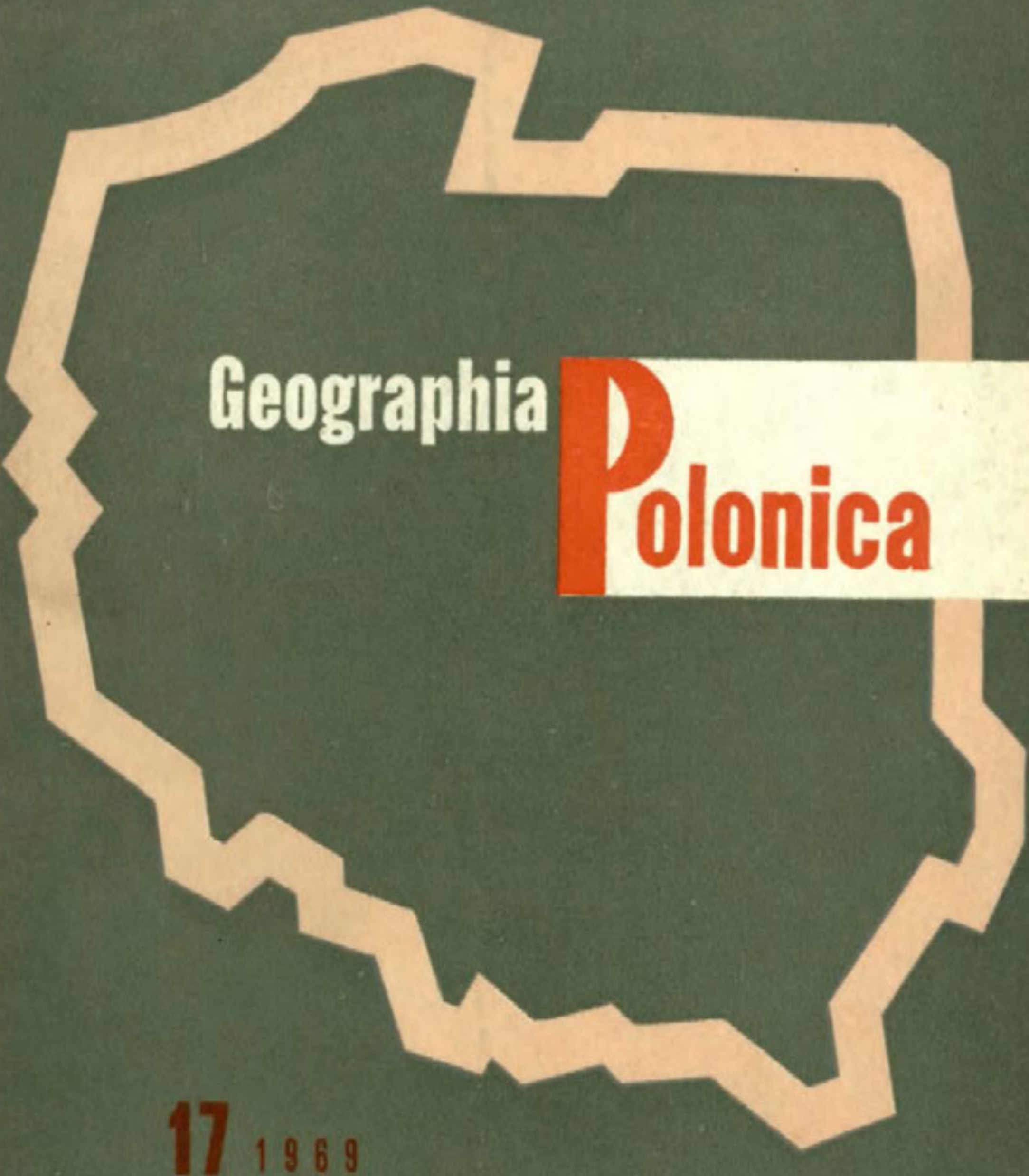
Geographia Polonica



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GEOGRAPHIA POLONICA 17, 1969

I. STRATIGRAPHY AND NEOTECTONICS

CLIMATOSTRATIGRAPHY AND ITS APPLICATION WITH PLEISTOCENE OF MIDDLE POLAND AS EXAMPLE

Stefan Zbigniew Różycki

INTRODUCTION

The system of the stratigraphical subdivision of Poland's Quaternary as presented in this paper has been published by the author in preliminary outlines in 1961 in a volume being a general introduction for the excursions into Middle Poland of the VIth INQUA Congress [29]. This scheme was documented by a number of cross-sections demonstrated in the field during these excursions [30, 31]. Certain fractions of the author's stratigraphical concept were also discussed in separate papers [32, 33, 36. 37. 41]. Further, the methodical basic rules on which the author constructed his new scheme served as topic for a number of specific publications [34, 35, 39. 40 - 42, 43]. Ultimately, a more extensive paper published by the author in 1967 [38] brought a survey of the sum of stratigraphical and palaeogeographical problems of Middle Poland during the Pleistocene.

METHODS OF RESEARCH AND THEIR APPLICATION

CLIMATOSTRATIGRAPHY AND ITS UNITS OF STRATIGRAPHICAL SUBDIVISIONS

Summing up all the above reflections on the specific features of the Quaternary stratigraphy the author considered it inadmissible to apply the classical biostratigraphical units which so far were in use in delimiting older formations, the duration of which has been set at three to five hundred thousand years by the most advanced methods. This time scale is unsuitable for what is required for the Quaternary stratigraphy, where a much higher accuracy is demanded, brought down to the order of ten thousands of years or, at times, to thousands of years. The author made up his mind, that the stratigraphical system to be applied for the Quaternary should be based on a climatostratigraphical method suitable for interlinking all the results obtained by the manifold methods of research applied to the Quaternary. Using climatostratigraphical criteria (i.e. amplitudes of climatic changes during warmer and cooler periods) one can also estimate more reliably the order of the stratigraphical units distinguished[1], applying the following taxonometric sequence: periods (first order, some 80 - 120 thousand years); stadials (second order, some 20 - 25 thousand years); phases (third order, a few thousand years); "etaps" (fourth order involving successive changes within phases). More detailed definitions of these units the author adds in a separate paper [34].

This concept of assigning stratigraphical units to the Quaternary turns the Holocene into an incomplete stadial of the Pleistocene, and what is used to be called "stadials" of the last glaciation (the Frankfurt - Leszno, the Brandenburg - Poznań, and the Pomeranian respectively) will drop to the order of phases; obviously, the duration of these phases cannot be set equal to the real stadials of the older glaciations.

Since the division into the newly suggested units pertains to both the cool ("glacial") and the warm ("interglacial") periods, and the way how they developed depends on facioclimatic conditions, it becomes necessary to define more accurately what kind of stadial or phase is meant in every instance, and this in turn requires indicating their meaning in the terms applied to the new units. For the cool periods involved in the continental glaciations these terms shall be: glacistadials and interglacistadials, and glaciphases and interglaciphases; for the warmer periods the terms are: calidostadials and frigidostadials, and calidophases and frigidophases.

These two groups of new terms by no means contradict each other, because during the cool periods the glacistadials may, at certain distances from the ice sheet front, bear the character of frigidostadials. On the other hand, the frigidostadials of the warmer periods will not correspond to the glacistadials.

THE SENSITIVITY OF GEOLOGICAL RECORD FROM THE QUATERNARY

The sensitivity of a geological record which depends on the degree how much a number of different dynamic factors have affected it, differs in different zones. This is why, contingent on the method applied, the climatostratigraphical results obtained lack an identical degree of particularization.

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[1] The duration of each of these units equals one half of each climatic oscillation, taking in its warmer or cooler period.

To give an example: methods referring to changes in ice sheet conditions and in permafrost range are apt to supply very accurate data on climatic fluctuations in the marginal zone of the ice sheet and its vicinity. However, with increasing distances from this margin, the traces left by periglacial processes grow increasingly obscure, and any climatic curve reconstructed from these traces becomes more and more incomplete. Farther away, out of the reach of the periglacial zone, all these methods lose their usefulness altogether.

In much the same way changes in the composition of the vegetation cover in the boundary zone between forest and tundra are apt to record even minor changes of past phases. In the forest zone these changes indicate for the most part only thermal changes during stadials, and even this in an icreasingly faint way the farther southward they extend. Farther away yet, the changes are almost fully blurred out and become visible only in fluctuations of a higher order. On the other hand, the farther away from the subarctic zone, the more distinctly will be noticeable the effect of all major changes in quantity and distribution of precipitation, and in ability of evaporation. Instead, a gradually increasing importance will acquire all studies of the past behaviour of water basins, of changes in the course of rivers, and of the way how chemical weathering has proceeded — further, studies of pedological and slopewash processes, of eolian phenomena, etc.

APPLICATION OF PALAEOGEOMORPHOLOGICAL METHOD FOR SUPPLEMENTING GAPS IN GEOLOGICAL PROFILES

The feasibility of consistently basing one's conclusions exclusively on any one of the selected methods is also limited by the discontinuity of the material at our disposal. Hence the necessity arises of making simultaneous use of every other kind of available research, although this may be of very diverse value for climatostratigraphical purposes; and particular attention must be given to those parts of the profile, where the interpretation of the geological evidence can be checked by means of several further methods.

However, even applying jointly all known methods which take into account as comprehensively as possible all invesitgations of the sediments determined in the fullest geological profiles, we cannot hope to obtain fully continuous geological pictures. The author attempts therefore in the present paper to solve the difficult problem of gaps in our Quaternary profiles by an exhaustive application of the palaeogeomorphological method for stratigraphical requirements. With this in mind he tried in each instance to determine the geomorphological configuration in which the sediments had originated. This effort yielded particularly interesting results with regard to integlacial water basins, because it made possible a classification and an estimation of the character and the extent of their drainage areas [33, 35, 41]. At the same time it came to light, that observations gained within the limits of different geomorphological units — recent or fossil — by no means involve identical periods of time and therefore cannot be directly correlated; on the other hand, there are many instances where those observations supplement each other. Particularly well in evidence is this, when one correlates data from till uplands which, while they can easily be identified for the different glaciations, show an excessive generalization for the periods when denudation was taking place. As next source reconstruction of the history of river valleys effectively supplements our knowledge of the interglacial periods, especially of their anaglacial parts [33]. These valley studies are considerably supplemented by conclusions reached from palaeobotanical examinations, which illustrate the connection between warmer periods and the glacial transgressions which followed them. Furtheron, the palaeogeomorphological method enables us to establish the sequence of the evolution of relief-forming processes and, in this way, it illustrates the course of the climatic changes producing these processes, even for the periods when denudation predominated — periods which in the profile appear as breaks in sedimentation. Most suitable for this purpose were detailed examinations in regions. where a dense network of bore holes presents the chance of reconstructing successive fossil surfaces. It proved possible to follow this procedure in several regions where drilling amounted to several hundreds per square kilometer, or at sites where deposits are well exposed along many kilometers. As an example may serve: studies of the Eemian Interglacial at Gołków [41], a number of unpublished papers dealing with Warsaw City and the region of Częstochowa and, finally papers by E. Rutkowski on the Konin region [47] and J. Czarnik on the Turek [4, 5] region.

Profitic though less detailed results were also obtained from certain regional palaeogeomorphological investigations, in which adventage was taken of an ample material from drillings and where these data were carefully correlated with field examinations.

An example of this kind of regional research are examinations undertaken by the Chair of Quaternary Geology of the Warsaw University and by the Laboratory of Quaternary Geology of the Geological Department of the Polish Academy of Sciences; so, prepared in cooperation with these institutions, papers are published by Z. Michalska [21, 22]. M. D. Domosławska-Baraniecka [8] and J. Nowak on North Mazovia [24, 25], K. Straszewska on the region of the Lower Bug River [50]. H. Ruszczyńska — Szenajch on the left bank of the Lower Pilica River [45, 46], papers not yet published, prepared by W. Laskowska-Wysoczyńska for the Sandomierz Depression [17], R. Więckowski for the region of Częstochowa [57], L. Lindner on the northern part of the Holy Cross Mountains [18] and K. Kopczyńska-Żandarska on Western Pomerania [12]. Much valuable observations were also reported in papers by J. Łyczewska [19], C. Radłowska [26], K. Balińska-Wuttke [12], and a number of other authors (see [38]).

The material obtained by methods described above is valuably supplemented by the research work done by the Łódź school with Professor Jan Dylik as director, which for the most part deals with periglacial phenomena [6 - 7], and by the palynological studies systematically carried on by the Botanical Institute of the Polish Academy of Sciences in Cracow founded by W. Szafer, for which A. Środoń [55] compiled a synthetic survey, and also by the Palaeobotanical Laboratory of the Geological Institute of the Central Geological Office. Also worth mentioning is a further method of research based on ecological changes in the faunal composition, which became applicable as the result of studies made by K. Kowalski [13, 14], and a numerous group of the palaeontological staff of the Zoological Laboratory of the Polish Academy of Sciences at Cracow and the Palaeontological Laboratory of the Polish Academy of Sciences at Warsaw. Very important for our knowledge of stratigraphy of both Pleistocene and Holocene were also the results obtained from archeological examinations which recently have been splendidly expanded: for the period of older cultures by W. Chmielewski [3] with cooperation of K. Kowalski [13, 14], T. Madeyska-Niklewska [20] and K. Wasylikowa [56], for the decline of the Paleolite by R. Schild, and for the Neolite by H. Więckowska and K. S. Kozłowski (cf. papers by these authors in this volume).

Important as age marks for the Younger Pleistocene are determinations of the absolute age made by the C^{14} method (a list of these analyses given on pp. 47 - 53). In accordance with these age data it was possible to verify the results gained by the fluoro-chloro-apatite method evolved by T. Wysoczański [58] and applied to the whole Quaternary; moreover, apart from giving age data, these latter examinations revealed the thermal conditions of the period from which the examined bone remnants were derived.

Excepting a few instances, sedimentological methods were applied only as supplementary ones considering them rather as additional means for determining the conditions and the environment in which the given sediments were deposited, and for establishing the direction from which they had been brought in.

Discussing the methods on which the author's concept was based, it proved profitable, for purposes of comparison, to take additionally into account as extensively as possible some recent research work consisting of observations made in Spitsbergen (1934, 1958), in the Antarctic (1959), in countries of Northern (1934, 1956, 1958) and Southern Europe (1957, 1961, 1965), as well as in SE Asia (1956, 1967), in N and W Africa (1959) and during excursion in the western and central part of the United States (1965).

THE SYSTEM OF SYMBOLS APPLIED TO CLIMATOSTRATIGRAPHICAL UNITS

For making it possible to apply the system of climatostratigraphical stratigraphy including its stadial and phasal units, there had to be chosen specific moments which could be considered more or less synchronous, admitting tolerable error limits. With this in mind the author adopted as suitable what might be called "crucial moments", in other words, points of time which initiated changes in the direction of the climatic fluctuations of periods and stadials. For the periods this means the peaks of calidophases of the interglacial optima and of the glaciphases of the maximum extent reached by the successive continental glaciations. In an analogous way, for the stadials this refers to the optima and pessima of the calido — and frigidostadials, and for the glacistadials and interglacistadials to the maxima of the stadial advance or retreat of the ice sheet [2]. Hence the author adopted these crucial moments as starting points for the symbols applied to his division into the known four large periods of glaciations (G) with Roman numerals used („Günz" — G I; „Mindel" — G II; „Riss" — G III; „Würm" — G IV), and into the three warmer Interglacials separating the glaciations (G/M — J I/II; M/R — J II/III; R/M — J III/IV). In cool periods the marking of the culmination glacistadial is done by adding "max". (for example G III max.) while for the warmest calidostadial of a given interglacial "opt." (for example J II/III opt.) or "opt. int" is added. The remaining units of the stadial order are marked by Arabian numerals, depending on how they occur with regard to a culminating glacistadial or calidostadial: when occurring afterwards by adding "plus", when before by "minus". Thus, the successive glacistadials of the penultimate glaciation will have the following symbols: G III−2; G III−1; G III max.; G III+1, G III+2, etc.; the symbols for the older interglacial will be successively: J II/III−2; J II/III−1; J II/III opt.; J II/III+1; J II/III+2, etc. For each calidostadial its stadial optimum

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[2] Further studies (not detailed here) on crucial moments determined by a variety of methods, have revealed shiftings of the order of phases, i.e. differences that are admissible with regard to the stadial units. Partly these studies involved for identical profiles the correlation between slopewash processes and palynological spectra.

will be marked also by adding "opt." or "opt. stad.", and for the pessima of the frigidostadials separating two calidostadials (for example J II/III+1/2) the phase of the greatest cooling is given the symbol "pess". (for example J II/III+1/2 pess). Identical symbols were applied to the glacial periods where the glaciphase of the maximum extent of ice sheet is marked by "max." (for example G III+1 max.) and where the phases of transgression and recession or deglaciation bear the abbreviations "tr."; "rec.", "degl." (for example G III+1; G III+1/2; G. III+2 tr.; G III+2 max. degl.). When it is the matter of distinguishing glaciphases, there is added to the symbol a third term in small characters of the Latin alphabet (for example G III+1−a; G III+1 max; G. III+1+a; G III +1+b; etc.), while the interphases separating the glaciphases are marked by quotients (for example G III+1+a/b).

Within the range of the interglacials, partly of some of the interglaciphases also (especially when well advanced palaeobotanical research can be made of use), one can also apply abbreviations specifying climatic conditions of stage phases, based on phytophases of the evolution of the vegetation cover[3]. It is customary to define by terms used for the last deglaciation and the Holocene (for example: arct., subarct., prebor., bor., atl.) or by similar terms. There also arose the necessity of distinguishing between boreal phases, depending on the direction of the climatic changes involved (anabor., katabor.); also conceivable are defining changes in a different way, before or after their optima (like: preopt., postopt.).

The complete system of symbolic signatures suggested above leaves free play when it comes to the boundaries between glacials and interglacials, and therefore it is possible to introduce supplementary symbols in the matter of these precarious and most controversial boundary zones, in which two kinds of symbols face each other: the one referring to glaciation maxima, the other to the principal optima of interglacials. These two systems of symbols may also penetrate each other and, depending on structural features, one can define them by symbols taken from either the glacial or the interglacial system. And only after research has proceeded much farer, it will be possible to decide which symbols to use (for example, passing from J II/III to G III can be expressed either by: J II/III+3=G III−2/3 or by J II/III+3/4=G III−2) and to point

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[3] The term "stage phase" refers to those units of the division, which as to their duration approximately correspond to units of the third order (phases), but for which no phase oscillations can be determined due to the blurring generalization they have suffered in consequence of their distance from the zone where the climatic changes occurred in greatest intensity, and which therefore are difficult to make out by the use of the palynological method.

out, where it would be most suitable to draw the dividing line between the cool (glacial) and the warm (interglacial) periods.

At first sight the system of symbolic signatures suggested above may seem complicated; however, after full comprehension of its fundamental motives, the system renders prompt and unequivocal information on the kind of climatostratigraphical unit involved in any given case, and where this unit is stratigraphically placed with regard to other units. The system by no means precludes the parallel application of local terms but, even, illustrates such terms in as clear a manner as possible and thus does away with many intricacies in regional terminology.

In the following chapters which are based on all the available data heretofore collected in the meridional sector of Middle Poland. an example shall be presented illustrating the results obtained from applying the methods and principles discussed above to the climatostratigraphy of Poland's Pleistocene, and from the use of the symbols suggested by the author.

The stratigraphical pattern of the Polish Pleistocene as it emerges from these studies — it might be called a polystadial pattern — ties in to some extent with B. Halicki's [10] polyglacial trends but, at the same time, it upholds the main structure of W. Szafer's [52] division based on palaeobotanical premises. Even so, the new pattern introduced by the present author differs from W. Szafer's division not only in the way how it goes into details, but also by its own merits: it bases on new facts (like data on the oldest Podlasian Glaciation G I, the series of which correspond to series of sediments radically different from those which were supposed to justify the problematic occurrence of a Szczecin Glaciation) and on a different interpretation of these series (like the stratigraphical position of the interglacial deposits at Węgorzewo and Przasnysz, the non-contemporaneousness of sites of the Mazovian Interglacial J II/III "Holsteinian", and the age difference between three series of younger loesses and glacial phases of the Baltic Glaciation, etc.).

The author challenges the stratigraphical pattern recently published by J. Mojski and E. Rühle [23] and their palaeogeographical concept, he considers the opinion held by these authors unsufficiently documented by methodical analyses of the material on hand.

THE PLEISTOCENE OF MIDDLE POLAND

MIDDLE POLAND — THE AREA OF QUATERNARY RESEARCH

Middle Poland is a classic area, where Pleistocene problems have been investigated, and these investigations brought many new ideas concerning the Quaternary of the whole country. Even before the theory of continental ice-sheets in Europe had been formulated. the limit of the continuous Quaternary cover containing numerous erratic boulders had been well established in Middle Poland, and loess had been recognized here as well (S. Staszic, 1805; J. B. Pusch, 1836). The glacial origin of the moraines (J. Siemiradzki, 1882) and, at least, a bipartition (J. Siemiradzki, 1891) or a tripartition (Ludomir Sawicki, 1921) of glaciation have been recognized long ago. The latter theory has been confirmed by both palaeobotanical (W. Szafer, 1928) and by geomorphological and geological works (J. Lewiński, 1930). Later investigations, especially those carried on after 1950, brought a more thorough knowledge of that area, and this was described in nearly 900 publications by about 130 authors (literature see [38]).

The area of Middle Poland, situated outside the reach of the last glaciation, shows a clearly marked arrangement, four times repeated, of parallel belts i.e. analogical geomorphological elements (from N to S: morainic uplands, zones of end morainic accumulation, outwash-plains, ice marginal streamways (*pradolinas*) and areas of ice-dammed lakes). But proceeding southward the thickness of the Quaternary cover decreases (from 100 - 200 m in the northern to 2 - 15 m in the southern part), the relief of glacial origin becomes more obliterated, and the differentiated relief of the older bedrock increases in influence.

POLAND IN THE TERTIARY

The central part of Poland was marked by a large depression occupied by the sea since the end of the Oligocene. By Early-Miocene times rivers penetrated this depression, cutting deep (60 - 90 m) valleys into the uplands built of Jurassic limestones and Cretaceous marls. In the Upper Miocene these valleys were filled with quartz sands (derived from the Mesozoic mantle of the Holy Cross Mountains upheaved during the Carpathian movements), and then with brown coal beds of considerable thickness. In the Central Drepression a large swamp-basin existed at that time (cf. [38], Fig. 5), and its vegetation was similar to the "cypress swamps" of to-day's Virginia, Louisiana and Florida. In the older Tertiary the glauconite Albian and Cenomanian sands, filling the depressions in the limestone uplands of the Polish Jura (with mogots of tropical karst), had been changed into glaring-red ferrous sands. On top of the peripheral Mesozoic mantle of the Holy Cross Mountains, ferricrete covers were formed on the outcrops of Middle Jurassic siderite limestones, and silicretes — on the Upper Jurassic limestones. At that time decalcification of the Upper Cretaceous marls took place also. In the Miocene the glaring-red colours of weathered material disappeared, and the sands accumulated during that time showing snow-white colours are perfectly sorted due to weathering processes.

During Pliocene time red weathering material (*terra rossa*) was formed on upland areas. It filled karst sinks and occurred together with rocks secondarily cemented by calcite (Węże, Rembielice Królewskie I, Podlesice); here a rich vertebrate fauna has been discovered in some places (see list of the fauna [29], page 26 - 29). The products resulting from weathering processes of different age were intensively washed out from the uplands and carried off by rivers and mud-streams into the Central Depression. In this area they cover deposits of brown coal, and they form a series of Pliocene variegated clays reaching thicknesses of 100 - 120 m (with *Zygolophodon borsoni* and *Tetralophodon longirostris*). The variegated clays show traces of small clay-lumps of different clay minerals composition and different colour. In the peripheral parts of the basin, gradually filled by the variegated clays, thin brown coal beds were formed. These beds occur now within the clays, and they contain pollens of trees and grasses indicating, that at that time several more humid phases existed, separated by longer periods of a drier climate.

THE PRE-PLEISTOCENE ("PREGLACIAL")

The Pleistocene boundary is marked by an abrupt change in the composition of the fluvial deposits, i.e. an abundant occurrence of gravels which are completely deprived of limestone grains; these gravels contain numerous silificated Mesozoic rocks from the Małopolska Upland and fairly numerous Paleozoic siliceous rocks from the southern part of the Holy Cross Mountains and from the Carpathian flysh. The gravels occur even in the central part of the Mazovian area where they form large alluvial fans (cf [38], Fig. 12). In addition to the rivers flowing from the south, other rivers flowing from the north (from Scandinavia ?) as well as from east and from west entered the closed basin of the Central Depression. The rivers carried different material, according to the area from where they arrived.

The deposits which cover the Pliocene series and which precede the oldest inland ice-sheet, have been defined as Pre-Pleistocene ("Preglacial"). They form two series, each representing a separate cycle of fluvial accumulation (gravels and coarse sands, medium sands and fine sands, gray uncalcareous silts); in the writer's opinion, they correspond to the Pretiglian (Pp I) and the Eburonian (Pp II) in Western Europe. They are separated by a peat-layer (Pp I/II) poorly preserved at some places. This peat contains pollens testifying to a considerably increasing warmth.

which may be compared with the Tiglian, and with Mizerna III (W. Szafer 1961) in southern Poland.

Within the karst sinks situated on the limestone uplands (Rembielice Królewskie II, Kamyk, Kadzielnia), *terra rossa* with numerous rodent remnants has accumulated The rodents testify to the Early-Pleistocene age of these deposits, and point to the alternating steppe environments and more humid periods during which some forest-patches appeared (list of the fauna see [29] page 35 - 36).

The end of the Pre-Pleistocene was connected with the next essential change of climatic conditions marked. among other factors, by increasing coolness, by a change in the distribution of annual precipitation, and by an altered trend in the development of weathering processes. It resulted, first of all, in the appearance of calcium carbonate within the clayey deposits and the weathering products containing numerous limestone fragments. Frequent were also limestones in the fluvial gravels of that time.

THE PODLASIAN GLACIATION — G I ("GÜNZ")

The first inland ice-sheet (Padlasian Glaciation; G. I; "Günz") entered north-eastern Poland, and it penetrated also the area of Middle Poland as far as 53° 30′ north latitude (Fig. 1). It came near to the environs of Warsaw but not to the town site. This ice-sheet carrying fresh (not wathered) Scandinavian rock material transgressed only into the north-eastern part of the Central Depression. In the central part of the Depression, only outwash accumulation took place. The Podlasian Glaciation is documented by many borings in northern Mazovia and Podlasie. It is represented by series of boulder clays reaching 20 m of thickness and even more. The boulder clays are divided into horizons corresponding to two glacistadials (the Mielnik Glacistadial G I max, and the Wyszków Glacistadial. G I+1). They are separated by an erosive surface, i.e. by not very deep erosive valleys filled with fluvial deposits which are covered by varved clays. The varved clays are overlain by fluvioglacial sands and gravels, which end the series of that interglacistadial (the Niegów Interglacistadial G I max./+1).

On the Małopolska Upland, situated 100 - 150 km to the south from the maximal extent of the Podlasian Glaciation, periglacial processes developed on a large scale for the first time. On upland surfaces they caused the formation of sharp-edged debris, composed entirely of local material with a considerable amount of weathered limestones. In karst sinks of the Polish Jura the above described debris overlies a Pre-Pleistocene clayey weathering-material, and it underlies a humus layer, which

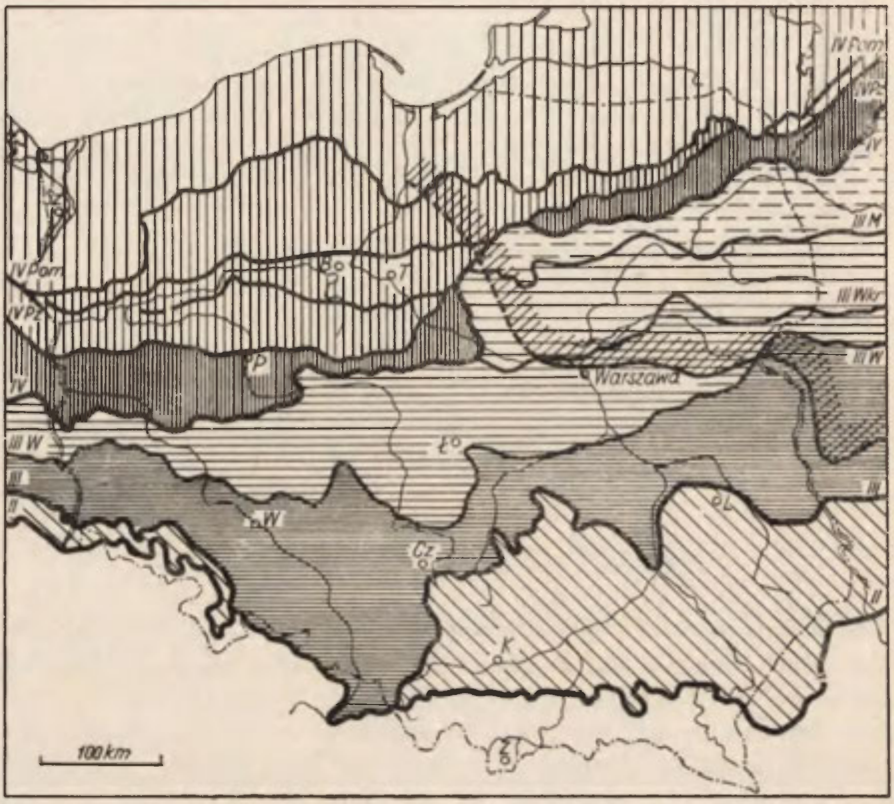


Fig. 1. The reach-lines of glaciations and of some glacistadials and glaciphases in Poland

I — Podlasian Glaciation (G I max); II — Cracovian Glaciation (G II max); III — Middle Poland Glaciation, Radomka Glacistadial (G III max); III W — Warta Glacistadial (G III+1); III Wkr. — Wkra Glacistadial (G III+2); III M — Mława Glacistadial (G III+2); IV — Baltic Glaciation (G IV), Leszno Glaciphase; IV Pz — Poznan Glaciphase; IV Pom. — Pomeranian Glaciphase

in turn is covered by a similar debris bed. However, the latter debris contains an admixture of Scandinavian material derived from moraines of the Cracovian (G II) Glaciation. Analogical debris series, developed on a yet larger scale, and weathering material moved by solifluxion down the slopes are known in the Holy Cross Mountains.

THE OLDEST PRZASNYSZ INTERGLACIAL — J I/II ("CROMERIAN")

The oldest interglacial (J I/II, G/M; "Cromerian Int."), which was not distinguished previously in Poland, proved itself well developed (Fig. 2). It has been called Przasnysz Interglacial, and it is represented by fluvial

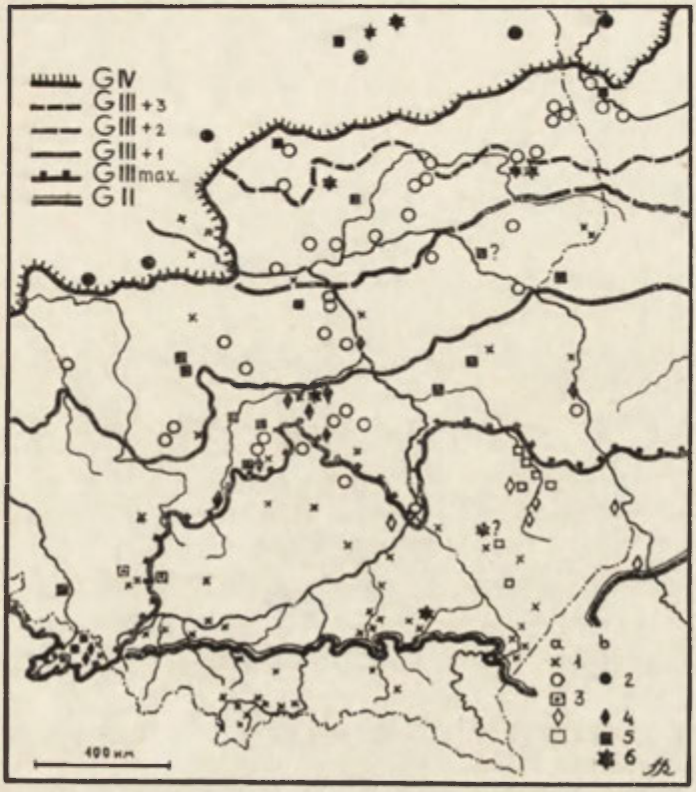


Fig. 2. Distribution of sites of organogenic deposits: *a* — not covered by boulder clay; *b* — covered by boulder clay

1 — G IV (early and late); *2* — J III/IV; *3* — G III+max/+1; *4* — G III and G III-1/-2=J II/III+4; *5* — J II/III; *6* — J I/II

and lacustrine deposits. The lacustrine series determined by borings in northern Mazovia and Podlasie are nearly 100 m thick. The previously elaborated pollen spectra from Węgorzewo [9] (Fig. 3) and from Przasnysz [49] are also of this same age. They were interpreted as belonging to the penultimate interglacial (J II/III), but they differ from that unit first of all by a high maximum of *Abies* (to 59 - 60%). The age of these series is established also, besides by their stratigraphic position, by presence (boring at Węgorzewo, 116 - 118,5 m), of *Arvicola aff. bactonensis* (Hinton) known from Cromer beds.

The fluvial deposits of the discussed interglacial are well developed too. They fill large valleys reachings a depth up to 50 - 60 m. These valleys have been filled during six cycles of fluvial accumulation. In the region of the lower Bug the two youngest cycles are separated by varved clays. This shows that their accumulation was already connected with

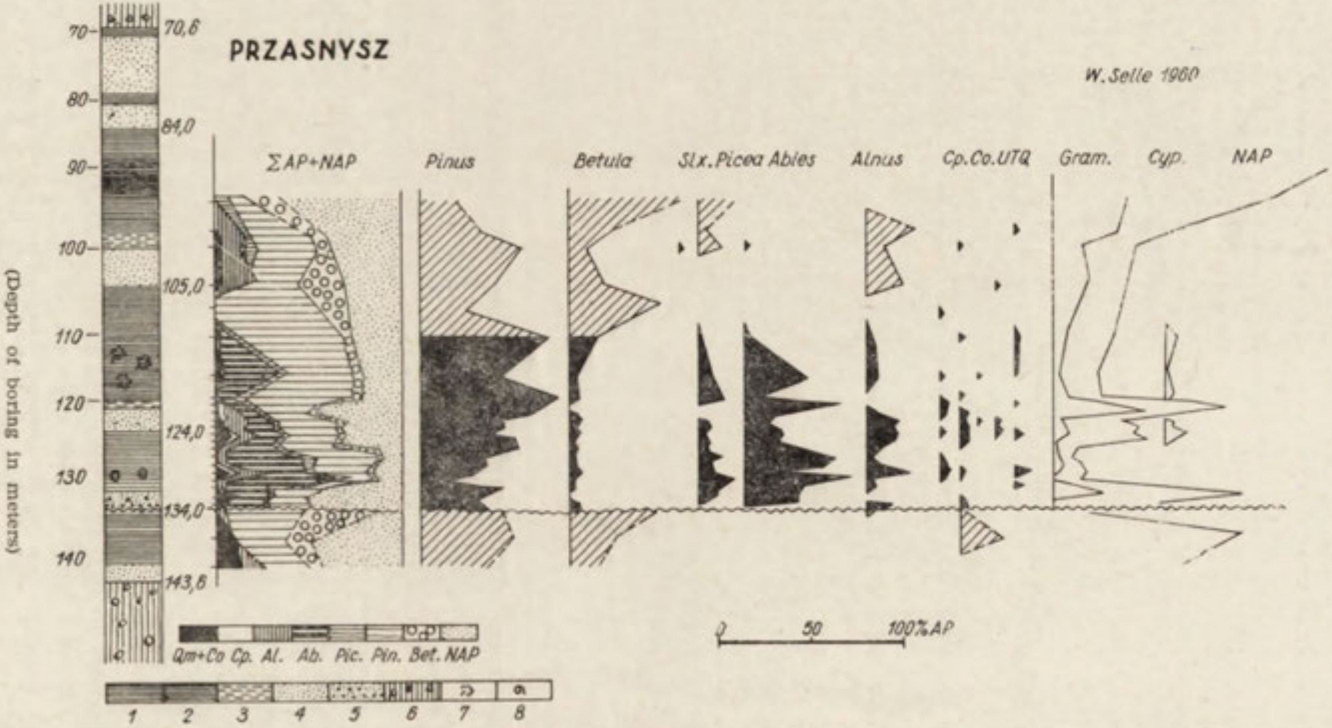


Fig. 3. Pollen diagram from Przasnysz [49]

1 — clay; 2 — clayey silt; 3 — silt; 4 — fine sand; 5 — sand with gravels; 6 — boulder clay (G I; G II); 7 — plant pieces; 8 — mollusks

frigidostadials corresponding to the two early glacistadial advances of the ice-sheet (G II—2, and G II—1), which did not pass the 53° parallel of north latitude.

CRACOVIAN GLACIATION — G II ("ELSTERIAN")

The main advance of the older glaciation (G II, Cracovian, South Polish Glaciation, "Mmdel") reached the foot of the Carpathians (Fig. 1). In the zone of the Małopolska Upland it encountered considerable obstacles in crossing the comparatively high elevations (relative height 100 - 300 m). These elevations caused considerable complications in the arrangement of ice-flow. The advancing ice was split up into large lobes which by-passed the more elevated areas unoccupied by ice, often flowing in lateral or even inverse direction, e.g. in the area of the Holy Cross Mountains (cf. [38] Fig. 21; [43] Fig. 7). The central part of the Polish Jura formed a "concave" nunatak and it was free of ice till the end of glaciation, being only an area of fluvioglacial accumulation.

The maximum glacistadial of the Cracovian Glaciation (G II max., the Przemyśl Glacistadial) was followed by two farther glacistadial advances. The first (G II+1, the Holy Cross Glacistadial) reached the Holy Cross Mountains; the second (G II+2) is clearly marked in north-eastern Mazovia (Fig. 4).

THE MAZOVIAN INTERGLACIAL — J II/III ("HOLSTEINIAN")

The period separating the end of deglaciation of the older glaciation (G II+2) from the main optimum of the following interglacial (J II/III, Great Interglacial, Mazovian Interglacial, "M/R") was characterized mainly, as far as we know, by intense denudation and downward erosion These processes were especially strongly marked in the Mazovian area (in the Vistula valley, by Warsaw, erosion went to a depth of about 60 - 70 m: cf. [29] fig. 14) and on the north-eastern slopes of the Małopolska Upland. Southward of the latter area the down-cutting of valleys was much less (in the Vistula valley near Zawichost only about 30 - 40 m). This was undoubtedly connecetd with upheaval movements in the zone of Kujawy and in the Holy Cross anticlinorium. The movements are clearly identified by a number of slide folds on the northern slope of that elevation, and they caused the shifting of some rivers into new beds (e.g. the interglacial valley of the middle Vistula, cutting through the Małopolska Upland, has been shifted 20 - 30 km eastward of its Pre-Pleistocene position).

The river valleys attained probably their maximum depth in the period of the main interglacial optimum (J II/III opt. int.; the Sulejów

Optimum), as seen from a preponderance of wood pieces of deciduous trees (*Acer* among others in their channel floors). This period was a turning point in the development of all interglacial river valleys; since that time they were filled in during four cycles of fluvial accumulation (Fig. 5) — the result of climatic conditions. These accumulations corresponded mainly to the boreal phases following the stadial optima. During the periods separating the above mentioned phases, organogenic deposits were accumulated in some ox-bow lakes. Their pollen profiles reveal in every case the sequence of climatic changes running from cool to comparatively warm phases (cf. [29] Fig. 9), but accompanied by a deterioration of climatic conditions which increased in the younger strata.

THE TRANSGRESSION OF THE MIDDLE POLISH GLACIATION — G III ("SAALIAN")

The climatic pessimum separating the two first stadial optima (J II/III +1, the Syrniki Calidostadial; and J II/III+2, the Olszewice Calidostadial) still contains conifer forest remnants of boreal type without the subarctic elements which are well marked in the later cool phases (preceding and following the Barkowice Calidostadial, J II/III+3). During these phases varved clays were accumulated in northern Mazovia (separating late cycles of fluvial accumulation), and the last cool phase (J II/III+3/4= G III — 1) resulted even in a boulder clay accumulation in the northern area. At that time the ice front reached the 53° parallel of north latitude (environs of Warsaw) and it dammed the Vistula valley. The result was the formation of large dammed lake, which flooded a considerable part of the middle Vistula valley, and of the lower Pilica River, and a vast area of the neighbouring uplands, reaching as far as the environs of Radom. This lake (the Lower Pilica Lake) was several thousand sq. km large and extended to about 100 km southward of the ice front (cf. [29] Fig. 29). In the northern part of the discussed lake varved clays were accumulated, while in its southern part gray unstratified silts (reaching 40 - 50 m of thickness) were deposited. The silts contain numerous remnants of water plants and pieces of wood brought from the south. Pollen profiles of the silt series show once more an increasing warmth, but not warmer than during the boreal phase (the Witaszyn Calidostadial, J II/III +4=G III — 1/max.). The maximum advance of the penultimate (Middle Polish, "Riss") glaciation (Radomka Glacistadial, G III max.) entered NE of the surface of the Lower Pilica Lake and reached the foot of the Mesozoic elevations surrounding the Holy Cross Mountains as well as the northern part of the Polish Jura [15, 43]. By way of the depressed zones separating these elevated areas several large ice-lobes (Radomka Lobe, Końskie Lobe, Koniecpol Lobe, Upper Silesia Lobe) advanced much farther to the south, even to the Moravian Gate. In their foreground dammed lakes developed, fed by rivers flowing from the south. Pollen profiles of these lake deposits reveal for the Radomka Glacistadial a tundra environment with short phases of increasing warmth ([29] Fig. 9 — Witaszyn).

Another rhythm of development show water basins in undrained depressins (of glacial and karst origin) situated on the uplands. During the first part of the discussed interglacial period these basins were mostly dry, but at the end of the interglacial (beginning with J II/III+3) they were, as a rule, full of water, forming lakes and peat-bogs. They represented some kind of ombro-evaporational stations, and the records of their humidity conditions show the corresponding changes of the air humidity. During the main part of the interglacial evaporation (due to temperature) was intense, so that the depressions used to be dry in spite of an abundant precipitation (decidous forests). But, even when that followed in the colder period, precipitation decreased. evaporation became so slight that the lakes persisted ([29] Fig. 11).

Approaching the Małopolska Upland (Fig. 1) the ice-sheet of the Radomka Glacistadial (G III max.), overran the uneven surface of more resistant Mesozoic rocks, and this furthered the increase of ice-erosion of the bedrock (*roches mountonnees* are known from the northern part of the Polish Jura and the north-western part of the Holy Cross Mountains). All this resulted in an accumulation of immense quantities of local material within the moraines (50 - 80% of morainic gravels of 1 - 5 cm diameter are of local origin).

THE RECESSION OF THE MIDDLE POLISH GLACIATION ("SAALIAN") AND ITS GLACISTADIALS — G III+1 (WARTA); G III+2 (WKRA); G III+3 (MLAWA)

The subsequent deglaciation (Fig. 1) during the Pilica Interglacistadial (G III max./+1) can probably be traced as far as to 53°30′ of north latitude. On the area free of ice during that interstadial (Fig. 4) erosion developed (valleys 15 - 20 m deep), followed by fluvial accumulation (one cycle). There also took place an aeolian accumulation (interglacistadial loesses, attaining a 3 m thickness), and soil formation began (poorly developed podzol soils). All these deposits were covered by the next advance of the ice-sheet (G III+1, Warta Glacistadial), which in several places approached as much as to 30 - 50 km the line of maximum extent of the Middle Polish Glaciation. The Warta Glacistadial (G III+1) was followed by the Bug - Narew Interglacistadial (G III+1/+2). The ice-front retreated at that time at least 150 km to the north, reviving fluvial erosion and causing the evolution of a new drainage system. During that time the large valley developed which encompassed the Bug Valley, the Warsaw

Basin and the Płock Basin, and which turned its outflow farther to the west through a tract similar to that of the Noteć - Warta ice marginal streamway (*pradolina*) (Toruń - Eberswalde Urstromtal). However, during the Wkra Glacistadial (G III+2) this outflow-way had been closed by a new ice advance, and this resulted in the formation of a large ice-dammed lake in the Warsaw Basin (cf. [29] Fig. 34). During the following ice-retreat, a number of minor ice-dammed lakes were formed on the background of the endmoraines representing glacial phases (Fig. 4).

The above mentioned interglacistadial retreat (the Regimin Interglacistadial, G III+2/+3) was followed by the last larger ice advance (Mława Glacistadial, G III+3). The morainic relief corresponding to the Mława Glacistadial is characterized by a much better preservation of "fresh" forms than that of forms connected with former glacistadials. These forms resemble rather the moraines of the last glaciation. However, the undrained depressions of the Mława Glacistadial age are not occupied by lakes; instead they are filled with wash-out sands covering organogenic series from the optimal period of the Eemian Interglacial.

THE LAST INTERGLACIAL — J III/IV ("EEMIAN")

The last interglacial (J III/IV, "R/W") is well known in Middle Poland from about 40 pollen profiles (Fig. 2) revealing its typical inland character. Its is characterized by its main optimum (J III/IV opt. int.; Żoliborz Optimum), with deciduous forests and abundant *Corylus*. During the kata-glacial part of this interglacial, downward erosion prevailed in the river valleys, and this brought stability to the new drainage system directed toward the bay of the Eemian Sea in the region of the lower Vistula. The valleys attained their maximum depth at the time of the main interglacial optimum; afterwards they were gradually filled with fluvial deposits representing two or three cycles.

On upland areas the differentiated morainic relief of the previous glaciation age (G III) still existed. The lakeland areas were found to extend 250 km farther to the south than today. Numerous undrained, or poorly drained depressions were occupied by lakes and bogs which were being filled with organogenic deposits (lacustrine marls, gyttia, peats). Numerous preserved depressions of this type testify to much less denudation in the discussed period than had been observed during the older interglacial (J II/III). This kind of occurrence of deposits of the latter interglacial is comparatively rare and connected only with the northernmore part of Middle Poland.

The main optimum of the last interglacial (corresponding to the proper

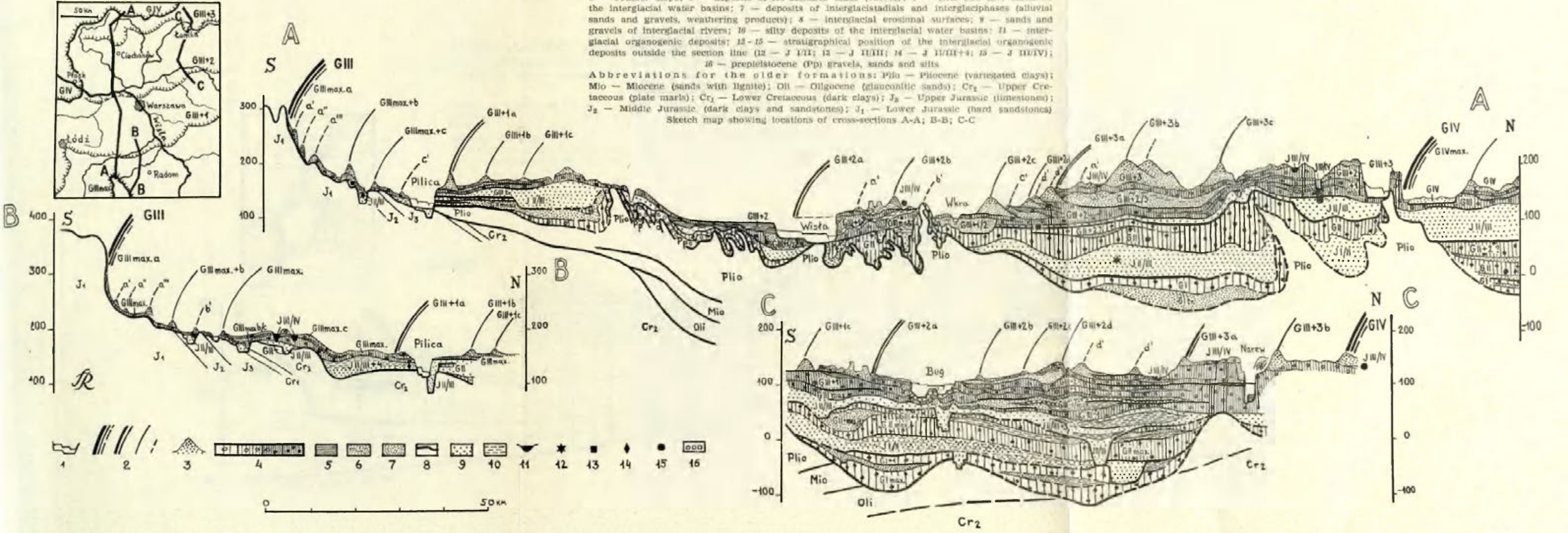


Fig. 4. Synthetical cross-sections through the Pleistocene of Middle Poland, based on the regional works of M.D. Domosławska-Baraniecka, K. Kopczyńska-Zandarska, W. Laskowska-Wysoczańska, L. Lindner, Z. Michalska, J. Nowak, H. Ruszczyńska-Szenajch and the author

1 — alluvial deposits of the Late Pleistocene (J III/IV; G IV, Hol.); *2* — positions of ice fronts in the maximum of glaciations and in the glacistadials and glaciphases; *3* — end moraines; *4* — boulder clays; *5* — deposits of ice-dammed lakes (varves); *6* — silts and fine sands of the interglacial water basins; *7* — deposits of interglacistadials and interglaciphases (alluvial sands and gravels, weathering products); *8* — interglacial erosional surfaces; *9* — sands and gravels of interglacial rivers; *10* — silty deposits of the interglacial water basins; *11* — interglacial organogenic deposits; *12 - 15* — stratigraphical position of the interglacial organogenic deposits outside the section line (12 — J I/II; 13 — J II/III; 14 — J II/III+4; 15 — J III/IV); *16* — prepleistocene (Pp) gravels, sands and silts

Abbreviations for the older formations: Plio — Pliocene (variegated clays); Mio — Miocene (sands with lignite); Oli — Oligocene (glauconitic sands); Cr_2 — Upper Cretaceous (plate marls); Cr_1 — Lower Cretaceous (dark clays); J_3 — Upper Jurassic (limestones); J_2 — Middle Jurassic (dark clays and sandstones); J_1 — Lower Jurassic (hard sandstones)
Sketch map showing locations of cross-sections A-A; B-B; C-C

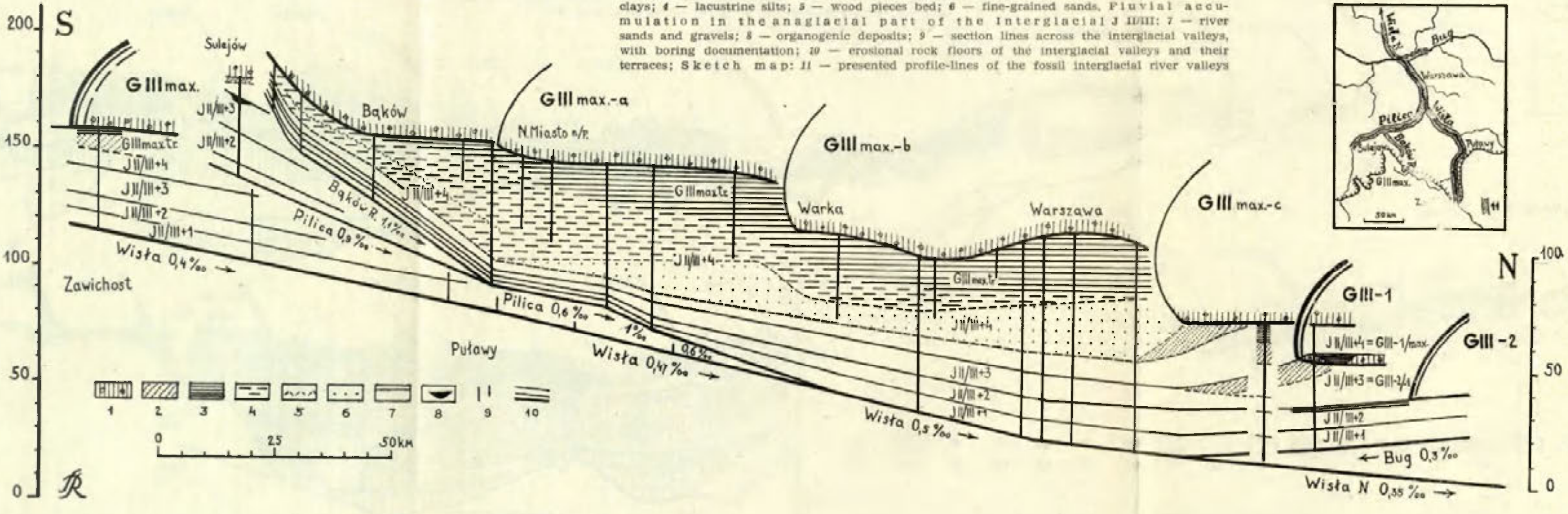


Fig. 5. The longitudinal profiles of the fossil river valleys of the middle Vistula drainage are in the time of the Mazovian Interglacial (J II/III, Holsteinian), and its relation to the advancing ice sheet front of the Middle Polish Glaciation (G III, Saalian).

Glacial drift accumulation: *1* — boulder clays; *2* — proglacial sands; *3* — varved clays; *4* — lacustrine silts; *5* — wood pieces bed; *6* — fine-grained sands. Pluvial accumulation in the anaglacial part of the Interglacial J II/III: *7* — river sands and gravels; *8* — organogenic deposits; *9* — section lines across the interglacial valleys, with boring documentation; *10* — erosional rock floors of the interglacial valleys and their terraces; Sketch map: *11* — presented profile-lines of the fossil interglacial river valleys optimal part of the Eemian Interglacial) was followed by a period lasting about 60 000 years. This period initiated an advance of the last Scandinavian ice-sheet (at about 24 000 B.P.), and it was characterized by four increasingly cooler climatic waves of the 2nd order of magnitude (the stadials). These waves are evidence of a distinct increase of continental climatic conditions. These conditions resulted in a quick disappearance of minor lakes. Some larger lakes continued to exist only as wet depressions during the time of the first two waves of climatic changes. These two comparatively cool frigidostadials (with pine-birch or birch forests but without arctic features) and the warm calidostadials (with pine forests and partly with conifer-decidous forests) following them have been called "Drna" (J III/IV+1) and "Drzasna" (J III/IV+2). Pollen profiles of these two periods are obtained only from those depressions which have been occupied by peat-bogs in that time. Nevertheless, they are found in the Mazovian area (Wola in Warsaw, Góra Kalwaria) as well as in the neighbourhood of the Holy Cross Mountains (Sławno), and also in the area of eastern Poland. Hence, they cannot be interpreted as resulting from local conditions (e.g. from forest fire, in M. Sobolewska's opinion), but they rather correspond to the Danish Amerfoort and Brörup.

THE DRY (LOESS) PERIOD PRECEDING THE LAST GLACIATION, G IV-2; G IV-1 ("EARLY VISTULIAN")

The organogenic interglacial series are overlain by fine- and medium-grained sands of denudation and aeolian origin. In the peripheral zones of depressions the sands are interdented with coarser deposits produced by solifluxion. Their stratigraphic counterpart on the morainic plateau is a layer of sands showing traces of frost disturbances and containing numerous ventifacts (deflation pavement) with thermic cracks. In the are east of Warsaw these sands are covered by a 1 - 1·5 m layer of loess-type deposits.

Undrained or poorly drained depressions of glacial origin — the main places of accumulation of organogenic deposits of the last interglacial — are lacking on the Małopolska Upland, outside the reach of the Middle Polish (G III, "Riss") Glaciation. In this area the younger loess lies on the strongly denuded surface of older glaciation deposits (G II, "Mindel") as well as on the older loess covered by forest soil, or immediately on the weathered older bedrock. Isolated patches of the younger loess occur also in some places in the area reached by the penultimate (G III) glaciation.

The loess material was brought-in by winds blowing from west and north-west, from the area where the previously mentioned "deflation pavement" was observed. It is proof of a further increase of a continental climate and of an increasing coolness following the second warm wave (Drzasna, J III/IV+2). In this way the proper cool period began, but not yet the glacial period.

The younger loess is represented by three series, separated by two layers of fossil soils of steppe- or forest-steppe type. The soils are better developed in the south-eastern part of the country, where they occur in nearly continuous horizons.

All the ^{14}C datings hitherto made of these soils show them to be older than 25 000 or 30 000 years B.P. Hence they can not be compared with the interphases which separated the glacial phases of the last glaciation (Leszno phase=Brandenburg phase; Poznań phase=Frankfurt phase; and Pomeranian phase), and the two lower series of the younger loess are older than these interphases. The above is clearly illustrated by a geological profile from Góra Puławska on the Vistula [48]. This profile shows the denuded surface of the younger loess with a fossil soil horizon covered with fluvial deposits of the IInd fill terrace, which northward adjoins the outwash terraces of the last (Baltic) glaciation. In the neighbourhood of this soil profile an unquestionably Middle Paleolithic site has been found (it mostly resembles the Middle Aurignacion from Krems). The artifacts of this site were found concentrated around two fireplaces with charcoal of *Salix, Larix* and *Pinus cembra* [27].

The fullest stratigraphic picture of the last interglacial period is revealed in a profile from Nietoperzowa Cave (cf. [30] Fig. 39) in the southern part of the Polish Jura [3, 13, 14]. The early cool phases (layers 16 and 15) and the Eemian optimum (layer 14) with a Mousterian culture with the Levaloisian technique and with fauna of a decidous forest were followed by two climatic fluctuations within the forest environment of a temperate climate (Fig. 6). These in turn were followed by two further fluctuations showing alternating subarctic and steppe-forest elements. The layers representing these last climatic fluctuations are directly connected with three younger loess series separated by two fossil soil horizons. The layer corresponding to the lower younger loess still contains a Lower Paleolithic Mousterian culture with an Acheulean tradition (Micoquian-Prondnik). The layer corresponding to the middle series of the younger loess contains an Upper Paleolithic Jerzmanowice culture (resembling the Altmühl Group from Middle Germany) whose older horizon was dated by the ^{14}C method as being 38.160±1.250 years B.P. (Gro 2181). Over the upper younger loess, which covers the above series, a few artifacts of Magdalenian type have been found in other caves. This shows that the upper series of the younger loess may correspond to an early phase of the advance of the Baltic Glaciation.

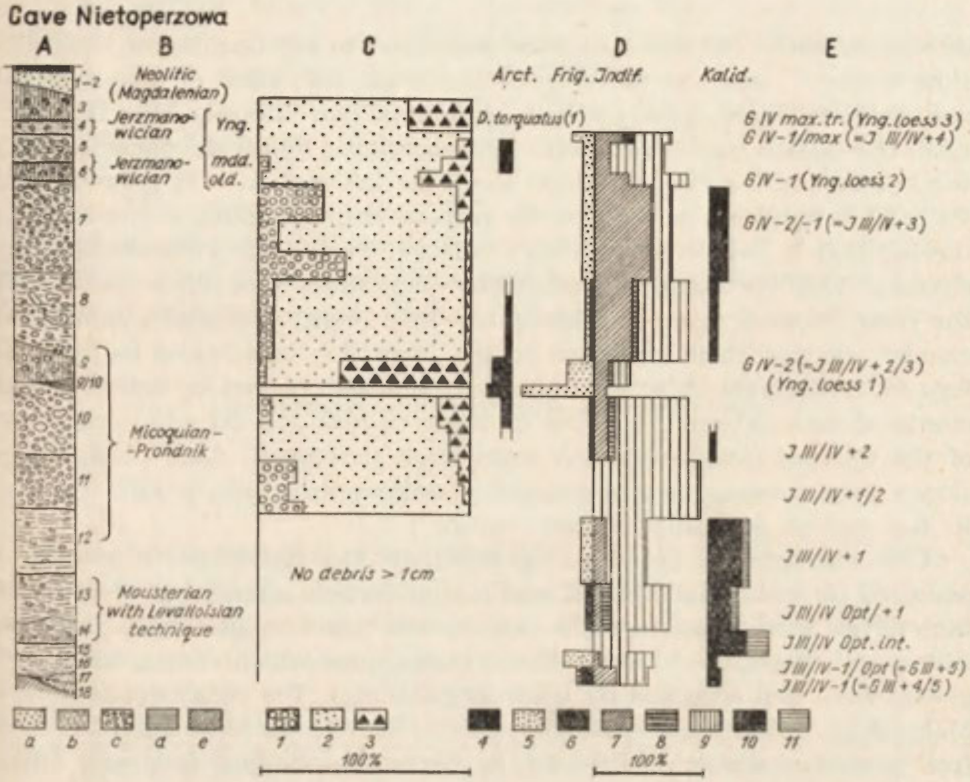


Fig. 6. Stratigraphic diagram for the profile from Nietoperzowa Cave (South Poland)

A — Geological profile: *a* — dusty silt and sand; *b* — younger loess; *c* — limestone rubble; *d* — weathering clay; *e* — Jurassique limestone; *B* — Horizons of paleolithic cultures after W. Chmielewski, *C* — Percentage of debris pieces of diameter larger than 1 cm, which are smoothed (1), partly smoothed (2) and sharp-edged (3), after T. Madeyska-Niklewska; *D* — Small rodent fauna after K. Kowalski. Tundra element: *4* — *Dicrostonyx torquatus* and *Lemus lemus;* Cold demanding element: *5* — *Microtus gregalis* (tundra-steppe); *6* — *Microtus nivalis* (forestless rocky hills). Not climatic indicator element: *7* — *Microtus aeconomus; 8* — *Arvicola terrestris; 9* — *Microtus agrestis.* Warm-demanding element: *10* — *Cletrionomys glareolus; 11* — *Apodemus* sp.; *E* — Stratigraphic interpretation

THE LAST, BALTIC GLACIATION — G IV MAX. ("VISTULIAN PLENIGLACIAL")

The last great advance of the ice sheet, called "Baltic Glaciation" (North Polish Glaciation; "Würm") did not reach the area of Middle Poland, but "entered" it by outwash accumulation connected with the terraces of rivers flowing from the area of the melting ice front. The large river gathering all the fluvioglacial tributaries (Muchawiec, middle and lower Narew, and the Vistula below Warsaw) was also joined by the waters of the Niemen River. The changeful history of the western part of this *pradolina* ("Urstromtal") — its shifting more and more to the north due to the retreat of the Baltic Ice Sheet and to the opening of new outflow ways — caused in the Warsaw Basin an alternation of accumulation and erosion. This resulted in the formation of two "steps" of the IInd terrace: the higher step — II b, with large parabolic dunes, is connected with the Leszno and the Poznań Glaciphases, the lower step — II a, (with Late Paleolithic Świder Tradition on its surface, corresponding at the most to the Bölling) is connected with accumulation during the Pomeranian Glaciphase. This ice marginal streamway (*pradolina*) was alimented by all the rivers flowing from the south, and this is why the above mentioned changes exerted their influence on the formation of terraces in the valleys of these rivers. A considerable part was also played by active movements of material on the slopes of these valleys and on adjoining parts of the uplands (solifluxion and sheet-wash processes). As a result these slopes were covered by a mantle of poorly sorted sands, gently inclined to the valleys (so called "slope terrace").

Other periglacial processes operated on the flatter surfaces of the morainic uplands. Their effect was a considerable smoothing of most of the convex morphological forms left by the previous glaciation, and the filling with deposits of nearly all the depressions which during the interglacial were still occupied by lakes or peat-bogs. The rocky crests of the Małopolska Upland and, especially, of the Holy Cross Mountains suffered frost processes which resulted in the formation of block-field and other crioclastic stone-covers.

THE LAST DEGLACIATION AND THE HOLOCENE

The deglaciation of the Baltic ice sheet proceeded rather quickly, and during the Oldest Dryas nearly the whole of Poland was already free of ice. However, renewed cool waves of the Older and the Younger Dryas exerted a strong influence on the whole country. They revived a tundra environment and a retreat of trees which had begun to appear during the warm waves of the Bölling and the Alleröd. In the lakelands (Northern Poland) the ice-blocks buried in morainic deposits survived until the Alleröd. Their decay gradually caused the formation of numerous lake depressions and the opening of new outflow ways towards the Baltic. This evolution deprived the Warsaw hydrographic basin of a considerable amout of the water it had been receiving previously. The Vistula valley gained also a direct outflow to the north — at first into the glacial lake of the late glacial period and, afterwards, into the sea that gradually occupied the Baltic depression. The above processes caused the lowering of the base level of all rivers in Middle Poland and an increase of dawnward erosion. This erosion lasted till the beginning of the climatic optimum of the Holocene.

In the Atlantic climatic phase, characterized by a preponderance of deciduous forests, large tree trunks were accumulated in considerable amounts within the river valleys (the so-called layer of "black oaks", whose ^{14}C datings gave 6500 years B.P.). The "black oaks" layer occurs most often at the bottom of the fluvial series of the older Holocene terrace (I b).

The pollen spectra from the same time show an increasing abundance of cereal pollens, and on the peat-bogs in the southern part of the country the beds of burnt peat. These facts point to the wide development which agriculture underwent at that time.

AN ATTEMPT OF SYNTHESIZING RESULTS

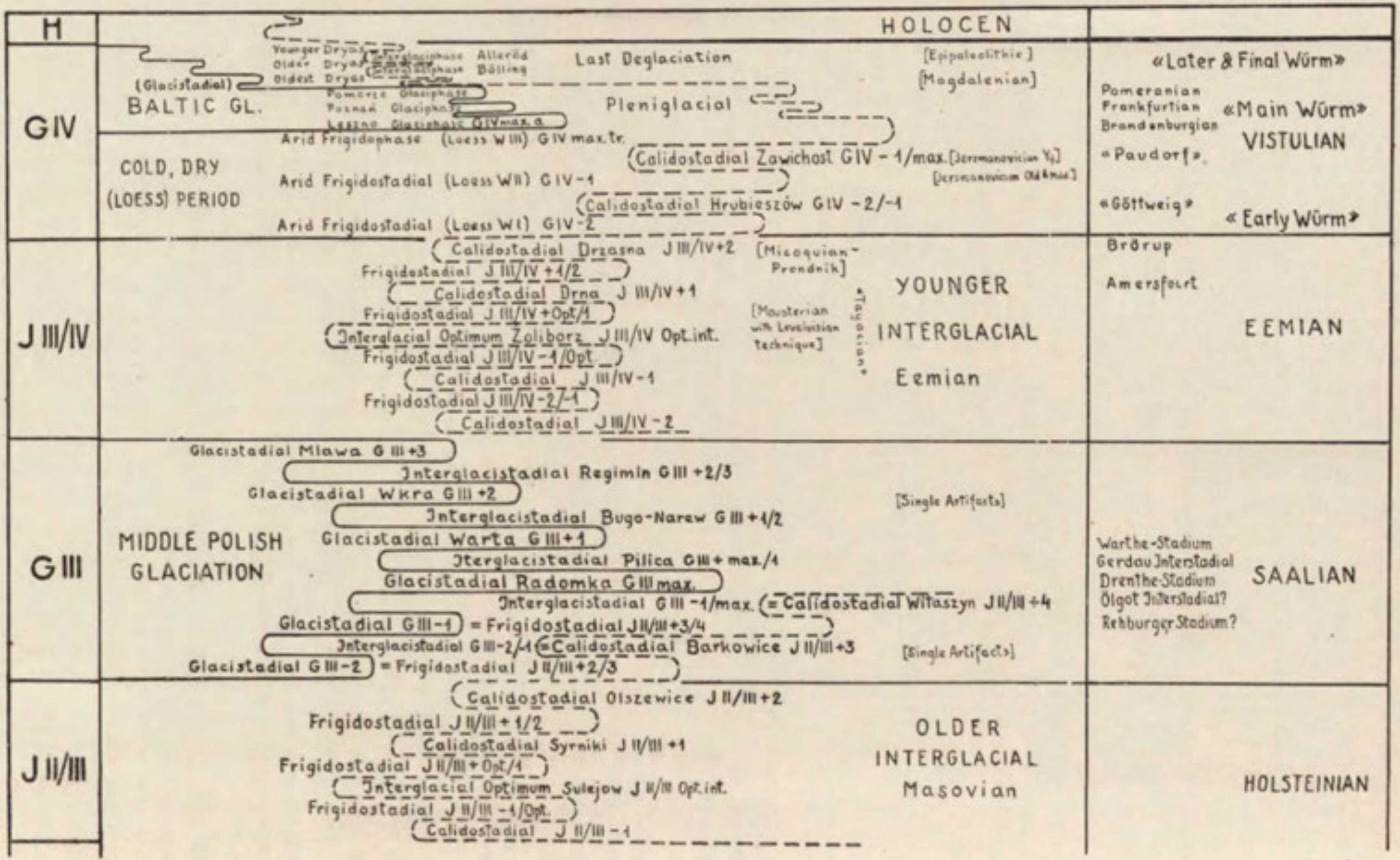
TENTATIVE SYNTHETIC GRAPHICAL CORRELATIONS

Figure 7 constitutes a summarized diagrammatical illustration of the concept evolved in the preceding chapters, indicating first of all the mutual position of the stratigraphical units of the stadial order, with due consideration of the Polish regional nomenclature commonly used for them.

It was the author's intention to present his suggestions, which are based on a much more ample source material than referred to in his paper, in a graphical picture fairly exhaustive yet as concise and lucid as possible, which would be at the same time linked with some additional observations. For this purpose he compiled graphs in the shape of a set of diagrams (Fig. 8), which illustrate not only the climatic changes taking place during the Pleistocene but also their different zonal positions in the sector covered by the investigations discussed; this sector lies between the 19° and 23° meridians, in the part bordered by latitudes 50° to 54° N.

The above graph consists of three parallel charts. The first (Fig. 8 A) shows the changes in the extent of the ice sheets (parallels of the maximum range) and the shifting of floral zones. The second (Fig. 8 B) reveals the variability of a number of climatic elements (radiation absorbed during the summer half-year, sum of annual precipitation, coefficient of evaporation, and periods favourable to durable snow accumulation). The third chart (Fig. 8 C) indicates, synthetically perceived, the course of processes of downward erosion and of accumulation in the valleys of larger rivers.

The first chart is documented by scores of palynological spectra from


H
HOLOCEN
G IV
Younger Dryas
Older Dryas
Oldest Dryas
Interglaciphase Alleröd
Interglaciphase Bölling
Last Deglaciation
[Epipaleolithic]
[Magdalenian]
(Glacistadial)
BALTIC GL.
Pomorze Glaciphase
Poznań Glaciphase
Leszno Glaciphase G IV max. a
Pleniglacial
Arid Frigidophase (Loess W III) G IV max. tr.
Calidostadial Zawichost G IV - 1/max. [Jerzmanovician Y1]
[Jerzmanovician Old & mid]
COLD, DRY
(LOESS) PERIOD
Arid Frigidostadial (Loess W II) G IV - 1
Calidostadial Hrubieszów G IV - 2/-1
Arid Frigidostadial (Loess W I) G IV - 2
«Later & Final Würm»
Pomeranian
Frankfurtian
Brandenburgian
«Main Würm»
VISTULIAN
«Paudorf»
«Göttweig»
« Early Würm»
J III/IV
Calidostadial Drzasna J III/IV + 2
[Micoquian-Prondnik]
Frigidostadial J III/IV + 1/2
Calidostadial Drna J III/IV + 1
Frigidostadial J III/IV + Opt/1
Interglacial Optimum Żoliborz J III/IV Opt. int.
[Mousterian with Levalloisian technique]
«Tayacian»
Frigidostadial J III/IV - 1/Opt.
Calidostadial J III/IV - 1
Frigidostadial J III/IV - 2/-1
Calidostadial J III/IV - 2
YOUNGER
INTERGLACIAL
Eemian
Brörup
Amersfoort
EEMIAN
G III
Glacistadial Mlawa G III + 3
Interglacistadial Regimin G III + 2/3
Glacistadial Wkra G III + 2
[Single Artifacts]
Interglacistadial Bugo-Narew G III + 1/2
MIDDLE POLISH
GLACIATION
Glacistadial Warta G III + 1
Iterglacistadial Pilica G III + max./1
Glacistadial Radomka G III max.
Interglacistadial G III - 1/max. (= Calidostadial Witaszyn J II/III + 4
Glacistadial G III - 1 = Frigidostadial J II/III + 3/4
Interglacistadial G III - 2/-1 (= Calidostadial Barkowice J II/III + 3
[Single Artifacts]
Glacistadial G III - 2 = Frigidostadial J II/III + 2/3
Warthe-Stadium
Gerdau Interstadial
Drenthe-Stadium
Ölgot Interstadial?
Rehburger Stadium?
SAALIAN
J II/III
Calidostadial Olszewice J II/III + 2
Frigidostadial J II/III + 1/2
Calidostadial Syrniki J II/III + 1
Frigidostadial J II/III + Opt/1
Interglacial Optimum Sulejow J II/III Opt. int.
Frigidostadial J II/III - 1/Opt.
Calidostadial J II/III - 1
OLDER
INTERGLACIAL
Masovian
HOLSTEINIAN

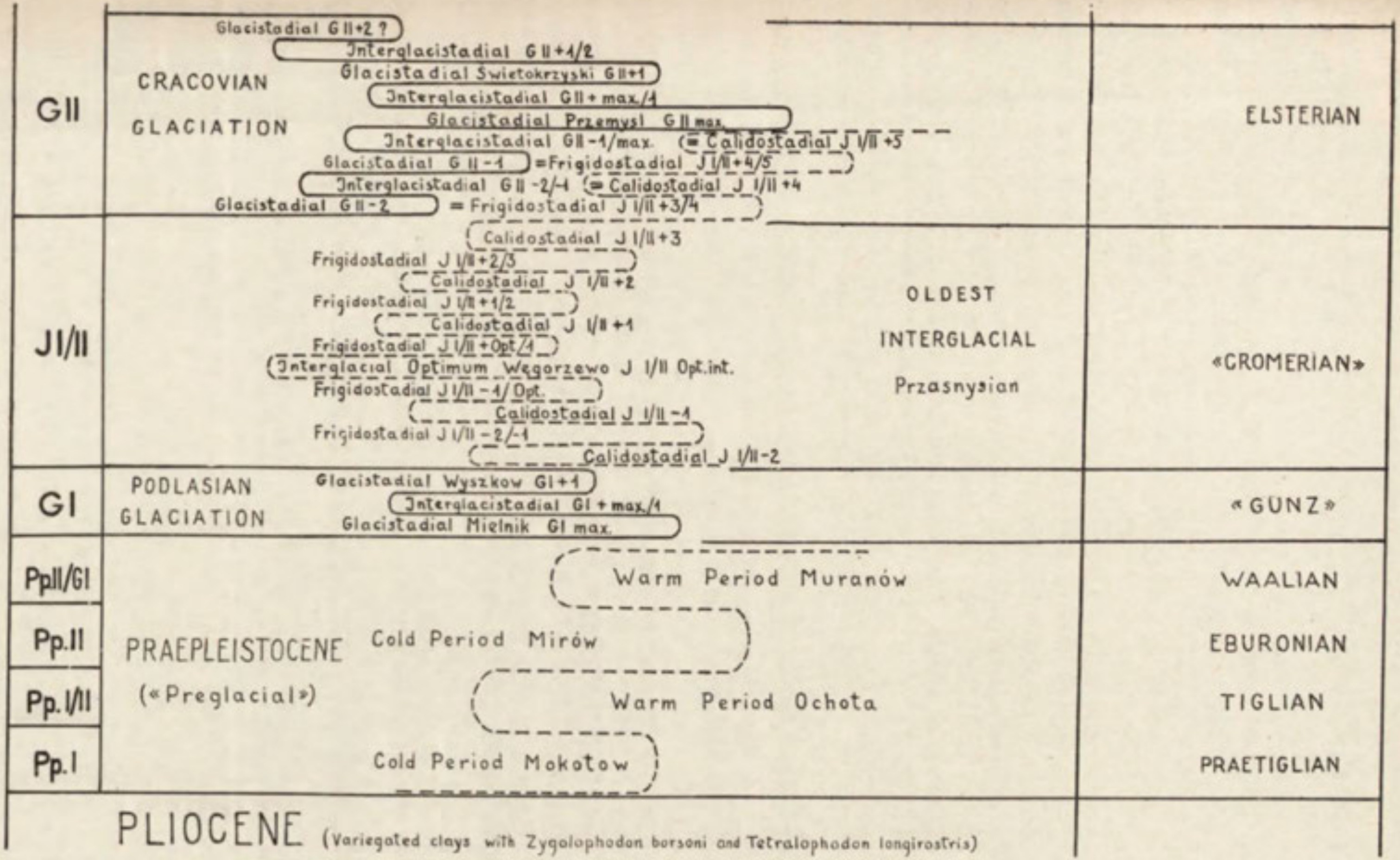


Fig. 7. The sequence (generalized) and nomenclature of the Pleistocene stages and sub-stages (stadials) in Poland

localities situated at different geographical latitudes, and from hundreds of geological cross-sections scattered all over the area discussed. In the first chart are some of the most important moments of the evolution of eolian processes and of the formation of periglacial deformations. The time scale is given in approximation only, taking it for granted that the oldest continental glaciation started at some 600 000 years B.P. In the upper line the symbols for the stadials are included in the "glacial" system, in the lower line in the "interglacial" system. In compiling this diagram it proved to be impossible to avoid certain interpolations for periods less clearly documented; these interpolations are shown in broken lines, and for more doubtful parts question marks are added.

The second chart (climatic in character) refers virtually only to the zone between 51° and 53° N. It is based on the interpretation of a number of phenomena, such as the conditions of the ice sheet, the changes observed in the water level of interglacial and ice-dammed lakes, processes of erosion and accumulation in river valleys. estimation of climatic conditions founded on vegetation cover and fauna, the development of eolian phenomena, etc.

On the X-axis no absolute values of climatic elements are given, inasmuch as in many instances they are controversial and difficult to assess judiciously. On the other hand, the author aimed at maintaining between these values relative proportions as rational as posible, paying particular attention to placing crucial moments correctly. Striking in these diagrams is the discrepancy appearing in a number of points between the rhythm in which thermal and precipitation waves occur. And this discrepancy is the reason why the cool stadials (glacial and loes-type) turn up in different forms, why the interglacial improvements of the climate show unequal values, and why essential differences can be seen in the character of the warmer stadials (e.g. in the anaglacial part of J II/III and in J III/IV).

The third chart is based on analyses of the course of processes of downward erosion and alluvial accumulation, and of the arrangement of present-time and fossil terraces — analyses obtained from the study of scores of section (documented by numerous bore holes) across the valleys of the principal rivers of Middle Poland (Vistula, Pilica, Wieprz, Bug, Narew). Most representative for the Older Pleistocene has been considered the valley of the great interglacial river (J I/II) which has been discovered in the region of the Lower Bug and of NE Mazovia. For the remaining part of the Pleistocene, beginning with the Holsteinian Interglacial (J II/III), the prevailing climatic conditions are well indicated by the Vistula valley in the region of Warsaw.

Moreover, this diagram reveals also historically, how several times

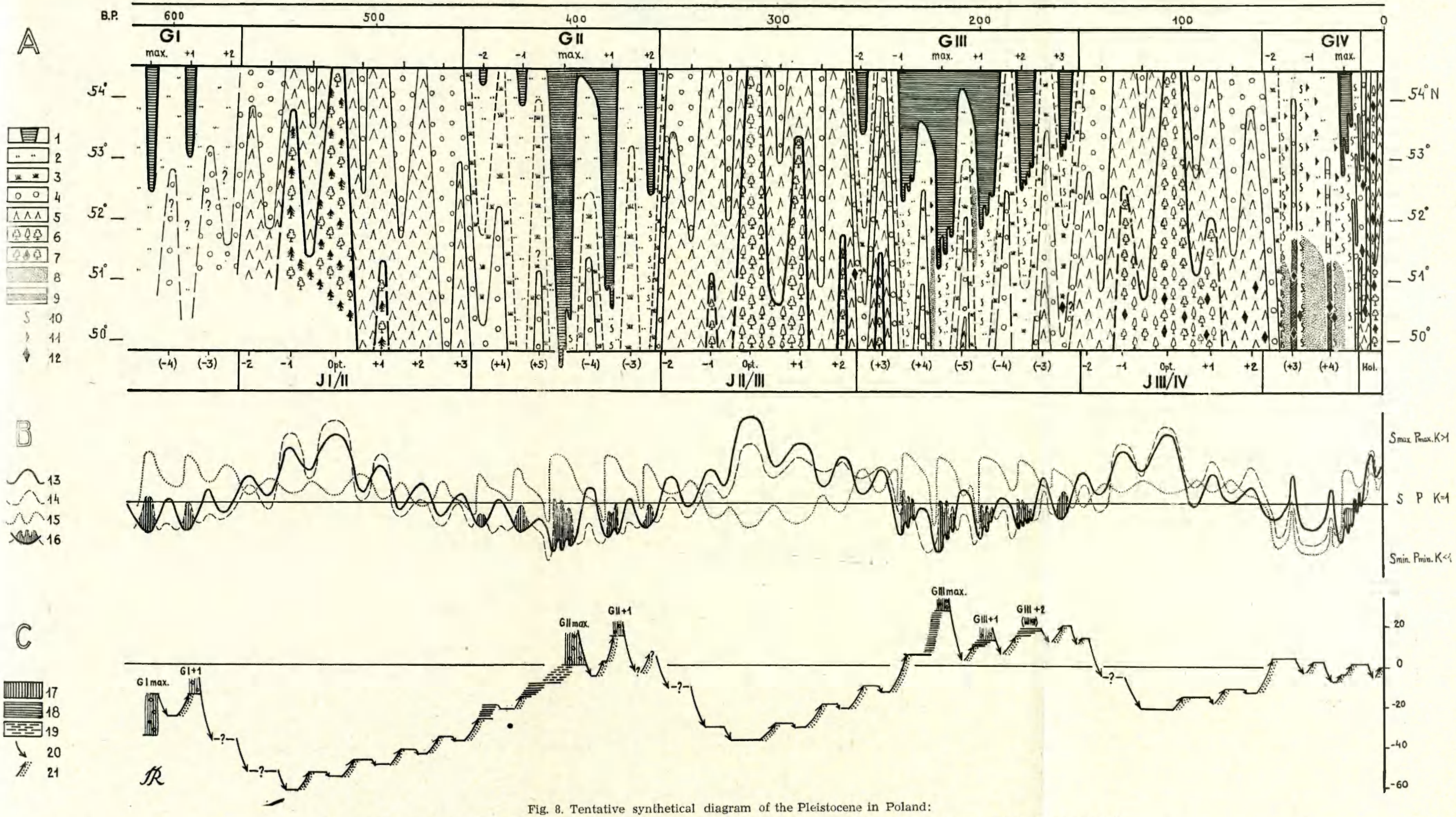


Fig. 8. Tentative synthetical diagram of the Pleistocene in Poland:

A — Latitudinal displacement of the landscape zones: *1* — ice-cap; *2* — tundra and cold steppe; *3* — shrub tundra; *4* — birch and pine-birch forest; *5* — pine and spruce forest; *6* — deciduous and mixed forest; *7* — fir forest with deciduous trees; *8* — loess accumulation zone; *9* — temperate steppe (fossil soils); *10* — periglacial phenomena; *11* — Eolian corrosion zone; *12* — man presence (archeological sites).

B — synthetic curve of changes of climatic indices: *13* — summer total solar radiation (S); *14* — annual precipitation (P); *15* — coefficient of evaporation possibility (K); *16* — glacial conditions.

C — History of the river valleys: *17* — glacial drift over alluvial deposits; *18* — varves of ice-dammed lakes in fossil river valleys; *19* — silt of water-basins; *20* — downward erosion; *21* — fluvial accumulation the evolution of the fluvial valleys of Middle Poland has suffered breaks by flooding of dammed lakes and by ice transgressions, and how afterwards this evolution used to start all over again, for the most part along the same valleys.

GENERAL CONCLUSIONS

The picture shown by the discussed set of charts and the above text presented by the author in the form of a brief summary of a much more extensive paper, illustrate the general concept held by the author on the Pleistocene stratigraphy.

On the whole he endorses the opinion — almost universally accepted today — on four great waves of cooling ("glaciations") and three warmer periods separating them; on this background he perceives 28 minor yet important climatic oscillations for which he distinguishes 56 climatostratigraphical units of second order ("stadials"), which occurred not only during the glacial periods but during the warmer interglacial periods as well.

In the stadial units the author beholds further dissimilarities and this enables him to distinguish within each unit several further oscillations of a still lower order ("phases"); for the whole Pleistocene he anticipates some 200 or more phases.

This — at first sight appaling — multiplicity of stratigraphical units in the detailed division of the Pleistocene which, incidentally, can easily be mastered by applying the symbolism suggested by the author, finds its justification in the remarkably rapid way how climatic changes have succeeded each other. The rate at which this took place, has been determined by research work on the last glaciation and on the Holocene — a research supported by numerous datings by means of the ^{14}C method. There seems to be no reason for assuming, that these changes may have occurred differently in the remaining part of the Pleistocene. Hence the prognoses, put forward by the author with regard to the probable further evolution of the climatostratigraphical system for the Pleistocene, are merely conclusions drawn from the research already accomplished.

All this seems also to imply forcefully, that from the point of view of taxonomy, the Holocene cannot be looked upon as a separate unit equalling in rank the Pleistocene. In fact, the Holocene is but the final calidostadial of the Pleistocene, and as such it should be assigned to the Pleistocene.

The application of stadial units in the subdivision of the whole Pleistocene (including interglacials) allowed clearer delimitation of cool and warm periods. It allowed also to draw some more general conclusions.

One of the most important conclusions says that the sequence of climatic changes during the Pleistocene results from the two not simultaneous rhythms of changes of temperature and of humidity conditions. The dominant influence on the course of events is undoubtedly exerted by the thermal changes, which are accented most clearly. Though, their influence is essentially modified by the arrangement of humidity conditions — as shown by the analysed material.

The discordance between the course of rhythm of these two kinds of waves of climatic changes results in different character of particular periods — cold as well as warm ones. The cold periods GII and GIII are characterised by particularly oceanic climate. They are rich in precipitation and thanks to it they show more numerous (5 - 6) and much better developed glacistadials marked by distant advances of ice sheets. The cold periods GI and GIV are characterized by more continental climatic conditions. They show poorer precipitation, and each of them has only 1 - 2 glacial stadials. The ice sheet of these stadials were of minor extents. The J II/III is also of more continental type, while J I/II and J III/IV show more humid climatic conditions.

The durations of the cold periods (not only glaciations) and of the warm ones are nearly the same (except the obviously shorter period GIV — ca 60 000 years), and they are an average 100 - 120 thousand years. So, the full cycle of main thermal fluctuation is ca 200 - 220 thousand years. Main cycle of humidity changes is of longer duration, and it reaches ca 300 thousand years.

