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DEVELOPMENT OF EOLIAN PROCESSES DURING THE PLENI- AND LATE VISTULIAN IN THE SOUTHEASTERN POLAND

Abstract

Periodicity of climate changes in the Vistulian is marked by eolian processes of different intensity. In the Upper Plenivistulian strong wind activity was predominant. As a result of differentiated eolian processes loess accumulation developed in the northern part of Roztocze Upland coversands formed in the southern part. Intensive eolian activity (27–13 ka BP) caused sand deflation in the Sandomierz Basin as well as a transport for a distance of several dozen to over 100 kilometers. The sand which was blown out along the convenient and associated with relief routes formed sandy streams of a WNW–ESE direction.

The most extensive development of eolian processes took place in the Oldest and Older Dryas and it is marked by the eolian relief development. The coversands, numerous deflation forms and dunes in the Sandomierz Basin and Roztocze Upland are the results of these processes. Distribution of dunes and eolian coversands in Roztocze point to their association with relief.

INTRODUCTION

Eolian events are good and sensitive indicator of the conditions and changes occurring in the natural environment. They are used in paleoclimatic reconstructions as an evidence of increasing dryness of climate as well as vegetation disappearance. The eolian problems are an important part of studies concerning environmental changes in the Pleistocene and Holocene periods. Recently they became the subject of many published papers and reviews (BROOKFIELD and AHLBRANDT, 1983; GREELEY and IVERSEN, 1985; PYE, 1987; KOSTER, 1988; SCHWAN, 1988; BÖSE, 1991). Analysis of dunes and eolian sands in Poland focuses on the Late Vistulian events, especially on those of the Earlier and Younger Dryas. These two stages were very important in the development of dunes (DYLIKOWA, 1969; WOJTANOWICZ, 1973; MANIKOWSKA, 1991; NOWACZYK, 1986; SZCZYPEK, 1986) as well as loess synthesis (JERSAK, 1977; MARUSZCZAK, 1986).

The South-Eastern Poland, especially the Sandomierz Basin and Roztocze Upland areas, are rich in eolian forms and sediments. In order to

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explain the development of eolian processes, besides the loess zone definition, reconstruction of wind activity in earlier stages of Vistulian is necessary. CAILLEUX (1942) found a large amount (40–60%) of matt grains in the sands appearing in a wide stretch of the Central Europe lowlands, in areas to the south of the Vistulian limits. He proposed a concept of their development in the periglacial environment as a result of strong wind activity. This idea was later commonly accepted. DYLIK (1953, 1969) also recognized an intensive activity of wind on the basis of numerous ventifacts as well as the predominance of grains indicating strong eolian abrasion. Recent studies of the eolian processes in the Central Poland (GOŹDZIK, 1981, 1991) and also in the Sandomierz Basin and Roztocze Upland (SUPERSON, 1987/88; BURACZYŃSKI, 1994) permitted reconstruction of variability of these processes in the Upper Plenivistulian and of eolian events of this period.

The periglacial zone is characterized by belt pattern of the occurrence of eolian processes (DYLIK, 1969; FRENCH, 1976; STARKEL, 1988). One of its symptoms is eolian facies differentiation to silty and sandy ones with a synchronous development (CATT, 1977; KOLSTRUP, 1980; SZCZYPEK, 1986; BURACZYŃSKI, 1994). The study of the eolian processes was conducted in the Eastern part of the Sandomierz Basin and in Roztocze Upland (Fig. 1) which is paticularly important in the development zone of eolian processes of both facies.

