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Morphological development of the Beskid Niski Mts and Ouaternary palaeogeograhy of the Polish Flysch Carpathians

The paper discusses main stages of geomorphic development of the eastern Beskid Niski Mts. in Quaternary times, with special attention being paid to palaeogeographic changes in the whole of the Polish Flysch Carpathians. A unique position of the Beskid Niski Mts. in the Carpathian chain is documented by a prolonged formation of the riverside level lasting up to the Nidanian (Elsterian 1) Stage, as well as by rapid reactivation of neotectonic movements along the southern boundary of the Jasło-Sanok Depression during the Last Glacial and Holocene. The number and height of the preserved terrace steps depend largely upon the size and intensity of tectonic uplift and not solely on climatic changes.

INTRODUCTION

The Beskid Niski Mts. form a large transversal depression in the Polish Flysch Carpathians (Fig. 1), being composed of several morphostructural units that show neotectonic tendencies and Quaternary geomorphic development different from those of surrounding regions. The morphostructure in question is bounded from the north by the vast Jasło-Sanok Depression (Fig. 2), cut into flysch deposits attaining 10 to 11 km in thickness (M. Książkiewicz, 1977), a figure unique in the Northern Carpathians. The eastern part of the Beskid Niski Mts. reveals present-day uplift rates exceeding 2 mm yr^{-1} (I. Joo et al., 1981). It also belongs to those few Carpathian areas where non-rejuvenated, watershed-type morphology has been preserved nearly intact. The region studied comprises a number of folds of the Magura, Dukla, and southern Silesian thrust sheets, built up from Upper Cretaceous — Oligocene flysch deposits,and cut by a series of oblique-slip faults. The Beskid Niski Mts. morphostructure is composed of mountaineous ridges trending NW - SE, i.e., obliquely to the axis of neotectonic uplift. In its western part, a

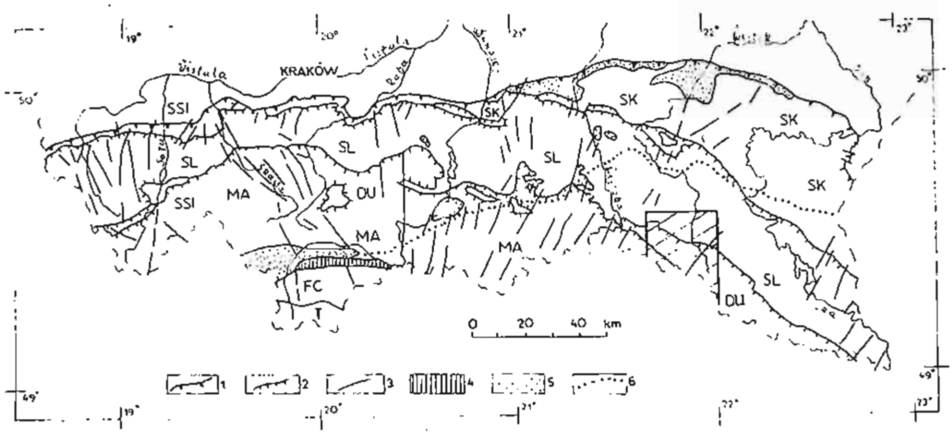

Fig. 1. Structural sketch of the Polish Carpathians (based on M. Książkiewicz, 1977)

Szkic strukturalny Karpat polskich (według M. Książkiewicza, 1977)

1 — Carpathian frontal thrust; 2 — subordinate thrusts; 3 — faults; 4 — Pieniny Klippen Belt; 5 — Miocene molasses resting on flysch deposits; 6 — axis of the regional gravity low; T — Tatra units; FC — Podhale Flysch; thrust sheets of the Outer Carpathians: MA — Magura, DU — Dukla, SL — Silesian, SSI — Sub-Silesian, SK — Skole; area studied in detail marked by hatchure

1 — główne nasunięcie karpackie; 2 — nasunięcia podrzędne; 3 — uskoki; 4 — pieniński pas skałkowy; 5 — molasy mioceńskie na utworach fliszowych; 6 — oś regionalnego minimum grawimetrycznego; T — jednostki tatrzańskie; FC — flisz podhalański; płaszczowiny Karpat Zewnętrznych: MA — magurska, DU — dukielska, SL — śląska, SSI — podśląska, SK — skolska; obszar badań szczegółowych zaszrafowano

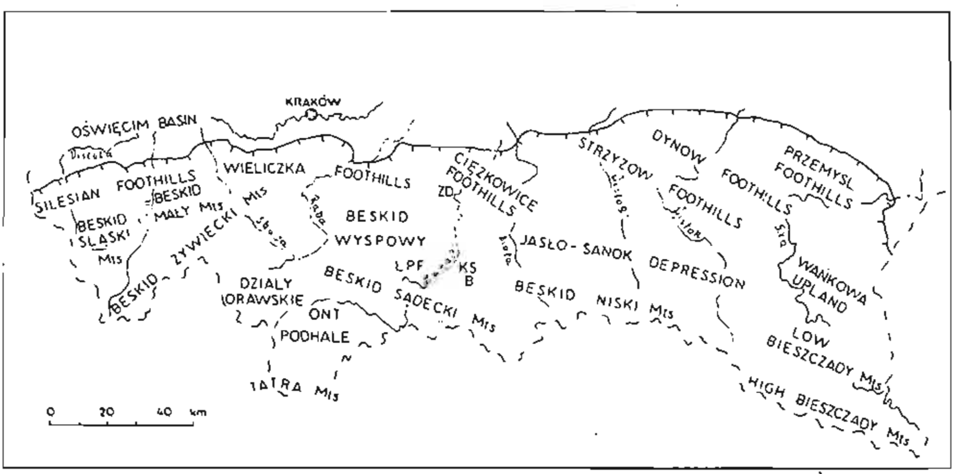

Fig. 2. Main physiographic units of the Polish Carpathians

Główne jednostki fizjograficzne Karpat polskich

ZD — Zakliczyn Depression; ŁPF — Łącko-Podegrodzie Foothills; ONT — Orava-Nowy Targ Basin; KSB — Nowy Sącz Basin

ZD — obniżenie Zakliczyna, ŁPF — Pogórze Łącko-Podegrodzkie, ONT — Kotlina Orawsko-Nowotarska, KSB — Kotlina Sądecka

rectangular drainage patterns dominates, the ridges being built from resistant sandstone complexes. The Jasło-Sanok Depression, in turn,

