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# THE TECTONIC INTERPRETATION OF LONGITUDINAL PROFILES OF THE CARPATHIAN RIVERS

(5 Figs.)

## *Tektoniczna interpretacja profilów podłużnych rzek karpackich*

*(5 fig.)*

A b s t r a c t. Longitudinal profiles of 14 Carpathian rivers were analysed and compared with their theoretical analogues. It was found that there is a distinct relationship between the shape of theoretical profile of the river and the deep structure of the Carpathian substratum, the location of the main dislocation zones and the areas subjecting to young tectonic movements.

## INTRODUCTION

The studies of stream long-profiles are very common in many geological, geomorphological and hydrological works. The term „equilibrium profile" was widely explained by Sternberg (1875), Baulig (1925), Mackin (1948), Holmes (1952), Hack (1957) and others.

According to Baulig (1925) the topographical stream long-profile reaches that of equilibrium when the river flows across a continuos alluvial cover, without dissecting or aggrading it. Makkaveev (1955) states that the „normal" stream long-profile could be considered as a profile formed during the most probable compensation of exogenic movements by channel processes. Scheidegger (1961) pointed out that in the case of dynamic equilibrium of flow the rate of erosion equals the rate of accumulation. According to Leopold and Langbein (1962), the „equilibrium profile" of the graded river is the profile of maximum probability and the one in which entropy is equally distributed, constituting a kind of the isotropic curve.

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Table 1

Selected formulae using to express longitudinal river's profile
Wybrane wzory stosowane w obliczaniu profilu podłużnego rzeki

| formula | explanations | author |
|---|---|---|
| $y = a - k\log/p - x/$ | y - elevation of the given point of profile above base level<br>a, k - constant, p - total length<br>x - distance from the mouth | J.F.N. Green /1934/ |
| $S = S_o\exp/-aL/$ | S - river gradient, L - distance from sources, $S_o$ - river gradient at the mouth, a - constant | S. Shulits /1941/ |
| $Y = A_o\exp/-k_1k_2t/$ | Y - elevation of the given point of profile above base level<br>$A_o, k_1, k_2$ - constant, t - time | A.N. Strahler /1952/ |
| $x = L/p/^H$<br>$H = \frac{\log x - \log L}{\log p}$ | x - distance from sources<br>L - total length, H - elevation of the given point of profile above base level, p = L/L+1 | J.T. Hack /1957/ |
| $\frac{\partial h}{\partial t} = \frac{1\partial^2 h}{c\partial L^2}$ | h - elevation of the given point of profile above base level<br>t - time, L - total length<br>c - constant | W.E.H. Culling /1960/ |
| $H = H_o/p/^x$ | H - elevation of the given point of profile above base level<br>$H_o$ - elevation of the initial point<br>x - distance from sources<br>$p = H_o/1+H_o$ | L.B. Leopold<br>W.B. Langbein /1962/ |
| $y = C - k\log/x+a/ + b/x+a/$ | y - elevation of the given point of profile above base level<br>x - distance from sources<br>c,k,a,b - constant | O.T. Jones /1970/ |
| $H = C - k\ln L$ | H - elevation of the given point of profile above base level<br>L - distance from sources<br>c,k - constant | J.T. Hack /1973/ |

The mathematical model of the „equilibrium profile" was many times improved (see Table 1). It was based on the channel equilibrium theory and the general diffusion equation (Green 1934, Strahler 1952, Culling 1960, Scheidegger 1961, Jones 1970, Hack 1973). There were also numerous attempts to simulate stream long-profile by computer, using the „random-walk" method (Leopold, Langbein 1962; Harbaugh, Bonham-Carter 1970). The given results seemed to support Penck's (1894) statement that „equilibrium profile" cannot be strictly expressed by a mathematical equation.

In this article a formula coming from the diffusion equation was applied. This formula describes the theoretical „equilibrium", or quasi-equilibrium, profile of the Carpathian rivers (cf. Fig. 1). The main purpose of this paper is to test a usefulness of the mentioned formula for drawing a conclusion connected with the sign and the intensity of young tectonic movements.

The logitudinal profiles of 14 main Polish Carpathian rivers were analysed. Nine of them had the VIth order (Olza, Wisła, Soła, Skawa, Poprad, Biała Dunajcowa, Ropa, Jasiołka, Osława), three — the VIIth (Ra-

Table 2

Parameters of the investigated Carpathian rivers
Parametry badanych rzek karpackich

| river | order | length km | height m a.s.l. headwater | height m a.s.l. mouth | mean slope ‰ | parameters of the K-stretch: distance from headwater % | elevation above the mouth m a.s.l. | length % |
|---|---|---|---|---|---|---|---|---|
| Olza | 6 | 91.95 | 860 | 190 | 7.29 | 27 | 360 | 48.6 |
| Wisła[1] | 6 | 41.80 | 528 | 255 | 6.53 | 54 | 305 | 27.9 |
| Soła | 6 | 89.25 | 830 | 225 | 6.78 | 24 | 445 | 40.0 |
| Skawa | 6 | 91.98 | 725 | 219 | 5.50 | 9 | 500 | 36.4 |
| Raba | 7 | 124.80 | 790 | 180 | 4.89 | 24 | 390 | 42.1 |
| Dunajec | 7 | 271.79 | 1750 | 170 | 5.81 | 16 | 630 | 55.4 |
| Poprad[2] | 6 | 63.85 | 470 | 292.5 | 2.78 | • | • | • |
| Biała | 6 | 100.95 | 775 | 185 | 5.84 | 34 | 305 | 45.7 |
| Ropa | 6 | 83.17 | 750 | 223 | 6.34 | 21 | 415 | 42.9 |
| Wisłoka | 8 | 160.55 | 587 | 154.5 | 2.69 | 28 | 255 | 49.4 |
| Jasiołka | 6 | 78.35 | 800 | 220 | 7.40 | 37 | 350 | 40.7 |
| Wisłok | 7 | 204.08 | 825 | 167.5 | 3.22 | 18 | 285 | 64.6 |
| Osława | 6 | 76.10 | 725 | 292.5 | 5.68 | 22 | 515 | 27.1 |
| San | 8 | 421.70 | 880 | 138 | 1.76 | 28 | 340 | 45.7 |

1 - from the junction of the Czarna and Biała Wisełka to the Goczałkowice Lake
2 - from state boundary to the mouth

ba, Dunajec, Wisłok) and two — the VIIIth (Wisłoka, San). A stream order was defined on topographic maps 1 : 100 000, according to Horton--Strahler's method (see Table 2), but long-profiles were collected from 1 : 25 000 maps.

The Carpathian rivers long profile studies were carried out only within the Eastern Carpathians, both during the 1930s and recently as well (Teisseyre 1938, Gofshtein 1964, Sobakar, Somov, Kuznetsova 1975). The results of these investigations indicate the differentiation of the youngest tectonic movements. From the Western Carpathians area we have only a work concerning the Podhale region rivers (Zuchiewicz 1979).

