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THE SUDETIC TRIBUTARIES OF UPPER ODRA TRANSFORMATION DURING THE HOLOCENE PERIOD

Abstract. In the border zone of the Eastern Sudety Mts (800–1,400 m a.s.l.) and their northeasters foreland (200–300 m a.s.l.), there is a clear change in relief of the alluvial plains as well as a change in structure and grain size of their associated sediments. Within the Eastern Sudety Mts, Holocene transformation of valleys was predominantly influenced by climate changes. It was mainly associated with valley floor widening which were inherited from past climatic events. In the mountains' foreland, Holocene transformation of valleys caused by climatic changes started at the end of Vistulian. The development of agriculture and progress in settlement, which started in the older Bronze Age, has considerably influenced the valley floors transformation during the last two millenniums. This caused large sedimentation of fine-grained alluvia (mainly overbank deposits) which originated from washing-out of slope mantles in the mountain part of the drainage basins and from the soils erosion in the foreland of the mountains.

Key words: Sudety Mts, Holocene, alluvia, human impact

In the border zone of the Eastern Sudety Mts (800–1,400 m a.s.l.) and their north-eastern foreland (200–300 m a.s.l.), there is a clear change in relief of the alluvial plains as well as a change in structure and grain size of their associated sediments. This makes it possible to look at the Holocene transformation of valleys, which developed in Pleistocene, in terms of their zone/horizon pattern (Klimek 1999). This paper shows the results of investigations on the Sudetic Upper Odra tributaries transformation during Holocene with regards to zonal/altitudinal aspect.

THE STUDY AREA

A vast massif of Hruby Jesenik (Praded 1,491 m n.p.m.) predominates in the landscape of Eastern Sudety Mts (Fig. 1). It is mostly built from gneisses of the "Eastern-Sudetic metamorphic". To the south-east, it borders with the hilly upland of Nisky Jesenik (500–800 m a.s.l.) which is built from Devonian and Carboniferous graywackes and sandstones of Culm facies. In the north-eastern direction, despite the lack of a clear continuation of the Sudetic

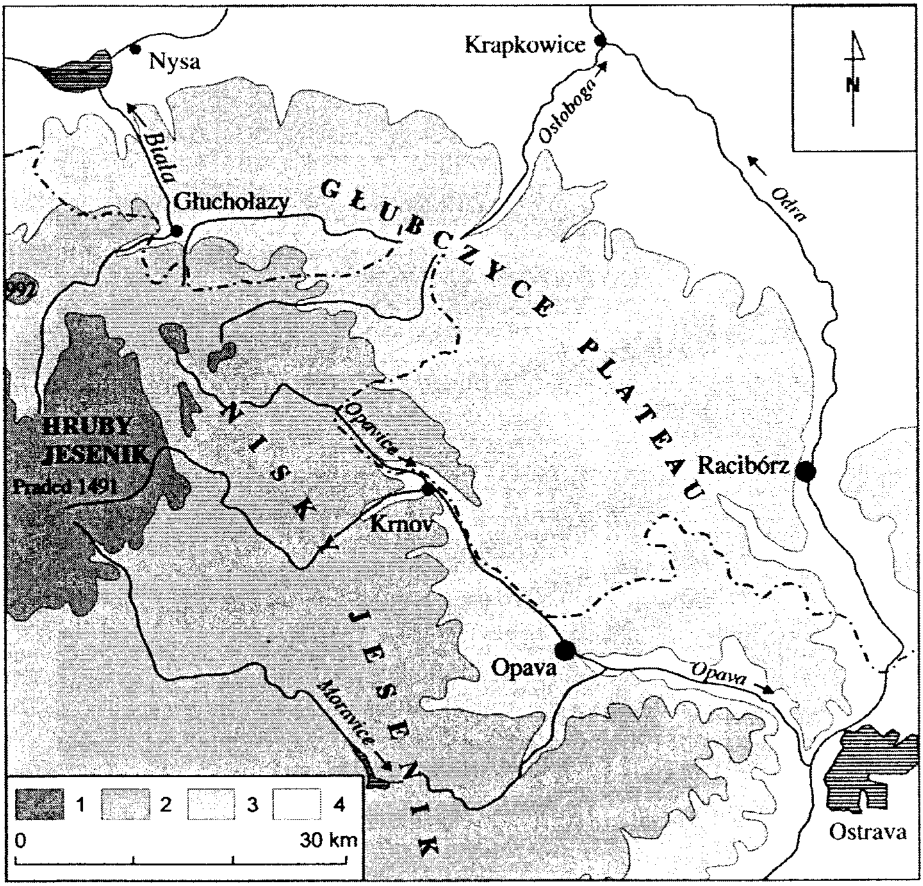

Fig. 1. The NE margin of the Eastern Sudety Mts. 1 — Hruby Jesenik massif (1,000–1,200 m a.s.l.), 2 — Nisky Jesenik upland (500–800 m a.s.l.), 3 — Głubczyce Plateau (260–300 m a.s.l.), 4 — plains

Marginal fault, Eastern Sudety Mts fall down at the distance of only several kilometres towards the Głubczyce Plateau (260–300 m a.s.l.) (Fig. 2). Towards the south-east, a wide (50–55 km) upland of Nisky Jesenik smoothes a bit this relief contrast (Fig. 3). The ice-sheets of older Scandinavian glaciations (South-Polish/Sanian and Middle-Polish/Odranian) reached the margins of Eastern Sudety Mts. These glaciations are represented by loose post-glacial sediments deposited at the mountains' foreland (Sawicki 1955; Baraniecki et al. 1956; Mocoun et al. 1965) and by older generation of coarse-facies slope covers which occur in the non-glaciated part of the mountains (Czudek 1997). During the subsequent Pleistocene cold climatic periods, the raised massif of Eastern Sudety Mts was subjected to the severe climate of periglacial zone. In these periods, especially in Vistulian, the slopes of valleys were covered with a thick mantle of coarse debris slope covers which originated from the weathered gneisses, graywackes and sandstones.

