Landform Analysis, Vol. 6: 3-16 (2008)

The problem of the genesis and relief of glacial basins: the case of the Ugoszcz-Żałe area, the Dobrzyń Moraine Plateau

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Abstract: The Ugoszcz-Żałe glacial basin has a predisposition in the top of the Tertiary (a depression with a full stratigraphic profile of the Pleistocene). The greatest influence on the relief was exerted by Vistulian inland ice. It was formed as a result of the actions of basal ice-currents integrated into the composite icestream of inland ice. In the Leszno and Poznań phases, an intensive exaration of the substratum and its subglacial erosion (glacial and fluvioglacial) appear. At the time of the maximum extent of the Vistulian inland ice, glacial, fluvioglacial and polygenetic channels, as well as glacial basins and troughs and also glacial levels and core forms of many drumlins may have been formed. The next stage of the subglacial morphogenesis was the Kujawy-Dobrzyń sub-phase, characterised by the instability of the edge of the inland ice (ingressions with the nature of ice surges). They caused the transformation of the relief of the basin and its surroundings (moraine levels and drumlinised remodelling of the substratum, the thrust-accumulation of marginal forms and the final formation of the outline of the relief during the areal deglaciation of the area). The consequence of these morphogenetic phenomena is the complex relations of the forms occurring here.

Key words: glacial basin, subglacial trough, channels, glacial levels, drumlins

Introduction

The larger forms of subglacial erosion connected with channels are considerably wider glacial basins or glacial troughs. The concept of glacial basin was formulated by Goldthwait & Smith (1968, p.435) as a gentle, wide and elongated subglacial depression connected with glacial erosion of the substratum predisposed by its oriented structure and/or the direction of the movement of the ice.

The concepts of glacial trough, tongue trough and (exaration) end depression are, in the sense of morphogenesis, the shape of the form and the localisation in the young glacial area, synonyms. They are distinguished by the parabolic shape of their depressions and being surrounded by a lobed layout of end moraines. Glacial troughs are formed under a distinct lobe of inland ice (Nechay, 1927). With regard to glacial troughs (depressions) thus defined, the concept of glacial basin is not a synonym for them, despite the similarity of a large part of the processes of litho- and morphogenesis during their formation.

Glacial basins are forms of the erosion and deformation of substratum deposits and of the deformation and sedimentation of inland ice's own deposits and of its meltwaters. They appear in the area beyond the marginal zone and also immediately around glacial troughs. As a whole, basins appear in a subglacial environment as a result of the erosion and drumlinisation action of the active basal, composite icestream of inland ice. In the immediate vicinity of a plateau basin, the surrounding ground moraine is often ideally levelled (the western surroundings of the Zbójno glacial basin). Meanwhile, in the border area between the basin and the morainic plateau lying at a higher level, kame forms occur (Röuk, 1978; Olszewski, 1994; 1997; 2000; Olszewski & Słupski 2001). A certain confusion is caused by the use of the term "basin" with reference

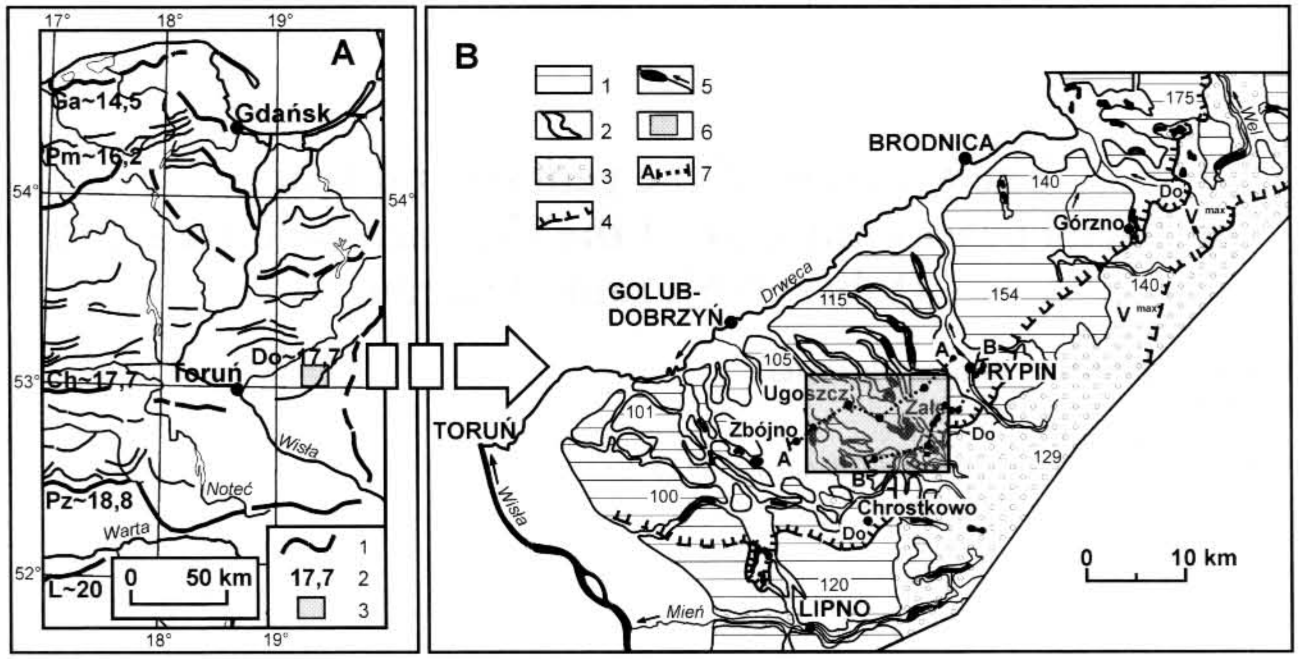

Fig. 1. Location of research area. A – Position against the background of the furthest extent of the last inland ice in central-northern Poland (after Kozarski, 1995). B – Position against the background of a geomorphological map of the Dobrzyń Moraine Plateau (after Niewiarowski & Wysota, 1995; modified).
A: 1 – main halt lines: Ga – Gardno phase, Pm – Pomeranian phase, Do – Dobrzyń subphase, Ch – Chodzież subphase, Pz – Poznań phase, L – Leszno phase, 2 – estimated age 14C in thous. years BP, 3 – research area. B: 1 – morainic plateau; 2 – subglacial channels; 3 – sandurs; 4 – halt lines of the Vistulian inland ice: V max – maximal extent of Vistulian inland ice, Do – Kujawy-Dobrzyń subphase; 5 – lakes and rivers; 6 – research area; 7 – geological cross-section lines (A and B).

to submarginal end depressions (troughs), e.g. "terminal basin" (Eng.), "Zungenbecken", including "Stamm-" and "Zweigbecken" (Germ.), "koncevoj bassejn" and "jazykovyj bassejn" (Russ.).

In some channels and subglacial plateau basins there occur groups of drumlins. Those on the Dobrzyń Moraine Plateau were first described by Nechay (1927) as the Zbójno drumlin field, and Liberacki (1961) identified the Ugoszcz drumlin field. Many theories on the subject of the genesis of drumlins stem from the complex internal structure and the linking of their genesis with one or several advances of inland ice. These problems remain unsolved ("Drumlins: The unsolved problem", Piotrowski & Wysota eds., 2001). What is important is to make a geological record of the older deposits and the fossil relief in order to define the predisposition of surface forms or its absence.