## METHODS

The methods of tectonic analysis of the stream long-profile on the basis of diffusion equation (Shulits 1941, Scheidegger 1961) were applied by Ivanov (1951) and further developed by Meshcheriakov (1965) and Volkov (1964, 1977). The formula of the theoretical stream long-profile is as follows:

$$h_o = (H_{max} - H_o)\left(\frac{l}{L}\right)^n$$

The construction of this profile is shown in the Fig. 1. The works of Ivanov (1951) and Zuchiewicz (1979) give a full description of this construction. The geometrical analogue of the river's profile has two points, at the headwater and at the mouth, in common with the topographical

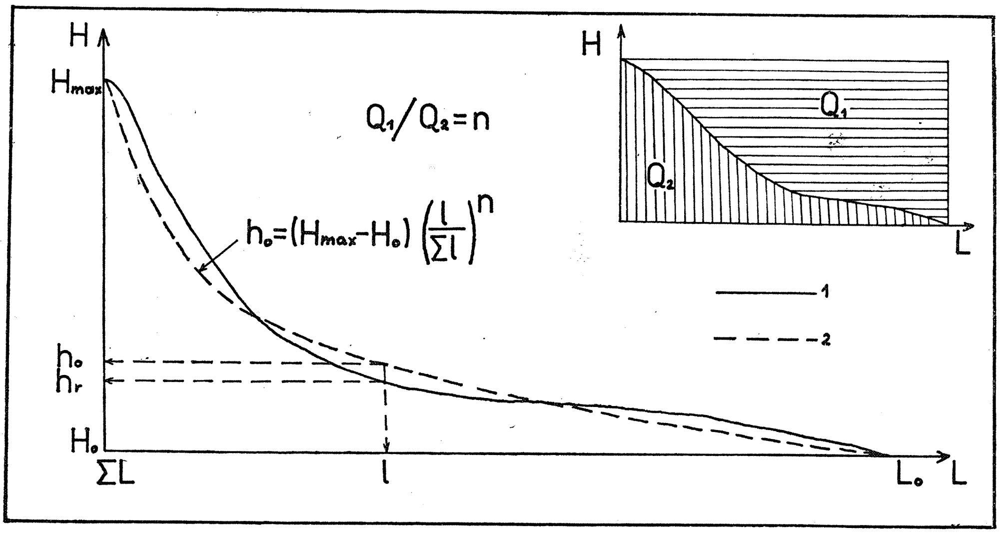


Fig. 1. Principles of plotting of the theoretical longitudinal rivers profile, according to Ivanov's method. 1 — topographical profile, 2 — theoretical profile

Fig 1. Zasady konstrukcji teoretycznego profilu podłużnego rzeki metodą Ivanowa: 1 — profil rzeczywisty, 2 — profil teoretyczny profile. In comparison with profiles calculated by Leopold and Langbein (1962) and Hack (1957, 1973), it is one of its most important advantages. The exponent $n$ equals, in most cases, 1 to 3. Ivanov (1951) stated that the comparison of these two profiles, the topographical and the theoretical one, allows to distinguish several stretches, in which the topographical profile runs over the theoretical one. The first might be connected with uplifted areas, the latter — with the lowered ones. This opinion seems to be connected with the Hettner's (1910) previous point of view. According to Chernysheva (1979), the stream long-profile reflects the total Holocene movements but it cannot reflect recent, instrumentally measured, movements of the earth surface. It comes from the fact that the changes in the river network appear later in comparison with the changes in tectonic pattern (cf. discussion in Starkel 1978). In other words, morphogenetic processes are not directly controlled by uplifting or sinking.

The longitudinal profiles of the investigated rivers are shown on the dimensionless diagrams (see Fig. 2). This method, firstly applied by Leopold, Wolman and Miller (1964) makes it possible to compare rivers of a different order and length.

In order to draw this diagram it is necessary to put on the $Y$ axis the ratios $H/\Sigma H$, the elevation of a point of the profile above the mouth, and on the $X$ axis the ratios $L/\Sigma L$, the distance of a point of the profile from the headwater divided by the total length (cf. Figs. 1, 2). The obtained diagram permits an analysis of profile concavity and also a precise determination of the degree of river maturity makes possible.

As a measure of profile concavity I applied a ratio $l_k$, calculated by dividing the length of the stretch $K$ by the length of the height of the triangle (Fig. 2), whose one side was the diameter of the diagram. Experimental investigations of the shape of river profile during tectonic diagonal upheaval (Makkaveev 1955, 1978) revealed several regularities. In spite of the intensity of the uplift, the increase of the mean river gradient ($S$) caused a translation of the $K$-stretch towards waterheads. During the rapid uplift this translation was very small but during the slower one — it was longer. There was introduced (Makkaveev 1978) a „bottom erosion ratio" ($E_k$) for mountaineous rivers which allows to compare streams of different orders. It was calculated as a fraction of the distance of the $K$-stretch from the headwater and the total stream length. The zone of maximum erosion dissection lies in the middle river course but with the increasing slope it moves towards the headwater. The profile concavity, measured by the $l_k$, grows with the decreasing intensity of uplifting movements. The position of the $K$-stretch marks the boundary between river-bed modelled by intensive bottom erosion and the downstream situated zone of lateral channel migration. The latter one reveals the predominance of accumulational processes. With the slow

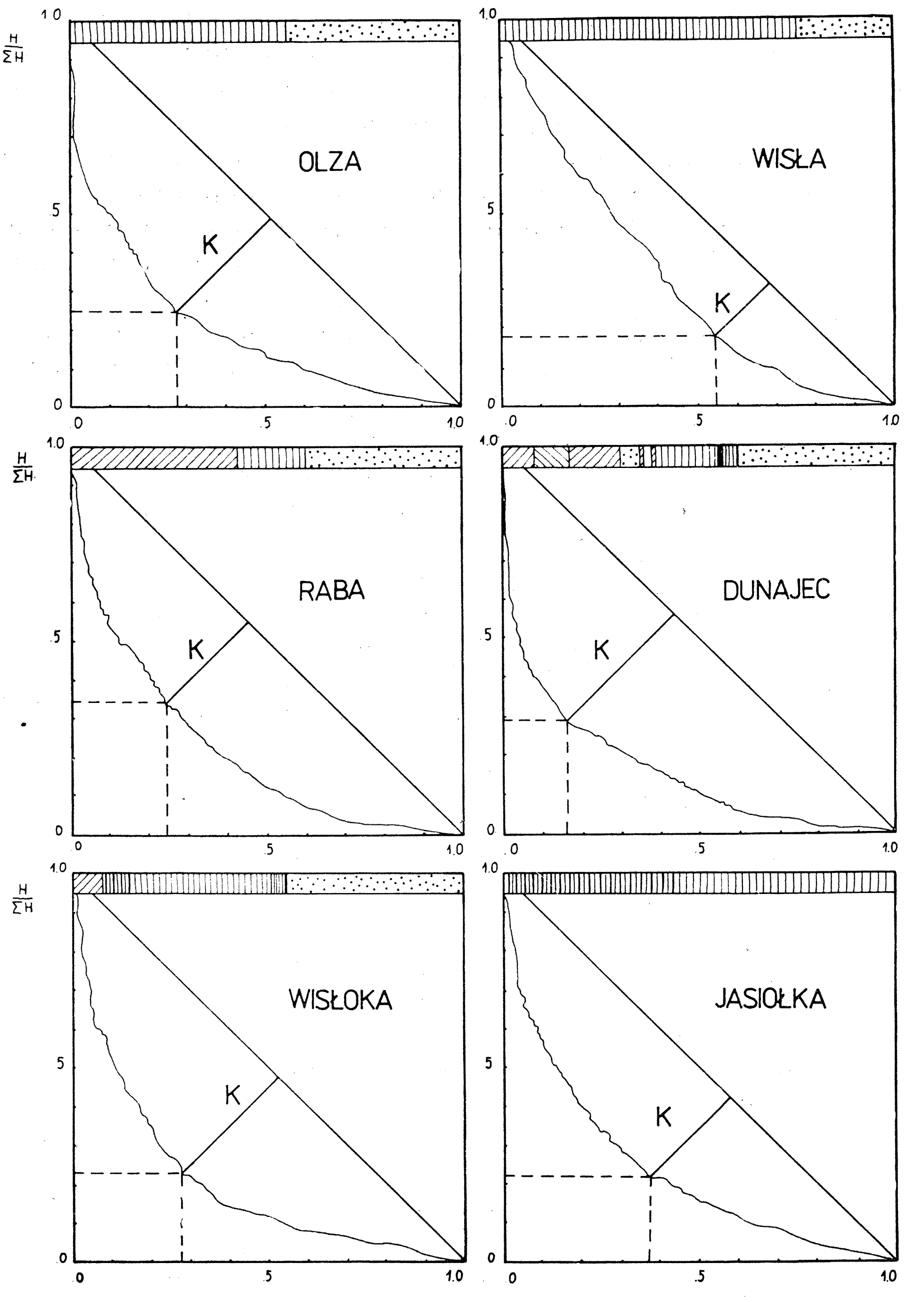
OLZA
WISŁA
RABA
DUNAJEC
WISŁOKA
JASIOŁKA
K
$\frac{H}{\Sigma H}$
1.0
.5
0

