STUDIA GEOMORPHOLOGICA CARPATHO-BALCANICA
VOL. XXIX KRAKÓW 1995 PL ISSN 0081-6434

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NEOTECTONIC TENDENCIES IN THE POLISH OUTER CARPATHIANS IN THE LIGHT OF SOME RIVER VALLEY PARAMETERS

INTRODUCTION

The Polish West Carpathians represent a typical fold-and-thrust belt, being composed of a number of nappes piled one upon another during the Middle to Late Miocene (Książkiewicz 1977, Oszczypko and Żytko 1987). The thrusting proceeded gradually with time towards the north and east (Jiřiček 1979), as a result of the oblique convergence between the North European and Pannonian plates (cf. Oszczypko and Ślączka 1985, Royden and Baldi 1988). The southward and westward subduction of the European plate beneath the Pannonian region, induced by N–S convergence of the African and European plates and the resulting eastward escape of the Pannonian continental lithosphere (cf. Burke and Şengör 1986, Royden 1988), were the main driving forces of these movements. By latest Miocene time, convergence was nearly finished across the northern flysch belt of the Carpathians (Sandulescu 1980, Rögl and Steininger 1983, Royden and Baldi 1988); the Early Pannonian and Plio-Pleistocene thrusting (Fig. 1) occurring only in the East and Southeast Romanian Carpathians, respectively (Oszczypko and Ślączka 1985, Sandulescu 1988, Royden 1988).

NEOTECTONIC SETTING

In the Pliocene and Quaternary (5.2–0 Ma), the Polish Outer Carpathians have been a subject of differential vertical and — possibly — some remnant horizontal movements, resulting in the formation of several neotectonic elevations and depressions (Klimaszewski 1966, Zuchiewicz 1989, 1991, Baumgart-Kotarba 1992; cf. Fig. 2). The rates of uplift have varied throughout this period (Zuchiewicz 1984, 1991), as have those of subsidence (Birkenmajer 1978, Baumgart-Kotarba 1983). The remnant horizontal motions

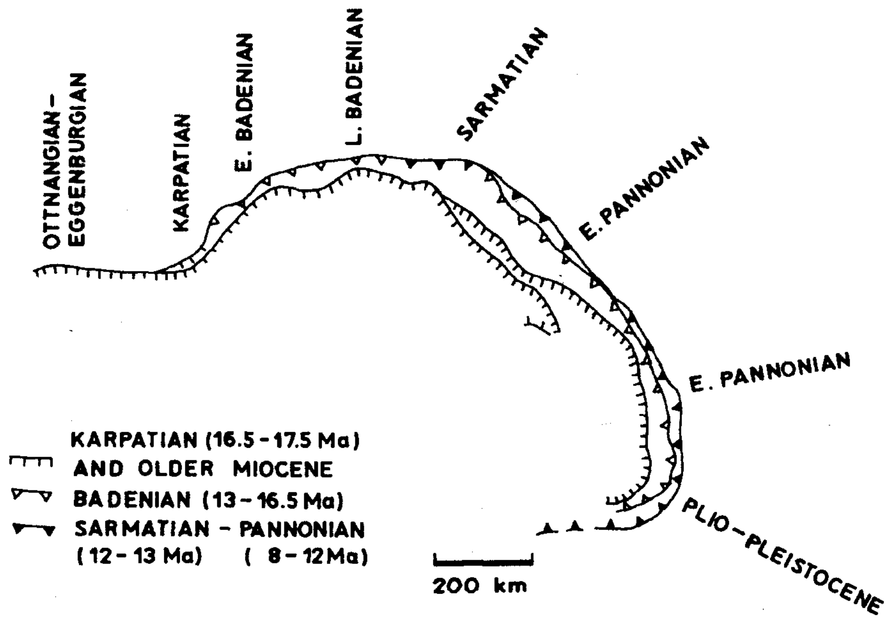


Fig. 1. Ages of the last episode of thrusting in the Outer Carpathians (redrawn from Royden 1988)
Ryc. 1. Wiek ostatniego epizodu ruchów nasuwczych w Karpatach Zewnętrznych (według Royden 1988)

are supposed to have occurred in eastern part of the area studied (Liszkowski 1982, Zuchiewicz 1988). One cannot exclude as well a possibility of fairly recent strike-slip movements at the boundary between the Inner and Outer Carpathians in the Orawa Basin (cf. Pospišil 1990, Baumgart-Kotarba 1992, Bac-Moszaszwili 1993).

The apparent amount of uplift of the medial sector of the Polish Outer Carpathians during Late Neogene and Quaternary times, inferred from geomorphic studies, ranges from 150–430 m on the south and 360–900 m in the middle to 180–310 m on the north. These figures conform very well with the results of seismostratigraphic studies performed on several seismic lines from the Carpathian Foredeep, that clearly indicate a minimum of >200 m rebound of the lithosphere during the post-Middle Serravallian times (Krzywiec and Zuchiewicz 1993). On the other hand, the total lithospheric rebound for the whole Polish Carpathians in the post-orogenic period is sometimes estimated at c. 4 km (Lillie; pers. comm. 1994).

Recent seismicity is usually confined to the inner (southern) side of the Pieniny Klippen Belt and to several strike-slip or oblique-slip faults that cross both the Slovak and Polish Carpathians. Most of these faults are very well portrayed in the photolineament pattern (e.g., Graniczny 1991).

Neotectonic elevations and depressions have been active throughout the past 5 Ma, leading to deformation of planation surfaces (Early Pliocene, Late Pliocene and earliest Quaternary in age), as well as in upwarping/downwarping

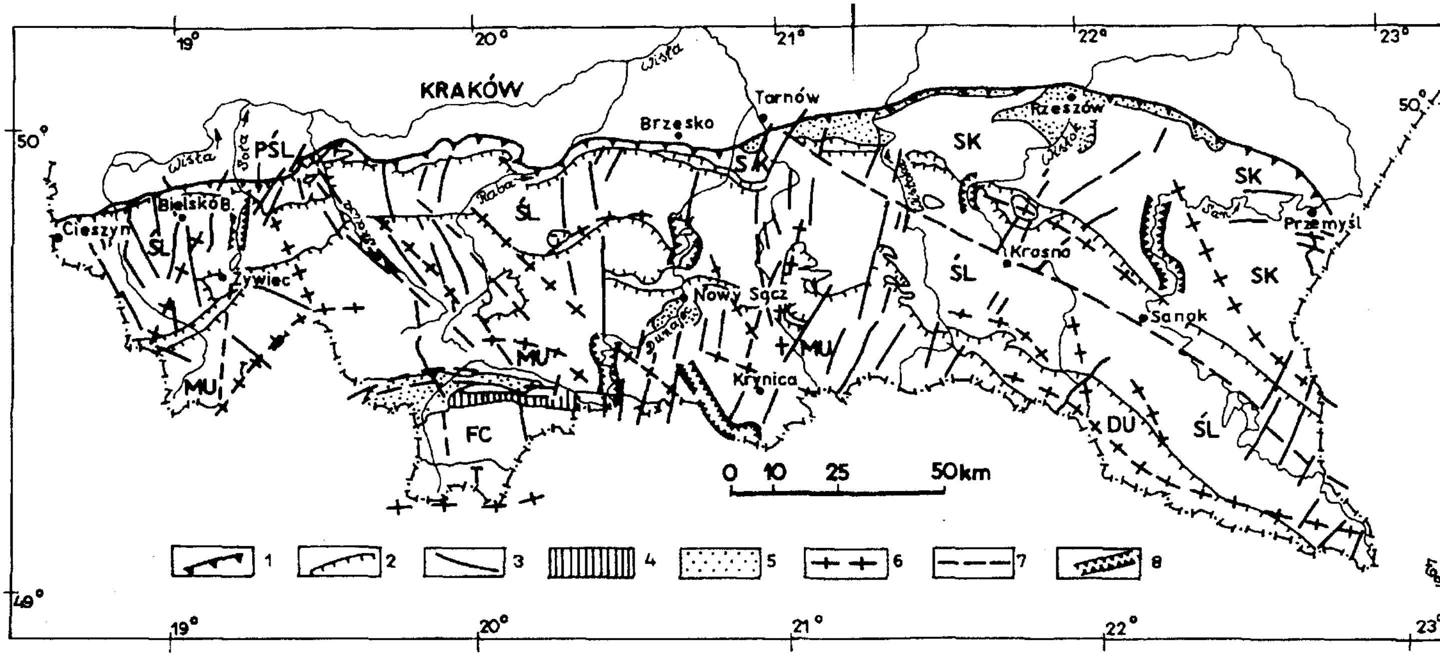


Fig. 2. Structural sketch of the Polish Carpathians (based on Książkiewicz 1977, Żytko *et al.* 1988–89, and Zuchiewicz 1991). 1 — Carpathian frontal thrust, 2 — subordinate thrusts, 3 — faults, 4 — Pieniny Klippen Belt, 5 — Miocene molasses resting on eroded flysch deposits, 6 — axes of neotectonic elevations, 7 — axes of neotectonic depressions, 8 — antecedent water-gaps. Inner Carpathians: T — Tatra units, FC — Podhale Flysch; thrust sheets of the Outer Carpathians: MU — Magura, DU — Dukla, ŚL — Silesian, PŚL — sub-Silesian, SK — Skole

