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ON ORIGIN AND AGE OF THE ORAWA BASIN, WEST CARPATHIANS

The intramontane Orawa Basin is situated at the boundary of the Inner and Outer Carpathians, in the zone of the change of orientation of the dominant structures of this region: the "Silesian" (SW–NE) orientation is replaced here by the "Tatra" (W–E) one (Tołwiński 1922). The Orawa Basin is a tectonic depression formed during Neogene times and enlarged in its NE part in the Late Pliocene and Early Quaternary. The present boundaries of the basin are mostly controlled by the extent of Neogene sediments. The subsiding Orawa Basin is filled with the Upper Badenian through Pontian, fluvial, mainly flood-plain (backswamps) series, up to 950 m thick. The erosional history of the basin was associated with general uplift, probably initiated in Late Pliocene times. Less resistant Neogene sediments were then eroded and removed by the Orawa river which used to flow into the Vah river via an antecedent gate. The next important tectonic pulse was the opening of the Wróblówka depression in NE part of the basin, which is now infilled by 112 m thick Quaternary sediments. These sediments document the outflow from the Tatra Mts through the basin into the Dunajec river valley, situated on the east (Baumgart-Kotarba 1991–1992).

SCOPE OF THE STUDY

Tectonic origin of the Orawa Basin is undoubtful. However, basing on the existing well-log data, two different interpretations have been proposed: one taking into account a Neogene syncline with the superimposed Quaternary syncline, whose axis would have been shifted to the north with respect to the previous one; and another hypothesis about a fault-bounded tectonic trough.

The aim of this paper is to discuss the above hypotheses, as well as to present new data pertaining to the role of horizontal strike-slip movements, resulting in the formation of a pull-apart basin. The author's hypothesis is that the basin was formed under extensional regime. According to this opinion, the Orawa basin was formed due to NW-directed rotation of the "Orawa Block" (Choč—Magura

Orawska area) and the coeval NE-directed shift of the "Tatra Block" (Tatras–Gorce Mts area). These movements took place along a large oblique-slip fault zone, called by Nemčok (1992) the Prosečno dislocation system, which is very well visible on satellite images. This zone has been named the lineament of the Western Tatra Mts margin (Baumgart-Kotarba 1981, 1983). The size of this article does not allow for the full documentation to be presented, as far as the origin of the whole West Carpathian arc is concerned; the aim of this study is to present a new hypothesis as to the origin of the Orawa Basin itself.

SYNCLINE OR FAULT-BOUNDED TROUGH?

Halicki (1930) was the first to propose the tectonic origin of the Orawa Basin. He inferred Quaternary age of diversified subsidence of fluvioglacial covers which build the Czarny Dunajec alluvial fan, shed during the antepenultimate glaciation of the Tatras. The zone of subsidence would have embraced the area comprised between the fan apex (Sucha Hora ridge) and the present-day course of the Czarna Orawa and Piekielnik Orawski streams. Detailed descriptions of Neogene sediments, drilled by the Czarny Dunajec IG–1 (922 m of Neogene and 28 m of Quaternary sediments), Koniówka IG–1 (450 m of Neogene deposits), Hladovka IG–1 (670 m of Neogene deposits), Jabłonka (> 100 m of

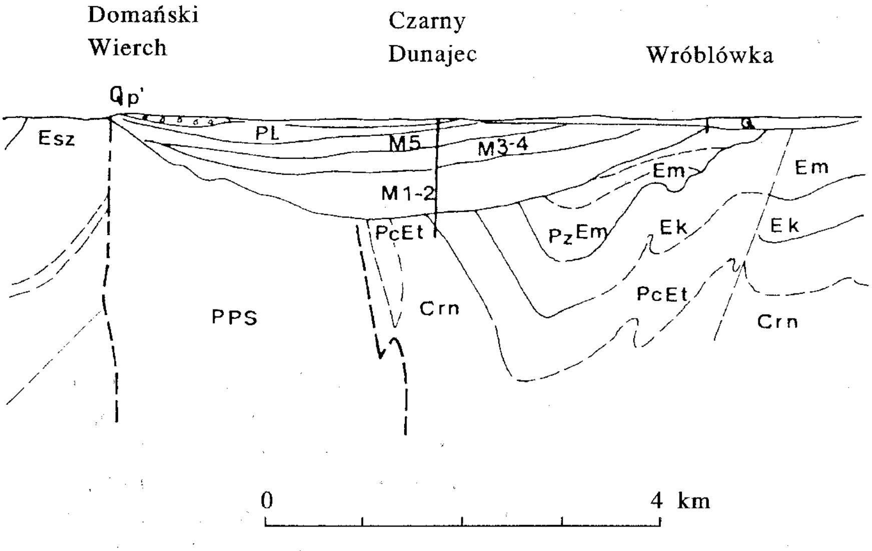


Fig. 1. Simplified fragment of geological cross-profile across Neogene syncline of the Orawa Basin according to Watycha (1976b)

Ryc. 1. Uproszczony fragment profilu geologicznego przez synklinę neogeńską Kotliny Orawskiej, wg Watycha (1976b)

Neogene deposits), and Domański Wierch wells (> 228 m of Pliocene freshwater molasses; cf. Oszast 1973; Watycha 1976a; Stuchlik and Oszast 1977; Woźny 1976), gave rise to discussions about synclinal (Watycha 1976ab; Klimaszewski 1988; Chowaniec *et al.* 1996) or trough-like character (Książkiewicz 1972; Baumgart-Kotarba 1991–1992; Pomianowski 1995) of the depression. Of particular importance is the position of the Wróblówka well, where 112 m of Quaternary sediments rests directly upon the eroded Magura flysch series. This fact has been interpreted by Watycha (1976a) as a result of the northward-directed shift of the Quaternary subsidence axis, as compared to that of the Neogene syncline (Fig. 1). On the other hand, Baumgart-Kotarba (1991–1992) claims that the Quaternary Wróblówka trough must be bounded by young faults, since the Wróblówka well is situated only 2 km to the south of a small hill built up of flysch strata, rising 4–5 m above the fan surface, and 2 km NE of the Czarny Dunajec well, wherein 28 m thick Quaternary alluvium overlies 922 m thick Neogene sediments. Fig. 2 shows the distribution of step-like arranged morphological horizons in the Tatras and upon the Podhale flysch in the Inner Carpathians, as well as in the Działy Orawskie Foothills and the Babia Góra range in the Outer West Carpathians. The age of the reconstructed planation surfaces is shown by a model of development of step-like arranged ridge levels in an uplifted region (Fig. 3). The Pannonian age determination of the planation A (1000 m a.s.l.) is rather arbitrary one, basing on the assumption that the Pannonian was characterized by deposition of fine-grained material, despite the alternation of dry and humid episodes. This may indicate extensive planation and tectonic quiescence (Baumgart-Kotarba 1983). Fig. 2 also shows the inferred location of faults in a N–S oriented profile along the Czarny and Biały Dunajec river valleys. The relationship of the Wróblówka trough to the Nowy Targ trough is still uncertain. In the latter trough, 60 m thick Quaternary sediments rest upon 40 m thick Neogene deposits at Nowy Targ (Chowaniec *et al.* 1996), whereas at Rogoźnik 36 m thick Quaternary sediments overlie > 15.5 m thick Neogene clays and sandy silts (*vide* wells cited by Pomianowski 1995).

