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Duplex structures within the Świątkowa Wielka tectonic window (Beskid Niski Mts., Western Carpathians, Poland): structural analysis and photointerpretation

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A tectonic window within the Magura nappe, situated near the village of Świątkowa Wielka in the Western Carpathians, reveals the Grybów unit overthrust in turn on the Dukla nappe. The thrust-sliced folds exposed in the tectonic window make up a classical interthrust contractional duplex. Its origin is related to the presence of a step in the basement beneath the Magura nappe. The Magura nappe is folded and thrust-faulted and cut, together with the Grybów unit by right-lateral strike-slip faults oriented NNW and left-lateral ones, oriented NE and NNE. A part of these faults have been reactivated as dip-slip faults. The differences in the structural directions between the window series and the Magura nappe indicate that folds oriented E–W had originated and have been partly thrust-faulted during the first phase under the influence of the Magura nappe overriding from the south to the north. The first stage was concluded in early Sarmatian time. The second stage involved deceleration of the Magura nappe starting from its front and additional forward movement of the southern part, which changed the direction of its movement to SSW–NNE when it overrode the step in the basement, thus completing the formation of the interthrust contractional duplex. This stage terminated with the formation of the post-thrusting strike-slip faults. During the last stage, at the end of Neogene, the area was subject to post-orogenic uplift and related reactivation of part of the strike-slip faults as dip-slip ones.

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Key words: Western Carpathians, flysch, duplex structures, structural analysis, photointerpretation.

INTRODUCTION

A small tectonic window in the Magura nappe is situated near the village of Świątkowa Wielka in the Western Carpathians (Fig. 1A). It reveals the Grybów unit (M. Książkiewicz, 1972; L. Koszarski, 1985), known also as the Ropa–Pisarzowa unit (H. Kozikowski, 1956; P. Karnkowski, 1963), overthrust on the Dukla unit (H. Kozikowski, 1956; P. Karnkowski, A. Tokarski, 1954) (Fig. 2). Our study is aimed at evaluation of the tectonics and structural evolution of the window.

The Świątkowa Wielka window, apparently discovered only after the World War II, was for many years nearly forgotten. The publications on its geological structure are few and incomplete (H. Kozikowski, 1956, 1958; P. Karnkowski, 1963; L. Koszarski, 1985). The authors have also used archive datafrom four boreholes drilled near Świątkowa Wielka in the first half of the 1950ties (Fig. 2), stored in Central Geological Archive, Polish Geological Institute (CAG PIG) in Warsaw. The only available detailed geological map was the provisional edition of the *Detailed Geological Map of Poland* 1:50 000 (L. Koszarski, A. Tokarski, 1968).

This report is based mainly on the authors' tectonic study in field — recorded on a map 1:10 000 and, to a large extent, on photointerpretation of aerial photographs 1:17 000. Photointerpretation was also helpful in tracing rock bodies of contrasting competence.

The present authors have encountered serious difficulties in this study, due to the great discrepancies in the lithostratigraphic divisions used for the strata exposed in the window. H. Kozikowski (1956) distingushed the Grybów Beds, the

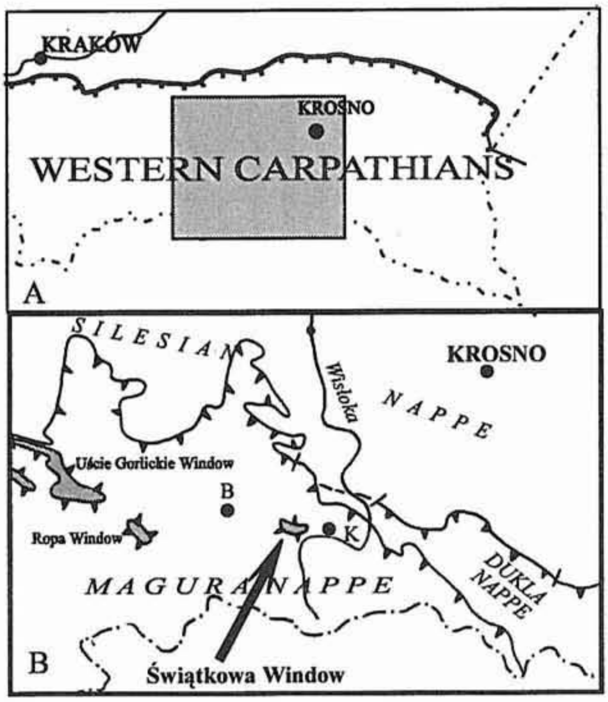

Fig. 1A and B. Location of the study area within the eastern part of the Polish Outer Carpathians
Tectonic windows of Bartne (B) and Kotań (K) are shown in Fig. 1B
Lokalizacja obszaru badań na tle wschodniej części polskich Karpat zewnętrznych
B — okno Bartnego, K — okno Kotania

shale-and-sandstone Krosno Beds and the Krosno Beds with thick-bedded sandstones. P. Karnkowski (1963), similarly as P. Karnkowski and A. Tokarski (1954), found in boreholes the Grybów Beds and the Sub-Grybów Beds, separated by the Variegated Shales. On the map (L. Koszarski, A. Tokarski, 1968) the following strata are shown as one unit: Hieroglyphic Beds, Globigerina Marls, Sub-Cergowa Marls with cherts, Sub-Grybów Marls, unnamed thick-bedded sandstones, Grybów Shales and the overlying shale-and-sandstone Krosno Beds.

The present authors have found, similarly as the earlier authors (H. Kozikowski, 1956; L. Koszarski, A. Tokarski, 1968; L. Koszarski, 1985), various types of exotic limestones near the southern margin of the window. Prof. A. Matyja and A. Drewniak M.Sc. have distinguished two types of these limestones in thin sections of samples provided by us. One is a grainstone with clasts of corals, calcareous algae and algae, probably of Jurassic microfacies. The other is a grainstone consisting of fragmented calcareous algae (red algae), probably of the genus *Litophyllum*. It includes also numerous planktonic foraminifers, probably Cretaceous ones, fill with sediment different from the host sediment. Single, imperfectly preserved specimens of *Heterostegina* have been found in it. There are also quartz and glauconite grains. The limestones are probably Miocene exotics with redeposited Cretaceous foraminifers. If so, the series of shales and sandstones with the exotics would be of Miocene age.