Ryc. 2. Szkic tektoniczny Karpat polskich (według Książkiewicz 1977, Żytko *et al.* 1988-89 oraz Zuchiewicz 1991). 1 — główne nasunięcie karpackie, 2 — nasunięcia podrzędne, 3 — uskoki, 4 — pieniński pas skałkowy, 5 — molasy mioceńskie leżące na zerodowanych utworach fliszowych, 6 — osie elewacji neotektonicznych, 7 — osie depresji neotektonicznych, 8 — przełomy antecedentne. Karpaty Wewnętrzne: T — jednostki tatrzańskie, FC — flisz podhalański; płaszczowiny Karpat Zewnętrznych: MU — magurska, DU — dukielska, ŚL — śląska, PŚL — podśląska, SK — skolska and/or faulting of rock socles of at least 8 Quaternary strath and cut-and-fill river terraces (Zuchiewicz 1991). Tectonically-induced changes in the drainage pattern have also been common. The amount of Quaternary uplift of the Outer Carpathians did not exceed 170 m (Zuchiewicz 1984, 1988).

The youngest (Late and/or post-Pliocene) episode of NE–SW oriented compression, inferred from the studies on joints and small-scale faults of an area surrounding the Pieniny Klippen Belt (Zuchiewicz 1994) is consistent with the results of studies on right-lateral transpressional movements along the margin of the Tatra massif (Late Pliocene, c. 3.3 Ma), suggesting — an inherited from the late Middle Miocene — northeastward directed shift of the Inner Carpathians (Bac-Moszaszwili 1993).

The Late Neogene clockwise rotation of σ_1 in the Carpathian-Pannonian region by at least 40° (Csontos *et al.* 1991) is to be noted. In the western part of the Polish Carpathians (Zuchiewicz 1994), the 100° of clockwise rotation close to the Pieniny Klippen Belt reveals the same sense.

Geomorphic studies (Liszkowski 1985, Zuchiewicz 1986), however, seem to indicate a Late Pliocene-Quaternary countercklockwise rotation of σ_1 from NE–SW to NNW–SSE. Similar tendency has also been confirmed by Csontos *et al.* (1991) for the Pannonian region.

The rates of Quaternary erosional dissection of rock socles of fluvial terraces in the Polish Carpathian valleys ranged from 0.02 to 2 mm/yr and increased in the Late Pleistocene and Holocene. Intensive dissection during the latest Pleistocene and Holocene was restricted, however, to certain regions, including the longitudinal elevations truncated by the Raba, Dunajec, and San river valleys. Three episodes of increased erosional activity have been encountered (Zuchiewicz 1991): 1. the Cromerian–Elsterian–1 to Elsterian 1/2 (800–472 ka): 0.15–0.21 mm/yr; 2. the Eemian and Early Vistulian (130–90 ka): 0.18–0.40 mm/yr; and 3. the latest Pleistocene and Holocene (15–0 ka): 0.20–2.00 mm/yr.

These episodes may indicate periods of more vigorous tectonic activity in the study area.

METHODS

Numerous attempts have been made to portray quantitatively the effects of young tectonic movements upon the shape and behaviour of longitudinal profiles of river beds in the Carpathian region (e.g., Zuchiewicz 1980, 1981, Bober and Oszczypko 1984), alongside with morphometric and morphotectonic analyses of landforms (Henkiel 1977–78, Zuchiewicz 1988; and others). Special attention has been paid to statistical analyses of the Carpathian drainage basins (Krawczyk and Zuchiewicz 1989, Zuchiewicz 1986, 1988), as well as to the time-series analysis of river-bed gradients (Zuchiewicz 1993). The applica-

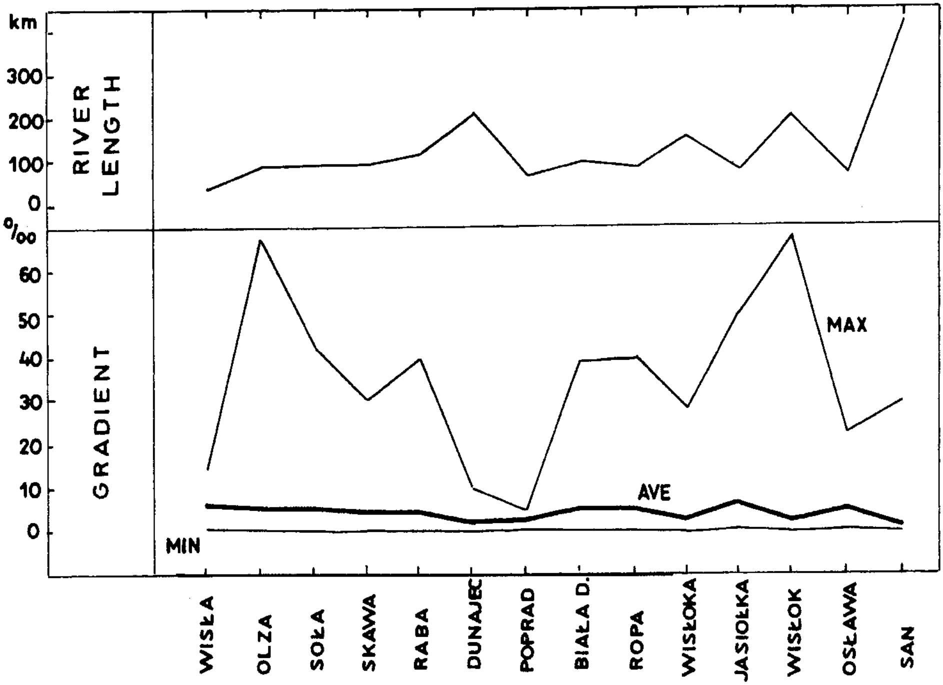


Fig. 3. River-bed gradients in the Polish Outer Carpathians. MAX — maximum, AVE — average, MIN — minimum values

Ryc. 3. Spadki koryt rzecznych w polskich Karpatach Zewnętrznych. Wartości: MAX — maksymalne, AVE — średnie, MIN — minimalne

tion of the dynamic equilibrium theory (cf. Bull 1990) should also be mentioned (Zuchiewicz 1993).

The aim of this paper is to present morphological consequences of neotectonic movements reflected in the differentiation of some morphometric parametres of the Carpathian river valleys. Five numerical indices have been chosen (Figs 3 and 4), including the river bed gradient, width of the valley floor, altitudes of the left and right valley divides, as well as the valley floor width-valley height ratio, calculated by the formula of Bull and McFadden (1980):

$$Vf = \frac{Vfw}{\frac{(Eld-Esc)+(Erd-Esc)}{2}}$$

where:

Vf = valley floor width — valley height ratio

Vfw = width of the valley floor

Eld, Erd, Esc = altitudes of the left and right divides and the stream, respectively.

