Geological Quarterly, Vol. 36, No 3, 1992, p. 361–374

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Eskers and kames of Hrubieszów Basin (Lublin Upland)

The relief, geological structure and lithological features of esker and kame as well as stages in their development were characterized. Subglacial eskers form erosion channel filled with fluvioglacial sediments. Kame developed in the open crevasse between dead ice blocks. The age of studied forms was documented by the thermoluminescence dating (TL) as San Glaciation (SII).

INTRODUCTION

In the course of the cartographic studies for the *Detailed Geological Map of Poland* in the scale 1:50 000, Komarów sheet, the presence of sand-gravel and sandy fluvioglacial sediments was observed. These sediments are preserved on eastern slope of the watershed between Łabuńka and Huczwa drainage basins (Fig. 1), filling the narrow and winding channel cut in Cretaceous rocks. They form the narrow hump on the surface, 5 km long and a few meters high, extending meridionally from the parallel valley near Cześniki to the northern edge of Grzęda Sokalska near Komarów (Fig. 2). Fluvioglacial sediments appear also at the sites of intersection of parallel valleys with erosion channel, forming flat accumulation sheets.

The studied sediments represent deposits of areal deglaciation, extending foremost toward the south-eastern part of the Lublin Upland. Similar sediments and forms are known from the Polichna region (J. Buraczyński, 1986; J. Buraczyński et al., 1982), Piaski region (M. Harasimiuk et al., 1984, 1988*a*) and Chełm region (J. Buraczyński, J. Wojtanowicz,1980/1981; J. Buraczyński, 1986).

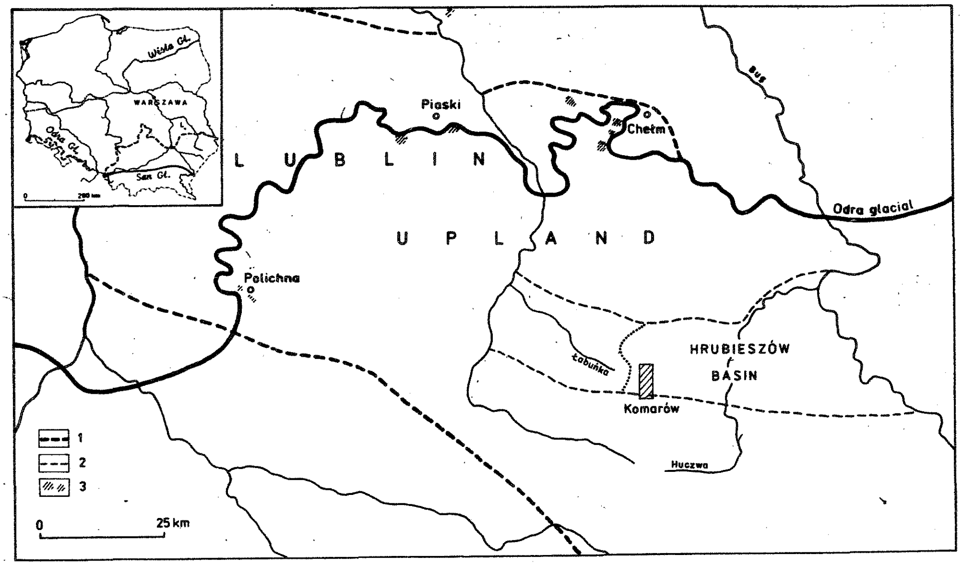


Fig. 1. Location sketch
1 — border of the Lublin Upland; 2 — border of the Hrubieszów Basin; 3 — kames
Szkic lokalizacyjny
1 — granica Wyżyny Lubelskiej; 2 — granica Kotliny Hrubieszowskiej; 3 — kemy

LITHOLOGY AND STRATIGRAPHY

Geological structure and lithology of fluvioglacial sediments was studied in three outcrops and several boreholes. They are best identified in the southern part near Ruszczyzna. Fluvioglacial sediments form narrow rampart on the plateau and hump slopes as well as flat sheets on the slopes of parallel valleys (Fig. 3). In the bedrock of rampart the coarse-grained sands with gravel of the local and Scandinavian rocks and the sand lenses in some places occur. These sediments fill the erosion channel (Figs 4, 5). The average size-grain (M_z) of the sand shows a great variation in the vertical profile where (M_z) values are in the range 0.54–1.55 (Fig. 6). Sorting of sediments is poor (σ_I = 1.41–1.65), especially in the series bedrock (σ_I = 2.11). The great variation in the petrographical contents of gravel and heavy minerals is observed in vertical profile (Fig. 7). The contents of Paleozoic limestones in the series bedrock is 46.2%, decreasing to 7.3% at the top. The contents of local rocks increases from 35.8% to 76.9%. As for heavy mineral contents in the series bedrock, biotite (34.4–35.5%) is prevalent over garnet (12.1–29.6%) and amphiboles (10.1–24.4%). Higher up garnet (33.0–35.7%) is dominating over tourmaline (16.9–19.9%) and amphiboles (13.9–14.7%). A quartz grain rounding (*Wo*) increases towards the top of series from 1204 to 1256.