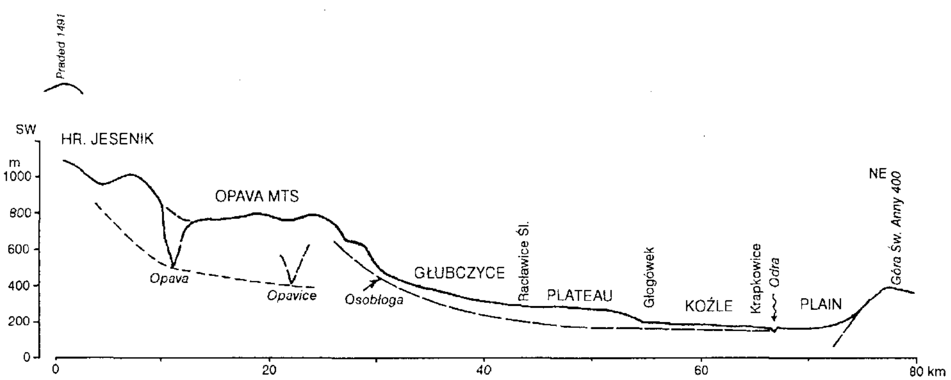

Fig. 2. SW–NE cross-profile of Eastern Sudety Mts and their foreland

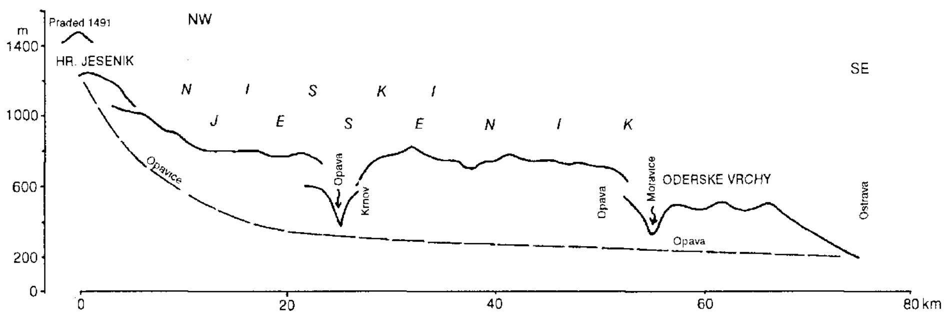

Fig. 3. NW–SE cross-profile of Eastern Sudety Mts

Within the Praded massif and its margins, gneiss outcrops on the steep slopes tended to develop cryoplanation terraces and to deposit extensive block fields at their base (Demek 1969; Czudek 1997; Koral 1998). These blocks were subjected to further disintegration during the down-slope migration and therefore, finer fraction of the blocks covers the lower parts of the slopes (Mocoun et al. 1965; Czudek 1997). At that time, a several-metre thick loess cover was deposited in the foreland of the mountains (Jersak 1991; Jary 1996) which masked secondary elements of the relief inherited from the period of Scandinavian ice-sheet decay.

VALLEY FLOOR MORPHOLOGY

Valley floors of the rivers, which developed during the period of periglacial climate, usually demonstrate braided channel patterns predominated by aggradation. Within the Eastern Sudety Mts, there are many examples of the pattern where lower parts of the slopes covered with clay-rich debris mantle turn into valley floors filled with coarse-fraction alluvia. In the area of Głubczyce Plateau, the slopes of transit valleys (Opava and Osobłoga) are mostly covered with silt mantle. In the transfer zone to the Silesian Lowland, vast alluvial cones occur.

Climate warming in Holocene and the succession of forest communities have changed the water circulation thus smoothing the river runoff. The raised summits of Eastern Sudety Mts presently receive more than 1,500 mm of precipitation per year. The location of the majority of the Hruby Jesenik massif above the upper forest limit and high slope inclination caused, that during specific synoptic patterns, floods associated with frontal precipitation are very large. For instance, the synoptic situation which occurred for 5 days in July 1997 produced the precipitation which reached more than 500 mm in Hruby Jesenik massif and its margins (Jesenik — 612 mm, Rejviz — 511 mm, Praded — 455 mm, Vidly — 501 mm) and a bit less in its northern foreland (Jarnołtówek — 314 mm, Głuchołazy — 306 mm) (Hradek 1999; Niedźwiedź 1999). In the Osobłoga valley which drains the northern slopes of Zlatohorska Vrchovina (including Opava Mts) which is raised 750–950 m a.s.l., in the Racławice Śląskie gauge profile (490 km^2), extreme runoffs of this river were 19–25 times higher than the average runoffs. At its tributary, the Prudnic stream at Prudnik (134 km^2), extreme runoffs were from 90 to 145 times higher then the average. During the catastrophic flood in July 1997, maximal river runoffs (Q_{max}) on the SE foreland of the Eastern Sudety Mts exceeded the century runoff (Q_{100}) by 130–180% (Hradek 1999). This caused considerable exceeding of maximal river stages recorded so far. The probability that such large floods occurred during the whole Holocene (Girguś, Stupczewski 1965; Klimek et al. 1998) coupled with an analysis of the structure and rate of sedimentation of the youngest alluvia represent a basis for the evaluation of Holocene transformation of the Pleistocene valley floors.

THE HOLOCENE TRANSFORMATION OF THE VALLEY FLOORS

The slopes of Hruby Jesenik are cut by a network of spring tributaries of the Moravica, Opava and Bela/Biała rivers (Fig. 1). In the headwater section of these valleys, in which slope inclination is several tens metre per kilometre, the results of Holocene slope cutting in the residual block and their rocky substratum are well visible. As a result, there are many rock steps and accumulation of large residual boulders from the washed-out periglacial slope cover (Photo 1). Deep erosion is still a predominating process here.

At the margins of Hruby Jesenik and in the area of Nisky Jesenik and Zlatohorska Vrchovina, deeply cut valleys with steep, locally rocky slopes predominate. Coarse and clay-rich slope covers pass at their foots into rather poorly defined valley floors which are raised 1–2 m above the channel. Here,

