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THE ROLE OF THE VISTULIAN AND HOLOCENE IN THE TRANSFORMATION OF THE RELIEF OF POLAND

Abstract

The author discusses the role of the last cold stage and of the Holocene in the relief transformation in Poland. He concludes that in the Vistulian there originated the young glacial relief of northern Poland (in the macro- and mesoscale), and the older relief of southern and central Poland acquired the features of periglacial transformation superimposed on the older forms.

The Holocene morphogenesis prepares a new regolith by chamical weathering. More active processes are restricted to less resistant rocks, steeper slopes, and areas with a lowered base level. In the young glacial zone the formation of valley patterns is going on, and denivelations are levelled. In many areas, substantial changes in the rate and direction of the evolution of slopes and of valley bottoms have been caused by man.

INTRODUCTION

The problem of the role of the periglacial morphogenesis and of the last 10,000 years of the Holocene forms a much disputed subject in the geomorphological literature (RAPP, 1967; BÜDEL, 1977). Many different opinions were expressed on the basis of the studies on the relief of Poland. Therefore, it is worth trying to make a recapitulation of the state of studies, the more so as the present author, since the very beginning of his activity, has been in favour of the studies on the changes, which took place in the Holocene. That period, being unique as regards the climate and man's economic activity, was to mark the relief with a specific stamp (STARKEL, 1960, 1977). Which of the morphogeneses: the periglacial, the glacial, or the temperate (Holocene) one, and in which form finds its reflection in the contemporary polygenic relief in the various parts of Poland?

Seventy five years have elapsed since the publication of the paper by W. ŁOZIŃSKI (1909) on the periglacial period. Thirty five years ago the monograph on the periglacial forms and deposits in the Polish Carpathians was published by M. KLIMASZEWSKI (1948). Thirty years ago J. DYLIK (1953) formulated his theory on the periglacial character of the relief of central Poland. Twenty five years ago there appeared the first papers estimating the intensity and effects of the present-day processes (DORYWALSKI, 1958; GERLACH, 1958, and others), and slightly later the present author tried to evaluate the role of the cold and warm

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stages in the Quaternary morphogenesis of the Flysh Carpathians (STARKEL, 1960, 1963). The new attempt at summing up is made, because in 1980 a general geomorphic map of Poland scaled 1 : 500,000 was published (STARKEL, 1980); it presents in a wholesale manner the share of the Vistulian and of the Holocene in the general picture of the relief evolution in Poland, and forms a cartographic accomplishment of the two-volume monograph "Geomorphology of Poland" (GALON, 1972; KLIMASZEWSKI, 1972).

In order to adequately determine the function of the last two morphogenetic periods it should be remembered that the age of Poland's relief varies in different regions, and that new features continually overlap the older elements. It is a subject of discussion, how far the primary features have been preserved in the present relief, and how far they have been obliterated by secondary transformations. To what extent does the proceeding degradation of older forms create new qualitative ones (MORTENSEN, 1963). For instance, in effect of continuous transformations, the older Neogene relief on flysch rocks, lowered in some places by 30 – 50 m in the middle and upper Pleistocene, can be reconstructed on the basis of the preserved remains of correlative deposits (STARKEL, 1965). Large elements of the old relief have been superimposed by younger ones. They decide upon meso- and microrelief and of the covers which build them (STARKEL, 1978). Among these, the complex of forms and cover formations which originated in the last glacial-interglacial cycle of the Quaternary, is the most pronounced. However, the functions of these two members is diametrically different. In the case of the Holocene, it is man's activity, which has essentially changed the rate and style of the transformation.

The territory of Poland is particularly suitable for making such comparisons because of the lithological diversity, age of the relief, and the fact that in the upper Vistulian, half of the country was covered with an ice sheet. In the Vistulian, the area of Poland was found within both periglacial and glacial morphogenetic regions, and in the Holocene in the temperate one which marked their role in the temporal sequence.

