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MORPHOMETRIC METHODS APPLIED TO THE MORPHOSTRUCTURAL ANALYSIS OF MOUNTAINEOUS TOPOGRAPHY (POLISH WESTERN CARPATHIANS)

(7 Figs.)

Wybrane metody morfometryczne analizy morfostrukturalnej rzeźby górskiej (Polskie Karpaty zachodnie)

(7 *fig.*)

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Abstract: This paper presents three morphometric methods applied to the morphostructural analysis of young, block-folded mountains (Dunajec drainage basin, Polish Western Carpathians, as an example). These methods (construction of base level, goniobase and isolong maps) allow for the interpretation of tectonic tendencies within a drainage basin and make possible the delineation of morphostructures subjected to neotectonic movements.

Key words: neotectonics, morphometric methods, morphostructural analysis, Polish western Carpathians, Dunajec river.

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Treść: W pracy omówiono, na przykładzie dorzecza Dunajca, trzy metody morfometryczne analizy rzeźby młodych gór o budowie blokowo-fałdowej, umożliwiające wnioskowanie o tendencjach tektonicznych obszaru. Metody te polegają na konstrukcji map powierzchni bazowych, map goniobaz i map izolong.

INTRODUCTION

Many geologists had described the close connection between the topography and the activity of young crustal movements (Penck 1919, King 1955, Schumm 1963, Louis 1969, Ahnert 1970). They proved that deformations of the earth's crust have many times resulted in the presence of anomalous features within drainage basins (cf. Doornkamp and Temple 1966, Kaitanen 1975). Various morphometric methods applied to the study of young tectonic movements were proposed. Among them are the analyses of hypsographic and clinographic curves (Strahler 1952, Zuchiewicz 1980) and the compilation of superposed profiles (Sparks 1961, King 1966). The maps of relief energy (Thauer 1955), drainage density (Khain and Malinovski 1956), valley gradients (Ivanov 1952), streamline surfaces, summit levels, generalized contours and many others (Dury 1952, Filosofov 1960, Berlant 1965, Shubina and Aristarkhova 1965, Pannekoek 1967, Howard 1973) were also used. For example, Pannekoek (1967) has described the block structure of the Alps and Pyrenees, using maps of generalized contours, summit levels and streamline surfaces.

During the last decade the analysis of trend maps was improved, especially in relation to the study of planation surfaces (Tarrant 1970, Unwin and Lewin 1971, Heikkinen 1975).

For the Slovak Carpathians Mazúr and Mazúrowa (1965) and Kvitkovič (1975, 1978) propose to compile a set of three maps: of the relief energy, the mean gradient angle and the topographical map. In the Polish Carpathians the analysis of summit level maps was carried out by Teisseyre (1928). Ozimkowski (1975) evaluated the size of the neotectonic upheaval of the Podhale region on the basis of comparison of maps of planation surfaces and erosional base levels.

METHODS

This article presents three morphometric methods applied to the analysis of Carpathian morphology. The maps of base levels, goniobases and isolongs of various orders were constructed. All these maps were drawn in the scale of 1 : 100 000.

The aim of this paper is to test a usefulness of these methods in the interpretation of neotectonic structures (morphostructures), which appear within the Dunajec drainage basin (Figs. 1, 2).

B a s e l e v e l m a p s were first applied by Dury (1952) and extensively used in the study of neotectonic features of platforms and young folded mountains by Filosofov (1960, 1970) and Pannekoek (1967). The

