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GEOMORPHOLOGICAL CHARACTERISTICS OF THE RIVER SAVA VALLEY BETWEEN KRŠKO AND PODSUSED

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Introduction. The river Sava valley sector between Krško and Podsused, as an object of the investigation, posseses some specifical morpnological features. It is not, however, a typical fluvial valley. In our case, there are no valley sides in the greatest part of the area being explored: in Krško and Samobor basins as like as in the contact zone of larger tributary vallels – Krka, Sutla and Krapina river valleys. Valley sides are jell developed only along the zone of Žumberak mountain. In other segments it is difficult to define a precise boundary of the area subdued to Sava river waters morphological activity.

Many authors investigated the region being explored, but only partially, as a part of superregional, broader area. There are studies and elaborates of very different charactr and an exploration intention.

Some geological and hydrogeological investigations habe been carried out by P. Miletic (1969), E. Prelogović (1970), D. Cijenović, E. Prelogović and D. Skoko (1976), E. Prelogović and D. cijanović (1976), and E. Prelogović, D. Cvijanović and D. Skoko (1978). Hydrological investigations carried out by the Sava Direction – Zagreb (1975) have no less importance.

There exist some geomorphological as like as physic-geographical characterized by various ways of approach to the problem. In this sence, one could put an attention to several differently aspected worke about the problematics of the explored region, such as S. Lipoglavšek - Rakovac (1951), S. Ilešič (1953). V. Kokole (1953), D. Dukić (1957), A. Melik (1959), J. Roglić (1963), J. Riđanović (1968), A. Bognar (1978) and S. Šterc (1979).

Geomorphological position. The river Sava valley between Krško and Podsused in macromorphological point of view enters the broader perialpine area of Yugoslavia. The Krško - Dobova subsector in its entirety belongs to micromorphological unit of krško basin, and the stream river valley segment Čatež–Podsused is a part of micromorphological entity of Samobor basin. The Save piercing sector between Podgračeno and Bregana at SW, and Harmica–Laduč sector at Ne, participates to a micromorphological unit of Marija Gorica hills at one, and submorphological tirety of Žumberak mountain at the other hand.

To N and NE the Sava valley is, in geomorphological sense, bounded by the Orlica glacisterrace and SW spurs of Marija Gorica hills as like as SW slopes of Medvednica mountain. However, it is not clearly expressed a contact zone of Sava valley and that of Sutla one, e.g. to its alluvial fan in the sector Dobova–Harmica, auch as the Sava valley contact to Krapina river valley in sector Zaprešić–Jarek.

The Sava valley boundary at SW (in Slovenia) is jell defined by the secarpments of Krško hribovje region and Žumberak mountain slopes in sector Čatež–Bregana. However, the Sava vallel contact, including its fluvial fan in SW part of Krško basin is not well defined. Conventionally in morphological sense, it would be the rim of younger pleistocene terrace along the line Drnovo – Mrtvice – Vihre – Skopice – Krška Ves, although the question of terrace body and Save deposits extension, remains open.

The Sava valley boundarl at SW, in Samobor basin, SE of Bregana to Sv. Nedelja and Rakitje is generally defined by the steep, tectonically predisposed slopes of Samoborsko gorje and their transition to glacis-terrace and river Sava terrace. Between Hrastina and Sv. Nedelja is pro-

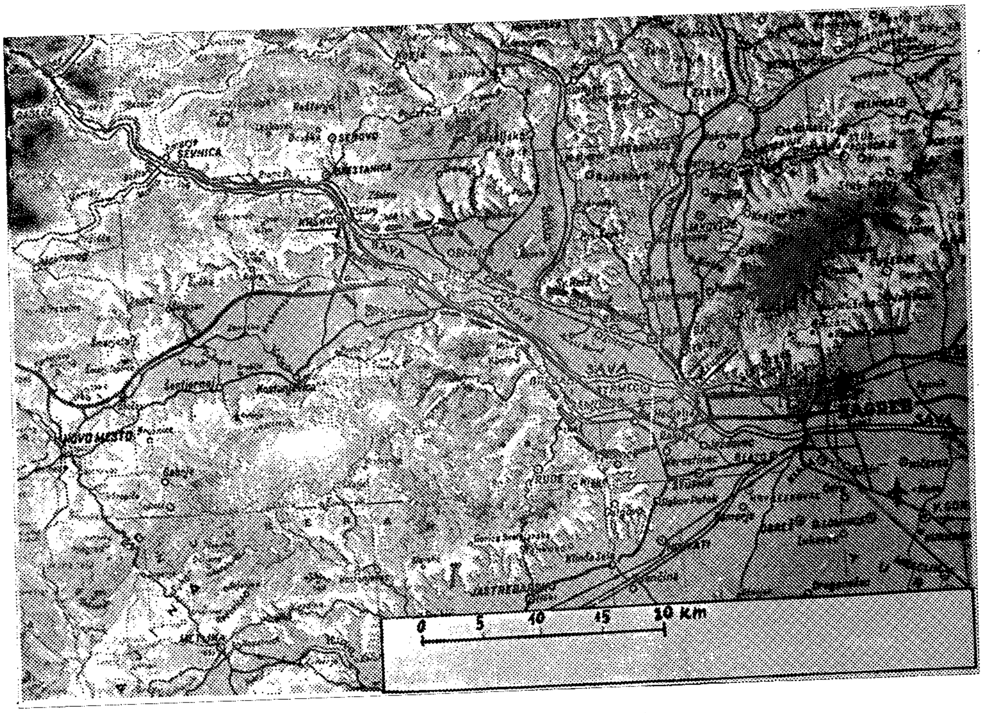


Fig. 1. Orientation map of the river Sava valley between Krško and Podsused

bably formed a younger subsided zone of the eam sector of Rakovica stream, close to NW Kozjak slopes. Tis part of Samobor basin is, consequently, a fan of the same stream, beneath jhat, eventually exist sunk Sava deposits. For this reason, just described part of the boundary remains undefined, and further investigations habe to determ it more precisely.

SE frontier of the area being explored is welledetermed by the tectonically predisposed rim of Rakitje terrace as like as about 1–15, km wide flood plain in the Sava strait at Podsused.

It is possible to make a conclusion that the explored Sava valley sector is not a valley in a strict sense. From morphological point of view, there are two accumulational plains as parts of Krško and Samobor intermountainous basins. An exception represents an aforesaid, tectonically predisposed Sava strait. It has directly influenced the morphological modelation and formation of the strait relief type.

Special tectonic structure, defined by the subside movements inside Samobor and Krško basins, mostly reflected in accumulation activity, clearll differentiate the Save vallel area from neighbouring, dominantll danudation-tectonical (Medvednica, Žumberak) and denudation-acumulational (Marija Gorica hills, Orlica glacis-terrace) relief.

Basic characteristice and stages of geomorpnological evolution. The reconstruction of geomorphological evolution is relatively aggravated for the period before younger Pleistocene, since there are nor sufficient number of indicator that would confirm it. However, it is neccesseary to make a brief retrospection of cartain more important events in an earlier stage of geological past, as a preraquisite of better understanding the contemporary structure and relief features.

Preneogean period. In this long lasting period, the movements of the old Pannonian mass rims, consolidated during the time of Hercyne orogenesis, as like as dominant varistic structure characterized by ction, have got a special geomorphological importance.

