References

Augustowski, B., 1968: Spostrzeżenia nad zmianami antropogenicznymi w korycie Ropy w Karpatach w okolicy Biecza. *Zesz. Nauk. WSP w Gdańsku* 10: 161–168.

Bobrowski, W. & Kociszewska-Musiał, G., 1959: Analiza żwirów Dunajca między Tatrami a Pieninami na tle morfologii i geologii obszaru zlewni. *Kwart. Geol.* 3, 2: 391–414.

Chełmicki, W. & Krzemień, K., 1998: Naturalne koryto rzeki Feshie w masywie Cairngorm Mts. i jego ochrona (Szkocja). *In*: *Bliskie naturze kształtowanie rzek i potoków*. IMGW, Politechnika Krakowska, Konferencja Naukowo-Techniczna, Zakopane: 239–240.

Chełmicki, W. & Krzemień, K., 1999: Channel typology for the River Feshie in the Cairngorm Mts, Scotland. *Prace Geogr*., z. 104, Instytut Geografii UJ: 57–68.

Choeley, R.J. & Kennedy, B.A., 1971: Physical geography. A systems approach. London, Prentice Hall: 1–370.

Dąbrowski, P., 1998: Renaturalizacja – Czarny Dunajec jako element ochrony bioróżnorodności regionu. *In*: *Bliskie naturze kształtowanie rzek i potoków*. IMGW, Politechnika Krakowska. Konferencja Naukowo-Techniczna, Zakopane: 225–234.

Kamykowska, M., Kaszowski, L. & Krzemień, K., 1999: River channel mapping instruction. Key to the river bed description. *In*: K. Krzemień (*Ed.*) *River channels, pattern, structure and dynamics*. *Prace Geogr*. z. 104, Instytut Geografii UJ: 9–25.

Kaszowski, L. & Krzemień, K., 1979: Channel subsystems in the Polish Tatra Mts. *Studia Geom. Carp.-Balc*. 8, Kraków: 149–161.

Krzemień, K., 1981: Zmienność subsystemu korytowego Czarnego Dunajca. *Prace Geogr*., z. 53, Instytut Geografii UJ: 123–137.

Krzemień, K., 1991: Dynamika wysokogórskiego systemu fluwialnego na przykładzie Tatr Zachodnich. *Rozpr. Hab*. Nr 215. Kraków: 1–160.

Krzemień, K., 1999: Structure and dynamics of the high-mountain channel of the River Plima in the Ortler-Cevedale Massif (South Tirol). *In*: K. Krzemień (*Ed.*) *River channels pattern, structure and dynamics*, Prace Geogr. Instytut Geografii UJ, 41–55.

Klimaszewski, M., 1972: Karpaty Wewnętrzne. *In*: *Geomorfologia Polski*. T. 1: *Polska Południowa*. Warszawa: 25–52.

Klimek, K., 1983: Erozja wgłębna dopływów Wisły na przedpolu Karpat. Ekologiczne podstawy zagospodarowania Wisły i jej dorzecza. T. 7: 97–108.

Klimek, K., 1987: Man's impact on fluvial processes in the Polish Western Carpathians. *Geogr. Ann*., 69-A, 1: 221–226.

Mosley, M.P., 1987: The classification and characterization of rivers. *In*: K. Richards (*Ed.*) *River channels, environment and process*. Inst. of Brit. Geogr., Special Publ. Series, Blackwell, Oxford: 295–320.

Nawara, K., 1960: Skład litologiczny żwirów Białki i Czarnego Dunajca. *Acta Geol. Pol*. 10, 3, Warszawa: 455–474.

Osuch, B., 1968: Problemy wynikające z nadmiernej eksploatacji kruszywa rzecznego na przykładzie rzeki Wisłoki, *Zesz. Nauk. AGH w Krakowie* Nr 219, z. 15: 283–301.

Rączkowska, Z., 1983: Types of stream channels in the Chochołowski drainage basin (The Polish Western Tatra Mts.), *Studia Geomorph. Carpatho-Balc*. 16, Kraków: 143–159.

Thorne, C.R., 1998: Stream reconnaissance handbook. Geomorphological investigation and analysis of river channels, John Wiley & Sons, Chichester: 1–133.

Verbraak P., 1999: Re-naturalisation projects for the River Meuse: New opportunities for nature with an integrated water management approach. *In*: M. Kucharczyk (*Ed*). *Problemy ochrony i renaturalizacji dolin dużych rzek Europy*. Lublin: 209–213.

Wasson, J.G., Bethemont, J., Degorce, J.N., Dupuis B. & Joliveau T., 1993: Approche ecosystémique du bassin de la Loire. Eléments pour l'élaboration des orientations fondamentales de gestion. Lyon, Saint-Etienne: 1–102.

Wyżga, B., 1991: Present-day downcutting of the Raba River channel (Western Carpathians, Poland) and its environmental effects. *Catena* 18: 551–566.

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The depositional conditions of longitudinal dunes based on investigations in the western part of the Lublin Upland, SE Poland

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Abstract: The development of longitudinal dunes depends on three overlapping factors: the strength and direction of winds, the amount of supplied sand, and the occurrence of vegetation which can fix the rising forms. It is assumed that longitudinal dunes in Polish territory were mainly formed from the arms of parabolic dunes, as a result of the deflation of the central parts of these dunes. However, it is possible that some longitudinal dunes in Poland could also have developed as primary forms.

The detailed studies of longitudinal dunes in the western part of the Lublin Upland have revealed an important structural differentiation resulting from various development conditions of each particular form. Three models of development of longitudinal dunes are derived from these investigations:

1) They are formed by undirectional winds deflating the central parts of parabolic dunes, when sand supply is small, and vegetation fixes the rising forms.

2) They develop after a change of wind direction by 90°, in consequence of transformation of a single transversal dune or a set of parabolic dunes formed in front of or on an obstruction.

3) They are primary forms originating at obstructions, when eolian material is transported by bidirectional winds from a narrow (up to 90°) sector.

Key words: longitudinal dunes, date Pleistocene, the Lublin Upland

Introduction

In many papers dealing with the formation conditions of inland dunes in Poland, the origin of longitudinal dunes has never been the principal concern. They have mainly been considered to be created by the deflation of the central parts of parabolic dunes (Galon, 1958; Wojtanowicz, 1969). It was also suggested that longitudinal dunes were primary forms which could develop into parabolic dunes (Dylikowa, 1969). Observations of longitudinal dunes being formed at present (Hack, 1941; Bagnold, 1954; McKee & Tibbits, 1964; Verstappen & Delft, 1968; Brookfield, 1970; Fryberger, 1979; Lancaster, 1980; Tsoar, 1983, 1984) reveal that shifting, bi-directional winds from a sector of <130° are the main factor stimulating their development; winds from the dominant direction have much lower velocities than those from the secondary direction – which are not necessarily frequent but strong. Longitudinal dunes appear to originate most often from barchans, but the possibility that they develop from parabolic or transversal dunes cannot be excluded. The occurrence of various obstructions, mainly vegetation, and small supply of eolian sand are also important for their development.