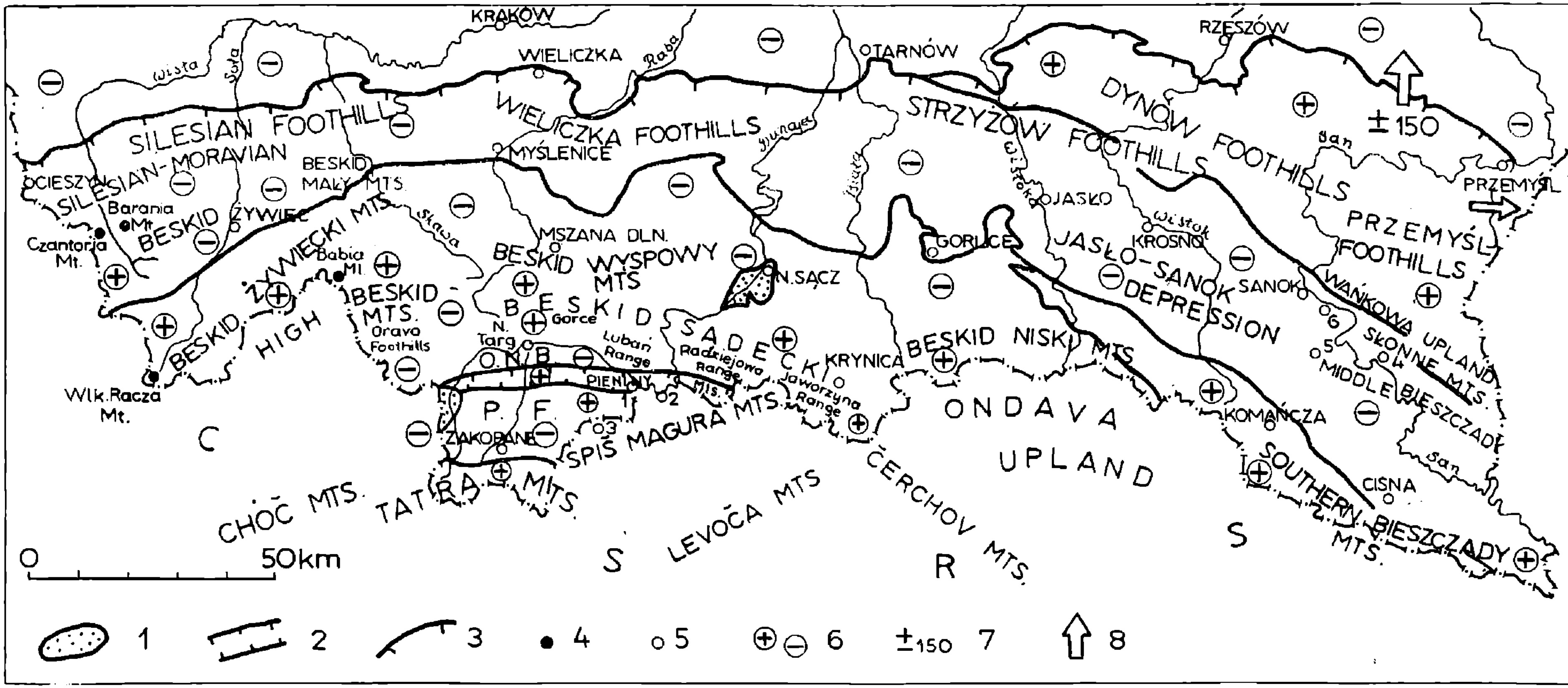
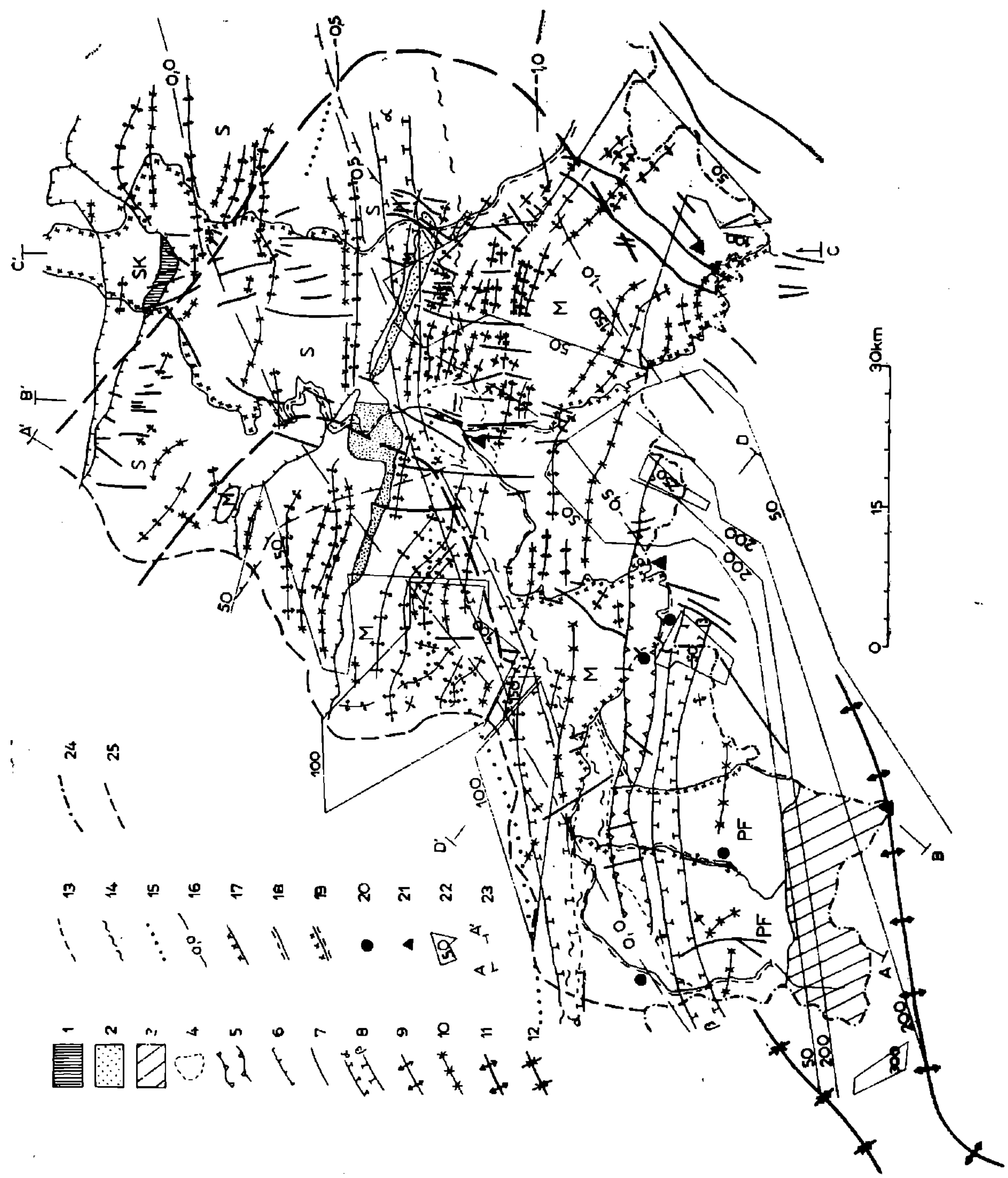


Fig. 1. Orographic sketch of the Polish Carpathians. 1 — Neogene deposits, 2 — Pieniny Klippen Belt, 3 — Carpathian border, 4 — summits, 5 — localities mentioned in the text: 1 — Niedzica, 2 — Spišska Stara Vés, 3 — Oštürna, 4 — Myczkowce, 5 — Tarnawa Górna, 6 — Zagórz. Pleistocene tectonic tendencies (according to Liszkowski 1975 and the author): 6 — relative direction of deformations of earth surface, 7 — absolute value of amplitude of deformations (± denotes differentiated movements of the block type), 8 — zones of inferred deformations related to horizontal mass transfer. O.N.B. — Orava—Nowy Targ Basin, P.F. — Podhale Flysch

Fig. 1. Szkic orograficzny Karpat Polskich. 1 — utwory neogeńskie leżące na Karpatach, 2 — Pieniński Pas Skałkowy, 3 — brzeg nasunięcia karpackiego, 4 — wierzchołki, 5 — miejscowości wymienione w tekście: 1 — Niedzica, 2 — Stara Wieś Spiska, 3 — Ošturna, 4 — Myczkowce, 5 — Tarnawa Górna, 6 — Zagórz. Plejstoceńskie tendencje tektoniczne (wg Liszkowskiego 1975 i autora): 6 — względny kierunek odkształceń powierzchni Ziemi, 7 — bezwzględne wartości amplitud odkształceń (± oznacza zróżnicowane ruchy typu blokowego), 8 — strefy przypuszczalnego występowania odkształceń związanych z poziomym transportem mas. O.N.B. — Kotlina Orawsko-—Nowotarska, P.F. — flisz podhalański



construction of such maps starts from the initial map of valley orders, distinguished according to Horton-Strahler's method. In the next step it is necessary to link the points where particular valley axes are crossed by contours of the same value, using smooth curves (isobases). In a given topographic sketch a series of base level maps has to be

