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RAJMUND GALON

MORPHOLOGY OF THE NOTEĆ–WARTA (OR TORUŃ–EBERSWALDE) ICE MARGINAL STREAMWAY

WARSAW 1961

WYDAWNICTWA GEOLOGICZNE

Drogiemu Staśkowi
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RAJMUND GALON

MORFOLOGIA PRADOLINY NOTECI–WARTY (LUB TORUŃSKO—EBERSWALDZKIEJ)

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ГЕОГРАФИЧЕСКИЕ ТРУДЫ
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РАЙМУНД ГАЛОН

МОРФОЛОГИЯ ПРАДОЛИНЫ НОТЕЦИ—ВАРТЫ (ЛИБО ТОРУНЬСКО-ЭБЕРСВАЛЬДСКОЙ)

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CONTENTS

MORE IMPORTANT STAGES IN EVOLUTION OF OPINIONS ON FORMATION OF ICE-MARGINAL STREAMWAY

1. The ice-marginal streamway * drained by the Lower Noteć and the Lower Warta, also known as the Toruń—Eberswalde ice-marginal streamway belongs to the largest valley forms in the postglacial lowland. Neither of the localities appearing in the name of this streamway describes its range. The head of this old valley should be looked for farer to the East, either in the valley of the Lower Drwęca or in the valley of the Vistula upstream of Toruń and, further on, in the valley of the Lower Narew. On the other hand, westwards of the Odra and of the valley gap near Eberswalde („The Eberswalde Gate") this ice-marginal streamway is continued in the present valleys of the Finow, Rhin and Havel rivers, which ultimately join the valley of the Elbe river. The term used in the title of the present paper has been chosen due to the fact that the ice-marginal streamway under discussion is now drained mainly by the Noteć and Warta rivers.

This ice-marginal streamway, while markedly variable both in gradient and width, and alternately revealing narrow stretches of gap type and extensive basin-shaped widenings, is drained by numerous rivers; even so, it clearly constitutes a unity. The first to notice this was H. Girard, as early as one hundred years ago (23); this author gave a description of the plateau spread between the Elbe and the Vistula and of the valleys extending in an east-west direction in this plateau. After O. Torell (1875) had established the fact of the glaciation of considerable areas of Europe by the Scandinavian inland ice, G. Berendt (6) was the first to draw a map of the Noteć—Warta ice-marginal streamway. He connected the formation of ice-marginal streamways on the postglacial lowland with the obstructions which river waters met in their northwards run-off while inland ice was present on the lowland and gradually withdrawing. When the lowland had been liberated from its ice covering, the rivers resumed their original, i. e. northward, direction of flow.

K. Keilhack (28, 29) was the first to reach the conclusion that the Noteć—Warta ice-marginal streamway is genetically connected with

* Polish „pradolina", German „Urstromtal".

the presence of inland ice during the Pomeranian stage, and that it constituted the path along which meltwater flowed away during this stage. Within this valley he observed two dammed lakes, of Toruń and of Kostrzyn (Küstrin), indicated by basin-shaped widenings of the valley and known as Toruń Basin * and Gorzów (Kostrzyn) Basin **; in these basins the main terrace, formed during the period of the fluvio-glacial run-off, is not inclined or only slightly. According to Keilhack's observation, this terrace lies at the altitude of 70 to 75 m. in the area of the former Toruń dammed lake, while along the former Kostrzyn lake it lies on a height of 35 to 45 m. The valley gap near Eberswalde is situated at a similar height.

From the Kostrzyn dammed lake, of some 40 meters' depth, in which not only waters of the ice-marginal streamway flowing from the East, but also Odra waters accumulated, the outflow took place through the valley gap near Eberswalde, the so-called Eberswalde Gate. Keilhack failed to explain, in a convincing fashion, the absence of glacial lake sediments in the Kostrzyn Basin, or to explain the fact that the main valley terrace in the gap near Eberswalde, thus west of the Kostrzyn Basin, shows a rise of several meters (a valley watershed).

G. Maas (52) disputes the concept of a genetic uniformity of the ice-marginal streamway and its connection with the Pomeranian stage, expressing the opinion that this valley is composed of several basins, previously separated from each other by terminal moraines. A number of later authors have also contested the uniformity of the valley line, in particular its comprising the valley gap near Eberswalde („The Eberswalde Gate") due to its abnormal height; they also challenge the concept of connecting the ice-marginal streamway genetically with the end moraines of the Pomeranian stage (E. Wunderlich, O. Schneider, P. G. Krause, S. Zeuner, G. Schulz, F. Solger, B. Beschoren, K. v. Bülow). On the other hand, Wahnschaffe (74, 75) agrees with Keilhack as to the existence of a continuous course of the ice-marginal streamway, comprising the widely discussed valley section near Eberswalde too, whereas, in his opinion, the Kostrzyn dammed lake has been at a higher situation. Wahnschaffe regards the present-day bottom of the valley as the result of postglacial erosion by the Odra river.

Thus the discussion as to the origin of the outwash valley has dealt rather with its western part, i. e. the Kostrzyn Basin, together with the

* Also called the Toruń—Bydgoszcz Valley Basin.

** This enormous depression extends on both sides of the Odra. It is customary to refer to its part situated on Polish territory as the Gorzów Basin, while the basin as a whole is called the Kostrzyn (Küstrin) Basin.

adjoining valley gap near Eberswalde, the morphological situation of which does not correspond to any concepts of a genetic uniformity of the ice-marginal streamway. Attempts, however were still continued to explain the formation of the ice-marginal streamway, in its western part, with the conception of a uniform run-off.

Of more recent authors, H. Louis (51) concedes the uniform character of the ice-marginal streamway. In his opinion, the Kostrzyn (Gorzów) Basin was, at that time, filled with dead ice, due to which meltwater flowed out westwards through the narrow gap of the ice-marginal streamway near Eberswalde. The swelling of the streamway terrace at that spot (the valley watershed at Zerpenschleuse) he regards as having been caused by some small tectonic movement.

A similar opinion has been expressed by Woldstedt (79). He rejects the hitherto prevalent concept of the Kostrzyn Basin, having been a dammed lake, while assuming this vast form to have been filled witch dead ice. During the Pomeranian stage there was formed, in the Toruń—Eberswalde ice-marginal streamway, a uniform erosive terrace, the so-called main Baltic terrace, extending westwards through the valley gap near Eberswalde. At that time, the waters of the Odra still continued to flow down the Warsaw—Berlin ice-marginal streamway. Instead of the present valley of the Lower Odra there existed a subglacial channel draining of the waters into the Toruń—Eberswalde ice-marginal streamway. Like Louis, Woldstedt ascribes the valley watershed in the valley gap to a tectonic uplift.

Woldstedt's reasoning is resumed by H. G. Ost (58, 59) who, investigating the outwash plains of the Gwda and Drawa rivers, established their connection, on the one hand, with end moraines of the Pomeranian stage and, on the other hand, with the main terrace of the ice-marginal streamway which, in numerous places reveals ice contacts (kame terraces). At the same time, however, Ost calls attention to the genetically complicated character of the ice-marginal streamway.

Among the most recent papers concerning the western part of the ice-marginal streamway, in particular of the Kostrzyn Basin, one of the most outstanding is a contribution by H. Liedtke (48, 49), which puts an end to the controversy on the problem of the run-off of streamway waters through the gap in this valley near Eberswalde. Like Louis and Woldstedt, this author assumes the entire Kostrzyń Basin having been filled with dead ice; meltwater could, therefore without any difficulty overflow this depression, as evidenced by outwash tracks suddenly breaking off at the northern and north-western side of the Basin, and continuing on the southern and western side of this vast form.

Liedtke envisages the development of the western part of the valley under consideration (the Warta ice-marginal streamway) in three stages. During the Pomeranian stage, meltwater made its way over the present Kostrzyn Basin south and westwards along various tracks, principally through the present gap of the Odra valley and the valley near Buckow (Rotes Luch), towards the Warsaw—Berlin ice-marginal streamway. During the stage of the gradual recession of the inland ice, succeeding the Pomeranian stage, meltwater flowing both from the north from the nearby inland ice, and from the east in the Noteć—Warta streamway, ran mainly westwards through the valley narrow near Eberswalde. Finally, during the third stage, when the inland ice had already receded into the area of the present Szczecin Lagoon (haff), the waters of the Warta ice-marginal streamway made their way exclusively northwards, through the present valley of the Lower Odra and the Randow river, and then westwards, along one of the Mecklenburg ice-marginal streamways. Consequently, H. Liedtke distinguishes two ice-marginal streamways, the Toruń—Eberswalde streamway and the Noteć—Randow streamway, he reaches the conclusion that, at a time when in the eastern part of the ice-marginal streamway meltwater continued to flow away from inland ice to the streamway, the more rapid recession of the inland ice in the west caused, the water there to make its way northwards. H. Liedtke attempted to demonstrate that the swelling of the bottom of the ice-marginal streamway west of Eberswalde were not caused by any tectonic uplift, but simply represent a periglacial alluvial cone of the Havel river (4 to 6 m. height).

Mention should be made of the research conducted by L. Pilarczyk (62) in the area of the Gorzów Basin, dealing principally with the valley of the Kłodawka river, which joins the Warta ice-marginal streamway near Gorzów, as well as with the terraces of this old valley in that region. The author describes the terraces of the Kłodawka valley and compares them with the terraces of the ice-marginal streamway in the light of existing German investigations. The Kłodawka is a typical outwash river, just like the Gwda and the Brda rivers. The morphological investigations of lateral valleys leading into the ice-marginal streamway are a valuable supplement to the studies dealing with terraces in the streamway, where such terraces, on the whole, appear but fragmentarily.

A fundamental evolution of views has taken place in the controversy on the origin of the ice-marginal streamway and, more particularly, of its western part, including the Kostrzyn Basin. The assumption of the existence of a deep dammed lake, which has made it possible for the waters of the ice-marginal streamway to pass the valley narrow near

Eberswalde, has been superseded by a thesis which assumes an erosional cutting of the basin by the waters of the Odra and Warta. This thesis, in turn, has been replaced by a concept in which the principal part is played by dead ice which at one time filled this extensive basin.

2. The deliberations mentioned above on the origin of the Noteć—Warta ice-marginal streamway and on its relation to the recession of the inland ice, mostly referred to the western part of the streamway under consideration. For, indeed, the fundamental cognition of the origin of the Noteć—Warta ice-marginal streamway depended on the explanation of the role played in the draining of the ice-marginal streamway by the valley gap near Eberswalde. How did investigation and discussion of the origin of the eastern part of the outwash valley simultaneously proceed? Just as, in the west, the Kostrzyn (Gorzów) Basin, so in the east the Toruń Basin evoked the greatest interest among geologists. For many years K. Keilhack's concept of an ice-dammed lake weighed heavily on the explanation of the origin of the outwash valley. But, even before him, in 1878, B. Berendt (6) prepared a map of the ice-marginal streamway, marking in this area two moraine islands, situated in the Toruń Basin and south of Nakło; he also discussed the problem of the northward diversion of the Vistula. Both P. Sonntag (70) and A. Jentzsch (26) proved to be partisans of the concept of the Toruń Basin having been a dammed lake. In Sonntag's opinion, this lake existed owing to end moraines blocking the waters from flowing westwards. At the same time, however, this dammed lake was alimented by waters flowing from the north, from the „Grudziądz dammed lake". The terrace, seventy-metres high, he supposes to be a trace of the dammed lake in the Toruń Basin. At a later date, when the dammed lake started to drain westwards, the water surface dropped to 55 metres a. s. l. The diversion of the waters of the Vistula towards the north this author assumes to have taken place due to river capture. At that time, the Vistula already flowed at a level of 42 meters a. s. l.

Among Polish geographers, St. Lencewicz (45) was the first to show interest in the so-called Toruń dammed lake. He demonstrated the fallacy of the dammed lake concept with regard to the Toruń Basin and, in turn, expressed the opinion that the ice-marginal streamway, formed during the Pomeranian stage was glaciated a second time with the ice lobe reaching as far as Płock, as indicated by recent glacial forms occuring in the Płock Basin. Subsequent to the shrinking of the glacier, the Vistula shaped a new, narrower track through the Toruń Basin. The moraine island within the Basin is a deposit of this glacier oscillation, while, in the opinion of both St. Lencewicz and A. Zierhoffer (85), the northward diversion of the Vistula was caused, by the uplift of the substratum on the Noteć—Brda watershed, west of Bydgoszcz (an analogy with the valley watershed west of Eberswalde!).

In his morphological study concerned the Kujawy region, R. Galon (13) assumed the existence of an ice-marginal streamway even before the last glaciation. At that time there existed, both in its area and on adjacent lands, more particularly so in the region of Aleksandrów Kujawski, Toruń, Gniewkowo, Bydgoszcz and Chełmno, a gigantic ice-dammed lake, in which inter-morainic varved clays had deposited, such as are met with here and in other localities. In the north the boundary of the ancient ice-marginal streamway was the Nakło moraine plateau edge, in the south the Szaradowo—Barcin moraine plateau edge. After the last glaciation, when the inland ice had receded to the area of the Pomeranian Lake District, the ice-marginal streamway was rejuvenated, though in a diminished form. Its southern boundary, within the Toruń Basin, was the Samoklęski edge (lower by some 10 to 15 metres than the Nakło edge). When the edge of the inland ice had reached the area of the Baltic, the waters of the Vistula were diverted northwards, along the same way by which so far the glacial watershad flowed in the opposite direction.

Thus R. Galon, like St. Lencewicz, has rejected the concept of a dammed lake to explain the widening of the ice-marginal streamway between Aleksandrów Kujawski and Nakło, while admitting, on the other hand, the existence, in the last interglacial, of an ice-dammed lake of dimensions exceeding those of the present-day basin. The nearly horizontal surface of the upper terrace, the so-called dammed-lake terrace, or streamway terrace, is explained by R. Galon as follows. The bifurcation of both river and young valley of the Vistula by the moraine island, situated near Bydgoszcz, led to a division of the course which, in turn, caused a decrease of river erosion in this valley section. At any rate, the existence of a basin-shaped widening of the ice-marginal streamway near Toruń does not prove the existence of any kind of dammed lake. It is merely the result of the division of the river and of fluvial erosion, without any features of a lake basin.

The problem of the origin of the ice-marginal streamway and, more particularly, of its basin-shaped widening, is examined again in R. Galon's next contributions (16, 17). His fundamental view concerning the origin of this streamway is unchanged. On the other hand, more recent research proved the existence of a considerable number of terraces established first in the region of Bydgoszcz and Fordon. The fact came to light that the upper terrace, hitherto by all investigators considered to be an ice-marginal streamway terrace, appears both in the ice-marginal streamway west of Bydgoszcz, and in the valley of the Lower Vistula near Grudziądz. At any rate, this terrace developed only after the Vistula had been diverted towards the ice-dammed lake of Gdańsk or the Baltic, meanwhile developed into an open sea. The outwash terrace along the Brda valley not only breaks off north of Bydgoszcz, above the middle terrace of the ice-marginal streamway but it also is higher than the upper terrace of the Brda valley, which passes into the upper terrace of the ice-marginal streamway (18).

Examining the dunes of the Toruń Basin, W. Mrózek (54) determined the exact shape of the moraine island within this basin; this moraine plateau proved to be considerably smaller than had been thought so far; most important of all, this author found, emerging from under the dune covering, a terrace fragment which may be considered a continuation of the outwash terrace of the Brda, or else of its transition step within the ice-marginal streamway. Consequently, the existence of a genetic connection of the Pomeraniam stage of the last glaciation and the outwash of the Brda river with the ice-marginal streamway of the Noteć—Warta has definitely been established.

3. Relatively little research has been carried out within the ice-marginal streamway of the Noteć—Warta between the basins described above, or the dammed lakes, according to the original conception of the diluvialists. These studies comprised mostly a detailed geological mapping, made by A. Jentzsch, J. Korn, R. Cromer and other Prussian geologists, with appropriate explanations, but without any possibility of embracing problems of a larger area of the ice-marginal streamway. J. Korn (35) was the only one to describe a larger area, adjacent to the ice-marginal streamway between the Odra lobe and the Gwda river. He established the existence of a small number of minor end-moraine belts in the foreland of the Pomeranian stage, and called attention to the outwash plains of the Drawa and the Gwda. According to Korn's research, in the course of the recession of the inland ice to the line of the moraines of the Pomeranian stage, a separate glacier lobe was formed which he calls the Drawa—Gwda Lobe. Korn has demonstrated that, independently of the outwash fields connected with the Pomeranian stage, there existed, in the neighbourhood of the ice-marginal streamway, older outwash plains, resembling valley terraces (incidentally they are interpreted in this way by some investigators) and connected with nearby end moraines. This accumulation of outwash deposits has more than once been the cause of a stagnation of waters within the ice-marginal streamway and of the formation of dammed lakes of short duration.

H. H. Ost (58, 59), mentioned previously, resumed the study of outwash problems already outlined by Korn, distinguishing, near the ice-marginal streamway, pre-Baltic outwash plains connected with the adjoining phases of the recession period inland ice, and Baltic terraces, incised into the pre-Baltic plains and corresponding to the outwash plains of the Gwda and Drawa; these terraces are genetically connected with the Pomeranian (Baltic) stage. Ost describes in detail the basin-like widening of the ice-marginal streamway in the area of the Gwda mouth (the Ujście—Piła Basin or Ujście Basin), and in the area of the Drawa mouth; he assumes then to have been filled with dead ice, as ostensibly indicated by kame terraces. On the Baltic terraces, both in the ice-marginal streamway and in the basin, post-Baltic terraces were incised, and melting kettles and subglacial channels appeared.

St. Kozarski and J. Szupryczyński (37) have filled the last breach existing in the detailed description of the whole length of the ice-marginal streamway, by analyzing the terraces situated in the Noteć ice-marginal streamway, between the Toruń Basin and the Ujście Basin, and by comparing the terraces of both these basins. In the discussed section of the ice-marginal streamway they found remnants of the highest ice-marginal streamway terrace, corresponding to the outwash terrace of the Brda i. e. to the Baltic terrace of the Gwda, which represents the most ancient run-off in the ice-marginal streamway. Consequently, Kozarski and Szupryczyński also confirm the genetic connection between the ice-marginal streamway of the Noteć and the Pomeranian stage. St. Kozarski (39) resumes the problem of the terraces in the ice-marginal streamway, in the section between Ujście and Czarnków, investigating the outwash plain south of Chodzież and particularly, the end moraines in the neighbourhood of Czarnków and Chodzież. They have the character of thrust moraines, and the author regards the widening in the ice-marginal streamway adjacent to the Chodzież moraines in the north, as a terminal depression of the ice lobe, formed between the Poznań stage and the Pomeranian stage. somewhat earlier Ost expressed the same opinion. J. Szupryczyński (73) determined that obvious moraine elevations northwards bordering on the ice-marginal streamway, such as e. g. Dębowa Góra, also have the character of thrust moraines, containing floe (xenolith) of the Tertiary clays.

In order to explain the development of the ice-marginal streamway of the Noteć in the section between the Toruń Basin and the Ujście Basin, we should also take into account the important although unpublished contribution by L. Sytnik (72), concerning terraces of the Łobżonka valley, a tributary of the Noteć ice-marginal streamway south of Wyrzysk, and a similar contribution by K. Koźlińska (40) concerning the valley of the Orla, which at its mouth, joins the Łobżonka. Like the above-mentioned terraces of the Kłodawka valley near Gorzów, the terraces of both the latter valleys facilitate determination of terrace in the ice-marginal streamway.

A separate group of contributions on the ice-marginal streamway represent studies devoted to the morphology and geology of the bottom of the ice-marginal streamway. L i e b e n a u's manuscript contribution (47) written in 1885 is the first to supply information concerning a fossil valley within the ice-marginal streamway in the Bydgoszcz region, incised into Tertiary sediments and filled with Quaternary deposits. M. Ż u r a w s k i's comment (86), based on numerous cores of borings carried out in Bydgoszcz for building purposes, confirms this discovery.

On the basis of the borings, supervised by J. Pacowska and carried out in the ice-marginal streamway of the Noteć river and the adjoining moraine plateau on both its banks, near Wyrzysk, St. G a d o m s k a (12) has pointed out the existence of three layers of glacial accumulation separated by fluvial and ice-dammed lake deposits. The two upper series of glacial sediments belong to the last glaciation. The ice-marginal streamway waters connected with the Pomeranian stage of the last glaciation have cut into the complex of Quaternary and Pliocene deposits, reaching right down to the Miocene. The bottom of the ice-marginal streamway lying at 3 m. a. s. l., has been filled with ice-barrage, fluvioglacial, fluvial and organogenic sediments of a total thickness of 42.5 metres. In the Gorzów Basin, on the other hand, according to the above-mentioned research of L. P i l a r c z y k (62), the thickness of deposits, mostly Holocene, filling the bottom of the ice-marginal streamway, reaches 9 m.

On the basis of 1070 peat soundings, T. C h u r s k i (10) managed to reconstruct, between Bydgoszcz and Santok the surface of the bottom of the ice-marginal streamway from under its covering of organogenic sediments showing there alluvial cones of the Noteć and Gwda, melting formes (kettles), river cut offs and aeolian formations. Subsequently, analyzing the organogenic sediments, T. Churski indicates the gradual inundation of the ice-marginal streamway pointing out areas where stagnant waters had existed from the moment when the waters of the Vistula took a shorter northward way along the valley of the Lower Vistula.

4. From the above survey of the numerous and varied studies carried out hitherto on the ice-marginal streamway of the Noteć—Warta, a number of conclusions of a more general character may be drained.

a) K. Keilhack's dammed lake conception has definitely been overthrown; according to this concept, there existed, within the ice-marginal streamway, dammed lakes collecting both meltwater and river water, in particular the Toruń Lake and the Kostrzyń Lake. At the same time it has been found that in numerous places of the ice-marginal streamway, more particularly so in the Ujście Basin, in the mouth basin of the Drawa and in the Kostrzyń Basin, there accumulated compact masses of dead ice, preserving vast valley areas from being aggraded by material carried by the ice-marginal streamway and by outwash waters.

Consequently, differences are clearly in evidence as to the origin of various basins or widenings of the ice-marginal streamway, particularly these situated between the Toruń Basin with its numerous fluvial terraces, its relatively few melting forms, and its isolated moraine plateau on the one hand and, on the other hand, the Kostrzyn Basin with its wide valley floor, once filled with dead ice and showing relatively few terraces, the latter of which have, in the opinion of the authors above mentioned, mostly the character of kame terraces. Both the Ujście Basin and the Drawa Basin connect, in an indirect way, the features of both extreme basins representing wide-spread valley junctions.

b) It appears that the ice-marginal streamway, cutting through numerous previously formed outwash plains, forms a compact morphological unit, even though it is composed of genetically different segments. Indeed, drainage, by the ice-marginal streamway went forth in a more complicated, more evolutionary, way than had hitherto been assumed.

c) The genetic connection between the Pomeranian stage of the last glaciation and the ice-marginal streamway, through the outwash tracks of the Brda, Gwda and Drawa and a number of smaller outwash valleys, has definitely been established, and in the ice-marginal streamway the main terrace corresponding to this ice-marginal streamway (proglacial) phase has been investigated. H. Louis called this terrace „Urstromtalterrasse", H. Liedtke „Haupterrasse", H. G. Ost the Baltic terrace, R. Galon the outwash terrace, St. Kozarski and J. Szupryczyński simply the upper terrace.

d) The upper terrace of the Toruń Basin, formerly misnamed ice-marginal streamway terrace, or even considered the bottom of an dammed lake, was not formed until the waters of the Vistula already partly made their way (bifurcation!) northwards, to the Gdańsk ice-dammed lake. Therefore, this terrace is younger than the Pomeranian stage.

e) In the ice-marginal streamway there appear a considerable number of younger valley terraces, connected with terraces of subsidiary valleys of tributaries to the ice-marginal streamway, in particular the valleys of the Drwęca, Brda, Gwda, Drawa, and several smaller ones.

f) From more recent investigations of H. Liedtke it appears that the valley watershed in the ice-marginal streamway, situated west of Eberswalde, is not the result of some minor tectonic uplift (some 4 to 6 high), but concurs with the alluvial cone of the Havel river which here entered the ice-marginal streamway from the north. Thus were thwarted the arguments in favour of the previous theory, accepted also with regard to other valley watersheds on the glacial lowland, such as the watershed between the Brda and Noteć in the ice-marginal streamway west of Bydgoszcz. However, in my opinion it should be emphasized that the cone of the Havel river built near Eberswalde in the marginal streamway could in no manner be the cause of turning the waters northwards into the present-day valley of the Lower Odra river — but that it rather might be the effect brought about by this diversion.

5. May we assume that the studies of the Noteć—Warta ice-marginal streamway, as presented above, fully solve the hitherto discussed geomorphological problems, and are further investigations justified? There can be no doubt that we now posess a morphological picture of the entire ice-marginal streamway (within narrower boundaries), since St. Kozarski and J. Szupryczyński recently investigated the section of the ice-marginal streamway between the Brda and the Gwda, while H. Liedtke threw new light upon the development of the Late-Pleistocene valley junction in the area of the Kostrzyn Basin.

The below-mentioned problems, however, continue to remain unsolved, and desirable seen to be the following studies:

a) an exact investigation of the structure of the Pleistocene and Holocene terraces within the ice-marginal streamway and its tributary valleys, as well as a description of the sediments filling the bottom of the ice-marginal streamway, in order to define the successive development stages of the entire ice-marginal streamway including both its extreme valley junctions i. e. the Toruń Basin and Kostrzyn Basin,

b) further studies, whether the flow of waters in the entire ice-marginal streamway has been simultaneous with the Pomeranian stage,

c) examination of the relation between the diversion of the Vistula and the diversion of the Odra,

d) further studies on the part played by dead ice in the development of the ice-marginal streamway and of forms within this streamway,

e) investigation of the relation between the ice-marginal streamway and the geological structure of its adjoining areas,

f) determination of the importance of the ice-marginal streamway of the Noteć—Warta in the gradual drainage of the valley system on the entire Polish Lowland, both during and after the Pomeranian stage,

g) drawing an exact cartographic picture of morphological conditions of the entire ice-marginal streamway, in particular of its valley terraces.

The author of the present paper has been conducting geological and geomorphological field work in the ice-marginal streamway between Bydgoszcz and Kostrzyn for a considerable number of years, although with numerous interruptions caused by more urgent scientific activities *. In the meantime, a number of publications have appeared containing the results of new investigations, frequently coincident with the results of the author's own field work (contributions by St. Kozarski and J. Szupryczyński), while other contributions constitute a valuable supplement to the author's own research, and facilitate the discussion of a considerable number of problems (e. g., contributions published by W. Mrózek, L. Pilarczyk, T. Bartkowski).

TERRACES OF ICE-MARGINAL STREAMWAY

In the ice-marginal streamway of the Noteć—Warta there appear two kinds of terrace levels, namely terraces connected with the ice-marginal streamway waters, i. e. the run-off of fluvial and outwash waters together, thus Pleistocene terraces, and terraces connected with river drainage, i. e. Holocene terraces. These same terraces also appear in valleys tributary to the ice-marginal streamway, in particular in the valleys of the Brda, Gwda, Drawa, and in a number of smaller valleys. All the terraces in the tributary valleys are inclined towards the ice-marginal streamway, and in the ice-marginal streamway itself they incline westwards. Only within both extreme basins, especially within the Toruń Basin, the surface of few terraces is nearly horizontal. In view of the Pleistocene origin of the great valley form under discussion, and the relatively small part played by Holocene fluvial processes in the further (erosive) transformation of the ice-marginal streamway, the description of the terraces deals principally with the ice-marginal streamway terraces proper, and subsequently only with fluvial terraces.

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* In the course of my field work I have often availed myself of the help of my assistant lecturers, in particular of T. Celmer, M. Liberacki and J. Szupryczyński; to all of them I wish to express my gratitude.

ICE—MARGINAL STREAMWAY TERRACE (V) OR 18—25-METRE TERRACE

The ice-marginal streamway terrace or outwash terrace represents the highest and oldest terrace level in the ice-marginal streamway; on this level outwash waters once mixed with fluvial (Vistula) waters. Near Bydgoszcz, this terrace makes its appearance as outwash terrace of the Brda, at an absolute altitude of 80 m., breaking off above the middle terrace of the ice-marginal streamway. Here, outwash terrace has a rather erosive character. The boulder clay almost reaches the surface of the terrace built of sands with a scanty admixture of pebbles. In the ice-marginal streamway or, to be exact, in the Toruń Basin there is, at first, no continuation of this terrace level. For, indeed, the remnant of a terrace discovered by W. Mrózek, in the midst of some dunes (54) south of Bydgoszcz, at an absolute altitude of 75 m., probably belongs, contrary to views formerly held, already to the next terrace. It seems possible that the fragment of a terrace described by W. Mrózek, situated near Aleksandrów Kujawski in the ice-marginal streamway at an absolute altitude of 81 m., represents the counterpart of the outwash terrace of the Brda, and consequently represents the oldest bottom of the ice-marginal streamway seen from the Vistula. In the ice-marginal streamway west of Bydgoszcz, on the surface of the subsequent terrace, there appear small fragments of this highest terrace, first described by St. Kozarski and J. Szupryczyński (37) as an upper terrace (IV). Such remnants have been preserved at Nakło, at 77 m. a. s. l., on the northern bank of the Noteć, and near Laskownica (75 m. a. s. l.), at Borowa Góra (73 m. a. s. l.) and at Strzelce (72 m. a. s. l.), on the left bank of the Noteć. The previously mentioned remnants in the ice-marginal streamway terrace have a flat surface, in places forming slight dunes. Their relative height with regard to the subsequent terrace is approx. 5 m.

At Nakło the ice-marginal streamway terrace is built of boulder clay, on the left bank of the Noteć of stratified sands. It shows, therefore, erosive-aggrading features, similarly to the outwash terrace of the Brda.

Next we do not meet any ice-marginal streamway terrace until the Ujście Basin along the Gwda valley and, further on, already in the ice-marginal streamway, at first on the left bank of the Noteć between Ujście and Czarnków, and then already on both banks of this river; the ice-marginal streamway terrace is partly incised in the moraine plateau, and partly in older outwash plains which themselves are incised in the moraine plateau. The absolute altitude of the ice-marginal streamway terrace in the neighbourhood of the confluence of Gwda and Noteć is some 70 m. and thus, in the section from the Brda valley to the Gwda valley, the level of the ice-marginal streamway terrace has subsided by some 10 metres (compare terrace long profile, Fig. 11). The terrace under consideration downstream of the confluence of the Gwda with the Noteć is a continuation of the outwash terrace of the Gwda which from the east is joined by the Noteć ice-marginal streamway terrace. Just like the N—S section of the ice-marginal streamway below Ujście is a continuation of the outwash valley of the Gwda. It is only below Czarnkow that the ice-marginal streamway once more regains its proper E—W direction.

The geological structure of the outwash terrace in the neighbourhood of Piła is illustrated by the following three exposures.

I) Exposure in the terrace (from the top):

a) 0.85 m. sand, obviously limonitized, with numerous pebbles and gravel,

b) 1.17 m. light yellow, medium-grained sand loccally with coarse-grained sand and gravel,

c) 0.80 m. pebbles, gravel and sand with rounded grain,

d) approx. 1 m. fine-grained light-yellow sand, downwards passing into a layer of boulders (fist size or bigger, rounded) and gravel. Nearby, in the neighbourhood exposure, there lies under the above-mentioned gravel:

e) 0.50 m. stratified deposit, alternately more sandy or more silty, underlain by a layer of stone pavement,

f) light-coloured, fine-grained or very fine sand.

The layers a — d probably represent outwash deposits, while the layers, clearly contrasting with the higher layers both as to colour, size and uniformity of grain, belongs to intermoraine fluvioglacial deposits, deprived of its moraine covering due to its having been destroyed by outwash waters. In still another exposure a large boulder of 1 m. diameter has been found as evidence of the erosive action of outwash waters and of the destruction of the ground moraine.

II) Along the boundary line between the outwash sand terrace and the next (transition) terrace, the outwash terrace presents a different structure (see Fig. 1):

a) 2.5 m. outwash sands (with pebbles),

b) approx. 1 m. compact boulder clay with blocks,

c) underneath: light-coloured intermoraine sands,

resembling those described above in items e) and f). Here the moraine clay has been preserved.

In other places within the outwash terrace south of Piła, outwash material in the shape of coarse-grained sands and gravels has also been observed. On the surface of the terrace a we'l-formed fist-size ventifact has been found too.

III) The structure of the outwash terrace near Romanowo. Here was found, in downward order:

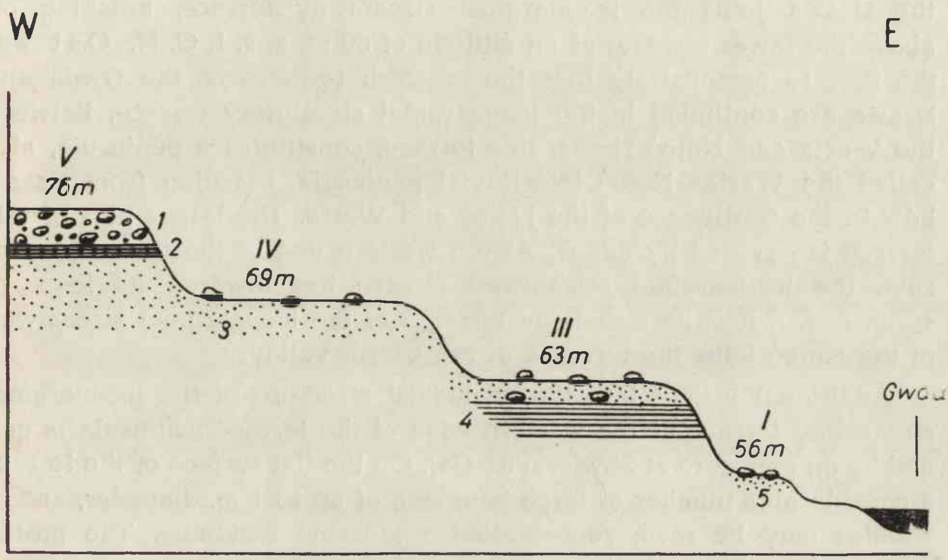

Fig. 1. Terraces of Lower Gwda valley (a terrace peninsula)

1 — outwash sands with pebbles; *2* — boulder clay; 3 — inter-moraine (fluvioglacial) sands; *4* — ice-boulders on the surface of terrace I. For Roman numerals see description on page 51.

a) 1.60 m. stratified sand and gravel, up to 3 mm. diameter, subrounded, with pebbles up to 2 cm. diameter, and larger,

b) 0.30 m. gravel, with numerous pebbles showing pavement features,

c) underneath, at 1.90 m. from the surface, there begin fluvioglacial series of coarse-grained sands. Lower still the slope reveals

d) dark-grey boulder clay.

Below the westward turn of the ice-marginal streamway, the outwash terrace appears in broad areas on both sides of the river at an al'itude from 65 to 60 m. a. s. l., reaching the mouth of the Drawa at the same level. The geological structure of the terrace of the ice-marginal streamway is illustrated by an exposure at Gulcz (65 m. a. s. l). Limonitized sand, 0,2 to 0,5 mm. diameter, wth well-rounded gravel (1 mm. and more), has been found here; pebbles of several cm. diameter also occur here. At a depth of 2.5 m. a pavement appears. On the surface of the terrace a great number of boulders and pebbles may be seen, among them a ventifact. The boundary line between the ice-marginal streamway terrace and the next, the so-called transition terrace, is indistinct.

On the lower Drawa, within the valley basin, the outwash track of the Drawa joins the ice-marginal streamway terrace, breaking off above the lower terraces at an altitude of 60 m. a. s. l. G. H. Ost was the first to demonstrate that the outwash terraces of the Gwda and Drawa are continued in the ice-marginal streamway terrace. Between the Warta and Noteć rivers, this terrace, constitutes a peninsula, also called the Warta—Noteć interfluvial peninsula, reaching from Czarnków to the confluence of the Noteć and Warta. The larger part of this terrace is covered by dunes. At the western end of the terrace peninsula, the ice-marginal streamway terrace has lowered its level to 46 m. a. s. l. It is here that the terraces of the ice-marginal streamway of the Noteć joins the terraces of the Warta valley.