On the background of these main waves of climatic fluctuations (of the 1-st order of magnitude) the stadial waves (of the 2-nd order) run. The latter ones last an average 20 - 25 thousand years. Apart from their own rhythm of changes they differ from one another depending on the way of interference of the waves of higher order. The waves of changes of the 3-rd order, i.e. phases, are even more differentiated in their course, because they depend on the climatic background created by the above quoted larger cycles of changes.

Cold period lasted in several cases (GI and GIV) much longer than glaciations themselves which appeared only in some parts of duration of these periods. In the regions of far extents of ice sheets (Central and East Europe, North America) and in regions of piedmot glaciers (foreland of the Alps) one gets impression that the periods separating glaciations are longer than glaciations themselves (i.e. duration of ice cover). This impression is correct because the ice covered these areas only during the climax glacistadials.

Among other observations dealing with more detailed problems it is worthy to note that a period of intensive development of eolian corrosion processes and loess accumulation, connected one with another, may fall to the same waves of cool stadials which the advances of ice sheets are connected with. They are however connected with the earlier parts of these stadials, characterised by more arid conditions (cool and dry). The development of ice sheets takes place later, when the thermic conditions are like those prevailing before, but there is a strong increase of polar--marine influence (cool and more humid) bringing the growth of precipitations.

The analysis of the history of the Polish rivers shows that at the beginning of every interval between ice sheet development (periodical and stadial) new deep valleys are cut down or older valleys are unburried. After the climatic optimum, in the anaglacial parts of interglacials, the accumulation takes place which brings the nearly full filling up of these formerly cut valleys. It must be noticed, however, that these observations deal with rivers flowing northwards and having their drainage areas or at least their lower courses covered by ice sheets. They are periodically separated from the direct influences of Pleistocene changes of the world ocean level what the course of the history of rivers on unglaciated areas depended on.

The materials allow to make further analysis of several other problems, among others the changes of the type of water balance, which are not considered in this paper. These problems and several other ones demand yet much more detail works and analysis of results of researches in other countries, not quoted here. They are left as a subject of another paper. The idea of this paper is to preseent results obtained from detail works made by means of coordinated methods on the large territory.

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GEOGRAPHIA POLONICA 17, 1969

SUR LES MOUVEMENTS NÉOTECTONIQUES EN POLOGNE

Edward Rühle

INTRODUCTION

Sur la base des recherches géologiques menées aussi bien en Pologne, que sur d'autres territoires on a constaté l'existence des mouvements tectoniques récents. La période au cours de laquelle on observe la disparition, dans le Sud de la Pologne, des mouvements à plissements de l'orogène alpin, revêt une grande importance pour les études sur les mouvements tectoniques récents dits — néotectoniques. Parallèlement aux mouvements des Carpates, il se forme dans leur avant-mur, une avant-fosse, dont la structure définitive se constitue à la fin du Tortonien et au début du Sarmatien. Depuis cette période, les mouvements, dits néotectoniques ont été enregistrés. Ils ne reflètent au début, que la phase finale de l'orogenèse alpine, mais plus tard, déjà au Pleistocène, apparaît un nouveau facteur (ayant une grande influence sur les mouvements de l'écorce terrestre), c'est à dire les mouvements glaciisostatiques liés aux glaciations continentales qui se répètent à plusieurs reprises. Les mouvements glaciisostatiques avaient un caractère rythmique lié aux périodes glaciaires et interglaciaires, ainsi que différaient nettement de la tectonique profonde de l'écorce terrestre. Les changements qui se sont produits en Pologne par suite des forces endogènes, depuis la fin du Tortonien jusqu'à présent, constituent le résultat des mouvements tectoniques et glaciisostatiques, ainsi que celui des phénomènes locaux liés à la tectonique salinaire et a la glacitectonique.

Bien qu'au cours des dizaines d'années écoulées on ait recueilli un matériel assez riche étant une base à la connaissance des mouvements néotectoniques, aucune oeuvre synthétique moderne à ce sujet n'a paru jusqu'à présent en Pologne. L'importance de la néotectonique, en ce qui concerne la connaissance de la structure géologique des différents pays, a augmenté considérablement ces derniers temps.

L'auteur de la présente communication va faire une analyse des matériaux permettant de dresser la première carte néotectonique de la

Pologne. Ce travail a été entrepris par l'auteur en 1964 à la suite de l'initiative du Prof. N. I. Nikolaiev — président de la Commission Néotectonique de l'INQUA et rédacteur de la Carte Néotectonique de l'Europe.

I. HISTOIRE DES ETUDES

On trouve les premières conclusions relatives à la néotectonique dans les oeuvres monographiques de E. Romer [13] et Ludomir Sawicki [19, 20] qui sur la base de la forme de la surface des Carpates, de la Podolie et de la brèche des rivières traversant le Massif de S^{te} Croix et le Pays des Lacs en particulier, expliquent plusieurs faits et phénomènes à l'aide des mouvements tectoniques récents. Ludomir Sawicki trouve entre autres, que la formation de la brèche de la Vistule, à proximité de la ville de Kazimierz, avait été occasionnée par des mouvements orogéniques qui ont eu lieu au Pleistocène.

Entre les années 1918 et 1927, le problème concernant les soi-disant mouvements épeirogéniques a soulevé une discussion énergique parmi les géologues et les géographes. Une opinion sceptique sur le problème de l'existence au Quaternaire des mouvements épeirogéniques a été exprimée par J. Lewiński et J. Samsonowicz [7]. Ceux-ci se sont énergiquement opposés contre les conceptions basées seulement sur les phénomènes morphologiques. De telles conceptions résultent, selon ces auteurs, d'une connaissance insuffisante du substratum quaternaire, d'autant plus que les problèmes concernant les mouvements tectoniques sont compliqués et difficiles à resoudre, lorsqu'on les base uniquement sur les données morphologiques. Par contre, A. Zierhoffer [24] et S. Lencewicz [6] liaient les nombreux éléments de la structure du profil tertiaire et quaternaire aux mouvements néotectoniques récents. Ils insistaient tout d'abord sur la présence des jeunes mouvements néotectoniques dans les endroits de brèches de nos fleuves, de la Vistule près de Varsovie, à l'Est de la ville de Płock, et à proximité de la ville de Toruń en particulier. Entre ces régions ayant des tendences à s'élever, S. Lencewicz indique aussi d'autres secteurs accentués par des mouvements tectoniques récents. Il observe l'utilisation des anciennes directions tectoniques par des formes nouvelles dans, entre autres, l'arête du „Plateau" de Łódź, la forêt de Kurpie, ainsi que dans les directions de nos cours d'eau, coulant du NNW au SSE.

Il est à remarquer que de nombreux faits considérés entre les années 1920 et 1939 comme étroitement liés à la néotectonique, constituent des phénomènes glacitectoniques.

B. Halicki et T. Olczak [1] ont entrepris, dans leur dissertation intéressante, le premier essai d'interprétation de la structure du Quaternaire en relation avec la répartition des anomalies gravimétriques sur la Basse-Plaine de l'Europe centrale. Ces auteurs supposent qu'un affaissement avait eu lieu sur les terrains de déficit de la pesanteur, tandis que sur les terrains se caractérisant par une pesanteur trop forte, une élévation du territoire avait été observée.

La dépendance mutuelle du champ de gravitation et de l'extension des glaciations ou de leurs stades atteste un rapport étroit entre le processus de la déformation de l'écorce terrestre sous le poid du glacier continental avançant et le champ de gravitation apparaissant en surface.

Les affleurements de terrains néogènes et quaternaires sur les rives de la Vistule, entre la ville de Dobrzyń et celle de Włocławek nous fournissent d'intéressants exemples quant aux mouvements néotectoniques et glacitectoniques. On y trouve des terrains miocènes et pliocènes, dont le sommet est recouvert de dépôts quaternaires qui y reposent en discordance. Ce problème a été étudié par J. Lewiński [8] et par J. Łyczewska [10, 11]. J. Lewiński a lié les phénomènes de plissements néogènes au mouvement qui a soulevé l'anticlinorium de la Cuyavie et à celui de glissements des terrains tertiaires vers le Nord-Est. D'après J. Łyczewska les phénomènes néotectoniques se faisant voir sur une superficie importante dans la vallée de la Vistule sont liés à une zone tectonique particulièrement active au Pleistocène inférieur, avant la glaciation de la Pologne centrale.

On observe des phénomènes néotectoniques sur la base des changements du bord de la Mer Baltique. sur son secteur compris dans les frontières de la Pologne. Les recherches géologiques détaillées du matériel provenant du forage Jurata sur la péninsule de Hel ont montré, d'après J. Samsonowicz [17] et R. Sandergren [18], la présence d'une série de terrains du Quaternaire supérieur.

Le problème concernant les mouvements de cette partie de la Mer Baltique a été présenté dans les publications de Z. Kotański [4], B. Rosa [14] et d'autres qui admettent que dans la période du Lac à Ancylus se sont produits des mouvements d'effondrements par suite desquels, s'est formée la dépression de Gdańsk. Les territoires voisins, eux aussi, se sont affaissés. grâce à quoi l'extension de la Mer à Littorines s'est élargie. Il est évident, qu'après la période de la Mer à Littorines, le continent a subi les mouvements isostatiques qui ont soulevé la plate-forme d'abrasion de la Mer à Littorines de 25 m par rapport à sa situation primaire.

Les Carpates constitutent une région particulièrement intéressante pour les études néotectoniques.

Les mouvements disparaissants de l'orogène alpin sont bien connus; ils avaient été observés encore au Sarmatien. Les données se rapportant aux mouvements de la période quaternaire sont beaucoup moins nombreuses. C'est Ludomir Sawicki qui le premier, en 1909 [19], a prête son attention à l'existance des mouvements néotectoniques dans les Carpates. W. Łoziński en 1922, touche dans sa publication, le problème du développement des rivieres des Carpates flischeuses. Les résultats beaucoup plus complets des recherches néotectoniques, basées sur les études morphologiques et géologiques ont été présentés par B. Świderski. Celui-ci constate dans les Carpates, au Pliocène et au début du Pleistocène, des mouvements à grands rayons, ce qui est attesté par le caractère différent de la dénudation et de l'érosion, en particulier sur les secteurs des vallées fluviales carpatiques.

Il est à remarquer que la Pologne constitue un territoire sur lequel les phénomènes séismiques — tremblements de terre — sont particulièrement rares et faibles. Ainsi cet élément de l'analyse des processus néotectoniques présente un intérêt peu important dans notre pays.

En ce qui concerne l'histoire des tremblements de terre en Pologne, c'est E. Janczewski [2] qui a décrit et analysé les tremblements souterrains à une intensité du IV degré de l'échelle de Marcalli-Sieberg. Ils ont englobé certaines parties des Monts de S^{te} Croix, la région de Lublin, la Podlasie et la partie-nord de la Masovie.

Les fissures de direction NW-SE se sont formées sur une superficie de quelques kilomètres. Les tremblements souterrains se sont répetés à plusieurs reprises. La répartition des terrains subis aux tremblements, ainsi que l'étendue de ces phénomènes montrent, que ces derniers ont été liés à la structure profonde des masses de l'écorce terrestre. J. Samsonowicz [16] trouve, quant aux Monts de S^{te} Croix, que les tremblements en question attestent l'animation des anciennes lignes de failles.

Les mesurages exacts des mouvements néotectoniques faits au cours des dix dernières années au moyen des méthodes géodésiques, nous permettent d'établir un point de vue justifié en ce qui concerne l'amplitude de ces mouvements.

Le premier essai dans ce domaine, pour le territoire de la Pologne centrale, a été fait par S. Pawłowski en 1955 [12]; il a établi la différence des résultats des mésurages entre les années 1870 et 1930. Cet auteur tire la conclusion, que les changements d'altitude relative positive tombent sur l'anticlinorium de la Poméranie et de la Cuyavie, alors que les ailes de celui-ci se caractérisent par un affaissement relatif. L'axe de l'affaissement se trouve dans le Sud, dans les environs de Poznań, tandis que dans le Nord, il s'étand du NW au SE. Il se dessine dans les environs de Gdańsk et d'Ilawa, une autre région des changements d'altitudes relatives, positives. S. Pawłowski observe des phénomènes néotectoniques dans plusieurs éléments de la structure, tout d'abord dans les endroits, où l'épaisseur de la couverture quaternaire n'est pas importante ainsi que sur les dômes salifères, c'est à dire là, où il existe des possibilités de mouvements élevants. Les mouvements néotectonique observés dans la Pologne centrale représentent 1 mm par an. Les pareils résultats ont été enregistrés par suite des études faites par T. Wyrzykowski et K. Schoeneich [22].

En 1959 T. Wyrzykowski a publié un communiqué préliminaire au sujet des renseignements sur les mouvements verticaux contemporains de la Pologne, obtenus grâce à l'application de la méthode de nivellement de précision. Cet auteur en ayant comparé les résultats des mesures qu'il a faites entre les années 1952 et 1955, a tiré la conclusion, qu'il existe des mouvements absolument petits de l'écorce terrestre aux valeurs négatives, égales à —0,5 mm/an et aux valeurs positives de +2 mm/an. Les plus grandes différences d'altitude de plusieurs points ont été constatées ces derniers temps aux environs de la ville de Lublin et dans les régions est de la Pologne. Dans la région des Carpates, ainsi qu'en Poméranie, entre la ville de Grudziądz et celle de Tczew on peut observer de faibles mouvements d'affaissement qui atteignent 0,5 mm/an.

Les autres considérations au sujet des mouvements contemporains en Poméranie de l'Ouest ont été présentées par K. Schoeneich [22].

Un bref aperçu historique sur les études et les observations concernant la néotectonique de la Pologne nous a fourni des résultats intéressants. Ces observations constituent une base pour le développement des nouvelles opinions concernant les problèmes de la néotectonique et fournissent des matériaux fondamentaux pour l'élaboration de la carte néotectonique générale de la Pologne.

II. METHODES D'ELABORATION DE LA CARTE NEOTECTONIQUE DE LA POLOGNE

La carte néotectonique de Pologne au 1 000 000e constitue le résultat d'une analyse des éléments particuliers rendus sur cinq esquisses ci-jointes (Fig. 1 - 5). Celles-ci présentent les principales unités tectoniques, la répartition et la puissance des sédiments néogènes et quaternaires, leurs relations avec les mouvements néotectoniques qui de leur part constituent le résultat des études sur la carte du relief du Miocène supérieur, du Pliocène et du Quaternaire, sur celle de l'épaisseur du Miocène supérieur du Pliocène et du Quaternaire, ainsi que sur les cartes lithologiques et de faciès qui illustrent en premier lieu les directions de l'éculement des vallées fluviales, l'inclinaison des terrasses fluviales et les changements de la ligne du bord de mers et de bassins épicontinentaux.

Les résultats des études magnétiques et gravimétriques, analysés d'une façon critique et rendus sur la carte, ainsi que les mesurages géodésiques de précision constituent un élément complémentaire important des matériaux susmentionnés.

Les principales unités tectoniques de la Pologne indiquées sur la Carte Tectonique de l'Europe au 2 500 000e constituent un élément fondamental qui a servi de base à l'établissement de la carte néotectonique de Pologne. La majeure partie du territoire de la Pologne se trouve à l'extrémité occidentale d'une grande unité tectonique, c'est à dire de la plate-forme de l'Europe de l'Est (Fig. 1). La partie sud-est de la Pologne

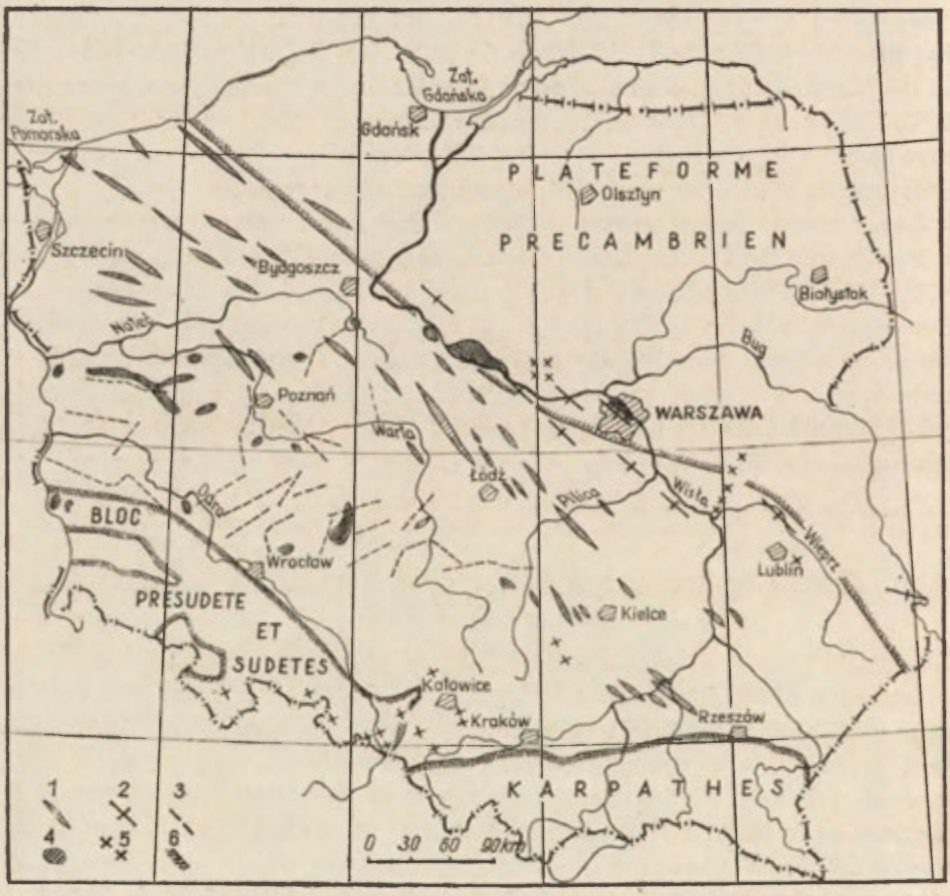

Fig. 1. Unités et éléments tectoniques et néotectoniques de la Pologne

1 — structures anticlinales plus importantes dans la couverture du Zechstein et du Mésozoïque ainsi que dôme salifères, 2 — dislocations néogènes, éopleistocènes et mésopleistocènes probables, 3 — cavités constatées et probables liées aux mouvements néotectoniques, 4 — terrains néogènes à plissement, 5 — endroits de tremblements de terre, 6 — anticlinorium silésien — principales unités tectoniques de la Pologne (d'après S. Sokołowski et J. Znosko)

est comprise dans l'orogène hercynien auquel appartiennent actuellement l'anticlinorium silésien et celui de S^{te} Croix. L'orogène hercynien repose en sa plus grande partie sous la couverture mésozoïque de plate-forme qui avait été localement plissée au cours des mouvements laramiques. Les terrains cénozoïques situés au-dessus des terrains mésozoïques recouvrent le relief de la structure ancienne sur presque tout le territoire de la Pologne du Nord (80$^0/_0$ du superficie). Le Quaternaire, le Miocène et le Pliocène continental et d'eau douce apparaissent dans la grande partie du territoire de la Pologne centrale et septentrionale sous forme de sables mélangés avec de la lignite et des argiles.

A l'extrémité sud de la Pologne, on observe un autre élément de la structure géologique appartenant à l'orogne alpin, qui s'était soulevé au Cretacé supérieur et au Tertiaire et avait plissé les dépôts du Cretacé supérieur et du Paléogène. Au Miocène, les mouvements liés aux nappes commencent à disparaître, tandis qu'à la fin du Tortonien et au Sarmatien on enregistre la formation de l'avant-fosse carpatique qui se remplit progressivement de dépôts sarmatiens horizontaux (Fig. 2). Au Tortonien et au Sarmatien le territoire de la Pologne centrale et septentrionale constitue un contient commun avec la Scandinavie.

Depuis la fin du Miocène et durant le Pliocène entier, le territoire de la Pologne subissait certaines modifications à la suite des mouvements tectoniques et glaciisostatiques (sur les territoire de l'anticlinorium de la Cuyavie et de la Poméranie on observe des mouvements de la tectonique salinaire) ainsi que par endroits par suite des phénomènes de type glacitectonique.

Il est beaucoup plus difficile d'évaluer la force des mouvements néotectoniques sur le territoire de la Basse-Plaine de Pologne, entre les unités susmentionnées de la Pologne méridionale et centrale et la plate-forme baltique et celle de l'Europe de l'Est.

Les résultats des études paléogéographiques attestent qu'il existait, au Pliocène sur la Basse-Plaine de Pologne, un bassin d'eau douce, dans lequel se groupaient les eaux venant des rivières de toutes les régions avoisinantes (Fig. 4 et 5).

Dans la période interglaciaire la plus ancienne, c'est à dire dans celle de Tegelen le fond du bassin s'est élevé et les eaux commencèrent à couler vers l'Ouest, c'est à dire vers l'embouchure actuelle du Rhin. Parallèlement, les mouvements élevants qui se sont accentués sur l'antéclise de la Mazurie et dans la partie-sud de l'élévation de Łeba, ont pour la première fois jalonné la dépression de la Baltique méridionale actuelle.

Sur la carte ci-jointe (Fig. 1) on a essayé d'indiquer — au moyen des isolignes — les mouvements qui avaient eu probablement lieu sur

Fig. 2. Épaisseur des dépôts marins et continentaux du Miocène supérieur (Sarmatien), du Pliocène et du Quaternaire en Pologne

1 — sédiments plus anciens que ceux du Miocène supérieur, situés en surface, 2 — épaisseur des sédiments marins et continentaux du Miocène supérieur, du Pliocène et du Quaternaire indiquée au moyen d'isolignes à une valeur inférieure à 25 m, 100 m, 200 m et supérieure à 250 m

le territoire de la plate-forme de l'Europe de l'Est, ainsi que sur celui de l'avant-fosse carpatique.

Le territoire de la plate-forme de l'Europe de l'Est nous fait preuve, que dans la Pologne de l'Est on a enregistré les mouvements plus forts, que ceux qui ont été observés dans la Pologne de l'Ouest. Les mouvements élevants les plus forts, de plus de 100 m, s'accentuent sur l'antéclise du Pays des Lacs de la Mazurie et sur celle de la Biélorussie.

Dans la partie sud-est de la Pologne, au Sud de la région de Lublin et au Roztocze, les mouvements élevants de plus de 100 m, s'étaient

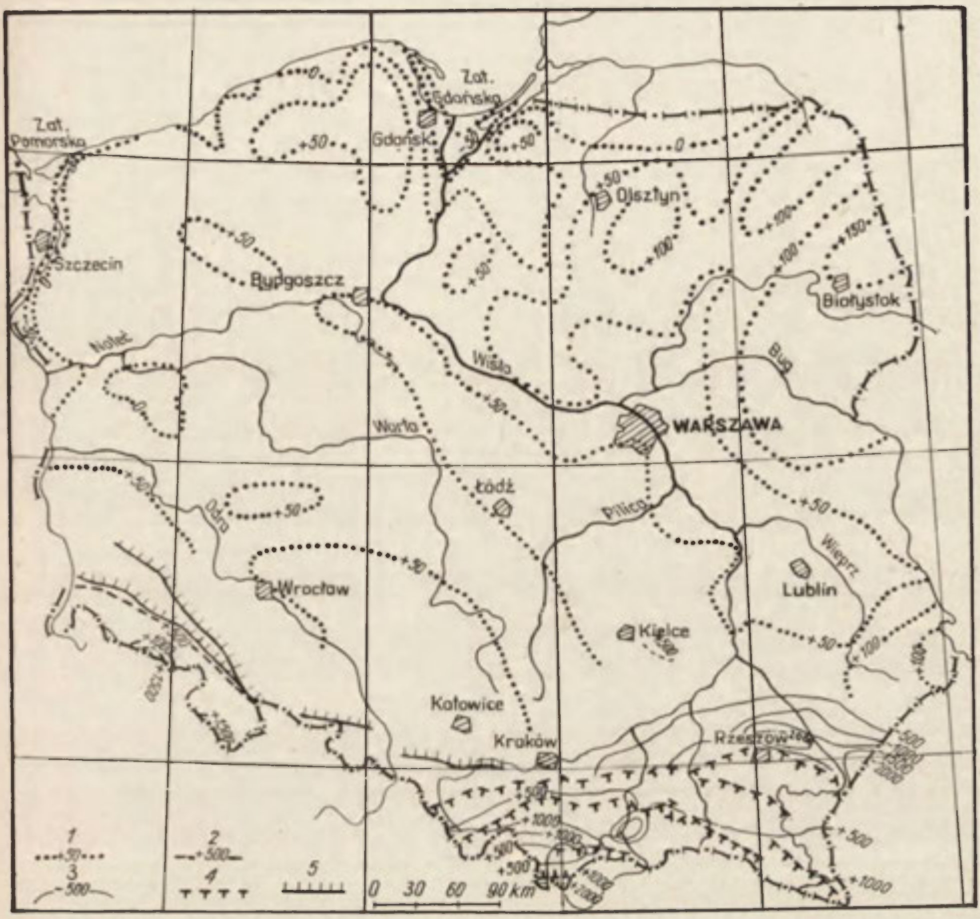

Fig. 3. Isoamplitudes des mouvements néotectoniques en Pologne

1 — isoamplitudes indiquées tous les 50 m sur le terrain de la couverture de plate-forme du Zechstein et du Mésozoïque sur la Basse-Plaine de Pologne, 2 — isoamplitudes indiquées tous les 500 m sur le terrain de l'orogène hercynien des Montagnes de S Croix et des Sudètes, 3 — isoamplitudes indiquées tous les 500 m sur le terrain de l'orogène alpin des Carpates et de l'avant-fosse carpatique, 4 — principaux charriages carpatiques, 5 — principales failles sur le terrain de l'anticlinorium silésien

produits au Quaternaire supérieur. Cela se reflète dans la morphologie des vallées fluviales et dans la nature de leurs sédiments. Les mouvements en question ne sont l'objet d'aucune relation avec la tectonique profonde.

La grande unité tectonique telle que l'effondrement marginal s'étendant sur l'extrémité sud-ouest de la plate-forme de l'Europe de l'Est, ne subit pas de mouvements élevants importants. La vallée de la Vistule moyenne et partiellement inférieure longe actuellement cette grande unité tectonique.

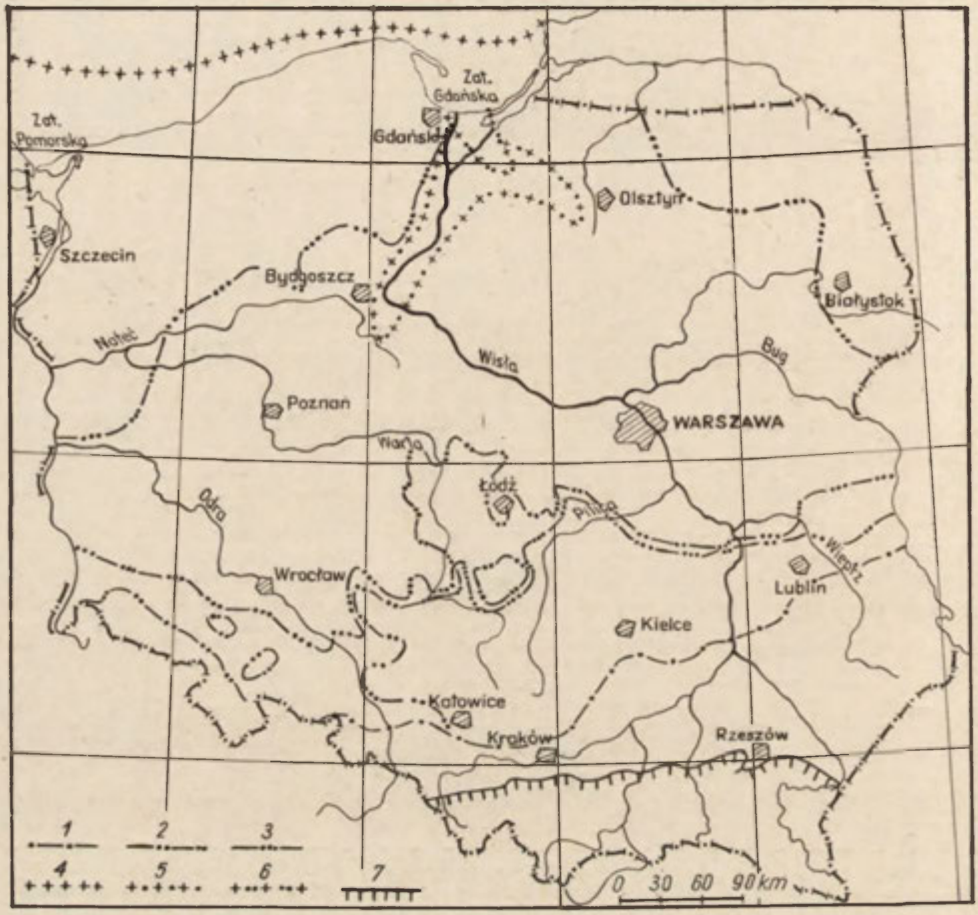

Fig. 4. Changemments de lignes cotières des mers et des bassins épicontinentaux en Pologne produits par suite des mouvements néotectoniques

1 — limite de l'extension de la transgression de la mer sarmatienne, 2 — limite sud de l'extension des sédiments continentaux, 3 — limite de l'extension du lac pliocène, 4 — limite de l'extension de la transgression marine à l'interglaciaire de la Masovie (Holstein), 5 — limite de l'extension de la transgression marine à l'interglaciaire éemien, 6 — limite de l'extension de la transgression marine au cours de la période de la Mer à Littorines, 7 — limite du charriage des Carpates

Entre l'élévation de Łeba et l'antéclise de la Mazurie on distingue la synéclise baltique, dans laquelle ont eu lieu des transgressions marines se répétant à plusieurs reprises. Les dépôts de cette synéclise ont été examinés minutieusement sur la basse Vistule, à son embouchure et aux bords de la Mer Baltique. Des mouvements d'affaissement à une amplitude de 100 m, se sont produits dans ces endroits.

La Pologne centrale se caractérise par une plus grande stabilité que

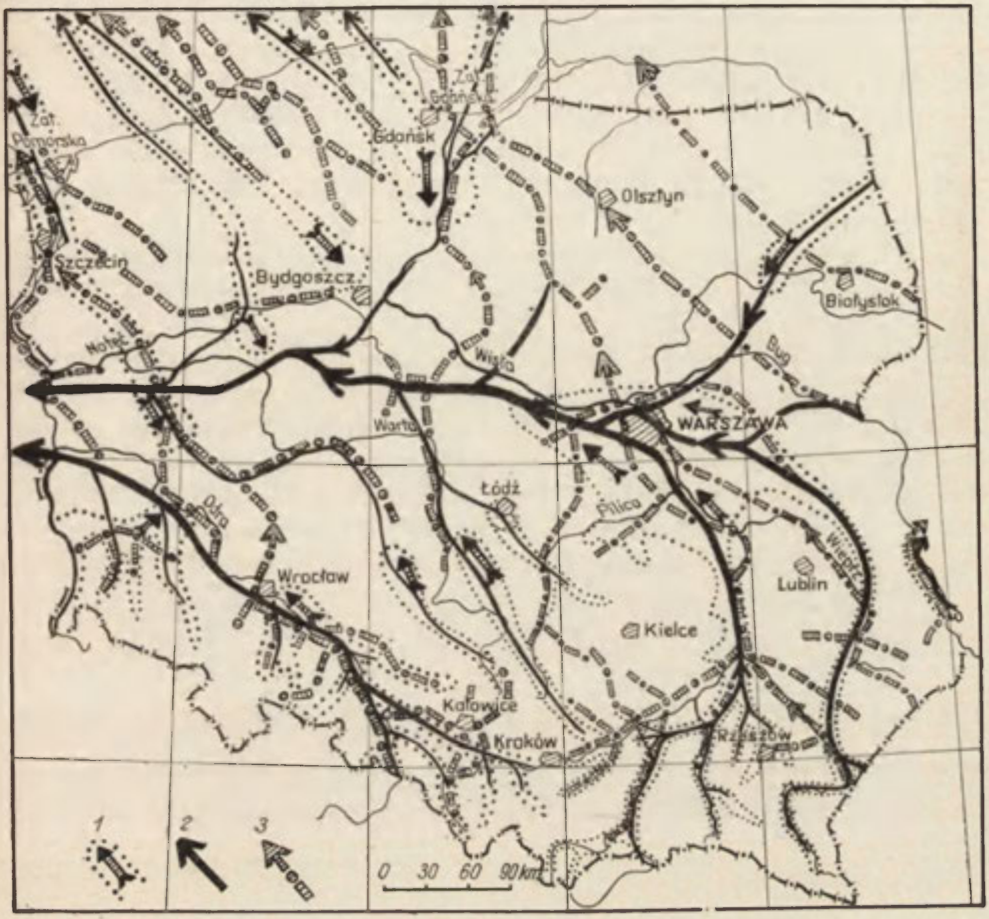

Fig. 5. Changements hydrographiques liés aux mouvements néotectoniques en Pologne

1 — terrain d'accumulation fluviale et direction des fleuves au Pliocène, 2 — fleuves et leurs directions à l'interglaciaire de Tegelen, 3 — fleuves et leurs directions à l'interglaciaire de Cromer

celle que l'on observe dans la Pologne de l'Est. De faibles mouvements d'affaissement s'accentuent dans la partie sud et ouest de la cuvette de Miechów, de Mogilno et de Łódź, ainsi que celle de Szczecin, traversées par la vallée de la Warte et de ses affluents.

Les mouvements néotectoniques observés sur le territoire des anciens orogènes calédonien et hercynien représentés par les Monts de S^{te} Croix élevés de 500 m dans la phase finale du Néogène et au Quaternaire, s'accentuent plus nettement.

Une plus grande amplitude de mouvements néotectoniques a été enregistrée dans l'avant-fosse carpatique, dont le fond s'est affaissé d'environ

2000 m. Cela a été prouvé par les résultats des études récentes menées au Nord-Est de la ville de Przemyśl, c'est à dire dans la région, dans laquelle les sédiments du Tortonien supérieur et du Sarmatien ont une puissance importante (Fig. 3). Comme il résulte de l'examen des niveaux pleistocènes d'arasements érosifs, élevés de 2000 m environ dans les Tatra, les mouvements provoquant l'élévation des Carpates avaient eu lieu en même temps.

Pour terminer le sujet concernant les mouvements néotectoniques, il est à remarquer que la Pologne est un territoire, où les phénomènes séismiques contemporains sont extrêmement rares et faibles.

Par suite d'une analyse des nombreux éléments rendus sur les figures 1 - 5, on a établi la maquette de la Carte Néotectonique de Pologne au 1 000 000e qui illustre les mouvements de la surface, divisée en terrains de plate-forme, terrains géosynclinaux et ceux de la zone alpine indiqués sur la carte au moyen des isolignes.

Par ailleurs, on a jalonné la limite des terrains géostructuraux suivants:

1. les structures anticlinales plus importantes dans la couverture du Zechstein et du Mésozoïque, ainsi que les dômes salifères,
2. les dislocations néogènes éopleistocènes et mésopleistocènes probables.
3. les axes constatés et probables des civités liées aux mouvements néotectoniques,
4. les terrains néogènes à plissement,
5. les endroits de tremblements de terre.

La communication en question a fait savoir aux participants au présent symposium, conformément à son but, l'état d'avancement des travaux sur la la Carte Néotectonique de la Pologne, faisant partie de la Carte Néotectonique de l'Europe au 2 500 000e.

Les esquisses des éléments particuliers que l'on a présentées ici et qui illustrent d'une manière indirecte les problèmes de la néotectonique de la Pologne, constituent la base de l'Atlas Néotectonique de l'Europe au 10 000 000e qui paraîtra dans l'avenir.

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GEOGRAPHIA POLONICA 17, 1969

STRATIGRAPHY OF SEDIMENTS AND PALAEOMORPHOLOGY OF THE MARGINAL ZONE OF THE WARTA STADIAL

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INTRODUCTION

The Mazowsze-Podlasie (Warta) stadial, distinguished by Woldstedt [43] as stratigraphic unit of the Quaternary changed many times its situation. It was successively defined as a recession phase of the Middle Polish Glaciation, as a separate glaciation, and even as a stadial of the North Polish Glaciation. The finally prevailing opinion determined it as the second stadial of the recession period of the Middle Polish Glaciation. This point of view was supported by numerous materials collected by the Geological Institute as a result of geological mapping and stratigraphical, palaeomorphological and petrographical investigations. These investigations concern a few sections of the marginal zone of the Warta stadial and enable to generalize these problems, in spite of the fact that in the range of the stadial there are up to now no sites of organic sediments, which would permit to determine by palaeobotanic methods the characteristics of the climate and the stratigraphical rank of the interstadial, preceding the Warta stadial. The interpretation of cross-sections through the marginal zone of the Warta stadial may lead to discussions on the classification to that interstadial of some sites of organic sediments, e.g. Łódź, Wylezin. The extent of the Warta stadial is shown in Fig. 1.

From a geomorphological standpoint, the zonality of forms and sediments connected with the Warta stadial is of interest. In a section crossing the range of the ice-sheet, the following zones may be distinguished: 1) block desintegration of the ice-sheet, of which the characteristic forms are kames, 2) fissural cracking of the ice-sheet, with prevailing forms of eskers and channels, 3) glacier front — end-moraines, 4) ice-sheet forefield — outwash plains and 5) peripheral fluvial terraces.

The investigations of some authors confirm the earlier already observed multiphase stagnation of the Warta stadial ice-sheet [22] presented

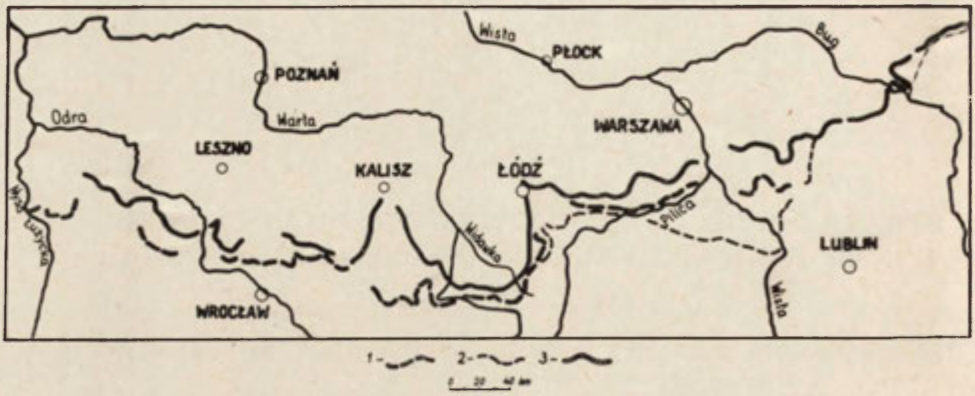

Fig. 1. The range of the ice-sheet of the Warta stadial in Poland

1 — range of the ice-sheet delimited on the basis of end moraines and other marginal forms as well as of thrusts and initial sites of outwash plains, 2 — range of boulder clays classified to the Warta stadial and supposed range of the ice-sheet in basins of larger rivers, 3 — course of inner distinct moraine courses

more extensively by S. Z. Różycki [24]. That is why in the map attached to this paper not only the main runs of the end-moraines is traced, along which the range of the Warta stadial is marked [21, 22, 44] but also its earlier stagnation phases, in the first place phase I, delimiting the maximal range of the Warta stadial ice-sheet. The stratigraphical position of the Warta stadial in the Middle Polish Glaciation has been discussed by S. Z. Różycki [27].

STRATIGRAPHY OF THE QUATERNARY OF THE WARTA STADIAL MARGINAL ZONE AGAINST THE BACKGROUND OF ITS SUBSTRATUM

The development of Quaternary sediments, the paleomorphologic development in particular glacials and interglacials, as well as the formation of the present surface are related in a marked degree to the outcrops of Mesozoic rocks. The effect of the Triassic outcrops is particularly distinct, as well as that of the Jurassic and Cretaceous rocks on the range of the Warta stadial ice-sheet. These outcrops are very numerous in the forefield of the Warta stadial end-moraines, whereas on the inner side of these moraine the Mesozoic outcrops occur only sporadically. This dependence is most easily recognized in the Widawka lobe, and in its forefield, where exist the richest geological materials. It is mainly on that example that the stratigraphy of the Quaternary and its substratum has been presented (Fig. 2, 3).

The most generally met Mesozoic rocks are limestones and marls of

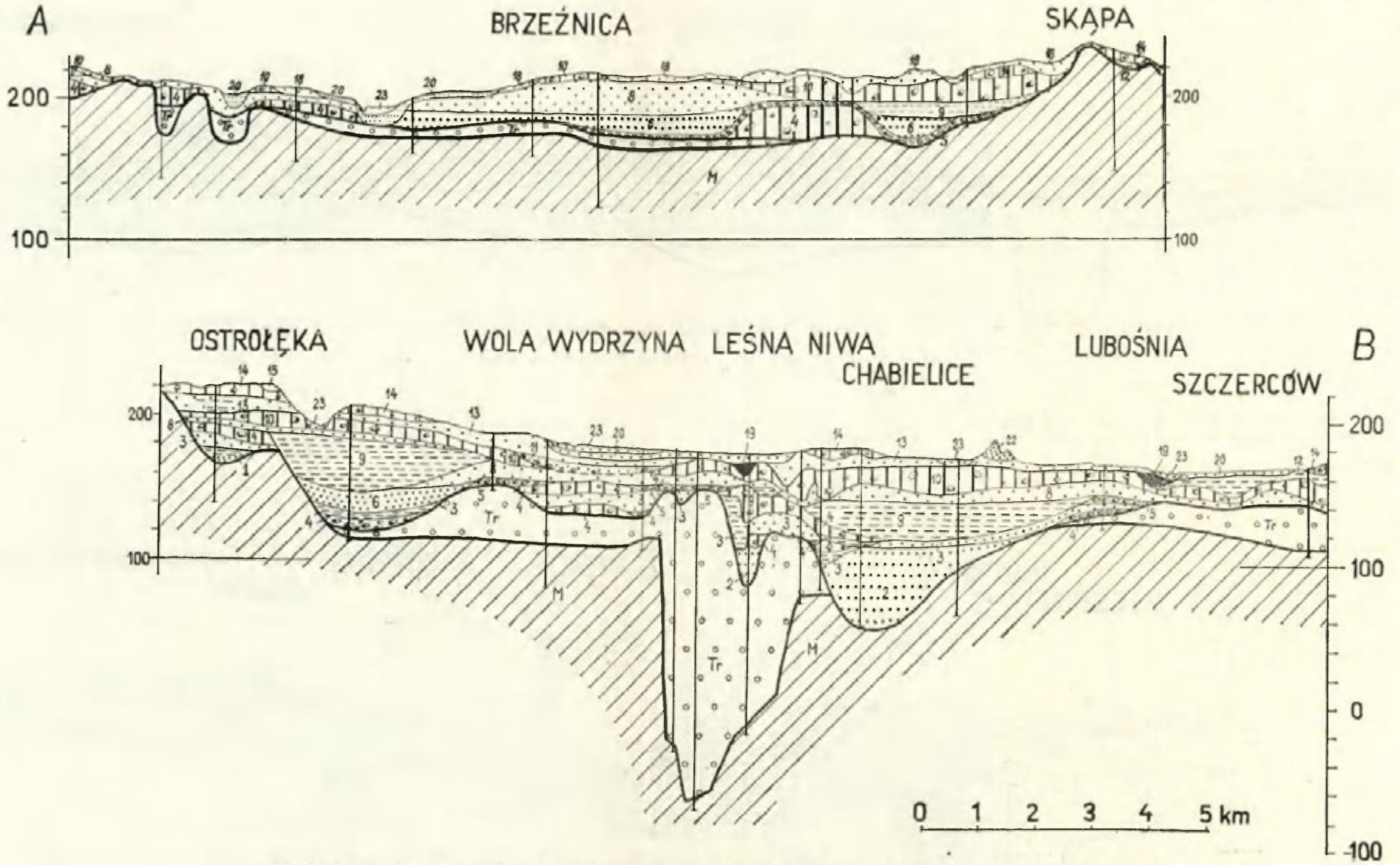

Fig. 2. Geological cross-section Brzeźnica—Szczerców (A-B) (Elaborated by Z. Sarnacka and S. Skompski)

M — Mesozoic, Tr — Tertiary, numerals as given in Table 1

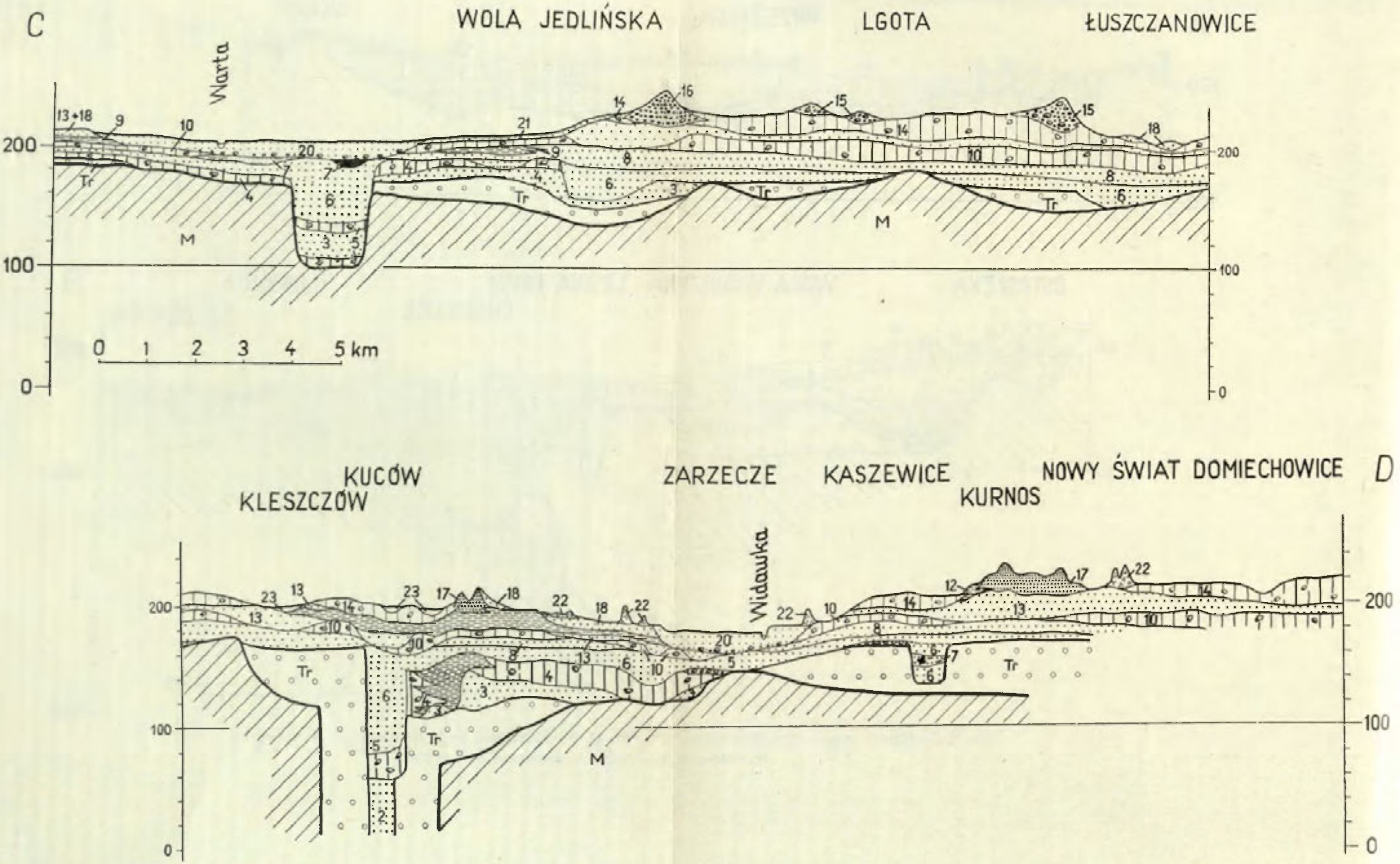

Fig. 3. Geological cross-section Wola Jedlińska—Domiechowice (C - D) (Elaborated by M. D. Baraniecka)

M — Mesozoic, Tr — Tertiary, numerals as given in Table 1 the upper Jurassic (Oxfordian, Kimmeridgian), sands and sandstones of the Albian, as well as sandstones, limestones, marls and bedrocks of the Upper Cretaceous („opoka") Upper Jurassics limestones, locally silicified form the positive elements of the relief. The planation surfaces developed on the Upper Cretaceous sediments. The least resistant Albian sediment became eroded, and along its outcrops valleys developed on the Tertiary.

The erosion preceding Upper Miocene lignite accumulation could be established some scores of kilometers north of the Warta stadial range, in the Turek region [4 - 7].

Besides erosion and denudation, a strong effect on the surface formation in the Tertiary was exerted by karst and tectonic processes, of which the influence is still visible in the present grid system of valleys with SW - NE and SE - NW directions. The most important tectonic element is the 400 m deep tectonic Kleszczów graben, ca. 45 km long and ca. 2 km wide. The varied Mesozoic relief was mainly levelled by Tertiary sediments, developed as sands, silts, clays, weathering clays, debris and lignites, of total thickness of often hardly more than a few meters, and reaching in the Kleszczów graben 430 m [Fig. 2, 3].

Jurassic, Cretaceous or Tertiary sediments are overlain by Quaternary sediments. The thickness of the Quarternary sediments in the marginal zone of the Warta stadial is strongly reduced, with the exception of depressions, in which the sediment profile of the Quaternary is the fullest, and the thickness exceptionally important, i.e. in the Kleszczów graben it reaches 318 m. The genesis of these depressions may be of threefold character: structural-erosional, karstic or tectonic.

It was erosion that exerted the strongest effect on the development of the surface. The valleys thus formed reflected in a high degree the course of the Palaeogene valleys, of which the framework depended on the Mesozoic structures. An example of interglacial valleys: Cromerian and Mazovian in the marginal zone of the Warta stadial or in its vicinity may be the valleys of the Garwolin region [9, 33], of the Pilica [25, 28, 30], of the Białobrzegi region [3, 31], of the Góra Kalwaria region [37], of Mielnik on Bug [35] and others.

Karst phenomena exerted also a not negligible effect on the relief of the Quaternary. Karst valleys filled with Quaternary sediments are known for instance from the Sulejów environs [28]. In some places, as e.g. in the vicinity of Działoszyn, karst hollows constitute 20 per cent of the total primary volume of the Upper Jurassic limestones [13]. A repetition of these ancient, mostly Palaeogene karst hollows are the renewed karst funnel, occurring on the surface of terraces connected with the recession of the Warta stadial [38].

Tectonic phenomena, comparatively little known up to now in the marginal zone of the Warta stadial have found their full documentation within the Widawka lobe and in its forefield.

All the above mentioned phenomena: erosion, karst and tectonics occur in the Widawka river basin. The cross-section samples taken from this region are a good illustration of the above discussed problems.

TABLE 1. Stratigraphical table of Quaternary sediments of the Widawka basin and adjacent areas (simplified)

Holocene			sands, muds and peats	23
Pleistocene	Baltic Glaciation		eolian sands	22
			periglacial dust and sands	21
	Eemian Interglacial		fluvial sands in the bottom with gravels and residual blocks	20
			gyttjas, peats and bituminal shales	19
	Middle Polish Glaciation	Warta stadial	fluvioglacial upper sands	18
			kame sands and silts	17
			esker sands and gravels	16
			sands, gravels and boulders of end moraines	15
			boulder clay	14
			lower fluvioglacial sands	13
			glacilacustrine silts and clays	12
		Pilica interstadial	fluvial sands with gravels and residual blocks (passing higher into fluvioglacial ones)	11
		Maximal stadial	boulder clays	10
			glacilacustrine silts, sands and clays	9
			fluvioglacial sands	8
	Masovian Interglacial (Great)		gyttjas and silty sands with plant detritus	7
			sands and sands with gravel admixture	6
			gravels and residual blocks	5
	South-Polish Glaciation		boulder clays locally in two stadial layers in some places in relict form	4
			glacilacustrine clays, silts and sands and fluvioglacial sands, locally in two stadial layers	3
	Cromer Interglacial		sands with flint and local rock breccia locally with peat intercalations (and fluvioglacial sands from transgression of the South-Polish Glaciation)	2
	Preglacial		sands, gravels and silts	1

We may distinguish here, among the Quaternary sediments (Table 1) preglacial sediments, four glacial horizons assigned to the South-Polish and Middle-Polish Glaciations, fluvial sediments of the Baltic Glaciation, fluvial and limnic sediments of three Interglacials and of the Holocene, of which the Eemian Interglacial was best studied from the palynological point of view [11], as well as from the faunistic one [16].

The preglacial formations of 13 m thickness occur in two sedimentary cycles, in shallow basins. Both cycles start within their lower part by sands with gravels and gravels. In their upper part, these formations gradually pass into silts. It may be supposed that both cycles correspond to the C and D horizons in the classification of J. Lewiński [14] from the Piotrków environments.

During the Interglacial (Cromer), deep valleys developed on tectonic bases as for instance the Grzymalina valley (Fig. 3) in the Widawka basin, filled up later with sands mixed with gravels and pebbles from local rocks as well as with clays and silts with lignite intercalations from the valley slopes. Within the interglacial series occur silts with plant detritus (Folwark) and peats (Aleksandrów). The tectonic as well as karst sinking of some parts of the valley during the interglacial elicited the accumulation of major thicknesses of the above mentioned sediments of the Cromer Interglacial, reaching sometimes 245 m [2].

TABLE 2. Correlation of major stratigraphical units (glaciations and interglacials)

Alpine scheme	Germany acc. to Woldstedt 1958		Middle Poland		U.S.S.R. acc. to K. K. Markov *et* al. 1964
Würm	Weichsel		North Polish (Baltic)		Valdai
Riss-Würm	Eemian		Eemian		Mikulińsk
Riss	Saale	Warta stadial	Middle Polish	Warta stadial (Podlasie-Masovian)	Moscow
		Ohe Interstadial		Pilica Interstadial	Odincov
		Drenthe stadial		Maximal stadial	Dniepr
Mindel-Riss	Holstein		Masovian (Great)		Lihvinsk
Mindel	Elster		South-Polish Cracow		Oka
Günz-Mindel	Cromer		Cromer		Preoka
Günz	?		—		?

The sediments of South-Polish Glaciation are best preserved in valleys, especially in the Grzymalina valley, where they attained the exceptional thickness — for this part of the Polish Lowland — of about 100 m. The sediments of two stadials may be distinguished here: the lower and the upper one, and in the upper stadial occur sediments of two phases, the older and the younger phase. In the stratigraphic profile may be established, starting from the bottom, the sediments developed at the time of the ice-sheet transgression of the lower stadial, which are a continuation of fluvial sediments of the Grzymalina interglacial series and present the passage from ice-dammed lake sediments to fluvioglacial ones, of a several scores meters thickness. These sediments are covered with bipartite boulder clay, of 10 to 20 m thickness, partly or locally washed out in the interstadial of South-Polish Glaciation. At the time of that interstadial the valleys were filled up with fluvial sands with gravels of about 20 m thickness. A further filling of valleys with fluvioglacial and ice-dammed lake sediments took place during the upper stadial, and consequently, the whole area was covered with boulder clay, of a thickness still exceeding locally 20 m.

At the beginning of the Masovian Interglacial, these boulder clays were strongly eroded. The accumulation of fluvial sand-gravel (at the utmost 82 m. thick, Fig. 3) occurred in two sedimentary cycles, of which each starts with sand-gravels, and ends with fine-grained sands or silts. In the top of fluvial sediments, lake sediments developed locally: sands, silts, gyttja and peats. Lacustrine sediments do not exceed 22 m.

The sediments of the Great Interglacial (Masovian), occurring in the forefield of the Warta stadial moraines have been well recognized from the geological point of view [26], as well as from the palaeobotanical one, e.g. at Olszewice [32, 40], at Barkowice Mokre [23, 25, 31, 34, 39], at Witaszyn [3], in the Lubartów, Włodawa [12, 18] and other regions.

During the Masovian Interglacial, tectonic dislocations took place, which affected the South-Polish and older glaciation sediments. The fault throw was estimated to about 50 m. [2].

The maximal stadial, the Pilica interstadial and the Warta stadial originated in the Middle Polish Glaciation (Fig. 2, 3). The transgressive sediments of the Middle-Polish Glaciation constitute ice-dammed lake sediments, of 30 m thickness, and fluvioglacial formations of about the same thickness. The ice-sheet of the maximal Middle-Polish Glaciation covered the whole area and the boulder clay of that age still constitutes the most general horizon of all boulder clays occurring in that area. Its unimportant, as a rule, thickness, reaches, however, locally some 22·0 m.

THE STRATIGRAPHIC POSITION OF THE WARTA STADIAL AND THE PALAEOMORPHOLOGY OF THE MARGINAL ZONE

STRATIGRAPHICAL BASES FOR THE ISOLATION OF THE WARTA STADIAL

The interstadial period between the maximal stadial and the Warta stadial was denominated the Pilica interglacistadial [24, 25]. It is represented in many areas of central Poland, as well by degradation processes as by accumulation of sediments, of established stratigraphic position [1, 2, 9, 10, 30, 33, 37]. The determination of the role of that interstadial is of decisive significance for the rank of the Warta stadial.

During the Pilica interstadial, denudation followed by erosion and finally fluvial accumulation were developed. The erosional depressions of this period have relative depths of the order of 20 to 30 m. The valleys were partially localized according to a predisposition, resulting from the relief of the postglacial maximal stadial. The effect of erosion manifested itself locally by the elimination of sediments from the recession of the maximal stadial and sometimes even by total washing off of boulder clay, occurring as a rule in a dense coating of important thickness. The erosional depressions were later covered by fluvial sands, passing higher, along with the transgression of the Warta stadial, into sands of the fluvioglacial facies.

In some areas as for instance in the Widawka basin it could be established that the distribution of valleys in the Pilica interstadial was partly dependent upon the course of earlier course of Quaternary and Tertiary depressions, of tectonic, and erosional character. The interstadial erosional depressions did not reach any great depth, as those of valleys dating from the older Quaternary, but developed on the other hand as wide depressions or a network of moderate sized valleys. Fluvial sediments, 10 m thick lie frequently on residual boulders and partly fill the depressions. Complete filling took place at the time of the ice-sheet transgression.

The Widawka basin, similarly as other highland areas in the marginal zone of the Warta stadial — presented at the end of the Pilica interstadial a comparatively levelled surface, slightly inclined north- or northwestward. On this surface existed series of valley- or basin-like depressions. These forms were predisposed by older relief elements, of structural and tectonic character as for instance in the tectonic zone of the Kleszczów graben.

The stratigraphic separateness of the Warta stadial is also confirmed — besides the above mentioned processes and sediments of the Pilica interstadial — by the results of petrographical investigations of boulder clays [36]. In the boulder clays of the Maximal and Warta stadials a petrographical differentiation of components was obtained in 5 - 10 mm fractions (Table 3). This differentiation is illustrated by petrographical indices:

S/C — sedimentany — crystalline rocks ratio,
C/L — crystalline roocks to limestones ratio.
A/B — non-resistant to resistant rocks ratio.

In the plaeomorphological development of the Warta stadial, it

TABLE 3. Petrographical indices of boulder clays of the Middle Polish Glaciation

Index	Boulder clay of the Warta stadial	Maximal Stadial
S/C	1·11	0·91
C/L	0·99	1·30
A/B	0·88	0·70

[1] The nomenclature used in countries neighbouring with Poland is given in Table 2.

was possible to distinguish the period of gradual transgression, a period of maximal extension of the ice-sheet, a stationary period and recession of the ice-sheet, as well as of desintegration of the ice-sheet into blocks.

TRANSGRESSION OF THE ICE-SHEET

In the forefield of the transgressing Warta stadial ice-sheet, in all the depressions, river basins and hollows, fluvioglacial sedimentation took place, and in favourable, ice-dammed lakes developed. The thickness of sands and sandy gravels of fluvioglacial origin amounts at the average to 2 - 5 m. In depressions with structural and tectonic bases, as e.g. in the Kleszczów graben zone, as well as in the axes of river basins, these sediments reach a thickness of 20 to 40 m.

In case of dammed up glacial and fluvial waterflow by the transgressing ice-sheet, ice-dammed lake sediments developed. Larger accumulations developed in wide depressions, as for instance in the Vistula basin, between Warka, Góra Kalwaria and Garwolin. On highlands, in areas of more differentiated relief, inclined northward as a rule, successive ice-dammed lake sediments were deposited on ever higher levels. In the Widawka basin, three such levels are found: the Widawka, Karolów and Szpinalów ones (Fig. 4a).

The best developed are the sediments of the largest and earliest formed Widawka ice-dammed lake. It stretched from the environs of Szczerców in the south, beyond Widawa in the north. As shown by the investigations of Z. Sarnacka, they developed in the valley of the Pilica interstadial. The first to deposit were varved clays, then silts and finally dust and fine-grained sands. Their thickness amounts mostly to 5 m, at the utmost to 13·5 m (Lubośnia). The sediments of that first accumulation reaches 165 m.a.s.l. Along with further transgression, directly in front of the ice-sheet, a fluvioglacial accumulation took place of variously grained sands, which occur in much more extensive areas than the

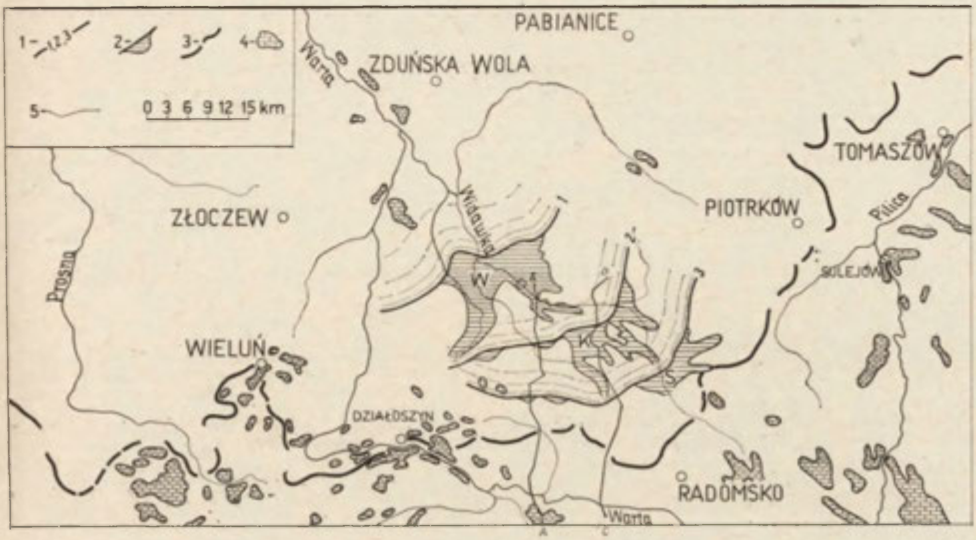

Fig. 4a. Palaeomorphology of the Warta stadial. Ice-sheet transgression

1 — ranges of the ice-sheet in successive phases of ice-sheet transgression, 2 — glacifluvial lakes in the forefield of the transgrading ice-sheet: W — Widawka, K — Karolów, S — Szpinalów; 3 — maximal range of the ice-sheet; 4 — outcrop of the Mesozoic rocks; 5 — geological cross-sections

accumulation basin. These sands presently crop out from under the boulder clays in the erosional escarpments and on denudation slopes, connected with accumulation sediments.

As the ice-sheet transgressed more and more southward, there developed a succesive, higher situated ice-dammed glacilacustrine area in Karolów and Folwark, of which the sediments occur as high as 200 - 205 m.a.s.l. The second glacifluvial lake lies at a distance of 10 - 15 km from Widawa. The last in turn is the Szpinalów ice-dammed lake, reaching up to 210 - 215 m.a.s.l. It lies at a distance of about 15 km, from the Karolów one. The sedimentation in the Karolów and Szpinalów basins started with fine-grained sands, pasing higher into silts, exceptionally into varved clay. In the highest parts occur locally a sedimentation of varved sands.

MAXIMAL RANGE OF THE ICE-SHEET

The maximal range of the Warta stadial ice-sheet (Fig. 4b) shows a far reaching dependence on the relief of the substratum, on which the ice-sheet transgressed. In the structure of that substratum participated Tertiary, Quaternary and Mesozoic rocks, older than the Warta stadial. In the area presently constituting the Warta stadial marginal zone they

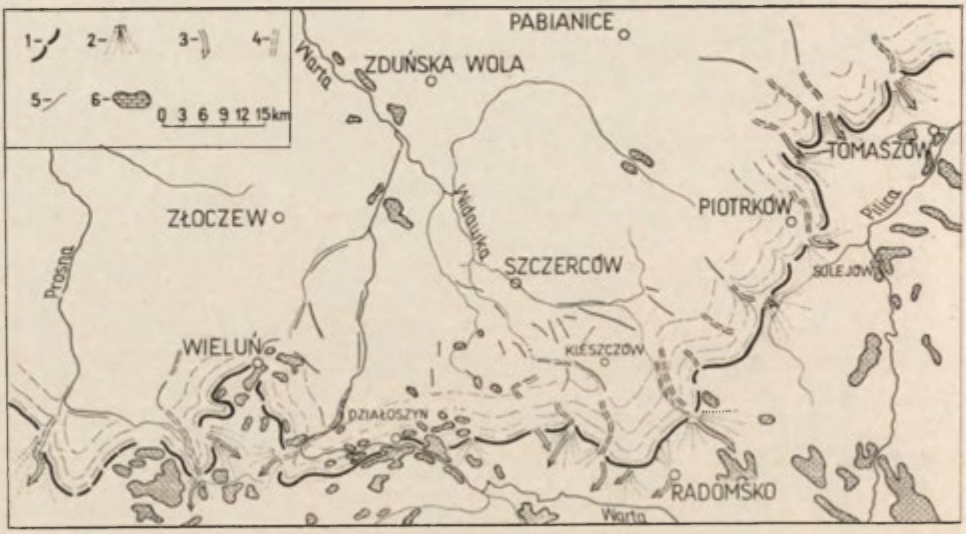

Fig. 4b. Palaeomorphology of the Warta stadial. Maximal extent of the ice-sheet

1 — maximal range of the ice-sheet; 2 — outwash plains; 3 — directions of melting waters outflow; 4 — fissures in the ice-sheet; 5 — cracks in the ice-sheet; 6 — outcrops of the Mesozoic

were frequently structural monadnocks, of more resistant Mesozoic rocks, sometimes overlain on slopes with Quaternary sediments. Such a situation is typical for Middle Poland, where the Warta stadial ice-sheet butted against the furthest north advanced margin of the Holy Cross Mts and Polish Jura. In west Poland, and partly E of the Vistula, Tertiary sediments many times hindered the free advance of the ice-sheet. This occurred namely in those parts where clayey Pliocen sediments, and sometimes also Miocene ones were folded in front of the Warta stadial and formed elevations in the pre-wartian relief. This kind of elevations may frequently have been covered by older Quaternary sediments. and thus within their limits occur more or less often outcrops of Tertiary sediments. As an example may be quoted here the hills of Ostrzeszów, Trzebnica, Mużaków [15, 19, 20] as well as some fragments of the elevations formed of Tertiary sediments in the forefield of the Lublin Upland (S. Gadomska, manuscripts).

In the uplands, where the transgressing ice-sheet was thrust onto flat surfaces or of a northward slope, the marginal glacial forms and the corresponding sediments developed rather well. Between the highland areas the southward spread of the ice-sheet was more extensive, and thus e.g. in the Vistula basin the Warta stadial ice-sheet advanced about 50 km farther southward than in the forefield of the Holy Cross Mts and the Lublin Upland. Supposedly the second, more northward lying area covered by the Warta ice-sheet was localized in the Odra basin, west of the Trzebnica hills.

In the southward extending lobes hardly any marginal form developed, and there are no end-moraines, eskers or kames. The major part of the thawed out material was carried off to the distal forefield. The only direct remnant is the far southward displaced occurrence of boulder clay of the Warta stadial in form of a comparatively dense horizon (A. Makowska, survey geological map). An instance of this is the area E and SE of Radom, in the vicinity of the Vistula basin.

The outwash accumulation in the forefield of the ice-sheet took place during its maximal range in convenient situations, i.e. there, where abundant affluence of water existed, and no network of draining valleys had developed in the forefield. Short outwash cones were then formed. The waters, after throwing off the sand and sandy-gravel material were drained by means of small streams to marginal depressions, which at present constitute parts of the Odra, Warta and Wieprz valleys. One of the main drains for instance, is found on the line of the Widawka valley (Fig. 4b).

Within the ice mass at the time of its maximal range developed cracks and crevasses, where eskers and crevasse fillings originated.

HALT AND RECESSION OF THE ICE-SHEET

The stabilization period of the ice-sheet front was distinguished by an accumulation of end moraines. In a series of segments of the marginal zone of the Warta stadial several main lines of moraines are known. In the best investigated area, in the Widawka basin, five courses were dinstinguished [8]. The most distinct in the surface relief is the fifth stretch, the youngest. This trend corresponds to the last stronger affluence of live ice masses in the Widawka basin, and locally traces of a separate transgression of the ice-sheet is known in form of thrust sediments. The fifth course of end moraines from the Widawka basin corresponds may be to the end moraines of the Grojec glaciphase [24,25], and probably as well to other moraine hills in west and east Poland, established in the hinterland of the Warta stadial range (Fig. 1).

Starting with the halt period of the ice-sheet on the line of the fifth cours of end moraines, the live ice of the glacier changes gradually into stagnating and dead ice. Along with the progression of this process systems of ice crevasses develop, craks broaden, in which eskers occur, while within the ice various depressions develop where kames accumulate (Fig. 4c).

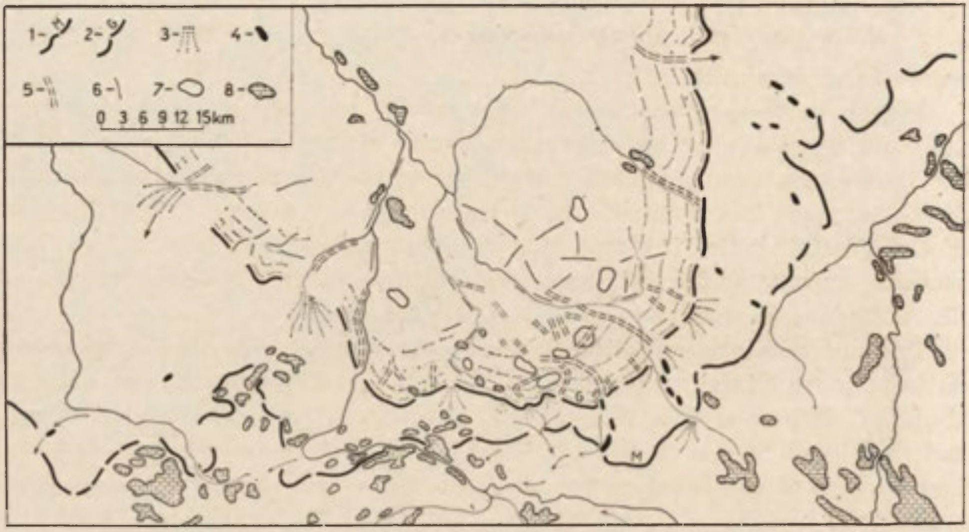

Fig. 4c. Palaeomorphology of the Warta stadial. The ice-sheet stagnation on the line of the fifth course of end moraines

1 — maximal range of the ice-sheet — M; 2 — range of the ice-sheet on the line of the Vth course of end moraines — G; 3 — outwash plains; 4 — eskers and hills of fissural accumulation; 5 — fissures in the ice-sheet; 6 — cracks in the ice-sheet; 7 — thaw depressions in the ice-sheet; 8 — outcrops of the Mesozoic

In the forefield of the ice-sheet appear at this time valley outwash plains, of which the amount depends on local conditions, as for instance on the distance of the marginal valley from the ice-sheet front, or from the level of waters in the marginal valley, constituting an erosion basis for streams flowing from the ice-sheet front. On the latitudinal parallel segment of the Warta between Radomsko and Dzialoszyn, on the northern shore may be distinguished two erosion-accumulation outwash plain levels. In the south shore of the valley may be found fluvial terraces, corresponding in height to outwash levels. Similar erosion-accumulation levels are known also north of Wrocław [41].

THE BREAKING UP OF THE ICE-SHEET INTO BLOCKS

The progressing thawing process of the ice-sheet leads to the widening of crevasses and areas, where the ice dissloved to the bottom. The thickness of the ice is simultaneaously waning. As a result of multilateral thawing, the ice-sheet divided into blocks (Fig. 4d). Gradually, all the forms of relief, developed in the ice emerged to the surface: eskers, channels, kames etc.

Fig. 4d. Palaeomorphology of the Warta stadial. The desintegration of the ice-sheet into dead-ice blocks

1 — maximal range of the ice-sheet — M; 2 — range of the ice-sheet on the line of the Vth course of end moraines — G; 3 — outwash plains; 4 — eskers and hills of fissural accumulation; 5 — kames; 6 — thaw kettles; 7 — blocks of dead ice; 8 — outcrops of the Mesozoic

In places where the ice had stopped in form of long standing blocks, thawing depressions developed. Between the ice blocks, a complicated system of flowing waters transporting and depositing finegrained sands with thin silt intercalations had also developed.

In larger, planated areas the thawing process of the ice-sheet took place without running waters and without the possibility of carrying off the material beyond the area of thawing ice blocks. These areas became an important though monotonus element of the postglacial relief. They constitute plane areas of boulder clays.

PALAEOMORPHOLOGICAL CHANGES AFTER WARTA STADIAL

The postglacial relief that developed after the thawing of the ice-sheet had a decisive effect on the course of surface sculptural processes following the Warta stadial. In the marginal zone of it, many elements of that relief are preserved up to now in their almost initial form, and on the majority of the area the ancient relief may be reconstructed on the basis of geological and geomorphological maps. Among the destructive agents which affected the relief after the Warta stadial the two most important ones were erosion and denudation:

Erosion started towards the end of the Warta stadial, lasted through the Eemian Interglacial period and partly also during the Baltic Glaciation. It embraced, however, only part of the area, namely the presently existing valleys, which were predisposed by various kinds of postglacial depressions and other factors, like tectonic movements, active on some areas as late as the Youngest Quaternary, as for instance may be seen in the Widawka basin, in the zone of the tectonic Kleszczów graben. This is confirmed by groups of lacustrine Eemian sedimentations, the widening of the Eemian-Baltic Widawka basin, the localization of lateral fluvial valleys, as well as the increase of Holocene sedimentation thickness. During the period of the Eemian Interglacial and of the Baltic Glaciation, there occurred some changes in the distribution of the fluvial network, owing to which erosion embraced important areas in some fluvial segments.

Denudation cooperated with erosion, as it developed simultaneaously. On the other hand, the most intensive denudation processes, in the first place various destruction of escarpments and slopes may be situated within the period of periglacial climate at the time of Baltic Glaciation. Denudation contributed, in favourable local conditions to the destruction of postglacial relief of the Warta stadial in some areas.

It should be stressed, finally, that Holocene relief processes are highly dependent on the Pleistocene history. It is easy to make out that the Warta stadial deglaciation highly affected the present relief. Besides, Older Quaternary and prequaternary structures had a strong repercussion, as well as the phenomena of Young Quaternary tectonics.

CONCLUSIONS

The analysis of the marginal zone of the Warta stadial (Fig. 1) enabled to draw a series of conclusions as to stratigraphy of sediments and palaeomorphological development. Of major significance was here the connection of the Warta stadial with the whole of the Quaternary history of the relief (Table 2, 3), as well as with the processes which took place in the Tertiary. Investigation also took into account the background of such processes as geological construction and Mesozoic structures, developed at the turning point between the Cretaceous and the Tertiary.

One of the best studied areas of the marginal zone of the Warta stadial is the Widawka basin, and that is the region wherefrom originate a series of essential examples and the basic part of proofs for the discussed conclusions.

The stratigraphical separateness of the Warta stadial is witnessed by residual and fluvial sediments of the Pilica interstadial (Fig. 2, 3) as well as by an erosional surface of this period, with valleys reaching a depth of 30 m. The confirmation of that separateness is found in the differentiation of petrographical composition of boulder clays (Table 3). The separateness of boulder clays is confirmed also by detailed geological maps, prepared for several thousand square kilometers.

The transgression of the ice-sheet of the Warta stadial in the marginal zone depended on the structure of the substratum, in whose construction participated Quaternary sediments older than the Warta stadial, Tertiary sediments and Mesozoic rocks. The trend of the ice-sheet transgression in the marginal zone and the division of the uniform ice coat into lobes was conditioned by details of ground surface configuration, generally inclined northward, onto which the ice-sheet advanced. The ice-sheet transgression brought about in many places the stemming of water flow and forming of ice-dammed lakes. In favourable conditions, a series of successive glacifluvial lakes developed, giving a picture of gradual phases of transgression (Fig. 4a). In sites of prewartian Mesozoic rock outcrops existed important local differences in heights, which induced, already at the period of transgression of the ice-sheet a differentiation, and initial crevasses which, at later periods were decisive for a varied course of deglaciation, and distribution of sediments and relief forms of the surface. The maximal scope of the Warta stadial is delimited by end moraines (Fig. 4b) or by boulder clays, in areas devoid of marginal forms. The differentiated character of deglaciation (depending on many earlier acting factors) conditioned e.g. in the Widawka basin the zonality of the relief developed at the end of the Warta stadial in the marginal zone. The most external zone is represented by the group of five courses of end moraines. It could be established that among these courses the most distinct (main one) is frequently the youngest, inner course (Fig. 4a). To the north of end moraine, zones of fissures in the ice-sheet could be distinguished (eskers, channels), a zone of kames as well as the innermost zone of thawing (Fig. 4d).

The flowing off of waters from the thawing ice-sheet is connected as well with the maximal scope of the ice-sheet as with the stabilization of the front on lines of inner moraine courses. In the first case short outwash cones developed, and in the other valley outwash plains, developed in several levels and connected with terraces of marginal valleys.

The palaeomorphological significance of the Warta stadial is also constituted by the fact, that the main features of the postglacial relief conditioned a new fluvial network. It is, in many places, not dependent on the design of valleys, of Cromer and Masovian Interglacial origin, filled up during transgression of the Middle Polish Glaciation and at the period of Maximal stadial, and also during the Warta stadial. This new, postwartian network of valleys persisted in the Warta stadial marginal zone up to now in its main outlines, damping the old Quaternary features of the relief.

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THE STRATIGRAPHY OF THE LAST GLACIATION IN THE TERRITORY OF POLAND

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The well known difficulties met with in distinguishing stratigraphical horizons in Quaternary deposits by the use of biostratigraphical criteria, which are so essential for identifying other formations [29, 44, 47, 56, 58], must be ascribed to: the radical and oft-repeated changes which have taken place in climatic conditions, to the predominance of uncommonly variegated facies of terrestrial over marine deposits, and to the short duration of the Quaternary. The recurrence of glaciations — a phenomenon rather rare in the history of the Earth — is the reason why in many areas which, like Poland, haven been thoroughly investigated, the Quaternary profile shows deposits, lithologically very much contrasted. To identify these deposits requires the application of specific methods of research many of which can not be put to use in part, or wholly, for investigations of older sediments.

The author refrains from discussing in detail the specific conditions of the Quaternary and from justifying the obvious and, in fact, commonly conceded necessity of applying a separate basis for the stratigraphical division of the Quaternary. But he calls to mind that this refers in the first place to the younger part of the Pleistocene, what is called the Neopleistocene and, in particular, to the stage mostly called the North-Polish or Baltic Glaciation, by others the Last or Vistulian Glaciation. In the European part of the Soviet Union the counterpart to the North-Polish is called the Valdai, also the Kalinin or the Mołogo-Sheksnian Glaciation, while in the German Lowland the term commonly used is the Vistula (Weichsel) Glaciation.

THE BASIS OF DIVISION OF THE LAST GLACIATION

As to Poland, this division has recently been the topic of several publications. In some of them [35, 43, 45, 47] this division was a part of the division of the whole Quaternary, which has been based on wide foundations. In other papers the divisions of the Last Glaciation in Poland endorsed today are based on only a number of different criteria, such as palaeobotany [51, 52], analyses of periglacial processes [13, 14], or on specially selected phenomena [34]. From the scrutiny and the appraisal of these criteria one may conclude, that of greatest significance for a correct reconstruction of the changes of climatic conditions ruling the Last Glaciation are palaeobotanical and lithofacial examinations, while of less importance is here geomorphological research. A particular place must be assigned to methods of determining absolute age data. For the most part it were climatic conditions which definitely controlled the character of processes and phenomena involved and, in consequence. also of the deposits produced. In this way the division of the Quaternary and, within the limits of this period, of the Last Glaciation is a climato-stratigraphical division as perceived by S. Z. Różycki [44, 45], G. Lüttig [29] and some Soviet authors.

Palaeobotanical examinations enable us, first of all, to establish in an accurate way both the lower and the upper limits of the deposits of the Last Glaciation as indicated by dozens of profiles of lacustrine deposits. Here the lower limit is represented by the boundary between the lowest glacial horizon *k* and the highest interglacial horizon *j*.as seen in the pollen diagrams illustrating the evolution of the vegetation cover after K. Jessen and V. Milthers [25]. Horizon *k* corresponds to a tundra vegetation which flourished under conditions of an arctic and subarctic climate. The upper limit of the Last Glaciation appears in the lacustrine deposits between horizons PB (IX) and DR-3 (X) of the division of vegetation development after T. Nillson [39]. This boundary line lies between the Younger Dryas (the last part of the Pleistocene) and the Preboreal time (the oldest Holocene).

In the division of the Glaciations, Stages and Interstages are units of the first order, and the most precise way how to define them is by using floral criteria, because they imply that the term Interstadial can be applied to a period of time, in which the summer temperature during the thermal optimum has been lower than that which ruled in the given region during the climatic optimum of the Holocene. From this formulation one may conclude, that in Poland's territory the vegetation cover during the Interstadials may have consisted of forest assemblages typical of at least for the Boreal climatic zone.

However, for the requirements of the Pleistocene stratigraphy the floral definition of an Interstage is insufficient; it is further necessary to know the duration of any unit under investigation. A number of methods can be used for this purpose; up to now it was for the most part the palaeogeographical method that used to be applied, based on the study of the lithofacies of the deposits found, of buried erosive-denudational surface and other elements, and on the examination of pollen diagrams and of the thicknesses of the deposits for which these diagrams were compiled. In this domain the future lies in methods determining the absolute age. However, all these methods lead to the conclusions, that the pollen diagrams refering to the Last Glaciation can be divided into two groups. To group one belong those diagrams which indicate the changes in the composition of vegetation towards the decline of glaciation. This group takes in the time from the Oldest Dryas up to the Holocene, and in its optimum phases it gives evidence of a park-type forest growth; the occurrence of forests of this type has alternated with periods containing a tundra-type vegetation. On the average, these changes in plant assemblages were of one-thousand years duration, and it is these phases which palaeobotanists call Stadials and Interstadials. To group two should be assigned those diagrams on which one can trace the evolution of the vegetation cover from tundras through coniferous forests to mixed forests with an admixture of forms typical of Interglacials, and upwards again passing into tundra assemblages. Diagrams of this type are also called Interstadials notwithstanding the fact, that they reflect a more definite increase in temperatures than the diagrams of group one, that they refer to deposits of much greater thicknesses and that, as indicated by many symptoms, they take in a much longer period of time than group one, i.e. periods amounting to something like a dozen, or more, thousands of years. In the author's opinion only group two can be considered to show diagrams representing true Interstadials, and it is only the periods referred to in the latter diagrams that should be considered units of the first order in the division of the Last Glaciation. From Poland's territory at least four diagrams of this type should be mentioned. The first. derived from lacustrine deposits at Konin on the Warta River [3, 46], is illustrated in Fig. 1. The second (Fig. 2) shows similar deposits found at Podgłębokie in Lublin Polesie [24, 36]. The remaining two diagrams are from old channel deposits in river valleys at Brzeziny [2] and at Wadowice [49] in the Carpathians; both the latter diagrams refer to deposits less thick.