L. Koszarski (1985) accepts also the presence in the Świątkowa Wielka window of the Mszanka, Cergowa nad Krosno-type sandstones. In this situation, the authors were compelled to generalize the existing lithostratigraphic divisions, using the principle of superposition, and combine them, in a tried way (W. Jaroszewski, 1972; L. Mastella, 1988) into greater entities according to their ductility (J. Handin, R. V. Hager, 1957; W. Jaroszewski, 1972).

Four units have been distingushed (from older to younger; Fig. 2):

1 — lower ductile unit — probably composed of the Grybów Beds, Hieroglyphic Beds, Globigerina Beds and Sub-Cergowa Beds;

2 — lower nonductile unit — these are probably Cergowa sandstones or the thick-bedded sandstones marked *pg* by L. Koszarski and A. Tokarski (1968), for instance the sandstones similar to the Mszanka Sandstones reported in this position by L. Koszarski (1985);

3 — upper ductile unit — probably composed mainly of the upper part of the Menilite Beds or Passage Beds and of the shaly Krosno Beds;

4 — upper nonductile unit — which may be equated with the sandstone part of the Krosno Beds.

For the Magura nappe, the authors have accepted the lithostratigraphic division by L. Koszarski and A. Tokarski (1968) which includes the Inoceramian Beds, Variegated Shales, Hieroglyphic Beds and Magura Beds (Fig. 2). The nonductile units include the Inoceramian Beds and the Magura Beds while the Variegated Shales and Hieroglyphic Beds are the ductile units.

TECTONICS

WINDOW (GRYBÓW) UNIT

The Świątkowa Wielka window is ovate in shape, elongated in the east-west direction (Fig. 2A). It is up to 4 km long and up to 1.2 km wide. It is bounded on the north and south by thrusts and on the east and west by faults. The western fault boundary and the southwestern overthrust boundary are uncertain, as they are covered by a large structural landslide. In general, the outline of the window as detailed by us is similar to that hitherto accepted (L. Koszarski, A. Tokarski, 1968).

Internal structure of the thrust slices. The Grybów unit (M. Książkiewicz, 1972) in the window is strongly deformed into thrust sheets. It includes seven slices large enough to be represented on a 1:10 000 map. Most of them extend for about 3 km, and the widths of their outcrops attain 370 m (Fig. 2). The thrust slices situated close to the Magura unit overthrust are smaller and in many places additionally sliced internally.

The strata within the slices are mostly overturned with attitude 110/54S. The strata with gentler dips towards the south and north are mostly in normal position. The regional structural axis within the window, determined from bedding, is oriented 110/8W (Fig. 3-**O**). The strike of the slices is forced by the strikes of their thrust surfaces. Strikes of the slices