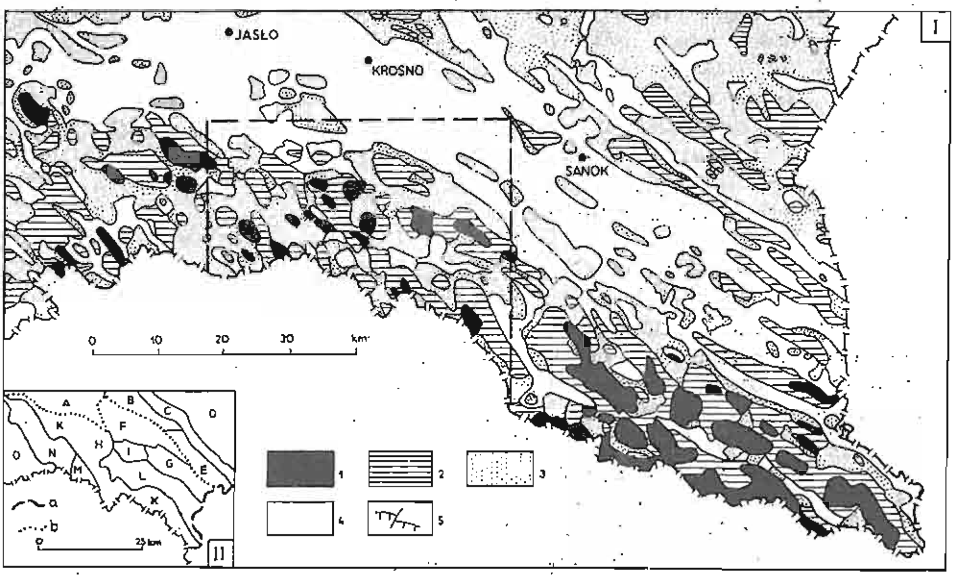

Fig. 3. I — Relief types in eastern part of the Polish Flysch Carpathians (based on L. Starkel, 1980*b*, simplified)

I — Typy rzeźby wschodniej części polskich Karpat fliszowych (według L. Starkla, 1980*b*; uproszczone)

1 — middle mountains of tbe butt and monadnock type; 2 — low mountains and high foothills bearing traces of Early Pliocene planation surfaces; 3 — middle foothills bearing traces of Late Pliocene planation surfaces; 4 — low foothills and intramontane depressions bearing traces of Early Quaternary planation surfaces; 5 — Carpathian frontal thrust

1— góry średnie o cechach wzniesień ostańcowych i twardzieli; 2 — góry niskie i wysokie pogórza z resztkami zrównań o założeniu wczesnoplioceńskim; 3 — pogórza średnie z resztkami zrównań o założeniu późnoplioceńskim; 4 — pogórza niskie i wysokie dna kotlin śródgórskich z resztkami zrównań wczesnoczwartorzędowych; 5 — brzeg Karpat

II — Geomorphic units of the eastern Beskid Niski Mts. and surrounding areas (based on L. Starkel, 1972; L. Starkel et al., 1973; T. Gerlach, 1972 and S. Gilewska, 1986; supplemented)

II — Jednostki geomorfologiczne wschodniego Beskidu Niskiego i obszarów otaczających (według L. Starkla, 1972; L. Starkla i in., 1973; T. Gerlacha, 1972; S. Gilewskiej, 1986, uzupełnione)

a — boundary between subprovinces of the West and East Outer Carpathians; b — northern boundary of the Beskid Niski mesoregion; solid lines — boundaries to subregions; A — Jasło Foothills, B — Sieniawa Depression (Sieniawa — Odrzechowa Basin); C — Wysoczany Ridge (Wysoczany — Mymoń Ridge); D — Besko Basin, Sanok Depression and SE part of the Beskid Brzozowski Mts.; E — Bukowsko Foothills; F — Iwonicz Foothills; G — Bukowica Ridge; H — Cergowa Group; I — Dział Ridge, K — Beskid Dukielski Mts., L — Jaśliska-Wisłok Depression; M — Tylawa Basin; N, O — foothills subregions of the eastern Magura Ridge

a — granica podprowincji Zachodnich i Wschodnich Karpat Zewnętrznych; b — północna granica mezoregionu Beskidu Niskiego; linie ciągłe — granice podregionów; A — Pogórze Jasielskie, B — Kotlinka Sieniawy (obniżenie Sieniawy — Odrzechowej). C — garb Wysoczan (Wysoczan — Mymonia), D — Kotlina Beska, obniżenie sanockie i SE część Beskidu Brzozowskiego, E — Pogórze Bukowskie, F — Pogórze Iwonickie, G — Pasmo Bukowicy, H — Grupa Cergowej, I — Pasmo Działu, K — Beskid Dukielski, L — Obniżenie Jaślisk — Wisłoka, M — Kotlinka Tylawy, N, O — subregiony pogórskie wschodniej części Pasma Magurskiego

comprises several flat-bottom basins separated by low foothills. This area occupies the Central Carpathian Depression, composed of strongly folded, poorly resistant shale-sandstone complexes. Fold axes are oriented NW - SE, whilst the morphological axis runs WNW - ESE.

Semi-consequent morphology dominates in southern part of the Jasło-Sanok Depression (Fig. 3), while Appalachian-type relief and morphological inversion are characteristic of the Fore-Dukla Zone (A. Henkiel, 1977). The Dukla Unit, however, displays resequent and, partly, semi--consequent relief types. All the geomorphic units conform with tectonic structures. Taking into account the degree of erosional dissection of fold structures, one can conclude about stronger uplift of the Dukla Unit, comparable with that of the Outer Skole thrust sheet (cf. A. Henkiel, 1977), in respect to slightly uplifted or even subsided southern part of the Central Carpathian Depression.

STATE OF GEOMORPHIC RESEARCH

A general geomorphological description of the Beskid Niski and Jasło-Sanok Depression has been given by J. Smoleński (1911), M. Klimaszewski (1948), L. Starkel (1972), T. Gerlach (1972), and L. Starkel et al. (1973). Evolution of landscape typology of the former area has been dealt with by J. Lach (1975) who concentrates mainly on mutual relationships between orographic and hydrographic networks and their structural control. H. Teisseyre (1936) and L. Bober (1984) discuss, in turn, the distribution and properties of landslides and landslumps. A sequence of the Wisłok and Jasiołka river terraces from southern part of the Jasło-Sanok Depression has been described by H. Świdziński (1930), M. Klimaszewski (1948), H. Świdziński and J. Wdowiarz (1953), I. Drzewicka-Kozłowska (1956), S. Wdowiarz and A. Zubrzycki (1985), and L. Koszarski (1985). Palynological analyses of peat bogs occurring in the Beskid Niski Mts. were conducted by S. Więckowski and K. Szczepanek (1963), W. Koperowa (1970) and K. Szczepanek (1983).

A concept of geomorphic evolution of the Polish East Carpathians in Plio-Quaternary times has been elaborated by L. Starkel (1965, 1969) and A. Henkiel (1977). Experimental studies on contemporary deflation and aeolian deposition have been carried out by S. Janiga (1975) in the Beskid Niski Mts., and by T. Gerlach and L. Koszarski (1968) in the southern Jasło-Sanok Depression. S. Janiga (1975) has also presented morphological consequences of land-use in the Jaśliska area (cf. Fig. 4).

QUATERNARY PALAEOGEOGRAPHIC EVOLUTION

During the earliest Quaternary (Biber, Praetiglian), erosional and erosion-accumulational terraces, described from the Dniester, Stryj, and San watershed area (130—150 m; I. D. Gofshtein, 1963), the Beskid Sądecki Mts (150—160 m), the Podegrodzie Foothills (140—150 m), and the Nowy Sącz Basin (120—130 m; cf. W. Zuchiewicz, 1984 *a*), were formed. Erosional flattenings 120—140 m high, previously assigned to the foothills or riverside levels (cf. M. Klimaszewski, 1937), should also be confined to this timespan. The same applies to the Witów Series (cf. L. Starkel, 1984), being equivalent to the Kozienice Formation in the South-Polish Uplands (J. Mojski, 1982) and to the Połaniec and Osiek Gravels, occurring in the northern part of the Sandomierz Basin (W. Laskowska-Wysoczańska, 1975). Climate of this period was boreal, cold, resembling the subarctic one (L. Stuchlik, 1987), typical for boreal steppe plant communities.