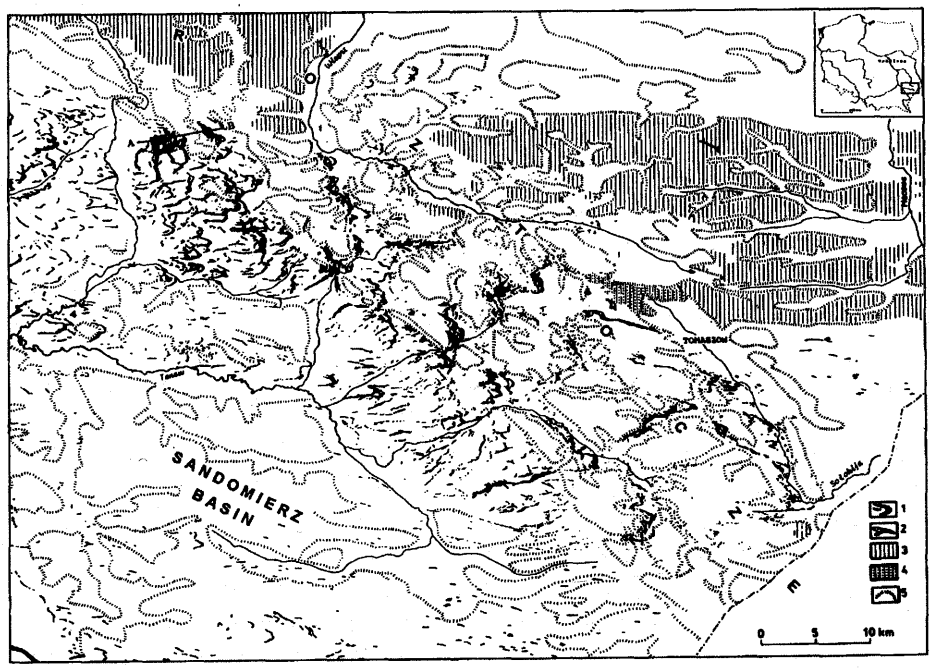

Fig. 1. Distribution of eolian sediments in Sandomierz Basin, in Roztocze Upland and adjacent regions.

1. dunes; 2. eolian coversand; 3. loess cover; 4. sandy loess; 5. scarps, slopes of humps and valleys; A–B – line of cross-section, Fig. 5.

CHARACTERISTICS OF EOLIAN FORMATION IN ROZTOCZE UPLAND AND SANDOMIERZ BASIN

During Plenivistulian the studied area was localized in the periglacial zone with actively developing eolian processes. The loess accumulation lasted through the whole Vistulian and ended about 15 ka BP (JERSAK, 1973; MARUSZCZAK, 1986). On the contrary, the eolian coversands developed in the extreme periods of the Lower and Upper Plenivistulian.

In Roztocze area there is a marked spatial differentiation of eolian facies in two zones: the loess zone in the northern part and the sandy zone to the south of it. Loesses appear in the northern stretch in Goraj Roztocze and partly in Tomaszów Roztocze and Grzęda Sokalska (Fig. 1). The area with diversified relief near Tomaszów Lubelski is a transitional zone (Fig. 2). On higher humps (320–340 m a.s.l.) the typical loess appears, with