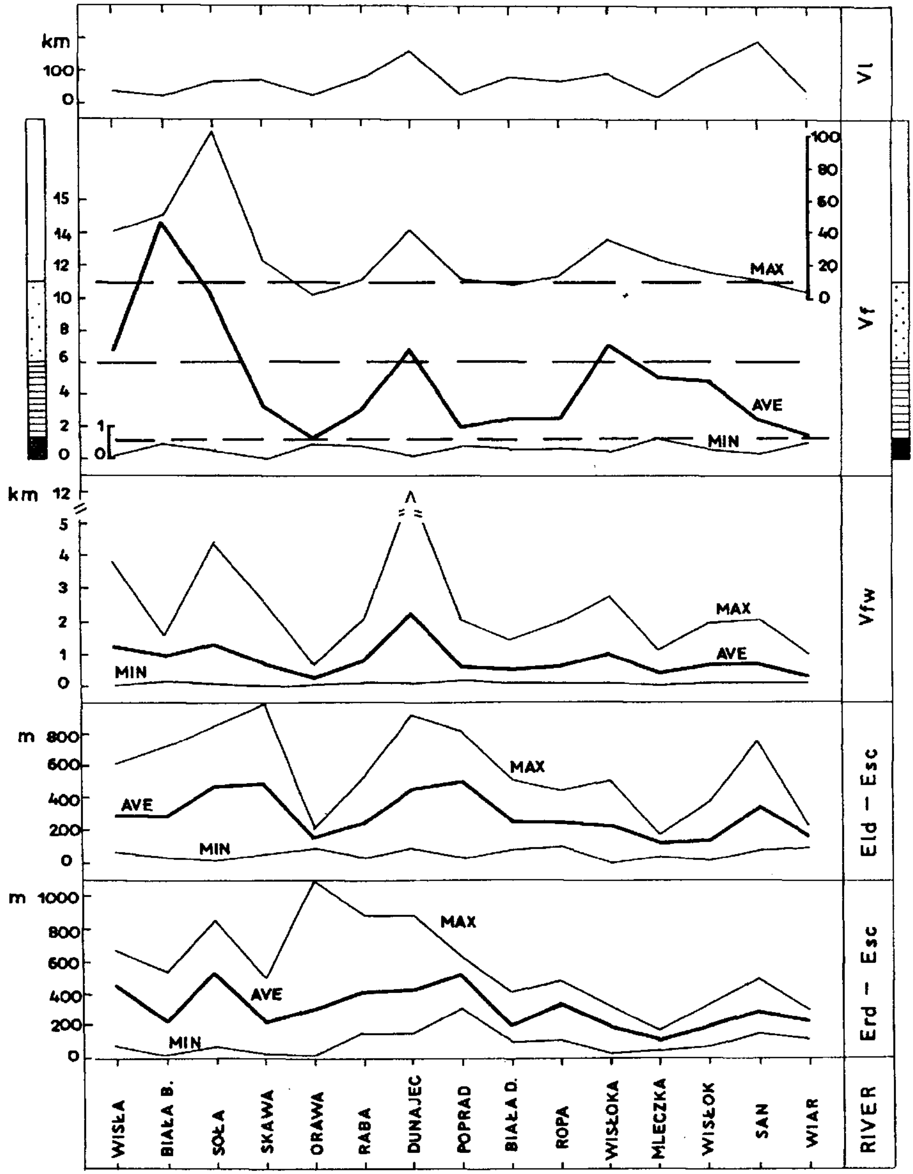


Fig. 4. Spatial distribution of some river valley parametres across the Polish Outer Carpathians. Vl — valley length, Vf — valley floor width-valley height ratio, Vfw — valley floor width, Eld–Esc — altitude of the left divide, Erd–Esc — altitude of the right divide; MAX — maximum, AVE — average, MIN — minimum values. Classes of recent tectonic activity: black — strong, dashed — moderate, dotted — weak, white — inactive

Ryc. 4. Zróżnicowanie niektórych parametrów dolin w polskich Karpatach Zewnętrznych. Vl — długość doliny, Vf — wskaźnik szerokości/wysokości względnej doliny, Vfw — szerokość dna doliny, Eld–Esc — wysokość zbocza lewego, Erd–Esc — wysokość zbocza prawego. Wartości: MAX — maksymalne, AVE — średnie, MIN — minimalne. Klasy współczesnej aktywności tektonicznej — pole: czarne — silnej, zaszrafowane — umiarkowanej, kropkowane — słabej, białe — brak aktywności

According to Bull and McFadden (1980), Vf ranges from 0.05 to 47.0; the boundary figures indicative for active, moderate and no recent tectonics being 1.3, 6.1, and 11.0, respectively.

All these parametres have been calculated for 1–km–long river valley segments on the scale of 1:25 000 (river bed gradients) and 1:50 000 (other indices), and then plotted in both discrete and smoothed form. Each time the highest possible polynomial that — controlled by the least-square method — fits the data best, has been applied (Figs 5–8). The zones showing abnormally high gradients, the lowest Vf and Vfw indices, as well as the highest altitudes of the right and left divides are portrayed in map view (Figs 9–12). These zones refer to individual peaks shown by polynomial curves (Figs 5–8).

MATERIAL

RIVER BED GRADIENTS

Max gradients (Fig. 3) display Olza, Wisłok and Raba rivers, whereas the maximum average gradients are represented by the Jasiołka, Osława, Biała Dunajcowa, and Ropa streams. Extreme values change from 0.0 m/km (Dunajec, Wisłoka, Wisłok, San) to 68 m/km (Wisłok); the average figures ranging from 1.65 (San) to 6.54 m/km (Jasiołka).

The highest average values characterize the Jasiołka (6.54) and Vistula (6.39 m/km) river beds; the lowest ones are confined to the San (1.65) and Dunajec (1.93 m/km) rivers.

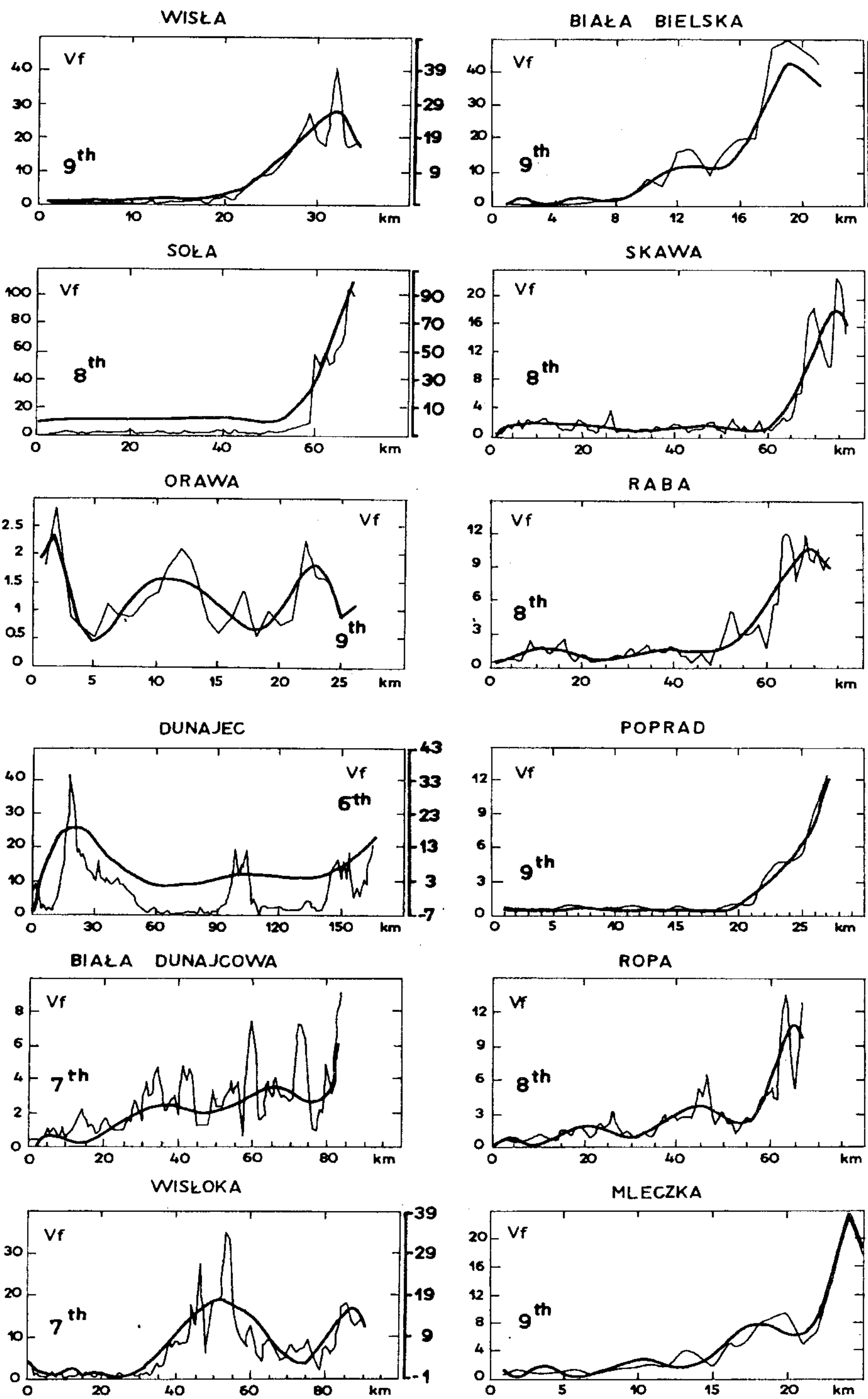
The maximum gradients calculated for 1-km-long river bed segments are observed in the Wisłok (68.0), Olza (67.5) and Jasiołka (50.0 m/km) river beds.