Additional insight into the geological structure of the ice-marginal streamway terrace at the western edge of the terrace peninsula is gained by an exposure at Skwierzyna-Gaj. On the flat surface of the terrace a considerable number of large boulders, of up to 1 m. diameter, and of pebbles may be seen, representing a moraine residuum. The profile reveals, from top to bottom:

a) 0.70 m. coarse-grained sand with gravel and boulders, strongly limonitized,

b) 0.50 m. stratified, light yellow, coarse-grained sand and gravel, with a disconform (discordant) structure,

c) 0.10 m. compact stone pavement, rounded boulders (head size and smaller), with strongly limonitized sand.

d) about 1 m. light-coloured, fine-grained stratified sand, cut obliquely by the superimposed pavement. Dip of strata $\pm 24°$ westwards,

e) 0.10 m. layer of pavement — rounded head-size boulders,

f) 0.55 m. sand, as in layerd,

g) underneath—sand with gravel and pebbles (moist, due to proximity of impervious layer).

Close by there is a fresh brick-yard pool. In this pit, 5 m. below the surface, one can see:

2.5 m. sand gravel and pebbles — probably an ice-marginal streamway deposit corresponding to layers: a to c,

2.5 m. light-yellow sands, as in d, resting on a pavement and on large boulders np to 1 m. diameter. Underneath, as a continuation of the preceding profile:

h) typical grey and chocolate-brown varved clays exactly stratified, of 4.5 m. thickness,

i) lower cross-bedded, light-coloured sands with intercalations of silty sands.

This profile shows that the ice-marginal streamway terrace is of an erosive, or erosive-aggrading character; the layers from: *a* to *c* rest, after the destruction of the moraine layer (boulders!) disconformly on fluvioglacial sands containing lenses of varved clays (a ice-dammed lake!).

At Polichno, in the northwestern angle of the terrace peninsula, where the ice-marginal streamway terrace lies at 46 m. a. s. l., rising some 20 m. above the bottom of the ice-marginal streamway, the following strata are revealed:

a) 6 to 8 m, stratified sand, resting on a stone pavement, underlain by

b) brown moraine clay with boulders.

A similar geological structure appears in the ice-marginal streamway terrace at Lipki Wielkie, while at Brzozowiec (43 m. a. s. l.), situated west of the Warta, yellow-brown boulder clay appears directly on the terrace surface (probably partly due to the proximity of the slope), in its turn covering varved clays.

In the section between the confluence of Noteć and Warta, and of Warta and Odra, there extends the most westward part of the ice-marginal streamway terrace in the Noteć—Warta ice marginal streamway; this terrace has an altitude of but 35 m. a. s. l. on the southern bank of the Warta near Słońsk, and as little as 32 m. a. s. l. north of the Warta. It seems probable that the terrace fragment situated north of the Warta river, near its confluence with the Odra, at 31 m. altitude, already belongs to the next (transition) terrace, or to some intermediate terrace level (of erosive character). In this section too, the ice-marginal streamway terrace is, on a considerable stretch, covered by dunes which constitute a continuation of the dune field lying in the area between the Warta and Noteć rivers. Moreover, here appear numerous irregular kettle remnants after melted dead ice, particularly characteristic of this western part of the ice-marginal streamway.

In the neighbourhood of Słońsk, the outwash terrace is built of stratified sands and gravels; the surface of the terrace is mostly flat, here and there diversified by closed depressions.

The above description proves that the ice-marginal streamway terrace has a rather erosive, or else erosive-aggrading character. The thickness of fluvial sediments on the top of this terrace is no more than some 1 to 2 m., while underneath the stone pavement underlying the mentioned above fluvial sediments there appear boulder clay or fluvioglacial and ice-dammed lake deposits. In several places, boulder clay rises to the very surface of the ice-marginal streamway terrace, or moraine residues in the shape of boulders appear on the surface of the terrace. Some of these boulders lying on the terrace surface show aeolian sculpturing; this is in agreement with the climatic conditions in which the ice-marginal streamway developed, situated in the foreland of the inland ice.

In order to establish the continuity of the ice-marginal streamway terrace and to eliminate unsuitable terrace fragments from its picture, a granulometric examination of terrace sediments was made from some more important places of this terrace. These measurements were carried out by Mr. W. Stankowski in the Sedimentological Laboratory of the Geographical Institute of the Adam Mickiewicz University in Poznań. Quartz grains were analyzed, chosen from the coarsest fraction, i. e. 0.8 to 1.0 mm. diameter. From each sample one hundred grains were selected, and the index of roundness of the material was established by means of a photographic projector, according to Kuenen, by applying the formula: $P = \frac{2r}{l}$; here $2r$ denotes the diameter of a circle inscribed into the most acute corner of the grain shape, while l denotes the largest perpendicular to the long axis of the grain. The indices of roundness of the grains found in these samples are compiled in a table shown on page 53. They were obtained in the following way. Angular and semiangular grains were separated out, choosing index 300 as upper limit. From the ratio of grains with indices above 300 to grains with indices below 300, there results the mean index for the sample in question, and consequently the intensity of the degree of rounding of the deposited material. The results obtained are shown in the form of a graph (Fig. 7). From this graph it results that throughout its whole length the ice-marginal streamway exhibits a continual increase of rounding, undisturbed by amalgamation of new outwash tracks on the way. This may be considered proof of the contemporaneous existence of the outwash of the Brda, Gwda and Drawa, as well as of equal lengths of all these outwash tracks.

The relative height of the main terrace of the ice-marginal streamway varies between 25 m. for the Brda, and 20 or even 18 m. near the confluence of the Warta and the Odra, taking into consideration the water level of the Noteć and the Warta.

Where are we to look for the continuation of the ice-marginal streamway terrace in the Kostrzyn Basin and the valley of the Lower Odra? As mentioned above, the ice-marginal streamway terrace cuts its way through older outwash plains, connected with the nearby end moraines.

These older outwashes are incised in the moraine plateau too, causing them to resemble terraces within the ice-marginal streamway (for instance, the outwash plains in the N—S section of the ice-marginal streamway, downstream from the confluence of the Gwda and the Noteć, absolute altitude 74 m.); at any rate, however, due to fluvial erosion they break off above the ice-marginal streamway terrace.

The problem of the relation between the older outwash plains and the ice-marginal streamway terrace described is particularly complicated in the Kostrzyn (Küstrin) Basin. Recent research in this region, conducted by H. Liedtke (48), has shown that during the principal phase of the Pomeranian stage there was no continuous course of the ice-marginal streamway, but instead there did exist several tracks of outwashes which today break off above the Kostrzyn Basin, while once they tended towards the Warsaw—Berlin ice-marginal streamway, flowing over the surface of dead ice which filled the bottom of the Basin and further on, cutting into the moraine plateau. The meltwater of the Pomeranian stage, collected in the region of the present Lower Warta valley, flowed away southwards to the Warsaw—Berlin ice-marginal streamway, using as channels the present gap valley of the Odra, i. e. the original fluwioglacial channel, as well as some smaller valleys east of the Odra valley. The continuation of the outwash plain of the Pomeranian stage, taking its beginning near Moryń (the Moryń outwash) and breaking off near the Kostrzyn Basin, along the line Czermin—Gozdawice—Siekierki—Stara Rudnica, at altitude 57 to 58 m. a. s. l., is to be seen in the fluvioglacial channel, the later valley, called Rotes Luch, which leads to the Warsaw—Berlin ice-marginal streamway. The meltwater which accumulated in front of the end moraines situated on the valley island of Neuenhagen (east of the mouth of the Finow valley), probably also flowed away in this direction, since the present-day ice-marginal streamway section near Niederfinow must have been filled with dead ice.

It is only the outwash sands which developed in front of more westward end moraines of the Pomeranian stage, i. e. in the neighbourhood of Liepe, Chorin, Joachimstal, known as Mönchsheide and Schorfheide, that reach the ice-marginal streamway near Eberswalde at the altitude of 47 to 45 metres, breaking off, by on erosive scarp, above the bottom of the ice-marginal streamway (36 to 38 m. a. s. l.), further west aggraded by the alluvial cone of the Havel to the altitude of 40 m. a. s. l. Only south of the Finow river, erosive remnants of outwash sands, kettles and other forms originated by dead ice have been preserved. Consequently, the bottom of the ice-marginal streamway, incised in the above-mentioned outwash plain connected with the main end moraine of the Pomeranian stage, is younger than the outwash, the waters of which flowed westwards a long the oldest ice-marginal streamway; and this bottom must have been formed at a later period, i. e. after the principal phase of the Pomeranian stage.

There now arises the question at what time the ice-marginal streamway in the neighbourhood of the Kostrzyn Basin started to function in a steady manner, and which terrace level illustrate this particular phase? In accordance with the research carried out by H. Liedtke and others, the bottom of the ice-marginal streamway near Eberswalde lies at a level of 36 to 38 m. a. s. l. Since the lover most fragments of the ice-marginal streamway terrace of the Lower Warta lie at the altitude of 35 m. a. s. l., any connecting of the ice-marginal streamway terrace along the Lower Warta with the higher situated bottom of the ice-marginal streamway in the Eberswalde Gate is out of question. Similarly, the terrace remnant on the western side of the Kostrzyn Basin near Wriezen (35 m. a. s. l.) lies too low with regard to the bottom of the ice-marginal streamway near Eberswalde. One small terrace step only, near Niederfinow, on the edge of the Eberswalde ice-marginal streamway section, lies at the altitude of 32 m. a. s. l. In H. Liedtke's opinion, a tectonic uplift in this place is beyond all question. Consequently, the bottom of the ice-marginal streamway in the Eberswalde ice-marginal streamway is older than terrace of the ice-marginal streamway along the Lower Warta.

Next arises the question, what outwash plain should be looked upon as connected with the ice-marginal streamway bottom west of the Odra, situated at the altitude of 36 to 38 m. a. s. l. H. Liedtke is of the opinion that, just as in the main phase of the Pomeranian stage during the subsequent phase of glacier retreat, when the melting dead ice had lowered its level in the Kostrzyn Basin, tracks of outwashes passed over these plains, but already at a lower level. The Myśla outwash breaking above off the Kostrzyn Basin at the altitude of 40 m. a. s. l. continues on the bottom of the ice-marginal streamway of Eberswalde, at the altitude of 37 m. The outwash which breaks off over the Basin in the neighbourhood of Witnica at 42 m. altitude also continues its course in the ice-marginal streamway. West of the Odra valley there extends an outwash track coming from Angermünde and traversing the end moraine of the Pomeranian stage, after entering the Eberswalde ice-marginal streamway. This outwash plain constitutes it proper bottom, at the altitude of 36 to 38 m. Consequently, the existence of the bottom of the Eberswalde ice-marginal streamway is connected with outwash drainage of younger age than the principal phase of the Pomeranian stage.

A number of authors connect the formation of the true valley floor west of the Odra with the recession phase, of the Pomeranian stage, or the Angermünde phase, the marginal forms of which extend on Polish territory from Raduń on the Odra towards Chojna where they gradually vanish. Other authors assume an even younger recession phase. Whatever the cause, the outwash plains, older than the ice-marginal streamway terrace in the Noteć—Warta ice-marginal streamway and younger than the outwash sands of the principal phase of the Pomeranian phase, are evidence of the non-simultaneous deglaciation within the lobe of the Odra and of the lobes of inland ice further east. At the time when the Odra lobe had already considerably shrunk, the inland ice continued to occupy in the east its largest, or nearly largest, stadial area. This fact has been pointed out, among others, by H. Ost.

Consequently, the ice-marginal streamway terrace in the Noteć—Warta ice-marginal streamway, connected with the outwash terraces along the Brda, Gwda and Drawa rivers at the time of the Pomeranian stage and reaching the line of the Odra at the altitude of 32 to 35 m. a. s. l., is not continued on the bottom of the ice-marginal streamway in the so-called Eberswalde Gate, situated at 36 to 8 m. a. s. l., but must be connected with a run-off already directed northwards within the Lower Odra valley. For, indeed, the small terrace step at 32 m. absolute altitude found in the neighbourhood of Niederfinow, can only considered a short-lived trace of an exceptionally high flood of waters flowing westwards from the Noteć—Warta ice-marginal streamway, possibly due to some bifurcation.

According to German research, there appear, on the valley island of Bralitz—Neuenhagen and further along the Lower Odra a number of terrace fragments, which may be considered a continuation of the ice-marginal streamway terrace in the Noteć—Warta ice-marginal streamway (see map, Fig. 10, and long profile of terraces, Fig. 11). First of all, on the above-mentioned valley island of Bralitz—Neuenhagen a terrace surface extends at 32 m. a. s. l., considerably variegated by kettles (just as in the neighbourhood of Słońsk), and built of sands and gravels, inclining northwards and over 3 m. thick. Thus, these deposits formations correspond to those of the ice-marginal streamway, such as occur, for instance, near Słońsk.

Since long the presence of obliquely stratified sands and gravel of varying thickness resting on an erosive surface of boulder clay, has been observed in many places of the terrace field in the neighbourhood of Hohensaaten. The surface of this terrace peninsula presents a slip-off (meander) surface, variegated by kettles and falling from 30 m. a. s. l in the west to 10 m. a. s. l. in the east, on the Odra, — probably proof of a rapid subsidence of the base — level of erosion. At any rate, indistinctly terrace steps may be observed; the highest of them lying at 30 m. altitude, may be a continuation of the ice-marginal streamway terrace under discussion Finally — as mentioned by H. Liedtke — in the Randow valley, which branches off from the Lower Odra valley near Schwedt in a northwesterly direction towards the Szczecin ice-dammed lake, there appear near Blumberg on a level of about 20 m. a. s. l., remnants of a terrace, which may be considered a continuation of the terrace of the ice-marginal streamway, the oldest northward run-off of the Odra, together with the waters from the Noteć—Warta ice-marginal streamway. This is the ice-marginal streamway, called by H. Liedtke the Noteć—Randow ice-marginal streamway which, in the area of the Noteć—Warta ice-marginal streamway, was fed by meltwater rivers from the inland ice surviving, in the east, in the Pomeranian stage. In the west, on the other hand, where the Odra lobe had already retreated while meltwater collected in the Szczecin ice-dammed lake, the combined waters of the Odra, flowing from the south, and the ice-marginal streamway waters from the east, already flowed northwards in an ancient subglacial channel, as ice-marginal streamway, into an ice-dammed lake, from which they escaped westwards through one of the Mecklenburg ice-marginal streamways *.

To this same phase of development belongs the terrace lying at 35 m. altitude, adjoining the western side of the Kostrzyn Basin near Wriezen, resembling a kame terrace. So far it has proved impossible to connect this terrace with the higher-lying bottom of the Eberswalde ice-marginal streamway (36 to 38 m.). H. Liedtke has explained that the Wriezen terrace already belongs to the phase of the Noteć-Randow ice-marginal streamway, and that if represents the bottom of the oldest northward flowing waters of the Odra.

The author of the present paper has had the opportunity ** of examining the more important exposures in the ice-marginal streamway terrace on German territory, and to express his viewpoint as to German opinions particularly those of H. Liedtke concerning the run-off of ice-marginal streamway waters northwards and, subsequently, along the valley of the Randow. On the above mentioned terrace peninsula at Hohensaaten, in a gigantic gravel-pit, located in the area of the ice-marginal streamway at approximately 30 m. a. s. l., the following deposits appeared:

* Probably through the Mecklenburgisch-Pommersches Grenztal.

** During an excursion to the German Democratic Republic, from August 26th to September 6th, 1960.

a) 2 m. fluvial sand with gravels and boulders,

b) 0.5 m. residual moraine pavement,

c) fluvioglacial deposits, comprizing unequigranular sands stratified alternat ly horizontally and obliquely.

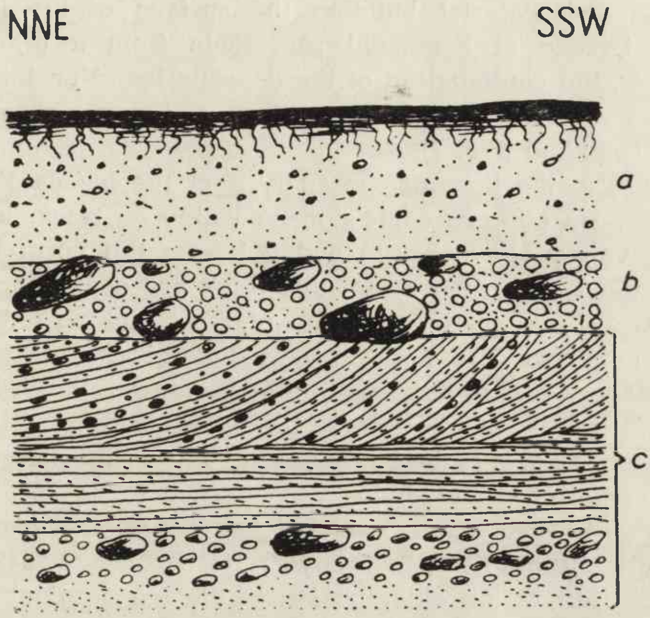

Fig. 2. Exposure in ice-marginal streamway terrace in the Randow valley in the neighbourhood of Bagemühl (German Democratic Republic)

a — unequigranular with preponderance of coarsegrained sands; *b* — boulder pavement in form of well-rounded boulders, up to 20 cm dia; *c* — discordantly underneath pavement, series of stratified sands interbedded by layer of gravel

A similar erosive character shows the most distant fragment of an ice-marginal streamway terrace, situated at Bagemühl in the Randow valley (approximately 20 kilometres north of the terrace fragment at Blumberg). On the flat wooded surface of this terrace (approximately 18 m. a. s. l., see long profile of terrace, Fig. 11) we note, on first sight, collected heaps of larger boulders. In this exposure appears (Fig. 2):

a) 0.5 m. unequigranular sands, with prevalence of coarse-grained sands in lower part,

b) 0.3 m. coarse gravel with boulders (up to 20 cm. diameter). The material is well rounded. Between sands and pavement there is a clearly marked erosive surface,

c) fluvioglacial deposits, intercalated by a 15 cm. layer of gravel with boulders.

In both exposures described above we note traces of a north-wards flow of ice-marginal waters along the Lower Odra valley and, further on, the Randow valley. These waters have incised in the moraine plateau. Their deposits rest on a series of fluvioglacial sediments, deprived of the hanging covering of boulder clay. A remnant of the latter consists of a stone pavement laid down between the ice-marginal streamway (fluvial) deposits and a series of fluvioglacial deposits.

The aggraded material building the surface of the ice-marginal streamway terrace at Bagemühl represents from a granulometrical point of view, the continuation of the deposits found on this terrace in the Noteć—Warta ice-marginal streamway, and shows a corresponding increase in rounding (Fig. 7).

Ultimately, in the light of our analysis of the ice-marginal streamway terraces, we observe a Pleistocene valley — track, beginning in the Vistula valley above Toruń and fed from the north by outwash terraces of the Pomeranian stage; this track proceeds, along the Odra and Randow valleys, in the direction of the shrinking Odra ice lobe. On the section from Toruń, where the ice-marginal streamway terrace appears at 81 m.a. s. l., to Bagemühl in the Randow valley, where, so far, the lowest fragments of this terrace have been determined at the altitude of some 18 m. a. s. l., the bottom of the ancient ice-marginal streamway falls 63 m. which, assuming the distance to be 458 km., equals a gradient of 1 : 7270. After reducing the Toruń—Bydgoszcz section, with its negligible gradient, the above ratio becomes 1 : 6420.

The traces left of the older phases of the ice-marginal streamway, mostly represented by outwash plains, are survived in the area of the higher-lying Eberswalde ice-marginal streamway, west of the present-day Odra. In the Warta ice-marginal streamway, east of the present-day Odra, there are elevated outwash tracks, breaking off above the ice-marginal streamway. These outwashes undoubtedly once fed the ice-marginal streamway, flowing westwards, towards the Eberswalde Gate, and southwards, into the Warsaw—Berlin ice-marginal streamway. Probably, from this same period are derived the outwash plains which extend in the Warta ice-marginal streamway along its southern side at a level higher than the ice marginal streamway terrace (see geomorphological map, Fig. 10).

TRANSITIONAL ICE-MARGINAL STREAMWAY TERRACE (IV), OR 15—22-METRE TERRACE

The author's field investigations revealed along the Lower Brda valley a terrace surface, cut direct in the outwash terrace which, as described above, is continued in the ice-marginal streamway terrace. This terrace, called terrace X, first appears for the first time north of

Koronowo, on the right bank of the Brda river, at 88 m. a. s. l.; even so, it seems quite possible that once this terrace has extended further upstream the Brda river. It clearly shows an erosive character. Near the ice-marginal streamway, the relative height of this terrace with regard to the Brda is 34 m. The X terrace, cut in the outwash terrace of the Brda, represents the phase of the forming of a fluvial run-off on the previous outwash track running along the present-day Brda valley, during the period preceding the northward diversion of the Vistula waters to the Gdańsk ice lake. Hence the term transition terrace.

In his paper on the outwash plain and the valley of the Brda (18), the author was inclined to connect the terrace level of 75 m. altitude, partly revealed from under its dune covering in the neighbourhood of Trzciniec south of Bydgoszcz, with the outwash terrace of the Brda. However, in view of hypsometrical and granulometrical considerations, it seems more probable that this is rather a remnant of a transition terrace eroded in the area of the Toruń Basin, a terrace which has survived in numerous places in the Noteć—Warta ice-marginal streamway. The same applies to the terrace remnant of 77 to 78 m. a. s. l., situated north of Toruń in the neighbourhood of Lulkowo. The largest compact area of the transition terrace, of an absolute altitude of 70 m., extends westwards in the immediate neighbourhood of the Toruń Basin, along side of the Noteć river from the region where it enters the area of the ice-marginal streamway (see map Fig. 10 and long profile of terraces, Fig. 11). In this region this terrace is situated barely 2 to 3 m. above the next terrace, called the upper terrace, which occupies the better part of the Toruń Basin and which, in view of its negligible gradient, was previously considered the bottom of the Toruń dammed lake. There can be no doubt, however, that the 70-metre surface south of Nakło is older than the terrace mentioned previously, if for no other reason than the fact that the 70-metre terrace constitutes the immediate morphological base of the remnants of the ice-marginal streamway terrace, described by St. Kozarski and J. Szupryczyński (37). However, as shown by the author (18) terrace IX of the Brda valley is the first that can be correlated with the upper terrace of the ice-marginal streamway (Toruń Basin), and, at the same time, with the upper terrace of the Lower Vistula valley. A fragment of this terrace, erosively incised in the transition terrace, of 67 m. absolute altitude, appears at Paterek, on the southern side of the ice-marginal streamway. In this respect the author's views differ from those of St. Kozarski and J. Szupryczyński, who connect 70-metre terrace from the neighbourhood of Nakło which they call the middle terrace, with terrace IX in the Brda valley and the Lower Vistula valley.

As mentioned before, the transition terrace occupies a considerable area in the ice-marginal streamway section between Nakło and Wyrzysk, reducing its altitude from 70 to 65 m. a. s. l. This terrace is mostly found south of the Noteć, noticeable on the northern bank of this river only by small steps. The terrace islands westwards of Nakło, in the neighbourhood of Jadwiżyn, already belong to the next terrace level. The surface of the transition terrace on which boulders as well as finer material occurs, shows a considerable number of shallow (kettles) the largest of which is a peat-filled depression in the neighbourhood of the Sipiory village. Numerous lakes occuring in this terrace have been investigated by both the above-mentioned authors; they ascribe the origin of these lakes to kettles formed by melting dead ice. Here and there on the transition terrace surface appear flat elevations of several metres' height (Polichnowo, Nadolnik); they seem to be wasted remnants of the terrace mentioned above, i. e. the ice-marginal streamway terrace. Moreover, on this terrace numerous dunes * may be observed, concentrated particularly south of Nakło and east of Sokolec.

In many places of the edge of the transition terrace layers of stratified coarse gravel and pebbles of fluvioglacial origin appear. The thickness of these fluvioglacial deposits often exceeds 10 m. Occasionally boulder clay occurs in the edge of this terrace, e. g. along the Paterek—Kowalewko road, or at Polichnowo, where gravel and boulders lie on the clay. On the other hand, at Józefkowo and Mieczkowo appear beneath a layer of sands, underlying by a residual, locally stratified stone pavement, fluvioglacial sands of varying bedding. At Paulina, remnants of moraine clay rest with boulders on the above fluvioglacial series. At Szamoty near Szamocin, on a level of 67 m. a. s. l., terrace sands cut off a layer of varved clay and, farther away from the edge, of moraine clay containing aggradation pockets. Similarly, at Strzelce (north of Wyrzysk) the transitional terrace is built of moraine clay.

In accordance with the opinion expressed by St. Kozarski and J. Szupryczyński, who in their contribution give a similar description of the transition terrace (which they call the middle terrace) in the discussed valley section it should be stressed that this terrace, in common with the higher situated ice-marginal streamway terrace, is incised in Pleistocene deposits consisting either of moraine clay or of fluvioglacial sands (and varved clays) covered by remnants of moraine clay or by residual stone pavement. These deposits are overlain by a layer of fluvial sands of approximately 1 metre thickness. Consequently, in the

* These dunes have been described by C. Irla (24).

Nakło—Wyrzysk section the transition terrace reveals the feature of a cut-and-fill terrace.

In the Ujście Basin the transition terrace recedes farer away. It has been identified in remnants appearing west of Dziembówko, on the outwash terrace of the Gwda river and in the eastern side of the Basin, as well as south of Piła next to the western part of the Basin, near Wrzącko. At any rate, the transition terrace accompanies the outwash terrace of the Gwda, just as it does the outwash terrace of the Brda, at a level lower by 7 to 11 m. (see map, Fig. 10). On the edge of the transition terrace (64 m. a. s. .l) of Dziembówko, the profile is as follows (Fig. 3):

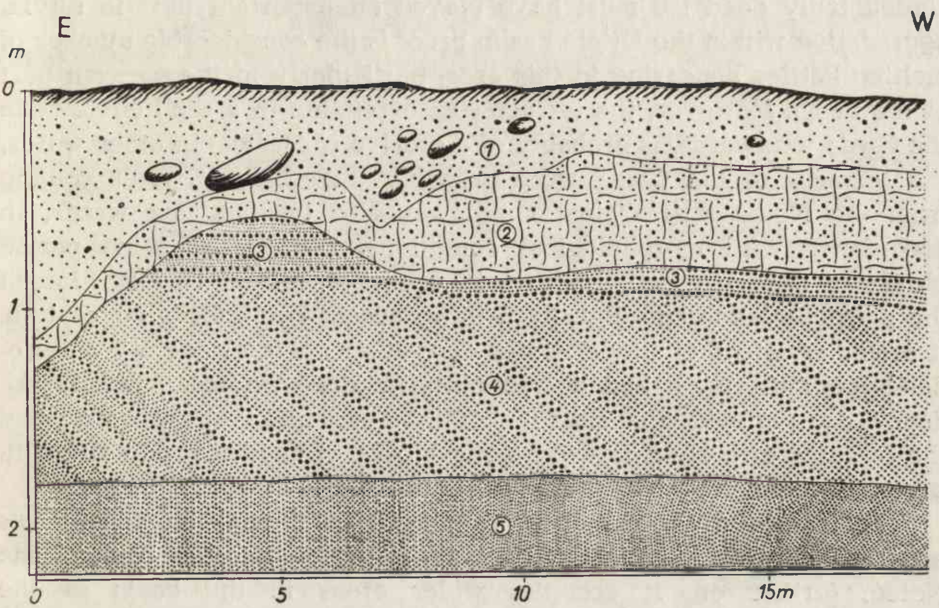

Fig. 3. Exposure in ice-marginal streamway transition terrace at Dziembówko (east of Piła)

1 — cover sand and residual deposits after erosion of boulder clay. Accumulation pockets; 2 — glacial clay; 3 — stratified fluvioglacial sands of various fractions; 4 — fine-grained sand with intercalated layers of coarse-grained sand — dip 32°S; 5 — sandy silt

a) cover sand deposits, erosion remnants of boulder clay, with blocks and aggraded pockets,

b) 0.60 m. boulder clay, with stone pavement at bottom,

c) 0.50 m. horizontally stratified fluvioglacial sands, obliquely cutting the underlying,

d) stratified and inclined silt layers,

e) horizontally stratified silts.

The above-mentioned silt layers have probably developed in the large ice-dammed basin, in which were also deposited although further westwards, the Piła clays (see description below). In the transition terrace, at Piła (Fig. 1), under a thin cover of sands with pebbles, there appear light-coloured inter-moraine sands. Thus here also the transition terrace is incised in older Pleistocene deposits.

At Stoba (south-west of Piła) and at Wrząćko there appear flat surfaces with well-marked step at the altitude corresponding to the transition terrace (65 and 63 m. a. s. l.), In exposures we note sands, gravel and even pebbles. According to H. G. O s t (58), these are came terraces aggraded by waters which, on one side, were walled in by dead ice. Undoubtedly dead ice must have played an important part in fluvial aggradation within the Ujście Basin; proof is the considerable number of melting kettles appearing in this area, particularly in the western part of the Basin. However, the terrace step extending in a semi-circle from the Gwda westwards, is probably of a erosive character; in other words, the terraces of the Gwda were probably undercut by water coming from the Noteć ice-marginal streamway and turning southwards, in accordance with morphological conditions. During the same period blocks of dead ice melted which, in consequence, led to distortion of the previous landscape. But, even if we accept H. G. Ost's conception, it seems certain that fluvial water depositing material against walls of dead ice must have had a free outflow, since no ice-dammed lake deposits are in evidence. Thus it should be assumed that the waters had the features of a river flowing along blocks of dead ice, depositing in a normal manner part of the material transported.

The transition terrace once more appears though indistinctly, as a narrow terrace remnant, at 60 m. a. s. l., on the right bank of the Noteć; further on, it occupies wider areas in the basin of the Lower Drawa. Near Gulcz (west of Czarnków), the ice-marginal streamway terrace, here at 65 to 63 m. a. s. l., shows an indistinct transition into a 58 m. a. s. l. terrace which subsides to 50 m. a. s. l. near the confluence of Drawa and Noteć. This indistinct interterrace step was known to German geologists already; in mapping the region of Krzyż and Wieleń they called it an outwash step. H. G. Ost distinguishes an external and an internal Baltic terrace; however, he erroneously considers the internal Baltic terrace; in our present terminology the transition terrace, to be ice-marginal streamway terrace proper.

A transition terrace also shows along the Drawa river accompanying, similarly as on the Brda and the Gwda, the Drawa outwash terrace (see map, Fig. 10) and occupying additionally the western part of the estuary basin of the Drawa, at the altitude of 56 to 51 m. a. s. l. The morphological map shows that waters flowing at the level of the transition terrace, partly undercut the outwash terrace, and partly also the moraine plateau with its end moraines. The previous continuity of the transition terrace east of the Drawa river was interrupted by the melting of blocks of dead ice which must have been existed in the substratum of the transition terrace. Evidence of the presence of dead ice in this period is the characteristic lobate shape of younger terraces throughout the area of the basin, first observed by H. G. Ost. In the basin west of the Drawa river the surface of the transition terrace was incised by tributaries of the Drawa and by the latter river itself, at a time when its mouth section was situated farer westwards than it is today. South of the Noteć river, facing its confluence with the Drawa river, the transition terrace forms, together with the next terrace, a clearly noticeable terrace island.

Within the area of the mouth basin of the Drawa, the geological structure of the transition terrace, has been identified in numerous places. Near Gulcz and Rosko,in the region where at 58 m. a. s. l. this terrace departs from the ice-marginal streamway terrace the edge of the transition terrace is built, right up to its top, of boulder clay. In the Rosko—Stępy section (57 m. a. s. l.) the boulder clay is overlain by a covering of sand mixed with scanty gravel, of some 2 m. thickness, and of a distinctly visible stone pavement. Near the Wieleń railway station, in the edge of an altogether flat terrace (55 m. a. s. l.), brown boulder clay also appears under a layer of sand with gravel and pebbles. On the other hand, at Drawsko, on a terrace island (50 m. a. s. l.), terrace sands of 1 m. thickness are cutting across underlying obliquely stratified fluvioglacial sands, while at Drawiny, on a terrace island (above 50 m. a. s. l.) situated northwestwards from Krzyż, in the terrace edge there is exposed a 4 m. layer of stratified sand with pebbles and boulders resting on varved clay. Thus, identically as in the Ujście Basin, the transition terrace has shows here too an erosive, or cut-and-fill (erosive-aggraded) character.

Further west, downstream, the transition terrace vanishes. Its counterpart in the Warta valley above Skwierzyna, thus before the Warta Valley enters the Noteć—Warta ice-marginal streamway proper, is a terrace of 42 m. a. s. l. altitude, also gradually vanishing downstream, but extending considerably up the Warta river; here the transition terrace accompanies the ice-marginal streamway terrace which, as described above, occupies the better part of the interfluvial area between the Warta and Noteć rivers. In the Gorzów Basin the transition terrace has probably been destroyed by meander erosion of the Warta flowing on the level of the next valley terraces. Only at Hohensaaten, at the beginning of the Lower Odra valley, (see description of ice-marginal streamway terrace on page 27) we notice, on the terrace peninsula, a meander level of 22 m. a. s. l., which in my opinion may be considered a continuation of the transition terrace (see long profile of terraces, Fig. 11), just like, further north, a terrace remnant near Blumberg, in the Randow valley, at 13 m. a. s. l. altitude. Consequently like the ice-marginal streamway terrace, the transition terrace uses the valley track of Noteć—Warta—Lower Odra—Randow, and represents the run-off of the first fluvial waters on the outwash plains east of the Odra lobe and, at the same time, of the waters of both Vistula and Odra. This run-off, preceding the northward diversion of the Vistula, continued to make its way along the Mecklenburg ice-marginal streamway* towards the Baltic ice lake, in view of the fact that in the mouth region of the present-day Odra the inland ice was still receding.

Taking into consideration the whole length of the transition terrace, from the neighbourhood of Bydgoszcz in the Toruń Basin (74 m. a. s. l.) to the remnant of this terrace near Blumberg in the Randow Valley (13 m. a. s. l.) it should be pointed out that, over a distance of approximately 388 km., this transition terrace falls 61 metres or, almost exactly, as much as the fall of ice-marginal streamway terrace (60 metres).

Within the area of the Noteć ice-marginal streamway the relative height of the transition terrace gradually increases, from 15 m. in the neighbourhood of Bydgoszcz—Nakło to 22 m. in the mouth basin of the Drawa. On the terrace peninsula of Hohensaaten this height is 20 m.

The granulometric analysis of the deposits of the transition terrace (within Polish territory), carried out by W. Stankowski in the Sedimentological Laboratory of the Geographic Institute of the A. Mickiewicz University in Poznań (Fig. 7), shows the degree of rounding of the grains to be more intensive and to increase more rapidly than that of the material laid down in the ice-marginal streamway terrace. At the same time, however, there may be observed an abrupt decrease of grain rounding at the mouth of the Gwda which supplied new outwash material. Evenso, further westwards the rounding of grains transported by ice-marginal streamway waters, increases again.

* Called Mecklenburgisch-Pommersches Grenztal.