The next stage of evolution of the Polish Carpathians (Biber — Donau, Tiglian A, Ponurzyca Interglacial) showed moderately warm and temperate climatic conditions (L. Stuchlik, op. cit.) and was characterized by erosional dissection which, in the Dunajec river basin, reached 25 to 60 m (cf. W. Zuchiewicz, 1984 a, 1987). Meanwhile, in Southern Poland the deposition of the lower part of the Krasnystaw Fm deposits began (J. Mojski, 1982).

During the Otwock Stage (Eburonian, Tiglian B), erosional and erosion-accumulational terraces, being associated with the so-called riverside level were formed (L. Starkel, 1984). The author (W. Zuchiewicz, 1987) assigns to them the followng terrace plains: 120 m terrace of the Soła river at Tresna, 100 m terrace of the Skawa and Raba rivers, 100—120 m terraces of the Dunajec and Poprad rivers, 90 m terrace of the Biała river, 90—110 m terrace of the San river, as well as 90 m terrace plains described from the San, Dniester, and Stryj watersheds. The Carpathians were then drained to the NE, via the Wieprz and Gorajec gaps (cf. J. Wojtanowicz, 1977—1978), whilst the North Polish Lowland witnessed accumulation of deposits that build the upper part of the Krasnystaw Fm. A pronounced climatic cooling at that time, typical of the cold steppe and boreal forest-steppe conditions (L. Stuchlik, 1987), was marked by the appearance of boreal elements within forests of the Slovak (cf .I. Vaškovský and E. Vaskovská, 1981) and Polish Carpathians.

Erosional deepening of the Carpathian valleys in the Celestynów Stage (Waalian?, Tiglian C) was increasing from 15—30 m in the Łącko-Podegrodzie Foothills, through 15—40 m in the Beskid Wyspowy Mts., up to 20—50 m in the Beskid Sądecki Mts. (W. Zuchiewicz, 1984 *a*). In the Sandomierz Basin, a NE-directed outflow (J. Wojtanowicz, 1977—1978) was then operating, and the paleo-San river flowed on the riverside plains to the Dniester valley. Climatic amelioration favoured recession of coniferous trees and made possible the expansion of deciduous and mixed forests. A moderately warm, interglacial or interstadial-type climate did prevail (cf. L. Stuchlik, 1987).

The Narewian Stage (Menapian?) was characterized by the termination of fluvio-lacustrine deposition in the Podhale region (cf. W. Szafer, 1953). All the main valleys of the Outer Carpathians, at least in their middle reaches, attained their present position. This is confirmed by the formation of 80—90 m terraces of the Soła, Skawa, and Raba rivers, 80—100 m terraces of the Dunajec and Poprad rivers, 80 m terrace in the Wisłoka and 70—80 terrace level in the San river valleys (cf. M. Klimaszewski, 1967; L. Starkel, 1972, 1984; W. Zuchiewicz, 1984 *a*, 1987). Accumulation of the so-called "preglacial gravels" began in the lower sector of the Dunajec valley (M. Klimaszewski, 1967). This was also the time of formation of the 70—80 m terrace plain within the San, Dniester, and Stryj watershed area (I. D. Gofshtein, 1963). An uplift of the South-Polish Uplands led to the cessation of NE-directed drainage in the Sandomierz Basin (J. Wojtanowicz, 1977—78). Gravel series occurring in the Subcarpathian Furrow, in turn, were laid down on rock socles rising at altitudes of 210—215 m a.s.l. (W. Laskowska-Wysoczańska, 1975; L. Starkel, 1984). Recent TL datings suggest even a Narevian age (716 ka BP) of the oldest till found in the Sandomierz Basin (W. Laskowska-Wy-

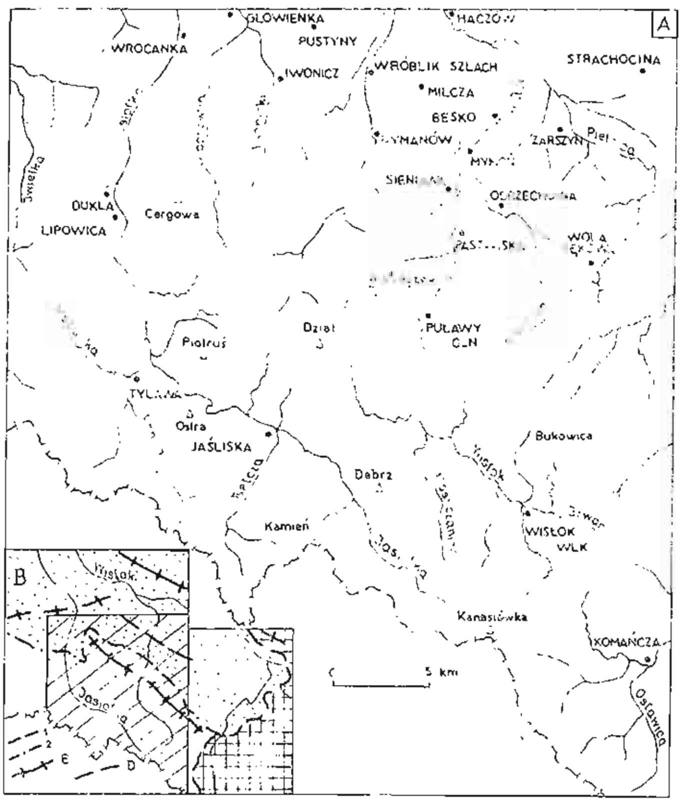

Fig. 4. Localisation sketch showing place-names referred to in the text (A) and main physiographic units of the area studies (B)

Szkic lokalizacyjny (A) oraz główne jednostki fizjograficzne badanego obszaru (B)

1 — boundary between subprovinces of the East and West Outer Carpathians; 2 — northern boundary of the Beskid Niski Mts.; E — axes of neotectonic elevations; D — axes of neotectonic depressions; dotted area — Jasło-Sanok Depression; dense hatchure — Low Bieszczady Mts.

1 — granica podprowincji Zachodnich i Wschodnich Karpat Zewnętrznych; 2 — północna granica Beskidu Niskiego; E — osie elewacji neotektonicznych; D — osie depresji neotektonicznych; obszar zakropkowany — Doły Jasielsko-Sanockie; obszar zaszrafowany — Bieszczady Niskie

soczańska, pers. comm. 1984). A sudden appearance of subaratic conditions in the Slovak Carpathians favoured development of cold parkland vegetation, associated with mean annual temperatures ranging from 0 to — 2°C (I. Vaškovský and E. Vaskovská, 1981).

Watershed areas of the eastern Beskid Niski Mts. were then affected by the formation of denudational flattenings of the riverside level, which lasted uninterruptedly throughout the early Quaternary. First signs of a deeper erosional dissection could be related to the Podlasie Stage (Cromerian s.s.?), while in the other Flysch Carpathian regions erosional processes are known to have commenced at the N/Q boundary (L. Starkel, 1969; A. Henkiel, 1977). Within upper reaches of the Jasiołka and Wisłok valleys, erosional terraces, presently observed at 35—50 m above river beds, were being formed. Similar altitudes of river terraces have also been recorded in the other Outer Carpathian regions (cf. L. Starkel, 1969, 1972). The depth of dissection in the axial part of the Beskidy Mts. has been estimated at 60 m (L. Starkel, 1972, 1984) or at 20—35 m (W. Zuchiewicz, 1984 *a*). Coeval fluvial series found in the Rzeszów area, however, rest on 190—200 m a.s.l. high rock socles (W. Laskowska-Wysoczańska, 1975). The stage in question was characterized by moist, temperate climate, with mean annual temperatures of 3 to 4°C, as well as by dry summer and rainy winter seasons (I Vaškovský and E. Vaškovská, 1981).

