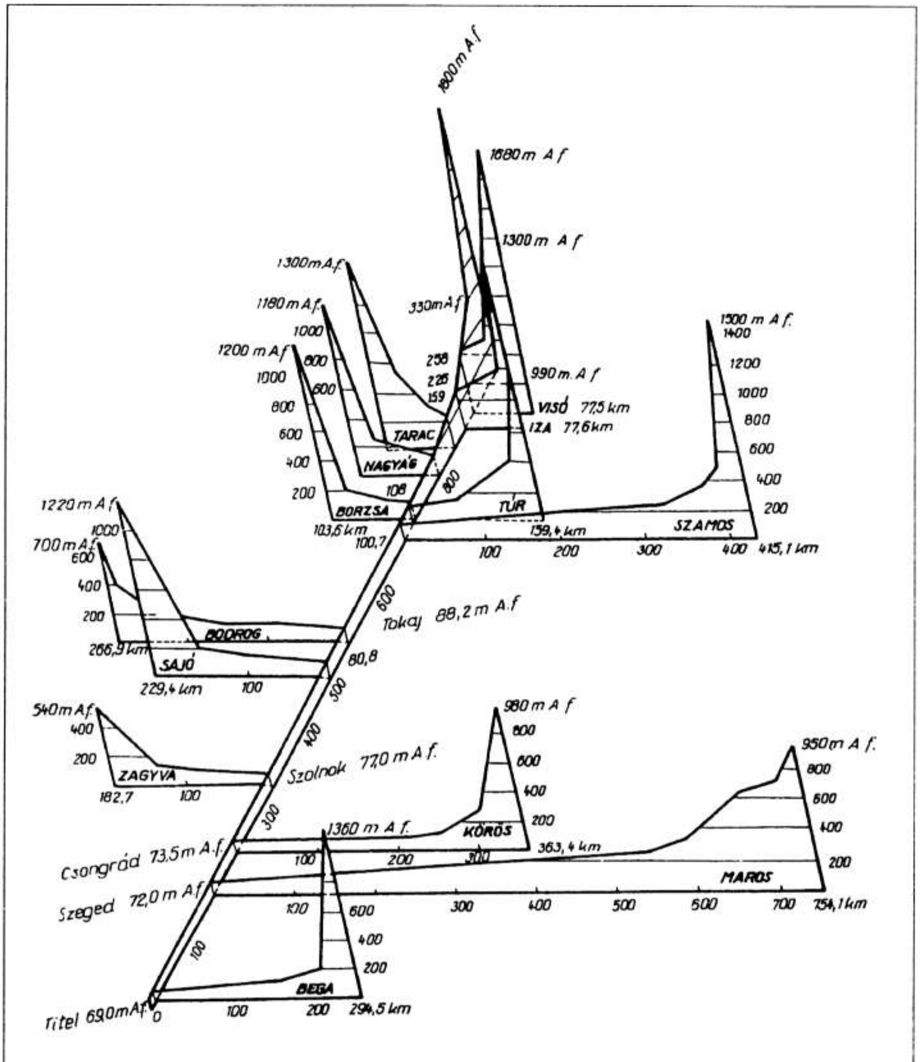

Figure 17. A schematic delineation of the conditions of bed gradient of River Tisa and its tributaries

A.f.: above Adriatic sea level

The first name is Hungarian, and the second Ukrainian or Rumanian: Borzsa/Borzhava, Nagyág/Rika, Tarac/Teresva, Visó/Vişeu, Túr/Tur, Szamos/Someş, Körös/Criş, Maros/Mureş

The water output of River Tisa is higher, 224 m^3/sec, that the average 126 m^3/sec of River Szamos. It is due to River Tisa's tributaries of great water discharge. River Szamos comes from the rather dry region of North Transylvania. Well beyond its confluence with River Tisa, River Szamos loses its dip and begins its large-scale deposition of gravel up near Szatmárnémedi. The vast gravel field of the Szatmári Plain has been built by the three major rivers, (Szamos, Kraszna and Túr) together with their affluents. This catchment area (Tisa-Szamos region) is a plain area indeed, where the great bend of Vásárosnamény came into existence in the last third of the Pleistocene. River Tisa, in accordance with its original course, turned south, united with River Szamos, and flowed toward the Berettyó in what is now called Ér Valley. The change was caused by the elevation of Nyírség. Nowadays in the 60 km section from Vásárosnamény to Chop River Tisa, as a plain-tract river, dips only 4 m, or 7 cm/km. From Chop downwards its dip and its speed increase. Its dip is 10 cm/km as far as Tokaj which is 86 km away. But the neck of the Tokaj Gate swells it again. At this gate River Tisa is joined by River Bodrog, which enters Bodrogköz together with its several tributaries and deposits a great deal of gravel on the flood plain between the two rivers.