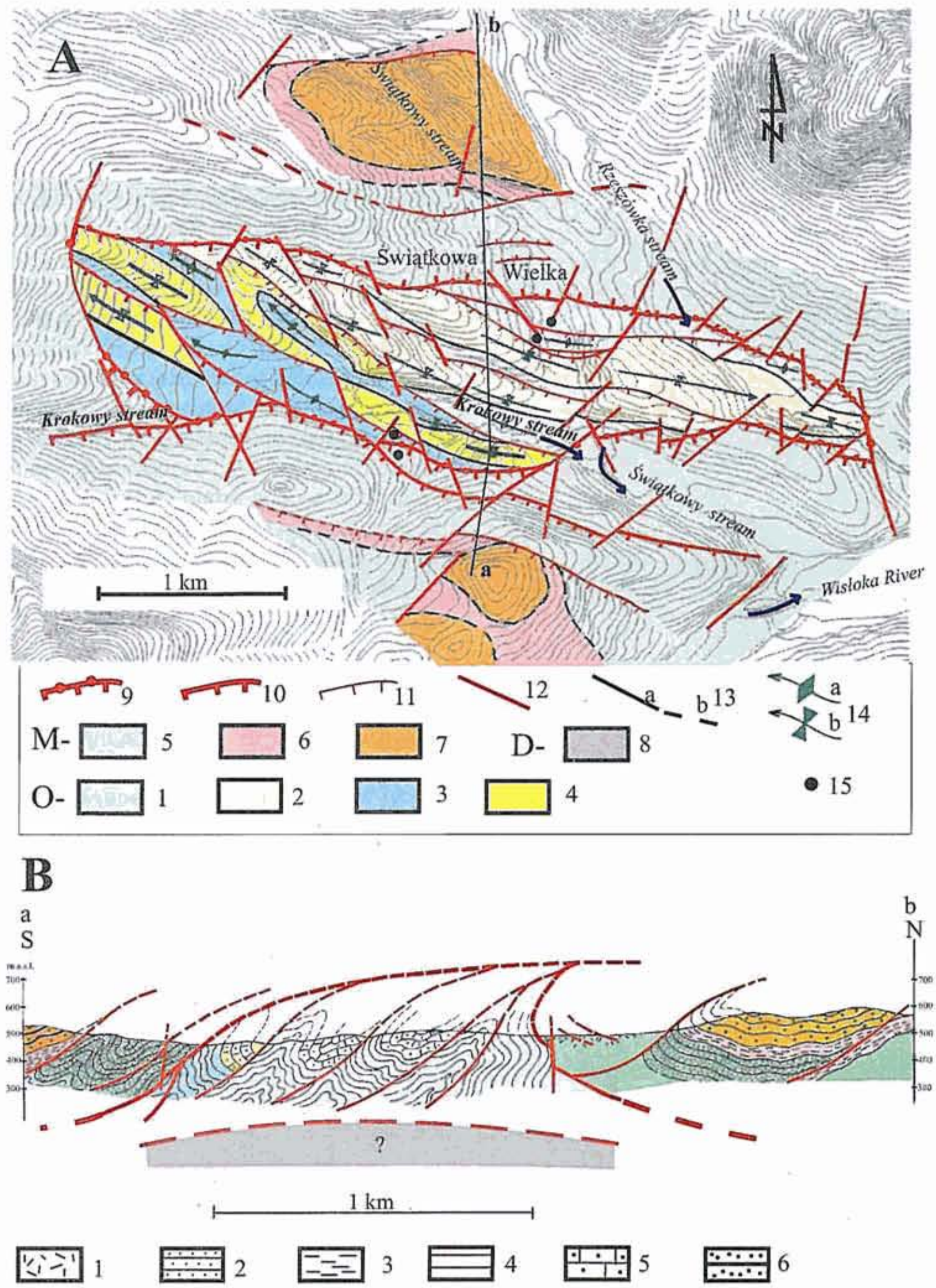

Fig. 2 A. Tectonic map of the Świątkowa Wielka window

O — Grybów (window) unit, lithological (competence) divisions: older: 1 — ductile, 2 — nonductile; younger: 3 — ductile, 4 — nonductile; **M** — Magura nappe, lithostratigraphic units (after L. Koszarski and A. Tokarski, 1968): 5 — Inoceramian (Ropianka) Beds, 6 — Variegated Shales, 7 — Magura Beds; **D** — Dukla nappe(?): 8 — undivided; thrust faults: 9 — of the Magura nappe, 10 — of the 1st order thrust slices, 11 — of the 2nd order thrust slices; 12 — faults; 13 — boundaries of competence units and lithostratigraphical divisions: a — proven, b — supposed; 14 — fold axes: a — of anticlines, b — of synclines (arrows show the direction of their plunge); 15 — location of boreholes; a–b — line of geological cross-section

B. Geological cross-section through the Świątkowa Wielka window (location on Fig. 2A)

1 — cataclasites, 2 — thin-bedded sandstones, 3 — variegated clayey shales, 4 — clayey shales of ductile units, 5 — medium- and thick-bedded sandstones of nonductile units, 6 — thick-bedded sandstones; explanations of colours in Fig. 2A

A. Mapa tektoniczna okna Świątkowej Wielkiej

O — jednostka grybowska (okienna), kompleksy litologiczne (podatnościowe): starsze: 1 — podatny, 2 — niepodatny; młodsze: 3 — podatny, 4 — niepodatny; **M** — płaszczowina magurska, ogniwa litostratygraficzne (według L. Koszarskiego i A. Tokarskiego, 1968): 5 — warstwy inoceramowe (ropianieckie), 6 — łupki pstre, 7 — łupki magurskie; **D** — jednostka dukielska(?): 8 — nierozdzielona; nasunięcia: 9 — płaszczowiny magurskiej, 10 — złuskowań I rzędu, 11 — złuskowań II rzędu; 12 — uskoki; 13 — granice kompleksów podatnościowych i ogniw litostratygraficznych: a — pewne, b — przypuszczalne; 14 — osie fałdów: a — antyklin, b — synklin (strzałką oznaczono kierunek ich zanurzania się); 15 — lokalizacja wierceń; a–b — linia przekroju geologicznego

B. Przekrój geologiczny przez okno Świątkowej Wielkiej (lokalizacja na fig. 2A)

1 — kataklazyty, 2 — piaskowce cienkoławicowe, 3 — łupki ilaste, pstre, 4 — łupki ilaste kompleksów podatnych, 5 — piaskowce średnio- i gruboławicowe kompleksów niepodatnych, 6 — piaskowce gruboławicowe; objaśnienia kolorów jak na fig. 2A

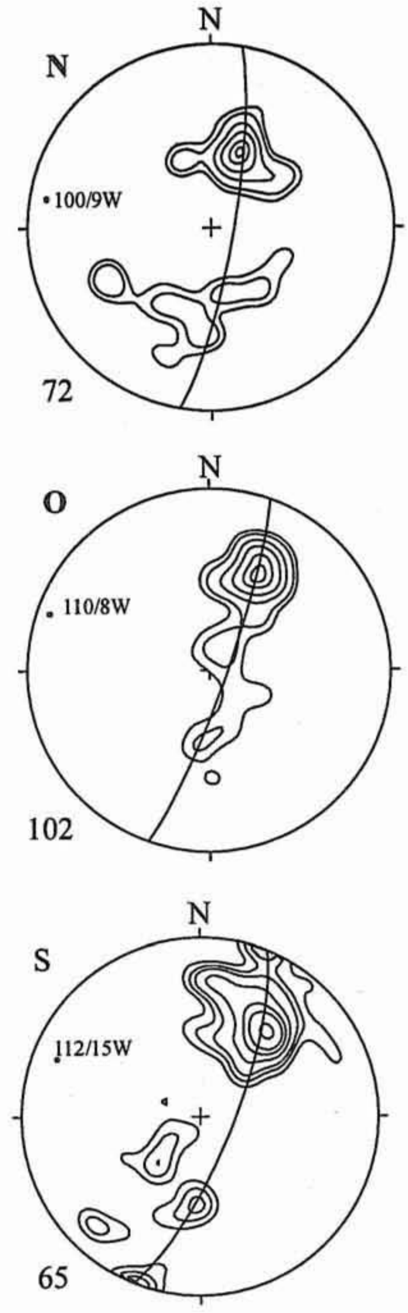

Fig. 3. Diagrams of bedding in the window unit (**O**) and in the Magura nappe in its northern (**N**) and southern (**S**) parts

Projection of poles to beds onto the lower hemisphere; contours at 2–4–6–8–12–16–20%; the number in the lower left shows the number of measurements

Diagramy położenia warstw w jednostce okiennej (**O**) oraz w części północnej (**N**) i południowej (**S**) płaszczowiny magurskiej

Projekcja na dolną półkulę normalnych do płaszczyzny warstwy; izolinie poprowadzono co 2–4–6–8–12–16–20%; liczba w lewym dolnym rogu oznacza ilość pomiarów

change from 105° in the northern part of the window to ca. 125° near the southern boundary (Fig. 2A).

Strata within the slices are usually folded into overturned folds with northerly vergence. In the central part of the window the folds are synclines with nonductile sandstones in their cores, and near the margins there are anticlines built of ductile shaly layers (Fig. 2). The interlimb of the folds are about 50° which indicates an advanced stage of their tectonic development (J. G. Ramsay, 1974). Most folds in the N and NE parts of the window have azimuths of their axes 105° (Fig. 4) and attitudes of their axial planes 105/45S, while in the SW part of the window there occurs a set of folds with axes striking at 125° (Figs. 2A and 4). The axes of these folds in the central and eastern part of the window plunge gently towards SE, and in the western part towards NW (Fig. 2A).

The lower-rank folds observed in the window are flexural-slip folds. Their position with respect to the higher-rank structures (folds and thrusts) indicates that they originated as drag folds (Fig. 5). Similarly as in the higher-rank folds, there are two groups of them (Fig. 4). The first group (f_F), with axis azimuths around 105°, occurs mainly within the thrust-sliced folds. The second group (f_N) with axis azimuths 115–125° accompanies, especially near the southern margin of the window, the thrust faults which separate individual thrust slices and the Magura nappe basal thrust.