The bottom layer is covered by two series of overlapping sediments. On the western side of the channel there are sands with silt interlayers, with mild, horizontal stratification. At the eastern slope blocks and gravels of local and northern rocks are clustered with marl weathering. Blocks and gravels are inserted into deep incisions in the lower sediment series. The dip of the sand strata entering block-gravel series reaches 80° what indicates an intensive slumping of material as a result of cessation of a support provided by ice block. The granulation of horizontally stratified sands changes towards the top. In the bedrock there is a coarse-grained sand with the admixture of medium- and fine-grained sand. In the middle part medium-grained sand dominates whereas at the top fine-grained sand is prevalent. The sand sorting is moderate (σ_1 = 0.78–1.00) and at the same time the best of all sediments in the profile. In the contents of heavy minerals garnet (44.5–47.2%) is prevalent over amphiboles (8.3–10.7%) and staurolite (5.3–8.3%). The quartz grain rounding indicates to decreasing dynamics of sand depositing waters. In the series bedrock quartz grains are better rounded (*Wo* = 1305) than at the top (*Wo*= 1210) because they were transported on greater distances.

In the block-gravel series (5.0–10.0 mm fraction) the local material (65.0%) is prevalent over Scandinavian one (35.0%). In the Scandinavian gravels Paleozoic limestones dominate over crystalline rocks (13.6%). The participation of sandstones and Paleozoic quartz is poor (1.9%) and quartz, dolomite and Paleozoic shale are absent.

The sandy and block-gravel series are cut in the bottom part of the slope by the fossil valley, filled with cross-bedded vari--grained sands with gravel, covered with debris of local rocks. Sands are poorly

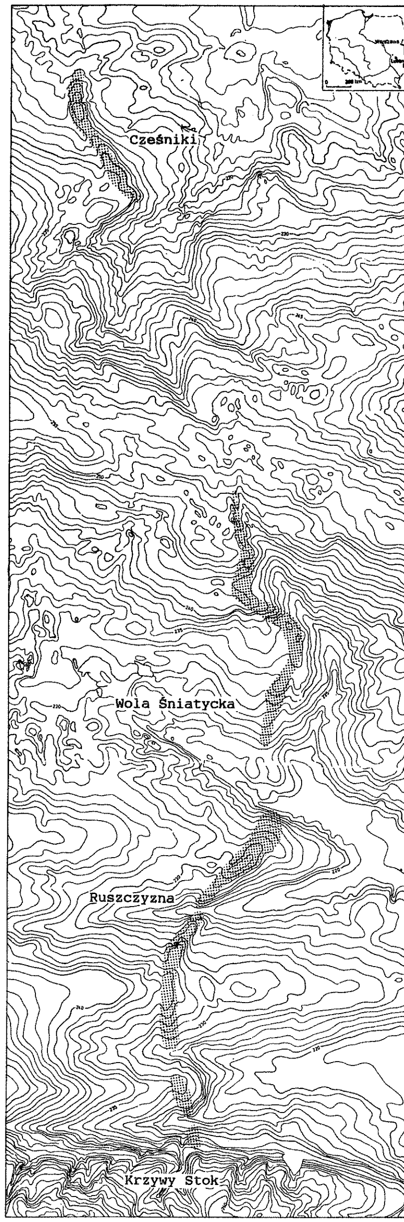
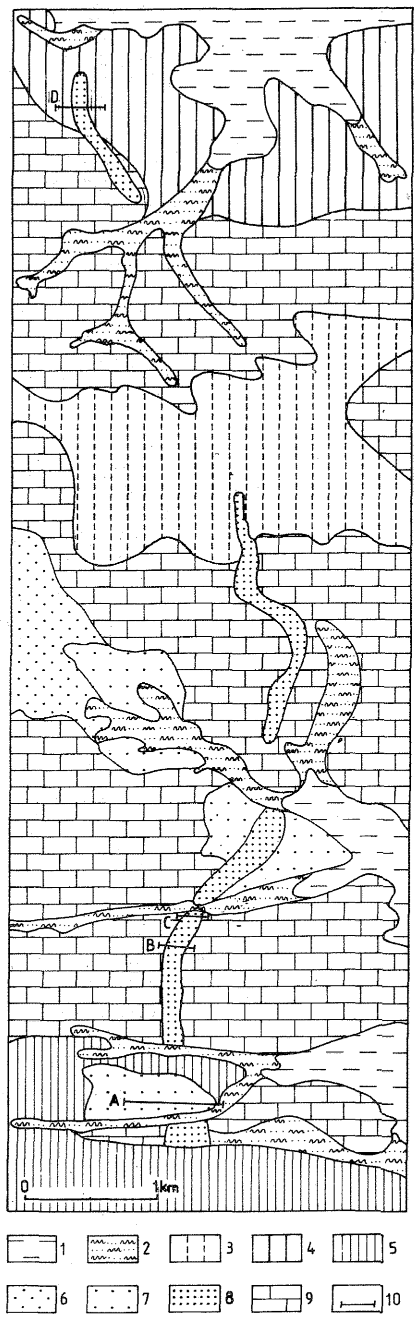


Fig. 2. Esker location of the relief background (contour lines at every 1.25 m)
Położenie ozu na tle rzeźby (poziomice co 1,25 m)



sorted (σ_I = 1.68), with equal admixture of fine and coarse fractions (Sk_I= 0.05). The contents of heavy minerals is similar to that of lower series, however the rounding of quartz grains is the poorest comparing to the whole profile (*Wo* = 1086).

The middle part of the rampart (Fig. 2) consists of two series: coarse-grained sands with gravel of local and northern rocks and covering them vari-grained sands. Block--gravel and debris series are absent.