River Tisa becomes a typical plain-tract river below the Tokaj Gate. The plain opens wide here. Leaving the marginal little basins the river arrives in the main basin. Its great left-side flood plain, the Hortobágy, is 20-25 km wide. The dip of the river before it arrives in the Szatmár Plain at Tiszaújlak (Vilok), along a 160 km stretch, is 8.2 m/km on average. From the edge of the Szatmár Plain to Tokaj, a 210 km distance, the average dip is 30 cm/km, while from Tokaj to Szeged, on a length of 480 km, it is merely 4 cm/km

The annual average water output of River Tisa is 200 m^3/sec at Tiszaújlak (Vilok), 450 m^3/sec at Tokaj and 790 m^3/sec at Szeged. River Tisa, enlarged by the mountain streams, is a significant river when it arrives in the Great Plain. Although it does not receive many tributaries on the Great Plain its average water output increases fourfold down to its confluence with River Danube, because it drains the ground water as well, to a great extent. This phenomenon plays an important role in the water movement of the layers 10-20 m under the surface

Regarding their hydrological parameters, mountain rivers differ to a great extent. What is more or less a common feature, however, is that all of the mountain rivers rise on the inner slope of the Carpathian sandstone mountain range.

In our evaluation we account for the river-heads and the immediate environs of River Tisa and its tributaries.

River Chorna Tisa rises at the foot of the Svidovec, 1680 m above sea level. It drains the waters of 567 sq. km, its length is 50.3 km, the direction of its course is first W-E, then N-S.

Its spring is on the northern slope of the NE-SE mountain range of the Svidovec Mountains. It becomes a rapid mountain stream from the confluence of several mountain rivulets in its environment. The valley is first wide, but it soon narrows, then another wide section ensues, where it unites with the stream Apsinec in the dense fir forests. On it there was formerly a mountain lake that held 200,000 m^3 of water. It ceased to exist, and now the mountain stream has only a 15-20 m wide bed, which was etched into the side of the Ocola Mountain. Here, in the mountainous surroundings we can already see several high elevations: the Bratkivska, the Chorna-Kleva, the range of the Svidovec southward, while eastward in the distance the towering mass of the Hoverla. From the valley a narrow path leads to the spring of River Chorna Tisa, where the crystal clear water stream trickles. In the upper section of River Chorna Tisa the Yasina Basin takes central stage. The Yasina lies 12 km long in the valleys of River

Chorna Tisa and the Lazeschina. The longest measure of the basin is 14 km, its width is 8 km. Concerning surface morphology, the area is a 200 m high hilly region. Its rock composition is shaley sandstone and micaceous sandstone saturated with crude oil to a certain extent.

The valley of River Chorna Tisa is 44.6 km long, the riverbed section down to its confluence with River Bila Tisa is 50.3 km. The highest point of the drainage area is 1788 m above sea level. The upper extremity of the riverbed section is at an altitude of 1680 m, the lower one is at 460 m. The catchment area is 564.4 sq. km, the total dip of the riverbed section is 1220 m, average dip is 24.2 m/km. The average dip of the whole valley section is 27.4 m/km.

River Bila Tisa has two springs. It is fed from the Hoverla setting off at an altitude of 1600 m. It gathers the waters of an area of 489 sq. km along a length of 34 km. North of Rahiv the two branches of River Tisa unite. The bigger branch, River Chorna Tisa retains its previous NNE direction. River Bila Tisa forms an E-W direction river valley. Its river-head area is on the western slope of the Chorna Gora alpine mountain range. From the confluence with River Bila Tisa the distance is 27 air km in a W-E direction to the peak of the Chorna Gora, 21 air km in a N-S direction to the Petros Mountains, while it is 25 air km to the peak of Pop Ivan. The peaks of the northeastern watershed provide a real alpine landscape (Konecz 1517 m, Sesul 1728 m, Petros 1784 m, Hoverla 2061 m, Chorna Gora 2020 m).

Especially noteworthy is the Chorna Gora range, which has several peaks higher than 2000 m (Hoverla 2061 m, Danec 1822 m, Turkul 1933 m, Tomnatek 2018 m, Chorna Gora 2020 m). At the southeastern edge of the alpine range another range begins (the Gora Vaskul 1737 m, Vihid 1471 m, Stig 1650 m), which constitutes the river-head area of the stream Tisora. Among the great watershed peaks we should also mention the Pop Ivan, the Magura peak (1489 m), and the Menchil (1880 m). Relief features provide a significant water basis to the affluents of River Bila Tisa. Some of the remarkable affluents are the streams Pavlik, Bogdan, Hoverla (White) on the right, and Balcatul, Kvasnivchik, Schaul and Stohovec on the left. There are several additional rivulets feeding River Bila Tisa.