Fig. 2 a

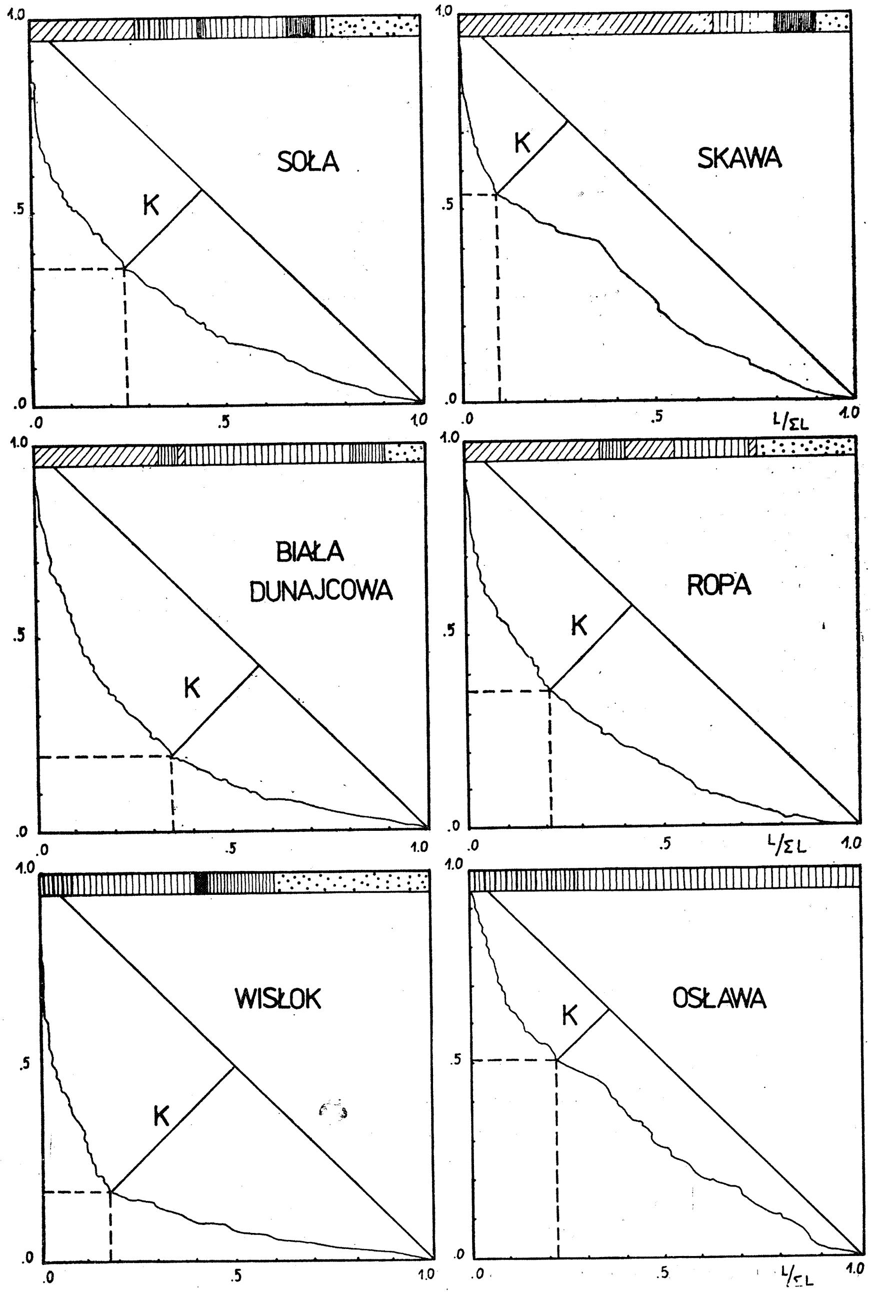


Fig. 2 b

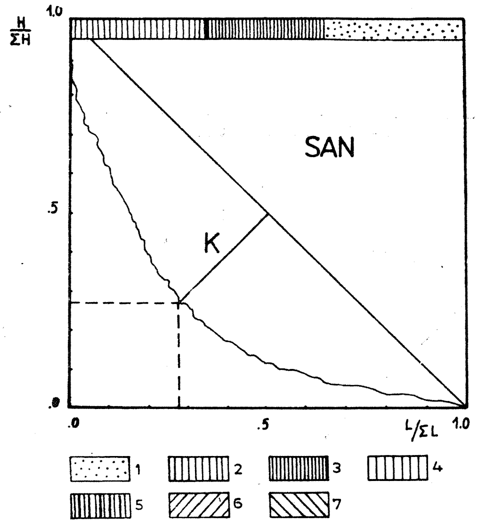


Fig. 2 c

Fig. 2 a, b, c. Dimensionless diagrams of longitudinal Carpathian rivers profiles. *K* — stretch measuring profile's concavity, *H* — elevation difference between the headwater and the mouth, *L* — total length. *1* — Miocene and other foreland beds, 2 — Skole nappe, 3 — Sub-Silesian nappe, External Flysch, 4 — Silesian nappe, 5 — Dukla folds, units in the tectonic windows below the Magura nappe, Fore — Magura nappe, 6 — Magura nappe, 7 — Pieniny Klippen Belt

Fig. 2 a, b, c. Diagramy bezwymiarowe profilów podłużnych rzek karpackich. *K* — odcinek obrazujący wklęsłość profilu, *H* — różnica wysokości między źródłami a ujściem, *L* — łączna długość cieku, 1 — miocen i inne utwory przedmurza, 2 — płaszczowina skolska, 3 — płaszczowina podśląska, flisz zewnętrzny, 4 — płaszczowina śląska, 5 — fałdy dukielskie, jednostki okien podmagurskich, łuska przedmagurska, 6 — płaszczowina magurska, 7 — Pieniński Pas Skałkowy

rate of uplift of a given drainage basin the length of the ,,erosional reach" gets shorter, i.e. the *K*-stretch moves towards the headwater. On the contrary, during the intensive upheaval the length of the mentioned reach gets slightly longer.