Complex studies of eolian forms in the western part of the Lublin Upland have revealed an important structural differentiation of the distinctive longitudinal dunes and an attempt was made to explain this phenomenon. The aim of this paper is to determine the origin of longitudinal dunes, i.e. to show the dependence of dune-forming processes on environmental conditions, and to classify the longitudinal forms.

Field work was conducted in sections perpendicular to the long axes of the studied forms. The research methods comprised macroscopic analysis of grain size, registration of sedimentary structures according to the classifications published by Hunter (1977), Borówka (1979, 1980), Goździk (1998) and Izmaiłow (1998), and measurements of structural direction components. On the basis of the data set an attempt is made to reconstruct the development stages of the particular forms.

Geomorphological features of longitudinal dunes

Longitudinal dunes in the western part of the Lublin Upland are usually symmetrical ridges to 500 m long and up to 6 m high, which run either rectilinearly or irregularly and often have peaks and saddles. They occur mostly as single forms or sets of ridges in the peripheries of dune areas, near the scarps of river terraces and loess patches, and in the border parts of interfluve planation surfaces. They are also found in the central parts of dune areas where they form two parallel or sub-parallel sets of ridges. The forms of NW-SE and W-E orientations predominate, whereas those

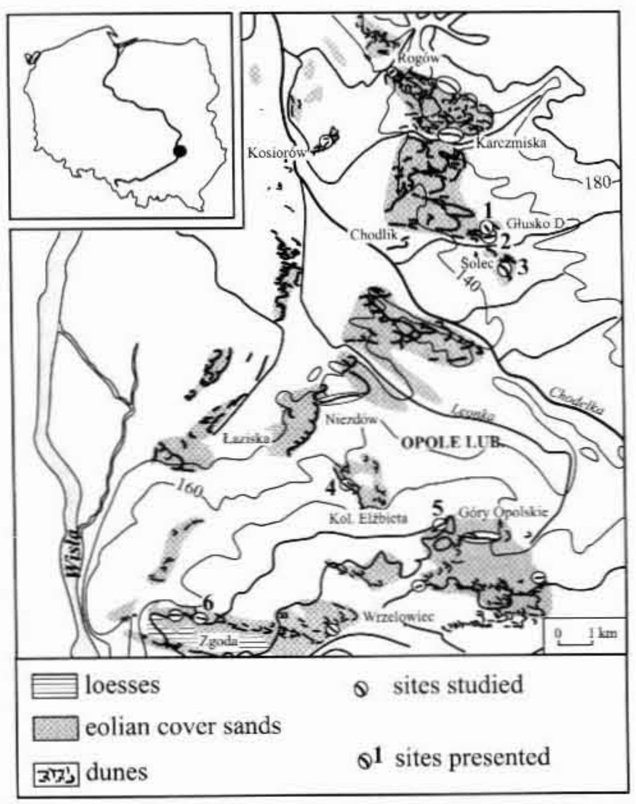

Fig. 1. Situation of the research sites in relation to distribution of eolian deposits in the western part of the Lublin Upland
1 – Głusko Duże I, 2 – Głusko Duże II, 3 – Solec, 4 – Kolonia Elżbieta, 5 – Góry Opolskie, 6 – Zgoda

elongated WNW-ESE and WSW-ENE are subordinate (Fig. 1).

The structure of longitudinal dunes is described at the most typical sites: Głusko Duże I, Głusko Duże II, Solec, Kolonia Elżbieta, Góry Opolskie, Zgoda.

Głusko Duże I. This NW-SE-trending dune is situated on the denuded morainic plateau which consists of tills overlain by discontinuous fluvioglacial or eluvial sands with gravels (Fig. 2). This form consists of one sandy series which is structurally differentiated, i.e. sandflow cone structure occurs on the SW slope, and tabular structure on the NE slope (Fig. 2B).

Sands with sandflow cone structure are typical of a distal slope in a dune frontal zone, where sediment is mobilised only by gravity. However, sands with tabular structure are typical of a slope on which material moves not only due to gravity but also across the slope as a result of its exposure to wind (Borówka, 1979, 1980). It is assumed that such conditions can also occur on the arms of parabolic dunes or on the slopes of longitudinal dunes (Stankowski, 1963). It is inferred, therefore, that the structural features of the deposits are probably an effect of the migration of a parabolic dune from the Nord-West to the South-East, and the form described is essentially a deflation remnant which was probably formed from the eastern arm of this dune (Fig. 2C).

Głusko Duże II. This WSW-ENE dune is situated in the contact zone of the denuded morainic plateau and the sandy higher river terrace (Fig. 3). The dune is composed of three sandy series which are separated by soils or erosion surfaces (Fig. 3B): 1) a lower series with high-angle cross-stratification, with different structures according to its situation in the longitudinal section of the dune: sandflow cones, trough or tabular structures; 2) a middle series with horizontal or low-angle cross-stratification; 3) an upper series, restricted only to the crest part of the dune, with horizontal stratification (in the dune top) or tabular structure (in the upper parts of dune slopes), and with sandflow cone structure (in the eastern part of the dune).

The lower sandy series, which accumulated during the first stage of dune development, has structures typical of a distal slope – sandflow cone structure and trough structure, and tabular structure which is a typical of dune arms (Borówka, 1979, 1980). These features suggest that this dune originated during a migration of two parabolic dunes when their arms joined in the final stage of their development (Fig. 3C). The western dune probably formed first. Such an interpre-