During the Palaeozoic era, some cristaline parts of the Samoborska gora – Medvednica –Kalnik zone have been probably raised, since there are indicators of terrestric sedimentation. In the middle and upper Permian rock structure doinate artz and breccia conglomerates, shales and siltites (Šikić, K. and oth., 1979). By the beginning of Triassic period there exist geosyncline conditions again accompanied bl the restitution of neritic, clastic carbonates sedimentation relations. Great thickness of dolomitelimestone complex represente an indicator of slow sinking processes in the basin, as like as a continous sedimentation during the sozoic era. However, the evidented sedimentation hyatus betjeen Triassic and Cretaceous deposits indicates a variablitity of performed sinking velocity, as like as some block structures habe been existed as individual intrabasin uphll structures. During the transition time from Cretaceous to Paleogene period, there habe been performed some significant changes. By reanimation of tectonic movements in deep fault zone along the Palaezoic hercynian cristaline structure rim, habe been formed a volcanic-sediment ock complex of NE–SW orientation (Samoborsko gorje, Medvednica, Klanik). The collected gossiles are characterized by an apt-turonan age (Šikić, K. and oth., 1979). During the time of Laramian movements the whole region has been significantly elevated. Paleogean sediments are absent and therefore it would be possible to conclude that Miocene period represents the end of the long emersion period.

Neogene–Older Pleistocene. During Miocene perioα, there has began the new sinking and, tly, transgresion phase. Sa a unce, Zagorje and Saca Tertiary marine basins have been formed, and at maximum of transpresion, by the sinking of Sv. Nedelja–Podsused barrier, were mutually connected. In this way, there have been destroyed all of previous structural and morphologic relations existing in pretertiary times. The sedimentation is sharacterized by marine and lacustrian deposits, lithologicaly represented clays, marls, snds, sandstones and Lythotamnium limestones (Šikić, K. and oth., 1979). ntegration of Parathetys have caused the reducing of sedimentation area, as like as the formation of separated basins accompanied by ever present water saltness diminishing. In the grater part of Zagorje n egan an emersion phase, although there are some indicators of Plio-pleistoene relict lake in the area N of Brežice. During the conditions of lacustiran sedimentation there have been sedimented clays, reddish sandl clays, sands and gravels, characterized by great vetical deposition developement (lithological profiles of deep bore holes exceeed 200 m). These factes point out that in sedimentation phase, the area has been predominantly subjected to intensive subsident processes. In the same time, at the end of Pliocene, as like as, eventually, in transitional period to Pleistocene, by the sion of Žumberak, Orlica and Medvednica blocks postdacian movements, as an introduction to the final phase of regional structure formation and morphological modelation, there existed well-defined intensive denudation of terrigenic clastic material. In lower parts of the area, there have been carried out sedimentation processes of thick proluvial deposits. The movements habe been performed along the younger faults, characterized by NW–SE rientation (so called Dinaric direction), as like as along remobilized inherited varistic faults of NE–SW direction, but locally, there have been an influence of Alpine tectonics (Žumberak mountain). Volcanic-sediment zone (NE–SW rection) is marked by lose of importance as an individual tectonic unit, and mostll enters in just formed east–Žumberak and Medvednica structure.

Younger Pleistocene – Holocene. The period is marked by fundamental relief developement importance. It represents a beginning of the tectonic movements reanimation along the old, dinaricly oriented faults, such as the important climate changes. At that time, the mountain blocke were subjected to another phase of scension (in neotectonic period, about 800 m, in Quarternary about 250 m: Prelogović, E., 1975). There habe been noted an intensive simultaneous structural blocks descension, and pratial fracuture of Neogene and older Pleistocene structures, oriented NE–SW, along the more important rim faults. The elevation between Podsused and Sv. Nedelja (as like as in Brežice neighbouring zone) have beeen destroyed, too. The result of this processes was a formation of Sava graben.

There are various opinios about river Sava jaters penetration into the area being explored, but the most of the authors confirm the hypothesis that this penetration, in just formed lands area has been occured in young Pleistocene times.

The existence ot three Sava fluvial terrace levels is an additional proof of aforesaid assertion.

Morphological postıton of the terraces, as like up to date direction of Sava flow, confirm the presumption of norther Sava bed postion during middle Pleistocene. The incistion of Sava ters, accompanied by migration of its river bed to S, has been probably predisposed dominantly by tectonic movements, e.g. by ding inside the main trench zone. However, it is possible to presume that phases of more intensive incision habe been caused by the combination of tectonic and climate facotrs. Supposition of their young Pleistocene (Würm), or older Holocene origin is deri-

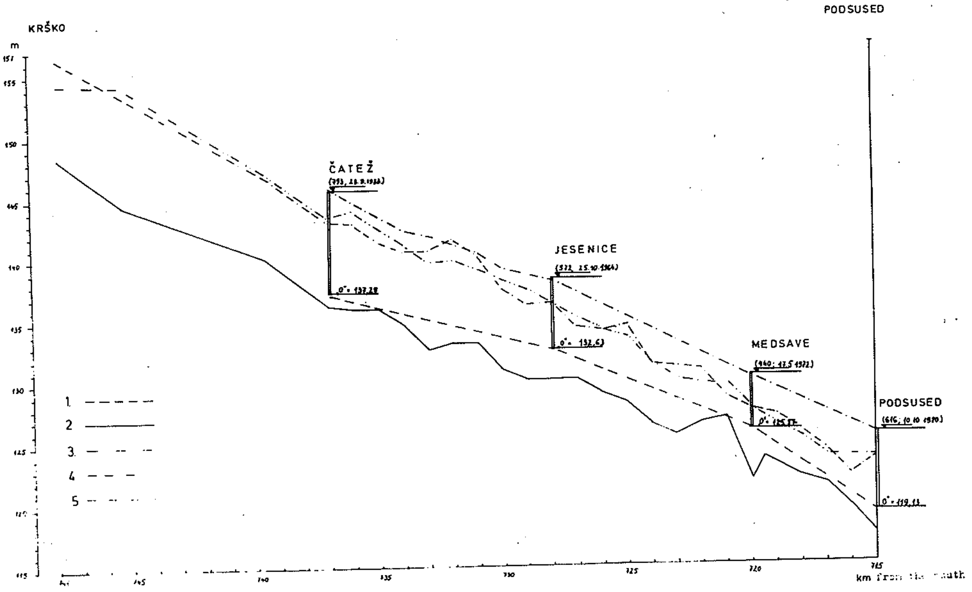


Fig. 2. Characteristic longitudinal profiles Legend: 1. longitudinal profile, 2. talweg, 3. left bank, 4. ringht bank, 5. very high water level.

ved from the fact of determed würian age of Brežice terrace sediments (Šercelj, A., 1970., accor-ding to Šikić, K. and otdh., 1979), such as by application of height correlation and river terrace superposition principle.

The incision of river Sava Würm terrace could be connected with intensive tectonic movements in the region during the younger Würm period (Bognar, A., and oth., 1976).