River Bila Tisa down to its confluence with River Chorna Tisa counts as a minor mountain river, although some of its parameters are higher than those of River Chorna Tisa. The length of the riverbed is 33.6 km, the length of the valley is 31.8 km. The highest point of the drainage basin is 2035 m.

At the upper extremity of the riverbed the banks are at an altitude of 1600 m, at the lower one they are at 460 m. The total dip of the riverbed section is 1140 m, average dip is 33.9 m/km. The average dip of the valley section is 35.8 m/km, and the catchment area is 486.9 sq. km.

River Vişeu rises at the easternmost part of the Maramuresh and flows into River Tisa at Valea Vişeului. The catchment area is 1606 sq. km, the source of its 80 km-long riverbed is in the Rodna Alps, at the foot of the 2305 m high Pietrosul Rodnei at an altitude of 1693 m. At low-water mark usual water output is 3.6 m^3/sec, the average is 29.4 m^3/sec, and at high-water mark it is 1020 m^3/sec. The river flows in a romantic region, in a narrow valley, down to the village Bistre. Between Bistre and Ruscova, however, there is a widened valley plain. The river is surrounded by various rocks and crystalline shales. Among them there are some kinds of lime deposit of various size, such as limestone shale and solid or breccia-like limestone. On both sides of the crystalline shales Carpathian sandstone can be found, which consists of Cretaceous, Eocene and Oligocene rocks. The right tributaries of River Vişeu are the streams Borşa, Vaser and Ruscova, the watercourse of the Bistra, and various other less important ones, of which the streams Bistra and Crasna may be mentioned. Except for the first stream all rise from the mountain mass of the Pop Ivan. None of the left watercourses of River Vişeu are significant.

River Iza rises in the Rodna Alps. Its catchment area is 1303 sq. km, its length is 83 km. It is the left tributary of River Tisa flowing along the fault structure of the valley of the Lăpus (M. Ţibleşului) and the M. Gutâi, whose SE-NW direction is also followed by River Tisa. Its usual water output is 1.58 m^3/sec at low-water mark, the average is 15.9 m^3/sec, at high-water mark it is 660 m^3/sec.

Below the confluence of River Iza and River Tisa, between the M. Oaş and the Vinogradiv mountains at the so-called 'Hust Gate', where the river valley widens, River Tisa first receives its northern tributaries:

- River Teresva which rises on the southwestern slopes of the Maramuresh Alps. The 1836 m high Syvula and the 1742 m high Popdja can be found in its river-head area. The catchment area of the river is 1224 sq. km, its length is 85 km. Usual water output at low-water mark is 3.57 m^3/sec, the average is 8.4 m^3/sec, at high-water mark it is 663 m^3/sec.
- River Tereblia, whose catchment area is 766 sq. km. Its length is 91 km, usual water output at low-water mark is 40.5 m^3/sec, the average is 4.18 m^3/sec, at high-water mark 356 m^3/sec. It rises on the southwestern slope of the Maramuresh Alps.
- River Rika. The highest point of its 1240 sq. km drainage basin is only 1288 m high. The length of the river is 93 km, its usual water output is 4.14 m^3/sec at low-water mark, the average is 27.0 m^3/sec, and 1667 m^3/sec at high-water mark.

From the right River Tisa receives two more major tributaries between Korolevo and its confluence with River Szamos:

- River Borzhava, the catchment area of which is 1418 sq. km, and its length is 104 km. The river rises at the foot of the 1681 m high Stoj, its water output is 1.66 m^3/sec at low-water mark, its average water output is 8.8 m^3/sec, at high-water mark 399 m^3/sec.
- River Túr (Tur), which flows into River Tisa in Hungarian territory already. The drainage basin is 1262 sq. km, the length of the river is 95 km, water output is 0.14 m^3/sec at low-water mark, the average water output is 8.8 m^3/sec, and 300 m^3/sec at high-water mark.

Down to its confluence with River Szamos the catchment area of River Tisa is 13.173 sq. km, whereas the altitude of the river valley decreases to 103 m at the lower edge of its 258 km long area, thus the dip of the Upper Tisa is 1577 m.

The mountain streams mentioned above have consistent courses in all cases, their river-head areas are mainly in the Maramuresh Alps.