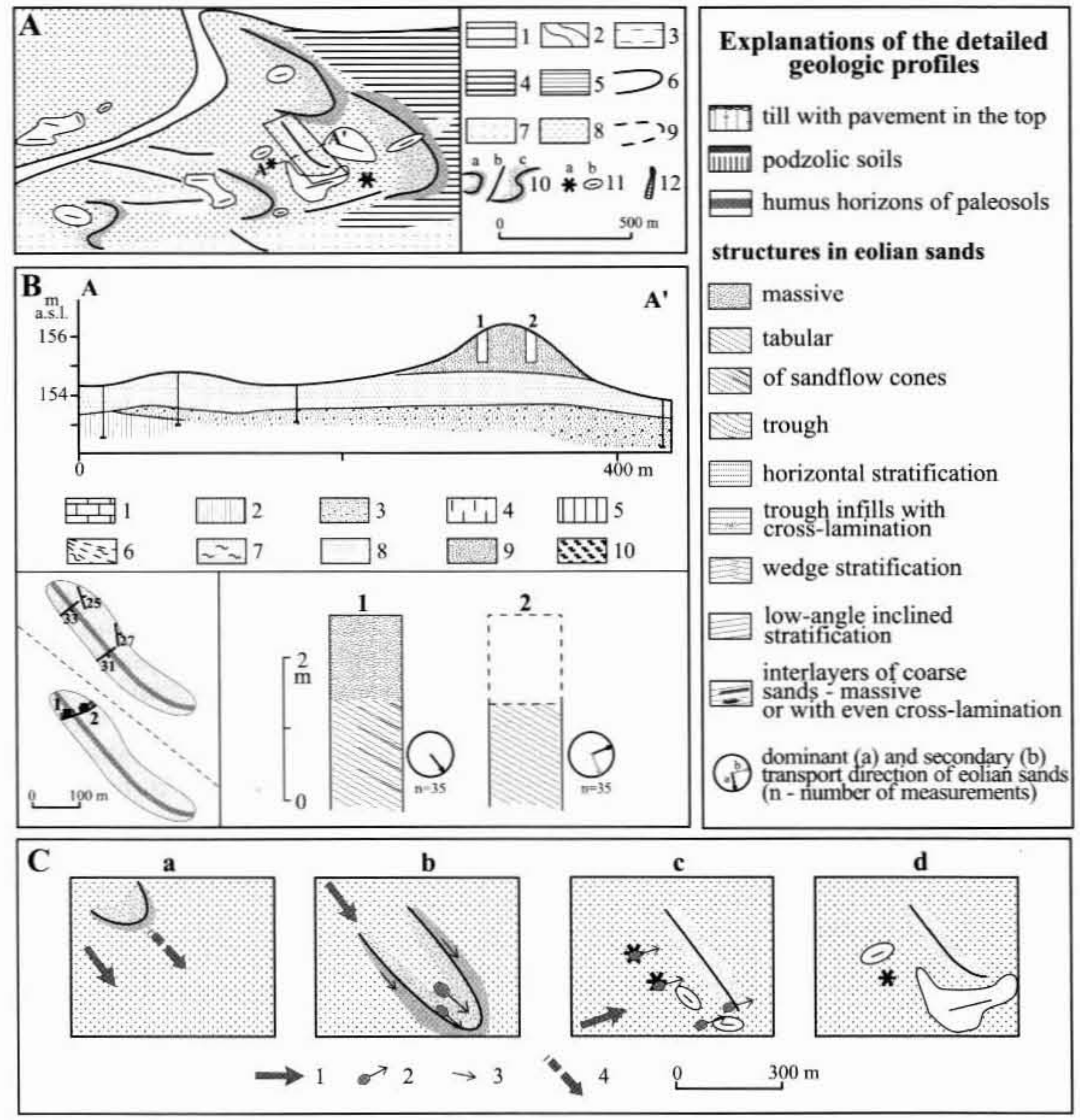

Fig. 2. Głusko Duże I Site
A – Geomorphological sketch of the research site:
1 – planation surfaces in the interfluve area, 2 – slopes, 3 – denudation pediments, 4 – denuded morainic plateaux, 5 – loess plateaux, 6 – dry erosion-denudation valleys, 7 – higher terraces, 8 – eolian covers, 9 – trough-like small valleys, 10 – dunes: a – parabolic, b – longitudinal, c – complex; 11 – deflation landforms: a – remnants, b – hollows; 12 – gullies. B – Geologic structure: 1 – Upper Cretaceous basement, 2 – tills, 3 – fluvioglacial or eluvial sands and gravels, 4 – carbonate loesses, 5 – decalcified loesses, 6 – loess deluvia, 7 – silty-sandy covers, 8 – eolian cover sands, 9 – dune sands, 10 – peats. C – Stages of dune development: 1 – direction of dune-forming winds, 2 – deflation-deposition processes, 3 – local direction of eolian material transport, 4 – direction of dune movement

tation is supported by an examination of the deposits in the profile No 3 (Fig. 3B). Sands with the trough structure typical of a distal slope are present in its lower part, and they are overlain by sands with the tabular structure typical of transport of material across a slope. These beds were probably the front of a small dune *sensu* Hunter (1977), on which sand accumulated as a result of the drift associated with the approach of the second dune. The next bed, which is separated from the earlier-formed structure by an erosion surface, displays tabular structure and structural direction components which provide evidence of the encroachment of western arm of the second parabolic dune. The structural direction components of the growing complex dune indicate the north-westerly dune-forming winds.

Then, a deflation processes produced a second erosion surface on which the middle eolian series later accumulated. Low-angle cross-stratification and cross-laminated infill of troughs indicate that deposition of the middle series was caused by migration of ripples along the crest of the earlier-formed complex dune. Structural direction components of the deposits filling the troughs give evidence of the dominant WSW wind.

In the last (the modern) stage there was progressive enlargement of the dune crest zone. The