Geomorphological studies of the northern margin of the basin between Pieniążkowice and Ludźmierz, and particularly the presence of characteristic "spurs" and "embayments" (i.a.: Pieniążkowice, Długopole, Krauszów embayments), appear to indicate the presence of both longitudinal and transversal faults situated between the northern, uplifted and southern, subsided regions (Fig. 4). The occurrence of faults running obliquely to the Neogene margin of the basin is documented by geophysical soundings (Pomianowski 1995). Tectonic differentiation of the NE part of the Orawa Basin is also indicated by the presence of erosional-accumulational terraces, 25 m (last glacial stage) and 40 m (penultimate glacial stage) high, near Długopole and Krauszów, as well as the 12–14 m high, accumulational (last glacial) terrace near Nowy Targ (Baumgart-Kotarba 1991–1992).

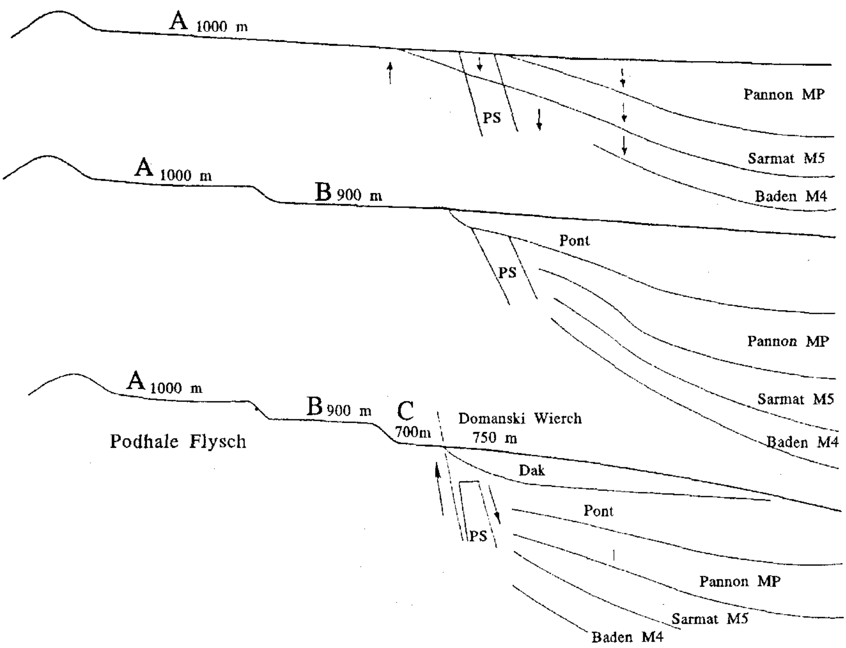
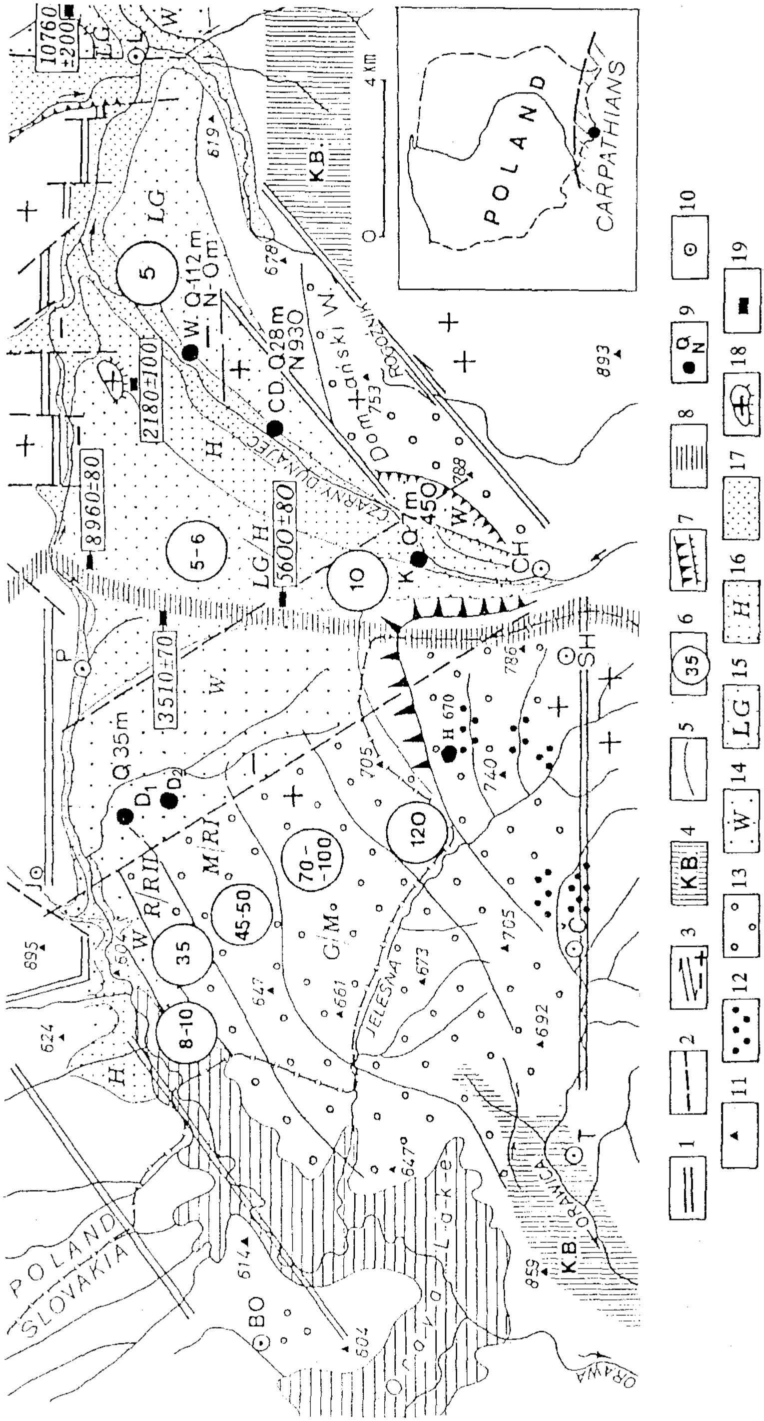