The range between the highest and lowest gradients is the highest for the Wisłok (68.0) and Olza (67.0) rivers; the lowest one being characteristic for the Poprad (4.5), Dunajec (10.0), and Vistula (13 m/km) river beds.

River-beds stretches showing abnormally high gradients, as compared to those of the neighbouring upstream and downstream reaches (Fig. 9), tend to be associated with areas of increased resistance of underlying bedrock in the West Carpathians, whereas in the medial and eastern sectors of this region the zones in question mark some of the most neotectonically elevated structures (cf. Zuchiewicz 1993).

VALLEY FLOOR WIDTH — VALLEY HEIGHT RATIO (Vf)

Minimum average values that may testify to the increased tectonic activity have been found to characterize the Orawa, Poprad, Biała Dunajcowa, Ropa, and Wiar rivers. The maximum figures, in turn, are characteristic for the Biała Bielska and Soła river valleys (Figs 4 and 5).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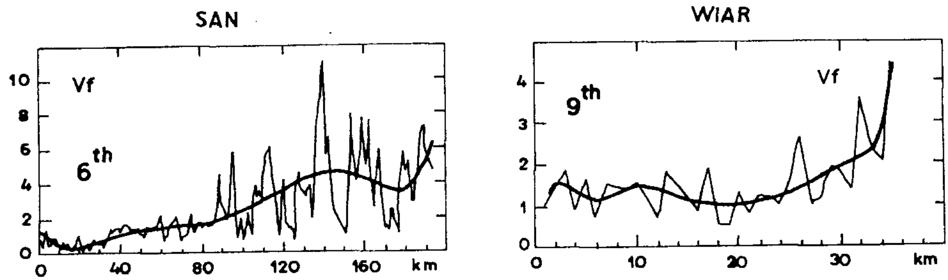


Fig. 5. Time-series plots of Vf values along the selected Polish Carpathian river valleys. Thick solid line represents the best-fit polynomial of a given order

Ryc. 5. Szeregi czasowe wartości Vf dla wybranych dolin Karpat polskich. Krzywe pogrubione przedstawiają wielomiany określonego stopnia, najlepiej aproksymujące dane wyjściowe

One can observe a general trend of decreasing Vf values from the west to the east, the most prominent minima being associated with the Orawa and Poprad-Biała Dunajcowa-Ropa river valleys.

The Orawa and Wiar river valleys display figures located at the boundary between the active and moderate tectonic activity, whereas the Poprad, Biała Dunajcowa and Ropa valleys belong to the moderate activity domain. Weakly moderate activity is also shown by those areas that are dissected by the Skawa, Raba, Mleczka, Wisłok and San rivers. At the boundary of slightly active and moderate domains of movements there are located figures represented by the Vistula, Dunajec and Wisłoka river valleys. On the other hand, the Biała Bielska and Soła rivers belong to the inactive domain.

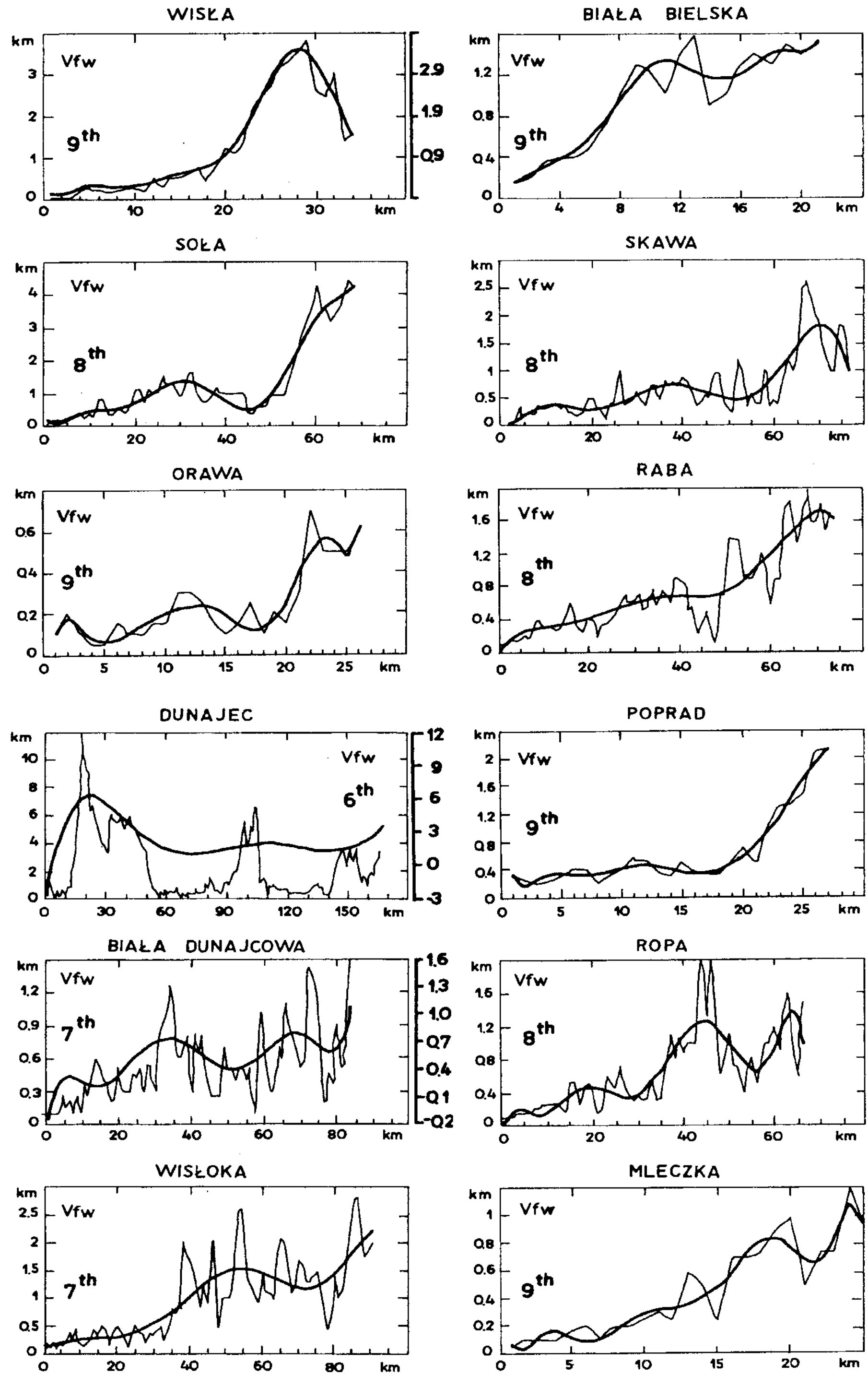
Discrete figures of Vf fall within the range of 0.0 to 103.5; average values being placed inbetween 1.23 (Orawa) and 14.72 (Biała Bielska). This range is the lowest in case of Orawa (2.36) and Wiar (3.93) valleys, attaining even 103.26 for the Soła valley that drains in its lower course the subsiding Oświęcim Basin.

VALLEY FLOOR WIDTH (Vfw)

The minimum average values of this parameter have been obtained for the Orawa, Poprad, Biała Dunajcowa, Ropa, Mleczka, and Wiar river valleys, showing nearly identical pattern as that displayed by the Vf values. One cannot trace, however, ony clear trend of the increase/decrease of this index (Figs 4 and 6).

The highest average values are confined to the Dunajec, Vistula, Soła, and — to a lesser extent — Wisłoka river valleys.