This article presents the newest results of research on the Ugoszcz-Żałe glacial basin (Chutkowski, 2002). They concern genetic references of the present relief to the formation of the older substratum and the spatial scope of these connections, a description and an evaluation of the systemic rank of convex subglacial forms and a morphological and structural description of drumlins.

Location of the research area

The Ugoszcz-Żałe glacial basin and its drumlin field lie in the central part of the Dobrzyń Moraine Plateau, to the NE of the Zbójno glacial basin (Fig. 1). It is situated in the immediate surroundings of the Sitnica lobe depression and the slightly further Chrostkowo-Nadróż end moraine of the Kujawy-Dobrzyń subphase (17.7 ka BP; Kozarski, 1995). These moraines in this part of the morainic plateau lie the closest to the line of the maximal extent of inland ice of the Vistulian glaciation, which caused great variety in the young-glacial relief and the deposits of this fragment of the Dobrzyń Moraine Plateau.

A review of the literature regarding the research area

The geology and glacial relief of the Dobrzyń Moraine Plateau are concerned by Nechay's paper (1927). He distinguished two ground moraine tills here: the upper yellowy-red one, belonging to the youngest glaciation, and the lower grey till. It follows from the Geological Map of Poland (scale 1:200,000), Brodnica sheet, edition A (Churski et al., 1978) and the explanations to it (Galon et al., 1979) that the area of the Ugoszcz-Żałe glacial basin is made up on the surface of sands, gravel and glacial boulders from the Poznań-Dobrzyń phase, while till only occurs within the surrounding upper morainic plateaux. Lamparski (1983; 1991) documents only the subterranean geological structure without commenting on the surface deposits. The newest research on the Ugoszcz-Żałe glacial basin and its close surroundings provides the basis for a newest take on many of the problems and knowledge about this area (Chutkowski, 2002).

Nechay (1927) was the first researcher of the channels and drumlins of the Dobrzyń Moraine Plateau, the creator of the concept of the morphogenetic role of ice-currents for the relief of this area, distinguishing as a consequence of their actions and of the outlet tongue of inland ice the Kików glacial trough.

The problem of subglacial channels was also studied by Niewiarowski (1988; 1995), Wysota (1993; 1994; 1995), Olszewski (1997; 2000; 2001a), Niewiarowski et al., (1995) and Chutkowski (2002). The element linking forms of various sizes – drumlins, channels and subglacial basins – is tilly glacial level: flat (without drumlins) and varied (drumlinised). The genesis of drumlins and moraine levels was studied by Jewtuchowicz (1956), Niewiarowski (1995), Liberacki (1961), Lamparski (1972), Wysota (1993; 1994; 2001a, b), Olszewski (1994; 1997; 2001a, b) and Chutkowski (2002).

Basalykas (1969) identified two groups of drumlins: regenerated inside-glacier onces, from drumlinised sandy-gravely kames, and the more numerous drumlins, "made of ground moraine and found in glaciodepressions" (p. 110). Ebers (1977) writes that "classic" ground moraine drumlins and drumlinoids (genetically and structurally composite)

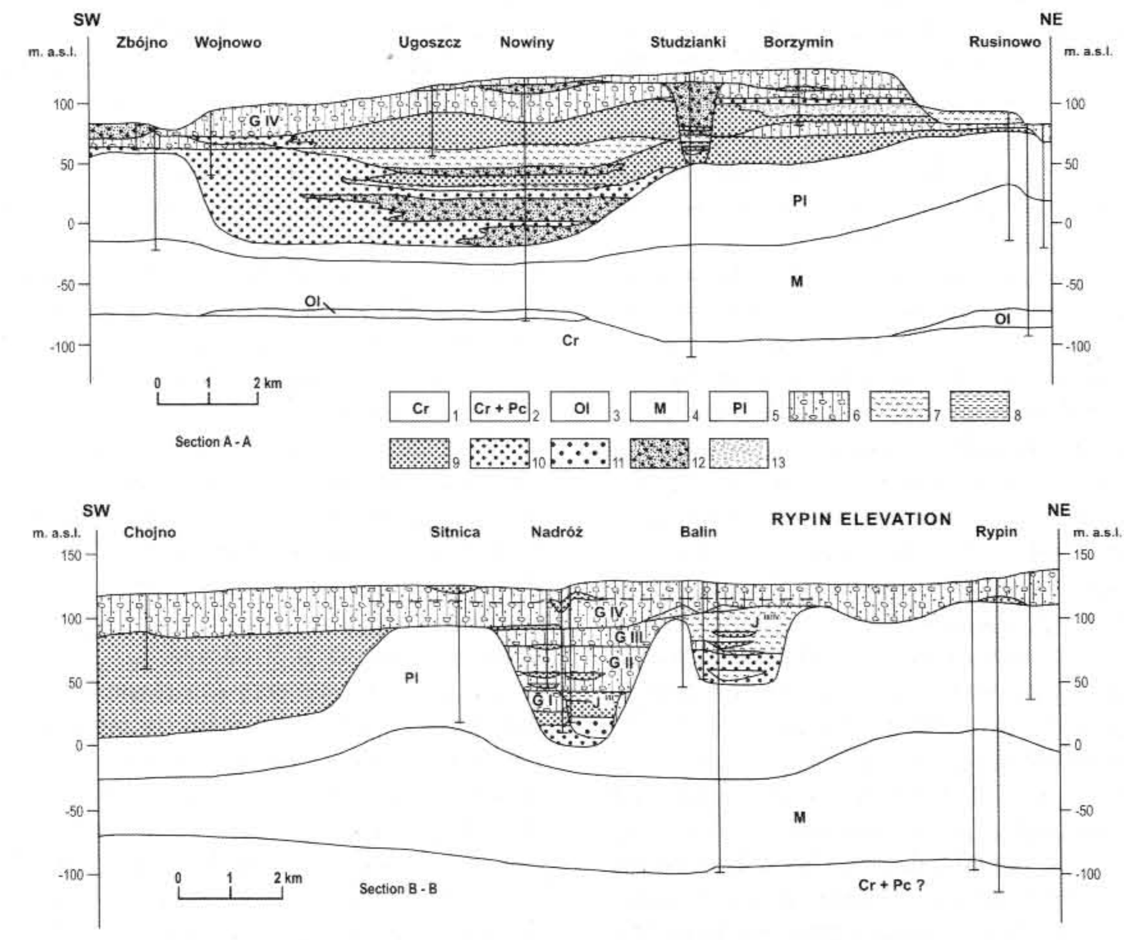

Fig. 2. Geological cross-sections: A and B after Lamparski (1983).
1 – Cretaceous, 2 – Cretaceous in places with Paleocene, 3 – Oligocene, 4 – Miocene, 5 – Pliocene; Pleistocene deposits: 6 – till, 7 – silt, 8 – clay, 9 – varved clay, 10 – fine-grained sand, 11 – medium-grained sand, 12 – coarse-grained sand, 13 – vari-grained sand, 14 – gravel, GI – Podlasie glaciation (Günz), JI/II – Przasnysz interglacial (Günz/Mindel), GII – Cracow interglacial (Mindel), JII/III – great interglacial (Mindel/Riss), GIII – Middle Poland glaciation (Riss), JIII/IV – Eem interglacial (Riss/Würm), GIV – Baltic glaciation; nomenclature after Różycki (1972).

are differentiated by their geological structure. In the rich literature, attention has been paid: to the location of drumlins; their formation and the role of subglacial deformations; the varied facies of the surfacial till cover of drumlins; the significant role of the thermal regime in the drumlinisation of the inland ice substratum; the coexistence of drumlins and kames (Baranowski, 1977; Röuk, 1978; Zakrzewska-Borowiecka & Erickson, 1985; Boulton, 1987; Menzies, 1987; Rose, 1987; Olszewski, 2001a, b).