UPPER TERRACE (III)
OR 10—12-METRE TERRACE

The upper terrace is of considerable extent in the Toruń Basin, showing a remarkably low gradient and a mean altitude of 70 m. a. s. l.* To be sure, near the mouth of the Drwęca we observe on this terrace altitudes of 72 m. and more; on the other hand, along the Bydgoszcz Canal, more particularly so in the peninsular narrowing of the terrace east of Nakło near Występ, we find altitudes of barely 67, and even as little as 65 m. a. s. l. Still these numbers are by no means convincing

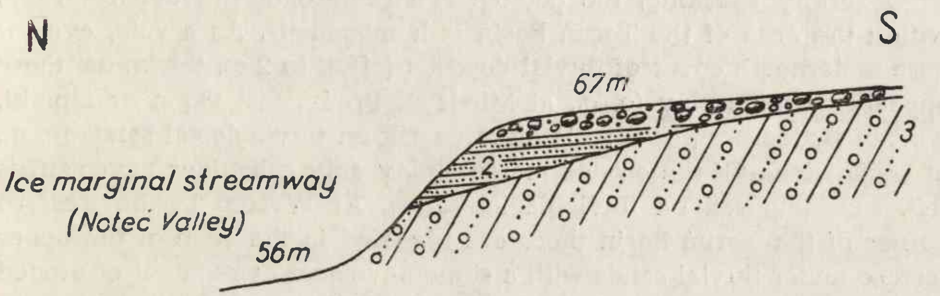

Fig. 4. Exposure in upper terrace at Paterek (south of Nakło)
1 — residual cover deposit (boulders, gravel); 2 — light-yellow stratified sands; 3 — brown glacial clay

evidence of a lowering of the terrace, since its surface, almost exclusively built of sands, is, as a rule, wind-eroded, while near Występ we observe a degraded interfluvial surface. The negligible gradient of the upper terrace in the Toruń Basin gave rise to the assumption of an dammed lake in this area (Keilhack). The present author made an attempt of explaining this fact as the effect of negligible lineal erosion brought about by division of the river course due to the existence of a valley island (13). By comparison with conditions in the Kostrzyn Basin, H. Liedtke ascribed the slight gradient of the upper terrace within the Toruń Basin to alluvial cones of numerous small rivers issuing into the Basin. I admit that aggredation of the Lower Brda within the area of the Toruń Basin may have contributed to a gradient reduction of the upper terrace. Moreover, the bifurcation of the Vistula waters occurring at the level of this terrace (17), undoubtedly caused a lessening of fluvial erosion and a local increase in fluvial aggradation therebay contributing to a reduction of gradient of the upper terrace in the Basin in the neighbourhood of Bydgoszcz. It may also be assumed that bifur-

* The terraces of tributary valleys issuing into the ice-marginal streamway will be described in the next chapter.

cation took place in the northern branch of the ancient Vistula. The southern branch of the river, on the other hand, unimpaired by the bifurcation, reached the narrow section in the ice-marginal streamway along the course of the present-day Noteć valley at a somewhat lower level, as shown by the altitude of the step in the upper terrace at Paterki, south of Nakło (67 m. a. s. l.) several metres lower than the mean altitude of the upper terrace in the Toruń Basin. Consequently, the origin of the exceptionally slight gradient of the upper terrace in the Toruń Basin presents an intricate problem; its solution requires special investigations, among others granulometric examination too.

Generally speaking, the geological structure of the upper terrace within the area of the Toruń Basin is homogenous. As a rule, everyw here underneath cover of fluvial deposits (of up to 2 m. thickness) there appears moraine clay (e. g., at Miedzyń, Prądy, Lisi Ogon or Lipniki, west of Bydgoszcz), or it rests discordantly on fluvioglacial sands (e. g., at Łochowice). Of the eroded moraine clay only a boulder pavement is left, superimposed on fluvioglacial sands. At Występ in the western corner of the Toruń Basin there are revealed in the edge of the upper terrace under fluvial sands with a stone pavement as remnant of eroded moraine clay, fluvioglacial sands of 4 m. thickness, underlain by grey moraine clay.

In the western part of the Toruń Basin, resembling the neighbourhood of Toruń, the surface of the upper terrace is flat or gently undulating. In it occur flat valley depressions extending southwestwards towards the ice-marginal streamway. The hummocks mutually separating these depressions seem to be superimposed forms, built of glacial clay or of sands with boulders. In many places where valley sands have been eroded, clay appears on the surface together with numerous boulders resting on it. In other places where the cover of river sands has been preserved, numerous dunes developed. Moreover, on the surface of the upper terrace frequently melting forms appear, filled, at times, by lakes (such as the Jezuickie Lake, south of Bydgoszcz), and particularly concentrated on the peninsula of the upper terrace in the western corner of the Toruń Basin where, due to intensified degrading processes, terrace sands are lacking, and moraine clay forms the terrace surface on wide areas.

The landscape features described above made P. Sonntag (70) erroneously interpret the formations observed near Łochowice as end moraines. There can be no doubt but that the upper terrace of the Toruń Basin shows an erosive, or a cut-and-fill character; this has been clearly pointed out in previous contributions (13, 16, 17). A ground moraine island within the upper terrace south of Bydgoszcz, definitely localized by W. Mrózek (54) at 85 m. a. s. l. represents the non-eroded surface of moraine deposits, into which Vistula waters flowing at the level of the upper terrace and, before this ice-marginal streamway waters, have cut their bed.

Westwards of the narrowed stretch of the ice-marginal streamway near Nakło, the upper terrace shows on both sides of the valley in remnants only. As described above, the main terrace level, down as far as the Ujście Basin, is the ice-marginal streamway transition terrace. A clearly discernible fragment of the upper terrace appears at Paterek (south of Nakło) at 67 m. a. s. l. This exposure shows the geological structure of the entire terrace, right down to the level of valley peat (Fig. 4). A top layer, 0,50 m. thick, of cover material (boulders, gravel etc.) lies on light-yellow stratified valley sands resting on brown moraine clay. On the terrace plain we observe an extensive depression without superficial drainage. Piled up on field boundaries are stone heaps containing blocks of 1 m. diameter. Thus, the upper terrace continues here to show an erosive character.

On the northern side of the ice-marginal streamway, near the junction of Łobżanka and Noteć, we observe at 65 m. a. s. l. two islands of the upper terrace. They are typical meander islands with a flat surface, covered by a coniferous forest; boulders may be seen on the surface of the terrace. St. Kozarski and J. Szupryczyński (37) have erroneously assigned these terrace remnants to their so-called central terrace, i. e. the transition terrace according to the terminology of this paper. Here, the profile is as follows:

a) 0.90 m. strongly limonitized sand with numerous rounded boulders of various sizes,

b) 0.30 m. coarse-grained sand (0.4 mm. diameter) at the bottom of this layer — a residual boulder pavement,

c) lower down — light-coloured fluvioglacial sands.

Minor islands of the upper terrace also occur on the bottom of the ice-marginal streamway near Milcz, northwest of Chodzież (60 and 59 m. a. s. l.) erroneously considered by German scientists to be remnants of end moraines. Neither do I agree with the two authors mentioned above, who assign the Milcz terrace islands to the level of the upper terrace level, i. e. to their middle terrace.

In the section between the narrowed stretch of the ice-marginal streamway near Nakło and the next narrowing issuing into the Ujście Basin, the upper terrace subsides from 67 m. (Paterek) to 59 m. (Milcz), all along this section showing the character of an erosion terrace, covered by a thin series of fluvial deposits. As to the interpretation of the terrace remnants in this section I disagree with both the above mentioned authors as emphasized above. I have pointed out before that in this section these authors distinguish an upper terrace corresponding to the ice-marginal streamway terrace in my present paper, a middle terrace corresponding to the transition terrace, and a lower terrace the ostensible counterpart of my upper terrace.

In my opinion the lower terrace distinguished by both these authors corresponds to the next terrace (see description on page 49-50), which subsides from 60 m. a. s. l. near Polichnowo (southwest of Nakło) to 55 m. a. s. l. in the neighbourhood of Chodzież. In their description and classification of terraces, these authors have omitted the upper terrace under discussion and made it part of their middle terrace which, in the present paper, corresponds to the transition terrace.

In the Ujście Basin, the upper terrace of the ice-marginal streamway appears along the Lower Gwda only in the shape of small but clearly noticeable terrace remnants, which are a continuotion of the corresponding terrace of the Gwda valley. The geological structure of the upper terrace may be traced on the terrace peninsula east of Piła in profiles of brickyard pits. These profiles reveal (see Fig. 1):

a) 0.80 m. yellow, coarse-grained sand with boulders on the flat surface of the terrace a residual stone pavement it visible, — thus is clearly an erosive terrace!
b) further down — light-coloured, even-grained intermoraine sands.

Nearly, in a brickyard pit, under sands with boulders and a pavement (of a total thickness of 2 m.) there appear dark, indistinctly stratified or non-stratified, silty ice-dammed lake clays. The surface of these clays is smooth but slightly sloping; and their top layers part disclose glaciotectonical disturbances. Similarly, on the eastern bank of the Gwda, where an older outwash plain and the outwash terrace meet, we also observe in the slope of the upper terrace, a compact, grey ice-dammed lake clay, covered by a 3 m. layer of sands with boulders.

The erosive character of the upper terrace is also in evidence in the continuation of the ice-marginal streamway beyond the Ujście Basin, at Walkowice (58 m. a. s. l.), where moraine clay or light — coloured fluvioglacial sands reach up to the surface of the terrace. Further down the ice-marginal streamway, the upper terrace appears also on the right bank of the Noteć, at Kuźnica Czarnkowska (55 m. a. s. l.) where it built of sands and gravel. It is only in the Drawa Basin that we meet with larger fragments of the upper terrace, a counterpart of a corresponding terrace of the Drawa valley penetrating the Basin at from 53 to 52 m. a. s. l. The upper terrace constitutes the southern part of a terrace island, situated south of the confluence of Drawa and Noteć

(46 m. a. s. l.). On the surface of this terrace there appear coarse-grained sands with numerous boulders.

Further westwards there extends a larger area of the upper terrace (43 m. a. s. l.), adjoining the ice-marginal streamway terrace south of Drezdenko. Only at Murzynowo (35 m. a. s. l.) where the upper terrace is observed at the mouth of the Warta valley into the Noteć—Warta ice-marginal streamway, the geological structure of this terrace is revealed in an exposure at the local brickyard. The profile is here as follows (Fig. 5):

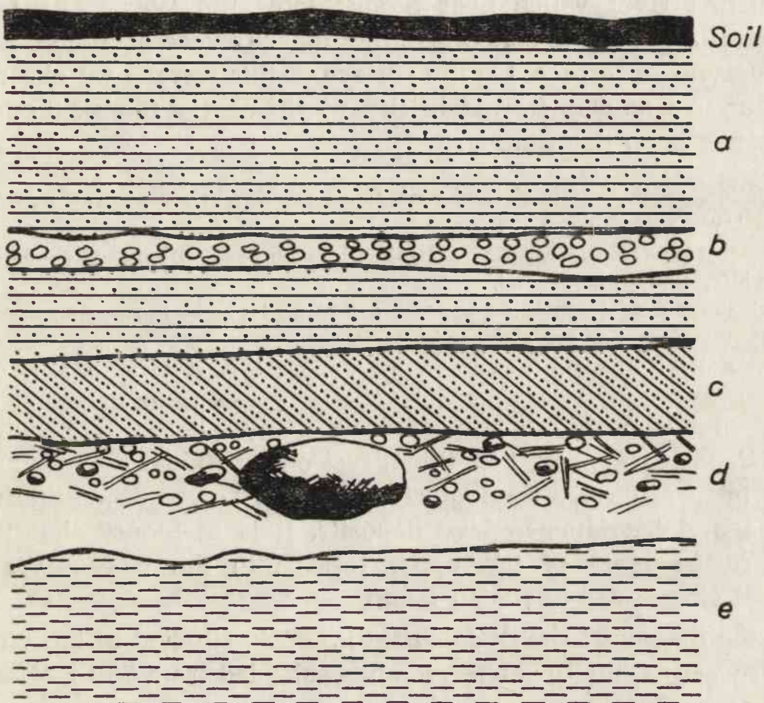

Fig. 5. Exposure in upper terrace in the Murzynowo brickyard (south of Drezdenko)

a) 1.5 m. horizontally stratified, light-yellow fluvial sands,

b) 0.20 m. small boulder pavement with lumps of transformed clay,

c) 1.5 m. of cross-bedded light-yellow fluvioglacial sands, mainly horizontally stratified in their upper part,

d) lower down — a layer containing pebbles strongly limonitized sands and gravel diagonally-bedded and numerous erratics, 1 m. and more in diameter, relicts of eroded moraine clay,

e) thick-laminated dark clay. Stratification horizontal.

On the right bank of the Warta, below the junction of the Warta valley with the Noteć—Warta ice-marginal streamway, near Brzozowiec (32 m. a. s. l.), the upper terrace with a flat surface is built of coarse-grained sand with numerous larger residual boulders (of up to 10 cm. diameter).

In the Gorzów Basin, the upper terrace has survived in the region of Słońsk (24 m. a. s. l.) in the shape of a triangle, produced during successive phase of terrace erosion by meanders of the Warta river flowing there at a lower level. Against the upper terrace lean lower terrace levels in the shape of small fragments or alluvial cones of the Krzemienna river which near Słońsk joins the Warta. As far as its geological structure is concerned, the upper terrace at Słońsk resembles the Murzynowo terrace. On the surface of this terrace we observe erratics of up to 1 m. diameter. In brickyard pits east of Słońsk the following profile has been determined:

a) yellow medium-grained sand with small pebbles below passing into,
b) a layer of boulder pavement,
c) fine gravel, downward passing into coarse gravel with fist-size boulders,
d) white, fine-grained sand,
e) at about 6 m depth there appears a 0.60 m. layer of brown moraine clay,
f) light yellow fine-grained sand,
g) at a depth of some 9 m. below the surface, i. e. at 15 m. a. s. l., grey clay.

The above profile is repeated in many places. Everywhere the fluvial deposits (approx. 1 m. thick) rest on a residual boulder pavement which, in turn, covers fluvioglacial deposits. Lower down there appear moraine and ice-dammed lake deposits. It is at Słońsk that the most westward fragment of the upper terrace in the Noteć—Warta ice-marginal streamway has been found.

On the distance from Bydgoszcz to Słońsk, situated in the vicinity of the Odra valley, the upper terrace has subsided from 70 to 24 m. a. s. l. i. e. a. decline of 46 m.

The relative height of the upper terrace oscillates between 12 m. in the neighbourhood of Nakło and 16 m. at the mouth of the Drawa; further on, it gradually decreases reaching 10 m. west of Kostrzyn.

In the Noteć—Warta ice-marginal streamway, the upper terrace shows a predominantly erosive character. The thickness of the fluvial deposits laid down on eroded Pleistocene sediments is, on an average, 1 to 2 m. Granulometrical analyses of the upper terrace deposits, carried out by W. Stankowski (Fig. 7), reveal the degree of rounding of the grains to be similar to that on the transition terrace. From the outwash plain or from the adjacent ground moraine, into which they are incised, the waters of the Gwda carry less rounded material. Gradually only, and along the bottom of the ice-marginal streamway already, the degree of rounding increases; after receiving the waters of the Drawa, which carries a load of less rounded material, no increase in rounding of the grains is observed.

The upper terrace of the ice-marginal streamway hitherto discussed is most closely connected with correlated terraces in the valleys of the Drwęca, Brda, Gwda and Drawa, and of smaller rivers (see the next chapter). It seems worth investigating how the upper terrace continues westwards, in the Kostrzyn Basin and in the Lower Odra valley. Conforming the results of P. Woldstedt's field studies, H. Liedtke discovered, on the terrace island of Bralitz—Neuenhagen, an erosive terrace at altitude of 16 m. a. s. l.

Fig. 6. Exposure in upper terrace at Meyenburg in Lower Odra valley (German Democratic Republic)
a — fine and medium-grained sands, with blurred horizontal lamination; *b* — gravels with pebbles, and rounded boulders, faibly visible horizontal bedding; *c* — fine and medium-grained sands, stratified, with varying degree of dip

A similar height shows this terrace on the eastern, Polish bank of the Odra, at Osinów Dolny, where it is incised in moraine clay containing numerous boulders and underlain by a series of fluvioglacial sands and gravels. Its counterpart is the meander-built terrace plain discovered on the terrace peninsula at Hohensaaten (15 m. a. s. l.). Further north, in the neighbourhood of Schwedt, terrace remnants with kettle depressions appear, described by P. Woldstedt (79). It is here that the Randow valley parts from the present-day Lower Odra valley. The terrace level investigated by us has here an altitude of 10 to 13 m. a. s. l., both in the Randow valley and in the Lower Odra valley, north of Vierraden. It is therefore, a b i f u r c a t i o n level, proving the simultaneous flow of the combined river waters along both the Randow valley and the Lower Odra valley. Over the distance of 380 kilometres which separates the neighbourhood of Bydgoszcz from the region of

Schwedt in the Lower Odra valley, the upper terrace has subsided 58 m.; thus taking into consideration the somewhat farer distance of the lowest points of both the ice-marginal streamway terrace and the ice-marginal streamway transition terrace, their relative difference in height is the same as that of the upper terrace.

The author has been able to investigate the geological structure of the above mentioned bifurcation terrace at both Meyenburg and Vierraden, where (in the Odra valley) samples of terrace material were also taken for granulometric measurements. At Meyenburg, where the upper terrace lies at the altitude of approx. 14 m. a. s. l., the following strata were revealed in a gravel pit (Fig. 6):

a) 0.35 m. fine- and medium-grained sands, with an ill-defined horizontal predominance of bedding,

b) approx. 0.60 m. gravel with pebbles and rounded boulders, with traces of predominant horizontal bedding,

c) lower down — fluvioglacial deposits comprizing crossbedded fine- and medium-grained sands which, towards the bottom, pass into horizontally stratified fine-grained sands intercalated by stratified silts.

At Vierraden a layer of pebbles and boulders, sorted by flowing water, cuts diagonally a stratified fluvioglacial sands. In both cases the terrace shows an erosive character. The aggraded material of the surface of the upper terrace situated north of Vierraden in the Odra valley resembles, as to its granulometric character, deposits found further upstream on the same terrace (Fig. 7).

In this manner has been established the continuation of the upper terrace of the ice-marginal streamway in the Kostrzyn Basin and the valley of the Lower Odra. The river waters which flowed at this level through the Noteć—Warta ice-marginal streamway arrived, partly, along valleys of former outwash rivers, partly by way of the valleys of the Vistula, Warta and Odra, flowing away partly, as heretofore, westwards along the Randow valley, but partly also northwards along the Lower Odra valley. Evidently at that time, the neighbourhood of the present-day mouth of the Odra must already have been free of ice. To this problem we will return in one of the next chapters.

TRANSITIONAL UPPER TERRACE (b), OR 7—9-METRE TERRACE (II)

At the inlet of the Drawa Basin there appears a very clearly marked terrace level of 44 m. altitude surrounding the terrace island south of the mouth of the Drawa and subsiding, within the area of the basin to 40 m. a. s. l. But, only slightly further west in the neighbourhood of

Drezdenko, this terrace declines to 36 m. a. s. l. Beyond this section with its exceptionally steep gradient, the terrace continues along the valley, showing a gradient correlated to the valley floor; thus, here a uniform relative height of 7 to 8 m. is maintained. The presence of this terrace has been observed over longer stretches of the ice-marginal streamway, of the Warta valley as well as the Lower Odra valley; everywhere it runs side by side with the upper terrace. Here, of course, we are facing a valley terrace, connected with eroding processes caused by an intense lowering of the base-level of erosion. However this eroding impulse failed to extend very far upwards in the ancient river bed. It reached as far as the vicinity of the mouth of the Drawa river and also shows in the Drawa valley (see map, Fig. 10) in the form of a terrace entering the Drawa Basin at 44 m. a. s. l.

Proof of the termination of the eroding processes which has caused the incision of the main river into the surface of the upper transition terrace and resulted in the formation of a corresponding terrace in the Lower Drawa valley, is the steep gradient of the highest section of this terrace within the area of the Basin (see profile of terrace, Fig. 11), characteristic for upper, intensively eroded valley sections, as well as the sharp shape of the initial section of the newly formed river bed, visible on the geomorphological map (Fig. 10).

Even so, I am inclined to identify an even higher fragment of this terrace in the Ujście Basin, at 55 to 57 m. a. s. l. It may be that the terrace under discussion has reached even further westwards, as seems to be indicated by a corresponding terrace along the Łobżonka valley (see description, page 57). Consequently, the eroding impulse, caused by the sinking of the base-level of erosion, must have reached up the ice-marginal streamway as far as the confluence of the Gwda and Noteć, or even further than that. The above mentioned terrace fragment lies barely 2 to 3 metres lower than the upper terrace described above and extends as prolongation of the outwash terrace of the Gwda, over the ice-marginal streamway floor in the neighbourhood of Ługi Ujskie. This terrace is built of coarse-grained sands with gravel and pebbles. Its surface is partly diversified by wind action.

H. G. Ost (58) believes that this upper transition terrace, aggreaded by flowing water, was walled by dead ice which in his opinion, filled the Ujście Basin at that time; and consequently this terrace represents some kind of kame terrace. As principal argument in favour of his concept Ost mentions the fact that here stratification „emerges into the open". Were it otherwise, the strara would have gradually subsided to the floor level of the ice-marginal streamway (representing deposits of an alluvial cone). I do not deny the possibility of blocks of dead ice occuring in the Ujście Basin during that period, the more so since, further west distinct traces of ice contact slope are in evidence within the area of this terrace. All the same, the existence of a very clearly discernible step in the surface of this terrace, with an abrupt breach in its stratification may be the effect of erosive cutting by the meandering Noteć river, the more so since the edge of the terrace clearly shows a bend, corresponding to the course of the river. Nor can I assume that the abowe-mentioned level of 55 to 57 m. should simply be a sunken, lower part of the outwash terrace of the Gwda river, lowered as a result of the melting of a huge block of dead ice (analogous with conditions on outwash plains in the neighbourhood of Eberswalde as described by H. Liedtke). This conjecture is contradicted by the mechanical composition of the deposits of this terrace, differing from the mechanical composition of outwash deposits (see Fig. 7). Thus it seems most probable that the terrace fragment at 55 to 57 m. altitude, adjoining the outwash terrace of the Gwda river in the Ujście Basin, is the highest preserved fragment of the upper transition terrace (b); incidentally, correlated with this terrace are similar terraces in the Gwda valley and also, in the Łobżonka valley.

As stated above, the upper transition terrace (b) is particularly well developed in the Drawa Basin. At Drawsk this terrace (42 m. a. s. l.) is built of moraine clay, with boulders on its surface. South of the terrace island, fine sand lies on its surface. A small exposure of the geological structure of the transition terrace (b) is visible at Skwierzyna Gaj, on the upper right bank of the Warta valley, close to its joining the Noteć—Warta ice-marginal streamway. Scattered on the level surface of this terrace are boulders. In the profile the following strata have been determined:

a) yellow, coarse-grained sand,

b) medium-grained sand, of approx. 1 m. thickness,

c) lower down — coarse gravel with boulders of various size (up to 30 cm. dia.). Intercalations of strongly limonitized sands.

Slightly further northwards at Murzynowo (30 m. a. s. l.), there also we observed, on the surface of the terrace, sands with numerous pebbles, identically as at Brzozowiec (26 m. a. s. l.), west of the Warta river. Consequently, the geological structure proves the erosive character of this terrace.

More important is the upper transition terrace (b) near Kołczyn; here its contour is strongly dissected, and its surface is variegated by numerous kettles. According to German opinions, major compact masses of dead ice rested on the bottom of the ice-marginal streamway.

Flowing between this ice and the edge of the ice-marginal streamway, river waters filled this space with aggraded material. When, later on, the ice melted, the ice contact slope of these fluvial deposits was transformed into a clearly noticeable, though strongly dissected, step. The geological structure of this terrace near Kołczyn is known from numerous exposures. Below I am presenting two of the more important profiles.

Profile 1

a) 1.30 m. coarse-grained sand (0.3—0.4 mm. dia.), with scanty, poorly rounded pebbles,

b) 1.10 m. fine gravel (up to 6 mm. dia), higher up passing into sand with gravel and pebbles. Oblique bedding (12° towards SW),

c) 0.10 m. boulder pavement, cutting the sands,

d) 0.12 m. stratified limonitized sand with scanty pebbles (1 to 2 cm. dia.) at bottom,

e) 0.30 m. horizontally stratified sand (0.2 mm. dia.), continuing downwards. In another place of this terrace, under dune sand of 1 m. thickness fossil soil was founds with remnants of a burial urn and ashes.

Profile 2 (former gravel pit)

a) 0.70 m. light-yellow, fine-grained sand,

b) 0.05 m. strongly limonitized gravel with pebbles,

c) 0.70 m. light-coloured gravel, obliquely stratified,

d) 0.50 m. gravel with pebbles up to 15 cm. dia., of pavement type,

e) 0.30 m. gravel, growing smaller downwards and passing into light-coloured fluvioglacial sands,

f) 0.50 m. light-coloured, medium-grained stratified sand.

At Kołczyn, the geological structure of the terrace is not unlike the hitherto determined structure. Fluvial waters have eroded the layer of boulder clay, covering the residual pavement by their deposits.

The stratified sands slope towards depressions (kettles?) in the terrace. However, it is not always easy to distinguish such later disturbances of these deposits from previous delta accumulation. At any rate, in must always be kept in mind that local streams must hawe played a conspicuous part in forming of terrace accumulation.

The problem of dead ice in the ice-marginal streamway and of the terrace connected with it requires further, more detailed investigation. It is precisely the terraces situated in the Gorzów Basin that constitute a suitable object for investigation of this kind.

The above description proves the upper transitional terrace (b) to be of an *erosive* character. On top of the erosivety cut boulder clay, or on a residual boulder pavement, fluvial deposits of several meters' thickness are laid down. It is only in the Gorzów Basin, where this terrace was formed in a hitherto indeterminate contact with dead ice, that fluvial deposits resembling a delta type appear, in connection with the inflow of waters of nearby small rivers. Coarser material occasionally appearing here may also be the result of incision of a water channel into massed ice *.

The granulometrical analysis of the deposits of the upper transition terrace (b), shows that downstream the degree of rounding increases very intensely, exhibiting a distinct interruption below the mouth of the Drawa, probably owing to the inflow of less rounded material carried by the waters of the Drawa river (Fig. 7).

What is the further course of the upper transition terrace (b) below the junction of Warta and Odra? In the neighbourhood of Kostrzyn, adjacent to a fragment of an ice-marginal streamway terrace of 32 m. altitude, lies a terrace level; like the former terrace, it is undercut by recent meander erosion of the Warta river and extends, in the shape of a clearly discernible lobe, at a height of 20 to 17 m. along the slope bottom of a plateau, spread above and below the mouth of the Myśla river. I am inclined to consider this terrace a fragment of a upper transition terrace (b), deformed by adjacent cone deposits laid down by the Myśla river, and by aeolian forms.

The continuation of the upper transition terrace (b) in the Kostrzyn Basin and in the valley of the Lower Odra river resembles the course of the upper terrace. According the field studies conducted by Liedtke and others, there occurs on the terrace island of Bralitz—Neuenhagen, below the upper terrace of 16 m. altitude a terrace fragment at a level of 12 m., corresponding to the upper transition terrace (b). This same terrace is also visible on the Polish side, at Osinów Dolny, at a similar altitude; it is built of fine-grained sands with intercalations of small pebbles. On the terrace peninsula near Hohensaaten, this same terrace appears at 11 m. a. s. l., and near Schwedt, in the Lower Odra valley — at the altitude of 10 m. a. s. l. This is probably the lowest fragment of this terrace so far identified. Consequently, within the known limits of the extent of this terrace, from Piła (57 m. a. s. l.) to Schwedt in the Lower Odra valley (10 m. a. s. l.), over a distance of some 242 km. the gradient of this terrace is 1 : 5140.

The relative height of the upper transition terrace (b) varies between 6 and 11 m. (in some places even up to 14 m.); at the mouth of the Gwda river it is 9 m., reaches its maximum height near the mouth of the Drawa river (from 14 to 11 m.), decreases to only 6 m.

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* The problem of the interrelation of blocks of dead ice and fluvial erosion has been discussed, among others, by T. Bartkowski (4).

near the junction of Noteć and Warta, and again increases to 7 to 9 m. further down. 7 to 9 m. is the mean value of the height of the upper transitional terrace (b).

Te be sure, the upper transition terrace (a) does not reach as far as the Toruń Basin, and its upper limit is probably the Ujście Basin. It has its counterpart not only in the Drawa valley, but also in the Warta valley, south of the ice-marginal streamway. This upper transition terrace (a) represents one of the briefer phases in the development of the ice-marginal streamway, in connection with the oscillations of the base-level of erosion brought about by the gradual recession of the inland ice.

TRANSITIONAL UPPER TERRACE (a), OR THE 5-METRE TERRACE (I)

At the point of northward diversion of the Vistula there has been preserved, near Ostromecko, a terrace fragment at the altitude of 65 m. (17). It is undoubtedly connected with the northward run-off of the Vistula, and has been preserved as a meander step. It seems possible, however, that this terrace is also continued in the Noteć—Warta ice-marginal streamway. In their observations of a section of the ice-marginal streamway, St. Kozarski and J. Szupryczyński (37) found, on its both sides, low-lying terrace remnants, of 60 m. altitude in the east and 55 m. in the west, i. e. north of Chodzież; this terrace they called the lower terrace. A distinct erosive step separates this terrace from the upper terrace, while downwards. i. e. towards the flood terrace, the morphological boundary is less marked, particularly in those places, where young alluvial cones were deposited on the upper transition terrace. According to the above-mentioned authors, inter- moraine sands and gravels built this terrace. On the level surface of the terrace a residual pavement with big boulders, of up to 0.5 m. diameter appear — thus plainly an erosive terrace! In numerous localities, such as Mieczkowo, Lipia Góra, Heliodorowo, irregular dunes have developed, 10 to 12 m. high.

The terrace of the Noteć ice-marginal streamway, described above and first investigated by St. Kozarski and J. Szupryczyński (37) in the section between Nakło and Milcz, continues not only in the Ujście Basin, but also near the mouth of the Drawa river, in the Gorzów Basin and in the Lower Odra valley; everywhere it is the first terrace extending above the flood terrace. Consequently, this is a terrace level extending from the Toruń Basin as far as the Lower Odra river and representing one of development stages of valleys on the glacial Polish Lowland. As far as my own nomenclature of terraces is concerned which I am basing on the division of terraces in the Toruń Basin and the Lower Vistula valley, I have termed the lowest terrace level in the ice-marginal streamway discussed the upper transition terrace (a), or the 4 to 5 m. terrace, taking into consideration its prevalent relative height (see description on page 51).

In the Ujście Basin, the upper transition terrace (a) appears along the lower Gwda river at 52 m. a. s. l., breaking off erosively, identically as, in its extension, the upper transition terrace (b), — against the peaty floor of the ice-marginal streamway. On the flat, wooded surface of this terrace, in the neighbourhood of Motylewo (south of Piła), dunes have developed, while in the terrace edga sands are exposed, containing considerable quantities of boulders in their top part. This proves the upper transition terrace (a) to be of erosive character. A similar terrace also appears somewhat further northward, encircling the repeatedly mentioned terrace peninsula at Piła (57 m. a. s. l. — see Fig. 7). Sands, gravel and boulders are building this terrace; this matérial reaches as far as the water level of the river, even lower. It has been found that the present-day bed of the Gwda river is incised in this gravel. Only on the flood terrace a slight cover of fluvial silts has been found.

Wider spread is this terrace in the Drawa Basin subsiding from 40 m. a. s. l. in the narrowed stretch of the ice-marginal streamway near Gulcz, to 29 m. a. s. l. south of Drezdenko, where gravel with pebbles forms the flat surface of this terrace. Along the Lower Drawa river the upper transitional terrace (a) appears too, breaking off against he peaty bottom of the basin. Here the edge this terrace shows the effect of melting blocks of dead ice.

At Jagodzin, south of Gorzów, the discussed terrace forms a terrace island of 23 m. absolute altitude. In the slope of the terrace the following strata are uncovered:

a) 0.95 m. sands (0.3—0.4 mm. dia.) and fine gravels (1—4 mm.), with many pebbles on the surface of the terrace,
b) 0.05 m. pavement built of rounded pebbles 3—5 cm. diameter,
c) lower down — gravel.

Thus the terrace continues to show an erosive feature.

Further fragments of the upper transition terrace (a) have been preserved along the Odra river too. Near the mouth of the Myśla into the Odra, there extends a terrace fragment at the absolute altitude of some 14 m., running along the foot of the upper transition terrace (b). Both terraces, as described above, have been deformed by cone alluvia, aeolian processes and, possibly, also by dead ice melting processes. Is should be emphasized that the morphological boundary dividing the two terraces is rather indistinct. The same terrace appears also on the left bank of the Odra river, near Schwedt, at 6 m. a. s. l., and further north again, in the neighbourhood of Gartz, at the altitude of 4.5 m. on the left bank, and at 4 m. a. s. l. on the right bank of the Lower Odra river.

Consequently, upon the discussed valley section, the upper transition terrace (a) subsides from 60 m. a. s. l. in the neighbourhood of Nakło, to a some 4 m. a. s. l. along the Lower Odra river near Gartz; considering the distance of some 316 km. separating these two localities, this means a gradient of 1 : 5530.

The relative height of the upper transition terrace (a) varies between 6 m. on the Noteć, and 3,5 m. on the Lower Odra, while locally it even decreases to as little as 2 m.; mostly it is 5 m.

Material for the granulometric analysis has been taken from one locality only, namely a point on the terrace island south of Gorzów. This analysis, carried out by W. Stankowski, shows a high degree of rounding (see Fig. 7), considerably higher than the degree of rounding of the deposits of the upper transition terrace at this place.

The upper transition terrace (a), of predominantly erosive character, represents the run-off of fluvial waters along the Warta—Noteć ice-marginal streamway and along the Lower Odra valley to the Baltic, similarly as the two successively higher terraces.

GENERAL REMARKS ON ICE-MARGINAL STREAMWAY TERRACES

The description hitherto presented shows that in the ice-marginal streamway there appear, above the valley floor (i. e. the flood terrace 1—2 m. high), five terraces disregarding fragments of a few local terraces of a transition character:

I. The upper transition terrace (a) *. or the 5 m. terrace (average gradient 1 : 5530),

II. The upper transition terrace (b), or the 7—9 m. terrace (average gradient 1 : 5140),

III. The upper terrace, or the 10—12 m. terrace (average gradient 1 : 6000),

IV. The ice-marginal streamway transition terrace, or the 15—22 m. terrace (average gradient 1 : 6360),

* The author uses terrace names taken from previous contributions (17, 18). See also Fig. 1.

V. The ice-marginal streamway or outwash terrace, relative height 18—25 m. (average gradient 1 : 6420 * or 1 : 7270 **).

All the above terraces distinguished in the Noteć—Warta ice-marginal streamway already appear in the Toruń Basin. It is only the upper transition terrace (a) that does not appears until the Piła Basin. The (outwash) ice-marginal streamway terrace and ice-marginal streamway transition terrace continue in the Randow valley; the upper terrace of the ice-marginal streamway shows a bifurcation character, passing not only into the Randow valley, but also showing in the Lower Odra valley. The remaining, lower terraces of the ice-marginal streamway appear, further on, exclusively in the Lower Odra valley. Consequently, three phases may be distinguished in the development of the terraces of the ice-marginal streamway, namely: 1) the phase of the Noteć—Warta—Randow ice-marginal streamway, 2) the bifurcation phase, and, 3) the ice-marginal streamway — Odra phase.

The vertical distance between the individual terraces is surprisingly alike (at an average 4—5 m.); this seems to be evidence of a regularity of the erosive rythm, caused by oscillations of the base-level of erosion. It is only in the initial part of the longitudinal profile of some of the terraces that their gradient increases and due to this, the distances between the terraces vary. Moreover, the average gradient of the younger terraces is slightly greater than that of the older terraces, which may have been caused by the shortening of the lower river course after it reached the Pomeranian Bay (Zatoka Pomorska).

All the terraces show an e r o s i v e or, e r o s i v e - a g g r a d i n g character, showing a 1—2 m. layer of fluvial deposits laid down on moraine and inter-moraine deposits. In accordance with the changing geological structure of the Pleistocene deposits there are alternately exposed, on the different valley terraces, boulder clay, stratified fluvioglacial sands and gravels, and varved clay; boulder clay most frequently appears on the higher terraces, while intermoraine deposits are found on the lower terraces (see, among others of terrace profile of the lower Gwda valley (Fig. 1). In view of the erosive character of the terraces, we frequently observe on their surface merely a moraine residuum, in the form of a pavement of boulders of varying size, while fluvial sands lie almost directly in top of fluvioglacial sands. On the terraces with a sandy surface dunes have developed, here and there forming compact dune fields. The problem of dunes in the Noteć—Warta ice-marginal streamway has a rich literature of its own. Among

* On the Bydgoszcz—Bagemühl section (Randow valley).
** In the Aleksandrów-Kuj.—Bagemühl section.