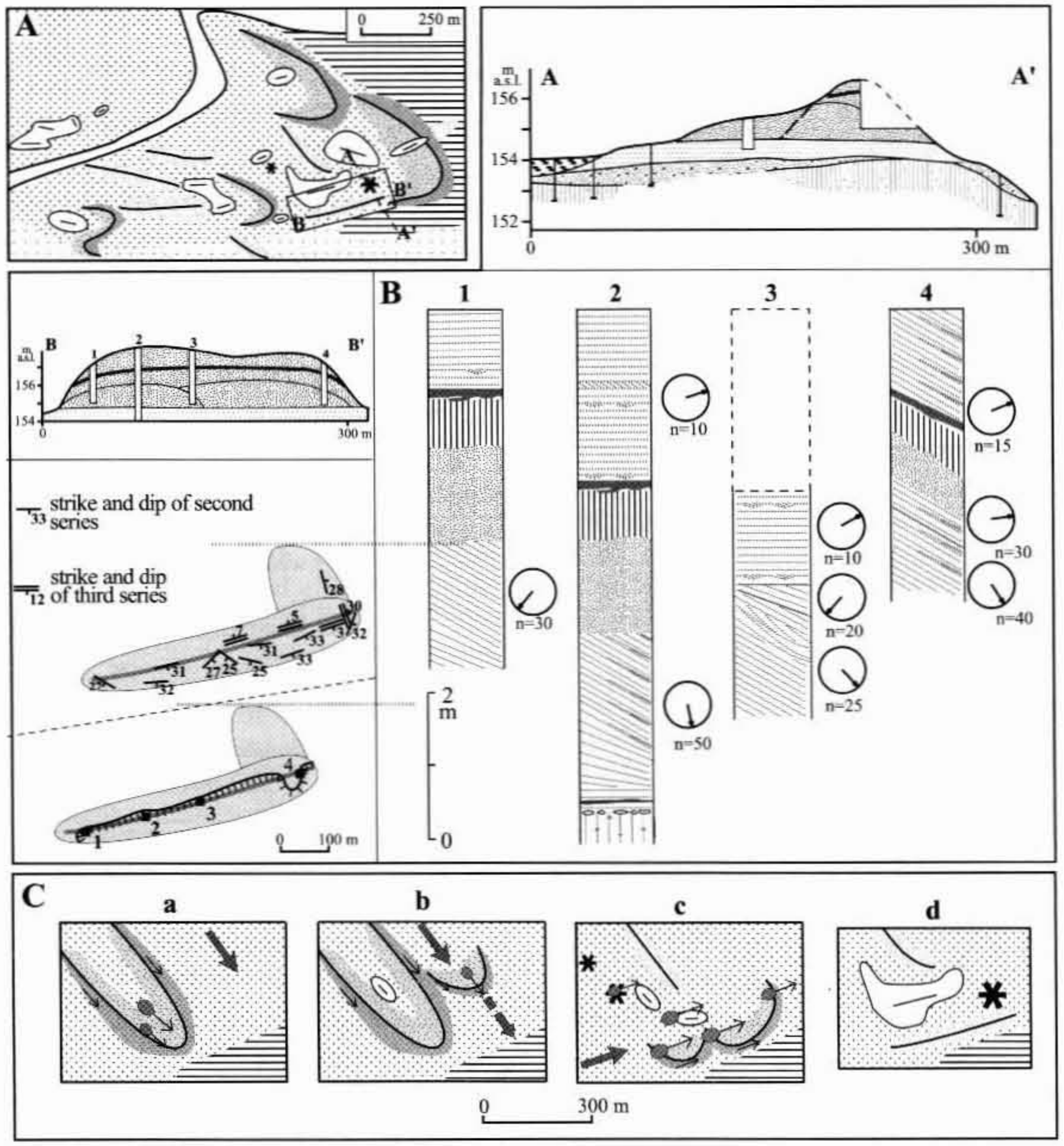

Fig. 3. Głusko Duże II Site
A – Geomorphological sketch of the research site, B – geologic structure, C – stages of dune development. Other explanations as in Fig. 2

structural features of the upper series, i.e. horizontal lamination and even cross-lamination, indicate that its deposition resulted from the movement of ripples and megaripples (Hunter, 1977; Pye & Tsoar, 1990; Goździk, 1998), and its direction components provide evidence of WSW wind.

Solec. This NW-SE dune is situated on the denuded morainic plateau (Fig. 4). It consists of one, structurally differentiated series (Fig. 4B). The windward part consists of sands with low-angle cross-stratification on the south-western slope, and with tabular structure on the north-eastern slope. Within the leeward part, the high-angle, cross-stratified sands with sandflow cone structures occur on the south-western slope, and sands with tabular structure on the north-eastern slope.

The structure of the windward part of the dune (sands with low-angle cross-stratification and tabular structure) is very similar to that of the parabolic dune arm (Rotnicki, 1970), while structures in the lee part reflect the migration of the parabolic dune front in the SE direction (Fig. 4C). Thus, this form must be a remnant of the eastern arm of a dune which was originally a stationary form as can be concluded from the low-angle cross-stratification in the proximal part of the dune (Stankowski, 1963; Rotnicki, 1970; Nowaczyk, 1976).

Kolonia Elżbieta. Two parallel dune ridges are elongated NW-SE (Fig. 5). They are situated

on the denudation pediment which consists of tills in places. The structure of both dunes is similar (Fig. 5B). They consist of one structurally differentiated series; the internal slopes of the dune complex are composed of the sands with sandflow cone structure, and external slopes – of tabular sands.

These features and the structural symmetry of these forms suggest that their origin was associated with the development of a single parabolic dune (Fig. 5C). Therefore, they provide evidence of the migration of the parabolic dune front in a SE direction, with constant north-western dune-forming winds, and they were probably formed from the arms of this dune. Such a situation may occur when vegetation encroaches on the lower dune parts, i.e. its arms (Hack, 1941; Galon, 1958; Verstappen & Delft, 1968; Wojtanowicz, 1969).

Góry Opolskie. This WSW-ENE form is situated in the north-western part of the plateau, in the contact zone with its slope (Fig. 6). It is directly

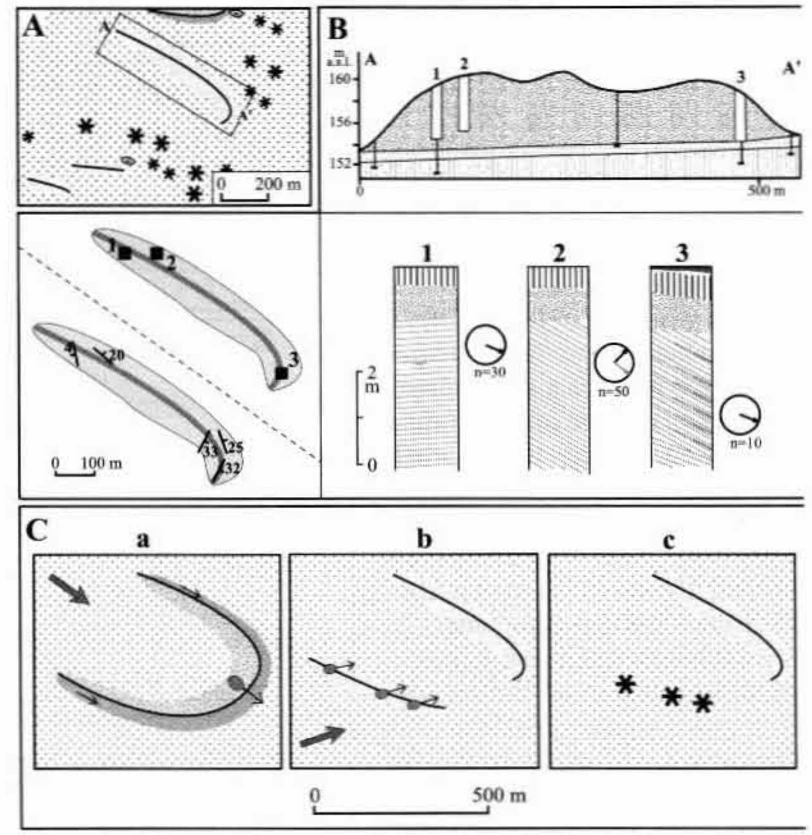

Fig. 4. Solec Site
A – Geomorphological sketch of the research site, B – geologic structure, C – stages of dune development. Other explanations as in Fig. 2