## RESULTS OF MEASUREMENTS

The lengths of analysed rivers vary from 40 to 420 km, and the elevation differences between headwaters and mouths reach 432—1570 m. The stream mean gradients are between 1.8‰ and 7.4‰. Wisłok and Dunajec reveal the greatest value of the profile concavity ($l_k$) and Osława and Wisła — the smaller.

Wisła, Jasiołka and Biała Dunajcowa show the highest values of the bottom erosion index. These rivers are characterized by the presence of the longest river-bed sections modelled by bottom erosion processes. The lowest indexes belong to Skawa and Dunajec. There is no distinct relationship between the index $E_k$ and: the mean stream gradient ($S$), the river length ($L$) and the measure of profile concavity ($l_k$). A weak linear relationship seems to appear between *H*, the elevation difference between the headwater and the mouth, and $E_k$ and $l_k$.

These data lead to the conclusion that the VIth order rivers have lower degree of maturity while the VIIth order rivers reached a high degree.

Table — Tabela 3

Correlation coefficients among chosen parameters of the Carpathian rivers
Zależności między wybranymi parametrami rzek karpackich

| | S (%) | $l_k$ (%) | L (km) | H (m) |
|---|---|---|---|---|
| $E_k$ (%) | + 0.01 | − 0.38 | − 0.25 | − 0.38 |
| $l_k$ (%) | − 0.41 | X | + 0.44 | + 0.54 |

The position of the *K*-stretch close to the headwater for all investigated rivers seems to indicate slow upheaval movements within the higher parts of considered drainage basins.

## ANALYSIS OF THE THEORETICAL PROFILES

The results of calculations (cf. Table 4) are shown in the figures 3, 4 and 5. The distribution of river reaches showing „+" or „—" values of $h_r - h_o$ were compared with geological (Sokołowski 1954, Świdziński 1954, Książkiewicz 1962, Fusán et al. 1967), tectonic (Unrug 1979), geotectonic (Dewey, Bird 1970; Ślączka 1975; Książkiewicz 1977; Połtowicz 1978) and neotectonic (Kowalski et Liszkowski 1970; Wyrzykowski 1971) maps. Downstream stretches of all investigated rivers reveal „—" values of $h_r - h_o$. This fact might be connected with overthrusting movements of the Flysch nappes on to the area of the Carpathian Foredeep or with the backward thrusting of the platform under the Carpathian orogene.

Only Skawa's downstream stretch, between Maków Podhalański and the mouth, is characterized by negative values. This is probably caused by:

a) the presence of Skawa's large dislocation zone which runs along the river course and,

b) the extremely high (923 m) thickness of autochtonous Miocene deposits (Ottnangian — Karpatian) which appear in Sucha Beskidzka (Ślączka 1976).

The shape of the theoretical stream profile hardly reflects lithological differentiation of the Flysch deposits (cf. Fig. 5). But main faults and overthrusts, however, are very distinctly pronounced in these profiles. Interrelationship between profiles breaks and the distribution of dislo-

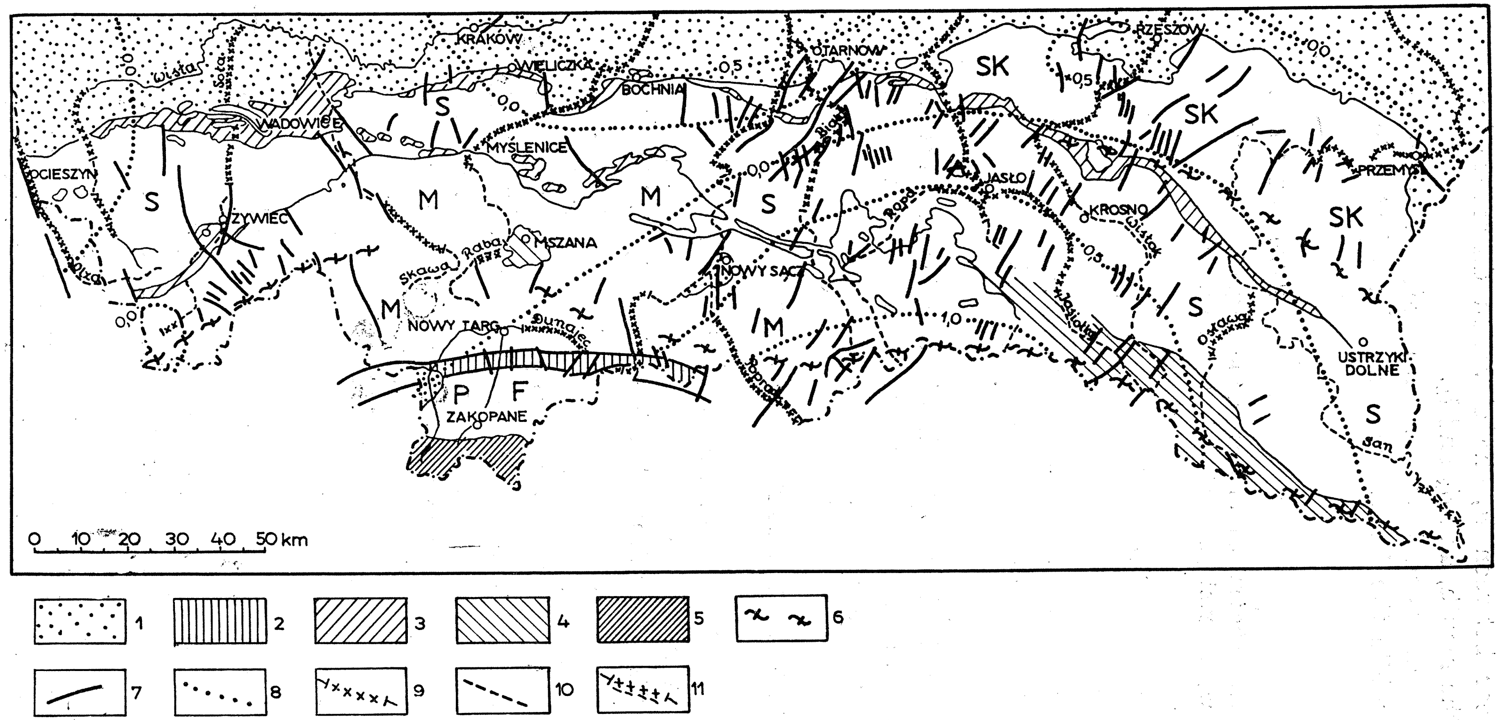


Fig. 3. Tectonis sketch of the Polish Carpathians (geology after: Książkiewicz 1962. Fusán et al. 1967, Unrug 1979). 1 — Miocene and other foreland beds, 2 — Pieniny Klippen Belt, 3 — Sub-Silesian nappe, External Flysch, 4 — Dukla folds, units in the tectonic windows below the Magura nappe, Fore-Magura nappe, 5 — Tatra units, 6 — axes of uplifted longitudinal elevations, 7 — main fault zones, 8 — isolines of the velocity of recent vertical crustal movements according to Wyrzykowski 1971). River-bed's stretches having following values of $h_r$ — $h_o$: 9 — positive, 10 — negative, 11 — transitional. SK — Skole nappe, S — Silesian nappe, M — Magura nappe, PF — Podhale Flysch