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Fig. 2. Tectonic map of the Dunajec drainage basin (compiled after: Sokołowski 1954, Maška, Matejka and Zoubek 1969, Michalik, Sikora and Ślączka 1964, Mahel 1965, Orkisz, Nickel and Szlachta 1965, Wyrzykowski 1971, Książkiewicz 1972, Pagaczewski 1972, Oszczypko 1973, Ślączka 1975, Sikora 1976, Unrug 1979, Zuchiewicz 1980). M — Magura nappe, SK — Skole nappe, S — Silesian nappe, PF — Podhale Flysch. 1 — Sub-Silesian nappe, External Flysch, 2 — units in the tectonic windows below the Magura nappe, Fore-Magura nappe, 3 — Tatra units, 4 — Neogene sediments lying on the Carpathian Flysch, 5 — Pieniny Klippen Belt, 6 — overthrusts, 7 — fault zones, 8 — deep crustal fractures: α — Pericarpathian (after Sikora 1976), β — Peripieninian, formed in the Cretaceous-Paleogene period (after Maška, Matejka and Zoubek 1960), 9 — axes of anticlines, 10 — axes of synclines, 11 — axes of post-Paleogene meganticlines and meganticlinal horsts, 12 — axes of post-Paleogene megasynclines and brachysynclines, 13 — reconstructed boundary of the Lower Badenian transgression (after Oszczypko 1973), 14 — axes of positive magnetic anomalies, 15 — axis of regional gravimetric minimum, 16 — supposed the Epivariscan platform southern boundary, 17 — isolines of the velocity of recent vertical crustal movements. River-bed stretches showing differences between the topographical and the theoretical profiles: 18 — positive, 19 — negative, 20 — transitional, 21 — epicentres of seismic quakes, 22 — places where seismic quakes coming from unknown epicentres were recorded, 23 — isolines of differences between goniobase lines of the IVth and the Vth order (in metres), 24 — cross-section lines, 25 — state boundary, 26 — drainage basin divide

Fig. 2. Mapa tektoniczna dorzecza Dunajca (opracowana na podstawie: Sokołowski 1954, Maška, Matejka and Zoubek 1960, Michalik, Sikora, Ślączka 1964, Mahel 1965, Orkisz, Nickel, Szlachta 1965, Wyrzykowski 1971, Książkiewicz 1972, Pagaczewski 1972, Oszczypko 1973, Ślączka 1975, Sikora 1976, Unrug 1979, Zuchiewicz 1980). M — płaszczowina magurska, SK — płaszczowina skolska, S — płaszczowina śląska, PF — flisz podhalański. 1 — płaszczowina podśląska, 2 — jednostki okien podmagurskich, 3 — jednostki tatrzańskie, 4 — utwory neogeńskie leżące na Karpatach, 5 — Pieniński Pas Skałkowy, 6 — nasunięcia, 7 — strefy uskokowe, 8 — rozłamy wgłębne: α — Perykarpacki (wg Sikora 1976), β — Perypieniński, utworzony w kredzie i paleogenie (wg Maška, Matejka and Zoubek 1960), 9 — osie antyklin, 10 — osie synklin, 11 — osie postpaleogeńskich megantyklin i megantyklinalnych horstów, 12 — osie postpaleogeńskich megasynklin i brachysynklin, 13 — przypuszczalna granica transgresji dolnobadeńskiej (wg Oszczypko 1973), 14 — osie dodatnich anomalii magnetycznych, 15 — oś regionalnego minimum grawimetrycznego, 16 — przypuszczalna południowa granica platformy epiwaryscyjskiej, 17 — izolinie prędkości współczesnych pionowych ruchów skorupy ziemskiej. Odcinki koryt rzecznych wykazujących następujące wartości różnic między profilem topograficznym a teoretycznym: 18 — ujemne, 19 — dodatnie, 20 — przejściowe, 21 — epicentra wstrząsów sejsmicznych, 22 — miejsca odczucia wstrząsów sejsmicznych o nieznanym epicentrum, 23 — izolinie wartości różnic między goniabazami IV i V rzędu (w metrach), 24 — linie przekrojów, 25 — granica państwa, 26 — dział wodny

drawn. The order of a base level surface is determined by the order of valleys, marked in the initial map. In the base level map of the 2nd order all valleys, except that of the 1st order, are to be drawn. In the map of the 3rd order all valleys, except those of the 1st and 2nd order, have to be marked, etc.

Isobases have to cross valley axes at right angles. They reveal the same features as topographic contours do: they neither cross each other nor pass beneath contours of the same value.

A series of base level maps makes it possible to construct a set of many other maps, e.g. the maps of differences among surfaces of various orders. "Taking away" the base level surface of the "older" order (n) from that of the "younger" one (n-1) it is possible to get a differential map of the n-1 order. This map informs about the size of erosional dissection of a given area during the period which lasted between the formation of these two base level surfaces.

Within uplifted areas valley gradients grow, so the distances among isobases are relatively short. The reverse situation takes place in the case of lowering movements.

Local anticlinal structures are characterized by the short distances among isobases (Filosofov 1970), in which case the pattern of isobases is a chain or a horse-shoe in shape. Within monoclines isobases are straight and parallel.

The Filosofov's method was critisized by Trotsyuk (1967) and Khain (1973). They stated that this method cannot be applied without giving any results obtained by using other geologic-geomorphic methods. According to these authors, the usefulness of Filosofov's method in mountaineous regions of complicated block-folded structure, is questionable.

For investigations of mountaineous morphostructures, the map of goniobases was proposed (Filosofov 1970). In order to draw this map, the points in which valley axes are crossed by contours, would be linked together by straight lines. Such a technique enables to construct the differential maps in a more precise way than in the case of base level maps.

Maps of isolongs (Gvin 1965, 1970) give the possibility of estimating the relation between tectonics and the valley order's growth, quantitatively. On this map isolines of valley lengths are to be marked. Data supported by measurements have to be related to the centres of measured stretches and then linked by smooth curves. The highest values of valley lengths are usually connected with narrow tectonic basins, but the lowest ones characterise tectonic upheavals. The isolong pattern reflects mainly buried uplifted areas. The degree of "concordance" between isolongs and tectonic maps reach the value of 85% (Gvin 1965).