Foundation of loess-like sediments in surface parties of terrace deposits, rrepresents a proff of just mentioned statement. Inkeeping with periglacial features of the region, there has been performed an accumulation of siltl material within favourable places of lat river terrace zone. Sn increased humidity of the explored area is reflected in the increased share of clay fraction and. tly, there have been developed various types of loess-like sediments Deforestation circumstances during period of Pleistocene has favoured derasional processes that played an importantrole in morphological modelation of the area.

The Holocene developement is marked by the modelation of the youngest fluvial relief forms, as river bed and flood plain, derasional forms over the terrace area, such as that on valley sides. In historical times there exists an important influence of anthropogenicactivity.

According to the Sava terrace height relations, their »O« gauge-points, as like height variations and sedimentary clcle thicknese characterized by different age, proved by realized bore holes and respect of the actualism principle, it is possible to estimate a value of recent vertical tectonic dislocations between 16 and 20 m.

Relief structure. Relief structure of the area is defined by the basic elements of river valley: river bed and fluvial lowland that includes flood plain and terrace plain area. There have been observed these elements according to the aspect of predominant morphological processes and relief evolution.

Sava river bed in the explored sector of the valley is defined by NWSE direction. Total lenght value between the Krško bridge to the bridge at Podsused amounts 34 km.

The width of permanent river bed varies in general about 100 m. although one could remark the river bed width variation in sector Krško -Čatež (where the width is smaller) at one hand, in relation to Čatež–Podsused sector (where it is wieder) on the other hand. It is a consequence of recently accomplished hydroregulation activities thorughout the Krško–Čatež river valley sector, as like as predominant natural types of morphological processes in downstreams segments.

There are measured various values of river bed depth in separate parts of the river flow. Sava river bed depth shows mximal values within local valley narrows, and at Čatež it reaches 4 m. Downstream values show a gradual decrease, so that their average varies about 3 m. There is a characteristic feature of abruptly increased river bed depth from 3 do 5 m at Medsave, while in downstream sector toward the river Krapina confluence and strait of Podsused the depth decreases again to value of 3 m.

Tab. 1. ABSOLUTE AND RELATIVE FALLS OF THE LONGITUDINAL PROFILE ACCORDING TO »O« GAUGE-POINT

Water-Gauge	»O« Gauge-Point	Distance (km)	Absolute fall (m)	Relative fall (⁰/₀₀)
Krško*)[1]	–	–	–	–
Čatež	137,28	11,5	–	0,87*)[1]
Jesenice	132,63	9	4,65	0,51
Medsave	125,87	7,5	6,76	0,90
River Krapina confluence*)[2]	120,84*)[2]	4,4	5,03	1,14
Podsused	119,13	1,4	1,71	1,22

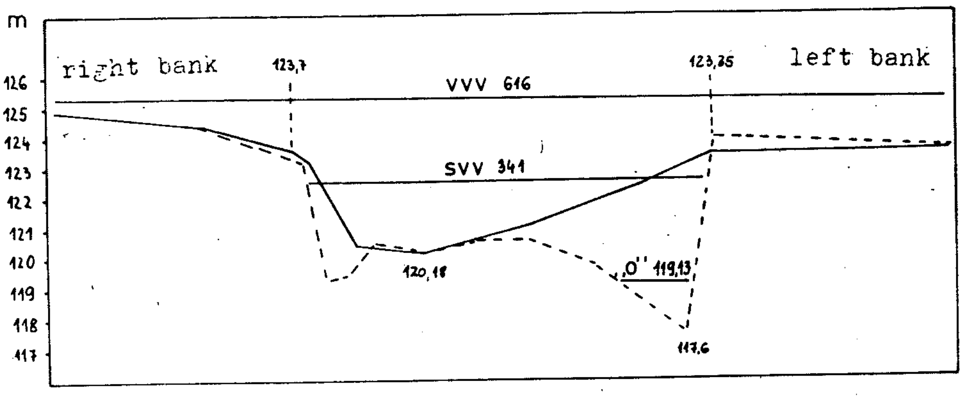
Tab. 2. THE RIVER BED DEVELOPEMENT COEFFICIENTS

Sector	L (km)	L min (km)	K
Krško – Čatež	11,5	11,1	1,03
Čatež – River Krapina confluence	21,6	19,5	1,10
River Krapina confluence – Podsused	1,5	1,5	1,00
Total Krško – Podsused	34,6	32,1	1,07

River bed talweg (Fig. 2.) ponts out two weil marked vertical bed joints: near Medsave and at Podsused. Upstreamly of the Medsave joint occurs an increased accumulation intensity. As consequence of the river waters retention and generaly decreased velocity of fluvial transport activity. There consequently exist numerous accumulation forms within the river bed: banks, accumulative and erosive river isles. At Podsused there is no accumulative and erosive river isles. At Podsused there is no accumulation, but dominate incicion processes and linear flow direction sa morpholoical consequence of these circumetances. The river bed developement coefficient value varies here about the minumal (theoretically) amount of 1,00 (Tab. 2.). The relative values of longitudinal river profile falls confirm the aid oppinion (Tab 1.). There are significant rivr bed developement coeficient variations between individual parts of the longitudinal profile, that is a mark of the real river valley profile unconformity.

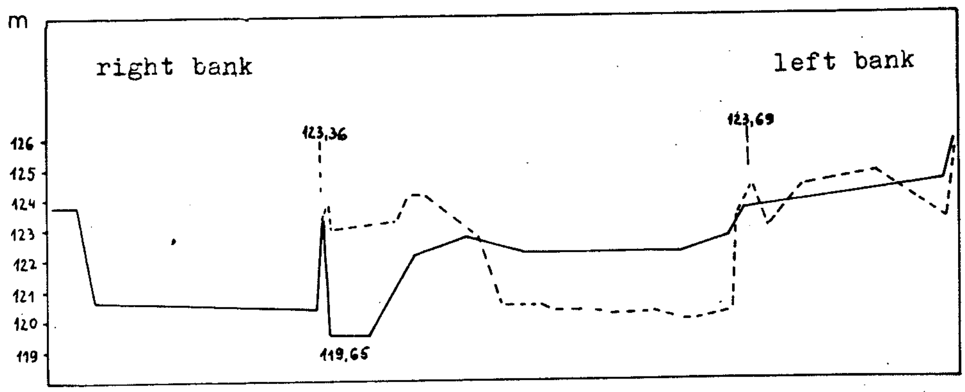
1 According to Ilešič, S., 1953.
2 Derived from the height value of »O« gauge-point »Podsused« and r level heights of both profiles.

---- 1971.



—— 1963

Fig. 3. Transversal river bed prifile at Podsused



—— 1963.

Fig. 4. Transversal river bed profile at river Krapina confluence

The greatest longitudinal valley profile tall is evidented betjeen river Krapina confluence and Podsused (1,22 %) and it is characterized by an outstanding erosive activity of the Sava flow within upstream waters mechanism. These facts indicate s NW–SE oriented fault activity, e.g. probable uplifting of its NE wing. Increased erosion values within this river bed segment obviously compensate the uplifting am ounts because of their mutual intensity equilibrium. The existence of fault is a cause of river Sava bed incision close to Sjevernjak slope marigns.

A comparative analysis of the transversal river bd profiles near Podsused on one hand, and at river Krapina confluence on the other (Fig. 3., 4.) during the period 1963–1971 points out another river bed form developement. It undenisbly shows in the meantime performed river bed migration to NE, still closer to Sjevernjak slopes.