The thrust faults which separate the thrust slices are well visible in outcrops and on air photographs. In those outcrops where they cut through shaly layers they are manifest as thin, about 1 m, zones of cataclasis consisting of distinctive grayish-blue clayey mass. The mass includes angular sandstone fragments, rarely exceeding 5 mm in size. Breccias occur where the thrusts cut through sandstone layers.

Below and above these thrust faults there occur numerous, often multiple slickensides, boudins, small faults and cleavage (Figs. 5 and 6). Small faults are usually low-angle Riedel shears R and R_1' shears (Figs. 5 and 6) (W. L. Bartlett *et al.*, 1981; L. B. Harris, P. L. Cobbold, 1985), originating when

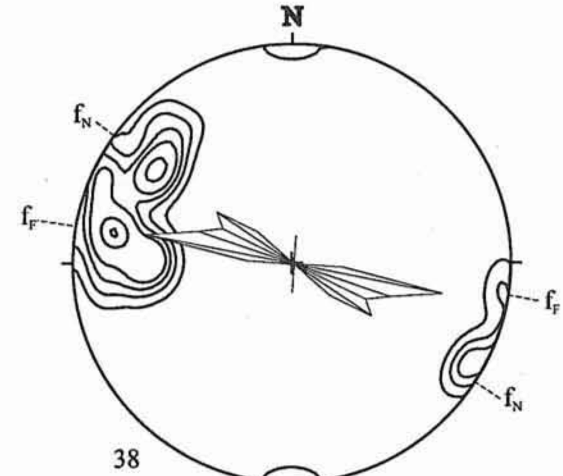

Fig. 4. Contour diagram of mezoscale fold axes orientation (f_N — adjacent to thrusts, f_F — within the slices) and rose diagram of fold axes of the folds within the Świątkowa Wielka window representable at a scale 1:10 000; other explanations as in Fig. 3

Diagram konturowy położenia osi mezofałdów (f_N — przynasunięciowych, f_F — w obrębie łusek) oraz rozeta kierunków osi fałdów o rozmiarach kartometrycznych w oknie Świątkowej Wielkiej; pozostałe objaśnienia jak na fig. 3

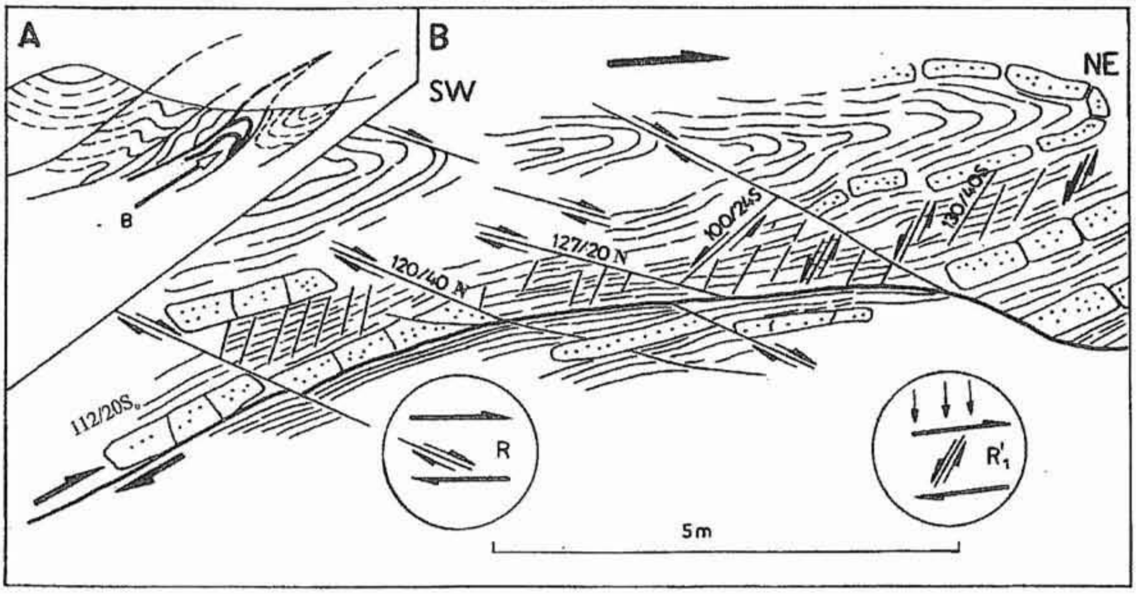

Fig. 5A. Location scheme of a small-scale fold (A) within a higher-rank structure
B. Recumbent fold, with small-scale faults and cleavage and schemes (in circles) explaining the machanics of their formation; exposure in the southern bank of the Krokowy stream, ca. 1 km from its confluence with the Świątkowy stream

A. Schemat lokalizacyjny fałdku (A) w obrębie struktury wyższego rzędu
B. Fałd obalony, z drobnymi uskokami i kliważem i schematami (w kółkach) wyjaśniającymi mechanizm ich powstania; odsłonięcie w południowym brzegu potoku Krokowego około 1 km od jego ujścia

the strata subject to faulting or folding have no or have only limited possibility to expand in the direction of their thickness (P. Vialon, 1979; J. F. Gamond, A. Giraud, 1982). The R and P shears are accompanied by small faults and R_1' cleavage (W. Jaroszewski, 1972; L. Mastella, 1988) (Figs. 5 and 6), which could have originated under a significant load as is suggested by theoretical considerations (W. Jaroszewski, 1972; M. V. Gzowski, 1975), corroborated by field observations (L. Mastella, 1988).