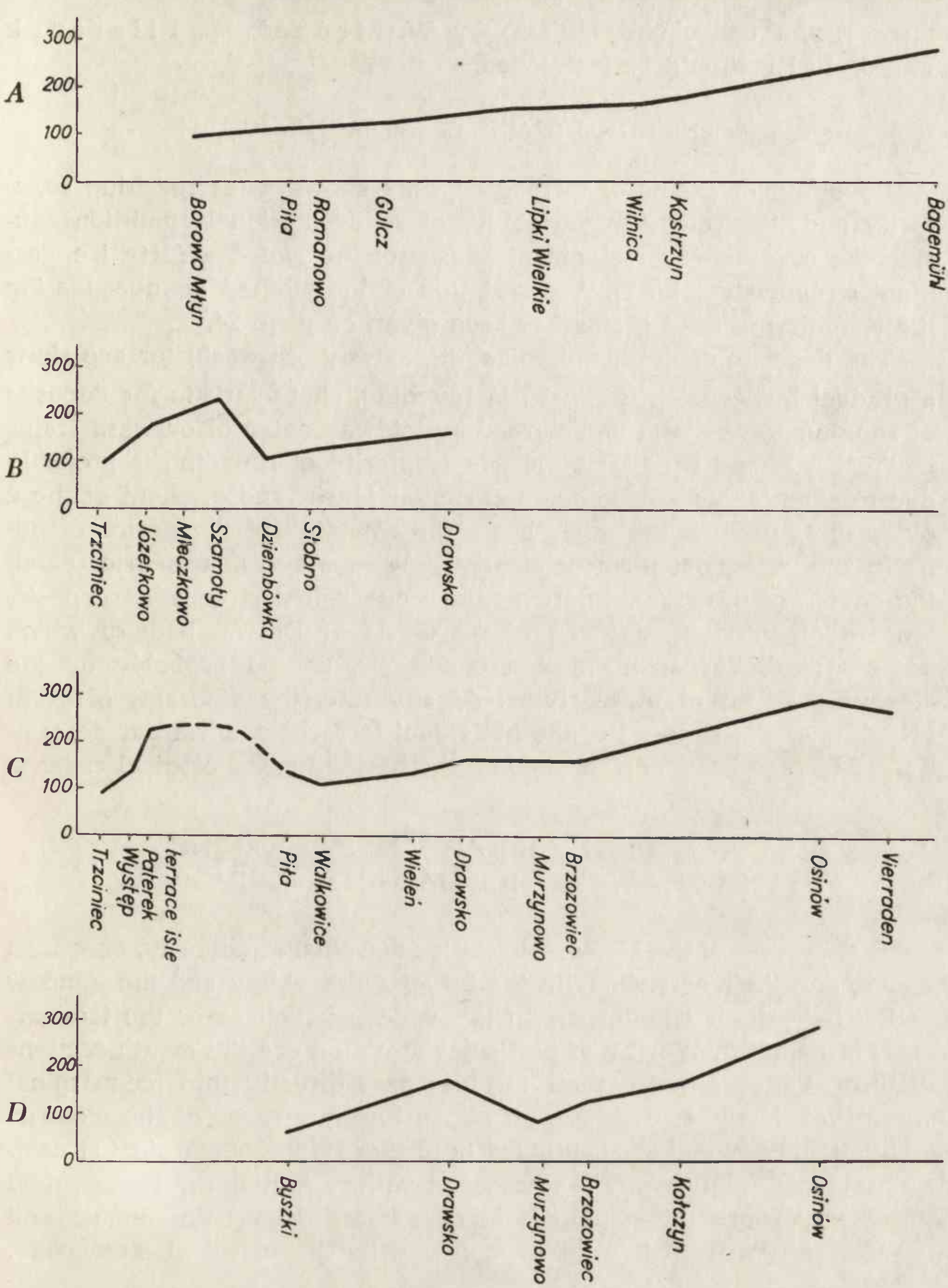

Fig. 7. Graphs of average rounding of grains of some of terrace deposits in Noteć—Warta ice-marginal streamway, Lower Odra valley and Randow valley, according to W. Stankowski's measurements

A — ice marginal streamway terrace; *B* — ice-marginal streamway transition terrace; *C* — upper terrace; *D* — upper transition terrace (b) more recent contributions, those by W. Mrózek, L. Pilarczyk and J. Irla should be mentioned.

ROUNDING OF GRAINS OF TERRACE DEPOSITS

Rounding of grains of terrace deposits shows a far reaching regularity and illustrates the variability of sedimentational conditions during the successive development phases of the Noteć—Warta ice-marginal streamway (Fig. 7). A description of the method of investigating the rounding of sand grains has been given on page 24.

The deposits of the ice-marginal streamway (outwash) terrace show a gradual but constant increase in rounding, characteristic for deposits of running waters, and undisturbed by midway entry of outwash trains of the Gwda and Drawa rivers; this regularity of rounding is probably due to simultaneous existence and similar lenght and gradient of these outwash trains. On the other hand, the rounding of the grains of deposits of subsequent terraces clearly shows marked disturbances along the course of the river, wherever the ice-marginal streamway deposits were augmented by deposits of the Gwda or Drawa, both of which possess dissimilar sedimentation conditions, caused probably by the steeper gradient of those rivers. At any rate, the diagrams of grain rounding of the deposits of the individual terraces confirm our description of terrace levels, established on the basis of morphological criteria.

TERRACES IN VARIOUS VALLEYS JOINING THE NOTEĆ—WARTA ICE-MARGINAL STREAMWAY

The terraces of the Noteć—Warta ice-marginal streamway, described above, and their extensions in the Lower Odra valley and the Randow valley have their counterpart in the valleys which enter the ice-marginal streamway. Worthy of particular attention are the mouth sections of those valleys, where their terraces pass directly into ice-marginal streamway terraces, or break off above lower terraces of the ice-marginal streamway and are continued in further-lying ice-marginal streamway terraces fragments. The terraces of valleys joining the ice-marginal streamway represent an important corroboration of both number and type of terraces which we distinguish in the ice-marginal streamway.

TERRACES OF DRWĘCA VALLEY (FIG. 8)

The comparative table of terraces found in the mouth section of the Drwęca valley and in the Toruń Basin (see page 56) proves the close

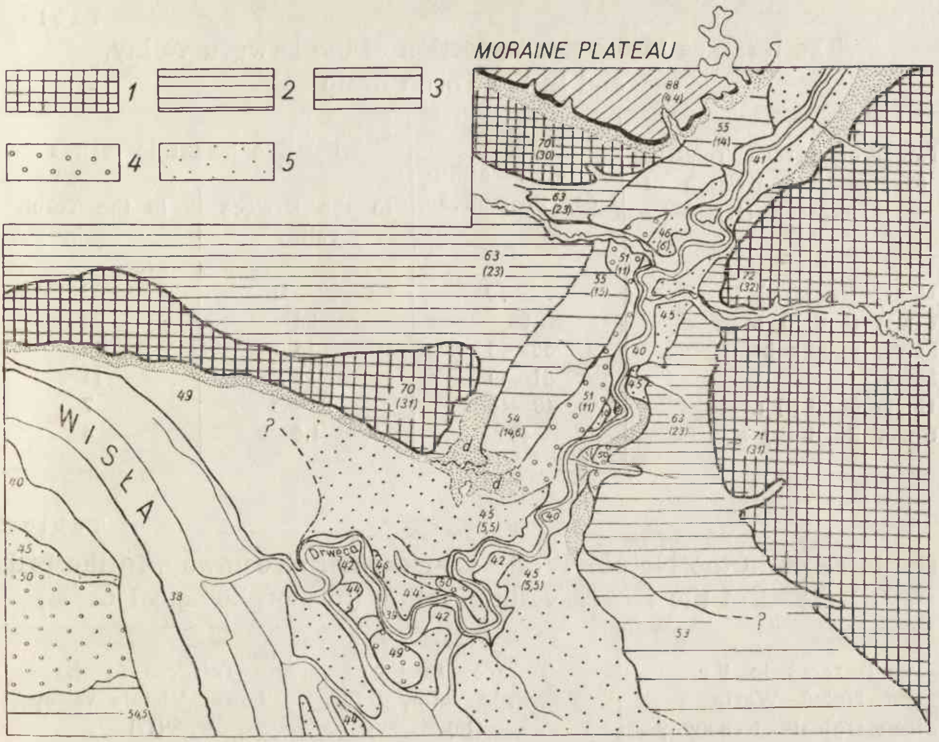

Fig. 8. Morphological map of mouth of Drwęca valley.
1 — upper terrace; 2 — upper transition terrace; 3 — lower middle terrace; 4 — lower terrace; 5 — upper flood terrace (I step)

connection between both valley levels which, incidentally, show almost identical relative heights. It should be emphasized, however, that in the discussed section of the Drwęca valley there does not appear any upper middle terrace, which, admittedly, is also lacking in the part of the Toruń Basin adjoining the Drwęca valley, but which further west and especially, near the mouth of the Brda river occupies wide areas, incidentally constituting west of Bydgoszcz the bottom of the ice-marginal streamway. Nor is there any middle step of the upper terrace. Particularly note worthy, however, is the fact that in the mouth section of the Drwęca valley no terrace higher than the upper terrace has been found, which might be considered a counterpart to of the ice-marginal streamway (outwash) terrace of the Noteć—Warta ice-marginal streamway. It must be admitted that this terrace does not exist in the Toruń Basin either. Even so there is a chance as mentioned before-that, a small terrace fragment, situated near Aleksandrów Kujawski at 81 m. a. s. l. and described by W. M r ó z e k, might be a remnant of this ice-mar-

Table 1

The terraces in the mouth section of the Drwęca valley, and in the Toruń Basin

Name of terrace (referring to the 1934 division of terraces, (17)	Absolute altitude, in metres	Relative height in metres	
		in the Drwęca valley	in the Toruń Basin
Upper (III step) t.	72—70	32—31	32
Upper (I step) t.	63	23	25
Lower middle t.	55—53	15	14
Lower t.	51—49	11	11
Upper flood (I) t.	46—44	6—5.5	7
Upper flood (II) t.	42	1.5	4

Table 2

The terraces in the Noteć—Warta ice-marginal streamway, in the Brda valley and in the Lower Vistula valley (in morphological order)

Terraces in the Noteć—Warta ice-marginal streamway	Terraces in the Brda valley (18)	Terraces in the Lower Vistula valley (17)
V. ice-marginal streamway t.	XI. outwash t.	
IV. ice-marginal streamway (transition) t.	X. transition t.	
III. upper t.	IX. upper t.	Vc. upper (step c) t.
II. upper transition (b) t.	VIII. transition t.	Vb. upper (step b) t.
I. upper transition (a) t.	VII. transition t.	Va. upper (step a) t.
Ice-marginal streamway floor (flood terrace)	VI. upper middle t.	IV. upper middle t.
Aggradation of the ice-marginal streamway with mud and peat bogs	V. lower middle t.	III. lower middle t.
	IV. lower t.	II. lower t.
	III. upper flood t.	I_3. upper flood (III step) t.
	II. upper flood t.	I_2. upper flood (II step) t.
	I. upper flood t.	I_1. upper flood (I step) t.

ginal streamway terrace. The problem is the more important since in the first phase of its existence, undoubtedly the E—W section of the Drwęca valley must have played the role of a valley of ice-marginal streamway type, carrying of the inland ice meltwater at the time of the Pomeranian stage (19). Field investigations of the terraces of the Drwęca valley are under way (J. Machinko and Z. Churski). They detected remnants of a terrace, higher than the upper terrace, not only in the N—S section of the Drwęca valley connected with the Ostróda outwash plains, but also in the lower-lying E—W part of the Drwęca valley.

TERRACES OF OUTWASH AND VALLEY OF BRDA RIVER

(see Table 2)

According to the author's research (18), all the terrace levels in the Brda valley, whether connected with the development of the Noteć ice-marginal streamway or with that of the Lower Vistula valley, have been preserved. The Brda valley is accompanied by an outwash plain terrace, which passes into an ice-marginal streamway (outwash) terrace within the area of the Noteć—Warta ice-marginal streamway. Altogether, eleven terrace levels have been determined here.

The terraces of the Brda valley are of essential importance for the reconstruction of the development of the Noteć—Warta ice-marginal streamway and the Lower Vistula valley, constituting an area of correlation with terraces of other valleys. Along the Brda river the outwash phase of the ice-marginal streamway phase is perpetuated as well as the time when all the river waters of the Lower Vistula Valley were diverted northwards and abandoned the ice-marginal streamway. The latter event took place at a time when the Brda river was flowing on a terrace 50 m. a. s. l. (middle lower terrace) with an eastward gradients, towards the Lower Vistula valley, in contrast with the westward gradient of the ice-marginal streamway. The detailed correlation of the Brda valley and the Brda outwash with terraces in the ice-marginal streamway has been given above, in the description of the successive terraces.

TERRACES OF ŁOBŻONKA VALLEY

According to L. Sytnik's * field studies in the Łobżonka valley, which in this respect resembles its tributary, the Orla valley (the latter

* Lesław Sytnik: Morfologia doliny Łobżonki (Morphology of the Łobżonka Valley), Master's thesis (in typescript), Toruń, 1958.

the subject of investigations by K. Koźlińska), the following terraces of erosive character appear there:

VI. the 15-metre terrace (?)	
V. the 10.5 to 13.5-metre terrace	all heights given with reference to the 2-metre flood terrace
IV. the 7.5 to 10-metre terrace	
III. the 5 to 6-metre terrace	
II. the 3 to 4-metre terrace	
I. the 2-metre terrace	

Taking into account the aggraded 2-metre flood terrace into which the Łobżonka river is incised, we may consider the II. terrace of the Łobżonka valley to be the counterpart of the 5-metre terrace in the ice-marginal streamway, the III. terrace of the Łobżonka to be the counterpart of the 7 to 9-metre terrace in the ice-marginal streamway, which admittedly appears only near the mouth of the Gwda river, the IV. terrace of the Łobżonka to be the counterpart of the 10 to 12-metre terrace in the ice-marginal streamway, and the V. terrace in the Łobżonka the counterpart of the 15 to 22-metre terrace in the ice-marginal streamway or in other words, the ice-marginal streamway transition terrace. L. Sytnik has found the VI. terrace (15-metre) of the Łobżonka valley in one place only, at Klawki and expresses his doubts as to its continuing in the Łobżonka valley. On the assumption that this highest valley level has been destroyed during the formation of the succedingly lower valley terraces, we may take it for granted that the highest terrace was formed at the time of the oldest ice-marginal streamway phase, as the floor of a river which joined the nearby ice-marginal streamway waters. The I terrace of the Łobżonka is observed mainly in the central and upper segment of the valley, and thus is less connected with the ice-marginal streamway as its base-level of erosion. The considerable height of the flood terrace of the Łobżonka valley must be ascribed to the period when the ice-marginal streamway was abandoned and its peat cover was developing. The small erosional steps, incised into the flood terrace of the Łobżonka, were probably formed during the meandering of the Noteć river. Consequently, the terrace of the Łobżonka valley fully correspond to the ice-marginal streamway terraces, confirming both their division and their genetic character.

TERRACES OF OUTWASH AND VALLEY OF GWDA RIVER

In his contribution mentioned above, H. G. Ost (58) describes mostly the outwash terraces showing along the Gwda valley, paying less attention to younger valley terraces which he calls post-Baltic terraces. Both the outwash and the valley trains of the Gwda constitute a striking analogy with regard to the terrace levels along the Lower Brda river. At any rate, there is no doubt as to a marked concordance between the Gwda terraces and the terraces in the ice-marginal streamway. As mentioned before, transition of the system of terraces of the Gwda river into the system of terraces of the Noteć ice-marginal streamway takes place within the Ujście Basin. Without taking into consideration the older, local outwash tracks which make their appearance on various heights in the neighbourhood of the outwash valley of the Gwda and of the ice-marginal streamway*, it may be claimed that the outwash terrace of the Gwda passes, with a considerable gradient, into the more gentle gradient of the ice-marginal streamway terrace (see map, Fig. 10), maintaining its direction as far as the bend in the ice-marginal streamway, near Czarnków. In view of the existence of a narrowed stretch of the ice-marginal streamway west of the mouth of the Gwda, we may consider the eastern part of the Noteć ice-marginal streamway to be merely a lateral branch of the ice-marginal streamway, starting with the meridional course of the outwash valley of the Gwda river.

Along the Gwda and the Noteć rivers there extend successive terraces, which may be traced both upstream in the Gwda valley and downstream along the Noteć ice-marginal streamway. For the first time fragments of the upper transition terrace (b) have been found here at 55 to 57 m. a. s. l.; its counterpart in the Gwda valley (north of Piła) is a fragment of alluvial terrace at 63 and 64 m. a. s. l. The terraces are reworked by widespread melting forms (kettles), dissected by small tributaries of the Noteć, and undercut by this river. The problem of kame forms, suggested by H. G. Ost, has been discussed on page 45.

TERRACES OF OUTWASH AND VALLEY OF DRAWA RIVER

Like along the lower Gwda, steep-gradient outwash terrace accompanying the Drawa river (described in detail by H. G. Ost), breaks off, by a clearly erosive scarp, above the mouth basin of the Drawa, further on continued in the ice-marginal streamway terrace, which, in the shape of extensive fragments, appears in this section of the ice-marginal streamway on both sides of the Noteć. Similarly as in the Gwda valley the valley terraces of the Drawa, including the outwash

* See, among others, the contribution by St. Kozarski, „Z zagadnień geomorfologicznych północno-zachodniej części Wysoczyzny Gnieźnieńskiej" (Some Geomorphological Problems of the North-Western Part of the Gniezno Plateau", Zeszyty Naukowe U. A. M., Poznań, 1959.

transition terrace occupy narrow area only. At any rate, in the Drawa valley all five terraces are represented as appear in the nearby ice-marginal streamway (see map, Fig. 10) The aera of the mouth of the Drawa shows numerous traces of shifts of the lower course of the Drwa; these shifts appear as fluvial channels on the terrace surfaces both of upper terraces, such as the ice-marginal streamway transition terrace, and of lower terraces, e. g. the upper transition terrace (a). The terrace island, situated south of the mouth of the Drawa river has developed due to meander (lateral) erosion of the Noteć. The mouth basin of the Drawa shows a mainly erosive (meander) character, developed in several phases, beginning with the level of the ice-marginal streamway transition terrace. The centre of this basin is occupied by the lowest terrace, i. e. the upper transition terrace (a), strongly dissected due to shallow kettles formed by dead ice.

TERRACES OF WARTA VALLEY

The contact between the terraces of the Noteć—Warta ice-marginal streamway and the terraces of the Warta valley is particularly important for tracing the development of the ice-marginal streamway, and for correlating it with the older valley network. The present-day Warta valley, running parallel with the Noteć valley, occupies the southern margin of a gigantic peninsula of the ice-marginal streamway terrace, to a large extent covered by compact dunes. Thus, the ice-marginal streamway terrace extends not only along the Noteć, but along the Warta river too. Beginning with the mouth of the Wełna river, the Warta, hitherto showing gap features, enters the area of the Noteć—Warta ice-marginal streamway. The southern side of the Warta valley consists of a moraine plateau, while on its northern side extends the ice-marginal streamway terrace, mostly covered by dunes. The terraces of the Warta river have developed parallel with the terraces of the Noteć. The highest terrace level in the Warta valley, incised in the ice-marginal streamway terrace, is the terrace which subsides from 61 m. a. s. l. in the neighbourhood of the junction of Wełna and Warta to 41 m. a. s. l. in the neighbourhood of the junction of Obra and Warta, in other words, not far from the place where the Warta valley joins the Noteć valley. This terrace corresponds to the ice-marginal streamway transition terrace; it was therefore already on the level of this terrace, i. e. in the phase immediately following upon the ice-marginal streamway period proper, that the fluvial waters of the Warta river, flowing from the south, joined the waters of the Noteć—Warta ice-marginal streamway.

Apart from the counterpart of the ice-marginal streamway transition terrace there appears, in the end segment of the Warta valley near Skwierzyna, a terrace level of 36—35 m. a. s. l., corresponding to the upper terrace in the ice-marginal streamway. On a terrace peninsula along the right bank of the Warta river, across from the mouth of the Obra a terrace fragment at 30 m. a. s. l. has been preserved. It corresponds to the upper transition terrace (b) in the ice-marginal streamway similarly as a nearby terrace fragment, of 27.5 m. altitude, corresponds to the upper transition terrace (a). Consequently it seems certain that the junction of the waters of the Warta, coming from the south, with the waters flowing along the Noteć—Warta ice-marginal streamway lasts without interruption from the time when, during the Pomeranian stage, the inflow of outwash waters from the north, from the inland ice, ceased.

The terraces of the valley of the Lower Warta were the subject of many contributions by both Polish and German scientists. Recently they have been described by T. Bartkowski (5) in his synthetic considerations of the development of the late-glacial hydrographic network in the central area of Wielkopolska. This author established the following relative heights of river terraces of the northern section of the Warta valley (i. e. downstream its gap section). For the direct comparison, the relative heights of the terraces of the Noteć—Warta ice-marginal streamway have been given on the Table 3.

Table 3

Warta valley	Noteć—Warta ice-marginal streamway
Terrace I 0—3 m.	Upper flood terrace
" II 3—6 to 4—7 m.	5 m.
" III 9—10 to 11—13 m.	7— 9 m.
" IV 9—11 to 15—17 m.	10—12 m.
" V 15—17 to 18—20 m.	15—22 m.

T. Bartkowski asserts that delimitation between terrace IV and terrace V is not always indisputable. This is easily understood, taking into consideration the very slight difference in their relative heights. I also think that a number of terrace remnants in the section of the Warta valley under discussion should be assigned not to terrace IV, but to terrace V, i. e. to the highest terrace in the Warta valley, corresponding to the terrace of the Noteć—Warta ice-marginal streamway.

Here, also, arises the problem of terrace VI, distinguished by T. Bartkowski as the highest level, no more fluvial, but constituting a transition stage to outwash forms. In his opinion, terrace VI occupies the entire area between the Noteć and Warta rivers (a terrace peninsula), and, further eastwards, the so-called ice-marginal streamway of the Wełna river.

In my own opinion, some misunderstanding occurs here. I consider it inadmissible to correlate local outwash terraces, connected with the halt of inland ice along the so-called Northern Poznań moraines, with the main ice-marginal streamway terrace (between the two rivers), which developed during the Pomeranian stage. Besides, as indicated by both description and longitudinal profile of the terraces in T. Bartkowski's contribution (5, Fig. 14), this level shows no westward gradient. Moreover, in the longitudinal profile, terrace VI is composed of two separate levels. The lower level, from 60 to 61 m. a. s. l., extending from Obrzycko westwards, may correspond to the ice-marginal streamway terrace, occupying — as shown by the author — the entire terrace peninsula; on the other hand the higher level (65 m. a. s. l.), extending at the same height eastwards beyond the mouth of the Wełna river, corresponds to an older outwash, which may also have has its run-off westwards even prior to the formation of the Noteć—Warta ice-marginal streamway (incidentally resembling the older outwashes in the Gorzów Basin, as demonstrated by H. Liedtke — see page 9). On the other hand, I agree with T. Bartkowski, that, in the gap segment of the Warta valley, at the level of terrace VI which terrace corresponds as to its relative height to terrace IV or V on the northern section of the Warta valley (17 to 20 m.), there might have existed a bifurcation of the waters coming from the Warsaw—Berlin ice-marginal streamway into the Noteć—Warta ice-marginal streamway. This is precisely the terrace which — as demonstrated above — corresponds to the ice-marginal streamway transition terrace in the Noteć—Warta ice-marginal streamway, as the oldest level entering by way of the Warta valley the Noteć—Warta ice-marginal streamway.

TERRACES OF KŁODAWKA VALLEY

At Gorzów, situated on the northern side of the Noteć—Warta ice-marginal streamway, below the entry of the Warta into the ice-marginal streamway, into this streamway enters the small Kłodawka valley which,according to L. Pilarczyk's investigations (62), has six terraces. The Kłodawka, like the Brda, Gwda and Drawa rivers, is an outwash river draining the Barlinek outwash, which is genetically connected with the moraines of the Pomeranian stage. The first, i. e.

the lowest of these terraces (1—2 m.) distinguished by this author, is the flood level of the ice-marginal streamway, while the second, third and fourth terraces appear, in the form of small ledges, both in the Kłodawka valley and at its outlet into ice-marginal streamway. In the Kłodawka valley, L. Pilarczyk discovered a fifth terrace and a sixth terrace too, which, in his opinion, is a prolongation of the Barlinek outwash. We are interested in the terrace of the Kłodawka valley because of their connection with the terraces of the Noteć—Warta ice-marginal streamway terraces, described above. Table 4 is a comparative table of the terraces from the neighbourhood of the mouth of the Kłodawka into the ice-marginal streamway (according to L. Pilarczyk), and of the terraces of the ice-marginal streamway (according to the author's own research):

Table 4

Mouth of the Kłodawka valley into the ice-marginal streamway	Total ice-marginal streamway
1) 5-metre terrace	5-metre terrace
2) 8-metre terrace	7— 9-metre terrace
3) 9—11-metre terrace	10—12-metre terrace
4) 12—14-metre terrace	15—22-metre terrace
5) 15-metre terrace	18—25-metre terrace

The above comparative table demonstrates the full agreement of the first three terrace levels distinguished. The fourth terrace of the mouth of the Kłodawka is probably a transition level, connected with a change of the base-level of erosion caused by a lateral shift of the meandring ice-marginal streamway waters, whereas the 15-metre terrace of the Kłodawka, the highest terrace level discovered along the Kłodawka, is connected with the 15 to 22-metre terrace of the ice-marginal streamway. This is the ice-marginal transition terrace. At this period there was no run-off of outwash waters any more, neither along the Brda nor the Gwda or the Drawa, nor — ever less so — along the Kłodawka, since the lobe of the Odra had undergone deglaciation earlier than the parts of the inland ice farer east, from which the outwash waters were flowing. Consequently, the 15-metre terrace of the Kłodawka is undoubtedly a river terrace, representing the oldest phase in the development of the Kłodawka river. On the other hand, the erosive plain at a level of 60 to 65 m. extending along the eastern bank of the Kłodawka valley represents in accordance with the opinions of Woldstedt and Liedtke, the level of an outwash run-off, older than the ice-marginal streamway terrace; a similar outwasch plain reaches the ice-marginal streamway above Santok, breaking off at approx. 60 m. a. s. l. above the terraces of the ice-marginal streamway, or an outwash, which ends erosively at approx. 40 m. a. s. l. on both sides of the Myśla valley above the Odra valley.

In the Finow valley, entering the Odra valley from the west, there appear, according to German investigations, 4- and 8-metre terraces. They correspond to terraces I and II in the Odra valley. In the Myśla valley, which enters the Odra valley from the east, three terraces have been found, of relative heights of 5, 9 and 15 m. respectively. Consequently they correspond to terraces I, II and IV of the Odra Valley. These terraces have been undercut by the Odra. Therefore their absolute heights in the places of undercutting are different (higher) than in the Odra valley.

The above survey of terraces in the valleys connected with the Noteć—Warta ice-marginal streamway confirms the division, made above, of the terraces in the ice-marginal streamway into five terrace levels, which appear, in larger or smaller fragments, over the entire length of the ice-marginal streamway (disregarding local outwash plains, which break off in erosive scarps above the ice-marginal streamway, and without considering the 1 to 2-metre over-flood terrace). In the light of this determination it has in turn been possible to interpret the morphological age and genetic character of terraces in the valleys connected with the ice-marginal streamway. This analysis leads us to a definition of the part played by the Noteć—Warta ice-marginal streamway, in the late-glacial drainage on the Polish Lowland presented in the final chapter of the present paper.

FLOOR OF ICE-MARGINAL STREAMWAY

After the Vistula waters had abandoned the ice-marginal streamway and, after an extended period of bifurcation, had definitely turned northwards, running off by the present-day valley of the Lower Vistula, the ice-marginal streamway floor was gradually filled with muds and peat bogs. A general picture of the floor of the ice-marginal streamway, for the section from Bydgoszcz to Santok, disregarding peats and deposits connected with them, was obtained by T. Churski (10) on the basis of 1070 sounding and borings, undertaken in 1954 to 1959 in the area of peat formations covering the ice-marginal streamway; this field work was carried out by Zakład Wykorzystania Torfowisk Instytutu Melioracji i Użytków Zielonych in Warsaw. T. Churski designed a contour map of the original floor of the ice-marginal streamway, with numerous cross-section and a longitudinal profile.

This survey proved that, underlying the organogenic formations, the floor of the ice-marginal streamway is greatly diversified. Depressions in the floor of the ice-marginal streamway frequently more than ten metres deep, are separated by swellings reaching up to the surface of the peat bogs. These swells are formed by alluvial cones of rivers entering the ice-marginal streamway. The largest of them, separating peat bogs, were formed by the Noteć and the Gwda. The bottom of the basin which underlying the peat, situated east of the cone of the Noteć riwer, lies at the altitude of 55 to 52 m. a. s. l., while the bottom of a basin, situated between the peat-covered cones of the Noteć and the Gwda, is lowered to a minimum height of 45 m. a. s. l., east of the mouth of the Łobżonka. In addition to these large depressions there appear numerous small elevations and hollows, some of them former river beds, other showing the shape of distinct kettles. Below the mouth of the Gwda there also may be noticed, on the floor of the ice-marginal streamway underneath the peat, oblong depressions of fluvial type and kettles. In the formation of peat-bogs, mostly of reed or reed-sedge type, there participated running waters, waters collecting in basins, spring waters and surface waters flowing down valley slopes. Usually the peat is markedly muddy. The total thickness of both gyttja and peat may reach as much as 15 m; as a rule, it is several metres.

The small lateral valleys of the ice-marginal streamway are filled with peat, e. g. the Śleska Valley, west of Nakło, investigated by Zofia and Zygmunt Churski (9). In the bottom part of gyttja and peat, in silt sediments there appears a macological fauna. The filling of the channel of the ice-marginal streamway with organogenic sediments must have started in the pre-Boreal period (60, 76).

Instead of peat, locally underlain by gyttja, sands, interbedded with peat and silts cover in many places the surface of the ice-marginal streamway floor. The thickness of the sediments which fill the former ice-marginal streamway bottom may amount to 9 m., as is the case, e. g., in the neighbourhood of Gorzów (62), where sands and fluvial gravel with pebbles lie underneath.

The rich and varied relief of the ice-marginal streamway bottom is a result both of the erosive and aggrading action of rivers, and of the melting of dead ice blocks. Filled with fluvial and organogenic deposits from the period when river flow in the ice-marginal streamway dwindled, the ice-marginal streamway floor represents the lowest valley level, formed by these waters prior to their abandoning the ice-marginal streamway and continuing their run-off along the Vistula valley (see comparative table of terraces on page 56). Between the towering ice-marginal streamway terrace and its now covered bottom there took place the entire geomorphological history of the late-glacial Noteć—Warta ice-marginal streamway, genetically connected with the Pomeranian stage, and developing up to the period when the Vistula waters changed their run-off to the north, along the Vistula valley.

And it is here that a now problem arises. Numerous borings within the area of the ice-marginal streamway have proved the existence of fossil valleys, reaching a great many meters below the floor of the ice-marginal streamway.

As early as in 1885 Liebenau (47) indicated in his geological atlas of Bydgoszcz the existence of a fossil valley, running parallel to the Lower Brda river (north of Bydgoszcz), incised in Pliocene clays and filled with fluvial and fluvioglacial deposits *. Recently, M. Żurawski (86) has described this same fossil valley a second time, unaware of Liebenau's contribution. According to M. Żurawski's description the width of the fossil valley is 1000 to 1500 m. Its bottom lies approx. 21 m. below sea level. The depth to which the valley is incised in Tertiary sediments reaches up to 65 m., while the depth of the valley bottom with regard to the present-day surface, represented by the upper middle terrace (55 m a. s. l.), i. e. the floor of the Noteć—Warta ice-marginal streamway (see table of terraces on page 56) amounts to 76 m.

The fossil valley in question has no kind of connection with the present-day postglacial valley of the Brda river. The present-day Brda flows along the lowest course since the time its valley was formed, or it flows in a channel filled with alluvia of several metres thickness. The author's investigations in the Brda valley (18), in the profile of the upper middle terrace north of Bydgoszcz, indicate, under a 0.70 m. top layer of soil and sands, 1.40 m. compact yellow boulder clay laid down on the Pliocène Poznań clays. At Tryszczyn, on the right bank of the Brda, sands and gravel appear on the above terrace directly on top of the Poznań clays, while on the surface of the terrace piles of coarser material may be seen, including boulders up to 1 m. dia. This shows that at the level of the terrace under discussion fluvial erosion reached as far as the surface of the Poznań clays. In the light of the above facts we have the right to consider the fossil valley in the neighbourhood

* See its description in the paper by R. Galon: Z geografii Bydgoszczy (A Contribution to the Geography of Bydgoszcz), in: Przegląd Bydgoski, Bydgoszcz, 1933.

of Bydgoszcz, appearing deep in the upper middle terrace, to be older than the boulder clay which here and there appears erosively on the surface of this terrace, while in other places it is replaced by a residual boulder pavement. The boulder clay has also been removed by the erosive action of waters flowing above the fossil valley.

I am inclined to leave open the question whether the removal of the fairly thin layer of boulder clay was brought about by the action of waters of the Noteć—Warta ice-marginal streamway while they incised progressively older Pleistocene deposits, reached the top of the Pliocene clays and cut into this deposit too, of whether this process occured partly too during the phase preceding the formation of the ice-marginal streamway in its present-day shape, for instance, during the period of the halt of inland ice along the northern edge of the ice-marginal streamway. Undoubtedly, the Noteć—Warta ice-marginal streamway made use of an older, perhaps even an interglacial valley track *.

The latter thesis seems to be supported by two cross-section through the Noteć ice marginal streamway in the neighbourhood of Dębowa Góra (Osiek on the Noteć river), presented in St. Gadomska's interesting contribution (12). This author had at her disposal material from two series of drillings carried out transversely to the ice-marginal streamway and the moraine plateau adjoining this streamway on both sides. Part of these drillings have pierced the Quaternary deposits and gave access to Pliocene formations (the Poznań clays) and Miocene sediments (quartz sands, silts and brown coal). The distance between both these profiles is barely a few kilometres, hence the cross-sections are much alike in this place. I am disregarding the profiles of the moraine plateaus, being interested, in accordance with the subject-matter of the present chapter, in the deposits filling the ice-marginal streamway. The profiles drawn by St. Gadomska indicate that underlying the present-day ice-marginal streamway bottom, filled with peat, there exists a fossil valley of more than 40 m. depth; in the first profile the width of this valley is some 5 km., and its floor lies at approx. 10 m. a. s. l., while in the second profile the width of the valley is 3.5 km with its floor at approx. 3 m. a. s. l. In St. Gadomska's opinion, this fossil valley was formed by fluvial erosion, most probably during the last interstadial, when both Pleistocene and Pliocene deposits were eroded and Miocene sediments were penetrated. This valley was subsequently filled with Quaternary deposits from the period of the youngest halt of inland ice during the Pomeranian stage, at the period of the Baltic glaciation and the late Glacial and post-Glacial. They are deposits of ice-dammed lake,

* See the author's view expressed in 1929 (13).

fluvioglacial, fluvial and organogenic origin. Their maximum thickness in the neighbourhood of Żuławka is 42.5 m.*

My own interpretation of both the above profiles differs from St. Gadomska's views as summarized above, as to the origin of the fossil valley. In my comment on the morphology of the Brda outwash and the Brda valley presented by St. Gadomska. I already pointed out that the outwash run-off connected with the halt of inland ice during the Pomeranian stage reached along the Brda valley, the ice-marginal streamway at a level of 80 m. a. s. l. This is the so-called outwash terrace, eroded principally in boulder clay. The counterpart of this terrace in the Noteć ice-marginal streamway is, as described above, the so-called ice-marginal streamway terrace, fragments of which, according to the research of St. Kozarski and J. Szupryczyński (37) also appear across from Dębowa Góra, at the altitude of 75 m. a. s. l. also as an erosive surface. During the successive development stages of the ice-marginal streamway, perpetuated in terrace levels, the fluvial waters, by stages, subsided more and more, depending on changes in the base-level of erosion, ultimately reaching the level of the present-day bottom of the ice-marginal streamway; this bottom is filled with a layer of organogenic deposits of several meters thickness, laid down during the period of stagnation of waters in the ice-marginal streamway, after it had been abandoned by the Vistula waters. Near the entry of the Łobżonka river the former bottom of the ice-marginal streamway lies at approx. 50 m. a. s. l. It was, therefore, within the range of these two heights, i. e. between 75 and 50 m. a. s. l., that the development of the ice-marginal streamway went forth, connected with the Pomeranian stage of the last glaciation and the post-Glacial period. Thus the fossil valley or ice-marginal streamway, described by St. Gadomska, cannot be assigned to the Pomeranian stage, and the various deposits which fill this valley are correspondingly older.