A significant longitudinal profile fall that varies about 0,87% along the Krško–Čatež sector is a result of performed regulation ies with an intension to shorten a river bed lenght and incresse of the profile fall. That statement s confirmed by thenumerous traces of well developed, although mostly buried meanders and abandoned loops.

On this gorund one can get a conclusion about different features of the water mechanism in the time before performed regulation actions, e.g. the longitudinal river profile was gentler and and stream developement coefficient greater ghen today.

Further follows a sector of significantly gentler longitudinal profile fall (0,5%) between Čatež and Jesenice. As reflection there st a typical middle stream waters mechanism characterized bl predominant meander forms, such as gradual accumulation coponent increase and accurence of coresponding relief forms of river bed, banks and isles (specially downstrem of Čateške toplice).

Anincrease of longitudinal river profile fall between Jesenice and Medsave to 0,9%, as like as in sector Medsave-river krapina confluence, where it amounts about 1,40%, in spite of predominant accumulation processes within the downstream jaters mechanism, could be explained by local, probably negative tectonic movements. As a proof there is an aforeseld well marked joint at Medsave, that points out the existence of NE–SW oriented fault as a zone of redent crust movements.

Significant influence on morphological modelation of the river bed show drawing river deposits, as a result of fluvioraption and corasion, such as suspended material that get a little influence on river bed depth increase, but plals a significant role within burying and, generally, accumulation prosesses.[3]

Tab. 3. DRAWING AND SUSPENDED MATERIAL TRANSPORT AT THE »PODSUSED« PROFILE, 1981.

1 9 8 1.	G (t)	P (t)
I	303	27 300
II	201	42 000
III	3936	161 800
IV	232	16 100
V	1682	80 500
VI	2028	99 400
VII	114	25 700
VIII	28	20 900
IX	860	196 000
X	1800	71 300
XI	97	9 600
XII	1754	102 200
YEAR	13035	852 800

G – Drawing material
P – Suspended material

3 Mineralogical Sava deposit content (analysis of »Podsused« sample have been performed by B. Šćavničar and M. Mimica, IGI, Zagreb, 1982.) shows a dominance of carbonate grains, as like as predominance of epydote, clorite and pyroxene among the heavy mineral content. The origin area of that deposits is limited by the Alps and Posavje fold region, as an area of intensive erosional activity.

It is obvious that the predominant influence to total fluvial transport of drawing material express shortlived graeat water waves. According to performed estimations, during the high-water period (3–4 days/year) usually flow by nearly 95% of total annual water bilance (Sava River Direction, Zagreb, 1975.). By the water level height increase, e.g. by discharge values, rpoportionally increase the average granulometric composition of drawing material. Water level height and quantity of drawing material are, tly, functionalll close related.

The river Sava bed, exluding the short rectlinear segments, mostly ders. The principle of water flow activitl in braided type of river bed is proved bl the Sava river bed transversal profiles. Their convex and concave lateral sides are ferantll orientated, according to the case od right or left hand meander.

The river bed developement coefficient of 1,10 in sector Čatež–river krapina confluence, in relation to ceofficient values fo 1,03 and 1,00 in rs Krško–Čatež respectively river Krapina confluence–Podsused, pointe out a fact of the most developed meanders over all the area being explored. The parameter values show fferences with regard to developement degree (a), maturity (b), sharpness of meander bends (y), as like as width and meander span relation (M/D).

Tab. 4. AVERAGE VALUES OF THE DERIVED PARAMETERS OF MEANDER DEVELOPING

	α $(\frac{m}{h})$	β $(\frac{H}{h})$	y $(\frac{4500}{R})$	$\frac{M}{D}$
Krško – Čatež	0,18	0,87	5,27	0,50
Čatež – River Krapina confluence	0,21	1,02	7,90	0,73

Downstream of Čatež it is possible to differentiate an older phase of meander developement stage, e.g. their parameters never exceeds the value of 1,57. There are regulation activities of river bed between Krško and Čatež generally responsible of aforesaid morphological relations.

The most developed meanders, characterized by the greatest sharpness, are jointed with existing bigger active faults. That is a proof of recent tectonic influence on meander developement. The fact is mostly related to Susedgrad and Čatež–Brežice area. The highest values of all parameters have meanders of Susedgrad II, Čatež, Mostec I, II and Medsave meander. High meander parameter values at Jesenice and rive Bregana confluence represent a ce of diminished longitudinal profile inclination as a fundamental predisposition of their developement.

It has been mentioned that hydroregulation actions influenced the water mechanism character as like as that of relief forms. The fact of previous completely different features and river developement in the Sava valley sector Krško–Čatež in relation to an abundance of great meanders, abandoned loops, backwater channels and isles impose upon some types of performed hydroregulation activities. The river Sava flow has been shortened still in wear 1775 by meander cut in intention to shorten a navigation time from one day to five hours betjeen Krško and Brežice. The meander at village D. Skopice has been cut in the wear 1874, but th river waters continued to flow along the old bed untill 1903. (Dukić, D., 1957).

In modern times, by river bed strenghtening, it became possible to stabilize the trace of shortened river bed. By this, it has been prevented the bed migration and the formation of backwater channels, but not the innudations that are from time to time of very large extension. According to field informations, in 1955/56 it has been carried out the meander resection between Podgračeno and Jesenice, within regulation activities at Sutla river confluence. It has been already noticed the meander cut between Otok and Medsave in the year 1925 (Dukić, D., 1957). Consequently, most of all here present abandoned loops have an antropogenic origin.

Flood plain, as the youngest relief unit of the Sava fluvial valley (plain), remains under modelation influence of Sava jaters. It is elongated in direction NW–SE, according to the general direction of the area being explored. The flood plain width is not uniform. The largest flood plain sectors are included within Samobor basin, and approximetely am ounts 5,5 km. Downstreamly,

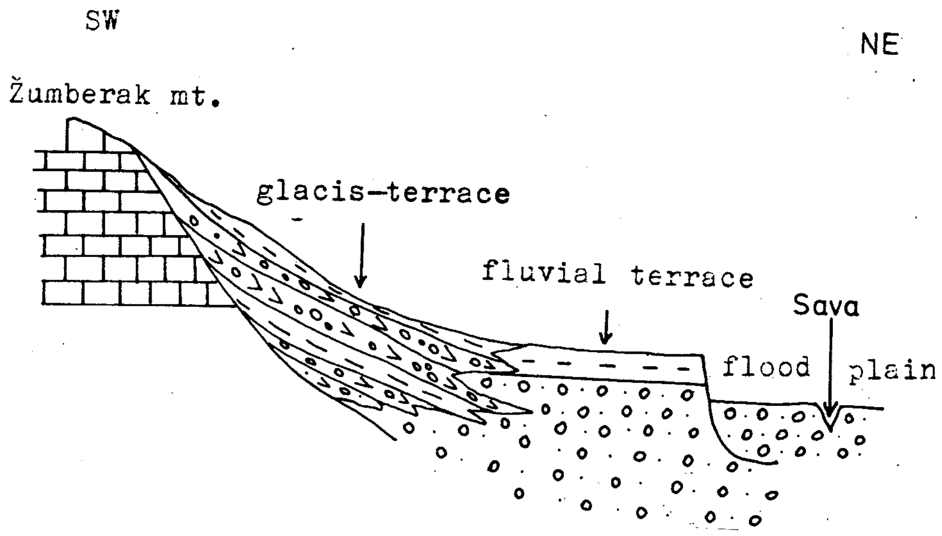


Fig. 5. River Sava fluvial terrace and glacis-terrace realtion near Ribnica – sketch