There are no traces of fluvial deposits from the N i d a n i a n and S a n i a n S t a g e s (Elsterian I, II, Günz — cf. K. Brunnacker et al., 1982), preserved in the eastern Beskid Niski Mts. This may testify to a predominance of physical weathering and solifluction processes over fluvial ones. In the Odrzechowa — Sieniawa Depression, however, one can observe small patches of erosion-accumulational terraces, described from Wola Sękowa (420—395 m a.s.l.), Głowienka, Wrocanka, and Iwonicz villages (cf. Fig. 4). S. Wdowiarz and A. Zubrzycki (1985) associate these terraces with the so-called Wygnanka Level. In the remaining mountain groups of the Beskidy Mts., these two stages manifested themselves by extensive accumulation of 5 to 20 m thick gravels and sands, supplied by pronival rivers (cf. L. Starkel, 1984), forming erosion-accumulational terraces within the San, Osława, Kalniczka, and Słupnica (30—60 m), Solinka and Wiar (30—40 m; cf. A. Henkiel, 1969, 1977; L. Starkel, 1972), and Strwiąż (20—30 m; A. Henkiel, 1969) river valleys.

The icesheet reached the Carpathian border in the San Stage (Elsterian II), extending as far as 350—450 m a.s.l. (cf. M. Klimaszewski, 1948; L. Starkel, 1984; J. Wojtanowicz, 1985) or even in the Nida Stage (Elsterian I), as revealed by fluvioglacial deposits found at Optyń near Przemyśl (M. Łanczont, 1986). Cold and dry climate (—2 do —5°C of annual temperature) favoured the expansion of tundra vegetation upon middle mountains and highly elevated basins (A. Środoń, 1977) and, along the Carpathian border, the deposition of loess (H. Maruszczak et al., 1972) did begin. Till and glacifluvial deposits in the Dynów Foothills fill fossil erosional channels, cut during the Podlasie Stage (T. Gerlach et al., 1985). In the Wisła, Soła, and Skawa drainage basins, in turn, valley bottoms which had been formed before the Nida (San?) Stage at the Carpathian border are, at present, deeply buried under younger sediments. This burial might have been related to the cessation of the connection between the Vistula and Odra drainages (M. Klimaszewski, 1958), or it could have resulted from young subsidence within the Oświęcim Basin (cf. L. Starkel, 1972). Ice-dammed lakes were being formed along the ice-margin and, in some cases (Zakliczyn Depression), new spill-ways are found to have been created (M. Klimaszewski, 1967). The present divide between the Vistula and Odra drainage systems is believed to have been formed after the maximum stadial of the Middle Polish Glaciation (cf. N. G. Kotlicka, 1975) while after the South-Polish Glaciations it was to be situated in the Oświęcim region.

A comparison of relative altitudes of early Quaternary terraces within main Carpathian valleys does not reveal any pronounced differentiation The highest altitudes are confined to the Beskid Sądecki Mts. and to the

Soła gorge in the Beskid Mały Mts. This may point to the role of uplifted longitudinal elevations and could suggest relatively uniform rates of early Quaternary dissection, except for the lowered Beskid Niski Mts. A drastic change was to occur only in the Masovian Stage (Holsteinian, Günz — Mindel). That was the time of increased fluvial activity (cf. L. Starkel, 1972, 1984) that led to formation of deep erosional furrows. The valley bottoms formed at that time can presently be observed at altitudes of 20—23 to 33—45 m above the present river-beds. Average altitudes of rock socles, dated back as for as the Holsteinian, range from 10 to 20 m (L. Starkel, 1969). Fluvial activity reflected climatic amelioration, marked by an increase of annual temperatures to 2—4°C (A. Środoń, 1977), as well as by the expansion of coniferous and, in Slovakia, also mixed forests (I. Vaškovský and E. Vaškovská, 1981).

In southern part of the Jasło—Sanok Depression, rock socles of the so-called Pustyny alluvial plain decrease from Rymarów to the Krosno Basin, from 30 to 20 m (M. Klimaszewski, 1948; T. Gerlach et al, 1983; S. Wdowiarz and A. Zubrzycki, 1985), and rise southwards up to 40—50 m (H. Świdziński, 1930; I. Drzewicka-Kozłowska, 1956). The paleo--Wisłok alluvial fan was shed by a meridional drainage system, supplying material from the Magura Unit (L. Koszarski, 1985). Some geologists (S. Wdowiarz and A. Zubrzycki, 1985; L. Koszarski, 1985) link the Pustyny and Haczów Levels, hitherto thought to be of various ages, into one "middle" terrace plain (345 m a.s.l.). Paleo-drainage operating on this level was directed northwards and utilized the Pustyny and Milcza-Haczów "gates", i.e., transversal depressions cut into the Mymoń Ridge.

Terrace steps (15—20 m high) composed of thin gravel series (Fig. 5), interfingering with solifluction deposits can, therefore be assigned to a sligghtly younger stage of development, associated with an interstadial warming during the Middle Polish Stage (Lublin Interstadial?, Treene, Fläming, Rügen). The lack of fluvial deposits preserved on higher situated terrace plains and within the 17—22 m terrace, forces one to apply morphostratigraphic criteria.

Relative altitudes of these terraces are higher than those of the Upper San (12—20 m; cf. L. Starkel, 1965), Wisłoka (12—22 m; cf. S. Pawłowski, 1925), and Strwiąż (A. Henkiel, 1969) river valleys (Fig. 6).

The two-fold division of the Middle-Polish Stage (Saalian) in the Outer Carpathians is clearly marked by the occurrence of two gravel series separated by peat or weathering horizons (cf. L. Starkel, 1980 *a*, 1984), as well as by the presence of separate erosion-accumulational terrace steps, described from the Dunajec (W. Zuchiewicz, 1984 *a*, 1984 *b*) and some Slovak rivers (cf. I. Vaškovský, 1977; J. Koštálik, 1984).

At the end of the Warta Stage (Riss) and during Eemian times, another climatic warming led to a dissection of fluvio-solifluctional covers and their rock socles. Mean annual temperatures exceeded the present ones by 2—3°C, and the precipitation totals were 50% greater as compared to the Late Holocene ones. The expansion of mixed forests reached the upper timber line (A. Środoń, 1977). Erosional deepening of valley bottoms in the eastern Beskid Niski Mts. ranged from 5—10 m in watershed areas up to 15—20 m at the boundary of the Jasło—Sanok