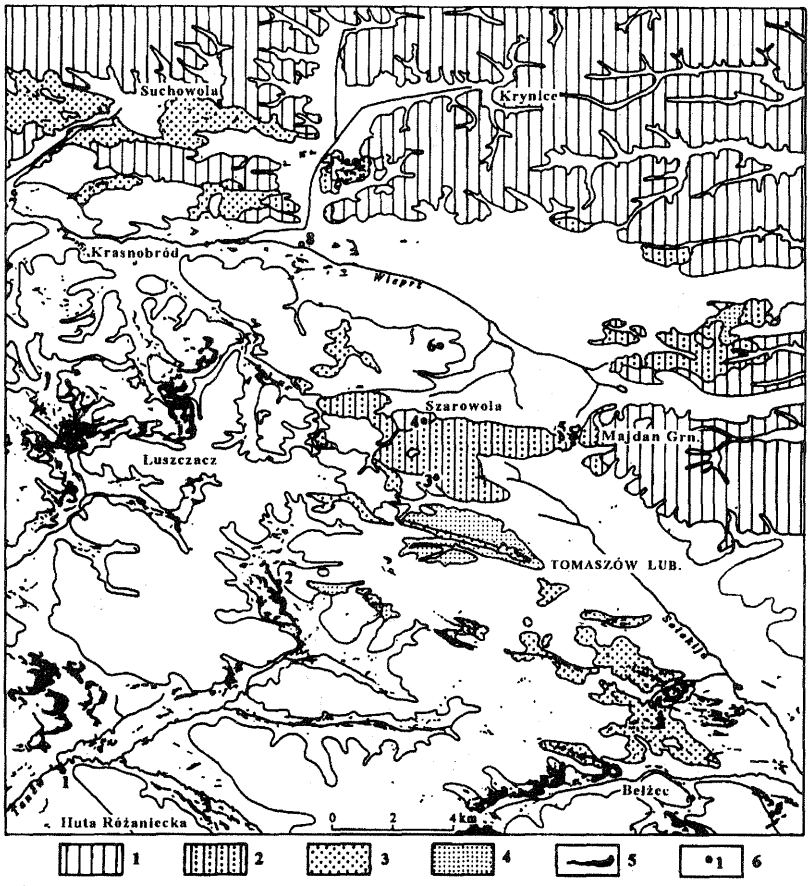

Fig. 2. Eolian sediments in the Roztocze Upland near Tomaszów Lubelski

1. loess cover; 2. periglacial sandy silts (sandy loess); 3. eolian coversands; 4. eolian-coluvial sands; 5. dunes; 6. profiles

an average of mean grain diameter $M_z = 5\varphi$ On the low hump (<300 m a.s.l.) near Wieprz and Sołokija valley, sandy loess (M_z= 3.8–4.5φ) with variable (10–35%) contents of sandy fraction (>0.25 mm) can be observed. The abrasion of quartz grains is good: W_o=1400–1500, and γ<50%, according to Krygowski's classification (BURACZYŃSKI, 1994).

Based on the dating by the thermoluminescence method (TL) it was established that sandy loess developed in the Lower and Middle Pleniglacial, whereas the typical loess developed in the Upper Pleniglacial. Transported by wind silts were deposited on the humps and sands were blown out from the upper Wieprz basin. The sandy loess was developing under the action of changing winds during the summer and winter seasons. In the Lower Pleniglacial (60–70 ka BP) an intensive sand blowing up occurred, consistent with the development of the lower coversands (BURACZYŃSKI, 1994).

Periglacial morphogenesis played an important role in the development of sandy covers in the Roztocze Upland (DYLIK, 1953, 1969; JAHN, 1956). Humps in this area underwent strong periglacial weathering. The weathered material transported from the slopes was deposited in valleys, where it was under influence of a braided river redistributing it evenly in the valley floor. The sand accumulation in the valley reached 10–15 m whereas along the Roztocze scarps it was as much as 20–30 m (Fig. 3) (JAHN, 1956; BURACZYŃSKI and BUTRYM, 1989).

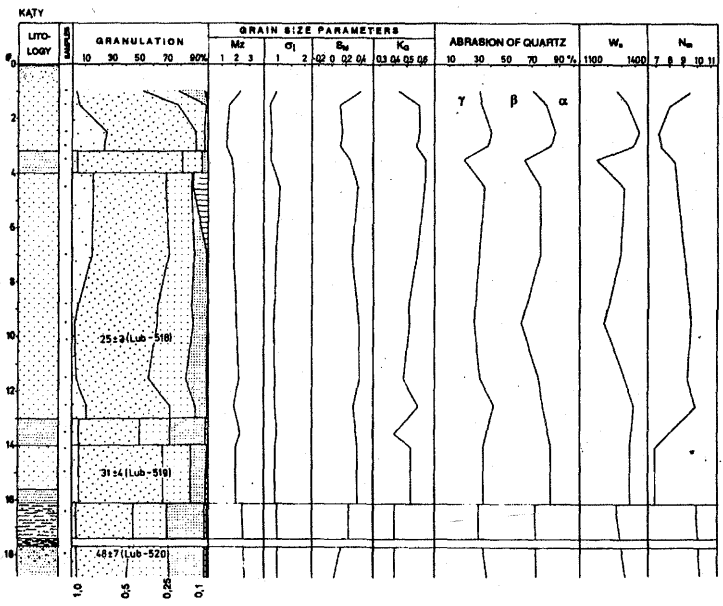

Fig. 3. Geological section Kąty. Content of size classes and grain size parameters in phi scale (M_z – mean grain diameter, Sk_I – skewness, δ_I – standard deviation) and abrasion of quartz (γ – percentage of grains well abraded, W_o – indice of abrasion, N_m – heterogeneous coefficient); TL age x 1,000 yrs BP