The northern part of the sheet of fluvioglacial sediments near Cześniki (Fig. 8) forms a low and narrow rampart located above the erosion channel. It is built, except for block-gravel series, of the same sediments as in Ruszczyzna profile (Fig. 4). The channel is filled with vari-grained sands with gravel of local and Scandinavian rocks (65.4% and 34.6% respectively). Above them there is a layer of sand with a small admixture of gravel. The upper series consists of debris of local rocks with an admixture of sand and marl weathering as well as the gravel of northern rocks. In the lower series of sediments medium-grained sand with an admixture of coarse-grained sand is prevalent (Fig. 9). It is poorly sorted (σ_I = 1.68) indicating to changing dynamics of glacial waters. As for heavy minerals contents, the greatest amounts are observed for garnet (35.4%) and amphi-

Fig. 3. Geological sketch of Komarów environ

Holocene: 1 — alluvial deposits, 2 — deluvial deposits; Baltic Glaciation: 3 — silts on marls and opokas, 4 — loess up to 3 m thick, 5 — deep loess, 6 — eolian sands; San II Glaciation: 7 — kame sands, 8 — sands and gravels of esker; Upper Cretaceous: 9 — marls and opokas; 10 — lines of geological sections (A, B, C, D)

Szkic geologiczny okolic Komarowa

Holocen: 1 — aluwia, 2 — deluwia; zlodowacenie bałtyckie: 3 — glina pylasta na marglach i opokach, 4 — less o miąższości do 3 m, 5 — less głęboki, 6 — piaski eoliczne; zlodowacenie sanu II: 7 — piaski kemowe, 8 — piaski i żwiry ozu; kreda górna: 9 — margle i opoki; 10 — linie przekrojów geologicznych (A, B, C, D)

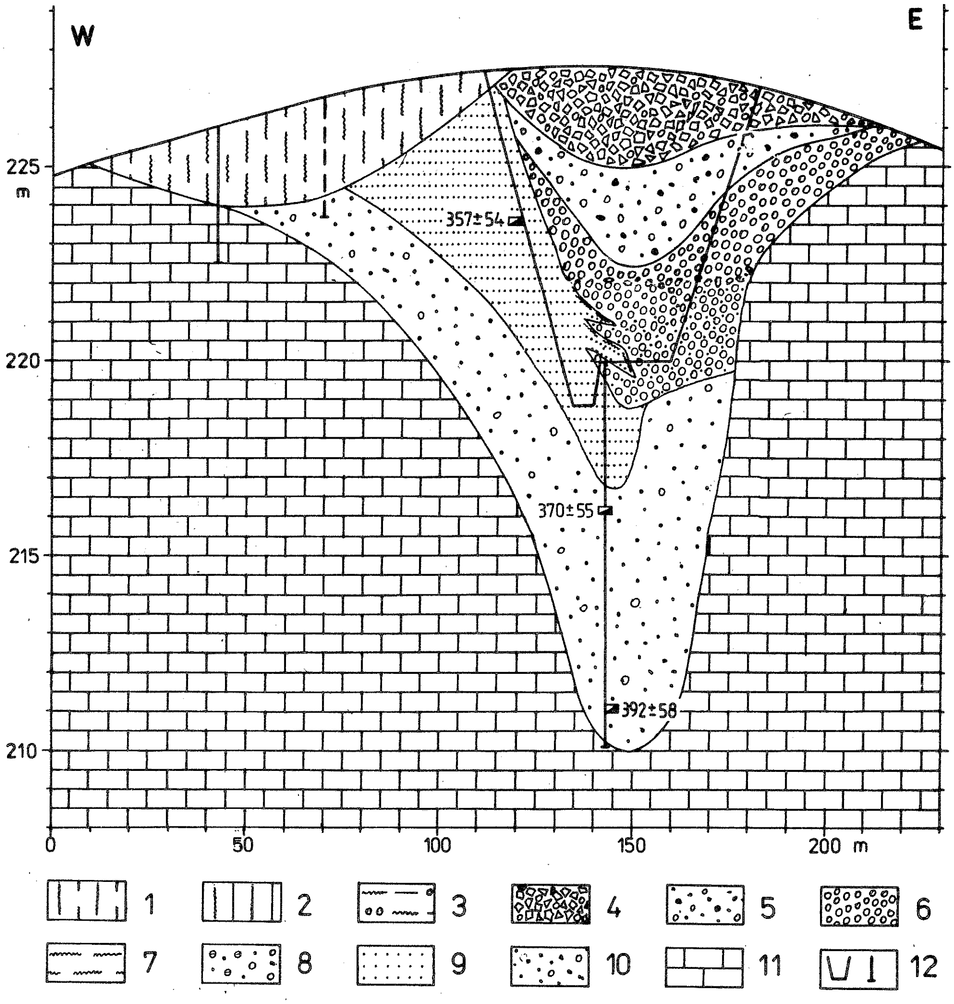


Fig. 4. Geological section C of esker in Ruszczyzna

Baltic Glaciation: 1 — loess, 2 — silt, 3 — deluvial deposits; San Glaciation: 4 — debris and gravel, 5 — sands with fine gravel, 6 — cobbles and gravels clustered with weathering, 7 — sandy silt, 8 — gravels and sands, 9 — horizontally stratified sands, 10 — coarse-grained sands with gravel; Upper Cretaceous: 11 — marls and opokas; 12 — outline of outcrops, boreholes