Fig. 3. Hypotethical situation of erosional evolution of the Podhale–Skoruszyna region and Outer Magura area during Neogene subsidence of Orawa Basin

Ryc. 3. Model formowania zrównań na Podhalu z osadami korelatnymi zapadliska neogeńskiego

Fig. 4. Long-term complex Czarny Dunajec fan evolution in the Orawa Basin — uplifted western part with six levels of terraces and subsiding north-eastern part. 1 — main tectonic limits of the Orawa Basin, 2 — faults or fault zones, 3 — inferred strike- and oblique- slipe fault, uplifted zone (+), subsidence zone (–), 4 — Klippen Belt, 5 — extent of terrace levels, 6 — height of morphological levels above the Orawa river bed (in metres), 7 — scarps and terrace edges, 8 — main European drainage divide, 9 — boreholes, 10 — villages, 11 — spot heights, 12 — the oldest alluvial covers (Upper Pliocene ?) with Tatra-derived pebbles, partly calcified, 13 — glacifluvial/fluvial terrace covers Riss, Mindel, Günz, with proluvial/solifluction loess-like sediments, 14 — Weichselian terrace and fan (Würm), 15 — Late Weichselian fan, 16 — Holocene alluvial terrace and fan, 17 — braid-plain, 18 — small hill built up of flysch rocks, 5 m high, 19 — radiocarbon dates of the lowermost peat layers

Ryc. 4. Rozwój złożonego stożka Czarnego Dunajca w czwartorzędzie w Kotlinie Orawskiej. 1 — główne linie tektoniczne, 2 — uskoki lub strefy uskokowe, 3 — kierunek uskoków przesuwczych i podnoszących, strefy podnoszone (+), strefy obniżane (–), 4 — Pas Skalicowy, 5 — zasięg poziomów terasowych, 6 — wysokość względna nad koryto Orawy, 7 — krawędzie, 8 — główny wododział europejski, 9 — lokalizacja wierceń, 10 — miejscowości, 11 — punkty wysokościowe, 12 — najstarsze (górnoplioceńskie ?) pokrywy aluwialne, z otoczakami tatrzańskimi, częściowo zkalcyfikowane, 13 — pokrywy aluwialne/fluwioglacjalne terasowe Riss, Mindel, Günz z osadami lessopodobnymi proluwialnymi i soliflukcyjnymi, 14 — terasa i stożek wistuliański (Würm), 15 — stożek późnowistuliański, 16 — terasa i stożek holoceński, 17 — równina aluwialna rzeki roztokowej, 18 — pagór fliszowy o wysokości 5 m, 19 — daty ^{14}C ze spągu torfowisk



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QUATERNARY EVOLUTION OF THE ORAWA BASIN

Detailed geomorphological mapping at the scale of 1 : 10 000, together with analyses of air photos (1: 7.000 to 1: 8.000) and terrace deposits make it possible to construct a model of tectonic evolution of the Orawa Basin in the Quaternary (Baumgart-Kotarba 1991–1992, 1993). The relief of the bottom of the Orawa Basin enables one to distinguish two different parts of the Czarny Dunajec complex alluvial fan. The western part, comprising 6 terrace levels, documents tectonic uplift; the eastern part with micro-relief of braided palaeochannels represents the Late Weichselian-Holocene fan and the subsided Wróblówka graben (Figs 4, 5). Terraces preserved in the western part display separate rock socles, cut into clay-silty Neogene sediments. The terraces attain the following heights above the present-day Orawa river bed: 10–12 m (last glacial stage, Würm), 35 m (Riss), 45–50 m (older Riss or Mindel), 60–70 m (Mindel or Günz), 100 and 150 m. Palaeochannels preserved upon the vast fan in the eastern and NE part of the basin document Late Weichselian, westward directed flow of the Czarny Dunajec

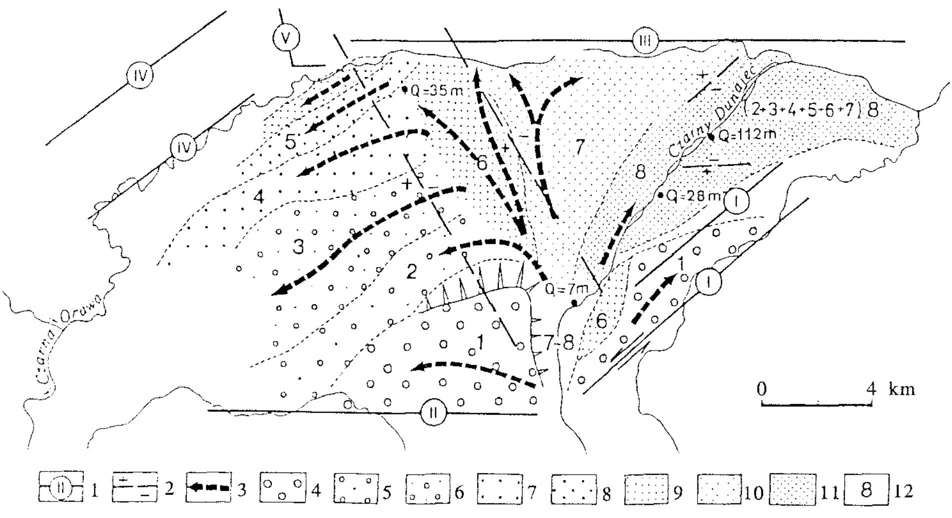

Fig. 5. Reconstruction of the Quaternary drainage pattern of the Czarny Dunajec river and stages of complex fan development. 1 — basin boundary associated with the contact between resistant flysch rocks and Neogene less resistant sand and silty clays: I — Domański Wierch line, II — Sucha Hora–Čimhova–Trstena line, III — Jabłonka–Krauszów line, IV — Czarna Orawa and Bobrov lines, V — Syhlec stream line, 2 — inferred faults, 3 — drainage directions, 4–11 — terrace levels of the Orawa Basin, 12 — stages of complex fan development (in uplifted zone: 1–6 and subsided: 7–8)

