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2. THE EFFECTS OF PLEISTOCENE ICE-SHEET LOADING-DELOADING CYCLES ON THE BEDROCK STRUCTURE OF POLAND

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Abstract. Pleistocene ice-sheet loading/deloading cycles result in fast, relatively short-term quasiperiodic and reversible glacioisostatic crustal deflections. Superposed on these are irreversible glaciotectonic deformations. The latter include not only the well-known fold and thrust structures of Cainozoic unconsolidated drift deposits, but also numerous Mesozoic bedrock deformations. In Poland, the last include: (1) fracturing, sheeting, brecciation and related brittle failure of rocks; (2) reactivated local to subregional faults, horsts and graben structures (glaciotaphrogenic distortions), portrayed partly as fault-bend and fault-propagation folds in the overlying drift-cover deposits; (3) reactivated or accelerated halokinetic structures (glacio-halokinetic deformations), as a result of the increased increment of instability; these are expressed as, e.g. salt stock's limb grabens; (4) reactivated regional deep-seated basement faults, fractures and/or zones of weakness (glaciorhegmatic deformations), inferred from the alignment of end moraine belts, coupled with large regional thickness gradients of Quaternary deposits and/or flowage fold structures of the pre-Quaternary drift deposits, as well as the bedrock for the large-scale ice-push pressure ridges, push moraines and/or glaciotectonic fold-thrust ridges. The non-structural, glacial-induced effects include excess near-surface horizontal stresses within the tectonically-undisturbed or only weakly disturbed Mesozoic rocks (glaciotectonic residual stress field), expressed as local pop-ups and related phenomena.

There are also some indications that the recent vertical crustal movements, at least in NE Poland, are not simply epeirogenic, but also include a component of postglacial isostatic re-adjustment movements. It is often impossible to discriminate between the true tectonic and glacioisostatic/glaciotectonic components of the Pleistocene crustal movements; although the timing and short-term transient nature and the very high strain rates and velocities of movements are indicative for the glacial-induced stress and strain system changes.

STRESZCZENIE

WPŁYW CYKLICZNEGO OBCIĄŻENIA I ODCIĄŻENIA POWIERZCHNI ZIEMI MASAMI PLEJSTOCEŃSKICH LĄDOLODÓW NA STRUKTURĘ I STAN ODKSZTAŁCEŃ PODŁOŻA PRE-KENOZOICZNEGO W POLSCE

Głównym efektem cyklicznego obciążenia/odciążenia litosfery masami plejstoceńskich lądolodów były względnie krótkotrwałe, quasi-periodyczne i odwracalne glacjoizostatyczne przemieszczenia jej swobodnej powierzchni. Na powyższe glacjoizostatyczne przemieszczenia nałożone były nieodwracalne deformacje glacjotektoniczne górnych warstw skorupy ziemskiej. Obejmują one nie tylko szeroko opisywane zaburzenia fałdowe i skibowo-łuskowe nieskonsolidowanych osadów kenozoicznych i staroplejstoceńskich, lecz także liczne nieciągłe deformacje podłoża prekenozoicznego. Te ostatnie obejmują w Polsce przede wszystkim reaktywację prekenozoicznych dyslokacji różnego typu i różnych wymiarów liniowych: od lokalnych i subregionalnych (tafrogenicznych) uskoków podłoża alpejskiego, po regionalne i supraregionalne (regmageniczne) uskoki podłoża hercyńskiego i kaledońskiego oraz wgłębnych rozłamów i stref osłabień podłoża krystalicznego. Zewnętrznym wyrazem tej reaktywacji są „epidermalne", nad- i międzyuskokowe deformacje fałdowe osadów pokrywowych, rowy tektoniczne, liniowo i nadrozłamowo usytuowane ciągi moren czołowych, akumulacyjnych i spiętrzonych oraz wałów wypiętrzeń glacjotektonicznych, subregionalnych zaburzeń fałdowych z płynięcia lub pełzania podłoża kredowego oraz podwyższone wartości regionalnych poziomych gradientów miąższości osadów czwartorzędowych. Spośród innych efektów należy wymienić: przyśpieszenie ruchów halokinetycznych wysadów solnych, zeszczelinowienie skał, kataklastyczne zniszczenie (delityfikacja) skał, oraz wymuszone zmiany znaku wektora długotrwałego trendu pionowych ruchów skorupy ziemskiej. Wysokie prędkości deformacji, sięgające 20–30 mm/rok, nie pozwalają zaliczyć wymienionych struktur do tektonicznych w sensie generowanych procesami endogenicznymi. Nie mogą one wobec tego zostać zakwalifikowane do neotektoniki. Jednak jednoznaczne zaszeregowanie tego typu struktur do glacjotektonicznych możliwe jest tylko poprzez bardzo szczegółowe badania litogenetyczne i stratygraficzne, pozwalające na precyzyjne ich umiejscowienie w czasie geologicznym (por. np. BARANIECKA 1971, 1975 a i b, 1979).