The geological structure of the Ugoszcz-Żałe glacial basin and its surroundings

In the formation of the Quaternary substratum of the Dobrzyń Moraine Plateau, apart from deep depressions: Mochowo and Lidzbark Welski, and elevations: Rypin and Płock, there also occur smaller depressions and elevations (Lamparski, 1983; 1991). The changes of level of the substratum vary from 104 m u.s.l. (Lidzbark Welski) to about 117 m a.s.l. in Rypin (Galon et al., 1979). The depressions and elevations are oriented NW-SE, repeated by or similar to that of the majority of channels and basins.

The research area lies in the zone of subordinate fossil depression. It extends on the Golub-Dobrzyń - Ugoszcz line and lies on the axis of the Mochowo depression. These two depressions are separated by a flat platform of Pliocene deposits (0 m a.s.l.), descending steeply into the bed of the Mochowo depression. This subordinate depression, about 10 km in width, begins with a distinct edge. Its bed reaches a depth of 22 m u.s.l. (Chutkowski, 2002). The Mochowo depression is filled with a 200-metre thickness of the complex of Quaternary deposits, mainly tills with Tertiary floes. The research territory and the Mochowo depression are bounded to the north-east by the Rypin elevation, with sqeezed and greatly thrust deposits of the nearby depressions (Lamparski, 1983; 1991).

In the region of Lake Kleszczyn (Studzianki - Borzymin profile), documentation has been carried out on the buried valley or channel giving the Kleszczyn-Żałe channels and those of Lakes Ostrowite and Głęboczek their morphogenetic predisposition (Churski et al., 1978). On the site of the area under discussion, there exist not only depressions of the Quaternary substratum (Fig. 2, profile A) but also depressions among Pleistocene deposits, recurring at least since the Middle Poland glaciation. Apart from that, in the south-eastern part of the Ugoszcz-Żałe basin, in the Nadróż region, is the beginning of a narrow but deep depression continuing in the direction of the Mochowo depression. This subordinate depression adjoins the Rypin elevation on the east and the small but high Sitnica elevation on the west (suggestions for the name - Chutkowski, 2002) with an absolute height reaching about 90 m a.s.l. (Fig. 2, B).

We claim that the territory of this deep depression became the site for the permanent formation of glacier lobes during subsequent glaciations, with the exception of the Vistulian, which should be clearly emphasized. Its legacy is moraine tills totally filling the fossil depression, narrow and not pronounced in the present relief, of the depression of Nadróż (Fig. 2, B). The top of the Tertiary in this depression is located at sea level and descends in the south-eastern direction, in accordance with the general direction of the movement of inland ice. The overall thickness of Pleistocene deposits in the fossil depression of Nadróż is 125 m (Chutowski, 2002).

Further to the SE, in the direction of Ruda - Sitnica (particularly to the SE of Sitnica), the glacial basin turns into the surface depression of the Sitnica glacier lobe (formerly: "Nadróż lobe"). At the base of this lobe, a level of Vistulian till about 30 m thickness has been found. It lies on the relatively high Sitnica elevation of Pliocene deposits (90 m a.s.l.). But there exists no geological predisposition of the relief of the terrain observed hitherto in the area of the Sitnica lobe and its Tertiary fossil elevation. We can also state that the formation of this lobe (an arched outline of marginal forms) was connected with the location of the older fossil depression, which, on the north-western (proximal) side, preceded the aforementioned high Tertiary elevation of the environs of Sitnica. Here we have a perfect example of the varied action of paleorelief on the development of the dynamics of the glacial lobe, and consequently on the geomorphological diversity of the youngest glacial landscape.

The bed of the Ugoszcz-Żałe glacial basin with the drumlin field is strewn with brown moraine till from the Poznań-Dobrzyń phase, with an average thickness of 5 m. In places with increased glacial exaration/erosion, connected with the existence of basal ice-streams - isolated (in channels) or composite (basinic) - this till may not occur at all or reach only a small thickness. The beds of the channels and interdrumlin grooves can reach the older grey till from the Leszno phase (Chutkowski, 2002).

On the higher morainic plateaux surrounding the basin lies a brown (dual) layer of Poznań-Dobrzyń till, directly below which - in the vicinity of the village of

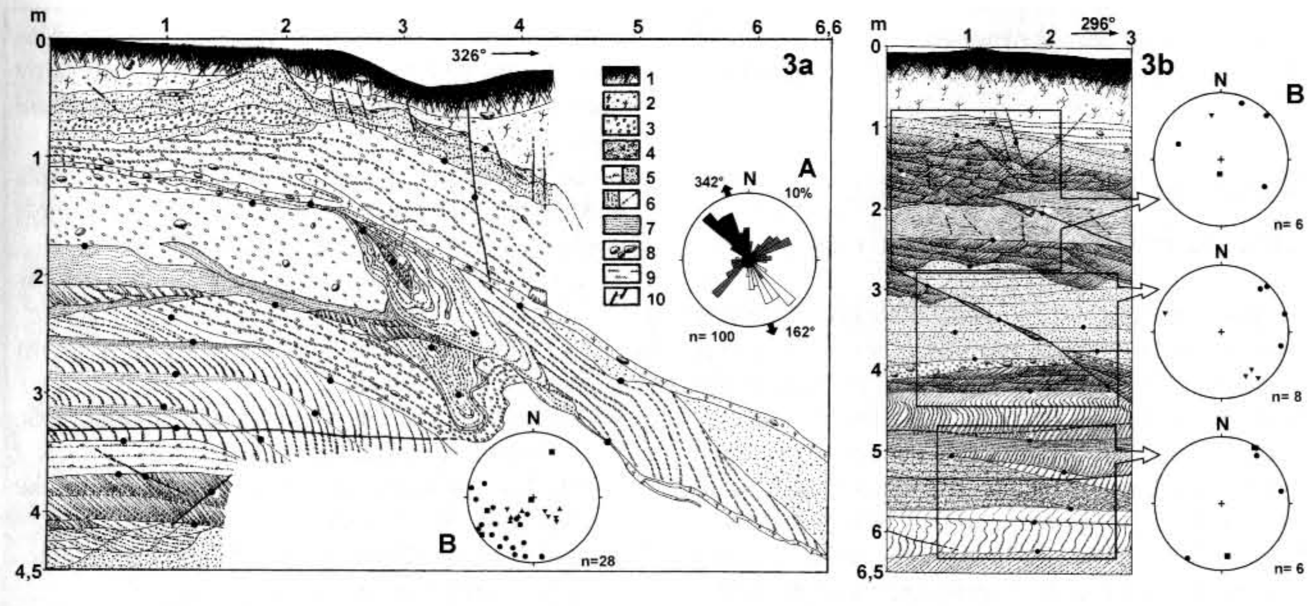

Fig. 3. Geological structure of morainic plateau promontory on the Okonin site in two exposures (3a and 3b) on the south-western slope of the basin (Chutkowski, 2002).
1 - soil, 2 - till, 3 - gravel, 4 - gravel with vari-grained sand, 5 - vari-grained sand with gravel, 6 - vari-grained sands, 7 - fine-grained sand, 8 - stones, 9 - clayey interbeds, 10 - faults; Structural diagrams: A - orientation of arrangement of longer and medium axis of clasts in till. Colours of diagram: black - asymmetrical longer axis, white - symmetrical longer axis, grey - asymmetrical medium axis. Arrows - resultant vector, n - number of measurements; B - orientation of layers and faults: symbols in point diagram: circles - poles of layers, squares - poles of plains of normal faults, triangles - poles of plains of compression faults, stars - axis of folds.