In the period of 25–15 ka BP in the Upper Plenivistulian, the climate was arctic, cold and dry, reaching the cold maximum (KOZARSKI, 1986). These conditions were favorable for intensive weathering and development of thick sandy covers. The braided rivers carried out large amounts of the material and deposited it on the foreland of Roztocze in a form of flat alluvial fans (BURACZYŃSKI and BUTRYM, 1989). In the Pomeranian phase the environmental conditions were similar to those observed in contemporary cold deserts with a strong wind activity (DIJKMANS & KOSTER, 1989).

The coversands are well sorted and loose. They are characterized by an average the mean grain diameter M_z=1.7–2.2φ and good abrasion of quartz grains: γ=40–50% and index W_o=1450–1500 (Fig. 4). Well marked changes

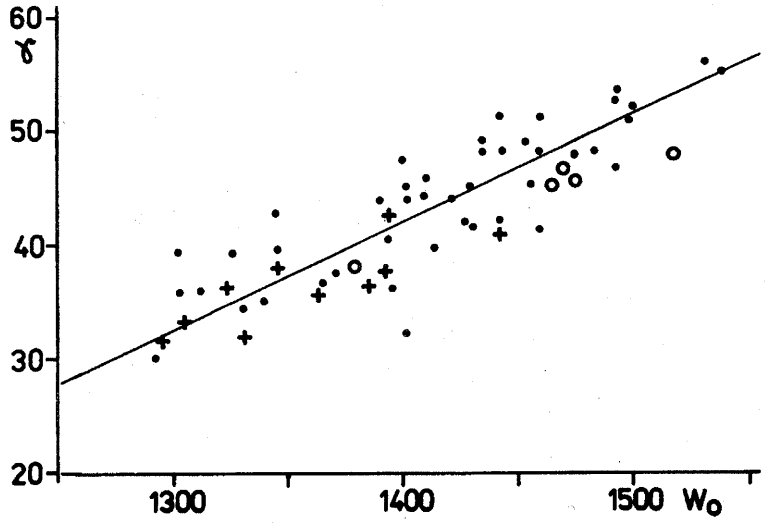

Fig. 4. Diagram of quartz grains abraded (0,8–1,0 mm) from the coversand. Percentage of type γ grains (well abraded) and W_o indice of abrasion according to KRYGOWSKI's method.

of eolian grain abrasion are the result of an intensive wind activity and long transport. The products of wind activity were marked distinctly in the Leszno and Poznań phases. The upper coversands in Roztocze occur in a different morphological situations. They line the floors of dry valleys with several meters thick layer and form patches of different sizes on the Cretaceous humps. Bigger patch (length 8 km, width ~ 500 m) with a WNW–ESE orientation are distinctly marked in the relief of the area (Fig. 2). The presence of the coversands on culminations is the evidence of intensive eolian processes.

The sands transported by western winds from the Sandomierz Basin were blown on the Roztocze humps by saltation and rolling. The amount

of transported material was relatively small. In the conditions of permafrost, sand grains were released by the ice evaporation. Only a thin sand layer, without an ice cement, was being blown out (SCHWAN, 1988). Sands were undergoing severals cycles of transfer. Especially intensive wind activity occurred in the period 20–15 ka BP (KOLSTRUP, 1980). The dry climate favored eolian transport of sand intensifying during the final Pomeranian phase. Then the material blown out from a sandy plain was transported and deposited in Roztocze Upland. It was a common process occurring from the Western Europe through the uplands of Poland (BÖSE, 1991; GOŹDZIK, 1981, 1991; SZCZYPEK, 1986).

At the Late Glacial (15.3–13.0 ka BP) the dissipation of permafrost and there was a significant change of the atmospheric ciculation with the preponderance of western winds. These events and the extreme climatic dryness supported strong wind blowing processes.