STAGES OF NEOGENE AND EARLY QUATERNARY FAULTING IN THE SUDETES AND THEIR FORELAND

The Sudetes, Fore-Sudetic block and neighbouring part of the Fore-Sudetic Monocline are complex block structures that have been formed mostly during the Neogene. Individual blocks are bounded by faults and fault zones, the most important of which are: the Middle Odra Fault Zone, Sudetic Boundary Fault, Intra-Sudetic Fault and, on the south, the Lusatian Thrust (Figs. 1 and 2). These faults have controlled ridge formation in the Sudetes and Fore-Sudetic block. Inbetween these principal faults there occur numerous subsidiary faults, as well as graben and horst structures which additionally modify the geomorphic expression of the area.

Fault systems active in the Neogene had already been formed in earlier times. Some of them originated during the Variscan orogeny and, particularly, during the Laramian movements at the turn of the Cretaceous and Paleogene (Fig. 1). The older fault zones were rejuvenated in Neogene times, during those movements that were associated with strong tectonics in the Carpathians and Carpathian Foredeep, affecting also the Metacarpathian Swell. The latter zone comprises the Sudetes and Fore-Sudetic block. The movements in question were strong enough to affect the whole of the crust, down to the Moho. Strong faulting in the Sudetes was also associated with basaltic volcanism, noticeable between the

Savian (Paleogene/Neogene) and Attican (Late Miocene) tectonic phases. This volcanism controlled hydrothermal activity that resulted in the formation of sinters, hydrothermal alteration of rocks, and metallization of tectonic zones; all of these features occurring throughout the area studied.

Tectonic pulses reached their climax in the Neogene, leading to strong uplift of individual mountain ranges along faults that bound the Sudetes and Fore-Sudetic block (Fig. 2). One can distinguish four phases of intensive uplift. The most important were the Styrian (Middle Miocene) and Valachian (Pliocene) phases, whereas the Savian (Early Miocene) and Attican (Late Miocene) ones were less strong and affected only selected areas of the region in question.

The majority of faults being active in the Neogene were also active in the Early Quaternary. This mobility might have been related to the final phases of the Valachian movements, as well as to reactivation of some faults under dynamic and static stresses induced by Pleistocene ice sheets. Manifestations of these movements include young morphologic scarps, deformations of longitudinal systems of buried valleys, and diversified thicknesses of glacial deposits on either side of the faults.

The Quaternary tectonic mobility has also been associated with hydrothermal activity, occurrences of mineral waters, gas exhalations and remanent seismicity, reported from the Lower Silesia in historic times (Fig. 3). Another related feature are recent subsidence, the rates of which are from 0.5 to 2.0 mm/yr and, in zones of anomalous velocities like that near Nysa, up to 6 mm/yr (Fig. 3). The neighbouring region in the Czech Republic displays recent uplift of 1.5 to 2.0 mm/yr.

The above-mentioned processes are most active in those zones that have been controlled by strong Neogene, especially Pliocene, movements. Such zones include strongly uplifted blocks, like the Karkonosze-Izera Massif, and the Sowie, Orlica, Bystrzyca and Biała Mountains. Faults separating these blocks are sites of numerous and strongest eartquakes (Fig. 3).

translated by *W. Zuchiewicz*

SUMMARY

AN ATTEMPT AT APPLICATION OF SELECTED MORPHOMETRIC METHODS TO ESTIMATION OF NEOTECTONIC MOVEMENTS IN THE SUDETY MOUNTAINS, SW POLAND, AND THEIR FORELAND

The authors' attempt is to check the possibility of adopting a few morphometric methods to estimate neotectonic movements in the Sudety Mts. Our investigations focus on the western part of the Sudety Mts. and their foreland, situated between the Nysa Łużycka and Bystrzyca rivers. The isobase, goniobase. and isolong maps, according to methods popularised by FILOSOFOV (1960, 1963, 1970). PANNEKOEK (1967), and GVIN (1965), have been constructed for this area. Similar methods have already been applied to the Carpathians by RĄCZKOWSKI et al. (1985).