Ugoszcz - there occurs grey till (20-25 m). The base of grey till descending in the direction of the morphological development of the basin (to the SE) indicates that there existed a fossil depression form here, confirmed by the presence of a fossil slope in the Żałe profile. It can be linked with the maximal advance of Vistulian inland ice or with an older one (Chutkowski, 2002).

The geological structure of the close surroundings of the basin is shown by the Okonin outcrop. It is situated on a promontory of the morainic plateau at the outlet of the Okonin channel into the basin. There occur here a series of fluvioglacial deposits with a thickness of over 15 m (Fig. 3; 3a), covered with a thin layer of surficial till. Its thickness increases towards the Okonin channel. Fluvioglacial deposits display the variability of the structure of stratification (Fig. 3; 3a). These formations are enveloped in a thin layer of till, above which is a fairly wide zone of transformation of the sandy-gravely deposits of the substratum by the foot of the inland ice. Structures of glaciomylonites and glaciocataclases confirm the great activity of the inland ice (Kozarski & Kasprzak, 1995).

The fluvioglacial deposits are covered with dark-brown basal lodgement till. The bends occurring here in individual layers towards the bed of the Lake Okonin channel and the studied basin at the point where these forms meet testify to the existence of a fossil depression on the border between the plateau and the channel, or even within the Ugoszcz-Żałe basin (Chutkowski, 2002).

The second exposure in Okonin (Fig. 3; 3b) presents fluvioglacial deposits, glaciotectonically deformed (compression faults). It follows from their location that the front of the shearing strain in horizontal faults was located at a depth of at least 5.5 m below the local moraine till base. The arrangement of the main strains causing the phenomenon of geological contractions was the cause of the elevation of layers on the line of their course.

The basal facies of till is confirmed by glaciodynamic structures at its contact with the fluvioglacial series and the separation plains, characteristic of lodgement till (basal transport and subglacial sedimentation). The orientation and sinking of clasts in the till indicates an advance of the ice mass from NNW (N 342-162°). The direction of flow of the inland ice is almost perpendicular to the morphological axis of the Okonin channel and convergent with the slope of the widened central part of the Ugoszcz-Żałe glacial basin. At the point where forms of different size (channel - basin) meet, the main form played a dominant role in the textural formation of surficial till. Presumably, therefore, confluence ice-steams perpendicular to each other could exist in the inland ice mass at different levels - basal and superbasal - or otherwise the channel was preserved by dead ice, on to which transgressed the younger active ice-stream of the basin from NNW (Fig. 3; 3b; Chutkowski, 2002).

Relief of the glacial basin: glacial levels and drumlins

The landscape of the Ugoszcz-Żałe glacial basin is characterised by a low expression of the relief, typical of basin drumlin fields, e.g. Zbójno. The bed of the basin is lowered by 5-27 m in relation to the surrounding morainic plateaux. It lies about 103.9 m a.s.l. in the Lake Ugoszcz trough, and at its lowest (92 m a.s.l.) in the south-eastern end part of the basin, near Lake Ruda. In the longitudinal profile of the basin, the rise of the higher level of end moraine in its central part (112 m a.s.l.) is visible. The morainic plateaux and marginal forms surrounding the southern and eastern edge of the glacial basin rise considerably higher, to 143.75 m a.s.l. (Fig.4). The difference in the absolute heights on the terrain under discussion is 51.45 m, but the difference in the relative heights does not exceed 25-27 m (Chutkowski, 2002).

The Ugoszcz-Żałe glacial basin, i.e. a wider and confluently composite glacial channel with a surface area of about 25 km2 and a NW-SE orientation, is filled with a drumlin field about 10.5 km long and with a maximum width of 3.3 km (Fig. 4 and 5). This basin starts with a low slope on the north side, between Giżynek and the village of Ugoszcz, and ends in the environs of Sitnica. Further to the SE of Sitnica it becomes a depression of the Sitnica glacier lobe, making contact with the Dobrzyń sandr with a fluvioglacial edge of the "ice-contact" type, and with the vestigial moraine hill in the environs of Nadróż.

This basin is a junction area linking subglacial channels. They enter it from the north and west of the channel: Piórkowo, Franciszkowo, Okonin, Obory-Parowa, Kleszczyn-Żałe and the channel of Lakes Ostrowite and Głęboczek. In the environs of Somsiory is the polygenetic Somsiory channel, which is part of the basin. It leaves the main part and goes SE, towards the marginal channel Ruziec, near Lake Ruda (Chutkowski, 2002). This channel, with a bed at a height of 105-102.5 m a.s.l., has a N 310-130° orientation. It is a branch of the Okonin basal inland ice ice-stream. Glacial ground moraine levels with drumlins occur inside it. These levels are intersected by a very narrow fluvioglacial channel, with sandy thresholds and boggy depressions of the bed. With the exception of a narrow fluvioglacial part, the channel is strewn with moraine till from the Vistulian glaciation. Also 15 drumlins, structurally and morphometrically fairly homogeneous, and three expanses of glacial level are made of morainic till.

On the bed of the basin Chutkowski (2002) distinguished five subglacial drumlinisation levels, according to the height of the base of the drumlins:

1) 116.0-114 m a.s.l., to SE of Lake Okonin (south-west slope of basin);
2) 112.5-110 m a.s.l., to E of Julianowo, on southern slope of basin of Lake Żałe;
3) 107.5-105 m a.s.l., between Ugoszcz and Giżynek, to the level in Julianowo;
4) 104-101.3 m a.s.l., situated in the trough of Lake Żałe, to W and N of lake;
5) 100-96 m a.s.l., in depression of Żałe channel junction, to east of basin.

Within these levels there occur drumlins. Their course is as a rule in accordance with the edge of the slope of that basin with an orientation of N 292-112°. The deviation from the average azimuth of the drumlins, on individual drumlinisation levels, from the morphological axis of the basin, are relatively small (maximum 12°). The exception is level three, where the accordance of the drumlins and its course is the greatest. This confirms the stabilised orientation and fairly rapid movement of the icestream. The distinguished drumlinisation levels do not form a distinct hypsometric order, like in the Zbójno basin. In the Ugoszcz-Żałe basin, they are, as far as the surface is concerned, in the majority of local importance (levels 1, 4 and 5). Only level 2 (112.5-110 m a.s.l.) and 3 (107.5-105 m a.s.l.) are wider.