The extreme values of Vfw range between 0.05 to 12.0 km; the average figures being placed between 0.24 km (Orawa) and 0.32 km (Wiar) to 2.27 km (Dunajec). The range is the lowest for the Orawa (0.65) and Wiar (0.90) rivers; attaining the highest figures for the Dunajec river valley (12.0 km), the latter cutting in its upper course the subsiding intramontane Orawa-Nowy Targ Depression.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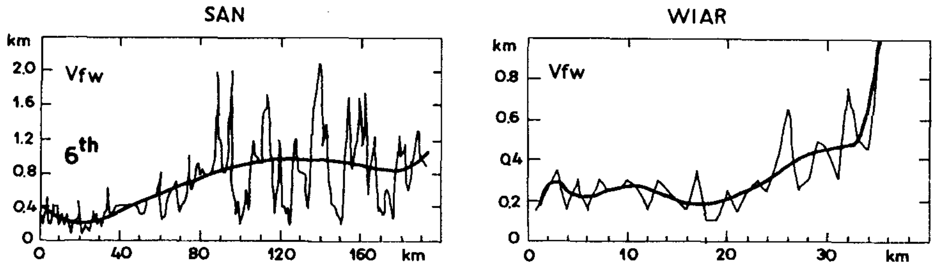


Fig. 6. Time-series plots of Vfw values along the selected Polish Carpathian river valleys. For explanation — see Fig. 5

Ryc. 6. Szeregi czasowe wartości Vfw dla wybranych dolin Karpat polskich. Objaśnienia — por. Ryc. 5

A comparison between the Vf and Vfw values shows that in some valleys of the Polish Carpathians there occurs a distinct drop in the discussed parameters at the outlet from the Carpathians. Such a trend may be indicative of still active tectonic movements in this zone (remnant horizontal movements?).

As far as Vf values are concerned, such a trend concerns the Vistula, Biała Bielska, Skawa, Raba, Wisłoka and Mleczka valleys, as well as the Ropa river valley in the Jasło–Sanok Depression. A similar pattern is displayed by the Vfw values revealed by the downstream reaches of the Vistula, Skawa, Raba, Mleczka, and Ropa valleys.

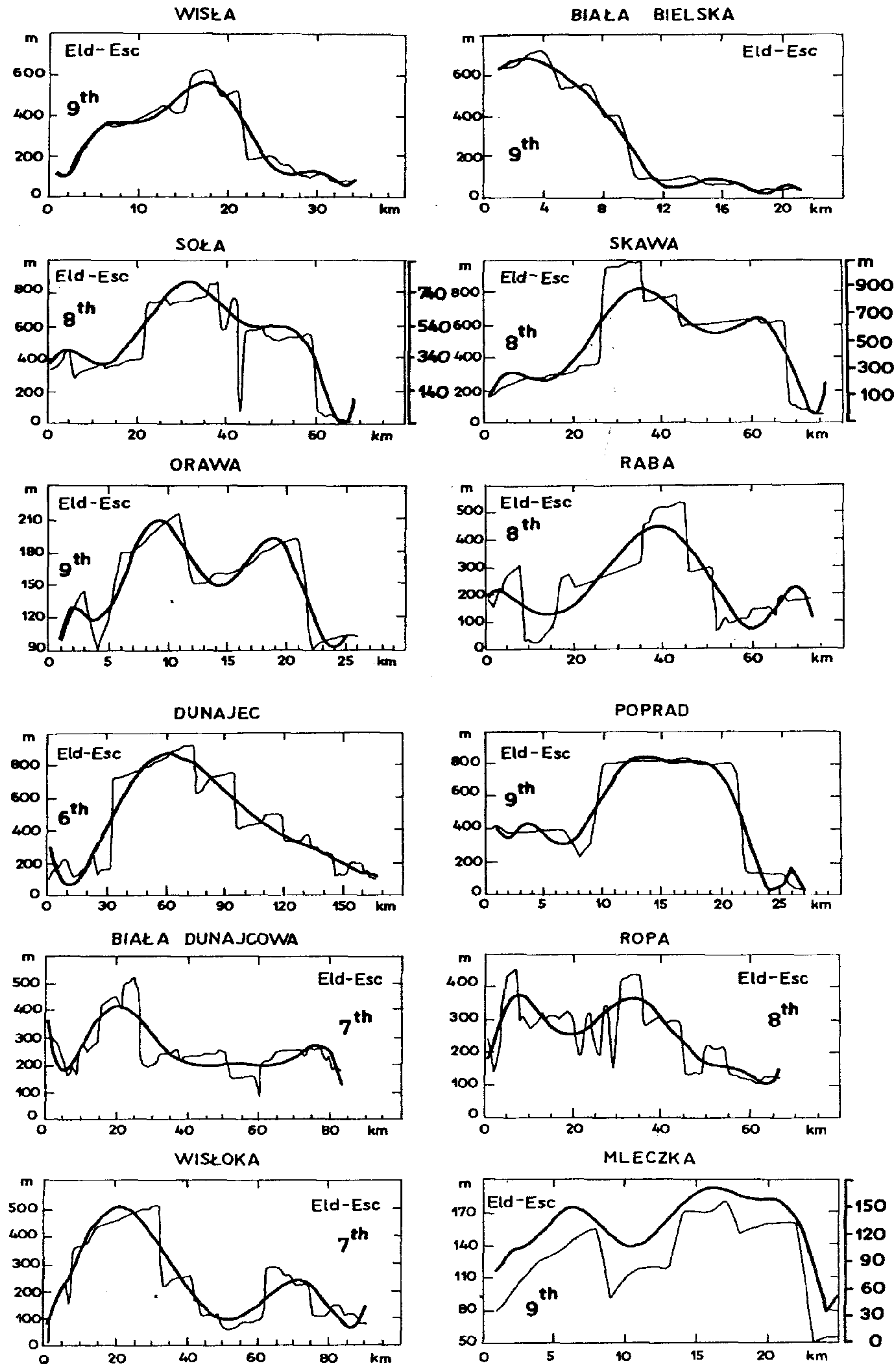
ALTITUDE OF THE LEFT DIVIDE (Eld–Esc)

Maximum average values of this parameter are revealed by the Soła, Skawa, Dunajec, Poprad, and San river valleys (Figs 4 and 7). Such a distribution of figures being indicative of intense uplift is fairly different from that displayed by the Vf and Vfw parameters. The highest average values (>500 m) are characteristic for the Skawa and Poprad rivers that dissect the most uplifted Plio-Pleistocene longitudinal elevations, built of relatively resistant rocks.

Extreme values fall within the limits of 10 m (Wisłoka) to 990 m (Skawa); the average figures ranging between 127 m (Mleczka) and 501 m (Poprad).

The lowest Eld–Esc values are characteristic for the Wisłoka (10 m), Soła (15 m), Wisłoka (23 m) and Raba (25 m) river valley segments; the highest ones are associated with the Skawa (990 m), Dunajec (920 m), Soła (855 m), and Poprad (830 m) rivers.

The range between minimum and maximum values is the highest for the Skawa (937 m), Soła (840 m) and Dunajec (823 m) river valleys; the lowest figures being confined to the Orawa (125 m), Mleczka (130 m) and Wiar (140 m) rivers.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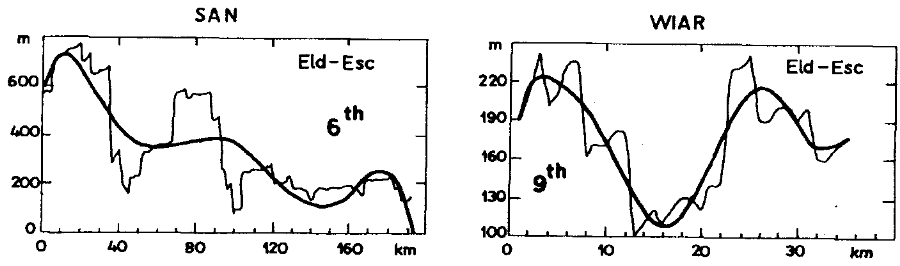


Fig. 7. Time-series plots of Eld–Esc values along the selected Polish Carpathian river valleys. For explanation — see Fig. 5

Ryc. 7. Szeregi czasowe wartości Eld–Esc dla wybranych dolin Karpat polskich. Objaśnienia — por. Ryc. 5

ALTITUDE OF THE RIGHT DIVIDE (Erd–Esc)

Maximum average values are shown by the Vistula, Soła, Poprad, Ropa and San river valleys; the overall trend displaying diminishing values from the west to the east, particularly well visible east of the Dunajec river (Figs 4 and 8).