The pollen diagrams from Konin, Podglebokie, Brzeziny and Wadowice have one feature of particular importance in common: they all occupy a similar stratigraphical position in the profile of the deposits of the Last Glaciation. This similarity lies in the fact, that the interstadial deposits are overlain by deposits developed under climatic conditions which furthered the spread of the inland ice; at Konin it is boulder clay which lies on top of the interstadial deposits. Palaeobotanical and geological examinations imply, that in all four sites the same Interstadial

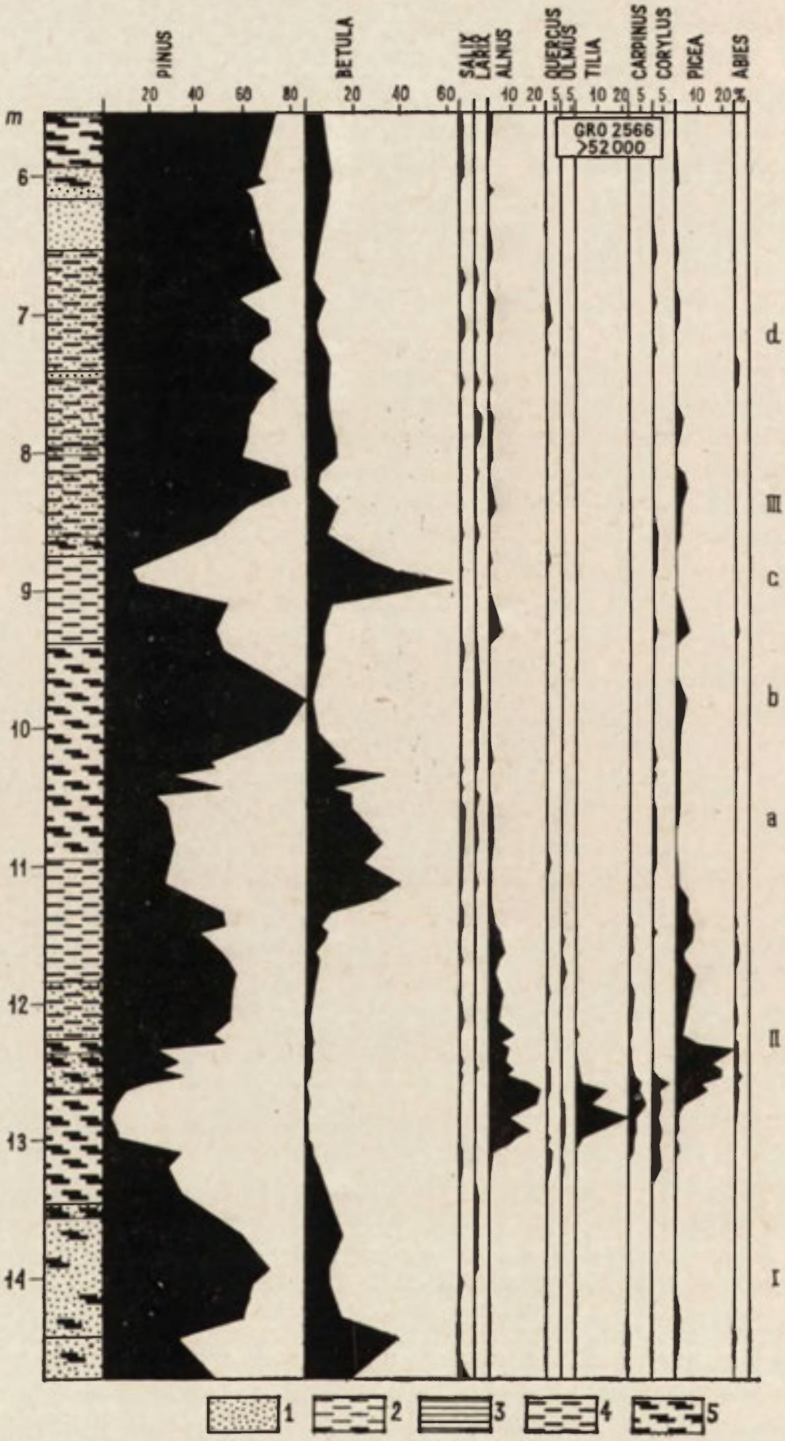

Fig. 1. Pollen diagram of Brörup Interstadial at Konin on the Warta River (after Z. Borówko-Dlużakowa, 1967)

1 — sands, 2 — silts, 3 — clays, 4 — gyttjas, 5 — peats

]

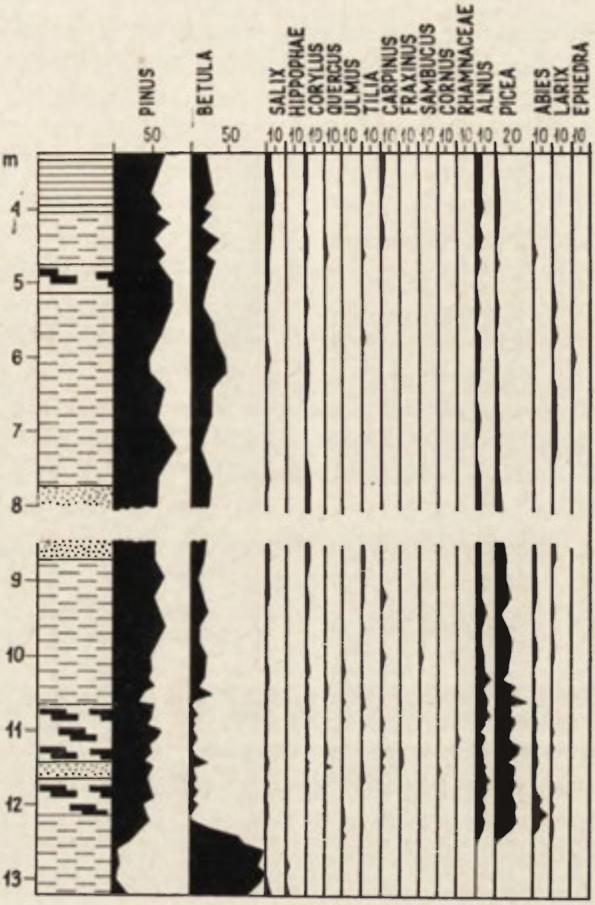

Fig. 2. Pollen diagram of Brörup Interstadial at Podgłębokie in Lublin Polesie (after Z. Janczyk-Kopikowa 1963)

For explanations see Fig. 1

is represented and that this Interstadial should be correlated with the Brörup Interstadial of Western Europe. As is well known, for the first time the stratigraphical position of the Brörup has been accurately determined in Denmark and, later on, in the Netherlands where it lies on top of deposits of the Eemian Interglacial and underneath deposits which were laid down during the maximum extent of the Scandinavian inland ice during the Last Glaciation. That the Brörup Interstadial at Konin is covered by boulder clay from the farest southward extent of the Last Glaciation proves, that this Interstadial preceded the transgression of this inland ice in the Polish Lowland. In this respect the pattern of the Konin profile approaches that of the Danish profiles [1] which, although showing no covering by glacial deposits, do underlie sediments which are facially passing into glacial deposits. On the other hand, the Podgłębokie profile lies in an analogous position as the Dutch profiles described by W. Z. Zagwijn [57], i.e. far in the forefield of glacial deposits of the Last Glaciation, in its periglacial zone [36]. Finally, the profile of the Brörup Interstadial at Wadowice is typical of the wide zone of the Carpathian foreland and the foothills of Southern Poland.

This shows that the pollen profiles from Konin, Wadowice and Podgłębokie represent a bench mark for the stratigraphy of the Last Glaciation in Poland and that, together with the sites known from Denmark and the Netherlands, they belong to the best documented profiles of the Brörup Interstadial in Europe. By means of these profiles the Last Glaciation can be divided into three horizons, namely Lower Stadial, Brörup Interstadial and Upper Stadial. E. Rühle [47] gave to the lower stadial the name of Szczecin Stadial, while to the upper one the name of Main Stadial — these names will be also used in this paper.

In the pollen diagrams the image reflected by the Szczecin Stadial are the tundra vegetation of phase *k* directly overlying the Eemian, and the tundra vegetation which indicate the lower part of the Konin and Podgłębokie diagrams.

However, palaeobotanical criteria are not the only means by which the principal division of the horizons of the Last Glaciation can be distinguished; just as important for this purpose are examinations of fossil soils. These soils appear for the most part in the loesses of the plateaus of Middle Poland (Fig. 3) and, moreover, in loamy-sandy periglacial covers such as occur in the Łódź Upland. Detailed examinations made in recent years brought evidence, that the loess cover mantling the soil from the Eemian Interglacial contains two horizons of fossil soil which are of local significance [32, 33]. The upper soil layer lacks the character of an index horizon for all-Poland; its profile is poorly developed and in many localities, especially in the western part of the loess area, this fossil soil is missing altogether. The lower fossil soil, on the other hand, is a continuous horizon encountered in all loess regions; over wide distances this horizon shows a typological similarity although, proceeding from east to west, its profile changes gradually. It is commonly admitted that this fossil soil dates back from the Brörup Interstadial. The profiles of this soil, especially those from the eastern part of the Lublin Upland and from Western Roztocze, are evidence that this fossil soil has developed under conditions approaching the Interglacials and in a climate as warm as it is today. The soil profiles are polygenetic, in other words, they are the result of successive soil-forming processes which took place under

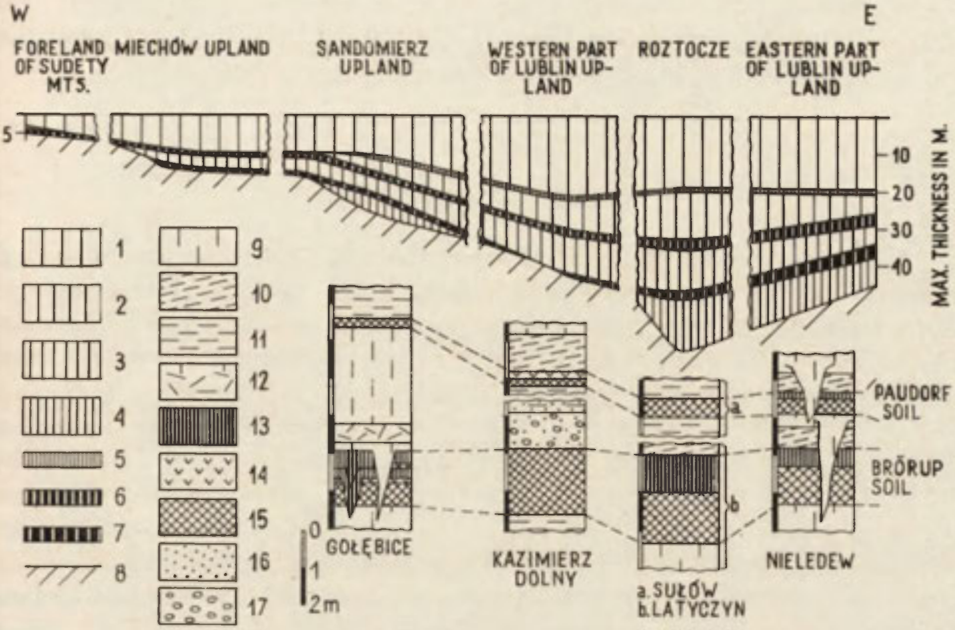

Fig. 3. Stratigraphical profile of loess in Polish uplands, and examples of profiles of fossil soils from the Last Glaciation

1 — loess of Leszno, Poznań and Pomeranian Phases of the Main Stadial, 2 — loess of Pre-Paudorf Phase of the Main Stadial, 3 — loess of the Szczecin Stadial, 4 — loess of the Middle-Polish Glaciation, 5 — soil of Paudorf Interphase, 6 — soil of the Brorup Interstadial, 7 — soil of the Eemian Interglacial, 8 — deposits of the older Pleistocene, 9 — subaerial loess, 10 — solifluction loess, 11 — alluvial loess, 12 — cley-like loess, 13 — soil horizon A_1, 14 — soil horizon A_2, 15 — soil horizon B, 16 — sands, 17 — gravels

successively different climatical and topographical conditions. Much the same conclusion was reached by B. Manikowska [31] in her analyses of a soil profile from the Brörup Interstadial in the Łodź Upland. In this profile the soil bears the character of a brown earth, locally degraded, which has developed underneath a cover of a forest vegetation in a moderately cool and rather humid climate.

Less definite are the criteria for dividing the deposits of the Last Glaciation in Poland, when examinations of other facies are taken into account. Here should be mentioned marine deposits called the Elbląg clays, discovered near the lower Vistula, they contain a fauna of Boreal molluscs [21] and these clays may be deposits of the Brörup Interstadial. It is known, that they overlie marine deposits with an Eemian fauna, but the determination of their true stratigraphical position is made difficult by their being glacitectonically disturbed and their lacking an undubitable connection with other definitely dated deposits of the Last Glaciation.

Next the author presents successively a concise stratigraphical characteristic of what considers important lithofacial types of deposits from the Szczecin Stadial. the Brörup Interstadial, and the Main Stadial.

THE SZCZECIN STADIAL

The Szczecin Stadial is mainly represented by loess deposits and, moreover, by eluvial and deluvial deposits of a periglacial environment, by fluvial deposits and, probably also, by glacial and fluvioglacial deposits. To the latter one many assign, with due reservations, the boulder clays and the glacitectonic disturbed sands and gravels described by J. Knauer [26] and by P. Woldstedt [55] which occur in the Szczecin region, as well as similar deposits from west of the Vistula estuary described by Z. Kotański [27]. All these sites require further investigation. More certain is that deposits of the Szczecin Stadial are part of the loess profiles. A loess horizon built of a variety of facies and showing a thickness of at least 5 m (Fig. 3) has been widely encountered in the Lublin Upland and in Western Roztocze and, also, in the Sandomierz Upland, placed between beds of Eemian soil and Brörup soil. The climatic conditions in which loess accumulated are today known to such extent, that with this knowledge as basis one can well reconstruct the palaeogeographical conditions of the Szczecin Stadial. Thus we may admit, that at those times the inland ice was covering at least the depression of what is today the Baltic Sea, and that the climate of that period was favourable to an accumulation of loess dust, specially in the eastern part of the Middle Polish Uplands, and to the development of processes and, at the same time, of deposits resulting from the existence of permafrost. This same kind of deposits may also occur in the region of Łódź and, most probably, one can also assign to them what is called the older periglacial mantle of the Ostrzeszów Hills, recently examined in detail by K. Rotnicki [42].

The cold period which occupies in time a position approaching that of the Szczecin Stadial in Poland, is also known from a number of other areas. This refers, for instance, to a horizon of a typically subaerial loess found in numerous profiles from Moravia [30, 37] and from Baden [5], and in profiles of Hungarian and Balkan as well as Ukrainian loesses. Traces of a periglacial environment in an identical stratigraphical position have also been discovered in a number of further European profiles; these traces consist of frost wedges and structures of swelling which in recent times have been described in detail from Belgium by R. Paepe and R. Vanhoorn [40].

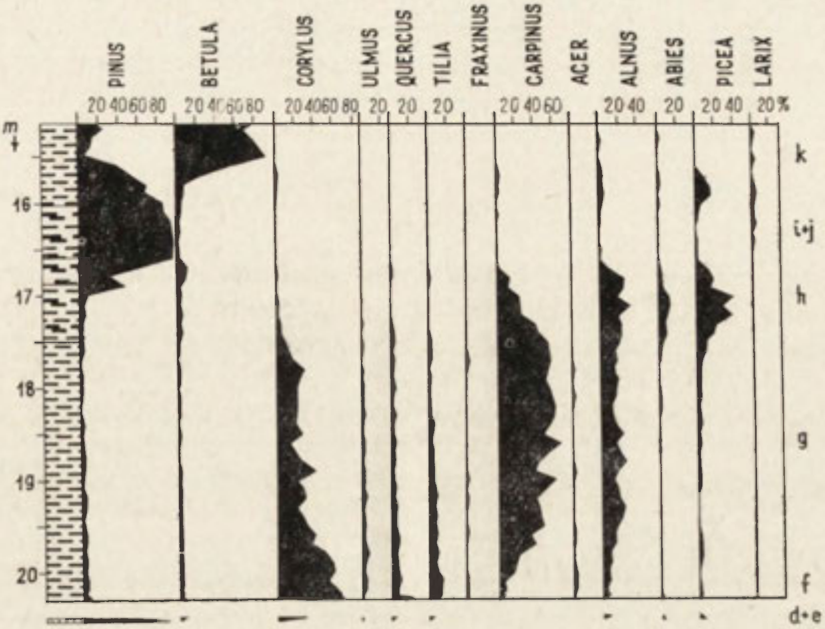

Fig. 4. Pollen diagram of the Eemian Interglacial at Kaliska in Kuyavia (after Z. Janczyk-Kopikowa, 1965)

For explanations see Fig. 1

As matters stand today, no satisfactory premises are available for distinguishing individual horizons dividing the Szczecin Interstadial. Some progress is hoped for from palaeobotanical examinations of the deposits which orginated during the decline of the Eemian and the rise of the Last Glaciation. In the higher part of some of the pollen diagrams of this period a slight increase in temperature can be observed which is separated from the youngest Eemian by a period of tundra vegetation. This arrangement is known from Kaliska in Kujavia [23] (Fig. 4) and from Szwajcaria in the Suwałki Lake District [4]. No exact date has been set for this improvement in temperature, but one may agree with the suggestion made by Z. Janczyk-Kopikowa [23] that this period should be correlated with the oldest temperature rise in the Last Glaciation in Western Europe known as the Amersfoort-Rodebaek Interstadial. Taking as basis the character of the diagrams from Kaliska and Szwajcaria one should in this case call this an oscillation or only an interphase, separated from the decline of the Eemian by a phase which, for the time being, shall be called the Pre-Amersfoort Phase.

The climatic changes which in the discussed profiles led to this subdivision into the Pre-Amersfoort Phase and the Amersfoort Interphase, are also recorded in the soil profiles of the Eemian Interglacial found in the loess areas. because these changes brought about, partly at least, a leaching process of the soil, a reduced thickness of horizon A, and some further transformations, due to which the upper part of the soil horizon has lost many features characteristic of an interglacial soil.

THE BRORUP INTERSTADIAL

Representative of the Brörup Interstadial in Poland are lacustrine deposits which in their palaeobotanical aspect have been investigated in a great number of profiles the most important of which have been enumerated above, and by fossil soils also.

All pollen diagrams show distinctly one climatic optimum and a vegetation cover which in the lowland indicates a climate similar to the present one, but not any warmer than the postglacial optimum. In the lowland profiles the upper parts of the diagrams cover a relatively long time — proof of a protracted period in which conditions were less favourable to the growth of thermophilous trees. So far none of the diagrams have revealed any three climatic optima separated by cooler periods, as are seen in some Danish pollen diagrams of this age and, likewise, in a few pillen diagrams of the Mologo-Sheksna Interglacial which as to age most probably correspond in the Eeastern European Lowland to the Brörup Interstadial.

The climatic changes which took place during the Brörup Interstadial are of necessity reflected in its soil profile. Basic data on this subject are supplied by the soil profiles obtained from the Lublin Upland, from Roztocze and from the Sandomierz Upland [32, 33. 34]. They indicate that for a certain time the Brörup soil must have been developing beneath a cover of forest vegetation, and that in the final period steppe conditions have ruled for a long time. It seems probable that the profile of this soil as it has survived until today, corresponds to the climatic optimum and to the final phase in the development of the vegetation cover, that is, to periods IIa and IIb in the Podgłębokie pollen diagram [24].

THE MAIN STADIAL

The stratigraphy of the Main Stadial has been based on deposits of a variety of facies. Of greatest importance for the division of the older part of this Stadial are its loess deposits; in the Main Stadial they appear in two horizons separated by a soil in the form of a brown earth, non- or only slightly calcareous, locally gley-like, for which so far neither origin nor typology have been determined. For the most part this is a skeletal soil with a profile contingent upon the kind of its substratum, its topographical situation, its local climate, etc. The position which this upper horizon soil occupies in Poland's loess profiles corresponds to the soil known from other European loesses as the counterpart of what is called the Paudorf Interstadial. However, the features specified above and a comparison with the soil of the Brörup Interstadial prove only a minor and rather short-lived temperature rise of the order of an interphase. This warmer Paudorf period has been well dated by means of the ^{14}C method, mainly in the loess profiles of Austria and Czechoslovakia where this soil developed in the time from 33 500 to about 28 000 years ago [22]. These dates show that the break in loess sedimentation of the Main Stadial lasted some 5000 years. This pause must have preceded the maximum extent of the inland ice; this can be seen, irrespectively of many other facts, from a comparison of the two loess horizons of the Main Stadial. The loess of the Pre-Paudorf Phase — this term should be applied to the lower part of this stadial — is much less extensively spread than, and at most half as thick as, the younger loess; further, in the Pre-Paudorf loess a solifluction phase predominates, in contrast to the prevailingly upper subaerial facies with periglacial structures, which must have developed in the continental subarctic climate ruling during the period of maximum inland ice extent.

In the Pleistocene profiles of the lowland, the traces of the Paudorf interphase are less definite. It is only from the Lusatia (Lausitz) ice marginal streamway (*pradolina*), situated in the German Democratic Republic, that important records are on hand. Under deposits of a fluvioglacial accumulation contemporaneous with the moraines of the Brandenburg Phase and, therefore, with the maximum inland ice extent of the Vistula Glaciation, peats and mud sheets [7] have been found the age of which has been determined: in the Skado profile it is 25 670±600 (Bln 110) and in the Lohsa profile 26 440±800 (Bln 221) years; this means the decline of the Paudorf Interphase. Pollen analyses of these deposits show for those times the occurrence of assemblages intermediate between a boreal pine forest and a subarctic park tundra, i.e. a vegetation climatically much less exacting than it was during the Brörup Interstadial. Simultaneously a tundra vegetation was covering Southern Sweden, from where F. Brotzen [6] has described clayey marine deposits with an arctic fauna from what is called the Göta-älv Interstadial. The age of these deposits is from $26\,700 \pm {}^{1300}_{1000}$ to $29\,000 \pm {}^{1300}_{1000}$ years, but these values require checking, because no age difference was observed between samples taken from the same profile at depths differing by 32 m.

The Pre-Paudorf Phase preceding the Paudorf is in Poland known from a loess horizon which has been identified in a number of exposures and bore hole profiles, mostly in the Lublin Upland in Western Roztocze and in the Sandomierz Upland. Locally this loess bed is up to 10 m thick; still, in the majority of loess profiles this horizon is lacking. Westwards the loess of the Pre-Paudorf Phase gradually vanishes, but in some profiles outside Poland it appears in a continuous layer, predominantly in a solifluction facies.

No glacial or fluvioglacial deposits of the Pre-Paudorf Phase are known, although they might be expected to occur in the farest northern part of Poland. Among further facies of Pleistocene deposits, to this horizon should additionally be assigned some deluvial periglacial covers in the Łódź Upland, as well as some fluvial and cave deposits which have been discovered, so far, only exceptionally. Recently E. Mycielska-Dowgiałło [38] found fluvial deposits of the Pre-Paudorf Phase in the Vistula valley near Tarnobrzeg; here sands and gravels of a constrative facies are intercalated with thin alluvial sheets containing pollen from a climate resembling the Preboreal; these deposits have been dated from 40 000 ± 2000 (GrN 4868) years ago. Similar as to age is a layer with a Jerzmanowice culture found in what is called Nietoperzowa Cave (Bat Cave) in the Polish Jura; this layer has been dated from 38 160 ± 1250 (Gro 2181) years ago [11]. From the sum of data gained from Nietoperzowa Cave it may be concluded that the Jerzmanowice culture developed in a humid and cool climate [10].

Little is known of the deposits of the Pre-Paudorf Phase although it lasted for a relatively long time (from some 50 000 to 33 000 years ago); this is why it is today a difficult matter to subdivide the deposits of that period. Even so, the facts stated above are proof, that these deposits bear the features of humid and cool climatic conditions and that they show clearly the influence of agencies pointing to an oceanic variety of the periglacial environment.

In the lowland area the glacial and fluvioglacial deposits, including fluvial deposits, must be assigned to the younger, the post-Paudorf part of the Main Stadial (Fig. 5); their stratigraphical division has been based on lithofacial and geomorphological criteria. In this way at least two and, locally, up to four horizons of glacial deposits have been distinguished, separated by fluvioglacial deposits. Regionally this pattern has been investigated relatively most accurately in the valley of the lower Vistula by R. Galon [15, 16, 17]. In many areas three horizons of glacial deposits have developed; the area in which each of these horizons occur is limited from the south by marginal zones containing an assemblage of characteristic land forms and relief features. The three marginal zones correspond to three phases: the Leszno, the Poznań and the Pomeranian

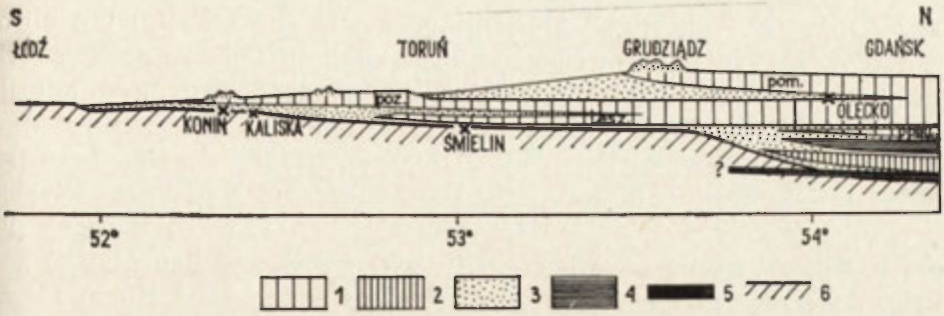

Fig. 5. Diagrammatical section across glacial deposits from the Last Glaciation in Poland

1 — glacial deposits of the Main Stadial. Phases: pom. — Pomeranian, poz. — Poznan, lesz. — Leszno, ppau — Pre-Paudorf, 2 — glacial deposits of the Szczecin stadial, 3 — fluvioglacial and ice-dammed deposits, 4 — marine deposits of the Brorup Interstadial, 5 — marine deposits of the Eemian Interglacial: Kaliska, Smielin — floral sites of the Eemian Interglacial, Konin — floral site of the Brorup Interstadial, Olecko — floral site of the Mazurian Interphase, 6 — bedrock

Phase, respectively, each of which is also represented by corresponding glacial deposits. The fluvioglacial, ice-dammed, lacustrine and fluvial deposits which separate the different glacial deposits belong to two Interphases: an older Pre-Poznań Interphase and a younger one, called the Mazurian Interphase. Here and there the lacustrine deposits of the Mazurian Interphase contain plant remnants characteristic of what is called the Mazurian Interstadial. A profile of this kind has been presented by B. Halicki [20] who has described lacustrine clays from near Olecko containing a fauna and flora. It is worth mentioning, that both east and west of Poland's territory deposits of the Mazurian Interphase are relatively well developed. In Lithuania and in the Russian Lowland they include lacutrine deposits and peats of what is called the Ula Interstadial and the Somino Interstadial; in the Zerwinos profile in Lithuania the lower part of these deposits has been dated from 18 359±950 (Vs-4), the upper parts from 17 340±840 (Vs-5) [50] and 16 260±640 (Mo 302) [9] years ago. In the German Democratic Republic the lacustrine deposits from Blankenberg [8, 28] seem to occupy a similar stratigraphical position.

Taxometrically of phase and interphase rank are also the youngest parts of the Main Stadial, which a long time ago were distinguised on the basis of palaeobotanical criteria as Stadials and Interstadials, beginning from the Bölling Interphase through the Phase of the Younger Dryas.

Correlated with part of the Main Stadial, from the Leszno Phase through the Pomeranian Phase, is in the non-glaciated area one loess horizon, the youngest, and one horizon of eluvial and deluvial periglacial covers and, also, of fluvioglacial deposits. However, in their vertical profile all these deposits differ much lithologically and facially; but all of them show also features in common, depending on their respective periglacial sedimentation environment. This type of environment left its traces in the form of syngenetic permafrost structures.

The youngest part of the Main Stadial, on the other hand, from the Bölling Interphase to the decline of the Main Stadial, has been divided on the basis of floral and palaeopedological criteria. To the deposits produced at that time have been assigned lacustrine, eolian (dunes) and fluvial deposits and, to a lesser degree, slope covers. The climatic conditions of this declining part of the Main Stadial have been relatively well determined from numerous pollen diagrams and from studies of the fossil soils of that age. A number of profiles have been dated by the ^{14}C method, and this made it possible to define accurately the duration of the individual phases and interphases and to correlate them with counterparts in adjoining areas.

COMMENT ON THE CHRONOLOGY OF THE LAST GLACIATION

As well known, the stratigraphical division and the chronology of the Last Glaciation bases to a constantly growing degree on determinations of the absolute age of the deposits involved. Among methods suitable for this purpose, best are results obtained by the ^{14}C method. As to their accuracy the some scores of datings known at present for deposits in Poland, including a number of datings from neighbouring countries, can be divided into three groups. Group one takes in the dates covering the time from the Bolling Interphase to the rise of the Holocene; for Central Europe, at least several hundred datings are on hand. New datings which are steadily being added, do not alter any of the age values determined in older datings of the deposits of this part of the Last Glaciation. And in view of the fact, that for the most part these deposits have been dated by their floral features, we may assume that the datings of this group show the true age of the deposits examined, and that further datings are not likely to change these determinations.

To group two the author assings the datings made for the period of the Paudorf Interphase and the time close to it. Here the datings involve deposits of a variety of facies, but their majority refer to fossil soils and to lacustrine deposits. While the first soil datings specified their age as being within the limits from 25 000 to 28 000 years, later improvements in the method of dating and of collecting samples have raised this age; form the — incidentally still incomplete — information recently supplied in a paper by T. van der Hammen, G. C. Maarleveld,

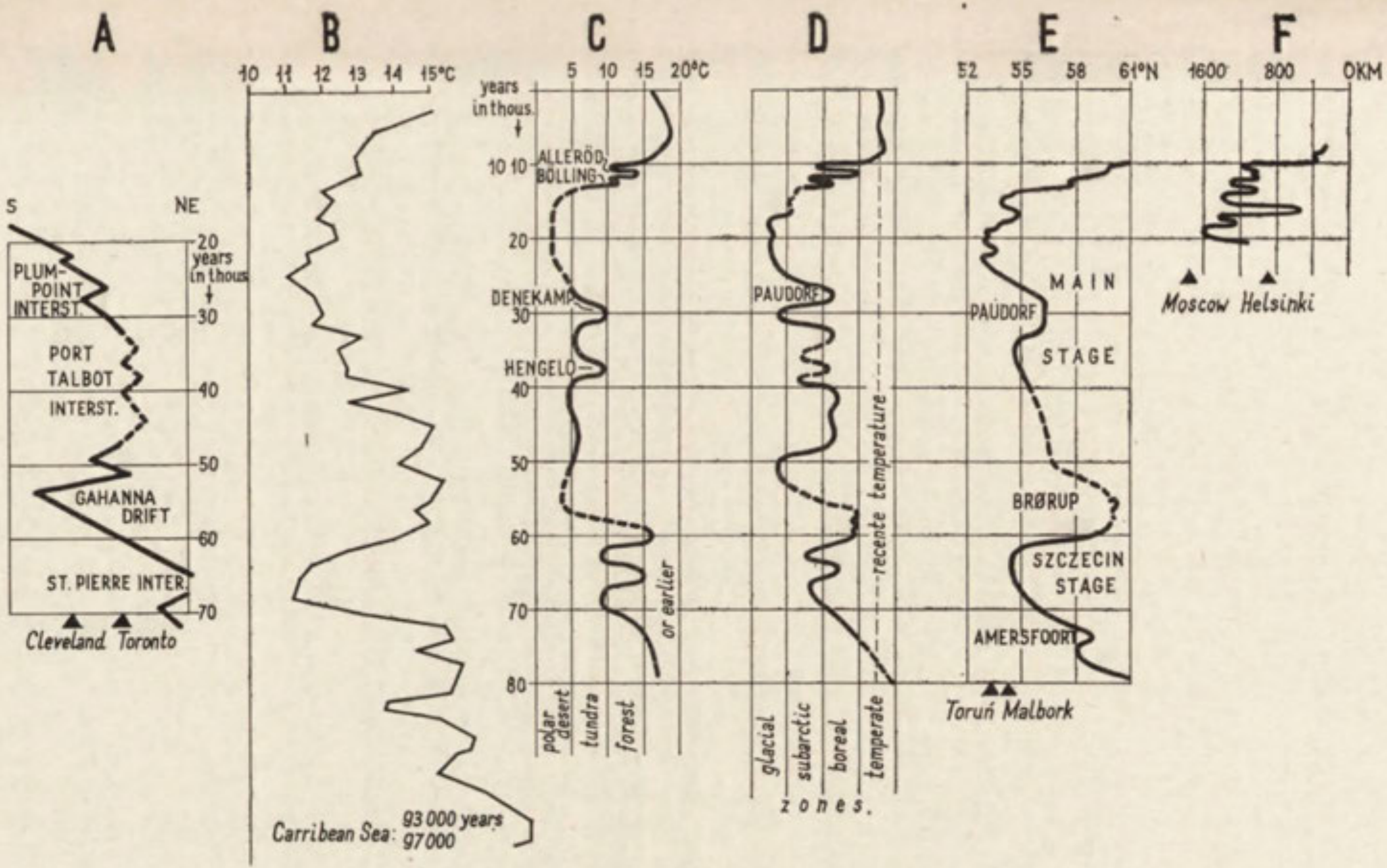

Fig. 6. Curves of the Last Glaciation

A — curve indicating extent of the Wisconsin Glaciation in NE part of the United States (after A. Dreimanis, J. Terasmae, G. D. McKenzie [12]); B — curve indicating palaeotemperatures for the North-Atlantic area (after J. N. Rosholt, C. Emiliani, J. Geiss, F. F. Koczy, P. J. Wangersky [41]). Absolute dating by means of $^{231}Pa/^{230}Th$ metod. C — climatic curve for the Last Glaciation in the Netherlands (after T. van der Hammen, G. C. Maarleveld, J. G. Vogel, W. H. Zagwijn [22]); D — diagrammatical curve indicating palaeotemperatures during the Last Glaciation, based on estimates of mean July temperatures (after H. Gross [19]); E — curve indicating extent of inland ice during the Last Glaciation in Poland; F — Dynamics of degradation of the Valdai Glaciation in the Russian Lowland (after N. Chebotaryeva, M. Vigdorchik, V. Grichuk, M. Faustova [9])

J. C. Vogel and W. H. Zagwijn [22] it appears. that latest datings fix the age of the Paudorf Interphase as being from 27 000 to 32 000 or 33 000 years. We may therefore assume, that this group of datings may even now be encumbered with some inaccuracies and that future datings may bring even higher values.

To group three belong all older datings and. in the opinion of many authors, their reliability decreases with increases in age. Thus, H. Gross [18] believes that all age data exceeding 53 000 years, as far as they still lie within the limits of the scale of the instruments used, may be at least 12 000 to 16 000 years low. In due consideration of the essential way how dating is done, one is prone to agree with this opinion. It must therefore be considered possible, that the datings refering to the Brörup Interstadial in the Danish and Dutch sites may only be vague approximations; the values of datings of deposits of earlier periods may be even less reliable. This latter remark refers to the only dating so far known of the Amersfoort Interphase which gave an age of 63 500 years, and this was, moreover, the lowest age figure stated for this interphase [22]. If this sort of reasoning is correct, it would overcome any probable argument against the importance of the stratigraphical rank ascribed in the present paper to the datings of the Szczecin Stadial, — an argument founded on the datings heretofore known for the Amersfoort Interphase and the Brörup Interstadial, which assumed between these two periods and age difference of barely 4000 to 5000 years. According to the curve for the Last Glaciation in Poland (Fig. 6), the Amersfoort Interphase occurred at least 75 000 years ago; this value is based on the asumption, resulting from the geological and palaeogeographical evidence presented, that the duration of the Szczecin stadial may have been only slightly less than that of the Main Stadial. And that, therefore, it may have lasted at least some 15 000 years, ending before the Brörup Interstadial, i.e. some 60 000 years ago.

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APPLICATION OF FLUORINE-CHLORINE-APATITE METHOD FOR DATING FOSSIL BONES

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The fossil bones of animals, often found in Quaternary and earlier deposits, are mostly poorly preserved; this prevents establishing the animal's species and, often, even fails to throw light on the age of the specimens found. This is why for a long time efforts have been made to develop other reliable methods of establishing the age of such bones. One of the earliest methods, going back to the 19th century, is the fluorine method used for determining the relative age of fossil bones. With progress in chemical methods and with their constant improvements, increased attention was paid to this method. A number of new reseach methods came to be used, where not only the fluorine content in the bone structure was taken into account but other components too. Besides chemical methods, the X-ray and the spectrographical methods also came into common use. Research of this type was made in many countries like France, Germany, the Netherlands, the Soviet Union, Italy, Great Britain, Hungary, the United States, and Morocco.

In Poland M. Wilczyński [3] was the first to attempt in 1960 the dating of fossil bones by Pidoplichko's collagen method [2]. In the same year Professor Dr. S. Z. Różycki prompted the present author to try dating fossil bones on the basis of the fluorine they contain and, later on, of their chlorine, phosphorus and collagen content [4 - 6]. These test were being made at the Department of Quaternary Geology of the Institute of Earth Sciences of the Polish Academy of Sciences, with Professor Dr. S. Z. Różycki in charge. Analyzed were for the most part bones found in Poland and derived from both open and cave localities, of Upper Miocene, Pliocene, Pre-Pleistocene, Pleistocene, Late-Pleistocene and recent age. Further, while these tests were under way, also tested were bones from different geological periods discovered in Bulgaria, the Soviet Union, Yugoslavia, the United States, Australia and Mongolia.

The determination of fluorine, chlorine and phosphorus was made by chemical methods, while the content of collagen was obtained by using the weight method in which bones were incinerated at a temperature of 790 + 10° C during one hour.

The application of known chemical methods for determining the content of the components mentioned was preceded by experimental analyses, in order to adapt the test methods to the components which were to be determined in bones and teeth.

The determination of the fluorine content was done by McIntyre's alizarine method. the chlorine content by Kuroda and Sandell's photometric method adapted by A. Jęczalik [1] to identifying small quantities of chlorine in phosphorites, and the phosphorus content by the magnesite method after Jęczalik's instruction which applies two successive precipitations of the magnesite mixture.

In his own method of determining the age of fossil bones the present author introduced, apart from the results of identifying the content of fluorine, chlorine, P_2O_5 and collagen in per-cent weights, a calculation of the mutual relations between the individual components mentioned, defining these relations by index values. The ratio of fluorine to P_2O_5 the author calls the fluorine-apatite index, the ration of chlorine to P_2O_5 the chlorine-apatite index. For the product of these indices the author uses the term fluorine-chlorine-apatite index, and the ratio of the weight of the mineral components to that of the organic components of the bones the author calls the index of collagen losses.

The tested bone material encompasses practically all the important stratigraphical series beginning with the Miocene up to recent times and, especially, the material from Nietoperzowa and Koziarnia Caves (Bat and Goat Caves) in the Polish Jura; thus it takes in those series of deposits whose stratigraphical position has been unequivocally determined by geological, archeological, palaeontological and ^{14}C dating, and it presents an interesting picture of the interrelation between the part played by the content of mineral components in the bones, and the content of collagen and organic chlorine on the one hand and, on the other, between fluorine. chlorine and mineral components, and phosphorus, where in time the fluorine content gradually increases.

From the results of this research work the author draws the following conclusions:

1. With time the fluorine content in fossil bones increases, but the fluorine determination alone is unsufficient for an accurate age definition of any investigated specimen.

2. The fluorine content grows forcibly during the Younger Pleistocene; in the Older Pleistocene this growth is less intensive.

3. In quantity, the components of the mineral part of the bones are in inverse proportion to the content of collagen and organic chlorine. The less collagen the bones contain, the more of the mineral components relatively speaking, appear in a given geological period.

4. For Holocene, Pleistocene and Pliocene bones the index of collagen deficiency is at the same time an index of the climatic changes.

5. In Young-Holocene bones, that is, those from recent times back to some 3000 years ago, the content of organic chlorine in the bones decreases in direct proportion to the decrease in organic components and in inverse proportion to the increase in fluorine and P_2O_5 content. In the subatlantic conditions of the climate of this period, the organic chlorine (apart from the chlorine permanently „crystallochemically” bound in the spatial lattice of the phosphate crystallites of the bones) was carried off, combined with a partial loss of the collagen contained in these bones.

6. Bones from the Older Holocene, the Pleistocene, the Pre-Pleistocene, the Pliocene and the Miocene, buried under identical environmental conditions, contain almost constant amount of chlorine, dependent only on the amount of phosphorus the examined bone sample contains.

7. For bones some 3000 years old, the chlorine-apatite index is the index of the geological environment in which they were buried.

8. Bones from near-identical environmental conditions show similar values in their fluorine-apatite and chlorine-apatite index.

9. In bones from periods older than some 3000 years ago, the fluorine and chlorine content is directly proportional to the P_2O_5 content, parallel with a gradual increase with time of the fluorine-apatite index.

10. By means of the fluorine-chlorine-apatite index introduced by the present author:

$$W_{(\mathrm{FClP})}=\frac{\%\mathrm{F}\cdot\%\mathrm{Cl}}{(\%\mathrm{P_2O_5})^2}\cdot 10^5$$

it is possible to correlate as to age the bones derived from different environments of a temperate climate, provided that separate age curves are compiled for localities open to the atmosphere.

11. For recent and Young-Holocene bones (up to some 3000 years age) collected from open localities, the fluorine-chlorine-apatite index shows constant values. The age of this kind of bones can be determined from their fluorine-apatite and collagen indices.

12. In the light of studies so far made by the author, the fluorine-chlorine-apatite method of dating fossil bones and, indirectly, of the deposits in which the bones were buried, can be applied to the area of Europe for the times from recent back through the Miocene; this

method should prove useful in geological, palaeontological, archeological and anthropological examinations.

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LIST OF GEOLOGICAL AND ARCHAEOLOGICAL SITES ON THE TERRITORY OF POLAND DATED BY MEANS OF RADIOCARBON [1]

The Committee of Quaternary Research of Polish Academy of Science assembled informations of radiocarbon dates concerning geological and archaeological sites in the territory of Poland. The results, although uncomplete are presented in this paper. Informations were received from the following institutions:

Institute of Botany, Polish Academy of Sciences, Cracow (IB PAN)
Department of Paleolithic Institute of Material Culture, Polish Academy of Sciences, Warsaw (ZP PAN)
Institute of Geography, Bolesław Bierut University in Wroclaw (IG UWr)
Geological Institute of the Central Geological Office in Warsaw (IG CUG)
Institute of Geography, Polish Academy of Sciences, Warsaw (IG PAN)
Geographical Institute of the Warsaw University (IG UW)
Archaeological Museum in Poznań (AM Pozn)
Institute of Geography, Nicholas Copernicus University in Toruń (IGF UT)
Institute of Pedology, Nicholas Copernicus University in Toruń (KG UT)
Committee of Marine Research, Polish Academy of Sciences (KBM PAN)
Warsaw Technical University (PW)

After names of sites the abbreviation of institution concerned is marked, which enables to find detailed informations. Analyses were made unselfishly by the following laboratories: Laboratory of Experimental Physics at Groningen (Gro)
Carbon 14 Dating Laboratory, Copenhagen (K)
Humble Oil Refining Company, Laboratory in Houston (Texas) (Hst)
Carbon 14 Laboratory, Heidelberg - Munich K/O (H)
Carbon 14 Laboratory, Hannover (Hv)
Laboratory of Leningrad Department of Archaeological Institute (RUL)

Some analyses were made in the Laboratory of Absolute Geochronology of the Polish Academy of Science in Gdańsk (Gd)

There are three points in the description of each site:
I — geological and geomorphological situation of a site and character of sediments, II — approximate determination of relative age of sediments, III — absolute age of a sample obtained by means of radiocarbon ^{14}C dating, symbol of the laboratory and symbol of the sample are added. The sites are put in the alphabetic order.

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[1] Compiled by Dr Zofia Michalska, Department of Quaternary Geology, Institute of Earth Sciences, Polish Academy of Sciences, Warsaw.

Błoto Mostowe, Puck district (KBM PAN)

I — A sample was taken from the Reda ice marginal streamway (*pradolina*) in the distance of 2000 m from the sea shore. The sample of alder wood taken from sands of the shore ridge of the older Baltic phase. This ridge is underbedded by pretransgressive peats and covered on sides by post-transgressive ones. The piece of wood was taken from the point situated 3 m a.s.l., II — Subboreal — Subatlantic Period, III — 1940±220 (Gd — 9).

Bruszczewo, Kościan district (AM Pozn)

I — site 5, settlement situated on a slope of peninsular hill surrounded by the old valley of Samica River. The east slope of the peninsula is high and steep with a small stream at the foot of it. The west slope is gentle and joins neighbouring morainic hills. References: Pieczyński Z., Ślady uprawy roli z młodszej epoki brązu w Bruszczewie, pow. Kościan (Traces of Agriculture of Younger Bronze Age at Bruszczewo, Kościan district), *Fontes Archaeologici Poznanienses*, 17 (1966), pp. 277 - 281; II — the end of the first and the beginning of the second period of the Bronze Age, III — 1340 BC (Gro).

Brzeg Dolny, 23 km north-west of Wrocław (IG UWr)

I — A sample of fossil wood was taken from a young mud deposit of the Odra River at the depth of 3·34 m. References: Dumanowski B., Jahn A., Szczepankiewicz S., The Holocene of Lower Silesia in the Light of Results of First Radiocarbon Dating, *Bull. de L'Acad. Pol. de Sc., Serie des Sc. Geol. et Geogr.*, 10 (1962) 1, pp. 47 - 52, II — Late Holocene III — 2700±115 BC (Hst, Analysis No. 1467).

Ćmielów, Opatów district (ZP PAN)

I — Middle Neolithic settlement, pit 231, II — Holocene, Subatlantic Period, III — 2650 BC (Gro).

Ćmielów, Opatów district (ZP PAN)

I — Middle Neolithic settlement, pit 180, II — Holocene, Subatlantic Period, III — 2725±110 BC (H).

Ćmielów, Opatów district (ZP PAN)

I — Middle Neolithic settlement, pit 243, II — Holocene, Subatlantic Period, III — 2650 BC (Gro).

Ćmielów. Opatów district (ZP PAN)

I — Middle Neolithic settlement, pit 200, II — Holocene, Subatlantic Period, III — 2800 BC (Gro).

Ćmielów. Opatów district (ZP PAN)

I — Middle Neolithic settlement, pit 192, II — Holocene, Subatlantic Period, III — 2810 BC (Gro).

Dobra near Limanowa, the valley of the Łososina River (IB PAN)

I — A sample of *Pinus cembra* wood found in the Last Glacial terrace on the boundary of a solifluction layer and underlying peat-muds, II — Paudorf Interstadial (determined by means of palynological analysis and geological data), III — 32550±450 BP (Gro IV 5111, J. C. Vogel).

Dobrzyków, Gostynin district (PW)

I — A sample was taken from a soil with pieces of charcoal at the depth of 0·5 - 0·6 m in dune sands, II — Subatlantic Period, III — 1540±210 in the geochronological scale, 1610±210 in the absolute scale (Gd — 27).

Dzierzgoń, Sztum district (IGF UT)

I — The sample of peat taken from the depth of 9·35 - 9·45 m from the bore hole, from the organogenic sediments of the Dzierzgoń River terrace, connected with the delta area of the Vistula River. Profile see below: 0·0 - 6·0 — peat, 6·0 - 9·35 — river silt, 9·35 - 9·45 — peat, 9·45 - 10·30 — gyttja, 10·30 m — sands and gravels, II — Turn from Preboreal to Boreal Period — according to the palynological analysis (after J. Stasiak 1967), III — 7140±360 BP (Gd — 65).

Elbląg (KBM PAN)

I — The sample of oak wood was taken from the layer separating the marine and eolian deposits in a slope zone of the Elbląg Upland (6 m a.s.l.), — Subboreal - Subatlantic Period, III — 1470±210 (Gd — 7).

Elbląg (KBM PAN)

I — The sample was taken from the peat layer between marine and eolian sediments in a slope zone of the Elbląg Upland (like the sample of wood described perviously), II — Subboreal — Subatlantic Period, III — 1800±220 (Gd — 8).

Gołaszewo, Włocławek district (PW)

I — The sample was taken from a soil with pieces of charcoal at the depth of 1·5 - 1·65 m in dune sands. II — Subatlantic Period. III — 130?±200 (Gd — 28).

Grzybiany near Legnica (IG UWr)

I — A sample of fossil wood was taken from organogenic deposits of the third terrace which is 2·5 m high (above the level of Koskowickie Lake). References: see Brzeg Dolny. II — —, III — 2850±115 BP (Hst, Analysis No. 1463).

Hamernia, Lubaczów district, the valley of the Lubaczowka River (IB PAN)

I — Two samples were taken from a layer of peat in a natural section of the south bank of the Lubaczowka River. The peat lays at the depth of 1·82 - 2·32 m under sands and sands with gravels and on a clay layer 1·63 m thick and a 50 cm thick layer of sand, II — basing on geological criteria W. Szafer (The Oldest Interglacial in Poland. *Acad. Pol. d. Sc. et d. Lettr. Bull. Intern., ser. B,* 1931) determined this peat as the Oldest Interglacial one (Sandomirien). Then E. Rühle and A. Środoń (Rühle E., Przekrój geologiczny doliny Lubaczówki pod Hamernią, Sum. Geological Section of the Lubaczowka Valley near Hamernia, *PIG Bull.* 66, 1952, pp. 285 - 309, Środoń A., Ostatni glacjał i postglacjał w Karpatach, Sum. Last Glacial and Postglacial in the Carpathians, *PIG Bull.* 67, 1952, pp. 27 - 77) basing on geological criteria considered this peat to be the Late Glacial and Holocene one, III — No. 10 — ⟩ 30000 BP (Hv — 171 J. Homilius), No. 11 — ⟩ 30000 BP (Hv — 172, J. Homilius).

Jakuszec — on the pass between Karkonosze and Izera Mountains — 900 m. a.s.l. (IG UWr)

I — A sample was taken from the bottom part of peat layer which is 3 m thick, II — —, III — 10075±210 BP (Hst, Analysis No. 1468).

Jerzmanowice, Olkusz district (ZP PAN)

I — Nietoperzowa cave, culture layer 6 of the section. References: Chmielewski W., *Civilisation de Jarzmanowice,* Wroclaw 1961, pp. 92, II — the advance of the Last Glaciation, III — 38160±1250 BP (Gro — 2181).

Karpacz, Karkonosze Mountains (IG UWr)

I — A sample was taken from a layer of ashes (coals) appearing on a terrace of the Łomnica River at the altitude 1030 m a.s.l., II — XVIII - XIX century, III — 150±100 BP (Hst, Analysis No. 1466).

Karsibór Peninsula, Świnoujście district (KG UT)

I — The sample of peat taken from the depth of 2·5 m in the depression between dune ridges. Profile see below: 0·0 - 1·9 — dark brown sphagnun peat highly decomposited, 1·9 - 2·3 — reed — sedge peat highly decomposited, 2·3 - 2·6 m — peat very highly decomposited contaminated by sand. Detail description of the terraine and the documentation in: Z. Prusinkiewicz, B. Noryśkiewicz, Zagadnienie wieku bielic na wydmach brunatnych Mierzei Świny w świetle analizy palynologicznej i datowania radiowęglem ^{14}C, *Zesz. Nauk. Tow. U. M. Kopernika, 14, Geografia V,* 1966. II — Firbas' zone VIII — according to palynological analysis, III — 4810±365 (Gd — 45).

Karsibór Peninsula, Świnoujście district (KG UT)

I — The sample of peat taken from the depth of 1·45 m in the depression between dune ridges. Profile see below: 0·0 - 0·8 — dark brown wood-peat very highly decomposited, 0·8 - 1·3 — wood-peat sufficiently decomposited, 1·3 - 1·5 m — reed peat sufficiently decomposited, with silt. References as above, II — Firbas' zone VIII — according to the palynological analysis, III — 3053±285 (Gd — 50).

Karsibór Peninsula, Świnoujście district (KG UT)

I — The sample of peat taken from the depth of 0·9 m in the depression between dune ridges. Profile see below: 0·0 - 0·3 — grey-brown sedge peat highly decomposited, 0·3 - 0·7 — brown peat almost completely decomposited. 0·7 - 1·0 m — sedge reed peat very highly decomposited. References as above, II — Firbas' zone IX — according to the palynological analysis, III — 2910±445 (Gd — 46).

Kępa Swarzewska, Puck district (KBM PAN)

I — A piece of oak wood deposited at the abrasion surface. The wood was probably redeposited and a determination of age cannot be based on it, II —, III — 1550±220 (Gd — 44).

Konin—Gosławice, Poznań voivodeship (IG CUG)

I — A sample was taken from a gyttja-peat layer about 6 m thick underbedded by sands and humic silts, filling up an erosional cutting. References: Rutkowski E., Czwartorzęd Wysoczyzny Północnokonińskiej i jego podłoże (Sum. The Quaternary of the North - Konin High-Plain and its Bedrock) *IG Prace,* 48 (1967), pp. 5 - 79, II — Late Glacial (palynological analysis by Z. Borówko-Dłużakowa, Archives of IG, 1960, elaboration continued), III — 11800±120 BC (Gro, 2024, Hl. de Vries 1961).

Konin—Marantów, Poznań voivodeship (IG CUG)

I — A sample was taken from 9 m thick layer of gyttja and peat underbedded by sands. These sediments are situated in the river valley eroded during the later part of the Eemian Interglacial and covered by a boulder clay of the Last Glaciation. References: as above, II — Brorup (on the basis of palynological and macrofloristical analyses, Borówko-Dłużakowa Z., Badania paleobotaniczne osadów młodoplejstoceńskich (Brorup) w Koninie—Marantowie (Sum. Palaeobotanical Studies of Late Pleistocene Deposits — Brorup — in the Konin - Marantów Area), *Prace IG*, 48 (1967), pp. 81 - 136), III — > 52000 BP (Gro 2566, Hl. de Vries).

Kraków—Rondo, the Vistula valley (IB PAN)

I — A sample was taken from a layer of peat in the Rendzina terrace. The peat is covered by sands and clays and underbedded by gyttja with lenses of dark-grey fine sand. There are sand and gravels of the Vistula river at the bottom of the terrace. Terrace sediments are underbedded by Tertiary clays (Krakowieckie clays). II — the end of the Younger Dryas (on the basis of palynological analysis), III — 9390±180 BP (H, 1458 - 1031).

Kraków—Zwierzyniec Quarter, the Vistula valley (IB PAN)

I — A piece of a trunk of a black oak *Quercus sp.* from a Holocene terrace of Vistula, II — —, III — 1775±280 BP (Gd — 15).

Kruklin, Giżycko district (IG UW)

I — Trunks of pine and birch covered by lacustrine sediments, II — Alleröd, III — 11390±210 BP (Hv, 122).

Laska near Brusy, Bydgoszcz voivodeship (IG CUG)

I — A sample was taken from a set of organic sediments: calcareous mud and gyttja underbedded by humic sands, 1·75 m thick. These sediments lay on high terraces of the lakes Duże Głuche and Małe Głuche in the northern part of Tuchola outwash plain. References: Słowiański W. Wczesnoholoceńskie osady jeziorne w Lasce koło Brus (Sum. Early Holocene Lacustrine Deposits at Laska near Brusy — Northern Poland), *Kwart. geol.,* 5 (1961), 3 pp. 720 - 736, II — Preboreal Period — on the basis of palaeobotanical analysis, Borówko-Dłużakowa Z., Analiza pyłkowa osadów jeziornych w Lasce koło Brus na Pojezierzu Pomorskim (Sum. Pollen Analysis of Lacustrine Deposits at Laska near Brusy), *Kwart. geol.,* 6 (1962), 1, pp. 170 - 176, III — 9680±160 BP (Hv, 123, J. Homilius 1961).

Łążek near Zaklików, Kraśnik district, the valley of the Sanna River (IB PAN)

I — A sample was taken from a peat layer 24 cm thick in a natural section of a terrace 7 - 9 m high. The peat layer is situated in the top part of sandy silt deposits of the terrace, dated as an equivalent of the Last Glaciation. The terrace sediments are underbedded by morainic sediments of Cracow Glaciation. References: Bielecka M., Warunki geologiczne występowania torfu interstadialnego w okolicy Zaklikowa (Sum. Geological Conditions of Occurrence of Interstadial Peat in the Region of the Zaklików—Sandomierz Lowland), *Kwart. geol.*, 4 (1960) 1, pp. 205 - 217, II — Alleröd — on the basis of a pollen analysis, III — 25580^{+3270}_{-2420} BP (Gd — 14).

Mikołajki, Mrągowo district (IG PAN)

I — A sample was taken from a set o gyttja and peat layers dated back by means of palynology on the time from Alleröd till Subatlantic Period. II — Preboreal Period, III — 9330 ± 400 BP (Gd — 61).

Mikołajki Lake, Mrągowo district (IB PAN, IG PAN)

I — A sample was taken from a 30 cm layer of peat overlaid by 5·3 m of grey calcareous gyttja. These sediments were obtained at the distance of 70 m from the lake shore, from the bottom of this lake which is 1·7 m deep in this place. The peat is underbedded by clay with sand and gravel (according to IB PAN) or by morainic material (according to IG PAN). References: Ralska-Jasiewiczowa M.. Osady denne jeziora Mikołajskiego w świetle badań paleobotanicznych (Sum. Bottom Sediments of the Mikołajki Lake — Masurian Lake District — in the Light of Palaeobotanical Investigations), *Acta Palaeobot.*, 7 (1966) 2, pp. 1 - 118, Wieckowski K., Osady denne jeziora Mikołajskiego (Sum. Bottom Deposits of the Mikołajki Lake), *Prace Geogr. IG PAN*, 57, (1966), pp. 7 - 112, II — Alleröd — on the basis on pollen analysis, III — 11040 ± 360 BP (Gd, — 36).

Mikołajki Lake, Mrągowo district (IB PAN, IG PAN)

I — A sample was taken from a peat obtained from the northwest part of the lake from a depth of 15·5 m at the distance of 150 m from the shore. The layer of the peat is 20 cm thick and underbedded by fluvioglacial sand and overlaid by calcareous gyttja. References: as above, II — Alleröd — on the basis of pollen analysis, III — 10700 ± 460 BP (Gd — 35).

Mierzeja Łebska (Sand-bar of Łeba) (IG PAN)

I — The first sample was taken from a humus layer (peat with pine bark) at the depth of 1·5 m (5·5 - 5·6 m a.s.l.) covered by 120 cm of recent eolian sand. The second sample (charcoals) was taken from a grey dune sand at the depth of 2·0 (5·0 - 5·5 m a.s.l.), just above an ortstein horizon. Unpublished material obtained by Prof. J. Kobendza, II — —, III — the first sample — 610±315 BP, the second one — 2035±315 BP (Gd).

Na Grelu near Ludzimierz, Nowy Targ district, the valley of the Czarny Dunajec River (IB PAN)

I — A sample of peat was taken from a peat bog which is 5·85 m thick. The bog is situated on a fluvioglacial terrace of the Last Glaciation. References: Koperowa W., Późny glacjal z północnych podnóży Tatr w świetle analizy pyłkowej (Sum. A Late Glacial Pollen Diagram at the North Foot of the Tatra Mountains), *Monogr. Bot.* n. 7, 1958, pp. 107 - 133, II — the decline of Alleröd or the beginning of the Younger Dryas, on the basis of pollen analysis, III — 10810±200 BP (K, H. Tauber).

Nieborowa — Uroczysko. Chełm Lubelski district (ZP PAN)

I — A sample of charcoals was taken from a fire place at the depth of 70 cm, at the bottom of the illuvial horizon (B 2/3) of subfossil podsol. Ground water level is now at the depth of 1·9 - 2·4 m, II — Holocene, Boreal Period, III — 6285±160 BC (RUL 620 sample 335).

Piaseczno near Tarnobrzeg, Rzeszów voivodeship (IG PAN)

I — A piece of wood from the bottom part of gravel deposits filling up the pre-Vistula valley. References: Mycielska-Dowgiałło E., Formy szczelinowe i inwolucyjne w piaskach i żwirach doliny Wisły koło Tarnobrzega (Sum. Frost Fissures and Involutions in Sands and Gravels of the Vistula Valley near Tarnobrzeg), *Biul. Perygl.* 16, 1967, pp. 203 - 215, II — Last Glaciation, III — 40700±2000 BP (Gro, GrN — 4868).

Przytor Peninsula, Świnoujście district (KG UT)

I — The sample of peat taken at the depth of 1·05 m in the depression between dune ridges. Profile see below: 0·0—0·7 — wood peat, sufficiently decomposited, 0·7—1·1 m — reed peat, almost completely decomposited, contaminated by sand. Detail description of the terrain and the documentation in: Z. Prusinkiewicz, B. Noryśkiewicz, Zagadnienie wieku bielic na wydmach brunatnych Mierzei Świny w świetle analizy palynologicznej i datowania radiowęglem ^{14}C, *Zesz. Nauk. Tow. U. M. Kopernika, 14 Geografia V,* 1966, II — Firbas' zone IX according to palynological analysis, III — 1405±230 (Gd — 49).

Przytor Peninsula, Świnoujście district (KG UT)

I — The sample of peat taken from the depth of 2·6 m in the depression between dune ridges. Profile see below: 0·0—0·3 — dark-brown sedge peat, highly decomposited, 0·3—2·6 .— peat sufficiently decomposited. References as above, II — Firbas' zone VIII — according to palynological analysis, III —4460±300 (GD — 47).

Przytor Peninsula, Świnoujście district (KG UT)

I — The sample of brown highly decomposited peat taken from the depth of 56 cm. The peat is highly contaminated by sand. References as above, II — Firbas' zone IX — according to palynological analysis, III — 145?±225? (Gd — 48).

Szczepidło, Konin district (ZP PAN)

I — Archeological site, fire-layer below illuvial horizon of an old soil in a dune, 10 - 60 cm above present ground-water level, II — Early-Middle Holocene, III — 22000±80 BP (RUL 618, sample 334) the result of radiocarbon dating is questionable.

Szewna near Ostrowiec Świętokrzyski, Opatów district (IG PAN)

I — A terrace of the Kamionka River (tributary of Kamienna) 6 m high (175 m a.s.l.) composed of loess-like silts with admixture of sands and Lias sandstone rubble. The silts are underbedded by a grey clayey, medium-grained sands, II — from decline of Last Glaciation till Holocene, III — the first sample — (charcoal) taken from the depth of 3·0 m — 4340±260 BP (Gd — 34), the second one — (wood) from 5·5 m — 2560±220 BP (Gd — 33).

Tuchlin on Bug River

I — A piece of a black oak wood from the bottom part of flood terrace sediments of Bug. References: Mościcki W., Pierwsze wyniki datowania wieku drewna kopalnego w Polsce metodą radiowęgla (Sum. First Results of Age - Determination of Fossil Wood in Poland by the ^{14}C Method), *Acta Geol. Pol.*, 3 (1953) 1, pp 187 - 190, II — —, III — 6500$\pm\frac{1150}{1300}$ BP (Gd).

Wadowice, the Skawa valley (IB PAN)

I — A sample of *Picea sp.* wood obtained from terrace sediments of the Last Glaciation. The wood was found in a peat layer unerbedded by sands and silts and covered by a set of loams and sands passing to a solifluction covering composed of clayey sands with coarse rubble of flysch sandstone. References: Sobolewska M., Starkel L., Środoń A., Młodoplejstoceńskie osady z florą kopalną w Wadowicach (Sum. Late Pleistocene Deposits with Fossil Flora at Wadowice), *Folia Quatern.*, 16 (1964), pp.

1 - 64, II — Brörup, on the basis of pollen analysis, III — > 40000 BP (K — 716, H. Tauber).

Witów, Łęczyca district (IB PAN)

I — A sample of charcoals was collected from the boundary of older and younger part of dune. References: Chmielewska M., Chmielewski W., (Res. Stratigraphie et chronologie de la dune de Witów district de Łęczyca), *Biul. Perygl.*, 8 (1960), pp. 133 - 141, Wasylikowa K., Roślinność i klimat późnego glacjału w środkowej Polsce na podstawie badań w Witowie koło Łęczycy (Sum. Vegetation and Climate of the Late-Glacial in Central Poland Based on Investigations made at Witow near Łęczyca), *Biul. Perygl.*, 13 (1964), pp. 261 - 417, II — the decline of Allerod or the transition period to the Younger Dryas, on the basis of pollen analysis, III — 10815 ± 160 BP (Gro. 828, Hl. de Vries).

Witów, Łęczyca district (IB PAN)

I — A sample was taken from gyttja layer covered by dune at the depth of 250 - 260 cm. References as above, II — The Older Dryas, on the basis of pollen analysis, III — 11900 ± 180 BP (K, 706).

Witów, Łęczyca district (IB PAN)

I — A sample was taken from gyttja layer covered by dune at the depth of 266 - 270 cm. References as above, II — The younger part of Bolling, on the basis of pollen analysis, III — 12100 ± 140 BP (K, 708, H. Tauber).

Witów, Łęczyca district (IB PAN)

I — A sample was taken from gyttja layer covered by dune at the depth of 270 - 276 cm. References as above, II — The older part of Bolling, on the basis of pollen analysis, III — 12260 ± 140 BP (K, 707, H. Tauber).

Witów, Łęczyca district (IB PAN)

I — A sample was taken from a layer of moss peat at the depth of 280·5 — 285·0 cm. References as above, II — the decline of the Oldest Dryas, on the basis of pollen analysis, III — 12240 ± 230 BP (K, 709, H. Tauber).

Witów, Łęczyca district (IB PAN)

I — A sample of *Pinus sp.* wood from the boundary of older and younger dune. References as above, II — the decline of Allerod, on the basis of pollen analysis, III — 11020 ± 170 BP (K, 952, H. Tauber).

Witów, Łęczyca district (IB PAN)

I — A sample of *Pinus sp.* wood from mesolithic culture layer at the border of peat bog and dune, II — Preboreal or Boreal Period, pollen analysis in elaboration by K. Wasylikowa, III — 8160±140 BP (K, 954, H. Tauber).

Witów, Łęczyca district (IB PAN)

I — A sample of *Quercus sp.* wood from neolithic culture layer at the border of peat bog and dune, II — in elaboration by K. Wasylikowa, III — 3410±110 BP (K, 953, H. Tauber).

Zator, Wadowice district, the Skawa valley (IB PAN)

I — Pieces of *Salix sp.* wood obtained from a peat layer in the Upper Pleistocene terrace composed of (beginning with the top) loess-like silt, peat muds with a layer of the peat underbedded by bluish loam and sands with alluvial gravels. References: Koperowa W., Środoń A., Pleniglacial deposits of the Last Glaciation at Zator, *Acta Palaebot.*, 6 (1965) 1, pp. 1 - 31, II — Pleniglacial, on the basis of pollen analysis and geological criteria, III — > 40000 BP (K, 719, H. Tauber).

Zelazna, Opole district (M S O)

I — The sample of the wild bees' nest wood, taken from the bottom of the Odra River in 1904. II —. III — 1100±200 BC (Gd — 6).

The above list must be supplemented with the results of radiocarbon dating made by the Gdańsk Laboratory of the Institute of Nuclear Research of the Polish Academy of Sciences, which have been published in 1967[2]. The following text is quoted after that paper.

List of results of measurements performed in 1962 - 1965

Gd — 22.	Sample of charcoal from excavated blast-furnaces of Boleszyn — furnace No 2	2080±240
Gd — 23.	Sample of charcoal from furnace No 10 at Boleszyn	2670±240
Gd — 24.	Sample of charcoal from the post-furnace cavestand No 1 at Boleszyn.	1580±210
Gd — 25.	Charcoal from furnace No 17 stand 1 at Podchelm, Kielce district	2580±220

Dating carried out from Sept. 1 to Oct. 10, 1962, on erquest of the Academy of Mining and Metallurgy in Cracow.

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[2] W. Mościcki, A. Bujko, J. Dudkiewicz, A. Zastawny, Gdańsk ^{14}C Laboratory Measurements, *Acta Physica Polon.*, 32 (1967) 1.

Gd — 37. Charcoal of Ostaniec (sample III No. 3) taken out of the dune sand on the Łeba Spit. 1920 ± 200

Gd — 38. Humus from the sandhills of the Łeba Spit. 490 ± 140

The measurements of the Gd — 37 - 38 samples were carried out on request of the Institute of Geography of the Polish Academy of Sciences, Warsaw.

Dates of measurements: Gd — 37 - 38 from Dec. 11, 1963 to March 7, 1964.

Gd — 62. Peat taken at Brzeźno from a depth of 8·0 m below terrain level. 7570 ± 370

Gd — 63. Peat sample, as above taken from a depth of 9·2 m. 8550 ± 330

The dating was performed from April 3 to 25, 1965 for the Department of Physical Geography at the Nicholas Copernicus University in Toruń.

Gd — 29. Peat from the sea bottom (test No 13). 5390 ± 300

Gd — 30. Peat from the sea bottom (test No 30). 9200 ± 400

The ages were determined between November 9 and 25, 1962 on request of the Institute of Oceanography in Gdynia.

Gd — 51. Peat from the upper surface of the Jamno Lake (No III). 6200 ± 600

Gd — 52. Peat from the lower section of the Jamno Lake (No III). 6390 ± 570

Gd — 53. Peat in which wood prevails, taken from the Szczecin Lagoon (samples 32 - 39). 6000 ± 320

Gd — 54. Peat taken from the Vistula Lagoon (No 10 — samples 44 and 45). 6340 ± 310

Gd — 55. Peat — Vistula Lagoon No 10 B — samples 60 - 65, 69 - 75. 5430 ± 310

Gd — 56. Peat — Szczecin Lagoon — samples taken from the depth of 1·23 - 1·41 m below the bottom level. 6420 ± 340

Gd — 57. Peat — Vistula Lagoon — samples No 2a, 92 - 93. 4380 ± 440

Gd — 58. Peat — Puck Bay — No 2, from a depth of 0·2 - 0·5 m below the bottom. 7600 ± 370

Gd — 59. Peat — Puck Bay — No 2, from a depth of 0·7 - 1·05 m below the bottom. 6590 ± 330

Gd — 60. Post-glacial peat from the Mecklenburg Bay (No 46 - 60). 5700 ± 590

The measurements were taken on November 21, 1964 and April 1, 1965 for the State Institute of Hydro-Meteorology.

II. GEOMORPHOLOGY AND PALAEOHYDROLOGY

THE GLACIAL RELIEF OF NORTH POLAND IN THE LIGHT OF THE DETAILED GEOMORPHOLOGICAL MAP OF THE POLISH LOWLAND IN 1 : 50 000 SCALE

RAJMUND GALON

This paper is intended to serve two purposes: to emphasize the most important assemblages of Quaternary landforms on the glacial lowland by means of a number of fragments of the Detailed Geomorphological Map concerning selected areas of the Polish Lowland and to explain to readers interested in geomorphological cartography how useful this map can be for this purpose. The area covering the Polish Lowland contains all the most typical form assemblages produced by the Pleistocene glaciation and by postglacial relief-forming processes. The above map, based on a geomorphological field survey made in 1 : 25 000 scale, has been compiled by the Department of Geomorphology and Hydrography of the Polish Lowland of the Geographical Institute of the Polish Academy of Sciences at Toruń; this collective work of geographers from Toruń, Poznań and Warszawa which took twenty years to prepare, is meant to stress the characteristic features of a glacial landscape and its dynamic transformations during the Late-Glacial and Postglacial. This, therefore, is a map limited in subject-matter treated and in extent; on top of this, it is simplified graphically, i.e. it lacks contour lines. This latter shortcoming is compensated by the map's morphometric and morphographic contents. For economy's sake the map shows only three colours (fragments of the map attached). In view of the Detailed Geomorphological Map embracing selected areas of the Polish Lowland being a preliminary edition, it is possible that in future a multi-coloured geomorphological map of the Polish Lowland in 1 : 50 000 scale will appear, with its contents adapted to the principles suggested by the Subcommission for Geomorphological Maps of the International Geographical Union, with Professor Mieczysław Klimaszewski as head. At any rate, the Detailed Geomorphological Map of the Polish Lowland, as compiled in Toruń and in its cooperating centres, covers actually a total of some 8736 sq. km; by this it takes a prominent place among similar cartographical publications (see Reference).

In turn the characteristics of the glacial landscape of the Polish Lowland shall be contemplated by a close study of the attached fragments of selected parts of the geomorphological map, which in 1 : 50 000 scale present the most important and most characteristic assemblages of lowland forms. In order to facilitate the appraisal of the geomorphological picture of the fragments of these selected parts, the — incidentally rather scanty — network of settlements and roads has been left out. As to their cartographical contents the individual fragments of the geomorphological map show certain differences; these are the result of an enrichment in the details shown, which the authors were able to add while successive sheets were being compiled; still, this in no way affects the essential cartographical features of the relief elements illustrated on the map.

In the selected twelve fragments of some of the sheets of the 1 : 50 000 Detailed Geomorphological Map concerning selected areas of the Polish Lowland, lines drawn in various thicknesses indicate the boundaries between moraine plateaus and valley or subglacial type depressions. It must be kept in mind, that the most significant feature of a lowland landscape of glacial origin is the upland character of the moraine plateau which represents the reference level with regard to the numerous positive forms the plateau contains on the one hand and, on the other, to the equally numerous negative forms dissecting this plateau like valleys, subglacial channels, undrained basins, etc. This plateau- or table-like nature of the glacial landscape of the lowland is clearly illustrated on the selected map fragments; these picture has been emphasized by the multitude of valleys and similar forms which, on the whole, are deeply and distinctly incised — as has been marked on the map by heavy lines indicating division lines between plateaus on the one hand and valleys or channels on the other. For all this, the moraine plateau, as has been said above, looks only to a limited extent like a flat surface; it is diversified by numerous marginal forms of the inland ice, by outwash plains left by meltwater streams, and by minor negative land forms typical of a young postglacial landscape (Fig. 1). The 1 : 50 000 map also shows all later transformations of the glacial relief, especially all depressions and more important breaks in land relief such as slopes of end moraines and valley slopes produced by the erosional and denudational processes which took place under the variable morphoclimatic conditions ruling during the declining phases of the Pleistocene and in the Holocene. Also pictured on the map are present-day relief-forming processes, and this illustrates the dynamics and the trends by which today's land relief is being transformed. This shows that, apart from palaeomorphological elements, the geomorphological map also contains dynamic accents and that, besides actually important morphometric and morphological illustrations it additionally brings morphogenetic explanations. Hence, to some extent, the map represents an abbreviated history of the evolution of the land relief as it is today, and an anticipation of transformations to come.

MAP No 1 (Sheet KOWALEWO, elaborated by W. NIEWIAROWSKI)

The study of the attached fragments of selected sheets of the discussed geomorphological map starts with a typical example of a moraine plateau dissected by subglacial channels; moreover, it contains minor lakes, and northwards it abuts upon the Drwęca valley. The channel valleys are relatively deeply incised as seen from the altitudes given on the map and, especially, from the thickness of the lines marking the height of breaks in altitudes when in excess of 20 m. The channels shown on the map distincly cross each other; one of them is rather narrow and has a flat peat-filled floor with small lakes, while the other, formerly a subglacial channel, is strongly disarticulated with a floor containing a variety of meltwater kettles.

Somewhat different in character is the edge of the Drwęca valley; it is very much dissected and shows a great number of small valleys often resembling slope ravines, especially where at the base of valley slopes fragments of older valley terraces lie spread out. This slope dissection of the Drwęca valley is evidence of an older age of this valley than that of the less strongly transformed scarps of the subglacial channels which did not develop until the decline of the Pleistocene or the rise of the Holocene. All along the slopes a zone of denudational degradation can be seen; this zone cuts back into the moraine plateau while at the slope bases colluvial deposits have accumulated forming a zone of aggradation. For the most part the moraine plateau is flat, only in some places it shows a undulant pattern. Visible are numerous kettles lacking surface drainage — an indication of the young age of this glacial landscape.

Thus this fragment of the geomorphological map presents an assemblage of Pleistocene land forms and a picture of relief-forming processes now under way which tend to extenuate the original glacial forms. These latter processes are particularly concentrated in the zone of valley slopes where they show typical features of what is called slope processes.

MAP No 2 (Sheet POZNAN, elaborated by E. TOMASZEWSKI)

This map fragment presents a moraine plateau dissected in its right--hand part by a typical subglacial channel containing a number of lakelets. The central part of this map, on the other hand, shows a wide terminal channel valley containing a lake up to 40 m deep, and passing on into a widespread outwash plain. The topography of this region indicates that during a stoppage of the inland ice an enormous outlet of glacial waters must have existed here from which an evorsively escaping meltwater stream flooded the wide forefield and piled up a typical outwash cone; near the channel outlet this cone consists of stratified gravels and, even, of well rounded pebbles intercalated with coarse sands, while farer away it is built of deposits of increasingly finer granulation.

MAP No 3 (Sheet ŁABISZYN, elaborated by B. ROSA)

This map shows the fragment of a landscape with marginal forms dating back from the Kuyavian Substage; this region is situated south--west of Bydgoszcz. Here can be seen a big fragment of a huge arc of end moraines with relative heights up to 70 m. The hinterland of these end moraines is an undulated moraine plateau. Inside the moraine arc, however lies an extensive flat depression accentuated by a peat-filled meltwater kettle which formerly held a lake. This is a typical terminal depression developed by exaration of a minor glacier tongue which afterwards, piling up its moraine material, formed in this way the arc of thrusted end moraines mentioned. Spread out at the bases of these moraines are minor size outwashes. The upper part of the map shows the fragment of a relatively small but distinctly developed glacial valley; by way of this valley meltwater from the inland ice ran off westwards, after the inland ice had retreated northwards. However, this flow was relatively short-lived because, later, for both the meltwater and the fluvial waters arriving from the south of the Noteć - Warta (also called the Toruń - Eberswalde) ice marginal streamway (*pradolina*) became the main runoff track. The discussed terminal depression is drained externally, northwards, and the valley of this creek also cuts by a sharp incision the former glacial valley which today is filled up with sandy deposits of outwash type.

MAP No 4 (Sheet SZTUM, elaborated by Z. EJTMINOWICZ)

Less easily discernible as to origin is the end moraine landscape shown in this map: these moraines belong to the internal morainic ranges of the Pomeranian Stage and are situated within the wide Vistula lobe south-east of Malbork. Here the crests of both accumulation and thrust moraines run from NNE to SSW with an undulating moraine plateau as background. They form clearly noticeable longitudinal ridges; the distances between these ridges extend beyond the margin of the selected fragment of the geomorphological map. The surface of the crests of these end moraines is much variegated; it contains numerous undrained depressions — proof of the young age of these marginal forms of the inland ice. Closed basins of this type can also be seen outside the end moraine ridges. The largest among them lies in-between moraine ridge courses, and in its deepest part it contains a lake with a maximum depth of about 30 m. This is a typical end moraine lake.

The relative height of the end moraines (with regard to the water level in the lake) reaches 37 m and, considering the lake bottom 67 m. Above sea level moraine plateau rises 35 to 40 m. Compared with the altitude of the moraine plateau shown in the preceding map which covered, further south, the region of Bydgoszcz, the surface of the region discussed here is, in keeping with its nearness to the Baltic Sea, more than 60 m lower. This is why here the moraine ridges show correspondingly lower absolute altitudes.

MAP No 5 (Sheet WĄBRZEŹNO, elaborated by W. NIEWIAROWSKI)

Also assigned to marginal forms of the retreat by stages of the inland ice must be all kinds of kames built of fluvioglacial or limnoglacial deposits. These land forms are evidence of deglaciation, by way of decay of the inland ice into separate blocks of dead ice. The attached fragment of sheet Wąbrzeźno shows two extensive though relatively low (no higher than 5 m) kame hillocks. In their neighbourhood lie more or less extensive and, mostly, peat-filled kettles which reduce the area occupied by the flat or hilly moraine plateau. These depressions are kettles left by former dead ice blocks. Irrespective of these forms the area shown is traversed by two subglacial channels and meltwater valleys which must have drained the water flow from melting dead ice blocks. The western, larger subglacial channel which became uncovered after the ice masses held inside had melted, caused a break-off and a collapse of one of the kame hillocks. Apart from the above mentioned wide kames, visible near the right-hand margin of the map fragment are what are so-called dead ice moraines, shaped like low little hills, as well as small-size esker ridges. Thus, this map is an illustration of a typical dead ice landscape.

MAP No 6 (Sheet LIPNO, elaborated by M. LIBERACKI)

This map pictures an assemblage of drumlins which are rather rare in the Polish Lowland; this one is situated near Zbójno an the Dobrzyn moraine plateau. Here the drumlins appear on some kind of surface which lies below the level of the moraine plateau. This plateau as well as the plain carrying the drumlins are dissected by subglacial channels filled in their deeper parts with lakelets. The difference in altitude between the moraine plateau and the floor of the subglacial channels is 25 to 30 m.

The drumlins appear in the shape of relatively narrow ridges averaging 5 to 9 m in relative height. Their structure consists of boulder clay in the crest part and of stratified fluvioglacial deposits underneath. The average length of these drumlins is from 150 to 750 m, their width from 70 to 150 m. The top of the drumlins lies lower than the top of the moraine plateau. The elongated depressions separating individual drumlins show the features of minor subglacial channels, with numerous small steps and hollows. The parallel run and the compact pattern of the drumlins is evidence of their common origin. At any rate, in the Zbójno region they originated subglacially with the co-action of erosive glacial waters, although a certain participation of erosion by ice is not excluded.

MAP No 7 (Sheet PISZ, elaborated by M. BOGACKI)

This map shows a small fragment of a wide and typical outwash plain, accumulated by meltwater flow during the Pomeranian Stage while the inland ice had stopped in Mazuria. The meltwater streams tended towards the Warsaw Basin, and they continued their flow by way of the Vistula valley into what was then the Notec - Warta ice marginal streamway (*pradolina*). The track of this ancient meltwater flow is followed today by the Pisa River, a tributary of the Narew; this river runs in its own valley incised several meters into the outwash plain. Numerous meanders and oxbow lakes of the Pisa River are evidence of the low gradient of this river valley. The sandy outwash surfaces are variegated by dunes, some of which show features typical of parabolic dunes, with deflation hollows in their centres. These dunes were produced during the declining phase of the Pleistocene by the action of western winds.

This fragment of the geomorphological map also involves the margin of a moraine plateau which shows a flat surface with an end moraine dating back from the maximum extent the Last Glaciation reached in this region.

MAP No 8 (Sheet NOWE MIASTO, elaborated by Z. CHURSKI)

Contrary to the preceding fragment of the geomorphological map which illustrated an outwash landscape, this fragment shows a relief with marked contrasts, caused by the deep incision of the Drwęca valley into the moraine plateau. In the area under discussion the difference between the floor of the Drwęca valley and the surrounding undulant surface of the plateau is locally as much as 60 m.

The edge of the moraine plateau is strongly dissected; small lateral valleys are deeply incised and reach far back into the moraine plateau causing its degradation. Apart from the larger valleys of erosive origin the zone of the valley slopes contains numerous tiny denuding valleys. For the most part the floors of these small lateral valleys abut upon the highest Drwęca terrace, at the level of which the meltwater streams were escaping, which had arrived from the inland ice farer north. Hence the age of these valleys is late-glacial, and these land forms must have developed in a periglacial climate.

The floor of the Drwęca valley contains erosive or erosive-accumulative (what is called cut-and-fill) valley terraces. Apart from the highest terrace mentioned, the map fragment shows the three next terraces which have been dated from the decline of the deglaciation period and the rise of the Holocene. The flood terrace is nowadays being widened by lateral erosion of the meandering river. The lower part of the map fragment shows in the valley terrace a peat-filled meltwater kettle.

MAP No 9 (Sheet KOWALEWO, elaborated by W. NIEWIAROWSKI)

This map fragment shows the lower reach of the Drwęca valley, a higher reach of which has been discussed in Map No 8. Here one notes a typical valley landscape. The broad highest valley terraces which adjoin the edge of the moraine plateau go back to the Pleistocene, and their origin dates from the time when the river carried both meltwaters and fluvial waters. Thus in its original phase the Drwęca valley functioned as an ice marginal streamway (Polish: *pradolina;* German: *Urstromtal*). The northern valley scarp is distincly marked, but it has been considerably transformed by slope processes as shown by the fairly wide zone of degraded and aggraded deposits. Nearer the Drwęca lie younger river terraces incised into the pradolina terraces. Particularly noteworthy is that a strongly broken-up subglacial channel traverses the Drwęca valley or to be exact, its ice marginal streamway (*pradolina*). This valley represents some sort of superimposed river drainage on top of the subglacial channel which, though of older age, was at that time filled with ice. This may therefore be called an epigenetic process. Ice melting in the subglacial channel and, simultaneously, the disruption of the terraces took place relatively late, as shown by the fact that some of the younger valley terraces have also suffered destruction. At present the subglacial channel is for the most part filled with peat.

MAP No 10 (Sheet RZĘCZKOWO, elaborated by M. PASIERBSKI)

On sandy valley terraces, dunes characteristic by their parabolic shape have developed. Large assemblages of such dunes appear in the widened valley of the Vistula called the Toruń Basin. The fragment of the geomorphological map under discussion shows the terraces marked I, III, V, VI. The dunes were formed on the upper terraces where they appear in compact assemblages which in their outlines resemble the shape of individual parabolic dunes. Typical of the dune ridges is the asymmetry of their slopes; in addition, from the west adjacent to the dunes lie deflation hollows from which the dune material was derived. One glimpse of the map shows that the dunes have been piled up by western winds. The dune-forming processes began during the Preboreal and continued through the Boreal; a later less intensive period coincided with the Subboreal. Today the dunes are being scattered; as a rule their height is from 10 to 25 m, but some reach heights up to 45 m.

MAP No 11 (Sheet CHEŁMNO, elaborated by E. DROZDOWSKI)

This map fragment takes in the valley of the lower Vistula including a stretch of the moraine plateau which adjoins this valley. Noticeable in the valley, apart from today's Vistula channel. are former channels of branch fragments of this river and extensive flood embankments. The height of the moraine plateau is close on 70 m above the valley floor. The surface of the plateau itself is partly flat and partly undulant; it is much dissected by lateral valleys. In the floor of the Vistula valley these lateral valleys have their extensions in the form of alluvial cones. Most important among these valleys is the hanging valley of Browina. Widespread are here the zone of slope degradation and aggradation both intermixed with the cones mentioned.

MAP No 12 (Sheet KOLNO, elaborated by M. BOGACKI)

The area shown on this map fragment lies outside the extent of the Last Glaciation; its relief is old-glacial. The cartographical picture illustrates very distinctly the differences in landscape features between the

Last Glaciation and the one preceding it. In the first place no sharp breaks, in land relief are to be seen. While the Last Glaciation lasted, the surface of the moraine plateau including its end moraines have been degraded, i.e. levelled out and lowered by periglacial processes. Shallow yet wide denudation valleys have made deep incisions into the plateau. The valley slopes are gently flat and covered by solifluction material. Locally the boundary between the valley slopes and the peat-filled valley floor is difficult to perceive. All in all, this is an old and monotonous land relief.

This last map and, especially, its sharp contrast with the preceding map fragment, may serve as example how to appraise the value of the Detailed Geomorphological Map of the Polish Lowland for pointing out genetic features, altitude differences, and the evolution of contemporaneous relief-forming processes in given regions of glacial origin.

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The unified key of the detailed geomorphological map of the world 1 : 25 0000 - - 1 : 50 000. Folia Geographica PAN, Oddz. Kraków, 1968, 2.

Map 1. Moraine plateau

Map 2. Marginal zone

Map. 3. End moraine formed by an ice tongue

Map. 4. End moraine landscape

Map. 5. Dead ice landscape with kames

Map. 6. Drumlin field

Map 7. Outwash plain

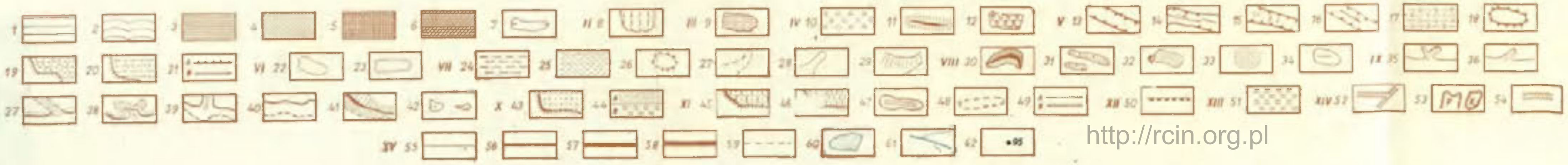
Map 8. Gap valley with deep lateglacial site valleys

Map 9. Subglacial channel crossing a pradolina (ice-marginal streamway)

Map 10. Inland dunes

Map 11. Valley slope of the lower Vistula

Map 12. Old glacial relief



EXPLANATION OF SYMBOLS

I. Pleistocene landforms produced by the depositional action of inland ice

1 — Flat moraine plateau (relative heights up to 2m, inclinations up to 2°), 2 — Undulant moraine plateau (relative heights 2 - 5 m, inclinations about 5°), 3 — Morainic hummocks preponderantly accumulative structure (relative heighs 5 - 10 m, varying inclination), 4 — Morainic hummocks preponderantly push structure (relative hights 5 - 10 m, varying inclination), 5 — Morainic hills preponderantly accumulative structure (relative heights above 10 m, varying inclination), 6 — Morainic hills preponderantly push structure (relative heights above 10m, varying inclination), 7 — Depressions due to uneven accumulation of inland ice.

II. Pleistocene landforms produced by the exaration action of inland ice

8 — Terminal basins.

III. Pleistocene landforms originated in the stagnant and dead ice zone

9 — Dead ice morainic hummocks (5 - 10m relative hight).

IV. Pleistocene landforms produced by the depositional action of glacial meltwaters

10 — Outwash plains, 11 — Esker ridges, 12 — Kame hillocks (5 - 10m relative height).