Moreover, I wish to call attention to certain inaccuracies in the interpretation of the borings presented by the above author, and to the possibility of assuming a different course of the processes of sedimentation. First of all, the „Noteć accumulation terrace" described by St. Gadomska, visible in both profiles, is identical with the ice-marginal streamway transition terrace described in the present paper and situated, within the area under discussion, at 66 to 68 m. a. s. l. It may not have been clear from examination of its bore samples that this is an erosive terrace, incised in stratified intermoraine sands (see description of terrace on page 30), here and there intercalated by varved

* St. Gadomska, op. cit., page 379.

clays or covered with boulder clay or residual boulders. The upper transition terrace (b), situated at the foot of this terrace near Lipia Góra at approx. 63 m. a. s. l., is similarly incised in stratified intermoraine sands and gravels and on the terrace surface heaps of big boulders are scattered*. In both cross-sections through the ice-marginal streamway the above-mentioned formation is the substratum for peat deposits filling the original bottom of the Noteć—Warta ice-marginal streamway. The stratified sands and gravels underlying the floor of this valley are continued in intermoraine sands beyond the ice-marginal streamway. It also seems probable that the series of sands and gravels underlying, in the area of the ice-marginal streamway, the intermoraine formation under discussion, is also continued in the sands which underlie the second boulder clay deposits on the glacial plateau adjoining the ice-marginal streamway. The conclusion which suggests itself is simple: the deposits filling the fossil valley are separated from the higher-lying bottom of the Noteć—Warta ice-marginal streamway by at least a series of intermoraine deposits with remnants of boulder clay. Consequently, this confirms the description of the development of the Noteć—Warta ice-marginal streamway given above, a development perpetuated by four erosive terraces beginning with the ice-marginal streamway terrace, and, at the streamway's bottom, slightly covered with organogenic formations. We note here a striking resemblance with the fossil valley in the neighbourhood of Bydgoszcz, described by M. Żurawski.

Next arises the question, how to explain the origin of the fossil valley described above in the depth of the Noteć—Warta ice-marginal streamway, in the neighbourhood of Dębowa Góra. I have my doubts whether such a river valley exists at that place at all, at any rate, on the basis of the cross-sections presented by St. Gadomska. Both the slopes of the fossil valley and the fossil terraces are suggestions not at all based on boring results. If we do assume the existence of a large river valley, it seems difficult to explain so big a difference in the levels of the floor of this valley on so small a distance (3 m. a. s. l. and approx. 10 m. a. s. l.), as well as the considerable difference in the width of this valley from 3.5 and 5 km.) and, finally, its being filled with ice-dammed lake deposits. It is possible that here we have to do with sedimentation basins filled with ice-dammed lake deposits; their later covering with intermoraine sands and boulder clay failed to level these depressions. The survival of these forms has probably con-

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* See photographe 2 in the paper by St. Kozarski and J. Szupryczyński (37).

tributed to the subsequent formation of an ice-marginal streamway, in spite of the existence of numerous elevations of end moraines in this area.

NOTEĆ—WARTA ICE-MARGINAL STREAMWAY AGAINST BACKGROUND OF GEOLOGICAL STRUCTURE OF MORAINE PLATEAU

The ice-marginal streamway, incised to a depth of some tens of metres into the moraine plateau, reveals along its slopes and on the surface of its erosive terraces the successive elements of a series of Pleistocene strata, and it deeply penetrates Pliocene and Miocene sediments too. In some places, the upper parts of the Pleistocene deposits have hardly been cut into, while in others, hight up on the slopes of the ice-marginal streamway and on its terraces, where the Pleistocene deposits are of smaller thickness, Pliocene Poznań clays are exposed. For indeed, as well known, the fossil surface of the Tertiary sediments is very much diversified.

The course of the Warta—Noteć ice-marginal streamway, excepting the Toruń and Kostrzyń Basins, does not exhibit any fundamental dependence with the relief of the Quaternary substratum, the orographical axes of which rather run cross-wise to the ice-marginal streamway. Hence the observed variability in the appearance of Tertiary sediments within the area of the ice-marginal streamway. This same cross-wise cutting of elevations of the Quaternary substratum by the ice-marginal streamway may be observed along the ice-marginal streamway section of the Brda valley, where the Poznań clays attain a height of 66 m. a. s. l., approaching the altitude of the surface of the upper terrace of the ice-marginal streamway (approx. 70 m. a. s. l.). The next incision of the ice-marginal streamway into Tertiary formations occurs along Dębowa Góra and subsequent moraine elevations, situated above the northern edge of the ice-marginal streamway, between the Łobżonka and the Gwda, as well as on the southern side of the ice-marginal streamway, in the neighbourhood of Chodzież. These elevations, however, are connected with glaciotectonic processes on the line of the fossil Kujawy—Pomerania anticlinal ridge, and some of these high-lying Tertiary formations form extensive xenoliths underlain by Pleistocene deposits. The next elevation of the Quaternary substratum to be cut by the ice-marginal streamway lies in the neighbourhood of the large terrace peninsula. Most clearly exposed are Pliocene Poznań clays, as well as Miocene quartz sands on the lower terraces of the Warta valley.

The thickness of the series of Pleistocene deposits, and, at the same time, the number of layers of boulder clay depends, as has been said above, on the relief of the Quaternary substratum. In accordance with the levelling role played by the cover of Pleistocene deposits on top of the sub-Quaternary surface, the number of both moraine layers and inter-moraine deposits increases in depressions of this surface, and decreases at its elevations.

In the slopes of the ice-marginal streamway there usually appears as their highest stratum the youngest layer of boulder clay, in numerous places interbedded by sands or silts. Below this frequently bipartite, boulder clay, there appers a series of intermoraine stratified sands and gravels intercalated by numerous lenses of varved clay and silts, and exposed on erosive terrace levels. Depending on the relief of the substratum, there appears below this series of intermoraine deposits a varying number of layers, separated by sands and silts. I am disregarding the specific problem of age interpretation of the Quaternary deposits, even of those intermoraine clays and sands which are exposed within the area of the ice-marginal streamway. This problem, as to Quaternary deposits appearing in the neighbourhood of the ice-marginal streamway, has been dealt with by E. Rühle (65), St. Gadomska (12), B. Krygowski (42), and others. However, following the example of Z. and Z. Churski (9), I wish to call attention to the marked variability of the structure of the Quaternary along the ice-marginal streamway, in view of numerous glaciotectonical dicturbances determined in this area, and the difficulty of tracing individual deposits over a longer stretch of land. Moreover, even on both the above-mentioned cross-sections of the Quaternary of the neighbourhood of the Noteć ice-marginal streamway near Dębowa Góra, barely a few kilometers distant from each other, the number of boulder clay layers differs.

At the same time, however, similarly as along the Lower Vistula (17), one series of strata in particular seems to have, relatively, the most regular and continuous course. This series of stratified sands and gravels and of varved clay, lying at the bottom of the upper boulder clay layers. These deposits, erosively incised, appear on nearly all terraces of the ice-marginal streamway. Long ago, the author has called attention to the observed accumulation of major series of varved clay, representing former ice-dammed lake basins, within the intermoraine formations in the region of the Toruń Basin and the Lower Vistula valley (19). Varved clay appears in numerous places of the Noteć ice-marginal streamway between Nakło and Piła, mostly exposed by the erosive surface of the ice-marginal streamway transition terrace. A major ice-dammed lake basin is contained in the mouth basin of the Gwda into the ice-marginal streamway, in the neighbourhood of Piła, reaching, at the least, from Dziembówko in the east beyond the western quarter of Piła. Here the clays are being utilized in numerous brick-yards (see Fig. 1). In the mouth basin of the Drawa, for instance on the ice-marginal streamway transition terrace at Drawiny, there also appear major series of ice-dammed lake clays underneath stratified sands. It is, however, the Gorzów Basin in particular, and as a wider form, the Kostrzyn Basin which abounds in ice-dammed lake clays, which appear within a large intermoraine deposit. Among more important localities where silts and varved clay appear in greater thickness, there should be mentioned Skwierzyna-Gaj and Murzynowo at the eastern side of the Basin, Brzozowiec within the Basin itself, Słońsk on its southern, Neuenhagen in the west and Witnica and the neighbourhood of Gorzów in the north. This indeed is an extensive ice-dammed lake basin, the sediments of which have been made accessible owing to the erosive action of outwash streams and ice-marginal streamway waters. Upon the ice-dammed lake deposits there most frequently lie intermoraine (fluvioglacial) stratified sands, deprived of their moraine covering by erosion; this is indicated by the considerable number of boulders which occur on the surface of the ice-marginal streamway terraces.

If, moreover, we take into consideration the interpretation given above of the fossil valleys or basins existing in the Noteć ice-marginal streamway and within the area of the ice-marginal streamway in the neighbourhood of Bydgoszcz, we might suggest the thesis of the predisposition of the present-day ice-marginal valley of the Noteć—Warta. It finds its expression not in the relief of the Quaternary substratum revealing orographical tendencies rather at variance with the course of the ice-marginal streamway, but in a string of depressions in the Pleistocene surface left after the penultimate glaciation (glaciotectonics?), filled with ice-dammed lake deposits. The deposits of the last glaciation failed to level the string of depressions, and consequently, it became the space for collecting meltwater and for its run-off to the west.

GEOMORPHOLOGICAL DEVELOPMENT OF NOTEĆ—WARTA ICE-MARGINAL STREAMWAY

PHASE PRECEDING POMERANIAN STAGE

An analysis of the ice-marginal streamway terraces and of streamway's bottom, and of their connection with the outwash terraces and the valley terraces of the Lower Vistula and the Lower Odra enables us to reconstruct the development stages of the Noteć—Warta ice-marginal streamway, from the time of the Pomeranian stage of the last glaciation right down to the present moment.

We still continue to do mere quesswork, in so far as the period preceding the Pomeranian stage is concerned, a period which reached back to the moment of the halt of the inland ice along the moraine extending along the Noteć. At the time of this Noteć phase there developed numerous marginal forms of inland ice, which owe their glaciotectonic structure to oscillating movements of the glacier edge. Connected with these processes is also the formation of terminal depression with thrust moraines in the neighbourhood of Chodzież (39). Along the Noteć thrust moraines existed depressions which owed their existence to either glaciotectonical processes, or to an inadequate aggradation of the ice-dammed basins formed during the penultimate glaciation. These depressions started to be filled up with silt deposits which now appear immediately under the organogenic deposits laid down on the floor of the later eroded ice-marginal streamway. At the time of these glacial oscillations there developed local outwash tracks of a general southward trend, at any rate running contrary to the later E—W course of the ice-marginal streamway, and concurring only with the meridional segment of the ice-marginal streamway downstream the mouth of the Gwda.

MAXIMUM PHASE OF POMERANIAN STAGE, OR PHASE OF OLDER LOCAL OUTWASHES

German investigations indicate that, in the area of the Kostrzyn Basin and of the ice-marginal streamway gap near Eberswalde *, the Noteć—Warta ice-marginal streamway was probably formed during the Pomeranian stage; however, owing to the different distance of the edge of the inland ice from the present-day path of the ice-marginal streamway which extends at least from Toruń to Eberswalde and even further westwards, the origin of this ice-marginal streamway is complicated. The western segment of this ice-marginal streamway was situated in close proximity of, and even in contact with, the end moraines of the Pomeranian stage (i. e. with the Odra ice lobe, reaching far to the south), while, on the other hand, the eastern section of the ice marginal streamway was situated far away from the front of the inland ice which ran along the line Czaplinek, Bobolice, Bytów and Kościerzyna, where the ice lobe of the Vistula began. Therefore, while in the west, in the region of the Kostrzyn Basin, outwash tracks deve-

* In particular, field studies conducted by H. Liedtke (48, 49).

loped gradually contributing to the formation of the ice-marginal streamway, in the east, in the forefield of accumulating marginal forms of the Pomeranian stage, the first outwash cones developed which did not reach as far as the present-day ice-marginal streamway.

But, in the light of H. Liedtke's research, even in the western part of the ice-marginal streamway its evolution passed several stages. At the same time of duration of the Odra ice lobe, meltwater, as indicated by the course of outwash tracks connected with this period, ran over and beyond the present-day Kostrzyn Basin, escaping along various ways into the Warsaw—Berlin ice-marginal streamway (see description on page 9), among others also through the ice-marginal streamway narrow near Eberswalde. This period saw the formation of the outwash surface which breaks off on the line Stara—Rudnica—Siekierki—Gozdawice above the Odra valley at approx. 58 m. a. s. l. At that time there probably also existed an outwash run-off, now breaking off at 65 m. a. s. l., along the Kłodawka valley, above the Warta ice-marginal streamway near Gorzów.

I am not convinced of the necessity of agreeing with German authors, assuming the filling of the Kostrzyn Basin with extensive, compact masses of dead ice (according to B e s c h o r e n of a thickness of as much as 50 to 80 m.) in order to make possible the flow of outwash waters from the present day northern side of this basin to its southern side and, further on, to the Warsaw—Berlin ice-marginal streamway. First of all, the present-day slopes of the Kostrzyn Basin owe their shape, and the Basin itself — its contour and depth, to younger erosion processes of the Odra and Warta (see map, Fig. 10) *. In all probability, and in accordance with the above-mentioned author's thesis of a continuos track of ice-dammed basins preceding the last glaciation, and of the predisposition of the present-day ice-marginal streamway, along with its characteristic depressions, there existed in the place of the present-day Kostrzyn Basin a depression in the moraine surface, where blocks of dead ice may have been buried in the moraine material. After the aggrading of the depression by outwash deposits, meltwater spread more southwards reaching the Warsaw—Berlin ice-marginal streamway; in doing this they cut into the moraine plateau, forming the present outwash surfaces which reach the edge of the plateau at a height of 55 to 65 m. a. s. l.

* This happens to be the weak point in the maps contained in H. L i e d t k e's contribution (48), where, on pages 38—39, the successive development stages of the ice-marginal streamway are given: no consideration has been given to the later (Holocen) erosive widening of the Kostrzyn Basin.

RECESSION PHASE OF ODRA ICE LOBE (ANGERMÜNDE—CHOJNA PHASE), OR PHASE OF YOUNGER LOCAL OUTWASHES

After recession of the Odra lobe to the line of the moraines of the Angermünde phase, which east of the Odra have their counterpart in the moraines of the neighbourhood of Chojna, there followed a new outwash forming. New outwash tracks cut into previous outwash plains, and lie at present at 40 to 50 m. a. s. l. above the Myśla valley and near Witnica. It therefore seems unnecessary to accept H. Liedtke's viewpoint that the surface of the ice masses in the basin has subsided exactly to such level as made possible the run-off of the outwash waters at the desired level.

During this phase it was not only outwash waters that passed from the east along the ice-marginal streamway of the Warta (the extent of this streamway is unknown) but, in accordance with H. Liedtke's opinion, for the first time they also ran off westwards through the ice-marginal streamway narrow near Eberswalde (see description on page 9). It was then that the ice-marginal streamway, probably comprising both the Warta ice-marginal streamway and the Eberswalde ice-marginal streamway, came into existence.

In this period it is yet appropriate to speak of the Toruń—Eberswalde ice-marginal streamway, as H. Liedtke does, since at that phase the eastern segment of the ice-marginal streamway, i. e. the Noteć ice-marginal streamway with the Toruń Basin, did not yet exist.

PHASE OF SHRINKAGE OF ODRA ICE LOBE OR PHASE OF THE OUTWASH-ICE-MARGINAL STREAMWAY TERRACE

In the meantime, while the oldest recession phase of the Pomeranian stage was going on east of the shrinking Odra ice lobe, outwash tracks in the shape of outwash valleys reached, along the present-day Wda, Brda, Gwda and Drawa rivers, down to the then shallow depressions in the zone of the Noteć moraines, transforming these depressions into a valley course which, even now, betrays its origin by its basin-like widenings and valley gaps. The water flow through the outwash valley of the Gwda river was probably stronger than the flow along outwash trains situated further, since it was the outwash valley of the Gwda that gave its direction to the succeeding section of the ice-marginal streamway, into which the upstream part of the ice-marginal streamway entered as lateral valley. It was then that the uniform out-wash and ice-marginal streamway level was formed, described above as the ice-marginal streamway terrace; to this terrace are correlated the outwash terraces of the Brda, Gwda and Drawa rivers.

This terrace lies at the altitude of 32 m. on the valley island of Bralitz—Neuenhagen in the Kostrzyn Basin, 3 m. lower than the bottom of the Eberswalde ice-marginal streamway, disregarding the later incision of the Finow river. Thus the run-off of ice-marginal streamway waters arriving from the Noteć ice-marginal streamway did not proceed westwards through the ice-marginal streamway gap near Eberswalde, but — as indicated by the further course of this terrace — northwards along the valleys of the Lower Odra and the Randow, where the ice-marginal streamway terrace has benn tracked as far as the neighbourhood of Blumberg and Bagemühl, at a height of 18 to 20 m. a. s. l. It is probable, however, that part of the waters, during exceptional floods perhaps overflowed westwards along the Eberswalde valley; proof may be a terrace fragment found at the outlet of the ice-marginal streamway gap, at 32 m. a. s. l. Consequently, a bifurcation must have existed here. At the same time the waters of the Odra joined the ice-marginal streamway waters, as indicated by a terrace fragment at Wriezen, at 36 to 37 m. a. s. l. H. Liedtke called the above ice-marginal streamway course the Noteć—Randow ice-marginal streamway.

During this principal phase the ice-marginal streamway run-off, comprising the outwash waters of the Vistula lobe and of minor ice lobes, situated west of the Vistula ice lobe, the Odra ice lobe was already shrinking. At any rate, active ice occurred only as far away as the neighbourhood of Szczecin, presumably along the line of local thrust moraines. The joint Vistula and Odra waters continued northwestwards along the Randow valley, and then, probably by the intermediary of the Mecklenburg ice-marginal streamway, into the Baltic ice-lake, which was then forming from the west.

Indeed, if the Odra ice lobe was already shrinking while the Pomeranian stage lasted in the area of the Vistula ice lobe and the minor ice lobes adjoining it in the west, the process of deglaciation must have been even more intense further west, i. e. in the region of the Danish islands.

The surface of both outwash terrace and ice-marginal streamway terrace is diversified by numerous melting forms (kettles). A particularly large number of these forms produced by melting of blocks of dead ice, are observed in the Gorzów Basin, this being a part of the Kostrzyn Basin.

According to the opinion of German authors (Ost, Woldstedt, Liedtke), the ice-marginal streamway terrace, similarly as the succeeding terraces, developed in the Gorzów Basin as a marginal terrace, aggraded by ice-marginal streamway waters between the slope of the moraine plateau and the cover of dead ice which occupied the deeper part of the ice-marginal streamway. Unfortunately, the above authors fail to explain the origin of the valley depression which, in the case under discussion must have existed prior to the formation of the ice cover.

It must be kept in mind that the area of the ice-marginal streamway under discussion lies in the nearest hinterland of the end moraines of the Poznań stage. This was, therefore, a zone where blocks of d e a d ice collected, a zone, moreover, connected with the depression of the moraine surface, occurring within the string of the inter-moraine ice-dammed basins described above. Blocks of dead ice were buried in moraine deposits. If blocks of s t a g n a n t ice also existed on the moraine surface, they undoubtedly melted as early as the initial outwash phases of the ice-marginal streamway, prior to the waters eroding the moraine surface to the level of the ice-marginal streamway terrace. Those blocks of d e a d ice, on the other hand, which were buried in moraine of fluvioglacial deposits, did not melt until the ice-marginal streamway waters had cut into the ice-marginal streamway terrace. For, indeed, if it had been otherwise, the kettles formed due to ice melting would have undergone filling by fluvial accumulation. Some of the ice blocks must have melted only after the next terraces in the ice-marginal streamway had been formed, since the discussed kettles appear simultaneously on several terraces (see map, Fig. 10).

In view of this interpretation of the part played by dead ice, the ice-marginal streamway terrace is therefore a normal valley terrace (of erosive feature); this, by the way, is indicated too by the even gradient of the terrace surface, shown in the longitudinal profile of the ice-marginal streamway (see profile of terraces, Fig. 11). It is too far-fetched an idea to assume, as do the above-mentioned authors, especially H. Liedtke, that the surface of the melting ice cover in the ice-marginal streamway subsided in stages, which was supposed to have permitted the waters to flow at increasingly lower levels and to build successive marginal terraces. Moreover, these terraces continue to appear, without any major disturbances in their gradient, further down, in the valley of the Lower Odra, responding to changes in the base-level of erosion in the initial Baltic area. The original extent of the ice-marginal streamway terrace has been erosionally curtailed not only by ice-marginal streamway waters flowing at the level of the present-day lower terraces, but also by the present-day Warta river (e. g. in the neighbourhood of Słońsk), — not to mention the entire destroying of this terrace, as well as younger terraces too in the basin-shaped quite flat, Odra valley upstream its meander segment (in the western part of the Kostrzyn Basin).

PHASE OF SHRINKAGE OF MINOR ICE LOBES EAST OF ODRA ICE LOBE, AND RETREAT OF VISTULA ICE LOBE I. E. THE PHASE OF THE ICE-MARGINAL STREAMWAY TRANSITION TERRACE

When, east of the shrinking Odra ice lobe, the inland ice had finally receded from the line of end moraines of the Pomeranian stage, there ceased the inflow of outwash waters from the north. On the outwash cones rivers developed, which cut their beds into the previously formed outwash surfaces and, after reaching the ice-marginal streamway, also into the main ice-marginal streamway terrace. The waters collected in the Noteć—Warta ice-marginal streamway were joined, from the south, by the waters of the Warta, which hitherto had been flowing westwards along the Warsaw—Berlin ice-marginal streamway. The combined waters of the ice-marginal streamway and the Odra still continued to make their way northwestwards along the Randow valley, through Mecklenburg territory, to the Baltic (the Baltic Ice Lake), then in the stage of formation. The lowest and most distant trace of the run-off of the ice-marginal streamway waters at the level of this terrace appears in the Randow valley near Blumberg, at 13 m. a. s. l. This was the period of maximum run-off of fluvial waters (no longer meltwater) along the Noteć—Warta ice-marginal streamway and, subsequently, along the Lower Odra valley. At the level of the ice-marginal-streamway transition terrace, along the valleys of the Odra and the Randow, flowed all the Odra waters, since now a run-off by way of the Eberswalde Gate was out of question, as well as the joint waters of Vistula and Warta and their tributaries, arriving both from mountaineous areas in the south and from recently formed outwash plains in the north.

PHASE OF UPPER TERRACE. THE BEGINNING OF THE BIFURCATION OF THE VISTULA

Simultaneously with the shrinking of the Vistula lobe and the formation of the Baltic Ice Lake in the bay which at that time reached as far as Tczew and Malbork, conditions developed for a direct run-off northwards of the Vistula waters. The history of this diversion is still unknown. One of the oldest attempts at explaining the origin of the diversion of the Vistula is P. Sonntag's concept of successive ice-dammed lakes (69). In any case, we must assume several phases of development in the area of the present-day Lower Vistula valley. At the time when the waters flowed at the level of the outwash-ice-marginal-streamway terrace, it was, in all probability, this valley by which the outwash waters of the Wda flowed southwards towards the ice-marginal streamway. A run-off of similar direction probably also existed at the level of the ice-marginal streamway transition terrace. During that period, however, morphological processes were proceeding which prepared the northward diversion of part of the Vistula waters. These processes comprised, first of all, the lowering of the watershed between the area of the Gdańsk ice-dammed basin and the Toruń Basin. It seems possible too that the passage of Vistula waters northwards may have been facilitated by the melting of blocks of dead ice along the line of the present-day Lower Vistula valley. The new passage was probably used initially by catastrophic floods only, and later on by normal flood waters of the Vistula. It is a fact that, at the level of the upper terrace which, at first, was considered by Keilhack and other geologists to be the bottom of the (Toruń) dammed lake, part of the Vistula waters made their way to the north, in all probability to an ice-dammed lake in the present-day mouth area of the Vistula, while another part of these waters flowed westwards along the Noteć—Warta ice-marginal streamway. In the light of the author's research (17) this fact is documented by upper terrace fragments both in the Toruń Basin west of Bydgoszcz, and in the Lower Vistula valley in the neighbourhood of Grudziądz.

The western arm of the bifurcating Vistula still continued to use the existing Noteć—Warta ice-marginal streamway, while the waters of the Vistula and of its tributaries, responding to changes in the Baltic base-level of erosion, cut into the ice-marginal streamway transition terrace. After joining the waters of the Warta, the ice-marginal streamway waters flowed into the Odra valley and, together with the latter river, made their way to the north. Part of the joint waters continued their way along the Randow valley to the northwest, but another part of them flowed northwards, in the direction of the Pomeranian Bay (Zatoka Pomorska), then in the stage of formation. This was already the second bifurcation run-off within one and the same river system. Its proof are terrace remnants observed in both valleys in the zone of bifurcation of the Odra and Randow valleys, at a level of 10 to 13 m. a. s. l.

PHASE OF UPPER MIDDLE TERRACE. TOTAL NORTHWARD DIVERSION OF BOTH VISTULA AND ODRA

The development of the Vistula valley was one phase later with regard to the development of the Odra valley, owing to earlier deglaciation in the west. The total run-off of the Odra waters towards the open Pomeranian Bay went forth as early as at the level of the 7—9 m. terrace in the ice-marginal streamway. It may very well be that precisely this drawing nearer to the base-level of erosion has been the cause of the river waters cutting down to the level of this terrace. This period must have been short, since this terrace does not extend as far as the Toruń Basin (see profile of terraces, Fig. 11). The bifurcation of the Vistula waters still continued at the level of the 5-metre terrace of the ice-marginal streamway, which had its continuation — similarly to the proceding terrace — exclusively in the Lower Odra valley, also down-stream the entry of the Randow valley. It was only after the lowest ice-marginal streamway level, i. e. the present-day floor of the ice-marginal streamway, filled with silts and peat, had been reached that the waters of the Vistula definitely diverted their course, henceforth to flow northwards along the Lower Vistula valley. This event was brought by the lowering of the base-level of erosion following the formation of a run-off to the then Baltic Ice Lake, probably through the Łeba ice-marginal streamway. The waters of the Vistula cut into the former valley bottom, here called the upper middle terrace, down to the level of the later lower middle terrace. The Brda followed the example of the Vistula, cutting into the upper middle terrace in the ice-marginal streamway with its opposite gradient, while the Noteć, flowing further west, continued to use the ice-marginal streamway. However, it is also conceivable that the Noteć initially proceded northwards across the present-day dune area towards the Vistula.

So far, there lacks confirmation of the thesis of a tectonic uplifting of the watershed between the Brda and the Noteć, supposed to be the principal cause of the northward diversion of the Vistula; among others, A. Zierhoffer put forth this hypothesis. I admit that near Bydgoszcz the Pliocene surface, as described above, clearly shows an elevation, however this form has been covered (levelled) by Pleistocene deposits and does not show on the present-day surface of the terrain. At any rate, the terraces which are older than the professed uplift, do not show any clearly marked deformities in their profile (see Fig. 11),while the elevation in the bottom of the ice-marginal streamway in the neighbourhood of the watershed west of Bydgoszcz is built of peat deposits, ending above the Brda valley by a sharp boundary (see profile, Fig. 11). Unquestionably, however, this problem still remains open and requires further, more detailed investigation.

TRANSFORMATION OF NOTEĆ—WARTA ICE-MARGINAL STREAMWAY AFTER NORTHWARD DIVERSION OF VISTULA RIVER

In the light of examinations of peat deposits in the Noteć ice-marginal streamway A. Wodziczko (76) was the first to attempt the reconstruction of the process of the transformation of this valley by erosion and accumulation processes, from the moment of the decline of this streamway, i. e. of the northward diversion of the waters of the Vistula. In his opinion, the bottom of the ice-marginal streamway is composed of extensive basins, filled with gyttja and peat bogs. On the basis of a pollen analysis, A. Wodziczko believes the oldest of these basins to be of pre-Boreal age. The above-mentioned deposits are characteristic for sedimentation in stagnant water which only locally were disturbed by flowing water. In her paper discussed above, St. Gadomska (12) reports to have found, on the bottom of the ice-marginal streamway at the foot of Dębowa Góra, clayey silts 1.5 to 7 m., thick containing a macological fauna. Higher up lie peats 3.6 to 4.6 m. thick with a substratum of gyttja. The above-mentioned contribution by T. Churski (10) on the morphology of the bottom of the Noteć ice-marginal streamway between Bydgoszcz and Santok (the entry of the Noteć into the Warta) confirms A. Wodziczko's view as to the existence of basins on the bottom of ice-marginal streamway *, underlying the organogenic deposits.

A similar geological profile of the bottom of the Warta ice-marginal streamway in the neighbourhood of Gorzów has been supplied by L. Pilarczyk (62). In view of the above facts it must therefore be assumed that, after the change in direction of the run-off of the Vistula and the simultaneous suspension of the bottom of the Noteć ice-marginal streamway with regard to the Brda valley and probably also to the Warta ice-marginal streamway, i. e. the western part of the Noteć—Warta ice--marginal streamway (between Santok and Kostrzyn), the bottom of the ice-marginal streamway was gradually filled with deposits laid down by sluggish rivers, especially the Noteć, or with deposits of basins of stagnant water.

According to studies made by T. Przybylski **, in this region peat started to be formed in the Younger Dryas. At the same time, minor rivers and their tributaries piled up alluvial cones of various size on the floor of the ice-marginal streamway. In this manner the bottom of the ice-marginal streamway obtained its morphological and geological diversity. Depressions were filled in, at first with gyttja and, later on, with peat formations developing as the result of inundations by the Vistula, when part of the flood waters continued to over-flow westwards along their previous bed. With the gradual increase of humidity of the climate during the Holocene the ground water table began to rise. The thickne s

* See description on page 64.

** Oral information.

of the peat cover started growing. Only the alluvial cones of major rivers entering the ice-marginal streamway (Noteć, Gwda, Drawa, Warta) rise, in the form of swells, from under the peat cover which also penetrated to small lateral valleys entering the ice-marginal streamway (e. g. the Śleska valley).

Parallel with geological and morphological processes proceeding on the floor of the ice-marginal streamway, there also took place relief-forming processes on its slopes and terraces. Since long attention was centered on the erosive incising of the slopes of the ice-marginal streamway and of valleys in general on the postglacial Polish Lowland (among others, also in the Lower Vistula valley); some authors interpret this slope dissection as morphological features of successive climatic phases (e. g., W. Okołowicz). The small lateral valleys issue into different valley terraces. This fact enables us to estimate their morphological age.

Many of these valleys originated under conditions of a periglacial climate, as indicated also by the soliflual covers on slopes and older terraces, as well as by aeologlyptoliths (ventifacts). H. Lembke (43) describes the periglacial valleys incised in the slopes of the Kostrzyn Basin. Z. and Z. Churski (9) characterize the asymmetrical valley of the Śleska (east of Nakło) as a periglacial valley. Many old, shallow valleys, filled with denudation material, dissect the slopes of the ice-marginal valley in numerous places, particularly where the slope recedes, e. g., east of Santok, or where at the foot of ice-marginal streamway slopes, terraces appear into which these small valleys pass (e. g. north of Bydgoszcz or in the neighbourhood of Osinów on the right bank of the Lower Odra). On the other hand, along recently undercut ice-marginal streamway slopes we observe old shallow valleys hanging high above the ice-marginal streamway bottom. As demonstrated by T. Churski (10) alluvial cones corresponding to these forms, emerge in the Noteć ice-marginal streamway form under a covering of peat. We also meet them on upper ice-marginal streamway terraces.

H. Lembke (44) describes alluvial cones in the Gorzów Basin, extending on the Odra flood plain and connected with dried plateau gullies. The same author has determined the existence of two interbedded alluvial cones of up to 5 m. height, as well as of river beds corresponding with changes in the base-level of erosion within the Kostrzyn Basin. I consider these latter cones to be younger than the alluvial cones descibed abowe which underlie the peats in the Noteć ice-marginal streamway. As to their age they are separated by the period necessary for filling the Warta ice-marginal streamway, or the

Odra valley, with alluvia, an occurrence which successively proceded after the free run-off to the Pomeranian Bay had begun *.

There can be no doubt that several generations of valleys, mostly incised, may be distinguished on the slopes of the ice-marginal valley. The oldest valley system was formed in periglacial conditions prevailing at the time of the last stages of the last glaciation. Correlated with these small valleys are, principally, the alluvial cones covered by peats on the bottom of the Noteć ice-marginal streamway, as well as on the terraces of the ice-marginal streamway. During the same period there also took place aeolian processes indicated by dune sands and by dunes buried in the peats. The formation of the peat cover, which presumably proceeded by stages, was interrupted by down wash and erosive processes along the sides of the ice-marginal streamway. On the slopes of the ice-marginal streamway there developed new erosive gullies incised in the hitherto existing wide lateral valleys. These new incisions in turn produced minor alluvial cones, which in numerous places appear on the peat cover, joining into a more or less continuous colluvial ledge at the foot of the slopes of the ice-marginal streamway **.

Alternating with erosive processes on the slopes of the ice-marginal streamway, aeolian processes took place on the sandy terraces of the ice-marginal streamway; they caused, in at least two phases, the formation of numerous dune areas, described by W. Mrózek (54), L. Pilarczyk (61), and others; these dune areas are particularly concentrated in the Toruń Basin and in the interfluvial area between Noteć and Warta.

Up to the postglacial climatic optimum there proceeded the melting of dead ice blocks, collected in large quantities in moraine deposits within the area of the ice-marginal streamway, this being the near backland of the marginal forms of the Poznań stage and of the Noteć end moraines. The incision of ice-marginal streamway waters into moraine deposits accelerated melting of the ice. Due to this, the ice-marginal streamway terraces show, besides the richness of aeolian forms, also a marked diversity of their surfaces in the form of numerous depressions, mostly filled with peat, and concentrated particularly in the

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* The problem of the filling of the Warta ice-marginal streamway and of the Odra valley with young fluvial sediments being a specific problem in itself, requires special examination.

** The problem of the development of the small lateral valleys which cut into the slopes of the Noteć ice-marginal streamway is the subject of special investigations conducted by Z. Churska on behalf of the Chair of Physical Geography of the Nicholas Kopernik University, Toruń. A number of Master's theses have also been written on the above topic.

Warta ice-marginal streamway, as well as in the form of subglacial channel lakes described, among others, by J. Bajerlein (3). The present-day river activity in the Noteć—Warta ice-marginal streamway, out of proportion with the great development rhythm of the ice-marginal streamway which now has come to an end, are negligible. Both the Noteć and the Warta, meandering over the extensive floor of the ice-marginal streamway, cause merely insignificant erosive or accumulative processes in their tributaries, from which they recede or which they approach, e. g. in the Łobżonka valley.

ON LATE-GLACIAL AND POST-GLACIAL DEVELOPMENT STAGES OF VALLEY SYSTEM ON POLISH LOWLAND

The problem of the development of the valley network in the course of the recession, towards the end of the last glaciation, of the inland ice from the Baltic regions situated between the Odra and the Niemen has a rich literature of its own. K. Keilhack (28, 29) was one of the first to show the relation between the inland ice and the proglacial valley network. He described the Toruń—Eberswalde ice-marginal streamway correlating it with the Pomeranian stage of the last glaciation. He also distinguished the Pomeranian ice-marginal streamway, formed at the time of the subsequent recession phases of the inland ice. Subsequent, and particularly the most recent years brought a considerable number of important and fundamental contributions which enable us to add a number of new topics to the problem of the development of valleys on the glacial lowland to envisage these valleys in a fuller light, and to determine their geological age. A particularly important part, in this respect is played by the present synthetic contribution on the Noteć—Warta ice-marginal streamway and on its connection both with outwash run-off and with river valleys extending from the south (see preceding chapter of present contribution). The ice-marginal streamway, being the central part of the late-glacial valley system, represents the key to the explanation of the origin of this valley network.

In the area under discussion, the development of this valley system beginning with the Pomeranian stage of the last glaciation, may be discussed in three phases, comprising a number of subphases. I am calling these phases the proglacial phase, the transition phase, and the Baltic phase.