The strikes of the thrust-fault planes, as determined from the shapes of their surface traces, change from ca. 105° in the northern part of the window to ca. 125° near its southern margin, with the 110° strike dominant (Fig. 7). This is a result of discordant thrusting of successive scales on one another (Fig. 2A). Additionally, the thrust faults that separate the slices truncate diagonally folds within the slices. This is a consequence of a small but clear difference between the

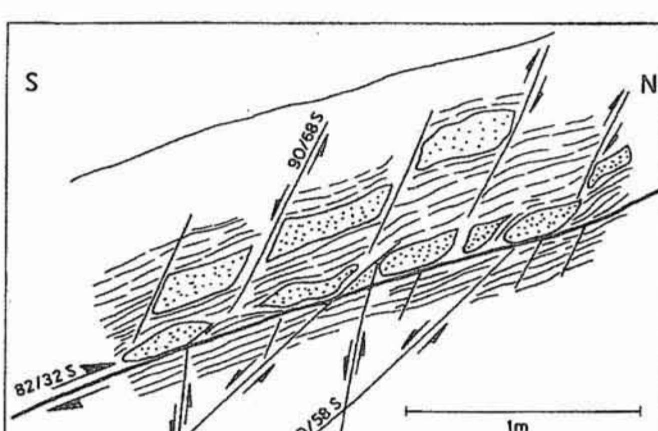

Fig. 6. Small shears and boudins in an exposure in the Świątkowy stream in the central part of the Świątkowa Wielka village

Drobne ścięcia i zbudinowania w odsłonięciu w potoku Świątkowym w środkowej części Świątkowej Wielkiej

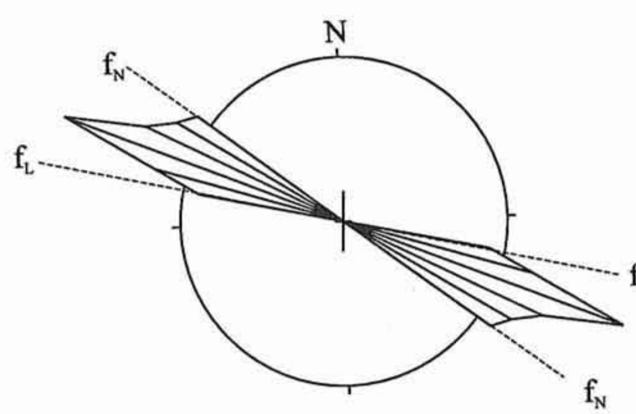

Fig. 7. Rose diagram of strikes of thrust slice surfaces in the Świątkowa Wielka tectonic window
Dashed lines mark the dominant directions of axes of the folds representable at a scale 1:10 000 from Fig. 4; other explanations as in Fig. 4

Rozeta biegów powierzchni złuskowań w oknie tektonicznym Świątkowej Wielkiej

Liniami przerywanymi zaznaczono dominujące kierunki osi fałdów o wielkości kartometrycznej z fig. 4; pozostałe objaśnienia jak na fig. 4

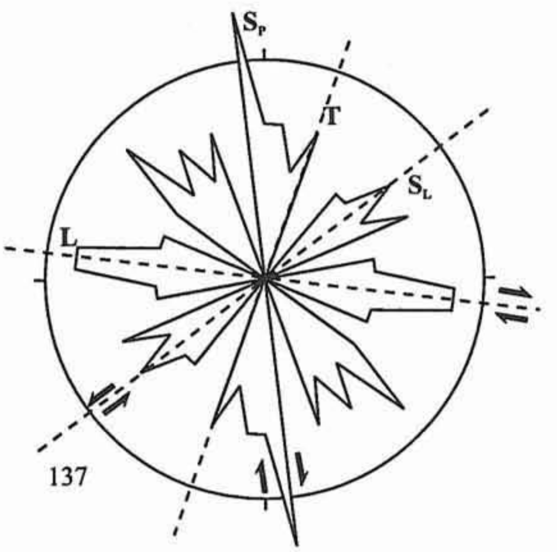

Fig. 8. Rose diagram of strikes of small strike-slip faults in the window unit
Arrows show dominant sense of movement along individual sets; symbols explained in text

Rozeta biegów drobnych uskoków przesuwczych w jednostce okiennej
Strzałkami zaznaczono dominujące zwroty przemieszczeń wzdłuż poszczególnych zespołów; objaśnienia symboli w tekście

dominating strikes of the thrust faults and the strikes of the fold axes (Figs. 4 and 7).

The dips of the thrust faults are very variable, even along each single surface. Generally, the analysis of their surface traces indicates that there is a trend to reduce the angle upwards, towards the overthrust of the Magura nappe (Fig. 2B). The analysis of the zones of breccias and cataclasites that occur in boreholes (P. Karnkowski, A. Tokarski, 1954) indicates that the thrust planes separating the slices become more gentle with depth, towards the basal thrust over the Dukla unit. Consequently, individual slices are sigmoidal in cross-section (Fig. 2B).

As a result, imbricated slices within the window form a classical contractional interthrust duplex (S. E. Boyer, D. Elliot, 1982; S. Mitra, 1986; N. J. Price, J. W. Cosgrove, 1991) (Fig. 2B). The fragment of the Grybów unit, deformed into a duplex and exposed from beneath the Magura nappe, is about 500 m thick, according to this interpretation of its structure. It has been tectonically shortened at least by half.

The reason for the so strong duplex shortening was probably a step in the basement of the Magura nappe, which served as a ramp. The step was probably of a more extensive nature as is indicated by the presence of a series of tectonic windows lying in prolongation of the Świątkowa Wielka tectonic window along its strike, including two near Kotań and Bartne (Fig. 1B) discovered recently by the team L. Kopciowski, L. Jankowski and Z. Zimnoch who are mapping sheet Osiek of the *Detailed Geological Map of Poland* 1:50 000 (L. Kopciowski, pers. comm.).

Small faults. Many strata within the window are cut by shears (Fig. 8) of decimetric length, with steep, usually slickensided surfaces. The direction and sense of the movement on them can be measuered thanks to the presence of tectoglyphs on their surfaces. The shears are mostly strike-slip faults and the displacement on them rarely exceeds 20 cm. They occur in local clusters, especially in the southern part of the window, near the higher-rank thrusts and faults.

The network of these small faults consists of five sets (Fig. 8). The $\mathbf{S_L}$ set with azimuth of ca. 60° is left-lateral. It is usually accompanied by less well developed right-lateral shears of the $\mathbf{S_P}$ set, with azimuth ca. 175°. These two sets intersect at ca. 65° and they probably form a conjugate system of shears originated in a stress field with horizontal axis of δ_1 oriented SSW–NNE. The senses of the shear set $\mathbf{T_o}$, with azimuth ca. 18° are both left-lateral and right-lateral. The origin of the **T** set of shears is not quite clear. The shears could have originated in alternation as complementary to the sets $\mathbf{S_L}$ and $\mathbf{S_P}$ when the values of δ_3 were negative due to uplift, which gave rise to the sets of shears with smaller shear angles.