BASE LEVEL MAPS

As the initial map for the interpretation of isobases pattern within the Polish Carpathians, the 4th order map was applied (Fig. 3). This map still reflects lithological differentiation. However, there exist

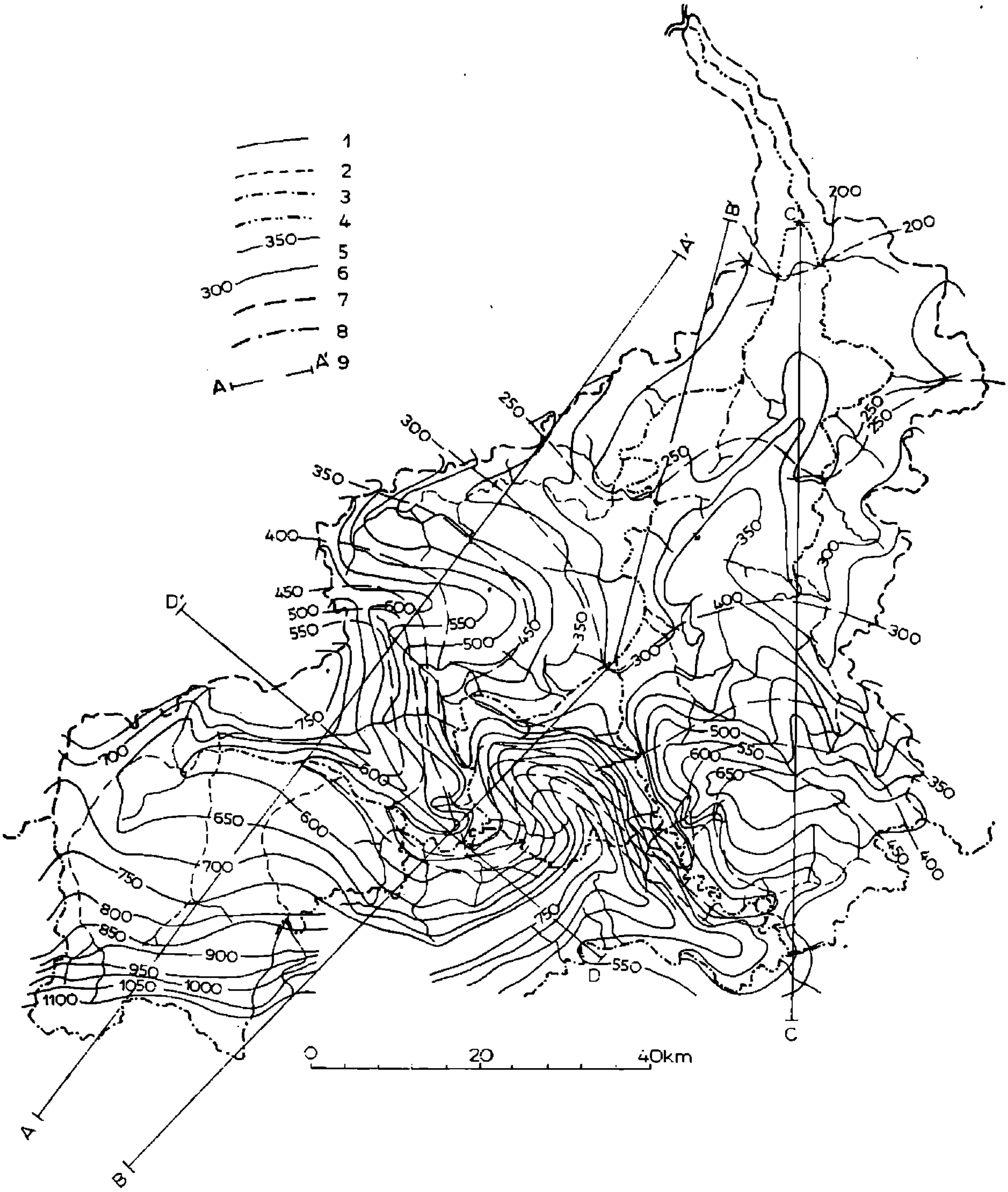

Fig. 3. Base-level map of the Dunajec drainage basin. Valleys of the: 1 — 4th order, 2 — 5th order, 3 — 6th order, 4 — 7th order. Isobases of the: 5 — 4th order, 6 — 6th order, 7 — divides, 8 — state boundary, 9 — cross-section lines
Fig. 3. Mapa izobaz dorzecza Dunajca. Doliny rzędu: 1 — IV, 2 — V, 3 — VI, 4 — VII. Izobazy rzędu: 5 — IV, 6 — VI, 7 — dział wodny, 8 — granice państwa. 9 — przekroje

several areas showing high isobase density. Thic fact may be connected with uplifting tectonic tendencies. The Beskid Żywiecki Mts., Tatra Mts., Pieniny Mts., Gorce Mts., Čerchov-Jaworzyna Range and Bieszczady Mts. belong to such areas (cf. Fig. 1). The Tatra Mts. are very distinctly pronounced. Long distances among particular isobases within several regions can be seen. These are as follows: the Orava—Nowy Targ and Nowy Sącz Basins, filled with thick Neogene—Quaternary sediments, the Vah—Poprad divide, the Jasło—Sanok Depression, the Komańcza—Zagórz and Tarnawa Górna—Myczkowce regions and the northern part of the Dunajec—Biała drainage basins, as well (Fig. 1).

The 5th order maps reveal a slightly different picture. The axes of Silesian and Żywiecki Beskid Mts., the Gorce Mts. and the Spiš Magura — Radziejowa Range are characterised by the highest concentration of isobases. In the Orava—Nowy Targ and Nowy Sącz Basins and in the West Carpathian Foreland this concentration is relatively small. The highly generalised, 6th order map, however, reveals only two regions of strong isobase density: the Beskid Wysoki Mts. and the Lubań—Eastern Pieniny axis.

GONIOBASE MAPS

The comparison of goniobase maps of the 4th, 5th and 6th order allows to distinguish three areas, characterised by a distinct isoline concentration (Fig. 4). These are as follows: the axis of the Beskid Żywiecki Mts., the Gorce Mts. and the Bieszczady Mts. Four regions reveal noticeably long spans among goniobases: the Żywiec and Nowy Sącz Basins, the Jasło—Sanok Depression and the Przemyśl Foothills (cf. Fig. 1).

Among "uplifted" areas, marked in the 4th order maps, the Beskid Mały Mts., the Czantoria — Wielka Racza region, the Choč Mts. and the Spiš Magura — Jaworzyna Ranges deserve to be mentioned. In the 4th and 5th order maps the Tatra Mts. can be seen, in the 5th order maps — the Beskid Niski Mts., in the 5th and 6th order maps — the Słonne Mts. and in the 6th order map only the Lubań — Pieniny axis is distinctly pronounced.

The Orava Foothills and the Orava—Nowy Targ Basin belong to areas of scarce isoline pattern. They are marked in the 4th order maps.