THE PERIGLACIAL ZONE IN THE VISTULIAN

For over 60,000 years, under the conditions of permafrost and treeless vegetation, the fundamental role was played by frost weathering, cryogenetic processes, deflation, as well as solifluction and slope wash on inclined surfaces (*cf.* DYLIK, 1967, 1969; JAHN, 1970). The overloaded rivers, active in the summer season, were of braided character. Owing to the short-distance transport and non-simultaneous phases of the revival of processes at the bottoms of valleys (late-spring snowmelt) and on slopes (summer congelifluction) there prevailed the filling of bottoms (aggradation) which – among others – was manifested in the

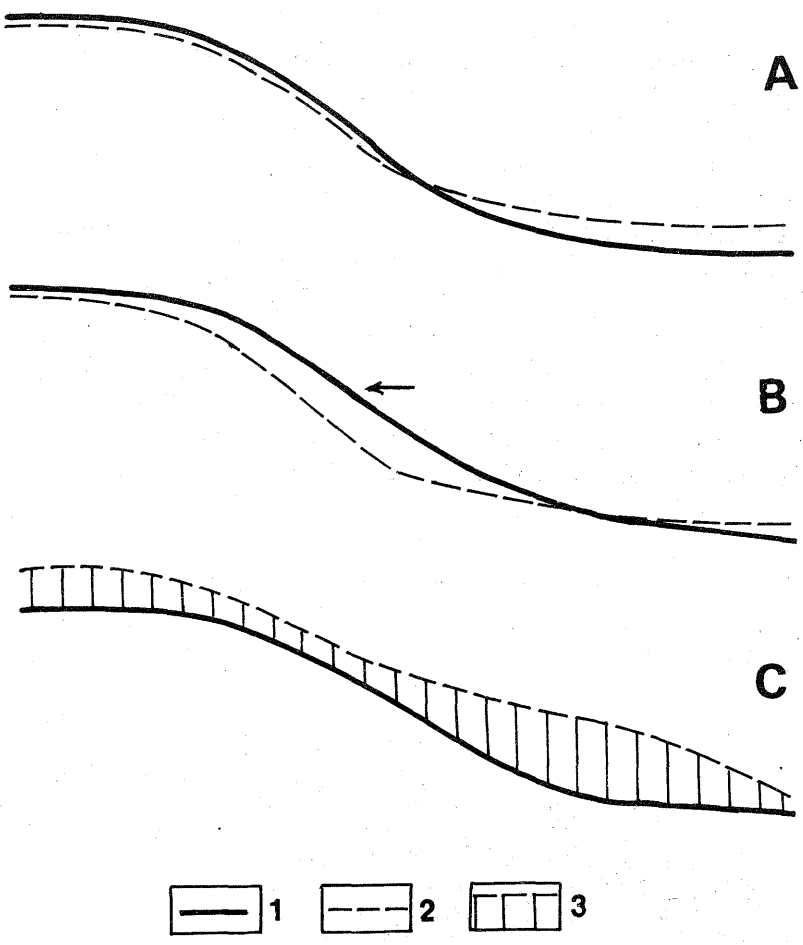

Fig. 1. Transformations of older slopes in the periglacial zone during the Vistulian
A – slight degradation of the upper segment, accumulation of solifluctional and deluvial covers in the lower one; B – intensive degradation of the upper segment, retreat and creation of cryopediment at the foot of slope; C – the slope overlain by a loess cover – thicker in the lower segment (in result of an additional shifting on the slope). 1) initial slope profile before the Vistulian; 2) final result of periglacial transformation; 3) loess cover

gentle passing of footslopes into valley floors. Interstadial warmings favoured the dissection and deepening of valley forms (STARKEL, 1969). The upper Vistulian (25,000 – 13,000 BP) was characterized by climatic continentality which was expressed in a greater activity of the wind (deflation pavements – DYLIK, 1969) and accumulation of loess which either filled the depressions or increased the geomorphological contrasts (JAHN, 1956; MARUSZCZAK, 1968).