The Ugoszcz-Żałe drumlins are basically composed of two levels of morainic till. The lower grey till comes from the Leszno phase of the Vistulian glaciation. Its thickness is about 25 m. It lies at varying depths. It occurs in drumlin forms at a depth of about 1 m, and so relatively shallowly. It is more often found in the western part of the basin, in the 2nd and 3rd drumlinisation levels (1-6 m below the surface of the terrain). Sandy brown till lies on the sandy grey till. Its age was determined by Churski et al. (1978) as being of the Poznań-Dobrzyń phase. This till displays a duality. Its lower sequence is made up of dark-brown till, above which lies light-brown surficial till with less continuous cover. Both tills were found in the excavation on the north side of the Ugoszcz – Brzuze road, at the inlet of the combined Piórkowo and Franciszkowo channels into the Ugoszcz-Żałe basin. They constitute the deposit that forms the low drumlins as a whole. The occurrence of light-brown surficial till within the bed of the basin is only fragmentarily found. It is

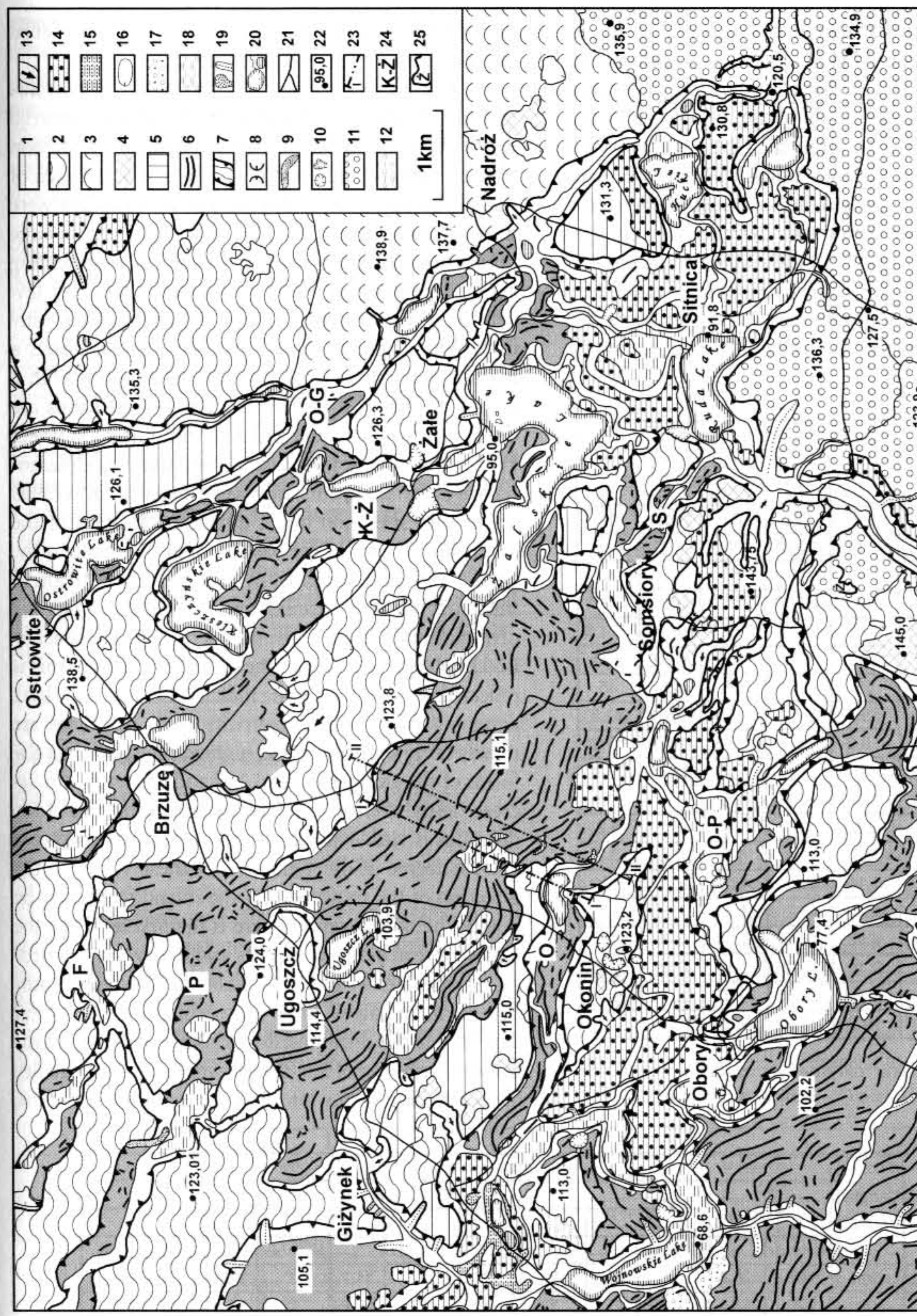

Fig. 4. Geomorphological map of the central part of the Dobrzyń Moraine Plateau with the Ugoszcz-Żałe glacial basin and its surroundings.
1 – flat moraine plateau, 2 – undulated moraine plateau, 3 – hummocky moraine plateau, 4 – push end moraine, 5 – ground moraine of depressed glacial levels in basin and glacial channels, 6 – drumlins, 7 – subglacial channels: edge and lower bands of slope, 8 – thresholds of channel bed, 9 – eskers, 10 – kettles and evorsion thresholds, 11 – sandurs, 12 – erosion plains of meltwaters, 13 – small meltwater valleys, 14 – kames and kame terraces, 15 – interkame ablation moraine covers, 16 – kettle-holes, 17 – plains of the ice-stagnant lakes, 18 – peat plains, 19 – small erosion and denudation valleys, 20 – lakes, rivers and small water bodies, 21 – roads, 22 – altitude points, 23 – hypsometric profile lines (I, II), 24 – letter identification of described channels (F – Franciszkowo, P – Piórkowo, O – Okonin, O-P – Obory-Parowa, S – Somsiory, K-Ż – Kleszczyn-Żałe, O-G – Lakes Ostrowite and Głęboczek), 25 – gravel-pit.

probably a deposit that was formed at the time of an ice surge (Niewiarowski et al., 1995), by transforming two lower lying tills, i.e. dark-brown and grey. One can say that the cores of the drumlins of the basin are basically formed by grey till. Their surface lagging is dark-brown till and sporadically light-brown (Chutkowski, 2002). Locally, at the outlet of the combined Franciszkowo-Piórkowo channel and on the fragment of the fourth drumlinisation level (descending in the form of a peninsula towards Lake Żałe), the occurrence of drumlins with a silt-clayey, limnoglacial core was observed (Fig. 4). A characteristic feature of the drumlins of this field is the lack of fluvioglacial deposits inside them (Chutkowski, 2002).

Morfometric parameters of drumlins		Ugoszcz - Żałe glacial basin					
		Total	Level				
			1	2	3	4	5
Number		381	59	223	61	22	16
Lenght l (m)	max	3900	540	3900	1520	550	480
	min	30	40	30	50	40	80
	mean	222,7	173,5	207,6	340,6	188,6	211,3
	std*	263,5	118	295,6	271,5	146,4	124,6
Width w (m)	max	180	100	150	175	120	180
	min	10	25	10	25	25	45
	mean	62,8	55,7	59,2	77,9	63,9	81,3
	std	27,8	19,2	26,7	29,8	24,6	37,9
Height h (m)	max	14,4	10	7,8	7,7	11,25	14,4
	min	0,4	0,4	0,4	0,5	1	1
	mean	2,5	2,8	2	2,7	3,8	5,2
	std	2	2,3	1,4	1,8	2,5	3,2
l/w	mean	3,36	3,11	3,33	4,13	2,75	2,71
	std	2,77	1,82	3,2	2,33	1,46	1,5
w/l	mean	0,41	0,42	0,43	0,33	0,49	0,41
	std	0,22	0,19	0,22	0,19	0,29	0,18
w/h	mean	35,87	30,64	39,35	37,72	20,81	20,45
	std	23,04	19,2	23,91	24,34	11,03	12,8

Tab. 1. Morphometric parameters of drumlins of the Ugoszcz-Żałe glacial basin (* – standard deviation).