An isobase map is constructed by linking points of the same elevation along river valleys of the same order, by using smooth curves. A goniobase map originates in a similar way, except that curves are replaced by straight lines. Goniobases and isobases of a given order delimit base-level surfaces of the same order. One can substract a base-level surface of an older order from that of a younger one. Residuals give the amplitude of erosional dissection during a timespan that elapsed between the formation of the two surfaces. Isolongs represent isolines of the length of valleys of the same order. Initial maps of valley orders have been drawn on 1: 50 000 topographic maps.

We analyzed base-level surfaces of the 4th and 5th order. The analysis did not reveal any new element in the existing neotectonic picture of the Sudety Mts. and their foreland. The Sudetic marginal fault and the Karkonosze Massif are distinctly marked as uplifted zones, whereas the Jelenia Góra and Kamienna Góra Basins appear to represent subsided structures. The amplitude of movements ranges from –80 m in the Jelenia Góra Basin to +40 m on the Sudetic marginal fault.

Difficulties in estimating the age of the both base-level surfaces make it impossible to determine the rate of movements. In other areas, small number of 4th-order valleys and the presence of river network strongly disturbed by the activity of Pleistocene icesheets, prevent the application of morphometric techniques.

SUMMARY

ROLE OF INITIAL RELIEF IN NEOTECTONIC RECONSTRUCTIONS: SELECTED EXAMPLES FROM THE SUDETY MOUNTAINS, SW POLAND

Main elements of the present-day morphology of the Sudety Mts. were shaped during Neogene times due to intensive block-type movements that led to the formation or reactivation of numerous faults, separating uplifted and/or subsided blocks. A detailed delimitation of faults active in Late Tertiary times, as well as of their throws has been difficult, since in large part of the Sudetes there are no correlative rock horizons preserved (Fig. 1). It has become a common procedure to use geomorphic criteria, chiefly by correlating summit surfaces, considered to represent an Early Tertiary planation surface, among neighbouring mountain massifs. Characteristic features of the Early Tertiary denudation morphology, representing initial topography for neotectonic stage of the development of that area, have usually been neglected.

The Tertiary (Paleogene) morphology of the Sudetes has been shaped primarily by selective weathering and subsequent removal of the regolith and exposure of the basal surface. Topography of the latter resulted from resistance of the bedrock and local morphological differentation, being different for various basement rocks (Fig. 2). The Neogene faulting, therefore, affected an area of differentiated relief, far from hitherto presumed advanced planation.

The importance of Early Tertiary denudation morphology in delimiting young fault lines and calculating their throws is illustrated on examples from the Jelenia Góra Basin, Western Sudetes (Fig. 3). The Basin, together with the neighbouring Karkonosze Massif, as well as the Karkonosze Foothills and Rudawy Janowickie Mts., are all composed of granites. The northern boundary of the Jelenia Góra Basin coincides with the main intra-Sudetic fault that separates granites and the Kaczawa Mts. greenschists. On the south, the Basin is surrounded by the Karkonosze Foothills, cut by a 200 m high fault-line scarp striking WNW–ESE. The character of the southern, 300 m high and 4 km long segment of this scarp between Miłków and Karpacz, has

not hitherto been deciphered (Fig. 4). A comparison among relative elevations of micrograniti ridges (up to 100 m above basal surface) that occur both in the Basin and in the Foothills enable one to suppose that the segment in question has also tectonic origin, and that the eastern scarp of the Karkonosze Foothills represents a fault escarpment, ca. 150–200 m high.

The Karkonosze Foothills display differentiated morphology of deeply-incised valleys and isolated massifs, that have been interpreted as an effect of erosional dissection of the uplifted, uniform block. Hilly landscape of that area is, however, largely initial one and represents topography of the basal surface of weathering. Local rectilinear scarps that are not related to lithological differentiation, are fault scarps subdividing the Karkonosze Foothills into numerous small horsts, grabens and tectonic steps (Fig. 5). A similar pattern has been observed in the Rudawy Janowickie Mts. where the Tertiary etchplain is dissected into several tectonic steps (Fig. 6).