The small faults of a nearly east-west trending shear set **L**, similarly as the few east-west trending higher-rank strike-slip faults are all right-lateral (Fig. 8). They might be related to the regional right-lateral rotation of this area (R. Unrug, 1980; C. Tomek, 1988). The origin of the 130–155° set is unclear. It is probably related to the processes of the Magura nappe overthrusting, as it is found mostly near its basal thrust.

Joints. In contrast to the small faults, the network of joints is regular and uniform over the whole area of the window. It consists of four joint sets with dominant directions: 30, 145, 100, 180° (Fig. 9). Taking into account the accepted terminology (L. Mastella *et al.*, 1997), two older shear sets have been distinguished: a right-lateral one $\mathbf{D_1}$ with azimuth 30° and a left-lateral one — $\mathbf{D_2}$ with azimuth 145°, forming a system of conjugate shears, intersecting at an angle of ca. 65°. The system originated under a horizontal, nearly meridional orientation of δ_1, the same as the direction of the **T** transversal set with azimuth 180°. The longitudinal set **L** with azimuth ca. 100°, coincides with the strikes of strata in the window (Fig. 9-**O**).

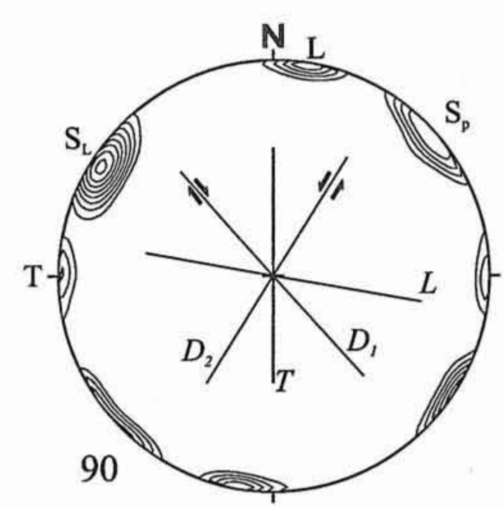

Fig. 9. Contour diagram of joint sets and joint directions in the window unit
Symbols explained in text; other explanations as in Figs. 3 and 8

Diagram konturowy zespołów ciosu i kierunki ciosu w jednostce okiennej
Objaśnienia symboli w tekście; pozostałe objaśnienia jak na fig. 3 i 8

MAGURA NAPPE

Only a narrow zone of the Magura nappe, adjacent to the window, has been studied by the authors (Fig. 2). The Magura nappe in this area is thrust over a flat surface on various elements of the Silesian, Dukla and Grybów units (*op. cit.*) (Fig. 2B). Its structure in this area is simple.

To the north of the window the Magura nappe is gently folded. A broad syncline is present here, built of gently dipping beds (Fig. 3-**N**), whose southern limb is dissected into thrust sheets and locally steepened along lower-rank thrusts (Fig. 2B). Generalized orientation of the syncline axis is 100/9W (Fig. 3-**N**) with a tendency to gentle plunging westward in the western part and eastward in the eastern part. Similarly oriented, with azimuth ca. 95°, are thrusts surfaces (Fig. 10) and axes of the few mezoscale folds present there.

On the southern side of the window, the Magura nappe consists of several piled up and internally folded thrust slices, so that the basal parts of the nappe are more intensively dissected by the thrusts. Folds in the thrust slices are reclined or overturned northward (Fig. 2B). Strata in normal position with attitude 128/51S prevail in their southern limbs, while in the steep northern limbs, dipping generally to the south, the strata are overturned (Figs. 2B and 3-**S**). Generalized orientation of the axes of these folds is 112/15W (Fig. 3-**S**). The strikes of the thrust surfaces that separate the thrust slices are oriented alike (Fig. 10). The attitudes of axes of mezoscale folds are different — their azimuths fall within the range 110–135° and the axes plunge eastward; the azimuth values are lower in the lower parts of the nappe and higher in the upper parts.

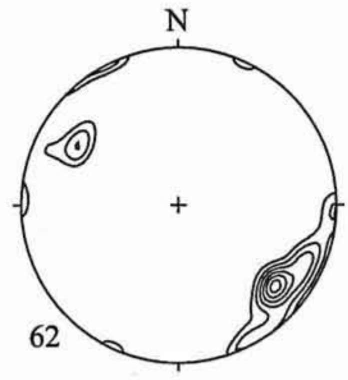

Fig. 11. Contour diagram of orientation of mezoscale folds in the southern part of the Magura nappe
Explanations as in Fig. 3

Diagram konturowy położenia osi mezofałdów w południowej części płaszczowiny magurskiej
Objaśnienia jak na fig. 3

FAULTS

The traces of large faults were determined by photointerpretation and confirmed in outcrops (Fig. 2A). The positions of faults are marked on slopes by dry narrow gullies in which breccias and cataclasites are exposed. On hilltops the fault zones are manifest as small depressions and shifts of hill axes. The faults are clearly cutting through both, the window series and the Magura nappe (Fig. 2A), which clearly indicates that they postdate the overthrusting of the Magura nappe. In outcrops they are visible as zones of breccias, cataclasites, concentrations of lower-rank faults and the presence of intensely folded shales and broken sandstone beds. A typical outcrop of such a large fault that cuts through the whole tectonic window and the Magura nappe is situated in the Świątkowy stream slightly above its confluence with the Krokowy stream (Fig. 2A).