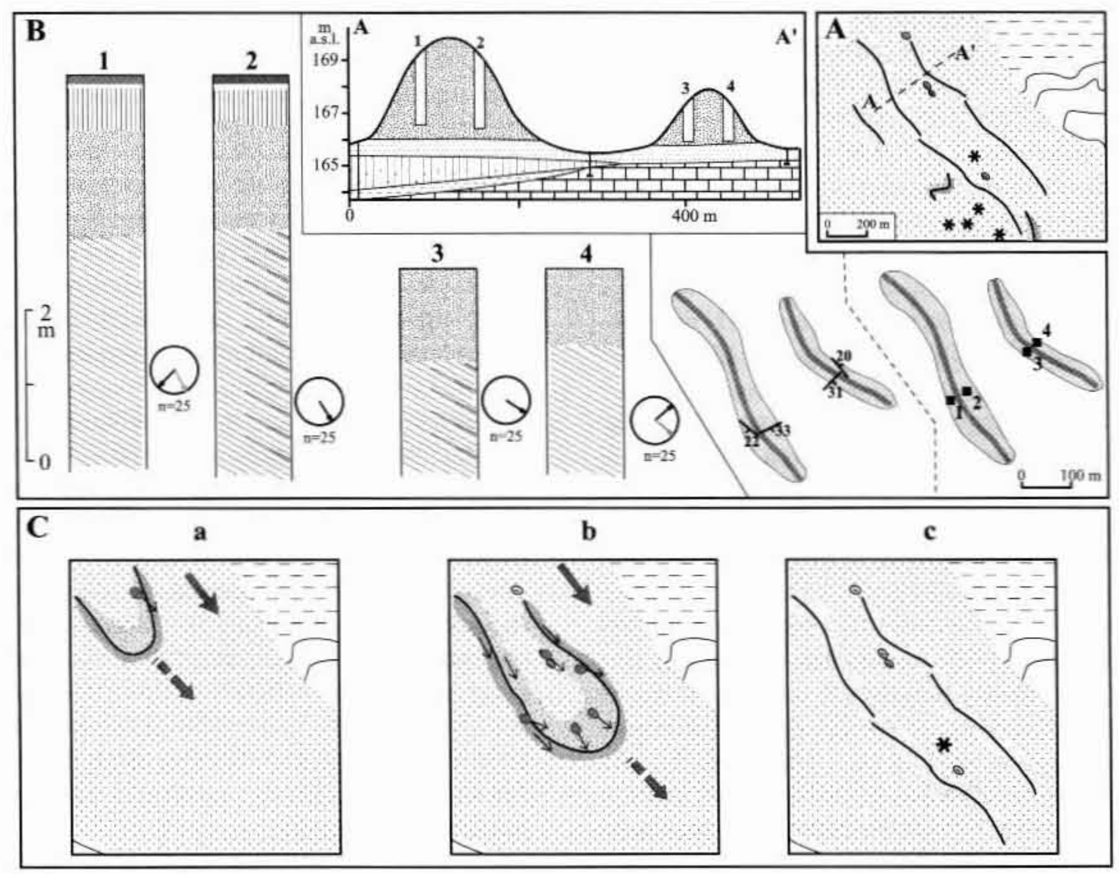

Fig. 5. Kolonia Elżbieta Site
A – Geomorphological sketch of the research site, B – geologic structure, C – stages of dune development. Other explanations as in Fig. 2

underlain by weathered Cretaceous rocks which are covered by a thin series of sandy and sandy-silty rhythmites (Fig. 6B). The dune consists of two sand series, separated by an erosion surface; the lower series has a sandflow cone structure, and upper one – tabular structure.

The structure of the sandflow cones which occur in the lower series is typical of a distal slope, and gives evidence of a migrating dune front. Owing to the small number of exposures, it is difficult to find if this represents front of a parabolic dune or of a transversal one. However, on the basis of structural direction components, it is concluded that these deposits were deposited in a SE direction. If it was a transversal dune, this direction would evidence of NW dune-forming winds. The determination of the wind direction would be more complicated if the lower series displayed a parabolic dune development. However, Kozarski (1962) considered that dip of beds in the highest (frontal) part of distal slope of a parabolic dune follows wind direction. Accordingly, if it is recognized that the structures building the lower series (i.e. structures of sandflow cones) occur only in the front part of a parabolic dune (as was indirectly suggested by Borówka, 1979, 1980), the orientation of these structures may also be indicative of a NW wind-flow during the construction of this series (Fig. 6C).

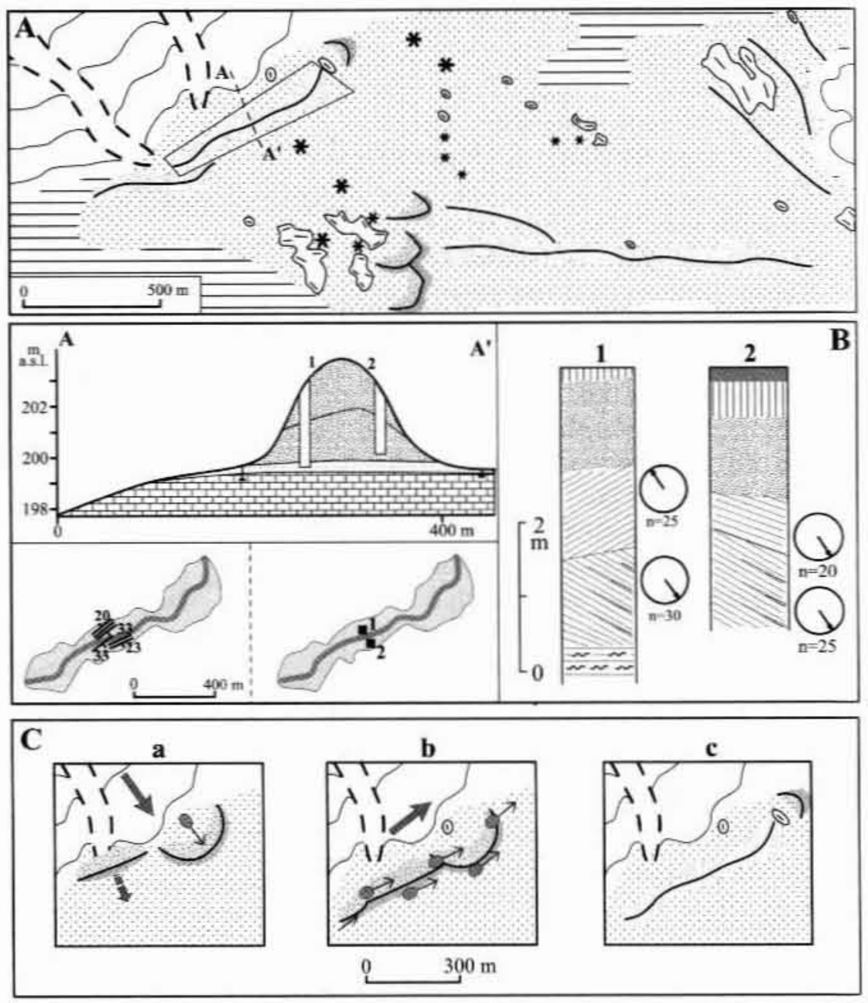

Fig. 6. Góry Opolskie Site
A – Geomorphological sketch of the research site, B – geologic structure, C – stages of dune development. Other explanations as in Fig. 2