Fig. 3. Szkic tektoniczny Karpat polskich (treść geologiczna wg Książkiewicza 1962, Fusán et al. 1967, Unrug 1979). 1 — miocen i inne utwory przedmurza, 2 — Pieniński Pas Skałkowy, 3 — płaszczowina podśląska, flisz zewnętrzny, 4 — fałdy dukielskie, jednostki okien podmagurskich, łuska przedmagurska, 5 — jednostki tatrzańskie, 6 — osie podnoszonych elewacji, 7 — ważniejsze strefy dyslokacyjne, 8 — izolinie prędkości współczesnych pionowych ruchów skorupy ziemskiej (wg Wyrzykowski 1971). Odcinki koryta wykazujące następujące wartości $h_r$ — $h_o$: 9 — dodatnie, 10 — ujemne, 11 — przejściowe. SK — płaszczowina skolska, S — płaszczowina śląska, M — płaszczowina magurska, PF — flisz podhalański

cation zones are clearer in the Eastern Carpathians. In the Western Carpathians large wrench faults (Unrug 1979) delineate boundaries between river reaches having „—" or „±" values of $h_r$ — $h_o$ in the south and the positive ones in the north.

The fractures within the Carpathian basement (Skawina — Skoczów, Kurdwanów — Zawichost, Żywiec — Sambor) are connected with the stream reaches showing positive values of $h_r$ — $h_o$.

The profile of Skawa reveals a sudden change of slope and very high positive value of differences of $h_r$ —$h_o$ within the „negative" reach. It lies just at the point where two large left strikeslip faults, W — E and NW — SE, cross each other. Boundaries of the positive reach in the middle river course are marked by faults cutting the Carpathian substratum: Kurdwanów — Zawichost and Żywiec — Sambor.

In the Eastern Carpathian these relationships get to be more complicated. The negative values of $h_r$ — $h_o$ refer to facture zones (Krynica — Jasło. Dubiecko — Giraltovce) orientated SW — NE. The highest positive values, however, link the following dislocations: Tarnów — Nowy Sącz (Biała), Jasło — Krynica (Ropa) and Tyczyn — Bardejov (Jasiołka). The sharp increase of the positive values of $h_r$ — $h_o$ in the Wisłoka profile can be seen between Jasło and Wróblowa where the river passes between two wrench faults. In the Jasiołka profile, between Zawadka Rymanowska and Jaśliska, there appear distinct disturbances connected with the Dubiecko — Bardejov dislocation zone. The boundaries between river reaches showing „+" values of $h_r$ — $h_o$ in the north and „—" in the south, mark the southern extent of the Pericarpathian deep crustal fracture (Pericarpathian lineament — cf. Sikora 1976) and the zone of regional gravimetric minimum (Ślączka 1975), as well. The „positive" values correlate with the greater thicknesses of the earth's crust within the fracture area (Sikora 1976).

In the Western External Carpathians, rivers crossing the structures uplifted during the Quaternary period, are characterized by „positive" values of $h_r$ — $h_o$, e.g. Soła within the Beskid Mały morphostructure, Skawa in the section which lies at the prolongation of the axis of the Beskid Wysoki uplifted elevation, Raba north of Myślenice.

The interrelationships between neotectonics and the shape of Ivanov's profile are most clearly visible in the profiles of the Dunajec and Poprad. The „negative" values of $h_r$ — $h_o$ characterise Dunajec river-bed stretches within the lowered Nowy Targ Basin [1], within the river-gap at Niedzica, which lies in the zone of the large transversal depression of the Pieniny Klippen Belt (Grochocka 1968) and within the Nowy Sącz Basin, as well. The extremely low, negative values of $h_r$ — $h_o$

[1] The Nowy Targ and Nowy Sącz Basins belong to the intermontane depressions filled by thick Neogene and Quaternary deposits. They have been lowered since the Miocene period.

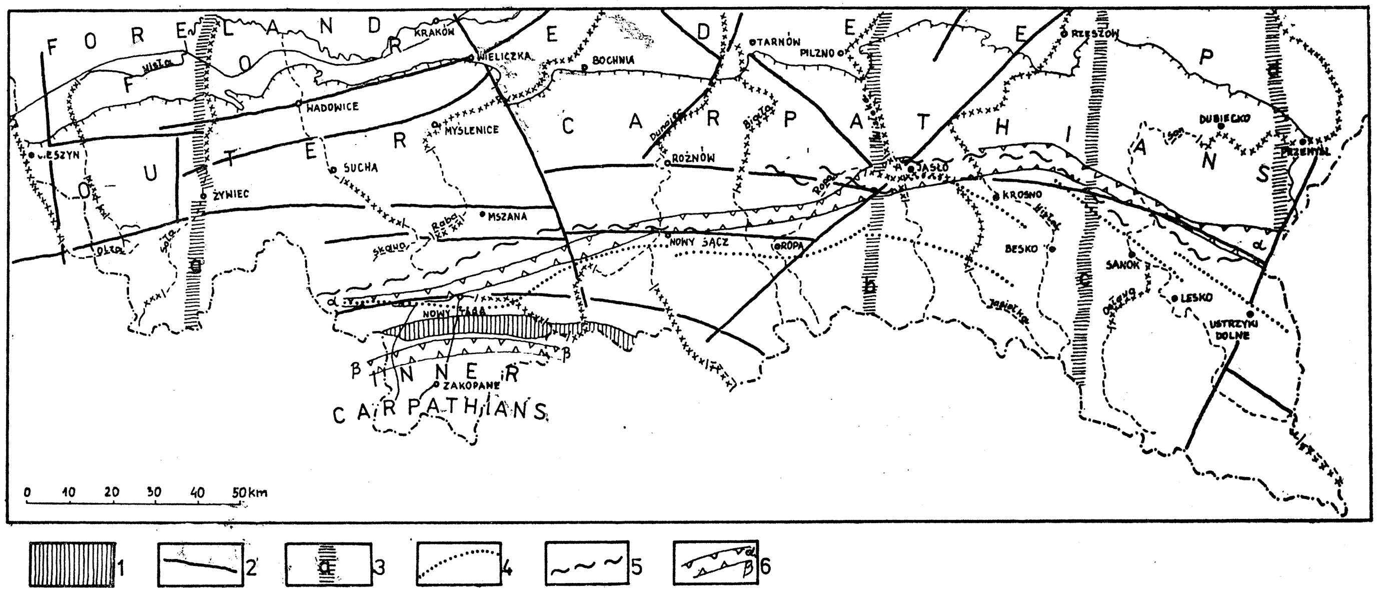


Fig. 4. Schematic map showing deep crustal elements of the Polish Carpathians (after: Ślączka 1975, Sikora 1976, Mahél et al. 1973, Połtowicz 1978). 1 — Pieniny Klippen Belt, 2 — dislocations within the Carpathian substratum, 3 — deep transversal fractures: a — Banska Bystrica — Żywiec, b — Prešov — Gorlice, c — Vihorlat — Sanok, d — Mukačevo — Przemyśl, 4 — axes of regional gravimetric minimum, 5 — southern border of the Epivariscan platform, 6 — deep crustal fractures: α — Pericarpathian, β — Peripieninian. For other explanations — see Fig. 3