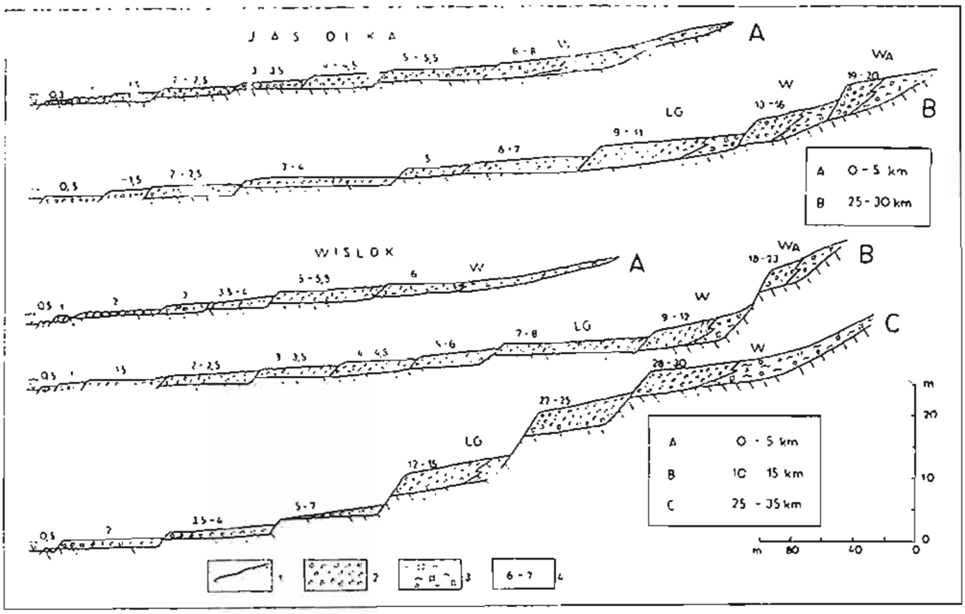

Fig. 5. Stratigraphic position of the Jasiołka and Wisłok river terraces within the Beskid Niski region

Pozycja stratygraficzna tarasów Jasiołki i Wisłoka w obrębie Beskidu Niskiego

1 — rock socle; 2 — fluvial series; 3 — periglacial deposits; 4 — relative altitudes, in metres; values given in kilometres refer to the distance from headwaters; WA — Wartanian, W — Vistulian, LG — Late Glacial

1 — cokół skalny; 2 — osady rzeczne; 3 — osady peryglacjalne; 4 — wysokości względne, w metrach; wartości podane w kilometrach wskazują odległość od źródeł

Depression. Average dissection of terrace rock socles in the Polish Carpathians, however, did not exceed 10 m (L. Starkel, 1969) and, in the Subcarpathian basins, erosion could not manage to reach valley bottoms cut during the Masovian Stage. In the Low Bieszczady Mts., in turn, older solifluctional covers were not dissected at all, and were exposed to intensive chemical weathering (cf. A. Henkiel, 1969). Climatic warming during Eemian times is marked by strong and deep-reaching weathering of the rock socle of the Sieniawa terrace. The Eemian was also a period of far-reaching hydrographical changes in southern part of the Jasło—Sanok Depression. The Pustyny alluvial fan became separated from the drainage system operating in the Magura Unit, as a result of tectonic movements of a transversal elevation, known to have embraced the Krosno Basin (cf. L. Koszarski, 1985).

During the Last Glacial Stage (Vistulian), fluvial and solifluction-deluvial series were deposited in the Beskid Niski Mts., forming two levels of erosion-accumulational terraces, namely: 15—22 m and 8—12 m. The higher terrace splits within downstream reaches of the Jasiołka and Wisłok valleys into two separate steps, which could be associated with the Older and Younger Pleniglacial or with the Early Glacial and Pleniglacial times, respectively. The first option seems to be confirmed by the presence of washout (deluvial) covers, overlying fluvial gravels and underlying solifluction deposits within the 21 m-high terrace of the Wisłok river at Puławy Dolne, as well as by the occurrence of Late Glacial wash-out covers on top of fluvio-solifluctional series of the 15—16 m high Jasiołka terrace at Jaśliska (Fig. 5).

The middle and lower reaches of the Jasiołka and Wisłok valleys during Pleniglacial times were subject to accumulation of gravel series, interfingering with solifluction tongues, whilst the upper valley reaches witnessed intensive solifluction. Altitudes of terraces do exceed 6—10 m within headwater sectors. The lack of sections showing contiguous sedimentary sequences may point to the importance of Early Glacial, interpleniglacial and Late Glacial lateral channel migration.

Downstream-increasing depths of erosional incision, together with the formation of a separate Late Glacial terrace step suggest, in turn, reactivation of tectonic subsidence within the southern Jasło—Sanok Depression. Altitudes of the Pleniglacial (mainly Late Pleniglacial — cf. L. Starkel, 1977, 1984) terrace in the remaining areas of the Polish Flysch Carpathians do not exceed 7/10/ to 15 m. Climatic changes during Pleniglacial times led to deposition of two-fold solifluction covers (L. Starkel, 1980 *a*), interstadial weathering horizons (L. Starkel, 1965; A. Henkiel, 1969), as well as peat bogs (L. Starkel, 1972, 1977, 1984). Mean annual temperatures in the Vistulian did not exceed 3°C (A. Środoń, 1977; I. Vaškovský and E. Vaškovská, 1981), and dropped below 0°C in the Younger Pleniglacial (L. Starkel, 1972, 1984). Deposition of solifluction covers at the base of slopes was accompanied by shaping of periglacial landforms (stone-fields, rock walls, tors) along the crest-lines of the Piotruś, Ostra, and Bukowica Ridges.

Downstream of the Jasiołka water-gap at Lipowica, the surface of the Pleniglacial terrace rises up to 21 m above the river bed, while thickness of its gravel series attains 10 m (cf. T. P. Kasela, 1985). In the Sieniawa Depression, the Pleniglacial alluvial plain relates to the so-called "II level" of M. Klimaszewski (1948), and the Mymoń (H. Świdziński, 1930) or Sieniawa Terrace (S. Wdowiarz and A. Zubrzycki, 1985) which, in SE part of the Krosno Basin, pass into the Haczów Level (15—20 m; M. Klimaszewski, 1948). Gravel series of the Sieniawa and Haczów alluvial plains mark the primary outflow of the paleo-Wisłok river through the longitudinal Odrzechowa — Rymanów Depression and the Wróblik Szlachecki wind-gap. This outflow ceased to exist in the Late Glacial or at the beginning of the Holocene. S. Wdowiarz and A. Zubrzycki (1985) relate the "Haczów Level" to the penultimate glacial stage, together with the "Pustyny Level" of M. Klimaszewski (1948). These authors date the formation of the Wisłok gorge near Besko for Early Holocene times.