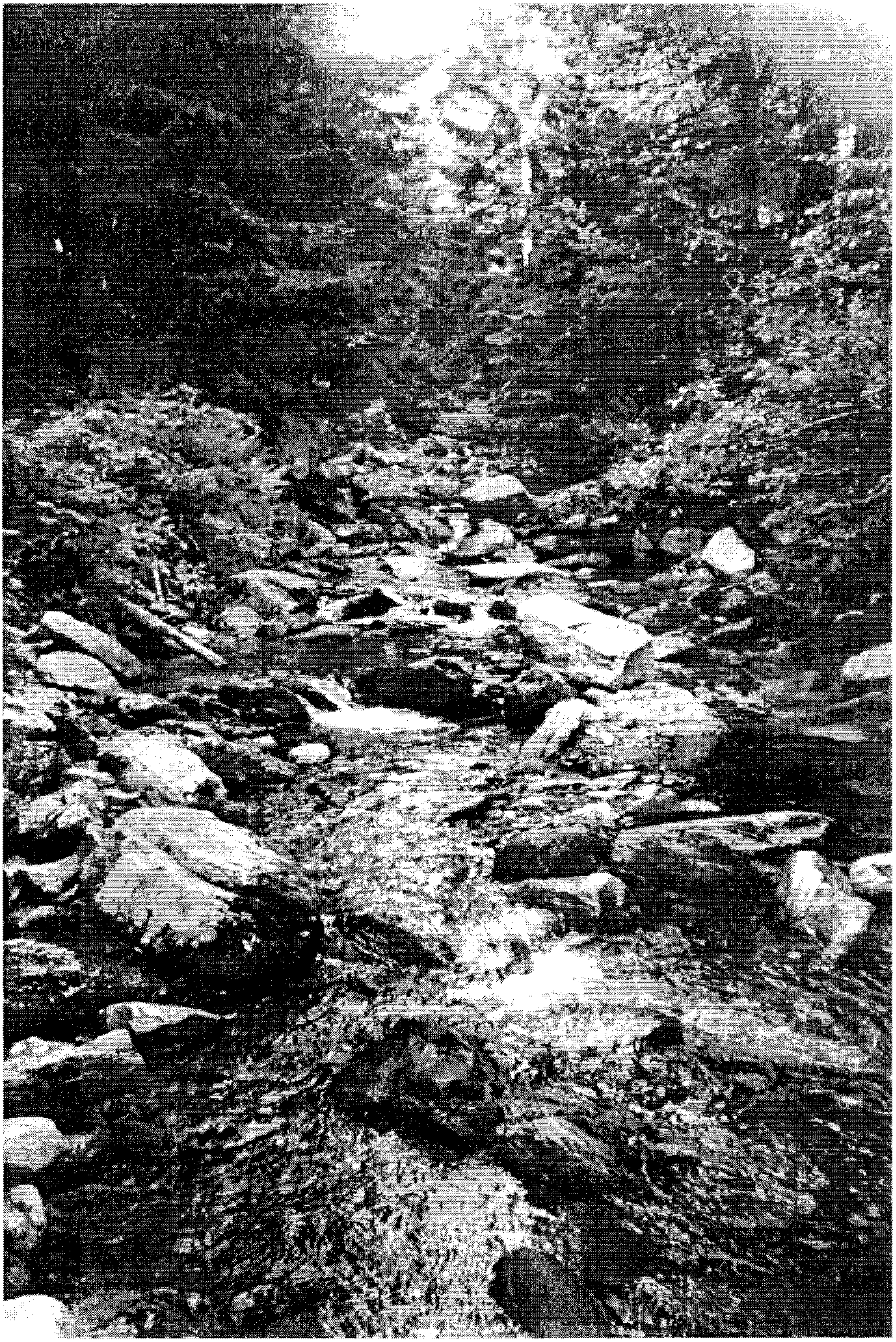

Photo 1. Headwater section of Bila Opava river. The residual boulders from washed-out periglacial slope covers

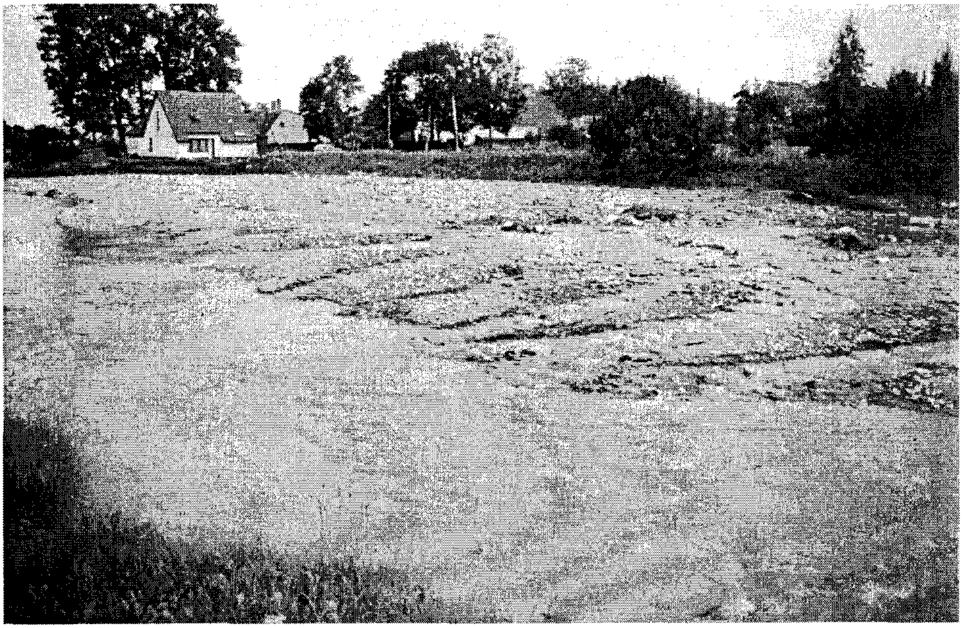

Photo 2. Opavica river within Nisky Jesenik upland. A coarse mid-channel bar

Photo 3. Opava river within Nisky Jesenik upland. The undercut of periglacial slope covers generated during flood of July 1997