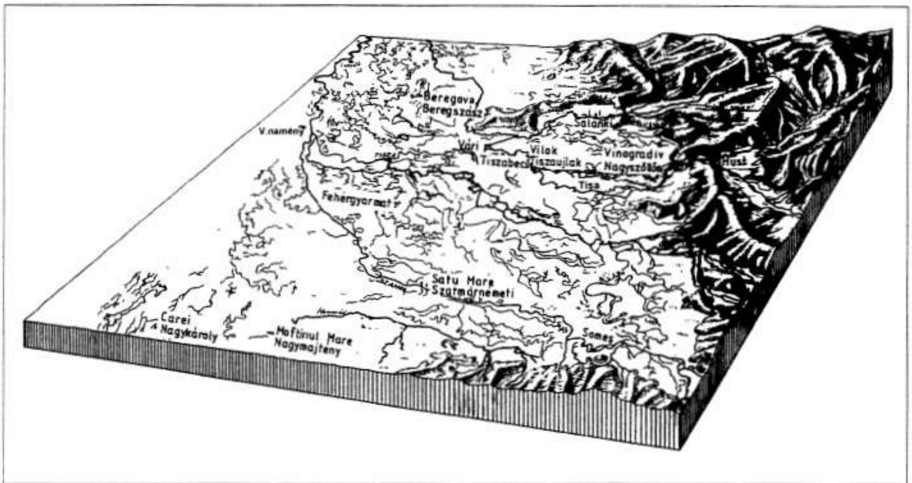

Figure 18. Changes of the beds of River Tisa and River Szamos in the Bereg-Szatmár Plain (after Borsy Z.)

The watercourses rise below the main ridge which serves as the watershed, and all run toward the centre of the Carpathian Basin. All of them are received by River Tisa. The present picture of the river system was created after the folding of the volcanic deposit. The volcanic mound blocked the watercourses running down the inner slopes of the sandstone deposit. Only the eroding process of the rivers of high water output was able to keep pace with the volcanic workings. These, such as River Tisa, River Borzhava, River Latorica and River Uzh were able to keep their valleys open even during volcanic accumulation, and so-called volcanic gates were created this way (Hust, Munkacheva, Uzhgorod gates). The lively force of the smaller rivers, however, did not manage to overcome the volcanic accumulation, these rivers were mounded behind the volcanic masses, were swollen and started searching for a course towards the breakthroughs and gates of the bigger rivers. That is why certain rivers developed a river system resembling a branching treetop. The most exemplary is that of the Uzh.

The hydrography of the depressions at the foot of the mountains is chaotic and meandering everywhere, but in this respect it is the Szatmár Plain that takes the lead. Both River Szamos and River Tisa wanders across the plain while developing huge bends, branching, reuniting, flowing into each other's bed. The reason for this very indefinite flow is not only the different alluvium-carrying capacities involved in the constructing and eroding processes, but the minor mosaic-like surface movement as well, which has been under way up to the present day. The Tertiary surface under the present river sediments has a very varied relief, but the transformation of the substratum did not stop in the Pleistocene or the Holocene; on the contrary, it even intensified (Figure 18.).

In front of the mountains the depth of the Pannon strata ranges from 400 m to 1200 m, with depressions of NW-SE direction in them. On top of the Pannon strata there is a sequence of Quaternary strata, which consists predominantly of large sediments:

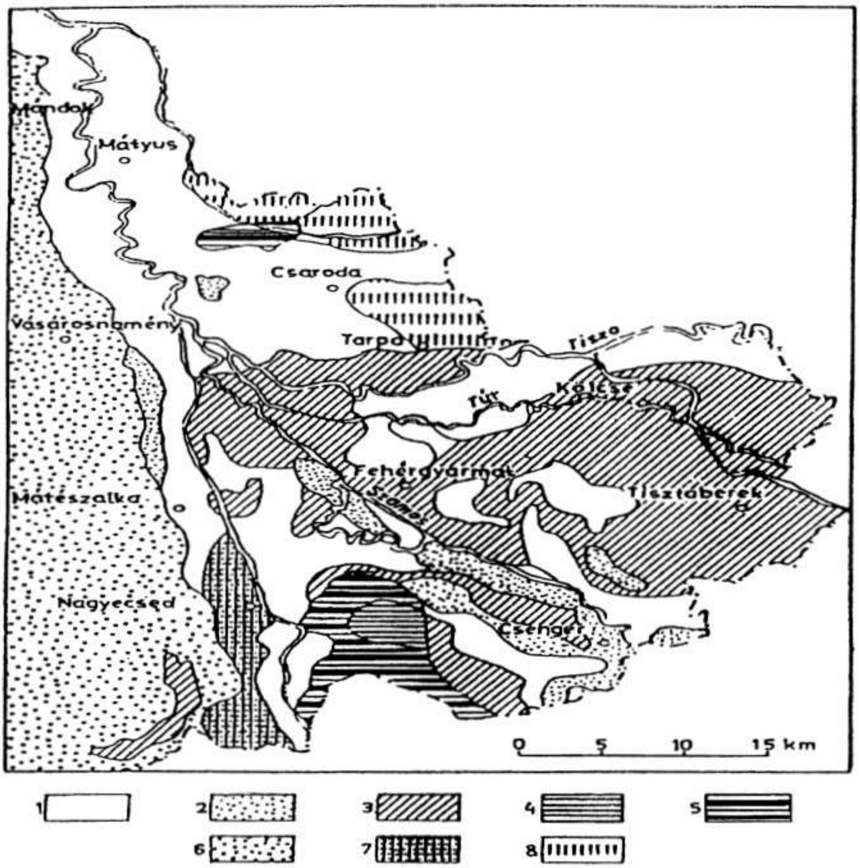

Figure 19. Near-surface deposits of the Szatmár-Bereg Plain
Caption: 1 alluvial soil; — 2 sand drift; — 3 silt; — 4 clay; — 5 mud-peat; — 6 sand drift; — 7 loessal sand; — 8 loess

gravel and gravelly sand. The depth of the sequence ranges between 50-200 m. In the plain area stretching south of River Tisa Quaternary deposits of various thickness were formed in a NW-SE direction corresponding with the courses of the rivers Kraszna, Szamos and Túr, and in an E-W direction corresponding with the courses of River Tisa and River Latorica. The Tisa-Szamos-Túr plain area was nearly filled up to the present ground level back in the periglacial Lower Pleistocene. It is covered by a comparatively thin sequence of layers formed by younger, Pleistocene and Holocene depositions. Sedimentation may already have started in the Pliocene. During the Quaternary six or seven layers of gravel accumulated in the trough at the foot of the mountain and later in the plain so formed, which indicates the periodicity of the sedimentation as well as the fact that the depression is not young.

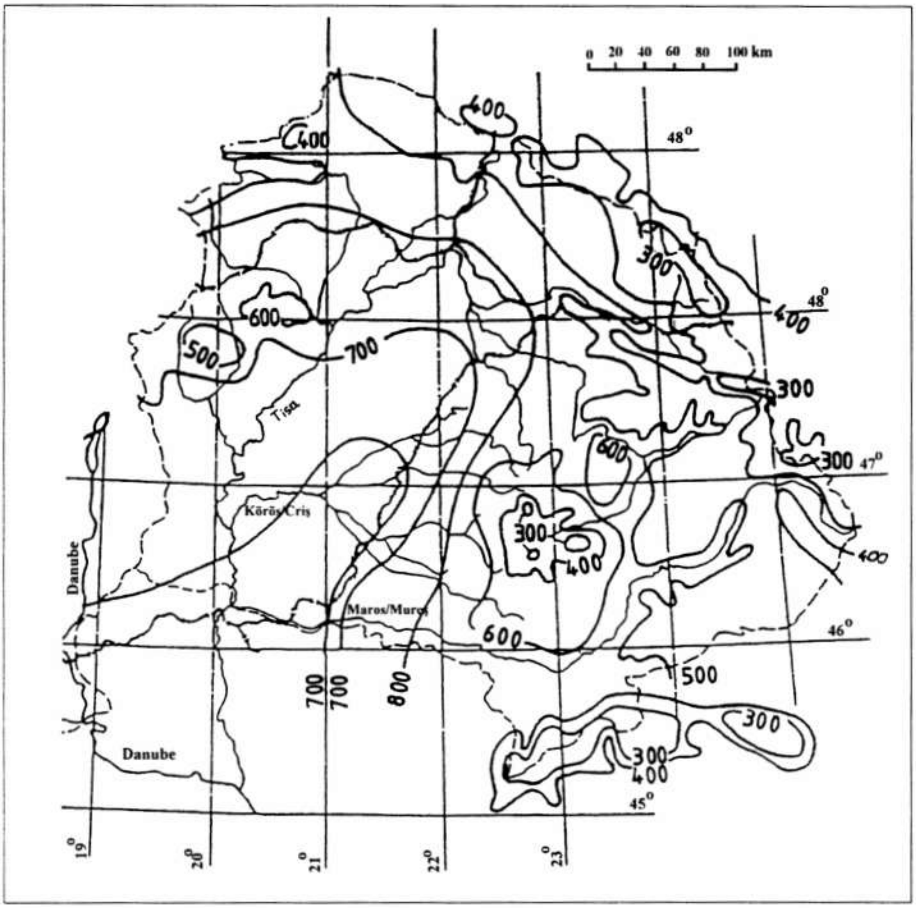

Figure 20. Average potential evapotranspiration over many years

The Holocene strata start with a layer of gravel and they become finer upwards: they turn into sand, silt and clay. Their thickness varies considerably: from some metres to 40-50 m. On their surface peat bogs have come into existence, in other places patches of alkaline soil can be seen (Figure 19.).