Fig. 4. Mapa głównych elementów tektonicznych Karpat polskich (wg Mahél et al. 1973, Ślączka 1975, Sikora 1976, Połtowicz 1978). 1 — Pieniński Pas Skałkowy, 2 — dyslokacje w podłożu Karpat, 3 — rozłamy poprzeczne: a — Bańska Bystrzyca — Żywiec, b — Preszów — Gorlice, c — Vihorlat — Sanok, d — Mukaczewo — Przemyśl, 4 — osie regionalnego minimum grawimetrycznego, 5 — południowa granica platformy epiwaryscyjskiej, 6 — rozłamy wgłębne: α — Perykarpacki, β — Perypieniński. Pozostałe objaśnienia — por. fig. 3

Table 4

Theoretical profiles of the Carpathian rivers
Teoretyczne profile rzek karpackich

| river | order | components of Ivanov's equation | |
|---|---|---|---|
| | | $H_{max} - H_o$ /m/ | n |
| Olza | 1–6 | 670.0 | 4.34003 |
| Wisła | 5–6 | 273.0 | 2.13104 |
| Soła | 4–6 | 305.0 | 1.72226 |
| Skawa | 3–6 | 301.0 | 1.26614 |
| Raba | 4–7 | 383.0 | 2.63599 |
| Dunajec | 6–7 | 410.0 | 2.05630 |
| Poprad | 6 | 177.5 | 0.97390 |
| Biała | 3–6 | 395.0 | 2.79811 |
| Ropa | 3–6 | 319.5 | 1.79607 |
| Wisłoka | 4–8 | 318.5 | 3.65343 |
| Jasiołka | 3–6 | 385.0 | 2.47325 |
| Wisłok | 3–8 | 377.5 | 3.99374 |
| Osława | 4–6 | 312.5 | 1.49322 |
| San | 5–8 | 565.0 | 2.79632 |

appear near the town Nowy Sącz where the highest thickness of Miocene deposits in the whole Nowy Sącz Basin occurs (Oszczypko 1973).

The positive values of $h_r$ — $h_o$ appear along the Dunajec river-bed within the antecedent Pieniny river-gap and also within the Beskid Sądecki Range where the interrelationship between the topographical and the theoretical profiles reflects the block structure of this range. The boundaries of particular blocks are connected with the dislocations distinguished by Tokarski (1975) in this part of the Magura nappe.

The „+" values shows also the Dunajec's theoretical profile downstream of Rożnów, i.e. to the north of the isoline of maximum disturbances of the Carpathian planation surfaces (Klimaszewski 1965). Extremely high values appear near Wojnicz.

The refraction geophysical profile running N — S and crossing the Nowy Sącz Basin reveals the presence in the surroundings of the town Nowy Sącz, of a strong negative gravimetric anomaly (—40 mgal), which could refer to the southern boundary of the Epivariscan platform. This border zone seems to be downsucked to the south, beneath the depth of 14 km (Ślączka 1971, 1975). To the north, however, the Carpathian substratum rises reaching near Zakliczyn the depth of 4 km. It is probable that this event can be correlated with the change of the sign of $h_r$ — $h_o$ from „—" to „+".

The topographic profile of Poprad runs above the theoretical one along the antecedent river-gap within the uplifted longitudinal elevation of the eastern part of the Beskid Sądecki Range. The negative values of $h_r$ — $h_o$ mark the southern (SE) boundary of the Nowy Sącz Basin.

East of Dunajec, the morphostructures subjected to the differentiated neotectonic movements are marked less distinctly in the rivers' profiles (Besko basin, Bieszczady and Słonne Mts. elevations — see Fig. 3, 4). The Jasło — Sanok Depression, lowered during the Quaternary, is not reflected in the longitudinal theoretical profiles of Jasiołka, Wisłok and San. The reasons for that are not clear. The main fracture zones are also weakly pronounced in the stream long-profiles. It can be suggested that the high thickness of the Flysch deposits supresses the tectonic impulses of the substratum. In the Polish Eastern Carpathians there appears a zone of maximum Flysch thicknesses which reach the depth of 10.5 km to the SSW of Krosno. This zone is located beneath the Central Carpathian Depression (Ślączka 1975). Further to the south, the crystalline substratum of the Carpathians probably rises up. Within the Western Carpathians, however, the small thicknesses of the Flysch deposits (3 — 5 km) do not cause this type of extinction.

Along the West Carpathian border the increase of positive values of $h_r$ — $h_o$ and the weak decrease of these values to the east of Dunajec can be seen.

The tectonic windows of Żywiec and Grybów (cf. Figs. 3, 4, 5) are marked in the long-profiles by a remarkable decrease of negative values of $h_r$ — $h_o$. The tectonic window of Mszana in an exception because of its location within the recently uplifted structure (Kowalski, Liszkowski 1970).

The distribution of the river-bed stretches which reveal positive or negative values of $h_r$ — $h_o$ seems to be connected also with the pattern of isolines of the velocity of recent vertical crustal movements (Wyrzykowski 1971). If this pattern is compared with geotectonic maps it is possible to draw an interesting conclusion. The southern boundary of the zone which links „negative" stretches of the investigated rivers presumably follows the boundary of the extent of the Badenian sedimentary basin (Połtowicz 1978). The northern border of the „—" zones, however, marks the extent of the Ottnangian deposits. This „negative" zone extends to the north of the Cretaceous — Tertiary subduction (Dewey Bird 1970, Książkiewicz 1977) of the Euroasiatic plate. The above remarks lead to the statement that the area of negative values of $h_r$ — $h_o$ within the Polish Carpathians marks the zone of the „Carpathian block (*sensu Sikora* 1976). This zone extends between the Peripieninian lineament to the south and the Pericarpathian one to the north. The Carpathian block is the place where the cordilleras were probably downsucked and where the nappes of the External Carpathians were probably rooted. Along the Pericarpathian lineament an abrupt upheaval of thrust planes of higher units on to lower ones can be observed. Today it is marked by the presence of tectonic promontories and outliers. The extent of the platform substratum is located far under the overthrust flysch not farther, however, than the axis of gravimetric minimum that runs parallel to the Pericarpathian lineament, somewhat south of it. The boundary between the basement nonregenerated by alpine orogeny and the basement partly under alpine regeneration is represented here (Ślączka 1975). This zone reveals the tendency to the downward movements.

There are several geophysical data allowing a conclusion that in the Carpathians there occur transversal lineaments. According to Mahél et al. (1973) these lineaments run along the following lines: Banska Bistrica — Zazriva — Żywiec, Prešov — Gorlice, Vihorlat — Sanok and Mukačevo — Przemyśl (cf. Fig. 4). The disruptions and disturbances of the axis of the Carpathian gravimetric minimum are located along these lines and cause that surprising phenomenon that the „negative" Jasło — Sanok Depression structure is so weakly reflected in the profiles of Wisłok, Osława and San.