Przekrój geologiczny C przez oz w Ruszczyźnie

Zlodowacenie bałtyckie: 1 — less, 2 — glina pylasta, 3 — deluwia; zlodowacenie sanu: 4 — gruz i żwir, 5 — piaski z drobnym żwirem, 6 — głazy i żwiry zlepione zwietrzeliną, 7 — mułek piaszczysty, 8 — żwiry i piaski, 9 — piaski poziomo warstwowane, 10 — piaski gruboziarniste ze żwirem; kreda górna: 11 — margle i opoki; 12 — zarys odkrywki, otwory wiertnicze

boles (16.0%) originated from the Scandinavian rocks as well as tourmaline (15.7%) from Tertiary rocks. Prevalence of garnet points to the frequent rewashing of sedi-

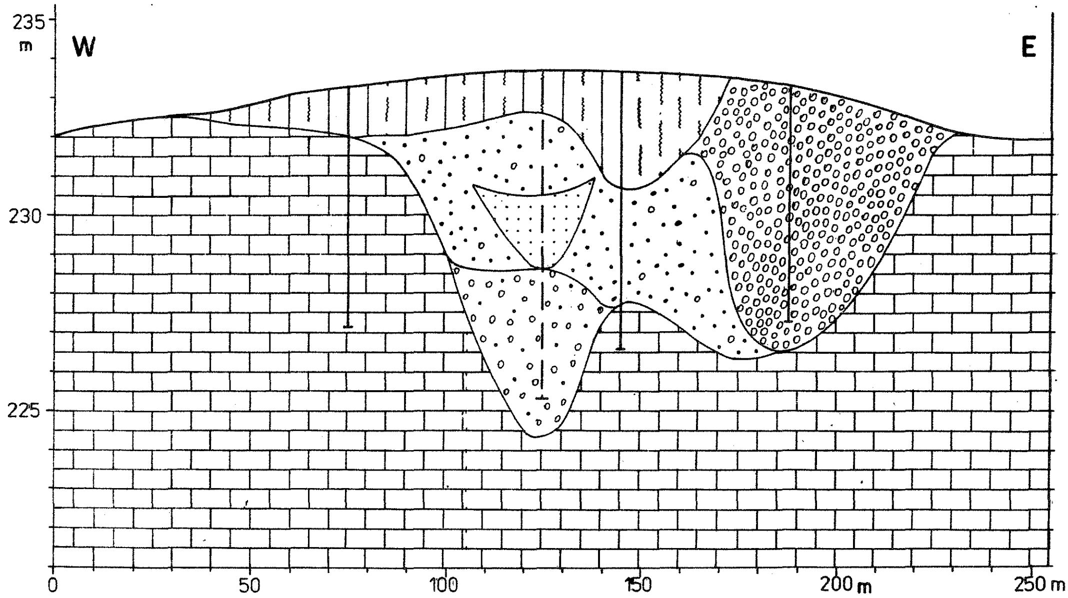
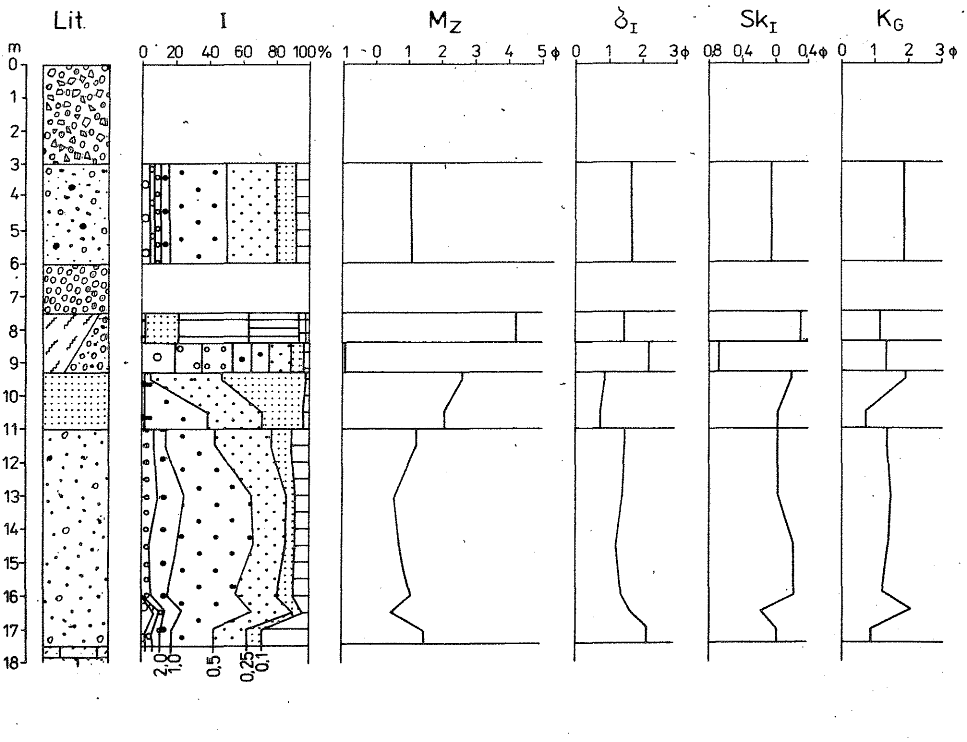


Fig. 5. Geological section B of esker in Ruszczyzna
Explanations — see Fig. 4
Przekrój geologiczny B przez oz w Ruszczyźnie
Objaśnienia jak dla fig. 4