The tabular structure representing the younger series was found on both slopes of the longitudinal dune. This seems to indicate a shift of dune-forming winds from the NW to the WSW. The erosion surface which separates the two series provides evidence of deflation processes which preceded accumulation of the longitudinal dune. Therefore, as a result of a wind shift, this dune was formed by the conversion of a transversal dune or a set of parabolic dunes. Of these alternatives, the second is supported by the morphological features, i.e. the irregular pattern of its crest, which resembles parts of parabolic dunes in some sections.

Zgoda. This WNW-ESE dune is situated on the scarp of a loess patch (Fig. 7). It is underlain by the sandy-silty cover which occurs on the loess deluvia. These deposits are transected by fossil, trough-like, small valleys. This dune consists of two series (Fig. 7B): a lower series with sandflow cone structure, and an upper with tabular structure on the slopes and with cross-wedge stratification in the crest zone.

The lower series may reflect the movement of a small parabolic dune (Fig. 7C). Its structural direction components suggest that the dune-forming west-north-westerlies were. The accumulation of this series could have left a row of deflation remnants which conditioned the development of the second series bearing the tabular structure on its slopes and cross-wedge stratification in the crest zone, i.e. typical of longitudinal dunes occurring in desert and semi-desert regions (Bagnold, 1954; McKee & Tibitts, 1964; Tsoar, 1982). These features and the structural direction components suggest that this dune was formed by two-directional shifting winds blowing from the WSW-NW sector. The erosional contact between the two series building this form seems to exclude

the possibility of its formation by transformation of a parabolic dune. Therefore, it is probable that this form was originally formed as a longitudinal dune.

Discussion and conclusions

1. In respect of origin, longitudinal dunes can be divided into primary forms which developed initially as longitudinal forms, and secondary forms which represent conversions from other dune types.

2. In respect of formation time, longitudinal dunes can be divided into simple types which were formed during one phase, and complex ones which were formed during repetitive dune-forming phases.

3. The development of longitudinal dunes is closely dependent on the co-operation of three factors (Hack, 1941). However, later studies indicate that these forms can also originate when sand supply is great and, most importantly, the winds are bi-directional within a narrow sector (Bagnold, 1954; Brookfiled, 1970; Fryberger, 1979; Lancaster, 1980; Tsoar, 1983, 1984). To summarize, the formation of longitudinal dunes depends on:

- the regime of dune-forming winds, i.e. their velocity and direction changes;
- relief and other features of land surface, i.e. the presence of obstructions, wet ground, and the obstacles which influence wind direction, and the direction of sediment deposition;
- the amount and availability of sand in alimentation areas or occurrence of non-longitudinal dunes which can be transformed into longitudinal types.

4. On the basis of the data presented in this study three development models of longitudinal dunes in the western part of the Lublin Upland (Fig. 8) may be assumed:

- In the first model (Fig. 8, I), the longitudinal dunes are formed by unidirectional, rather strong winds which remove the central parts of parabolic dunes, especially when sand supply is small, and vegetation fixes the rising forms, i.e. in the manner proposed by Hack (1941), Galon (1958), Verstappen & Delft (1968), and Wojtanowicz (1969). The common conversion of only one parabolic dune arm into a longitudinal dune may be explained by the deflation of the second arm after a change of wind direction.
- In the second model (Fig. 8, II), the longitudinal dunes develop after a change of wind direction through 90°. They represent conversions from a single parabolic or transversal dune, or a set of parabolic dunes earlier-formed usually against or on top of an obstruction. This model is somewhat similar to that proposed by Tsoar (1984) though there are significant differences: the change of wind direction occurs