DEVELOPMENT OF EOLIAN RELIEF

Deflation plays a significant role in denudation processes of the periglacial zone (DYLIK, 1969, FRENCH, 1976). The blown out material from the surface of loose and unprotected by vegetation sediments underwent spatial segregation into sand and silt. Sand was transported by saltation and silt by the way of suspension. The sorting out of this material was taking place on a flat area from which it was blown out and transported on a large distance by low winds. When a relative height of the terrain changed (humps, edges) the wind speed and silt accumulation decreased (JAHN, 1956).

According to LAMB (1977), an atmospheric circulation in Central Europe during Pleniglacial (20 ka BP) showed the prevalence of the eastern winds. The eolian processes were dependent on the season. In summer weak and changing winds from NW direction predominated. At the beginning of summer sedimentation was associated with the aqueous accumulation of silt which after drying out was deflated and transported by low winds. On the other hand, the winter sedimentation was controlled by strong east (NE) gravitational winds that could carry up the sand grains by saltation or roll them away on the ground. Deflated in small amounts sand was transported during snowstorms. This indicates that eolian coversands were developed mainly in winter.

The deflation processes initiated in the Upper Plenivistulian, developed intensively during the Oldest Dryas, reaching the maximum in the Older Dryas (DYLIKOWA, 1969; MANIKOWSKA, 1985). An intensive wind activity on the sandy plain of the Sandomierz Basin was marked by the development of blow-out depressions and humps as well as parabolic dunes

(WOJTANOWICZ, 1973; BURACZYŃSKI, 1994). Deflation processes were progressing unevenly, being more intensive in the places where permafrost disappeared and causing the development of big blow-out depressions.

Flat and sandy plain created favorable conditions for the development of eolian processes. Their action resulted in stretches of parabolic dunes forming ridges divided by a flat deflation zone. The edge of Roztocze became a barrier in a way of moving dunes and undisturbed transport of sand towards East. The accumulation of the transversal ridges in front of the edge indicates to an intensive transport of the material. The activity of the eolian processes in the edge zone can be seen in the cross–section (Fig. 5). In the Sandomierz Basin the deflation and transport of sandy

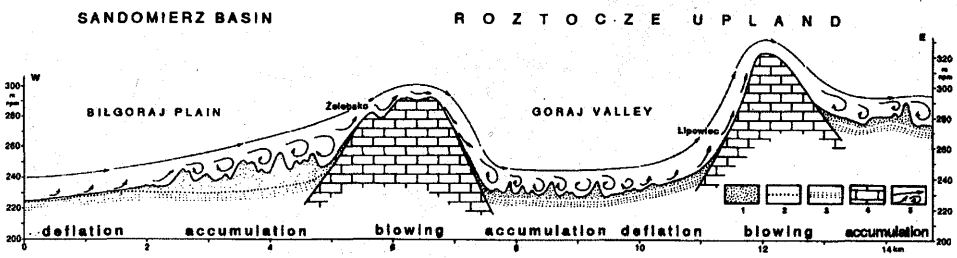

Fig. 5. Relief forming activity of wind in the Roztocze Upland

1. eolian sands: dunes and coversands; 2. blow-out surface; 3. sandy plain and terrace; 4. badrock; 5. wind circulation over topographic barrier, deflation and reversing windflow.

material occurred. The moving dunes stopped in front of the 40 meters high edge of Roztocze. On a 2 kilometers wide stretch several transversal ridges over 10 m high developed. They are separated by lowerings 100–200 m wide. They stopped at some distance from a barrier due to the activity of the reversing windflow. Sand deflation through this topographic barrier was smaller therefore on the leeside the low (5–7 m) transverse dunes were formed. Farther away from the slope deflation prevailed and the sand transport is evidenced by small dunes. The material from the valley was transported into Roztocze through the rising humps.

Large dune groups occur in Roztocze mainly in valleys and depressions. On the culminations there are solitary forms or low rows of linear dunes. A large complex dunes near Łuszczacz is an exception since it developed in a specific morphological situation (Fig. 2). These dunes originated at the crossroads of deflation of the material from two alimentation areas, Sopot and Szum basins. An extensive transport of material caused filling up of the upper part of the Krasnobród valley as well as the entering of dunes on culmination. Ten meters high transversal dune is rising over the Cretaceous hump (350 m a.s.l.). It is the biggest transverse ridge located on the Roztocze culmination.