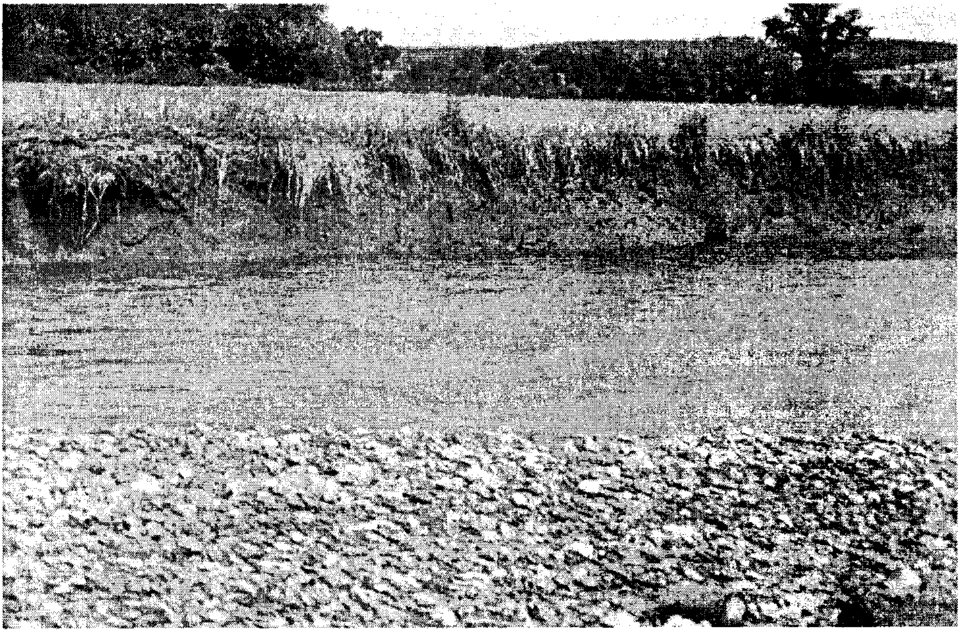

Photo 4. Opava river downstream of Krnov. The fine-grained overbank deposits

due to the surplus of coarse-grained load which has been delivered to river channels, coarse gravel-bed channel with point bars (Photo 2) and braided channels in wide sections of the channel predominate. River-control projects, which have been carried out for many years in many sections of the valley, has changed this natural channel pattern. During floods, lateral migration of channels takes place in the natural sections of the valleys, which destroys Pleistocene coarse-fraction alluvia within the widenings of the valleys. Locally, well-preserved periglacial structures occur (Photo 3). In other places of such valleys, the bases of the slopes which are covered with periglacial debris mantle are undercut during floods (Photo 4). This makes a rich source of bed and suspended load of these rivers. The relief at the base of the valley slopes as well as the observations of modern floods activity (Hradek 1999) suggest that Holocene transformation of the valleys in the margins of Hruby Jesenik and in the adjacent zone of Nisky Jesenik and Zlotohorska Vrchovina was mainly associated with the widening of Pleistocene alluvial plains at the cost of undercutting and retreat of their slopes. Presumably, extreme floods considerably influenced the development of these processes. This is confirmed by coarse-gravel interbeddings of alluvia associated with gravel accumulation in the valleys' widenings which can be observed at the Opavica river near Opawica and the Osoblaha near Arnultovice.

At the foreland of the Eastern Sudety Mts, the valleys of the Upper Odra tributaries with longitudinal slope from 1.5 to 2.5 metre per kilometre intersect the

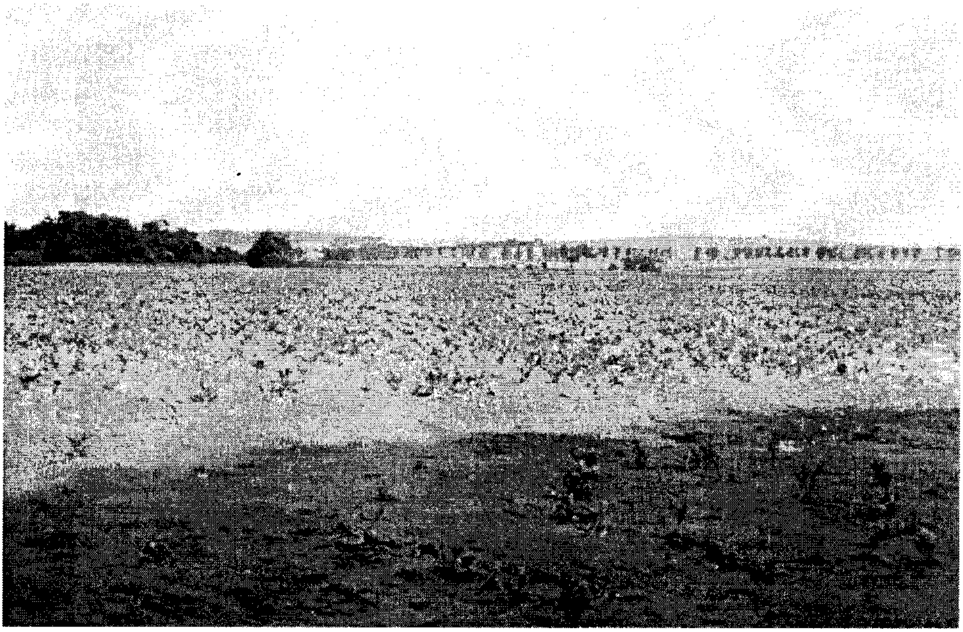

Photo 5. Opava valley near Branice. The result of overbank deposition during flood of July 1997

Photo 6. Osobłoga valley in lower section. The palaeomeander of younger generation at high water stage

Głubczyce Plateau as well as Orava and Racibórz Basins, both located at the margins of the plateau (Fig. 1). In many sections of the Opava (downstream of Krnov and the middle Osobłoga downstream of Osoblaha), smooth convexo-concave slopes of valleys manted with loess have been preserved since the Pleistocene period. These slopes "go down" to a recent horizon of the alluvial plain. This suggests the lack of Holocene dissection of these sections of the valleys caused with lateral channel migration. The Osobłoga channel in its middle course showed in the past a clear trend of axial shifting towards the right/southern valley slopes. This was presumably associated with tectonic-structural conditions of the Quaternary substratum, i.e. inclination of more resistant deposits of Upper Miocene/Pliocene towards the east (Kościówko 1982). The remnants of this trend are represented by 25 m high bow-like undercuttings of the right valley slope which curve radius is in the range of 400–600 m. A very well developed undercutting of this type is located in the 15th kilometre of the Osobłoga course between Racławice Śląskie and Rzepce (Fig. 4). The depressions at the base of these undercuts play the role of backswamps. They are filled with silts and clays with organic interbeddings which total thickness is up to 3 m. In the lower course of the Osobłoga, at the base of such undercuts of the Pleistocene terrace, palaeomeanders with organic fillings occur. The oldest horizons of organic silts from the depth of 2.2 m indicated the radiocarbon age of 10,200 ± 75 BP (Wójcicki 2000). Considering the time necessary to deposit 0.1 m thick complex of silts which underlay the dated organic complex, it may be assumed that the meandering Osobłoga started to undercut the edge of the 8–10 m high Pleistocene terrace at least in Younger Dryas/Preboreal. This shows that as early as in Upper Vistulian, rivers which flew out from Eastern Sudety Mts displayed a meanderic course at the distance of only several kilometres of the mountains margin. This was probably caused by an early succession of forest communities in the foreland of the mountains and by the decreasing of mountain part area of the drainage basin in influencing its hydrological regime.