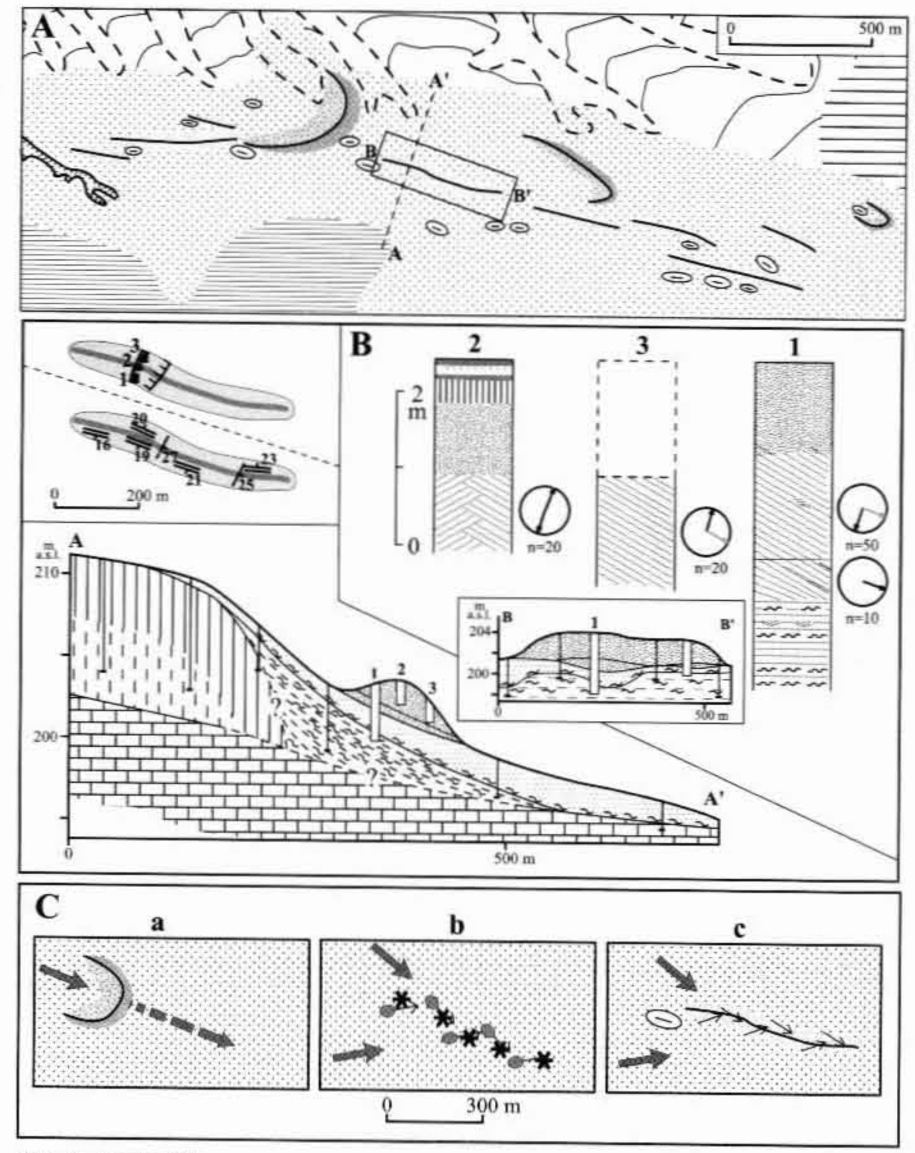

Fig. 7. Zgoda Site
A – Geomorphological sketch of the research site, B – geologic structure, C – stages of dune development. Other explanations as in Fig. 2

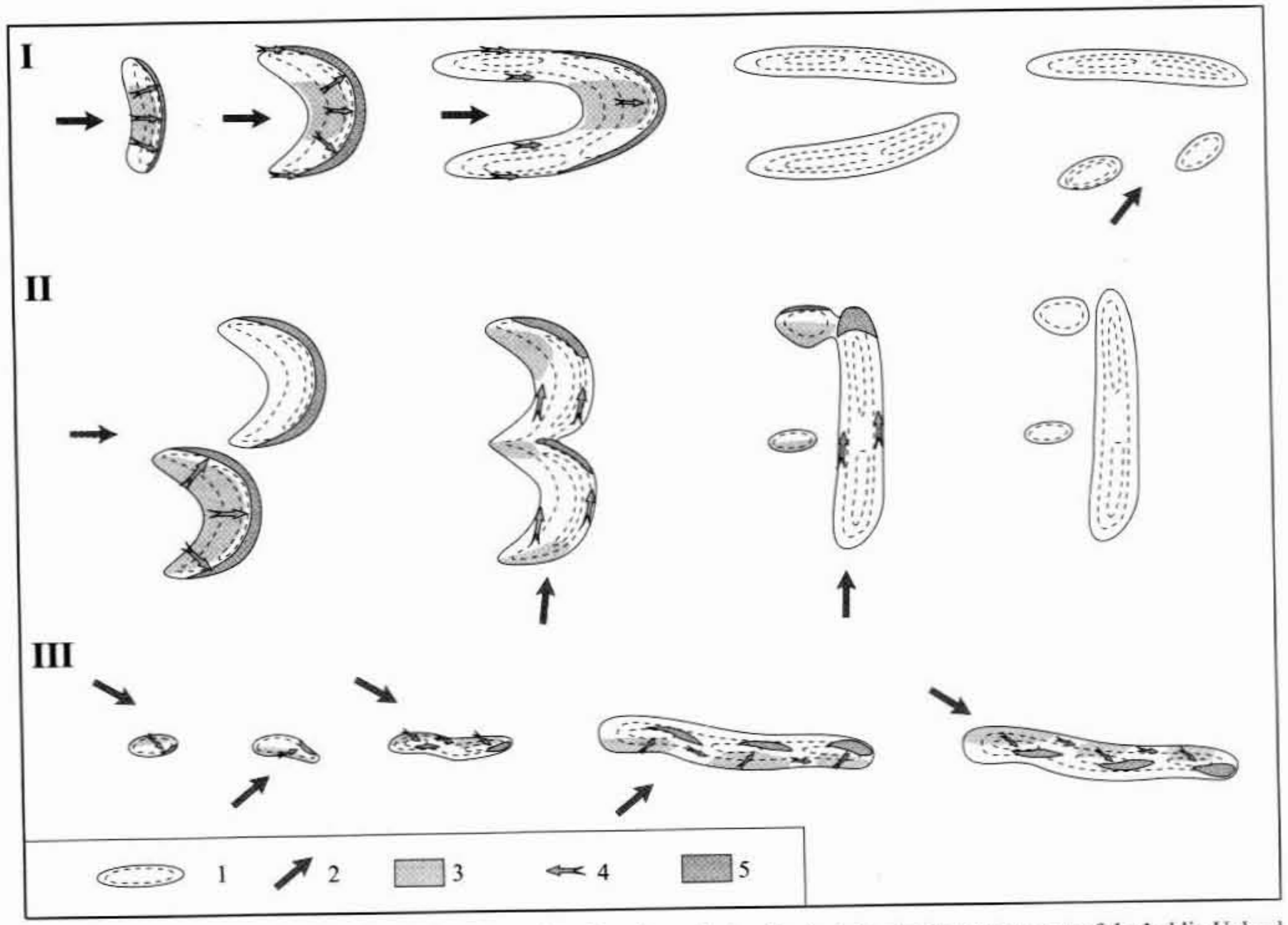

Fig. 8. Development models of the longitudinal dunes based on the analysis of typical sites in the western part of the Lublin Upland
1 – eolian forms, 2 – dominant direction of dune-forming winds, 3 – surfaces submitted to deflation, 4 – directions of sand transport on dunes, 5 – areas of sand deposition

only once, the longitudinal dune originates in the place of a previous form, and a smaller volume of sand is added on the lee flank, in the windflow direction.

- In the third model (Fig. 8, III), the longitudinal dunes are primary forms originating on obstructions, when eolian material is transported by bi-directional winds from a narrow (up to 90°) sector, i.e. in the aerodynamic conditions described by Bagnold (1954), Fryberger (1979), Lancaster (1980), Tsoar (1983, 1984).