Ryc. 5. Rekonstrukcja kierunków odwodnienia przez Czarny Dunajec i stadia rozwojowe złożonego stożka Czarnego Dunajca. 1 — granice kotliny przy kontakcie małoodpornych utworów neogeńskich z odporniejszym fliszem: I — Domański Wierch, II — Sucha Hora–Čimhova–Trstena, III — Jabłonka-Krauszów, IV — strefa Czarnej Orawy–Bobrova, V — potok Syhlec, 2 — przypuszczalne uskoki, 3 — kierunki odwodnienia, 4–11 — poziomy terasowe Kotliny Orawskiej, 12 — oznaczenia poziomów terasowych w części podnoszonej: 1–6 i obniżanej: 7–8 river into the Orawa and Vah drainage basins. This is also evidenced by the radiocarbon date of the bottom part of the Puścizna Rękowianska peat bog (8960 ± 80 yrs BP), as well as by palynological studies of clays underlying the peat bog, which were deposited at the end of the Younger Dryas (Obidowicz 1988, 1989). Similar age determinations have been obtained for the Na Grelu peat bog (Koperowa 1962). The latter has developed upon the Late Weichselian terrace, which is a continuation of the Czarny Dunajec fan, presently dissected by 5–6 m.

The author accepts simultaneous outflow of the Czarny Dunajec river into the both Black Sea and Baltic drainage basins in Quaternary times. The development of the Wróblówka trough or a series of smaller troughs between Wróblówka and Nowy Targ, as well as of the Frydman graben, enabled the outflow of the Czarny Dunajec river towards the east, i.e. towards the Dunajec river. If this model (Figs 4, 5) is confirmed by geophysical studies, recently conducted by a team led by Prof. Dr R. Ślusarczyk, University of Mining and Metallurgy from Kraków (Grant No 6PO4E 020 08), the mechanism of the formation of NE part of the Orawa basin will be still a matter of debate. The question is whether Quaternary subsidence in Quaternary times is a continuation of tectonic processes active in the Neogene.

REVIEW OF TECTONIC HYPOTHESES

To construct a model of Quaternary tectonic evolution of the Orawa Basin, one has to test the hitherto proposed hypotheses of the Neogene origin of this basin. These include:

(1) pull-apart basin hypothesis (Pospišil 1990; cf. Fig. 6),

(2) hypothesis of both left- and right-lateral horizontal motions along the western Tatra margin–Krowiarki–Domański Wierch fault (Bac-Moszaszwili 1993; cf. Fig. 7), and

(3) hypothesis of the releasing bend-type structure (Pomianowski 1995; cf. Fig. 8).

All these hypotheses accept strike-slip movements, although the fault azimuths and sense of motion are taken in a different way. The model proposed by Pospišil (1993) includes the Tatras, Skoruszyna–Podhale syncline, Pieniny Klippen Belt and southern part of the Magura Nappe. The system of right-lateral strike-slip faults between the Zazriva sigmoid and the Orawa Basin can explain the origin of the sigmoid itself, but it cannot explain the northermost position of the Pieniny Klippen Belt east of the Orawa basin. The suggested left-lateral sense of motion along the Ružbachy fault, however, is not confirmed by the orientation of the Pieniny Klippen Belt east of the Dunajec river gorge in the Pieniny Mts. It appears, therefore, that the pull-apart basin hypothesis *sensu* Pospišil (1990, 1993) cannot be accepted for that part of the Carpathians.

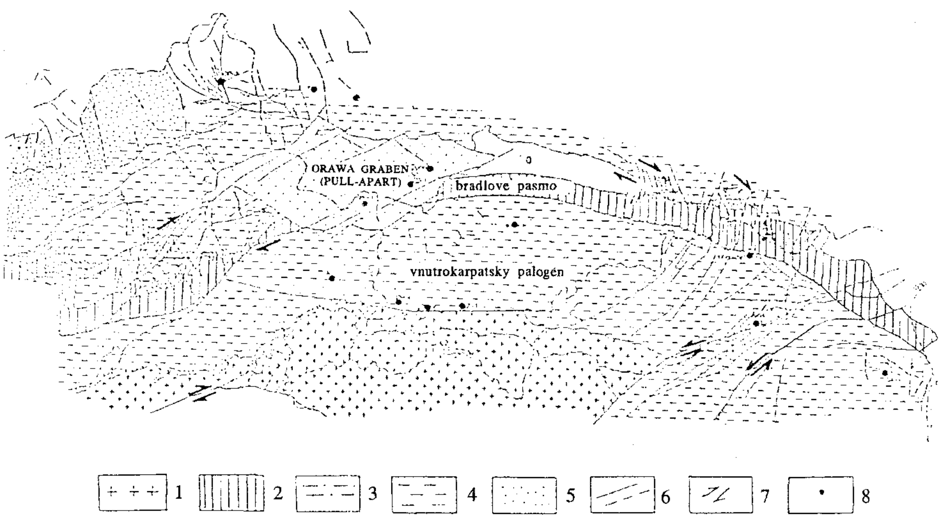

Fig. 6. Interpretation of the main fault systems on the background of geophysical sounding and geological maps around the Orawa Basin after Pospišil (1990, 1993). 1 — pre-Mesosoic rocks, 2 — Klippen Belt, 3 — flysch of Magura nappe, 4 — Outer flysch of Skoruszyna , 5 — Neogene, 6 — faults, 7 — assumed direction of strike-slip movements, 8 — location of drillings

Ryc. 6. Interpretacja głównych systemów uskoków na podstawie badań geofizycznych i map geologicznych w otoczeniu Kotliny Orawskiej wg Pospišil (1990, 1993). 1 — utwory przedmezozoiczne, 2 — Pas Skalicowy, 3 — flisz płaszczowiny magurskiej, 4 — flisz wewnętrzny Skoruszyny, 5 — neogen, 6 — uskoki, 7 — przypuszczalny kierunek ruchów przesuwczych, 8 — lokalizacja wierceń

Bac-Moszaszwili (1993, 1995) attempts to explain the origin of the Zazriva (Parnica) sigmoid and the Orawa Basin formation by young activity of the left-lateral Krowiarki–Domański Wierch fault. This author concludes about the change of the sense of movement from left-lateral to right-lateral in the Rhone orogenic phase, trying to explain in this way very young thrust of the Choč massif upon the western Tatra margin and overthrusting of the Domański Wierch series upon the Paleogene flysch of the Podhale syncline. Leaving aside the doubtful presence of such thrusts, the supposed change of the sense of movement is not reflected in the structure of the Zazriva sigmoid.