The Opava and Osobłoga valleys, in the foreland of Sudety Mts, are filled with alluvia several metres thick. These are composed of coarse gravel up to 10 cm in diameter (channel facies) which are locally covered with thick mantle of silt-clay overbank deposits. In the lower course of the Osobłoga, channel deposits are characterised by sandy-gravel material predominately composed of quartz. In the foremountain course of the Opava, directly downstream of Krnov (Fig. 1 and 2) the meandering channel banks are built from fine-grained overbank deposits with large share (up to 33%) of 0.05–0.02 mm fraction with a distinct domination of 0.02 mm fraction (Photo 5). Between Krnov and Branice, the thickness of these fine-grained overbank deposits reaches 4 m and their base is situated 2 m below the average water level in the channel. This suggests a long-term trend of overbank sedimentation.

Branice gauge station closes the mountain part of the Opava drainage basin which covers an area of 606 km^2. In the period 1967–1997, the amplitudes of

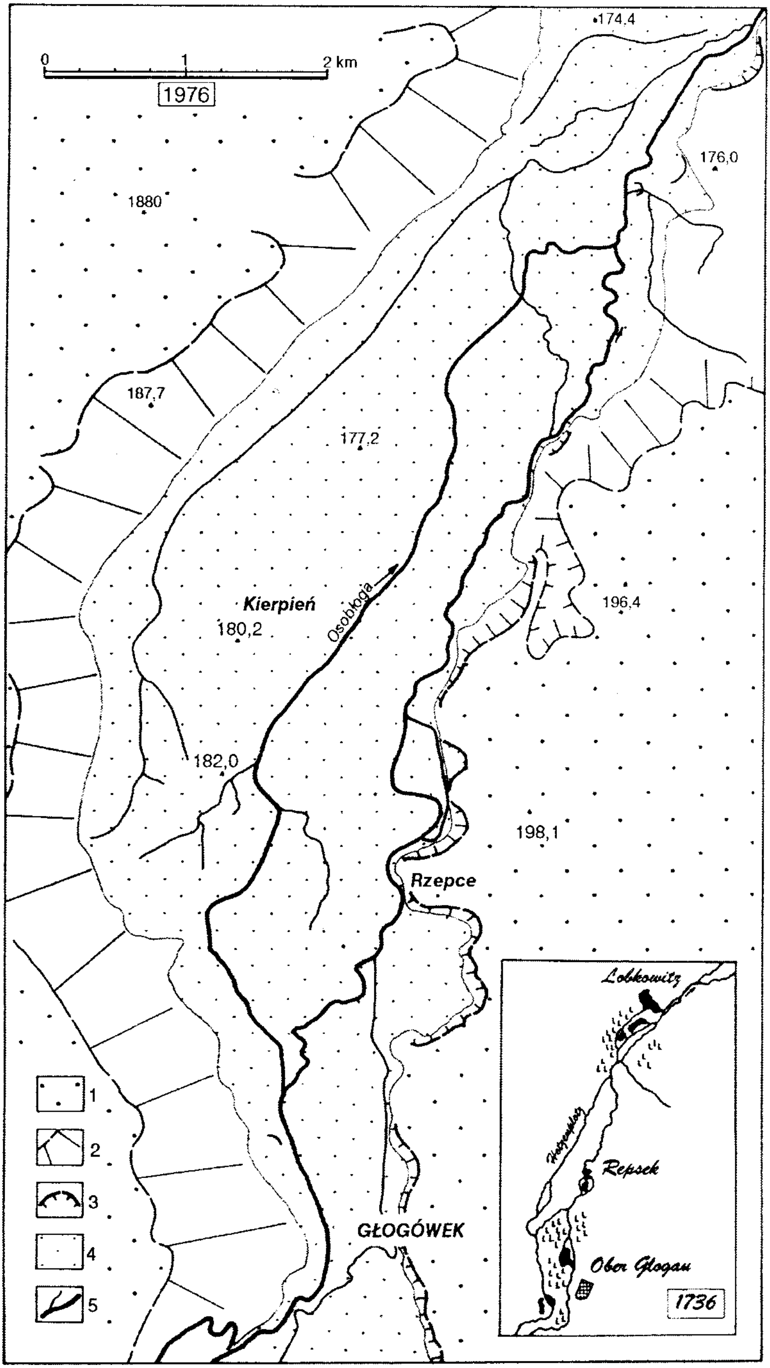

Fig. 4. Geomorphic sketch of Osobłoga valley in lower course. 1 — Pleistocene terrace, 2 — Late-glacial valley side, 3 — Late-glacial and Holocene undercuts, 4 — Holocene valley floor, 5 — present-day channel pattern