The described network of faults consists generally of two sets oriented NNW–SSE (**U$_p$**) and NE–SW (**U$_l$**) (Figs. 2A and

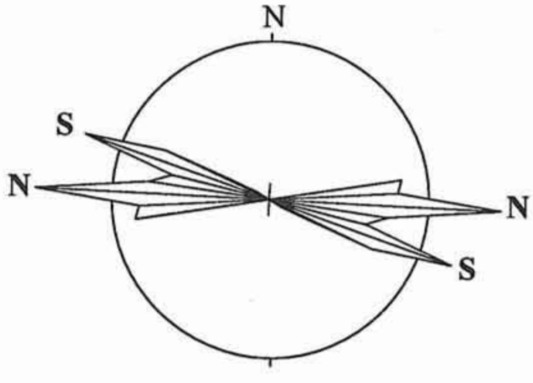

Fig. 10. Rose diagram of strikes of thrust slices in the northern (N) and southern (S) parts of the Magura nappe

Rozeta biegów powierzchni złuskowań w północnej (N) i południowej (S) części płaszczowiny magurskiej

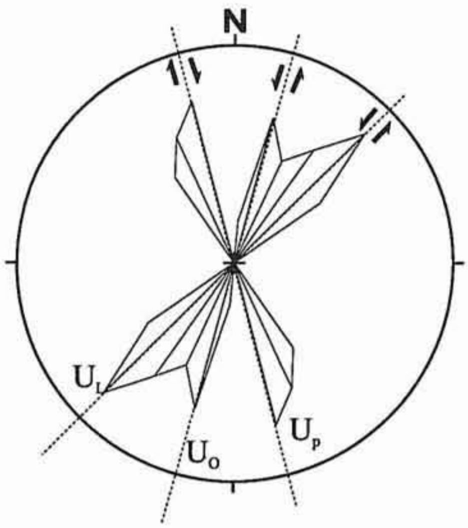

Fig. 12. Rose diagram of orientation of the faults representable at a scale 1:10 000 within the Świątkowa Wielka tectonic window and its margin
Symbols explained in text; other explanations as in Fig. 8

Rozeta kierunków uskoków o rozmiarach kartometrycznych w oknie tektonicznym Świątkowej Wielkiej i jego obrzeżeniu
Objaśnienia symboli w tekście; pozostałe objaśnienia jak na fig. 8

12). The faults of a subordinate set U_0, oriented NNE–SSW, occur as splay faults oriented NE–SW (U_1). Data from outcrops, shifts of surface contours of folds along the discussed faults and the *en echelon* arrangement of lower-rank faults within fault zones (Fig. 2A), all indicate that the faults are strike-slip and oblique-slip faults with the strike-slip component predominant. The criteria listed above indicate that nearly all NNW–SSE oriented faults are right-lateral, while many NE–SW and NNE–SSW oriented ones are left-lateral. As the angle between the NNW–SSE faults and the NE–SW faults is ca. 60°, they may be regarded as conjugate shears created simultaneously in a stress field with δ_1 ca. 16°. This conclusion is somewhat weakened by the fact that a small part of the discussed left-lateral faults shows evidence of earlier right-lateral movement.

Additionally, the faults with both dominant directions were reactivated by vertical movements after the strike-slip phase. In most cases the eastern limbs are downthrown in the eastern part of the study area, and western ones in the western part. So the central parts of the window were uplifted along these faults.

CONCLUSIONS

The hitherto poorly known structure of the tectonic window of Świątkowa appeared to be a classical contractional inter-thrust duplex developed above the Dukla nappe and beneath the Magura nappe. It consists of seven major horses a few hundred metres wide and up to 3 km long. The horses are internally folded, with lower-rank thrusts, especially close to the Magura nappe overthrust.

The strong folding and thrusting within the window and the consequent significant shortening of the strata in cross-section, all may indicate that the structure was formed above a step in the basement beneath the Magura nappe, during the overthrusting of the latter. The step was of regional extent as is suggested by the existence of tectonic windows along the strike of the Świątkowa window.

Two clearly different directions of axes of large folds, lower-rank folds, thrust surfaces and small-scale shears occur within the window. One group, comprising those striking ca. 100° dominate in the northern part of the window, while the other — striking ca. 120° — in the southern part. Similarly in the Magura nappe, the structural grain in its northern part is almost exclusively ca. 100°, while both directions occur together in the southern part. This indicates that the structures in the tectonic window and in the Magura nappe formed in close relationship in two stages.

The first stage consisted in the formation, under the influence of the Magura nappe overriding from the south to the north, of folds striking approximately E–W in the Magura nappe itself as well as in the window unit. Late in this stage folds in the window unit were partly cut by thrust faults.

In the second stage, the Magura nappe was progressively slowing down, starting from the front. The southern part, pushed against the step in its basement caused the formation of new and reactivation of older thrust slices, creating in this way a typical contractional interthrust duplex within the window series. A gradual change in the direction of thrusting resulted in reorientation of some of the existing thrust slices, and formation of new ones, extending approximately NWW–SEE. This stage terminated in creation of a network of small strike-slip faults, which were then turned into greater strike-slip faults by cumulation of movement. These faults were created under a constantly oriented horizontal compression oriented SSW–NNE. This marked the final phase of horizontal push, similarly as in the Mszana Dolna tectonic window (L. Mastella, 1988). The fact that these faults cut through both, the window unit and the Magura nappe, proves that they formed after the thrusting had ceased.

During the final stage of the tectonic evolution of this area, a part of the original strike-slip faults were reactivated as normal faults, thus recording the phase of postorogenic uplift.

The age of the termination of the processes related to the first stage can be referred to the early Sarmatian, by reference to the data by other authors (N. Oszczypko, A. Tomaś, 1985; M. Cieszkowski *et al.*, 1992). According to M. Cieszkowski *et al.* (1989), the Magura nappe was additionally thrusted after the early Sarmatian, which could correspond to our second stage. The postorogenic uplift of the area is related to terminal Neogene time (M. Cieszkowski *et al.*, 1992).

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REFERENCES

BARTLETT W. L., FRIEDMAN M., LOGAN J. M. (1981) — Experimental folding and faulting of rocks in limestone layers. Tectonophysics, **78**, p. 255–277.

BOYER S. E., ELLIOT D. (1982) — Thrust systems. Bull. Am. Ass. Petrol. Geol., **66**, p. 1196–1230.

CIESZKOWSKI M., GONERA. M., OSZCZYPKO N., ŚLĘZAK J., ZUCHIEWICZ W. (1988) — Lithostratigraphy and age of Upper Miocene deposits at Iwkowa, Polish West Carpathians. Bull. Pol. Acad. Sci., Earth Sci., **36**, p. 309–329, no. 3–4.

CIESZKOWSKI M., OSZCZYPKO N., ZUCHIEWICZ W. (1992) — Tektonika środkowej części płaszczowiny magurskiej. Przew. LXIII Zjazdu Pol.Tow. Geol. w Koninkach, p. 20–30.

GAMOND J. F., GIRAUD A. (1982) — Identification des zones de faille a laide des associations des fractures de second ordre. Bull. Soc. Geol. France, **24**, p. 755–762.

GZOWSKI M. V. (1975) — Osnovy tektonofizyki. Nauka. Moskva.