It is also possible that the zone of positive values of $h_r - h_0$ in the long-profiles of the East Carpathian rivers (Tarnów — Przemyśl) is connected with the presence of the Mid-Polish aulacógene which seems to be continued under the Carpathian Foredeep and the Carpathians themselves (Pożaryski, Żytko 1979).

## FINAL REMARKS

The method of analysis of the stream long-profile, presented above, has been used almost exclusively for the plain rivers. In my opinion this method may be useful for the interpretation of the neotectonics of young folded mountains.

The location of the topographic prfile above the theoretical one could indicate the uplifting tendencies. Rapid changes of the values of $h_r - h_0$ may indicate the presence of the activitated Tertiary and the older fracture zones.

The greater depths to the Moho discontinuity within the Carpathians, connected with deep crustal fractures, are strongly correlated with the change of the sign of young movements from „—" to „+". The special distribution of the „negative" reaches of the East Carpathian rivers the extent of the zone of maximum Flysch thicknesses. The sign of values $h_r - h_0$ seems to reflect the tectonic tendencies of the deep Carpathian substratum and the pattern of isolines of the recent vertical crustal movements as well.

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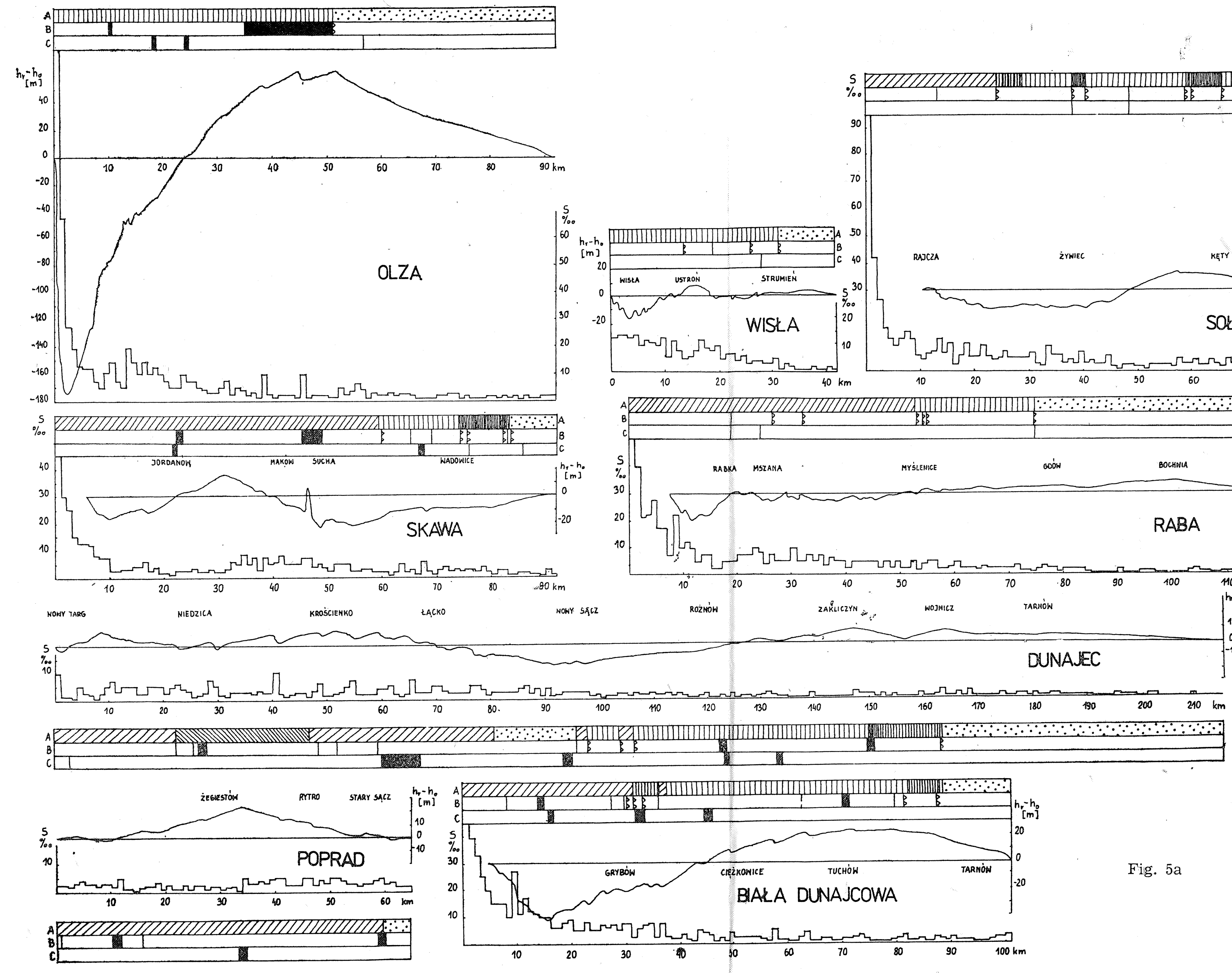
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STRUMIEŃ
RABKA
MSZANA
MYŚLENICE
GDÓW
BOCHNIA
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NIEDZICA
KROŚCIENKO
ŁĄCKO
NOWY SĄCZ
ROŻNÓW
ZAKLICZYN
WOJNICZ
TARNÓW
ŻEGIESTÓW
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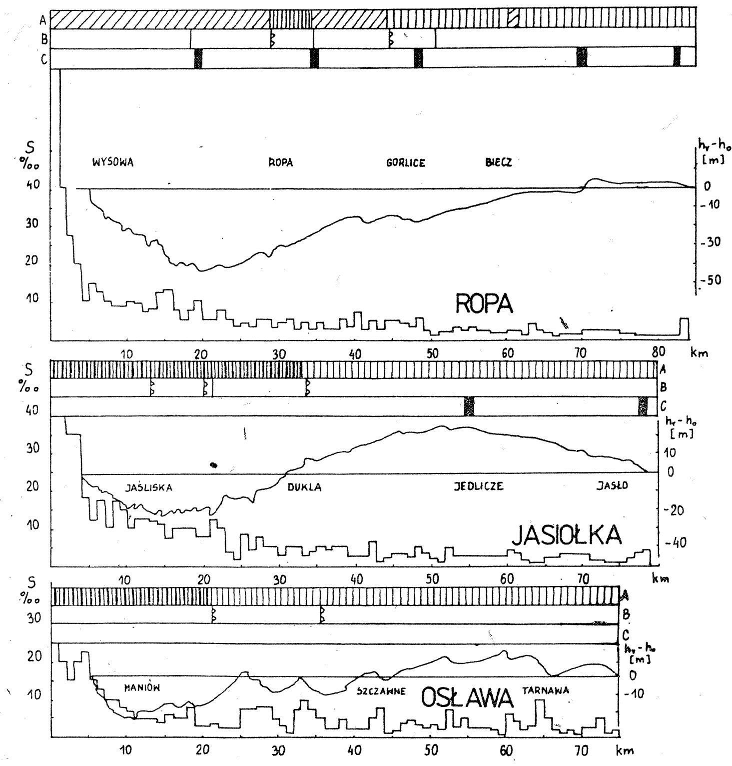
STARY SĄCZ
GRYBÓW
CIĘŻKOWICE
TUCHÓW
TARNÓW