Geophysical interpretation by Pomianowski (1995) documents well faults controlling the Orawa Basin. The throws of these faults attain several hundred metres and bound the larger area than that described by Watycha (1976a). The deepest part of the basin extends into its Slovak part. Of special importance is the presence of oblique faults, associated with the Lipnica, Zubrzyca and Machajowa faults of Watycha (1977), which point to close relationship between the Orawa depression and structural pattern of the Magura Nappe. Pomianowski (1995) assumes that close to the generally

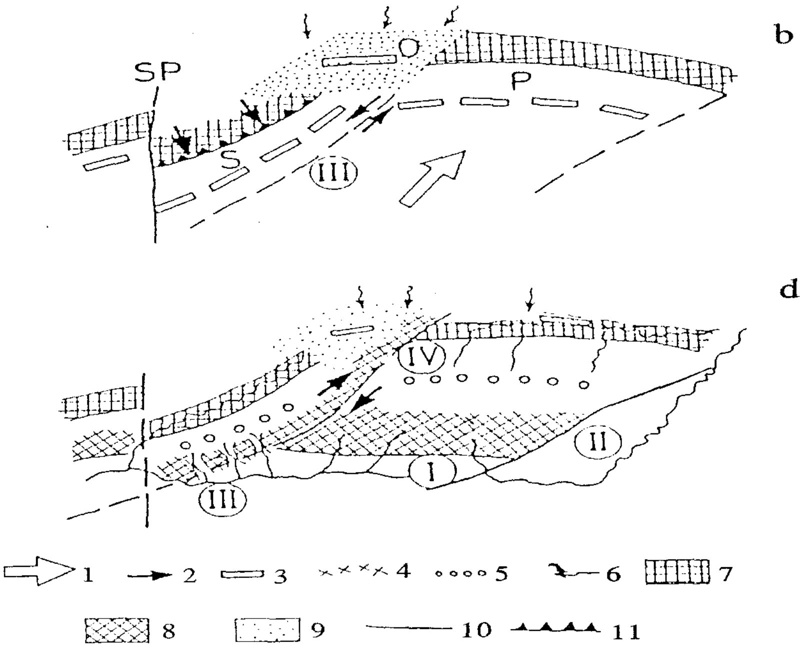

Fig. 7. Selected stages of tentative reconstruction of neotectoic evolution of the Tatra Mts area according to Bac-Moszaszwili (1993), b. Late Badenian., d. Rhodanian phase. 1 — directions of tectonic stress, 2 — direction of tectonic movements, 3 — zones of tectonic depressions, 4 — anticlines, 5 — Gubałowsko-Skoruszyński Range, 6 — drainage directions, 7 — Pieniny Klippen Belt, 8 — uplifted area, 9 — sediments laid down in tectonic depressions, 10 — fault, 11 — thrust fault

Ryc. 7. Wybrane stadia z próby rekonstrukcji neotektonicznej ewolucji regionu Tatr wg Bac-Moszaszwili (1993), b. późny baden, d. faza rodańska. 1 — kierunki nacisków tektonicznych, 2 — kierunki przemieszczeń tektonicznych, 3 — strefy obniżeń tektonicznych, 4 — antykliny, 5 — grzbiet Skoruszyńsko-Gubałowski, 6 — kierunki płynięcia wód, 7 — Pas Skalicowy, 8 — obszar podnoszony, 9 — osady w obniżeniach tektonicznych, 10 — uskoki, 11 — nasunięcia

left-lateral major strike-slip fault along the Pieniny Klippen Belt (cf. Birkenmajer 1985, 1986), a local change of the stress field took place, leading to the formation of a number of dip-slip and oblique-slip faults which bound the depression. The author cited (Pomianowski 1995) concludes about synsedimentary character of the depression, developing also in Quaternary times. The formation of the basin as a "releasing bend" structure would have occurred at the end of thrusting in the Outer Carpathians, whereas the block-type character is similar to the other Neogene Carpathian basins, like the Vienna, Trenčin or Ilava basins. He underlies, however, that the weak point of such an hypothesis is the lack of near-surface manifestations of large-scale motions of blocks within the substratum.

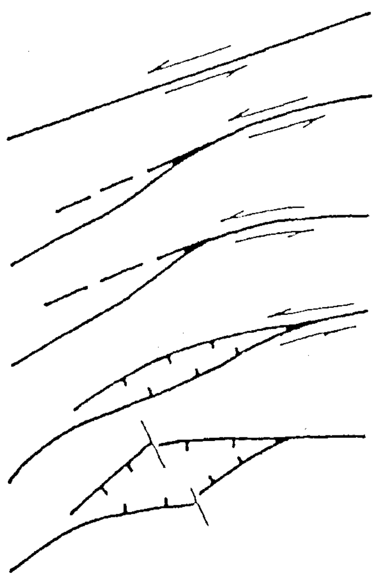

Fig. 8. Model of the Orawa Basin formation as geological structure of "releasing bend" type according to Pomianowski (1995)

Ryc. 8. Model formowania depresji orawskiej jako struktury typu „releasing bend", wg Pomianowski (1995)

ROLE OF THE "WESTERN TATRA MARGIN–DOMAŃSKI WIERCH" LEFT-LATERAL STRIKE-SLIP FAULT IN SHAPING OF THE ORAWA BASIN

Trying to reconstruct the origin of the Orawa Basin, I also accept the pull-apart basin hypothesis, although taking into account another structural plan. I suppose that the Orawa Basin became open due to block-type horizontal movements being common for the both Inner and Outer Carpathians. During folding and thrusting of the Outer West Carpathians, when the whole orogen was migrating towards the north (Oszczypko 1995; Oszczypko and Tomaś 1985, Kovač *et al.* 1989b), individual blocks were formed due to friction exerted by the crystalline substratum. In this way, the Bohemian Massif hampered the northward movement of the westernmost part of the Carpathians that led to the palaeomagnetically documented northwesterly rotation of the western segment of the Carpathians, including the Male Karpaty block and the Trenčin segment of the Vah valley as far as Žilina, by 43° since the Eggenburgian and 37° since the Karpatian (Kovač *et al.* 1989a). It appears that the similar mechanism was responsible for the "stopping" of the Carpathians in the Mala Fatra region, whereas the more easterly segments could have migrated further to the north. The crystalline substratum of the Beskid Śląski (Silesian Beskid) Mts occurs at depths of 1 to 2 km, whereas