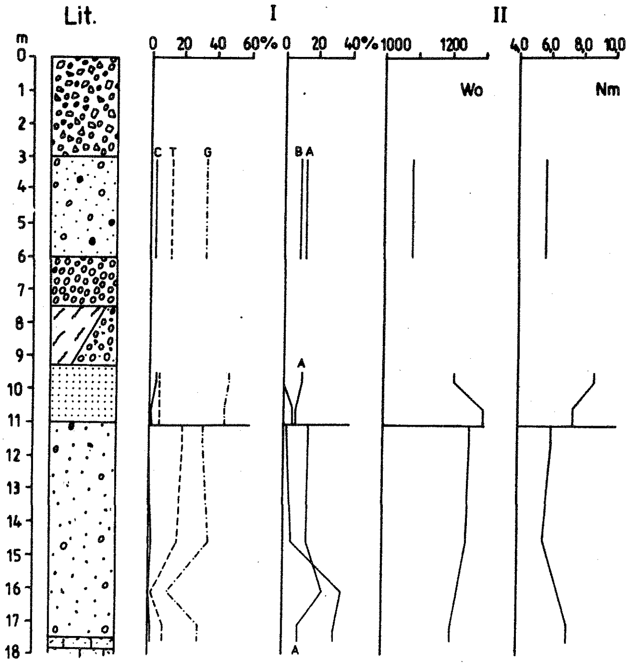


Fig. 7. Heavy minerals (I) and quartz grain rounding index (II) in profile C
C — zirkon; T — tourmaline; G — garnet; A — amphiboles; B — biotite; Wo — rounding index of quartz grains; Nm — nonhomogenous rounding of quartz grains

Minerały ciężkie (I) i wskaźniki obróbki ziarn kwarcu (II) w przekroju C
C — cyrkon; T — turmalin; G — granat; A — amfibole; B — biotyt; Wo — wskaźnik obróbki ziarn kwarcu; Nm — wskaźnik niejednorodności obróbki ziarn kwarcu

ments (E. Mycielska-Dowgiałło, 1980). The quartz grain rounding (0.5–0.8 mm) is the best of all fluvioglacial series (*Wo* = 1207) what indicates to a great and variable dynamics of the glacial waters.

Fig. 6. Grain-size composition and parameters (I) in phi scale of esker sediments in section C
1 — debris; 2 — cobbles and gravels clustered with weathering; 3 — medium-grained sands with gravel; 4 — coarse-grained sands with gravel; 5 — sands with small admixture of gravel; 6 — silty sands with gravel; 7 — coarse-grained sands; 8 — horizontally stratified sands; 9 — structureless sands; 10 — silts; 11 — dusts; 12 — pavement; 13 — marls, opokas; M_z — mean diameter, σ_I — graphic standard deviation; Sk_I — graphic skewness; K_G — graphic kurtosis

Zawartość frakcji i wskaźniki uziarnienia (I) w skali phi osadów ozu w przekroju C
1 — gruz; 2 — głazy i żwiry zlepione zwietrzeliną; 3 — piaski średnioziarniste ze żwirem; 4 — piaski gruboziarniste ze żwirem; 5 — piaski z niewielką domieszką żwiru; 6 — piaski mułkowate ze żwirem; 7 — piaski gruboziarniste; 8 — piaski poziomo warstwowane; 9 — piaski bezstrukturalne; 10 — mułki; 11 — pyły; 12 — bruk; 13 — margle, opoki; M_z — średnie ziarno; σ_I — graficzne odchylenie standardowe; Sk_I — skośność graficzna; K_G — kurtoza graficzna

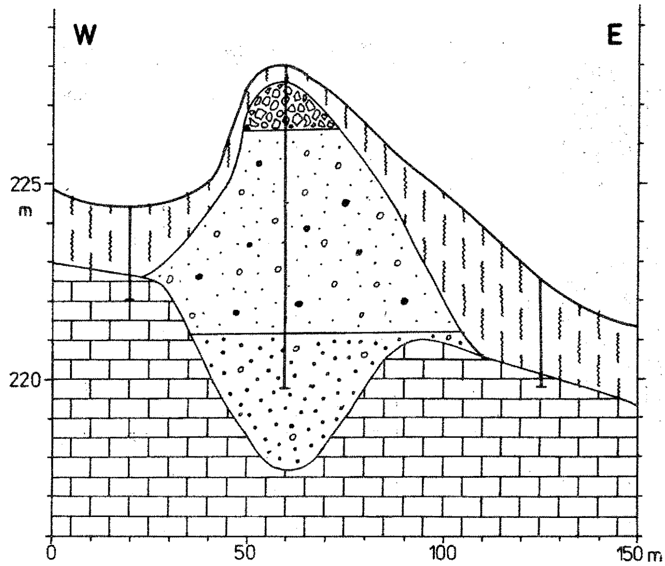


Fig. 8. Geological section D of esker in Cześniki
Explanations — see Fig. 4
Przekrój geologiczny D przez oz w Cześnikach
Objaśnienia jak na fig. 4

The granulation of sands with a slight admixture of gravel is similar to that of horizontally stratified sands in Ruszczyzna profile. The amount of fine-grained sands increases towards the top of the series with simultaneous decrease in the amount of coarse-grained sands. This indicates to decrease in the transporting power of water.