5. Preliminary studies of some forms suggest that two additional development models of longitudinal dunes may be considered (Fig. 9):

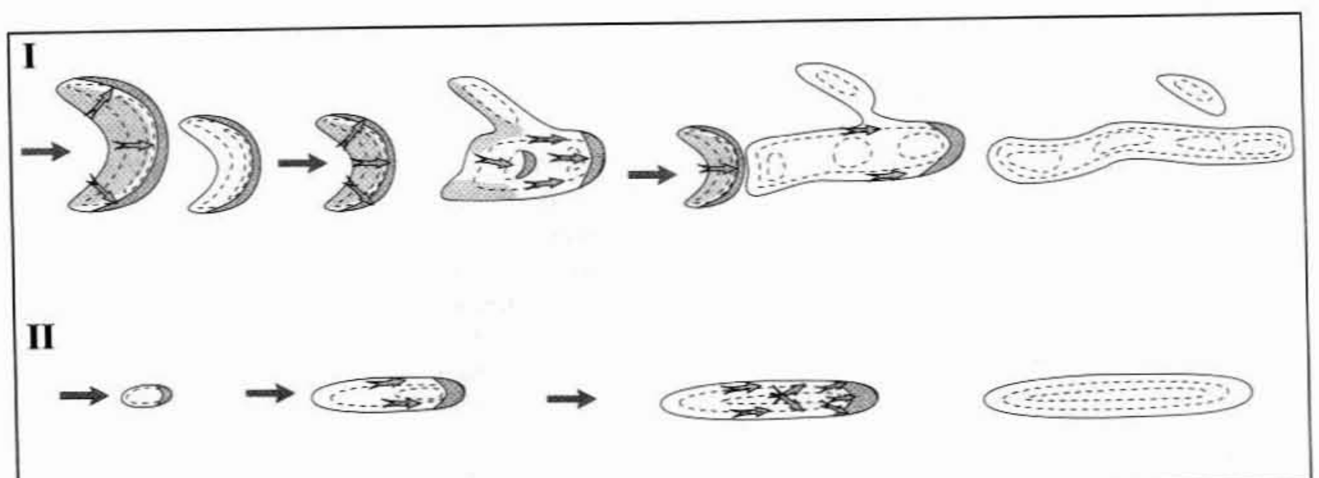

Fig. 9. Development models of the longitudinal dunes based on the preliminary investigations. Other explanations as in Fig. 8

a) dunes of complex structure (Fig. 9, I) originate through the addition of successive parabolic forms, when the wind direction is stable;

b) longitudinal dunes are primary forms (Fig. 9, II), and material is deposited in the manner described by Bagnold (1954, p. 193). In that case, the direction of dune-forming winds and the mode of sediment accumulation was controlled by land configurations.

However, these models have yet to be tested fully and further, more detailed investigations are desirable.

References

Bagnold, R.A., 1954: *The physics of blown sand and desert dunes*. Methuen, London: 265 pp.

Borówka, K.R., 1979: Accumulation and redeposition of eolian sands on the lee slope of dunes and their influence on formation of sedimentary structures. *Quaestiones Geographicae* 5: 5–22.

Borówka, K.R., 1980: Współczesne procesy transportu i sedymentacji piasków eolicznych oraz ich uwarunkowania i skutki na obszarze wydm nadmorskich. *Prace Komisji Geograficzno-Geologicznej* 20: 126 pp.

Brookfield, M., 1970: Dunes trends and wind regime in Central Australia. *Zeitschrift für Geomorphologie*, Suppl-Bd. 10: 121–153.

Dylikowa, A., 1969: Problematyka wydm śródlądowych w świetle badań strukturalnych. *In:* R. Galon *(Ed.) Procesy i formy wydmowe w Polsce*. PWN, Warszawa: 39–74.

Fryberger, S.G., 1979: Dune forms and dune regime. *In:* E.D. McKee *(Ed.) A Study of Global Sand Seas*, United States Geological Survey, Professional Paper 1052: 137–169.

Galon, R., 1958: Z problematyki wydm śródlądowych w Polsce. *In:* R. Galon *(Ed.) Wydmy śródlądowe Polski*. PWN, Warszawa: 13–31.

Goździk, J., 1998: Struktury sedymentacyjne w eolicznych piaskach pokrywowych w Polsce. *In:* E. Mycielska-Dowgiałło *(Ed.) Struktury sedymentacyjne i postsedymentacyjne w osadach czwartorzędowych i ich wartość interpretacyjna*. UW, Warszawa: 167–191.

Hack, J.T., 1941: Dunes of the Western Navajo Country. *Geographical Review* 31: 240–263.

Hunter, R.E., 1977: Basic types of stratification in small eolian dunes. *Sedimentology* 24, 3: 366–387.

Izmaiłow, B., 1998: Struktury sedymentacyjne piasków wydmowych. *In:* E. Mycielska-Dowgiałło *(Ed.) Struktury sedymentacyjne i postsedymentacyjne w osadach czwartorzędowych i ich wartość interpretacyjna*. UW, Warszawa: 153–166.

Kozarski, S., 1962: Wydmy w Pradolinie Noteci koło Czarnkowa. *Badania Fizjograficzne nad Polską Zachodnią*, IX, Poznań: 37–60.

Lancaster, N., 1980: The formation of seif dunes from barchans – supporting evidence for Bagnold's model from the Namib Desert. *Zeitschrift für Geomorphologie N.F.* 24, 2: 160–167.

McKee, E.D. & Tibbits, G.C., 1964: Primary structures of a seif dune and associated deposits in Libya. *J. Sedim. Petrol.* 34: 5–17.

Nowaczyk, B., 1976: Geneza i rozwój wydm śródlądowych w zachodniej części pradoliny warszawsko-berlińskiej w świetle badań struktury, uziarnienia i stratygrafii budujących je osadów. *Prace Komisji Geograficzno-Geologicznej* 16: 108 pp.

Pye, K. & Tsoar, H., 1990: *Aeolian sands and dunes*. The Academic division of Unwin Hyman Ltd., London.

Rotnicki, K., 1970: Główne problemy wydm śródlądowych w Polsce w świetle badań wydmy w Węglewicach. *Prace Komisji Geograficzno-Geologicznej* 11, 2, PTPN: 146 pp.

Stankowski, W., 1963: Rzeźba eoliczna Polski północno-zachodniej na podstawie wybranych obszarów. *Prace Komisji Geograficzno-Geologicznej* 6, 1, PTPN: 146 pp.

Tsoar, H., 1982: Internal structure and surface geometry of longitudinal (seif) dunes. *Journal of Sedimentary Petrology* 52: 823-831.

Tsoar, H., 1983: Dynamic processes acting on longitudinal (seif) sand dune. *Sedimentology* 30, 4: 567–578.

Tsoar, H., 1984: The formation of seif dunes from barchans – a discussion. *Zeitschrift für Geomorphologie, N.F.* 28, 1: 99–103.

Verstappen, H.Th. & Delft, I.T.C., 1968: On the origin of longitudinal (seif) dunes. *Zeitschrift für Geomorphologie* 12, 2: 200–220.

Wojtanowicz, J., 1969: Typy genetyczne wydm Niziny Sandomierskiej. *Ann. UMCS*, B 24, 1: 1–45.