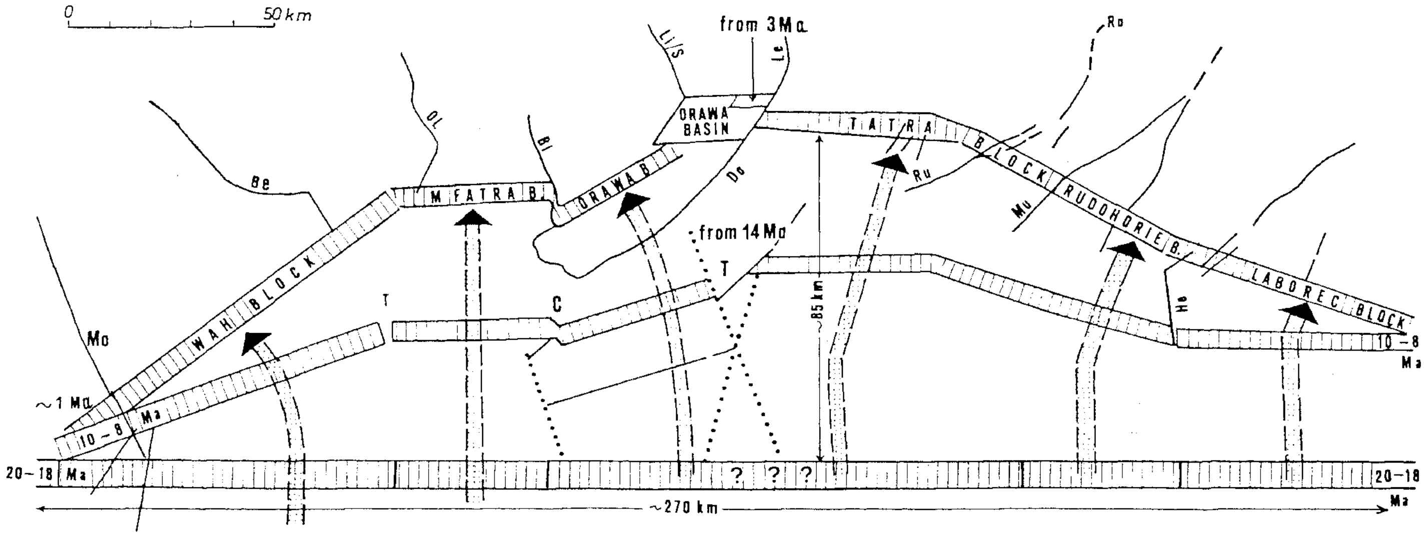

Fig. 10. Hypothetical model of the formation of the Western Carpathian arc during three time spans: 20–18, 10–8, and about 1 million years ago. Hachures show Klippen Belt, while arrows mark assumed direction of the movements of the blocks distinguished in the paper (Wah, Mala Fatra, Orawa, Tatra, Rudohorie, and Laborec). The model shows openning of the Orawa Basin due to tension and formation of Zazriva sigmoid related to rotation of Orawa Block. Main faults (limits of blocks): Mo — Morava fault, Be — Bečva fault, Ol — Olza fault, Bi — Biała fault, Li / S — Lipnica and Syhlec fault, Do / Le — Domański Wierch and Lepietnica fault, Ru — Ružbachy fault, Ro — Ropa fault, Mu — Muran fault, Ho — Hornad fault. T — tension, C — compression

Ryc. 10. Hipotetyczny model formowania łuku Zachodnich Karpat w wybranych trzech okresach: 20–18 10–8 i około 1 mln lat temu. Zaszrafowano strukturę Pasa Skalicowego, strzałkami oznaczono przypuszczalny kierunek ruchu wyróżnionych bloków: Wagu, Małej Fatry, Orawy, Tatr, Rudohoria i Laborca. Model pokazuje otwieranie się zapadliska orawskiego w warunkach tensji i formowanie sigmoidy Zazrivy w warunkach rotacji Bloku Orawy. Główne uskoki (granice bloków): Mo — uskok Moravy, Be — uskok Bečvy, Ol — uskok Olzy, Bi — uskok Białej, Li / S — uskok Lipnicy i Syhlca, Do / Le — uskok Domańskiego Wierchu/Lepietnicy, Ru — uskok Ružbachów, Ro — uskok Ropy, Mu — uskok Murania, Ho — uskok Hornadu. T — strefy tensji, C — strefy kompresji close to Nowy Sącz Jurassic strata of the North-European Platform have been drilled at a depth of 5.5 km (Geological Atlas 1988–1989). One can explain in this way the NW-directed rotation of the Carpathians between the Zazriva sigmoid and Orawa Basin, i.e. the segment comprising the Choč massif, Skoruszyna syncline, Pieniny Klippen Belt between Zazriva and Trstena, and a fragment of the Magura Nappe within the Magura Orawska and eastern Beskid Żywiecki Mts. In the light of this hypothesis, the Orawa Basin would have been formed under extensional regime which existed between the Orawa Block, rotating by 40–42° towards NW, and the north-eastward migrating Tatra Block. The principal oblique-slip fault is the sinistral fault bordering the southern Choč which continues along the western Tatra margin, and then through the Inner Carpathian Paleogene flysch via Oravice and Krowiarki pass, along Domański Wierch and, finally, along the NNE–SSW oriented Lepietnica river valley towards the western margin of the Mszana Dolna tectonic window. The Tatra Block, including the Tatras, Podhale syncline, Pieniny Klippen Belt between Rogoźnik and Ružbachy fault, and Gorce Mts, was shifted along this oblique-slip fault towards the NE, being simultaneously uplifted. This uplift is evidenced, i.a., by the relationship between the Domański Wierch series (Birkenmajer 1978) and the reconstructed system of step-like arranged planation surfaces (A, B, C, D) in Podhale area (Baumgart-Kotarba 1983) on one hand, and to clayey-silty, lignite-bearing sediments which fill the central part of the Orawa basin (950 m in Czarny Dunajec and 450 m in Koniówka wells) on the other. Moreover, large thicknesses of the thick-bedded Magura sandstones occurring west of the Lepietnica river valley, as compared to the relatively thin cover of these sandstones in the Gorce and Beskid Żywiecki Mts (Sokołowski 1959), point to the uplift of the Gorce Mts. in relation to the subsiding part of the Magura Nappe in the Działy Orawskie Foothills (Pieniążkowice and Sieniawa Pass region).