It was a characteristic feature of the periglacial morphogenesis that denudation processes occurred everywhere over extensive areas (and not in some localities only), and showed considerable efficiency which on the less resistant flysch

members achieved a lowering of slope surface by 10 m. Practically, all slopes and plains were covered with periglacial, residual or accumulational deposits (DYLIK, 1956; KLATKA, 1962). In central Poland there followed an essential transformation of the old relief of earlier glaciations. There originated residual ridges, outliers, corrosional valleys, and cryoplanation plains (DYLIK, 1953). However, a number of forms of the zone of older glaciation, built of coarse glacifluvial deposits, preserved the primary features of kames, eskers, or marginal moraines (KLAJNERT, 1966; ROTNICKI, 1966). In the areas built of older and more resistant rocks there often originated cryoplanation terraces (BAUMGART-KOTARBA, 1973), tors, and block fields (RÓŻYCKI, 1967), and on less resistant ones the footplains of solifluction and deluvial deposition (KLIMASZEWSKI, 1971; STARKEL, 1969), or cryopediments (Fig. 1).

The Lateglacial (13,000 – 10,000 BP) was marked by aeolian activity and dune stabilization (DYLIKOWA, 1967, and others). The channels of braided rivers were

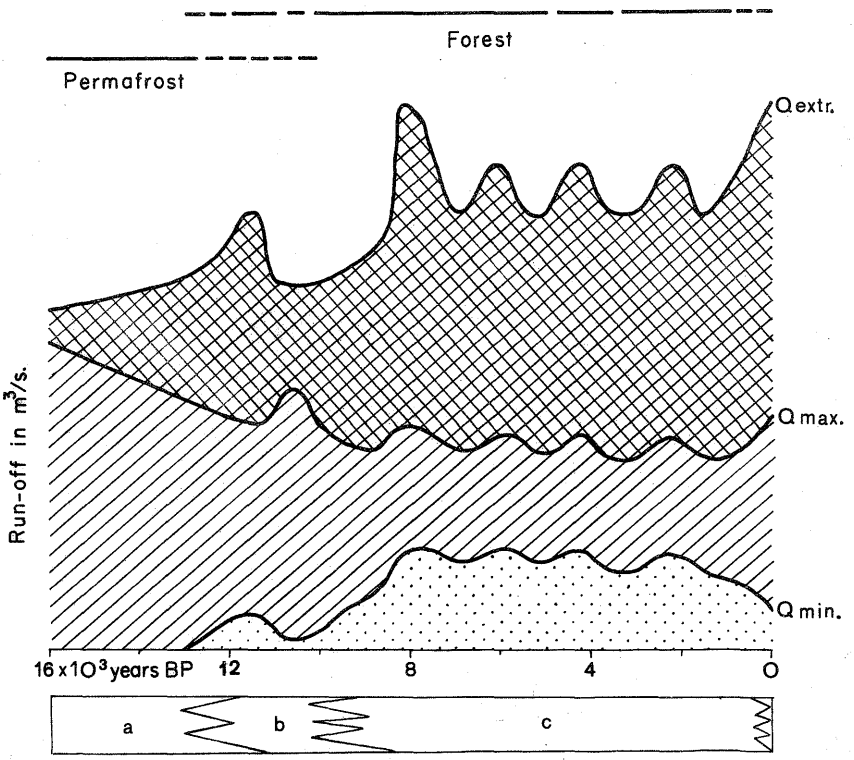

Fig. 2. Changes in the environmental and fluvial regime in the Lateglacial and Holocene inducing alterations of channels from braided into meandering ones

a – braided channels; b – large-size palaeomeanders; c – small-size palaeomeanders

the main sources of material (BARANIECKA, 1982). At the same time, in consequence of the encroachment of forest vegetation and of the melt out of permafrost, the less overloaded rivers changed from braided into meandering ones and deepened their channels (FALKOWSKI, 1975; Fig. 2). The retreat of the ice sheet and the lowering of the base level gave an additional and essential impuls to downcutting of valley bottoms. This was started in the Vistula river valley by the Otwock terrace related to the greatest extent of the last ice sheet (BARANIECKA, 1982). There originated Lateglacial erosional-accumulational steps, the lower ones with large palaeomeanders (KOZARSKI and ROTNICKI, 1977; STARKEL, *et al.*, 1981; SZUMAŃSKI, 1983). In mountain valleys, too, that phase of cutting caused disturbances in the equilibrium of slopes.