A result of the activity of the basal ice-currents is also the irregular distribution of moraine material along the drumlin forms. This causes a differentiation of their shape, length, width and height. In the area of the glacial basin under discussion, 381 drumlins were distinguished (Tab. 1). They are characterised by a large proportion of short forms (up to 200 m), representing about 61.5% of the whole population. There are few very long forms (over 1000 m), which represent only 0.8%. From among all the drumlins situated here, a considerable part, 37.7%, is made up of forms with a length of 200-1000 m (Tab. 2). The longest forms are characteristic of the 2nd and 3rd drumlinisation levels. Within their limits, the greatest morphometric differentiation of forms appears: from very long drumlins (3900 m) to very short (30 m). A distinct elongation of the forms in this part of the basin should be linked to the greater and more stabilised dynamic of the icestream in the initial phase of drumlinisation. The three remaining drumlinisation levels of the basin (1, 4, 5) are characterised by the greater bulk of the drumlins (Tab. 1). This is reflected in the values of the indices of elongation (l/w), flattening (w/h) and izometricity (w/l). So, these are mostly fairly short forms but higher and wider than the forms of the aforementioned 2nd and 3rd levels. An increase in the average values of the relative heights of the drumlins is visible in the easterly direction. However, a greater degree of differentiation of these values in the direction of the movement of the inland ice should be noted. The only exception here is the first level (1), the largest, spread between Paproty and Radzynek. It is situated in the lateral zone of the basin, to some extent outside the main course of the icestream. For a typological approach to the drumlins, Rose's (1987) objective classification (criterion of length) was applied, which divides glacier erosion forms into flutes, megaflutes, drumlins, megadrumlins and streamlined hills. According to this criterion, there are barely 144 typical drumlins (200-1000 m) on the area of the Ugoszcz-Żałe field, which represents 37.7% of all the described forms (Tab. 2, Chutkowski, 2002). The mutual morphostratigraphic correlation of the drumlins on the various drumlinisation levels is difficult to evaluate.

Type	Lenght l (m)	Ugoszcz - Żałe glacial basin											
		Total		Level									
				1		2		3		4		5	
		Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
flutes	<100	108	28,4	17	28,8	74	33,2	7	11,7	7	31,8	3	18,8
megflutes	200	126	33,1	24	40,7	77	34,5	12	19,6	7	31,8	6	37,5
drumlins	500	116	30,4	16	27,1	56	25,1	30	49,1	7	31,8	7	43,7
	1000	28	7,3	2	3,4	15	6,7	10	16,4	1	4,6	-	-
megadrumlins	1500	1	0,3	-	-	-	-	1	1,6	-	-	-	-
streamlined hills	>1500	2	0,5	-	-	1	0,5	1	1,6	-	-	-	-
Sume		381	100	59	100	223	100	61	100	22	100	16	100

Tab. 2. Division of subglacial forms for the Ugoszcz-Żałe glacial basin in the Rose system (1987).

The majority of the channels entering the basin zone of the Ugoszcz-Żałe drumlin field are characterised by the occurrence of drumlins. An exception is the region at the base of the Sitnica lobe, where kames dominate in the form of ridges, hills, hummocks and tableforms (Fig. 4), which are built of sandy, or more rarely, silt-clayey formations. The cumulation of these forms occurs in the area of the Żałe channel junction, i.e. in the south-eastern part of the glacial basin. The kame hills and the accompanying kettle-holes form a varied kame-kettle-hole landscape around Sitnica (Fig. 4). The co-occurrence here of forms with extremely different genesis and environment – drumlins and kames – produces an unequivocal sedimentation and chrono-stratigraphic situation (Raukas & Tavast, 1994; Olszewski, 2000).

Selected channels and their drumlins in the surroundings of the basin

The Franciszkowo channel (N 300-120°) in the western part is polygenetic. Several drumlins occur on the tilly glacial level. It is intersected by a fluvioglacial channel. To the east, the Franciszkowo channel joins the Piórkowo channel. There are 20 drumlins on the higher tilly level (Tab. 3). Short forms dominate (up to 200 m), representing 65% of the population (Tab. 4).

The Piórkowo channel (N 311-131°) is a long form stretching to the south from the slope of the ice-marginal streamway of the Drwęca. In the south-eastern part, it lies evenly with a parallel of latitude (N 294-114°), linked with the orientation of the Ugoszcz-Żałe glacial basin that it flows into. The western part of the channel has a complex genesis; the ground moraine level is intersected by a fluvioglacial channel. There are several drumlins on this level. Further to the E, at the point where the form changes direction and narrows, there is an esker descending from the plateau

Morfometric parameters of drumlins		Channels				
		Franciszkowo	Piórkowo	Okonin	Kleszczyn-Żałe	Ostrowite-Głęboczek
Number		20	52	26	37	29
Lenght l (m)	max	410	350	1090	520	550
	min	65	40	60	30	30
	mean	190,5	134,4	252,1	164,1	159,5
	std*	114,4	72,5	233,5	112,2	125
Width w (m)	max	110	120	105	160	110
	min	30	25	30	25	20
	mean	60,3	59	61,1	63,9	57,6
	std	17,4	19,8	19,6	34,7	20,9
Height h (m)	max	5	6,3	14,25	12,5	10
	min	0,4	0,26	0,8	1	0,3
	mean	2	1,6	4,8	3,1	3,7
	std	1,3	1,1	3,6	2,9	2,4
l/w	mean	3,11	2,29	3,96	2,77	2,64
	std	1,59	1,15	2,95	1,52	1,73
w/l	mean	0,4	0,52	0,37	0,55	0,5
	std	0,19	0,2	1,9	0,77	0,24
w/h	mean	40,45	53,38	22	31,79	25,19
	std	30,18	35,05	16,78	24,94	27,33

Tab. 3. Morphometric parameters of drumlins in the channel surroundings of the Ugoszcz-Żałe glacial basin (* – standard deviation).

Type	Lenght l (m)	Channels									
		Franciszkowo		Piórkowo		Okonin		Kleszczyn-Żałe		Ostrowite-Głęboczek	
		Number	%	Number	%	Number	%	Number	%	Number	%
flutes	<100	17	28,8	74	33,2	7	11,7	7	31,8	3	18,8
megflutes	200	24	40,7	77	34,5	12	19,6	7	31,8	6	37,5
drumlins	500	16	27,1	56	25,1	30	49,1	7	31,8	7	43,7
	1000	2	3,4	15	6,7	10	16,4	1	4,6	-	-
megadrumlins	1500	-	-	-	-	1	1,6	-	-	-	-
streamlined hills	>1500	-	-	1	0,5	1	1,6	-	-	-	-
Sume		59	100	223	100	61	100	22	100	16	100

Tab. 4. Division of subglacial forms for the channel surroundings of the Ugoszcz-Żałe glacial basin in the Rose system (1987).

to the bed of the channel. Its further part (to the E) has a glacial genesis. Here, right up to the basin, the channel has 52 small, tilly drumlins of considerable morphometric homogeneity (Tab. 3). According to the Rose (1987) classification, forms with a length of under 200 m are dominant (88.4%). Typical drumlins constitute only 11.6% of those in the channel (Tab. 4; Chutkowski, 2002).