The Quaternary opening of the Orawa Basin in its NE part shows that the tectonic development has not yet been completed. The main argument in favour of differences in the mechanism of motion of the Orawa and Tatra Blocks is the relationship of the Pieniny Klippen Belt to the surrounding structural units. The Klippen Belt is thrust back upon the Skoruszyna flysch (Pospišil 1993; Gross *et al.* 1993, 1994), whereas in the Tatra Block it is nearly vertical and thrust upon the youngest lithostratigraphic members of the Magura Nappe (Cieszkowski 1992). The rotation of the Orawa Block is probably responsible for oblique arrangement (NW–SE) of young anticlines and synclines within the Magura Nappe, hitherto interpreted as a result of folding in the East Carpathians being superimposed upon older folds in the West Carpathians (Aleksandrowski 1985). The axis of regional gravity low between the Zazriva sigmoid and Trstena is arranged en echelon (Woźnicki *et al.* 1987), which can also be a result of the rotation of the Orawa Block. As far as geomorphic arguments are concerned, besides formerly discussed indicators of young tectonics in the Orawa Basin, one should also take into account that the Domański Wierch hill blocks the drainage from the Gubałówka Foothills which, together with characteristic orientation of the valley pattern — for instance Cichy, Wojcieszacki and Pasieka streams, could be diagnostic for the activity of strike-slip faults (cf. Reading 1980; Keller and Rockwell 1984).

AGE OF THE ORAWA TROUGH

The age of the trough is determined by Neogene sediments filling the basin. Basing on palynological analyses of Oszast and Stuchlik (1977), one should accept Late Badenian, i.e. Serravallian age (cf. Zuchiewicz 1993). Therefore, I suppose that the Orawa Basin opening took place within the time-span of 14 to 3 Ma. The subsidence was probably interrupted in Late Pliocene times, since the Romanian sediments are lacking from the Domański Wierch series. I conclude that at the turn of the Pliocene and Quaternary a general uplift of the basin together with surrounding regions took place, leading to erosional removal of less resistant Neogene sediments. The subsequent opening of the trough was resumed in the Quaternary (Mojski and Watycha 1984), as documented by Tatra-derived crystalline gravels deposited directly upon eroded Magura sandstones in Wróblówka.

FINAL REMARKS

The above presented hypothesis differs from previous ones by assuming common tectonic history of the both Inner and Outer Carpathians since the Styrian orogenic phase. A possibility of continuation of faults inbetween these units has already been discussed by Sikora and Żytko (1960) and Unrug (1980), particularly in relation to the Zazriva and Bielsko faults (eastern margin of the Beskid Śląski Mts). It seems that the Styrian phase affected not only tectonic movements within the Magura Nappe, but also controlled synsedimentary subsidence of the Orawa Basin. This hypothesis could have been more easily acceptable, if Cieszkowski's (1992, 1993) suggestions were confirmed. The author cited points to a very short time-span which elapsed between the folding of the Magura Nappe after the Langhian / Serravallian and the opening of the Orawa intramontane trough in the Late Badenian (Serravallian). Such an hypothesis appears to be confirmed by the presence of the second (younger) set of andesitic dykes close to Wżar and Bryjarka, being associated with young horizontal displacements, interpreted by Birkenmajer (1985) as a phase of the Styrian movements. Moreover, the pattern of Bouguer gravity anomalies indicates that not only the Tatras, but also the Niske Tatry Mts (up to Banska Bystrica — upper Hron valley line) could have been thrust upon light rock masses of high electric conductivity, encountered at a depth of 6–15 km (Lefeld and Jankowski 1985) below the Tatras. This fact can also support the hypothesis about the NE-directed shift of the Tatra Block.

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STRESZCZENIE

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W SPRAWIE GENEZY I WIEKU KOTLINY ORAWSKIEJ, KARPATY ZACHODNIE

Tektoniczne pochodzenie Kotliny Orawskiej nie budzi wątpliwości. Zasadnicze różnice poglądów dotyczą interpretacji, czy Kotlina Orawska jest synkliną (Watycha 1976a i b, Klimaszewski 1988, Chowaniec *et al.* 1996), czy zapadliskiem (Książkiewicz 1972; Baumgart-Kotarba 1991–1992; Pomianowski 1995). Ostatnio aktualna stała się interpretacja Kotliny Orawskiej jako basenu typu pull-apart (Pospišil 1990, 1993, Baumgart-Kotarba 1993). Jednak przyjmując hipotezę powstawania basenu w wyniku rozrywania autorzy przyjmują inny zespół uskoków przesuwczych.

Autorka opierając się na wynikach analiz palinologicznych Oszast i Stuchlika (1977) uważa, że neogeńskie zapadlisko orawskie kształtowało się od górnego badenu po środkowy pliocen (dak). Następnie przyjmuje podnoszenie Kotliny wraz z otoczeniem i erozyjne odpreparowanie w małoodpornych utworach neogeńskich. W czwartorzędzie doszło do tektonicznego powiększania Kotliny wskutek rozwoju zapadliska (zapadlisk?) Wróblówki i Nowego Targu. Dno współczesnej Kotliny Orawskiej zajmuje złożony stożek Czarnego Dunajca (ryc. 4 i 5), który w czwartorzędzie kierował się do zlewiska Morza Czarnego, płynąc z Orawą do Wagu, bądź na wschód w stronę przełomu Dunajca i do Wisły.