Relying on the research so far we can consider it proved that the rivers flowing from the Northeastern Carpathians and Transylvania built up a uniform talus pile until the end of the Pleistocene in the northeast of the Great Plain. The talus pile unit disappeared as a result of the periodic subsidence of the Bereg-Szatmár Plain and the Bodrogköz, commencing in the Lower Holocene and as a result of the elevation of Nyírség. It can similarly be considered proven that River Szamos changed its course many times in the Holocene as a result of a gradually intensifying subsidence of the western part of the Bereg-Szatmár Plain compared with its surroundings, and that the sand-drift group of Nyírség was formed in the Holocene, with its main features created in the Hazel Age.

Natural flora of the catchment area of the Upper Tisa

In the drainage basin of River Tisa the country planning of the human society, primarily activities affecting the vegetation of the catchment areas in the mountains, have an impact on the magnitude of flowage. In this respect we give preference to the catchment areas of the mountains because it is well-known that this factor does not play an important part in the plain drainage basins having little relief energy. For example, in the plain of River Tisa where annual precipitation is 600 mm on average, and annual evaporation reaches 700 mm, there is in fact no remarkable flowage, and this fact would not be otherwise if the entire Great Plain were covered with forests. However, in the catchment areas of River Tisa in the mountains, particularly in the Northeastern Carpathians and the Transylvanian high-mountain areas, precipitation exceeds potential evaporation by 10% to even 50% (Figure 20.) Actual figures within these extremes depend mainly on the structure of vegetation and the categories of soil composition controlled by it.

The flooding period and the water output at flood increase. Consequently, the formerly built dikes seem more and more underplanned to retain the high water output that fills up the flood plains very rapidly. Unfortunately, country planners hardly take into consideration the characteristic features of our age: the more and more intense exploitation of forests and other agricultural sources greatly increase the flowage coefficient of the catchment areas in the mountains, which can multiply peak water output and it can increase the total amount of soil and detritus washed down, mainly at the river sections well below the drainage areas. This issue is one of the gravest problems of conservation, and it definitely deserves more attention than it has been paid so far! (Table 4., Figure 21.).

Name of the drainage area	Area of forests sq. km	Proportion of the area covered by forests, %
Upper Tisa	6163	48
Szamos and Kraszna	6095	32
Bodrog	5180	39

Table 4. Stretch of forests in the catchment area of the Upper Tisa

The degree to which the drainage basins of River Tisa and its tributaries in Romanian territory were covered with forests appears as I (before branches of intensive cultivation were introduced) and it appears as II representing present time (according to Conek and Velcea). This reflects the destruction of the forest assets (Figure 22.). Nevertheless, it is not enough to compare past and present, so our figures are relative.