The northern boundary of the Jelenia Góra Basin is marked by a rectilinear scarp, coinciding with the main intra-Sudetic fault. It is a compound fault scarp, formed in two stages (Fig. 7). During Early Tertiary times, due to less intensive weathering of metamorphic rocks, a fault-line scarp of variable height was formed. During Neogene reactivation of faulting, the lower part of the scarp became a typical fault scarp, 100–150 m high. The correlative morphologic horizon is formed here not by summit surfaces but by the lowest-situated remnants of basal surfaces of weathering which, within greenschists, mark morphologically-distinct passage of flats elevated 100–150 m above the Basin bottom.

translated by *W. Zuchiewicz*

SUMMARY

MORPHOLOGIC EFFECTS OF NEOTECTONIC MOVEMENTS IN THE WAŁBRZYCH FOOTHILLS, MIDDLE SUDETY MOUNTAINS, SW POLAND

The Middle Sudety Mts., near Świebodzice have a complex tectonic pattern, including several blocks of different tectonic history (Fig. 1). This region can be subdivided into three parts: the highland (420–800 m a.s.l.) which corresponds mostly with the outcrops of Permian volcanites, the flat plateau (Cieszów horizon) lying at 380–420 m a.s.l., and the mountain foreland (below 300 m a.s.l., Fig. 1). The Cieszów horizon (Fig. 2) was formed during late Pliocene and Lower to early Middle Pleistocene, most probably due to fluvial activity (Fig. 5). The Cieszów horizon was covered at least twice by Scandinavian ice-sheets during the younger Middle Pleistocene, last time by the ice-sheet of the Odranian glaciation. The pre-Odranian river valleys are mostly infilled with glacial deposits and pre-Odranian terraces have been found only occasionally (Figs. 3, 4). The recent valleys are deeply incised down to 80–100 m. They have usually bottle-shaped morphology, showing several wide depressions separated by narrow valleys and/or gorges, and are characterized by very irregular longitudinal profiles (Figs. 2, 3, 4, 5). The depressions are characterized by flat valley floors and downstream increase in thickness of alluvial sediment and of the number of terraces. In turn, narrow parts of the valleys have usually bedrock channels, very often with rapids and small waterfalls. Sinuosity increases much in those narrow valleys which have alluvial channels. The river gorges and breaks in longitudinal profiles are clearly connected with faults in the bedrock, but they are receded upstream from the fault lines. Four post-Odranian terraces have been recognized (Fig. 3, 4). The lowermost, late Holocene terrace, occurs only in the lower reaches of the valleys. The Middle, Weichselian, terrace occurs only in the Chwaliszów and Cieszów Depressions and near the Sudetic Marginal Fault, near Dobromierz and Pełcznica (Fig. 1). In turn, the

Lower, late Weichselian/early Holocene terrace and the Upper, Eemian/pre-Eemian terrace occur throughout all the valleys. The Upper Terrace does not continue into the Fore-Sudetic Block. The tilting of terracces is common (Fig. 4). The upper parts of river valleys are characterized by a downstream decrease in height of all terraces. Different parts of river valleys, which are connected with separate tectonic units in the bedrock, have their own terrace systems.

The isostatic uplift after older glaciations was about 30–40 m, up to 60 m (Fig. 6). The post--Odranian uplift history is more complex and multistage. These neotectonic movements have two components (Fig. 6). The first one is a general uplift of the region, which has been induced by isostatic unloading after the decay of the Odranian ice-sheet. The total uplift was about 80–100 m. This system has been disturbed in the inner part of the region. The response of several tectonic blocks was highly differentiated; some blocks indicated larger uplift, the other indicated little uplift or even relative subsidence. Rotation of blocks is also very probable; oblique-slip faulting can not be excluded.