The Okonin channel (N 275-95°) links the Zbójno and Ugoszcz-Żałe basins. It begins at the fork of the Wojnowo-Pęcherek channel (Olszewski, 2000; Słupski, 2000) and ends at the eastern shore of Lake Okonin (Fig. 4). Here it joins the Ugoszcz-Żałe basin, thereafter representing the effect of the action of the composite ice-stream (Chutkowski, 2002). The drumlin forms occurring in it are geologically varied. At the outlet of this channel from the Zbójno basin, the proportion of tilly forms increases (Słupski, 2000). Further to the east, there is an increase in the proportion of drumlins made of stratified sands, silts and clays. In the eastern part of the channel, i.e. nearest to the Ugoszcz-Żałe basin, tilly forms predominate once more. The drumlins on the glacial bed of the channel display large disproportions of length (Tab. 3).

The Obory-Parowa channel is an extension of the Wojnowo-Pęcherek channel, and together with it links the Zbójno and Ugoszcz-Żałe basins. It lies evenly with a parallel of latitude and is of considerable width (850-1100 m). It is the widest of the channels in the morainic plateaux surrounding the basin. Its bed is filled with areal deglaciation forms (tableforms and kame terraces with kettle-holes). The southern part of the channel is intersected by a widening (in the direction of the basin) fluvioglacial channel. If the direction of the glacial current on the Obory - Somsiory section (i.e. along the channel) was directed from the west to the east, then the hypsometry of the kame levels, inclined from the east to the west, indicates a western outflow path for the meltwaters, into the Zbójno basin.

The Kleszczyn-Żałe channel (N 330-150°) is part of the Radomin-Brzuze channel. Its ground moraine level with drumlins is lower by only about 3-4 m in relation to the surrounding morainic plateau. The fundamental bed of the channel by Lake Kopiec is indented in the drumlinisation level by about 10-12 m. At the inlet of the channel into the Ugoszcz-Żałe basin, there is a distinct threshold. It lowers the bed of the channel by about 17 m. The distinct inclination of the threshold and the presence of an evorsional kettle emphasises the contribution of fluvioglacial waters in the genesis of the channel. Their occurrence may confirm the presence of a fossil depression reproduced inside the channel, and on the whole area of the Żałe channel junction. In its northern part, it partially joins the neighbouring channel of Lakes Ostrowite and Głęboczek. Because of the confluent-defluent character of this area (Olszewski, 1994), it has been named the Kleszczyn channel junction. There are 37 drumlins, not very varied morphometrically, in this channel, made of brown surficial till (Tab. 3 and 4; Chutkowski, 2002).

The channel of Lakes Ostrowite and Głęboczek (N 315-135°) stretches from Trąbin in the north to Nadróż in the south. It continues on the eastern area of the edge of the Sitnica lobe up to the ravined snout of the meltwaters flowing beyond the limits of the lobe, to the NW of Rogowo. The central part of this channel joins the Kleszczyn-Żałe channel. Its glacial bed descends to the SE and indents to about 38 m in comparison with the morainic plateaux. The drumlins occurring here, including proper ones, of which there are only 24.2% (Tab. 3 and 4), are in the majority built of talus till (Chutkowski, 2002).

Relation of the basin to other forms of relief - discussion

Considering the issue of the links of lithology and the subquaternary surface relief with subsequent Pleistocene palaeosurfaces and with the Vistulian subglacial surface, Galon (1972), Mojski (1981) and Lamparski (1983, 1991) paid attention to the predisposition of forms or their independent development. Mojski (1981) considered the role of the older (deeper and wider) channels in the development of the erosion and deposition of younger deposits, and the fact that larger channels are filled with moraine till, which is a "product of the melting of inland ice, which filled and partially shaped such a form" (p. 92). Thus, based on geological evidence, he recognised their glacial morphogenesis. Wysota (1995) expresses a similar view in relation to the glacial channel of Brynica.

In connection with Niewiarowski's (1995) classification of erosional subglacial forms, we discuss the differences between two categories of convex forms - glacial troughs and glacial basins, of which this system only mentions troughs.

According to Nechay (1927; p. 78), a trough (the Kikół trough) is "in morphologically relation, a depression created by a glacier tongue (Zungenbecken)". It was formed within a narrow ice outlet of inland ice. In the subglacial interior of the trough, there may form a deepened part - clearly an exaration final depression. Glacial troughs may also be lacking

Channels	Width of Ugoszcz-Żałe glacial basin (m)		Change in width of basin +/- (%)
	above outflow of channel	below outflow of channel	
Franciszkowo-Piórkowo (F-P)	1800	2600	44,4
Okonin (O)	2000	2910	45,5
Obory-Parowy (O-P)	2940	3080	4,7
Kleszczyn-Żałe (K-Ż)	2200	2770	25,9
Ostrowite and Głęboczek (O-G)	3070	3000	-2,3
Mean	2402	2872	24,1

Tab. 5. Changes in the width of the Ugoszcz-Żałe glacial basin with reference to the inlets of selected channels.

this. The Kikół trough has glacial levels, a few tilly drumlins, lake channels and a kame plateau (to the S of Lake Lubinek). The smaller outlet glacial trough in the environs of Górzno demarcates the extent of the Dobrzyń oscillation. Its drumlin relief, exaration lake basins and push end moraines surrounding it create a great contrast in the landscape (Niewiarowski et al., 1995; Wysota, 1995). The Górzno glacial trough is a branch of the wider depression of the Brynica lobe basin.

Glacial basins, located on the axis of ice-currents, are formed by their confluent (convergent) action on the subglacial substratum (Raukas & Tavast, 1994). They are the effect of the erosional and deformational work of an integrated icestream. Glacial basins lie in the more distant surroundings of marginal forms. They are initiated by separate glacial or polygenetic channels confluently directed towards the central glacial depression. The Ugoszcz-Żałe glacial basin was formed thanks to the following:

- the predispositional existence of a depression of the subglacial surface during the Vistulian glaciation, and particularly during the Kujawy-Dobrzyń oscillation;
- the glaciodynamic joining (confluence) of individual channel glacial currents in the wider composite ice-stream (Tab. 5; Fig 5, 6);
- the fall in the dynamism of the icestream in the central part of the bed of the basin and in its distal part (two morainic plateau areas in the environs of Bąkowizna), at the contact point with the Sitnica lobe.