W artykule przedstawiono hipotezę otwierania się Kotliny Orawskiej w warunkach tensji między Blokiem Orawy, podlegającym rotacji ku NW a Blokiem Tatr przemieszczającym się ku NE. Podstawową rolę w tworzeniu Kotliny Orawskiej odegrał uskok zrzutowo-przesuwczy Choczu — zachodniego obrzeżenia Tatr–Krowiarek–Domańskiego Wierchu–Lepietnicy, opisany przez Nemčoka (1993) jako „prosečňanský poruchový systém". Uskok ten w odcinku: zachodni brzeg Tatr–Domański Wierch opisała Bac-Moszaszwili (1993) jako uskok Krowiarek (nad Suchą Horą). Przyjmuje ona początkowo lewoskrętny zwrot tego uskoku a następnie w fazie rodańskiej — prawoskrętny, podczas gdy autorka zwrot wyłącznie lewoskrętny. Przyjęcie rotacji Bloku Orawy obejmującego masyw Choczu, synklinę fliszu wewnętrznego Skoruszyny, Pas Skalicowy między sigmoidą Zazrivy a Trsteną oraz Magurę Orawską i przesuwanie na NE Bloku Tatr z Niżnymi Tatrami, Tatrami, synkliną Podhala, Pasem Skalicowym od Rogoźnika po uskok Ružbachów, a prawdopodobnie po uskok Murania i z płaszczowiną magurską na wschód od doliny Lepietnicy powoduje konieczność nowego spojrzenia na rozwój tektoniki Karpat Zachodnich (ryc. 10).

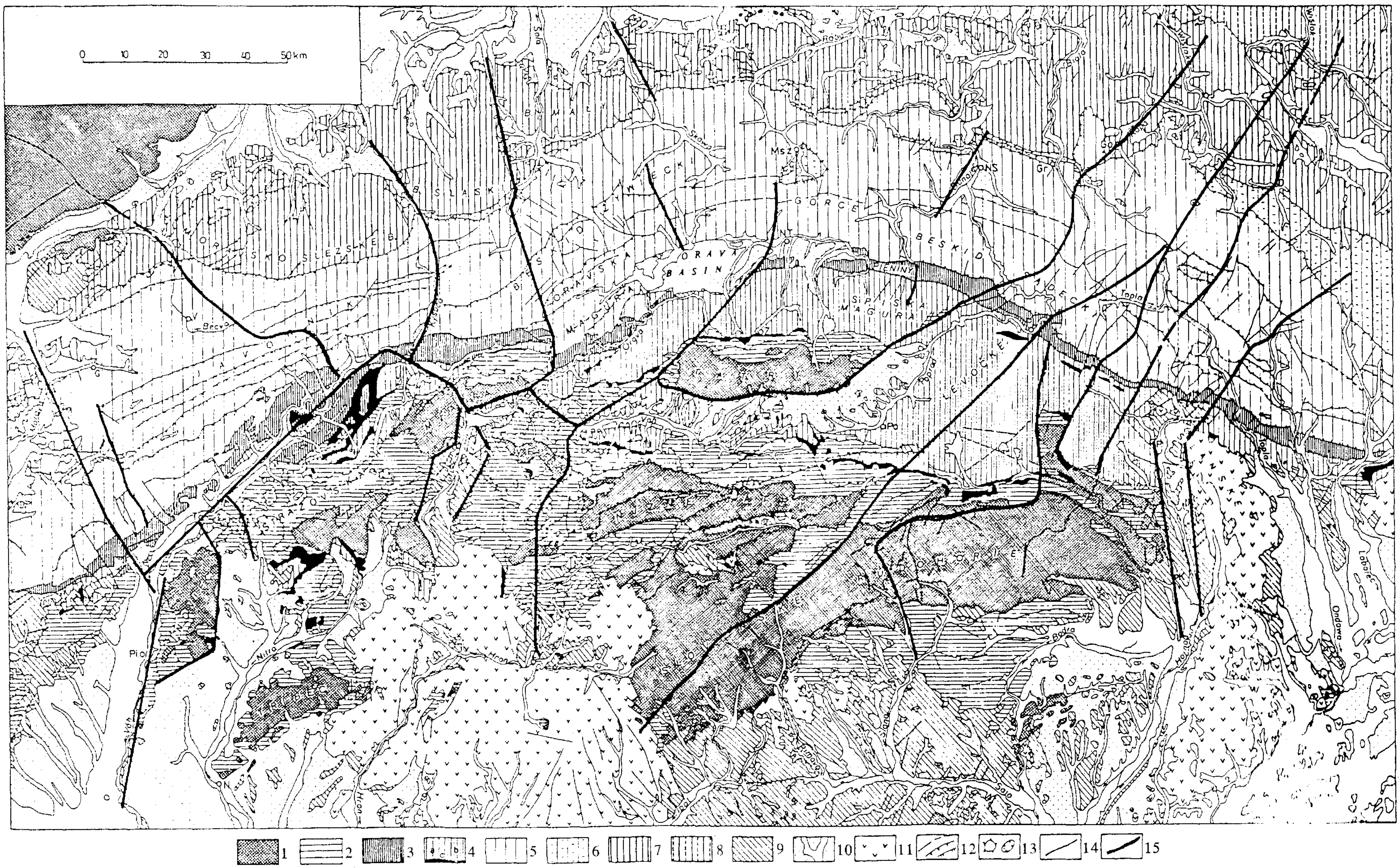

Fig. 9. Simplified geological map (based on Buday *et al.* 1960; Fusan *et al.* 1967) showing principal faults that bound tectonic block distinguished by the author. 1 — granitoid and metamorphic rock, 2 — mainly mezozoic sedimentary rock folded and thrusted of Inner Carpathians (autochtonous, Križna and Choč nappes), 3 — Klippen Belt, 4 — Inner Carpathian flysch: a — Eocene, b — Upper Eocene, c — basal conglomerate, 5 — Magura nappe, 6 — Dukla and Grybów units, 7 — Silesian nappe, 8 — Subsilesian nappe, 9 — Neogene molassa, 10 — Quaternary deposits, 11 — volcanites, 12 — overthrust and faults, 13 — tectonic windows and remnant of nappes, 14 — faults, 15 — boundary of distinguished blocks

Ryc. 9. Uproszczona mapa geologiczna (na podstawie Buday *et al.* 1960; Fusan *et al.* 1967), pokazująca główne uskoki rozdzielające bloki tektoniczne wyróżnione w prezentowanej hipotezie. 1 — granity i skały metamorficzne, 2 — sfałdowane i nasunięte głównie utwory mezozoiczne Karpat Wewnętrznych, 3 — Pas Skalicowy, 4 — flisz wewnętrzny: a — eocen, b — górny eocen, c — konglomeraty, 5 — płaszczowina magurska, 6 — jednostka Dukli i Grybowa, 7 — płaszczowina śląska, 8 — płaszczowina podśląska, 9 — molasy neogeńskie, 10 — utwory czwartorzędowe, 11 — wulkanity, 12 — nasunięcia, 13 — okna i wyspy tektoniczne, 14 — uskoki, 15 — granice wyróżnionych bloków