SUMMARY

MORPHOLOGIC AND GEOLOGIC EFFECTS OF THE NEOTECTONIC MOVEMENTS AT THE SUDETIC MARGINAL FAULT, NE SOWIE GÓRY MTS., MIDDLE SUDETY MTS., SW POLAND

The Sowie Mts. in Sudeten, SW Poland, are separated from their foreland by the NW–SE trending Sudetic Marginal Fault – the major fault of this region. This fault manifests itselft as a distinct, more than 100 m high scarp. Other faults are perpendicular, diagonal or parallel to the major fault. These faults have been rejuvenated during the Pleistocene, due to glacioisostatic compensation movements. The evidence for the Pleistocene fault activity includes: steepening of the longitudinal profiles of valleys („breaks") on the fault lines, numerous fault scarps (basal scarplets), distinct downstream divergence of terraces, cutting several terraces by the Marginal Fault and, finally, the lack of lateral contact between fluvial gravels in mountain valleys (terraces) and in the fore-mountain area (alluvial fans), which formed a continuous alluvial surface before faulting. The size of the faulting is about 10–20 m. The fault activity and uplift were regionally differentiated. The greatest uplift was in the same region where the fault amplitude was the greatest also during the main Neogene uplift of the Sudeten. The Pleistocene fault activity have diminished consecutively from the Drenthe time, when the Scandinavian ice-sheet came into the Sudeten. Minor uplifting is observed, however, up to-day. The total Pleistocene uplift of the Sowie Mts. is about 40–50 m.

SUMMARY

SUB-QUATERNARY MORPHOLOGY OF THE SILESIAN-CRACOW REGION. SOUTH POLAND, AND ITS MORPHOGENETIC EVOLUTION

The sub-Quaternary surface of the Silesian-Cracow region (Figs. 1, 2), partly or totally covered with Pleistocene and Holocene deposits (Fig. 3), is entirely controlled by the structure of Mesozoic substratum on the north (Silesian-Cracow Monocline), Paleozoic substratum in the central part (Variscan Upper Silesian Trough) and Miocene substratum on the south (Carpathian Foredeep; cf. Fig. 1). Its morphostructural evolution (Fig. 4), controlled by tectonic development of the Carpathian foreland and by changeable palaeoclimatic conditions, is confined mostly to Neogene and Eopleistocene times. The final stages of morphogenesis, most clearly discernible in recent morphology, occurred in the Late Miocene, Pliocene and Eopleistocene. That was the time of formation of principal geomorphic features of the area studied, including structural escarpments, horsts, grabens, and denudational basins. The Paleogene and Early Miocene morphostructural landforms were remodelled to such an extent that they represent either fossil forms (Carpathian Foredeep) or were completely destroyed (Metacarpathian Swell). This is evidenced by residual occurrence of Neogene regoliths on the Metacarpathian Swell, preserved only within karst hollows on the uppermost denudational flats (Fig. 3).

Preglacial deposits, younger than Tertiary strata and devoid of Scandinavian erratics, represent Eopleistocene and Early Mesopleistocene timespan that preceded the true „glacial" Pleistocene. These deposits developed in three principal facies: residual-karst, deluvial-colluvial, and alluvial ones. The Eopleistocene morphogenesis was associated with formation of deeply-cut river valleys, being controlled by changes of climate and the erosional base level. The latter changes resulted from glacioisostatic and glacioeustatic movements during the first continental glaciations in the northern hemisphere.

The buried valley network of the region in question belonged to the North Sea drainage basin and formed a part of the pre-Odra river valley catchment area. The drainage divide of the latter coincided in southern Poland with axes of neotectonically uplifted structures, namely the Cracow „Bolt", the Metacarpathian Swell, and the Middle-Polish Swell (Fig. 2). Recent valleys in sub-Carpathian basins and peripheral parts of the central depression (north of Częstochowa) follow the courses of fluvioglacial streamways that were formed during successive Pleistocene glaciations.

Scandinavian icesheets of the Sanian (Elsterian) and Odranian (Saalian) stages played important role in remodelling the sub-Quaternary surface. Deeply-incised valley depressions frequently resemble subglacial channels, whereas elevations within plastic Miocene deposits of the Carpathian Foredeep represent glaciotectonic ridges (Fig. 2). Young tectonic mobility, induced by irreversible glacioisostatic movements, was another remodelling factor. This is implied, among other features, by variable, inconsequent gradients of river valleys and damming-up of selected valley reaches. The latter process is sometimes difficult to explain solely by glacial transgressions.