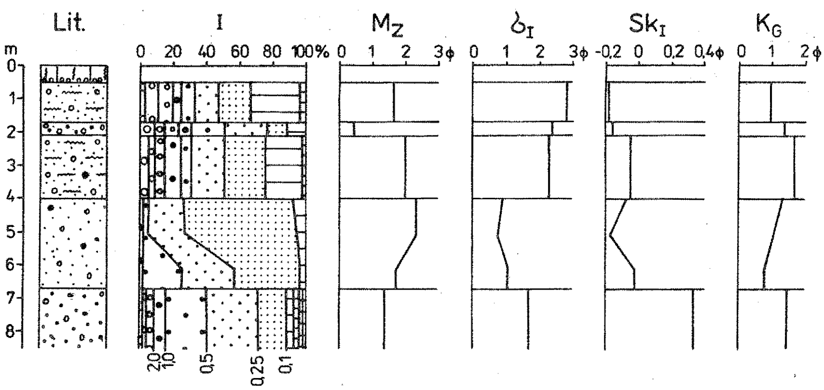


Fig. 9. Grain-size composition and parameters (I) in phi scale of esker sediments in section D
Explanations — see Fig. 6
Zawartość frakcji i wskaźniki uziarnienia (I) w skali phi osadów ozu w przekroju D
Objaśnienia jak na fig. 6

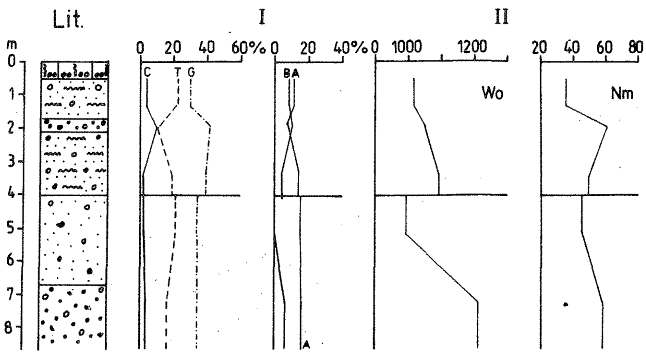


Fig. 10. Heavy minerals (I) and quartz grain rounding index (II) in profile D
Explanations — see Fig. 7
Minerały ciężkie (I) i wskaźniki obróbki ziarn kwarcu (II) w profilu D
Objaśnienia jak na fig. 7

This is confirmed by the rounding of quartz grains which in the top is the poorest of the whole profile (Fig. 10). The upper series consists of poorly sorted, vari-grained sands with considerable admixture of debris, gravel and silt. The contents of heavy minerals is similar to that of the lower series. Quartz grains are better rounded than in the middle series, but worse than in the lower series.

At the sites where the channel crosses with the parallel valleys, wide sheets and sandy humps occur. Their lower series is formed of coarse-grained sands with gravels and the upper one of stratified sands (Figs 3, 11). As for granulation, heavy mineral contents and quartz grain rounding (Figs 12, 13), lower series is similar to the series of Cześniki and Ruszczyzna profiles. On the other hand, the upper series at its 4.5 m deep part is characterized by a distinct decrease of the quartz grain rounding and a great increase in the garnet contents (Fig. 13). This indicates to the change of alimentation direction.

GENESIS, STAGES OF DEVELOPMENT AND AGE OF SEDIMENTS

Localization and shape of erosion channel as well as of cutting it parallel valleys filled with fluvioglacial sediments classify these forms as subglacial eskers. This is also indicated by a great lithological variability of sediments (Z. Michalska, 1971). On the other hand, horizontally stratified sands with silt interlayers form crevasse kames what is confirmed by a great dip of the strata at the edge of the form. This indicates to the disturbances of the back-ground as a result of fast melting and retreat of the ice wall.

Geological and lithological analysis of esker and kame sediments indicates to variable conditions of development of these forms. The first step leading to formation of tunnel and crevasse forms was cutting channels in the Cretaceous rocks by the under-ice waters. At the time the front of ice-sheet reached the northern edge of Grzęda Sokalska. Subglacial waters were flowing down into the depression near the