V. Pleistocene landforms produced by the erosional action of glacial meltwaters.

13 — Subglacial channels, — 14 Subglacial channels partly transformed by rivers, 15 — Elevations and swell in the bottom of subglacial channels, 16 — Valleys cut by meltwater rivers outside ice margin, 17 — Erosional plains, 18 — Remnants of moraine plateau on outwash, 19 — Cut-and-fill terraces of ice marginal streamways (pradolina), 20 — Erosional terraces of ice marginal streamways, 21 — Escarpments a) of moraine plateau b) of terraces.

VI. Other Pleistocene landforms

22 — Kettles (dead ice depressions), 23 — Drumlin hillocks and ridges.

VII. Pleistocene landforms originated under periglacial climate

24 — Denudation plains, 25 — Morainic hummocks transformed by periglacial processes, 26 — Remnants of moraine plateau, 27 — Denudation valleys (dells), 28 — Dry valley, 29 — Slopes and escarpments transformed by periglacial processes.

VIII. Lateglacial and postglacial (Holocene) landforms (landforms of eolian origin)

30 — Regular shaped dunes, 31 — Dune ridges, 32 — Irregular-shaped dunes, 33 — Eolian sand plains, 34 — Deflation basins.

IX. Lateglacial and postglacial (Holocene) landforms of erosional and denudational origin

35 — Small V-shaped valleys, ravines, gullies, 36 — Lateral hanging valleys, 37 — Small denudation valleys (dells), 38 — Small denudation valleys at the back of erosional valleys, 39 — Alluvial cones, 40 — Gentle denudation slopes, 41 — Degradation and aggradation zone, 42 — Small depressions of various origin.

X. Postglacial (Holocene) landforms produces by the depositional action of rivers

43 — Fill terraces plains, 44 — Flood plains and delta plains A) without peat B) with peat.

XI. Postglacial (Holocene) landforms produced by the erosional action of rivers

45 — Cut-and-fill terraces plains, 46 — Erosional terrace plains, 47 — Former river beds water filled (ox-bow lakes), 48 — Former river beds — dry, 49 — Escarpments A) of moraine plateau B) of terraces.

XII. Postglacial (Holocene) landforms produced by the action of lakes and the sea

50 — Cliffs.

XIII. Landforms produced by vegetation

51 — Peat plains.

XIV. Anthropogenic forms

52 — Embankments, [illegible], dams, earthwalls, 53 — Quarries, clay-, sand-, gravel-, and other pits, 54 — Excavations.

XV. Scale of thickness.

55 — Escarpments to 5 m, 56 — Escarpments 5 - 10 m, 57 — Escarpments 10 - 20 m, 58 — Escarpments above 20 m, 59 — Indistinct escarpments of moraine plateau and terraces, 60 — Rivers, 61 — Lakes, 62 — Altitude points.

GEOGRAPHIA POLONICA 17, 1969

CHANGEMENTS DU NIVEAU DES LACS COMME RÉSULTAT DES OSCILLATIONS DU CLIMAT PENDANT L'HOLOCÈNE (SUR L'EXEMPLE DU NE DE LA POLOGNE)

Jerzy Kondracki

C'est depuis dix années qu'un groupe de scientifiques de la Chaire de Géographie Physique de l'Université de Varsovie et du Laboratoire de Géographie Physique des Lacs de l'Institut de Géographie de l'Académie Polonaise des Sciences étudie l'évolution des lacs du NE de la Pologne. A ces recherches prirent part sous ma direction les scientifiques de ces deux instituts en faisant des études bathymétriques, hydrologiques, géomorphologiques, sédimentologiques, tourbologiques et paléobotaniques. Les premiers résultats furent présentés en 1961 au cours d'une excursion dans le NE de la Pologne, pendant la durée du 6^e Congrès de l'INQUA, et référés en 1965 au 15^e Congrès International de Limnologie à Varsovie [3, 4]. Les ouvrages terminés et publiés, on peut en dresser le bilan et tirer les conclusions concernant les relations entre les oscillations du niveau des lacs et celles du climat.

Depuis longtemps la science s'intéresse au problème des changements du niveau des lacs postglaciaires. Au début du XX^e siècle les géologues allemands: P. G. Krause, E. Kraus, F. Kaunhoven, Hess von Wichdorff et d'autres au cours de leurs études en ancienne Prusse Orientale sont tombés d'accord que les lacs de cette province étaient nés pendant la récession de la dernière glaciation et tout d'abord avaient un niveau bien plus haut qu'actuellement. Une telle opinion était fondée sur les soi-disant hautes terrasses d'abrasion des lacs. Leur relative hauteur par rapport à l'actuel niveau d'eau aurait eu 32 m (Hochterrasse) à l'état maximum, et 16 m durant la phase plus jeune de l'évolution [2]. Les observations postérieures démonstrèrent qu'on a consideré comme terrasses de lacs les aplatissements des versants de l'origine diverse, les affaissements, les cames, les terrasses de cames etc. Les mollusques trouvés dans quelques endroits n'avaient rien de commun avec les actuels réservoirs d'eau, mais provenaient de lacs disparus de la glaciation tardive ou de l'interstade; certains de ces dépôts lacustres apparaissaient sous une couche morainique.

Il y a une quarantaine d'années, un ouvrage de A. Quednau [1] sur les changements du niveau du lac Mamry (Mauer-See) évoqua un certain intérêt. L'auteur, bien qu'il se soit référé aux opinions sur les grands lacs dont la surface diminuait petit à petit jusqu'à leur étendue actuelle, avança une nouvelle thèse. En s'appuyant sur la tradition locale, sur les noms, les documents d'archives et sur certaines observations personnelles il affirmait qu'au XV^e siècle la partie méridionale du lac Mamry avait un niveau de 2 à 3 m plus bas qu'actuellement, tandis que le bord septentrional démonstrait les traces d'émersion. Il tira de ces données la conclusion qu'il y avait lieu une récente inclinaison tectonique du bassin du lac. Tout en ne niant pas ces faits nous constatons à présent que ses conclusions n'étaient pas justes, car on peut trouver aussi bien les traces d'un plus haut niveau d'eau que celles d'un plus bas dans tout le système des grands lacs de Mazurie, et que ces modifications avaient lieu dans différentes périodes.

Ultérieurement, en 1937, H. Gross [2] en analysant les dépôts des lacs disparus tira l'attention sur la tourbe gisant sur leur base qu'il détermina comme provenant de l'Alleroed. Ceci jeta une nouvelle lumière sur l'âge des lacs: ce n'est que pendant l'Holocène qu'ils ont apparu sur les lieux des glaces mortes ensevelies, et une période dépourvue de lacs a précédé leur naissance, lorsque la tourbe se formait sur les terrains des marécages naissants [1, 2].

Comme il résulte de l'examen des anciennes études allemandes, elles n'ont pas donné une opinion claire sur le problème de l'âge et de l'évolution des lacs. Un nouveau point de vue sur le problème des oscillations du niveau des lacs ont donné les travaux paléolimnologiques en URSS, et particulièrement en Lithuanie, voisin de la Pologne, où Garunkštis, sur la base de la morphologie de la zone côtière des lacs, est arrivé à la conclusion, que le niveau d'eau était dans la période préboréale et au début de la boréale inférieur à l'actuel, qu'il était le plus haut dans l'optimum atlantique du climat, qu'il a baissé dans la période subboréale et qu'il s'est remis à monter dans la période subatlantique [3].

En Pologne, l'examen des couches du calcaire lacustre, au bord du Lac de Kruklin, en Mazurie a fourni les premières données sur les oscillations du niveau des lacs pendant l'Holocène [3. 9]. Une série de dépôts de la zone littorale y etait découverte après un abaissement artificiel du niveau d'eau a 4 m d'épaisseur. Les études sédimentologiques, paléobotaniques ainsi que la fixation de l'âge de la base par la méthode du carbone radio-actif ont permis de déterminer l'âge du lac et les changements de la profondeur de l'eau là où se formaient les dépôts. Le lac est situé dans la zone de dépôts fluvio-glaciaires et remplit la cavité qui à l'origine était dépourvue d'écoulement. La profondeur maximale de cette cavité par rapport à la surface du sandre qui l'entoure est du 46 m. Dans la base des dépôts lacustres apparaissent les mêmes sables et graviers que sur la plaine de sandre qui entoure le bassin du lac. Sur ces sables, au-dessous des dépôts lacustres apparaît une couche de humus avec les racines de pins *in situ*; l'âge du bois a été fixé à 11399 ± 310 d'années et correspond à l'interphase de l'Alleroed. Dans ce temps-là il n'y avait pas encore de lac, et la surface du sandre était couverte de forêt. Une petite couche d'argile d'environ 40 cm, de la période du Dryas supérieur constitue le commencement des dépôts lacustres. Depuis la période préboréale se déposait le calcaire lacustre, et dans la partie supérieure du profil apparaît un petit dépôt de tourbe, de 40 cm, sur laquelle gisent 10 cm de calcaire couvert d'une petite couche de humus.

La tourbe supérieure date de la fin de la période atlantique et du début de la période subboréale, tandis que le calcaire lacustre qui la couvre, de la fin de la période subboréale et de la période subatlantique. Le caractère des dépôts et l'analyse des macrofossiles, et particulièrement l'apparition des niveaux avec: a) le *Lychnothamnus* et le *Tolypellopsis* dans la base, b) la *Najas marina* au milieu et c) *Chara* dans la série sommitale calcaire montrent les modifications de la profondeur de l'eau. Tout d'abord le lac était moins profond; à la fin de la période boréale et au début de la période atlantique (dépôts de *Najas marina*) il était plus profond en atteignant dans la zone littorale 8 m, et ensuite sa profondeur diminua jusqu'à l'apparition de la tourbe, pour s'approfondir de nouveau dans la période subatlantique. Les traces d'une forêt de pins dans la base des dépôts lacustres ont confirmé l'opinion de H. Gross qu'un affaissement du sol avait lieu, au fur et à mesure que les blocs de glace morte fondaient, ce qui a été également observé par les chercheurs lituaniens. Le développement initial du bassin du lac et l'accroissement de la profondeur de l'eau étaient liés surtout aux modifications thermiques qui provoquaient la fonte des glaces mortes, et, dans un moindre degré, à l'augmentation des précipitations et à la montée du niveau des eaux souterraines étant donné que la première moitié du Holocène n'était pas humide (fig. 1). Depuis la période atlantique le bilan des précipitations et de l'évaporation jouait le rôle principal démontrant la prépondérance du premier facteur qui provoquait la montée du niveau des eaux souterraines et celle du niveau des lacs. L'observation s'impose que le diagramme illustre les modifications de la profondeur de l'eau dans la zone littorale, ce qui n'équivaut pas aux oscillations du niveau du lac, car au début avait lieu l'affaissement du fond et ensuite le bassin fut en partie rempli de dépôts.

Les examens ci-dessus n'ont pas embrassé les dépôts de fond des parties profondes du bassin du lac, couverts par les eaux du lac actuel,

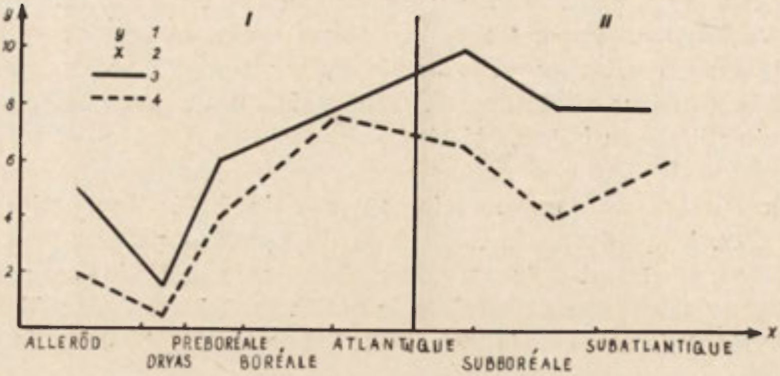


Fig. 1. Diagramme des changements de température d'après Woldstedt et des changements de profondeur de l'eau du lac Kruklin (dans la zone littorale) d'après J. Stasiak (1963)

1 — températures en centigrades et profondeur de l'eau en mètres (dans la zone littorale du lac Kruklin); 2 — périodes climatiques; 3 — moyennes annuelles de temperature; 4 — profondeur de l'eau dans la zone littorale

tandis que le problème de la modification de l'étendue du lac et des formes de la rive n'ont été examinés que d'une façon générale, sur la base de cartes géologiques et topographiques, sans examens détaillés du terrain. On s'est occupé de ces problèmes dans la région du lac Śniardwy [11], le plus grand lac de Pologne et de sa branche, le lac de Mikołajki [5,7. 13]. On s'est servi d'une sonde du type „core sampler" de sa propre construction [13], avec laquelle on a pu prélever, mêmes des plus profondes parties du lac, des échantillons non troublés de dépôts de fond dépassant 10 m d'epaisseur. En somme, environ 150 noyaux de dépôts ont été examinés, ce qui a permis de connaître leur épaisseur variable, oscillant de zéro à 13 m, et le degré dans lequel le bassin primordial fut rempli de dépôts. Le lac Śniardwy et le lac de Mikołajki atteignirent une étendue maximale au début de leur développement, lorsque leur niveau dépassait de 4 m le niveau actuel. Cependant ce réservoir n'était pas profond, car à la fin de l'Alleroed et pendant le Dryas superieur une glace morte gisait encore au-dessous de son fond. Tout comme sur le lac Kruklin, dans la base des dépôts calcaires lacustres et également dans les plus profondes parties des bassins apparaît une tourbe de l'âge de l'Alleroed (datée palynologiquement et par la méthode du carbone radio-actif), qui a dû se former à peu près sur le même niveau que dans la base des tourbières entourant le lac actuel, et ensuite s'affaissait au fur et à mesure que fondait la glace morte. Les dépôts lacustres gisant sur les tourbières manifestent une variabilité insignifiante, ce qui témoignerait d'une relative stabilité du régime des lacs examinés durant tout l'Holocène. On peut donc supposer que les modifications du climat n'étaient pas suffisamment grandes pour influencer le caractère de dépôts, ce qui pourtant n'exclut pas certaines oscillations du niveau d'eau liées à la variabilité des précipitations. La comparaison de la base des dépôts lacustres à l'actuelle forme du fond démontre que le degré du remplissage des bassins lacustres est de 20% à 35%, mais les réservoirs petits et plats ont été souvent complètement remplis et ensuite transformés en tourbières.

L'analyse des formes et des dépôts côtiers du lac de Mikołajki [5] a permis de supposer que l'amplitude absolue des oscillations du niveau d'eau depuis la phase initiale des espaces plats inondés à un niveau dépassant l'actuel d'environ 4 m, jusqu'au niveau le plus bas au début de la période boréale attengnait 8 m. Toutefois on observe certaines divergences d'opinions à ce sujet.

En faveur d'un bas niveau des lacs pendant la période boréale parle le manque de dépôts lacustres de cette âge dans les tourbières côtières. Le fait est intéressant que dans quelques endroits du lac de Mikołajki on a trouvé sous les dépôts du lac, à une profondeur de 6 - 8 m de la surface du lac du bois carbonisé (pourtant il semble qu'il se trouvait dans une couche secondaire). L'âge des couches contenant ce charbon de bois fut fixé à la période boréale [13, 5]. En raison du manque de données sûres quant au niveau des lacs dans cette période, les divergences entre les opinions de divers auteurs sont assez grandes. Cependant, se référant à la stratigraphie des tourbières côtières dont la base se trouve en plusieurs endroits à une profondeur d'environ 4 m au-dessous du niveau des lacs et accuse un haut degré de décomposition, on peut supposer que le niveau des lacs se trouvait alors au moins 4 m plus bas qu'actuellement. Dans ce cas-là les lacs se seraient transformés en réservoirs sans écoulement dont la quantité d'eau serait le résultat de l'équilibre entre les précipitations dans le bassin-confluent et l'évaporation. Les lacs boréaux, malgré un niveau plus bas qu'à la fin de l'Alléroed et pendant le Dryas supérieur, étaient pourtant plus profonds que dans ces périodes, car pendant la période préboréale les glaces mortes ont probablement définitivement fondu. Dans la vallée de la Pisa qui écoule vers le Sud les eaux des lacs examinés, la plus profonde incision fut datée à la période préboréale. Ensuite le niveau de cette rivière montait continuellement, et la vallée se remplissait de dépôts dont l'épaisseur atteint 4 à 7,5 m [1]. Depuis la période boréale on peut constater une montée du niveau de l'eau aussi bien dans les lacs que dans les rivières. L'augmentation des précipitations et une montée générale du niveau des eaux souterraines en sont la cause.

Le niveau des lacs pendant la période atlantique était sans aucun doute plus haut que dans la période boréale. Cependant certains auteurs prétendent qu'il était plus haut que l'actuel [9, 11], tandis que d'autres qu'il était plus bas [5]. Puisque en ce temps là a eu lieu, comme on l'admet, une hausse de la température moyenne annuelle d'environ 2° (par rapport à la température actuelle), l'évaporation a dû également augmenter, ce qui équilibrait dans une certaine mesure l'augmentation des précipitations. Vu le manque dans cette période de traces distinctes d'un niveau d'eau plus haut que l'actuel, on peut admettre que l'équilibre hydrodynamique s'établissait d'une manière semblable comme celui de nos jours, malgré un plus grand nombre de précipitations annuelles. Dans la période subboréale une régression eut lieu dont le correspondant était l'interruption de la formation des tourbières. Cette baisse du niveau des eaux souterraines peut être évaluée à environ 2 m. Dans ces conditions l'écoulement des lacs aurait diminué jusqu'au minimum ou bien cessé, et les précipitations dans le bassin-versant seraient équilibrées par l'évaporation. Finalement, dans la période subatlantique l'eau monta de nouveau en atteignant un niveau d'environ 1 m plus haut que l'actuel. Les témoins en sont les anciennes falaises et les cordons litoraux qui ferment les anciennes baies couvertes aujourd'hui de tourbe [5, 11]. Au XVIII^e et XIX^e siècles le niveau des lacs a été artificiellement baissé par les travaux d'amélioration et de régulation et il s'est fixé à la hauteur actuelle. Ainsi on ne pourrait pas lier ces modifications du niveau d'eau aux changements du climat, et il faut admettre que dans la période subatlantique les précipitations, l'écoulement et l'évaporation se présentaient d'une manière semblable comme dans les conditions actuelles. Dernièrement on projette une nouvelle élévation artificielle de l'eau, nécessaire à la régulation de l'écoulement dans les rivières et à l'irrigation des prairies.

Les études faites au bord du lac Mamry qui, comme on l'a mentionné dans l'introduction, il y a quelques disaines d'années, furent le point de départ aux hypothèses portant sur les changements du niveau des lacs de cette région, ont démontrées l'existence de traces d'une initialement plus vaste étendue du lac ne dépassant pourtant nulle part une hauteur de 4 m par rapport à la nappe actuelle, et également un niveau d'eau plus bas, ce qui a été témoigné par la trouvaille au fond du lac, à une profondeur d'environ 2 m, d'une tourbe de laîche subatlantique. On a ici executé entre autres des examens du fond du lac à l'aide de plongeons et un fragment d'une „carte de paysage" du fond; cependant on n'a pu trouver des traces de constructions et de routes inondées dont écrivait A. Quednau en 1927. Les résultats de ces examens ne sont pas encore publiés.

Les échantillons de dépôts de fond provenant des parties profondes du lac Mamry ont demontré aussi leur âge holocénien, donc la naissance de l'actuel bassin du lac après la fonte de la glace morte. Ainsi on ne peut pas considérer les dépôts argileux apparaissant sur la côte Est de ce lac comme ceux de même réservoir. Leur emplacement démontre qu'ils étaient déposés dans un lac situé entre des blocs de glace qui remplissaient le bassin du lac contemporain. Ce réservoir a disparu comme bien d'autres au déclin de la glaciation, et le nouveau lac est né sur une autre place, après la fonte des blocs de glace morte. Ainsi l'interprétation du développement du lac Mamry est différente de celle qu'on admettait auparavant.

D'intéressants faits ont été observés dans d'autres parties du pays des lacs du NE de la Pologne [10]: l'apparition et la disparition de petits réservoirs d'eau au cours de la période subatlantique, ce qui témoignerait que c'est justement cette période qui appartient aux plus humides. Les dépôts subatlantiques des lacs et les tourbes qui les couvrent, atteignent par endroits 6 m d'épaisseur. Il résulte des études palynologiques que le Subatlantique du NE des confins de la Pologne [10] peut être divisé en trois étages: le Subatlantique I (les années —750 à —400) où se signale la diminution de la quantité de pollens d'arbres à feuilles et une augmentation simultanée de la quantité de pollens de sapins, donc un refroidissement et une humidification du climat; Subatlantique II (années —400 à 1100) avec une nouvelle croissance des arbres à feuilles, tel que: chêne, orme, charme, érable et même hêtre ainsi qu'avec l'apparition des pollens des céréales; enfin Subatlantique III (depuis l'année 1100 jusqu'à nos jours), où au détriment des arbres à feuilles se répandent les pollens des céréales, et la quantité de pollens des sapins augmente de nouveau. Dans cette dernière sous-période avait lieu la formation des tourbes et l'extinction des petits lacs.

En résumant les résultats des études mentionnées on peut affirmer que les oscillations des niveaux des lacs avaient, selon le lieu, un cours varié, mais qui reflétait en lignes générales le cours des changements du bilan d'eau et des oscillations de la température. Ce ne sont pas des grandes précipitations qui ont causé le haut niveau des lacs dans la phase initiale du déclin de l'Alleroed et pendant le Dryas supérieur (+4 m). Ce haut niveau est dû au fait que le fond des lacs était couvert de glace morte, à la température annuelle moyenne peu élevée et à une basse évaporation qui en a été l'effet. L'écoulement fluvial ne s'était pas encore formé dans cette période. Dans la période préboréale l'approfondissement des réservoirs était provoqué par la fonte des glaces mortes et lié à la baisse du niveau des eaux souterraines. Le plus bas niveau des lacs était 4 m d'environ au début de la période boréale. Pendant la période atlantique le niveau des lacs monte à peu près au niveau actuel, tandis que dans la période subboréale il baisse à ca. —2 m. Dans la période subatlantique III le niveau des lacs semble avoir été le plus haut (+1 m) et sa baisse actuelle est due aux travaux hydrotechniques exécutés au cours des deux derniers siècles. Cependant il y a des données que vers la fin du Subatlantique II le niveau des lacs de Mazurie était de ca. 2 m plus bas que l'actuel.

En s'appuyant sur les oscillations du niveau d'eau évaluées de cette manière, nous pouvons essayer de calculer celles des précipitations. Nous prenons pour base du calcul l'équation du bilan d'eau pour les bassins -versants des grands lacs de Mazurie. En partant de l'équation générale: $P=H+S$ on peut écrire que:

$$\Delta P=\Delta H+\Delta S+\Delta R$$

c'est à dire que le changement de l'indice des précipitations est la somme des changements des indices de l'écoulement, de l'évaporation dans tout le bassin-versant et de la rétention dans les lacs rassemblants les eaux de surface et les eaux souterraines de tout le bassin-versant.

Les modifications de la rétention du système des grands lacs de Mazurie furent calculées pour les niveaux d'eaux citées ci-dessous par l'extrapolation des changements de la capacité du plus grand lac, du lac Śniardwy [11] qui couvre environ 1/3 de la surface des grands lacs.

TABLEAU 1. Calcul des changements de l'indice de la rétention

Niveau de la nappe d'eau	Surface des lacs en km^2	ΔR	
		Million m^3	mm
+1 m/117 m au-dessus du niveau de la mer	335 (109%)	321	100
0 m/116 m ,, ,, ,,	307 (100%)	0	0
−2 m/114 m ,, ,, ,,	260 (84%)	− 567	−180
−4 m/112 m ,, ,, ,,	200 (65%)	−1027	−325

En faisant le calcul des modifications de l'indice des précipitations on a pris comme surface du bassin-versant 3.155 km^2 [6, 11].

On peut négliger dans les considérations suivantes les modifications de l'écoulement en admettant qu'à un niveau de −2 m l'écoulement des lacs diminuerait jusqu'au minimum ou cesserait complètement, et le bilan d'eau ne serait réglé que par l'équilibre des précipitations et de l'évaporation de l'eau dans le basin-versant. La diminution de la rétention serait donc le résultat de la diminution des précipitations et éventuellement d'une augmentation de l'évaporation. Le niveau d'eau des temps modernes, plus haut que l'actuel, correspondait à peu près aux conditions actuelles des précipitations et de l'évaporation, car la baisse du niveau des lacs au cours des deux derniers siècles a été

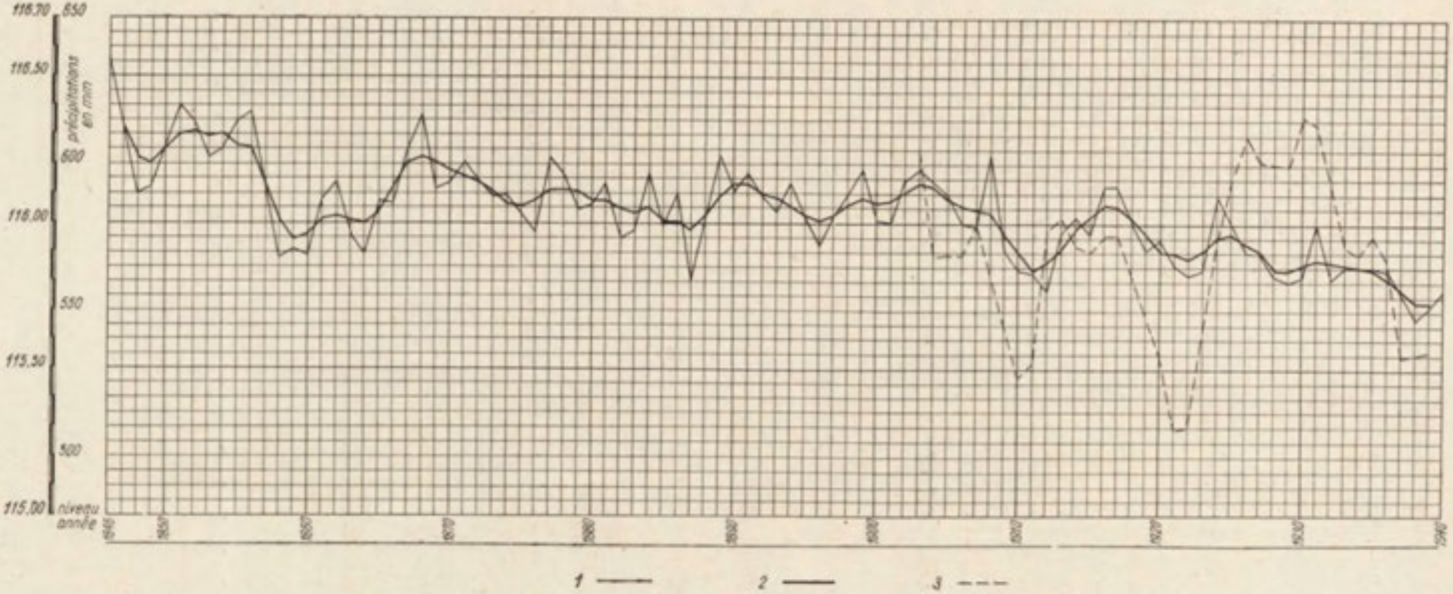


Fig. 2. Moyennes annuelles du niveau des grands lacs mazuriens pour les années 1846 - 1940 d'après L. Skibniewski et Z. Mikulski (1954)

1 — niveaux annuels véritables, 2 — niveaux égalisés; 3 — précipitations moyennes égalisées

provoqué par des travaux hydrotechniques et non pas par un changement de la somme des précipitations. Ceci est temoigné par le diagramme des niveaux d'eau et des précipitations relativement aux années 1846 - 1940 [8] (voir la fig. 2). Dans cette période les moyennes annuelles des niveaux d'eaux ont baissé plus d'un mètre, tandis que les précipitations accusaient, il est vrai, des irrégularités dans les limites de ca. 510 mm à 625 mm, mais dans différentes périodes et en général elles n'ont pas diminué. Néanmoins on peut supposer que pendant „La Petite Epoque Glaciaire" (XVI^e - XVIII^e siècle) les précipitations étaient un peu plus abondantes et l'évaporation moindre.

Une relation étroite entre l'évaporation et la température peut servir de base au calcul des modifications de l'évaporation, ce qui résulte du diagramme élaboré sur les données de trois postes situés au NE de la Pologne (fig. 3). Le diagramme montre qu'un changement de température d'un degré correspond au changement de l'indice de l'évaporation de ca. 40 mm. En admettant que pendant l'optimum climatique (la période atlantique) la moyenne annuelle de température était de 2 degrés plus haute (par rapport à l'actuelle), l'indice de l'évaporation serait monté de 80 mm. En admettant que le niveau des lacs correspondait dans cette période à l'actuel, on peut prétendre que l'augmentation de l'évaporation correspondait à celle des précipitations du même rang.

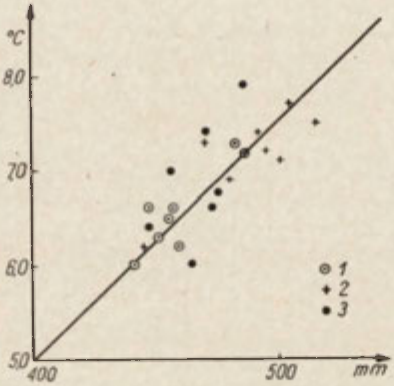


Fig. 3. Dépendance de l'évaporation du terrain de la température de l'air (d'après Z. Mikulski)

1 — Suwałki, 2 — Ostrołęka, 3 — Olsztyn

En s'appuyant sur les données mentionnées nous passerons au calcul de la somme moyenne annuelle des précipitations pour les oscillations particulières des niveaux d'eau en partant de la période boréale. On ne peut pas faire ce calcul pour les phases antérieures du climat, car les changements du niveau des lacs furent provoqués par d'autres facteurs, non seulement par les oscillations des précipitations et de l'évaporation.

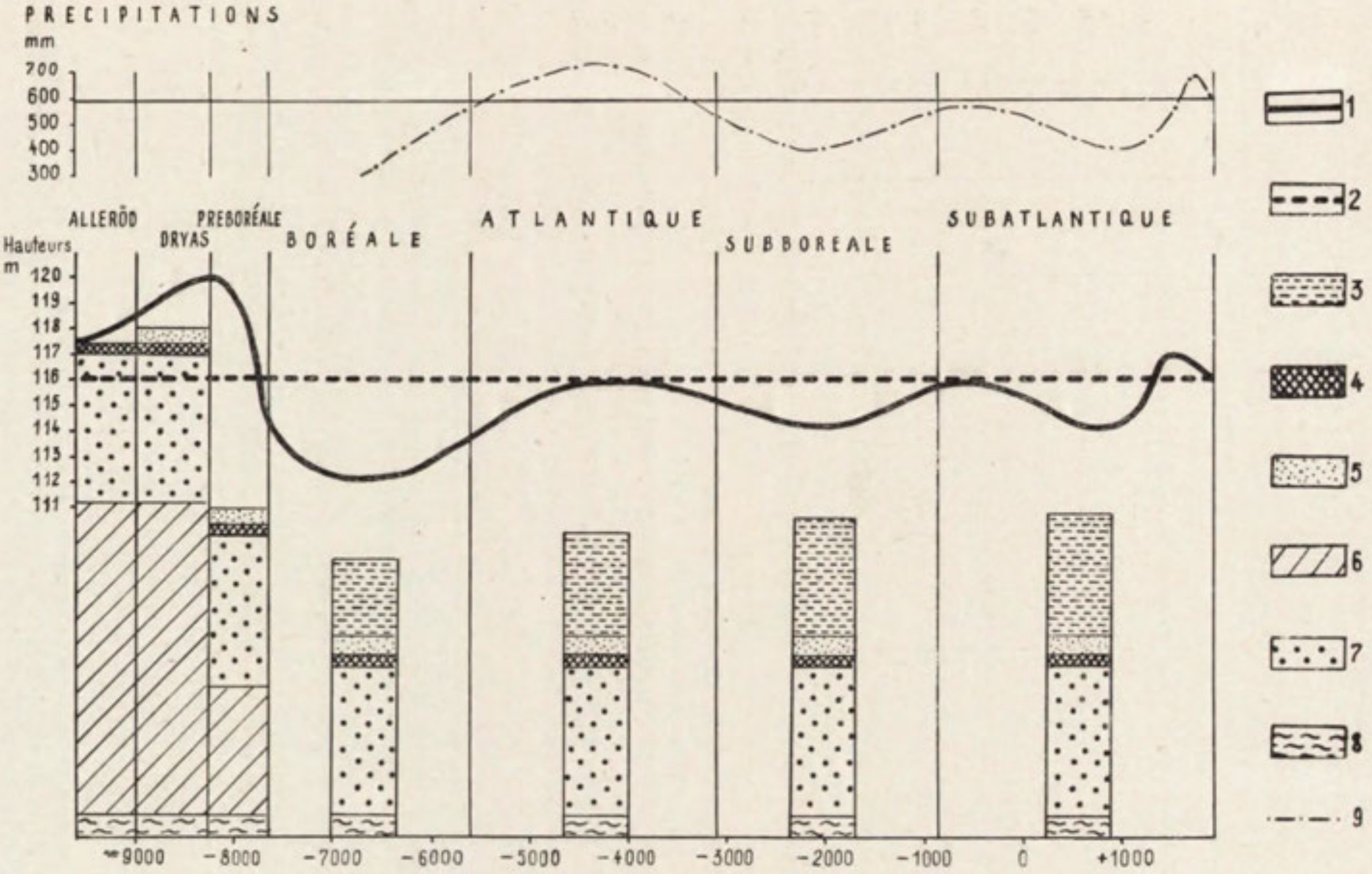


Fig. 4. Changements du niveau grands lacs mazuriens et les sommes calculées des précipitations

1 — courbe des changements du niveau d'eau; 2 — niveau d'eau contemporain; 3 — gytia; 4 — tourbe de l'Alléroed; 5 — sables et argiles du Dryas; 6 — glaces mortes; 7 — sables et graviers fluvio-glaciaires; 8 — matériel glaciaire; 9 — courbe des changements des précipitations

TABLEAU 2. Changements du niveau des lacs et sommes moyennes des précipitations de plusieurs années

Périodes et années	Changements du niveau des lacs en mètres	ΔR	ΔS	ΔP	P
		mm			
Contemporaine (1891 - 1930)	±0	0	0	0	580
Subatlantique III (1500 - 1800)	+1	100	−40	60	640
Subatlantique II (1000 - 1400)	−2	−180	0	−180	400
Subatlantique I (−750 à −400)	±0	0	0	0	580
Subboréale (env. −1500)	−2	−180	0	−180	400
Atlantique (env. −4000)	±0	0	+80	80	660
Boréale (début −6800)	−4	−325	+40	−285	295

Cependant on peut supposer qu'au déclin du Pleistocène les précipitations et l'évaporation étaient plus petites.

Ainsi nous calculons les précipitations par l'équation suivante: $P = Po + \Delta P$, en admettant que Po = précipitations contemporaines, et ΔP = somme de $\Delta R + \Delta S$ exprimée en milimètres. Les précipitations des années 1891 - 1930 furent estimées à 580 mm [11], celles des années 1951 - 1960 à 572 mm [6].

Le diagramme ci-joint (fig. 4) montre le rythme des oscillations du niveau du lac et celui (qui lui correspond) des précipitations sur la base des modifications du profil du fond du lac, présentées schématiquement dans les périodes particulières du climat. Naturellement c'est un tableau approximatif, mais il montre l'ordre de grandeur des modifications et la codépendance des phénomènes. La variabilité des précipitations se trouve dans les limites de variabilité des traits caractéristiques des zones climatiques de l'Europe du NE, tandis que les prétendues plus grandes oscillations du niveau des lacs, donc également les différences importantes entre les moyennes des précipitations de plusieurs années étaient peu probables.

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CONTRASTES D'ACCUMULATION EN DEHORS DES MORAINES FRONTALES DE LA POLOGNE CENTRALE (RISS)

JANINA ŁYCZEWSKA

INTRODUCTION

L'élément dominant de la Pologne centrale sont les plateaux et les chaînes des montagnes de la région de Sainte-Croix et du Jura Polonais (appelé aussi le Jura Cracovien [2, 9]).

La région de Sainte-Croix embrasse le massif paléozoïque relevé sous la forme des chaînes des montagnes principales (les Montagnes de Sainte-Croix) ainsi que les chaînes des montagnes et collines mésozoïques et tertiaires placées sur la périphérie de la région. Leur situation est conforme à la direction tectonique principale qui règne en Pologne centrale, c'est à dire du Sud-Est au Nord-Ouest.

Le Jura Polonais représente un élément analogue de structure mésozoïque qui forme la chaîne distincte des montagnes.

Les zones de culminations, mentionnées ci-dessus, sont devenues un facteur décisif à la transgression de l'inlandsis de la Pologne centrale (Riss). Il les entoura du Nord et dirigea sa maximale masse de glace le long du bord occidental du Jura Polonais vers le Sud et même en dehors de la Porte-de-Moravie.

L'influence de la calotte glaciaire entourant du Nord-Est, du Nord et du Nord-Ouest la région de Sainte-Croix et le Jura Polonais a trouvé son expression sous la forme des phénomènes périglaciaires de nature fluvio-glaciaire, fluvial, fluvio-périglaciaire, de solifluxion et éolienne. L'alternation des divers effets d'accumulation et de dénudation liés à ces forces dynamiques formèrent des dépôts caractéristiques et des formes morphologiques sur l'espace de la Pologne centrale. Ces effets ont persisté et même se sont accentués pendant la glaciation Baltique (Würm).

I. GÉOMORPHOLOGIE DE LA RÉGION DE SAINTE-CROIX ET DU JURA POLONAIS PENDANT LA GLACIATION DE LA POLOGNE CENTRALE (RISS)

L'inlandsis de la Pologne centrale (Riss) dans sa phase maximale, en touchant du Nord l'avant-pays des montagnes de Sainte-Croix et du

Jura Polonais, réussit à peine à s'introduire de petites langues éphémères dans les dépressions parmi des hauteurs et surtout dans les vallées. Ainsi il a coulé en suivant la vallée de la Vistule jusqu'à son défilé près de Zawichost. A l'Ouest de la Vistule il attegnit le Nord-Est du bord tectonique du massif de Sainte-Croix et même le traversa par endroit à l'aide de petites langues qui ont pénétré les vallées des rivières et les dépressions tectoniques de ce bord montagneux.

Au Nord la masse principale de la calotte glaciaire passa à côté d'un socle mésozoïque du plateau de Końskie—Suchedniów en le contournant de l'Ouest par la vallée de Drzewiczka et celle de la Czarna Sulejowska (affluents droits de la Pilica moyenne). Là elle s'introduisit jusqu'à Końskie et se dirigea vers Radoszyce. Mais ici le socle suivant des confins Nord-Ouest de la chaîne de Przedbórz, près de la ville Przedbórz, lui interdit de continuer sa pénétration. Toutefois l'inlandsis avec son lobe large passa la dépression de la partie septentrionale du bassin de la Nida, entre la chaîne de Przedbórz et le Jura Polonais, en barricadant les vallées du bassin de la Haute-Warta et de la Pilica. Pourtant la diffusion continue de la calotte glaciaire au bassin de la Nida est arrêtée par un barrage sous la forme d'un socle puissant du Jura Polonais, près de Częstochowa. Cette fois-ci la pression de l'inlandsis sur les hauteurs du Jura fut marquée par des dislocations glacitectoniques [8, 10]. Il faut faire remarquer à l'absence des structures glacitectoniques en bordure des montagnes de Sainte-Croix, malgré l'attaque continuelle et intensive de la calotte glaciaire contre les hauteurs se trouvant sur cette zone.

D'après S. Z. Różycki [10] au-delà de Częstochowa le front de la phase maximale de l'inlandsis de la Pologne centrale a avancé vers le Sud, dans la direction de la Basse Silésie en donnant une série de formes d'accumulation des moraines frontales près de Wrzosowa, Kamienica Polska, Siedlec etc. Pourtant l'inlandsis ne s'est pas approché directement de l'escarpement rocheux du Jura Polonais, étant protégé de l'invasion du glacier par des rochers mésozoïques du plateau se trouvant tout près de la chaîne du Jura. De même les élévations du plateau mésozoïque de Końskie - Suchedniów ont protégé les montagnes de Sainte-Croix.

Les plateaux et les montagnes, mentionnées ci-dessus, formaient un obstacle infranchissable sur la voie de l'inlandsis de la Pologne centrale. Tous ces espaces restèrent libres des glaciers, mais ils en étaient entourés du Nord-Est, du Nord et de l'Ouest. Cependant l'activité indirecte de l'inlandsis était énorme et significative pour cette région, c'est-à-dire, pour la région de Sainte-Croix et pour le Jura Polonais. Car c'est là que se sont concentrés les processus dynamiques dans les conditions périglaciaires en troublant le cycle normale de l'évolution géomorphologique.

II. PROCESSUS DE LA DÉNUDATION ET DE L'ACCUMULATION PENDANT LA GLACIATION DE LA POLOGNE CENTRALE (RISS)

Le facteur le plus essentiel des changements dynamiques c'était le blocage de la principale artère d'eau, la Vistule, qui drainait la Pologne centrale, méridionale et orientale vers le Nord. C'était toujours le réseau fluvial qui formait ce terrain du point de vue de la géomorphologie, en registrant aussi bien l'influence de la tectonique du substratum que toutes les modifications de la sédimentation, de la dénudation et du climat ayant lieu pendant le Quaternaire. Sur le territoire de la Pologne centrale, libre de glaciers, l'action des eaux courantes ne cessait point, au contraire, elle redoublait considérablement en conséquence de la fonte des glaciers, de l'augmentation des précipitations et du blocage des confluents des rivières par l'inlandsis.

Le bassin de la Nida, qui drainait les montagnes de Sainte-Croix et le plateau meridionale de cette région, a reçu en plus les eaux du bassin de la Haute-Pilica et partiellement celles de la Warta qui drainaient le Jura Polonais. En outre le bassin de la Nida était approvisionné par les eaux du front de l'inlandsis. Tous ces eaux multipliées s'écoulaient vers le Sud-Est. Vers la même direction coulaient les eaux d'autres rivières de la région de Sainte-Croix: de la Czarna Staszowska, de la Koprzywianka, de l'Opatówka et temporairement aussi celles de la Kamienna. La Vistule moyenne formait la base de l'érosion pour toutes ces eaux, dont le niveau se soulevait peu à peu. Par conséquent la vallée de la Vistule moyenne bientôt ne pouvait les renfermer. C'est alors que les eaux se sont concentrées dans un vaste réservoir de rétention, qui formait le lac endigué, situé au confluent du San dans la Vistule près de Sandomierz. Il était parfaitement approprié à ces fins grâce aux conditions exceptionnellement favorables de la structure de son substratum, formée encore pendant la régression de la Mer Tertiaire vers le Sud-Est. Ce lac endigué avait été également submergé pendant la glaciation de Cracovie (Mindel) et recueille jusqu'à nos jours les eaux de crue.

RÉSULTAT DU BLOCAGE D'ÉCOULEMENT DU RÉSEAU FLUVIAL DE LA POLOGNE CENTRALE — L'ACCUMULATION FLUVIO-PÉRIGLACIAIRE DE LA RÉGION DE SAINTE-CROIX

Le blocage de l'écoulement des eaux sur l'espace libre de la calotte de l'inlandsis de la Pologne centrale provoquait une disparition graduelle de l'érosion du lit, le remplissage des vallées par des dépôts et finalement le débordement. Les eaux montantes, l'accumulation occupait des espaces de plus en plus vastes, en remplissant tous les abaissements du terrain et en formant des couches de dépôts jusqu'à une altitude de 300 m environ. Il s'est formé un énorme espace inondé, caractéristique pour les terrains arctiques et subarctiques contemporains. Il était notamment aprovisionné par des rivières périodiques et fougueuses qui faisaient un grand travail d'érosion latéral en augmentant les processus de solifluxion.

Le cadre de ce débordement était marqué par les hauteurs elevées au dessus du niveau de 300 m environ: du Nord-Est par les plus hautes chaînes des montagnes de Sainte-Croix, du Sud-Ouest par celles du Jura Polonais, du Nord-Ouest par le front de la calotte glaciaire.

Les phénomènes, mentionnés ci-dessus, ont été reconstruits grâce aux études géologiques détaillées menées sur le terrain situé dans le bassin de la Nida, allant des montagnes de Sainte-Croix jusqu'à la Vistule moyenne. Le communiqué résultant est publié par J. Łyczewska [4, 5]. L'auteur admit le terme „dépôts d'accumulation fluvio-périglaciaire" pour déterminer une série de sable intercalé de graviers, de cailloux et de débris des roches locales. Les sables sont mis en place par l'eau courante, les intercalations proviennent d'un écoulement de solifluxion. L'auteur a distingué deux cycles de l'accumulation fluvio-périglaciaire: le premier lié à la glaciation de la Pologne centrale (Riss), quand le niveau d'accumulation atteignit l'altitude de 300 m environ, c'était le débordement maximale pour la région de Sainte-Croix; le second — lié à la glaciation Baltique (Würm) — a occupé un espace bien plus petit, ne dépassant pas le cadre des vallées d'interglaciaire Eemien (Riss-Würm) qui étaient entaillées dans la nappe fluviopériglaciaire précedente.

ACCUMULATION FLUVIO-PÉRIGLACIAIRE DE LA RÉGION DU JURA POLONAIS ET LE PROBLÈME DU SABLE À L'ALTITUDE DE 400 M DANS LA PARTIE SOMMITALE DU JURA

Les phénomènes d'accumulation fluvio-périglaciaire sont répandus aussi dans le Jura Polonais. Il y existe une nappe sablonneuse plus ancienne encore que mentionnée ci-dessus, elle pourrait donc provenir de la glaciation de Cracovie (Mindel).

S. Z. Różycki [10] avance l'opinion que le Quaternaire du Jura Polonais se compose en majeur partie de sables intercalés de nombreux débris de silex. Ces sables couvrent le niveau des calcaires jurassiques alterés profondément, en remplissant toutes les vallées et dépressions du terrain. Les sables qui se trouvent tout près de l'escarpement du Jura Polonais, en atteignant l'altitude de 400 m environ, présentent un problème des plus intéressants. Cette couche sablonneuse est encore aujourd'hui considérable malgré que d'énormes quantités de sables en aient été balayées, en formant de vastes cônes de déjections au pieds du Jura Polonais. L'âge d'accumulation de sables correspond, d'après S. Z. Różycki, à la situation dans laquelle le Jura Polonais était entouré des glaciers, montant plus haut que la chaîne des montagnes du Jura. Ce serait donc. d'après cet auteur, le sable fluvio-glaciaire, accumulé pendant la glaciation de Cracovie (Mindel), quand le Jura Polonais a présenté une forme concave, plus basse que les murailles de la calotte glaciaire l'entourante. S. Z. Różycki propose le terme „oasis jurassique entre-glaciers" pour déterminer cette grande unité rocheuse, entourée de tous les côtés de murs de glace.

A côté de cette hypothèse il ne faut pas exclure celle qui ferait provenir l'accumulation fluvio-périglaciaire pour la genèse du sable resté dans les hautes régions du Jura Polonais. Ça pourrait être un fragment d'un vaste niveau d'accumulation fluvio-périglaciaire atteignant l'altitude de 400 m. Cet événement aurait pu être lié aux ingressions et récessions de l'inlandsis de Cracovie (Mindel).

Par contre le remplissage des dépressions et des vallées apparaissant au-dessous de l'escarpement du Jura Polonais atteint l'altitude de 300 m environ. Du côte de l'Ouest du Jura Polonais une nappe de ces sables a fait apparaître un phénomène bien rare, c'est-à-dire une région déserte, appelée le désert de· Błędów. L'accumulation des sables est liée à plusieurs stades de la glaciation de la Pologne centrale (Riss). Les récoulements et les découlements des eaux courantes aussi que les processus de solifluxion provoquaient une variabilité des dépôts sablonneux. Comme J. Lewiński [3] a dit en 1914, l'accumulation des sables dans un bassin de la Przemsza se manifeste à l'altitude de 300 m et atteint de 80 m d'épaisseur, en remplissant les plus profondes vallées périglaciaires et se répandant sur l'énorme surface d'aplanissement. Les sondages cités par J. Lewiński, ainsi que dans tous les autres travaux de plus en plus actuels, indiquent la composition suivante de la série d'accumulation: ce sont les couches de sable non-épaisses intercalées de petits cailloux, de graviers et par endroits d'argiles gris ou jaunes. Les graviers sont composés pour la plupart de quartz, de calcaires locales et de rares galets de roches scandinaves. J. Lewiński a constaté l'analogie de cette série de dépôts à l'accumulation de sable qu'il avait observé dans les montagnes de Sainte-Croix, tout en faisant la remarque que ce phénomène est bien plus intense près du Jura Polonais dans le bassin de la Przemsza.

La série sablonneuse, dite ci-dessus par J. Lewiński, ressemble à la série d'accumulation fluvio-périglaciaire de la région de Sainte-Croix et elle a été formée aux mêmes conditions géomorphologiques et climatiques. La région du Jura Polonais et celle de la Sainte-Croix étaient libres de la calotte glaciaire et représentaient la zone commune des phénomènes périglaciaires en dehors de la glaciation de la Pologne centrale (Riss).

S. Z. Różycki [10] nous présente une coupe détaillée des dépôts des sables, qui se manifeste au pied de l'escarpement occidentale du Jura

Polonais, près de Włodowice. C'est une zone où le matériel de roches scandinaves apparaît encore rarement. On y a distingué 5 niveaux des couches: le plus élevé forme une surface légèrement déclivée, entaillée dans les calcaires jurassiques, recouverte d'une série de décombres calcaires et des argiles alterés; on y observe des signes de troubles provoqués par le gel; le niveau suivant se trouve quelques mètres au-dessous, c'est une couche d'accumulation sablonneuse intercalée de nombreux graviers et de blocs de roches locales, elle s'étend sur l'espace bien élargie et forme une couche principale; la surface de ce niveau est fortement entaillée par une vallée, remplie de sable stratifié, qui nous donne le troisième niveau; — dans ces dépôts on peut observer des surfaces de lavage, de matériel fortement éolisé, des troubles d'involution et d'écoulement; dans la partie sommitale de cette série de sable apparaissent de gros sables non stratifiés, avec une addition de nombreux silex, de débris et de galets de calcaires locales. Ce sont les produits de la solifluxion et du délavage des pentes et des niveaux situés plus haut, en outre on y marque une activité du vent. Le quatrième niveau est entaillé dans le précedent — il est aussi formé par une couche de sable stratifié. Le fond actuel de la vallée forme le dernier niveau. En concludant S. Z. Różycki ne trouve pas que les dépôts de la coupe ci-dessus soient pareils au schéma stratigraphique du Quaternaire.

Etant donné que l'espace du pied occidentale du Jura Polonais, près de Włoszczowice, ne porte pas de traces de la pénétration de l'inlandsis de la Pologne centrale (Riss), dont la frontière passe un peu vers l'Ouest, je serais supposée de considérer „le principale niveau d'accumulation sabloneuse" comme correspondant à la phase maximale de la glaciation de la Pologne centrale (Riss), tandis que les niveaux successifs de l'érosion et de la sédimentation comme correspondant aux interstadiaires et stadiaires de la glaciation de la Pologne centrale (Riss) et celle de la Baltique (Würm) ainsi qu'à l'interglaciaire de l'Eemien et du Holocène.

En étudiant des coupes situées à l'Est du Jura Polonais, S. Z. Różycki [10] a observé les dépôts quaternaires se composant en majorité aussi de sable. Les fragments d'argiles morainiques de la glaciation de Cracovie (Mindel) et de limons sous- et supramorainiques sont situés au dessous de sables dominant sur la surface de l'étendue de cette région. L'accumulation des dépôts sablonneux est due à la perturbation du cours et du développement du réseau fluvial, car les affluents de la Haute-Pilica ont formé un écoulement invers, c'est-à-dire, au lieu vers le Nord, ils ont coulé vers le Sud-Est, à la Nida. Dans des couches de sable on trouve des intercalations caractéristique de graviers, de cailloux et de débris irréguliers de roches locales avec un peu de roches scandinaves, montrant l'activité de la solifluxion sur les pentes voisines. Tout celà c'était le résultat de l'invasion de l'inlandsis de la Pologne centrale (Riss) dans la partie septentrionale du bassin de la Nida et des conditions du climat périglaciaire. Jusqu'à nos jours on observe dans cette zone beaucoup de vallées mortes, suspendues et abandonnées, toutes modelées dans la série des sables intercalés de graviers et de débris de roches locales et scandinaves. La formation ci-dessus et particulièrement marquée dans les niveaux qui gisent de 16 à 18 m au dessus du fond de la vallée actuelle de la Haute-Pilica.

Les bassins de la Warta, de la Pilica et de la Nida sont unis par de vastes surfaces sablonneuses. On peut les considérer comme une nappe d'accumulation fluvio-périglaciaire du temps de la glaciation de la Pologne centrale (Riss). C'est alors que l'écoulement normale de ces rivières a été bloqué et que s'est formé un écoulement commun à l'avantage de la Nida qui menait toutes ces eaux vers le Sud-Est. La haute base d'érosion de la Moyenne-Vistule a eu comme conséquence l'absence d'un facteur de l'érosion du lit. Ceci causait l'écoulement des eaux qui charriaient sur une large front le matériel rocheux. C'était une accumulation étendue atteignant les surfaces des hauteurs et les versants des montagnes plus élevées. Dans la proximité de hautes crêtes avait lieu des coulées de solifluxion avec une prépondérence des roches locales, c'est-à-dire: des silex et des débris calcaires jurassiques de la chaîne du Jura Polonais et celle de Przedbórz, — des roches paléozoïques et mésozoïques des montagnes de Sainte-Croix, et enfin des roches crétacées et tertiaires du plateau de la Petite Pologne. Une certaine quantité de matériel morainique (de la glaciation de Cracovie-Mindel), conservé comme les fragments sur les versants des élévations, c'était jointe par endroits au matériel local.

PSEUDO-MORAINES FRONTALES AUPRÈS DE SĘDZISZÓW AU CENTRE DU BASSIN DE LA NIDA

Un phénomène intéressant est lié à l'écoulement des matériaux morainiques du Pléistocène inférieur, conservés par endroits. Dans la susdite zone périglaciaire de la glaciation de la Pologne centrale (Riss) les plaques d'argile morainique plus ancienne, conservées sur les pentes d'élévations, attaquées par de processus de la dénudation, formaient des écoulements penetrées jusqu'au débordement fluvio- périglaciaire. Au bord de cet espace inondé avait lieu un délavage de matériaux de la solifluxion: les limons, les sables et les graviers fins avaient été transportés plus loin, tandis que les gros graviers et les blocs rocheux restaient au bord de l'espace inondé, au pied ou au milieu du versant. Ce gros materiel lavé formait des agglomérations résiduelles semblables à celles des moraines frontales. Ces pseudo-moraines frontales apparaissent par exemple autour de Sędziszów près de Jędrzejów, en impliquant un sujet de discussions sur la pénétration de l'inlandsis de la Pologne centrale (Riss) jusqu'au centre du bassin de la Nida. On observe aux environs de Sędziszów (Nowa Wieś, Tarnawa, Białowieża, Swaryszów, Pawłowice, Wojciechowice, Krzcięcice, Słaboszowice) un seul type de séquence de dépôts: les dépôts sablonneux du débordement fluvio-périglaciaire en liaison avec des dépôts de pente déplacés par la solifluxion. Les larges vallées entaillées dans les couches crétacées sont tapissées par une épaisse série de sable fluvio-périglaciaire de la glaciation de la Pologne centrale (Riss). Cette série atteint les versants crétacés jusqu'à l'altitude de 300 m environ. Au pied des versants, qui ont constitués autrefois la bordure de l'espace innondé fluvio-périglaciaire. apparaissent des bandes ou bien des tertres isolés, formés de matériaux de graviers et de gros blocs rocheux scandinaves et locales. Ce sont des agglomérations d'un matériel résiduel d'une moraine détruite qui avec les fragments de l'argile morainique étaient déplacés par des processus de la solifluxion. Délavées de marne et de sable fin elles ont pris une forme d'une concentration d'un gros matériel rocheux. Mais elles ne peuvent être considérées comme les dépôts des moraines frontales.

ACCUMULATION MÊLÉ: FLUVIO-GLACIAIRE ET FLUVIO-PÉRIGLACIAIRE

Il faut encore souligner un autre type de perturbation de l'accumulation en zone périglaciaire auprès du front de l'inlandsis de la Pologne centrale. Dans cette zone avait lieu l'accumulation de dépôts fluvio-glaciaires liée directement avec le front de l'inlandsis. C'étaient des couches de sable et de graviers stratifiées provenant de la calotte glaciaire, alternant l'un à l'autre, qui s'intercalaient avec des couches locales de l'accumulation fluvio-périglaciaire. Il est presque impossible de fixer exactement la limite entre les dépôts fluvio-glaciaires et fluvio-périglaciaires. La prépondérance graduelle du matériel local de solifluxion dans les dépôts sablonneux de l'accumulation d'eau courante décide de la disparition de l'influence directe de l'inlandsis.

III. PROCESSUS DE LA DENUDATION ET DE L'ACCUMULATION PENDANT LA GLACIATION BALTIQUE (WÜRM)

Pendant l'interglaciaire Eemien le niveau d'accumulation fluvio-périglaciaire de la Pologne centrale a été fort taillé par des vallées de rivières qui ont repris leur base d'érosion abaissée. Il est formé un système de profondes vallées éemiennes. Mais à la fin de l'interglaciaire, à la suite de l'avance de l'inlandsis Baltique (Würm), apparaissait une nouvelle perturbation du système de drainage.

ACCUMULATION FLUVIO-PÉRIGLACIAIRE

L'érosion latérale a élargi les vallées éemiennes et ensuite une nouvelle accumulation les a remplis de dépôts sablonneux intercalés du matériel de solifluxion. Cette nappe de dépôts qui s'est formée pendant la glaciation Baltique (Würm) ne dépassa pas le cadre des vallées éemiennes, car les conditions d'un grand blocage de l'écoulement de la Vistule qui eut lieu au temps du glacier précédent, n'ayant plus apparu. En revanche les phénomènes des coulées de solifluxion se sont augmentés, se développant largement sur les pentes des hauteurs. Leur matériel pérégrinait sur de grandes distances même si les pentes étaient douces (I. Jurkiewicz fait savoir qu'un des, provenant de la chaîne de Przedbórz, avait parcouru 2,5 km). Ces processus menaient à la formation d'une série superficielle de graviers et, au pied des hauteurs, avec addition du matériel plus gros.

Les processus éoliens, tout en formant des espaces de déflation, augmentaient la concentration du gros matériel sur la surface des sables fluvio-périglaciaires.

Les dépôts accumulés dans les conditions périglaciaires de la glaciation Baltique (Würm) sur l'espace de la Pologne centrale, ont été nommés: dépôts fluvio-périglaciaire du temps de la glaciation Baltique. Leur principale étendue d'accumulation était limitée au cadre des vallées éemiennes, mais elle embrassait aussi des processus de transformations et de perturbations superficielles hétérogènes sur tout le terrain de la Pologne centrale.

PROCESSUS ÉOLIENS — LOESS ET SABLE ÉVENTÉ

Outre les écoulements de solifluxion il faut mentionner en premier lieu les processus éoliens. Ils s'effectuaient au cours de toutes les glaciations dans les conditions géomorphologiques et climatiques appropriées. Les dépôts du loess et du sable éventé en sont le résultat.

Les plateaux de la Pologne centrale, sur l'avant-pays de la glaciation Riss, représentaient par endroits des conditions favorables à l'accumulation des poussières du loess. On constata l'apparition du loess de la glaciation de la Pologne centrale, nettement sur le plateau de Miechów, dans le Jura Polonais et sur le plateau de Kielce-Sandomierz et aussi dans les montagnes de Sainte-Croix. C'étaient les mêmes terrains sur lesquels dominait l'accumulation suivante du loess, c'est-à-dire pendant la glaciation Baltique. Une telle convergence des espaces loessiques des deux glaciations aux étendues, pourtant bien différentes, donne à penser. Ainsi il existait pendant la glaciation Baltique des espaces bien plus vastes pour l'accumulation du loess, qui étaient avancés bien plus loin vers le Nord. Mais les poussères loessique en même temps ne remplissaient que les espaces méridionaux, ceux qui étaient occupés par le loess du temps de la glaciation de la Pologne centrale.

S. Z. Różycki a fait l'attention sur le manque de dépendance entre l'espace morainique de l'inlandsis contemporain et la source du loess transporté par le vent. Egalement il énonça l'opinion que c'étaient les vents de l'Ouest qui transportaient le matériel loessique des plaines de l'Europe centrale et le déposaient en Pologne centrale et même plus loin vers l'Est.

Mais l'opinion ci-dessus que la source du matériel loessique est située dans la zone des plaines de l'Europe centrale, ne trouve pas une confirmation aux espaces loessiques de la région de la Pologne centrale. On y observe que l'intensivité et la direction du vent portant le loess, s'est répetée au temps des deux glaciations. Ceci est démontré par les faits suivants: l'accumulation du loess se succédait sur les mêmes espaces (en excluant au temps de la glaciation baltique les espaces bien étendues situées près de la zone des plaines de l'Europe centrale), aussi la direction et la manière de diffusion du loess étaient semblables pendant ces deux glaciations.

Les observations faites dans les environs de Pińczów, Chroberz, Działoszyce ont démontré l'apparition d'une couche de craie marneuse du Crétacé locale, décomposée toute particulière. C'est une formation poudreuse, compacte, jaune, atteignant un mètre d'épaisseur, d'une structure et d'une teinte tellement semblable au loess qu'il est impossible de la distinguer du loess subaéral, y superposé par endroit. L'indice ce ne sont que les debris de la craie marneuse, qui sont nombreux et enfoncés dans le dépôts du simili loess. C'était déjà en 1931 que Z. Sujkowski a constaté que la craie marneuse décomposée peut être la source du matériel loessique. Cet auteur découvrant dans la composition pétrographique du loess de Volhynie la présence des structures organiques provenant de la craie et déposant sur une couche secondaire (Foraminifères, Coccolites). La ressemblance du loess au calcaire décomposé, apparaissant par endroits sur les surfaces du terrain, est aussi relatée aux observations de J. Malinowski sur le plateau de Lublin [6].

Les observations du domaine de l'accumulation du loess, citées plus haut, suggèrent que les terrains des plateaux calcaires de la Pologne centrale et de la Pologne orientale, avec leurs surfaces découvertes et décomposés de craie marneuse, pouvaient être l'une des sources du matériel loessique par excellence calcaire. Egalement les vastes étendues des argiles morainiques, restés sur l'espace de la Pologne centrale après la glaciation de celle-ci, pouvaient être une source du matériel loessique du même type. Mais les argiles morainiques pouvaient aussi fournir des poussières de quartz qui est un deuxième propriétaire important d'un dépôt loessique.

Un autre type d'espace d'alimentation du loess est représenté par les vastes espaces sablonneux et desséchés de la Pologne centrale. Les dépôts superficiels fluvio-périglaciaires devenaient pendant les phases particulières du climat sec, au Pléistocène, l'objet de processus éoliens, de l'éventation des sables. Ces processus conduisaient à la selection des grains et à la séparation des poussières accumulés ensuite en dehors des espaces des dunes. Les processus éoliens persistent sur de vastes espaces jusqu'à nos jours, en créant par endroits des paysages déserts, par exemple le Désert de Błędów à l'ombre de l'escarpement occidentale du Jura Polonais et celui des environs de Raków, sur l'avant-pays méridionale des montagnes de Sainte-Croix. Les poussières de quartz provenant des terrains sablonneux pouvaient être la source d'un important propriétaire du loess. Il est aussi possible que les intercalations des limons et des marnes se trouvant dans les dépôts fluvio-périglaciaires, ont délivré de poussières marneuses emportées par le vent.

Quelques observations et des remarques au sujet susdit sont conformés à certaines publications de H. Maruszczak [7]. Cet auteur fait une remarque sur la distance insignifiante entre les espaces d'alimentation du loess et ceux de l'accumulation; sur la participation des poussières provenants des espaces sablonneux à la formation d'une fraction sablonneuse dans les dépôts du loess.

Il est difficile de déterminer la direction des vents transportant le loess, car l'accumulation du loess avait tendence à accentuer, par sa masse de poussière, le relief du substratum.

La composition caractéristique du loess dans laquelle domine la poussière du quartz et du calcaire, démontre que les espaces sablonneux et marneux étaient la source de son alimentation. L'apparition des étendues sablonneuses, „désertiques" sur le côté occidentale des terrains loessiques (Fig. 1), est très intéressante: de vastes étendues sablonneuses avec le „désert" de Raków apparaissent à l'Ouest du plateau loessique de Sandomierz, aussi le Désert de Błędów, avec son vaste terrain de sable, touche de l'Ouest le plateau loessique de Miechów. Ces deux plateaux loessiques pouvaient donc recevoir les poussières, du quartz surtout, de deux régions désertiques mentionnés. D'autre propriétaire du loess, calcaire, pouvait provenir aussi bien de ces régions sablonneux (les dépôts sablonneux

Fig. 1. Esquisse géologique des dépôts quaternaires de la région de Sainte-Croix et du Jura Polonais (interprétation de J. Łyczewska sur la base de la Carte Géologique de Pologne [12]

1 — roches du substratum sans nappe de dépôts quaternaires; 2 — zone des moraines frontales de la glaciation de la Pologne centrale (Riss); 3 — argiles morainiques; 4 — sables et graviers fluvio-glaciaires et fluvio-périglaciaires; 5 — sables et graviers fluvio-périglaciaires; 6 — loess; 7 — vallées contemporaines des rivières; 8 — localités citées dans le texte

fluvio-périglaciaires étaient bien intercalés des argiles et des limons de solifluxion) que des régions morainiques de la Pologne centrale situés autour de l'espaces considérés et aussi bien des plateaux crétacés voisins.

Le problème de la direction des vents, créateurs du loess, n'est pas encore déchiffré.

CONCLUSION

Les plateaux et les montagnes de la Pologne centrale étaient un élément important dans la disposition et le développement des phénomènes dynamiques du Pleistocène. Les élévations de ce terrain formaient des barrages qui étaient forcés d'une manière diverse par l'inlandsis. Une composition caractéristique des dépôts accumulés sur l'espace de la Pologne centrale se réalisa au temps de la glaciation de la Pologne centrale (Riss): à partir de la zone de dépôts glaciaires des moraines frontales les dépôts fluvio-glaciaires se répendaient vers le Sud, tandis que plus loin vers le Sud, cette fois-ci sans les influences glaciaires, se formaient les dépôts périglaciaires sous forme d'accumulation fluvio-périglaciaire, éolien et de la solifluxion.

Les phénomènes mentionnés se répétaient au temps de la glaciation Baltique (Würm) mais déjà sans influences fluvio-glaciaires et avec l'accumulation fluvio-périglaciaire limitée par le cadre des vallées éemiennes. En revanche l'étendue des coulées de solifluxion et de processus éoliens y étaient plus grands. Les processus éoliens formaient parfois des espaces de déflation, parfois ceux d'accumulation aussi bien des dunes sur les vastes surfaces sablonneuses desséchées. que du loess couvrant les élévations et leurs versants desséchés.

Cet article traite aussi un problème intéressant du sable accumulé à l'altitude de 400 m, conservé dans le Jura Polonais. La question se pose si ce sont des dépôts de „l'oasis jurassique entre-glaciers" du temps de la glaciation de Cracovie (Mindel) ou bien s'ils sont un fragment de l'accumulation fluvio-périglaciaire conservé en condition favorables, provenant du temps de l'ingression et de la régression de cet inlandsis.

Dans une situation semblable, au sommet des montagnes, se sont conservés les sables fluvio-périglaciaires sur la chaîne de Pińczów. Son altitude atteint 300 m, ils provient du temps de la glaciation de la Pologne centrale (Riss). Dans le cas des sables au sommet du Jura Polonais l'altitude atteint 400 m — l'accumulation fluvio-périglaciaire en devrait être plus ancienne. Ce serait le premier niveau d'accumulation fluvio--périglaciaire du temps de la glaciation de Cracovie (Mindel). Le second niveau à l'altitude de 300 m environ occupe l'étendue la plus vaste et provient du temps de la glaciation de la Pologne centrale (Riss). Le troisième niveau fluvio-périglaciaire, ce de la glaciation Baltique (Würm), ne remplit que des vallées éemiennes.

Un type différent d'accumulation se formait dans le voisinage du front de l'inlandsis de la Pologne centrale, où l'accumulation fluvio-glaciaire alternait avec l'accumulation fluvio-périglaciaire.

Les processus éoliens ont crée encore un type d'accumulation. Ces processus étaient intenses à l'époque des glaciations, en dehors de la calotte glaciaire, dans la zone périglaciaire, en imprimant une marque morphologique accentuée dans la région de la Pologne centrale. Ils ont formé des espaces de sables éventés ainsi que des nappes du loess. Il est probable que le vent emportait la poussière loessique des couches fluvio-

-périglaciaires desséchées et décomposées, ainsi que des argiles morainiques et aussi des couches décomposées des calcaires formant des plateaux et des montagnes de la Pologne centrale.

La présente communication sur des phénomènes dynamiques ayant lieu pendant le Pléistocène dans la région de la Pologne centrale, indique une série de problèmes qui ne sont pas encore expliquer, et qui demanderaient de longues années d'études. Leurs résultats permettraient de déchiffrer la stratigraphie et la classification des dépôts quaternaires de types divers.

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III. ACCUMULATION PHENOMENA

SEDIMENTS AND FORMS OF THE FAR EXTENTS OF SCANDINAVIAN GLACIATIONS IN SW POLAND

Stanisław Szczepankiewicz

INTRODUCTION

The analysis of the borders course of Scandinavian ice sheet glaciations, revealed in Europe the occurrence of some areas of their far extent. In four places the ice sheet transgressed markedly 50° northern geographical latitude. This concerns the so-called Don, Dniepr and Dniestr lobe in the USSR territory, as well as the lobe of the Upper Odra, in Poland and Czechoslovakia. The maximal extent of the ice sheet is composed of several segments of various ages. The extent of the Don and Dniepr lobes is represented by the Dniepr Glaciation (Middle Polish, Saale, PGl). On the Upper Dniestr appears the border of the Oka Glaciation (South Polish, Mindel, Ap. Gl).

In Polish and Czechoslovakian territory, in the Sudety Mountains and the Moravian Gate the situation is exceptional. There are traces of the farthermost extent of the Southern Polish glaciation (Mindel, Ap.Gl) in Europe. Here also, the borders of the two large European glaciations are almost overlapping. Their course in the Sudety corresponds to the maximal vertical range of the ice sheet in Europe (about 590 m.a.s.l.). This is the third specific feature of SW Poland.

It is essential for further discussions that in all the above mentioned lobes the ice sheet overstepped the European watershed line [14]. West of the Moravian Gate and the Sudety, the watershed line runs far to the south of the ice sheet extent, which may have effected the motion of ice masses.

While for the USSR areas in the range of the three above lobes numerous elaborations are available, there are none for the Upper Odra lobe. from the standpoint we are taking in the present paper. This fact, next to the specificity of the SW Poland Quaternary was a decisive factor in the attempt to elucidate the problem in this paper.

As a result of detailed investigations performed in this area in chosen zones, an attempt of a "triaxial" concept of Quaternary sedimentation stages and relief development was undertaken. It was based on the intensification of research in three directions: a) in a valley of a big river, b) on the cross-section of the river basin and c) on the vertical distribution of the covers of the highest, isolated culmination. In the light of the analysis of sediments and forms, it became possible to reconstruct also the vertical extent and the shape of the ice sheet in the marginal zone, the ice-mass movement and the character of deglaciation.

BASIC MATERIAL

The "triaxial" concept was realized in this case, by systematizing earlier materials and carrying out of new investigations in the Odra valley, on the cross-section Żmigród-Wałbrzych, and in the Ślęża massif. The problem of forms age was elucidated by means of palaeobotanic, palaeozoologic, archaeologic studies, and by results of ^{14}C test.

THE ODRA VALLEY, BETWEEN GŁOGÓW AND RACIBÓRZ

The preliminary analysis of material is based on the characteristics of the relief and structure of the Odra valley in two extreme cross-sections. The first one was carried out near Głogów. There occurs a system of three Holocene terraces, out of which the third, highest, is shown in longitudinal profile (Fig. 1). It is Postatlantic. This system is a general one for the whole of the investigated segment of the Odra valley. Besides, there exists near Głogów a terrace with dunes, of North-Polish Glaciation age.

On the right side of the river valley appears also a North-Polish outwash horizon. In the left part there are kame steps, connected with the Warta stage. In the longitudinal profile appear important differences in the development of the terraces (Fig. 1).

A striking example of this is visible in the second, marginal, transverse profile, investigated in the Racibórz region. In the right valley part, the highest Holocene terrace (about 7 m) adheres to the basal slope surface, developed in Tertiary clays. The high right-hand slope of the valley develops contemporaneously under the effect of intense mass-movements, whereas the left-hand one, protected by a loess cover dis-

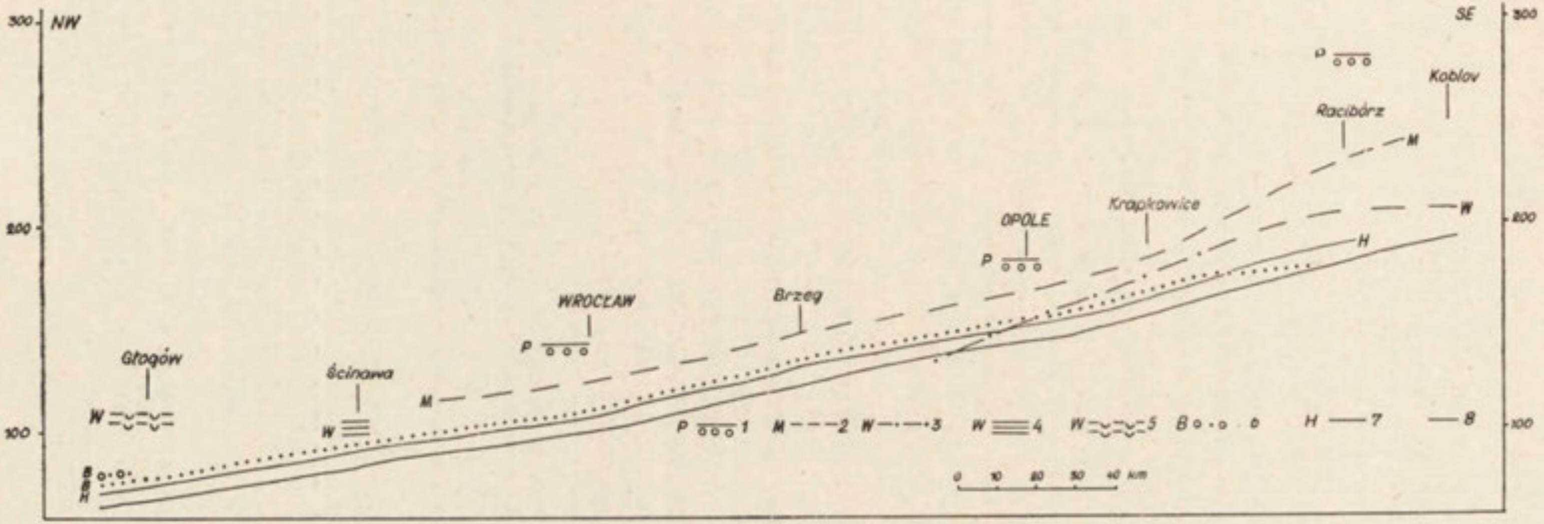

Fig. 1. Longitudinal profile of the Odra valley

1 — Pliocene horizon; 2 — kame terrace of the Odra stage (Maximal P Gl 1); 3 — cone-terrace of the Warta stage (P Gl 2); 4 — ice-dammed lake level of the Warta stage (P Gl 2); 5 — kame terrace of the Warta stage (P Gl 2); 6 — North Polish fossil horizon and terrace (L Gl); 7 — holocene terrace; 8 — river level

plays the presence of terraces. The loess cover, 6 to 10 m thick is situated rather unexpectedly. Concomitantly with the mud cover of the Holocene terrace it forms the bottom of the valley. Loess is also lying on the upper terrace of the Warta stage and on the upland. The gravel horizon sinks below the Holocene and North Polish loess sediments (Fig. 1); it is slightly younger than the loesses. The longitudinal profile of the Odra valley, studied in detailed investigations, connects these two marginal transverse cross-sections. It reveals the valley forms and sedimentation types, not necessarily always connected with the fluvial sedimentation (Fig. 1).

The Holocene sedimentations, dated by ^{14}C test developed after the climatic optimum. The North-Polish age terrace (Weichsel, Würm, L Gl) near Głogów is related to the outwash area of the same age in the right--hand part of the valley. In the upper course of the Odra the gravel North-Polish level bears a fossil character. Its sediments fill a channel of the Eemian age, developed in sediments of older glaciations, and of the Tertiary.

Water sedimentation, connected with the Warta stage manifests in the longitudinal profile of the Odra valley a marked differentiation. In the Baruth-Głogów ice marginal streamway (*pradolina*) it forms kame steps on the inner side of the course of the Warta stage moraines. These steps are overhanging at a great height the present bottom of the Odra valley. In the Ścinawa depression this period is represented by ice-dammed lake sediments. In the Wrocław-Bremen ice marginal streamway (*pradolina*), the Warta horizon is represented by outwash sediments. Beginning with Opole, up the river, the Warta horizon presents a cone-like terrace. Its fragments rest on shelves of glacial or Tertiary sediments. The higher level of accumulation in the Odra valley zone bears the character of kame terraces. The low position above the river of kame forms and the presence of several horizons of glacial, fluvioglacial and fluvial sediments, beneath the present bottom sedimentation excludes the possibility of existence of high fluvial filling up in the Odra valley and probably in many other fluvial valleys of the Pleistocene Glaciation. The sediments connected with the South-Polish Glaciation (Elster, Mindel Ap Gl) fill up a deep incision in the valley, eroded in Tertiary formation. The Pliocene gravels high overhanging the present valley bottom indicate the important scale of the erosion in periods preceding the South Polish Glaciation (Ap Gl). The age of that incision is determined by the upper Pliocene gravels and the moraine bottom in the valley. The stratigraphical situation of the sediments and the fossil levels in the valley indicate a gradual rise of the bottom surface, mainly as a result of successive sedimentations of various origin.

THE CROSS-SECTION OF THE ODRA RIVER BASIN

Investigations in the zone of the cross-section revealed several essential facts. Of particular significance are the four interglacial sites. The scope of the elder information material has been recently greatly extended. The occurrence of four horizons with fossil flora in the Żmigród profile confers it a unique character. Two of them are undeniably of interglacial character (Fig. 2). The Żmigród profile suggests conclusions concerning not only the age of sedimentation series [18] but is also of a decisive importance for the problems of development of various of ice marginal streamways (*pradolina*). The second important point of the cross--section is the well-known position of the Eemian Interglacial from the Trzebnica region. It lies in the range of the thrust moraines of the Warta stadial. Near Wroclaw, the cross-section cuts exactly dated Odra valley formations.

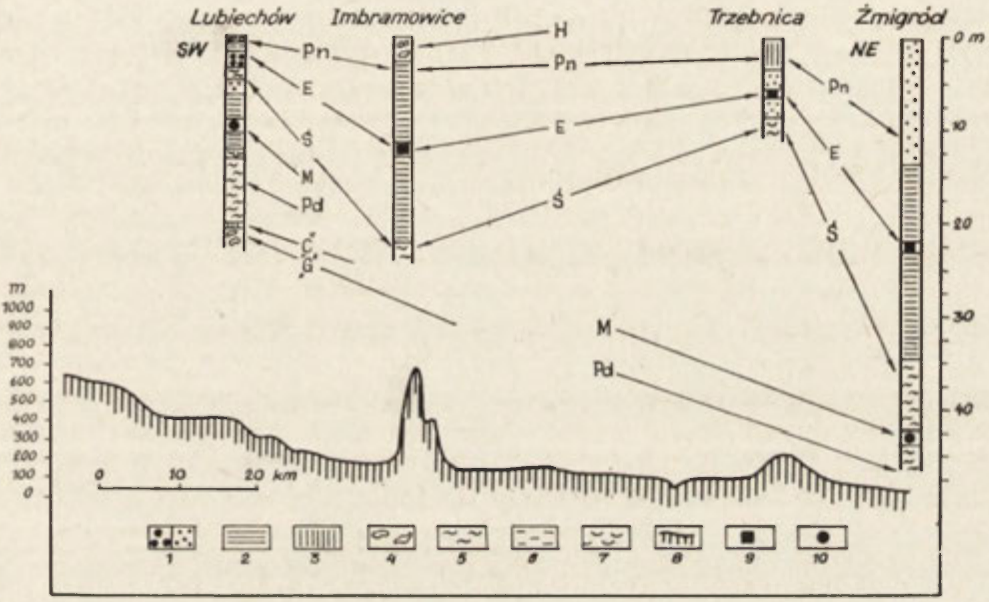

Fig. 2. Cross-section of the Odra basin

1 — gravels and river sand; 2 — lake sediment; 3 — eolian sediment; 4 — periglacial slope structure; 5 — boulder clay; 6 — weathering of the type „Terra fusca"; 7 — weathering of the type „Terra rossa"; 8 — fossil flora and fauna; 9 — fossil fauna; „G" — Günz Glaciation; „C" — Cromer Interglacial; Pd — Southern Polish Glaciation (Ap Gl); M — Masovian Interglacial (Holstein); S — Middle Polish Glaciation P Gl; E — Eemian Interglacial (Eem); Pn — North Polish Glaciation (L Gl, Wurm); H — Holocene

Extending into the left-hand side of the river basin, it is supported by two interglacial sites. Late investigations (1961) have established that the Imbramowice site cannot be related with the Mazovia Interglacial (Holstein), only to the Eemian one. A basic importance may be ascribed in the Sudety to the interglacial site of Lubiechów. This is the first interglacial site discovered in the Sudety [19]. Its intermorainic position has revealed the presence of two Scandinavian glaciations in these mountains. This position indicates that the limits of maximal extent of Southern-Polish (Elster, Ap Gl) and Middle-Polish (Saale P Gl) Glaciations are in the Sudety almost identical. The cross-section was carried up to one of the high positions of ground moraine in the Sudety, and at the same time in Europe (560 m.a.s.l.). Three basic hypsometric levels may be distinguished in the area crossed by the studied cross-section: a) about 100 m in the zone of the Baruth-Głogów and Wroclaw-Bremen ice marginal streamway (*pradolina*), with delimitating treshold of thrust moraines in the old watershed zone; b) about 200 m in the foothill zone, and c) about 400 m in the mountainous foreland of the Sudety Mountains. It should be stressed that in the pradolina zones the subquaternary substratum lies in the vicinity of the present sea level. The fact of such a hipsometric differentiation strongly affected the extent and shape of the Scandinavian ice sheet in the area of its maximal transgression. This effect also played its part during the deglaciation. In the area of Poland and Sudety Mountains, the ice sheet butted against the orographic bar-

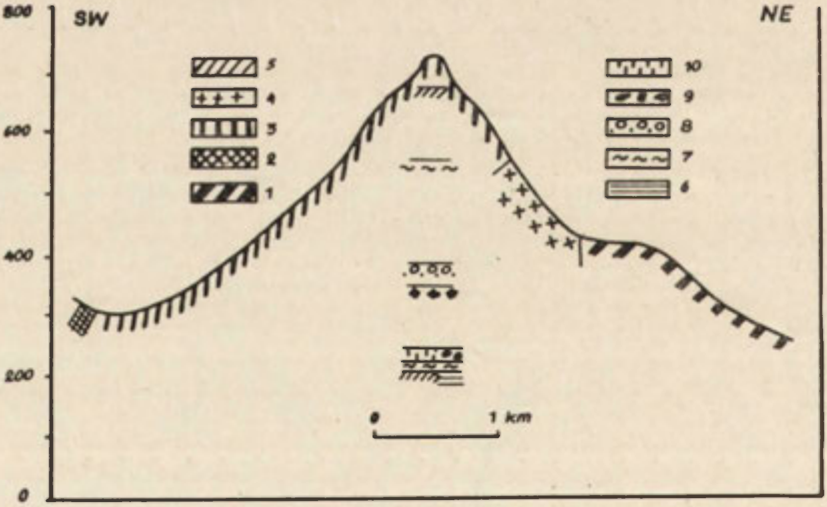

Fig. 3. Sediments in the vertical profile of the Ślęża Massif

1 — amphibolite; 2 — serpentine; 3 — gabbro; 4 — granite; 5 — Tertiary weathering sediments; 6 — Tertiary clay; 7 — boulder clay; 8 — sand and kame gravel; 9 — periglacial rubble; 10 — dust sediment

rier, thus presenting a classical area for investigations on the behaviour of the ice mass arrested in its forward movement. In the foothill zone of the Sudety there exist optimal conditions for the elucidation of the problem of vertical range of the ice sheet, of its shape, and the ice mass movement. These conditions are connected with the foreground culminations particularly with that of the Ślęża massif. Of basic importance for the elucidation of the ice sheet transgression processes and deglaciation stages are the covers in the vertical profile of the Ślęża Massif (Fig. 3).

VERTICAL PROFILE OF THE ŚLĘŻA MASSIF

The absolute altitude of the Ślęża Massif is 718 m; its relative altitude is about 500 m. It is at a 20 km distance from the edge of the Sudety Mountains and about 40 km from the high position of the ground moraine in the Walbrzych-Sudety. The important distance from the Sudety threshold, its altitude and isolated situation predestinated the Ślęża to be the third, vertical axis of the admitted system. As a result of investigations, several types of sediments and covers were established in its vertical profile (Fig. 3). The summit and slopes of the main culmination are composed of gabbro and granite. On the other hand, the low elevation of the massif base are built by amphibolite. In the Sudety ground moraines, as well granite, gabbro. and amphibolites, originating from the Ślęża massif were found. The latter ones were transported to a distance of about 40 km in S direction, and lifted from about 40 m.a.s.l. to about 560 m.a.s.l. Observations concerning the movement of rocky material from the culminations of foreground of Eastern Sudety confirm the fact of such type transportation [20]. It gives an idea on the ice mass movements (Fig. 4).

In the Ślęża, at 680 m.a.s.l. and at about 480 m relative altitude a layer of Tertiary weathering material was found, but there are no signs of any glacitectonic disturbance of any kind nor of any erratic material. On the other hand, a thick ground moraine was found at 530 m.a.s.l. and 330 m relative altitude. It should be stressed that the altitude of erratic material, occurrence in the East, Central and West Sudety amounts to about 590 m.a.s.l. On this basis could be reconstructed the almost horizontal course of the ice-sheet surface in the marginal zone, supported by the Sudetys edge. The earlier accepted inclination has no pertinent basis [4]. The ice sheet in this region had most probably a stronger inclination but not below the snow-line [1], i.e. at a distance of 120 - 150 km from its border. From the fact of rocky material transportation from the premountainous zone into the mountains appears a movement resultant of 6%, in proximal direction. This fact also explains the character of orographic barrier forcing, connected rather with an "extrusion flow" kind of motion within the ice mass. This concerns probably the European area west of the Moravian Gate, whereas in East European areas it should be considered that in the lobes of the Don and the Dniepr the "extrusion flow" motion type was replaced by a process of free flowing of ice, south of the European watershed. This explains also the highest thickness in the marginal zone of the ice sheet in SW Poland and the lowest in Eastern Europe.