THE GLACIAL ZONE DURING THE VISTULIAN

The Scandinavian ice sheet has left in northern Poland thick series of till and glacifluvial deposits, which wholely conceal the former interglacial relief (GALON, 1972). The retreat of ice followed in stages, with frontal deglaciation occurring alternately with areal deglaciation (ROSZKO, 1968); this was accompanied by origination of outwash plains on the foreland of terminal moraines, and of parallel ice marginal streamways, along which there were carried away the waters from the melting ice sheet, and those flowing out of the periglacial zone (GALON, 1968). The process of melting out of the dead ice blocks, burried at various depths, followed with a delay and lasted to the early Holocene (GALON, 1972). The transformation of meltout deposits under the conditions of a cold climate was essential for the course of deglaciation and for the final outlook of glacigenic forms. The cold climate marked its stamp by permeating the ground with permafrost, as well as by solifluction and washing which smoothed the slope profiles (DYLIK, 1958; KOZARSKI, 1974), and by blowing out sandy bars in the braided channels (MANIKOWSKA, 1982). The erosional valley sides of marginal streamways were dissected by dozens of corrosional and dry valleys (CHURSKA, 1966). The retreat of the ice sheet caused the lowering of the base level for the waters of the Vistula and Odra rivers, and the creation of ever lower situated steps of erosional terraces (GALON, 1934; DROZDOWSKI and BERGLUND, 1976). The incision was relatively rapid, since the 1st overflood terrace in the lower Vistula valley was formed in the Alleröd, or even earlier. To the lowered base of the river Vistula there were in turn adjusted the valley bottoms of its tributaries, in the basins of which the melting out of dead ice from subglacial channels produced complicated patterns of depressions slowly included in the fluvial systems (NIEWIAROWSKI, 1968; GOŁĘBIEWSKI, 1981).

RELIEF TRANSFORMATION IN THE PERIGLACIAL ZONE DURING THE HOLOCENE

The warming up of the climate and the invasion of forest vegetation which occurred in the Bolling and Alleröd (and again mainly in the Northern Poland at the beginning of Preboreal period), induced a change in the complex of geomorphic processes. The deep percolation of water favoured intensive leaching

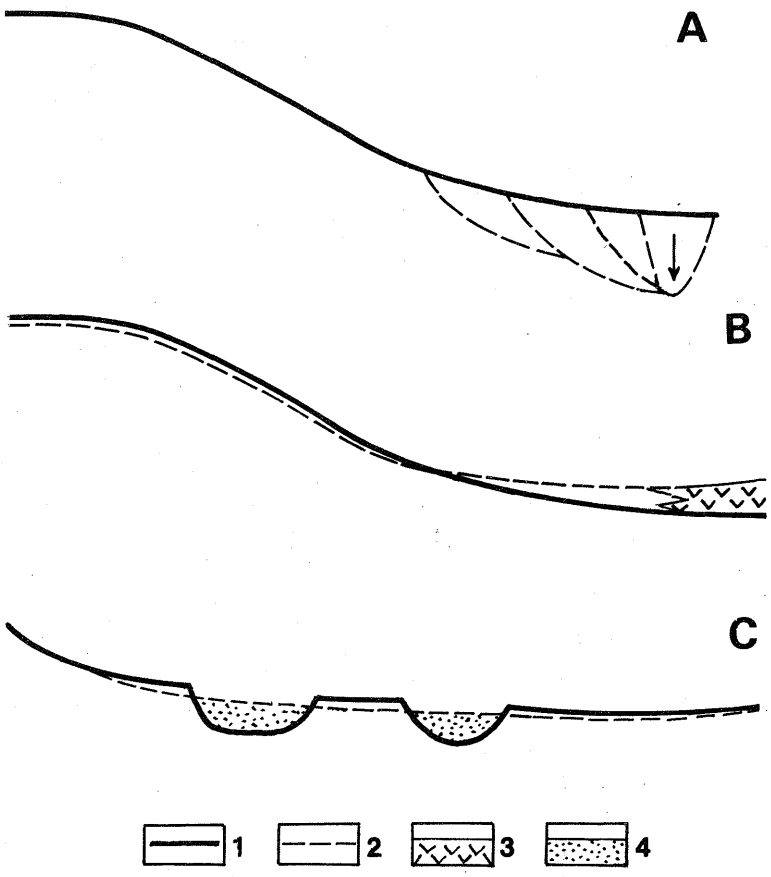

Fig. 3. Transformation of slopes and valley bottoms in the Holocene

A – the slope rejuvenated "from under" in consequence of the lowering of the base level (deepening of the valley bottom); B – stable slope smoothed in the period of agricultural activity with aggradation at the bottom in consequence of the lack of valley bottom deepening in the Holocene; C – creation of the long profile of a new river in a young glacial area flowing through lake reservoirs in dead-ice depressions. Maturation of the profile by filling the lowerings and dissection of elevated humps between them. 1. initial slope profile (or long profile of the valley) before the Holocene; 2. final profile after transformation; 3. organic deposits; 4. deltaic, lacustrine and peat deposits