Dunes in the Sandomierz Basin and Roztocze Upland are arranged in belts with a distinct orientation (Fig. 6). They run in parallel in WNW–ESE and W–E directions according to the prevailing direction of dune forming winds. The course and situation of these belts in the Sandomierz

Fig. 6. Map of distribution of dunes and directions of major sandflows in Sandomierz Basin and in Roztocze Upland; contour lines 10 m

Basin indicate their dependence on the main relief conditions. A bulk transport of sand took place mainly on flat and concave latitudinal-oriented areas. On the Roztocze Upland an orientation of these belts depended on direction of the valleys.

Sandflow was developing under the influence of winds along the markedly organized route. The length of the dune belts indicates that the sandflow involved the distance from a few dozen kilometers up to over 100 kilometers (GOŹDZIK, 1991). Sandy streams developing in the Sandomierz Basin cross Roztocze and continue further towards East in the Bug Basin.

Eolian events in Vistulian were continuous, with the short periods of decreasing activity and the long periods of dune migration. An average speed of dunes migration in Vistulian can be calculated as 10 meters/year (GOŹDZIK, 1991).

CONCLUSIONS

The periglacial processes played an important role in the development of eolian covers during Plenivistulian (Fig. 7).

ka B.P.	Chronostratigraphy			Deposits and relief features
	HOLOCENE			
10	YOUNGER DRYAS	LATE	VISTULIAN	windblowing processes, dunes
11	ALLERÖD			organic deposits (peat, gyttia)
11.8	OLDER DRYAS			main formation of parabolic dunes and blowout depression, coversand
12	BÖLLING			soil
13	OLDEST DRYAS			eolian coversand and dune formation
	EPE			?
14.3	POMERANIAN PHASE	UPPER		deflation, primery dunes
15.5	POZNAŃ PHASE			strong windblowing processes, coversand slope and fluvial sands accumulation
20	LESZNO PHASE			intensity frost weawering
27	DENEKAMP	M		solifluction, sand and mud

Fig. 7. Chronostratigraphy of eolian processes in the Sandomierz Basin and Roztocze Upland.

1. Climatic conditions of the periglacial zone favored weathering and sand accumulation. Sands deposited as a result of fluvial activity. An intensive deflation on vast, with no vegetation plains caused the blowing out of dusts and sands as well as development of loess and coversands.

2. In Roztocze Tomaszowskie, a lithofacial segregation of deposits to silt, sandy-silt and sand zones was evident. Sandy loess creates a transitional zone between loess and coversands in the area of changing winds. The northern foreland of the upland was the source of blow-in silts from NE direction.

3. During the period of 20–15 ka BP an intensive deflation developed under the influence of western winds. The sand which was blown out along the convenient routes associated with relief, formed sandy streams of a WNW–ESE direction. They developed on a distance of several tens to over 100 kilometers.

4. The activity of sandy streams was important in the formation of eolian coversands in the Roztocze Upland. Due to the sand blowing out from Sandomierz Basin, eolian coversands were formed in the valleys and culminations of the Roztocze. In the conditions with strong wind activity,

the eolian sediments are very dynamic and can be blown away repeatedly. The conditions in the Upper Plenivistulian were similar to those presently observed on the cold deserts with strong wind activity.

5. Disappearance of the permafrost in the period of 15–13 ka BP put in motion large amounts of sand and started a dune development. The greatest effect of the eolian activity in the Oldest and Older Dryas was the development of eolian relief in Sandomierz Basin and Roztocze. Numerous deflation forms and dunes in the Sandomierz Basin during the Late Glacial are the evidence of the eolian processes intensity. Distribution of dunes and eolian coversands in Roztocze points to their association with the relief. Large linear dunes developed in valleys, along their leeside slopes. Whereas on the culminations the linear dunes, marking route of the sandy streams, were formed.

6. Eolian events controlled by climate developed simultaneously in the Sandomierz Basin and Roztocze Upland. Both these regions were closely connected and interdependent. The basin was the area of an intensive deflation and the source of material for dune development. A diversified relief of Roztocze affected the accumulation and distribution of the coversands as well as the dune development. In Roztocze dunes appear in different morphological situations: in valleys, on slopes and also on culminations.

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