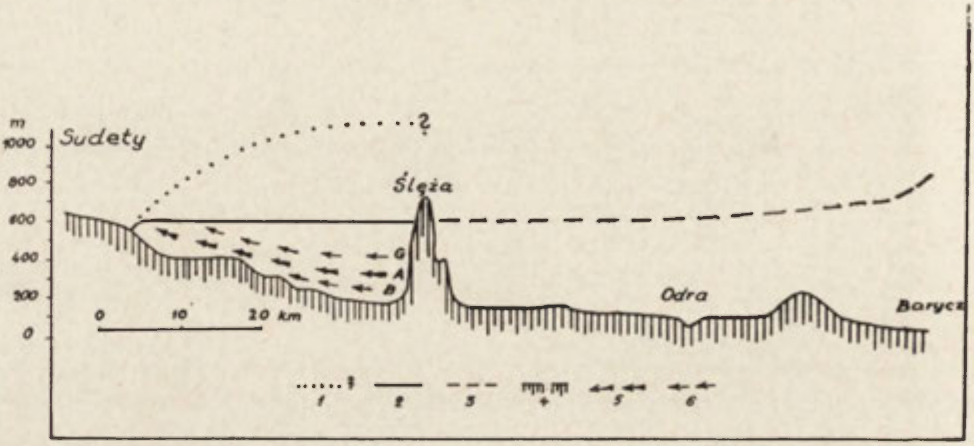

Fig. 4. Reconstruction of the ice-sheet surface in its marginal zone

1 — surface inclination according to earlier opinions; 2 — reconstructuted surface of the ice-sheet; 3 — hypothetical glacier surface; 4 — subglacial substratum; 5 — resultant of the amphibolite movement; 6 — resultant of the granite and basalt movement

The analysis of the vertical profile of the Ślęza massif determines also the character of deglaciation in the premountainous zone (Fig. 3). The sedimentation of the thick ground moraine on the pass 530 m. a.s.l., of a kame form at 380 m, and again a ground moraine at the foot of the massif, finally of kames and ground moraine on the adjacent plain indicates on the areal course of deglaciation. The initial surface was, according to investigation, an almost horizontal surface. Mostly areal, was also the deglaciation in the lower part of the Odra valley depression. This is witnessed by kame terraces and ground moraines, hidden under the contemporaneous bottom of the river valley. The course of glaciation and the stages of deglaciation were studied on the example of the maximal phase of Middle-Polish Glaciation, of which sediments and forms occur contemporaneously in the relief of SW Poland. This relief basically overlying the decayed forms of Southern Polish Glaciation, of an almost identical extent in the investigated area. It may be assumed with great approximation that glaciation and deglaciation during the older glaciation followed a similar cource in this area. Certain differences were the result of preglacial relief.

THE COURSE OF SOME PROCESSES ON THE BACKGROUND OF THE QUATERNARY SEDIMENTS AND LAND-FORMS

In the investigated part of Poland as in many other areas the relief presents a disharmonious character. The landscape shows fragments of an old planation surface, preserved under a thick Tertiary weathering covers, as for instance in the Ślęża massif. Locally occur exhumed surfaces of Pliocene gravels. The analysis of fossil relief indicates that at the turn of the Pliocene and the Pleistocene, rather more so at the beginning of the Pleistocene. violent erosive processes had developed. This is confirmed by an amplitude of about 70 m of Pliocene cone level dissection (Fig. 1, 2). The comparison between the situation of the South-Polish moraine bottom (Mindel. Ap Gl) in the Głogów-Baruth ice marginal streamway (*pradolina*) and its situation in the Sudety valleys indicates a much wider amplitude of the early-glacial relief than the present one. The deeply cut valley network became a system, collecting numerous sedimentation series in the investigated area. Basing on the analysis of sediments and fossil forms, several kinds of processes may be reconstructed. Rubble and gravels, drilled in deep, fossil valleys are connected with the periglacial climate of the "Günz" Glaciation ice-dammed lake, clay found in the valleys of Sudety and of their forelands, are bound with the transgression of Middle-Polish Glaciation (P Gl). They indicate a progressive blocking of particular segments of those valleys by the ice-sheet. There is no important fluvial filling in the valleys. On the other hand, there are thick series of glacial and fluvio-glacial sediments, connected with the South and Middle-Polish Glaciations (Ap Gl, P Gl). To these series may be ascribed the gradual flattening of river valleys. The successive erosion of the decline of the Glacial and of the Interglacial beginning could not eliminate the mass of accumulated material.

The highest fluvial accumulation is connected, according to the results obtained, with the Warta stage. In this case. the secondary banking of the maximal stage sediments plays its role. The result of Eemian erosion is the fossil channel, subsequently filled up with Early Würm sediments. With this period, with its maximum, is connected also the eolian sedimentation of loess type. In the interfluvials, a permanence of watershed zones was established, as well as the deposition of glacial and fluvoglacial sediments. A sedimentation of kame and fluvial type is particularly frequent. This is an effect of areal deglaciation and long-lasting stagnation of dead ice in valley depressions.

The valley and watershed zones are connected by their "lining" with glacial and fluvioglacial sediments of the same age.

The direct effect of the ice sheet on the substratum is expressed in the investigated area by multiphased glacitectonic disturbances. With these processes are bound all more important culminations of the SW Polish Lowland.

CONCLUSIONS

As illustrated by the materials obtained it may be considered as established that the Sudety displayed two different glaciations: the South-Polish (Ap Gl) and the Middle-Polish (P Gl). The development of the valley network started with a deep indenture, most probably early--glacial, the sediments of fluvial terraces being generally deposited on glacial sediments.

The maximal filling is connected with the Warta stage, represented by the sediments of cone-like terraces, above them there appear kame forms of the maximal stage of Middle-Polish Glaciation (P Gl).

In the area of SW Poland there is a lack of ice marginal streamway (*pradolina*) forms of a continuous character. In the process of areal deglaciation, after thawing of durable watersheds. the flow of waters had a multidirectional character.

Some gates have a glaci-epigenic character. An established lack of high gravel-sand fillings was replaced by dead ice.

Warta moraines developed on the mentioned area as a result of tri-phasic glacitectonic disturbances of longlasting watershed. In the Upper Odra lobe, the surface of the ice sheet was almost horizontal. This phenomenon was favoured by the orographic barrier of the Sudety Moutains. The movement of ice masses in the area west of the cross--section of the glaciation border with the European watershed was of "extrusion flow type", whereas in the East it was constituted by a partly free flow of ice masses in the Don and Dniepr lobes.

These conclusions concern in their majority regions of relative tectonic calm, in the farther extent of two separate Scandinavian glaciations.

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GEOGRAPHIA POLONICA 17, 1969

BOULDER CLAY FESTOONS ACCUMULATED IN FRONT OF THE ICE SHEET

KATARZYNA STRASZEWSKA

During field investigations performed in the interfluve area between the Bug and Narew rivers, east of the Warsaw Basin, marginal forms differing in shape, from known up to now ice-margin forms were met with.

These features are extensive, reaching over a score km in length and a few km wide, ridge-shaped, of asymmetric profile in cross-section, with flattened top-surface, steep short proximal and gentle, long distal slopes. In shape they resemble a fan, or a series of fans connected with one-another. They are mostly composed of boulder clay.

Up to now these features had no place in the nomenclature of glacial forms. To those already described, the term of "escarpment" was applied for the proximal slope — the Opinogóra escarpment [8 - 10], the Ostrów escarpment [14]. These terms were rather due to tradition and originated from the striking aspect of the characteristic slope, which, according to contemporaneous knowledge of the geological structure of these forms, suggested the connection of their genesis with tectonic phenomena [8, 9], or with erosion processes [20].

The term "escarpment" does not determine with accuracy the mentioned forms, as the escarpment is only one element of the discussed forms, notwithstanding the fact that it is the most obvious element. A more adequate term could be suggested by calling them boulder-clay festoons, or marginal boulder-clayey festoons.

In the interfluve area of the Bug and the Narew, two such festoons have been distinguished: the Ostrów one, near Ostrów Mazowiecka, and the Sokoły festoon, situated to the SE of the small town of Sokoły (WSW of Białystok). Both these forms are situated within the range of the Middle-Polish Glaciation (Riss), and are connected with its recession.

The situation of the Ostrów and Sokoły festoons is analogous: both of them separate areas of different character and origin of relief. Their forefield bears distinct traces of meltwater activity, while their hinterland is characterized by the occurrence of glacigenic forms — end moraines, outwash fans, kames and other forms of dead ice.

The Sokoły festoon extends from NW to SE, its steep slope has a NE inclination, the gentle one is SW directed. It is not large — about 10 km long and 1 · 5 to 3 · 0 km wide (Fig. 1). Its asymmetry is very distinct. The north slope is about 13 m high. The festoon has the shape of an oblong ridge, cut by a steep escarpment from the NE, with a flattened top and very gently inclined SW slope. It separates (as mentioned above) two different relief zones (Fig. 1). Southward lies the morainic upland reaching higher elevation than the festoon itself, cut by valleys formed by meltwater flowing southward to the marginal Nurzec valley.

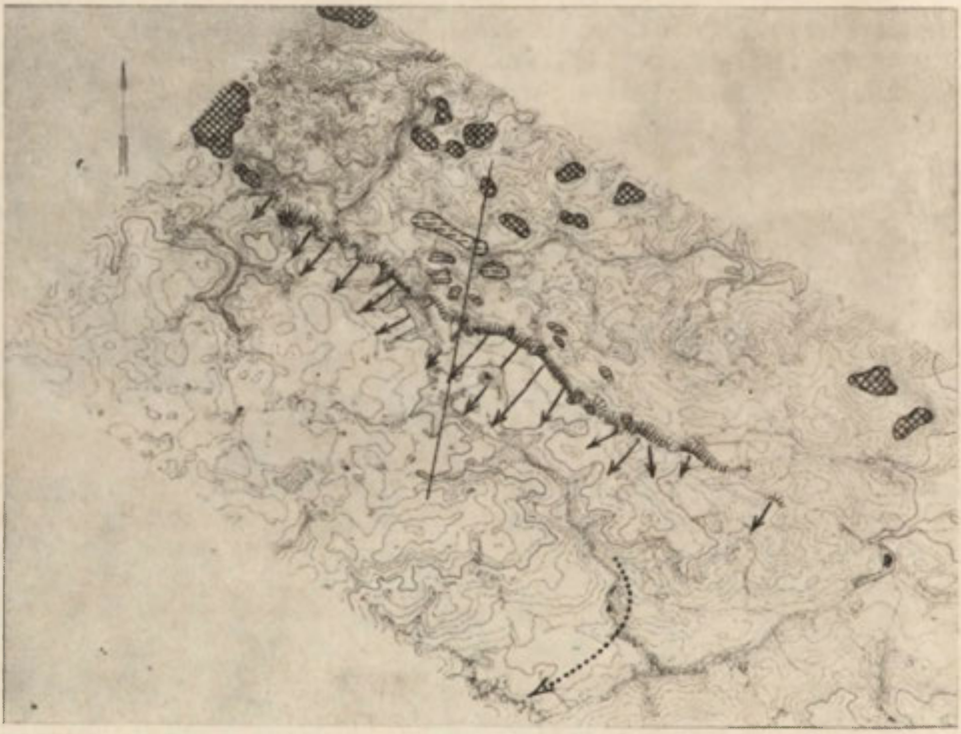

Fig. 1. Hipsometric-geomorphological sketch-map of the Sokoły festoon and its surrounding (for explanation see Fig. 1)

To the north lies an area of strongly differentiated relief, typical for the ice-margin zone.

The synthetic profile of the sediments of the Sokoły festoon, starting from the surface donwards is as follows (Fig. 2):

1. boulder clay, sands of kames and sands and gravels of dead ice moraines,
2. boulder clay as well as sands, gravels and boulders of ice-margin accumulation,
3. ice-dammed lake sediments: warved clays and silts.

On the surface of the Sokoły festoon occurs boulder-clay several meters thick. In the northern zone, boulder clay overlays silts or fluvioglacial sands. In some places it is replaced by gravels or interbedded with ice-marginal deposits.

To the northern slope of the Sokoły festoon kame hills adhere locally. In its farther hinterland kames, dead ice moraines, and other related features occur. The development of the Sokoły festoon had probably the following course:

1. The advance of the ice-sheet onto the area of former ice-dammed lake and the establishment of its front in the zone of the present northern slope of the Sokoły festoon;
2. the melting of the ice-sheet and accumulation of boulder clay between the ice-margin and the elevated area of the forefield as a result of lack of water-outflow, thus no segregation of material. In the final phases, a variable accumulation of boulder clay or of gravels and sands of ice-margin origin;
3. poor outflow of water collected in the forefield of the festoon by the stream flowing paralelly between the south slope of the festoon and the elevations of the forefield;
4. the stagnation of the ice sheet, the development of holes in the dead ice at the contact of the newly developed slope of the festoon and in its further hinterland, formation of kames and other forms of dead ice.

The analysis of the shape and structure of the Sokoły festoon as well as the process of their formation and geomorphological situation induce the author to consider this form as corresponding to an end moraine of specific type. developed in conditions of forcible accumulation of clayey glacial material.

The Ostrów festoon is a slightly NE bent bow running from WNW to ESE (Fig. 3). It represents a much larger form than the Sokoły festoon. It is about 30 km long, and 1·5 to 3·0 km wide. The proximal slope, turned N and NE is from 9 to 15 m high. In the Ostrów Mazowiecka region it is composed of rounded, flat-topped elevations, or of elongated ridges connected with one another. The southern, distal slope

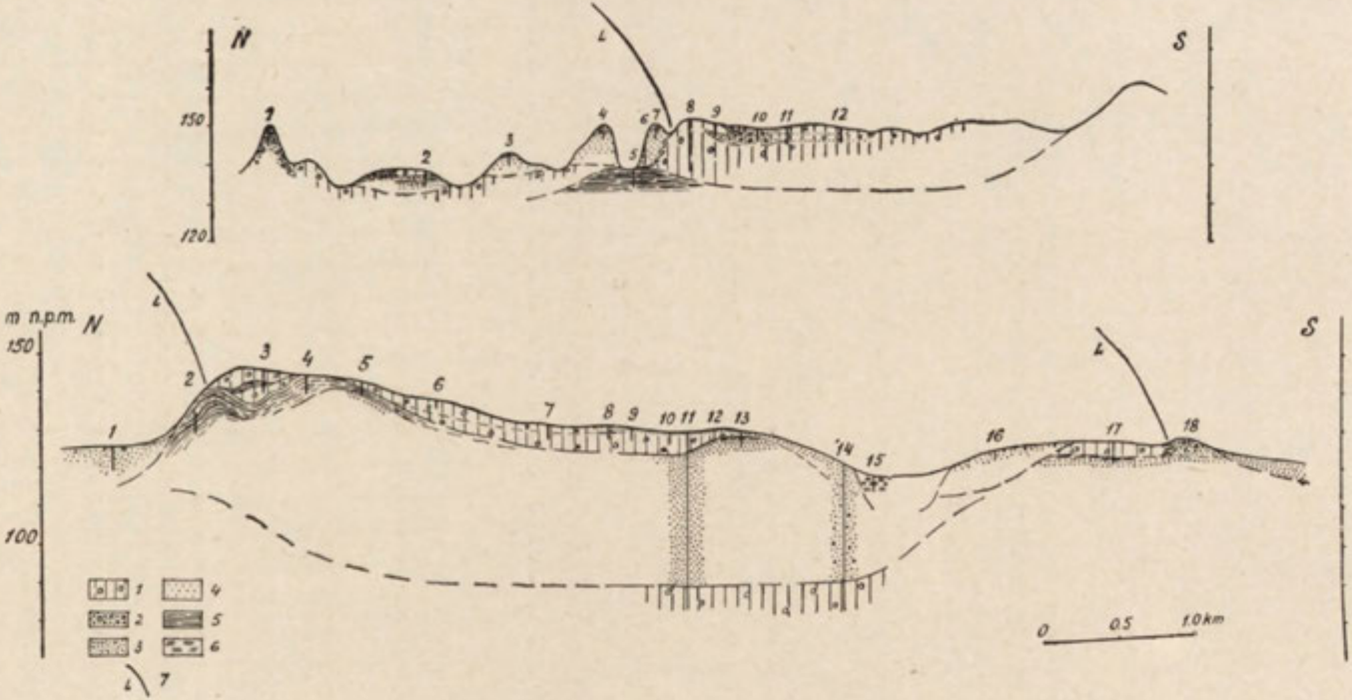

Fig. 2. Geological cross-sections of the Sokoły festoon (uper part) and the Ostrów festoon (below)

1 — boulder clay; 2 — gravels and sands with stones; 3 — outwash sands; 4 — sands of kames and similar forms; 5 — ice-dammed lake sediments; 6 — peats; 7 — extent of the ice-sheet front

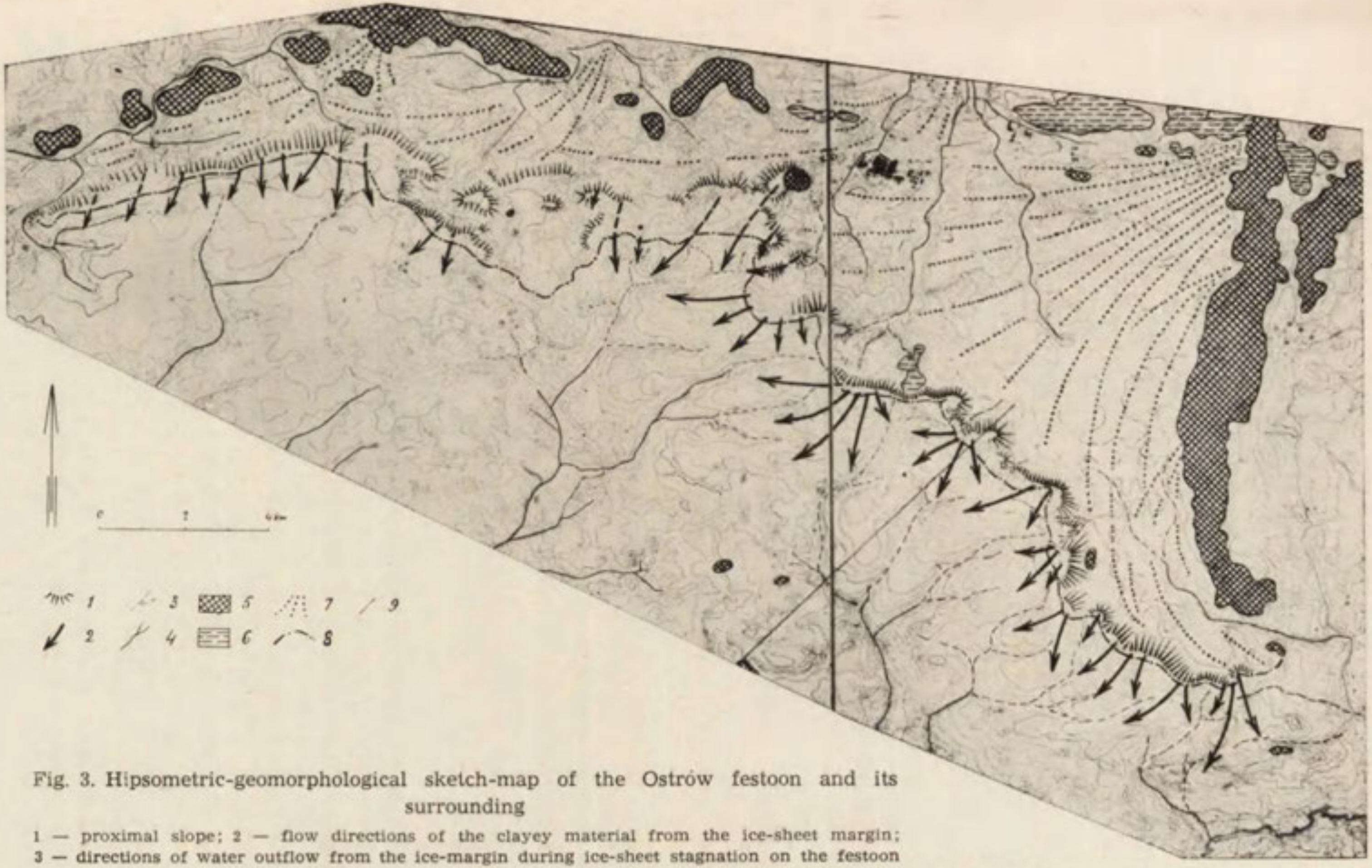

Fig. 3. Hipsometric-geomorphological sketch-map of the Ostrów festoon and its surrounding

1 — proximal slope; 2 — flow directions of the clayey material from the ice-sheet margin; 3 — directions of water outflow from the ice-margin during ice-sheet stagnation on the festoon line; 4 — drainage network; 5 — features of ice-marginal accumulation; 6 — areas of kames and akin forms; 7 — outwash outflow areas; 8 — recent watershed

of the festoon is gentle and long. It gradually passes to the south into the IV surface of the Bug and Narew valley.

The surface is an outwash plain. inclined towards the valleys of these two rivers, cut by flat valleys of their tributaries, of which the source area are the wide depressions of the northern slope of the Ostrów Festoon.

The northern border of the festoon is represented by the outwash plain, situated at the foot of the festoon and north of that outwash an assemblage of marginal forms (associated with the terminal depressions) of two lobes [14] occurs. They are well known since a long time in the literature under the name of the Czerwony Bór moraine.

The sediments of the Ostrów festoon (form top to bottom) are as follows (Fig. 2):

1. Ice-margin gravels and younger fluvioglacial sands, younger boulder clay,
2. ice-dammed lake sediments: varved clays and silts, silts and pelitic sands,
3. older fluvioglacial sands and gravels,
4. older boulder clay.

The older fluvioglacial sediments fill the depression in the older boulder clay, and are situated markedly above its top (up to 140 m), especially along the northern slope of the Ostrów festoon. Their top is gently inclined towards the south, and steeply to the north. The older fluvioglacial sediments run to the south and have no prolongation to the north. They represent a fossil outwash plain. composed of a series of connected fans, and their course is in concordance with the course of the Ostrów festoon.

The outwash plain sediments are overlain by ice-dammed lake sediments and by younger boulder clay. Ice-dammed lake sediments occur in a thin layer on the southern slope of the festoon while in the north their thickness reaches over 6 m (Fig. 2). They show glacitectonic disturbances, especially in the zone of the northern slope. The younger boulder clay covers the whole area of the Ostrów festoon. The thickness of the clay increases to more than 4 - 5 m within the elevations of the northern slope. It shows here interbeddings of ice-dammed lake sediments, and on the southern slope sandy interbeddings.

The younger fluvioglacial sands appear in two zones: to the south of the Ostrów Festoon where they form an outwash plain called the IVth surface, and to the north, where the outwash plain is slightly younger, and lies between the Ostrów festoon and the Czerwony Bór moraine.

At the front of the southern outwash plain small, strongly eroded ice-margin accumulation hils occur. Hills composed of the typical ice-margin sediments, better preserved, adhere to the northern slope of the

Ostrów festoon. Their sediments locally cover disturbed ice-dammed lake deposits.

The process of the Ostrów festoon forming could be summed up in the following points:

1. the filling up of the depression in the older boulder clay with fluvioglacial sediments and the development of the outwash plain in front of the ice sheet,

2. the retreat of the ice margin and the formation of an ice-dammed lake north of the outwash plain, and — may be — of small, shellow ice-dammed lakes on the surface of its southern inclination,

3. the advance of the ice-sheet, the disturbance of the ice-dammed lake sediments.

4. the halt of the ice-sheet on the line presently traced by the extent of the younger boulder clay and morainic hillocks (Fig. 2),

5. the flow of abundant fluvioglacial waters, the formation of end-moraine hills and extensive southern outwash plain,

6. the melting of the ice-sheet, the establishment of its margin on the line of the northern slope of the Ostrów festoon. The water erosion of the forefield, the gradual decrease of water quantities, the building on of the northern slope of the festoon by clayey material, creeping down from the ice-sheet margin and forming flat, dome-like cones, the accumulation in some points of typical ice-margin sediments, the development of end moraine hills.

7. the melting of the ice sheet and the retreat of its front to the line of the Czerwony Bór moraine and its western prolongation,

8. the drainage of meltwaters along the foot of the northern slope of the Ostrów festoon towards the Bug and Narew valleys, partly undercutting and burying the festoon slope (reduction of its height from above a score to 9 - 15 m).

The Ostrów festoon is a fairly complex form, as well in respect to shape as to structure and genesis. The author is inclined to treat its part composed of elevations and ridges as marginal form a derivate of 1) the predisposition of the substratum relief — the existence of fossil outwash plain, 2) pushing the foreland sediments, 3) specific ice-margin complex accumulation partly of ice-contact type? [3].

The Opinogóra escarpment, known since a long time in the literature [8, 9] and described by Michalska [10] is the largest among boulder-clay festoons. Its length equals that of the Ostrów festoon and amounts to 30 km, it is several km wide, and reaches a height of 40 m (Fig. 4). Its situation also differs from all others — it runs from north to south. Its characteristics approximate those of the described above forms, yet it is asymetric not only in its transverse cross-section. but also in the longi-

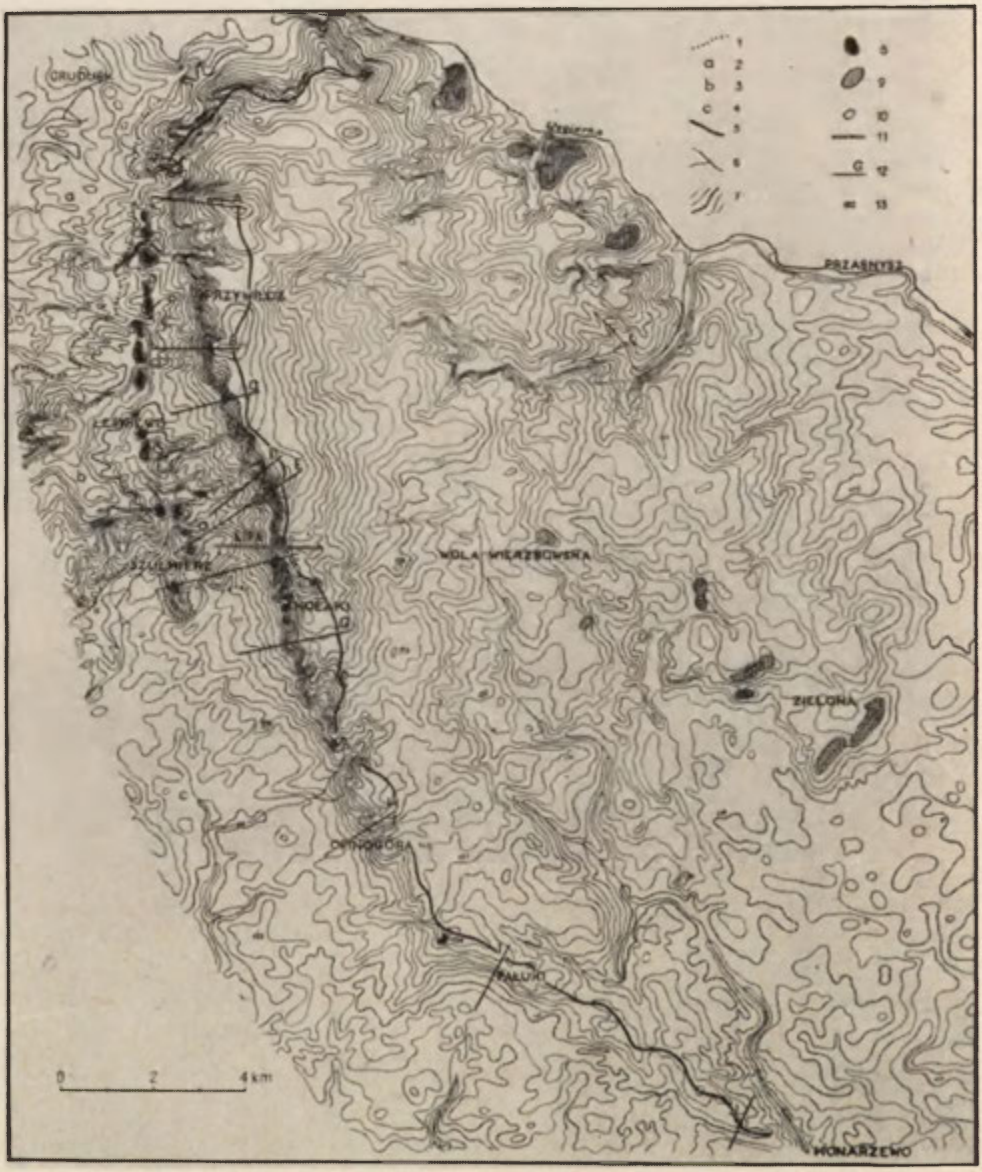

Fig. 4. Sketch-map of the Opinogóra escarpment and its surrounding (after Z. Michalska)

1 — limits of geographical units of the forefield; 2 — lake abrasion zone; 3 — morainic upland; 4 — zone of denudation; 5 — main water-divide in the escarpment zone; 6 — river network; 7 — contour lines every 2, 13 ad 17 (thick lines) meters; 8 — culminations in the forefield and in the escarpment zone built of sands and gravels; 9 — hills of ice-sheet margin accumulation in the escarpment background; 10 — undrained depressions or their distinct traces; 11 — line of the geological cross-section; 12 — lines of topographical profiles; 13 — more important hipsometric points

tudinal one: the height of its proximal slope decreases from N. to S. Besides, its outline approximates a triangle, whereas the two preceding forms are of elongated shape.

Its environment is analogous to that of the Ostrów and Sokoły festoons. The foreground is an upland with traces of waterflow, its hinterland — an area of dead ice. It is constructed of boulder clay (Opinogóra clays [10]), and in some places, above its proximal slope occur sediments of ice-margin accumulation. Michalska connects the development of the Opinogóra escarpment with a specific ice-margin accumulation in a "concavity" between two lobes of the ice sheet of one of the stages of Middle-Polish Glaciation. Michalska supposes that the character of the accumulation may have been the result of an eastern, "cool" exposition of the ice sheet front.

The author is inclined to call the Opinogóra escarpment, similarly as the two above described features — the Opinogóra festoon.

The process of development of forms, analogous to clay festoons is well known and was described from polar countries. S. Z. Różycki [13] who investigated in 1934 the frontal zone of the Finsterwalder glacier on the Spitsbergen, pointed to the existence of the flat surface that was a result of the boulder clay flow from the front of the ice sheet.

The process of glacial material flow from the ice front in the form of ablation moraine, laying as a rule on a ground moraine was described by Klimaszewski [7]. This process is also mentioned by Szupryczyński [15], who established that in front of the southern edge of the Warenskiöld glacier extends a zone of ablation moraine, deposited directly on the substratum, and not on a ground moraine: "From the ice front flows a strongly watered surface moraine, forming immediately before the ice front a zone of moraine mud". The two last authors do not, however, characterize more precisely the forms developing as a result of ablation moraine flow. But from the map of Szupryczyński [15] "Relief of the marginal zone of the Warenskiöld glacier" it clearly results that the distal slope of the ablation moriane zone is, generally speaking, gently declining from the glacier and it forms locally fairly characteristic relief of the connected cones. The zone of the ablation moraine is supported by the front of the glacier, of which the melting probably induces the development of a steep proximal slope. The zone of the ablation moraine, occuring in front of the glacier, has thus, as a form, a full analogy to the boulder-clay festoons. The only difference here is the distribution of forms. as the zone of ablation moraine of the Warenskiöld glacier appears in the hinterland of ice-morainic ridges marking the furthest extent of its front.

The material of the clay festoons is defined by the author as boulder clay. The material of recent forms developing in the Spitsbergen, and analogous to the cley festoons occurring in Poland, is described by these authors as ablation moraine. The discussion of the accumulation process of the material in both cases proves, that genetically, the material is the same. One should mention here the classification of the boulder clays by M. D. Domosławska-Baraniecka. This classification was presented at the Session of the Commission on Origin and Lithology or Quaternary Deposits in Poznań, February 1968. M. D. Domosławska-Baraniecka distinguisnes the facies of pushed baulder clay, understood as the boulder clay developed at the front of an active ice. According to M. D. Domoslawska-Baraniecka and S. Skompski [2] the clayey end-moraines occuring in the area of the lobe of the Widawka (tributary of the upper Warta) and representing the forms of the type of the Opinogóra escarpment [10] are built of such boulder clay.

Forms resembling clay festoons are mentioned also in the paper of E. I. Deviatova [1], who described in the marginal zone of the Valdai ice sheet, in the Arkhangielsk region a ridge (griada), with a flat top, steep proximal and gentle distal slopes, formed of boulder clay.

It seems thus that clay festoons are by no means exceptional forms as well in polar countries, presently glaciated, where the process of their development may by observed, as in postglacial areas of the European Lowland, though they are not frequently encountered. They develop in front of the ice, in specific conditions, i.e. in such conditions that do not create possibilities of segregation of glacial material. The reasons for the existence of such conditions may depend on the character of deglaciation, the shape of the ice margin, its exposition, relief of the foreground, relief of the substratum and other factors.

As was already mentioned, clay festoons had not, up to now, their own place in the nomenclature of glacial forms.

In the classification of end moraines [3 - 7, 11, 12, 16 - 19], forms of the type of clay festoons are never mentioned, though some authors describe clayey moraines [3, 12], and Flint [3], stresses their specific relief, as compared with other morainic forms.

In the classification of end moraines various criteria are applied, putting forward as a rule the dynamics of the ice sheet margin. From the point of view of this criterion, moraines are divided into accumulative and pushed ones. Some stress is also put on: the process of development of moraine forms, their shape, their lithological composition, the shape of the ice-margin, the place of their formation in relation to the front of the ice sheet and other factors.

Taking into consideration the above mentioned main criterion of subdivision of moraines, clay festoons should be classified as accumulation moraine forms of the stagnant ice-front [18] or as complex moraine forms composed of accumulative glacial material partly pushed up (like the Ostrów festoon).

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THE RELATION OF THE DRWĘCA VALLEY TO THE NOTEĆ - WARTA ICE MARGINAL STREAMWAY (*PRADOLINA*) AND ITS ROLE IN THE GLACIAL AND LATE GLACIAL DRAINAGE SYSTEM [1]

WŁADYSŁAW NIEWIAROWSKI

INTRODUCTION

The topic of a large number of detailed studies have been the morphology and the evolution of the Noteć—Warta (Toruń-Eberswalde) ice marginal streamway (*pradolina*) and the part it has played in the drainage of the Polish Lowland, both during the Pomeranian stage of the Last Glaciation and afterwards. A critical evaluation and a summing-up of the research undertaken in this matter up to now can be found in a comprehensive paper dealing with this ice marginal streamway, published by R. Galon [7]. Thanks to this paper. later supplemented by several further publications of the same author [3, 8], as well as to investigations made by other scholars (among them [14]), this is today for all of Poland the ice marginal streamway which has been most thoroughly examined and reported on. On the other hand, so far its further north-eastern reach, the Drwęca valley, has not been examined in the same thorough way, and this is why up to now the part it has been playing in this important ice marginal streamway track of North Poland has not been elucidated in its details.

Admittedly, mention of the lower reach of the Drwęca valley dates back from the rise of the present century. German authors [10, 11] have distinguished here the highest terrace levels, what they called "basin levels", linking them with the runoff of glacial waters from the adjoining Chełmno Morainic Plateau and with the escape of these waters into the Toruń Basin and, further on, westward by means of the Toruń-Eberswalde ice marginal streamway. By this interpretation they took for granted, that the runoff of these waters by way of this ice marginal streamway and the valley of the lower Drwęca was contemporaneous.

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[1] Polish *pradolina* = English *ice marginal streamway* = German *Urstromtal.*

It must be stressed, however, that at those times evidence was lacking which would have justified linking the development of these two important runoff tracks, and the formation of terrace levels by this flow, with correlatable halting periods of the last inland ice. The reason is, that there was not at hand any comprehensive identification of the number of existing terraces or an exhaustive study of the outwash tracks in connection with the successive stoppages of the inland ice, nor any detailed tying-in of the outwash tracks with the ice marginal streamway runoff. This led to certain incongruities. To give an example: the formation of the so-called basin levels in the lower Drwęca valley and the westward escape of the glacial waters by way of the ice marginal steamway was considered [10, 11] to be linked with the ice stoppage on the Chełmno Morainic Plateau, but at the same time K. Keilhack [12] assumed, that it was only during the Pomeranian stage that an ice--dammed lake was formed in the Toruń Basin, from which the waters were supposed to have started their westward ice marginal streamway runoff.

S. Lencewicz [17] was the first to consider the Drwęca valley to have played an important part in the formation of the Noteć—Warta ice marginal streamway track. Refuting the concept of an ice-dammed lake in the Toruń Basin he believed, that what was called the upper terrace of this basin had been formed by glacial waters flowing in from the Drwęca valley which, after having passed the Toruń Basin, escaped westwards through the Noteć—Warta ice marginal streamway. According to this author it was only at the level of the next, the "middle" terrace, that this runoff was joined by Vistula waters and that both then continued westwards by the way of the ice marginal streamway. Into the Vistula ice marginal streamway as it existed at that time, a glacier tongue was supposed to have transgressed; and it was probably after it had melted that the Vistula flow, together with the tributary Drwęca waters, started its northward course towards the then forming Baltic.

It was R. Galon [5] who in 1931 prepared the first comprehensive paper discussing the entire Drwęca valley; at that time he distinguished four terraces, ascribing the formation of the upper terrace to the flow of glacier waters from the Chełmno Plateau and their further runoff by the Noteć—Warta ice marginal streamway. The middle terrace he linked with the inland ice stoppage during the Pomeranian stage and with the meltwater runoff by way of the Ostróda and Iława outwashes. In his opinion it was at the level of this terrace that the glacier waters continued to escape westward through the ice marginal streamway mentioned. The two lower terraces he believed to have developed when the Vistula waters turned northward.

At a later date R. Galon dealt in detail with the valley of the lower Vistula [2] where he distinguished eight terraces and, after the Second World War, also with the Brda outwash and valley [6] where he discovered eleven terraces; meanwhile new evidence had accumulated on the number and the evolution of terraces in the Noteć—Warta ice marginal streamway [7, 13, 15] and on the relation of this one to the outwashes of the Pomeranian stage. All this made it plain, that the opinions held so far as to the interrelation between the ice marginal streamway and the Drwęca valley had to be abandoned. Even so, the material then available precluded any conclusive reflections in the matter of these mutual relations. At last, a series of detailed investigations made in the Drwęca valley made it possible to reconstruct the principal stages of its evolution and to explain the part this valley has played in the history of the Noteć - Warta ice marginal streamway and in the glacial and late-glacial drainage. Let us enumerate one by one the contributions to this research: the report on the morphology and the relief evolution of the lower Drwęca reach as well as the connection of outwashes of the Chełmno Morainic Plateau with this valley, given by the author of the present paper [22], the study of some parts of this valley by Z. Churski [1], and the linking of the levels of the Ostróda and Iława outwashes previously identified by L. Roszkówna [25] with the Drwęca terraces, which has recently been accomplished by E. Wiśniewski [28]. Thus, now the following successive principal stages can be set apart in this evolution: 1) the period in which the glacial waters from the Wąbrzeźno end moraines escaped during the Krajna phase of the Last Glaciation, 2) the period of the runoff of glacial and fluvial waters during the Pomeranian stage and the Kashubian - Warmian phase, and 3) the flow period of fluvial waters during the Late Glacial and the Holocene.

THE FORMATION OF THE LOWER REACH OF THE DRWĘCA VALLEY AND ITS PART IN GLACIAL DRAINAGE

In its course between Brodnica and its inflow into the Vistula, amounting to some 60 km, the valley of the lower Drwęca constitutes an extensive land form characterized by four basin-like widenings in which the valley reaches widths of 6·5 to 8 km, and by narrower gap sections separating the widenings, where the width is from 2 to 4·5 km. In this valley section the author distinguished eleven terraces, some of which extend no more than some 20 km upstream [22]. In numbering the individual terraces, in the further course of this paper the author complied with the pattern which R. Galon [6] applied in his description of the morphology of the outwash and the valley of the Brda River. This latter valley he considers a model for all of North Poland, because of its great number of terraces which have all been correlated with the Noteć-Warta ice marginal streamway as well as with the valley of the lower Vistula. The same pattern of terrace numbering he has also applied to the Noteć - Warta ice marginal streamway [8].

The valley of the lower Drwęca is situated at the dividing line between the Chełmno and the Dobrzyń Morainic Plateaus, in the area of a ground moraine extending between the Chrostkowo, Rypin and Górzno end moraines ascribed to the Kuyavian phase, and the Wąbrzeźno end moraines supposed to have originated during the Krajna phase of the Last Glaciation [4, 9]. The Wąbrzeźno end moraines run north of the valley, 7 to 18 km off. Three outwash tracks issue from these moraines: the Jabłonowo, the Wąbrzeźno, and the Chełmża outwash, respectively [21]. Thus the relation of these outwashes to the lower reach of the Lower Drwęca valley is a matter of outstanding importance. The Jabłonowo outwash ends at the level of 96 - 97 m a.s.l. above the Drwęca valley; here it is undercut, hanging some 22 m above terrace VI which lies at the margin of the outwash, and some 30 m higher than the Drwęca flood terrace. Similar are conditions seen with regard to the Chełmża outwash; where it reaches the valley scarp, it hangs some 8 - 9 m above terrace X, and some 2 - 3 m above terrace XI which in this region survived as the highest and oldest of the Drwęca terraces. It is only between the Wąbrzeźno outwash and the highest Drwęca terraces that no definite morphological boundary can be traced, and an escarpment observed here accounts merely for some 1 to 1·5 m. This latter fact seems to explain the assumption previously held, that here the Wąbrzeźno outwash passes directly into what used to be called the basin levels (or the upper Drwęca terrace) which further on tie in with the upper terrace of the Toruń Basin and the Noteć - Warta ice marginal streamway; this is why it was believed, that already at the time when the inland ice had stopped at the line of the Wąbrzeźno end moraines, glacial waters were escaping by way of the lower Drwęca valley and the Noteć - Warta ice marginal streamway. In the light of later research this problem proved more complex.

As mentioned before, more recent investigations of the Noteć - Warta ice marginal streamway [6, 4] brought evidence that the Brda outwash, formed during the Pomeranian stage, leads directly into a terrace preserved in the eastern part of the Noteć - Warta ice marginal streamway — proof of their contemporaneous origin. On the other hand there is now no doubt that the Wąbrzeźno end moraines, belonging to the Krajna phase which preceded the Pomeranian stage, must be older than the

Pomeranian stage [4, 9, 27] and that, therefore, a simultaneous runoff from two stoppage places of the inland ice, entirely different in age and situated far from each other, was out of the question. Admittedly the absence of end moraines near the Vistula valley made it difficult to collate the Wąbrzeźno end moraines with the Krajna phase moraines extending west of the Vistula; even so, most probably the Southern - Wąbrzeźno end moraines from which the outwashes under discussion (of Jabłonowo, Wąbrzeźno and Chełmża) issue, can be linked with the ice stoppage on the line of the Noteć moraines situated in the near northward vicinity of the Noteć - Warta ice marginal streamway. Incidentally this is how these land forms have been parallelized in a number of recent publications [4, 9]. Taking the above for granted, it is certain that this period could not possible have witnessed the existence of the Noteć-Warta ice marginal streamway nor, even less, a runoff of glacial waters from the inland ice border line extending along the line of the Wąbrzeźno moraines.

A further important point affects this problem: in the region of the Drwęca valley investigations have revealed [22], that the outwashes originating from the Wąbrzeźno end moraines are older than the highest terrace XI surviving in the Drwęca valley which, in turn, ties in with the oldest terrace of the Noteć - Warta ice marginal streamway and therefore cannot have been formed prior to the Pomeranian stage. Now here arises the problem: whither went the glacial waters escaping from the Wąbrzeźno end moraines? J. Machinko [18] suggested they might have run southwards, towards the Dobrzyń Plateau, because in her opinion no lower Drwęca valley existed yet at that time. However, field studies in both the valley and the adjoining plateau failed to confirm this theory, because no traces of such runoff were discovered anywhere on the plateau and, moreover, the plateau rises southwards and lies at much higher altitude than the outwashes under discussion. Nor is it conceivable, that the water may have been carried off by way of the subglacial channels of this region because they also rise southwards. Thus there remains as the only logical conclusion the notion that the meltwater streams, arriving by way of the three principal outwashes from the Wąbrzeźno end moraines, must have combined in the line of today's lower Drwęca valley into one marginal stream (Fig. 1). The formation of this stream must have been furthered by a depressed zone in the surface of the ground moraine; this depression was part of a system of older depressions and, probably also, of fragments of some ancient valley which had not been fully levelled by the last inland ice [22, 24]. However, this stream must have been much less voluminous than the river which was to develop in this line later on, during the Pomeranian stage and the

Kashubian - Warmian phase, and this may explain why no traces of this most ancient runoff in the lower Drwęca valley have survived in the shape of terraces. At any rate it may be considered a proven fact that, at the time the inland ice had halted in the zone of the Wąbrzeźno end moraines, an oldest part of the valley of the lower Drwęca was formed, at least from where the Jabłonowo outwash ended and farer on downstream. It is also conceivable, that in this same period a further, north-eastward oriented part of this valley came into existence, starting out from moraines which were eastward extensions of the Wąbrzeźno end moraines.

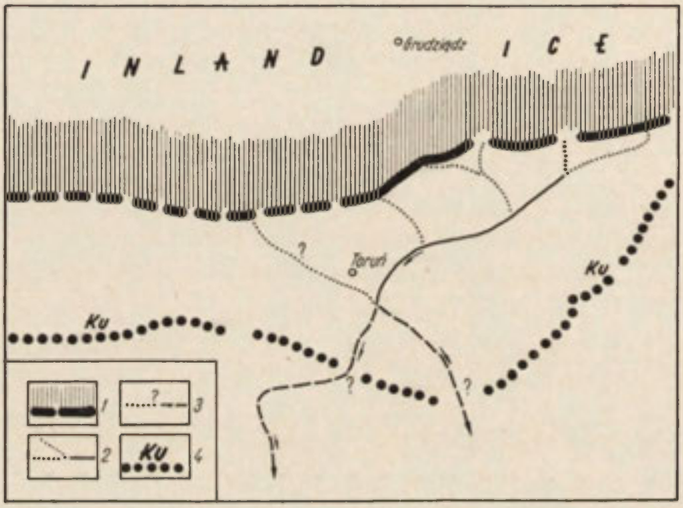

Fig. 1. Flow of glacial waters through the Drwęca valley during inland ice stoppage at line of southern Wąbrzeźno end moraines

1 — inland ice margin, 2 — identified outwash and valley runoff tracks, 3 — probable runoff tracks, 4 — main ice border line of inland ice during the Kuyavian phase

For all this, the lack of appropriate research data from neighbouring regions leaves open the question whither the waters of the discussed river continued. It seems probable that they escaped by way of an ancient valley 1·5 to 2 km wide, which existed in Kuyavia and now contains the channels of the small Tążyna river and the Parchański Canal and which further south follows the line of Gopło Lake. Nor can we eliminate the possibility, that the meltwaters in question may have found their way southwards into today's Vistula valley, downstream from the Drwęca inflow — to some degree forecasting the later-date Vistula gap from the Płock Basin into the Toruń Basin. This question requires further detailed research. At any rate, field examinations [22] revealed, that after the inland ice had retreated from the Chełmno Plateau to where it halted during the Pomeranian stage, the flow of this runoff must have been rather insignificant; only after the Pomeranian stage had set in, there began a very intensive evolution of this river and the valley it formed.

THE PERIOD OF THE RUNOFF OF GLACIAL AND FLUVIAL WATERS DURING THE POMERANIAN STAGE AND THE KASHUBIAN - WARMIAN PHASE

The Pomeranian stage of the Last Glaciation in Poland was of fundamental importance not only upon the formation of the Noteć - Warta ice marginal streamway but on that of the Drwęca valley as well. In his examination of the lower reach of the Drwęca valley [22], the author found in the Elgiszewo Basin at the level of 84 m a.s.l. a lobe of the — now highest — terrace XI, 2 km long and 1 km wide. Everything seems to confirm the belief, that this terrace fragment is a continuation of what is called the outwash terrace identified by Z. Churski [1] in the region of Kurzętnik in the Drwęca valley where it extends in the level of 110 - 115 m a.s.l. At both localities these fragments lie directly upon the next-lower terrace X which already appears as a more continuous horizon. The fragment from Kurzętnik has been tied in with the second and third levels of the Ostróda outwash which in turn, according to E. Wiśniewski [28], combine already in the Drwęca valley near Gierłoż into one level situated at 111 - 117 m a.s.l. L. Roszkówna believes, that the Ostróda outwash levels mentioned above date back from the time the inland ice halted in Mazuria on the Miłomłyn - Bramka line [25], and that this line marks in this region the southern margin reached by the ice during the Pomeranian stage [27]. Recently R. Galon [3, 8] expressed the opinion, that the Brda outwash terrace (terrace XI) is not the result of the runoff from the maximum extent of the Pomeranian stage, being of somewhat younger age, and that this ice stoppage in Mazuria might also be younger, not representing the true maximum range of the Pomeranian stage in this region.

At any rate, all the above seems to prove that. while the inland ice had halted on the Miłomłyn - Bramka line, meltwater streams were issuing from the glacier face and escaping by way of the second and third level of the Ostróda outwash into the Drwęca valley, whence they continued, eroding a wide valley track. True enough, so far it has not been established in detail how the reach of the Drwęca valley, some 60 km long, has been developing in the space between Drwęckie Lake (the lower end of the Ostróda outwash) and the previously formed part of the lower

Drwęca valley; however, the surviving fragments of terrace XI are undeniable proof, that already a continuous runoff existed from the border of the inland ice (halted on the Miłomłyn - Bramka line) by way over the Ostróda outwash and, further, by the Drwęca valley. By the addition of this new part, the Drwęca valley track gained a considerable north-eastern extension — a fact which markedly enlarged the drainage basin and the volume carried by the river.

An additional very important event of this period was the formation of a further water runoff from the Drwęca valley by way of the Toruń Basin, and the junction of these waters with the meltwater flow from the Brda outwash, so that they escaped together by way of the Noteć-Warta ice marginal streamway (Fig. 2). If one now considers the alti-

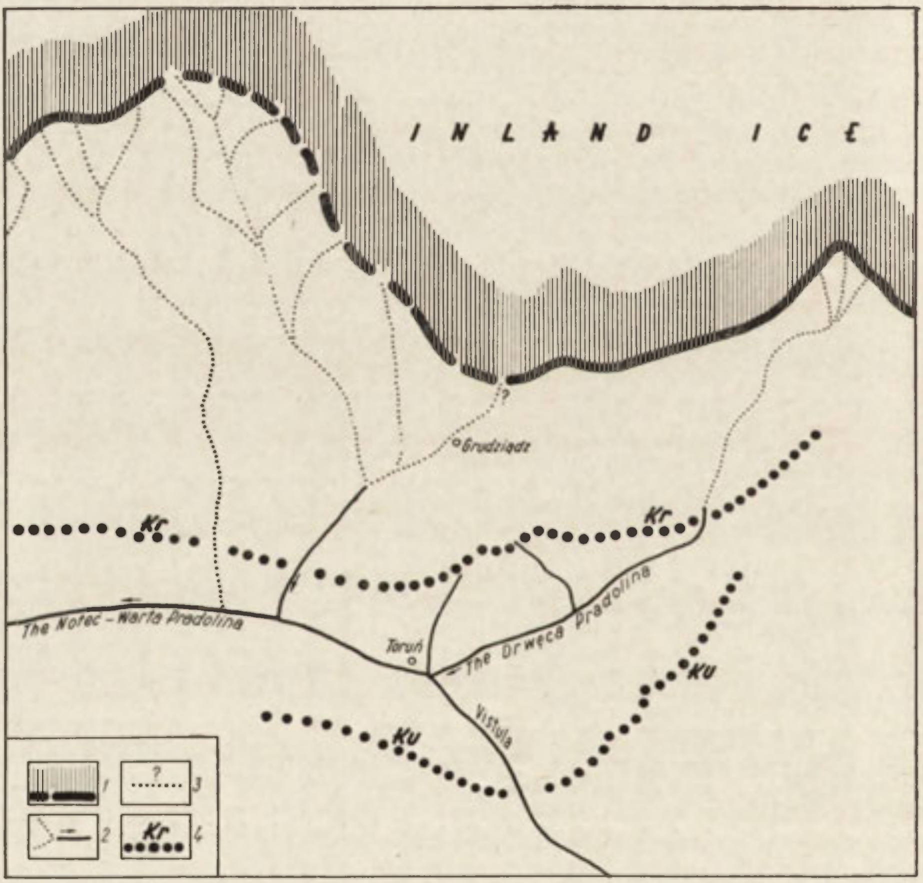

Fig. 2. Diagram of runoff of outwash and ice marginal streamway waters during the Pomeranian stage

1 — inland ice margin, *2* — identified outwash and valley runoff tracks, *3* — probable runoff tracks, *4* — main ice border line of inland ice during the Krajna phase tudes, on the one hand, of terrace XI in the lower Drwęca valley and, on the other, of the fragments of the highest terrace surviving in the Toruń Basin which also might be called terrace XI, i.e. the fragment described by M. Kucharski [16] from near Aleksandrów Kujawski (80 - 81 m a.s.l.) and a fragment recently distinguished by W. Mrózek (oral information) at the base of the Kuyavian Morainic Plateau (78 - 80 m a.s.l.), one may well imagine that all of them constitute fragments of one contemporaneous terrace level.

R. Galon [7] assigns an identical age to the terrace fragment from near Aleksandrów Kujawski, the Brda outwash terrace XI and the highest ice marginal streamway terrace (V) in the Noteć - Warta ice marginal streamway. Thus we may now assert, that at the time when in the Noteć - Warta ice marginal streamway water ran at the level of the highest (V) ice marginal streamway terrace, part of this water consisted of glacial waters derived from the inland ice halted in Mazuria on the Miłomłyn - Bramka line; these latter waters, arriving over the Ostróda outwash, penetrated the Drwęca valley and escaped by this valley at the level of terrace XI, passing the Toruń Basin at the level of this same terrace. This means that the Drwęca valley track has been definitely the north-eastern continuation of the Noteć - Warta ice marginal streamway. R. Galon [7, 8] suggests, that from the south, Vistula waters may have joined this westward runoff at the level of terrace XI.

While it was for the most part glacial waters that were escaping at those times by the track of the Drwęca valley, there is no doubt that this river was also fed by fluvial waters arriving from non-glaciated areas, perhaps carried by Struga Wąbrzeska, Struga Toruńska and, probably, a further number of minor tributaries. With this in mind one may consider the Drwęca valley an ice marginal streamway track. Beginning with this period and throughout the time that the Noteć - Warta ice marginal streamway was in operation, the Drwęca valley has always been closely associated with this ice marginal streamway.

The next phase, important in the evolution of the lower Drwęca track, has been the stoppage of the retreating inland ice on the line of the Dzierzgoń end moraines, — an event recently assigned by L. Roszkówna [26] to what she calls the Kashubian - Warmian phase, that is, a phase younger than the Pomeranian stage. From these moraines started the so-called upper level of the Iława outwash [19, 25] which slants towards the Drwęca valley, ending at the level of 107 - 109 m a.s.l. [28]. The extension of this outwash within the valley can be traced for a long distance downstream because this level has survived remarkably well. To it belongs a terrace fragment near Kurzętnik (100 - 105 m a.s.l.) and a number of benches of greater or lesser extent. The author calls this

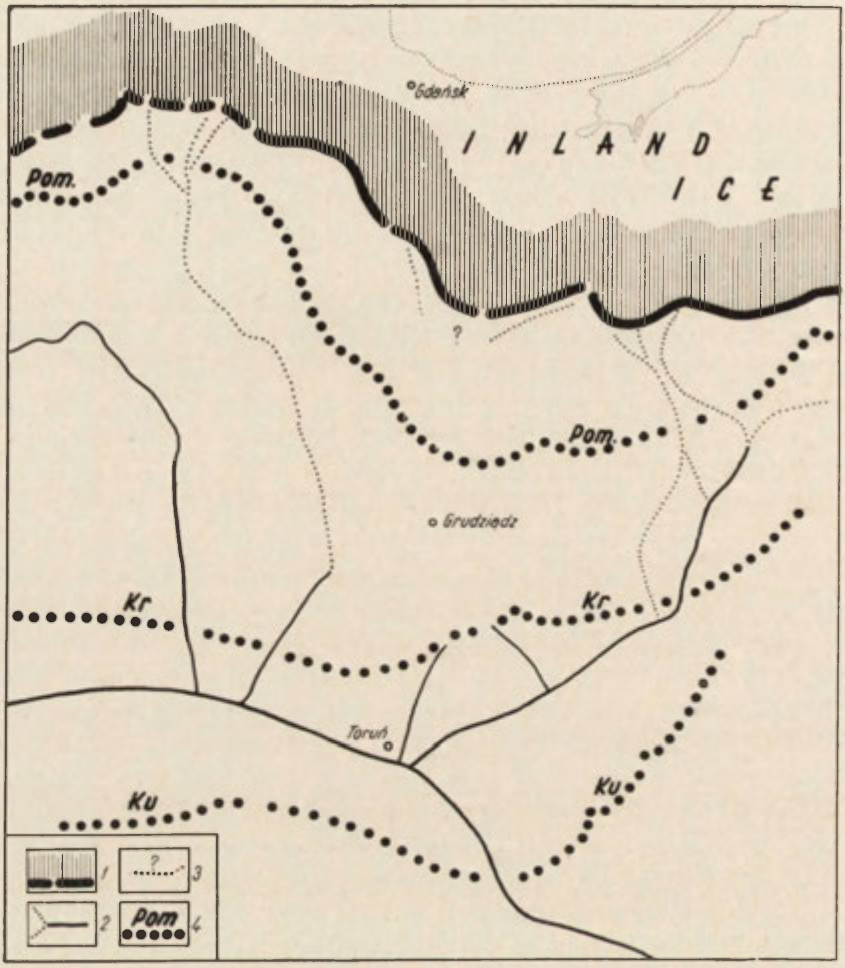

Fig. 3. Diagram of water runoff during the Kashubian-Warmian phase. For markings see Fig. 2

Pom — main ice border zone of inland ice during the Pomeranian stage

level terrace X [22], because beyond any doubt it can be correlated with the so-called outwash terrace which W. Mrózek [20] discovered in the Toruń Basin, further fragments of which have also been identified by other authors [23, 24].

Terrace X of the Drwęca valley and the Toruń Basin links up with terrace X of the Brda valley and with this what is called the transition ice marginal streamway terrace IV in the Noteć - Warta ice marginal streamway [7, 8]. This clearly implies, that at the level of terrace X glacial and fluvial waters continued to escape in the region of the Drwęca valley by means of a track which had developed during the Pomeranian stage. However, the glacial waters joined this track by way of another outwash track starting out from the glacier margin situated further north. And, apart from the Iława outwash, probably also at the level of this terrace, from branches of the Iława outwash, along the large lake channels of the Brodnica Lake District, meltwater streams were arriving into this valley (Fig. 3). Judging from terrace fragments on both sides of the Drwęca valley it can be said, that at the time when the water was at the level of terrace X the Drwęca valley had a width of at least 5 - 6 km [22] and that, after the Drwęca had joined the Vistula in the Toruń Basin, the Vistula valley near Toruń was as much as 19 km wide [23].

Worth-mentioning is that it was already at the level of Terrace X in the Brda valley that the flow of fluvial waters started [6], and that this must be the reason why terrace X in this valley is poorly developed, while at the level of that same terrace X in the Drwęca valley glacial waters were still escaping in copious quantities. The cause of this difference is that, after the inland ice had retreated from the main zone of end moraines of the Pomeranian Stage, north of the Brda outwash the meltwater streams ceased to run southward, because meanwhile new runoff tracks in a western direction had been developing in the hinterland of the end moraines. On the other hand, in Mazuria, in the region of the Dzierzgoń moraines, the meltwater was escaping by way of new outwash tracks but continued flowing in the same southward direction as before, finding its way into the Drwęca valley. This shows that at the level of ice marginal streamway terrace IV, the counterpart of terrace X in the Brda valley [7] and terrace X in the Drwęca valley and the Toruń Basin, glacial waters also continued to flow, starting out from the ice margin which had stopped in the zone of the Dzierzgoń end moraines mentioned before.

By no means clear is up to now the problem of the water flow in the Drwęca valley at the next level, that of terrace IX. In the Ostróda and Iława outwashes it was still possible [19, 25, 28] to identify the lowermost levels which originated from the end moraines near Myślice [25], belonging to the recession moraines of the Kashubian - Warmian phase [26]; these levels penetrate the Drwęca valley at the altitude of 98 - 100 m a.s.l. It is possible, that in the Drwęca valley this level continues in terrace IX which in turn certainly ties in with terrace IX of the Toruń Basin (R. Galon's [2] previous nomenclature called this the upper terrace Vc), with terrace IX of the Brda valley (Table I) and with upper terrace III of the Noteć - Warta ice marginal streamway [7]. Taking it for granted that the lowest outwash levels mentioned continued in terrace IX of the

Drwęca valley, we would have to assume that at this time the inland ice was still covering the area of today's estuary of the Vistula; however, R. Galon [2] asserts on the basis of surviving fragments of a terrace which is the counterpart to Terrace IX in the Grudziądz Basin of the lower Vistula valley, that it has been at the level of terrace IX that for the first time a bifurcated runoff from the Toruń Basin set in, during which only part of the water continued to run westwards by way of the Noteć - Warta ice marginal streamway while the other part proceeded northwards, by way of the lower Vistula valley, into the Gdańsk ice-dammed lake which had developed in the area occupied today by the Vistula estuary and the lowlands surrounding it. We see that this problem requires further detailed research work. At any rate, terrace IX of the lower Drwęca valley is one of the very widely developed terraces; at the time when it was being formed, its width was as much as 5 km in its basin-like widened parts. None of the lower terrace levels of the Drwęca valley show a width as large as this.

THE PERIOD OF WATER RUNOFF DURING THE LATE GLACIAL AND THE HOLOCENE

While it still remains an open question whether the glacial waters, escaping directly from the ice edge, have been flowing at the level of terrace IX of the Drwęca valley, there seems to be no doubt that at the level of the lower Drwęca terraces only fluvial waters were carried, which probably were additionally fed by meltwater flow from isolated buried blocks of dead ice. Next, the inflow of waters arriving into the valley by way of outwash tracks ended, and this brought a marked decrease in the Drwęca drainage basin and in the water volume carried. In consequence it appears, that at the level of the late-glacial terraces (VIII - IV) the valley, even in its widened sections, did not exceed a width of 1·5 — 3 km, and that at the level of the Holocene terraces the river was nowhere wider than 1 km, even in its meanders where the river tends to widen its bed [22]. True enough, the width of a river channel does by no means depend solely on the volume of flow but also, among other factors, on the climatic conditions under which this flow is taking place. Obviously also intensified was the trend of widening the valley floor by permafrost conditions which occurred during the cold periods of the Glacial and Late-Glacial.

The cessation of the flow of glacial waters reduced the Drwęca River to a relatively medium-size tributary of the Vistula, and this is why the Drwęca reacted readily to all changes occurring in the Vistula flow.

TABLE 1. Interrelation between terraces of the Drwęca, the lower Vistula and the Brda valleys, and of the Noteć—Warta ice marginal streamway

Terraces in Drwęca valley, after the Author [22]			Vistula terraces in Toruń Basin, after W. Mrózek [20]; relative altitude, in m	Terraces in Noteć--Warta ice marginal streamway (after R. Galon [7])	Brda terraces (after R. Galon [6])	Terraces of lower, Vistula, after R. Galon [2]; relative altitudes, in m
At inflow into Toruń Basin, absolute altitude in m	Relative altitude above Drwęca level at Lubicz, in m	Relative altitude above Vistula level, in m				
XI 84*	–	–	43 - 45**	V ice marginal streamway terrace	XI outwash terrace	–
X 77 - 78	37 - 38	40 - 41	outwash terrace 40 - 42	IV ice marginal streamway transition t.	X transition terrace	–
IX 71 - 73	32 - 34	35 - 37	upper terrace 36 - 40	III upper terrace	IX upper terrace	Vc upper terace 41
VIII 66	27	30	upper terrace 32 - 36	II upper transition terrace	VIII transition terrace	Vb upper terrace 37
VII 62 - 63	23 - 24	26 - 27	upper terrace 28 - 32	I upper transition terrace	VII transition terrace	Va upper terrace 32
VI 57	18	21	upper middle t. 19 - 25	ice marginal streamway floor (flood terrace)	VI upper middle terr.	IV upper middle t. 25 - 27
V 53	14	17	lower middle t., 14 - 19		V lower middle terr.	III lower middle t. 17 - 22
IV 50	11	14	lower terrace 10 - 14	aggradation on pradolina floor, by silting up and by peat formation	IV lower terrace	II lower terrace 10 - 15
III 45	6	9	upper overflood terrace 5 - 8		III overflood terrace	upper overflood terrace 5 - 9
II 43	3 - 4	6			II overflood terrace	
I 41	1 - 2	3 - 5	lower overflood terrace 3 - 5		I overflood terrace	lower overflood terrace 3

* In Elgiszewo Basin, some 20 km from the Vistula valley.

** Oral information by M. Mrózek.

It might be added here, that some influence upon increasing the drainage basin of the Drwęca — incidentally this applies to other North Poland rivers as well — had the period in which the numerous buried dead ice blocks were melting; this particularly refers to the ice preserved in narrow channel valleys where in the tracks of these previously ice blocked channels icemelt produced some of the larger Drwęca tributaries like Ruziec, Rypienica, Struga Rychnowska, etc.

As was said before, beginning with terrace XI we observe a complete analogy and correlation of the Drwęca terraces with the terraces of the Toruń Basin, the Brda and the Noteć - Warta ice marginal streamway: and beginning with terrace IX, this also includes the terraces of the lower Vistula valley (Table 1). Among other facts this table also indicates that, apart from the levels of terraces XI to IX, the Drwęca waters together with Vistula waters alimented the flow in the Noteć - Warta ice marginal streamway also at the levels of terraces VIII to VI; and that, beginning with terrace IX, a bifurcated flow continued from the Toruń Basin, partly westwards by way of the Noteć - Warta ice marginal streamway and partly northwards through the lower Vistula valley [2, 7]. As a matter of course the part which Drwęca waters played in this joint runoff was considerably reduced when the flow of glacial waters by way of the Drwęca valley ended.

Since the time when the flow through the Noteć - Warta ice marginal streamway had ceased, the waters of both Vistula and Drwęca ran exclusively northwards by way of the lower Vistula valley. This complete change of direction took place during the Alleröd [7] or the Younger Dryas [8]. The last Pleistocene terrace which was formed in the Younger Dryas [22] is terrace IV, and it is this terrace that terminates the Pleistocene cycle of evolution of the Drwęca valley.

The Drwęca valley is one of the most outstanding elements in the relief of the Polish Lowland and, as has been demonstrated above, it played a very important role in the drainage of glacial runoff and in the formation of another prominent land form, the Noteć - Warta ice marginal streamway. In common with the Brda valley, the Drwęca valley is conspicuous by having a complete set of terraces correlated with both the Noteć - Warta ice marginal streamway and the lower Vistula valley.

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GEOGRAPHIA POLONICA 17, 1969

TYPES AND STAGES OF DEGLACIATION IN AREAS OF THE ODRA LOBE IN WESTERN POMERANIA

ANDRZEJ KARCZEWSKI

In the course of end moraines belonging to the Pomeranian stage of the Baltic Glaciation (Würm), in the area of Mecklenburg and Western Pomerania which are situated on both sides of the lower Odra there is a distinct flexion southward, determining the extent of the so-called Odra lobe. Keilhack [13, 14]. when working out the end moraines of the North European Lowland, paid attention to two clear ice tongues calling them the glaciers of the Odra and Wisła which in later literature were named the Odra and Wisła lobes. The ice mass of the Odra lobe formed a lateral branch of the main south Baltic ice stream that had shown its greatest activity of frontal pressure in the area of Denmark and partly in Mecklenburg, too. The Odra lobe was thus nourished insufficiently, and an additional factor i.e. the influence of the oceanic climate of West Europe caused that the deglaciation of the mentioned areas [7, 16, 17, 19] had a specific course. S. Kozarski [16], basing on results of investigations carried out by others and himself, paid attention to the fact that in end moraines of the Pomeranian stage, lying to the west and east of the Odra lobe, glacitectonic structures prevail, while in the lobe itself an accumulative end moraine predominates. Besides in the west and south part of the area a quicker recession can be observed while the east wing of the Odra lobe margin shows signs of an almost complete stagnation.

The type of frontal deglaciation connected with successive stages of the retreating ice margin with minimum oscillations (a few glacitectonic structures) will thus predominate in the south part. As a result we have got the classical pattern of glacial forms i.e. end moraines, outwash plains.

On the ground of the author's observations in the area of Western Pomerania (Myślibórz Lake District and Szczecin Lowland) it can be found that with a farther recession of the inland ice from the end moraines of the Pomeranian Stage northward a greater areal disappearance of the inland ice margin can be seen, especially from the line of end moraines belonging to the Szczecin phase (Rosenthaler Staffel). From this line the areal disappearance of the Odra lobe can be accepted. Hartnack [8] was the first to mention the importance of the areal deglaciation of the north-east part of Western Pomerania, while analyzing the system of glacial valleys. A year later K. v. Bülow [2] found that the zones of dead ice had played a great role as a morphodynamic factor of this area. In 1932 the same author [3] admitted that the decay and wastage of edge belts of the inland ice had been rhythmical. The present author's paper [9 - 12] show, too, the important role of areal deglaciation as a result of which groups of forms connected with the activity of passive melting or that of dead ice, had been formed.

In Fig. 1 the recession stages of the Odra lobe in the area of Mecklenburg and Western Pomerania have been shown. When considering the

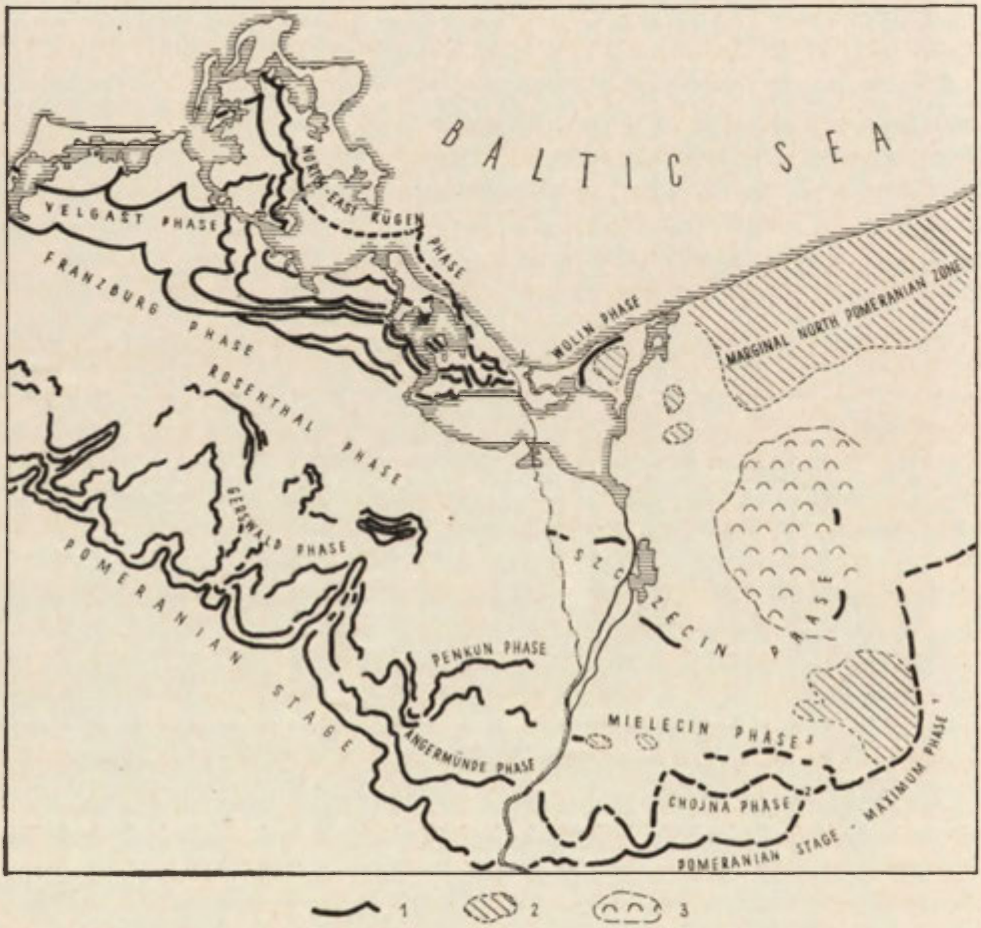

Fig. 1 Deglaciation stages in areas of the Odra Lobe in Western Pomerania
1 — end moraines; 2 — North Pomeranian marginal zone; 3 — drumlins area

areas west of the Odra material found in a German collective work, ed. by J. F. Gellert [4] was made use of. With the help of this work and his own observations from the area of Western Pomerania the present writer compared the end moraine belts on both sides of the lower Odra valley with their short morphogenetic characteristic. In this way five lines of the inland ice stoppage, determined by the course of end moraines and one zone of marginal forms, have been distinguished. They are end moraines of the maximum phase, Chojna and Mielęcin phases, of the Pomeranian stage, end moraines of Szczecin phase, North Pomeranian marginal zone, as well as end moraines of the Wolin phase.

The maximum extent of the Odra lobe of the Pomeranian stage (Pommersches Stadium) is determined by end moraines of the maximum phase passing Feldberg, Templin, Chorin, Neuenhagen, Stara Rudnica, Golice, Moryń, Chełm Górny, Babin, Ławy, Trzcinna, Karsko, Barlinek, Recz and Ińsko.

The end moraine hills are mostly of accumulative character [17, 19], though according to these authors there are a few glacitectonic disturbances both in the west and the east wings. From Feldberg north-westwards, in the course of thrust end moraines a number of very distinct curves can be met, limiting small lobes.

During the recession of the Pomeranian stage that was then lasting the inland ice margin took, a new line determined by end moraines running through Gerswalde, Angermünde, Schwedt, Raduń, Mętno, Moryń, Golice, Piaseczno nad Barlinek where they join with moraines of the maximum phase. This belt is called the Chojna phase [17]. To the west they join with end moraines of the Angermünder Staffel. The genetic type of hills and hillocks is similar to the former belt, the distances between arches being 2 - 10 km. The connection of both end moraine belts near Barlinek allow S. Kozarski [17] to state that along the lower Odra there was a bipartition of the Pomeranian stage. The main evidence of this conclusion is, above all, the relation of the outwash plains of both phases, and two terraces in the Noteć-Warta ice marginal streamway corresponding to them.

This is a group of hills of a relative hight from 5 to 60 m. Stratified sands and fluvioglacial gravels take part in their internal structure, and in a few cases (block packing [1]) or stony-clayey material. The type of accumulative end moraine dominates, here, too.

In the area of Myślibórz Lake District, 3 to 17 km north of the Chojna phase moraines there is a belt of end moraines, called by the author the Mielęcin phase of the Pomeranian stage. It is determined by hills situated

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[1] A term suggested by S. Kozarski.

between Widuchowa, Lubicz, Banie, Mielęcin, Wołczyn, Jesionowo, Pełczyce and Będargowo. Here, too, the mentioned end moraine belt joins with moraines of the maximum phase of the Pomeranian stage. The line limiting the extent of the margin of this phase, especially in the section between Widuchowa and Mielęcin runs through two areas (Krzywin-Dębogóra and Banie-Lubanowo) showing a different marginal development from the end moraines. These are two groups of hillocks, of a relative height from 8 to 16 m, belonging to dead ice moraines surrounded by numerous kettle holes. The hillocks are built mostly of boulder clay while stratified fluvioglacial material occurs in the cores of these forms. The morphological situation of both areas is rather interesting. They are lying on a very distinct morphological threshold, occuring between two levels of the morainic plateau. Here optimal conditions for the formation of a rich system of fissures occurred (T. Bartkowski). The great number of dead ice blocks left gave later, after their melting a greatly diversified relief of the marginal zone. There are two big glacial channels running from these areas southwards. The bottoms of these channels are occupied by outwash and kame levels [10] which drainned the mentioned marginal areas.

The different hills and hillocks, going eastwards, are built above all, of stratified fluvioglacial deposits, which are often disturbed because of thrust movements of the ice margin or melting of dead ice blocks. In the structure of almost all positive forms boulder clay takes its part, either as a layer covering fluvioglacial nuclei, or, much more seldom, as scales in glacitectonik disturbances. The fact that end moraines of the Mielęcin phase join with moraines of the maximum phase of the Pomeranian stage near Będargowo (Fig. 1) proves the tripartition of this stage. The moraines of the Mielęcin phase are prolonged west of the Odra in the arch of the Penkun end moraine (Penkuner Staffel [1]) which runs from Penkun, Schmölln, Prenzlau to north-west. In the collective work, edited by F. Gellert [4] the name Penkuner Staffel, has not been mentioned, and this belt is called Gerswalder Staffel.

Considering the distances between end moraines of the maximum phase and moraines of the Mielęcin phase of the Pomeranian stage, the greatest distances can be seen in the Odra Lobe axis, i.e. along the lower Odra valley. Here, in the southern part, the greatest retreat of the ice margin northwards can be observed.

During the retreat of the inland ice, from the line of the Mielęcin phase of the Pomeranian Stage, towards the end moraines of the Szczecin phase a considerable number of dead ice lumps remained in the forefield in some areas. These lumps after melting left a rich ketle hole relief and dead ice moraines. This is met particularly near Dolice.

The position of end moraines of the Szczecin phase (Rosenthaler Staffel) based on the present state of investigations is rather uncertain. According to some studies the differences in time of their location depends on the fact that the end moraine belt of this phase developed before the development of end moraine belonging to the Pomeranian stage (they would be so-called overridden moraines [22, 25]), according to other this belt was the result of a normal oscillation of the inland ice when it retreated from the moraines of the Pomeranian stage [20, 21, 24]. In the investigated area end moraines of the Szczecin phase are determined with the morainic hills or hillocks forming a belt on the line Stolec, Głębocin — north part of Warszewo Morainic Plateau, Bukowe Hills, Bobrowniki Rampart (Marianowo-Dzwonowo), Dobra. These are forms of different size, their common feature in the internal structure being the occurrence above all, of glacitectonic structures with disturbed Tertiary. The so-called Szczecin Hill — Warszewo Morainic Plateau. Stobno-Rampart, Bukowe Rampart belong, according to W. Schulz, who refers to works of other investigators, to the Rosenthaler Staffel. As far as the northern part of the Warszewo Morainic Plateau, is concerned, where quite a different type of glacitectonic structures is met, with a lesser rhythm, as well as the Bukowe Hills (top part), the present author agrees with W. Schulz's conclusion. The central and southern parts of the Warszewo Morainic Plateau and the Stobno Rampart. however, are numbered among the higher morainic plateau horizons with glacitectonic structures within their internal structure, because of the character of the glacitectonic structures (pushing "en block" of Tertiary) and the occurrence of clayey cover on the surface [10]. Considering structural measurements, however, as well as the type of the development of glacitectonic structures two generations of structures in the Bukowe Rampart can be distinguished. The lower series, built of Tertiary, deposits with disturbances of fold (Żydowce) or imbricate type (Śmierdnica) having structural axes discordant with the morphological one, should be rather refered to the Middle Polish or the Cracovian Glaciation, while the upper series to the Szczecin phase of the Baltic Glaciation. The structural axes of the rampart converge here with the morphological one, and typical disturbances are mainly scales. We can thus speak that glacitectonic disturbances lased there out [18]. In the Bobrowniki Rampart there occur disturbances of Tertiary and fluvioglacial deposits in the form of folds and scales, whose axes cover exactly the morphological axis. The hillocks near Dobra are the last fragment of end moraines of the Szczecin phase. The internal structure of this complex is different. It is mostly built of fluvioglacial deposits showing a 50° inclination toward NW or NE.

During the recession of the inland ice towards the north on the line of end moraines of the Wolin phase in the area between Przybiernów, Golczewo, Gryfice and Płoty in the south, and the Baltic shore in the north, the inland ice breaks into a number of lumps on an immense area. This is caused by the rigid rampart of the Kujawy-Pomerania anticlinorium occurring in the substratum. Here the recession of the inland ice did not run in a linear way but was determined by the marginal zone in which groups of dead ice forms are met as kames or other fissure forms, the dead ice moraine etc. In the area of the marginal zone P. Woldstedt [25], H. Kliewe [15], W. Schulz [24] determined the belt of end moraines of the Velgast phase (Velgaster Staffel). Polish authors [6, 7] in their synthetic elaborations discussing the problems of Scandinavian glaciations in Poland determine, with the help of different works, the belts of end moraines in areas situated to the north of the Pomeranian ice marginal streamway. It has been found, however, that these forms, arreanged, at times, in distinct belts cannot be taken as end moraines when considering their internal structure [10].

The system of forms reconstructs the course of fissures only, in which they were accumulated. This compact area of the marginal zone would correspond to the end morainic belts of the Franzburger and Velgaster Staffel west of the Odra [4]. The last position of the ice margin in the area of West Pomerania is determined by end moraines of the Wolin phase corresponding to end moraines of the Nordost Rugensche Staffel, west of the Odra. Most of the material building the described forms is composed of Pleistocene deposits, as boulder clays or fluvioglacial deposits, that took part in glacitectonic disturbances. Floes of older rocks (Mesozoic) can be often met. In the forefield of the mentioned belt of end moraines there is a number of forms as eskers. esker-kames which can be included in the area of North Pomeranian marginal zone. The Mokrzyce Hills alone represent an end moraine of the oscillating type.

Summing up the result of investigations it can be stated that in the area of the Odra lobe two zones may be distinguished, one with the predominance of frontal deglaciation and the other with predominating areal deglaciation. On the southern part, between the belt of end moraines belonging to the Pomeranian Stage of the maximum phase and the line of end moraines belonging to the Szczecin phase a clear supremacy of frontal deglaciation can be found, while starting with moraines of the Szczecin phase where the Odra lobe is in the stage of disappearence, areal deglaciation predominates.

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SOME REMARKS ON THE ORIGIN OF DRUMLINS

Stanisław Baranowski

It is generally accepted that although drumlin forms have been investigated and described for more than a hundred years, no solution of their origin has so far been obtained.

Up to recent years drumlins have been investigated mainly as individual forms and little attention has been paid to their space arrangement. A few years ago some authors found that an organized geometry of drumlins in the field is their charcteristic feature, and others pointed out that features similar to drumlins were observed at the fronts of some contemporary glaciers. It seems desirable to consider the genesis of drumlin formation in the light of these recent contributions.

REMARKS ON SOME ASPECTS OF DRUMLIN DISTRIBUTION

The existing theories, a good account of which are given by Charlesworth [3] and Czechówna [4] were unable to furnish an explanation of the nonincidental regularity in distances between the particular drumlins. The problem was pointed out by Werth as early as in 1909 [25]. When describing the drumlins of the vicinity of Kórnik in Greater Poland he called attention to the mathematical precision of their distribution. Then for many years this characteristic of the drumlins passed unnoticed until Gravenor and Maneley [8], Reed, Galvin and Miller [17] published their papers and the regularity of drumlin distribution was proved. It appeared then, too, that the curve of the frequency distribution of distances between the longer axes of adjacent drumlins in the field has usually a distinct maximum, and very often also one or more secondary maxima. These secondary maxima of frequency are usually located at distances which suggest that there exist a prefered wavelength for each field. An example of such distribution is shown in the diagram from the drumlin field in Montezuma, N. Y. (Fig. 1).

Gravenor and Maneley [8] suggest that flutings of surfaces in the

Alberta State which "[. . .] in many cases are gradational features to drumlins [. . .] have been developed through the action of alternating parallel high and low pressure zones at the base of ice" (p. 727). These authors, however, do not go further in explaining what might have been the reason for the occurrence of pressure zones in so even distances. In Reed's and his collaborators' [17] opinion both "[. . .] location of drumlin fields and spacing of drumlins within fields are controlled by characteristics of the moving ice" (p. 209).

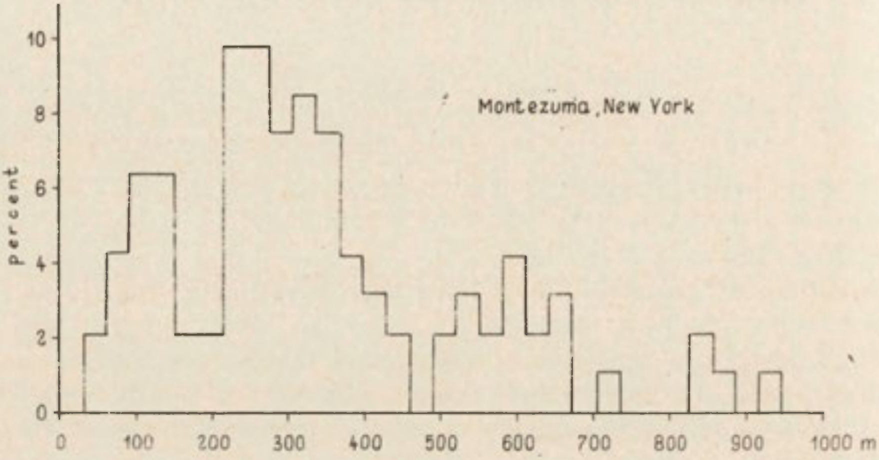

Fig. 1. Perpendicular spacing in the Montezuma drumlin field, New York; after Reed, Galvin and Miller [17]

The space distribution of drumlins in north-west Ireland (Ards Peninsula) was recently a subject of Vernon's [24] interest. This author gives a diagram of frequency distribution of distances between the longer axes of his drumlins. No significant maximum of frequency distribution was found. However, as we know from the Charlesworth [2] correspondence on this paper, Vernon took into account only less than 60 percent of all drumlins that exist in the region concerned.

In order to find out whether some other drumlin fields also show a regular distribution of drumlins the present author has collected the frequency of distances between the longer axes of adjacent forms in one of the biggest known drumlin fields — near Wadena in USA, and in a small but well developed drumlin field near Zbojno in Poland. Measurements for the Wadena field were based on Wright's [26] map, and those for Zbojno field on a map given by Jewtuchowicz [13]. In both cases it was assumed that the longer axes of drumlins run through the geometrical axes of the forms. The distances were counted along the chosen profiles that crossed long axes of drumlins approximately at right angles. In the case of the Wadena field these profiles, 28 in number, were in average about 5 km apart, and in the Zbójno field 40 profiles were spaced half a kilometre from each other. All the drumlins crossed by the profile line and close to this line were counted. In Wadena some 633 distances were measured, and at Zbójno this figure was 421. The results are shown as histograms in Fig. 2 and Fig. 3.