Values of differences between goniobase maps of various orders were calculated (Fig. 5). The highest ones (250—300 metres) are connected with maps of the 4th and 5th order. They reach a value of 350 metres in the Western Tatra Mts. The differences between surfaces of the 5th and 6th order are smaller (50—200 metres). In both cases there is a remarkable decrease in difference values in the Eastern Carpathians. Negative values (—50 metres) appear within two areas: the Ošturna — Niedzica — Spisška Stara Vés region and the Cisna Basin (the Western Bieszczady Mts.).

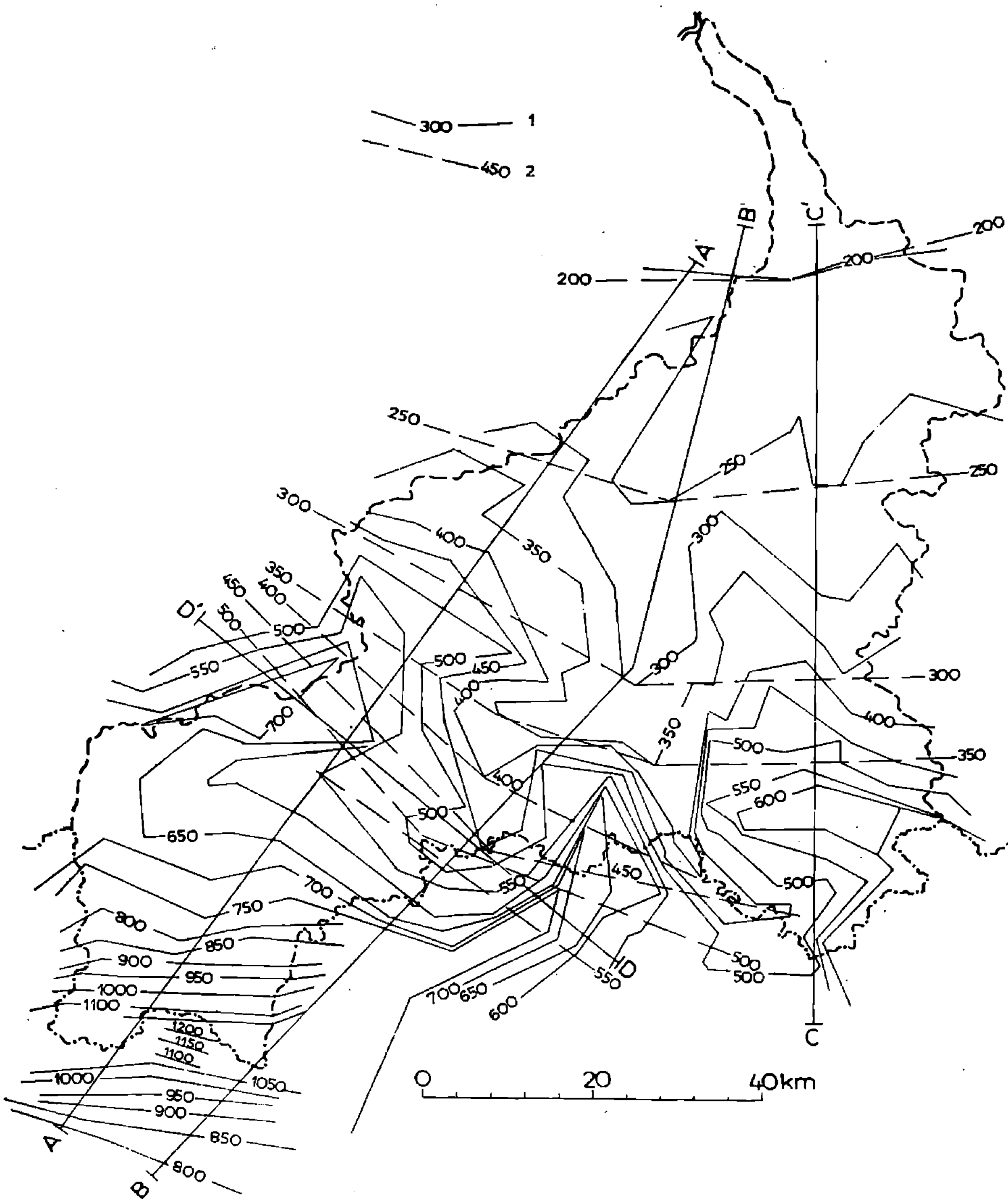

Fig. 4. Goniobase map of the Dunajec drainage basin. Goniobases of the: 1 — 4th order, 2 — 6th order. For other explanations — see Fig. 3

Fig. 4. Mapa goniobaz dorzecza Dunajca. Goniobazy: 1 — IV rzędu, 2 — VI rzędu. Pozostałe objaśnienia — por. fig. 3

The values calculated allow for estimating the total sum of erosional deepening which took place between the formation of the 6th (Pliocene?) and the 4th (Early Quaternary?) order base level surfaces.

This sum reaches the value of 300—400 metres in the Barania Mt. group, 200—400 m in the Babia Mt. region and 100 m within the Wańkowa Upland. The "lowering" of the Niedzica — Spišska Stara Vés