and the formation of deep brown and podzolic soils. Under suitable hydrogeological conditions there developed karstic processes on carbonate rocks and gypsum (SZCZEPANEK, 1971), piping forms on loess (MARUSZCZAK, 1958; ŚNIESZKO, 1983), and landslides on flysch rocks (GIL, *et al.*, 1974). The erosional-denudational forms on the scarps built of permeable deposits which developed under permafrost conditions, were brought to a standstill (KLATKOWA, 1965). The slopes inherited from the Vistulian began to be transformed, mainly depending on the changes in the situation of the base level (Fig. 3). In the cases of valley bottom deepening and undercutting of slopes (e.g. in the Carpathians and in the Vistula river valley), the slopes became rejuvenated from the bottom upslope by gravitational processes, piping, and erosion (STARKEL, 1960). Where the axes of valleys were not deepened, on uplands and old glacial plains at footslopes, there occurred the deposition of the material washed out from the slopes, and the valley bottoms not nourished by large streams gradually became converted into peat-bogs (NAKONIECZNY, 1967; ŚNIESZKO, 1983; ŻUREK, 1975). On flattened and old glacial areas built of permeable deposits, the infiltration of water and slight gradients caused conservation and "fossilization" of the relief (KLATKOWA, 1972). Thus, the difference in the lithology of the substratum, and in the changes of the situation of the base, played an essential role in the degree of transformation of the periglacial relief during the Holocene. On the whole that transformation was slight up to the Mediaeval times, except in some mountainous regions and loess plateaux (STARKEL, 1960; MARUSZCZAK, 1968).

An essential change followed when man deforested the slopes and took them under agricultural cultivation (locally already 6,000 – 6,500 BP). The overland flow increased several hundred times (SŁUPIK, 1973) and induced soil washing (GERLACH, 1966). The valley bottoms became filled with alluvial loams, and at the footslopes deluvial covers started to accumulate, even in the area of the Łódź Plateau (DORYWALSKI, 1970). The tendency to aggradation at river valley bottoms was often marked already at the Roman times, and became general in the Middle Ages (KLATKA, 1958; LINDNER, 1977; STARKEL, *et al.*, 1981). In the zones in which strong winds blew, the process of deflation began to play an essential role (GERLACH and KOSZARSKI, 1968). On steep slopes, shallow mass wasting became more common (STARKEL, 1960). In the recent centuries, the dense network of cart-roads facilitated the runoff and the formation of flood waves which resulted in the transformation of river channels (FRÖHLICH and SŁUPIK, 1980). Since the XVIIIth century, as the cultivation of potatoes has increased, there may be observed a pronounced tendency to braiding in the river channels of the Carpathian tributaries of the Vistula (KLIMEK, TRAFAS, 1973, and others). Man's direct interference in the rivers (stream channelization, dam construction) induced general changes in the evolution of channels and flood plains.

TRANSFORMATION OF THE YOUNG GLACIAL RELIEF DURING THE HOLOCENE

The shaping of the young glacial landscape of Northern Poland was locally continued in the early Holocene (ca. 8000 – 7000 BP) together with the melting out of dead ice blocks burried in deep subglacial channels which is indicated by the lowering of the water level of many lakes (KONDRACKI, 1969). The forest and the disappearance of permafrost brought the denudation processes to a stop on escarpments and hilly marginal moraines. Together with the encroachment of forests and the change of river channels from braided to meandering ones there stopped the shifting of dunes on outwash plains and terraces in the ice marginal streamways (GALON, *et al.*, 1969). Chemical weathering and the formation of soils became the chief processes of the Holocene morphogenesis. At the same time, lakes were subjected to overgrowing with vegetation and draining; these parallel processes have been marked up till now in the shrinking of the area of lakes by about 60% (KALINOWSKA, 1961). Inactive ice marginal streamways underwent continuous filling with organic deposits (GALON, 1972). Subglacial channels and other depressions from the period of deglaciation were included in the new network of valleys (RACHOCKI and KOUTANIEMI, 1980), but no drastic changes occurred in connection with the stoppage of the deepening of large valleys in their lower courses due to Littorina transgression (ROSA, 1963). Thus, in the zone abandoned by the ice sheet there followed the maturation of the long profile of "young" river valleys (FALKOWSKI, 1971; Fig. 1).