HANDIN J., HAGER R. V. (1957) — Experimental deformation of sedimentary rock under confining pressure: tests at room temperature on dry samples. Bull. Am. Ass. Petrol. Geol., **47**, p. 718–755.

HARRIS L. B., COBBOLD P. L. (1985) — Development of conjugate shear band during bulk simple shearing. J. Struct. Geol., **7**, p. 37–44.

JAROSZEWSKI W. (1972) — Mesoscopic structural criteria of tectonics of non-orogenic areas: an example from the north-eastern Mesozoic margin of the Świętokrzyskie Mountains (in Polish with English summary). Stud. Geol. Pol., **38**.

KARNKOWSKI P. (1963) — Remarques sur la structure géologique du Flysch de la partie orientale des Karpates Polonaises d'aprés des forages profonds (in Polish with French summary). Rocz. Pol. Tow. Geol., **33**, p. 457–469, no. 4.

KARNKOWSKI P., TOKARSKI A. (1954) — Karty otworów wiertniczych Świątkowa 1–4 (teczka 22, arkusz Jasło). Centr. Arch. Geol. Państw. Inst. Geol. Warszawa.

KOSZARSKI L. (1985) — Geology of the Middle Carpathians and the Carpathian Foredeep., **3**, stop 51, p. 213.

KOSZARSKI L., TOKARSKI A. (1968) — Szczegółowa Mapa Geologiczna Polski w skali 1:50 000, arkusz Osiek. Wydanie tymczasowe. Inst. Geol. Warszawa.

KOZIKOWSKI H. (1956) — Ropa–Pisarzowa unit, a new tectonic unit of the Polish Flysch Carpathians (in Polish with English summary). Biul. Inst. Geol., **110**, p. 93–129.

KOZIKOWSKI H. (1958) — The Magura nappe and its relation to the substratum (in Polish with English summary). Acta Geol. Pol., **8**, p. 179–211, no. 2.

KSIĄŻKIEWICZ M. (1972) — Budowa geologiczna Polski, Tektonika, Karpaty, **3**. Inst. Geol. Warszawa.

MASTELLA L. (1988) — Budowa i ewolucja strukturalna okna tektonicznego Mszany Dolnej, Polskie Karpaty Zewnętrzne. Ann. Soc. Geol. Pol., **58**, p. 53–173, no. 1–2.

MITRA S. (1986) — Duplex structure and imbrication thrust system: geometry, structural position and hydrocarbon potential. Am. Ass. Petrol. Geol. Bull., **70**, p. 1087–1112.

OSZCZYPKO N., TOMAŚ A. (1985) — Tectonic evolution of marginal part of the Polish Flysh Carpathians in the middle Miocene. Kwart. Geol., **29**, p. 109–128, no. 1.

PRICE N. J., COSGROVE J. W. (1991) — Analysis of geological structures. Cambridge University Press.

RAMSAY J. G. (1974) — Development of chewron folds. Geol. Soc. Am. Bull., **11**, p. 1741–1754.

TOMEK C. (1988) — Geophysical investigation of the Alpine-Carpathian Arc. In: Evolution of the northern margin of Tethys: the results of IGCP Project **198**, p. 167–199.

UNRUG R. (1980) — Tectonic rotation of flysch nappes in the Polish Outer Carpathians. Rocz. Pol. Tow. Geol., **50**, p. 27–34, no. 1.

VIALON P. (1979) — Les deformations continues-discontinues des roches anisotropes. Eclogae Geol. Helv., **72**, p. 531–551.

Dupleksy w oknie tektonicznym Świątkowej Wielkiej (Beskid Niski, Karpaty Zachodnie): analiza strukturalna i fotointerpretacja

Streszczenie

W Karpatach Zachodnich w rejonie Świątkowej Wielkiej występuje małe okno tektoniczne (fig. 1), w którym spod płaszczowiny magurskiej odsłania się jednostka grybowska (M. Książkiewicz, 1972) nasunięta na płaszczowinę dukielską (fig. 2) (P. Karnkowski, A. Tokarski, 1954). Występująca w oknie jednostka grybowska składa się z siedmiu łusek o rozmiarach kartometrycznych. Łuski te mają postać obalonych na północ fałdów: w centralnej części okna — synklin, a przy jego brzegach wtórnie sfałdowanych (fig. 5) — antyklin (fig. 2). Łuski te tworzą klasyczny (S. E. Boyer, D. Eliot, 1982), międzynasunięciowy dupleks kontrakcyjny. Przyczyną jego powstania był prawdopodobnie próg w podłożu płaszczowiny magurskiej. Płaszczowina ta po północnej stronie okna składa się z płaskiej synkliny, a od strony południowej — z kilku wewnętrznie sfałdowanych łusek. Duże uskoki przesuwcze — komplementarne: NNW prawoskrętne i NE (z opierzającymi je NNE) lewoskrętne (fig. 8) tną zarówno płaszczowinę magurską, jak i okno (fig. 2). Są to uskoki w części odmłodzone jako zrzutowe.

Różnice kierunków strukturalnych w obrębie okna (fig. 3-O, 4, 7 i 8) oraz między S i N częścią płaszczowiny magurskiej (fig. 3-N,-S, 10 i 11), wskazują, że w pierwszym etapie pod wpływem nasuwającej się z S na N płaszczowiny magurskiej powstały, i częściowo były łuskowane, fałdy o kierunku równoleżnikowym. Drugi etap to wyhamowanie od czoła płaszczowiny magurskiej. Jej część południowa, przekraczając próg w podłożu, zmieniła kierunek nasuwania się na SSW–NNE, formując dupleks międzynasunięciowy. Etap ten kończy się powstaniem ponasunięciowych uskoków przesuwczych. W ostatnim etapie, postorogenicznego wypiętrzania, część tych uskoków jest odmładzana jako zrzutowe.

Na podstawie badań innych autorów (N. Oszczypko, A. Tomaś, 1985; M. Cieszkowski i in., 1992) można uznać, że procesy tektoniczne etapu pierwszego zakończyły się we wczesnym sarmacie. Po tym okresie nastąpiło dopchnięcie płaszczowiny magurskiej (M. Cieszkowski i in., 1988), co odpowiadałoby etapowi drugiemu. Ze schyłkiem neogenu wiązać należy (M. Cieszkowski i in., 1992) postorogeniczne wypiętrzanie badanego obszaru.