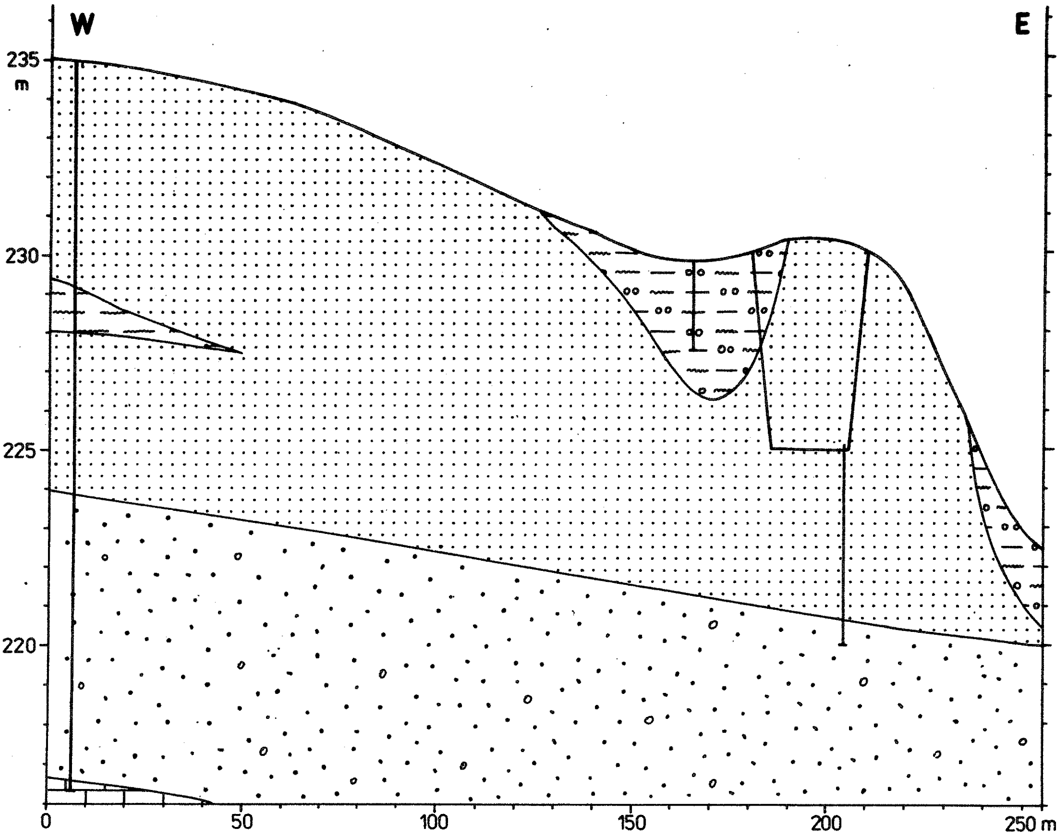


Fig. 11. Geological section A of kame in Krzywystok
Explanations — see Fig. 4
Przekrój geologiczny A przez kem w Krzywymstoku
Objaśnienia jak na fig. 4

ice-sheet edge through the system of meridional channels and parallel valleys. From there they flew towards east to the Huczwa Valley and further down towards the Bug Valley. The gravitational flow of subglacial waters is consistent with the interpretation of several researchers of eskers (I. Leiviskä, 1928; V. Tanner, 1934; P. Jaspersen, 1953; S. Skompski, 1963; T. Murawski, 1985).

The next step was filling up channels and valleys with sand-gravel fluvioglacial sediments. At the early step of a subglacial accumulation the water dynamics was variable. It is proved by a great differentiation of the granulation index and variable contents of heavy minerals and gravels. At the later phases of accumulation the water dynamics was balanced as a result of widening of the subglacial tunnels and transporting power was weaker. This is indicated by a small fluctuation of the granulation index and smaller sand grains. After depositing the lower series, waters began to erode the

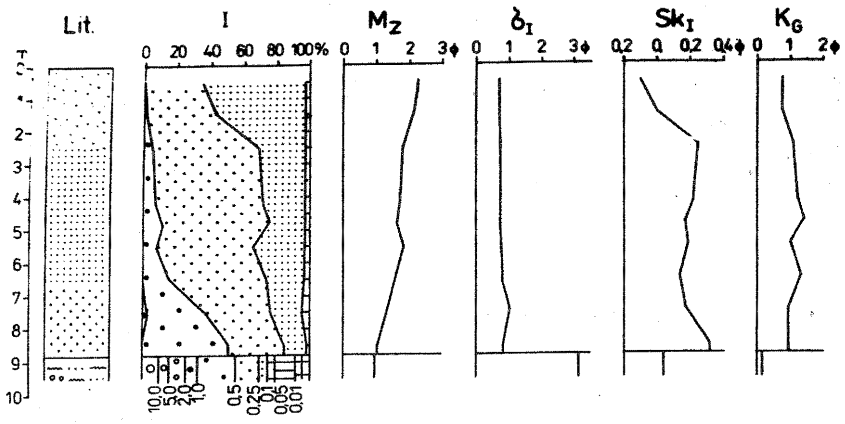


Fig. 12. Grain-size composition and parameters (I) in phi scale of kame sediments in section A
Explanations — see Fig. 6
Zawartość frakcji i wskaźniki uziarnienia (I) w skali phi osadów kemu w przekroju A
Objaśnienia jak na fig. 6

base, cutting at the edges of esker a few meters deep bed. The relation of esker forms to peri-esker and under-esker channels was observed by several researches (among them: R. Błachowski, 1936*a*, *b*; L. Roszkówna, 1951; K. Rotnicki, 1960; S. Skompski, 1963; S. Kozarski, 1966/1967; Z. Michalska, 1971; K. Brodzikowski, A.J. van Loon, 1987). The considerable width of the glacial tunnels was favourable for preservation of fluvioglacial sediments (S. Kozarski, 1966/1967).

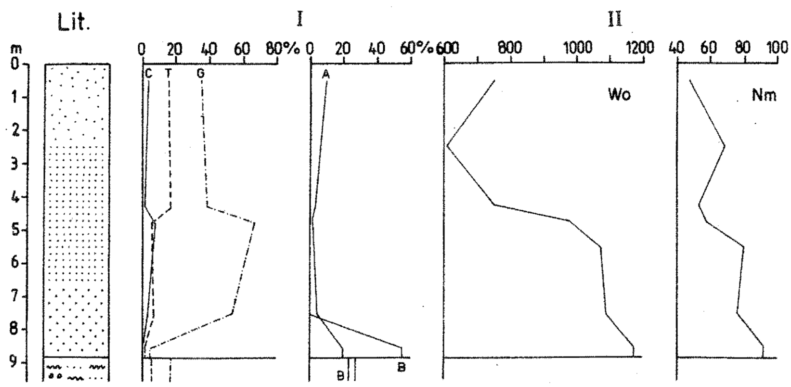


Fig. 13. Heavy minerals (I) and quartz grain rounding index (II) in profile A
Explanations — see Fig. 7
Minerały ciężkie (I) i wskaźniki obróbki ziarn kwarcu (II) w profilu A
Objaśnienia jak na fig. 7