The Ugoszcz-Żałe glacial basin directly adjoins the Sitnica lobe, which underlines the morphogenetic relationship between these two macroforms. The basin spatially expanded widthways until ice-currents of glacial channels reached the central basin area. At the contact point of these two entities - the basin and the Sitnica lobe - external channels stop coming into the basin. The last channel, of Lakes Ostrowite and Głęboczek, runs from here within the lobe as a fluvioglacial form. Basal and subglacial meltwaters

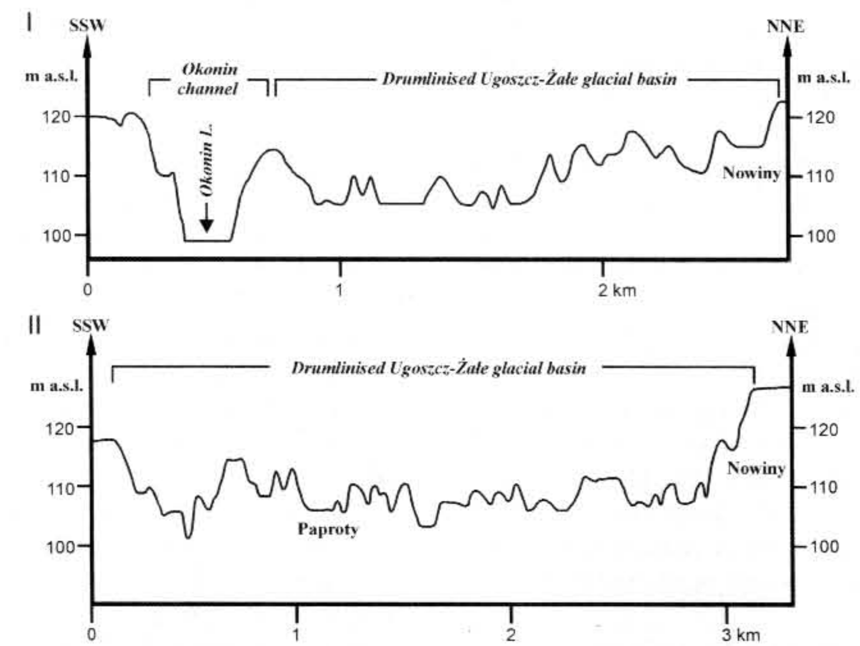

Fig. 5. Hypsometric profiles (I, II) of the central part of the Ugoszcz-Żałe glacial basin.

from the Sitnica lobe, two inner peripheral channels, the eastern of Huta Nadróż and the south-western Ruda-Charszewo channel (through the depression of Lake Kościan, 108.5 m a.s.l.), managed to get outside the lobe. This happened because of the ravined snout mentioned above (between Lake Kościan and Młynik village).

If glacial troughs can be defined as marginal-submarginal outlet forms, then glacial basins belong to the morphogenetic submarginal-subglacial zone. They are the site for channel initiation pushed more towards the proximal side of the interior of the inland ice. On the other hand, troughs extend into its distal (marginal) extent. The immediate vicinity of the Ugoszcz-Żałe glacial basin and the Sinica lobe is in effect their mutual geographical continuation. Based on this example, in which it is possible fairly accurately - based on the mutual relations of the channels (glacial and polygenetic) to the glacial basin - to define the border between the basin and the lobe, this indicates that only the Sitnica lobe can be defined in the morphological sense as a (marginal) glacial trough. The glacial trough (Sitnica) is a morphogenetic continuation and ending of the Ugoszcz-Żałe glacial basin (Fig. 4).

Conclusions

The authors reached the following conclusions:

1. there is a considerable link between the formation of the subquaternary substratum and the present relief of the Ugoszcz-Żałe glacial basin and its surroundings; some parts of the basin display a relationship with the relief of the pre-Vistulian substratum;
2. the distal part of the basin (Żałe channel junction) lies on the site of a reproduced of fossil depression. However, the area of the Vistulian Sitnica glacial lobe, in contrast, is not a site for the permanent recurrence of this type of form;
3. the distal sections of the channel flowing into the basin have a glacial character. The basin is the site of glacioconfluence (convergence) of basal currents, which in its proximal surrounding formed separate glacial channels of the Dobrzyń oscillation. The arrival of subsequent channels at the Ugoszcz-Żałe basin causes an increase in its width, which confirms the concept of its confluent morphogenesis;
4. a great structural and textural similarity in the till of the Ugoszcz-Żałe glacial basin bed indicates a relative homogeneity of the conditions and processes of glacial sedimentation;
5. drumlins occurring in channels are shorter than in the Ugoszcz-Żałe glacial basin. However, they are similar to them as regards height and width, which indicates that the development of the length of drumlins is favoured by a considerable width of the basin;
6. Kame forms in the southern surroundings of the basin and in the Obory-Parowa channel that reaches it are an indicator of the stagnation of the inland ice and its slab-block degradation. They are located, in the first case, on a distinctly elevated moraine plateau of the border between the basin and the glacial trough of the Sitnica lobe (Fig. 4).

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Landform Analysis, Vol. 6: 15-27 (2008)

The geomorphological effectiveness of extreme meteorological phenomena on flysch slopes

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Abstract: Extreme events tend to cause large-scale slope system changes. During the last ten years, a series of extreme meteorological events caused considerable transformation of the slopes and valleys in various parts of the Carpathian Mountains. This paper presents the geomorphological effects of extreme rainfall and thaw events on the slopes of two catchments: the Łososina catchment (Beskid Wyspowy) and the Hoczewka catchment with an area around the Solińskie Lake (Bieszczady Niskie). The bulk of the discussion concerns a study carried out in the Łososina catchment after three separate extreme events that were followed by a considerable transformation of the slopes due to landsliding. The studies carried out in the Bieszczady Range, where a single extreme event produced only spatially limited effects, were mainly used for comparison. The disparity between the responses of the two slope systems was a result of differences between the systems themselves, including their geology, geomorphology and landslide record, and of the difference in the scale of the extreme events.

Kay words: extreme events, heavy rainfall, landslies, flysch slopes, Beskid Wyspowy, Bieszczady Niskie

Introduction

While extreme events normally occur very seldom, they tend to constitute a powerful factor in the development of the local relief. During extreme events, threshold values are exceeded for the occurrence of various processes and a high landform building potential disturbs the equilibrium of natural systems, such as slope and channel systems (Thornes & Brunsden, 1978). Extreme meteorological events can have a simple or complex nature, different durations and geographical extent (Starkel, 2003). Simple extreme events include short and intensive downpours of limited coverage. Complex extreme events may include situations where a torrential rainstorm coincides with long-duration rainfall, or where a spring thaw is accompanied by intensive rainfall (Starkel, 2003). A series of events occurring in a short span of time (days, months or years) are know as clusters of events (Starkel & Sarkar, 2002). If the interval between the events is short enough, the system may have insufficient time to recover the balance and fails to return to its prior status. Subsequent extreme events contribute to the evolution of a new balance in the natural system.

A recent increase in popularity among researchers of extreme events began after the disastrous rainfalls of July 1997, which caused flooding in the Vistula and Odra river catchments and a reactivation of slope mass movements. The studies undertaken at the time were continued, as intensified landsliding activity was recorded in various parts of the Carpathian Mts. during subsequent years (1998, 2000, 2001, 2002 and 2005). In 1997, geomorphological effects of extreme rainfall events were recorded in several areas including the Polish Tatras (Kotarba, 1998), the Beski Wsypowy range and the Wielickie Foothills (German, 1998, Poprawa & Rączkowski, 1998, Gorczyca, 2004). During subsequent years, extreme events produced both new landslide forms and a further development of those originated in 1997 in many areas of the Flysch Carpathian Mts. (Beskid Sądecki, Beskid Średni, Beskid Wyspowy, Beskid Niski and the Wielickie, Ciężkowickie and Strzyżowskie Foothills; Sądecka