The highest average values characterize the Soła (>500 m) and Poprad (500 m) rivers; the lowest ones are confined to the Mleczka river valley (c. 100 m).

Extreme values fall within the limits of 10 m (Orawa) to 1048 m (Orawa); the averages ranging from 106 m (Mleczka) to 542 m (Soła).

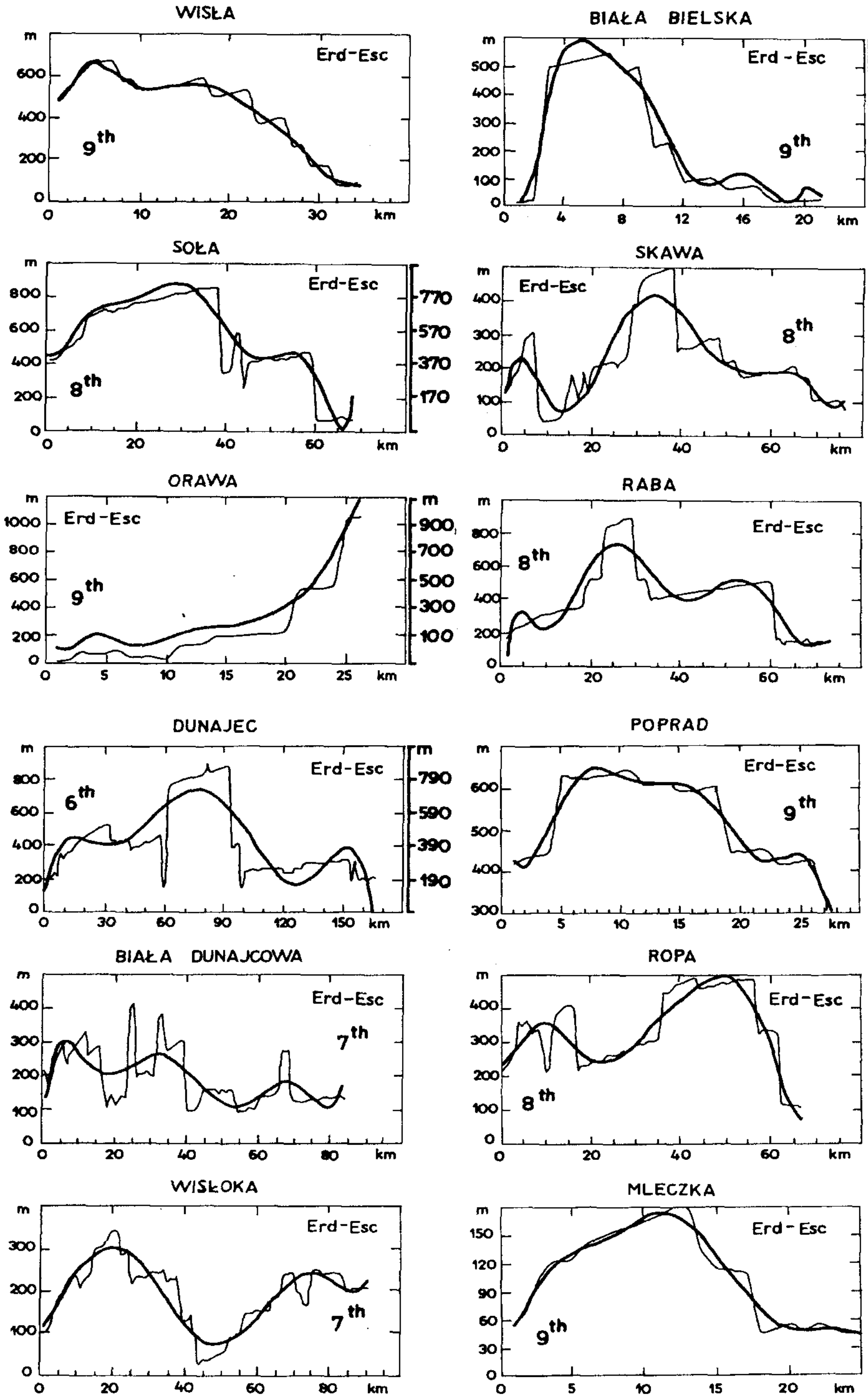
The lowest Erd–Esc values are typical for the Orawa (10 m), Biała Bielska (13 m), Wisłoka (25 m), Skawa (35 m) and Mleczka (45 m) river valley segments; the highest ones tend to associate with the Orawa (1048 m), Dunajec (895 m), Raba (890 m) and Soła (855 m) rivers.

The range between maximum and minimum values is the highest for the Orawa (1038 m), Soła (785 m), Dunajec (743 m) and Raba (740 m) river valleys; the lowest differences being encountered in the valleys of Mleczka (135 m), Wiar (205 m) and Wisłoka (270 m).

Comparing the Eld–Esc and Erd–Esc values, one can take notice of similar distribution of maximum average values in the Soła, Poprad, and San river valleys. The greatest asymmetry, in turn, is shown by the Skawa and Biała Bielska valleys.

DISCUSSION

Minimum values of the valley floor width-valley height ratio (Vf), revealed by polynomial smoothing of discrete data calculated for 1–km–long segments of the Polish Carpathian river valleys (Fig. 5), tend to cluster into 1 to 4 zones within individual valleys. Boundaries of these zones coincide with either faults and thrusts or large regional photolineaments (e.g., Biała Dunajcowa, Ropa,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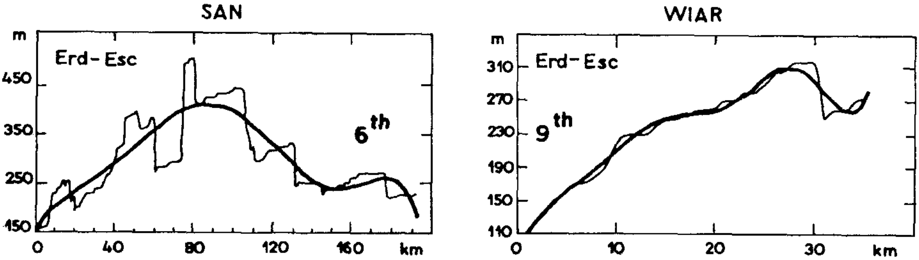

Fig. 8. Time-series plots of Erd–Esc values along the selected Polish Carpathian river valleys. For explanation — see Fig. 5

Ryc. 8. Szeregi czasowe wartości Erd–Esc dla wybranych dolin Karpat polskich. Objaśnienia — por. Ryc. 5

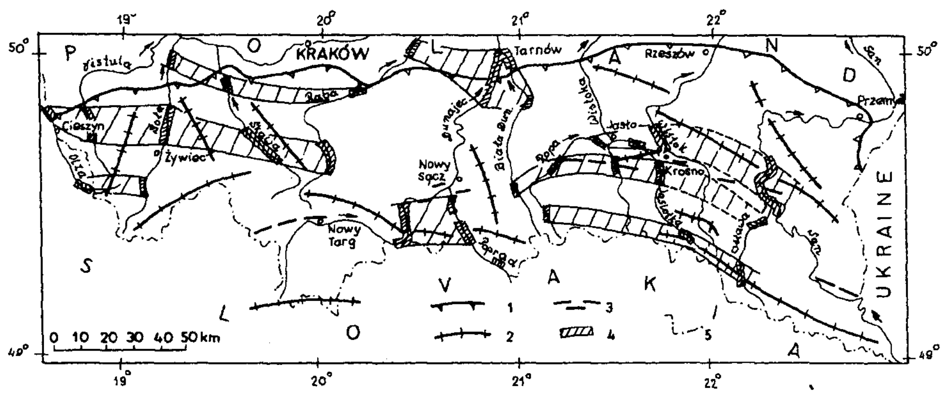

Fig. 9. Map showing the distribution of abnormally high river-bed gradients in the Polish Outer Carpathians. 1 — Carpathian frontal thrust, 2 — axes of neotectonic elevations, 3 — axes of neotectonic depressions, 4 — zones of abnormally high river-bed gradients, 5 — state boundary

Ryc. 9. Rozmieszczenie stref anomalnie wysokich spadków koryt rzecznych w polskich Karpatach Zewnętrznych. 1 — brzeżne nasunięcie Karpat, 2 — osie elewacji neotektonicznych, 3 — osie depresji neotektonicznych, 4 — strefy anomalnie wysokich spadków koryt, 5 — granica państwa

Wisłok, San); they are rarely delimited by local magnetic anomalies (Wisła, Wisłoka). In some areas the zones in question are located at the prolongation of or just at the axes of neotectonic elevations (Wisła, Dunajec, Poprad, Wisłok, San, and Wiar; cf. Fig. 10) that also correlate with the zones of abnormally high river-bed gradients (Fig. 9).