PROGLACIAL PHASE

The proglacial phase, simultaneous with the Pomeranian stage of the last glaciation, was distinguished by the decisive influence upon the development of valley forms, exerted by meltwater streams

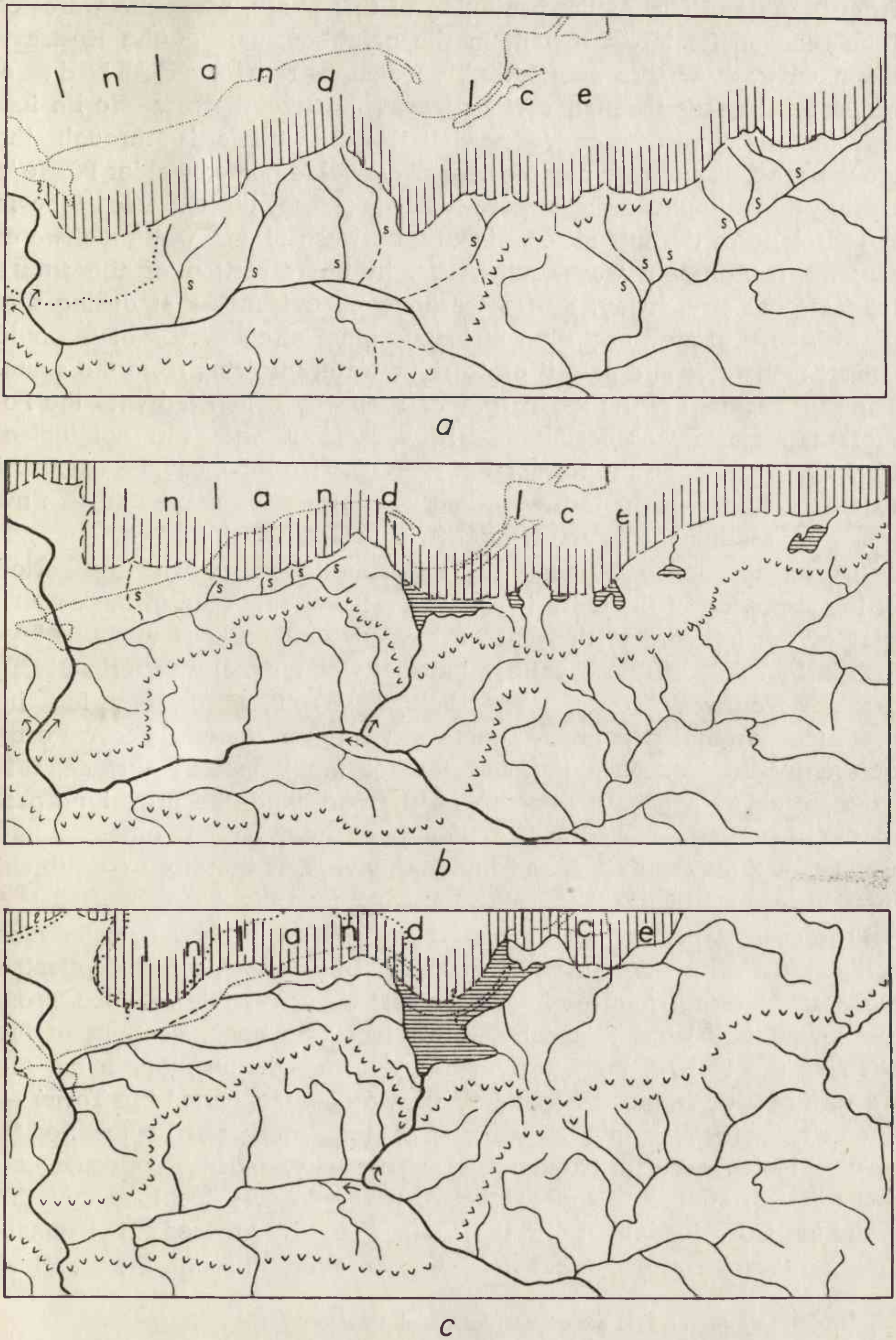

Fig. 9. Development of valley network in Northern Poland

a — proglacial phase; *b* — transition phase, initial sub-phase; *c* — transition phase, final sub-phase. Divergent arrows mark places of bifurcation from the inland ice. At the beginning of this phase, when the Odra ice lobe reached its farest extent, in the neighbourhood of the Kostrzyń Basin outwash waters overflowed, as demonstrated by H. Liedtke, either southwards through various tracks into the Warsaw—Berlin ice-marginal streamway, or (somewhat later) westwards through the ice-marginal streamway narrow near Eberswalde („Eberswalder Pforte"). During this sub-phase there were formed, east of the Odra ice lobe in the foreland of the inland ice, gigantic outwash plains, while meltwater streams made their way southwards, in the direction of the future ice-marginal streamway. So far we have no evidence that during that period there existed any kind of ice-marginal streamway which would collect meltwater and pass it on to river waters flowing from the south. The first segment of the ice-marginal streamway connected with the Pomeranian stage was formed — in agreement with the opinion of H. Liedtke — on the foreland of the Odra ice lobe, but the eastward extent is unknown. In the meantime, fluvial waters continued to flow westwards along the Warsaw—Berlin ice-marginal streamway.

During the next sub-phase (Fig. 9a), simultaneously with the period of the shrinking of the Odra ice lobe at a faster rate than of the eastern part of the inland ice, there were formed numerous outwash valleys („s" in Fig. 9a); by these valleys the meltwater streams, after building extensive outwash cones, made their way southwards, entering the great ice-marginal streamway course which ran peripherally to the edge of the inland ice. During the decline of the Pomeranian stage, this ice-marginal streamway collected, on the one hand, the prevailing part of meltwater streams from the inland ice and, on the other, of the waters, of the Carpathians and Sudetian rivers. It therefore constituted the central part of the then valley network (see Fig. 9a).

The eastern part of this mighty valley course, in older contributions called the Wilno—Warsaw ice-marginal streamway *, mostly collected meltwater issuing from the inland ice east of the Vistula ice lobe. From the south, they were joined by waters from the upper sections of the Niemen, the Narew, the Bug and the Vistula. On the other hand, the western part of this ice-marginal streamway course, called the Toruń — Eberswalde ice-marginal streamway, a term only partly justified **, or the Noteć—Warta ice-marginal streamway, mostly collected the meltwater from the inland ice between the Vistula ice lobe and the shrinking Odra ice lobe. From the south, the Odra entered this ice-marginal streamway after having shaped a gap valley through the marginal

* Recently J. Kondracki (34) resumed this term.

** See my comment on this subject on page 75.

forms of the Poznań stage and abandoned the lower part of the Warsaw—Berlin ice-marginal streamway. On the other hand, the middle course of the Warta still joined the Odra through the above ice-marginal streamway, while the Warta received a tributary flowing from the north through the later gap section of the Warta valley in the vicinity of Poznań*.

This major part of the combined waters of the Vistula and the Odra, collected in the Kostrzyn Basin, ran off by the Lower Odra valley and, subsequently, by the Randow valley, escaping, by way of the Meckleburg ice-marginal streamways, into the Baltic Ice Lake, then at the stage of formation of the Mecklenburg coast and the Danish Islands. This was the reason why H. Liedtke introduced the term Noteć—Randow ice-marginal streamway for this ice-marginal streamway course. The remaining part of the ice-marginal streamway waters continued (occassionally) to use the ice-marginal streamway gap near Eberswalde, inconvenient though it was owing to its narrow floor. Consequently, there existed here a bifurcation of ice-marginal streamway waters, principally maintained by high floodwaters. The above description shows that deglaciation proceeded unevenly, i. e. more rapid in the west than in the east, presumably the effect of the more marime climate prevailing in the west.

The outlined reconstruction of the development of the valley network during the decline period of the Pomeranian stage has been based principally on an analysis of the terraces of the Noteć—Warta ice-marginal streamway in their connection with outwash tracks. I took into consideration contributions like: the investigations by H. G. Ost (58, 59) of the outwashes of the Gwda and Drawa rivers, and their counterpart, the ice-marginal streamway terrace, the results of the field work of St. Kozarski and J. Szupryczyński (37) in the area of the Noteć ice-marginal streamway between Bydgoszcz and Piła, the studies of W. Mrózek (54) in the Toruń Basin, and the research done by the author of the present contribution himself, who traced the outwash terrace of the Brda and its counterpart, the terrace in the Noteć—Warta ice-marginal streamway, the Lower Odra valley and the Randow valley. Availing himself of the research conducted by H. Liedtke (48) also in the area of the Kostrzyn Basin, the present author reconstructed the system of the outwash and ice-marginal streamway run-off of the period of the Noteć—Rędowa ice-marginal streamway, which streamway extended from the outwash terrace of the Brda and the Toruń Basin in the east to the fragments of the ice-marginal streamway terrace in the

* See contribution by T. Bartkowski (5).

Randow valley in the west (see Fig. 11). At those times, outwash waters of the Wda river were probably flowing southwards along this valley of the Lower Vistula into the Toruń Basin. For reconstructing the valleys existing during this sub-phase, on the aera E & S of the present-day valley of the Lower Vistula, greatly useful proved to be the investigations of St. Lencewicz (46), concerning the middle Vistula valley, of J. Kondracki (32, 33, 34) dealing with the area of Mazury, of W. Okołowicz (57) on the development of the Niemen valley, and of L. Roszkówna (64) on the morphology of the western part of the Mazurian Lake District.

TRANSITION PHASE

As demonstrated above, at the time of the maximum of the Pomeranian stage, meltwater from the nearby Odra ice lobe ran off through various ways into the Warsaw—Berlin ice-marginal streamway and, only later on, westwards by way of the ice-marginal streamway near Eberswalde. The westward run-off of the collected fluvioglacial and fluvial waters along the Noteć—Warta ice-marginal streamway, and later on, after receiving the waters of the Odra, northwards towards the shrinking inland ice (with a partial westward bifurcation flow through the Eberswalde gap in the ice-marginal streamway (see Fig. 9a) was already a symptom of the final phase of the Pomeranian stage. The run-off along the valleys of the Odra and the Randow to the Baltic, then at the stage of formation, was at the same time the initial step towards the next phase in the development of the valley network, viz. to the transition phase. On the back of the end moraines of the Pomeranian stage, in the course of the gradual recession of the inland ice a network of marginal valleys, interconnected by ice-dammed basins, was developed.

Along those valleys there flowed fluvioglacial waters, supplemented by the flow of minor rivers forming on the northern slope of the main end moraines of the Pomeranian stage. During a longer halt of the inland ice, probably simultaneous with the North-Rügen stage, the Pomeranian ice-marginal streamway was formed, described by K. Keilhack (29), K. v. Bülow (8) and many other authors (see Fig. 9b).

South of the main end moraines of the Pomeranian stage, in conditions of a periglacial climate, rivers meanwhile began to flow along the hitherto outwash valleys, draining extensive outwash cones. They were heading for the ice-marginal streamway, in which the waters of the entire river network of Poland's territory were collected, flowing at the level of the so-called ice-marginal streamway transition terrace which had cut to depth of aprox. 5 metres into the ice-marginal streamway terrace corresponding to the proglacial phase. This terrace appears not only in the Noteć—Warta ice-marginal streamway. It was also found in outwash valleys and in the Lower Odra and Randow valleys, along which the waters ultimately ran off towards the Baltic Sea. The same terrace has also been found to exist as highest valley level at the entry of the Warta valley into the ice-marginal streamway. During that period there already existed a gap valley of the Warta in the neighbourhood of Poznań, and the waters of the Warta joined the river waters flowing in the Noteć—Warta ice-marginal streamway. It was only part of the Warta waters — in accordance with the opinion of T. Bartkowski (5) — that continued, by bifurcation, to run westwards along the Warsaw-Berlin ice-marginal streamway.

In he next sub-phase, at the level of the upper terrace, began the diversion of the Lower Vistula while the waters of the Odra ran nor h-wards to the ice-liberated area within the present-day Pomeranian Bay. But the transition phase still persists. This is why only part of the waters of the Vistula make their way to the north while the remaining waters, due to bifurcation, flow westwards into the Noteć—Warta ice-marginal streamway (17). Similarly, part of the waters collected in the Lower Odra valley flowed, by bifurcation, westwards along the Randow valley. But the greater part of the fluvial waters of the Odra, which then represented the main mass of fluvial waters on the Lowland a ter receiving the waters of the Pomeranian ice-marginal streamway, ran off by a valley, submerged today, extending along Uznam (Usedom) and Rügen, to the Baltic which was then at the stage of formation.

Where did the waters of the Lower Vistula flow to? At that time, the Bay of Gdańsk was undoubtedly still occupied by the ice lobe of the Vistula. On its forefield there was spread out a terminal depression, surrounded by a fringe of stadial moraines. According to the prevailing opinion of authors, this area was occupied by an extensive glacial lake, the so-called Gdańsk ice-dammed lake, described mainly by P. Sonntag (69). Recently, Z. J. Kotański (36) also dealt with this subject, pointing out the remnants of ice-dammed lakes in the neighbourhood of Żuławy Gdańskie (the Vistula Delta), at a height of 40 to 45 m. a. s. l., on the other hand ascribing the origin of lower-situated abrasion terraces (17 to 20 m. a. s. l.) on the margin of the moraine plateau to the Littorina Sea. However, in this author's opinion, the problem is still open to dispute and requires detailed investigations. At any rate, a considerable amount of both geological and morphological evidences points to the existence of an ice-dammed lake at that time, a lake which increased in size while subsiding at the same time, as the inland ice was receding to the area of the Baltic. Whether the ice-dammed lake disappeared when the inland ice entirely left the land, or whether the present-day Vistula Delta and the Gdańsk Bay at once became a marine bay, remains a controversial question*.

During one of the successive phases of the halt of the inland ice, in the period of the Older Dryas (see Fig. c), there was formed the Pregoła (Pregel) ice-marginal streamway, described, among others, by B. Körnke (41); its waters ran into the ice lake situated in the area of the present-day Vistula Delta. The outflow from this lake was through the Łeba ice-marginal streamway and, further westwards, through one of the numerous marginal valleys along the front of the inland ice. At that time, the extent of the inland ice must have been as differentiated, as before. In the Bay of Gdańsk and the Pomeranian Bay the inland ice had probably a lobate extent; this is also suggested by the results of H. Kliewe's research (31). It is solely on both sides of the Bay of Gdańsk that, on the basis of marginal forms observed, we are able to precisely establish the extent of the inland ice during that particular phase of deglaciation.

The great ice-marginal streamway, situated south of the main end moraines of the Pomeranian stage, continues to be the most important part of the drainage system of the Lowland. There continues to exist bifurcation of the waters of the Vistula which, in turn, flows at the level of the upper middle terrace. For, indeed, the oldest peat bogs in the Noteć ice-marginal streamway west of Bydgoszcz were formed during the Younger Dryas, thus in the period when the inland ice had already receded into the area of Scandinavia. On the other hand, as shown by the analysis of the terraces in the Lower Odra valley, all the waters of the Odra ran off northwards by an ice-marginal streamway, at present submerged, along Uznam (Usedom) and Rügen towards the Baltic, receiving from the east waters of marginal rivers of the inland ice.

BALTIC PHASE

The full diversion of the waters of the Vistula towards the open Bay of Gdańsk (at the level of the lower middle terrace of the Lower Vistula valley — Alleröd), as well as the formation of a watershed in the ice-

* On the basis of an analysis of the underwater relief and the geological structure of the Vistula Delta, the author of the present paper favour the latter alternative (21).

marginal streamway near Bydgoszcz, and the entry of the Niemen river into the Baltic Ice Lake inaugurate the last phase in the development of the Lowland valley network, viz. the Baltic phase. Lessened is the importance of the Odra, deprived as it is of the inflow of waters from the Vistula through the ice-marginal streamway. During that period the mouth of the Odra, in contrast with the mouths of both the Vistula and the Niemen was far removed from the present-day shore in the area of the Baltic. It was during the Baltic phase that the fundamental incongruity as to the direction of run-off of the rivers of the Polish Lowland was finally perpetuated. On the one side surviving outwash valleys, directed to the south, on the other, the northward-directed gap valleys of the Odra, the Vistula and the Niemen, as well as the valleys of minor Baltic rivers which, in meandering courses, by the intermediary of gap valleys, are headed towards the nearby sea. The rivers respond to postglacial oscillations of the level of the Baltic Sea by forming erosive valley terraces and by river bed aggradation. The Noteć—Warta ice-marginal streamway, the gradient of which was not suited for the present-day, mostly small, rivers flowing in it, obstructs the influence of the Baltic base-level of erosion and becomes a dead valley. Meanwhile, the proximity of this base-level of erosion to the tributaries of the Lower Vistula and Lower Odra causes an intensive development of their valleys, as indicated by number of valley terraces, mostly erosive terraces such as, e. g., the nine terraces in the Brda valley.

After the present paper had been prepared there has appeared an interesting essay by A. Kowalska* which, among other topics, deals with the interdependence of the sub-Pleistocene surface and the present-day relief of the territory of the Odra Basin. Generally speaking, this author's opinion as regards this interdependence agrees with my own opinion. Even so, I can not agree with this author as to her assuming a full interdependence between the Noteć—Warta marginal streamway and the Pleistocene Substratum. On this topic, I have explained my own viewpoint on p. 70 of this paper.

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RAJMUND GALON

MORFOLOGIA PRADOLINY NOTECI—WARTY (LUB TORUŃSKO-EBERSWALDZKIEJ)

STRESZCZENIE

GŁÓWNE PROBLEMY PRACY

Po dokonaniu krótkiego przeglądu prac dotyczących pradoliny Noteci—Warty i omówieniu poglądów dotyczących genezy tej rozległej formy * autor wysuwa następujące problemy lub zadania:

a) dokładne prześledzenie i poznanie budowy teras plejstoceńskich i holoceńskich w pradolinie i dolinach do niej uchodzących oraz opis osadów wypełniających dno pradoliny w celu określenia kolejnych faz rozwojowych całej pradoliny łącznie z obu skrajnymi węzłami dolinnymi, tj. kotlinami Toruńską i Kostrzyńską,

b) dalsze przestudiowanie zagadnienia jednoczesności odpływu pradolinnego w powiązaniu ze stadium pomorskim,

c) określenie stosunku odwrotu Wisły do odwrotu Odry,

d) dalsze studia nad rolą martwych lodów w rozwoju pradoliny i form w pradolinie,

e) zbadanie stosunku pradoliny do budowy geologicznej sąsiedniego obszaru,

f) ustalenie roli pradoliny Noteci—Warty w przebiegu odwodnienia dolinnego w czasie i po stadium pomorskim na obszarze całego Niżu,

g) sporządzenie dokładnego obrazu kartograficznego stosunków morfologicznych całej pradoliny, w szczególności teras dolinnych (z odpowiednimi przekrojami i profilami podłużnymi).

Autor prowadził badania geologiczne i geomorfologiczne w pradolinie od Bydgoszczy do Kostrzynia i miał okazję poznać ważniejsze odsłonięcia w terasach dolnej Odry oraz w dolinie Rędowy na terenie Niemieckiej Republiki Demokratycznej. Badania dotyczyły głównie teras dolinnych.

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* Szczegółowe omówienie literatury dotyczącej genezy zachodniej części pradoliny łącznie z Kotliną Kostrzyńską znajdzie czytelnik w pracy H. Liedtkego (48) a wschodniej części, w szczególności Kotliny Toruńskiej, w pracach R. Galona (13, 17, 18).

TERASY W PRADOLINIE NOTECI—WARTY

W pradolinie Noteci—Warty występują dwa rodzaje poziomów terasowych, mianowicie terasy związane z odpływem pradolinnym, tj. odpływem połączonych wód rzecznych i sandrowych, czyli terasy plejstoceńskie, oraz terasy związane wyłącznie z odpływem rzecznym, czyli terasy holoceńskie. Terasy te występują także w dolinach uchodzących do pradoliny, w szczególności w dolinie Brdy, dolinie Gwdy, dolinie Drawy i w szeregu mniejszych dolin. Wszystkie terasy w dolinach uchodzących do pradoliny nachylają się w kierunku pradoliny, a w pradolinie ku zachodowi. Jedynie na terenie obu skrajnych kotlin, a zwłaszcza Kotliny Toruńskiej, nachylenie teras jest mniej wyraźne*. Ze względu na genezę plejstoceńską omawianej wielkiej formy dolinnej i stosunkowo mały udział holoceńskich procesów rzecznych w dalszym (erozyjnym) przekształceniu pradoliny opis teras dotyczy najpierw właściwych teras pradolinnych, a następnie teras rzecznych.

Z badań autora, który nawiązał do wyników badań innych autorów, wynika, że w pradolinie występuje ponad dnem dolinnym pięć teras, jeżeli nie brać pod uwagę nielicznych lokalnych listew terasowych o charakterze przejściowym (ryc. 10 i 11):

I. górna terasa przejściowa (a)** czyli terasa 5-metrowa, (średni spadek 1 : 5530),

II. górna terasa przejściowa (b) czyli terasa 7—9-metrowa (średni spadek 1 : 5140),

III. górna terasa czyli terasa 10—12-metrowa (średni spadek 1 : 6000),

IV. terasa pradolinna przejściowa czyli terasa 15—22-metrowa (średni spadek 1 : 6360),

V. terasa pradolinna lub sandrowa o wysokości względnej 18—25-metrowa (średni spadek 1 : 6420*** lub 1 : 7270****)

Wszystkie wyżej wyróżnione terasy w pradolinie Noteci—Warty występują już w Kotlinie Toruńskiej. Jedynie górna terasa przejściowa (b) pojawia się dopiero w Kotlinie Pilskiej. Terasa pradolinna przejścio-

* Częściowo nawet przeciwne (dolne terasy Brdy).

** Autor zachował nazwy teras, stosowane w jego dawniejszych pracach (17, 18). Patrz także tab. 1.

*** Na odcinku Bydgoszcz—Bagemühl (dolina Rędowy).

**** Na odcinku Aleksandrów Kujawski—Bagemühl (dolina Rędowy).

wa znajduje swój dalszy ciąg w dolinie Rędowy (Randow), górna terasa pradoliny posiada charakter bifurkacyjny, a więc przechodzi nie tylko w dolinę Rędowy, lecz zaznacza się także w dolinie dolnej Odry. Pozostałe, niższe terasy pradoliny występują tylko w dolinie dolnej Odry. Zatem w rozwoju teras pradoliny można wyróżnić trzy fazy, mianowicie: 1) fazę pradoliny Noteci—Warty—Rędowy (H. Liedtke), 2) fazę bifurkacyjną i 3) fazę pradolinno-odrzańską.

Odstęp pionowy pomiędzy poszczególnymi terasami jest zadziwiająco podobny (przeciętnie 4—5 m), co świadczyłoby o regularności rytmu erozyjnego, wywołanego wahaniami podstawy erozyjnej. Jedynie w początkowej części profilu podłużnego niektórych teras nachylenie ich wzrasta, a odstępy pomiędzy terasami ulegają odchyleniom. Poza tym średni spadek młodszych teras jest nieco większy od spadku starszych teras, co zapewne pozostaje w związku ze skróceniem dolnego biegu rzeki — po osiągnięciu Zatoki Pomorskiej.

Wszystkie terasy posiadają charakter erozyjny lub erozyjno-akumulacyjny. Jako dowód służyć może 1—2-metrowa warstwa osadów rzecznych na utworach morenowych i międzymorenowych. Zgodnie ze zmienną budową geologiczną plejstocenu, na poszczególnych terasach dolinnych odsłaniają się na przemian gliny morenowe, warstwowane piaski i żwiry fluwioglacjalne oraz iły warwowe, przy czym najczęściej gliny morenowe pojawiają się na wyższych terasach, natomiast utwory międzymorenowe na niższych terasach (por. m. in. profil teras nad dolną Gwdą — ryc. 1). W licznych wypadkach na powierzchni teras, w związku z ich charakterem erozyjnym, zachowało się tylko rezyduum morenowe w postaci bruku głazowego różnej wielkości, a piaski rzeczne leżą prawie bezpośrednio na piaskach fluwioglacjalnych (ryc. 5). Na terasach o powierzchni piaszczystej rozwinęły się wydmy, tworząc gdzieniegdzie zwarte pola wydmowe.

Osady terasy pradolinnej (sandrowej) wykazują charakterystyczny dla osadów wód płynących powolny lecz stały wzrost obtoczenia ziarna (ryc. 7), niezaburzony włączeniem się po drodze szlaków Gwdy i Drawy, co zapewne wynika z równoczesności istnienia i podobnej długości i spadku owych ciągów sandrowych. Natomiast obtoczenie ziarn osadów następnych teras wykazuje bardzo wyraźne zaburzenia swej linii rozwojowej z biegiem rzeki tam, gdzie do osadów pradoliny dołączają się osady Gwdy lub Drawy o odmiennych warunkach sedymentacyjnych, wywołanych zapewne większym spadkiem owych rzek. W każdym razie wykresy obtoczenia ziarn osadów poszczególnych teras potwierdzają obraz ciągów terasowych wyróżnionych w świetle kryteriów morfologicznych.

TERASY W DOLINACH BOCZNYCH

Wyżej opisane terasy pradoliny Noteci—Warty wraz z ich dalszym ciągiem w dolinie dolnej Odry i dolinie Rędowy posiadają swoje odpowiedniki w dolinach uchodzących do pradoliny. Zbadano odcinki ujściowe doliny Drwęcy, sandru i doliny Brdy, doliny Łobżonki, sandru i doliny Gwdy, sandru i doliny Drawy, terasy doliny Warty powyżej ujścia Noteci i szereg mniejszych dolin. Tabela 1 ilustruje relacje zachodzące pomiędzy terasami pradoliny Noteci—Warty, doliny i sandru Brdy oraz doliny dolnej Wisły.

Przegląd teras w dolinach powiązanych z pradoliną Noteci—Warty potwierdził wyżej wykonany podział teras w pradolinie na pięć poziomów terasowych występujących większymi lub mniejszymi fragmentami na całej długości pradoliny (bez uwzględnienia lokalnych powierzchni sandrowych, urywających się ścianą erozyjną nad pradoliną, oraz bez uwzględnienia 1—2-metrowej terasy zalewowej).

Tabela 1

Zestawienie teras w pradolinie Noteci—Warty, w dolinie Brdy i w dolinie dolnej Wisły (w układzie morfologicznym)

Terasy w pradolinie Noteci—Warty	Terasy w dolinie Brdy (18)	Terasy w dolinie dolnej Wisły (17)
V. pradolinna	XI. sandrowa	
IV. pradolinna przejściowa	X. przejściowa	
III. górna	IX. górna	Vc. górna (stopień c)
II. górna przejściowa (b)	VIII. przejściowa	Vb. górna (stopień b)
I. górna przejściowa (a)	VII. przejściowa	Va. górna (stopień a)
dno pradoliny (terasa zalewowa)	VI. środkowa wyższa	IV. środkowa wyższa
Agradacja dna pradoliny przez zamulenie i zatorfienie	V. środkowa niższa	III. środkowa niższa
	IV. dolna	II. dolna
	III. nadzalewowa	I_3. nadzalewowa (III stopień)
	II. nadzalewowa	I_2. nadzalewowa (II stopień)
	I. nadzalewowa	I_1. nadzalewowa (I stopień)

DNO PRADOLINY

Z kolei autor analizuje dno pradoliny, które po utracie wód rzecznych uległo zamuleniu i zatorfieniu. Z badań T. Churskiego (10) wynika, iż dno pradoliny pod utworami organogenicznymi jest bardzo urozmaicone. Zagłębienia wypełnione obecnie torfem przekraczają nieraz 10 m. Poza tym występują tam wały akumulacyjne usypane przez rzeki wpadające do pradoliny (Noteć, Gwda).

Poniżej zatorfionego dna pradoliny występują kopalne doliny i zagłębienia, wypełnione utworami zastoiskowymi. Z tego wynika, iż dno pradoliny posiada predyspozycję morfologiczną, pochodzącą być może z ostatniego interglacjału.

BUDOWA GEOLOGICZNA STREFY DOLINNEJ

Pradolina jest wcięta w wysoczyznę morenową na 20—40 m, wgłębiając się również w utwory plioceńskie i mioceńskie. Lecz przebieg pradoliny Warty—Noteci z wyjątkiem Kotliny Kostrzyńskiej nie zdradza zasadniczej zależności od konfiguracji podłoża czwartorzędu, którego osie orograficzne raczej krzyżują się z pradoliną. Stąd owa zmienność w pojawianiu się utworów trzeciorzędu w obrębie pradoliny. Tego rodzaju przecięcie elewacji podłoża czwartorzędu przez pradolinę obserwujemy wzdłuż pradolinnego odcinka doliny Brdy, gdzie iły poznańskie osiągają 66 m n. p. m., zbliżając się do powierzchni górnej terasy pradoliny (około 70 m. n. p. m.). Następne wcięcie pradoliny w utwory trzeciorzędowe występuje wzdłuż Dębowej Góry oraz następnych wzniesień morenowych, położonych nad północnym skrajem pradoliny pomiędzy Łobżonką i Gwdą, a po stronie południowej pradoliny w okolicy Chodzieży. Elewacje te wiążą się jednak z procesami glacitektonicznymi na linii wału kujawsko-pomorskiego i niektóre z tych wysoko położonych utworów trzeciorzędowych tworzą rozległe porwaki podesłane osadami plejstoceńskimi (39, 73). Następna elewacja podłoża czwartorzędu, przecięta przez pradolinę, przypada na okolice wielkiego półwyspu terasowego, a zwłaszcza Kotliny Gorzowskiej. Najlepiej są odsłonięte plioceńskie iły poznańskie i mioceńskie piaski kwarcowe na niższych terasach doliny Warty.

Równocześnie jednak można wysunąć tezę o predyspozycji dzisiejszej pradoliny Noteci—Warty, wyrażonej w postaci ciągu zagłębień powierzchni plejstocenu po przedostatnim zlodowaceniu (glacitektonika?), wypełnionych utworami zastoiskowymi (ryc. 1). Osady ostatniego zlodowacenia nie wyrównały owego ciągu zagłębień, toteż stał się on miejscem skupienia się wód roztopowych i ich odpływu ku zachodowi.

ETAPY ROZWOJU PRADOLINY

1. Analiza teras pradoliny i jej dna oraz ich powiązania z terasami sandrowymi i dolinami dolnej Wisły i dolnej Odry pozwala odtworzyć etapy rozwoju pradoliny Noteci—Warty od czasów stadium pomorskiego ostatniego zlodowacenia do chwili obecnej.

Nadal jeszcze pozostajemy w sferze domysłów, jeżeli idzie o okres poprzedzający stadium pomorskie, sięgający wstecz do momentu postoju lądolodu wzdłuż moren nadnoteckich. W czasie tej fazy nadnoteckiej powstały liczne formy marginalne lądolodu, zawdzięczające swą glacitektonikę ruchom oscylacyjnym krawędzi lodowcowej. Z tymi procesami wiąże się także powstanie depresji końcowej wraz z morenami spiętrzonymi w okolicy Chodzieży [39]. Wzdłuż moren spiętrzonych istniały zagłębienia, które zawdzięczały swe istnienie bądź to procesom glacitektonicznym, bądź to niedostatecznemu wyrównaniu basenów zastoiskowych przedostatniego zlodowacenia. Zagłębienia te zaczęły się wypełniać osadami mułkowymi, które obecnie występują bezpośrednio pod osadami organogenicznymi na powierzchni później zerodowanego dna pradoliny. W czasie owych oscylacji lodowcowych powstały lokalne szlaki sandrowe o ogólnym kierunku południkowym, sprzecznym z późniejszym równoleżnikowym przebiegiem pradoliny, a zbieżnym jedynie z południkowym odcinkiem pradoliny poniżej ujścia Gwdy.

2. Jak wykazały badania niemieckie na terenie Kotliny Kostrzyńskiej i zwężenia pradolinnego pod Eberswalde *, pradolina Noteci—Warty powstała prawdopodobnie w czasie stadium pomorskiego, lecz ze względu na zróżnicowane oddalenie krawędzi lądolodu od obecnego szlaku pradolinnego, sięgającego co najmniej od Torunia do Eberswalde i jeszcze dalej na zachód, jej geneza jest złożona. Zachodni odcinek tej pradoliny znajdował się w bliskim sąsiedztwie, a nawet kontakcie z morenami czołowymi stadium pomorskiego (tj. daleko na południe wysuniętego lobu Odry), natomiast wschodni odcinek pradoliny był zdala położony od krawędzi lądolodu przebiegającej przez Czaplinek, Botolice, Bytów, Kościerzynę, gdzie rozpoczynał się lob Wisły. W konsekwencji, gdy na zachodzie, w regionie Kotliny Kostrzyńskiej, rozwijały się szlaki sandrowe, przyczyniające się powoli do powstania pradoliny, na wschodzie, na przedpolu gromadzących się form marginalnych stadium pomorskiego tworzyły się pierwsze stożki sandrowe, nie docierające do obecnej pradoliny.

Lecz i w zachodniej części pradoliny ewolucja jej w świetle badań H. Liedtkego przebiegała w kilku etapach. W czasie trwania lobu Odry

* W szczególności badania H. Liedtkego (48, 49).

wody roztopowe, jak wynika z przebiegu szlaków sandrowych związanych z owym okresem, przekraczały obecną Kotlinę Kostrzyńską, odpływając różnymi drogami do Pradoliny Warszawsko-Berlińskiej, między innymi przez zwężenie pradolinne pod Eberswalde. Z okresu tego pochodzi powierzchnia sandrowa, urywająca się na linii Stara Rudnica—Siekierki—Gozdowice nad doliną Odry na wysokości około 58 m. W tym czasie istniał zapewne także odpływ sandrowy, urywający się obecnie na wysokości 65 m, wzdłuż doliny Kłodawki nad pradoliną Warty (Gorzów).

Nie jestem przekonany o konieczności przyjęcia za badaczami niemieckimi wypełnienia Kotliny Kostrzyńskiej rozległymi zwartymi masami martwego lodu (wg Beschorena nawet o grubości 50—80 m) dla umożliwienia przepływu wód sandrowych z obecnego północnego skraju tej kotliny do skraju południowego i dalej do Pradoliny Warszawsko-Berlińskiej. Przede wszystkim obecne zbocza Kotliny Kostrzyńskiej zawdzięczają swój kształt, a kotlina swój zarys i głębokość, młodszym procesom erozyjnym Odry i Warty (mapa 10) *. Prawdopodobnie, zgodnie z wyżej podaną tezą o ciągłości basenów zastoiskowych poprzedzających ostatnie zlodowacenie i predyspozycji obecnej pradoliny wraz z charakterystycznymi dla niej kotlinami, w miejscu obecnej Kotliny Kostrzyńskiej znajdowało się obniżenie powierzchni morenowej, przy czym w materiale morenowym mogły być zagrzebane bryły martwego lodu. Po wyrównaniu zagłębienia przez sedymentację sandrową, wody roztopowe rozpościerały się bardziej na południe, dochodząc do Pradoliny Warszawsko-Berlińskiej, przy czym wcięły się one w wysoczyznę, tworząc obecne powierzchnie sandrowe dochodzące do skraju wysoczyzny na wysokości 55—65 m n. p. m.

3. Po wycofaniu się lobu Odry do linii moren fazy Angermünde, znajdujących swój odpowiednik na wschód od Odry w morenach okolic Chojny, nastąpiła nowa faza sandrowa. W poprzednie powierzchnie sandrowe wcięły się nowe szlaki sandrowe, znajdujące się obecnie na wysokości 40—50 m n. p. m. nad doliną Myśli oraz w okolicy Witnicy. Zbędne jest tu zatem przyjęcie poglądu H. Liedtkego, że powierzchnia mas lodowych w kotlinie obniżyła się do takiego właśnie poziomu, który umożliwił odpływ wód sandrowych na pożądanej wysokości.

W tej fazie nie tylko wody sandrowe przechodziły ze wschodu pradoliną Warty (nie wiadomo o jakim zasięgu), i zgodnie z poglądem

* Na tym właśnie polega słaba strona szkiców A. Liedtkego (48) na str. 38/39, podających kolejne fazy rozwoju pradoliny, że nie uwzględniają późniejszych erozyjnych rozszerzeń Kotliny Kostrzyńskiej.

H. Liedtkego odpływały po raz pierwszy zwężeniem pradolinnym pod Eberswalde na zachód. Wtedy powstała pradolina, obejmująca zapewne pradoliny: Warty i Eberswaldzką. Nie można jeszcze mówić w tym okresie o Pradolinie Toruńsko-Eberswaldzkiej, jak to czyni H. Liedtke, ponieważ w tej fazie wschodni odcinek pradoliny — pradolina Noteci wraz z Kotliną Toruńską jeszcze nie istniała.