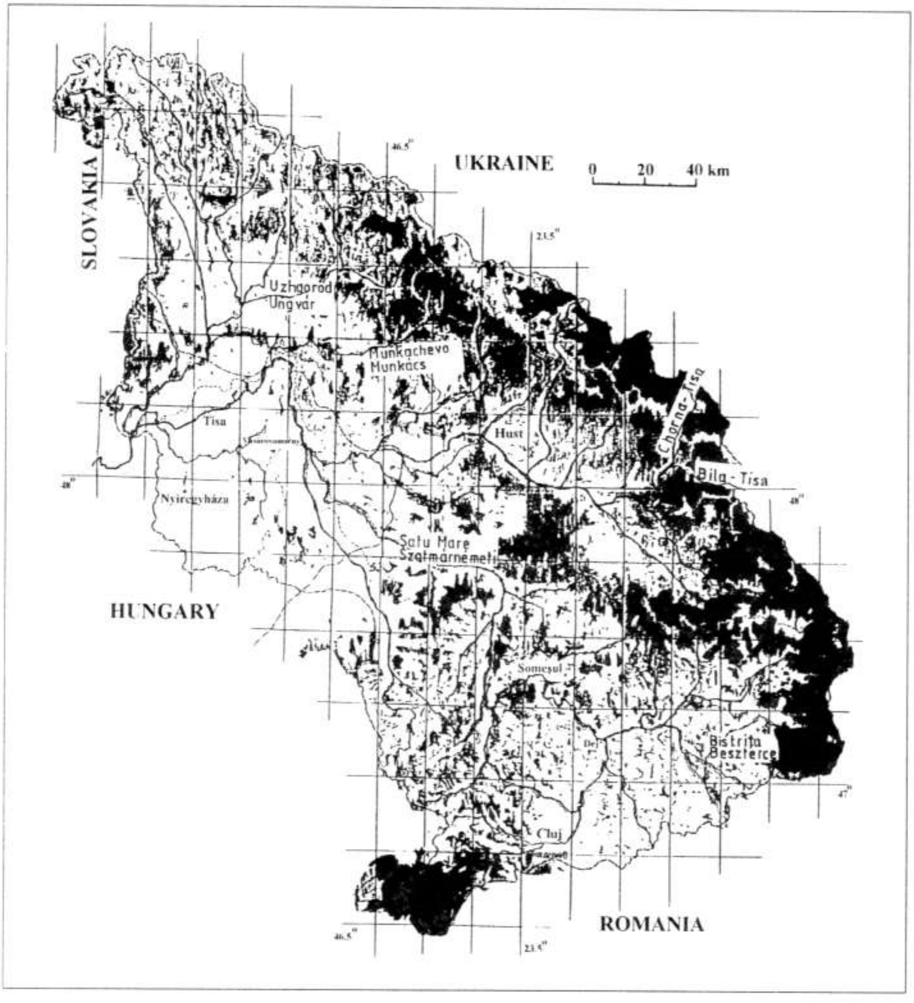

Figure 21. Forest cover of the Upper Tisa (after the hydrological atlas published in 1955 by VITUKI)

A solution would be if we only reflected the changes of the 20th century, if we had any data at all. It is known that we do not possess official figures about the widespread deforestation along River Tisa or the main changes in the branches of cultivation. The forests of the Carpathian Basin and the surrounding mountainous areas are planted forests, the trees of which should be exploited and the area reforested in a planned way, thus their natural decay cannot be permitted. Forest soil stores water, while field soil wastes water. A forest decreases water output of precipitation until the forest floor and the soil is soaked with water. After that it cannot act as a water retainer.

Before human interference, deforestation and swamp draining activities, the wooded-steppe areas of the interior of the basin system were surrounded by forests of