translated by *W. Zuchiewicz*

SUMMARY

SELECTED SECTIONS OF YOUNG FAULT-RELATED DEPOSITS IN NORTH-WESTERN PART OF THE LUBLIN UPLAND

Two fault-line scarps and two sediment-filled tectonic troughs related to the margins and interior of the Bełżyce Plain neotectonic block, NW part of the Lublin Upland, have been studied. The scarps at Dobre (western part of the Plain) and Kolonia Wąwolnica (one of interior scarps) reveal the presence of coarse-clastic, angular colluvium intertonguing with proluvial sands and aeolian loesses. These deposits are dated by the thermoluminescence method for Pleniglacial (Dobre) and older stadial through Pleniglacial (Kolonia Wąwolnica) times of the Vistulian stage. The colluvium in question is related to either final (Dobre) or main (Kolonia Wąwolnica) phases of the fault scarp development. Orientation of

fractures measured in exposed bedrock (limestones, opokas, gaizes of the Upper Maastrichtian through Palaeocene) enables one to consider faults at Dobre and Kolonia Wąwolnica as thrust and oblique-slip faults, respectively. Both these faults originated in a stress field characterized by a WNW–ESE orientation of the maximum compression axis.

The narrow, fossil Poniatowa–Plizin depression is situated in front of the denudationally remodelled, SW escarpment of the Bełżyce Plain. The bottom part of sedimentary fill of the depression is composed of lacustrine and glacial deposits of the San stage, whereas the middle part comprises slopewash and colluvial deposits derived from the hanging wall. The latter deposits, TL-dated for the beginning of main stadial of the Odra glacial stage are overlain, together with denuded surface on the hanging wall, by tills of the Odranian age.

The section at Sobianowice–Włóki, situated in eastern part of the Bełżyce Plain block, was studied several years ago by the use of more simple methods. The section represents the base of a fossil fault--line scarp of throw up to 53 m, on hanging wall of which tills of the Nidanian age are preserved. Within the trough, angular colluvium related to the main tectonic episode underlies glaciolacustrine deposits of the Sanian age. Manifestations of these movements (debris- and mudflows) make their appearance again within deposits of the maximum stadial od the Odra stage.

All the four sections studied testify to Pleistocene tectonic activity that manifested itself by colluvial deposition during anaglacial phases of successive glacial stages. This activity might have been related to glacioisostatic impulses.

translated by *W. Zuchiewicz*

SUMMARY

NEOTECTONIC INTERPRETATION OF LONGITUDINAL PROFILES OF TERRACES IN MIDDLE PARTS OF THE WISŁOK AND JASIOŁKA RIVER VALLEYS, POLISH OUTER CARPATHIANS

Jan KUŚMIEREK & Janusz MAGIERA

INTRODUCTION

Analysis of longitudinal profiles of river channels and terraces is one of the most sensitive tools in investigations of young and contemporaneous crustal movements (cf. GREGORY, SCHUMM 1987, OLLIER 1987). This method has been applied in the present study, aimed at the analysis of contemporaneous mobility rooted in a deeper substratum of the flysch orogen. This mobility comprises both regional uplift, resulting from isostatic instability, and local movements caused by still active overthrusts, faults and folds. The significance of the latter seems to be of considerable importance, as it can be inferred from the present analysis.

The area investigated (Fig. 1) has been earlier subject to a regional neotectonic study (ZUCHIEWICZ 1987). Similar morphotectonic analyses have been carried out in more active parts of the Polish Carpathians since the beginning of the twentieth century (cf. SAWICKI 1909, ROMER 1929, HALICKI 1930, KLIMASZEWSKI 1934, SMOLEŃSKI 1937, BAUMGART-KOTARBA 1978, 1983, ZUCHIEWICZ 1978, 1980, 1984).

Selected reaches of two rivers – Wisłok and Jasiołka, which cross areas of considerable geomorphic contrasts, have been examined.

WISŁOK RIVER VALLEY

The examined reach of the Wisłok river valley lies within a frontal part of the Dukla Unit and the Silesian Nappe (Figs. 1, 2, 3). Four sectors were distinguished revealing different tendencies in variability of the terrace altitudes and the channel gradients. Decreasing or slowly increasing altitudes of the terraces are observed in two cuts of the valley (measurement points I–VIII and XIX–XXII), both lying within a broad and shallow syncline. The terrace altitudes increase considerably within a front al fold of the Dukla Unit and two zones with narrow anticlines and scales (IX–XIX and XXIII–XXVIII).