toward Podsused, the flood plain, speciallI left side plain, becomes gradually narrow, as a result of Sava river bed migration toward Sjevernjak slopes. The right river side, towards terrace area of Rakitje is reducet to 1,5 km. Upstreamly of Bregana, on the left river side, flood plain becomes abrouptly narrow throughout whole segment until Podgračeno, the most narrow flood plain point, and amounts only a few meters. In the same time, left side plain shows no significant straithen tendency until Brežice, where it is influenced by the protruded position of Brežice terrace, and its Jidth varies between 0,5–1,0 km. Within Krško basin the flood plain width amounts 4 km.

The flood plain boundary toward the terrace plain is generally well defined by several terrace steps. There exist well marked flood plain area contact with terrace plain as 14 m high step. Similar features dominate along the flood plain contact towards the other terrace gragments. This contact zone is all over marked bl an arch shape of terrace step, as a reflection of meander activity.

There is a very narrow flood plain zone betjeen Ribnica and Podgračeno, that contacts probabll a combination of Sava fluvial and glacis-terrace (Fig. 5.)

Flood plain is inclined from NW to SE. Absolute altitudes vary between 154 m at NW and 126 m at SE, and average decline of this valley section amounts to 1 m/km^2. Relief dynamics is negligible (less than 5 m/km^2), and represents distinetly flat area.

River Sava flood plain is formed by accumulation-erosive activity of its waters. Its geological structure is marked by dominance of gravels, sands, silt and clay. The most intensive morphological modelation of the unit is relatedwith the relatively short periods of high water level. In accordence to pluvio-nival regime of the Sava waters, There are two precipitation maximums: in spring (march, april) and in autumn (november). River Sava fans show one well marked fluvial rhytm of sedimentation. The floor horizon is made by Banatica marl strata. In regard to granulometric sontent, it can be noticed an increased share of coarse clastics proportionally to increase of the depth (Fig. 6., 7.). The deposits are marked by the crose stratification, a proof of their fluvial origin.

There are some regularities in the surface strata, made by dominantly fine clastic structure. With a distance of recent Sava river bed, it could be noted an increase of share, that is the thickness of fine clastic fluvial deposits, such as silt and fine grained sand (Fig. 8.). In accordance to the mechanism character inundation waters, that are marked by the most intensive transport

Tab. 5. CHARACTERISTIC WATER LEVELS AND AMPLITUDES IN THE PERIOD 1971 – 1981.

JESENICE (»O« GAUGE-POINT: 132,63)

Max. high water level	Date	Min. low water level	Date	Absolute amplitude	Average annual amplitude		
529	30. 1. 1979.	– 112	3. 10. 1980.	641	349		
Very low water level	**Date**	**Very high water level**	**Date**	**Amplitude of extreme water levels**	**Medium low water level**	**Medium water level**	**Medium high water level**
– 112	3. 10. 1980.	572	25. 10. 1984.	684	– 62	30	287

MEDSAVE (»O« GAUGE-POINT: 125,87)

Max high water level	Date	Min. low water level	Date	Absolute amplitude	Average annual amplitude		
440	17. 8. 1981.	– 77	17. 5. 1972.	517	295		
Very low water level	**Date**	**Very high water level**	**Date**	**Amplitude of extreme water levels**	**Medium low water level**	**Medium water level**	**Medium high water level**
– 77	17. 5. 1972.	440	17. 8. 1981.	517	– 22	64	273

PODSUSED (»O« GAUGE-POINT: 119,13)

Max high water level	Date	Min. low water level	Date	Absolute amplitude	Average annual amplitude		
616	10. 10. 1980.	– 49	16. 8. 1981.	665	346		
Very low water level	**Date**	**Very high water level**	**Date**	**Amplitude of extreme water levels**	**Medium low water level**	**Medium water level**	**Medium high water level**
– 49	16. 8. 1981.	616	10. 10. 1980.	665	– 5	91	341

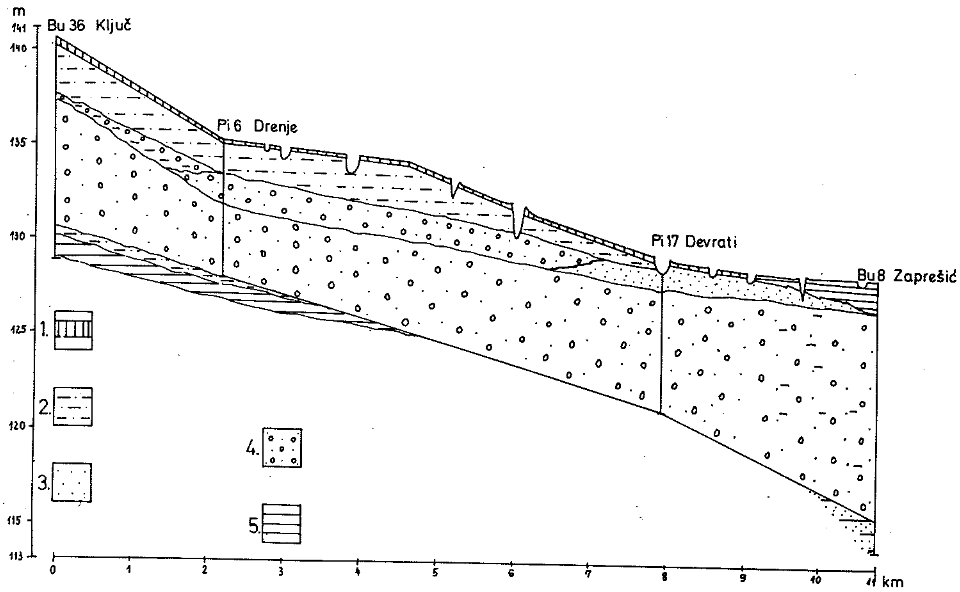


Fig. 6. Longitudinal geomorphological-geological profile through river Sava flood plain between Ključ (Bu 36) and Zaprešić (Bu 8)
Legend: 1. humus, 2. silt, 3. sand, 4. gravel with sand, 5. clay.