The erosion phase was followed by a collapse of the parallel tunnel top and dividing the ice-sheet into the dead ice blocks. The crevasses were formed, wider at the sites of crossing with meridional tunnels, where the deposition of stratified sands and silts occurred. The crevasse became wider during the accumulation of kame sands what is indicated by the decreasing of sand grains toward the series top and better quartz grain rounding in the bedrock. Fast retreat of the crevasse walls at the outlet of the esker tunnel caused slumping of sands and kame silts as well as an interbedding with the material of the subglacial river. In the glacial tunnel the peripheral valley got covered with block-gravel material. The final step of deglaciation was a development of the ground moraine cover with a large amount of the local material.

The age of fluvioglacial sediments in Ruszczyzna profile was determined by the thermoluminescence method. Vari-grained sands of the lower series were dated at 392 ± 58 ka (Lub-2011) and 370±54 ka (Lub-2014) and the stratified sands of the upper series at 357±54 ka (Lub-2059). These ages are to be discussed yet because they indicate to Liwiec Glaciation (L. Lindner, 1991; M.D. Baraniecka, 1990). The sediments of the maximal range of this glaciation were found in the middle part of Polesie Lubelskie (L. Dolecki et al., 1987/1988). The range of the Odra Glaciation is located presently 40 kilometers to the north from the studied area (J. Buraczyński, 1986; L. Lindner et al., 1985; M. Harasimiuk et al., 1988*b*; M.D. Baraniecka, 1990). Therefore, the studied fluvioglacial sediments should be rather classified as the San II Glaciation, because only at that time the Hrubieszów Basin was entirely covered by the ice-sheet (Z. Janczyk-Kopikowa et al., 1980).

During younger glaciations the erosion was active mainly at the periphery of esker, cutting shallow valleys in the block-gravel series of esker and in kame sands. During the Baltic Glaciation the esker fragments and adjacent valleys were covered with loess.

CONCLUSIONS

1. The ice-sheet covering the western part of the Hrubieszów Basin underewent the areal deglaciation, creating forms and sediments in tunnel and crevasses. Presumably it was a process of wider range, involving the entire basin.

2. Subglacial eskers were shaped by two erosion stages and two accumulation stages.

3. In the studied area the types of the areal deglaciation forms are associated with the relief of the area — eskers formed on the slopes and hump, and kames in the valleys.

4. On the basis of geological analysis and TL dating it's assumed that eskers and kames of the western part of the Hrubieszów Basin developed during the San Glacia-

tion. However, further studies of Quaternary forms of the entire basin are needed, as well as comparative studies in neighbouring areas.

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Received: 10.05.1992

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OZY I KEMY KOTLINY HRUBIESZOWSKIEJ (WYŻYNA LUBELSKA)

Streszczenie

Na dziale wodnym Wieprza i Bugu stwierdzono występowanie ozów i kemów. Osady ozów leżą w wąskiej rynnie wyciętej w skałach kredowych, tworząc na powierzchni terenu południkowy wał 5 km długości i kilku metrów wysokości (Figs 1, 2). Osady kemowe występują w równoleżnikowych dolinach przecinających ozy. Ozy zbudowane są z dwóch serii: piasków gruboziarnistych ze żwirami oraz głazów i żwirów, charakteryzujących się dużą zmiennością wskaźników uziarnienia, składu minerałów ciężkich, obróbki ziarn kwarcu oraz składu petrograficznego żwirów. W kemach obserwuje się poziomo warstwowane piaski z przewarstwieniami mułków. W miejscach przecięcia się ozu z kemem utwory kemu leżą na dolnej serii ozu, a w części peryferyjnej kemu osady obu form zazębiają się (Figs 3–5). Cechy litologiczne piasków kemowych wskazują na malejącą dynamikę wód lodowcowych. Średnia średnica ziarn, wysortowanie osadu oraz obróbka ziarn kwarcu maleją ku stropowi (Figs 6–13).

Analiza geologiczna osadów ozów i kemów wskazuje na zmienne warunki ich rozwoju. Dwa etapy erozji przedzielały okresy akumulacji osadów. Pierwszą fazą rozwoju było wycięcie przez wody podlodowe rynny w skałach kredowych. Rynna została następnie wypełniona osadami wodnolodowcowymi. O zmiennej dynamice wód podlodowych świadczy duże zróżnicowanie wskaźników uziarnienia oraz zmienny skład minerałów ciężkich i żwirów. Po utworzeniu się dolnej serii ozu subglacjalnego czoło lądolodu podzieliło się na równoleżnikowe bryły stagnującego lodu. Wody podlodowcowe rozcięły wschodnie części ozu. Wcięcie to zostało następnie zasypane serią głazowo-żwirową. Jednocześnie z zasypywaniem rynny między bryłami stagnującego lodu akumulowane były piaski i mułki kemowe. Szybkie cofanie się ścian lodu powodowało obsuwanie się pakietów osadów kemowych oraz przeławicenie ich materiałem ozowym.

Osady badanego ozu datowano na 390 i 370 ka, a kemu na 357 ka. Daty te wskazują na zlodowacenie Liwca. Jednak bardziej poprawne jest zaliczenie ich do maksymalnego stadiału zlodowacenia sanu, gdyż Kotlina Hrubieszowska była objęta tym zlodowaceniem.