The supposedly active zones marked by the minimum Vf values (Fig. 10) strike more or less parallel to the Outer Carpathian thrust sheets, their number increasing to the east of the Dunajec river valley from 3 to 7. Some of them either parallel or cross the Carpathian frontal thrust.

A similar pattern is displayed by the low valley floor width (Vfw) values (Fig. 6), although the number of narrow-valley-zones is more evenly distributed throughout the area studied (5 in the west and 6 in the medial and eastern Carpathians). Most of these zones follow frontal thrusts of individual nappes, coinciding as well with the axes of some neotectonic elevations.

Another picture presents the distribution of increased Eld–Esc (Fig. 7) and Erd–Esc (Fig. 8) values that denote altitudes of the left and right divide of a valley (cf. also Fig. 11), respectively. The boundaries of high-altitude zones usually coincide with thrusts, faults, and increased river-bed gradients, as well as with the orientation of neotectonic elevations. As compared to the Vf and Vfw parametres, a smaller number of the zones marked by peaks on polynomial curves does not show any structural control (9–12 versus 15–17; cf. Table 1).

Table 1

Structural control on boundaries of zones showing decreased (Vf and Vfw) and increased (Eld–Esc and Erd–Esc) values of river valley parametres in the Polish Outer Carpathians

Uwarunkowania strukturalne stref o obniżonych (Vf i Vfw) oraz podwyższonych (Eld–Esc i Erd–Esc) wartościach parametrów dolin rzecznych polskich Karpat Zewnętrznych

parametre		Vf	Vfw	Eld–Esc	Erd–Esc
faults	n	4	9	6	7
	%	8.0	14.5	13.0	12.1
thrusts	n	11	15	13	17
	%	22.0	24.2	28.3	29.3
photoline-	n	5	5	3	6
aments	%	10.0	8.1	6.5	10.3
magnetic	n	2	1	2	2
anomalies	%	4.0	1.6	4.3	3.4
increased					
river-bed	n	5	9	6	11
gradients	%	10.0	14.5	13.0	19.0
neotectonic	n	6	8	4	6
elevations	%	12.0	12.9	8.7	10.3
no apparent					
structural	n	17	15	12	9
control	%	34.0	24.2	26.2	15.6
Total:	n	50	62	46	58
	%	100	100	100	100

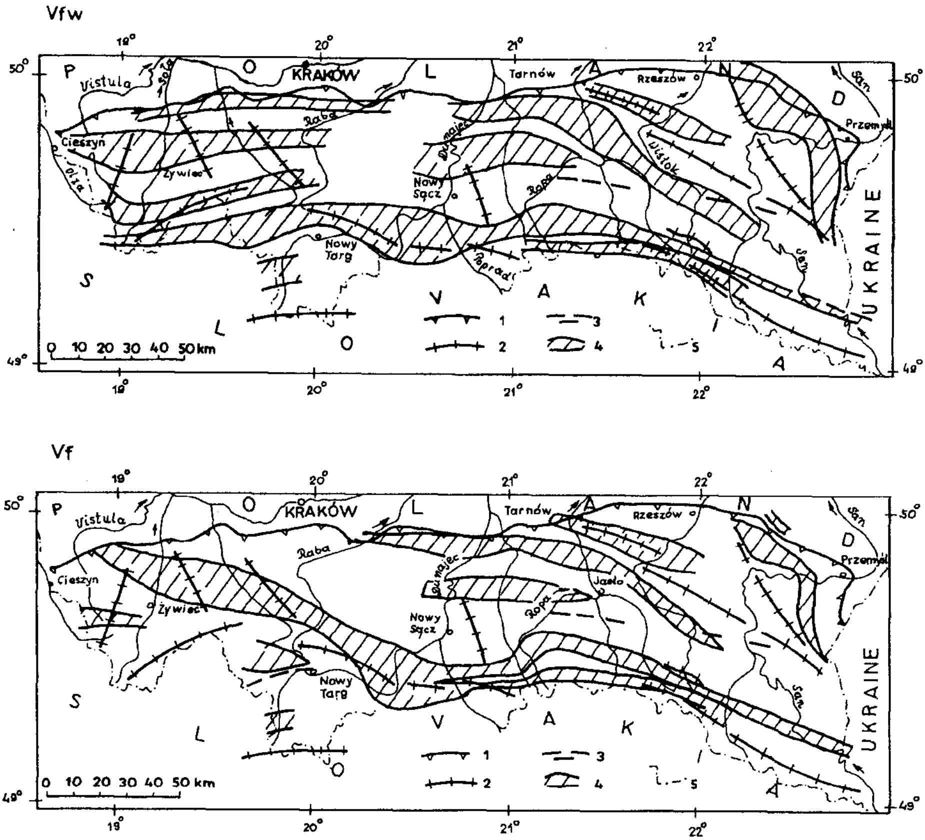

Fig. 10. Maps showing the distribution of minimum values of Vf and Vfw in the Polish Outer Carpathians. 4 — zones of minimum values of Vf and Vfw; for other explanations — see Fig. 9

Ryc. 10. Rozmieszczenie stref obniżonych wartości Vf i Vfw w polskich Karpatach Zewnętrznych. 4 — strefy obniżonych wartości Vf i Vfw; pozostałe objaśnienia — por. Ryc. 9

The zones of increased relief range in number between 6 in the western through 3 in the medial to 4–5 in the eastern sectors of the Outer Carpathians, showing fairly good coincidence with the location of neotectonic elevations and frontal thrusts of nappes (Fig. 11).

Fig. 12 shows those zones that are common for the two pairs of parametres, i.e. Vf/Vfw and Eld–Esc/Erd–Esc. Such zones could be considered to reveal the most intense erosional dissection and — probably — still active tectonic processes.

If Eld–Esc/Erd–Esc zones correlate in large part with the areas of increased resistance of the bedrock, although being coincident as well with some neotectonic elevations, the Vf/Vfw zones do not show any clear lithological control and may reflect fairly recent activity. Their distribution differs somewhat from that of neotectonic structures mapped by classical geomorphic methods, particularly in the Moravo-Silesian Beskidy Mts and in the Podhale region. Of special

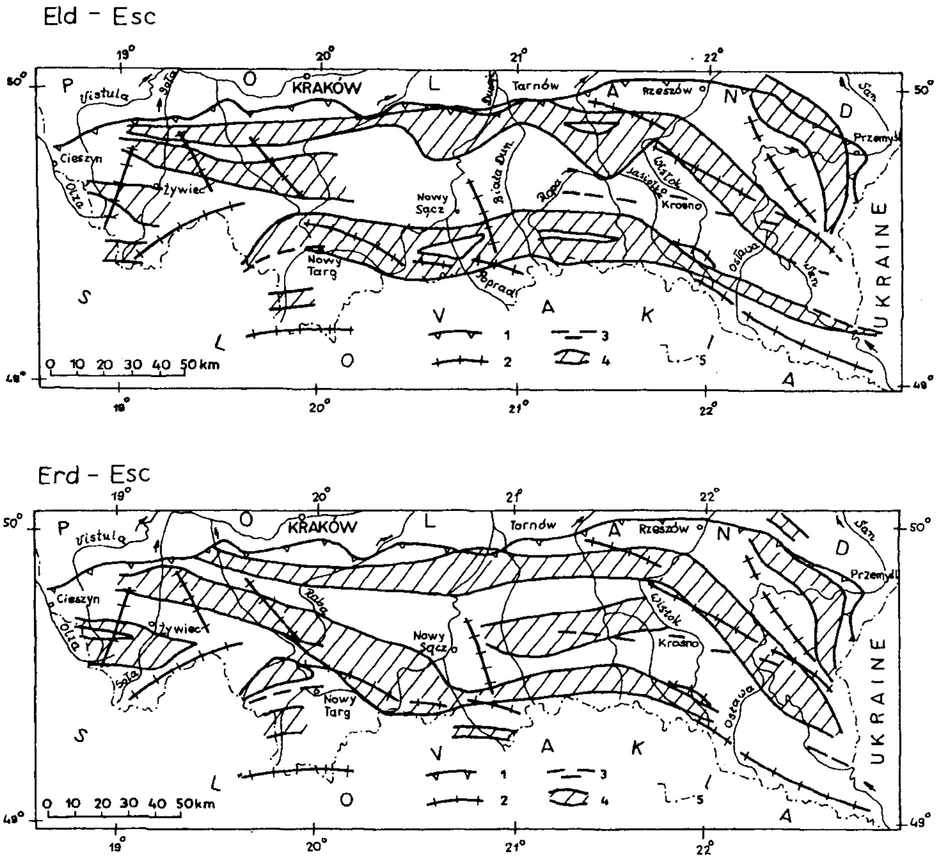

Fig. 11. Maps showing the distribution of maximum values of Eld–Esc and Erd–Esc in the Polish Outer Carpathians. For explanation — see Fig. 10