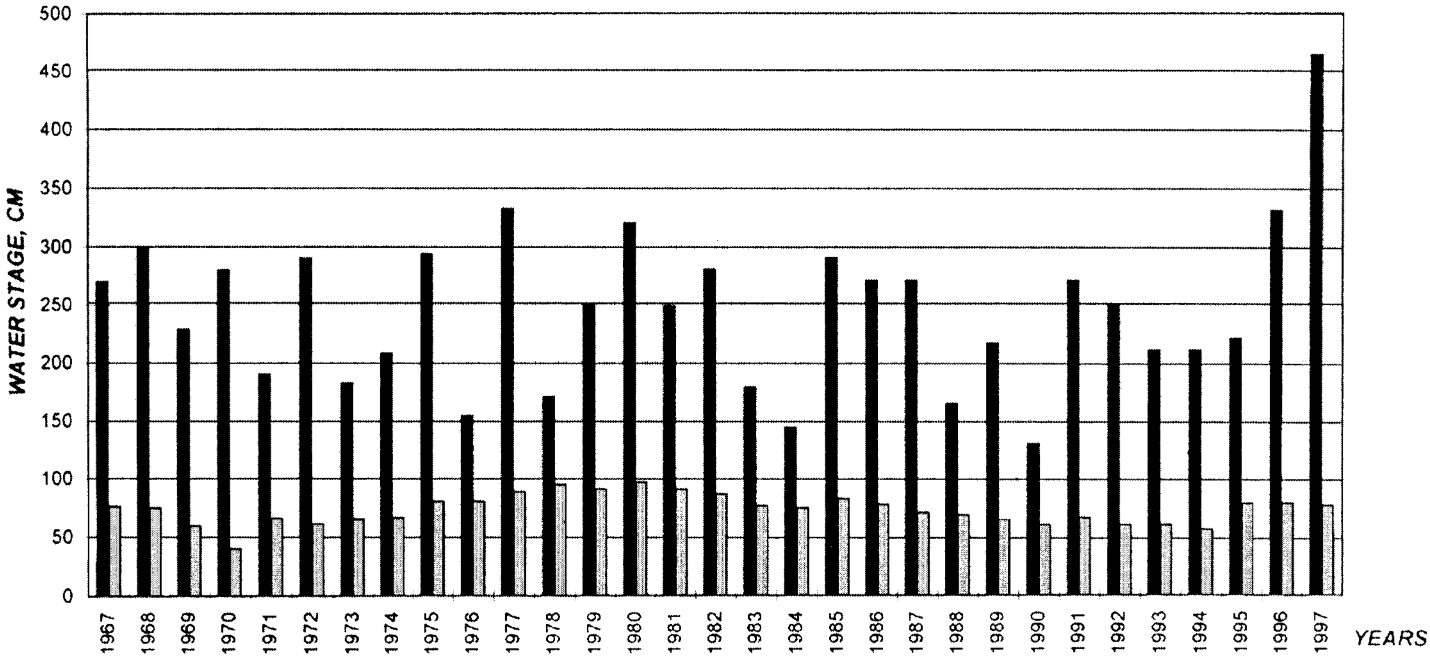

Fig. 5. Yearly water stage amplitudes of Opava river at Branice gauge station

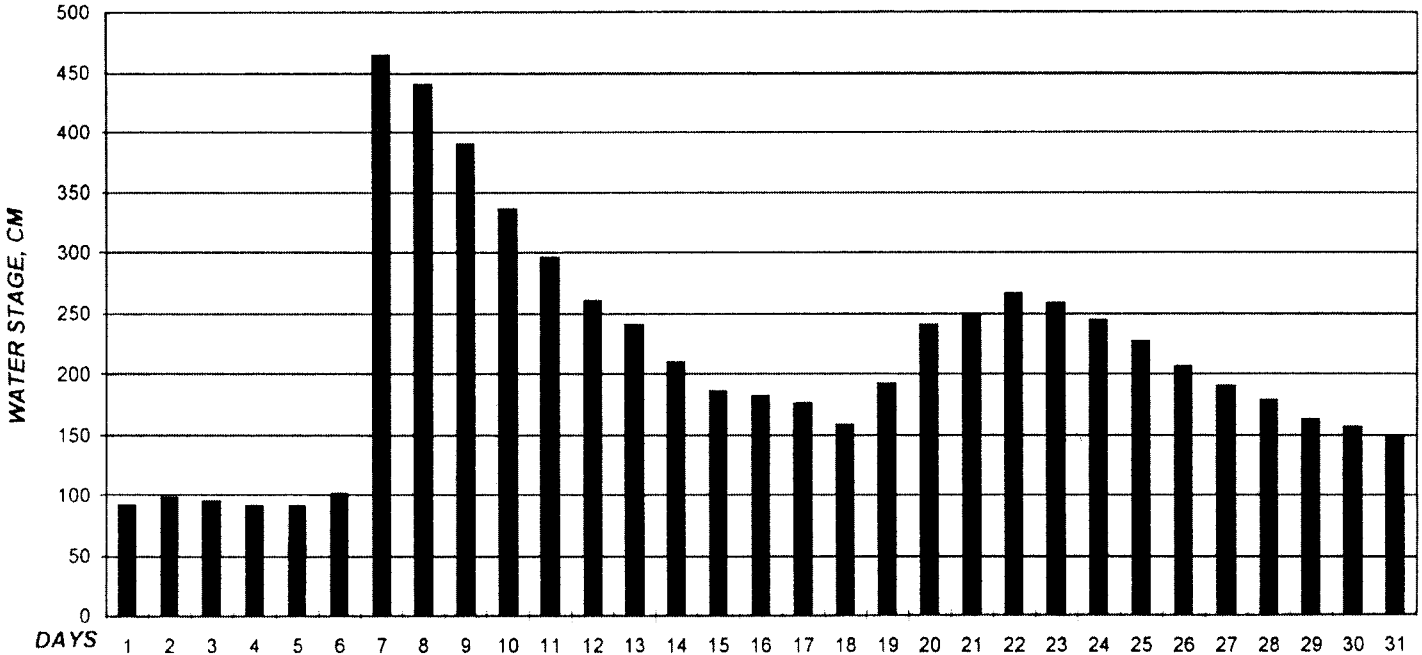

Fig. 6. Opava river water stages during July 1997

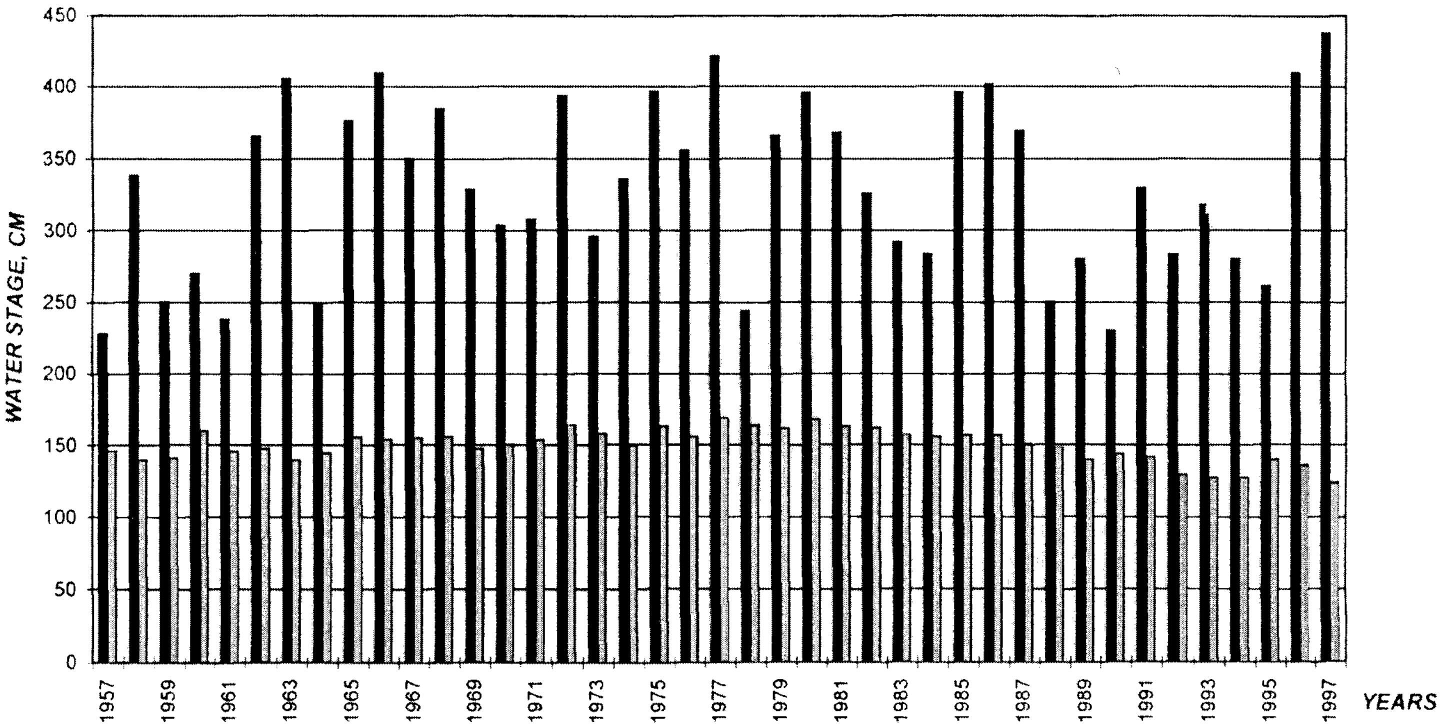

Fig. 7. Yearly water stage amplitudes of Osobłoga river at Racławice Śląskie gauge station

annual fluctuations of water level reached 150–250 cm (Fig. 5). Overbank discharge occurred on average every 2.5 years. During the flood in July 1997 caused by intensive precipitation in the upper part of the drainage basin, the flood wave showed a rapid rise. During 24 hours from 6th to 7th July, the water level raised by 362 cm (Fig. 6). The decrease of the flood wave back to an original level took 11 days. After the flood, a layer of silt several centimetres thick covered the valley floor. Gravel bars were also deposited at the convex parts of the meanders.

In the Osobłoga valley downstream of Racławice Śląskie, the channel shows a meanderic course. In some places it was regulated mostly in the 19th century. In the widening of the valleys, between Głogówek and Pisarzowice, it is divided into several channels forming an inland delta 6 km long and 2 km wide (Fig. 4). Despite regulation works which were carried out here before the 18th century, traces of the old meanderic channels are still visible in the plain relief. It may be presumed that they represented a system of anastomosing channels which originated from the turn of Pleistocene and Holocene periods and which have been preserved in later times due to intensive overbank sedimentation of fine-grained alluvia carried out from the upper part of the valley. At the base of the bow-like undercuts of the right slope of the Osobłoga valley, flat floors of backswamps are locally situated several tens of centimetres below the level of the alluvial plain adjacent to the channel. They are filled with non-carbonate fine-grained silts with domination (over 50%) of 0.05–0.002 mm fractions. The silts are 3 m thick. Lack of traces of the palaeochannels suggests that they became fossilised by the overbank deposits in the zone of flood basins. Fine waste-mantle material washed out from periglacial slope covers in the Sudetic Mountains as well as loess covers from Głubczyce Plateau were the source of this fine-grained material. Lack of organic matter, which would be helpful for dating, makes it difficult for the author to determine the beginning of this intensive sedimentation.