Greater heights of the terraces are due to both neotectonic uplift, resulting from activity of overthrusts and folds, as well as to intense headward erosion. The latter is proved by the breaks of the channel gradient, especially well pronounced in the lowermost cut (XXI–XXII). This cut was affected by the development of the Besko water-gap, dated back to the Middle Polish (Riss) glaciation (KLIMASZEWSKI 1948) or to the Holocene (6.5–7 ka BP; WDOWIARZ, ZUBRZYCKI 1985).

The effect of resistance of the flysch rocks to weathering and erosion of longitudinal profiles of the river channel and terraces is most apparent in the vicinity of measurement point IX (Fig. 3 a and 3 d). Generally, it is of minor significance, however.

JASIOŁKA RIVER VALLEY

Longitudinal profile of the Jasiołka River valley is much less disturbed (Fig. 4). Somewhat greater heights of the terraces occur within the Fore-Dukla overthrust and the southern limb of the Iwonicz Zdrój anticline (I–VI). Two other elevations of the low terraces (inundational L_1 and L_2 and suprainundational R) occur within synclines (V–VII and XI–XIII), however. In turn, lowering of these terraces are observed within two other anticlines (VII–VIII and IX–X).

As there is no obvious effect of lithology of the valley floor, all the data point to oscillating movements of the substratum of the Jasiołka river valley.

CHARACTER OF THE NEOTECTONIC MOVEMENTS AND THEIR RELATIONSHIPS TO THE EVOLUTION OF THE TECTOGEN

Maxima of the altitudinal differences of the pairs of terraces are distributed in such a way that proves a migration of the most active zones from the south to the north during formation of the higher terraces (W and S_2; Fig. 5). The migration was repeated in the Holocene (terraces L and R). Similar phenomenon was observed in the upper San river valley (KUŚMIEREK 1990).

General tendencies of the height variability observed along the longitudinal profiles of the river terraces and channels point to still active folding of the tectonic structures. It is well pronounced in the zones of deeply – sunk basement, coinciding with the zones of the strongest compression of the flysch cover (KUŚMIEREK, NEY 1988, KUŚMIEREK 1992). The rate of the compression, depicted by the layout of isothymes (Fig. 6), is higher along the Wisłok river than in the Jasiołka valley. It reflects the described differentation of neotectonic activity of the two valleys.

Synorogenic compression proceeded stage by stage and migrated gradually to the axis of the geosyncline (Fig. 6). This phenomenon occured also in the post-inverse stage of development of the Carpathians. Although neotectonic mobility is dominated by the regional isostatic uplift, the oscillation of local elevations occurs, which points to the still not entirely released compressional stresses.

SUMMARY

THE REFLECTION OF VERTICAL CRUSTAL MOVEMENTS IN MORPHOLOGY OF THE WESTERN PODHALE REGION, SOUTH POLAND

Young tectonic activity in the Podhale region is evidenced by hypsometric disturbance of the interfluve planation levels and Pleistocene river terraces.

Longitudinal profiles of the four interfluve flats (planation surfaces; cf. Fig. 1) mapped display variable, northward-directed tilt of the Tatras, as well as a still decreasing gradient of consecutively younger surfaces. In the eastern part, between Biały Dunajec and Bystry streams, all geomorphic levels show smaller gradients, alongside with greater relative and absolute elevations whereas their extent is larger than that in the western part of the area (Fig. 2). The latter displays twice as much higher gradient of interfluve levels, which are more disturbed and less elevated in the northern zone (Fig. 3).

Local differences among parameters of interfluve levels may have resulted from vertical motions of relevant tectonic blocks that have shown scissor-like movements with respect to one another. Such a trend seems to be confirmed by the lack of lateral continuity of the Pieniny Klippen Belt and by the position of the Domański Wierch fan.

The Pleistocene neotectonic activity of the blocks in question, together with that of the Orava Basin, is documented by relative position of the three accumulation levels along the Biały and Czarny Dunajec streams (Fig. 4). A reversed pattern of terraces within the Orava Basin results from continuous subsidence of this region. Relatively high rock socles of terraces in the Gubałówka Foothills region, in turn, are indicative of uplift (Fig. 5) whereas differentiated hypsometry of planation levels within the sub-Tatra Graben might have reflect changeable vertical movements.

translated by *W. Zuchiewicz*