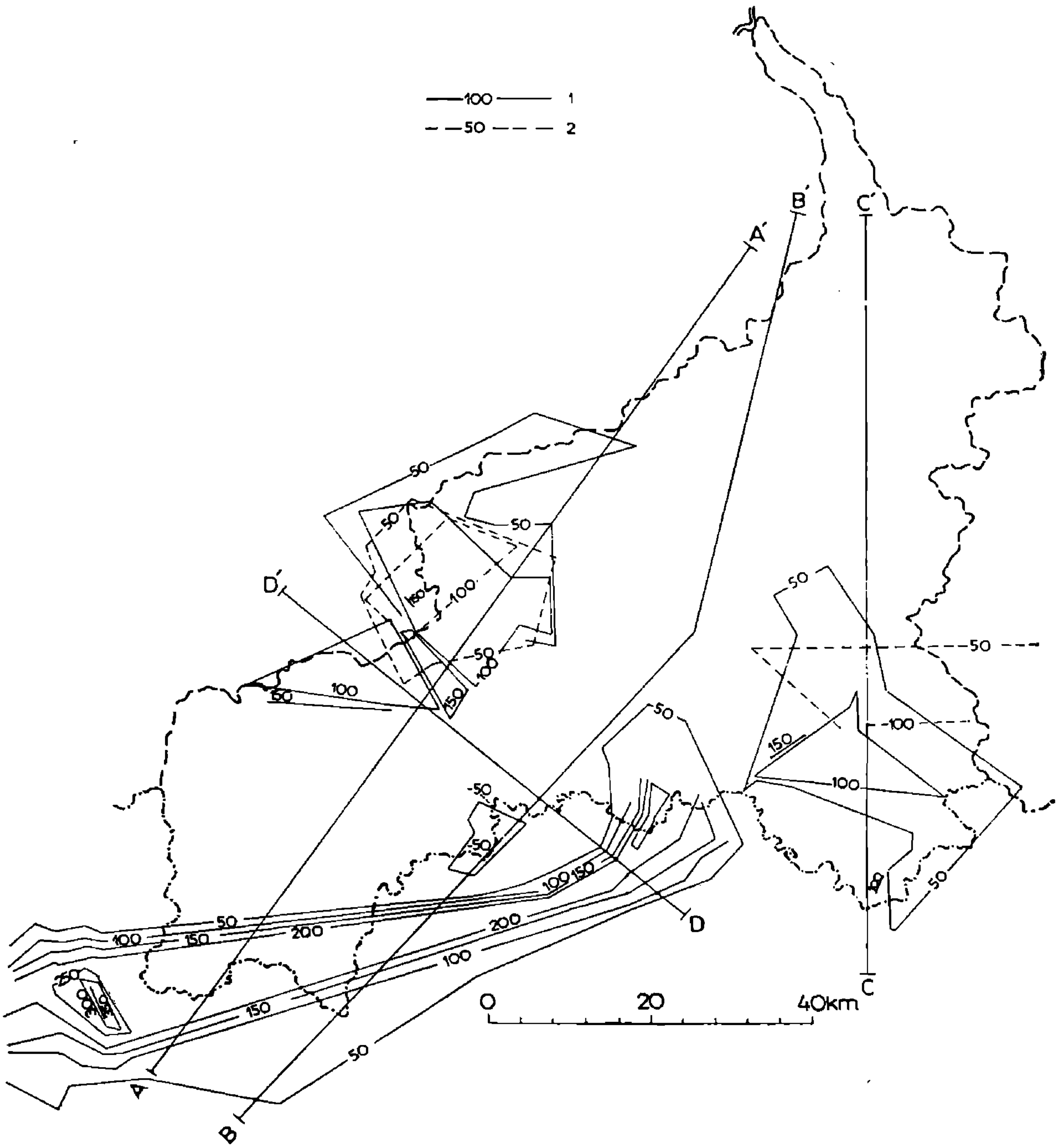

Fig. 5. Map of differences among goniobases of various orders. Isolines of differences between goniobases of the: 1 — 4th and 5th order, 2 — 5th and 6th order. For other explanations — see Fig. 3

Fig. 5. Mapa wartości różnic między goniobazami różnych rzędów. Różnice między goniobazami: 1 — IV i V rzędu, 2 — V i VI rzędu. Pozostałe objaśnienia — por. Fig. 3

area equals 100 metres. Those areas seem to reveal long-term tectonic tendencies.

"Uplifted" areas are marked in the differential maps as longitudinal elevations (the Beskid Żywiecki Mts., the Choč — Tatra — Pieniny Mts., and the Słonne Mts.) or "blocks" (the tectonic window of Mszana, the Western Bieszczady Mts., the Barania Mt. group). The distribution of these regions in the maps of various orders seems to point to a noticeable differentiation of erosion rates and, probably, indicates the presence of young tectonic movements. It can be assumed that the Lubań Range and the Pieniny Mts. have been activitated first.

Within the Dunajec drainage basin a belt of "zero" values of differences among base level surfaces can be seen (Fig. 2). This belt includes the Orava — Nowy Targ Basin, the Podhale region, the Nowy Sącz Basin and the area extending to the north of the southern boundary of the Epivariscan Platform (Ślączka 1975) and the southern boundary of the Lower Badenian sedimentary basin (Oszczypko 1973). It might be connected with lowering tectonic tendencies which are most distinctly pronounced within the Orava — Nowy Targ (Klimaszewski 1965, Książkiewicz 1972) and the Nowy Sącz Basins (Oszczypko 1973). Such tendencies relate to the axes of local positive magnetic anomalies (Orkisz, Nickel and Szlachta 1965). Negative values appear along the SSW—NNE orientated zone, running from Ošturna to Niedzica. This zone lies within the Peripieninian deep crustal fracture (Maška, Matejka and Zoubek 1961, Sikora 1976) and can be linked with the large Niedzica dislocation (Grochocka-Piotrowska 1968). Positive values of differences are connected with the neotectonically uplifted Choč—Tatra, Spiš Magura and Beskid Sądecki Ranges (Lukniš 1959, Starkel 1969, Kopecký 1972, Kvitkovič 1975, Mazúr 1976). These areas can be linked with blocks which were distinguished in the northern Slovakia by Kvitkovič and Plančar (1975). They also correlate with those river-bed stretches, in which the topographical profile runs above the theoretical one (Zuchiewicz 1980). According to Ivanov (1952) such relationships can indicate the presence of young uplifting movements.

ISOLONG MAPS

In the isolong map of the Dunajec drainage basin, isolines of lengths of the 4th and 5th order valleys were drawn (Fig. 6). Isolongs of the 4th order are grouped into several areas which appear within large mountain ranges. The Podhale region, the Tatra Mts., the Gorce Mts., the Lubań and Čerchov—Jaworzyna Ranges and the vicinity of the Dunajec gorge across the Ciężkowice Foothills are characterised by the lowest values (1—5 km) of isolongs. The region of the Ciężkowice Foothills is crossed by a large fault zone (Oszczypko 1973, Unrug 1979). The highest values (15 km) concentrate within the Gorce Mts. and the western part of the Beskid Niski Mts., following the axis of a regional gravimetric minimum (cf. Fig. 2). The highest values of the 5th order isolongs (25—35 km), however, follow the axis of the Orava—Nowy Targ Basin, the Podhale and the SW part of the Dunajec drainage basin.