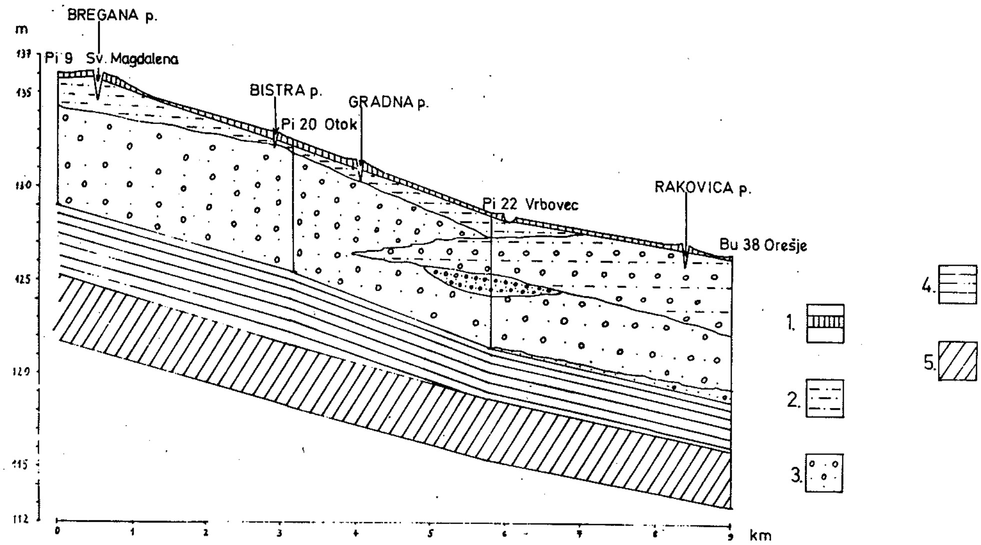


Fig. 7. Longitudinal geomorphological-geological profile thorugh flood plain between Sv. Magdalene (P19) and Orešje (Bu 38)
Legend: 1. humus, 2. silt, 3. gravel with sand, 4. clay, 5. Banatica marl strata.

along the river banks, where the most ot material is accumulated, and specially coarser fragments. As a result the narrow bank zone is elevated about 0,5–1,0 m above the other flood plain areas. By the distance increase of Sava river bed, the strenght of inundation waters becomes jeaker and only the finest, suspended particles can be sedimented in this remote zone.

In spite of well developed fluvial strate complex–with thickness of 7–10 m, there are noticed local variations. Longitudinal geomorphological-geological profile through Sava flood plain between Ključ and Zaprešić (Fig. 6.), especially between Devrati and Zaprešić, shows the constant increase of gravel strata thickness. In the same time, the longitudinal rpofile of the rignt side flood plain zone between Sv. Magdalena and Orešje (Fig. 7.) shows no above mentioned features. Additionally, the transversal profile through Sava valley in sector Šibice – Sv. Helena (Fig. 8.) refelects an obviously expressed flood plain asimetry (left side bank is lower than right side one). As conclusionce area with the focal zone downstresmly of line Medsave – Drenje, and at left side Sava river bank.

Relief structure of flood plain area is defined by the dominant Sava river waters mechanism type. In according to morphological activity of middle stream waters mechanism mostll in the region being explored, as dominating microrelief flood plain types, exist abandoned loops and point bars.

By an increase of accumulation component (for instance, upstreamly of Medsave) there are locally noticed a presence of backwater channels, banks and isles. The downstream water mechanism influence in Sava valley sector Medsave-river Krapina confluence is manifested by river isles and a dense network of backwater channels developement.

Performed regulation actions at Krško – Čatež sector prevent a natural developement of relief forms. Nevertheless, the remnants of numerous ancient abandoned loops and backwater channels, presented today in mature developement phase under the influence of organic burying, point out at formery significant influence od downstream waters mechanism activity. A short sector betjeen river Krapina confluence and Podsused is subwected to the upstream waters mechanism influence.

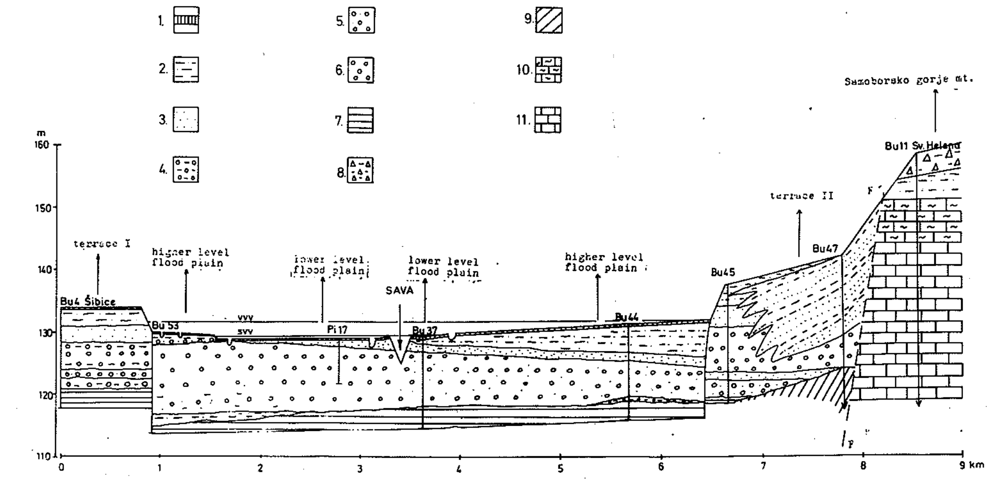


Fig. 8. Transversal geomorphological-geological profile through river Sava valley between Šibice (Bu 4) and Sv. Helena (Bu11)
Legend: 1. humus, 2. silt, 3. sand, 4. gravel, 7. clay, 8. clay with rock fragments, 9. marl, 10. marly limestone, 11. limestone.

Within the flood plain area one could differ two altitude levels – higher and lower flood plain level. An average lower level altitude above the »O« point varies between 1–3 m and, consequently, seasonal waters of middle and middle high water level inundate the area. Higher level flood plain altitude would be inundated only during very high Sava water levels, since it overtops a »O« point for 3–5 m. It generally shares a most of flood plain area. Point bars and the highest river isles sections represent a morphological form makr of the higher flood plain level. There are linear hollows as abandoned loops, backwater cjammečs. draomage furrows, as like as lowel level flood plain parts included in it.

By differentiating the Sava flood plain levels, it is noteworthy to mark a presence of a fluvio-erosional step, developed in sector Dobova–Javorje. This step within higher flood plain level define a sport of 0,5–1, Om higher area which, in spite of its altitude, during very high water levels remains inundated.

The flood plain sector Dobova–Ključ is present in a combination with Sutla river fan. The fan that expands between Rigonce and contemporary Sava river bed, is probably very young, since thickness of its deposits does not surpass a value of 3 m. In the horizons under these silt material there is Sava accumulation complex, marked by predominance of sands and gravels.

These factors assembled together point out a probability of tectonically predisposed Sava river bed Holocene migration to the south. During the perod 1955156 there have been performed significant regulation actions, primarily orientated to Sutla river bed shortening by means of meander cut, as like as Sava meander resection in sector Podgračeno–Jesenice. As a result, there are many dry beds of former Sutla meanders today, that are covered by shrubby (willow, elder–tree) and grass vegetation types. Former Sutla meanders get very sharp bends, and their resection have been obviously performed during IV–V phase of their developement. The abandoned loops of Krško basin flood plain show generally a mature burying stage as a result of an early meander cut, such as Sava river bed strenghtening. In the downstream sectors abandoned loops are younger, periodically or permanently holding water.

Therrace plain. There is a zone of former Sava flood plain, present in several levels above recent Sava flood plain. They overtop »O« point for a various altitude values, but today are not subdued to inundate water influence. The word is here about a dry Sava fluvial terrace area as morphogeneticalll integral part of river Sava valley. Dominant morphological processes that have contemporary influence in this region are marked by mainly derasional activity component, as like as by strong anthropogenic actions.