The deforestation of moraine plateaux by man induced a revival of slope processes, the more so as the edges of subglacial channels and of the spillway of the lower Vistula valley preserved their considerable inclination (ROSZKÓWNA, 1963). Washing and linear erosional processes, and locally also gravitational and aeolian ones, favoured the slow maturation of slope profiles.

In the Baltic coastal zone there followed a straightening of the coastal line either due to the abrasion of cliffs, or the formation of barriers which closed the lagoons, or thanks to the creation of deltas (ROSA, 1963; MOJSKI, 1982).

REGULARITIES IN THE EVOLUTION OF POLAND's RELIEF DURING THE VISTULIAN AND THE HOLOCENE

The constant interest of the research workers in relief evolution and in the course of sedimentation during the Vistulian and the Holocene results in obtaining a very clear view on the morphogenetic role of these periods.

1. Most features of Poland's relief date back to the last cold stage. The glacial relief of northern Poland (in the macro- and mesoscale) originated in the Vistulian while the older relief of southern and central Poland acquired the

character of periglacial transformation (in the meso- and microscale) imposed on primary features.

2. All Tertiary and Quaternary forms older than the Vistulian (planation surfaces, slopes, valleys, relief of older glaciations) are pronouncedly marked with the stamp of periglacial transformation during the last cold stage. Depending on rock resistance, morphometry, and the relation to the changes in the base level, that transformation is either of the character of a slight modification of the primeval relief with the creation of residual cryogenic regoliths in the upper parts of slopes, and the presence of solifluctional and deluvial deposits at the foot of slopes, or is a considerable transformation with the development of cryoplanational terraces and cryopediments with corrosional valleys and outliers, or development of a cover of loess or deluvial formations which conceal the older relief (Fig. 1).

3. The Holocene morphogenesis fulfills a determinated function in the last glacial-interglacial cycle of relief evolution. Due to deep water percolation and the cover of forests, the relief of the cold stage has been preserved, and by way of chemical weathering and soilforming processes it prepares a new saprolite to be removed during the next cold stage. More vivid slope processes are limited to steeper slopes and some types of the substratum (flysch, loess, certain rocks undergoing karstification). The change in the position of the base, which in mountainous areas has been lowered (Fig. 3), is an additional but essential impuls deciding upon the rejuvenation.

4. In the young glacial zone, the Holocene fulfills the role of an essential period, in which denivelations are levelled by lacustrine and fluvial accumulations, and by the formation of new river valley patterns (Fig. 3).

5. In result of man's growing interference, the Holocene is something more than a link of the slow adaptation in the glacial-interglacial cycle of the Quaternary. The increasing rate of the process of water and aeolian areal denudation, as well as that of fluvial activity is so great that it leads to transformations not lesser per time unit than the periglacial climate, at a simultaneous preservation of the features of the hydrological regime of the temperate climatic zone leading to the rise in frequency of this process on a catastrophic scale. By his direct interference in the environment, man disturbs the mechanism of natural phenomena and changes the direction of the evolution of slope and valley bottoms.

6. In the glacial-interglacial cycle, a special and essential place is occupied by the transitional Lateglacial phase in which vanishing periglacial processes occur simultaneously with the inaugurated processes characteristic of the morphogenesis of the temperate climate. In that period there occurred the deepening of valleys conditioned both by the climate and by the lowering of the base after deglaciation. Thus, conditions were created for the disturbance of slope

equilibrium continuing during the Holocene. The melt out of dead ice blocks and permafrost occurred simultaneously, and the channels subjected to transformation into meandering ones and dune systems were created and stabilized.

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