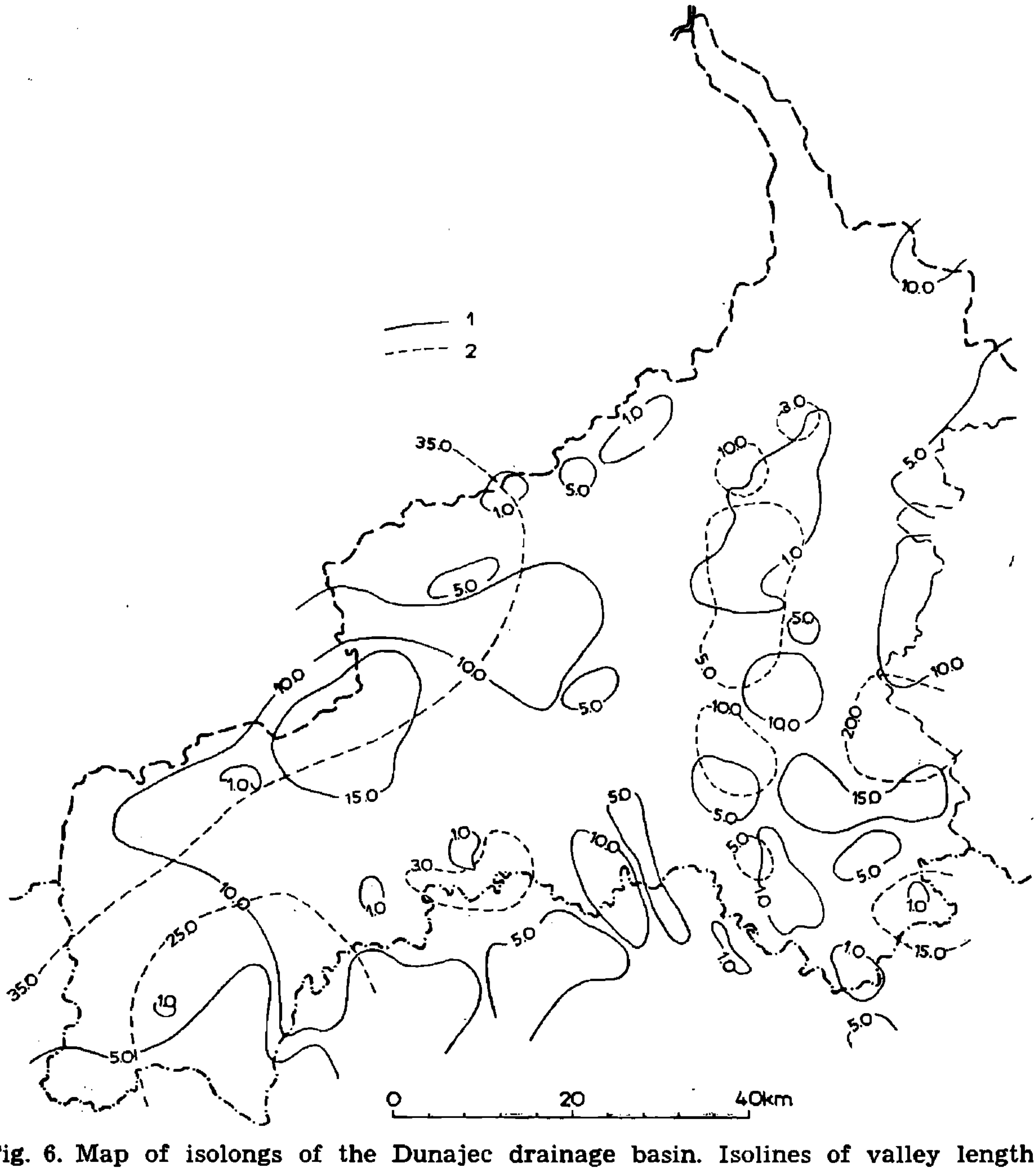

Fig. 6. Map of isolongs of the Dunajec drainage basin. Isolines of valley length: 1 — of the 4th order, 2 — of the 5th order. For other explanations — see Fig. 3
Fig. 6. Mapa izolong dorzecza Dunajca. Izolinie długości dolin: 1 — IV rzędu, 2 — V rzędu. Pozostałe objaśnienia — por. Fig. 3

The lowest ones (3 km) appear in the Pieniny Mts., the northern part of the Jaworzyna Range and the northern Ciężkowice Foothills.

The pattern of isolongs which reveal the lowest values of valley lengths also informs about the distribution of areas subjected to young uplifting movements. The Gubałówka Range, the Pieniny Klippen Belt, the Beskid Sądecki Mts. and the Ciężkowice Foothills are among them.