Ryc. 11. Rozmieszczenie stref podwyższonych wartości Eld–Esc i Erd–Esc w polskich Karpatach Zewnętrznych. Objaśnienia — por. Ryc. 10

importance is the increasing number of high-activity zones in the eastern part of the Polish Outer Carpathians, one of them being situated even in front of the orogen (cf. Fig. 12).

CONCLUSIONS

All the discussed morphometric parametres differ throughout the Polish Outer Carpathians, and cluster into a number of zones that could be correlated with neotectonically (Pliocene-Quaternary) active areas. Some of them are delimited by thrusts, faults or large regional photolineaments, whereas the other simply mark uplifted regions independent of older tectonic structures, although being parallel to the general strike of the Outer Carpathian thrust sheets.

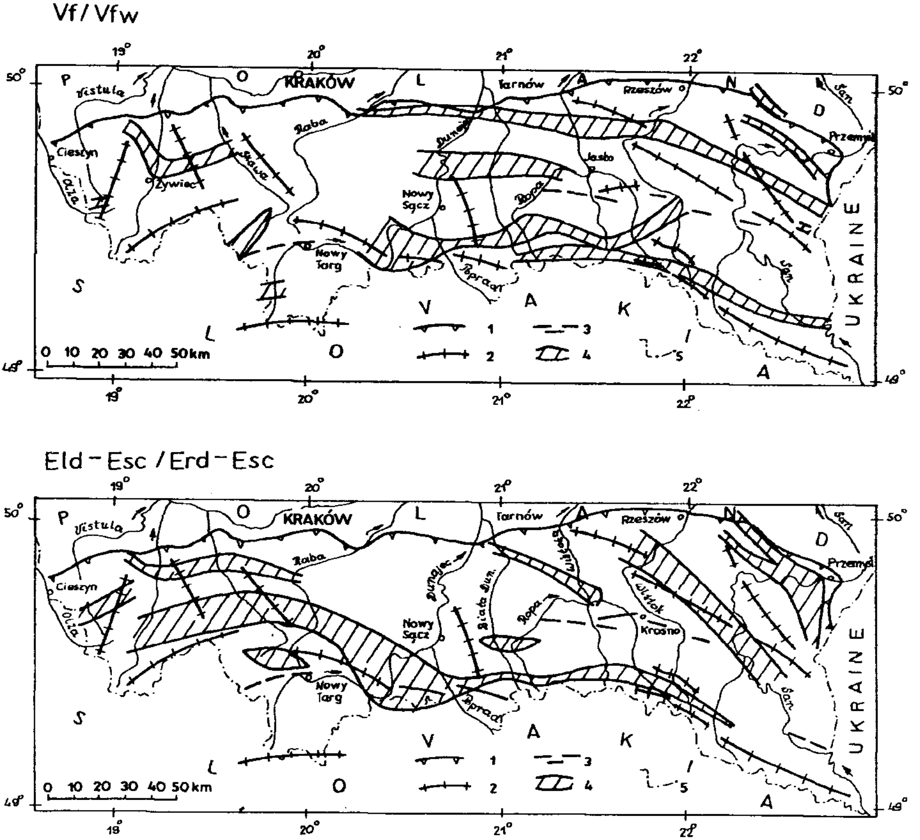

Fig. 12. Map showing the distribution of minimum (Vf/Vfw) and maximum (Eld–Esc/Erd–Esc) values within zones common for the two pairs of parametres in the Polish Outer Carpathians. For explanation — see Fig. 10

Ryc. 12. Rozmieszczenie obniżonych (Vf/Vfw) i podwyższonych (Eld–Esc/Erd–Esc) wartości w obrębie stref wspólnych dla obu par parametrów dolin w polskich Karpatach Zewnętrznych. Objaśnienia — por. Ryc. 10

The spatial distribution of the zones in question is peculiar for two reasons: first, they generally parallel fold and thrust axes, secondly — they become more numerous to the east of the Dunajec river valley. Moreover, some of these structures are located at or even in front of the present-day Carpathian frontal thrust. Such a pattern could suggest an eastward-increasing tectonic activity of the Carpathian realm, the character of which is probably due to some remnant folding within the flysch cover. This conclusion is also supported by the fact that the width of high-activity zones rarely exceeds 10–15 km, and that the Carpathian sole thrust represents a fairly regular surface (cf. O s z c z y p k o *et al.* 1993), undisturbed by faults occurring in the substratum. This excludes a possibility of block-type motions within the Carpathian basement, as well as isostatic movements of such small-scale blocks of the flysch cover. Remnant horizontal stresses within the flysch nappes in the eastern part of the Polish Carpathians have already been suggested by Liszkowski (1982) and Zuchiewicz (1988).

ACKNOWLEDGEMENTS

This research has been supported by the Committee for Scientific Research (Komitet Badań Naukowych) Grant No. 6 6134 92 03p/01.

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STRESZCZENIE

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TENDENCJE NEOTEKTONICZNE POLSKICH KARPAT ZEWNĘTRZNYCH W ŚWIETLE ANALIZY NIEKTÓRYCH PARAMETRÓW DOLIN RZECZNYCH

Artykuł omawia przejawy młodych ruchów tektonicznych w Karpatach Polskich (Ryc. 1, 2), znajdujących swoje odzwierciedlenie w zróżnicowaniu parametrów morfometrycznych głównych dolin rzecznych (Ryc. 3, 4). Uwzględniono następujące parametry: spadek koryta, szerokość dna doliny (Vfw), wysokości względne zbocza lewego (Eld–Esc) i prawego (Erd–Esc) oraz wskaźnik szerokości dna–wysokości zboczy (Vf), zaproponowany przez Bulla i McFaddena (1980) dla oceny stopnia aktywności tektonicznej obszaru. Wymienione parametry mierzono dla 1-km długości odcinków dolin na mapach w skali 1:25 000 (spadki koryt) oraz 1:50 000 (pozostałe wskaźniki). Wyniki pomiarów przeanalizowano metodą szeregów czasowych, aproksymując dodatkowo dane wyjściowe wielomianami różnych stopni (Ryc. 5–8). Rozmieszczenie stref o maksymalnej (spadki, wysokości względne) lub minimalnej (Vf, Vfw) wartości, odczytanej z krzywych wielomianów, przedstawiają Ryc. 9–12. Granice tych stref w znacznej mierze dowiązują do rozmieszczenia uskoków, nasunięć i głównych fotolineamentów, a także lokalizacji stref o podwyższonych spadkach koryt i osi elewacji neotektonicznych (Tab. 1).

W obrębie polskich Karpat Zewnętrznych strefy grupujące zbliżone wartości parametrów, wskazujących na młodą aktywność tektoniczną, układają się mniej więcej równolegle do rozciągłości głównych nasunięć i fałdów. Dodatkowo, ilość tych stref wzrasta ku wschodowi (na wschód od doliny Dunajca). W tym samym kierunku zaczynają się też pojawiać struktury usytuowane tuż przy brzegu nasunięcia karpackiego, a nawet w obrębie zapadliska przedkarpackiego. Szerokość rozważanych stref nie przekracza na ogół 10–15 km. Może to sugerować młode, resztkowe ruchy fałdowe w obrębie pokrywy fliszowej; tym bardziej prawdopodobne, iż spąg głównego nasunięcia karpackiego ma przebieg regularny i nie jest zaburzony przez uskoki podłoża platformowego. Ruchy blokowe struktur fliszowych o tak niewielkiej długości falowej są trudne do zaakceptowania.