4. W tym czasie, przy trwającej maksymalnej (lub recesyjnej?) fazie stadium pomorskiego na wschód od zanikającego lobu Odry, szlaki sandrowe w postaci dolin sandrowych dotarły wzdłuż obecnej Wdy, Brdy, Gwdy i Drawy do ówczesnych płytkich zagłębień w strefie moren nadnoteckich i przeobraziły je w ciąg dolinny, zdradzający jeszcze obecnie przez swe kotlinowate rozszerzenia i zwężenia dolinne (bramy) swe pochodzenie. Prawdopodobnie dopływ wód doliną sandrową Gwdy był silniejszy niż szlakami bardziej wschodnimi, ponieważ dolina sandrowa Gwdy nadała kierunek niżej położonemu odcinkowi pradoliny, do którego dołącza się wyżej położona część pradoliny w charakterze doliny bocznej. Wtedy powstał jednolity poziom sandrowo-pradolinny, wyżej opisany jako terasa pradolinna, do której nawiązują terasy Brdy, Gwdy i Drawy. Terasa ta znajduje się na wyspie dolinnej Bralitz-Neuenhagen w Kotlinie Kostrzyńskiej na wysokości 32 m, o 3 m niżej od dna Pradoliny Eberswaldzkiej, nie licząc późniejszego wcięcia rzeki Winawy (Finow). Zatem odpływ wód pradolinnych, przychodzących z pradoliny Noteci, nie odbywał się już przez zwężenie pradolinne pod Eberswalde na zachód, lecz — jak wynika z dalszego przebiegu tej terasy — na północ doliną dolnej Odry i Rędowy, gdzie prześledzono terasę pradolinną aż w okolicy Blumberg i Bagemühl na wysokości 18—20 m n. p. m. Jest jednak prawdopodobne, że część wód, być może w czasie wyjątkowych powodzi, przelewała się Pradoliną Eberswaldzką na zachód, o czym świadczy listwa terasowa u wylotu zwężenia pradolinnego na wysokości 32 m n. p. m. Zatem istniała tu bifurkacja. W tym czasie także wody Odry włączały się do wód pradolinnych, o czym świadczy listwa terasowa w Wriezen na wysokości 36—37 m n. p. m. H. Liedtke nazwał powyższy ciąg pradolinny pradoliną Noteci—Rędowy.

W czasie tej głównej fazy odpływu pradolinnego, obejmującego wody sandrowe lobu Wisły i mniejszych lobów lodowcowych, położonych na zachód od lobu Wisły, lob Odry był już w stadium zaniku. W każdym razie aktywny lód znajdował się dopiero w okolicy Szczecina, być może na linii tamtejszych moren spiętrzonych.

Połączone wody Wisły i Odry odpływały doliną Rędowy na północo-zachód a następnie, zapewne za pośrednictwem pradoliny meklemburskiej*, do tworzącego się od zachodu bałtyckiego jeziora lodowego. Jeżeli bowiem w czasie trwania stadium pomorskiego w obrębie lobu Wisły i sąsiadujących od zachodu drobniejszych lobów lodowcowych lob Odry był już w stadium zaniku, to proces deglacjacji był zapewne jeszcze intensywniejszy bardziej na zachodzie, tj. w regionie wysp duńskich.

Powierzchnię terasy sandrowej i terasy pradolinnej urozmaicają liczne formy wytopiskowe. Szczególnie wiele form powstałych przez wytopienie się brył martwego lodu występuje w Kotlinie Gorzowskiej jako części Kotliny Kostrzyńskiej.

Według poglądów niemieckich (O s t, W o l d s t e d t, L i e d t k e) terasa pradolinna powstała, podobnie jak i następne, w Kotlinie Gorzowskiej jako terasa marginalna, usypana przez wody pradolinne pomiędzy zboczem wysoczyzny a pokrywą martwego lodu, zajmującą głębszą część pradoliny. Autorzy ci niestety nie tłumaczą pochodzenia zagłębienia dolinnego, które w danym wypadku musiało istnieć przed tworzeniem się pokrywy lodowej. Należy sobie uprzytomnić, iż omawiany obszar pradoliny znajduje się na najbliższym zapleczu moren czołowych stadium poznańskiego. Była to zatem strefa gromadzenia się brył martwego lodu, związana nadto z zagłębieniem powierzchni morenowej, występującym na linii wyżej opisanych międzymorenowych basenów zastoiskowych. Bryły martwego lodu były zagrzebane w utworach morenowych. Jeżeli znajdowały się także bryły stagnującego lodu na powierzchni morenowej, to uległy one niewątpliwie stopnieniu już w czasie początkowych, sandrowych faz pradoliny, przed wcięciem się wód do poziomu terasy pradolinnej. Bryły martwego lodu, zagrzebane w utworach morenowych lub fluwioglacjalnych, uległy stopnieniu dopiero po wcięciu się wód pradolinnych w terasę pradolinną. W przeciwnym bowiem wypadku powstałe wskutek wytopienia zagłębienia wytopiskowe uległyby zasypaniu przez akumulację rzeczną. Niektóre bryły wytopiły się dopiero po powstaniu następnych teras w pradolinie, gdyż dane zagłębienia wytopiskowe występują równocześnie na terenie kilku teras (mapa, ryc. 10).

Zatem w świetle powyższej interpretacji roli martwego lodu, terasa pradolinna jest normalną terasą dolinną (o charakterze erozyjnym), na co zresztą wskazuje regularny spadek powierzchni terasowej w profilu podłużnym (por. profil teras ryc. 11). Zbyt koncepcyjne jest przyjęcie przez powyższych autorów, zwłaszcza H. Liedtkego, fazowego obniżania się powierzchni topniejącej pokrywy lodowej w pradolinie, co w efekcie

* Mecklenburgisch-Pommersches Grenztal.

miało umożliwić płynięcie wód w coraz niższym poziomie i powstanie kolejnych teras marginalnych. Zresztą terasy występują bez większych zaburzeń swego spadku dalej, w dolinie dolnej Odry, reagując na wahania poziomu podstawy erozyjnej w obszarze nadbałtyckim. Terasa pradolinna została erozyjnie uszczuplona w swym pierwotnym zasięgu nie tylko przez wody pradolinne płynące w poziomie obecnych niższych teras, lecz także przez dzisiejszą Wartę (np. w okolicy Słońska), nie mówiąc o całkowitej jej likwidacji, podobnie jak i młodszych teras, w kotlinowatej, obecnie płaskiej dolinie Odry powyżej jej odcinka zakolowego (w zachodniej części Kotliny Kostrzyńskiej).

5. Gdy lądolód również na wschód od zanikającego lobu Odry wycofał się ostatecznie z linii moren czołowych stadium pomorskiego, ustał dopływ wód sandrowych z północy. Na stożkach sandrowych rozwinęły się rzeki, które wcięły się w poprzednio utworzone powierzchnie sandrowe, a po osiągnięciu pradoliny — także w główną terasę pradolinną. Do wód zgromadzonych w pradolinie Noteci—Warty dołączyły się od południa wody Warty, które dotąd płynęły Pradoliną Warszawsko-Berlińską na zachód. Połączone wody pradoliny i Odry kierowały się nadal doliną Rędowy na północo-zachód przez obszar Meklemburgii do tworzącego się Bałtyku (bałtyckiego jeziora lodowego). Najniżej i najdalej położony ślad odpływu wód pradolinnych w poziomie tej terasy występuje w dolinie Rędowy w pobliżu miejscowości Blumberg na wysokości 13 m n. p. m. Był to okres maksymalnego odpływu wód rzecznych (już nie roztopowych) pradoliną Noteci—Warty, a następnie doliną dolnej Odry. W poziomie terasy pradolinnej przejściowej odpływały doliną dolnej Odry i doliną Rędowy nie tylko wszystkie wody Odry, skoro odpływ przez zwężenie pradolinne pod Eberswalde już całkowicie nie wchodził w rachubę, lecz także połączone wody Wisły i Warty z ich dopływami, przychodzącymi zarówno z południa z obszarów górskich, jak i z północy z niedawno usypanych pól sandrowych.

6. Wraz z zanikaniem lobu Wisły i pojawieniem się bałtyckiego jeziora lodowego w ówczesnej zatoce, sięgającej po Tczew i Malbork, wytworzyły się warunki dla powstania bezpośredniego odpływu wód wiślanych na północ. Dzieje tego odwrotu są jeszcze nieznane. Jedną z najstarszych prób wyjaśnienia genezy odwrotu Wisły jest koncepcja kolejnych zastoisk P. Sonntaga (69). W każdym razie musimy przyjąć kilka faz rozwojowych na terenie obecnej doliny dolnej Wisły. W okresie płynięcia wód w poziomie terasy sandrowo-pradolinnej tędy zapewne płynęły wody sandrowe Wdy w kierunku południowym ku pradolinie. Odpływ o podobnym kierunku istniał prawdopodobnie także

w poziomie terasy pradolinnej przejściowej. W tym jednak okresie miały miejsce procesy morfologiczne, które przygotowały odwrót części wód wiślanych ku północy. Polegały one przede wszystkim na zmniejszeniu działu wód pomiędzy gdańskim basenem zastoiskowym a Kotliną Toruńską. Nie jest wykluczone, że to przechodzenie wód wiślanych na północ zostało ułatwione przez wytapianie się brył martwego lodu na linii obecnej doliny dolnej Wisły. Z nowej drogi korzystały zapewne w pierwszej fazie wody katastrofalne, później regularne wody powodziowe Wisły. Faktem jest, że w poziomie górnej terasy, uważanej pierwotnie przez Keilhacka i innych badaczy za dno zastoiska (toruńskiego), część wód wiślanych kierowała się na północ zapewne do zastoiska w obecnej strefie ujściowej Wisły, a część wód pradoliną Noteci—Warty na zachód. Fakt ten jest udokumentowany — w świetle badań autora (17) — występowaniem fragmentów górnej terasy zarówno w Kotlinie Toruńskiej na zachód od Bydgoszczy, jak i w dolinie Wisły w okolicach Grudziądza.

Zachodnie ramię bifurkującej Wisły korzystało nadal z dotychczasowej pradoliny Noteci—Warty, przy czym wody Wisły i jej dopływów, reagując na wahania bałtyckiej podstawy erozyjnej, wcięły się w terasę pradolinną przejściową. Po połączeniu się z wodami Warty wody pradolinne wpływały do doliny Odry i wspólnie z nią kierowały się na północ. Część połączonych wód kierowała się — jak dotychczas — doliną Rędowy na północo-zachód, lecz część tych wód równocześnie odpływała na północ w kierunku tworzącej się Zatoki Pomorskiej. Był to już drugi odpływ bifurkacyjny w obrębie tego samego systemu rzecznego. Świadczą o nim szczątki terasowe występujące w rozwidleniu dolin Odry i Rędowy w obu dolinach, w poziomie 10—13 m.

7. Rozwój doliny Wisły był o jedną fazę opóźniony w stosunku do rozwoju doliny Odry, co było następstwem wcześniejszej deglacjacji na zachodzie. Całkowity odpływ wód odrzańskich ku otwartej Zatoce Pomorskiej nastąpił już w poziomie 7—9-metrowej terasy pradoliny. Być może, że właśnie owe zbliżenie bazy erozyjnej było przyczyną wcięcia się wód rzecznych do poziomu tej terasy. Nie był to okres długi, gdyż terasa ta nie sięga do Kotliny Toruńskiej (profil teras ryc. 11). Bifurkacja wód wiślanych trwała jeszcze w poziomie terasy 5-metrowej pradoliny, stwierdzonej — podobnie jak poprzednia terasa — wyłącznie w dolinie dolnej Odry, także poniżej doliny Rędowy. Dopiero po osiągnięciu najniższego poziomu pradolinnego, tj. obecnego koryta pradoliny wypełnionego mułkami i torfami, nastąpiło ostatecznie przerzucenie się wód wiślanych doliną dolnej Wisły na północ. Fakt ten po-

został w związku z obniżeniem się podstawy erozyjnej po wytworzeniu się odpływu do ówczesnego bałtyckiego jeziora lodowego prawdopodobnie poprzez pradolinę Łeby. Wody wiślane wcięły się w dotychczasowe dno dolinne, nazwane terasą wyższą środkową, do poziomu późniejszej terasy środkowej niższej. W ślad za Wisłą poszła Brda, wcinając się w terasę wyższą środkową w pradolinie, o przeciwnym nachyleniu, natomiast bardziej na zachodzie płynąca Noteć nadal korzystała z pradoliny. Nie jest jednak wykluczone, że pierwotnie Noteć płynęła poprzez obecny obszar wydmowy ku północy w kierunku Wisły.

Jak dotąd, nie sprawdziła się teza o wydźwignięciu obszaru wododziałowego pomiędzy Brdą a Notecią jako głównej przyczynie odwrotu Wisły na północ. Co prawda powierzchnia pliocenu — jak pisano — wykazuje w okolicy Bydgoszczy wyraźny garb, lecz forma ta została otulona (wyrównana) osadami plejstoceńskimi i nie zaznacza się na obecnej powierzchni terenu. W każdym razie terasy, starsze od owego rzekomego dźwignięcia, nie wykazują żadnego wyraźnego zniekształcenia swego profilu (ryc. 11), a kulminacja dna pradolinnego w sąsiedztwie działu wód na zachód od Bydgoszczy jest zbudowana z utworów torfowych, kończących się wyraźną granicą nad doliną Brdy. Niewątpliwie jednak zagadnienie to jest jeszcze otwarte i wymaga dalszych, bardziej szczegółowych badań.

8. W świetle badań różnych autorów wypada przyjąć, iż po dokonaniu zmiany kierunku odpływu Wisły, przy równoczesnym zawieszeniu dna pradoliny Noteci w stosunku do doliny Brdy, a zapewne także w stosunku do pradoliny Warty, tj. zachodniej części pradoliny Noteci—Warty (pomiędzy Santokiem a Kostrzynem), dno pradoliny wypełniło się osadami bądź to leniwie płynących rzek z Notecią na czele, bądź to zbiorników wody stojącej. Według badań T. Przybylskiego (ustna informacja) początek zatorfienia przypada na młodszy dryas. Równocześnie mniejsze rzeki i potoki usypały na dnie pradoliny stożki napływowe różnej wielkości. W efekcie dno pradolinne uzyskało swą rozmaitość zarówno morfologiczną jak i geologiczną. Zagłębienia napełniały się wodą w czasie powodzi Wisły, gdy część wód przelewała się jeszcze dawnym szlakiem ku zachodowi. Z czasem wypełniły się one gytią i utworami torfowymi. W miarę fazowego wzrostu wilgotności klimatu w holocenie podniósł się poziom wód gruntowych. Miąższość pokrywy torfowej zaczęła wzrastać. Jedynie stożki napływowe większych rzek wpadających do pradoliny (Noteć, Gwda, Drawa, Warta) wyzierają w postaci progów spod osłony torfowej, która weszła także w dolinki boczne uchodzące do pradoliny (np. w dolinę Śleski).

Równolegle do procesów geologicznych i morfologicznych na dnie pradoliny odbywały się procesy rzeźbotwórcze na jej zboczach i terasach. Od dawna zwrócono uwagę na erozyjne rozcięcie zboczy pradoliny, jak i dolin na niżu polodowcowym w ogóle (m. in. w dolinie dolnej Wisły), przy czym niektórzy badacze interpretują je jako wyraz morfologiczny kolejnych faz klimatycznych (np. W. Okołowicz). Boczne te dolinki wychodzą na różne terasy dolinne, co umożliwia określenie ich wieku morfologicznego.

Wiele z tych dolin powstało w warunkach klimatu peryglacjalnego, o którym świadczą również pokrywy na zboczach i starszych terasach oraz graniaki eoliczne. H. Lembke (43) opisuje dolinki peryglacjalne, rozcinające zbocza Kotliny Kostrzyńskiej. Z. i Z. Churscy (9) charakteryzują asymetryczną dolinę Śleski (na wschód od Nakła) jako dolinę peryglacjalną. Wiele starych, płytkich dolin, wypełnionych materiałem denudacyjnym, rozcina zbocza pradoliny w licznych miejscach, zwłaszcza tam gdzie zbocze jest cofnięte, np. na wschód od Santoka, lub gdzie u stóp zboczy pradolinnych występują terasy, w które dolinki te przechodzą (np. na północ od Bydgoszczy). Natomiast wzdłuż niedawno podciętych zboczy pradoliny spotyka się stare płytkie dolinki, wysoko zawieszone nad dnem pradoliny. Odpowiadające tym formom stożki napływowe — jak wykazał T. Churski (10) — występują w pradolinie Noteci pod pokrywą torfową. Są one także spotykane na wyższych terasach pradolinnych. H. Lembke (44) opisuje w Kotlinie Gorzowskiej stożki napływowe rozpościerające się na aluwiach rzecznych i powiązane z obecnie suchymi dolinkami na wysoczyźnie. Stwierdził on występowanie dwóch włożonych w siebie stożków napływowych do 5 m wysokości i koryt rzecznych, odpowiadających zmianom podstawy erozyjnej w kotlinie. Stożki te — jak sądzę — są zapewne młodsze od wyżej opisanych stożków napływowych pod torfami w pradolinie Noteci. Dzieli je okres wypełnienia pradoliny Warty lub doliny Odry aluwiami, co miało miejsce już w czasie swobodnego odpływu wód do Zatoki Pomorskiej *.

Niewątpliwie na zboczach pradoliny można wyróżnić kilka generacji dolin włożonych przeważnie w siebie. Najstarsze zespoły dolin powstały w warunkach peryglacjalnych, które istniały w czasie ostatnich stadiów ostatniego zlodowacenia. Dolinkom tym odpowiadają przede wszystkim stożki napływowe występujące pod torfami na dnie pradoliny Noteci oraz na terasach pradoliny. W tym okresie odbywały się także procesy eoliczne, o czym świadczą piaski wydmowe i wydmy otulone torfami. Tworzenie się pokrywy torfowej, co zapewne odbywało się

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* Zagadnienie wypełnienia pradoliny Warty i doliny Odry młodymi osadami rzecznymi, jako zagadnienie specjalne, wymaga osobnego rozpatrzenia.

etapami, było przerywane procesami deluwialnymi i erozyjnymi na skrajach pradoliny. Na zboczach pradoliny powstały nowe dolinki erozyjne nacinające dotąd istniejące szerokie dolinki boczne. Im odpowiadają niewielkie stożki napływowe, występujące w licznych miejscach na pokrywie torfowej i łączące się w mniej lub więcej zwartą listwę deluwialną u stóp zboczy pradoliny*.

Na przemian z procesami erozyjnymi na zboczach pradoliny odbywały się procesy eoliczne na piaszczystych terasach pradoliny, w następstwie których powstały w co najmniej dwóch fazach liczne zespoły wydm, opisane przez W. Mrózka (54), L. Pilarczyka (61) oraz innych, skupiające się szczególnie w Kotlinie Toruńskiej i międzyrzeczu Noteci—Warty. Aż do polodowcowego optimum klimatycznego trwało wytapianie się brył martwego lodu, skupionych w dużej ilości w osadach morenowych na terenie pradoliny jako na bliskim zapleczu form marginalnych stadium poznańskiego oraz nadnoteckich moren czołowych. Wcinanie się wód pradolinnych w utwory morenowe przyspieszyło proces wytapiania się lodów. W efekcie terasy pradoliny wykazują obok bogactwa form eolicznych również znaczne urozmaicenie swej powierzchni w postaci licznych zagłębień przeważnie zatorfionych, szczególnie skupionych w pradolinie Warty, a także w postaci jezior rynnowych, opisanych m. in. przez J. Bajerleina (3). Obecna działalność rzek w pradolinie Noteci—Warty, niedostosowana do wielkiego rytmu rozwojowego zamarłej obecnie pradoliny, jest minimalna. Noteć i Warta, meandrując po rozległym dnie pradoliny, powodują jedynie niewielkie procesy erozyjne lub akumulacyjne w dopływach, od których się oddalają lub do których się zbliżają, np. w dolinie Łobżonki.

ETAPY ROZWOJU POLODOWCOWEJ SIECI DOLINNEJ NA NIŻU POLSKIM

Zagadnienie rozwoju sieci dolinnej, w trakcie wycofywania się lądolodu przy końcu ostatniego zlodowacenia z terenów nadbałtyckich pomiędzy Odrą i Niemnem, ma bogatą literaturę. Jeden z pierwszych K. Keilhack (28, 29) wyjaśnił stosunek lądolodu do proglacjalnej sieci dolinnej. Opisał on pradolinę Toruńsko-Eberswaldzką i powiązał ją ze stadium pomorskim ostatniego zlodowacenia. Wyróżnił także

* Zagadnienie rozwoju bocznych dolinek, rozcinających zbocza pradoliny Noteci, jest tematem specjalnego studium, prowadzonego przez Z. Churską z ramienia Katedry Geografii Fizycznej UMK. Wykonano także szereg prac magisterskich w powyższym zakresie.

pradolinę pomorską, wytworzoną w czasie następnych faz recesyjnych lądolodu. Późniejsze, zwłaszcza ostatnie lata przyniosły wiele ważnych i podstawowych prac, które pozwalają dorzucić szereg nowych momentów do zagadnienia rozwoju dolin na niżu polodowcowym, widzieć je w pełniejszym świetle i określić ich wiek geologiczny. Szczególną rolę w tym względzie odgrywa niniejsze studium syntetyczne dotyczące pradoliny Noteci—Warty i jej powiązania zarówno z odpływem sandrowym jak i dolinami rzek, idących z południa (por. poprzedni rozdział niniejszej pracy). Pradolina, jako centralny człon późnoglacjalnego systemu dolinnego, jest kluczem do wyjaśnienia genezy owej sieci dolinnej.

Rozwój dolin na omawianym obszarze, począwszy od stadium pomorskiego ostatniego zlodowacenia, może być rozpatrywany w trzech fazach z szeregiem subfaz. Nazywam je fazą proglacjalną, fazą przejściową i fazą bałtycką.

1. Faza proglacjalna, przypadająca na stadium pomorskie ostatniego zlodowacenia, odznaczała się decydującym wpływem wód roztopowych lądolodu na rozwój form dolinnych. Na początku tej fazy, gdy lob Odry miał swój największy zasięg, wody sandrowe w okolicy Kotliny Kostrzyńskiej przelewały się — jak to wykazał H. Liedtke — bądź różnymi drogami na południe do Pradoliny Warszawsko-Berlińskiej, bądź (nieco później) przez zwężenie pradolinne pod Eberswalde („Eberswalder Pforte") na zachód. W tej subfazie na wschód od lobu Odry tworzyły się na przedpolu lądolodu olbrzymie pola sandrowe, a wody roztopowe dążyły na południe w kierunku przyszłej pradoliny. Jak dotąd nie ma dowodu, że w tym okresie istniała jakaś pradolina, która by zbierała wody roztopowe, łącząc je z wodami rzek idących z południa. Pierwszy ciąg pradolinny związany ze stadium pomorskim wytworzył się — zgodnie z poglądem H. Liedtkego — na przedpolu Odry, lecz jego zasięg ku wschodowi jest nieznany. Tymczasem wody rzeczne odpływały na zachód Pradoliną Warszawsko-Berlińską.

W następnej subfazie (ryc. 9a), przypadającej na okres szybszego zaniku lobu Odry niż pozostałej wschodniej części lądolodu, powstały liczne doliny sandrowe („s" na ryc. 9a), którymi wody roztopowe po usypaniu rozległych stożków sandrowych dążyły na południe, uchodząc do wielkiego szlaku pradolinnego, który zajmował położenie peryferyczne w stosunku do krawędzi lądolodu. Pradolina ta w okresie schyłkowym stadium pomorskiego zbierała przeważającą część wód roztopowych lądolodu z jednej, a wód rzek karpackich i sudeckich z drugiej strony. Była ona zatem centralnym członem ówczesnej sieci dolinnej (ryc. 9a.)

Wschodnia część tego potężnego szlaku dolinnego, zwana w dawniejszych pracach Pradoliną Wileńsko-Warszawską *, zbierała głównie wody roztopowe, uchodzące z lądolodu na wschód od lobu Wisły. Od południa włączały się wody górnych odcinków Niemna, Narwi, Bugu i Wisły. Natomiast zachodnia część owego szlaku pradolinnego, zwana Pradoliną Toruńsko-Eberswaldzką (co jest tylko częściowo słuszne) ** lub pradoliną Noteci—Warty, zbierała głównie wody roztopowe z lądolodu pomiędzy lobem Wisły a zanikającym lobem Odry. Od południa wpadała Odra, która zdołała wytworzyć sobie dolinę przełomową przez formy marginalne stadium poznańskiego, nie korzystając już z dalszej części Pradoliny Warszawsko-Berlińskiej. Natomiast środkowa Warta łączyła się z Odrą jeszcze przez powyższą pradolinę, przy czym Warta otrzymywała dopływ płynący z północy przez późniejszy odcinek przełomowy doliny Warty (okolice Poznania) ***.

Połączone wody Wisły i Odry, zbierające się w Kotlinie Kostrzyńskiej, odpływały w głównej swej masie doliną dolnej Odry, następnie doliną Rędowy, by za pośrednictwem jednej z pradolin meklemburskich uchodzić do tworzącego się u wybrzeży Meklenburgii i wysp duńskich bałtyckiego jeziora lodowego. Z tego powodu H. Liedtke wprowadził dla omawianego szlaku pradolinnego, w owym okresie, nazwę pradoliny Noteci—Rędowy. Pozostała część wód pradolinnych korzystała nadal z niewygodnego, bo ciasnego zwężenia pradolinnego pod Eberswalde. Zatem istniała tu bifurkacja wód pradolinnych, podtrzymywana głównie przez wody powodziowe. Z powyższego opisu wynika, że deglacjacja przebiegała nierównomiernie, tj. szybciej na zachodzie niż na wschodzie, co mogło być następstwem bardziej morskiego klimatu na zachodzie.

Rekonstrukcja wyżej nakreślonego obrazu rozwoju sieci dolinnej w okresie schyłkowym stadium pomorskiego została oparta przede wszystkim na analizie teras pradoliny Noteci—Warty w ich powiązaniu ze szlakami sandrowymi.

Autor zrekonstruował system odpływu sandrowo-pradolinnego z okresu pradoliny Noteci—Rędowy, sięgający od terasy sandrowej Brdy i szczątków terasy pradolinnej w Kotlinie Toruńskiej na wschodzie do fragmentów terasy pradolinnej w dolinie Rędowy na zachodzie (ryc. 11), uwzględniając także studia H. G. Osta (58, 59), St. Kozarskiego i J. Szupryczyńskiego (37), W. Mrózka (54), H. Liedtkego (48) i in. Dla rekonstrukcji dolin występujących w tej fazie na wschód i południe od dzisiejszej doliny dolnej Wisły,

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* Ostatnio J. Kondracki nazwę tę wznowił (34).

** Por. uwagi na ten temat na str. 103-104.

*** Por. pracę T. Bartkowskiego (5).

którą w owym czasie zapewne płynęły na południe do Kotliny Toruńskiej wody sandrowe Wdy, pożyteczne okazały się badania St. Lencewicza (46), dotyczące doliny Wisły, J. Kondrackiego (32, 33, 34) poświęcone obszarowi Mazur, W. Okołowicza (57) dotyczące rozwoju doliny Niemna i L. Roszkówny (64) o morfologii zachodniej części Pojezierza Mazurskiego.

2. Faza przejściowa. Jak wskazano, w czasie maksimum stadium pomorskiego wody roztopowe z pobliskiego lobu Odry odpływały różnymi drogami do Pradoliny Warszawsko-Berlińskiej, a później dopiero pradoliną pod Eberswalde na zachód. Odpływ połączonych wód fluwioglacjalnych i rzecznych pradoliną Noteci—Warty ku zachodowi, a następnie po przyjęciu wód Odry na północ, ku zanikającemu lądolodowi (z częściowym bifurkacyjnym odpływem przez zwężenie pradolinne pod Eberswalde na zachód (ryc. 9a) był już wyrazem końcowego etapu stadium pomorskiego. Odpływ wód dolinami Odry i Rędowy do tworzącego się Bałtyku był równocześnie wstępnym krokiem do następnej fazy rozwoju sieci dolinnej, mianowicie do fazy przejściowej. Na zapleczu moren czołowych stadium pomorskiego, w trakcie etapowego (fazowego) wycofywania się lądolodu na teren obecnego Bałtyku, rozwijała się sieć dolin marginalnych, powiązanych ze sobą kotlinami zastoiskowymi, dolinami tymi płynęły wody fluwioglacjalne uzupełnione wodami niewielkich rzek, które tworzyły się na północnym skłonie moren stadium pomorskiego. Podczas dłuższego postoju lądolodu, zbiegającego się zapewne z fazą północno-rugijską, powstała pradolina pomorska, opisana przez K. Keilhacka (29), K. v. Bülowa (8) i wielu innych (ryc. 9b).

Tymczasem na południe od moren czołowych stadium pomorskiego, w warunkach klimatu peryglacjalnego, dotychczasowymi dolinami sandrowymi zaczęły płynąć rzeki, odwadniając rozległe stożki sandrowe. Dążyły one do pradoliny, w której skupiały się wody całej sieci rzecznej obszaru Polski, płynąc w poziomie tzw. terasy pradolinnej przejściowej, która wcięła się na około 5 m w terasę pradolinną odpowiadającą fazie proglacjalnej. Terasa ta występuje nie tylko w pradolinie Noteci—Warty. Stwierdzono ją także w dolinach sandrowych, w dolinie dolnej Odry i Rędowy, którędy wody ostatecznie odpływały, kierując się ku Bałtykowi. Terasę tę stwierdzono również jako najwyższy poziom dolinny w ujściu doliny Warty do pradoliny. W tym okresie istniała już dolina przełomowa Warty pod Poznaniem i wody Warty łączyły się z wodami rzecznymi płynącymi w pradolinie Noteci—Warty. Jedynie część wód warciańskich — zgodnie z poglądem T. Bartkowskiego (5) — kierowała się jeszcze bifurkacyjnie na zachód pradoliną Warszawsko-Berlińską.

W następnej subfazie, w poziomie górnej terasy zaczęła się wyodrębniać dolna Wisła, a wody Odry odpływały na północ do wyzwolonego z lodu obszaru w obrębie obecnej Zatoki Pomorskiej. Lecz faza przejściowa jeszcze trwa. Dlatego tylko część wód wiślanych kieruje się ku północy, gdy tymczasem pozostałe wody odpływały bifurkacyjnie na zachód pradoliną Noteci—Warty (17). Podobnie część wód skupionych w dolinie dolnej Odry odpływała bifurkacyjnie doliną Rędowy na zachód. Lecz większość wód rzecznych Odry, reprezentujących główną masę wód rzecznych na Niżu, po przejęciu wód z pradoliny pomorskiej, odpływała podmorską obecnie doliną wzdłuż Uznamu i Rugii do tworzącego się wówczas Bałtyku.

Dokąd odpływały wody dolnej Wisły? Niewątpliwie w owym czasie Zatoka Gdańska była jeszcze zajęta przez lob Wisły. Na jego przedpolu rozpościerała się depresja końcowa otoczona wieńcem moren stadialnych. Według przeważającej opinii badaczy obszar ten był zajęty przez rozległe jezioro lodowe, tzw. zastoisko gdańskie, opisane przede wszystkim przez P. Sonntaga (69). Ostatnio w tej sprawie wypowiedział się Z. J. Kotański (36), wskazując na ślady zastoiska w sąsiedztwie Żuław Gdańskich na wysokości 40—45 m n. p. m., natomiast niżej położone listwy abrazyjne (17—20 m n. p. m.) na skraju wysoczyzny uznał jako ślad morza litorynowego. Zagadnienie to, zdaniem tego autora, jest nadal dyskusyjne i wymaga szczegółowych badań. W każdym razie wiele faktów geologicznych i morfologicznych wskazuje na istnienie w owym okresie zastoiska, które powiększało się a równocześnie obniżało w miarę wycofywania się lądolodu na terenie Bałtyku.

Czy doszło do ostatecznego zaniku zastoiska, gdy lądolód całkowicie opuścił ląd, czy też obecne Żuławy wraz z Zatoką Gdańską stały się od razu zatoką morską — pozostaje sprawą dyskusji *.

Podczas jednej z kolejnych faz postoju w okresie starszego dryasu (ryc. 9c) powstała pradolina Pregoły opisana m. in. przez B. Körnkego (41); jej wody uchodziły do jeziora lodowego na terenie obecnej delty Wisły. Odpływ z tego jeziora nastąpił przez pradolinę Łeby, a dalej na zachód przez jedną z licznych dolin marginalnych wzdłuż krawędzi lądolodu. Zasięg lądolodu był w owym czasie zapewne jak i poprzednio zróżnicowany. Prawdopodobnie w zatokach Gdańskiej i Pomorskiej lądolód posiadał lobowe wygięcia. Wskazują na to również wyniki badań H. Kliewego (31). Jedynie po obu stronach Zatoki Gdańskiej na podstawie występujących tam form marginalnych można dokładnie ustalić zasięg lądolodu w owej fazie deglacjacji. Wielka pradolina na

* Autor w świetle analizy rzeźby podwodnej i budowy geologicznej delty Wisły wypowiedział się za drugą ewentualnością (21).

południe od moren stadium pomorskiego odgrywa nadal rolę najważniejszej arterii wodnej na Niżu. Nadal istnieje bifurkacja wód Wisły płynących z kolei w poziomie wyższej terasy środkowej. Najstarsze bowiem osady torfowe w pradolinie Noteci na zachód od Bydgoszczy pochodzą z młodszego dryasu, przeto z okresu gdy lądolód wycofał się już na teren Skandynawii. Natomiast, jak wynika z analizy teras w dolinie dolnej Odry, wszystkie wody Odry odpływały na północ podwodną obecnie pradoliną wzdłuż Uznamu i Rugii do Bałtyku, przyjmując od wschodu wody rzek marginalnych lądolodu.

3. F a z a b a ł t y c k a. Dokonanie pełnego odwrotu wód Wisły do otwartej Zatoki Gdańskiej (w poziomie niższej terasy środkowej doliny dolnej Wisły — Alleröd?) i wytworzenie się działu wód w pradolinie, jak również dotarcie wód Niemna do bałtyckiego jeziora lodowego, otwierają ostatnią fazę w rozwoju nadbałtyckiej sieci dolinnej, mianowicie fazę bałtycką. Maleje znaczenie Odry, pozbawionej dopływu wód pradoliną z Wisły. Ujście Odry w owym okresie, w odróżnieniu od Wisły i Niemna, znajdowało się na terenie Bałtyku z dala od obecnego lodu. W fazie bałtyckiej utrwaliła się ostatecznie owa zasadnicza sprzeczność w kierunku odpływu rzecznego na Polskim Niżu. Z jednej strony — przetrwałe doliny sandrowe, skierowane na południe, z drugiej strony idące na północ doliny przełomowe Odry, Wisły i Niemna oraz doliny mniejszych rzek nadbałtyckich, dążące krętymi biegami za pośrednictwem krótkich dolin przełomowych do pobliskiego morza. Rzeki reagują na polodowcowe wahania poziomu Bałtyku przez tworzenie teras dolinnych i akumulację. Pradolina Noteci—Warty, o spadku niedostosowanym do dzisiejszych przeważnie małych rzek w niej płynących, hamuje wpływ bałtyckiej bazy erozyjnej i staje się doliną martwą. Tymczasem bliskość tej bazy erozyjnej w stosunku do dopływów dolnej Wisły powoduje intensywny rozwój ich dolin, o czym świadczy ilość teras dolinnych, przeważnie erozyjnych—np. dziewięć teras w dolinie Brdy.