All the noticed terraces are characterized by fluvial fan type (gravel accumulation) and their formation is bounded with the stream incision into proper deposition. They are not found continuosly, but only in fragments. There are three determed terrace levels (Tab. 6) and at absoulute altitude in average of 133 m, 150 m, and 175 m. Relative altitudes correlation within »normal« morphogenetic circumstances, would point out three terraces of various age. But, in addition to the tectonic relations complexity in the time and space, it is unpossible in our case to determ the terrace age without performing correspondent pollen or C^{14} analysis of terrace fragments samples.

The lowest fragment of drained morphological step of an altitude od 132–134 m is founded only at Zaprešić. Its relative altitude amounts about 7 m above the »O« point of Medsave watergauge.

Tab. 6. ABSOLUTE AND RELATIVE ALTITUDES OF THE TERRACE FRAGMENTS

Terrace	Average absolute altitude		»O« Gauge-Point		Average relative altitude	
Drnovo – Krška Vas II	(157–153)	155	Čatež	137,28	(15,7–19,7)	17,7
Krško – Gaberje II	(160–155)	157,5	Čatež	137,28	(22,7–17,7)	20,2
Sp. Pohanca – Artiče III	(180–170)	175	Čatež	137,28	(42,7–32,7)	37,7
Ribnica – Samobor II						
a) Ribnica – Klokočevac	(153–150)	151,5	Jesenice	132,84	(20,1–17,1)	18,6
b) Klokočevac – Samobor	(150–145)	147,5	Medsave	125,87	(24,1–19,1)	21,6
Zaprešić I	(134–132)	133	Medsave	125,87	(8,1 – 6,1)	7,1
Lužnica II	(141–139)	140	Medsave	125,87	(15,1–13,1)	14,1
Rakitje terrace II	(144–142)	143	Podsused	119,13	(22,87–24,87)	23,87

By a gentle inclined step it is devided from the higher flood plain level that overtops for about 3 m. The boundary toward the first higher terrace at Lužnica ia clearly defined by the 6–7 m high terrace step. In surface structure of the terrace participate loess-like sediments and fine grained sands. Gravels are present at depth of 5,40 m and locally show an increased share of caly component, together with sand intercalations. Tectonics played probably the pedominant influence in formation of this stadial terrace. It would be possible to conclude that an increased subsident movements all over the sunk area S and E of Zaprešić have influenced an intensification of erosional processes, that is, the river Sava incision, well expressed immidiatelly upstreamly of the subsidence area. In the same time there has been performed mainly fine grained suspended material, that proves a survacely present loesslike sediment thickness of 3 m.

Next higher morphological step is the largest terrace unit It is found, although only fragmentary, along a whole river Sava sector being explored, at both river sides. Absolute altitude varies from 160 m at Brežice to 142 m near Rakitje. Relative height values above »O« point lies between 17,7 and 22,7 m.

Terrace contact toward flood plain area is generally well defined by 6–8 m high step. Contact of terrace fragment Lužnica to lower (younger) Zaprešić terrace accompanied by Jell marked 6–7 m high step. An exception is Brežice terrace with step height of 14 m. Similar values shows tectonically predisposed relief step of Rakitje terrace body in the sector betjeen Rakitje and Sv. Nedelja. Both terraces are aharacterized by significant tectonic dislocations.

Rakitje terrace[4] represents a fragment of formerly complete terrace that has been subsequently sunk. This fact is proved by its sherply marked shape orientated along direction NW–SE, the same as that of Kozjak – NW Medvednica step. The lowest part of Sava flood plain area is immediately NW of the terrace, that is, close to Kozjak slopes, and it is an additional proof of here present active subsident processes. Its contemporary inundation possibility indirectly points out to relatively younger subsidence activity of this part of Samobor basin.

The highest point of Brežice terrace, related close to river Sava, ammounts 160 m, that is, 22,7 m above »O« point of Čatež water-gauge, while, by increasing distance of the river bed, their absolute altitudes vary between 155 and 158 m (17,7 – 20,7 m of relative height) in sector Brežice–Artiče, until to next morphological step of higher terrace. Consequently, transversal terrace profile is opposite to »normal« (conform) one, an indication of the terrace inclination toward a river bed (Fig. 9.). It obviuusly deals with tectonic dislocations, that is, subsident movements in the middle of the terrace body

The terrace is predominantly archly shaped, specially at Drnovo, Mrtvice and Vihre, as like as all over right river side area in the Krško basin. There is an abandoned loop completely buried and covered by vegetation along the terrace rim at Drnovo. As in Roman times existed there a river Sava port of Neviodunum, it is evidently that 2000 years ago, river Sava flew along this place, forming great meander bends.

The terrace fragment Drnovo–Krška Vas towards Sava plain is characterized by a well developed terrace step, while at south, it is gently inclined in sense of conicaly shaped slope surface. Morphologically it is probably a complex fluvial fan made by accumulation of Sava nad Krka rivers.

Mineralogical analysis results[5] of sand and gravel samples from Mrtvice–Brege location, such as cross stratification point qut the Sava origin of the terrace.

Sand structure in relation to Sava bed deposti, characterized by well expressed domination of carbonate grains within total mineralogical compostion, as like as granates and dolomites with relative considerable share of epydotes, proves that accumulation has been performed by Sava river activity. The pebble types confirm aforesaid fact in regard to their petrological structure, which correspond to upstream regions composition.

Terrace fragment Ribnica–Samobor is characterized by an elongated, mainly continuously morphologically well developed slope debris cover, accumulated at the contact to Žumberak mountain and Samoborsko gorje. The absence of river Sava terrace and just mentioned glacisterrace between Ribnica and Čatež could be explained by no »normal« terminus, since it was cut by the river Sava activity

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4 Roglić J. (1963) was the first who used the term »Rakitje terrace« to denote a terrace area of Sv. Nedelja and Rakitje.

5 The analysis is performed by B. Šćavničar and M. Mimica, IGI, Zagreb, 1982.

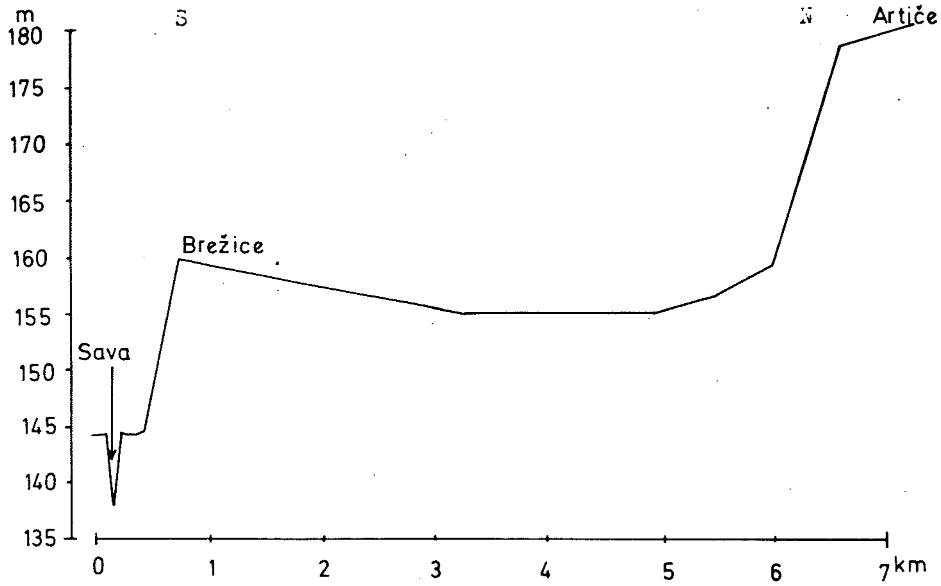

Fig. 9. Sketch of transversal profile of Brežice terrace

Derasional complex thickness above terrace fans locally varies. An opened profile between Klokočevac and Bregana shows the gravel of Sava origin at the depth of 2,35 m. At surface, there is proluvial material accumulated over the terrace body. Bore hole Bu–47 also shows a part of Sava sediments locally destroyed by slope processes activity, so that, fluvial deposits get a reduced thickness.