Late Glacial climate favoured intensive erosional dissection, associated with a change of drainage pattern from braiding to meandering one (cf. L. Starkel, 1977, 1980 *a*). These changes led to the formation of a separate erosional step, cut into the Pleniglacial terrace. Large-scale washout processes on slopes preceded expansion of forests (L. Starkel, 1980 *a*), slopes were modelled by mass movements and suffosion, while in the valley bottoms rapid organogenic accumulation began, being initiated in Bölling and widespread during Alleröd times (M. Ralska-Jasiewiczowa, 1972, 1980; S. W. Alexandrowicz et al., 1985). The Bölling phase is marked by prograding expansion of boreal forests with stone-pine, larch, and Pinus silvestris (M. Ralska-Jasiewiczowa, 1980), attaining 1000 m a.s.l. in the Alleröd (cf. W. Szafer, 1953). During colder phases (Older and Younger Dryas), the timber line became lowered down to 500—600 m a.s.l. (W. Szafer, 1953; A. Środoń, 1977) whereas slopes were mantled again by solifluction-deluvial covers. Increased fluvial activity is documented by the presence of alluvia which underly and/or interrupt Alleröd peat deposition (W. Koperowa, 1970; M. Ralska-Jasiewiczowa, L. Starkel, 1975). In the San valley, however, the Alleröd peat fills erosional channels cut into Pleniglacial alluvia (M. Ralska-Jasiewiczowa, 1980). The phase in question is the first distinct phase of organogenic deposition within the Jasło—Sanok Depression, the Beskid Niski Mts., and the Low Bieszczady Mts. (cf. A. Środoń, 1977; M. Ralska-Jasiewiczowa and L. Starkel, 1975; L. Starkel, 1977, 1980 *a*; K. Szczepanek, 1983). In southern part of the Jasło—Sanok Depression, numerous lakes filling Pleniglacial deflational hollows, were formed (T. Gerlach and L. Koszarski, 1968). These basin began to overgrow during the Younger Dryas, known to have been characterized by a slight increase in climatic continentality (S. W. Alexandrowicz et al. 1985). In the eastern Beskid Niski Mts, Pleniglacial terraces (15—21 m) of the Jasiołka and Wisłok rivers became dissected by 2 to 8 m. Erosional channels cut at the end of Older Dryas (?) and during Alleröd times were filled by younger alluvia, 2 to 5 m thick, interfingering sometimes with periglacial deposits and/or mantled by wash-out covers.

A decrease in fluvial activity in the Flysch Carpathians, accompanied by widespread accumulation of organogenic deposits, marks the beginning of the Holocene (M. Ralska-Jasiewiczowa and L. Starkel 1975; L. Starkel 1980 *a*; S. W. Alexandrowicz et al., 1985). Climatic warming intensified ground-water circulation which led to the formation of brown-forest and podzolic soils and favoured mass movements, suffosion, and lateral channel migration (E. Gil et al., 1974). The dissection of alluvial covers and their rock socles in upper valley reaches during more humid phases was accompanied by episodes of channel infilling and mud deposition at the Carpathian border (L. Starkel, 1984, 1986). An increase in overland flow and soil erosion due to deforestation started 6.5—6 ka BP (L. Starkel 1977, 1986) and was responsible for another stage of wash-out deposition on slopes. Intensive aggradation in valley bottoms dates back to the Roman and Middle Ages times (L. Starkel, 1986) while development of braided channel pattern began at the close of the 18th century (K. Klimek and K. Trafas, 1972). The present-day phase of increased fluvial activity, in turn, is known to have commenced at the last century, due to flood-control and irrigation works (cf. R. Soja, 1977; K. Klimek, 1974; L. Starkel, 1980 *a*, 1984).

Humid phases appeared at the Boreal/Atlantic (8.5—8 ka BP) and Atlantic/Subboreal (5—4.5 ka BP) boundaries, as well as during the Atlantic (6.5—5.9 ka BP). These phases were responsible for the termination of peat bog development in some areas (M. Ralska-Jasiewiczowa, 1980; W. Koperowa, 1970) or the creation of new bogs in the other (K. Pekala et al., 1972). Within the Jasło—Sanok Depression, organogenic deposition lasted up to Neolithic times (S. W. Alexandrowicz et

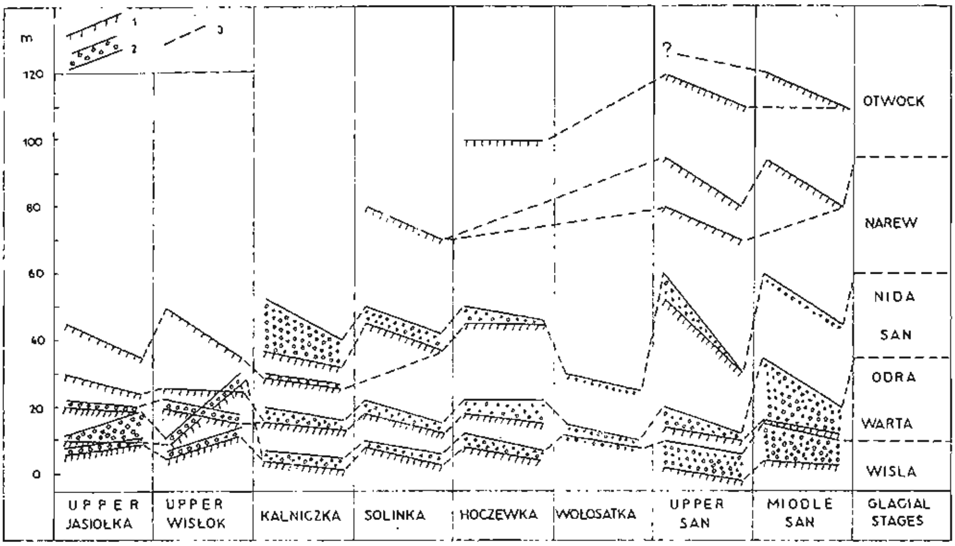

Fig. 6. Terrace stratigraphy in eastern part of the Polish Flysch Carpathians (Upper Jasiołka, Upper Wisłok — this paper; Kalniczka, Solinka, Hoczewka — L. Starkel, 1965; Wołosatka — K. Pękala et al., 1972; Upper San — L. Starkel, 1965; Middle San — A. Wójcik, 1976, K. Pękala, 1973; correlation and age interpretation by the author)

Pozycja stratygraficzna tarasów rzecznych w dolinach wschodniej części polskich Karpat fliszowych (korelacja oraz interpretacja wieku według autora)

1 — rock-cut terraces, rock socles; 2 — fluvial covers of erosion-accumulational terraces; 3 — supposed correlation

1 — tarasy skalne, cokół skalny; 2 — osady rzeczne tarasów skalno-osadowych; 3 — przypuszczalna korelacja

al., 1985). These processes were coeval with intensive erosion in upper reaches of the Beskid Niski valleys, and led to the formation of separate rock socles of three terraces in the Jasiołka and Wisłok valleys (Fig. 5). The lower — situated floodplains, therefore, could relate to Subatlantic episodes of fluvial activity. Human impact has become visible in this region since the close of the Atlantic phase, while the period of widespread deforestation started in the younger Subatlantic (cf. W. Koperowa, 1970). Low-lying flood plains and recent gravel bars are characterized by poor sorting and rounding of alluvia, closely resembling those deposited under periglacial conditions.

Boreholes drilled in the Besko alluvial fan (W. Koperowa, 1970; S. Wdowiarz and A. Zubrzycki, 1985) reveal the presence of lacustrine chalk, overlain by two layers of peat, separated by clays and sandy clays. The top and bottom horizons of the lower peat layer have been dated by C-14 method at 7 850 ± 100 and 9 531 ± 150 BP, respectively. Malacological assemblages found in the chalk indicate an early Holocene age (S. W. Alexandrowicz, pers. comm. 1985). These deposits have hitherto been considered Late Glacial ones (W. Koperowa, 1970; L. Starkel, 1972). The Besko alluvial fan is 3 km wide and approximately 15 m thick. Distal parts of this fan are composed of clayey gravels laid down by the paleo-Pielnica river, the channel lag deposits being overlain by sandy muds, gyttjas and peat which, in turn, underly the upper, 1.2—3.7 m thick gravel series. The latter is thought to record the influx of paleo-Wisłok material into the Besko Basin at 6—7 ka BP (S. Wdowiarz and A. Zubrzycki, pers. comm. 1986).