OBJAŚNIENIA DO RYCIN

Ryc. 1. Terasy doliny Gwdy na wschód od Piły (półwysep terasowy)
1 — piaski sandrowe z głazikami; *2* — glina lodowcowa; *3* — piaski międzymorenowe (fluwioglacjalne); 4 — iły zastoiskowe pod brukiem morenowym (cegielnia); 5 — piaski i żwir z głazami na powierzchni terasy I

Ryc. 2. Odsłonięcie w terasie pradolinnej w dolinie Rędowy (Randow) w okolicy Bagemühl (NRD)
a — piaski różnoziarniste z przewagą piasków grubych; *b* — bruk w postaci głazów dobrze obtoczonych o średnicy do 20 cm; *c* — niezgodnie leżąca pod brukiem seria warstwowanych piasków przedzielonych warstwą żwirów

Ryc. 3. Odsłonięcie w terasie pradolinnej przejściowej w Dziembówku (na wschód od Piły)
1 — piasek pokrywowy i utwory rezydualne po ścięciu erozyjnym gliny morenowej, kieszenie akumulacyjne; *2* — glina lodowcowa; *3* — warstwowane piaski fluwioglacjalne o różnej frakcji; *4* — piasek drobnoziarnisty z przewarstwieniami piasku gruboziarnistego — upad 32° na południe; *5* — mułek piaszczysty

Ryc. 4. Odsłonięcie w górnej terasie w Paterku (na południe od Nakła)
1 — utwór pokrywowy rezydualny (głazy i żwir); *2* — jasnożółte warstwowane piaski; *3* — brunatna glina lodowcowa

Ryc. 5. Odsłonięcie w górnej terasie w cegielni Murzynowo (na południe od Drezdenka)
a — poziomo warstwowane jasnożółte piaski rzeczne; *b* — bruczek z kawałkami przerobionego iłu; *c* — jasnożółte piaski fluwioglacjalne o różnym nachyleniu; *d* — warstwa głazików, silnie zlimonityzowanych piasków i żwirów o warstwowaniu przekątnym oraz liczne bloki

Ryc. 6. Odsłonięcie w górnej terasie w Meyenburg w dolinie dolnej Odry (NRD)
a — piaski drobno- i średnioziarniste o niewyraźnej laminacji horyzontalnej; *b* — żwiry z głazikami i głazy obtoczone, słabo widoczna laminacja horyzontalna, *c* — piaski drobne i średnioziarniste, warstwowane, o zmiennym nachyleniu

Ryc. 7. Wykres średniego obtoczenia ziarn niektórych osadów terasowych w pradolinie Noteci—Warty, dolinie dolnej Odry i dolinie Rędowy (Randow) według pomiarów W. Stankowskiego.
A — t. pradolinna; *B* — terasa pradolinna przejściowa; *C* — górna terasa; *D* — górna terasa przejściowa (b).

Ryc. 8. Szkic morfologiczny ujścia doliny Drwęcy
1 — górna terasa; *2* — górna terasa przejściowa; *3* — niższa środkowa terasa; *4* — dolna terasa; *5* — terasa nadzalewowa (II stopień); *6* — terasa nadzalewowa (I stopień)

Ryc. 9. Rozwój sieci dolinnej w Polsce północnej
a — faza proglacjalna; *b* — faza przejściowa, etap początkowy; *c* — faza przejściowa, etap końcowy. Rozbieżne strzałki oznaczają miejsca bifurkacji

Ryc. 10. Terasy pradoliny Noteci—Warty. Szkic morfologiczny
1 — wysoczyzna morenowa i moreny czołowe; *2* — starsze sandry; *3* — terasa sandrowa i pradolinna (terasa V); *4* — terasa pradolinna przejściowa (terasa IV); *5* — górna terasa (terasa III); *6* — górna terasa przejściowa (b) czyli terasa II; *7* — górna terasa przejściowa (a) czyli terasa I; *8* — wydmy; *9* — zagłębienia wytopiskowe, *10* — jeziora. Dno pradoliny i niższe (młodsze) terasy związane z doliną dolnej Wisły pozostawione bez oznaczeń. Cyfry oznaczają wysokości bezwzględne. Przy opracowaniu niniejszej mapy uwzględniono także wyniki badań T. Bartkowskiego, B. Dammera, St. Kozarskiego, B. Krygowskiego, H. Liedtkego, H. Lembkego, W. Mrózka, H. G. Osta, J. Szupryczyńskiego

Ryc. 11. Profil podłużny teras pradoliny Noteci—Warty oraz dolin dolnej Odry i Rędowy (Randow)
1 — dno pradoliny; *2* — terasy prawobrzeżne; *3* — terasy lewobrzeżne; *4* — terasy po obu stronach rzeki; *5* — określenia cyfrowe teras; *6* — rekonstrukcja dawnych den dolinnych; *7* — torf; *8* — fragment profilu pierwotnego dna pradoliny; *9* — wysokości bezwzględne

РАЙМУНД ГАЛОН

МОРФОЛОГИЯ ПРАДОЛИНЫ НОТЕЦИ—ВАРТЫ (ЛИБО ТОРУНЬСКО-ЭБЕРСВАЛЬДСКОЙ)

РЕЗЮМЕ

ОСНОВНЫЕ ПРОБЛЕМЫ ИССЛЕДОВАНИЯ

Автор проводил геологические и геоморфологические исследования прадолины от Быдгощи до Кострджина и кроме того имел возможность познакомиться с наиболее важными обнажениями в террасах нижнего течения Одры и в долине Рандов (на территории Германской Демократической Республики). Исследования касались главным образом террас.

В прадолине Нотеци-Варты существуют две категории террасовых уровней, а именно: террасы, связанные со стоком вод прадолины, т. е. соединенных речных и ледниковых вод, или плейстоценовые террасы, и террасы, связанные исключительно с речным стоком, или голоценовые террасы. Террасы эти существуют также в долинах, впадающих в прадолину, особенно в долинах Брды, Гвды и Дравы. Все террасы в долинах, впадающих в прадолину, наклонены в ее сторону, а в ней самой — к западу. Только на территории обеих краевых котловин, а особенно Торуньской котловины, наклон террас в настоящее время менее выразителен.

ТЕРРАСЫ В ПРАДОЛИНЕ НОТЕЦИ И ВАРТЫ

Из исследований автора, а также из ссылок его на результаты исследований других авторов следует, что в прадолине над ее дном (т. е. 1—2-метровой поймой) существует пять террас, не считая немногочисленных локальных террасовых уровней переходного характера:

I. верхняя переходная (а) или 5-метровая терраса (средний уклон 1 : 5530)
II. верхняя переходная (б) или 7—9-метровая терраса (средний уклон 1 : 5140)
III. верхняя или 10—12-метровая терраса (средний уклон 1 : 6000).

IV. прадолинная переходная терраса или 15—20-метровая (средний уклон 1 : 6360)

V. прадолинная или зандровая терраса с относительной высотой в 18—25 метров (средний уклон 1 : 6420 * или 1 : 7270 **)

Все вышеупомянутые террасы прадолины Нотеци — Варты существуют в Торуньской котловине. Только верхняя переходная терраса (а) появляется в Пильской котловине. Прадолинная переходная терраса продолжается и в долине Рандов, верхняя терраса прадолины носит бифуркационный характер т. е. переходит не только в долину Рандов, но и в низовья Одры. Остальные более низкие террасы прадолины существуют ниже в низовьях Одры.

Вертикальные промежутки между отдельными террасами удивительно одинаковы (приблизительно 4—5 *м*), что должно свидетельствовать о регулярности ритма эрозии, вызванной колебанием эрозионного базиса. Только в верхней части продольного профиля некоторых террас наклон их возрастает, а промежутки между террасами изменяются. Кроме того средний наклон более молодых террас немного больше наклона террас более древних, что вероятно связано с сокращением длины нижнего течения реки после прорыва ее в Поморский залив.

Все террасы являются эрозионными, или эрозионно-аккумулятивными с 1—2-метровым, реже более мощным, слоем речных отложений на моренных и межморенных осадках. Согласно изменчивому геологическому строению плейстоцена в террасах обнажены моренная глина, слоистые пески, флювиогляциальный гравий и ленточные глины, причем чаще всего моренная глина появляется в более высоких террасах, а межморенные отложения на более низких террасах (м. пр. профиль террасы в нижнем течении Гвды — рис. 1). Во многих случаях на поверхности террас в связи с их эрозионным характером сохранились только остатки морены в виде валунника с валунами разной величины, а речные пески лежат почти непосредственно на песках флювиогляциальных.

На песчаных террасах образовались дюны, переходящие местами в сплошные дюнные комплексы.

Отложения прадолинной (зандровой) террасы выказывают характерный для осадков текучих вод медленный, но постоянный рост окатанности (рис. 7), не нарушенный присоединением к ней зандров Гвды и Дравы, что по всей вероятности является результатом одновременного существования похожих длины и наклона этих зандров.

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* На участке Быдгощ — Багемюль (в долине Рандов).

** На участке Александров Куяв. — Багемюль (в долине Рандов).

Окатанность зерен отложений следующих террас выказывает ясное нарушение линии своего развития с течением реки там, где к осадкам прадолины присоединяются отложения Гвды или Дравы, седиментирующие в иных условиях, вызванных вероятно большим наклоном этих рек.

ТЕРРАСЫ В БОКОВЫХ ДОЛИНАХ

Описанные выше террасы прадолины Нотеци-Варты с их продолжением в долине низовьев Одры и долине Рандов имеют свои аналоги в долинах, впадающих в прадолину. Были исследованы низовья Дрвенцы, зандра и долины Брды, долины Лобжонки, зандра и долины Гвды, зандра и долины Дравы, террасы долины Варты выше устья Нотеци и ряд меньших долин.

Исследование террас в долинах, соединяющихся с прадолиной Нотеци—Варты подтверждает произведенное выше подразделение террас в прадолине на пять террасовых уровней, появляющихся в виде меньших и больших участков вдоль всей прадолины (не приняты во внимание локальные зандровые поверхности, обрывающиеся эрозионным уступом к прадолине и 1—2-метровая пойменная терраса).

ДНО ПРАДОЛИНЫ

В дальнейшем автор анализирует дно прадолины, которое, после потери речных вод, подверглось заполнению суглинками и торфом. Из исследований Т. Хурского (10) следует, что рельеф дна прадолины, покрытого органогенными отложениями, очень неровный. Глубина впадин, заполненных в настоящее время торфом, доходит до 10 *м* и больше. Кроме того существуют аккумулятивные валы, насыпанные реками, впадающими в прадолину (Нотець, Гвда).

Ниже заторфованного дна прадолины находятся погребенные долины и впадины, заполненные отложениями застойных озер. Из этого вероятно следует, что существовало морфологическое предрасположение, унаследованное прадолиной возможно от времени последнего межледниковья.

ГЕОЛОГИЧЕСКОЕ СТРОЕНИЕ ДОЛИННОЙ ЗОНЫ

Прадолина врезана на глубину 20—40 *м* в моренное плато, а также в отложения плиоцена и миоцена. Но все же ход прадолины Варты—Нотеци, исключая Костржинскую котловину, не выказывает прямой зависимости от рельефа основания плейстоценовых отложений, орографические оси которого пересекаются прадолиной.

Однако одновременно с вышесказанным можно выдвинуть тезис, по которому существует унаследованное современной прадолиной предрасположение в виде ряда впадин на плейстоценовой поверхности, оставшихся после предпоследнего ледниковья (гляциотектоника?), заполненных осадками застойных озер (рис. 1). Отложения последнего ледниковья не выравняли ряда этих впадин, благодаря чему они стали местами скопления талых вод и их стока на запад.

Анализ дна прадолины и ее террас и их увязка с зандровыми и долинными террасами низовьев Вислы и Одры дает возможность воспроизвести этапы развития прадолины Нотеци—Варты от времени поморской стадии последнего ледниковья до настоящего времени.

Что касается периода от времени пребывания края ледника на линии наднотецких морен до поморской стадии — наши сведения находятся в сфере предположений.

Прадолина Нотеци—Варты образовалась во время поморской стадии. Генезис ее сложен, так как расстояние края ледника от прадолины не на всех участках было одинаково. Западный участок этой прадолины находился вблизи и даже непосредственно у самых конечных морен поморской стадии (т. е. далеко на юг выдвинутой ледниковой лопасти Одры). В результате — в то время как на западе, в районе Костржинской котловины, создавались зандры, подготовляющие постепенно образование прадолины, на востоке перед краевыми формами поморской стадии, образовывались первые зандровые конуса выноса, не доходящие до современной прадолины.

Однако и в западной части прадолины ее эволюция проходила несколькими этапами. Во время существования лопасти Одры талые воды, как это следует из направления стока зандровых вод, связанных с этим периодом, пересекали современную Костржинскую котловину, направляясь разными путями в Варшавско-Берлинскую прадолину, между прочим через суженную часть прадолины под Эберсвальдэ.

Я не считаю возможным согласиться с мнением немецких ученых, что Костржинская котловина была заполнена сплошной массой мертвого льда и только при этом условии был возможен сток ледниковых вод из современной северной части этой котловины в ее южную часть и дальше в Варшавско-Берлинскую прадолину. Современные склоны Костржинской котловины, форма и глубина ее обязаны своим происхождением более молодым эрозионным процессам Одры и Варты (рис. 10).

После отступления лопасти Одры до линии морен фазы Ангермюндэ, имеющих свое продолжение на восток от Одры в виде морен окрестностей Хойны, наступила новая фаза образования зандров. Новые зандры врезались в более древние зандровые поверхности. Во время этой фазы не только зандровые воды протекали с востока по прадолине Варты (неизвестно в каких границах), но согласно мнению Г. Лидтке стекали первый раз суженным участком прадолины под Эберсвальдэ на запад. Тогда образовалась прадолина, включающая, вероятно, прадолину Варты и Эберсвальдэ.

Во время максимальной (или рецессивной) фазы поморской стадии на восток от исчезающей лопасти Одры, зандры в виде зандровых долин достигли вдоль современных Вды, Брды, Гвды и Дравы до существовавших в то время мелких впадин в зоне наднотецких морен и преобразовали их в долину, о происхождении которой свидетельствуют котловинообразные расширенные и более узкие долинные участки (ворота).

Образовался единый прадолинно-зандровый уровень, описанный выше под названием прадолинной террасы, с которой увязываются зандровые террасы Брды, Гвды и Дравы.

Прадолинные воды из прадолины Нотеци стекали не через сужение долины под Эберсвальдэ на запад, но, как это следует из дальнейшего направления террасы, на север вдоль нижнего течения Одры и долины Рандов, где прослежена прадолинная терраса еще в окрестностях Блюмберг и Багемюль на высоте 18—20 м н. у. м. Возможно однако, что часть вод, может быть во время исключительно больших наводнений стекала через прадолину Эберсвальдэ на запад.

Во время этой главной фазы прадолинного стока, собирающего ледниковые воды лопасти Вислы и меньших лопастей, расположенных на запад от нее, лопасть Одры уже исчезала. Во всяком случае активный лед находился в окрестностях Щецина, быть может на линии тамошних морен напора. Соединенные воды Вислы и Одры текли по долине Рандов на северо-запад, а затем впадали в образующееся на западе Балтийское ледниковое озеро. Если во время поморской стадии в пределах лопасти Вислы и меньших лопастей, находящихся на запад от нее, лопасть Одры отмирала, то процесс дегляциации был еще более интенсивным дальше к западу т. е. в области датских островов.

Рельеф поверхности зандровой и прадолинной террасы разнообразят многочисленные формы, образовавшиеся от таяния мертвого льда. Особенно много таких форм существует в Гожовской котловине, являющейся частью Костржинской.

Когда ледниковый покров окончательно исчез из зоны конечных морен поморской стадии и на восток от отмирающей лопасти Одры, сток ледниковых вод с севера прекратился. На зандровых конусах выноса образовались реки, врезавшиеся в создавшиеся перед этим зандровые поверхности, а на территории прадолины и в главную прадолинную террасу. Воды прадолины и Одры направлялись по-прежнему по долине Рандов на северо-запад через территорию Мекленбургии в образующееся Балтийское море (Балтийское ледниковое озеро). Самый отдаленный и самый низкий след стока прадолинных вод на поверхности этой террасы находится в долине Рандов возле Блюмберга на высоте 13 м н. у. м. Это был период максимального стока речных вод (уже не талых) по прадолине Нотеци — Варты, а затем долиной нижнего течения Одры.

Отмирание лопасти Вислы и образование Балтийского ледникового озера создало благоприятные условия в существующем в то время заливе, доходящем до Тчева и Мальборка, для непосредственного стока вод Вислы на север. История прорыва Вислы к северу еще неизвестна. Одной из первых попыток ее выяснения является концепция очередных застойных озер П. Зоннтага (70). Во всяком случае следует принять несколько фаз развития территории современной долины нижнего течения Вислы. Во время стока вод на уровне зандрово-прадолинной террасы этим же путем, по всей вероятности, стекали зандровые воды Вды к югу в сторону прадолины. Сток того же направления существовал, вероятно, также на уровне переходной прадолинной террасы. Однако во время этого периода происходили морфологические процессы, подготовлявшие прорыв части вод Вислы к северу. Новый путь в первой фазе использовали, вероятно, катастрофические воды, позднее воды регулярных разливов Вислы. Известно, что часть вод Вислы направлялась по поверхности верхней террасы, которую Кайльгак и другие исследователи считали дном застойного озера (торуньского), к северу в застойное озеро, находившееся в зоне теперешнего устья Вислы, а часть вод на запад вдоль прадолины Нотеци— Варты.

Западный рукав текущей в двух направлениях Вислы использовал прадолину Нотеци — Варты, причем воды Вислы и ее притоков, реагируя на колебания эрозионного базиса, врезались в переходную прадолинную террасу. После соединения с водами Варты воды прадолины сливались с водами Одры и вместе с ними направлялись к северу. Часть слившихся вод направлялась, как и до того времени, по долине Рандов на северо-запад, а одновременно часть их стекала на север в направлении образующегося Поморского залива. Это был второй бифуркационный сток в одной и той же речной системе.

Развитие долины Вислы запоздало на одну фазу по сравнению с развитием долины Одры, что явилось результатом более ранней дегляциации на западе. Бифуркация вод Вислы продолжалась еще на уровне 5-метровой террасы прадолины.

И только после перехода на самый низкий прадолинный уровень т. е. на современное дно прадолины, заполненное суглинком и торфом, произошел окончательный прорыв вод Вислы на север, в долину ее теперешнего нижнего течения. Факт этот был связан с понижением эрозионного базиса после образования стока в существующее в то время Балтийское ледниковое озеро, вероятно, по прадолине Лэбы. Воды Вислы врезались в прежнее дно долины, названное „более высокой средней террасой", до уровня младшей „более низкой средней террасы". Вслед за Вислой в „более высокую среднюю террасу" прадолины, обладающую противоположным уклоном, начала врезаться Брда, а протекающая на западе Нотець в дальнейшем пользовалась прадолиной.

До сих пор тезис, по которому водораздельный участок между Брдой и Нотецью подвергся поднятию, что явилось главной причиной прорыва Вислы к северу, не находит подтверждения. Поверхность плиоцена — как сказано выше — образует в окрестностях Быдгощи поднятие, но форма эта, покрытая плейстоценовыми отложениями, не отражается в рельефе современной поверхности.

После изменения направления стока Вислы дно прадолины покрылось отложениями медленно текущих рек, главным образом Нотеци, или-же отложениями стоячих вод. Из исследований Т. Пржибыльского следует, что начало заполнения долины торфом относится к периоду младшего дриаса.

Одновременно с геологическими и морфологическими процессами, происходившими на дне прадолины, на ее склонах и террасах происходили рельефообразующие процессы.

Много боковых долин образовалось в перигляциальных условиях. О существовании этих условий свидетельствуют покровы на склонах и древних террасах, асимметрия поперечного профиля и ветрогранники.

С эрозионными процессами на склонах прадолины чередовались эоловые процессы на песчаных террасах прадолины, в результате которых образовались в течение не менее двух фаз многочисленные комплексы дюн, особенно в Торуньской котловине и на водораздельном пространстве между Нотецью и Вартой. До самого периода климатического оптимума послеледниковья продолжалось вытаивание глыб мертвого льда, нагроможденных в большом количестве в моренных отложениях на территории прадолины, расположенной с дистальной стороны от маргинальных форм познанской стадии и в зоне наднотецких конечных морен.

ЭТАПЫ РАЗВИТИЯ ПОСЛЕЛЕДНИКОВОЙ ДОЛИННОЙ СЕТИ В ПРЕДЕЛАХ ПОЛЬСКОЙ НИЗМЕННОСТИ

По вопросу развития долинной сети в период отступания ледника с территории Прибалтики между Одрой и Неманом в конце последнего оледенения существует богатая литература. К. Кайльгак один из первых выяснил отношение ледникового покрова к прогляциальной долинной сети. Он выделил поморскую прадолину, образовавшуюся во время следующих после поморской фаз рецессии ледника. Позже, в особенности в последние годы, появилось много важных, посвященных этому вопросу, работ, которые дают возможность узнать много нового о развитии долин на территории, оставленной ледником, и определить геологический возраст этих долин. Особенное значение имеет настоящая синтетическая работа, касающаяся прадолины Нотеци — Варты и ее связи с зандровым стоком и долинами рек, текущими с юга (см. предыдущую главу настоящей статьи). Прадолина, как главный элемент позднеледникового времени, является ключом для выяснения генезиса этой долинной системы.

Развитие долин изучаемой территории, начиная с поморской стадии последнего оледенения, можно рассматривать в трех фазах с рядом субфаз. Автор называет их прогляциальной, переходной и балтийской фазами.

1. Прогляциальная фаза. Во время прогляциальной фазы, относящейся к поморской стадии последнего ледниковья в развитии долинных форм решающее значение имели талые ледниковые воды. В начале этой фазы, во время наибольшего распространения лопасти Одры, зандровые воды в окрестностях Костржинской котловины текли, как это доказал Г. Лидтке, либо разными путями на юг от Варшавско — Берлинской прадолины, либо (немного позже) через суженный участок прадолины возле Эберсвальдэ („Eberswalder Pforte") на запад. Во время этой субфазы на восток от лопасти Одры перед краем ледника образовывались огромные зандровые поверхности, а талые воды направлялись к югу по направлению будущей прадолины. До сих пор не доказано существование в это время какой-либо прадолины, в которой собирались бы талые воды сливаясь с речными водами, текущими с юга. Первая приледниковая ложбина связанная с поморской стадией, образовалась, согласно мнению Г. Лидтке, у края лопасти Одры, но далеко ли протягивалась эта

форма к востоку — неизвестно. Тем временем речные воды текли на запад вдоль Варшавско — Берлинской прадолины.

Во время следующей субфазы (рис. 9а), соответствующей периоду более быстрого отмирания лопасти Одры, по сравнению с остальной, восточной частью ледникового покрова, образовались многочисленные зандровые долины („s'' на рис. 9а), по которым талые воды, насыпав большие зандровые конуса выноса, направлялись к югу, вливаясь в большую прадолину тянущуюся вдоль края ледника. В этой прадолине в конце поморской стадии собиралась с одной стороны большая часть талых вод ледникового покрова и вод карпатских и судетских — с другой. Таким образом прадолина эта являлась центральной осью долинной сети этого периода (рис. 9а).

В восточную часть этой огромной ложбины стока вод, в прежних работах называемой Виленско—Варшавской * прадолиной, стекали главным образом талые воды ледникового покрова, расположенного на восток от лопасти Вислы. С юга присоединялись воды верховьев Немана, Нареви, Буга и Вислы. В западной же части этой ложбины, называемой Торунско-Эберсвальдской прадолиной (что верно только отчасти) или прадолиной Нотеци — Варты собирались главным образом талые воды ледникового покрова расположенного между лопастью Вислы и исчезающей лопастью Одры. С юга впадала Одра, которая выработала долину прорыва, пересекающую маргинальные формы познанской стадии, не пользуясь уже дальнейшей частью Варшавско-Берлинской прадолины. Варта же в ее среднем течении соединялась с Одрой еще через упомянутую прадолину, причем принимала приток, текущий с севера вдоль участка её долины, носящего характер долины прорыва (окрестности Познаня **).

Большая часть вод Вислы и Одры, собирающихся в Костржинской котловине стекала по долине нижнего течения Одры, по долине Рандов, а затем по одной из мекленбургских прадолин и впадала в образующееся у берегов Мекленбургии и датских островов Балтийское ледниковое озеро. Остальные же воды прадолины использовали в дальнейшем неудобную узкую часть прадолины у Эберсвальдэ. Итак, здесь происходила бифуркация вод прадолины, поддерживаемая главным образом полыми водами. Из вышесказанного следует, что дегляциация происходила неравномерно, т. е. быстрее на западе, медленнее на востоке, что могло быть следствием влияния морского климата на западе.

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* Недавно Е. Кондрацки возобновил это название.

** См. статью Т. Бартковского (см. литературу).

Представленная выше реконструкция развития речной сети в конце поморской стадии основана прежде всего на анализе террас прадолины Нотеци-Варты и их связи с зандрами.

Автор воспроизвел систему зандрово — прадолинного стока в период существования прадолины Нотеци — Рандов от зандровой террасы Брды и остатков прадолинной террасы в Торунской котловине на востоке до участков прадолинной террасы в долине Рандов на западе (рис. 11), учитывая исследования Г. Т. Оста, Ст. Козарского, Я. Шупричинского, В. Мрузка, Г. Лидтке и других. Для реконструкции долин, существующих во время этой субфазы на восток и юг от современной долины низовьев Вислы, по которой в это время, вероятно, стекали в Торунскую котловину зандровые воды Вды, послужили между прочим исследования Ст. Ленцевича, Е. Кондрацкого, В. Околовича и Л. Рошкувны.

2. Переходная фаза (рис. 9b). Как уже было указано, во время максимума поморской стадии, талые воды лопасти Одры стекали разными путями в Варшавско-Берлинскую прадолину, а потом по прадолине у Эберсвальдэ на запад. Сток соединенных флювиогляциальных и речных вод по прадолине Нотеци—Варты на запад, а затем после слияния с водами Одры на север по направлению к исчезающему ледниковому покрову) с частично бифуркационным стоком через суженный участок прадолины под Эберсвальдэ на запад (рис. 9a) был отражением конечного этапа поморской стадии. Сток вод по долинам Одры и Рандов в образующееся Балтийское море являлся началом следующей фазы развития долинной сети, а именно переходной фазы. В то время как на территории современной Балтики происходило этапами (фазами) отступание ледника, на север от конечных морен поморской стадии развивалась сеть маргинальных долин, соединенных друг с другом котловинами застойных озер. По этим долинам текли флювиогляциальные воды, пополненные водами небольших рек, которые образовывались на северном склоне морен поморской стадии. Во время более продолжительной остановки ледника, соответствующей, вероятно, северноругийской фазе, образовалась поморская прадолина, описанная К. Кайльгаком, К. Ф. Бюловым и многими другими (рис. 9b).

Тем временем на юг от конечных морен поморской стадии в условиях перигляциального климата по зандровым долинам потекли реки, собирающие воды больших зандровых конусов. Они направлялись в прадолину, в которой сливались воды речной сети всей территории Польши. Они текли по поверхности т. наз. прадолинной переходной террасы, которая врезалась на глубину 5 *м* в прадолинную террасу соответствующую прогляциальной фазе. Терраса эта существует не только в прадолине Нотеци-Варты. Она найдена также в зандровых долинах, в долине нижнего течения Одры и Рандов — по этому пути воды стекали, направляясь в Балтийское море. Эта терраса в виде самого высокого террасового уровня найдена при впадении Варты в прадолину. В это время уже существовала долина прорыва Варты под Познанем и воды Варты сливались с речными водами, текущими по прадолине Нотеци—Варты. Только часть вод Варты, согласно мнению Т. Бартковского (5), направлялась еще по Варшавско—Берлинской прадолине на запад.

Во время следующей субфазы на уровне верхней террасы начало отделяться нижнее течение Вислы, а воды Одры текли на север на освобожденную от льда территорию современного Поморского залива. Однако переходная фаза еще продолжалась. Поэтому только часть вод Вислы направлялась на север, а остальная их часть текла на запад по прадолине Нотеци—Варты. Также и часть вод, собирающихся в долине нижнего течения Одры, текла по долине Рандов на запад, но большая часть речных вод Одры — главная масса речных вод Польской низменности — после слияния с водами поморской прадолины стекала по находящейся в настоящее время ниже уровня моря долине вдоль островов Узнам и Рюген в образующееся в то время Балтийское море.

Куда стекали воды нижней Вислы? Несомненно в то время Гданский залив был еще покрыт льдом лопасти Вислы. Многие геологические и морфологические данные свидетельствуют о существовании в то время застойного озера, которое расширялось одновременно с понижением его уровня по мере отступания ледника на территорию Балтики.

Во время одной из очередных остановок ледника в период старшего дриаса (см. рис 9c) образовалась, описанная м. пр. Б. Кёрнке, прадолина Преголы, воды которой вливались в ледниковое озеро на территории современной дельты Вислы. Сток этого озера происходил по прадолине Лэбы и далее на запад по одной из многочисленных маргинальных долин вдоль края ледника. Край ледника в то время был, вероятно, как и прежде извилист, и на территории Гданского и Поморского заливов выгибался в виде лопастей. Это подтверждают результаты исследований Г. Кливэ. Большая прадолина, тянущаяся на юг от морен поморской стадии, играет в дальнейшем роль самой важной водной артерии на территории Низменности. В дальнейшем продолжается бифуркация вод Вислы, текущих на уровне более высокой средней террасы. Об этом свидетельствует факт, что наиболее древние торфянистые отложения в прадолине Нотеци на запад от

Быдгощи относятся к периоду младшего дриаса, т. е. к периоду, когда ледник отступил на территорию Скандинавии. Как следует однако из анализа террас в долине нижнего течения Одры, все ее воды текли на север по находящейся в настоящее время ниже уровня моря прадолине вдоль островов Узнам и Ругия в Балтийское море, принимая с востока воды маргинальных рек ледника.

3. Балтийская фаза (рис. 9с). Полный переход вод Вислы в открытый Гданский залив (на уровне более низкой средней террасы долины нижнего течения Вислы — Аллеред) и образование водораздела в прадолине, а также переход вод Немана в Балтийское ледниковое озеро обозначают начало последней фазы в развитии долинной сети Прибалтики, а именно — балтийской фазы. Значение Одры, лишенной стока вод Вислы по прадолине, уменьшается. Устье Одры находилось в это время, в противоположность Висле и Неману, на территории Балтики далеко от современного берега. Во время балтийской фазы окончательно определился резкий контраст направления речного стока Польской низменности: с одной стороны сохранившиеся занровые долины, направленные к югу, с другой стороны — направленные на север долины прорыва Одры, Вислы и Немана, а также долины меньших прибалтийских рек, устремляющих свой извилистый бег долинами прорыва к близлежащему морю. Реки отмечают послеледниковые колебания уровня Балтики образованием долинных террас и аккумуляцией. Прадолина Нотеци — Варты с уклоном, не приспособленным к современным, преимущественно малым рекам, по ней протекающим, препятствует влиянию балтийской эрозионной базы и становится мертвой долиной. Тем временем близость этой базы к притокам нижнего течения Вислы становится причиной интенсивного развития их долин, о чем свидетельствует количество долинных террас, преимущественно эрозионных, напр. 9 террас в долине Брды.

Объяснения к рисункам

Рис. 1. Террасы долины Гвды на восток от Пилы (террасовый полуостров)
1 — зандровые пески с валунами; *2* — валунная глина; *3* — межморенные пески (флювиогляциальные); *4* — ленточные глины под валунником (кирпичный завод); *5* — песок и гравий с валунами на поверхности 1 террасы. Террасы обозначены римскими цифрами (см. описание на стр. 117).

Рис. 2. Обнажение на прадолинной террасе в долине Рандов в окрестностях Багемюль (ГДР)
a — разнозернистые пески с преобладанием крупнозернистых; *b* — валунник в виде хорошо окатанных валунов диаметром до 20 *см*; *c* — несогласно залегающая под валунником серия слоистых песков, переслаивающихся со слоем гравия

Рис. 3. Обнажение в прадолинной террасе в Дзембувке (на восток от Пилы)
1 — покровный песок и остаточные отложения после эрозионного срезания валунной глины. Аккумулятивные карманы; *2* — ледниковая глина; *3* —

слоистые флювиогляционные пески разной фракции; *4* — мелкозернистый песок с прослойками крупнозернистого — уклон 32° на юг; *5* — супесь .

Рис. 4. Обнажение в верхней террасе в Патерке (на юг от Накло)
1 — покровное (остаточное) отложение — валуны, гравий; *2* — светло-желтые слоистые пески; *3* — бурая валунная глина

Рис. 5. Обнажение в верхней террасе кирпичного завода Мужиново (на юг от Дрезденка)
a — горизонтально слоистые светло-желтые речные пески; *b* — валунник с кусками переработанной глины; *c* — светло-желтые флювиогляциальные пески с разным уклоном слоев; *d* — слой валунчиков, сильно лимонитизированных песков и гравия с диагональной слоистостью и многочисленные большие валуны

Рис. 6. Обнажение в верхней террасе в Мейнбург в долине нижнего течения Одры (ГДР)
a — мелко- и среднезернистые пески с неясной горизонтальной ламинацией; *b* — гравий с валунчиками и окатанные валуны; малозаметная горизонтальная ламинация; *c* — мелко и среднезернистые пески, слоистые с изменчивым уклоном

Рис. 7. График средней окатанности зерен некоторых террасовых отложений в прадолине Нотеци—Варты, долине нижнего течения Одры и долине Рандов (по измерениям В. Станковского)
a — прадолинная терраса; *b* — переходная прадолинная терраса; *c* — верхняя терраса; *d* — верхняя переходная терраса (b)

Рис. 8. Обзорная морфологическая карта устья долины Дрвенцы
1 — верхняя терраса; *2* — верхняя переходная терраса; *3* — более низкая средняя терраса; *4* — нижняя терраса; *5* — надпойменная терраса (II ступень); *6* — надпойменная терраса (I ступень)

Рис. 9. Развитие сети долин в северной Польше
a — прогляциальная фаза; *b* — переходная фаза, начальный этап; *c* — переходная фаза, конечный этап. Расходящиеся стрелки обозначают места бифуркации

Рис. 10. Террасы прадолины Нотеци—Варты. Обзорные морфологические карты
1 — моренное плато и конечные морены; *2* — древние зандры; *3* — зандровая терраса и прадолинная (терраса V); *4* — прадолинная переходная терраса (терраса IV); *5* — верхняя терраса (терраса III); *6* — верхняя переходная терраса (b) или терраса II; *7* — верхняя переходная терраса (a) или терраса I; *8* — дюны; *9* — термокарстовые впадины; *10* — озера
Дно прадолины и более низкие (молодые) террасы, связанные с долиной нижнего течения Одры, не обозначены. Цифры обозначают абсолютную высоту. При составлении настоящей карты были использованы результаты исследований В. Мрузека, Ст. Козарского, Я. Шупричинского, Г. Г. Оста, Г. Лидтке, Г. Лембкэ, Т. Бартковского, Б. Даммера, Б. Крыговского и других.

Рис. 11. Продольный профиль террас прадолины Нотеци—Варты и долины нижнего течения Одры и Рандов
1 — дно прадолины; *2* — правобережные террасы; *3* — левобережные террасы; *4* — террасы по обеим сторонам реки; *5* — обозначение террас в цифрах; *6* — реконструкция древнего дна долин; *7* — торф; *8* — участок профиля первичного дна прадолины; *9* — абсолютная высота

Fig. 11. Longitudinal profile of terraces of the Noteć—Warta ice-marginal streamway and of valleys of Lower Odra and Lower Randow

1 — bottom of ice-marginal streamway; 2 — right-bank terraces; 3 — left-bank terraces; 4 — terraces on both sides of river; 5 — numeral designations of terraces; 6 — reconstruction of former valley floors; 7 — peat; 8 — fragment of profile of original valley floor; 9 — absolute heights

Fig. 10. Terraces of Noteć—Warta ice-marginal streamway. A morphological map

1 — moraine plateau and end moraines; 2 — older outwash sands; 3 — outwash- and ice-marginal streamway terrace (terrace V); *4* — ice-marginal streamway transition terrace (terrace IV); 5 — upper terrace (terrace III); *6* — upper transition terrace (b), or terrace II; *7* — upper transition terrace (a), or terrace I; *8* — dunes; *9* — meltwater kettles; *10* — lakes

The bottom of the ice-marginal streamway and lower (younger) terraces, connected with the Lower Vistula valley, have been left unmarked. Numerals denote absolute heights. In compiling the present map, the results of the investigation conducted by the following authors have been taken into consideration: T. Bartkowski, B. Dammer, St. Kozarski, B. Krygowski, H. Liedtke, H. Lembke, W. Mrózek, H. G. Ost, J. Szupryczyński

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