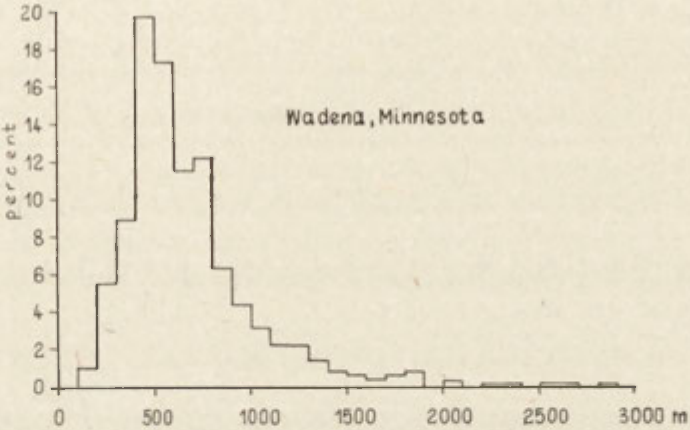

Fig. 2. Frequency distribution of distances between the longer axes of adjacent drumlins in the Wadena drumlin field, Minnesota

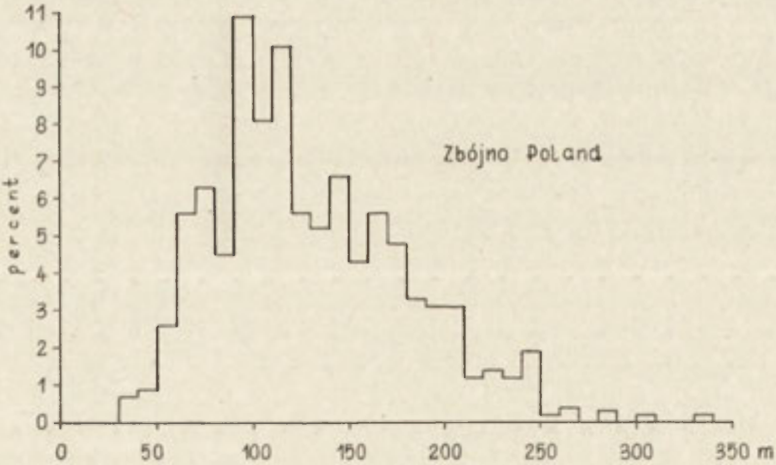

Fig. 3. Frequency distribution of distances between the longer axes of adjacent drumlins in the Zbojno drumlin field, Poland

The Wadena drumlin field characterizes itself by one distinct maximum of frequency at distances from 400 to 600 m (over 30% of all distances). No multimodal distribution has been found. The drumlins are practically never spaced at distances smaller than 200 m apart.

The drumlin field near Zbojno has only one frequency maximum from 90 to 120 m. There in the north-west part of the field somewhat smaller distances prevail with some signs of a multimodal character of distribution (not shown in Fig. 3).

In both Wadena and Zbojno the drumlins are clearly arranged not only with their long axes exactly in the direction of the basal ice flow, but also in certain, characteristic for each field (or its bigger section) distances in the direction perpendicular to the ice flow. These results agree well with those of Gravenor and Maneley [8] and Reed, Galvin and Miller [17].

It seems very likely that most of the well developed drumlin fields show a similar regularity in the distribution of drumlins. It is then a characteristic of drumlins which in the discussion on their origin should not be omitted.

THE FLUTED MORAINE PROBLEM IN RELATION TO DRUMLINS

Most of the authors who have been interested in drumlins thought them to be completely missing at the present glaciers. The only exception were de Quervain and Schnitter [15] who maintained that they had seen a single drumlin coming out from beneath the snout of the Biferten Glacier in Greenland. Considering the wide diversity of conditions which we now observe at the fronts of the existing glaciers this lack of drumlins is rather puzzling.

Hoppe [10] was probably the first who pointed out a certain similarity existing between the pleistocene drumlins of the Norrbotten region in Sweden, and forms that have been observed at the fronts of some glaciers. He says: “In some areas there is a striation of till surfaces, perhaps better described as flutings than drumlinization [...] A similar fluting is a normal feature in front of existing retreating glaciers in northern Sweden. as well as elsewhere in the world” (cf. Hoppe, Schytt [11] p. 204 - 205).

Vernon [24] went even further saying that: “Drumlins are one of a group of streamlined forms described as ‘ice-moulded’. Also in this group are subglacial ridges” (p. 407). It is clear from the context that the same subglacial ridges were described by Dyson [6], and also by Hoppe and Schytt [11] as “fluted moraine” surfaces. Vernon therefore sees a close relation between the genesis of drumlins and the contemporary "fluted moraine".

"Fluted moraine" surfaces have been observed at the fronts of many existing glaciers in Northern Europe [11, 16, 21], in Northern America [6], in Iceland [11] and in Greenland [15]. The present author of this observed them also in Spitsbergen [1] in the forefield of the Werenskiöld Glacier (Fig. 4), where they are abundant in places kept clear of the animated action of water. There the "fluted moraine" is in the form of long ridges and furrows situated parallelly each to the other and ideally in the line of the movement of the glacier. The width of the ridges is quite constant (1·5 to 2·5 m), their height changes from several to about 30 centimetres, and their length reaches 80 to 150 metres. The ridges at the snout of the Werenskiöld Glacier are spaced evenly enough, and the most frequent distance lies between 3 and 5 metres (52% of all measured ridges). A similar regularity of distances was pointed out by Schytt [11]: "It is very striking that all the ridges are at a distance of a little more than a metre from one another" (p. 111).

Unfortunately so far there is no agreement concerning the explanation of the origin of the "fluted moraine". Vernon [24] is apt to think that both "fluted moraine" ridges and drumlins originated from the squeezing

Photo S. Baranowski

Fig. 4. "Fluted moraine" surface at the Werenskiold Glacier snout, south-west Spitsbergen

up of the till into subglacial caves and grooves made in the lee of knobs and boulders, an explanation which was given for drumlins first by Hoppe [9]. The trouble is that this hypothesis can hardly explain very long drumlins and ridges of flutings (which was pointed out by Schytt [21]), and it cannot explain the organized arrangement of these forms in the field.

Schytt, who has done the most extensive work on the "fluted moraine" problem [11, 19, 20, 21] is of the opinion that the ridges were built by the pressing of the water-logged ground moraine into caves and tunnels formed in the basal ice in the lee of knobs in the glacier bed and in the lee of big well embedded boulders. To explain the long ridges he assumes that simultaneously with the pressing process some of the moraine material was frozen to the basal ice, which was brought about there by the release of pressure. As the result of the movement of the glacier the frozen morainic material came down forward leaving space for another portion of the moraine to be pressed in there.

Actually many of the ridges have big boulders on their up-glacier sides. It is true, however, too that the ridges occur also where there are no big boulders or where they are rare, which was pointed out by Hoppe [11]. Besides it is doubtful if these boulders were arranged under the glacier in such a way as to give such regularly spaced ridges.

It is, however, noteworthy — and many investigators paid attention to it — that the drift that built the forms at the glacier bed was first in unfrozen state and was well saturated with water. This could be explained in the light of Lliboutry's [14] remarks on the conditions at the glacier bottom: „Heat flow through the Earth melts about 5 mm of ice per year at the bottom of a temperate glacier, and the heat produced by plastic deformation in the basal layers melts a further few centimeters. This latter melting takes place within the ice [...]" (p. 53).

In addition Lliboutry mentioned the possibility of the existence of interstitial water in the basal ice. This water, in cases when the subglacial hydraulic system is filled or flooded, may take up a considerable fraction of the environment.

It seems, therefore, that there are situations at the glacier bed, certainly in the temperate and probably in the subpolar type of the glaciers where either till or basal ice or both are well saturated with water. These conditions should be taken into consideration when tracing the genesis of the "fluted moraine" and drumlins.

The above mentioned abundance in liquid water at the glacier bed, the mechanical composition of the "fluted moraine" surfaces with its always considerable percentage of silt fraction. the well pronounced regularity of distance between the ridges, their abundance at the fronts of some glaciers and their geographical restriction to the glaciers of subpolar type only have suggested to the author that the genesis of the "fluted moraine" might have been related to changes in the thermal regime at the glacier base.

The causes of such changes could have been various, and most probably the following factors were of importance: a) changes of temperature at the glacier surface, b) changes in the thickness of the glacier caused by the increase or decrease of surficial ablation, c) changes in the flow rate of the glacier and — related to this process — the amount of heat produced, d) changes in the rate of snow accumulation in the firn region of the glacier and the resulting changes in the transfer rate of the cold ice from the surface of the glacier to its interior.

Robin [18] estimates that if at the surface of the Greenland ice sheet, in its central part, accumulation of snow decreased from the present 30 to 10 cm of ice per year it would rise the temperature from −12 to 0° at the base of the ice sheet, even if the surface temperature remains the same all the time. Such changes then are caused principally by the climatic fluctuations. It is believed that a glacier in the course of its existence could have passed through the alternating thermal regimes, and it is naturally to assume that "thermal fronts" dividing the cold and warm regimes at the glacier base went easier downstream the glacier in accordance with the movement than in the opposite direction.

The present author in his paper [1] suggested that the formative mechanism of the "fluted moraine" is connected with frost action, i.e. frost heaving at the glacier bed, a process modified by the movement of ice.

THE ORIGIN OF DRUMLINS

It seems very likely that the formative mechanism of drumlins was substantially similar to that of the "fluted moraine" surfaces. The following is suggested:

Before a change in thermal regime from warm to cold happened there had been for a long time good conditions for a basal melting of the glacier, and for the accumulation of ground moraine and its soaking with water. In some places of course water could penetrate even into older substratum (Fig. 5a). It is likely too, that if the outflow of the interstitial water — produced by heat due to plastic deformation in the basal ice layers — was blocked, it could fill all ice-free spaces there.

Owing to climatic change a cold thermal regime appeared at the base of the glacier and the cold thermal front progressed downward in accordance with the flow of the glacier. At this progressing front the liquid water which was collected in the ground moraine and in the substratum froze, and some heaves and bumps were formed due to

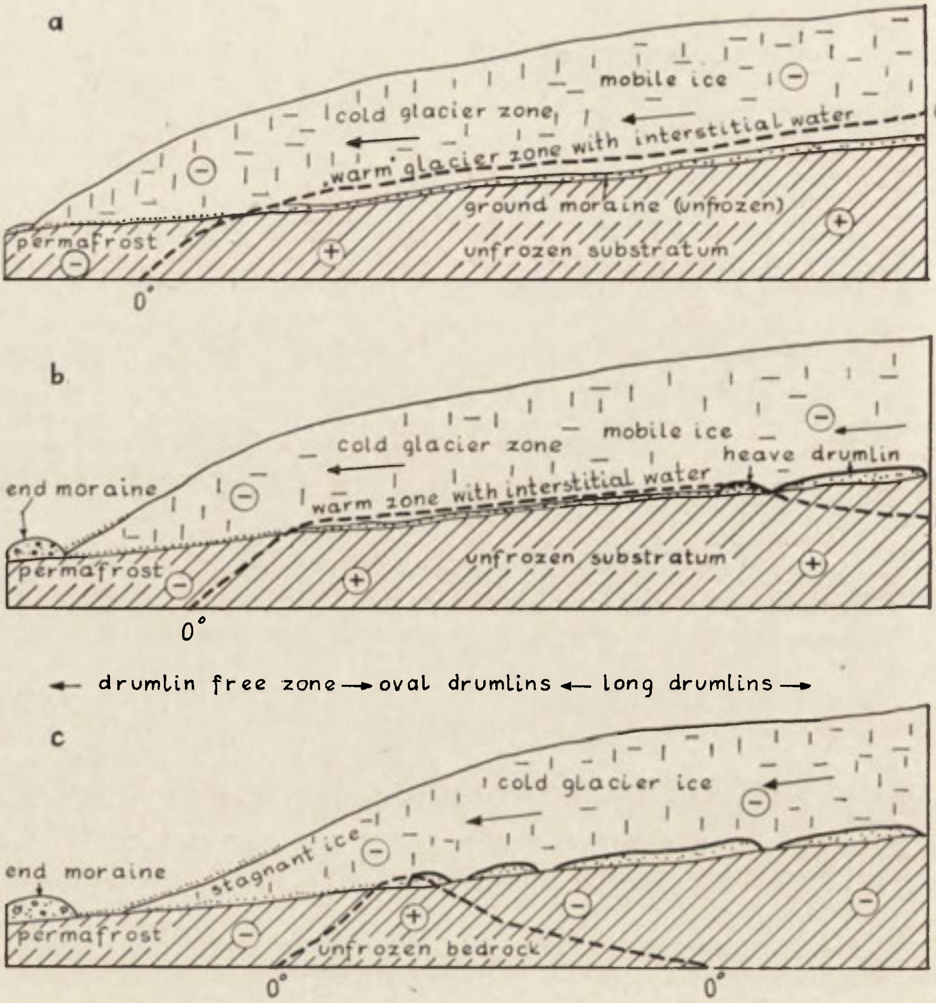

Fig. 5. Longitudinal sections of the glacier with thermal front marked; a — before drumlins started to form in the field, b — at the beginning of their formation, and c — by the end of formation

increase in volume (Fig. 5b and Fig. 6a). Probably deformations in the basal glacier ice could also have taken place if there was only a very thin ground moraine or even in case of its absence, that is if interstitial water in the basal ice layers froze. Heaves and protuberances were spread along the thermal front in fairly even distances which depended most probably on the magnitude of hydrostatic pressure, i.e. on the thickness of ice. The heights of the heaves were dependent on the amount of water that was subjected to freezing.

As the downward movement of ice at the glacier base continued the thermal front went down too, and heaves and protuberances at the glacier bed continously developed in the same direction. In such a way parallel ridges were formed which we call drumlins (Fig. 5c and Fig. 6b). They consist of ground moraine or of underlying unconsolidated rock in places where the water could collect. In some other places they were cut out of the bedrock by protuberances made in the basal ice which had been filled with interstitial water (Fig. 7).

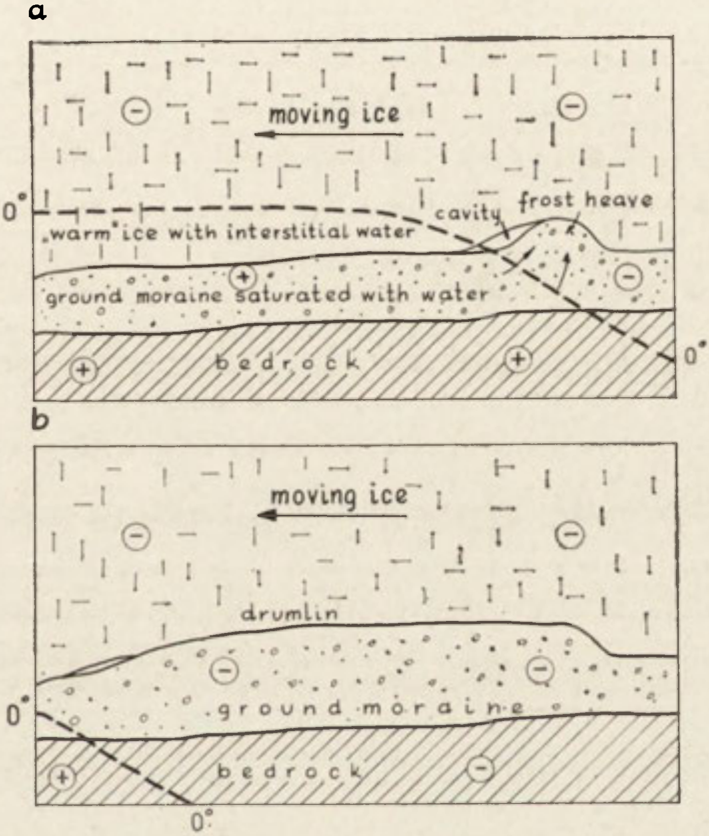

Fig. 6. Suggested scheme of the drumlin formation; a — initial frost-heave stage b — fully developed form stage

The process of the formation of the ridges or protuberances lasted until the downward motion of the thermal front went slower or remained at the same rate as the movement of the glacier at its base. If the thermal front was quicker than the ice, which could have happened in the vicinity of the glacier front, only short ridges or oval drumlins were

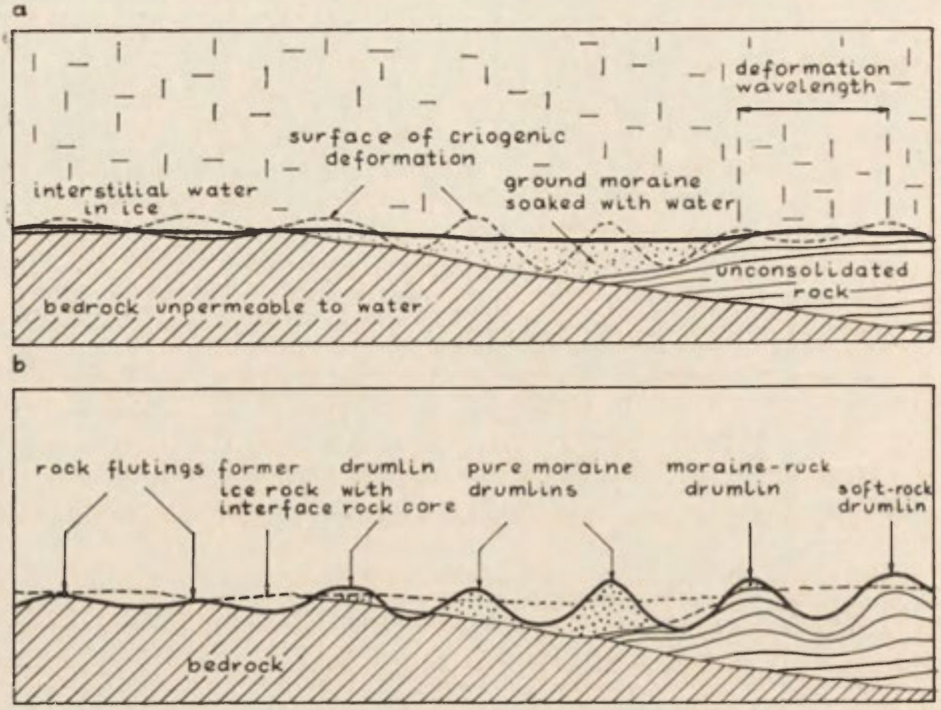

Fig. 7. Hypothetical cross-section through the glacier base where different types of drumlins developed; a — at the moment of appearance of the cold thermal front at the glacier base, b — after the glacier retreat

formed. However, as the frontal zone in the subpolar glacier type has always cold thermal regime, there were no conditions for the development of drumlins in this outermost zone bordering with the end moraine. Drumlins of one field were most probably formed during a fairly short period of time of the order of several decades or a few hundred years. They were oriented in the direction of the last ice movement in the region.

At this point it is necessary to say that bedrock knobs or boulders could have been of help in the formation of drumlins as on their leeward side lower pressure and then sometimes even cavities developed permitting for water-soaked moraine to press in there. An important thing here is, however, that such prominences of bedrock were not indispensable for the drumlin formation. A more decisive factor was the presence of criogenic pressure caused by the water refreezing process at the glacier base. It follows that accumulation forms, such as "crag and tails" were formed in the lee of prominences probably in the absence of criogenic pressure and so genetically may have little connection with true drumlins.

The explanation presented above accounts for the paralellism of the drumlins and their elongation in the direction of the glacier flow, features that are most characteristic for most drumlins [3, 7, 10]. It accounts also for their symmetry the stability of their dimensions in one field, and the constancy of distances between the longer axes of adjacent forms which factors are independent of any differing topographical and lithological conditions [8]. A similar regular distribution is a common feature for some geomoprhological forms at the ground surface in the tundra, such as frost mounds, thufures and sorted circles. According to Jahn [12] and Shchukin [22] at least some of the above mentioned forms derive from frost action. Although this seems evident, there have been nevertheless very few remarks or explanations concerning the regular distribution of these forms or their sizes [1].

The above presented hypothesis also accounts for the diverse geological structure of drumlins. It may explain the so often observed glacitectonic perturbations and bendings of the internal layers of these forms. The mechanism suggested helps to understand why drumlins with rock nuclei can be found side by side with pure morainic forms and why the rock flutings are gradational to true drift drumlins. In the light of this conception it seems also possible to explain the orientation and plunge of the elongated stones typical for drumlins in some regions [5, 26], and for the "fluted moraine" ridges [19].

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[1] From a theoretical point of view an increase of volume depends on the amount of water which refreezes. So the more water is in the ground the higher the heave should be. Pressure inside the heaves depends on the magnitude of forces that contracts the criogenic pressure [23], providing the temperature falls well below the pressure melting point. In the case of the surficial heaves these contracting forces are rather weak due to the comparatively thin layer of rock material covering the layer of freezing water. In the case of the subglacial heaves the pressure is proportional to the overlying weight of the ice i.e. to its thickness. It is likely that the width of the influence zone of a heave depends on the magnitude of hydrostatic pressure. So, the bigger the thickness of the glacier the larger the distances between the heaves and consequently the larger the distances between the adjacent drumlins.

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CLIMATIC OR TECTONIC ADAPTATION OF THE RELIEF OF YOUNG MOUNTAINS IN THE QUATERNARY

Leszek Starkel

POSING THE PROBLEM

The zone of young mountains of the Alpine system is a region of intense uplift movements. Simultaneously, the variability of the climate in the Quaternary was particularly distinctly marked here by the oscillations of climatic and morphogenetic vertical zones. Uplift movements condition the vertical cutting, one can expect therefore to encounter in this zone young convex slopes and deeply cut valleys with erosional terraces reflecting the rhythm of uplifting. Apart from these, there occur surfaces of glacis type, characteristic of certain types of climate, whereas the terraces related to glaciations constitute indubitably a reflexion of the climatic rhythm.

Many misunderstandings have made their way into the literature dealing with this subject. The same forms are interpreted in a different way. It has come to that from the differences in the rock floors of successive terraces conclusions are drawn on the existence of a separate phase of movements and on the dimensions of uplifting, while simultaneously the terrace level is assigned to a determined glacial period.

What and under what conditions plays a more important role in the Quaternary history of young mountains: uplift movements or climatic changes? This question remains open and is far from being solved. Attempting to settle it one must, before analysing the results of investigations in various mountain ranges, determine the character of uplift movements, as well as the type of climatic changes in the zone of Alpine orogeny.

DIFFERENTIATED UPLIFT MOVEMENTS AND THEIR EFFECTS IN THE QUATERNARY

Assuming that the boundary of the Quaternary is at the boundary between the Levantian and Villafranchian, all movements of the so-called

Valachian phase have to be included into the Quaternary. Consequently, the piemonts of the Carpathians [12, 56], of the Bulgarian mountains [22], or of the Atlas [43] were being formed already in the Quaternary, thus the dimensions of Quaternary dissections are larger than those of Lower Quaternary piemonts. The total magnitude of uplifting in the Quaternary ranges from 100 to 300 m in many parts of the Carpathians, amounting to 500 - 800 m in the Balkan Peninsula, and up to 1000 - 2000 m in the Caucasus, Parmir, or in the Himalayas. These movements have a diversiform style. They are either geanticlinal warpings of mountain ridges, e.g. in the Caucasus, or an uplifting of mountain blocks along fault lines (Rhodope, Pamir), or else there revive small folded structures (border of the Caucasus, Balkan Foreland), or form new ones at the border of mountains (Rumanian Subcarpathians, Siwaliks).

The rhythm of the movements is varying. Conclusions in this respect are drawn either on the basis of the size of the throw (uplifting) of sediments or of Upper Pliocene and Lower Quaternary planation surfaces on the lines of faults, more frequently, however, on the basis of the amplitudes of the deepening of valleys dissecting the uplifting area.

On the whole, the results are concordant as regards the principal phase of movements in the Lower Quaternary (Valachian phase proper). The later phases, however, are poorly documented with the exception of warping terraces of determined age [54, 58]. It is a question open to discussion whether from the rejuvenation of valleys a conclusion can be drawn on the magnitude of movements if the rivers are cutting in with a considerable delay [39, 63, 64], this being best shown by hanging valleys on border scarplets of mountains of the Rhodope zone. Simultaneously, there exist not rejuvenated Pliocene valleys [30]. The magnitude of the uplift of the axial parts of mountains is therefore probably greater than the amplitudes of the deepening of valleys in this zone [3]. However, the rhythm of movements cannot be denied. It is marked not only by the hanging erosion-denudational levels [24] but also by the magnitude of the actual uplifting established by repeated levellings. In the western part of the Caucasus the uplifting amounts to 10 mm per year [50]. If in the whole Quaternary this movement would have been of invariable activity the amplitudes of the uplifting of this part of the Caucasus would be reaching 10,000 m (while the present height amounts up to 3000 m above sea-level).

CLIMATIC CHANGES IN THE QUATERNARY

In the zone of young mountains there occurred changes both of temperature and humidity. Together with the shifting of morphogenetic vertical zones they brought about changes in the activity of slope and fluvial processes. The most stable are the forest belts. Effects in the form of deepening of valleys depend here only on the flow volume and rock resistance. On the other hand, both in the subnival zone (periglacial, above the timber line) and in the forest-steppe and steppe vertical zone below the forest belts in the mountains of the Mediterranean and Central Asia region the type of relief modelling and the fluvial action are influenced by the increased delivery from slopes.

In the Quaternary these zones were subject to variations. Although, as was shown by the latest investigations carried out by van der Hammen [18], Wright [71], Butzer [4], and others, the picture of these changes was more complex (arid period in the Late Glacial in Europe, general humid phase during the Atlanticum — covering North Africa), the author, not wishing to complicate excessively this problem. limited himself to the comparison of glacial and interglacial periods in the Middle and Upper Quaternary.

Both in southern Europe and in the mountains of Asia there occur 5 vertical zones, which in the Quaternary had a different rhythm of changes. The highest zone lies at the present time above the snow-line (e.g. the Caucasus above 3000 - 3500 m, Pamir 4500 m), which, apart from short periods in the interglacial climatic optimum, remained within the range of nival climate and glaciers.

The second zone is the present subnival one, lying in the glacial periods above the snow-line (above 1500 - 1800 m in the Carpathians and above 2200 m in Rhodope).

The third zone is represented by forest belts, lying in the glacial periods above the timber line and often within the reach of glacier tongues (it is particularly well developed in the Carpathians).

The fourth zone, "permanently" wooded, including among others, the lower parts of the mountains of the Balkan Peninsula and the Caucasus, remains invariably within the range of forests.

Finally, the mountain areas, lying in the glacial periods in the forest vertical zone, belonging nowadays to the steppe zone or even to semideserts (Atlas, mountains of the Near Eeast). There probably existed in these zones varying conditions for relief development (in consequence of various processes). The contemporary and Pleistocene periglacial belt have been particularly closely investigated [20, 26, 66].

On the basis of investigations of terraces in Alpine and other valleys a number of theories were set up, which for the mountains of Europe accept phases of accumulation in glacial periods [55, 60] and of erosion in the interglacials. Some authors modify this picture maintaining that the essential phases of erosion occurred at the beginning of glacial periods [59], or at their decline [67]. What is usually overlooked in these schemes is that big valleys of high mountains of the Alpine type, cutting various morphogenetic vertical zones, are supplied both by proglacial and extraglacial streams, this taking place in the glacial periods and at the present time as well. The actual picture is more differenciated [62, 65, 70].

THE ROLE OF TECTONIC MOVEMENTS AND CLIMATIC CHANGES IN THE QUATERNARY EVOLUTION OF THE RELIEF OF PARTICULAR MOUNTAIN RANGES

1. WESTERN AND EASTERN CARPATHIANS

The depth of dissection of the Upper Pliocene level is accepted as the measure of uplifting in the Quaternary. In the Polish and Slovakian Carpathians the valley planation niveau lying at a height of 80 - 150 m above the floors of valleys was regarded until quite lately as the Upper Pliocene level [40, 42, 61, 64]. In the Ukrainian Carpathians either the Łojowa level, altitude ca. 100 m [23], or the Krasna level, altitude ca. 150 m [15] are recognized as Lower Pleistocene level, some authors accepting in this respect the Quaternary dissections up to 300 m [1]. The latest results of investigations on the Cindeşti formation in Rumania [38] and on gravels from Witów in the foreland of the Polish Carpathians [12] allow to relate the valley level of pediment character to the Lowest Quaternary (Villafranchian). Thus, the Quaternary dissection may reach 200 m.

The Quaternary movements on the northern slope have the character of geanticlines. According to Cys [6] and Gofstein [15], they gradually die out, which would be evidenced by the diminishing intervals between rock floors of terraces. In the Upper Quaternary the lifting up in the intramountain basins changed into the inward flexing. On the southern side a fault-tectonics prevails — here not only Pliocene levels but also Quaternary terraces are cut by breaks [35].

In the valleys there occur 4 - 5 systems of rock or alluvial terraces. The covers of 3 principal terrace levels were related to the Scandinavian and Tatra glaciations [27, 63], whereas in the not glaciated valleys the age of the covers is evidenced by their indenting with periglacial slope sediments [11, 42]. The delivery from slopes devoid of forest cover brought about in the glacial periods a fluvial accumulation, in the warm periods a deepening, and in the transitional ones a lateral erosion and formation of slip-off meanders. The deepening, conditioned by tectonic tendencies, concentrated in the interglacial periods; its scale was related to the duration of these periods (Mindel-Riss interglacial — cutting of about 20 m into the rock; Riss-Würm — cutting of 10 m). In the longitudinal profiles of valleys a zone of maximum accumulation runs from the border to the interior of mountains during the glaciations, whereas the new phase of accumulation at the border of mountains is related to the Late Glacial and Holocene erosion which took place in them [62].

In the Western and Eastern Carpathians the climatic rhythm is therefore distinctly superposing on the tectonic tendencies, leading to a cyclic deepening of valleys (Fig. 1).

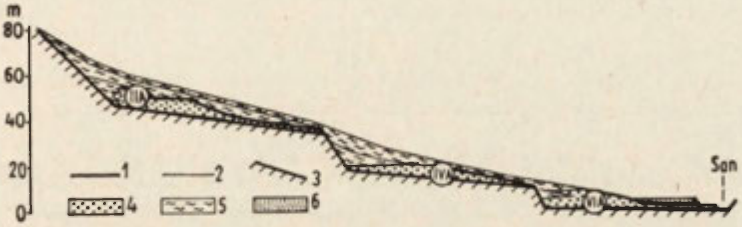


Fig. 1. Schematic cross section and phases of the development of the San River during the Quaternary (after Dziewański-Starkel [11])

1 — erosional plains, *2* — accumulation niveaus, *3* — rock base floors, *4* — Pleistocene fluvial sediments, *5* — slope covers, *6* — Holocene fluvial sediments

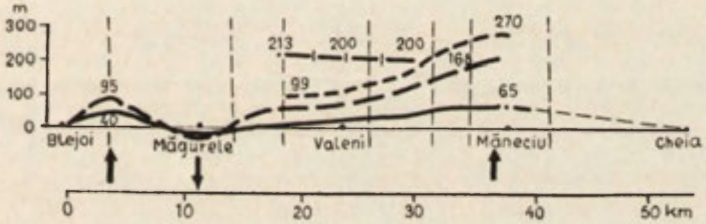
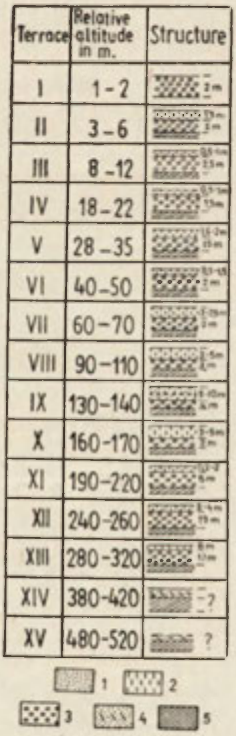


Fig. 2. Deformations of the Teleajen terraces as the effect of neotectonic movements. The highest niveau of Lower Quaternary (after Niculescu [52])



Terrace	Relative altitude in m.	Structure
I	1-2	
II	3-6	
III	8-12	
IV	18-22	
V	28-35	
VI	40-50	
VII	60-70	
VIII	90-110	
IX	130-140	
X	160-170	
XI	190-220	
XII	240-260	
XIII	280-320	
XIV	380-420	?
XV	480-520	?

→

Fig. 3. Quaternary Terraces in Subcarpathians zone between Cilnau and Şuşita (after Grumazescu [16])

1 — sands, *2* — sandy loams, *3* — gravels, *4* — weathering covers, *5* — substratum

In the longitudinal profile of valleys there appear distinctly hanging valleys of tributaries, testifying to a retardation of erosion in relation to the movements. In the Tatra Mts [30] and other Carpathian ranges the non-dissected floors of Pliocene valleys were firn basins during the glacial periods. The maturing of slopes in these valleys without changes of base level is a reflexion of the changing climatic conditions. In the upper parts of the Moravian-Silesian Beskids [7] the formation of altiplanation terraces independent of the lowered base level was also observed.

2. RUMANIAN CARPATHIANS

The depth of dissection of piemonts from the border of the Levantian and Quaternary in Transylvania amounts to 100 - 200 m [48, 56]. In the Southern Carpathians the amplitudes of uplift movements are greater, reaching 400 - 900 m [57]. Apart from the uplift of whole mountains, younger and younger zones of the Subcarpathians are successively included into the active zone, e.g. dissections after the Great Interglacial amount in the western part up to 130 m [58]. New folding structures develop, also warped are Upper Quaternary terraces [2, 52] (Fig. 2).

The deepening of valleys of the southern slope of the Carpathians is cyclic, this being evidenced by terrace levels. In the foreland of the Vrancea Mts Grumazescu [16] observed the occurrence of 13 terrace levels with thin gravel covers, the highest of which reaches 320 m above the river channel (levels without gravels occur up to 500 m — Fig. 3). This system of terraces shows no relation to climatic variations. In the valley of Teleajen Niculescu [52] observed a group of 7 terraces which, after N. Popp, he tries to associate with glacial periods (similarly as Roşu). However, the connecting of the lower levels with different parts of Würm is little convincing; how can one relate a 50-metres deep dissection of a uplifted anticline to the interstadial period? Thus, Badea's [2] opinion seems to be right, maintaining that the Subcarpathian terraces reflect above all the rhythm of tectonic movements. Actually, in various regions the intervals between various terraces grow larger — it can be presumed that the intensity of movements increased in these places at determined periods.

The influence of climate in the development of valley floors is marked only from the height of 1000 - 1200 m above sea-level. In the Jiu valley and Braşov depression the author observed through valleys and flat feet of slopes covered with solifluxional and alluvial sediments (a typical phenomenon in the Polish Carpathians). Presumably, the timber line persisted in the Last Glacial longer at that height. The absence in the lower parts of similar forms and covers indicates that in the forest vertical zone there occurred no climatic impulses which would interrupt the deepening of valleys. It seems, however, that the deepening of valleys must be in some way related to the oscillations of water flow volume and its transporting power.

In the high mountain ranges (Rodna, Fogaraz, Reteşat, Godeanu) at an altitude of 1500 - 2100 m there occur hanging non-rejuvenated valley floors, which in the glacial periods were a zone of action of glacial and nival processes [51, 53].

3. STARA PŁANINA (BALKAN)

The uplifting of the northern slope of Stara Płanina had the character of a non-uniform warping. The anticline zones were uplifted by 10 - 30 m more intensely than the depression (syncline) zones, where the values of uplifting are of the order of 100 m [17, 45]. These terraces, 6 - 7 in number, are related to rhythmical uplift movements.

The southern slope: a system of tectonic lines, was rejuvenated in the Quaternary. The northern border of the Sofia Basin was uplifted by at least 160 m. Three erosion-denudational levels, lower than that with Pliocene sediments, testify to 4 phases of uplifting in the Quaternary [24]. In the Zlatica Depression fragments of alluvial fans were broken on the slope of the fault-line scarp. The fresh steep facets visible on this scarp indicate almost contemporaneous movements [47]. In valleys dissecting the scarp are marked steps in the longitudinal profile — erosion does not keep up with the movements. In the Tvardica Depression the planation surface from the Levantian is thrown by 400 - 500 m, i.e. from 750 - 800 m to 350 - 400 m, while the distinct facets attain a height of up to 500 m [46]. The presence of only low terraces (up to 50 m) shows that the most intense uplifting and dissection occurred in the Lower Quaternary. The periodicity of the movements is also evidenced by the very weak contemporaneous uplifting below 1 mm/year in the western Balkan [17].

Did climatic changes influence the course of deepening? In the western part of the Balkan, at a height of over 1000 m above sea-level, the author observed valley depressions of dellen-type and a covering of the upper sections of valleys with slope covers. This accumulation impeded erosion. In the valley of the river Vidina investigated by Mishev [45] remarkable is the presence of thick gravels and loamy alluvia in the upper course of the river, at an altitude of over 600 m. In spite of a gradient of 22 per cent, their thickness on some terraces amounts up to 30 m (gravels up to 20 m). On the other hand, downstream, at a gradient of 4 - 6 per cent, their thickness decreases to several metres. In the author's opinion the climatic accumulation related to the lowering of the forest vertical zone (up to 1100 m in the Last Glacial) disturbed in the upper course the process of valley deepening brought about by the uplifting of the area.

4. RHODOPE AND MACEDONIAN MTS

They are composed of a number of fault blocks and deep tectonic troughs. The uplifting here is often very intense (up to 6 mm/year in Macedonia [36]. The magnitude of Quaternary vertical movements amounts to 300 - 350 m in the Vardar valley [37], exceeding 500 m in the Struma trough in spite of a dissection of only 200 - 300 m [22]. The northern slope of Witosha shows a movement of the order of 300 - 400 m [13], whereas if the gravels on the Kapitoto prove to be Upper Pliocene, it could attain up to 700 m. The movements in the Quaternary were of varying intensity and, as was observed by Lilienberg [36], had often opposed tendencies. Actually, for instance, the area of Rhodope with distinct facets is being uplifted only quite insignificantly [17].

Erosion-accumulation terraces are common in depressions and uplifted forelands (Pliocene and Lower Pleistocene piemonts), whereas in mountains they are poorly developed. In the lower basins they show a relationship to the changes of the Mediterranean Sea level. Remarkable

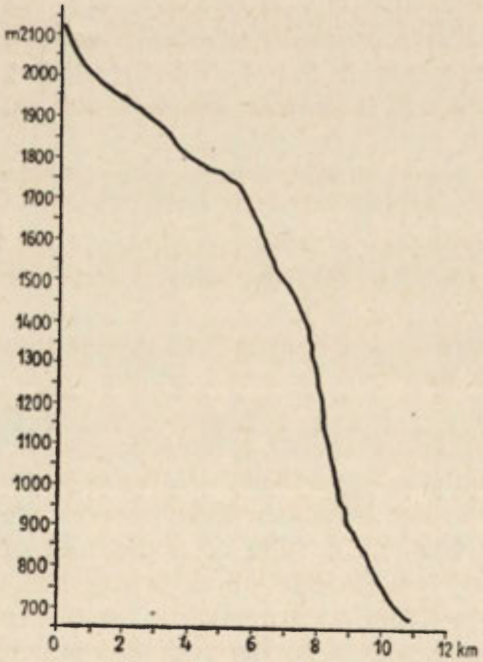


Fig. 4. Longitudinal profile of the Bojana River on the northern slope of Witosha Mts. (after Georgiyev [13])

is their varying number. The nearer to the present river channel the smaller are the differences in height. Presumably, these lower terraces — alluvial cones can be related to processes of weathering and denudation in the surrounding mountain groups, which attain after all a height of 2900 m. In the Rila Mts terrace sediments are distinctly related to terminal moraines of mountain glaciers from Würm [14]. In the Dimitrov Basin (upper Struma) Ivanov [21] observed a larger number of levels of low terraces in valleys dissecting the slope of Witosha (2290 m above sea-level) — this is perhaps a trace of the superposition of the climatic rhythm upon the tectonic one having occurred here as well.

In the high mountains (Pirin, Rila, Prokletie) not rejuvenated valleys have been preserved, transformed by glaciers; their floors constitute a base-niveau for denudation processes. This is illustrated by the longitudinal profile of a valley in the Witosha range (Fig. 4). The uplift movements were so strong that rivers flowing on resistant rocks are incapable of reaching the lowered base-level.

5. AUSTRIAN ALPS

The amplitudes of deepening in the Quaternary are rated here at 100 - 300 m [70]. The main phases of movements took place in the Lower Quaternary and in the Mindel-Riss Interglacial. The terrace levels since the days of the classical studies of Penck, Brückner and others are associated with glacial periods, for they refer to moraines of glaciers which advanced to the foreland. However, the age of terrace covers changes in the longitudinal profile. On the eastern border of the Alps Winkler v. Hermaden [70] calls attention to the glacial age of alluvia far in the mountains and interglacial one in the foreland. A common phenomenon is the etagement of valleys [19], the old ones being places of accumulation of firn and ice. The relief of these sections transformed by glaciers, has the features of a relief which has outlasted, shaped by the climatic regime.

6. CAUCASUS

The young tectonic movements in the Caucasus have been the subject of numerous investigations. The amplitudes of uplifting are of the order of 1000 - 2000 m [5, 9], whereas the deepening of valleys amounts to several hundreds of metres — on an erosional terrace up to 300 m high glacial sediments are lying related to the Mindel period. Towards the north-west the magnitude of the movements decreases, this being related to the greater maturity of valley forms [3]. The style of uplifting is varying. In the north-western part Muratov and Lilienberg [50] observed an uplift in the form of a wide ridge — in the axis of the range the present uplifting amounts to 10 mm/year. Hence, postglacial dissections often attain 50 m [5, 54]. Terraces of main valleys show in the glaciated part a distinct relation to climatic variations, e.g. on the Inguri terraces lying at an altitude of 300 - 350, 200, and 50 - 60 m there occur boulder clays and fluvioglacial sediments of 3 successive glaciations [5] (Fig. 5).

The depth of Caucasian valleys, amounting to 3000 m and continuing to increase, is the cause that the lateral valleys are hanging, while the processes in the main valleys are determined by those taking place in various vertical zones. In the glacial periods the upper tree line was being lowered to 1200 - 1400 m (1800 - 2000 m nowadays), and the snow-line even to 2000 m [5, 41]. In the forest zone Muratov [49] observed the formation of migthy alluvial fans at the outlets of lateral valleys in the case when part of the catchment area is lying above the tree line. Similar fans, but dissected, are lying lower at the outlets of valleys, part of which in the glacial period was in the subnival zone. This testifies best to the rightness of the thesis that accumulation connected with climate moves often in valleys below the zone in which strongly eroded valley-heads are found.

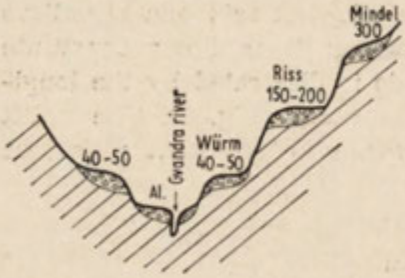


Fig. 5. Cross section of the Gwandra valley on southern slope of Caucasus (after Cereteli [5])

One also encounters in the Caucasus classical examples of the development of valleys and slopes independent of tectonic tendencies. In valley-heads of the Inguri Basin the author observed a widening of glacial troughs by erosional and sliding processes — the base-niveau for these processes is the valley bottom, not taken in as yet by the rejuvenation advancing upstream. The border lines of climatic-floristic vertical zones often constitute the boundaries of processes leading to the development of forms independent of base-level changes. Muratov [49] observed an actual formation of plains of solifluctional accumulation at the height of the present upper tree line (1800 - 1900 m above sea-level), as well as inactive steps descending to 1350 m, which testify to a different course of the tree line in the glacial period.

Thus, in the Caucasus, taken in by the mighty Alpine glaciation, a rhythm of climatic variations is distinctly accentuated in the relief, in spite of an indubitably intense Quaternary tectonics.

On the southern border of the Caucasus, in the region of Tbilisi, the deepening of valleys in the Quaternary reaches 300 m [5]. Here, however, the rhythm of climatic variations was different. The forest zones in the glacial period descended down (the present lower tree line lies at an altitude of 500 m), hence conditions for vertical cutting existed rather in the cold periods. On the other hand, at the present time there develop in a semiarid climate plains of pediment type recurring to fluvial terraces [63, 64]. Here also the tectonic tendencies are disturbed by the rhythm of climatic changes.

7. MOUNTAINS OF THE BORDERING ZONE OF THE MEDITERRANEAN SEA

The scale of Quaternary movements in the Mediterranean Basin also amounts to hundreds of metres. Oscillations of sea-level superpose in the evolution of valleys on tectonic variations. In the Atlas Mts and on the Iberian Peninsula Dresch [8], Reynal and Mensching [44] observed a system of stepwise lying erosion-accumulation glacis, formed during pluvial periods synchronized with the glacial ones. Thus, in the course of the rejuvenation of valleys the climatic rhythm has been reflected. The presence of fossil forms and covers of the subnival vertical zone at a height being often below 1000 m (Mallorca, Greece, etc.) would point to the possibility of a modification of the process of valleys deepening during the cold periods [20]. The presence in the Late Glacial of steppes on the lowlands of Macedonia and Spain [18] indicates that forest zones could have subsisted during the whole Glacial period in Spain, Italy, or Greece at a height of the order of 500 - 1000 m above sea-level. In the valleys of this zone one can expect that climatic changes are not accentuated in the evolution of valleys.

8. PAMIR AND THE HIMALAYAS

The Himalayas and the Pamir are mountains showing the greatest contrasts. Canyons of valleys of a depth of several thousand metres often dissect upland areas of oscillations of level amounting to several hundreds of metres. The Quaternary dissections on the Indian side are of the order of 1000 - 2000 m [25]. In the Pamir the size of the dissection on the scale of the whole Pliocene and Quaternary amounts to 2000 - 2500 m [33].

The Quaternary deepening of the order of 1000 m attains the highest values in main valleys and in the marginal part of the Pamir and Tian-

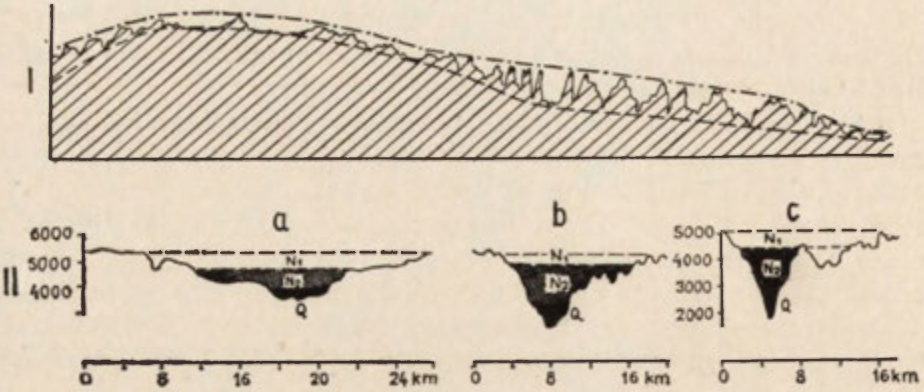


Fig. 6. Type of rejuvenation of Pamir relief in Neogene and Quaternary (after Kostienko [31])

I. Schematic cross section with different depth of valleys in the central and in the border zone of Pamir. II. Types of dissection in Pamir: *a* — in central zone — (Alitshur valley), *b* — at the border between higher and lower zone (Gunt valley), c — deep dissected relief of lower zone (Piandsh valley), N_2 — rejuvenation in Pliocene, Q — in Quaternary

-shan, which presumably was the most intensively uplifting zone in the Quaternary. Far in the mountains the size of the dissection decreases — the valley floors are often lying at an altitude of 5000 - 6000 m (Fig. 6). This may testify to the youth of the movements, showing, moreover, that the headward erosion did not reach the valley-heads [3]. The uplifting here did not reflect upon the rejuvenation of the relief, but lowered the tree- and snow-line, while favouring the formation of glaciers it contributed to the enlargement of an area with a different trend of evolution of the relief. In the Russian Pamir Kostienko [32, 34] differentiated several morphogenetic vertical zones. In the glacial zone above the snow-line (altitude $>$ 4700 m) the base-niveau for processes are surfaces of glaciers or floors of high lying valleys. The feet of slopes are covered with solifluction and gravitational covers indenting with moraines. The trend of evolution is conditioned here by the climate and the type of the substratum.

The periglacial vertical zone of an altitude ranging from 3500 to 4700 m is characterized by a greater intensity of processes. The base level for slopes are usually glacier tongues.

The next extraglacial vertical zone (1500 - 3500 m), predominantly wooded, is a zone of deepening of valleys. The steep convex slopes are modelled by gravitational processes of various type, the material, however, is carried away beyond the area of the mountains.

Finally, in the foreland zone (ca. 1000 - 2000 m) in a warm and arid climate where the movements are weaker, the slopes become distinctly terraced and on the background of a general deepening there appears a different rhythm (controlled by climatic variations).

The climatic conditions of the extraglacial zone create the best possibilities for the deepening of valleys. The climate of the upper zones inhibited the deepening of valleys, leaving its mark on the relief of the Pamir. A separate question is to what an extent the Tertiary landscape became transformed under those conditions. Kostienko estimates that the lowering of the high parts of the Pamir in the Pliocene and Quaternary jointly amounts to 400 - 500 m.

9. MOUNTAINS OF INDONESIA

The mountain ranges of the Indonesian islands are at the stage of formation. This, apart from volcanism and earthquakes, is evidenced by

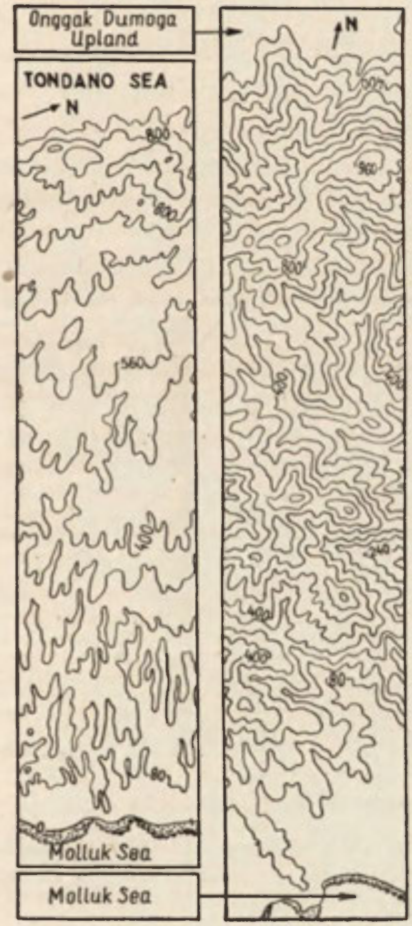


Fig. 7. The North-Celebes geantikline lowered to the Molluk-Sea. On the left young stadium of relief evolution connected with young uplifting. On the right older stadium after deep dissection (after Verstappen [68])

the fact that crystalline massifs have not as yet outcropped from under the cover of sedimentary rocks, e.g. in New Guinea [68]. The periodicity of movements is marked here and it appears that erosion acts with a distinct retardation if the movements are more rapid than the possibilities of degradation. On the basis of measurements of contemporary processes Verstappen [68] observed that uplifting weaker than 1 mm/year can in a tropical climate be compensated by degradation. On the other hand. the example of the Minahasa geanticline on the Celebes (Fig. 7) shows distinctly that erosion acts with retardation at a more rapid movement. The part uplifted later has not yet been dissected, there appears a gently inclined planation surface, whereas the area uplifted earlier to an identical height is dissected by deep valleys.

Here also in the high mountain ranges there existed in the glacial periods conditions for valley glaciers (in New Guinea the snow-line in the Glacial period was 3500 m above sea-level) disturbing the process of rejuvenation [69].

TYPES OF ADAPTATION OF THE RELIEF IN THE QUATERNARY

As can be seen from the brief description of the Quaternary evolution of mountain ranges of Alpine type, there occurs here a considerable variety of transformations. In the rejuvenation advancing from the border of the mountains a rhythm of either tectonic or climatic variations is more distinctly marked. In the not rejuvenated, usually high elevated parts of mountains, the trend of evolution recurs to the rhythm of climatic variations. In spite of numerous gaps in investigations and problems remaining unresolved, 3 basic types of relief evolution can be discriminated, in which tectonics and climate play a different role (Fig. 8).

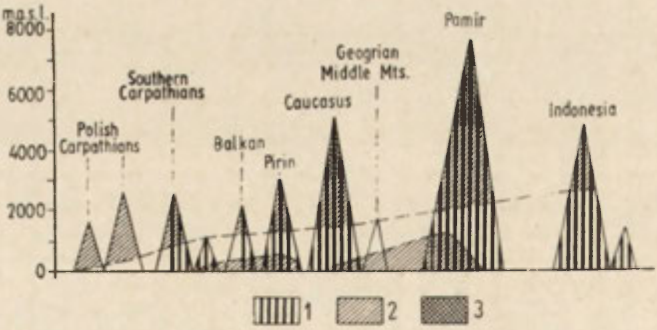


Fig. 8. General morfogenetic zones in the Alpine mountain system in the Quaternary

1 — higher uplifted zones, 2 — zones with different climat-morphogenetic tendencies in glacial and interglacial periods, 3 — zone above snowline

a) Regions where tectonics plays a predominant role in the rejuvenation of the relief. The climate in these regions is not able to disturb the permanent uplifting tendencies (neither the periodical movements). They represent areas of intense uplift movements (300 - 2000 m). Only the erosion of big rivers keeps up with the uplifting (Himalayas, Caucasus), the smaller ones are hanging (Fig. 4). The rejuvenation is distinctly a function of time. The terrace levels reflect the rhythm of movements (mountains of Bulgaria). The non-disturbance by the climate is often related to the conformity of climatic and tectonic tendencies. Such conditions exist in the vertical zone covered with forests both in the glacial and interglacial periods, e.g. on the Balkan Peninsula below 1000 m above sea-level. In other words, changes in the delivery from slopes were insignificant here, bringing about no alternate phases of erosion and accumulation.

b) Regions, in which the rhythm of climatic variations superposes upon and disturbs the deepening conditioned by uplift movements. In the lower mountains this is favoured by weak uplift movements. To these regions belong areas of middle mountains of the temperate zone (Carpathians), which during the glacial periods remained within the range of a treeless periglacial climate (with small Alpine glaciers). The terraces in the valleys reflect the rhythm of climatic variations, although the phases of erosion and accumulation in the whole longitudinal profile were not occurring simultaneously [65]. A similar rhythm of deepening is marked in valleys of high, intensively uplifting mountains, whose deepening by rivers was interrupted by glacial and fluvioglacial accumulation (Caucasus, Rila, Pamir). Also in the zone of semiarid cilimate changes of the humidity and situation of climatic-floristic vertical zones are reflected in the rhythmic deepening of valleys and evolution of slopes (Atlas).

c) Regions, in which the evolution of the pre-Quaternary relief takes place under the exclusive influence of climatic variations, upon which uplift movements and the accompanying them deepening have no significant influence[1]. They represent areas, where owing to the resistance of the substratum or the not reaching of erosion to valley-heads, deepening does not occur and the base-niveau for slope processes undergoes no change. Such valleys usually lie above the tree line (they were often glaciated in glacial periods). There occurs a retreat of rocky slopes, a dissection of slopes, and formation of glacis-like surfaces at the base of slopes.

The highly uplifted parts of the Caucasus or of the Pamir found

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[1] This does not concern stable or subsided areas, the paper referring exclusively to young, uplifted mountains.

themselves in the nival vertical zone, where oscillations of the surface of glaciers are a base-niveau for slope processes — the climate controls here the changes of base-level. The intense uplifting of these mountains created indirectly conditions for an atectonic evolution of the relief. However, here also a deepening of valleys takes place by means of glacial erosion.

The independent course of denudation processes is also observed within all fragmented planations preserved between deep cut valleys. Thus, in the Central European Mountains in the cold periods under favourable structural conditions altiplanation terraces were formed. The local base-levels for climatic slope processes are wide benches of higher terraces.

CONCLUSION

The role of movements and climatic variations in the Quaternary evolution of mountains of Alpine type is a complicated problem. However, it can be reduced to several basic statements.

a) The first question is whether deep and backward erosion is able ot keep up with the rate of uplift mouvements in a given terrain. If it does keep up there exists the possibility of reading the phases of these movements from valley forms (e.g. the southern border of the Balkan). If it does not keep up one should not reconstruct the course of movements from the analysis of erosion terraces. This appears most distinctly in fault mountains and is reflected in the longitudinal profile of rivers.

b) The retardation of the rejuvenation of the relief in the Quaternary is most often related to climatic variations. The climate determines the scale of the delivery of material to river channels and controls the transporting power of rivers. The forest vertical zones are characterized by the least delivery to the river channel; that is why the oscillations of the forest lines disturb the scale of delivery from slopes. These changes lead to the formation of terrace levels. Where the role of tectonics in rejuvenating the relief is eliminated there exist conditions for the maturing of relief connected with climatic variations.

c) The scale and rate of climatic adaptation of the inherited older relief and adaptation to tectonic oscillations of level depend on the resistance of the substratum. Hence the great difference existing for example between the relief of the Rumanian Subcarpathians and the similarly uplifted horsts of Macedonia or Rhodope, built of crystalline rocks.

d) The different situation of the described mountains of Alpine orogeny from the temperate zone through subtropical to the equatorial one, and their different height, create conditions for the existence in these mountains of a varying number of Quaternary morphogenetic vertical zones, in each of which the relations between tectonic and climatic influences in the evolution of the relief develop differently. Usually, the higher the vertical zone and the further it lies in the mountains the smaller is the influence of tectonics, while on the relief of uplifting mountains the climatic rhythm of the Quaternary leaves its mark (Fig. 8) transforming the landscape of planations and valleys inherited from the Tertiary.

e) The mean lowering of the relief of uplifting mountains is the measure of morphological effectiveness of the climate. For the Alps it is estimated at about 32 m [70], for the Polish Flysch Carpathians at 30 - 50 m (from the moment of the dissection of the surface of the Villafranchian age [64]). On the other hand, the measure of the morphological effectiveness of movements is, apart from the height of tectonic escarpments, the depth of Quaternary valleys, which in the highest mountains of the world exceeds 1000 m.

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GEOGRAPHIA POLONICA 17 1969

THE EOLIAN PHENOMENA IN WEST-CENTRAL POLAND WITH SPECIAL REFERENCE TO THE CHRONOLOGY OF PHASES OF EOLIAN ACTIVITY

Stefan Kozarski, Bolesław Nowaczyk, Karol Rotnicki, Kazimierz Tobolski

INTRODUCTION

A considerable growth of interest in the problem of eolian phenomena in West-Central Poland could be traced in the course of the last decade. As a result, numerous papers dealing with this subject have been published. The growing interest has been followed by a broadening of the scope of problems under consideration. Whereas in previous publications morphological features of the dunes as well as the structural and textural features of their sands has been accentuated, the more recent works are rather concerned with problems of chronology of phases of intensive eolian activity leaving their marks not only in the relief, but also in the formation of cover deposits and the fossilization of Late Würm ice-wedges. Thanks to detail investigations in a large number of sites (Fig. 1) the relation between dune sands and peats has been established; in addition, fossil soil appearing in dunes have been examined. The age of peats and fossil soils was determined by means of the pollen analysis, and in some sites archeological materials and radiocarbon[1] dating have also been used as age indicators.

The facts gathered allow for assuming that the main, climate-conditioned phases of eolian activity coincided with the Late Würm cold periods. Eolian activity in Holocene, was limited in space, and not caused by climatic changes, but by man intervention in the geographical environment.

MAIN PHASES OF EOLIAN ACTIVITY IN WEST-CENTRAL POLAND

At the initial stage of investigating eolian phenomena in West-Central Poland, the question of their age attracted only a marginal interest. The

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[1] The authors express, herewith, their thanks to Dr. H. Tauber (Copenhagen) for the ^{14}C data of gyttja and peats from the site in Węglewice.

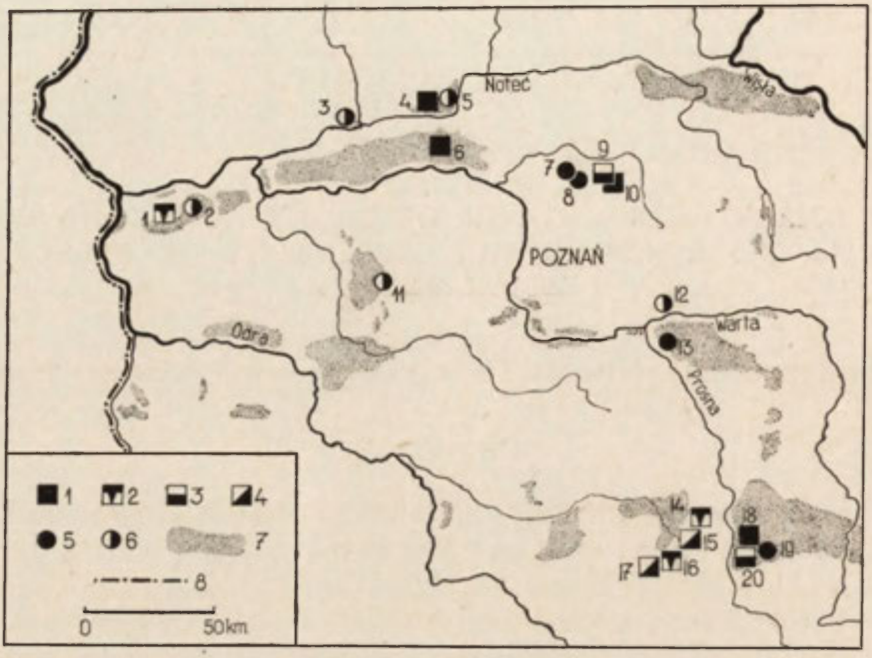

Fig. 1. Distribution of investigated sites

1 — Czarnów, *2* — Grodzewo, *3* — Brzegi, *4, 5* — Czarnków Zanotecki, *6* — Elżbiecin, *7* — Sarbia, *8* — Popowo Kościelne, *9, 10* — Gorzewo, *11* — Nowy Tomyśl, *12* — Pietrzyków, *13* — Ciemierów, *14, 15* — Ostrzeszów, *16, 17* — Rojów, *18, 19, 20* — Węglewice
Explanation of signs; Late Wurm: *1* — dunes, *2* — ice- wedges with eolian filling material, *3* — eolian cover sands, *4* — niveo-eolian sands; Holocene: *5* — peats interdigitating with dune sands, *6* — fossil soils in dunes; *7* — main dune fields, *8* — state boundary

predominant view then was that the age of dunes was either Ancylus [1, 12, 39], Ancylus and Litorina [10] or Litorina [22]. S. Krukowski [19] was the first to refer their age as Late Würm basing his view on the stratigraphical position of archeological findings in dunes. Afterwards, most authors followed this view [7, 8, 20, 27, 28, 34]. Only S. Majdanowski [24] stuck to the view that inland dunes came into being through the last glaciation and are not synchronic in Poland. Lack of more accurate investigations did not allow for the fixing of an exact number and age of dune-forming phases.

In the period of the past decade complex investigations of inland dunes and accompanying them eolian cover sands have been undertaken in numerous areas of West-Central Poland. The research aimed at determining the number and age of phases of eolian activity in the selected areas, and also at discovering causes for eolian phenomena in individual phases.

As for solving the questions just touched upon the key sites have been Węglewice, Czarnków Zanotecki, Gorzewo and Elżbiecin (Fig. 1). The first one of them occurs in the Riss glaciation area, the remaining are within the reach of the last glaciation. In all these sites, the geological structure of dunes and eolian sand covers have been thoroughly examined in order to determine the kind of their relation to the substratum and organogenic deposits filling up deflation basins in the neighbourhood of dunes. Special attention has been focused on contact zones of eolian series and organogenic deposits. It has been found that some organogenic layers are deposits corresponding to mineral series of eolian origin. Paleobotanical investigations in numerous profiles rendered it possible to reconstruct climatic conditiones in which the eolian phenomena were developed, as well as the age of phases of eolian activity.

The site in Węglewice deserves special attention since it depicts fully all eolian events in the area discussed (Fig. 2). The parabolic dune together with the peat-bog to the east lie on the sands and silts of the II Prosna terrace in Grabów Basin. The terrace deposits come from Early Würm and the older phase of Pleni Würm [31]. Within the dune three series of eolian sands have been stated. The common feature of their mutual relations is that any younger series partly covering the older one is shifted to the east. The bottom part, the oldest one, with the 2 - 4 m thickness, gradually passes in the direction of the peat-bog, into a layer of a very sandy silt with some admixture of organogenic substance. The layer is tripartite, for its middle part holds a bit more organogenic sub-

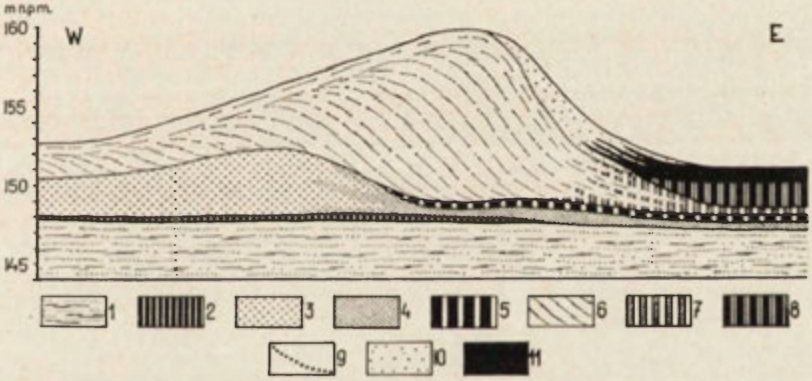

Fig. 2. Węglewice. Geological section through the dune

1 — silts and silty sands of the II Prosna terrace, *2* — humus sands and organogenic silts of unknown age; Oldest Dryas, Bolling and Older Drays: *3* — bottom series of dune sands, *4* — eolian silty sands with organogenic detritus; *5* — Allerod gyttja; Younger Dryas and Early Pre-Boreal: *6* — middle series of dune sands, *7* — eolian sands with organogenic detritus; Pre-Boreal and Boreal: *8* — peat, *9* — fossil soil; Atlantic, Sub-Boreal, Sub-Atlantic: *10* — top series of dune sands, *11* — peat stance than the bottom and top ones. The paleobotanical analysis shows that the layer was formed in Oldest Dryas, Bölling and Older Dryas [38]. It is covered by a gyttja dating from Alleröd and containing very little eolian sand. The gyttja in its turn, is covered by an eastward-shifted middle eolian series with the thickness up to 9 m. That is the basic series building the dune. It is almost entirely of the structure of an east-migrating dune. At the steep eastward slope, the series passes into piled-up layers of sandy silt and sand with some admixture of organogenic substances and sandy peat. The layers are of Younger Drays in age and the initial phase of Pre-Boreal. The layer of Pre-Boreal and Boreal peats that rests on them also covers eolian deposits at the bottom of the eastward slope and does not interdigitate with them. The third, top eolian series 0·5 - 2·0 m thick is on the eastward slope of the dune head and also on the northward slope of the arms. It is separated from the middle series by a fossil soil layer. In the contact zone of the dune and the peat-bog the top series interdigitates with peats of different age, Atlantic, Sub-Boreal and Sub-Atlantic. The above facts give enough evidence for distinguishing two main Late Würm phases of eolian activity in the South of discussed area. The one that appeared before Alleröd and the other that came after this period.

The third and the youngest series is a proof for the far less intensive Holocene phase of eolian activity that started in the Atlantic period. The phase will be fully discussed later on.

The two main phases have left their marks in the neighbourhood of dunes, as two series of eolian cover sands separated by an Alleröd gyttja.

There have been found traces of Late Würm main phases of eolian activity in the north of discussed area, too. The evidence for the earlier, Pre-Alleröd phase is a series of eolian cover sands resting on slopes and on the bottom of a subglacial channel near Gorzewo [25] (Fig. 3). In the channel the sands contain some organic substance admixture. Pollen analysis points that the top layer of these sands comes from Older Dryas [25, 38]. It is covered by an Alleröd gyttja. It is possible that the thin (15 cm) series of eolian sands resting on the Alleröd gyttja and under Early Holocene peats comes from Younger Dryas and is a remnant from the younger phase of Late Würm eolian processes. But still, the phase is quite conspicuous in the form of Czarnków Zanotecki dune field [14, 15] and also in the eolian sand admixture in organogenic deposits from Younger Drays in the peat-bog close to the dunes of Elżbiecin [37]. In Czarnków Zanotecki (Fig. 4) the dune field arose in Younger Dryas and Pre-Boreal. The upper limit of the field's age is accounted for by the peat bottom layer in deflation basins dating back, according to pollen analysis [29], to the beginning of Boreal period. The lack of traces from

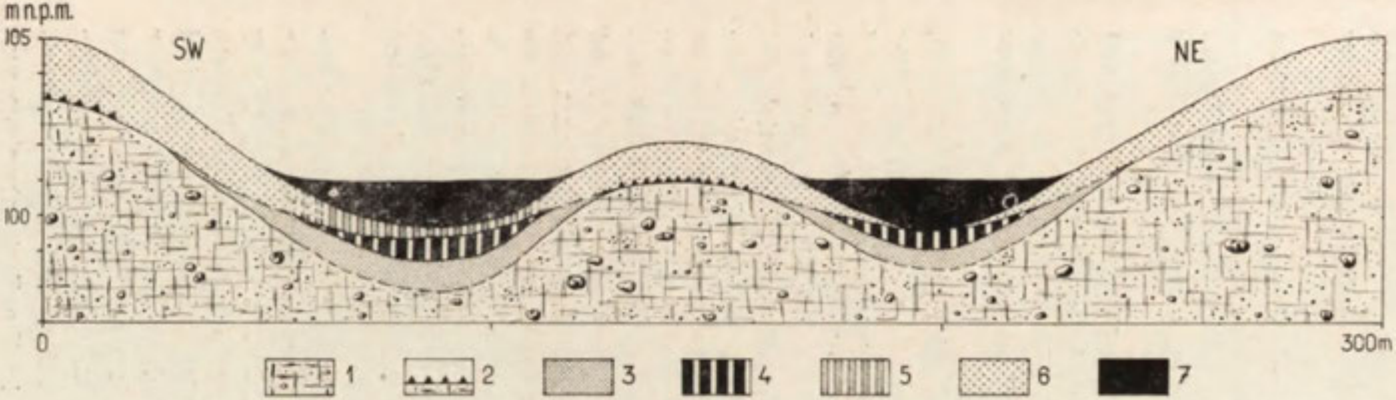

Fig. 3. Gorzewo. Geological section of the Late Würm deposits within the channel-valley
1 — boulder clay, 2 — eologlyptolithes, 3 — Older Dryas eolian sands, 4 — Alleröd gyttja; Younger Dryas: 5 — sandy silt, 6 — eolian cover sand; 7 — Holocene peat

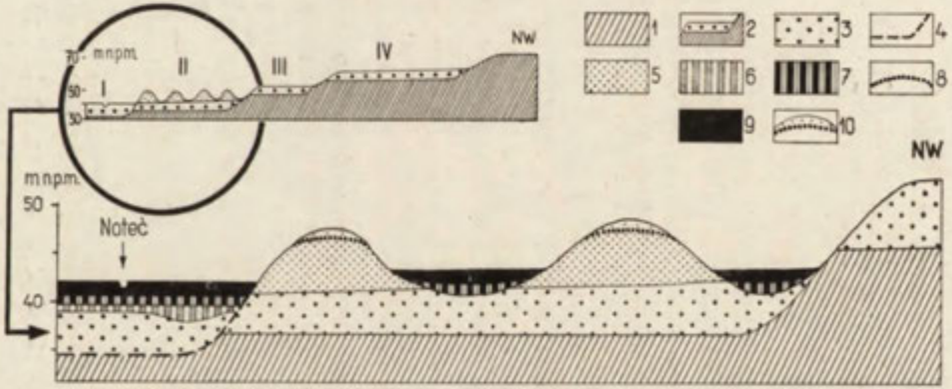

Fig. 4. Czarnków Zanotecki. Geological section through the dune field in the Noteć—Warta ice marginal streamway (*pradolina*)
1 — substratum (Miocene quartz sand interbedded by brown-coal, Pleistocene boulder clay and sands), 2 — terrace covers: IV — Pomeranian stage, III — Oldest Dryas, II — Older Dryas, I — Younger Dryas; 3 — fluvial gravel, sand and silt, 4 — Alleröd erosional incision; Younger Dryas and Pre-Boreal: 5 — dune sands, 6 — gyttja and peat; 7 — Boreal peat, 8 — Atlantic/Sub-Boreal fossil soil, 9 — Atlantic, Sub-Boreal and Sub-Atlantic peat, 10 — Post-Atlantic dune sands

the older phase of eolian activity is due to the fact that the dune field is situated in the Notec-Warta ice marginal streamway on its second terrace, shaped in Late Würm, most probably not sooner than in Older Dryas [15, 16].

The facts presented permit us to state that there were two main phases of eolian activity in West-Central Poland (Fig. 5).

1. The older phase covered: Oldest Dryas, Bölling and Older Dryas. At that time the bottom series of dune-building sands, and the lower series of eolian cover sands were formed.

2. The younger one occurring during the whole Younger Dryas and the beginning of Pre-Boreal. In the investigated dune fields this phase came to its close during different parts of Early Pre-Boreal. As to the age at that time the middle series of dune-building sands and the upper series of eolian cover sands were formed.

The phases were strictly conditioned upon climate, protecting them, what is evidenced with paleobotanical investigations. Fossil plant remnants, examined by means of pollen analysis, are very helpful at giving the chronology of eolian events and besides, thanks to them, we can view the eolian activity in the light of real facts, climatic, floristic and of ecological nature. The older phase which lasted over two stadials did not, as can be judged from the hitherto known materials, die out in Bölling interstade either. The deposits from Weglewice may serve as an evidence here. The material reveals that after Bölling there was an more intensive dunesand accumulation in Older Dryas. This kind of differentiation between eolian processes, even within the older phase, is yet another point in favour of a close connection between eolian events and the nature of climate. The connection will be fully understood when we realize the existing interdependence of climate and vegetation cover. In reference to the dune-building processes this interdepedence is a multifarious one, and so, in some cases vegetation is a helping factor, but also, in some extreme cases, a dense forest cover on a dune even fixes the latter.

The first trees (mainly birches) appeared in the south of Greater Poland during Bölling. Ligneous birches, with some number of pines, formed loose, light-pierced forests in the shape of parks. Their density was not too great, which can be judged from the scale in the pollen diagram of herbaceous plants pollen values, among which there are some typical heliophytes. It is difficult to judge, on the basis of the materials at our disposal, the scope of eolian processes that took place in Bölling. Perhaps they were local phenomena not having much influence on the dune formation. Yet, if we compare these deposits with the Older Dryas material, it must be said that the presence of forests in the first interstage was

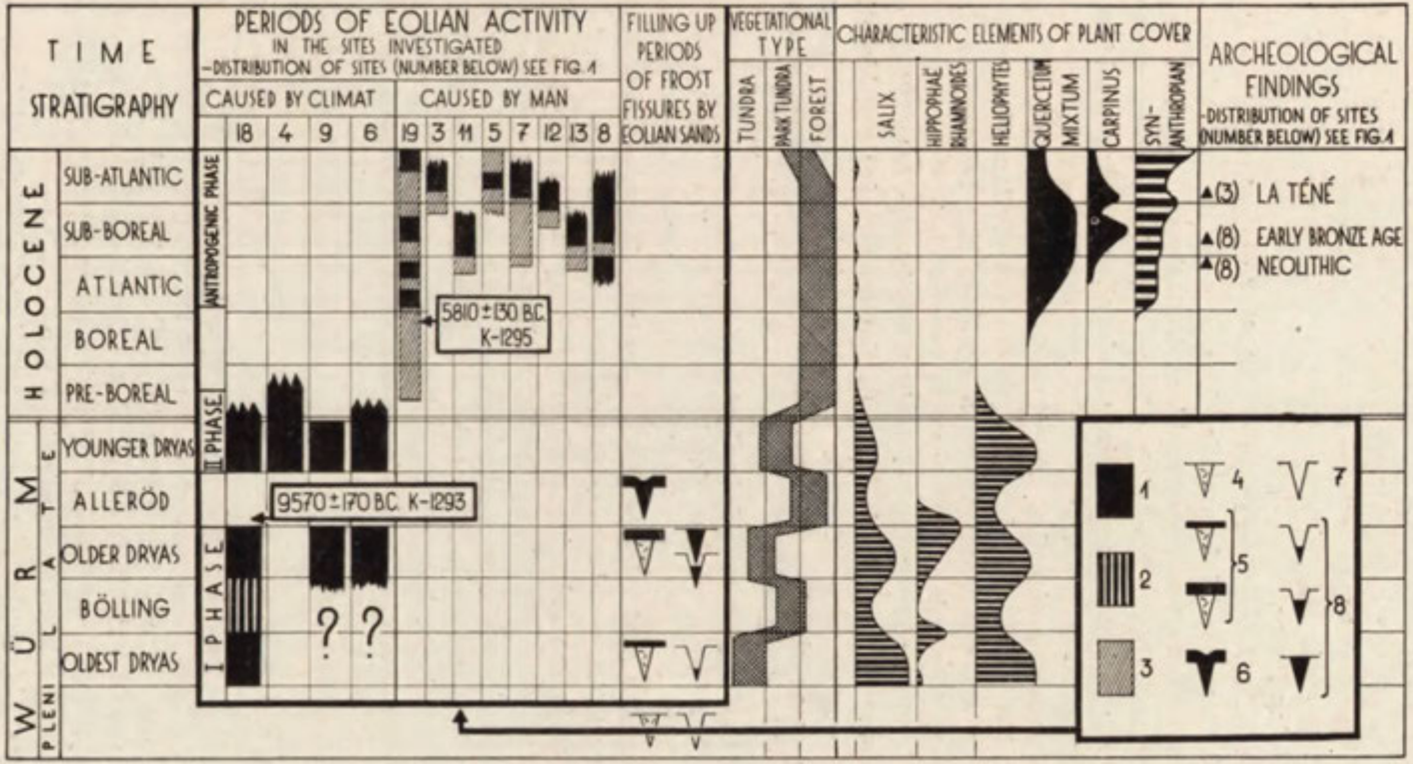

Fig. 5. Correlation table of eolian events and influencing them factors

Explanation of signs: 1 — periods of eolian activity, 2 — period of slight eolian activity, 3 — Holocene peats and fossil soils, 4 — period of ice-wedge polygons origin, 5 — periods of niveo-eolian sand accumulation on the ice-wedge polygons, 6 — period of ice-wedge polygons fossilization due to melting of ground ice and filling up by niveo-eolian sands, 7 — period of sand-wedge polygon origin, 8 — periods of sand-wedge polygon fossilization due to filling up by eolian sands still a check to dune evolution. In Older Dryas, as the consequence of the climate change, the light-pierced forests are reduced to single tufts of trees. At the same time, herbaceous plants and various shrub forms were gaining ground and this fact could be, in the changed climate, a dune co-building factor.

Within the Late Würm there was a period of undoubtful dune stabilization — it was Alleröd interstade. The process of maintaining the hitherto moving sands was very rapid at that time. The evidence for that lies in organogenic dune-dividing layers free from eolian material, numerous macroscopic remains of pines and pollen spectra speaking for the presence of forest communities.

The younger phase of eolian activity appeared in the climate unfavourable for the existence of forest vegetation. Pollen diagrams for Younger Dryas are characterized by a considerable decrease of trees giving open way to shrub and herbaceous vegetation that was spreading at that time. Younger Dryas, as set against the former Late Würm cold periods had some remarkable features in the area under consideration. First of all, there was a considerable expansion of steppe vegetation, and second, there came about, particularly in dune areas, the phenomenon of the water-table rise in the lowerings close to dunes. Similar facts were stated also by K. Wasylikowa [40] in Central Poland.

The dune-forming processes clearly marked in Younger Dryas deposits are perhaps a stronger indication of the existing connection with the dominating type of climate. This interdependence runs along the climate — vegetation — dune evolution line. The cooler climate in Younger Dryas (mean July temperature 12°C against at least 16°C in Alleröd [40]) led to pushing the polar forest line southward. In our area there were at that period loose, light-pierced tree communities of birch and pine for the most part. The rapid shrinking of forest areas led to renewed eolian activity. Moving sands became now ground for the expansion of psammophilous vegetation, that must have played a major part in building dune forms. As soon as climatic conditions became favourable at the beginning of Holocene, the new expansion of forest communities followed. Eolian sands, as a rule, were soon covered by either trees or sod vegetation. Traces of sands in the Pre-Boreal organogenic deposits prove the continuous Younger Dryas eolian activity. These processes have been said to occur also in the early phase of Pre-Boreal. They were local in their extent and limited to only a few, more favourable areas, less liable to vegetation expansion. In all dune areas in our territory, dunes were stabilized in Pre-Boreal by vegetation. This stabilization lasted as late as the Atlantic Period.

In both Late Würm phases of eolian activity the origin of dunes and accumulation of eolian cover sands went on under the influence of western winds. It has been proved by following facts:

1. The structure and slope assymmetry of dunes; the leeward slope in all the dunes examined, is their eastward slope.
2. Dunes are situated east of deflation basins.
3. The transgression of dunes on peat-bogs from west (Fig. 3).

In regard to the number and age of main phases of eolian activity the results presented here are in accordance with the facts from Central Poland [2, 4, 40]. That points, on the one hand, to the synchronic character of the main phases of eolian activity within a larger area and, on the other hand, reveals that the phases were climatic conditioned. The characteristic of vegetation cover — as obtained by means of pollen analysis — and through that the reconstruction of climatic conditiones in each phase of Late Würm — allowed for selecting the essential features of a morphoclimatic environment most favourable for an intensive eolian activity.

LATE-WÜRM NIVEO-EOLIAN SANDS AND THE ROLE OF EOLIAN SANDS IN THE FOSSILIZATION OF ICE-WEDGES

Besides the formation of dunes and eolian cover sands that accompany the dunes, the Late Würm eolian processes are responsible for the origin of niveo-eolian sand covers. This kind of covers has been found [31] in denudational valleys moulded in push end moraines of the Warta stage (Ostrzeszów Hills). Thorough research [31] has proved the sands could appear in two morphological situations. In the axial parts of denudational valleys where their thickness is at least 1·7 - 2·0 m, and also on gentle, waning slopes bearing characteristic of the pediment and representing the zone of transport between the steep slope and axial part of the above mentioned valleys. Here the thickness of sands is less and varies from 0·5 - to 1·5 m.

Despite the differences as to their morphological situation, the sands concerned always constitute a continuous cover extending from the waning slope to the axial part of the valley. Their common property is distinct stratification parallel to the slope inclination, but which gradually enters a regularity (rhythmically stratified slope deposits), because of the occurrence of silt layers, 5 - 10 cm one from another, and 2 - 15 mm thick. The horizontal extent of each layer is considerable, and the building material is of very good sorting, if 60 - 80% of the material are 0·1 - 0·5 mm grains. Granulometric investigations have demonstrated that apart from their excellent sorting, the sands are particular for the high percentage of round grain. Analyses of 1·0 - 1·25 mm quartz grain abrasion show that 30 - 40% of the grain are round. As to their mechanical composition the sands under discussion are identical with the dune sands in the Ostrzeszów Hills and the Odolanów Basin, and as to the roundness the similarity is very great, because the dune sands contain but 10% more round grain. The fine lamination that is so characteristic for them, their grain-size, and. above all, the shape of quartz grain permit us to put them among [31] the class of phenomena termed as Late Glacial niveo-eolian or niveo-fluvial sands [3, 5, 6, 9, 23, 32] recognized also in denudational valleys in Central Poland [11].

The same conclusion may be drawn from their stratigraphical position. As regards the axial part of denudational valleys they form the top series of deposits. Only in the superficial part, down to 0·5 m in depth, they are covered by structureless sands with single pebbles. The situation is different in the case of waning slopes of pediment character. There, geological cross-sections show the sands as appearing in two positions [31] which let us to try to settle the age of sands. The problem will be dealt with in two exemplary cross-sections: the first

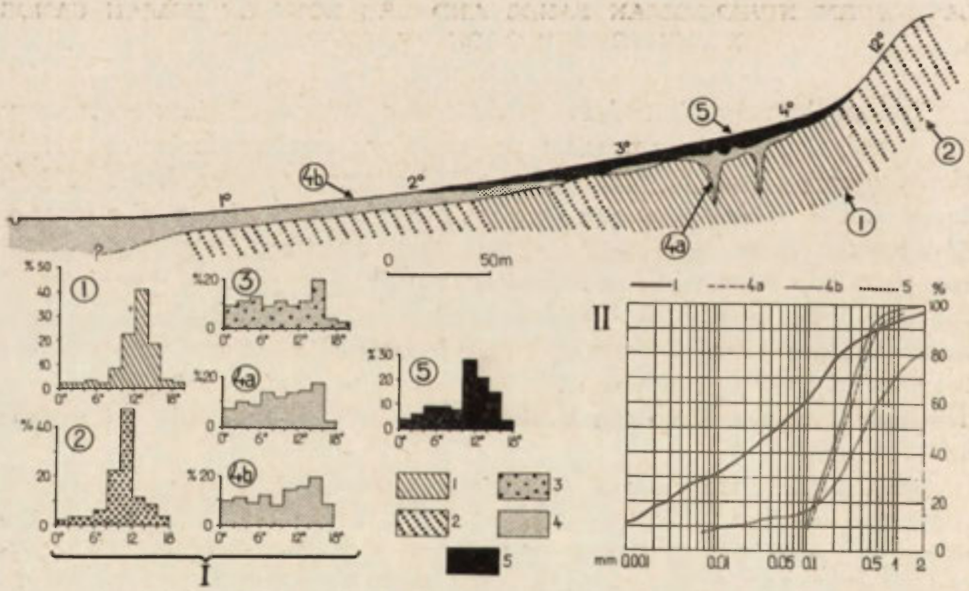

Fig. 6. Rojów. Niveo-eolian sands on degradation surface of waning slope in Olszyna valley

1 — outcrops of glacitectonically pushed boulder clay, 2 — outcrops of glacitectonically pushed Quaternary sands and gravels; 3 — eolian sands taken from dune situated 1 km west of profile; 4 — delicately laminated niveo-eolian sands, 4a — niveo-eolian sands filling ice-wedges, 5 — sand-gravel congelifluction series; I — roundness histograms of quartz grains (1 - 1.25 mm), analyses made by the method and apparatus of B. Krygowski (1964), II — grain-size distribution

one is from Rojów (Fig. 6) and the other from Ostrzeszów. In the first site the niveo-eolian sands crown the substratum denudation surface represented by glacitectonically disturbed boulder clays, sands and gravels and Pliocene clays. The sands also fill up ice- wedges developed in the boulder clay. The niveo-eolian sand cover is overspread, especially in the middle and upper part of the slope, by the congelifluxion deposit composed of sands and gravels. In the other site, the Ostrzeszów Valley, the niveo-eolian sands may be observed at the lower part of the waning slope only, directly over the substratum denudation surface represented by Pleistocene sands and gravels. In the middle and upper parts, the niveo-eolian sand cover rests on a series of down-wash silts and semi--autochtonic congelifluxion series with disturbances resulting from the cryostatic pressure in the active layer. The ice-wedges stated in the middle part of the slope are also filled up by niveo-eolian sands which in turn are covered by a congelifluxion cover consisting of gravels and sands. Regardless of differences both cross-sections share some characteristics that may be basic for later conclusions, it is the existence of ice-wedges under the niveo-eolian sand cover, and the fact that the sands fill up the ice-wedges and that congelifluxion deposits spread over the niveo-eolian sands.