Fig. 5a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MANIÓW
SZCZAWNE
TARNAWA

Fig. 5b

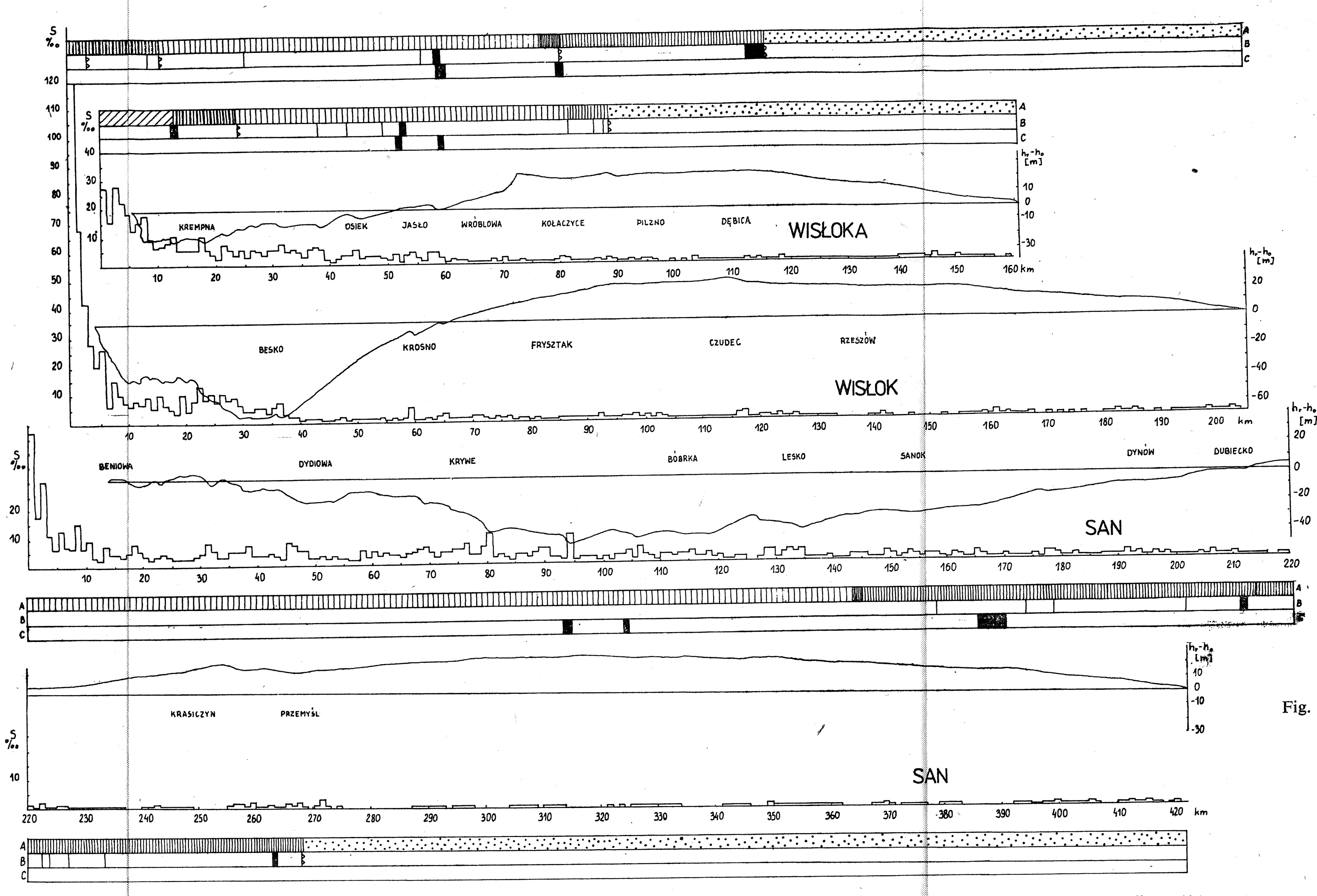


Fig. 5a. Stream-gradient analysis and diagrams of differences between the topographical and theoretical profiles of the West Carpathian rivers. S — stream gradient, $h_r$ — elevation of the given point of the topographical profile above river's mouth $h_o$ — elevation of the given point of the theoretical profile above river's mouth. A — main tectonic units — cf. Fig. 2., B — Tertiary fault zones, C — faults within the Carpathian substratum

Fig. 5a. Diagramy spadków rzek zachodniokarpackich oraz różnice pomiędzy profilem rzeczywistym a teoretycznym. $S$ — spadek cieku, $h_r$ — wysokość danego punktu profilu rzeczywistego nad ujściem, $h_o$ — wysokość danego punktu profilu teoretycznego nad ujściem, A — główne jednostki tektoniczne — por. fig. 2., B — trzeciorzędowe strefy dyslokacyjne, C — uskoki w podłożu Karpat

Fig. 5b. Stream-gradient analysis and diagrams of differences between the topographical and theoretical profiles of the East Carpathians rivers. (Ropa, Jasiołka, Osława) For explanations — see Fig. 5a

Fig. 5b. Diagramy spadków rzek wschodniokarpackich (Ropa, Jasiołka, Osława) oraz różnice pomiędzy profilem rzeczywistym a teoretycznym. Objaśnienia — por. fig. 5a

Fig. 5c. Stream-gradient analysis and diagrams of differences between the topographical and theoretical profiles of the East Carpathian rivers (Wisłoka, Wisłok, San). For explanations — see Fig. 5a

Fig. 5c. Diagramy spadków rzek wschodniokarpackich (Wisłoka, Wisłok, San) oraz różnice pomiędzy profilem rzeczywistym a teoretycznym. Objaśnienia — por. fig. 5a

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## STRESZCZENIE

Przeanalizowano profile podłużne 14 większych rzek Karpat polskich i porównano je z ich profilami teoretycznymi (fig. 3, 4, 5, tab. 1, 2) obliczonymi metodą Ivanowa (1951). Konstrukcję profilu teoretycznego przedstawia fig. 1.

Profile podłużne zestawiono na diagramach bezwymiarowych (fig. 2), uniemożliwiających analizę wklęsłości profilu. Stwierdzono słaby stopień dojrzałości cieków rzędu VI (*sensu* Strahler) i daleko posuniętą dojrzałość rzek VII rzędu.

Przedstawiona metoda analizy profilu podłużnego, stosowana dotychczas prawie wyłącznie dla rzek równinnych, może być przydatna w interpretacji neotektoniki młodych gór fałdowych. Położenie profilu rzeczywistego powyżej teoretycznego (fig. 5, tab. 4) zdaje się świadczyć o tendencjach wypiętrzających, poniżej — o ruchach obniżających. Skokowe zmiany wartości odchyleń między profilem rzeczywistym a teoretycznym wskazują na obecność odmładzanych dyslokacji — zarówno trzeciorzędowych, jak i starszych. Zwiększonym miąższościom skorupy ziemskiej Karpat, związanym z głębokimi rozłamami, odpowiada zmiana znaku młodych ruchów tektonicznych z ujemnego na dodatni.

Specyficzne rozmieszczenie odcinków rzek o odchyleniach „ujemnych" wyznacza zasięg maksymalnych miąższości fliszu, na północ od krawędzi subdukcji kry euroazjatyckiej.