Some of village wells (at Trebež) point out a loess-like sediment above Sava deposits thick about few meters. This fact confirms a Würmian age of Brežice terrace (as like as probably terrace fragments Ribnica–Samobor and Lužniža, according to application of altitude corelation principle). Polena analysis of terrace sediments, carried out by A. Šercelj (1970., according to Šikić, K. and otdh., 1979.), confirm its Würmian age, too.

The highes morphological step has a fragmentary extension, but only at left Sava river side between Sp. Pohanca and Artiče. The terrace is disected by deep derasional valleys and represents a mature transformation and destruction phase.

It is separated from the Brežice terrace by well marked relief step (up to 20 m). Relative height above »O« point of water gauge Čatež in average am ounts about 38 m. These significant height differences are probably a consequence of tectonic movements. Gravel deposit thickness of about 65 m (according to GV 14) points out performed subside movements just in the time of fluvial material accumulation.

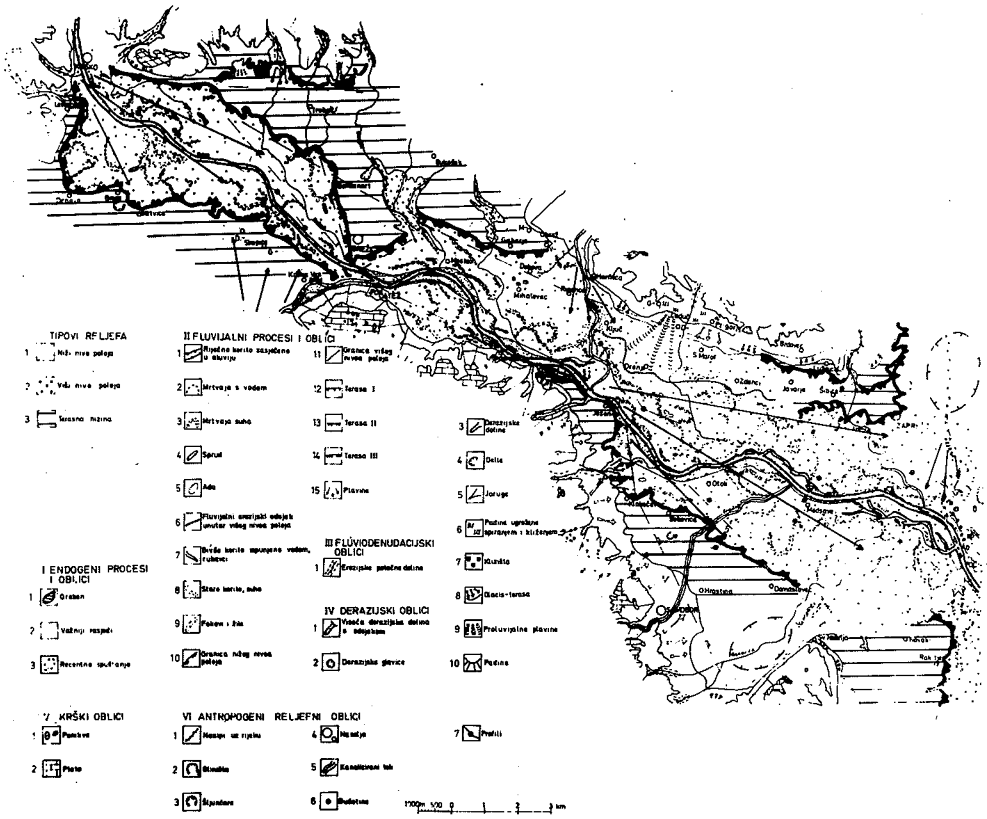

Fig. 10. Geomorphological map of the river Sava valley between Krško and Podsused
Legend: Types of relief: 1. lower level flood plain, 2. higher level flood plain, 3. terrace plain.
I Endogenous processes and forms: 1. ridge, 2. importent faults, 3. recent subsidence.
II Fluvial processes and forms: 1. river bed incised in alluvium, 2. abandoned loop, holding water, 3. abandoned loop, dry, 4. sandbar, 5. river isle, 6. fluvioerosional step within higher level flood plain, 7. former river bed, holding water, backwater channel, 8. former river bed, dry, 9. drainage furrows, 10. boundary of lower level flood plain, 11. boundary of higher level flod plain, 12. terrace I, 13. terrace II, 14. terrace III, 15. fans.
III Fluvio-danudational forms: 1. erosional brook valleys.
IV Derasional forms: 1. hanging derasional valley with step, 2. derasional cone summit, 3. derasional valley, 4. delle, 5. deep derasional valley, 6. slopes threatened by slopewashing and landsliding, 7. landslides, 8. glacis-terrace, 9. proluvial fans, 10. slopes.
V Karst forms: 1. swallow-hole, 2. plateau.
VI Man-induced relief forms: 1. river embankment, 2. clay-hole, 3. gravel-hole, 4. settlements, 5. canalized stream, 6. bore-holes, 7. profiles.

SAŽETAK

GEOMORFOLOŠKE OSOBINE DOLINE SAVE OD KRŠKOG DO PODSUSEDA

Borna Nikolić

U reljefnoj strukturi doline rijeke Save između Krškog i Podsuseda ističu se osnovni morfološki elementi: savsko korito i fluvijalna nizina, unutar koje se izdvajaju morfogenetske cjeline poloja – niži i viši nivo, te terasna nizina rijeke Save. U morfostrukturnom smislu, dolina Save, ili točnije, nizina Save u Krškoj i Samoborskoj zavali, ulazi u širu kategoriju akumulacijsko-tektonskog reljefa, odnosno međugorske potolinske zone.

Današnja slika reljefa istraživanog dijela dolina Save, rezultat je mladih procesa vezanih za tektonske pokrete i egzogeno modeliranje tijekom mlađeg pleistocena i holocena.

U morfogenetskom smislu razlikujemo recentne procese i oblike fluvijalne erozije i akumulacije u okviru savskog korita i poloja, te reliktne oblike, nastale istim procesima u geološkoj prošlosti, predstavljene riječnim terasama. One se danas nalaze pod utjecajem derazijskih i erozijskih morfoloških procesa, te su u različitoj fazi preoblikovanja i uništavanja.