In the lower course of the Osobłoga, upstream of Krapkowice, in the distance of 25 km of the margin of Eastern Sudety Mts, the valley floor of the width of 0.4–0.8 km is limited on the left by an erosional edge of the Vistulian 2.5 m high terrace. A system of braided channels in preserved on that terrace. This shows that the lower section of the valley was significantly deepened after the terrace was built. Here, in the direct neighbourhood of the channel, a younger generation of palaeomeanders occurs. Their radiuses are in the range of 30–50 m (Photo 6). They are filled with fine-grained mineral deposits with organic interbeddings. A total thickness of these deposits reaches 3 m and the organic layers are from 0.2 to 0.3 m thick. Sporadicity of organic interbeddings and their small thickness show the lack of longer periods of organic sedimentation which resulted from intensive overbank sedimentation, especially in the final phase of palaeochannel filling. This was probably caused by frequent overbank disgharges. The results of palaeobotanical expertises of one of such interbed-

Photo 7. Osobłoga channel in lower course. The 3 m thick complex of fine-grained overbank deposits capping a palaeomeander fil with organic material dated to 1,120 ± 30 year BP

dings from the depth of 1.0–1.3 m at Steblów I/3 site suggest a sub-Atlantic age of this organic matter (Nalepka 1999, personal information), mainly due to the occurrence of cereal pollen (*Cerealia* 2.3%). In the undercutting of the channel bank near Steblów, an outcrop of the palaeomeander filling was found. Its floor is situated below the level of mean water (Photo 7). The radiocarbon dating of the organic part of this filling, which is overlaid by 3 m thick complex of mineral deposits, indicate the age of 1,120 ± 30 BP (Gd-2,773). It may be assumed therefore that a mean rate of sedimentation of the upper part of the palaeomeander filling was from 2.6 to 2.7 mm per year. The discussed examples show that the Osobłoga channel in its lower course has had a distinctive meandering character for at least the last two millenniums. In other sections of the Osobłoga undercut in the lower section of the valley, silty clay of the thickness of 2–3 m occurs. It covers fine gravel and sandy channel deposits. In the overbank deposits, a silt fraction makes 60% of their composition and the fraction < 0.002 mm is in the range of 10–17%. A clear pattern of younger generation of palaeomeanders in the lower course of the Osobłoga proves their rapid infilling with fine-grained mineral deposits. A continuous and relatively thick cover of silt-clay overbank deposits shows, that in that part of the valley, intensive lateral migration of deep and narrow Osobłoga channel with simultaneous intensive overbank sedimentation has dominated in that section of the valley for at least several centuries.