The study of the Ostrzeszów Hills geomorphic development [31] shows that waning slopes of pediment character came into being during Pleni-Würm, after the Paudorf interstage, and, for this reason, all deposited covers on them must be related to the Late Würm. Since the process of intensive melting of ground ice took place in Alleröd, it follows that niveo-eolian sand covers, which fill up ice-wedges were formed before Alleröd. This view-point has a strong support in the fact that the youngest congelifluxion series appears on niveo-eolian sands, and it must be connected with the last, Late Würm cold stage. It may be held then that, most probably, the niveo-eolian sands from the area in question come from the Older Dryas or maybe even from the Oldest Dryas. At characterizing the geological sections from Rojów (Fig. 6) and Ostrzeszów respectively, special attention has been given to the phenomenon of filling up ice-wedges by eolian sands. These sections render it possible to reconstruct the sequence of events in relation to the fossilization of ice-wedges, too. Frost fissure polygons originated in Late Würm, but still they are older than niveo-eolian sands. The sands were deposited on polygons with fissure ice. Niveo-eolian sands replaced the ground ice after its melting. The sequence of events as presented here was not the only one found in West-Central Poland. In fact, there were at least two ways of ice-wedges fossilization.

The sequence must have been different in the case of frost fissure polygons not topped by eolian sand covers. Let us take the Czarnów site for an example (Fig. 7). Here, the frost fissure polygon occur in the Poznań phase boulder clay of the last glaciation. So, it could come to existence during the Pomeranian phase at the soonest. The fissures reach up to the surface. There are no cover deposits over them. Nevertheless, among the sands that are the only filling material in fissures there are 17·5 - 19% of round quartz grain. These grains, according to the abrasion index determined after B. Krygowski's method [21], as well as the distribution of whole samples in the histogram of the analyzed sands, prove that the filling material in fissures is in a great part of eolian origin. Since, as it has been said above, there are no cover deposits over the fissures, it should be inferred the eolian material got into the fissures during its transport and not after its deposition. The given facts lead to the following conclusions:

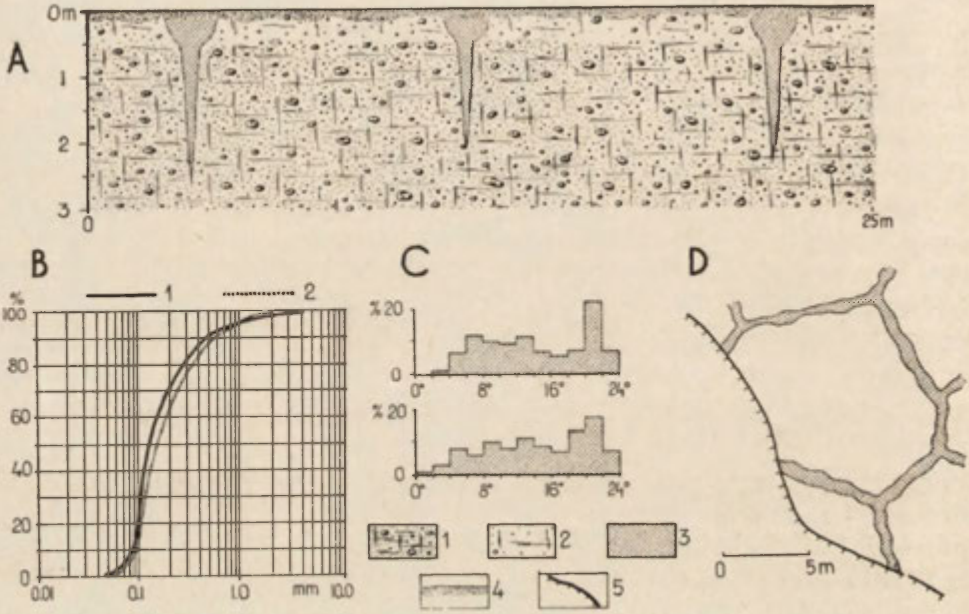

Fig. 7. Czarnów. Sand-wedge polygon

A — vertical section, B — grain-size distribution of the filling sands: 1 - 1 m depth, 2 - 2 m depth; C — roundness histograms of the filling sands; D — ground plan of the sand-wedge polygon; 1 — boulder clay, 2 — sand boulder clay, 3 — filling eolian sands, 4 — soil, 5 — scarp of the clay-pit

1. The frost fissure polygon belongs, most likely, to the structures called sand-wedge polygons,

2. Late Würm eolian processes marked their presence here not by forming covers but by direct sand transport into the fissures under the process of fossilization.

HOLOCENE EOLIAN ACTIVITY

It has been shown above that the main phases of eolian processes coincide with the Late Würm cold periods. Yet, there are reasons for averring that eolian processed caused by favourable climatic conditions did not die out rapidly at the end of Würm, but that they slightly overpassed that period and were still active at the beginning of Pre-Boreal. The presence of eolian sands in bottom layers of Pre-Boreal peat in the neighbourhood of dunes supports this contention [37, 38] which has also been pointed out in the first part of this paper. Another strong support is provided by the fact of the formation of peats in deflation basins from Boreal period on [14, 15, 29]. All symptoms of later eolian activity, as noted in West-Central Poland, from the Atlantic period till now, point that there were, for the most part, transformations of the Late Würm dunes rather than arising of new, small dune forms. Until recently [8, 15, 17, 35] the Sub-Boreal period was regarded as an important, climate-conditioned period of eolian activity. New facts indicate, however that it was only one of a number of periods with eolian activity that was not influenced by the climatic conditions.

Our views on eolian processes in Holocene are based on observations of fossil soils that appear in dunes and on the mutual relation between dunes and peats. The geological and morphological properties of dunes have been taken into acount, too. As a rule, the fossil soil horizons from one to three in number appear in constant geological and geomorphological positions. Usually, they are in the top of the eolian sand middle series with the thickness from a few to a dozen or so meters. Fossil soils are topped by the upper series of sands whose thickness is 1 - 3 m at an average. In the places where fossil soils have vanished from, single layers of dune sands are separated one from another by the discordance plane. In all the sites analyzed fossil soils have been found in head parts (distal slope) of parabolic and bow-shaped dunes with their arms pointing westward, or on distal slopes of south arms [14, 15, 17, 18, 35]. There is also a regularity in the relation of the upper series of dune sands to Holocene peats, that is to say, the head parts of parabolic dunes and bow-shaped dunes (distal slope) interdigitate with the peats east of a dune [33, 38], while longitudinal dunes transgrade on the peats from north [25]. The just mentioned facts lead us to the conclusion that, in the period of Holocene transformations of dunes, like in Late Würm and nowadays, the winds were predominatly western with a northern component.

One of the distinguishing marks in fossil soils and peats separating the upper series of dune sands is the presence of charcoal. In fossil soils it occurs in the whole profile, while in peats at their top only. There are some other significant facts worth mentioning. Very important for later conclusions is, sometimes together with fossil soils and sometimes in their vicinity, the presence of archeological findings. In some cases [14, 15, 17, 38] they are of the Early Bronze Age, and in one from the la Tene period. Similar findings were encountered [18, 25, 26] in Holocene peats interdigitating with the dune where one could trace a Neolithic hatchet and pieces of vessels from the Early Bronze Age.

The age of fossil soils and peats has been determined with the help of pollen analysis which certifies that they are from various periods of Holocene with the Atlantic period as the starting point (Fig. 8). The common property of all the materials examined so far is a striking regularity in the palynological image. The regularity reveals in the gradual growth from the bottom topwards — besides the general sum of NAP, mainly *Gramineae* — of sporomorphs giving the evidence for the presence of man. Among them are the pollen grains of *Rumex acetosella, Plantago lanceolata* t.m.m., *Centaurea cyanus, Artemisia, Chenopodiaceae* and *Cerealia*. It should be emphasized that this growth is traceable in the examined profiles regardless of the age of the material being analyzed.

When putting together the before mentioned presence of charcoal in fossil soils and peats with archeological findings the pollen analysis will reveal obvious and gradual stepping-up of man's activity that led to a limited in space dune migration. In the light of existing views [13, 36] it seems that the decisive factor here was the type of farming, e.g. hoe-cultivation, with which the cyclic burning of some forest areas was connected. The land taken for cultivation was not on dunes themselves but in their close neighbourhood, which fact depended on ecological conditions. Yet, by forest burning close to dunes there must been cases of fire in the forests that occupied the dunes.

Besides the previously mentioned topward growth of sinanthropic forms there may be traced, in a few cases, some phases of afterfire forest regeneration and local eolian activity. It has also been stressed [38] that there had existed a certain connection between phases of vegetation cover regeneration and man's settlement (in the interpretation of M. Ralska-Jasiewiczowa [30]). One of the investigated sites pictures this connection exceptionally well [18, 26]. A small dune, interdigitating in its front with a peat-bog, has near its surface a humus layer whose profile presents a streak of dark-grey sand with a thin layer of very sandy

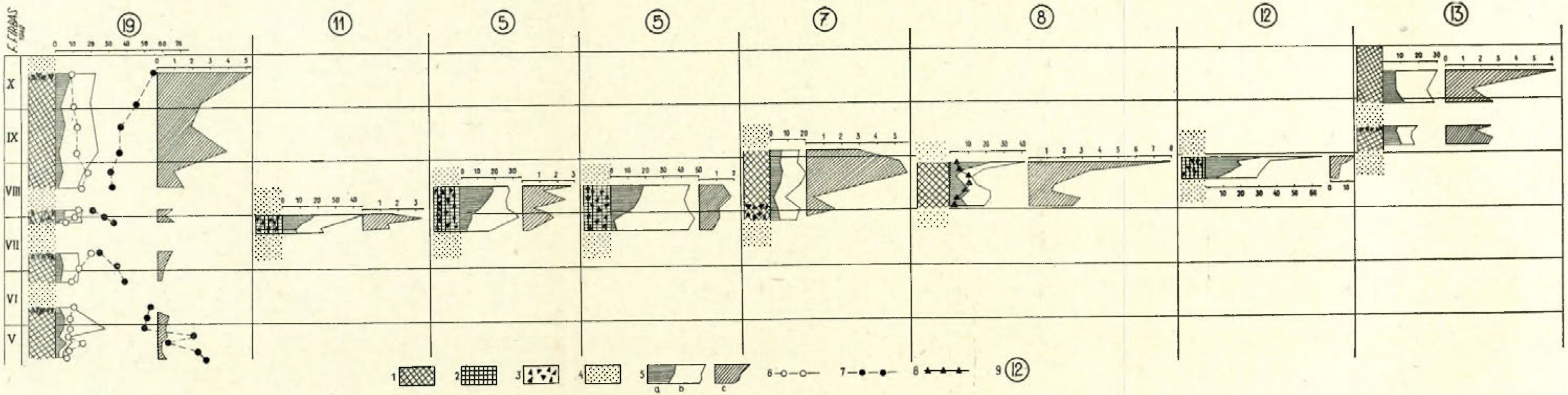

Fig. 8. Stratigraphical position of the palyonologically analyzed Holocene peats and fossil soils and simplified pollen diagrams

1 — peat, 2 — fossil soil, 3 — charcoal, 4 — dune sand, 5 — percentage of herbaceous plants pollen grain, a — *Gramineae*, b — sum of NAP, c — indicators of synanthropian plants, 6 — *Betula*, 7 — *Pinus*, 8 — *Carpinus*, 9 — number of site (distribution of sites see Fig. 1)

peat in between [26]. In the humus layer, under the peat layer, a hatchet has been discovered and whose age has been set as Neolithic. Above the humus layer pieces of Early Bronze Age vessels were found. Palynological investigations proved that there had been, in the site discussed, two sum culminations of sinanthropic plant sporomorphs. The culminations coincided with the decrease of *Carpinus*. In the middle part we can see a clear-cut culmination of *Carpinus* pollen grain. The decrease of *Carpinus* in the upper part came together with a considerable growth of forms signalling man's presence and corresponds with the charcoal containing layer. In the site viewed we can then find a symptomatic relation between man's presence and his activity. His presence finds its expression in the growth of the sporomorphs of the plants accompanying man, and also in archeological findings; his destructive activity, on the other hand, reveals itself in *Carpinus* communities ruin and the appearance of charcoal. After a succesive forest regeneration, most probably that of the mesophilous type, there were again traces of man's destructive activity which in their final effect led to a renewal of eolian processes. The proof for that is provided by the eolian sand layer covering the humus one.

The facts, as presented here, make it possible to wind up that eolian activity in Holocene was not cyclic nature nor climate-conditioned one, but continous, though limited in space to those areas where man interferred in their vegetation cover [18, 38]. Thus, eolian activity led to minor transformations of Late Würm dunes, and only sporadically to formation of new, small dune forms. The breaks in the parabolic and bow-shaped dunes continuity or deformations of their northern arms are its morphological reflection. From the geological structure results that the head parts of dunes were shifted towards east due to the accumulation of a new eolian sand series 1 - 3 m thick, which influenced also the height of dunes.

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GEOGRAPHIA POLONICA 17, 1969

LE LAC DE BARRAGE GLACIAIRE DE GDAŃSK D'APRÈS DES RECHERCHES RÉCENTES

Ludmiła Roszko

L'article présent est un communiqué réunissant les données obtenues par l'auteur au cours des recherches effectuées dans la région de Pasłęk. Ces recherches faites dans le terrain font voir sous un jour nouveau le problème du lac de barrage glaciaire de Gdańsk — problème d'un grand intérêt scientifique, tant pour la reconstruction de l'évolution de la vallée de la Basse-Vistule que pour la connaissance des phases préliminaires du développement de la Mer Baltique. Nous fournissant de nouvelles informations, les recherches concernant ce sujet peuvent aussi enrichir nos connaissances sur l'origine et le développement des lacs de barrage glaciaires. Un ouvrage plus vaste, ayant pour sujet le lac de barrage glaciaire de Gdańsk, est préparé actuellement par l'auteur.

Les lacs de barrage glaciaires constituent les éléments les moins durables parmi les phénomènes morphologiques accompagnant le recul de l'inlandsis. Formés dans des conditions topographiques determinées, devant le bord de l'inlandsis, ils disparaissaient par suite de sa récession.

Pendant la dernière glaciation, sur les terrains de la Pologne, apparaissait un certain nombre de lacs de barrage glaciaires qui laissaient comme vestiges des plaines, formées d'argiles, de vases et parfois localement de sables fins. Leur présence dans la partie intérieure des arcs des moraines frontales du stade de Poméranie, là, où le terrain inclinait vers le N, rendait possible l'accumulation des eaux de fonte entre le haut rempart des moraines poméraniennes, élevé jusqu'à 300 m d'altitude et le bord de l'inlandsis reculant vers l'abaissemant baltique.

En dehors des moraines stadiales poméraniennes, à partir du stade de Leszno jusqu'au stade de Poméranie, les eaux de fonte pouvaient s'écouler librement, suivant l'inclination du terrain, en formant de vastes plaines fluvio-glaciaires. Les vallées proglaciaires (pradoliny) de Barycz, de Varsovie—Berlin, de Warta—Noteć interceptaient ces eaux, les dirigeant par suite vers l'ouest et la Mer du Nord. La facilité de l'écoulement vers le S et le W, conformément à l'inclination de la plaine germano-

-polonaise, rendait tout-à-fait impossible la formation des lacs de barrage glaciaires dans ces terrains; elle contribuait par contre au développement du système des plaines fluvio-glaciaires et des vallées proglaciaires. Les lacs de barrage glaciaires n'apparaissaient qu'autour de l'abaissement baltique et encore il en faut relever la régionalisation différente. A l'ouest et vers le nord de la Pomeranie prévalait d'une manière décisive le nombre des vallées proglaciaires (pradoliny), formant un réseau d'un dessin bien compliqué d'ailleurs. Elles reconduisaient les eaux proglaciaires et extraglaciaires vers le W et le NW, ce qui fit que les lacs de barrage glaciaires ne pouvaient y apparaître que sporadiquement. Par contre plus loin vers l'Est, en commençant par la région de la Basse-Vistule et au nord du Pays Lacustre de la Mazourie, apparaissaient exclusivement les lacs de barrage glaciaires.

La ligne de démarcation entre ces étendues à morphogénèse différente se deplaçait graduellement vers l'est, en mesure que les terrains libérés de la callotte de glace prenaient contact avec la mer Baltique naissante.

Il faut relever le fait intéressant qu'à la localisation des lacs de barrage glaciaires corresponde un abaissement tectonique du substratum cristallin (syneclise peribaltique), ce qui nous autorise à supposer l'influence de ce dernier sur leur apparition. Des conditions géologiques et tectoniques s'accentuent de plus en plus en mesure qu'on avance vers le N des pays situés sur la mer Baltique, où la couche des roches sedimentaires, se tassant sur le substratum cristallin, devient de plus en plus mince. L'influence du substratum cristallin sur la localisation des lacs de barrage glaciaires a été constatée par plusieurs géographes, s'occupant de pays situés sur la mer Baltique. Les élevations du substratum cristallin qui existent aux alentours de Łeba avaient eu un rôle différent, servant pendant une certaine période de temps comme ligne de partage des eaux des lacs de barrage de Szczecin et de Gdansk. Après la récession progressive du bord de l'inlandsis, les eaux du lac de barrage glaciaire de Gdańsk commencèrent à s'écouler vers l'Ouest.

L'article présent prend en vue exclusivement les terrains situés à l'est de la Basse-Vistule.

Les dépôts des lacs de barrage glaciaires ont été pour la première fois reconnus en 1876 dans la plaine de la Pregola par A. Jentzsch [3] qui les décrivit, leur donnant le terme de „Deckton". Des sédiments analogiques ont été constatés plus tard dans la plaine de Sępopol, de Braniewo (de Młynary) et aux environs de la Basse-Vistule.

Les géographes qui succédaient à Jentzsch acceptaient son point de vue. Ainsi donc P. Sonntag [6, 7] appuyait ses considérations concernant le développement de la vallée de la Basse-Vistule sur l'opinion de son prédécesseur. Ce ne fut que C. Gagel [1, 2] qui ébranlait la conception de A. Jentzsch en expliquant d'une autre manière la genèse du „Deckton". Il le considérait comme une moraine de fond. Elle serait composée de sédiments de Perm, transportés des terrains de la Lithuanie, qui auraient donné une teinte rouge aux argiles du deckton. Dès ce moment il y eut controverse à ce sujet parmi les géologues, quoique la plupart inclinait à accepter l'opinion de C. Gagel, sans toutefois y acquiescer sans restrictions. Ainsi donc le problème de la genèse de ces sédiments n'a pas été résolu.

La conception de A. Jentzsch et de P. Sonntag, concernant le lac de barrage glaciaire de Gdańsk, a été oubliée avec le temps et completement rejetée par certains géographes.

Le problème du lac de barrage de Gdańsk a été à nouveau relevé par Z. J. Kotański [4] et puis par l'auteur [5] au cours de ses recherches faites dans la région de Dzierzgoń et de Pasłęk (fig. 1). Une courte note de l'auteur apparaissait en 1961 signalisant la présence, aux environs de Dzierzgoń, des argiles rouges dont la genèse pouvait être attribuée a un lac de barrage glaciaire (fig. 4). Ces argiles se déposaient sur des terrasses (sortes de dégrés) d'un plateau morainique, adhérant à un abaissement tourbeux uni au delta de la Vistule. Des recherches posté-

Fig. 1. Esquisse morphologique des plaines du lac de barrage glaciaire de Gdansk et des terrains voisins

1 — des arrêts de l'inlandsis marqués par des moraines terminales et les plaines fluvio-glaciaires. La ligne coupée — un arrêt hypothétique. 2 — les plaines du lac de barrage glaciaire; 3 — la plaine de Braniewo; 4 — la delta de la Vistule

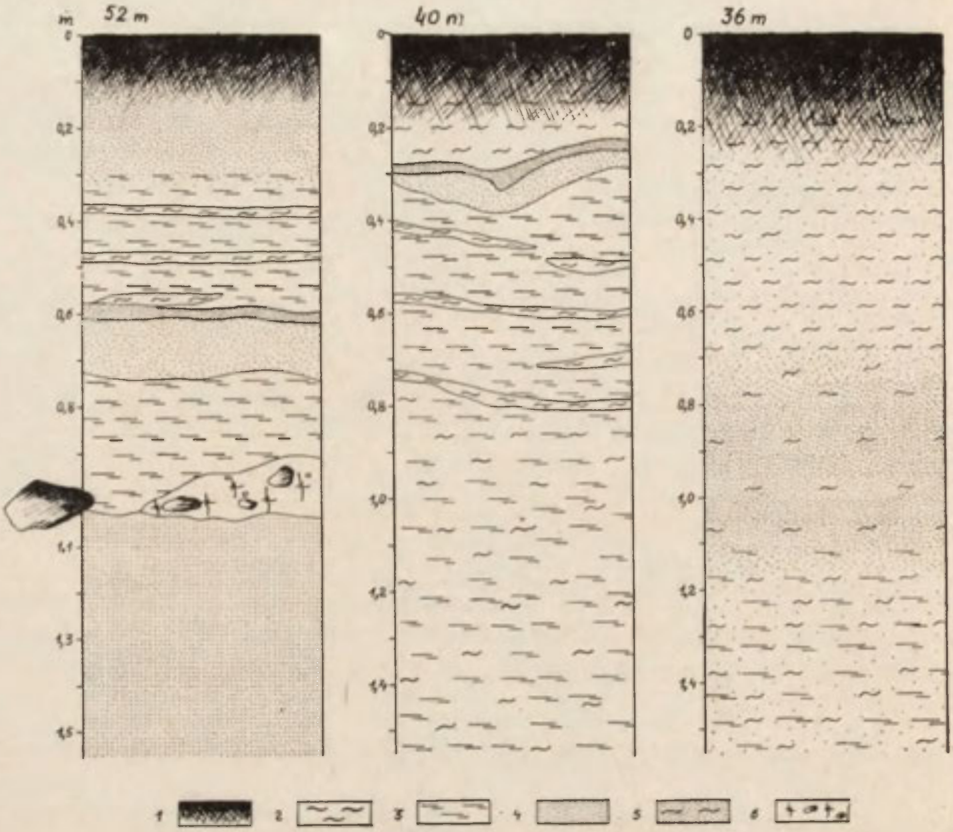

Fig. 2. La structure géologique des terrasses du lac glaciaire aux environs de Pasłęk et de Dzierzgoń

1 — le sol, 2 — les argiles, 3 — les vases, 4 — les sables, 5 — les sables argileux, 6 — l'argile à blocaux

rieures permirent de constater l'existence d'analogiques formations argileuses et vasseuses le long du plateau morainique, entourant du côté Sud le delta de la Vistule, sur l'espace qui s'étend de Malbork à Pasłęk, en passant par les environs de Dierzgoń. Ces dépôts occupent surtout de vastes terrains dans la région de Pasłęk, où ils échappaient à l'action érosive du Nogat, grâce à leur situation entre le plateau morainique de Elbląg et un autre plateau morainique se trouvant au Sud. Il est à noter que les cartes géologiques marquent tous ces terrains comme appartenant à la moraine de fond composée d'argile à blocaux. Il n'y a que les alentours de Malbork qui y sont indiqués comme sédimentations argileuses.

La structure géologique des terrains en question diffère de la structure classique des lacs de barrage glaciaires car il y manque des argiles

Fig. 3. La structure stratifiée des depôts du lac de barrage glaciaire. Sur la photographie on peut voir les couches plus sombres d'argile et les couches plus claires de vase

à varves typiques (fig. 2, 3). Néanmoins l'auteur considère les sédiments qui y apparaissent comme issus d'un lac de barrage glaciaire. On y rencontre le plus souvent des matériaux argileux et vaseux stratifiés (non à varves cependant — fig. 2). Parfois y apparaissent des argiles non stratifiés, d'un mètre d'épaisseur le plus souvent, ou des vases à structure analogique. On y trouve aussi localement des cailloux, dont on rencontre aussi (rarement) d'assez grandes agglomérations. Ils appartiennent presque exclusivement aux marnes crétacés sénoniens arrachés par l'inlandsis du fond du Golfe de Gdańsk. Ils sont un élément caractéristique pour l'argile à blocaux qui forme le plateau morainique et les moraines terminales au sud du delta de la Vistule. Ils parvenaient au fond du lac de barrage glaciaires par des voies différentes: apportés par la glace flottante, issus du bord de l'inlandsis fondant, ou des masses de glace morte, enfin transportés par le vent d'hiver.

Les argiles et les vases cités plus haut ne sont pas typiques pour les lacs de barrage glaciaires classiques, mais c'est à cause de cela précisément qu'ils peuvent devenir typiques pour les lacs de barrage glaciaires qu'ils représentent, notamment pour les lacs glaciaires peu profonds, de courte durée et entourés de terrains beaucoup plus élévés. Les eaux de ces derniers avaient pu apporter en s'écoulant une grande quantité de matériaux, surtout dans des conditions du climat périglacial, à procès de dénudation particulièrement intense.

Il est vrai que les structures stratifiées et à couches à peine ébauchées auraient pu représenter aussi des moraines d'ablation, mais cette interprétation nous paraît inadmissible. I° le caractère même des sédiments et leur localisation autour de l'abaissement du Golfe de Gdańsk s'y oppose. 2° le relief du terrain témoigne de l'existence d'un bassin d'eau. Ce relief ne s'éloigne pas en grandes lignes du relief reconnu par la littérature scientifique comme appartenant aux terrains des lacs de barrage glaciaires de la région baltique (8, 9, 10, 11, 12, 13, 14, 15, 16 et les autres). Ici comme là, les plaines des lacs de barrage glaciaires forment un certain nombre de degrés à dénivellation, atteignant 10 m qui font voir l'abaissement successif du niveau du bassin. On peut observer la série la plus complète de ces degrés, depuis le plus haut, de 80 m d'altitude, jusqu'au plus bas, de 15 m, aux alentours de Pasłęk. Près de Dierzgoń n'apparaissent que des degrés plus bas, de 40 m à 50 m d'altitude (fig. 4), près de Malbork ils ne dépassent pas 40 m. Il est probable que les degrés situés le plus bas ont été recouverts de sédiments du delta de la Vistule.

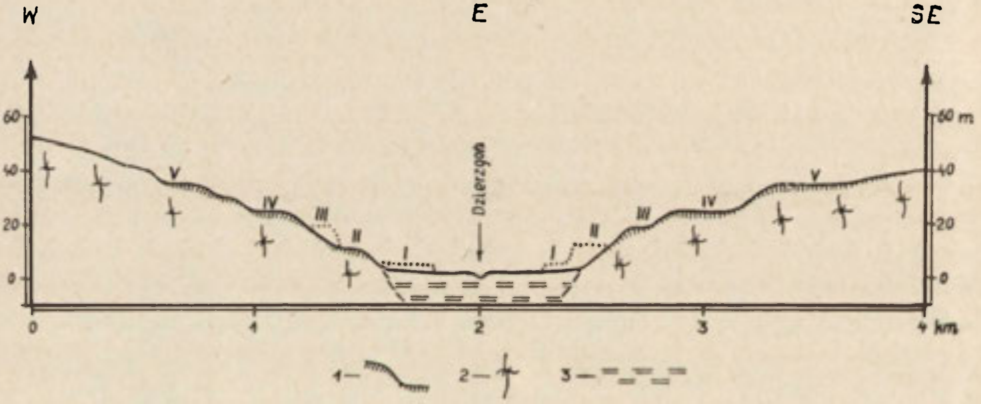

Fig. 4. Coupe à travers des terrasses du lac de barrage glaciaire dans le bassin de Dzierzgoń

1 — des argiles et des vases, 2 — l'argile à blocaux, 3 — la tourbe

La localisation mentionnée tantôt des terrasses du lac de barrage glaciaire autour du delta actuel de la Vistule démontre l'évolution successive de ce lac à mesure que se produisaient de nouveaux bassins. Le lac glaciaire de Pasłęk était le plus ancien, ensuite se formait le bassin de Dzierzgoń qui confluait avec celui de Pasłęk. Le lac glaciaire de Gdańsk se formait le dernier, communiquant avec les deux bassins déjà formés et constituant ainsi un seul lac glaciaire auquel nous reservons le nom traditionnel du lac de barrage glaciaire de Gdańsk.

Le relief des terrasses est bien varié. Parfois il est difficile d'y voir un niveau uniforme. Cette variété du relief est un phénomène secondaire dû à la fonte des blocs de glace morte, assez nombreux comme le fait voir une suite de creux de culot de glace morte. A la variété du relief contribuait aussi l'érosion en profondeur intense qui se développait en mesure de l'abaissement du niveau de base, en connexion avec les phases préliminaires de la mer Baltique.

La situation des terrains en question, le long du plateau morainique, parle en faveur de notre thèse. Ces terrains sont situés à l'extremité nord du plateau morainique, inclinant vers le Golfe de Gdańsk, donc dans des conditions qui contribuaient à la formation des lacs de barrage glaciaires.

Le lac de barrage glaciaire de Gdańsk n'a pas été un phénomène isolé. Des bassins analogiques s'étendaient à sa suite vers l'Est et le Nord-Est. Les uns se trouvaient sur les terrains actuels de la Pologne (la plaine de Braniewo et de Sępopol), les autres — en Lithuanie (les lacs glaciaires aux alentours de Pregola et de Niémen), ou bien dans d'autres pays de la côte baltique.

Le lac de barrage glaciaire de Gdańsk, ainsi que les autres, évoluant petit-à-petit autour de la calotte de l'inlandsis reculant, constitue une phase préliminaire du développement de la mer Baltique et une période de transition vers sa stabilisation.

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IV. PALAEOBOTANY

THE EARLY EEMIAN INTERGLACIAL IN CENTRAL POLAND

JERZY NIKLEWSKI

The Interglacial J III/IV (Eemian) belongs to the periods of the Quaternary in Poland which in respect of palaeobotanical investigations have been most carefully examined and fully elaborated. It is a stratigraphical key horizon, easily recognizable by the application of the method of pollen analysis because of the characteristic palynological picture of at least two optimal phytophases: *f* and *g* (in the nomenclature of K. Jessen and V. Milthers [12]). The phases mentioned and particularly the phase *f* with characteristic *Corylus* culmination are developed in a rather similar way on considerable territories from the British Isles to East Europe and they have therefore the guiding character in the sense close to that in which such notion is understood in the historical geology. New and new pollen diagrams of the Eemian Interglacial confirm the picture and at most they add to it new interesting floristical details.

Contrary to that phases preceding the optimal period are relatively less known. Many Eemian profiles of Central Poland, among them some profiles of an essential importance such as the profile from Sławno [20], begin only in the optimal period or just before it. Particularly, we have very little informations about the history of vegetation of the transition period from the Glaciation G III (Middle Polish Glaciation) to the Interglacial. Almost in all profiles from Central Poland comprising also the earlier phases of the Interglacial, the Eemian vegetation appears to us at once in the shape of more or less thick forests of the cool temperate climate.

One of the profiles of possibly full development is undoubtedly the classical profile from Bedlno near Końskie [18]. In the lowest sample of the profile the authors detected the presence of macroscopic remains of *Dryas octopetala, Salix herbacea* and *Betula nana* being the Late

Glacial tudra elements. On this basis the stage I of K. Jessen and V. Milthers with the dominance of arctic and subarctic vegetation (op. cit. p. 335) has been distinguished in Bedlno. The pollen spectrum of that sample, representing almost a halfmetre segment of the profile, however, does not represent a tundra character.

The pollen profiles of the Eemian Interglacial at Glowczyn in Mazovia, elaborated by the present author [13], do not contain also the pollen spectra of the Late Glacial character and begin only in the forest period of the early Interglacial. No spectrum represents the open tundra vegetation or the steppe-like tundra vegetation which should be reflected, among others, in high percentages of pollen of herbaceous plants like in the sediments, for instance, of the Oldest Dryas or the Older Dryas. In the bottom sample 57 from the bore hole G2 at Głowczyn the quantity of the NAP pollen (chiefly *Gramineae, Cyperaceae* and *Ericaceae*) reaches 16·5 per cent (about 20 per cent in the spectrum corrected accordingly to Iversen's method [11]). Later the quantity of the pollen of herbaceous plants rapidly drops to the values close to an average for the whole profile. If we omit the relatively considerable percentage of the pollen of thermophilous trees being most probably on a secondary bed here, then in the pollen spectra till the beginning of the optimal period *Pinus* and *Betula* are dominant. Three culminations of the pine pollen divided by two birch maxima are visible in this segment of the profile. The last Early Interglacial pine culmination has been already laid on the beginning of the rise of the oak curve (likewise in some other Eemian profiles). The profile G28a comprising in the principle only the early part of the Interglacial is represented by samples taken at smaller intervals. The third *Pinus* maximum is followed here by the rapid growth of *Quercus* curve characteristic for the beginning of the optimal part of the Interglacial. Below one may recognize two birch maxima between the three pine maximum at Glowczyn preceding the growth of *Quercus* curve and than 80 per cent of the pine pollen, about 6 per cent of the birch pollen and only about 8 per cent of the pollen of herbaceous plants. There is no ground for distinguishing the stage I accordingly to K. Jessen and V. Milthers. The lower part of the diagram G2 and the diagram G28a comprise the early part of the Interglacial belonging to the phases d-e, accordingly to K. Jessen and V. Milthers, when pines and birches were main forest components. The lowest segments of the profiles with the pollen of the pine, the birch and the aspen (the presence of which in the forests of that phase was emphasized by the mentioned authors of the classical subdivision of the Last Interglacial, op. cit. p. 336) should correspond to the phase *d*. The phase *e* in turn should comprise the segment preceding the rapid growth of the oak curve. The phase is distinguishable by the appearance of small quantities of the pollen of thermophilous trees and, among others, especially of the pollen of elm, the curve of which has here small but still legible culmination.

First of all, however, the mentioned above obvious culminations of *Pinus* and *Betula* curves folowing one another are striking the eye. It is possible to believe that they reflect the genuine changes of composition of forests surrounding the Interglacial lake, in which either pine or birch were becoming dominant. The reasons for such changes could be various, either of a local character or the more general ones, for instance, climatic oscillations. It seems however rather doubtful to believe that local transformations of a succesional type (for instance, destroying of the pine forest by a fire and its regeneration through the birch stadium with the aspen) could so much reflect themselves in the diagrams in which rather a long period is represented by relatively innumerable spectra. Probably some more general factors at least of a regional extent has been active here. Indeed, some of the pollen profiles of the Eemian Interglacial of Central Poland indicate the analogical oscillations of the quantity of the *Pinus* and *Betula* pollen in the early phases of the development of vegetation. The Główczyn diagrams could be compared best with the profile of the bore hole 4 from Warsaw [15] bored in the northern part of an Interglacial Żoliborz Lake. It is an Interglacial site laid most closely to Główczyn of all known sites of that age. Spectra 41 and 42 from the bore hole in Warsaw could correspond with the third pine maximum at Główczyn preceding the growth of *Quercus* curve and following the inconsiderable *Ulmus* culmination. The spectrum 47 of Warsaw corresponds relatively closely with the second birch culmination in Główczyn and the spectrum 52 with the second pine culmination. The lower horizons from the bore hole 4 in Warsaw contain an admixture of the pollen of thermophilous plants derived from the eroded boulder clay of the bottom of the Żoliborz Lake. Here, however, the pine and birch pollen is dominant in the spectra too and the spectrum 53 from Warsaw corresponds with the first birch culmination in the Główczyn diagrams and the spectrum 55 with the first pine maximum well outlined in the lowest horizon of profile G28a. For the lowest Warsaw spectra with the oldest *Betula* culmination there is no equivalent in Główczyn; perhaps they represent the decline of the birch phase *c* unrecorded in either of Główczyn diagrams.

The course of the pollen curves in Główczyn profiles, particularly in the profile G2, indicates also a striking similarity to the pattern of culminations and minima in the mentioned classical profile at Bedlno. The pollen spectrum of the sample 72 [18] containing the remains of the subarctic shrubs and dwarf shrubs does not represent a clearly tundra character and may be approximately compared with the spectrum 57 from the bore hole G2 at Główczyn. Above, two birch and two pine culminations appear like in the Główczyn and Warsaw profiles.

For better illustration of the character of pollen profiles of the early Eemian Interglacial in Central Poland the correlation diagrams based on the pollen tables concerning the period in question have been set up. All the spectra have been brought to an uniform percentage basis, where the total sum of the pollen of trees and the hazel was considered 100 per cent. The application of such percentage system has been necessary since the various profiles had been elaborated in different years and with different methods and some of them, elaborated as long as 40 years ago, like the profiles from Szczerców and Dzbanki, [14] do not contain any quantative informations about the NAP pollen. The vertical scale of the diagrams has been changed and the characteristic culminations of pine and birch pollen have been accepted as synchronization points. Such well expressed culminations may be observed in the mentioned Szczerców and Dzbanki diagrams; they may correspond with the second and third pine culmination and with the second birch culmination in Główczyn. Similar picture is given by diagram from Otapy [3] situated in the eastern part of Mazovia - Podlasie Plain. On the other hand, however, less clear picture has been shown by the profile of the Eemian peat bog at Kalisz [19] where the third culmination of the pine pollen seems to be laid on the already clearly increased *Quercus* and *Corylus* percentages. The same third pine culmination does not become clearly visible in the profile from Góra Kalwaria [16]. The other profiles of the Eemian Interglacial in Central Poland either contain no early phases at all or do not present their sufficiently full picture. The group of the profiles from the north-east Poland and the Niemen basin [4, 6, 17] has been excluded from comparison. The development of vegetation on those territories was different and the profiles in question cannot be taken into account here, accordingly to the obligatory principles of synchronization of pollen diagrams [7, p. 197].

The relatively low percentage of the NAP pollen show clearly that the changes of vegetation recorded in the Główczyn diagrams consisted only in the dominance either of the pine or the birch in the composition of forests. Larger patches of the open vegetation in the principle did not exist already. Only in the places with particularly disadvantageous environment for trees, perhaps somewhere on northern slopes of the Główczyn moraine, existed some relict groups of light-demanding species which survived here at least till the end of the phase d. Among these heliophytes were: *Ephedra* represented by at least two species, *Helianthemum, Artemisia* and some other plants of *Compositae,* species of the families *Caryophyllaceae* and *Chenopodiaceae, Plantago media, Polygonum, Rumex, Thalictrum* and *Hippophaë*. The arctic-alpine element was represented by *Selaginella selaginoides* and *Saxifraga oppositifolia* type. Most of the pollen types in question appears in small quantities, some of them quite sporadically. It is not easy therefore to investigate their occurence in relation to the *Pinus* and *Betula* culminations. The whole sum of the NAP pollen does not indicate any larger oscillations. The appearance, however, of some heliophilous plants represented in the diagrams by more or less continuous pollen curves indicate a relation to the birch culminations, especially when *Artemisia* is concerned, the curve of which indicates not very high but legible maxima in the "birch horizons". Similarly, the curve of *Chenopodiaceae* has been shaped. The permanent appearance of *Thalictrum* pollen seems to be connected with the first birch culmination. In similar way, also the low *Juniperus* maximum is related to that part of the phase *d*. Other heliophytes occur sporadically only and do not form continuous curves but they are dispersed in the deposits of the whole phase. It seems that in the segments of phase *d* characterized by the domination of the birch, conditions advantageous for rather inconsiderable expansion of heliophylous plants or at least their more intensive pollen production were shaped.

TABLE 1. The spectra of the first birch culmination compared with the surface spectrum from Lapland

	Pinus	*Betula*	*Picea*	*NAP*
	%			
Finnish Lapland: the pine–birch forest with dominance of birch (Petsamo [2])	55·0	42·0	3·0	31·0
Głowczyn G2, sample 56	57·3	41·0		12·8
Głowczyn G28a, sample 49	59·3	35·9	0·4	17·5

It seems to result that the development of the Eemian vegetation in Central Poland in the period since the decline of the Middle Polish Glaciation until the climatic optimum of the Interglacial was not continuous. There were two cool climatic oscillations of small scale in the phases *d* and *e*. They were incomparable to the cold phases of the decline of the Last Glaciation when after periodical development of forests the subarctic and arctic vegetation returned into Polish territories. It seems that after the initial birch phase *c* (*vide* bottom of the profile Warsaw 4) the pine forest developed. It is recorded among others in the lowest horizons of Główczyn profiles. Later *Pinus* lost its importance, *Betula* re-expanded and the spectra 56 from profile G2 and 49 from profile G28a indicate the prevailing position of pine-birch forests with the dominance of the birch. The conclusion of that kind might be drawn from a comparison of the spectra mentioned above with those of the surface samples from the present forest zones neighbouring in south with the arctic forest boundary [1, 2, 8 Fig. 7b]. In the composition of these forests certain role was played by the aspen too. The pollen of *Populus* representing probably *Populus tremula* appears in a little more considerable quantities than somewhere else just in the "birch spectra" or in the spectra directly neighbouring with the "birch" ones. It is justified to believe that the pine was partly eliminated by some regional factor of a climatic nature and forests with dominance of birch and with aspen developed. When the factor in question ceased the pine forests regenerated again, recorded by spectra 55 - 56 from the bore hole G2 and 48 from the profile G28a. These spectra together with data obtained by L. Aario [2] and V. P. Gritchuk [9] are presented in Table 2.

TABLE 2. The spectra of the second pine culmination compared with the surface spectra from Northern Europe

	Pinus	*Betula*	*Picea*	*Alnus*	*NAP*
			%		
The pine forests in Finnish Lapland (Petsamo [2])	72·0	23·0	5·0	less than 1·0	26·0
The pine forests in Karelia [9]	61·5	24·0	1·0	13·0	19·6
Główczyn G2, sample 54	91·4	8·3	0·2	–	7·9
Głowczyn G28a, sample 48	78·5	18·0	0·5	0·2	19·1

This stage of pine forests development was followed by a new climatic change resulting in a more radical elimination of pine from the Glowczyn area and considerable portions of Central Poland. Referring again to the data obtained by L. Aario [2] and T. van der Hammen [10] (quoted after K. Wasylikowa [21]) one may conclude that the birch forest developed, with an admixture of pine which survived here and there. The aspen most probably took also part in a composition of the forest.

In the further development of the vegetation the pine forest characterizing in this case the beginning of the phase *e* developed again. Since this time there is visible a distinct one-directional tendency of climatic changes conditioning the vegetation development from the coniferous forest of the cool temperate climate to the rich multispecies deciduous forest characteristic for the interglacial optimum.

Neither biometrical analysis of the birch pollen provided us with a satisfactory result nor any macroscopic remains of *Betula* were found in the section of the profile just being discussed and it is unknown what species of *Betula* took part in the composition of forests with dominance of *Betula*. It is therefore rather difficult to search strictly-treated analogies of assemblages recorded in the spectra of this phase to the vegetational subzones neighbouring with the polar forest boundary in Northern Scandinavia. It is however justified to believe that the twofold invading of forest with the birch prevalence and with the aspen on the place of thick pine forests was connected with temporary climatic aggravations and some inconsiderable but observable shifts of vegetational subzones. The climate, still cool but by no means of the arctic type, enabled some limited patches of heliophilous vegetation to endure here and there.

TABLE 3. The spectra of the second birch culmination compared with the surface spectra from Northern Europe

	Pinus	*Betula*	*Picea*	*Salix*	*NAP*
	%				
The birch thickets in Finnish Lapland (Petsamo [2])	39·0	58·0	3·0	less than 1·0	33·0
The birch forest in Finnish Lapland (Petsamo [2])	33·0	64·0	1·0	2·0	27·0
The birch forest with pine in Finnish Lapland (Petsamo [2])	36·0	60·0	2·0	1·0	33·0
The subarctic birch forest in Swedish Lapland with an admixture of pine 400 m, above sea level (T. v. d. Hammen [10])	25.0	75·0			25·0
Głowczyn G2, sample 53	40·2	57·6	0·2	0·3	6·8
Głowczyn G28a, sample 46	49·0	49·2		0·2	7·2

An attempt at distinguishing of cooler climatic oscillation in the early part of the Eemian Interglacial in Central Poland may naturally have a provisional character since it is based on a relatively small and incomplete material. The increase in the density of the network of Interglacial sites as well as detailed investigations on densely sampled profiles will undoubtedly bring some new stratigraphical and palaeobotanical facts which will allow to learn more about the transition period from the Middle Polish Glaciation to the Eemian Interglacial.

This stage is rather not very well known not only in Central Poland but also in other areas (compare G. von der Brelie [5] Fig. 1). It is possible to expect that further detailed investigations of new and new Interglacial sites will bring much more data which will either confirm or correct or deny the above presented attempt of correlation and interpretation of the older part of pollen profiles of the Last Interglacial in Central Poland.

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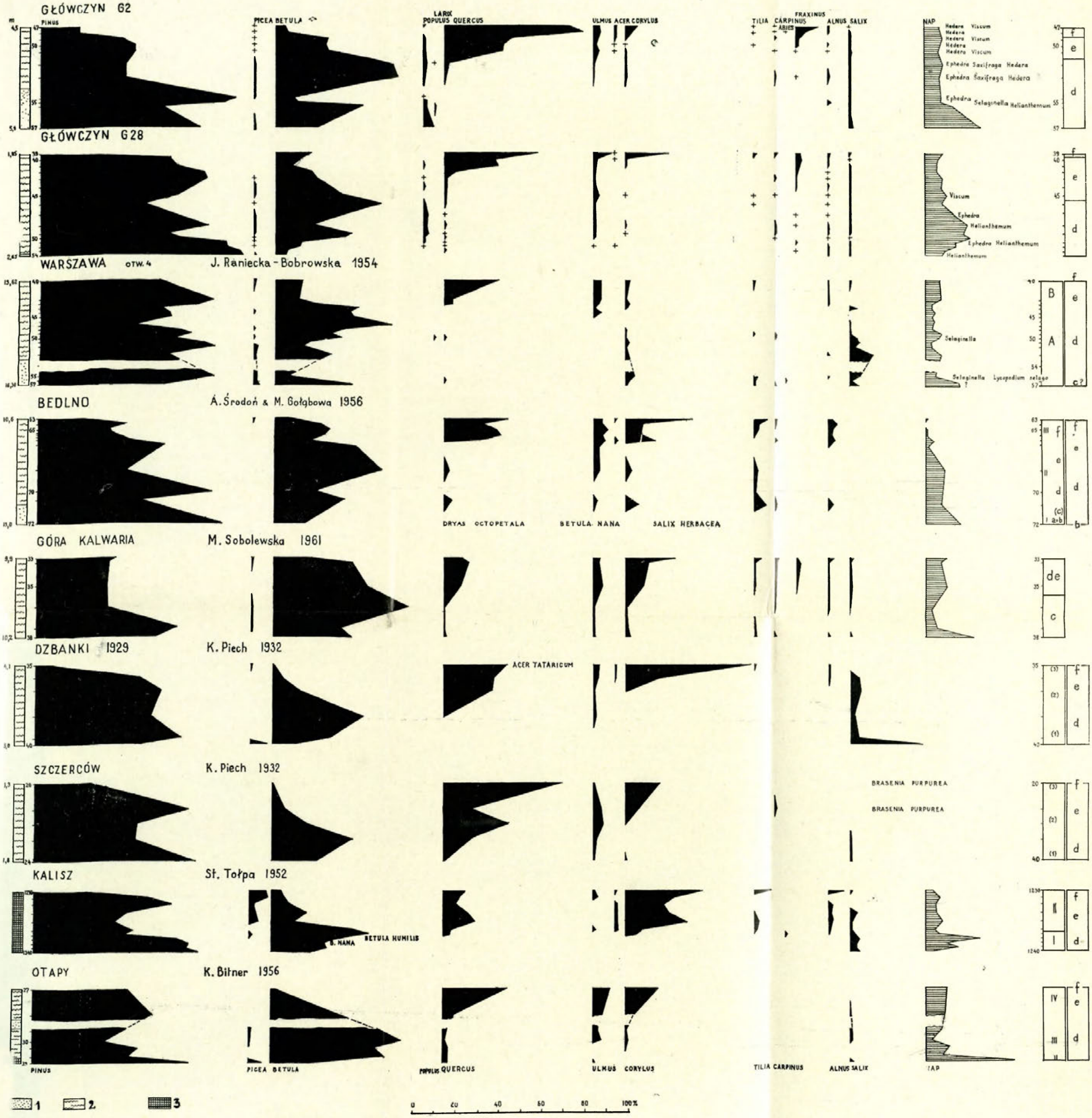

Fig. 1. Comparison of early phases of the Eemian Interglacial in Central Poland (for explanation see the paper)

1 — sands, 2 — lake sediments, 3 — peat

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PALYNOLOGICAL INVESTIGATIONS OF LATE GLACIAL AND HOLOCENE DEPOSITS AT KONIN

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INTRODUCTION

The palaeontological site at Konin represents an important stratigraphical link in the Quaternary geology of Poland, mainly due to the following reasons:

1. development of thick organogenic deposits dated by means of palynological analysis on several Late Glacial phases and interphases, and on Holocene periods;
2. relation to the older series of Brörup age (elaborated by E. Rutkowski and by the present author [23]);
3. favourable situation that the Quaternary deposits, making here up an overburden to the brown coal seams, are found within the mine area, and therefore some sections, highly interesting for the palaeobotanical studies, are accessible at the exposures;
4. both series are dated by means of radioactive carbon isotope ^{14}C: a) Brörup — 52 000 years (GRO 2566), b) Late Glacial — 11840 + 180 years, up to the present time (GRO 2024) — (Hl. de Vries, 1959) [1].

The age of the older series was proved by a find of mammoth (*Mamnonteus primigenius Blum.*) fossils, which were investigated to determine fluoro-apatite contents (W. W. Danilova, Institute of Petrography and Geochemistry, Academy of Sciences of the USSR).

Such a sequence of the Quaternary deposits, which date also the old stratigraphical stages at one locality only, is considerably rare, thus highly valuable; so far not known to occur in Poland.

Either of the organogenic series consist of gyttja and peat formations, thus of the deposits guaranteeing an undisturbed pollen spectrum [28].

The section here considered contains a series of shale-like lacustrine clays at the base, 0·55 m in thicknes, which passes into a more than

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[1] New radiocarbon datings see p. 271.

4 m thick series of detritus gyttja, with a constant amount of mollusc shells. The 0·5 m thick lacustrine series is overlain with a peat bed, 1·5 m in thickness.

DESCRIPTION OF SECTION

The geological situation of the deposits under consideration was presented in more detail by E. Rutkowski [23]. Here, a fact should be mentioned that the Late Glacial and Holocene deposits at Konin occur in the younger channel. The thickness of the accumulated organogenic deposits here considered reaches up to 6·60 metres. A simplified description of the lithology of these deposits is as follows:

0·45 - 1·95 m — highly decomposed, almost black peat,
1·95 - 2·10 m — dark grey gyttja,
2·10 - 2·70 m — almost black gyttja,
2·70 - 3·70 m — dark brown gyttja, passing into lighter one, and showing distinct stratification; numerous shells of gastropods,
3·70 - 4·85 m — grey gyttja stratified towards the bottom, changing its colour into black; at the top part — shells of gastropods,
4·85 - 6·00 m — black gyttja characterized by compact consistency, with numerous shells of molluscs, and with intercalations of vivianite,
6·00 - 6·35 m — lacustrine, stratified clay, light bronze in colour, darker at the bottom,
6·35 - 6·45 m — shale-like lacustrine clay, dark-greenish in colour,
6·45 - 6·60 m — shale-like, lacustrine, humus and arenaceous clay dark in colour,
6·60 — sand with pebbles.

According to E. Rutkowski's observations, the bore hole sections, examined within the North-Konin moraine plateau, have demonstrated that the channels are filled in with organogenic deposits which, as a rule, occur at a depth from 6·0 to 7·0 m.

On the other hand, in the meltwater depressions are found organogenic deposits, whose thickness does not exceed 1·5 m. Moreover, there are observed the following type sedimentary differences: as it was already mentioned before, gyttja and peats occur in the channel deposits, whereas within the depressions in boulder clays lacustrine marls predominate, covered with a clayey peat bed of small thickness.

E. Rutkowski was able to make some interesting observations as to the relation between the sedimentation of organogenic deposits and of mineral talus formations, depending upon the distance from the shore of the basin. Approximately in the middle of the sedimentation of organogenic deposits, the talus sedimentary processes were strongest. In this case, these processes are reflected in the organogenic deposits in the form of middle-grained and fine-grained or clayey sand intercalations brought into the basin from higher localities.

According to E. Rutkowski's supposition, the increased intensity of the talus processes may be related to the phase of the Older or Younger Dryas.

These phenomena have not been recorded in the section analysed by the present author. The section under discussion probably comes from the central portion of the basin, thus giving a more complete material necessary to reconstruct the history of plants.

METHODICAL REMARKS

The materials for palaeobotanical analyses were gathered at one exposure [23]. Samples for pollen analysis were taken from a monolith, 5 cm apart, each having approximately 12 cu. cm. The rest of the materials was destined for the analysis of macroscopic plant remains.

The samples for palynological analysis were prepared in different ways. For the most part maceration was applied, using acetolyse method. According to the character of the deposits, the maceration was preceded by:

1. a treatment with hydrochloric acid (HCl) in samples disclosing numerous calcareous shells,
2. a treatment with 15% hydrogen peroxide solution (H_2O_2) during a period from 30 to 60 min. in peat and dark gyttja samples, mainly because of numerous amorphous organogenic remains.

Mineral sediments such as clays or sands underwent flotation using a mixture of cadmium and potassium iodides, and then were macerated by means of acetolysis method.

Palynological analysis was made of samples from 123 horizons, taken 5 cm apart. Numerous samples, particularly peat samples, were additionally several times macerated using nitric acid (HNO_3) and potassium hydroxide (KOH). Despite the thorough examinations, I thought the results of the analysis to be negative since, among others, I ascertained either the selective destruction of sporomorphs, or the corrosion of the sporomorphs preserved. This is an open methodical problem related to the technique of maceration, which should be explained later.

It seems that here an alternative exists: either the selective occurrence of sporomorphs is a result of maceration processes, or that of preservative conditions of sporomorphs in the deposit. If the corrosion of pollen grains takes place in the deposit, the degree of destruction of the corroded pollen grains should increase due to the maceration process.

No doubt the reaction against the chemical reagents is, in the corroded pollen grains, different from that in the well preserved ones.

W. C. Elsik [6, 7] discusses the microbiological destruction of sporomorphs, caused by bacteria and fungi. The corrosion of pollen grains, particularly as concerns that of Alnus pollen grains, has also been considered by J. Stasiakowa [24]. The observations of this author concern the horizons of the Sub-Boreal period. Most of the pollen grains were decomposed; instead of them, numerous spores of musci appeared. According to the author, the phenomenon can be explained by the emergence of these beds at the decline of the Sub-Boreal period. The opinion given by J. Stasiakowa has not been proved by the results obtained during the examinations of an analogous phenomenon at Konin. For the most part, the samples revealing corroded pollen grains, are found within the Sub-Atlantic period. In addition, some corroded and decomposed sporomorphs occurred also in the older Holocene periods, i.e. in the Boreal and Atlantic ones.

For the analyses made recently, the material was taken from the monoliths destined for macrofloristic examinations, where the pollen grains found in a larger sample were not so strongly affected by air processes.

At each horizon 200 tree pollen grains were determined. The percentage of the sporomorphs is shown in the total pollen diagram. The sum total (=100%) comprises here the sporomorphs of trees, shrubs, and herbaceous plants, except for pollen grains of water and bog plants, as well as for spores of ferns, Musci, Algae and Fungi.

The percentage of the sporomorphs not considered in the total assemblage has been calculated as a percentage relation to the sum total.

As concerns the stratigraphical subdivision of the Post-Glacial, no obligatory subdivision exists now in Poland. Various authors base in their considerations on various stratigraphical schemes.

Taking into account the most exhaustive elaborations of the Late Glacial [15, 22, 32], the development phases in the section at Konin have been distinguished on the following bases.

1. stratigraphy given by Jessen [12], Iversen and Van der Hammen [9 - 11] for the Late Glacial;
2. stratigraphy given by Blytt-Sernander for the Holocene.

AGE OF DEPOSITS

The spore-and-pollen-section at Konin reflects some changes in plant cover, which took place at the time from the Oldest Dryas phase to the Sub-Atlantic period, inclusive.

According to J. Iversen (after K. Wasylikowa [32]), the culmination of birch (*Betula*) preceding the Alleröd interphase, should be related to the Bölling interphase. If so, the phase of the Oldest Dryas would be represented in the section at Konin by two samples taken at the bottom. The bottom part of the section (from 6·55 to 6·20 m). represented by lacustrine shale-like clay, contains an assemblage of sporomorphs characteristic of the decline of the Oldest Dryas, and of the older part of the Bölling interphase. Above the depth of 6·20 metres detritus gyttjas revealing a great amount of $CaCO_3$ were laid down, and peats were deposited. These beds reflect the history of vegetation and climate. beginning with the younger part of the Bölling interphase, through the phase of the Older Dryas, the Alleröd interphase, the phase of the Younger Dryas, and the Holocene periods up to the Sub-Atlantic period.

One of the horizons in the section of Konin was dated by means of radioactive carbon isotope ^{14}C by Prof. Dr Hl. de Vries at the Laboratory in Groningen. The absolute age of the horizon ±6·0 m was 11840±180 years (GRO 2024), up to the recent time. The material for absolute dating did not come from the section now elaborated by the present author, nevertheless the date obtained in the laboratory coincides with the Older Dryas phase [2].

A general examination of the spore-and-pollen-diagram allows us to state that the bipartite subdivision is a characteristic feature of the diagram under consideration. In an interval from 6·60 to ±3·70 m curves of Pinus and Betula predominate, corresponding in age to the Late Glacial. Higher up, there are developed curves of deciduous tree pollen grains, which are characteristic of the development of Holocene forests.

THE OLDEST DRYAS

In the light of the accepted stratigraphical subdivision, the phase of the Oldest Dryas has been determined as a period of woodless tundra with birch-willow brusches and with assemblages of *Hippophae rhamnoides* L.

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[2] Dr M. A. Geyh has established in Hannover in 1969 the age of five samples from the examined profile (Ergebnisse von Radiokohlenstoff — Analysen, Gutachten. Personal communication in the archive of the Geological Institute). The results of these datings are as follows: the age of a sample from a depth of 6·39 - 6·44 m = 12980±130 years B. P. (Hv 2306) coincides precisely with the results of palynological analysis, thus confirming the age of the Oldest Dryas. The age of a sample from a depth of 5·99 - 6·04 m = 11880±130 years B. P. (Hv 2307) is coincident with the date obtained by Hl. de Vries who assigned this level to the Older Dryas. The other dates: Hv 2308: 9600±100 years B. P.; HV 2310 : 7585±70 years B. P.; Hv 2309 : 6630±530 years B. P. — relate to the Holocene.

The phase of the Oldest Dryas is reflected in the diagram as a consequent dependence in the occurrence of sporomorphs. The considerable percentage of the herbaceous plants such as *Gramineae, Artemisia, Chenopodiaceae, Dryas, Gypsophila fastigiata, Helianthemum, Koenigia, Plantago, Ranunculaceae, Rubus chamaemorus, Selaginella selaginoides,* and *Umbelliferae* is a characteristic feature of the Oldest Dryas. Indeterminable cysts of algae, as well as spores of musci and fungi were numerous, too.

A marked occurrence of the lower plant spores is an evidence of severe climatic and edaphic conditions.

The tree vegetation is represented by the sporomorphs of *Pinus, Betula* and *Larix*. The occurrence of *Hippophaë rhamnoides L.*, which attains here a high percentage, amounting to 7·5% of the plant association, is very interesting as well. Hairs of *Hippophaë rhamnoides L.* found in the samples examined may also be referred to this period. Moreover, there appear here some representatives of *Ephedra* and *Myrica,* too.

The pollen grains of fructicose forms, i.e. of dwarf birch (*Betula nana*) or of short birch (*Betula humilis*), found among the birch pollen grains, is also worthy of being stressed. At that time, pine (*Pinus*) occurring at Konin amounted approximately to 15·2%. K. Wasylikowa [32] based on the results obtained by palaeobotanists from Denmark, Netherlands and Norway accepts the pine pollen grains as a secondarily deposited element brought from remote areas.

As concerns the section at Konin, the low amount of pine pollen grains allows us, as compared with the remaining components, to accept an interpretation founded on far transportation, too. This problem can definitely be solved after obtaining the results of macrofloristic analyses, which will show the properties of the environment.

It should be stressed, when characterizing the then plant association, that the phase of the Oldest Dryas was distinguished here mainly by the predominance of herbaceous and fruticose vegetation.

In this phase there occurs the first and the greatest culmination of the curve of grass (*Gramineae*) pollen grains, amounting to 48·2%.

At that time, small-leaved, short vegetation, characteristic of tundra, appeared with a large amount of heliophytic plants. The occurrence of *Hippophaë rhamnoides L.* is here a characteristic feature.

BÖLLING

The Bölling interphase commences a considerable change visible in the diagram as an absolute predominance of birch, and as a decrease of the herbaceous plant curve (NAP).

Biometrical measurements of the birch pollen grains have shown the values from 24 to 32 μ, thus proving the presence of such tree forms as *Betula pubescens* and *Betula verrucosa.* The maximum percentage of birch pollen grains amounts to 49·9.

According to K. Wasylikowa [32], thin birch forests grew in the vicinity of Witów at the time of the Bölling interphase. These were of park character, lacking any pine admixtures.

In the section at Konin, the Bölling interphase can be observed to occur at a depth from 6·40 to 5·95 m. Here, both the beginning and the decline of the interphase may be distinctly seen, expressed as an increase in the quantity of birch pollen grains. On the other hand, the middle part is characterized by a marked predominance of pine pollen grains, which attain here their maximum, amounting to more than 58·0%. Such a percentage of pine — even after a correction considering the far transportation — is an evidence of the occurrence of pine *in situ.* On account of a type of lacustrine deposits, developed here in the form of gyttja, no basis exists to recognize any part of the Pinus sporomorphs as material redeposited. Besides the pollen grains of *Pinus, Salix, Larix* and *Betula,* also the presence of *Alnus, Quercus* and *Corylus* has been ascertained. Such forms as *Ephedra* and *Hippophaë* appear again.

Higher up, the curve of *Gramineae,* which discloses a considerable value at the bottom part (more than 40·0%), decreases to obtain the average value amounting to about 30·0%. The pollen spectrum of the Bölling interphase reveals a small amount of such representatives as *Artemisia, Chenopodiaceae, Helianthemum, Labiatae, Myriophyllum, Potamogeton, Ranunculaceae, Rubiaceae, Thalictrum, Umbelliferae, Sphagnum* and *Lycopodium.*

As compared with the previous period, the difference concerns mainly birches, which at the Bölling interphase time occurred mainly as arborescent forms.

The pine that, beginning with the Bölling interphase, is distinguished in the diagram by a uniform high-percentage curve, cannot be excluded. Therefore, it should be added to the characteristics of the Bölling interphase cited above [32] that at that time thin park birch-pine forests developed, as proved also by the presence of the following heliophytic plants: *Ephedra, Hippophaë rhamnoides, Artemisia, Helianthemum* and *Rubiaceae.*

THE OLDER DRYAS

During the Older Dryas phase (ascertained in the deposits at a depth from 5·95 to 5·50 m) birch (*Betula*) revealed its maximum value, amounting to 20·0%. The percentage of herbaceous plants (NAP) increases once more, and vegetation similary as in the vicinity of Witów, is smaller in the phase of the Older Dryas than in the Bölling interphase.

At the time of the Older Dryas the pollen grains of *Artemisia* attain their highest amount. The curve of *Betula* pollen grains from that time is characterized by the presence of three spices, analogically to that of the *Artemisia* pollen grains. The maximum percentage of grasses (*Gramineae*) coincides with the maximum occurrence of pine. The sporomorphs of *Salix* and *Picea* appear and among the herbaceous plants are found *Chenopodiaceae, Compositae, Comarum, Cyperaceae, Scabiosa, Umbelliferae, Polypodiaceae* and *Sphagnum.* The presence of numerous but indeterminable spores of musci and fungi has also been recorded by the present author.

Analysing the discussed stratigraphical stages of the Late Glacial with the aid of the curves of pine and birch pollen grains, we may try to illustrate the principles of the development of floristic periods. Both in the Bölling interphase and in the phase of the Older Dryas, 3 oscillations can be observed, expressed by the predominance of birch at the beginning and at the decline of the phase or interphase. as well as by the prevalence of pine in the middle portions, which prove an amelioration in climatic conditions during the periods under consideration.

Such a cyclic nature had probably been characteristic also of the Oldest Dryas which, in the section at Konin, was ascertained only as concerns its final part, in which birch had also predominated.

In accordance with the interpretation of the pollen section at Konin, the phase of the Older Dryas can roughly be related to that of the Oldest Dryas. But it differs here in having the following features: 1. the lack of heliotrophic plants, 2. the lower curve of NAP pollen grains, 3. the greater percentage of the pollen grains of *Artemisia* and *Polypodiaceae,* 4. the presence of the *Picea* pollen grains and 5. the large amount of indeterminable spores of fungi and musci.

So far, no data are available as concerns birch species. This, however, can no doubt be solved by the analysis of macrospore fossils, and by the biometrical examinations of pollen grains.

The character of the deposits, the well preserved sporomorphs, and their high frequency are sufficient bases to draw a conclusion that the pollen grains correspond to a primary deposit. Thus, even taking into account the considerable amount of the pollen grains disseminated by pine, and a great ability of these grains to be blown from remote areas, particularly throughout a forestless region, we may however accept that, at the time under consideration, pine participated in the plant association of the North-Konin moraine plateau. May be, the plant association was of tundra type, with groups of birch-pine trees.

ALLERÖD

The pollen grains of thermophilous plants found to occur in the Alleröd interphase are regarded by most authors as sporomorphs of a sediment redeposited. The problems of the Late Glacial stratigraphy are considered till now with the aid of the insufficient evidence materials. As concerns the area of Poland, the Late Glacial sections have been described by many authors [1, 2, 5, 13 - 22, 24, 25, 27, 30, 32]. At the best, these sections reflect the floristic phases of the Older Dryas, or of the Alleröd interphase. Climatic changes, established on the basis of palaeobotanical analysis of deposits from the Oldest Dryas, proved by ^{14}C dating, have been published after the examination of the localities at Grel [15] and at Witów [32]. The section at Konin is the next one of the same value.

The rejection of the thermophilous plant sporomorphs of the Alleröd interphase, as those being laid down secondarily, may be substantiated in the case of mineral deposits only. As I have mentioned before, the section at Konin is characterized by an undisturbed series of lacustrine gyttja.

Both differences and similarities in the succession of the sporomorphs can be distinctly seen in the pollen diagram. The appearance of the thermophilous plant sporomorphs in the Alleröd interphase is striking, and analogous to the Alleröd oscillation in various pollen sections.

It appears to be impossible that just in the Alleröd interphase so a strong contamination of redeposited sediment with pollen grains could have taken place. Forcible arguments that could prove such a supposition are lacking at present, however.

It seems that a consequently increasing warming should also be taken into account. The warming allowed at least an island-like development of deciduous trees with hazel; the whole development of these trees took place at the Holocene time only.

As it is illustrated by the character of the pollen curves, the section at Konin is a fairly well evidence that the Alleröd warming allowed to develop not only the light birch and birch-pine forests with willow, but also to develop the island-like forests with thermophilous trees. These are reflected in the pollen spectrum as the increased percentage of pollen grains of such representatives as *Alnus, Ulmus, Quercus, Tilia, Carpinus* and *Corylus*.

In the section of Konin, the Alleröd interphase can be referred to the beds found at a depth from 5·50 to 5·10 m. Besides the plants mentioned before, this period was characterized by the occurrence of *Ericaceae* that probably lived in a symbiosis with pine. Grasses and carices occurred in 10%, on the average.

In addition to these plants there appeared also: *Alisma, Artemisia* in traces, *Comarum, Filipendula, Lysimachia, Myriophyllum, Nymphaeceae, Sparganium, Thalictrum, Typha, Polypodiaceae* and *Sphagnum.*

THE YOUNGER DRYAS

Cooling that took place at the Younger Dryas time, observed in the pollen section at a depth from 5·10 to 4·70 m, distinctly influences the pollen spectrum. The following are its characteristic features: 1. high-percentage curves of birch and pine pollen grains with a slight predominance of pine ones, 2. distinct decrease in the amount of thermophilous plant pollen grains, which occur in traces only. 3. participation of grass pollen grains, amounting to 8·5%, 4. low percentage of herbaceous plants, 5. appearance of pollen grains of *Rubus chamaemorus* which, as a glacial relict, is restricted to-day in Poland to certain localities only. At present, it does not occur in the North-Konin moraine plateau.

Moreover, there are found representatives of such plants as *Ericaceae, Alisma, Artemisia, Comarum, Lysimachia, Nymphaeaceae* (which, beginning with the previous period, occur in the whole section), *Potamogeton, Ranunculaceae, Rosaceae, Saxifraga, Typha* and others.

The climate of the Younger Dryas was Sub-Arctic, milder, however, than that of the Older Dryas. Light birch and birch-pine brushes, with willow, and elm as a new element, predominated.

PRE-BOREAL PERIOD

The culminations of birch and pine curves determine the lower boundary of the Pre-Boreal Period. At that time, a consequent development began of elm (*Ulmus*), alder (*Alnus*), oak (*Quercus*), linden (*Tilia*) and, first of all, hazel (*Corylus*).

BOREAL PERIOD

The Boreal Period is represented at a depth from 4·20 to 3·70 m. In the pollen section, the lower boundary is determined by the end of birch culmination and by the maximum of pine. Among new trees there are found *Picea* and *Carpinus.* The percentage of the pollen grains of *Gramineae* is lower.

ATLANTIC PERIOD

This period is distinguished by the predominance of mixed forests with a characteristic succession of 1. linden (*Tilia*) culmination, and 2. oak (*Quercus*) culmination at the decline phase of the Atlantic Period.

At that time there appeared also sporomorphs of *Carpinus, Fagus* and *Picea.* In the diagram, the continuous curve shows the occurrence of *Nymphaeaceae* pollen grains, and the maximum of *Typha* — approximately 4·0%. The value of the curve of *Polypodiaceae* amounts to about 10%.

The determination of the upper boundary of the Atlantic Period frequently depends upon the first appearance moment of the *Abies* and *Plantago lanceolata* pollen grains. In the case of the pollen section at Konin, this condition has been fulfilled, since both the *Abies* and the *Plantago* pollen grains are, for the first time, found in the spore-and-pollen assemblage.

The presence of the *Trapa natans* pollen grains, rarely found in the deposits, is also a valuable evidence of the Post-Glacial climatic optimum there.

SUB-BOREAL PERIOD

During this period, the percentage of the elm pollen grains decreases, whereas the oak pollen grains still play an important part in the percentage composition of the tree pollen grains.

Generally speaking, we may say that this is a transition phase between the period of development of mixed oak woods. and the period of beech (*Fagus*) expansion. In the section at Konin, the percentage of beech pollen grains is insignificant.

The part of hazel distinctly decreases. On the other hand, in the pollen spectrum are found sporomorphs of *Populus, Ligustrum* and *Viburnum.*

Among the herbaceous plants, an important role is played by the synanthropic plants such as *Centaurea cyanus, Cerealia, Humulus lupulus,* cf. *Panicum, Papaver. Plantago, Rumex, Solanum, Urtica* and *Viscum album.*

Moreover, there is also observed a culmination of the spores of *Polypodiaceae* and an increase in the percentage of grasses and carices.

SUB-ATLANTIC PERIOD

In the Pomeranian area and in the Mazury Lake District, the Sub--Atlantic Period is characterized by the expansion of hornbeam and beech. In the section at Konin the curves of these plants run, similarly as in the spore-and-pollen-sections of Central Poland, as broken lines.

The influence of Man, protecting the pine trees, decided upon their marked participation. The sporomorphs of cultivable plants and of weeds occur as previously. The curves of both *Gramineae* and *Cyperaceae* increase. The highest culmination of the spores of *Polypodiaceae* appears, amounting to 267·0%

INFLUENCE OF MAN UPON VEGETATION OF THE NORTH-KONIN UPLAND

In the Holy Cross Mountains [27], within the Mazurian [22] and Kartuzy [26] Lake Districts and in the Kuyavian [25] and Greater Poland (Wielkopolska) [30] regions mainly wheat (*Triticum*) and also rye (*Secale*) were cultivated, beginning with the Atlantic Period. The lack of weeds and of corn in the diagram from Górno and Bliżyn [27] points to a fact that the humid valleys, in which peat bogs are located, were influenced by the activity of Man, at the last time.

The occurrence of such sporomorphs as *Artemisia, Chenopodiaceae, Rumex, Plantago* and *Centaurea* during the Younger Dryas, at the Pre--Boreal and Boreal periods, proves woodless conditions, whereas the presence of these sporomorphs at the time of the predominance of dense forest assemblages is an evidence of the activity of Man, and not of worse climatic conditions.

K. Szczepanek [27] has demonstrated that within the area of the Holy Cross Mountains, the Sub-Atlantic Period is characterized by the presence of the *Rumex* pollen grains that reach in the diagram up to 64·7%. Such a high percentage does not find any equivalent in other sections. Since the *Rumex pollen* grains occur in the clayey peat, the author is of the opinion that this is an evidence of the local soil erosion, and of the disappearance of forests in the area under consideration.

The section at Konin does not disclose any distinct changes in the general composition of tree vegetation in favour of cultivable plants and weeds, which might suggest a disappearance of forests in the area of study. After some corrections in the total diagram, certain differences would appear, at least due to a fact that the part of the pollen grains of synanthropic plants is strongly restricted to a depth from 2·00 to 0·40 m. The maximum values of the pollen grains of synanthropic plants (in terms of AP = 100·0%) correspond approximately to 5·0%, whereas, according to the total calculation, they amount to 3·5%.

A decrease in the percentage of the pollen grains of deciduous trees at the top parts of the section, and an increase in the occurrence of the pine pollen grains, are fairly characteristic. Simultaneously, a culmination of the pollen grains of *Gramineae* can be observed, together with a decrease in the value of the curve of *Polypodiaceae*.

In contrast with the sections from the Holy Cross Mts., the Wielkopolska region and the Mazury Lake District. where rye (*Secale*) and wheat (*Triticum*) had been the main cultivable plants, the pollen grains of rye (*Secale*) occurred in the section at Konin only sporadically, and the pollen grains of wheat (*Triticum*) were so far not ascertained to occur even as single indviduals. On the other hand, the pollen grains of millet (*Panicum*) were found to occur there. The pollen grains of corns are presented in the form of one curve as *Cerealia,* in which, besides the pollen grains of rye (*Secale*), also sporomorphs were found, frequently characterized by considerably smaller dimensions (30 - 36μ) than those of *Secale* (70×55μ) or *Triticum* (61×52μ)

All the sporomorphs of *Gramineae,* which are below 40μ in diameter, are thought by M. Ralska-Jasiewiczowa [22] to belong to wild grasses. She points out, citing Gaerte, that millet *(Panicum)* has been ascertained to occur in a culture locality at Ostrowiszki, near Węgorzewo, and referred to the early or middle bronze age. The cultivation of millet has been ascertained also when examining a lacustrine dwelling of bronze/ iron age. A. Kozłowska suggests that millet was the best plant for cultivation on soils after cleaning or burning of forests there (after [22]).

The grains of cf. *Panicum* discovered in the deposits at Konin highly differ from those of wild-growing grasses mainly in having a distinct structure and a well developed broad ring.

To solve the problem of history of plants in the area of the North--Konin moraine plateau in more detail, necessary are further microfloristic and macrofloristic examinations, as well as dating of several horizons by means of radioactive isotope ^{14}C.

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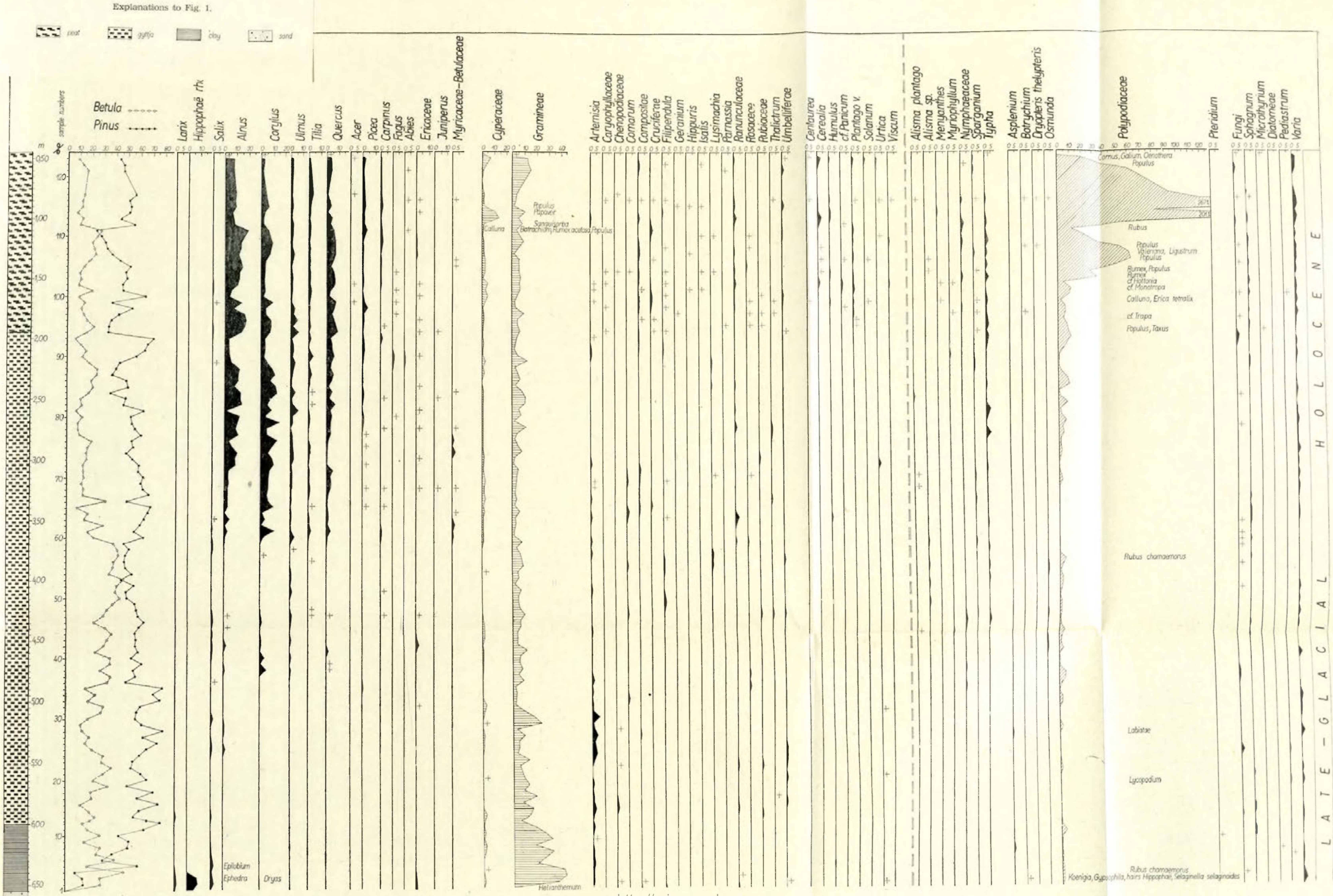

Fig. 1. Pollen diagram of the Late Glacial and Holocene deposits at Konin

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RÔLE DE LA VÉGÉTATION DANS LA FORMATION DES DUNES

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L'observation du rôle de la végétation dans le processus de la formation des dunes est la plus facile là où les dunes se constituent actuellement, c'est-à-dire dans les secteurs d'accumulation du bord de la mer, et également dans ceux où l'on procédait à l'essai de fixation des sables mouvants des dunes continentales dispersées par le vent. Pendant plusieurs années, j'ai fait des recherches dans ce domaine avec mon mari, le prof. dr Roman Kobendza, botaniste. Elles ont permis d'établir que la formation de dunes exige: 1° du sable mobile comme matière, 2° du vent comme élément de transport, 3° une végétation comme élément de formation dunaire.

Les vents se manifestent dans toutes les zones climatiques. Leur influence sur les sables mobiles dépend de la force, persistance et constance de leur direction. Des vents même faibles entraînent la formation de rides de sable „Ripple marks". Sur une surface de sable encore humide, les premiers grains sont à peine secs, qu'ils sont déjà enlevés, roulés par le vent et déposés en mosaïques fantastiques sur les plages du littoral, ou sur les sables mobiles continentaux. Les rides de sable sont une forme de déplacement, du transport des grains de sable dans la direction du vent jusqu'à l'obstacle rencontré, qui partage le cours du transport, le canalisant des deux cotés de l'obstacle. Devant ce dernier, à la suite de tourbillons d'air, se forme un fossé éolien, par contre derrière l'obstacle, s'élève une petite dune en forme de prisme qui diminuera de hauteur et de largeur. Dans le cas de vents constants dans leur direction, on observerait la formation de ces petites dunes, dont la hauteur ne dépasserait pas celle de l'obstacle. Cependant dans la nature, ou pour le moins dans notre latitude géographique, des vents de direction constante n'existent pas. Au changement de direction du vent, les petites dunes formées sont dispersées et le sable est transporté et déposé dans d'autres coins abrités.

L'obstacle, présenté par la végétation sur place, arrête le sable, mais ce processus dépend de la compacité des plantes en question. Une touffe serrée jouera un rôle analogue à celui d'un obstacle mort, par contre un groupe de plantes espacées arrêtera le sable à l'intérieur de ce groupe, et ce n'est que derrière le monticule érigé et maintenu par la végétation que se formera une petite dune-éphéméride, et devant elle — un fossé éolien, comme devant un obstacle mort.

Les vents forts transportent de plus grandes quantités de sable et à plus grande vitesse. Le processus même ne consiste pas seulement à rouler les grains de sable sur la surface de déflation, mais également à les transporter dans l'air. La grandeur des grains des sables de dune permet de déterminer la force des vents qui ont formé la dune.

Les conditions atmosphériques spécifiques, même dans notre zone climatique, peuvent dans des conditions climatiques spéciales provoquer la formation d'une trombe d'air, qui par un mouvement en tourbillon peut enlever le sable mobile à une hauteur de quelques mètres et le précipiter sur l'obstacle rencontré (forêt) ou sur la surface au moment de l'arrêt du mouvement en tourbillon, ou au début d'une précipitation atmosphérique. Ce sont des phénomènes très rares.

Un vent de courte durée, constant dans sa direction, mais fort, et qui dispose d'une grande surface de sables mobiles, forme parfois, même dans nos conditions climatiques, des barkhanes. Ce sont des arcs, dont le côté concave fait face au vent, les bras s'allongent en sens contraire, conforme à la direction du vent. Ce sont des formes communes dans les déserts. Elle apparaissent parfois sur nos surfaces de sables mouvants, par exemple sur la barre de Łeba. Les bras contenant une plus petite masse de sable se déplacent plus rapidement que l'arc du barkhane lui-même. La pente extérieure (proximale) est relativement douce, par contre, le sable glisse à l'intérieur de l'arc entrainé par son propre poids, formant la pente intérieure (distale) à un angle de 30 à 36°.

Les formes de dunes stabilisées sont dues uniquement à la végétation. La plante graduellement recouverte de sable ne périt pas, mais développe toutes sortes d'adaptations spéciales à ces conditions écologiques. Des racines adventives poussent sur les tiges des plantes ensevelies. Ces racines absorbent l'eau des précipitations atmosphériques des couches de sable fraîchement accumulées et nourrissent la plante des sels fondus dans cette eau. En même temps ces racines retiennent et fixent le sable mobile. Les sommets des pousses entièrement ensevelies se dirigent vers le haut, sortent comme tiges à la surface, développent de jeunes feuilles qui recouvrent le sable, le protégeant contre la déflation.

Certaines plantes, les psammophytes, accusent des capacités nettement phénoménales de pousser dans le sable, de retenir les masses de sable accumulées. Les graminées connues de notre littoral: *Ammophila arenaria, A. baltica, Elymus arenarius, Agropyron junceum* forment sous terre

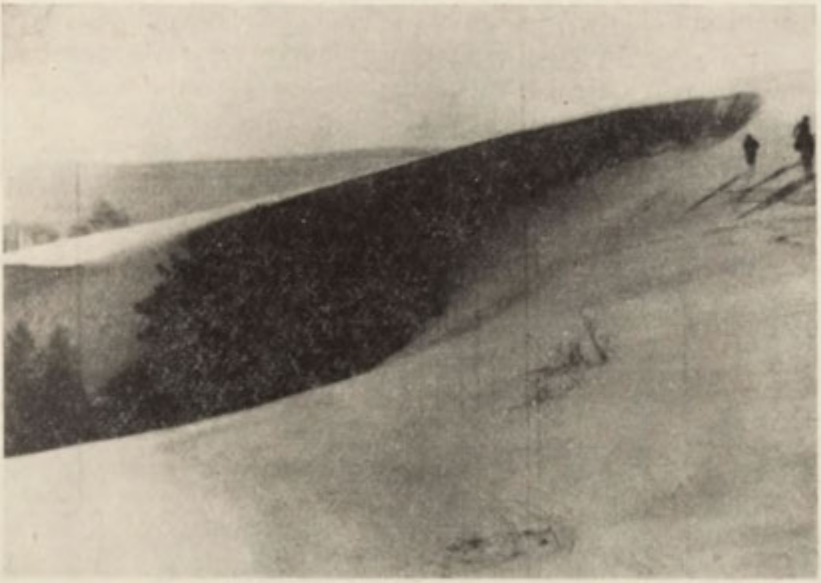

Photo. S. Kopeczek

Fig. 1. Dune en forme de barkhane sur la barre de Łeba

un réseau de rhizomes atteignant des dizaines de mètres qui s'entrecroisent. Ce réseau est pourvu d'un système de longues racines ligneuses et dégage sans cesse de nouveaux exemplaires à la surface du sable. Ces organismes de plantes sont ensevelis tout l'hiver. Dès le printemps le réseau des jeunes rhizomes maîtrisent les couches de sable agglomérées. Les tiges et les feuilles des nouveaux exemplaires jeunes de ces rhizomes se développent et atteignent la surface. Il suffit d'observer attentivement les parois des remparts des dunes partagées en deux par les vagues de tempête, pour voir les rhizomes de ces plantes inappréciables placés en couches et les fils de leurs très longues racines qui pendent. Les rhizomes et leurs racines remplissent le rôle d'un réseau qui soude le sable d'une manière durable et qui progresse. Les anciens rhizomes, mis à nu accidentellement sur une pente, peuvent réveiller de nouveaux bourgeons adventifs et donner vie à de nouvelles plantes. Les rhizomes les plus anciens et les plus profondément ensevelis périssent. Les espèces des graminées psammophiles sont les pionniers des formes dunaires du bord de la mer. Ces plantes croissent rapidement et forment une flore abondante non seulement grâce à l'humidité du climat, mais aussi grâce à la fertilité relativement élevée des sables du littoral. Le vent apporte du littoral non seulement des grains minéraux, mais encore des déchets animaux, des coquilles calcaires et des déchets végétaux qui enrichissent le sable en humus. Cela facilite le développement d'une abondante végétation des premiers remparts dunaires. Mais c'est le mouvement du sable lui-même qui joue le rôle essentiel dans le développement des plantes psammophiles. L'ensevelissement continuel provoque la nécessité du renouvellement du système des rhizomes et des racines, et par cela même de l'exploitation sans la concurrence d'autres plantes des nouveaux sables fraîchement accumulés. Selon les recherches de Marshall [2] le développement de *Ammophila* est lié à la capacité de développer de nouvelles racines sur les noeuds de rhizomes. Cette capacité diminue sensiblement avec l'âge, car sur ces noeuds se forme un épiderme grossi. C'est pourquoi *Ammophila* tend à disparaitre sur les anciens remparts dunaires „gris".