DEVELOPMENT OF RIVER TERRACES: SOME REMARKS

The eastern Beskid Niski Mts. are characterized by a different pattern of Pleistocene terraces, as compared with the other, more strongly uplifted morphostructures. Early and Middle Pleistocene fluvial activity is manifested only in the form of erosional breaks or benches that mark consecutive stages of dissection of the riverside level. Slope processes, active during these stages, led to the formation of cryonival glacis and/or bog cirques. The size of slope degradation in one glacial-interglacial cycle has been estimated at 10 m, as compared to 30—50 m during the whole of the Pleistocene (cf. L. Starkel, 1972, 1986). Holocene denudation, in turn, is thought to be responsible for a lowering of the surface of the Polish Carpathians by 0.5 m (L. Starkel, 1986).

The Jasiołka and Wisłok erosion-accumulational terraces, bearing poorly preserved fluvial covers, belong to relatively young landforms, formed at the end of the penultimate and during the last glacial stages (Fig. 5, 6), as well as in Holocene times. Poor state of preservation or a complete lack of older terrace steps can be explained by the proximity of the studied valleys to the main European drainage divide. The latter has undergone insignificant uplift, as compared to the other mountaineous regions.

A lower number of Pleistocene terraces in respect to the number of glacial-interglacial cycles is usually being thought to result from different succession of cold and warm phases during cycles of various age. The youngest cycle (Vistulian — Holocene) terminated with a warm phase that was preceded by a glacial pessimum allowing, therefore, for the development of distinct terrace steps (Pleniglacial, Late Glacial, Holocene ones). The shaping of terraces formed during earlier cycles, however, had largely been controlled by the intensity of tectonic movements (Fig. 7). This is clearly indicated by a comparison of terrace steps that developed in areas showing different tectonic tendencies, like the Alps and their foreland (G. Kukla, 1981; K. Brunnacker et al., 1982; V. Šibrava, 1986) or the Outer Carpathians (cf. W. Zuchiewicz, 1984 b). The number of Quaternary terraces within main Carpathian valleys changes from 5 to 9.

CONCLUSIONS

The lowest possible amount of Quaternary uplift of the Beskid Sadecki Mts. could be estimated at 150—170 m, while that of the Beskid Niski Mts. did not exceed 30 to 120 m. Neopleistocene terraces of the Jasiołka and Wisłok rivers reveal rock socles, the altitudes of which increase downstream, towards the Jasło—Sanok Depression (Figs. 6, 7). This is especially true for the Wisłok terraces in the Sieniawa Depression, dissected to a depth of 30—35 m. Such a rapid erosional dissection, unparalleled to the other Outer Carpathian rivers, may have resulted from

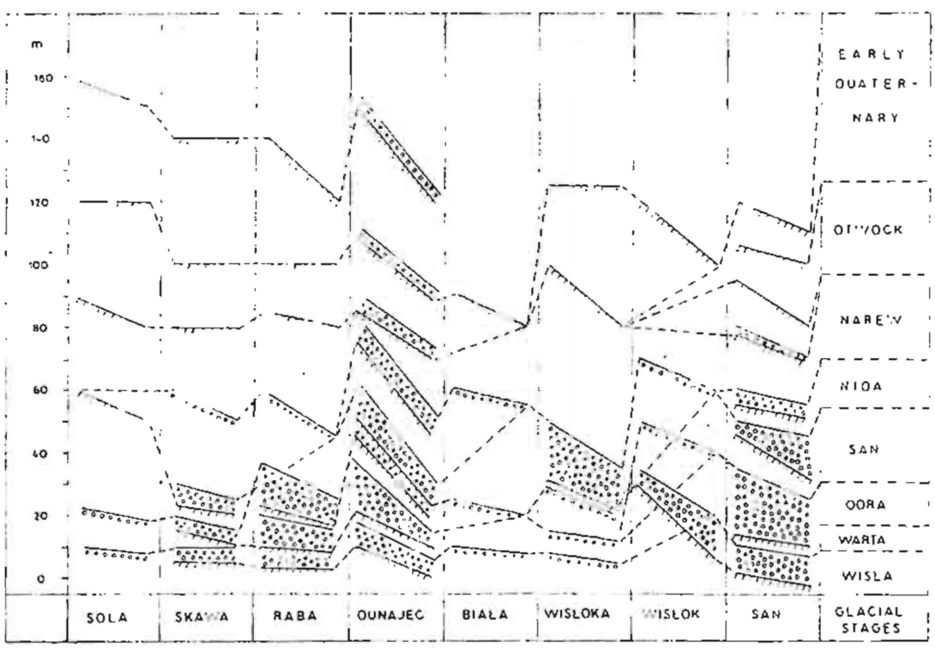

Fig. 7. Terrace stratigraphy in the Polish Flysch Carpathians (Soła — J. Szaflarski, 1932; Skawa — J. Szaflarski, 1931, M. Klimaszewski, 1948, Raba — W. Stolfówna, 1932, M. Klimaszewski, 1948; Dunajec — W. Zuchiewicz, 1984*a*; Biała — J. Bugajski, 1934; Wisłoka — S. Pawłowski, 1925, M. Klimaszewski, 1948; Wisłok — A. Fleszar, 1914, M. Klimaszewski, 1948, I. Drzewicka-Kozłowska, 1956, T, Gerlach et al., 1985; San — L. Starkel, 1965)

Pozycja stratygraficzna tarasów rzecznych w głównych dolinach polskich Karpat fliszowych

Correlation and age interpretation by the author; for other explanations — see Fig. 6
Korelacja oraz interpretacja wieku według autora; pozostałe objaśnienia jak na fig. 6

young (Vistulian — Holocene) subsidence in front of the tectonically active Besko thrust fold. The lowering of the Besko — Zarszyn Basin favoured strong headward erosion, observed in the Wisłok river valley between Sieniawa and Moszczaniec. Another example of Late Pleistocene — Holocene neotectonic movements is provided by a tilt of rock socles of Last Pleniglacial and Late Glacial terraces towards the thalweg. A similar relationship has been described by L. Starkel (1965) from the Upper San drainage basin, when discussing older Pleistocene terraces. The Late Pleistocene was also a period when tectonically controlled hydrographic changes in the Krosno Basin and in front of the Beskid Rymanowski Mts. took place (cf. also T. Gerlach et al., 1983, 1985; L. Koszarski, 1985).

The Beskid Niski morphostructure reveals only two distinct stages of tectonic activity in the late Cenozoic: at the end of the Pliocene and during Early Quaternary times, and the younger one, connected with the Vistulian and Holocene. Neotectonic episodes described from the

Western Flysch Carpathians (cf. W. Zuchiewicz, 1984 b) manifested themselves less intensely and embraced the southern part of the Jasło—Sanok Depression.

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ROZWÓJ MORFOLOGICZNY BESKIDU NISKIEGO A CZWARTORZĘDOWA PALEOGEOGRAFIA POLSKICH KARPAT FLISZOWYCH

Streszczenie

Wschodnia część Beskidu Niskiego obejmuje szereg struktur fałdowych jednostek: magurskiej, dukielskiej oraz śląskiej (fig. 1, 2), złożonych z utworów o zróżnicowanej odporności na procesy denudacyjne i warunkujących wytworzenie rzeźby typowej dla niskich gór i wysokich pogórzy, z resztkami zrównań o założeniu plioceńskim i wczesnoczwartorzędowym (fig. 3). Obszar objęty badaniami szczegółowymi leży w obrębie kilku jednostek fizjograficznych (fig. 4), odznaczających się rzeźbą właściwą nieodmłodzonym obszarom wododzielnym w części południowej oraz wskazującą na intensywne odmładzanie w części północnej.