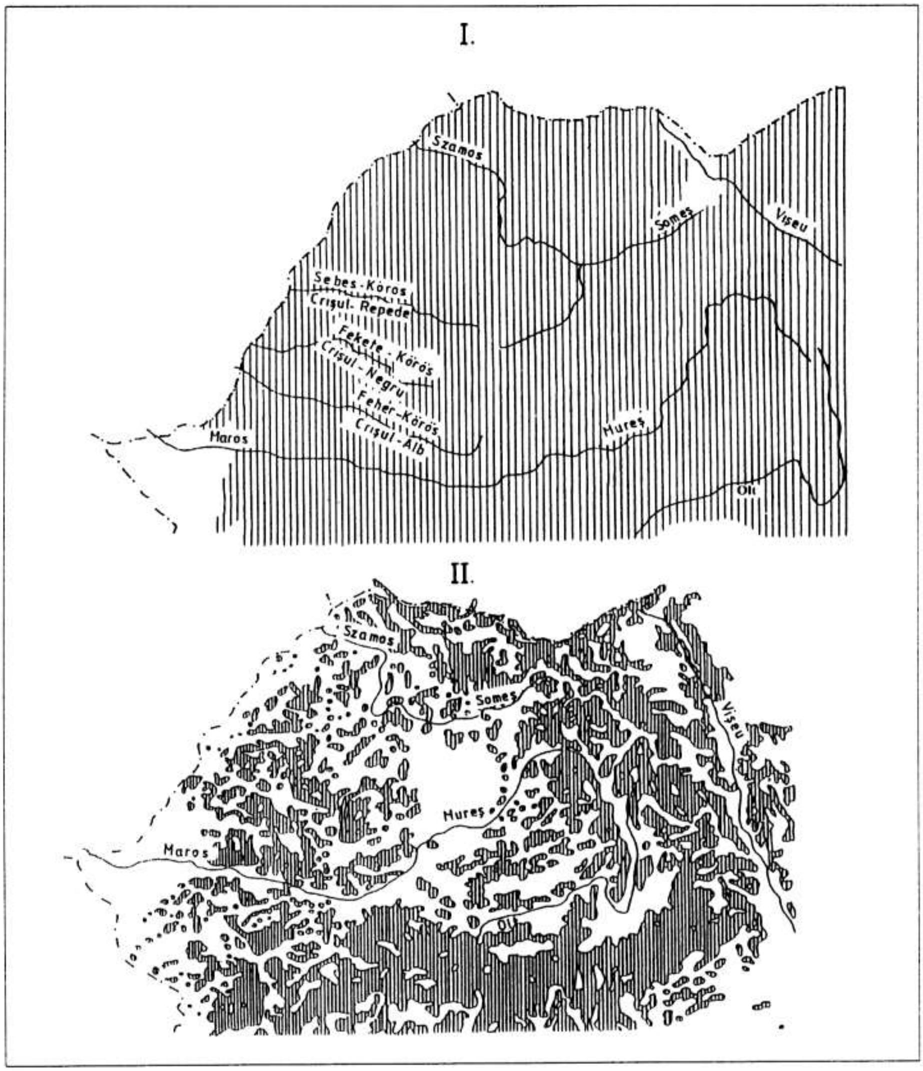

Figure 22. The proportion of area covered by forests in the catchment areas of River Tisa and its tributaries in Romanian territory, before the introduction of cultivation branches (I), and at present (II) (according to Conek and Valcea)

altitudinal zonal distribution on the hilly and mountainous areas, both around and within Hungary. As temperature on average decreases with altitude and precipitation increases, it is evident that oak trees, which need a great deal of heat and light but only little water, are replaced at higher altitudes by beech forests which need less heat and light but more water. At higher altitude beech forests are replaced by simple pine forests, especially stocks of spruce that prefer wet and cool climate.

The floristic distribution of the vegetation of the Carpathian Basin and its mountainous environment reflects the present climate, and indirectly the relief in the cities. In the flora of the Carpathian region the northwestern and northern mountainous area differs from the Northeastern Carpathians: in the former the number of species is lower, but the number of the so-called 'Pontain' and continental species, which are common with those of the southern Russian steppes, is higher. There are even more significant differences between the distribution of the plant communities determined by climate and relief.

As neither the temperature nor the amount of precipitation, nor any other climatic factor exclusively depends on altitude, we can only approximately say that the upper boundary line of oak forests is 700 m on the Northwestern Highlands and 800 m in the east. The beech areas are between about 300-1300 m, the pine forests are between 500-1400 m in the northwest and 800-1500 m in the east. Above them we can find subalpine and alpine flora.

In the Eastern Beskyds, and even more so in the Maramuresh Alps, (more precisely in the Popadja, the Svidovec, the Hoverla and the Pop Ivan) the top of the mountain range reaches above the timber line, into the zone of the Swiss pine shrubs with sporadically scattered larch and cembra pines. In the Maramuresh Alps it extends even higher, into the region of alpine grass full of colourful flowers. In the Maramuresh Alps stocks of dwarf juniper and hellebore lead from the zone of Swiss pine alternating with green alder to the alpine grass.

There is, of course, undergrowth - grass stratum and shrub stratum - in some of the oak and beech stocks themselves. It is the richest in the often forest park-like, sparse oak stocks that, besides hornbeam, frequently grow together with lime, maple, crab, wild pear and wild cherry, and that have less close foliage. Here the presence of flowering shrubs such as cornel, thorn bush, wild rose and blackthorn is especially common. This is a "colourful forest" indeed, different from the dark beech forest with closed canopy, where the flowers of the herb layer grace flourish only in early spring. The poorest undergrowth is in the pine forests.

Obviously, the flora of very steep slopes is rather poor, because rubble cannot persist in such places. On the other hand, in many places it is the flora itself that delays the movement of rubble. For example, on the slopes of the V-section valleys intersecting our mountain ranges: if the trees are cut down the slope often becomes bare. From the rubble coming to the surface, soil is formed by chemical processes that depend on both the climate and plant physiological processes. In the area of our highest and wettest mountains, mainly covered by pine forests and to a lesser extent by beech forests, the soil is eluviated, acidic, humic, grey forest soil, which is poor in nutrients. In some places it is lithosol mixed with large pieces of rubble. In the beech region mostly brown forest soil can be found, and this leads over to the saturated, humic, dark brownish-blackish open-country soils of the centre of the basin, to the soils with higher salt content. Even on the various rocks, these soil zones which depend primarily on the features of the climate, therefore having formed as a result of a slow process, are broken by the ever-regenerated fresh alluvial soil of the river valleys, often even by the sediment fields consisting of gravel and covered only by a thin layer of silt.

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Mihály Andó
Physical Geographical Institute
József Attila University
H-6701 Szeged
P.O.Box 659
Hungary