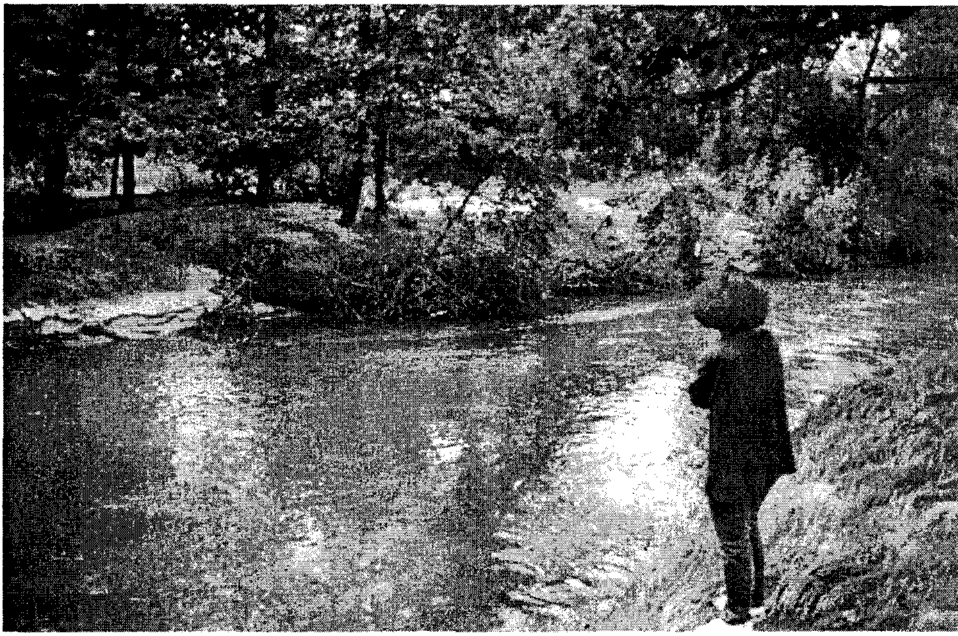

Photo 8. Osobłoga valley in lower section. The sand shadows deposited within riperian vegetation during flood of July 1997

The amplitude of river stage fluctuations and the frequency of overbank discharges give information about the modern processes of overbank sedimentation. In the direct foreland of the Eastern Sudety Mts, downstream of the junction of two main tributaries, the Racławice gauge station closes the drainage area of about 500 km^2. In the period 1957–1997, annual amplitudes of floods reached here 1.5–2.5 m (Fig. 8) and overbank discharges occurred in average every 6.6 years. During the flood in July 1997, the water level rised here 304 cm. In the lower section of the Osobłoga, upstream of Krapkowice, the water layer reached 2 m above the alluvial plain surface, i.e. up to 5 m above the mean river stages in the channel. This was partly due to the high water stage in the Odra river. Several centimetre thick layer of silts was deposited on the alluvial plain as a result of this flood. In the zone of dense riparian vegetation, sand shadows were deposited which built up the natural level (Photo 8).

CONCLUSIONS

The large thickness of the overbank deposits in the Opava valley in the direct Eastern Sudety Mts foreland and in the middle and lower courses of the Osobłoga valley show that the Holocene transformation of these valleys was associated with intensive overbank sedimentation which has masked older elements of relief inherited from the Pleistocene/Vistulian. The fillings of younger generations of palaeomeanders in the lower part of the Osobłoga suggest that intensification of this process may have occurred for at least 2,000 years. Wash-out of periglacial slope covers in the Sudety Mts as well as the loess cover of Głubczyce Plateau were main sources of these fine-grained alluvia.

The natural environment of the Sudetic tributaries of the Upper Odra has always favoured the penetration of these areas by man (Kaczanowski and Kozłowski 1998). The location of this area close to the northern entrance of Moravian Gate encouraged early penetration of southern archaeological cultures to north, along the Morava Valley. As early as in the older Bronze Age (1,600–1,300 BC) agricultural-gatheres nations migrated from the Moravian area and later created compact settlers' structures of Lusitian culture. Forest clearance and ploughing must have been an important stage of deforesting of the loess areas. It was one of the first serious stimulation of soil erosion. The process of soil erosion in the Osobłoga valley continued in the Iron Age by the Celts coming from the south in the La Tene period (pre-Rome, about 400 BC) until the Roman influences (Godłowski 1980). Later Migration perod which started 400 AD caused settlement waste.

In the early Medieval times, at list since the 6th/7th century, Golęszyce tribe (Parczewski 1982) settled in the Opava drainage basin which then belonged to Great-Moravian Country. The development of settlement associated with economic expansion of this country at the end of the 9th century was probably a reason of an intensive soil erosion, suspended load increase, and overbank sedimentation in the Opava valley in the direct foreland of the Sudety Mts. This intensive sedimentation of fine-grained overbank deposits continued in the Osobłoga valley in the early Medieval times (Foltyn 1998) especially in the period of the Opole Duchy development. At that time, this intensive agricultural colonisation of the drainage basin (Panic 1992) and dense population which reached 20 people per km^2 on the most fertile soils (Ładogórski 1955) resulted in the intensive soil erosion within the Głubczyce Plateau. Large floods due to clearence which occurred for the last several centuries covered probably as large area as it was during the flood in June 1997.

It may be assumed therefore that within the Eastern Sudety Mts, Holocene transformation of valleys was predominantly influenced by climate changes. It was mainly associated with valley floors widening which were inherited from past climatic events. Only their headwater tributaries were clearly deepened. In the mountains' foreland, Holocene transformation of valleys caused by climatic changes started at the end of Vistulian. The development of agriculture and progress in settlement which started in the older Bronze Age have considerably influenced the valleys transformation during the last two millenniums. This caused large sedimentation of fine-grained alluvia (mainly overbank deposits) which originated from washing-out of slope mantles in the mountain part of the drainage basins and from the soils erosion in the foreland of the mountains. Clear zonality/horizontality of the valleys' transformation may be detected.

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STRESZCZENIE

K. Klimek

TRANSFORMACJA SUDECKICH DOPŁYWÓW GÓRNEJ ODRY W HOLOCENIE

W strefie pogranicza Sudetów Wschodnich (800–1400 m n.p.m.) i ich północnego przedpola (200–300 m n.p.m.) bardzo wyraźnie zaznacza się zmiana rzeźby równin aluwialnych oraz zmiana struktury i granulometrii budujących je aluwiów. Stwarza to możliwość spojrzenia na holoceńską transformację dolin o założeniach plejstoceńskich w ujęciu strefowym/piętrowym.

W obrębie Sudetów Wschodnich holoceńska transformacja dolin uwarunkowana była przede wszystkim zmianami klimatycznymi. Polegała ona głównie na poszerzaniu ich den odziedziczonych z poprzedniego okresu zimnego. Jedynie ich dopływy źródłowe były wyraźnie pogłębiane. Na przedpolu gór holoceńska transformacja spowodowana przyczynami klimatycznymi rozpoczęła się już pod koniec vistulianu. W ostatnich dwu tysiącleciach istotny wpływ na jej przebieg wywarł rozwój rolnictwa i osadnictwa zapoczątkowany co najmniej w starszym okresie epoki brązu. Obie te przyczyny spowodowały intensywną sedymentację, głównie pozakorytową, drobnoziarnistych aluwiów pochodzących z rozmywania zarówno pokryw stokowych u podnóży zboczy dolin w górskiej części dorzeczy, jak również z erozji pokryw lessowych na przedpolu gór.