Brak starych tarasów czwartorzędowych (fig. 5) pozwala sądzić, iż etap formowania poziomu przydolinnego obejmował cały starszy plejstocen. Począwszy od piętra południowopolskiego (Nidy, Sanu), fragmenty poziomu podlegały przeobrażeniom w warunkach morfogenezy peryglacjalnej. Zostały wówczas uformowane spłaszczenia podstokowe przypominające kriopedymenty lub cyrki mlakowe.

Intensywna erozja wgłębna w interglacjale wielkim, i przypuszczalnie z początkiem zlodowacenia środkowopolskiego, zaznaczyła się we wschodniej części Beskidu Niskiego wycięciem tarasów skalnych o wysokości 27—30 do 33—45 m. Tarasy związane z piętrem Warty zachowały się w dolinie Jasiołki (17—22 m) oraz Wisłoka (18—23 m). Ocieplenie i zwilgotnienie klimatu w interglacjale eemskim sprzyjało wycięciu rynien o głębokości 5—7 m w źródłowych odcinkach Jasiołki i Wisłoka

do 10—13 m w Kotlince Tylawy i 18—19 m w rejonie Pastwisk — Sieniawy. Osady rzeczne z ostatniego piętra chłodnego budują pokrywy dwóch poziomów tarasowych o wys. 15—30 m i 8—12 m, powstałych w pleniglacjale i późnym glacjale. Wysokość tarasu pleniglacjalnego wzrasta z biegiem rzek od 6—8 m do 20—31 m. Taras ten łączy się w rejonie Sieniawy (dolina Wisłoka) z tarasem Mymonia (Sieniawy), wyznaczającym pierwotny równoleżnikowy odpływ wód paleo-Wisłoka w południowej części Dołów Jasielsko-Sanockich. Przepływ ten został przerwany w późnym glacjale lub z początkiem holocenu, prowadząc do uformowania przełomu Wisłoka w Besku. Tarasy holoceńskie reprezentują trzy poziomy tarasów nadzalewowych oraz dwa poziomy tarasów zalewowych, skalno-osadowych lub akumulacyjnych.

W porównniu z innymi, silniej wypiętrzonymi morfostrukturami polskich Karpat Zewnętrznych (fig. 6, 7), wschodnia część Beskidu Niskiego odznacza się odmiennym wykształceniem plejstoceńskich tarasów rzecznych. Brak lub bardzo słaby stan zachowania tarasów starszych może być efektem usytuowania tego obszaru w pobliżu głównego działu wodnego Karpat oraz znikomego, w stosunku do innych grup górskich Beskidów, wypiętrzenia neotektonicznego. Głębokie rozcięcie tarasu z ostatniego glacjału na południowym obramowaniu Dołów Jasielsko-Sanockich sugeruje uaktywnienie młodych ruchów tektonicznych, obejmujących dno kotlinki Beska — Zarszyna i/lub podnoszących skibę Beska.

Poprzeczna do rozciągłości Karpat depresja Beskidu Niskiego ujawnia jedynie dwa wyraźne etapy wzmożonej aktywności tektonicznej u schyłku kenozoiku: starszy, obejmujący schyłek pliocenu i wczesny czwartorzęd oraz młodszy, związany z ostatnim glacjałem i holocenem. Oddźwięki faz tektonicznych opisywanych z zachodniej części Karpat były tutaj znacznie słabsze i dotyczyły głównie południowej strefy Dołów Jasielsko-Sanockich, warunkując zmiany sieci hydrograficznej.

Витольд ЗУХЕВИЧ

МОРФОЛОГИЧЕСКОЕ РАЗВИТИЕ НИЗКОГО БЕСКИДА И ЧЕТВЕРТИЧНАЯ ПАЛЕОГЕОГРАФИЯ ПОЛЬСКИХ ФЛИШЕВЫХ КАРПАТ

Резюме

Восточная часть Низкого Бескида включает рад складчатых структур единиц: магурской, дукельской и силезской (фиг. 1, 2), сложеныых осадками с разной стойкостью к денудационными процессам и обуславливающих образование рельефа типичного для низких гор и высоких пригорков с остатками плоскостей с плиоценовым и раннечетвертичным заложением (фиг. 3). Область подвергиута детальным исследованиям находится в пределах нескольких физиографических единиц (фиг. 4), характеризующихся рельефом соответствующим неомоложенным водоразделяющим территориям в южной части и рельефом указывающим на интенсивное омоложение в северной части.

Недостаток старых четвертичных террас позволяет считать, что этап формирования околодолиинного уровня продолжался весь старший плейстоцен. Начиная с южно-польского яруса (Ниды, Сана) фрагменты этого уровня подвергались преобразованиям в условиях перигляциального морфогенеза. Тогда сформировались подсклоновые плоскости похожие на криопедименты или млаковые цирки.

Интенсивная глубинная эрозия в большом межледннковьи и вероятно в начале средне-польского оледенения обозначились в восточной части Низкого Бескида вырезкой скальных террас высотой 27—30 до 33—45 м. Эти террасы, связаны с ярусом Варты, сохранились в долине Ясёлки (17—22 м) и Вислока (18—23 м). Потепление и увлажнение климата в ээмском межледниковии способствовало вырезке желобов глубиной 5—7 м в источниковых отрезках Ясёлки и Вислока, до 10—13 м в Котловнне Тылявы и 18—19 м в районе Паствиск — Сенявы. Речные осадкн последнего холодного яруса слагают покровы двух террасовых горизонтов высотой 15—30 и 8—12 м, образовавшнхся в пленигляциале и позднем гляциале.
Высота пленигляцнальной террасы увеличается с ходом рекн с 6—8 до 21—31 м. В районе Сенявы (долина Вислока) эта терраса соединяется с террасой Мымоня (Сенявы), которая определяет первичный параллельный сток воды палео-Вислока в южной части Ясельско—Саноцких Ям. Это течение было прорвано в позднем ледниковом периоде или в начале голоцена, что привело к сформированию перехвата Вислока в Беске. Голоценовые террасы представляют три горизонта надпойшенных террас и два горизонта пойш, скально-осадочных или аккумулятивных.

В сравнении с другими, сильнее поднятыми морфоструктурами польских внешных Карпат (фиг. 6, 7), восточная часть Низкого Бескида отличается иной формой плейстоценовых речных террас. Отсутствие или очень слабое сохранение старщих террас может быть эффектом расположения этого района вблизи главного водораздела Карпат, а также очень малого, в сравненин с другими горными группами Бескидов, неотектонического поднятия. Глубокое рассечение террасы из последнего леднникового периода на южном окаймлении Ясельско-Саноцких Ям, указывает на повышение активности молодых тектонических движений, охватывающих дно котловинки Беска — Заршина и/или поднимающих складку Беска.

Поперечная к простирании Карпат депрессия Низкого Бескнда указывает только два этапа усиленной тектонической активности в конце кайнозоя: старший — охватывающий конец плиоцена и ранний четвертичный период и младший — связанный с последним ледниковым периодом и голоценом. Отзвуки тектонических фаз описыванных в западной части Карпат были здесь более слабые и связанные главным образом с южной зоной Ясельско-Саноцких Ям, обуславливая изменения гидрографической сети.