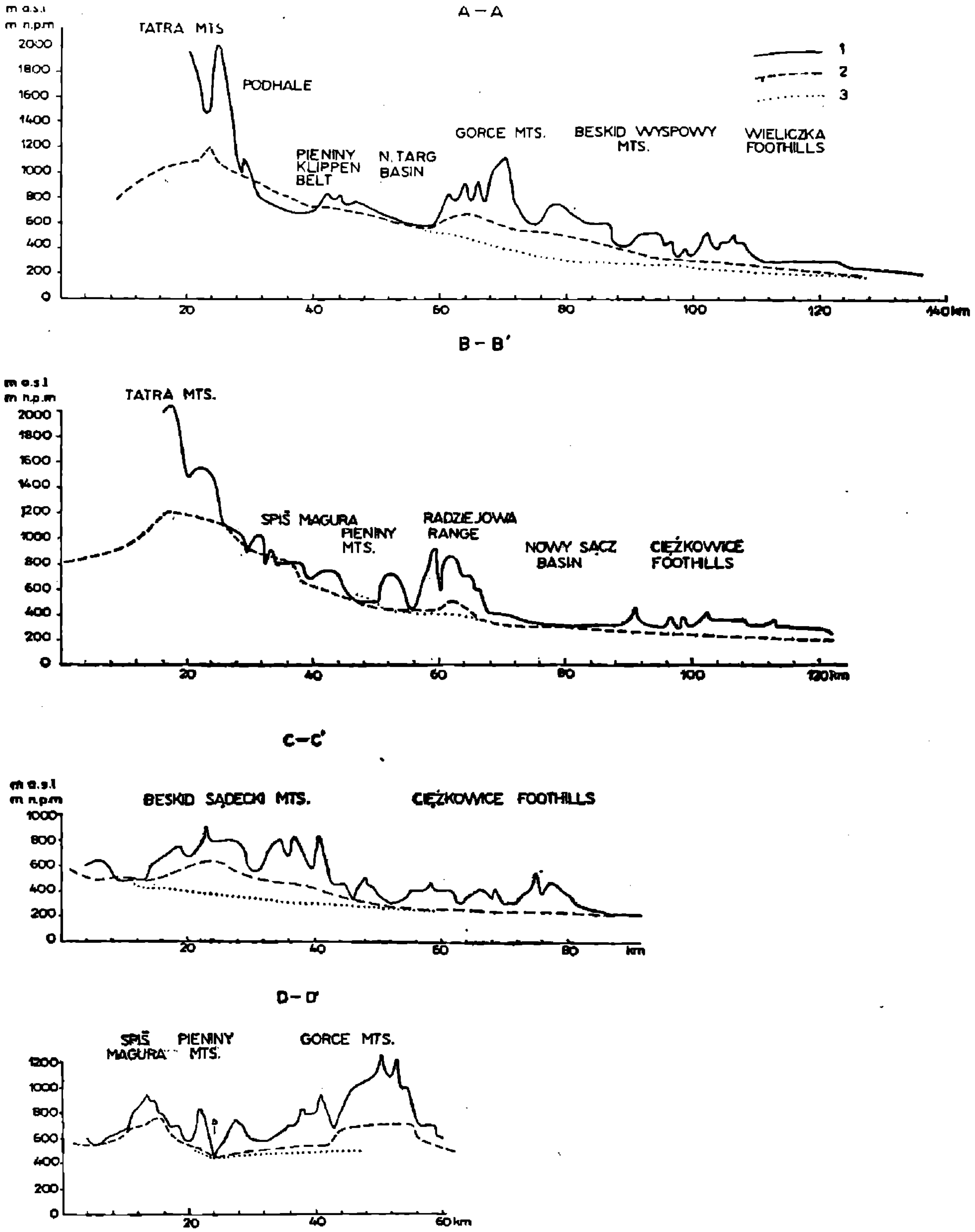

Fig. 7. Cross-sections (cf. Fig. 2). 1 — line of topographical cross-section, 2 — line of the 4th order base surface cross-section, 3 — line of the 6th order base surface cross-section

Fig. 7. Przekroje poprzeczne przez dorzecze Dunajca. 1 — przekrój topograficzny, 2 — przekrój przez powierzchnię bazową IV rzędu, 3 — przekrój przez powierzchnię bazową VI rzędu

In Fig. 7. four cross-sections of the Dunajec drainage basin are shown. They present interrelations among base level surfaces of various orders and the contemporaneous topography. The calculation of denivelations between the present-day topographical surface and the 4th order base level surface (Early Quaternary?) can be made. These values seem to indicate relative tectonic tendencies. The size of dissection is as follows:

the Tatra Mts.	400—900 metres
the Spiš Magura Range	50—100
the Pieniny Mts.	50—250
the Beskid Sądecki Mts.	200—500
the Beskid Wyspowy and the Ciężkowice Foothills	200
the Wieliczka Foothills	50— 80

Negative values characterise the middle part of the Podhale region reaching — 100 metres.

FINAL REMARKS

The review of selected morphometric methods seems to prove their usefulness in the analysis of young, block-folded mountain morphology. These methods allow for the interpretation of those tectonic tendencies, which are reflected in the mountaineous topography and make possible the delineation of various morphostructures.

It seems to be worthwhile to use a whole array of various methods (base level maps, goniobase maps, isolong maps and differential maps) which, in connection with the results obtained by field geologic-geomorphic surveys, can help in detailed paleogeographical reconstructions.

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STRESZCZENIE

Artykuł przedstawia trzy morfometryczne metody analizy rzeźby młodych gór o budowie blokowo-fałdowej (Fig. 1, 2), umożliwiające wnioskowanie o tendencjach tektonicznych obszaru. Metody te polegają na konstrukcji map powierzchni bazowych (Dury 1952, Fiłosofow 1960), map goniobaz (Fiłosofov 1970) oraz map izolong (Gwin 1965). Mapy przedstawiające dorzecze Dunajca wykonano na podkładzie topograficznym w skali 1 : 100 000.

Konstrukcja map izobaz (Fig. 3) opiera się na wykreśleniu łagodnych krzywych łączących punkty przecięcia się osi dolin określonego rzędu (wg klasyfikacji Hortona-Strahlera) z poziomicami o tych samych wartościach. Zagęszczanie się izobaz świadczy o wzroście spadku doliny, a tym samym o tendencjach wypiętrzających. Rozszerzanie się izobaz obserwuje się na obszarach obniżanych.

W podobny sposób wykonuje się mapy goniobaz (Fig. 4). Różnica polega na łączeniu się punktów przecięcia się osi dolin z poziomicami za pomocą linii prostych.

Wykreślenie szeregu map izobaz i goniobaz pozwala obliczyć różnice między powierzchniami różnych rzędów (mapy resztowe — por. Fig. 5), a tym samym — wnioskować o rozmiarach erozji, jaka miała miejsce w okresie pomiędzy formowaniem się badanych powierzchni.

Mapy izolong (Fig. 6) przedstawiają izolinie długości dolin różnych rzędów. Izolinie o najwyższych wartościach okonturowują wąskie zapadliska tektoniczne, izolongi zaś o wartościach najniższych charakteryzują tektoniczne wypiętrzenia.

W obrębie dorzecza Dunajca zerowe wartości różnic pomiędzy izobazami IV, V i VI rzędu charakteryzują Podhale, Kotlinę Orawsko-Nowotarską i Kotlinę Sądecką. Wartości ujemne zaznaczają się pomiędzy Ošturną i Niedzicą, dowiązując do strefy dyslokacyjnej Niedzicy. Najwyższymi wartościami odznaczają się Choč, Tatry, Magura Spiska oraz Beskid Sądecki.

Na mapach izolong, izolinie o najwyższych wartościach (25—35 km) biegną na obrzeżeniach Kotliny Orawsko-Nowotarskiej i Podhala, natomiast izolinie o wartościach najniższych (3 km) charakteryzują Pieniny, Pasmo Jaworzyny Krynickiej i północną część Pogórza Ciężkowickiego.

Na przekrojach poprzecznych przez dorzecze Dunajca (Fig. 7) zaznaczają się wzajemne relacje pomiędzy powierzchniami bazowymi IV i VI rzędu a współczesną powierzchnią topograficzną. Umożliwia to obliczenie rozmiarów erozji (wypiętrzenia?) pomiędzy okresem formowania się powierzchni IV rzędu (wczesny plejstocen?) a najmłodszym holocenem. Najwyższymi wartościami odznaczają się Tatry (400—900 m) oraz Beskid Sądecki (200—500 m). Wartości ujemne zaznaczają się w obrębie środkowego Podhala — 100 m).

Wymienione metody umożliwiają wnioskowanie o młodych tendencjach tektonicznych uwidaczniających się we współczesnej rzeźbie. Stosowanie kompleksu różnych metod morfometrycznych w połączeniu z wynikami terenowych badań geologiczno-geomorfologicznych może być pomocne przy szczegółowych rekonstrukcjach paleograficznych.