Photo. R. Kobendza

Fig. 2. *Ammophila arenaria* et *Lathyrus maritimus* sur les dunes blanches du Littoral

Sur les sables continentaux éparpillés, des graminées psammophiles sont ensemencées et plantées afin de retenir et de fixer la sable. Ces graminées ne se développent pas avec l'exubérance observée sur le littoral, parce que le climat est nettement plus sec, plus pauvre en précipitations et les sables des dunes continentales contiennent moins de sels minéraux et d'humus. Cependant, au cours de la période de formation des dunes continentales les sables des sandr et des vallées proglaciaires étaient de beaucoup plus riches en composants minéraux (azote, phosphore, potassium et calcium) donc plus fertiles, rendant possible la végétation et le développement de bien des espèces de plantes.

En principe toutes les espèces de plantes herbacées peuvent s'adapter au milieu mouvant des sables, à l'ensevelissement constant par des couches toujours nouvelles de ces sables, à condition que ce processus s'effectue graduellement. L'échelle de ces adaptations est énorme, grâce à quoi, à côté des graminées psammophiles, on observe sur ces dunes un grand nombre d'espèces de plantes qui varient la monotonie des dunes blanches et des dunes continentales éparpillées.

Le rôle des arbres et des arbustes dans la formation des dunes est encore plus grand. Avant tout, parce que ces organismes sont sensiblement plus forts et plus grands. L'effet de leur action est donc plus rapide et plus visible. La majorité des arbres et des arbustes feuillus et des conifères ont la capacité de faire pousser des racines adventives de leur tronc et de leurs branches ensevelis par le sable, mais uniquement quand l'ensevelissement se produit graduellement par couches. Les sommets des tiges enracinées atteignent la surface souvent même après un ensevelis-

Photo. R. Kobendza

Fig. 3. *Pirus communis* enseveli par les sables. Mis à nu, on peut voir la masse des racines adventives

sement complet sous le sable. Les arbres croissent alimentés partiellement par le vieux système de racines, mais principalement par le jeune système de racines adventives, qui se développent sur les troncs et sur les branches, en absorbant les eaux des précipitations des couches supérieures des sables fraîchement accumulés. En déterrant les arbres et arbustes ensevelis pendant des années, on découvre le cours intéressant du processus. Il s'avère avant tout, que non seulement les espèces végétant normalement sur le sable, mais même les espèces telles que *Alnus glutinosa* liées à un milieu humide supportent l'ensevelissement. La partie du tronc de l'arbre enseveli qui se trouve au dessus de la surface du sable est en général plus grosse que la partie ensevelie, exposée à la pression de la couche agglomérée de sable. Il est facile de différencier, dans la masse de sable aggloméré, les accroissements annuels des couches de sable, soulignés par une ligne plus sombre, enrichis par l'humus provenant des feuilles tombées et imbibées par la masse des minuscules racines adventives de l'arbre enseveli. Ces racines sont riches en mycorhizes, qui facilitent la décomposition des substances organiques. On y voit l'influence dominante de l'action des vents d'hiver. Ils agglomèrent sur les feuilles, tombées en automne, une couche de sable de 20 à 50 cm d'épaisseur. Le plus vieux système inférieur des racines se décompose avec le temps et disparaît. Tout le système d'alimentation doit donc baser sur le jeune système des racines adventives, pourvu en mycorhizes.

Les bourgeons adventifs commencent à se réveiller sur un grand nombre de qualités d'arbres et arbustes comme *Padus avium, Pirus communis.* Ces bourgeons se développent, dans le sable, en tiges blanches dépourvues de feuilles, munies d'écailles, qui s'acheminent vers la surface en perçant le sable aggloméré pendant l'hiver. Ayant atteint la surface, les tiges blanches se transforment en tiges normales, munies de feuilles. Ces tiges fleurissent ensuite et produisent des fruits. L'attention est attirée par l'abondance des fleurs et des fruits, produits par les spécimens d'arbres ensevelis par les sables.

Ces conditions de végétation sont très bien supportées par les saules et tout particulièrement par les *Salix acutifolia* qui, grâce à leurs propriétés, sont employés à la fixation des sables mobiles. Dans la coupe d'une dune, formée grâce à la croissance constante des tiges ensevelies de ces saules, on voit dans le sable aggloméré. les tiges ensevelies et l'enchevêtrement des racines.

Juniperus communis trouve sur les sables mobiles des conditions spécialement favorables. Ses branches s'enracinent au contact de la surface humide du sable et encore plus facilement après leur ensevelissement.

Pinus silvestris, élément populaire de la flore dunaire, occupe une place à part dans le processus d'ensevelissement par les sables mobiles.

Le pin enseveli. avec une partie de ses branches même, ne produit pas de racines adventives, ni sur son tronc, ni sur ses branches. Malgré cela, en découvrant les branches des pins, on voit un grand nombre de jeunes racines avec des sommets pourvus de coiffes et un enchevêtrement de mycorhizes. Un certain nombre de spécimens ont été mis à nu par le prof. R. Kobendza et lui ont permis de constater, que ces racines sont directement liées au collet de la racine, c'est-à-dire à la partie de la racine située le plus près du tronc. Ces racines ne se dirigent pas vers la profondeur, mais vers la surface. Elles accusent donc un géotropisme négatif. Leurs ramifications forment des racines minuscules qui atteignent les couches du sable fraîchement aggloméré. C'est ainsi que l'arbre assure le développement d'un système de jeunes racines qui l'alimentent en

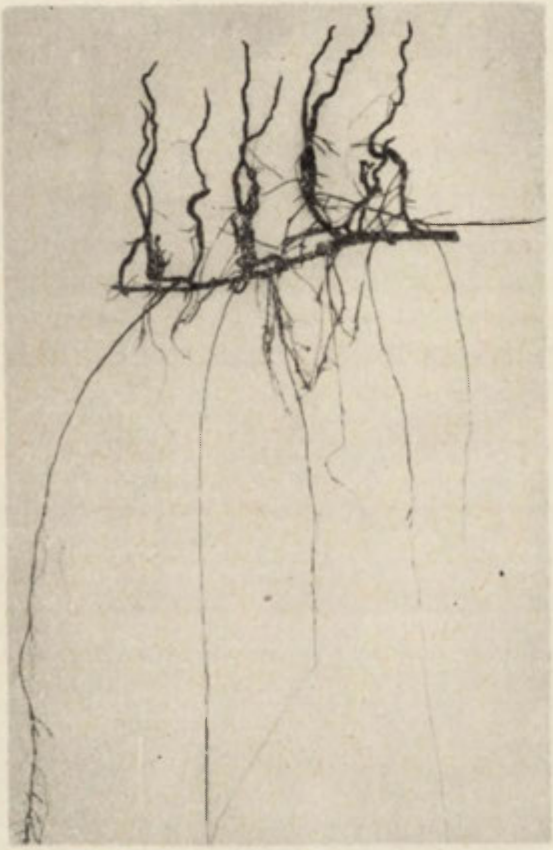

Photo. R. Kobendza

Fig. 4. *Padus avium* et ses tiges blanches mises à nu

eau et en substances nutritives. Le vieux système inférieur des racines se décomposent graduellement.

Certaines espèces d'arbres à feuilles accusent encore une capacité qui leur donne la possibilité de végéter même pendant la déflation provoquée par le vent. Leurs racines peuvent produire de jeunes tiges. Les jets de ces racines de *Betula. Sorbus aucuparia, Robinia pseudacacia* accélèrent le processus de la fixation des sables. Ces espèces sont donc exploitées dans la remise en culture.

Le processus de l'ensevelissement des arbres et des arbustes par des sables mobiles a un tout autre aspect quand les masses de sable prennent la forme de front d'une dune mobile et se déversent en masse sur la forêt de l'avant-terrain. Les arbres et les arbustes ensevelis, étouffés, périssent rapidement. Après un certain nombre d'années, sur la pente extérieure de la dune mobile, les moignons des arbres morts seront mis à nu. Au cours de l'ensevelissement, non seulement les feuilles et les petites branches, mais aussi le bois du tronc se décomposent. Ce n'est que l'écorce qui enveloppait autrefois les troncs qui résiste à la décomposition et se dresse comme des poteaux sur la surface blanche des sables.

Les observations présentées se rapportent aux processus qui se développent actuellement sur les sables mobiles. Ils sont certainement une répétition des processus datant de la période de la formation des dunes continentales. Les grandes masses de sable, accumulées sur les champs de sandr, dans les vallées proglaciaires, étaient soumises à l'action des vents de l'époque périglaciaire et du tardif glaciaire.

La végétation contemporaine de la toundra était composée en plus des mousses, de graminées, cypéracées, sous-arbrisseaux, et même d'arbustes: *Salix, Betula, Juniperus communis. Elymus arenarius* est aujourd'hui largement répandus en Sibérie, en Amérique du N. et en Islande. *Ammophila* ne paraît pas aujourd'hui dans la flore de l'Arctique, mais par contre, un grand nombre d'espèces de graminées et de cypéracées ont la capacité de développer un système de rhizomes et de racines dans les sables fraîchement accumulés.

C'est sur la limite entre les superficies sablonneuses et les vallées humides adjaçantes qu'existaient les conditions optima à la formation des dunes. La végétation se développait dans les vallées dès que les conditions thermiques le permettaient. Le sable seul n'était pas favorable à l'existence de plantes. A la limite de ces deux milieux, les remparts dunaires s'accumulaient, grâce à l'action des plantes végétant au bord des marais. Le rempart était une forme primitive de la dune. Il se formait à la limite de la surface sablonneuse et humide.

Les remparts de ce genre apparaissent nettement dans la morphologie des dunes de la *pradoline* de la Vistule dans les environs de Varsovie.

Photo. A. Kobendza

Fig. 5. Arbres morts sur la barre de Łeba

Photo. R. Kobendza

Fig. 6. Le désert de Błędów (S. Pologne) — terrain de déflation. L'absence de végétation psammophile entraine l'absence de formes dunaires

A l'Ouest de Varsovie, dans le parc national de Kampinos, ces dunes sont disposées parallèlement à l'axe de la vallée, dans la direction de l'Est à l'Ouest, par contre sur la rive droite de la Vistule — en direction du Nord, au Sud, elles suivent la vallée du canal de Bródno.

Sur les îles sablonneuses au milieu de marais, quelques dunes paraboliques ont pu se constituer. Leurs contours reprenaient la forme de la barre. La majorité des dunes paraboliques a été formée par la transformation des remparts dunaires primitifs sous l'influence des vents, dont l'action a été changée par rapport aux vents primitifs. Le climat des dernières phases de la glaciation baltique (Würm) subissait de grands changements. Les directions des vents, qui dominaient dans notre latitude géographique, variaient du Nord, par Nord-Ouest, Ouest et Sud-Ouest au Sud, comme le démontre la structure des dunes de la forêt de Kampinos [1] et du bassin de Płock [3].

Aucune dune ne peut se former sur des surfaces de sable, même étendues, mais dépourvues de végétation. Un exemple spectaculaire est fourni par le désert de Błędów (S de Pologne), où de petites dunes accompagnent les bords de la petite rivière ou bien se forment à l'abri de la forêt.

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V. SEDIMENTOLOGY

GENETIC INTERPRETATION OF LITHOLOGICAL FEATURES OF POLISH LOESS

Henryk Maruszczak

The recent score of years brought an accumulation of factual material enabling us to define fairly accurately the lithological and genetic features of Poland's loess deposits. On the whole, these features may be claimed to resemble those found in corresponding sediments of neighbouring countries. Even so, detailed analyses revealed that a number of indices refering to the features mentioned show seemingly slight yet, in fact, fairly important deviations from the standards adopted in a variety of synthetic publications and in textbooks. These deviations are convincing evidence of the divergent geographical conditions under which loesses developed in Poland. And this is why in dealing with the present problem, these unconforming features shall be discussed in the first place.

The author wishes to emphasize, that all the facts to be put forward in our contemplation refer exclusively to what are called the younger loesses which date back from the the Last Glaciation and which appear in their original sites of deposition. Incidentally, theirs is the dominant share among the loess covers of Poland. Older loess deposits are poorly preserved; usually they are rather transformed and relatively little investigated.

GRAIN FEATURES

It is characteristic of those Polish loesses which appear in well developed and thicker beds, that as a rule their grain size distribution is as follows: a) sandy grains of $>0{\cdot}1$ mm diameter constitute 0 - 10%; b) coarse silt from 0·1 to 0·05 mm — 10 - 20%; c) medium-size silt from 0·05

TABLE 1. Differences in grain size and carbonate content in the different facies of original loess covers from the Last Glaciation, depending on their geomorphological situation. Results of examinations of three loess profiles from the western bank of the Bystrzyca River in the city area of Lublin

Situation of examined profile	Loess facies	Depth in m from which sample was taken	Grain size composition, in percent values; grain fractions in mm								Mean grain size in mm	Carbonate contents in %
			1 - 0·5	0·5 - - 0·25	0·25 - - 0·1	0·1 - - 0·02	0·05 - - 0·02	0·02 - - 0·006	0·006 - - 0·002	less than 0·002		
Lublin - Helenów (brick yard) interfluve between Bystrzyca valley and Czechówka Zero of profile 217 m a.s.l. Distance some 5 km W from axis of Bystyrzca valley	eolian	2·1 - 2·6	0·5	0·2	0·4	9·9	52	22	5	10	0·028	11·07
		3·1 - 3·6	0·1	0·2	0·3	10·4	50	24	5	10	0·027	12·71
		4·1 - 4·6	0·1	0·1	0·4	10·4	50	23	7	9	0·027	10·25
		5·1 - 5·6	0·1	0·1	0·2	8·6	50	23	5	13	0·025	8·41
		6·1 - 6·6	0·3	0·2	0·3	9·2	49	23	6	12	0·026	8·00
		7·1 - 7·6	0·1	0.1	0·1	8·7	53	22	6	10	0·027	6·15
		8·1 - 8·6	0·0	0·2	0·1	8·7	51	22	6	12	0·026	6·36
		9·1 - 9·6	0·0	0·1	0·2	9·7	46	25	6	13	0·024	7·18
		10·1 - 10·6	0·1	0·2	0·3	6·4	45	29	6	13	0·021	8·00
		11·1 - 11·6	0·0	0·2	0·5	7·3	42	29	9	12	0·020	5·74
		Mean values for 10 samples	0·13*	0·16*	0·28	8·9	48·8	24·2	6·1	11·4	0·025	8·39
Lublin - Sowiński str. (brick yard) Slope of Bystrzyca valley (lower slope part)	eolian-deluvial	0·8 - 1·3	0·0	0·1	0·2	18·7	46	21	6	8	0·030	11·34
		1·8 - 2·3	0·1	0·2	0·3	18·4	48	18	7	8	0·030	9·66
		2·8 - 3·3	0·0	0·2	0·4	21·4	45	19	5	9	0·031	11.09
		3·8 - 4·3	0·0	0·2	0·7	18·1	45	20	7	9	0·029	11·75
		Mean values for 4 samples	0·03	0·17	0·40	19·15	46·0	19·5	6·3	8·5	0·030	10·96

Zero of profile 198 m a.s.l. Distance some 1·3 km W from axis of Bystrzyca valley	deluvial	4·8 - 5·3	0·6	1·5	2·8	19·1	44	17	7	8	0·032	8·56
		5·8 - 6·3	0·0	0·2	1·1	22·7	47	15	4	10	0·034	7·89
		6·8 - 7·3	0·1	0·2	0·6	21·1	47	16	8	7	0·032	7·81
		7·8 - 8·3	0·0	0·1	0·4	24·5	48	15	6	6	0·034	6·72
		8·8 - 9·3	0·1	0·7	0·4	24·8	49	11	5	6	0·037	5·46
		9·8 - 10·3	0·1	0·2	0·9	18·8	50	19	5	6	0·032	7·73
		10·8 - 11·3	0·0	0·2	1·9	21·9	51	12	7	6	0·035	5·54
		11·8 - 12·3	0·1	0·4	2·3	23·2	48	12	7	7	0·035	5·21
		Mean values for 8 samples	0·13	0·44	1·68	22·01	48·0	14·6	6·1	7·0	0·034	6·87
Lublin - Rury Wizytk. (sand pit) Overflood terrace of River Bystrzyca	eolian	0·8 - 1·3	0·3	0·7	1·4	26·6	45	14	6	6	0·036	13·02
		1·8 - 2·3	0·1	0·5	1·2	23·2	47	15	6	7	0·034	11·34
		2·8 - 3·3	0·1	0·6	1·9	24·4	47	14	6	6	0·035	10·50
		3·8 - 4·3	0·1	0·3	2·5	23·1	46	13	8	7	0·034	8·82
		Mean values for 4 samples	0·15	0·53	1·75	24·32	46·3	14·0	6·5	6·5	0·035	10·92
Zero of profile 187 m a.s.l.	alluvial	4·8 - 5·3	0·2	0·8	6·1	31·9	40	10	6	5	0·042	8·88
		5·8 - 6·3	0·1	0·9	6·3	34·7	40	8	6	4	0·044	7·14
		6·8 - 7·3	0·5	3·3	19·4	30·8	29	8	4	5	0·056	5·88
		7·8 - 8·3	0·9	5·6	23·4	31·1	29	6	2	2	0·068	5·04
		Mean values for 4 samples	0·43	2·65	13·80	32·13	34·5	8·0	4·5	4·0	0·049	6·74

* Apart from quartz grains there occurred numerous $CaCO_3$ concretions, or their fragments, in samples taken from 6.6 to 7.6 m depths.

to 0·01 mm — which is the basic component — 40 - 70%; d) fine silt from 0·01 to 0·005 mm — 5 - 15%; e) clay of < 0·005 mm — 10 - 20%, where colloidal clay of less than 0·001 mm accounts for no more than 5 - 10%. The figures show, that the Polish loess has a relatively high coefficient of sorting — a feature much resembling that of the loesses of Volhynia and Podolia [17]. Worthy of attention is the slight share of clayey fractions — a share notably lower than found in the loesses of Western Europe [1, 9] as well as in Bulgarian [8] and in South-Ukrainian [17] loesses. This grain size feature seems to be the main factor, why Polish loesses — judging by the density of the gully network cutting them [24] — are more readily subject to erosion; no wonder, since the matrix cementing the larger grains consists of the clayey fractions combined with carbonates.

The above pattern of grain size distribution refers principally to typically eolian loess facies, and often it does not take in the deluvial or alluvial facies, because in comparison they usually contain more of the coarse and less of the finer fractions than are found in the basic fraction (Table 1). Still, no distinct regularity has been observed in this respect. There are regions, where the deluvial and alluvial facies differ only little from the eolian facies [15]; elsewhere it happens, that the alluvial fraction is better sorted and contains more of the basic fraction than the eolian facies [29]. This is why in his further reflections on grain size distribution the author does not take into consideration the deluvial and alluvial facies.

Characteristic of the eolian facies of the Polish loess is its average grain size, from 0·020 to 0·040 mm; most often this average lies between 0·025 and 0·035 mm. These figures are evidence, that the predominant part of the material of Polish loess deposits is derived from near — by sites — a fact pointed out long ago by A. Malicki [19]. Grains brought in from afar — from distances of the order of hundreds of kilometers — show mostly sizes ranging from 0·05 to 0·003 mm. This has been distinctly established by examinations of atmospheric dust which at present is arriving to Poland from far Ukraine [36, 38]. Hence a grain brought in by far transport is some 100 to 1000 times heavier than that of the average grain found in Polish loesses. The significance of these figures is outright tremendous! The authors who persist in their opinion that long-distance transport has been predominant, are falsely interpreting the result of measurements of the dust grains deposited during dust storms [30].

Further proof of the predominance of local, i.e. short-distance transport are also the differences in spatial and topographical distribution of grain sizes in the eolian loess facies. In depressed areas and, especially, in overflood terraces of larger valleys, the grain averages a much greater size than on higher surfaces near watershed lines. A detailed example illustrating this fact from near Lublin (Table 1) shows, that the difference in weight of average size grains, found in two extreme situations mentioned, is like 1 : 0·36. This indeed seems to be a very convincing scale of spatial differentiation, which undoubtedly has been dependent on the carrying capacity of near-surface winds and on the distances from where locally the dust orginated. Had long-distance air transport predominated, no such differences would have been possible.

This leads to the conclusion, that the mean grain size in the eolian facies of Poland's loesses has been contingent on the velocity of local winds, as is also shown by a comparison with loesses from other regions. Comparisons of this type are not easy to make, because it is inadmissible to correlate grain size measurements made by unlike methods. For precluding errors the author took into account only measurements made by identical methods in south-eastern Poland and in regions of the lower Danube basin. In the former area the mean grain size is some 0·028 mm, in the latter it is 0·022 mm. Hence the grain of Polish loess is about twice as heavy as the Danube grain. This estimate agrees fairly well with the result obtained from a reconstruction of the velocity of winds which has accumulated the loesses in the two correlated areas. By entirely different criteria it has been established, that the mean velocity of these winds has presumably been in Poland slightly below 3·0 m/sec while about 2·0 m/sec on the lower Danube [23].

On the other hand, much more difficult to determine is whether the main grain size of the Polish loesses shows definite differences dependent on their regional-geographical situation [11, 15, 16. 21, 28, 32]. The typical facies of eolian loesses observed in various regions of southern Poland do not show any essential differences in grain size. This disavows the theory commonly accepted in older Polish publications that a distinct disunion exists between zones of loess alimentation and zones of loess sedimentation [13] and, indirectly, this endorses the belief that spatially these two zones are interdented [14, 19, 20]. Thus we now assume that the sources of loess dust in Poland have been widely scattered; according to H. Maruszczak [22] this has been one of the specific features of the conditions under which in the periglacial zone of the eastern part of Central Europe loess accumulation has been taking place. As far as loesses were accumulating in the temperate zone of Europe, the sources of loess dust were more definitely localised in areal extent; this is indicated by differences in loess grains found both along the lower course of the Danube and in directions perpendicular to the course of this river [8].

Much less information is on hand on the morphology of loess grains. Authors of older papers report this grain to be mostly angular [35]; more recent authors hold that the quartz grains, even those of the silty loess fraction, are fairly well rounded [32]. So far, however, J. Butrym [2] and J. Cegła [4] are the only authors who have published the results of their quantitative examinations of grain abrasion in the silty fraction of Polish loesses. Among the quartz grains of the 0·1 - 0·005 mm range they found: 24 - 65% angular, 20 - 65% partly rounded, and 4 - 27% well rounded grains. Easier than the silty grains to examine would have been the sandy loess grains; but as to these, little research was undertaken so far. Published data as well as archival material in the author's possession indicate that in the 0·25 - 0·1 mm fraction angular grains account for 10 - 30%, partly rounded grains for 40 - 60%, and well rounded grains for 15 - 35%. In the 1·0 - 0·5 mm fraction there are: 0 - 5% — and exceptionally 9% — angular, 5 - 50% partly rounded, and 40 - 95% well rounded grains. On top of this, the sand grains show a high degree of matting, and by this they closely resemble analogous fractions of dune sands [23]. Incidentally it seems worth mentioning, that not much lower are the indices of rounding and matting for corresponding grains of slope and fluvial deposits encountered in Southern Poland near loess beds. And because the latter deposits may have been the source material of loess dust, one may conclude from the data presented above, that the effect of one cycle of eolian action must have been relatively small. From the correlation of a variety of data H. Maruszczak [23] assumes, that this effect was limited to an increase of barely a few, at most some 10% in the share of well rounded grains in the 1 0 - 0·5 mm fraction. This is why one must ascribe the high index of quartz grain rounding in the loesses for the most part to their complicated geological history. These grains must have been displaced many times, every time subject to a variety of destructive forces, until they came to rest at the place from which they became the source of loess deposit formation.

The author's attempt of correlating loesses occurring in the eastern part of Central Europe revealed, that Poland's loess deposits show an exceptionally high index of grain abrasion. As an illustration of this fact is seems worth mentioning that, for instance, in the Roumanian loesses the 0·25 - 0·1 mm fraction consists of 40 - 95% angular, 5 - 55% partly rounded, and barley 0 - 5% well rounded grains [23].

This clearly indicates, that a more complicated geological history of the grain and, at the same time, a high index of its rounding constitute a further most important feature, by which the Polish "periglacial" loess differs from what is called the "temperate climate" loess of the type found in the lower Danube basin.

CHEMICAL AND MINERALOGICAL PROPERTIES

The chemical composition of the Polish loess shows little differences both in spatial extent and in the individual vertical profiles. Silica (SiO_2) strongly predominates and represents 67 - 82% of the sum of the chemical components. Apart from this it is only aluminium oxides (Al_2O_3) which occur in greater quantity, but never more than 10%; next are calcium oxides (CaO) and iron oxides (Fe_2O_3) [11, 16, 21, 28, 36]. How much of each of these components are represented depends on the grain size of the analyzed fraction. Thus, the percentage of silica changes — with regard to the values mentioned for the whole test sample — in plus in the coarser fraction (rising to 98%) and in minus in the fine fractions (dropping to some 50%) while, obviously, the share of the remaining components undergoes inverse changes [11].

Remarkable is — as pointed out much earlier by J. Tokarski [35] — the particularly high share of SiO_2 which is higher in Poland than in the Western-European [1, 9, 33], the Bulgarian [26] and the South-Ukrainian [17] loesses; a share similar to that of Poland show the loesses of Volhynia [17, 35] and Bielorussia [3, 7]. Hand in hand with the exceptionally high share of SiO_2 goes a small share of the remaining components which for the most part are of low resistance to destruction. The result is, that the source material of the Polish loesses is characterized by a high index of weathering and transformation with regard to its mother rock types.

Among the chemical components worthy of special comment are the carbonates characteristic of the Polish loesses. For the most part it is calcium carbonate ($CaCO_3$), because usually magnesium carbonate ($MgCO_3$) occurs only in negligible quantities. In unweathered Polish loesses the carbonate content mostly varies between 4 and 18% while the average for whole profiles is 7 - 10% (Table 1); and this content has proved almost identical in all Polish loesses so far investigated [11, 15, 16, 21, 28]. It should be noted that, on the whole, a definitely higher carbonate content has been determined in all those countries mentioned above where the silica content is lower than in Poland. Also observed was, that in the Polish loesses the carbonates occur as: grains of limestone rocks, detritus of organogenic forms, calcite dust, fissure coatings (pseudomycella), root effervescenses, and various types of concretions. Grains of limestone rocks and detritus, representing probably the most original forms from the phase of transport of loess material, appear only in minor quantities; predominant among them is calcite dust which is fairly evenly distributed throughout the deposit and which usually accompanies the silty and clayey loess fractions. Together with colloidal clay this dust forms the substance, which covers the quartz grains and in this way "cements" the loess bed [16]. These features of the calcite dust are evidence of the transformations which must have taken place in the deposit after it had accumulated. All the remaining carbonate forms which might be called forms of a later carbonate growth, did not develop either until the epigenetic phase of transformations after accumulation had reached its end. The new forms, like concretions, are of relatively small size, mostly of the order of 2 - 4 cm, exceptionally of more than 10 cm diamater [5]; most probably this was caused by the relatively small total quantity of carbonates in the Polish loesses.

The different forms in which the carbonates occur are convincing proof, that the epigenetic transformations during and directly after accumulation have had a decisive effect upon the development of the typical loess features. This refers in the first place to some sort of compactness and, connected with it, a marked porosity of the loess deposits. Even so, the relatively small carbonate content has the effect, that this compactness is lower than in the loesses of western Europe and, particularly, of south-eastern Europe. This seems to be a second feature due to which the Polish loess is relatively readily subject to erosion.

Relatively little research has been undertaken on quantities in the composition of the light minerals, and few data are found in literature on this subject. For all this it can be said, that there is a definite prevalence of quartz which usually appears in a share of 60 - 77%; in the coarsest sandy fractions this index rises to 90 - 95%. Second place is usually taken by feldspars, though their share is slight, only about 5% and barely 2 - 5% in the coarsest fractions. Among the feldspar varieties orthoclase occurs most frequently; less often found are microcline and plagioclase [11, 16]. Among further components muscovite and biotite might be mentioned which — mostly in the coarser fractions — occupy fourth or fifth place. A fairly characteristic accessory mineral is glauconite which, incidentally, also appears in the group of heavy components; while it occurs in small quantities only, it is found in the majority of the samples examined [11, 16]. This seems worth mentioning, since undoubtedly this mineral is mostly derived from sedimentary local rocks of Poland's loess zone.

As to the components of light minerals the Polish loesses resemble very much a variety of periglacial loose deposits adjacent to them in the field. For the most part the differences observed are caused by differences in grain size of the individual genetic groups of these deposits. Very distinct features of similarity come only to light when comparing, for instance, the sandy fractions of the Polish loesses with dune or fluvial sands [22, 23]. This similarity is clearly emphasized, when the data mentioned above with regard to the Polish loesses are compared with corresponding data on sands of different origin [31].

As matters stand today, the composition of the heavy minerals appears to be better known than that of the light minerals. To be sure, the total share of heavy minerals in the Polish loesses is extremely small, barely some 0·1% on the average (Table 2); even so, their investigation leads to interesting conclusions. The group of heavy minerals shows a distinct predominance of components of highest resistance (zircon, tourmaline, rutile, distene, staurolite) over less, or little, resistant components (garnet, epidote, amphibole, pyroxene, biotite). Most often zircon takes first place, much less often garnet or other minerals [10, 11, 12, 21, 25, 32, 36]. Today in greatest detail known is the group of heavy minerals found in the loesses of the Lublin Upland. To this loess area refer most of the series of analyses hitherto published, 47 in all, which have been made by one author (Table 2, Item 19). In this series the sequence of the four principal components is as follows: 1) zircon 38%, 2) garnet 20%, 3) rutile 14%, 4) tourmaline 10%. The ratio of the most resistant to the less resistant minerals in this series is 1 : 0·47. In other regions of this same loess zone the sequence of the main components is much the same (the Cracow Upland for instance); or there occur differences insofar as that the third, here and there even the second place is taken by amphibole (like in the Głubczyce Plateau and the NE part of the Sandomierz Upland). In the last-named group of regions the ratio of components of different resistance tends definitely to an increase in the divisor, i.e. in this case of the components easier subject to destruction; thus, at Buszkowice (item 13 in Table 2) this ratio is 1 : 1·04, and the mean value of this index, illustrating the degree of weathering of the heavy mineral group, approximates for Poland's loesses the ratio 1 : 0·7.

As far as the composition of the heavy minerals is concerned, the features of the Polish loesses often show proportions intermediate between those of the bedrock adjacent to the loess zone and those of glacial deposits [10, 12]. For instance, when in the neighbourhood local bedrock predominates, the heavy mineral group of the loesses contains a higher share of more resistant components (like most of the loesses of the Lublin Upland). Where, on the other hand, the region contains lobes of deposits of glacial origin, the share of the less resistant components is higher, especially that of garnet and amphibole (as observed in the NE periphery of the Sandomierz Upland). This shows, that the composition of the heavy minerals convincingly indicates the local provenance of material building the Polish loesses.

A group of heavy minerals similar to that occurring in Poland can be found in the Volhynian [35, 36] and Bielorussian [7] loesses, whereas

TABLE 2. Composition of haevy minerals in unweathered Polish loesses from the Last Glaciation

No.	Region and locality where samples were taken from	Number of analyzed samples (in brackets depths in m from which samples where taken)	Share of haevy minerals in weight %	Opaque minerals in %	Share of transparent minerals in percent values (for Σ=100%)														Author of analysis, and source of data given in Table
					amphibole	apatite	biotite	chlorite	distene	epidote	glauconite	garnet	pyroxene	rutile	staurolite	tourmaline	zircon	others	
	Sudetes foreland and Głubczyce plateau																		
1	Wadachowice, 20 km NE of Ząbkowice Śl.	1 sample (3·0)	0·06	28	11	2	8	3	2	6	+	22	4	9	1	3	29	–	R. Racinowski (unpublished)
2	Ciepłowody, 14 km NNE of Ząbkowice Śl.	1 sample	?	40	–	2	–	–	–	–	–	23	3	7	–	10	37	18	W. Raczkowski [32]
3	Sudetes Foreland (near Rogów and Henryków)	mean of 6 s.	?	?	7	2	9	1	1	2	+	20	3	9	1	6	30	8	R. Racinowski and W. Raczkowski
4	Racibórz-Ocice	1 sample (1·5)	?	32	18	–	–	–	–	6	–	10	4	9	4	4	44	–	M. Krysowska [6]
5	Racibórz-Ocice	mean of 5 s. (1·5 - 3·2)	?	33	16	–	–	–	–	7	–	12	2	6	2	5	47	2	Idem
	Carpathian foothills																		
6	Wadowice	1 sample	?	32	6	–	–	4	–	3	–	18	–	8	3	8	46	4	M. Krysowska [34]
7	Pikulice (1) near Przemyśl	1 sample (ca 1·0)		21	–	–	–	1	–	2	–	46	–	12	1	5	26	7	A. Kęsik (unpublished)
	Cracow Upland																		
8	Zwierzyniec near Cracow	1 sample (ca 2·0)	0·04	30	4	–	10	–	7	–	–	21	—	4	4	11	29	9	J. Tokarski et al. [36]
9	Zwierzyniec near Cracow	mean of 6 s. (1·0 - 7·5)	0·10	36	5	–	7	–	5	–	+	23	–	5	4	6	35	10	Idem

	Holy Cross Mnts and Sandomierz Upland																		
10	Brzezie, 30 km ENE of Kielce	1 sample	?	?	8	—	—	—	5	1	—	32	—	8	3	2	41	—	B. Grabowska-Olszewska [11]
11	Kania near Opatów	1 sample	?	?	11	—	—	—	3	6	—	23	—	13	—	3	41	—	Idem
12	Buszkowice (5), 10 km NE of Opatów	1 sample (2·0)	?	?	18				6	20		17		7	4	7	20	—	B. Grabowska [10]
13	Buszkowice (5), 10 km NE of Opatów	mean of 7 s. (2·0 - 6·5)	?	?	15	—	—	—	5	13	—	23	—	10	2	7	25	—	Idem
14	Gołębice near Sandomierz	1 sample	?	?	11	—	—	—	4	7	—	24	—	8	2	5	39	—	B. Grabowska-Olszewska [11]
	Lublin Plateau and Roztocze																		
15	Kazimierz on Vistula River	1 sample (4·0)	0·12	36	10	1	3	1	1	—	+	14	—	18	1	11	40	—	R. Racinowski [25]
16	Lublin-Rury 1	1 sample (10·75 - - 11·25)	0·06	20	5	1	3	—	1	1	1	26	—	9	2	10	41	—	Idem
17	Góry, 20 km W of Zamość	mean of 9 s. (1·8 - - 16·8)	?	?	8	6	—	—	3	5	—	23	—	11	1	4	39	—	J. Malinowski [21]
18	Zaporze, 30 km WNW of Zamość	mean of 3 s. (1·5 - 3·5)	?	?	6	—	—	—	4	7	—	31	—	12	6	8	25	—	Idem
19	Lublin Plateau and Roztocze	mean of 47 s.	0·10	29	6	+	4	1	3	1	2	20	+	14	2	10	38	—	R. Racinowski [25]

this group differs markedly in the countries situated SE of Poland where it contains a considerable share of less resistant components. As an illustration of this let it be said, that in the basin of the lower Danube the ratio of the more resistant to the less resistant heavy minerals is 1 : 1·54 in Roumania and 1 : 2·44 in Bulgaria [25]. This comparison clearly indicates, how much the group of heavy minerals in the Polish loesses differs by its exceptionally high index of weathering.

Little investigated so far is the composition of clayey minerals, and up to now it has been almost exclusively examined qualitatively. A method of analyzing quantitatively, suggested by J. Tokarski [36], has never been put to use on a larger scale in loess research. Up until today, the most comprehensive examination of clayey minerals in loess deposits has been made by B. Grabowska-Olszewska [11] for the Sandomierz loesses. This author, applying a variety of research methods, demonstrated that these loesses contain a marked predominance of illite, with kaolinite and montmorillonite rather present as accessory minerals; similar results were found for the loesses of Western Roztocze [21]. On the other hand, S. Uziak [37] discovered that characteristic of the loesses of eastern Poland is an interstratified series of illite and montmorillonite and that, in some instances, montmorillonite takes first place. However, quantitative analyses made for the loess profile from Lublin-Rury revealed illite to constitute 70 - 80% and montmorillonite 5 - 25%, while kaolinite mostly appears in mere traces [1].

Hence we must assume, in spite of the present rather fragmentary status of research, that among the clayey components illite plays the dominant role. And it must be concluded, that the chemical processes which produced this group of minerals, took place mainly under conditions of a fairly humid and not very warm climate, and in an environment distinguished by a rather acid soil reaction.

Of similar importance is illite in the group of clayey minerals determined in the loesses of the Bielorussian forest zone [7] and in the forest-steppe zone of Volhynia and Podolia [17], while in the steppe areas of southern Ukraine occurs an illite-montmorillonite or montmorillonite-illite combination [17, 18]. Likewise in the Bulgarian loesses the part played by montmorillonite and kaolinite, apart from the usually dominant illite, is more pronounced than in the Polish loesses [27].

The results obtained from chemical and mineralogical examinations clearly indicate, that significant for the Polish loesses are: a) the auto-

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[1] The composition of the clayey minerals in the loess profile from Lublin - Rury has been determined in Amsterdam in a chemical laboratory run by Professor J. P. Bakker. The present author is indebted to his colleague Dr A. Kęsik for granting him access to the results of these examinations.

chthonous derivation of their material, and b) compared with the original components represented in the various primary rocks, a strong pauperization in the share of their less resistant components. The comparison with neighbouring areas implies, that these features are the mark of the zonal geographical conditions under which the loess material has been formed, as indicated by the similarity with the Bielorussian and the Volhynian-Podolian loesses or, to be exact, by the intermediate position between these two which the Polish loesses hold. Like the foreign loesses mentioned, in Poland they have developed under similar geographical conditions during the Quaternary. In the Pleistocene, the areas of southern Poland, of southern Bielorussia and the NW part of the Ukraine where these loesses occur, have all been alternately situated in a glacial, a periglacial, and a temperate zone. Today they all lie in the zone of mixed forests of a temperate climate or the zone of a forest-steppe. The oft-repeated climatic changes undoubtedly furthered a destruction of the mineral deposits covering the ground surface. This must have occurred under conditions in which soil similar to podsolic type has been formed, with a rather effective leaching of the less resistant components. This is why the Polish loess is poorer in regard to its mineralogical composition than the Western European loess, where the raw material of the loess was mostly formed by processes typical of the brown soils of leafy woods. The material of the rich Bulgarian and, particularly, the South-Ukrainian loesses has developed under conditions of a definite predominance of the processes forming the steppe-chernozem soils.

The chemical and mineralogical shortage of the raw substance of the Polish loesses is too marked to be explained merely by destructive forces supposedly active during only one loess-forming cycle. Undoubtedly involved were complicated and diversified transformations to which this substance has been subject during the long periods preceding its sedimentation. In consequence, our interpretation of the chemical and mineralogical examinations leads to the same conclusions as those obtained from our studies of loess grain abrasion.

CERTAIN PHYSICAL PROPERTIES

Among the physical properties of the Polish loesses considered from the viewpoint of the problems dealt with in this paper, particular attention should be given to their porosity and their tendency of subsidence.

The porosity index of unweathered loess, deposited during the maximum of the Last Glaciation, varies in Poland between 40 and 50%, with 42 - 45% as mean values [11, 15, 16, 21]. In horizons of weathered loesses, i.e. decalcified and loamy, this index drops and is mostly 35 - 40%.

A similar porosity show the loesses of Bielorussia [3, 18] and of Volhynia and Podolia [17]. Higher values were determined for the loesses of South Ukraine where the porosity reaches values as much as 56 - 63%. with averages of 45 - 48% [17, 18]. Also higher is the porosity of typical Bulgarian loesses; their mean value is 46 - 50% [27].

The relatively low porosity of the Polish loess is closely linked with the pecularities of its grain and its chemical and mineralogical composition. Particularly significant in this respect is the slight content of colloidal clay and of carbonates which form the cementing matrix of the Polish loess.

The subsidence is the term applied to the tendency of settling (a compacting of the particle structure) which loesses show upon saturation with water. For the youngest unweathered loess beds from the maximum of the Last Glaciation this index of subsidence under loads of 3kg/sq. cm is 2 -3% and, rather rarely, as much as 6% [11, 16, 21]. Older loesses, the more so when weathered, show usually an index of less than 2%, so that their structure may be considered stable. Similar is the subsidence index for the loesses of Volhynia and Podolia, while these values are markedly higher for South Ukraine and Bulgaria where they average 5 - 10% [17, 27].

This shows that, generally speaking, the structure of the Polish loesses is relatively stable — a feature closely connected with their slight porosity. This is why they are only slightly affected by the evolution of suffosion processes, which account for the formation of drainageless depressions of the *stiepnyie bludtsa* type and which in Polish loess areas are less common than in Bulgaria or the Ukraine [24].

CONCLUSIONS

The most important conclusions to be drawn from the analysis of grain features and from chemico-mineralogical and physical examinations of the Polish loesses may be formulated as follows:

1. The material forming the Polish loess shows sundry evidence of its autochthonous origin, especially: a) morphological grain features similar to those found in periglacial dune, slope and fluvial deposits near loess banks; b) mineralogical features resembling those of both the deposits mentioned and the local strata forming the substratum, as well as glacial and fluvioglacial deposits occurring in southern Poland.

2. The loess material shows a strong pauperization with regard to some of the substances which originally were part of the bedrocks. This is seen in the predominance of components of highest resistance over those less resistant, noticeable in the groups of both light and heavy minerals. This paucity is so marked, that it cannot be ascribed only to the forces which might have been operating during one single loess-forming cycle. Implying indirectly that the loess substance go back to a complex and manifold geological evolution. Proof are the high values of grain abrasion which can only be explained by assuming, that in the past the grains have been affected by a variety of agencies operating in a number of successive cycles.

3. In appearance the Polish loesses come nearest to the loesses of Bielorussia and Ukraine, being placed halfway between one and the other. On the other hand, they differ considerably from the loesses of western and south-eastern Europe by the indices of destruction of their substance. This suggests that the Polish loess shows features of a zonal-geographical type. The characteristic traits of this loess forming material have developed in the Quaternary under conditions, in which repeatedly changes have occurred between a glacial, a periglacial, and a more temperate climate. This must have furthered the displacement of loose grains from place to place, and their exposure to the action of a variety of destructive agencies. The marked pauperization of the chemical and mineralogical composition of these grains is presumably the effect of weathering and soil-forming processes of a type resembling podsolization — processes characteristic of zones of mixed forests which were a common feature of phases of a temperate climate. On the other hand, the substance of Western-European loess, less pauperized and less destructed, developed for the most part in zones of leafy woods, while in south-eastern Europe these zones were rather forest-steppes and steppes.

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The stamp of an autochthonous origin of the Polish loess indicates, that the material it consists of was mostly derived from local sediments of various origin. Under definite physico-geographical conditions there was formed in these sediments a dust — the source material from which loesses developed. Thus it must be assumed that, by protogenetic stages, processes of transformation and weathering of the mineral material have played an important part in creating the features the loess shows today. Even so, this does not mean that one can explain the origin of the Polish loess from the viewpoint of eluvial and weathering hypotheses, or of the more complex, intricately conceived geochemical theory in K. I. Markov's approach (1965). The assumption of a decisive role played by geochemical processes is thwarted by the grain composition of the loess, because the high coefficient of sorting of this deposit can only have been achived by an eolian agency. And only the selective capacity of this agency can have produced these thick covers of fairly homogenuous deposits which emphasize the grain size of the predominant basic fraction. This appraisal of the effect the eolian agency must have had, is by no means contradicted by the autochtonous origin established for the Polish loess, because it must have been developing with a marked co-action of local near-surface winds. This latter belief is supported by both the indices and the weight data of the mean loess grain and the differences found for these indices, depending on the ground relief. Only the older, traditionally conceived opinion that long-distance transport of dust particles has predominated, would imply an allochthonic derivation of the basic substance of the loess.

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GEOGRAPHIA POLONICA 17, 1969

POSITION OF BOULDER CLAY AMONG OTHER SEDIMENTARY ENVIRONMENTS BASED ON SOME GRAIN ABRASION PARAMETERS[1]

Bogumił Krygowski

INTRODUCTION

It is a well known fact that boulder clays have a special place in the big family of different sediments, representing different sedimentary environments. Their position in this family was, however, determined mainly in a descriptive way, without respecting grain abrasion parameters. Just these parameters are discussed in this paper from the point of view of their usefulness for the determination of boulder clay position, as well as its nature.

The following parameters, seen also in Fig. 2. have been used:

a) grain abrasion index — W_0[2]
b) heterogeneity index of grain abrasion — N_m
c) frequency of histogramic types of grain abrasion

Ad a) The formula of the grain abrasion grade is as follows:

$$W_0 = 2400 - \frac{\sum(nk)}{N} \cdot 100 \qquad \text{(see Krygowski, [7])}$$

where: W_0 — index of abrasion
n — number of grains in angle classes
k — mean angle characterizing a given angle class
N — number of grains in sample examined

Ad b)

$$N_m = Q_3 - Q_1$$

where: N_m — index of heterogeneity
Q_1 and Q_2 — quartiles

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[1] Examined quartz grains only.

[2] The abrasion index has been determined on bulldozer graniformameter [6, 7, 10].

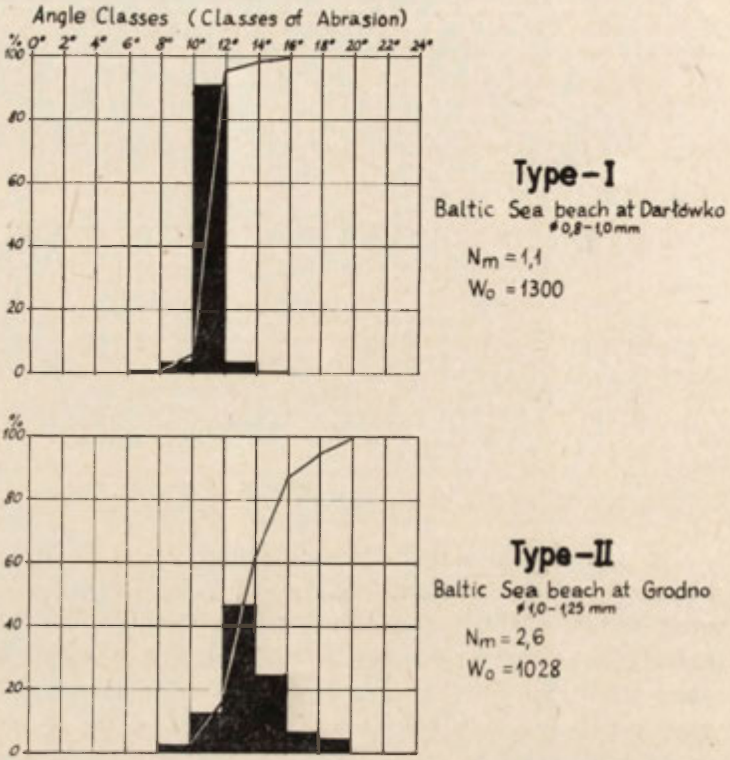
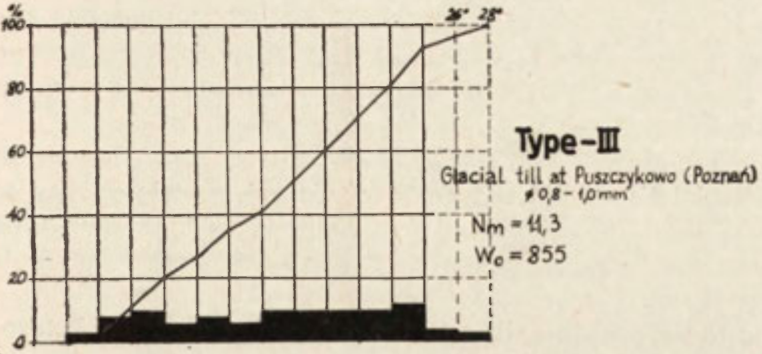


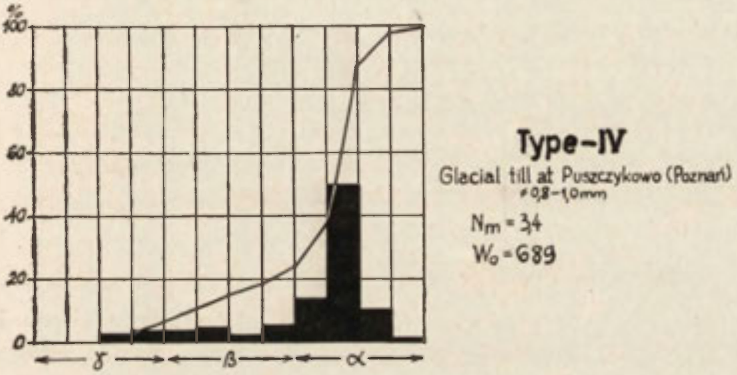
Fig. 1. Main histogram types of sand abrasion (=types
grain, p — moderately,

Ad c) Basing on several hundreds of grain abrasion histograms representing different sedimentary environments four main histogramic types have been distinguished [3, 4]. In this paper only the main types are discussed (Fig. 1).

Type I shows a histogram with an extreme vertical tendency, just expressed by one high column, one abrasion class (angle of glassplate 10° - 12°) embracing almost 100% (strictly 91%) of the total analyzed grain sample. Such a histogramic type indicates that an extremely strong shape-sorting process dominated in the environment represented by it (Baltic Sea beach — Fig. 1). It is connected with the rhythmical, monotonous wave movement of water on the beach slope. Thus the low heterogeneity ($N_m = 1{\cdot}1$) of the beach sand abrasion.

Type III is an antagonist of type I. The histogram shows a distinct horizontal tendency expressed by the presence of more or less the same amount (%) of grains in all abrasion classes. It means that in this case the dynamics was quite different if compared with the former. The deposition was chaotic because of an almost ideal absence of the shape-





of dynamics) in sedimentary environments (γ — well abraded α — angular grain)

-sorting process in this environment, i.e. in the environment of pure glacial clay when the deposition was a result of the glacial ice only, without collaboration of active water.

Similar histogramic types are also characteristic for other environments, e.g. for the dune ones.

Type II represents histograms having a transitional position between the both former types I and III. Its Gauss-like distribution would indicate that both tendencies vertical and horizontal, acted here more or less in equilibrium. Due to the heterogeneity index value — N_m amounting to 2·6 it seems that the dynamics, registered by this histogramic type, is nearer to histogram Type I ($N_m = 1 \cdot 1$) than to histogram type III ($N_m = 11 \cdot 3$).

It is worth mentioning that histogram type II is characteristic for sea beach sand and especially for river sediments.

Type IV (bi-and poli-modal)[3] is probably a combination of at least

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[3] Term used according to Pettijohn [11], p. 34, 35, Krumbein [2] and others.

two histogramic types, in our case of types II and III. Supposedly the sand sample represented by this histogram reflects a mixture of two different sands, shape-sorted in two different sedimentary dynamics: one acting chaotically and the other sorting according to shape.

The shape-sorting process because of a short transport distance in the given case (glacial till) could not destroy this sui generis duality of the sand [4]. I would like to mention that such dualistic sedimentation type is not easily found, for instance, in the sea beach environment, but it is often found in the rivers.

If we arrange the types according to the increasing abrasion heterogeneity N_m-values we shall get a different succesion of types than in Fig. 1. It is as follows:

Type	Heterogeneity index of grain abrasion N_m
I	1·1
II	2·6
IV	3·4
III	11·3 [5]

Ending the brief description of the four main histogramic types it should be stressed that we are finding in some sedimentary environments all the types presented above. It is, undoubtedly, an interesting fact indicating that all dynamics can take place in seperate environments. Though the frequency of seperate types in a given environment is decisively most important. Just the frequency values of main histogramic types allow to determine the sedimentary dynamics in the given environment and so to determine the kind of the environment itself.

NATURE AND POSITION OF BOULDER CLAYS IN THE LIGHT OF SOME GRAIN ABRASION PARAMETERS

Let us now interpret Fig. 2 including different sedimentary environments, characterized by means of a few parameters, described above.

A remarkable difference can be easily found between the separate environments, especially in the range frequency of grain abrasion expressed by histogramic types.

In no case the presence of two environments expressed by the same abrasion parameter values is met, although some similarities are found.

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[4] The origin of bimodal histograms was similarly explained by several investigators [1].

[5] The highest possible N_m-value is 12.

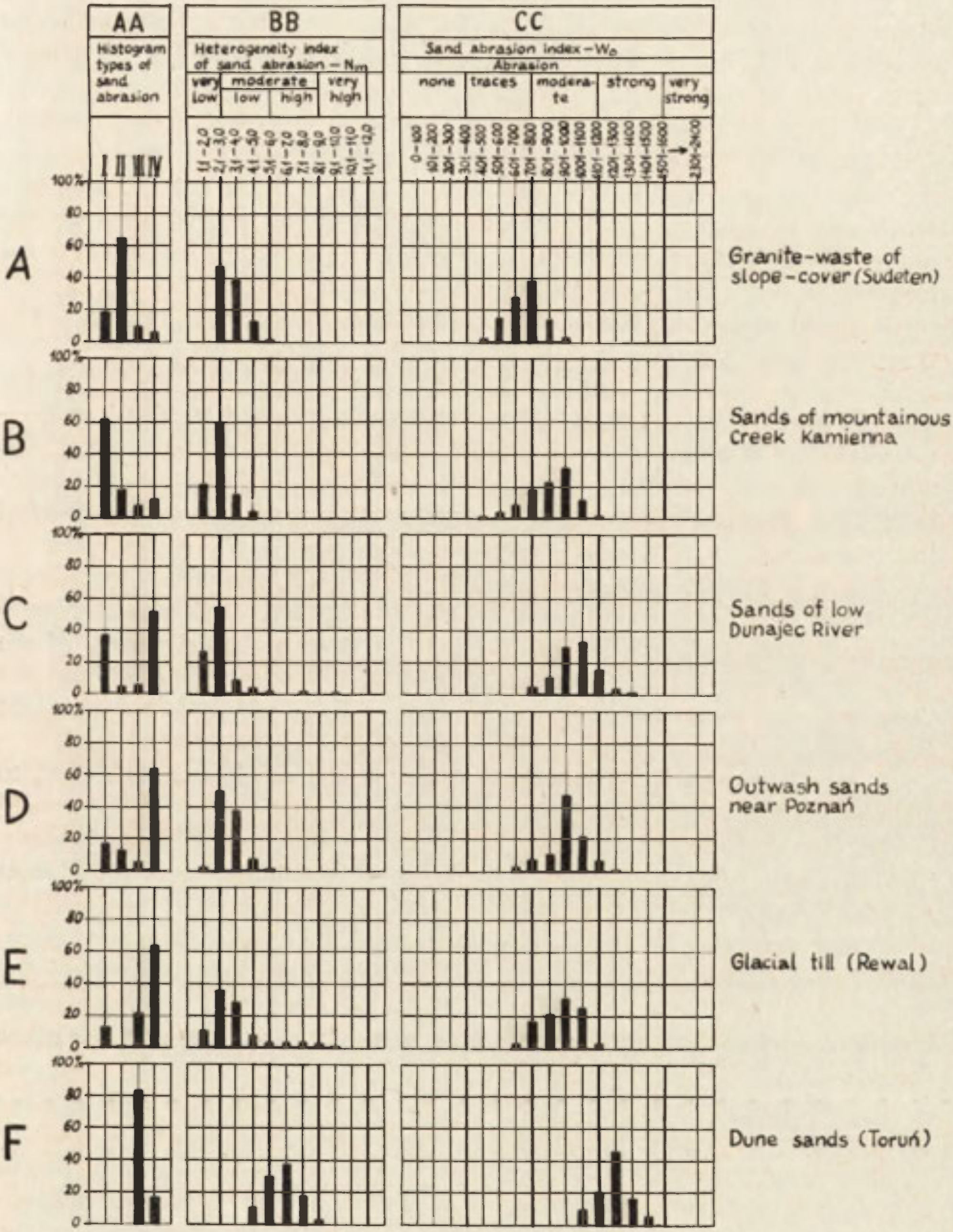

Fig. 2. Sedimentary environments (A, B, C, D, E, F) in light of some sand abrasion parameters (zones: AA — histogramic types. BB — N_m, CC — W_0

The first environment (Fig. 2 A) namely the granite waste of the slope-cover (Sudety Mts — Karkonosze) is characterized by the maximum of type II (65%). Type I is in the second place (18%). The high frequency of these types, which in other environments, as for instance in fluviatile ones, reflects a shape-sorting activity, has here, a rather primary origin, connected with the textural charakter of granites.

Therefore the maximum frequency of type II does not express, any sedimentary dynamics. We can say that, it is not a true sedimentary environment, but primary source material not changed by sedimentary agents.

It is necessary to keep this fact in mind analyzing the other, i.e., true sedimentary environments.

The granite slope-cover material (Fig. 2A) described above, which made already a short way in the mountainous creek (Cr. Kamienna) — a typical abrasion mill[6] — represents quite a different picture (Fig. 2B) when compared with the former environment. The very strong shape-sorting, a result of extremely active flowing water, has been reflected in the high column (above 60%) representing type I.

This process has been registered in the distinct growth of the homogeneity of grain abrasion, shown by the heterogeneity index (Fig. 2, zone BB) amounting to low values only (up to 3). A remarkable growth of the abrasion degree (W_0) in comparison with the former environment, has been noted by the shift of the whole W_0 column silhoutte to the right (zone CC).

A small transport distance in a mountainous creek was sufficient to change the grain abrasion picture of the primary material.

The lower Dunajec River (Sub-Carpathian Basin — Fig. 2C) having, in comparison with mountainous rivers, small gradients, gives a different picture.

Two maxima in the frequency of dynamical types can be seen here: type I (frequency 47%) and type IV (52%). The first represents the dynamics with a strong tendency to shape-sorting the other a "collaboration" of two dynamics: an ordering one (shape-sorting) and the other causing chaos.

In the grain abrasion process (Fig. 2, zone CC) there is further progress.

The dune environment (Fig. 2F) represents a peculiar picture in the light of the considered parameters. It is quite different from the environments characterized above. The "chaotic" dynamics, expressed by the high frequency (above 80%) of type III is here dominating. Type IV —

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[6] Term used for instance by Pettijohn [11].

already an expression of the shape-sorting process — has been registered with 18% only. It would mean that the chaotic "sedimentary" tendencies are a feature of high rank for the dune environment. It has been reflected in the low heterogeneity index values (Fig. 2, zone BB), too.

The abrasion grade of grains (Fig. 2, zone CC), expressed by high abrasion index values (W_0 between 1000 and 1500) indicates a well known fact in literature [1] that dune sands are abraded most.

What is the position of boulder clays in this sui generis "classification"? The succession of columns (Fig. 2, zone AA), representing the frequency of the four main dynamic types. is different when compared with other environments, described above. The highest frequency (column) representing type IV is most important here.

According to the opinion quoted earlier in this paper is should mean that a cooperation of two tendencies: ordering and disordering the deposition process, was most decisive here. The rather remarkable frequency of type III (above 20%) shows also that this dynamics — an expression of extremaly chaotic sedimentation — was taking part in the formation of boulder clays. It shows, moreover, that in this case the morainic material was deposited without the action of water. Contrary to the former case, it may be that the intensity of crack — and crevasse — water has been registered, just by high frequency of type IV, described already above.

Further (Fig. 2, zone BB) a wide distribution of the heterogeneity frequency — N_m (columns from 1·1 up to 10) expresses the chaotic nature of boulder clays well.

The abrasion (Fig. 2, zone CC⁻) is in general more edvanced than in the first two environments (A, B) but remarkably lower in reference to the eolian environment.

A great similarity with the outwash environment (Fig. 2 D) in all parameters can be understood. The outwash sand represents, as it is well known, the product washed out of the boulder clay. In spite of this process the outwash sand lost hardly anything from the features of boulder clay, what is seen in the parameters above.

Basing on the analysis, presented above, it seems to be possible to determine the nature of the boulder clay environment more exactly than before.

1. The fact that the frequency of type IV grows up to 63% indicates that such kind of boulder clay is most typical, i.e. such kind which was formed at the direct ice accumulation at its bottom and with some activity of the flowing water (mainly in cracks and crevaces).

2. The other kind of boulder clay, registered by type III, was formed

when the water agent was absent and when a clean ice accumulation at the bottom was met. The frequency of this type amounts only to 22%. This type of boulder clay, representing, no doubt, the most glacial, clean glacial kind of clay is less frequent.

3. If we add that the remaining types II and I already represent dynamics with intensive water activity, keeping in mind type IV (also "water-like") then the absolute prevailing of the "ice-water" boulder clays is apparent (together above 75%). "Clean ice" clays have the second place (with above 20%).

4. The above data lead also to the following conclusion: the more "water"-like is the clay the higher number of craks and crevaces in the ice must have existed.

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GEOGRAPHIA POLONICA 17, 1969

SELECTED PROBLEMS OF LITHOLOGY AND PETROGRAPHY OF THE BOULDER CLAYS IN CENTRAL AND EASTERN POLAND

Roman Racinowski, Jan Rzechowski

INTRODUCTION

The boulder clay is the characteristic deposit in the regions covered with ice-sheet during the Quaternary. The common appearance of boulder clays, their widespreadness and lithological individuality cause that this kind of glacial deposits may perform the task of indicator horizons for stratigraphy of glaciated areas. That is why the determination of lithologic-petrographical properties of boulder clays posesses particular importance, because such a characteristic makes it in turn possible to recognize their lithotypes. Only the knowledge of features of different lithotypes of boulder clays (stratigraphical, regional etc.) allows for an exact stratigraphical correlation, as well within the limits of one region as in relation to other regions.

Keeping this in mind, the authors accomplished a paper of complex characteristic of the lithology of boulder clays in Central and Eastern Poland [44]. This characteristic is achieved through make-up and heuristical interpretation of the results of about 5,000 granulometric, petrographic, mineralogic, morphoscopic and geochemical analyses. For this research were sampled 60 bore profiles of a maximall thickness of Quaternary deposits more than 300 m and 38 exposures. For the purpose of completing the complex picture the authors made-up and recalculated the results of examinations of other authors of about 20 profiles, among which materials there were some as yet unpublished. The result of this work is an extensive monograph of lithology of boulder clays, which with regard to lack of space in this report can not be presented as a whole.

That is why the authors determined to present below with large shortenings of course only materials characterizing the most important properties of boulder clays of the Eopleistocene and Mezopleistocene, i.e. clays of the oldest glaciation (Podlasie Glaciation, after **S. Z. Różycki [50]**)

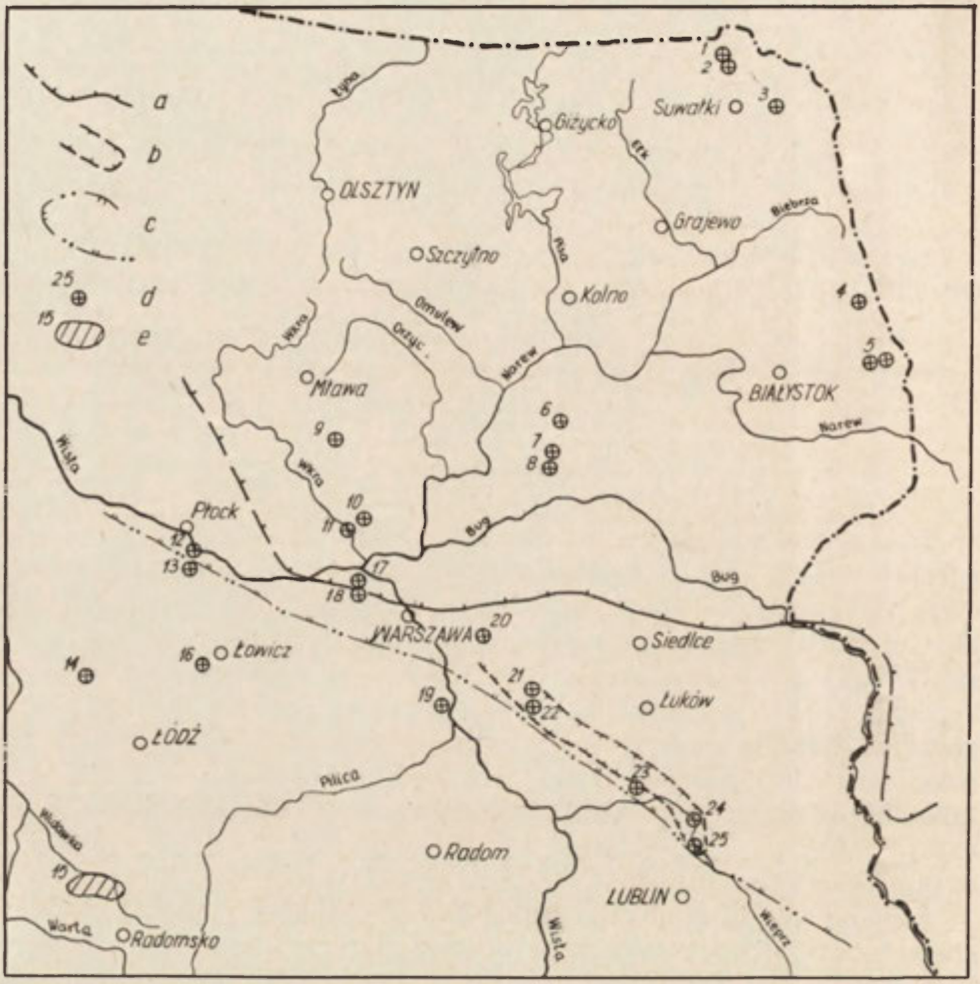

Fig. 1. Dislocation of examined profiles and geological cross-sections

Explanations: *a* — Limit of the Oldest Glaciation after S. Z. Różycki [50]; *b* — hypothetical border of Lublin ice-tongue (Lublin lobus?); *c* — hypothetical limit of the appearance of boulder clays of the first stage of Cracovian Glaciation; *d* — examined profiles or cross-sections with relative number (analogous as in the tables); *e* — area of middle Widawka river basin (with 11 boreprofiles)

and of the South-Polish (Cracow) Glaciation. On such a choice was of influence among others the fact, that these horizons of boulder clays up to the present are very little known and their correlations are therefore open to discussion.

For the treatment bore profiles were choosen which bore through the Quaternary deposits of large thickness: usually of more than 100 m and often of more than 200 m. Moreover in such profiles appear some

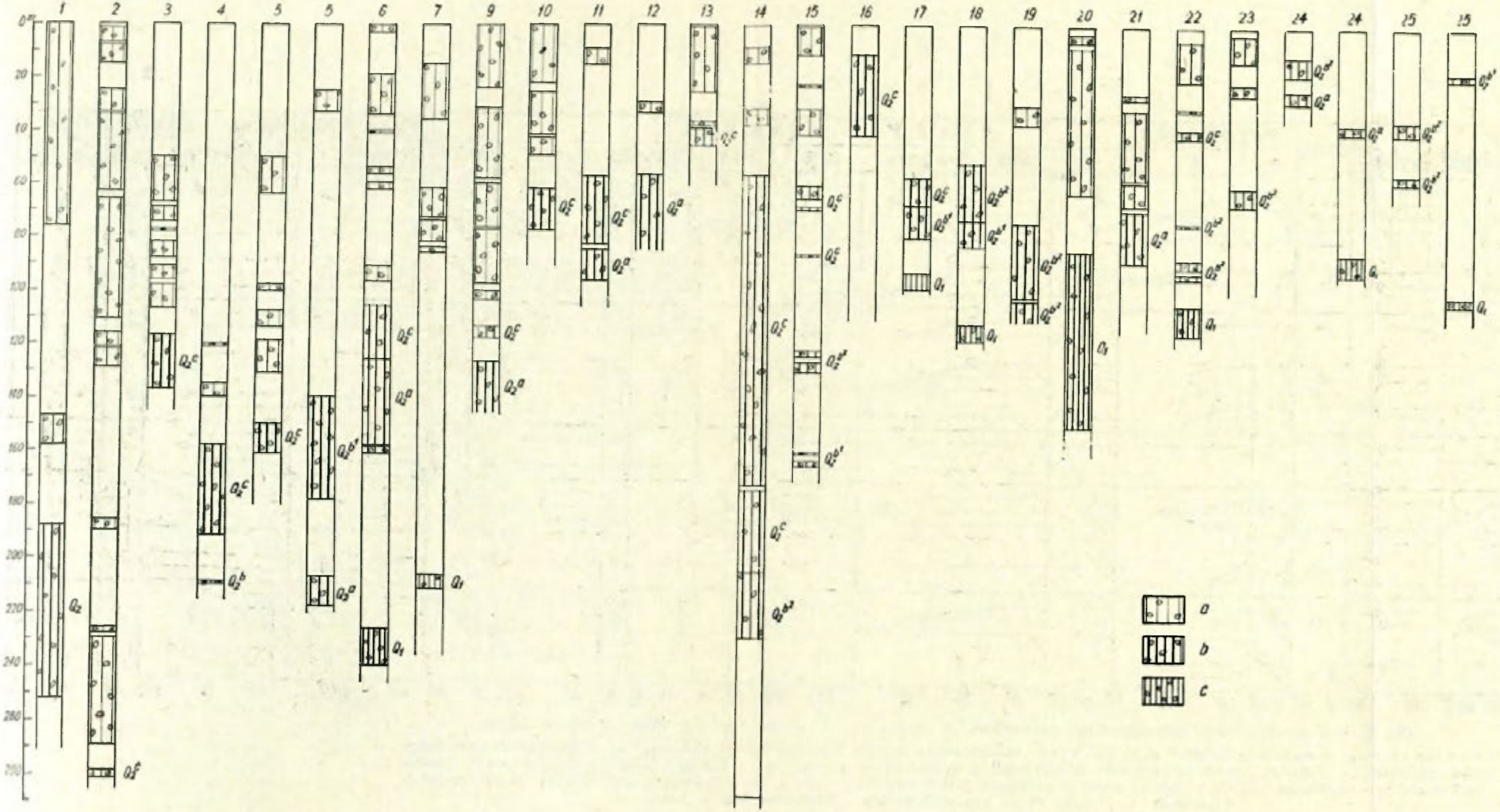

Fig. 2. Schematic lithological profiles of examined bores

Explanations: numbers 1, 2 . . . 25 as in Fig. 1, *a* — boulder clays of Middle-Polish (Q_3) and North-Polish (Q_4) Glaciations, *b* — boulder clays of Southern-Polish (Mindel) Glaciation, *c* — boulder clays of Oldest (Günz) Glaciation; stratigraphical symbols: Q_1 — Oledst Glaciation, Q_2a — first stage of Southern-Polish Glaciation, Q_2b^1 — older phase of the second stage of Southern-Polish Glaciation, Q_2b^2 — younger phase of the second stage of Southern-Polish Glaciation, Q_2c — third stage of Southern-Polish Glaciation.

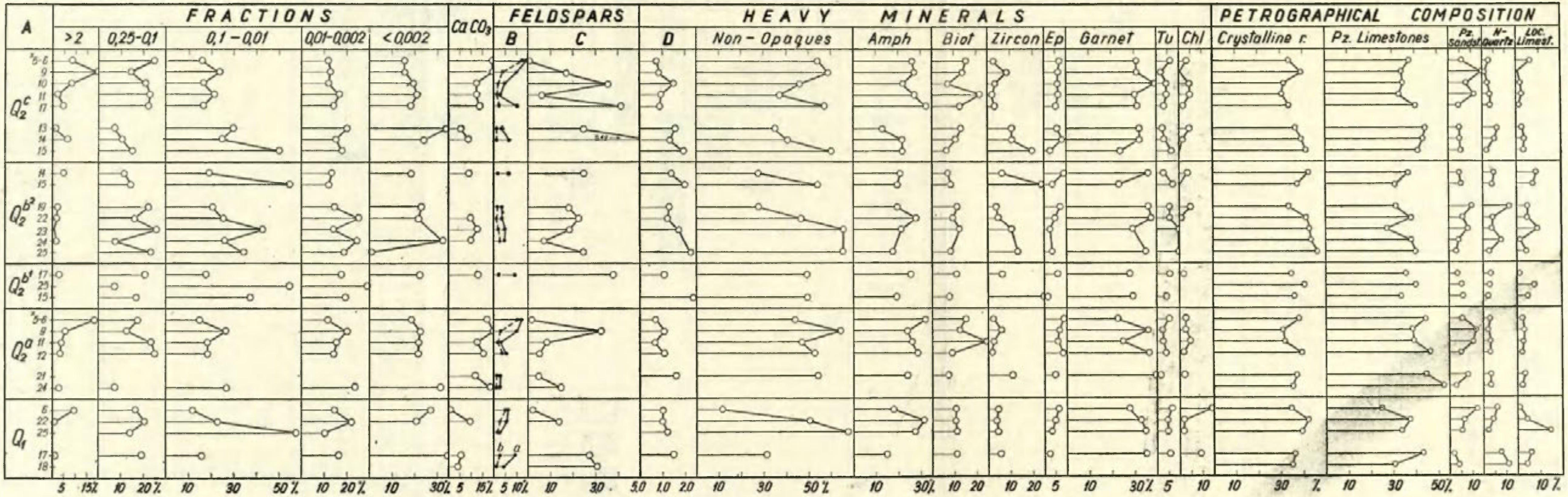

Fig. 3. Certain mineralogic-petrographical parameters of boulder clays (plotted on the bassis of mean values)

Explanations: stratigraphical symbols as in Fig. 2, A — stratigraphical symbols and numbers of profiles, x — petrographical composition from Kruszyniany — profile [5] and others parameters from Tyszki [6], B — contents of feldspars, *a* — feldspars total, *b* — plagioclases; C — feldspars index; D — weathering coefficient (index); Amph — amphibole, Biot — biotite, Ep — epidote, Tu — Tourmaline, Chl — chlorite; in petrographical composition: r. — rocks, Pz. — Paleozoic, Sandst. — sandstones, Loc. — local.

horizons of boulder clays, every one of large thickness as well. The further condition for the choice was the presence of interglacial deposits of which the stratigraphical position was already defined by way of paleobotanical analysis. This last condition was fulfilled in some key-profiles, which are at present principal for stratigraphy of Quaternary of this area (cross-section at the Szurpiły, Ostrów Mazowiecka, Ferdynandów, Serniki, Brzozówka, Dobiesz and profiles at basin of the Widawka River — see Fig. 1 and 2). These basic profiles or geological cross-sections moreover have, fully elaborated not only boulder clays but all kinds of Quaternary deposits. The correlation of all other profiles with key--profiles is realized by way of comparison and analogy. With this correlation was made use of published and handwritten materials which were kindly made available by a large group of geologists from Geological Institute and in particular by M. D. Domosławska-Baraniecka, S. Gadomska, A. Makowska, J. Nowak, Z. Sarnacka, A. Ber, J. E. Mojski, A. J. Nowicki and S. Skompski [1].

Several of the examined profiles (Grzybowo, Tyszki, Ostrów Mazowiecka, Sielc, Serniki) were lately interpretated by Z. Michalska [29, 30], S. Z. Różycki [49] and K. Straszewska [66], on the basis of macroscopic description.

Within the first two glaciations are dealed out some stratigraphical units having the range of stage and phase S. Z. Różycki [49, 50]; E. Rühle [53]): in the Podlasie Glaciation two stages and in the South-Polish Glaciation three or even four stages. In the profiles where the lithology of boulder clays was examined, this research succeeded in distinction of five horizons of clays of this age among which several bipartite. The oldest of these horizons was designed to the Podlasie Glaciation (Günz) and the four younger ones to the South-Polish (Mindel) one. Beside the above given causes about the choice of the assumed profile for the research decided its localization as well, i.e. the principle that the examined profiles, if possible, should be equally distributed over the studied area was observed (Fig. 1 and 2). Despite of this, in several regions more profiles were examined than in others — which can be concluded from the lack of bore profiles representing the mentioned requirements in several parts of eastern and central Poland.

Samples for laboratory examinations were collected with intervals of 0·5 m or 1·0 m. Several profiles, however, had samples collected every 0·25 m, but there were profiles as well in which it was necessary to

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[1] We thank all mentioned persons cordially for the putting within our reach of their own materials in the form of description of bore-profile and cross-section, as well as samples of boulder clays. At the same time we express our gratitude for their penetrating and fruitfull discussions.

connect samples of intervals of 2·0 m, because of the rather small volume of the bailer sample. The key profiles possessed core samples and the others marchdrilling samples. Of every examined interval of profiles an assay sample of clay was collected for mineral and geochemical analyses: the rest of samples were washed to obtain the gravel fractions for petrographical test. Methods and procedures of performing the analyses were discussed in detail in another article [61]. In this place it may be stressed that for the results of the analytical datations full statistical elaborations were realized. Lack of space, however, permits to present only the mean values of properties of different horizons of boulder clays, and to give the deviations from the means.

BOULDER CLAY OF THE OLDEST GLACIATION (PODLASIE GLACIATION)

Among the examined geological profiles boulder clay of the oldest glaciation appear in: Tyszki, Ostrów Mazowiecka, Borowie, Serniki, Brzozówka and Dębły (Figs. 1, 2). In these profiles, as well as in others in this area, below the deposits of Cromerian Interglacial only one horizon of boulder clays is found. This clay lie mostly immediately on bedrocks of the Quaternary [9, 11, 29, 30, 31, 36, 55, 60, 66]. In the granulometry of boulder clays of this age an influence of local Quaternary bedrock is clearly visible. Namely the fraction, which is the main part of local bedrock dominates in the boulder clay. So in northern and central Mazovia dominates the fraction with a diameter lower than 0·002 mm, which is connected with the appearance of pliocene loams in the bedrock. On the other hand on the foreland of the Lublin Upland a mixed influence of local sandy or silty tertiary deposits is marked (Table 1).

Besides argillaceous fractions the main component in clays of the oldest glaciation is the fine sandy fraction (0·25 - 0·1 mm). In the northern parts of Mazovia this clay is much more gravelly than further South. In the interval of 100 km appears a tenfolded decrease of the contents of gravel material. In the same distance the contents of the coarse sand fraction decreases more than twice while the quantity of medium sand material remains constant. At the same time takes place an increase of the contents of all fractions in the diameter limits 0·25 - 0·002 mm (Table 1). The biggest increment here show the aleuritic fractions (0·1 - 0·01 mm).

Carbonate contents of the oldest clays increase from 0·7% in Tyszki to 9·5% in Borowie and 4·0 - 5·7% in the neighbourhood of Warsaw. This feature has a close connection with the lithology of bedrock too. Borowie for example lies in the area of appearance of Cretaceous carbonatic rocks. The low contents of carbonate in clays of the Warsaw Basin is probably connected with the presence of Pliocene uncalciferous deposits in local bedrock. On the other hand such a low calciferousity of clays of the northern and central part of Mazovia, however may be connected with the exaration of old weathering covers through the inland ice (Table 1). This indicates also the low value of weathering coefficient of heavy minerals (Table 3). It is true that in certain of these profiles appear an unusal amount of plagioclases (in Tyszki — 5$^{0}/_{0}$), but this can be explained by a smaller distance from the Scandinavian alimentation area. The influence of old weathering covers is perhaps expressed in the large contents of chlorites too (Table 3). Share of these minerals decreases violently in southern direction which is a result of their small resistance

TABLE 1. Grain-size distributions of boulder clays (mean values)

Glaciations and stages			Localities (name and number from Fig. 1)	Percent of fractions with diameter of: (in mm)									
				over 2·0	2·0 - - 1·0	1·0 - - 0·5	0·50 - - 0·25	0·25 - - 0·10	0·10 - - 0·5	0·05 - - 0.01	0·01 - - 0·005	0·005 - - 0·002	below 0·002
Southern-Polish (Cracovian, Mindel) Glaciation	third stage		Sokółka (4)	0·2	1·9	8·5	14·3	35·6	21·4	17·9[c]	—	—	—
			Tyszki (6)	8·6	3·8	7·7	12·5	24·6	8·0	7·7	7·2	4·3	15.6
			Grzybowo (9)	19·8	2·4	5·1	6·9	14·3	12·8	10·9	7·2	5·2	15·4
			Świercze (10)	8·1	8·2	5·4	10·1	20·9	8·6	7·7	7·0	4·8	19·1
			Popielżyn (11)	1.9	1·0	5·5	10·6	22·8	10·5	10·5	10.3	6·1	20·8
			Brzozówka (17)	4·4	5·1	8·4	12·0	22·0	9·1	7·7	6·9	7·0	18·1
			Jadwigów (13)	1.1	0·7	2·9	4·9	7·1	14·2	15·5	11·3	8·4	33·9
			Łęczyca (14)	6·7	1·9	6·9	10·9	10·2	13·7	11·1	9·3	5·5	23·9
			Widawka (15)	—	2·3[a]	2·1	13·6	14·8	31·6	18·3	7·2	10·4[b]	—
	second stage	younger phase	Łęczyca (14)	4·6	3·2	14·6	15·9	11·2	11·8	7·2	7·6	5·4	18·3
			Widawka (15)	—	2·1[a]	1·3	15·0	14·3	25·4	29·0	7·7	4·9[b]	—
			Dobiesz (19)	2·1	1·5	5·6	11·6	21·9	9·5	11·1	8·0	6·1	22·5
			Borowie (22)	1·7	1·7	3·1	6·6	15·8	11·3	13·8	13·6	11·4	21·1
			Ferdynandów (23)	—	2·4[a]	4·1	11·8	25·6	23·8	18·6	6·7	7·1[b]	—
			Luszawa 7 (24)	1·3	0·5	3·3	5·3	7·2	12·4	13·4	16·8	7·4	32·3
			Serniki A (25)	—	6·5[a]	5·2	11·5	23·3	17·3	16·8	9·7	9·0	0·8
		older phase	Widawka (15)	—	2·6[a]	2·1	22·4	16·8	24·0	13·0	15·1	3.9[a]	—
			Brzozówka (17)	2·8	3·1	6·1	10·4	20·9	9·3	8·1	8·8	8·4	22·1
			Serniki C (25)	—	1·4[a]	2·6	4·8	7·6	27·8	26·8	12·8	16·0[b]	—
	first stage		Tyszki (6)	18·3	5·7	6·0	8·0	17·3	7·7	7·1	7·4	4·0	18·6
			Grzybowo (9)	5·4	1·8	4·6	7·3	12·6	14·4	11·9	11·7	8·3	22·1
			Popielżyn (11)	3·8	1·2	6·4	10·5	23·3	8·8	9·2	9·1	6·2	21·5
			Piaski (12)	3·3	1·6	5·6	10·5	24·9	9·8	8·3	10·1	4·1	21·6
			Luszawa 7 (24)	2·2	1·3	3·8	6·0	7·4	13·4	12·2	15·6	7·2	31·0
			Luszawa 8 (24)	3·0	0·7	2·1	3·9	7·3	13·1	14·9	14·1	9·7	31·1
Oldest (Günz) Glaciation			Tyszki (6)	9·3	4·2	9·4	8·1	16·4	6·6	5·0	7·2	7·1	26·7
			Brzozówka (17)	0·8	1·8	4·0	8·0	19·2	6·8	8·6	8·3	8·0	34·5
			Borowie (22)	0·3	0·9	4·6	8·9	20·6	12·4	10·2	10·7	11·2	20·5
			Luszawa 8 (24)	4.6	1·8	5·5	7·6	9·2	14·7	12·1	9·2	6·9	28·2
			Serniki C (25)	—	3·6[a]	6·2	9·1	13·9	34·5	22·7	5·0	5·0[b]	—

[a] — Fractions with a diameter over 1·0 mm
[b] — Fractions with a diameter below 0·005 mm
[c] — Fractions with a diameter below 0·05 mm

against destruction. In the same direction the contents of transparent minerals increases (nearly six-folded) and parallelly the participation of the opaque minerals decreases. The main minerals of the heavy fraction are garnets and amphiboles. There are more and more garnets and amphiboles the more to the South. Amphiboles however are at the same time much more numerous in eastern Poland. It is necessary to count, to the characteristic features of the oldest clays a permanent quantity of biotite (10·3 - 10·8⁰/₀) and a very low frequency of zircons and rutiles (lower than 5·0⁰/₀).

In the gravel materials of the oldest clay the main components are crystalline rocks (34·3 - 41·8⁰/₀) and paleozoic limestones (25·0 - 43·3⁰/₀)

TABLE 2. Carbonate contents and frequency of feldspars (mean values)

Glaciations and stages			Profiles (name and number from Fig. 1)	Frequency of feldspars			Feldspars index	Carbonate contents %
				K-feldspars KF	Plagioclases Pl	Feldspars total		
				%				
Southern-Polish (Cracovian, Mindel Glaciation)	third stage		Tyszki (6)	0·8	13·0	13·8	0·06	19·5
			Grzybowo (9)	6·3	3·7	10·0	1·70	19·6
			Świercze (10)	2·6	1·9	4·5	3·55	12·7
			Popielżyn (11)	1·0	1·7	2·7	0·59	12·6
			Brzozówka (17)	7·8	2·2	10·0	4·11	13·6
			Jadwigów (13)	2·4	1·2	3·6	2·44	5·0
			Łęczyca (14)	5·4	1·1	6·5	5·49	8·7
	second stage	younger phase	Łęczyca (14)	4·5	1·5	6·0	2·48	8·8
			Debły (18)	3·0	0·8	3·8	3·56	2·9
			Dobiesz (19)	1·8	1·4	3·2	1·80	—
			Borowie (22)	1·9	1·3	3·2	2·24	9·4
			Ferdynandów B (23)	2·8	1·9	4·7	1·82	12·5
			Luszawa 7 (24)	1·5	2·7	4·2	0·69	9·8
			Serniki A (25)	—	—	—	2·44	—
		older phase	Brzozówka (17)	7·1	2·0	9·1	3·78	12·9
			Debły (18)	3·0	1·9	4·9	2·05	3·8
	first stage		Tyszki (6)	1·6	10·2	11·8	0·14	16·6
			Grzybowo (9)	7·2	2·7	9·9	3·22	19·7
			Popielżyn (11)	1·0	1·7	2·7	0·83	12·4
			Piaski (12)	1·7	3·5	5·2	0·49	15·5
			Dębe Małe (21)	0·8	1·8	2·6	0·44	11·7
			Luszawa 8 (24)	1·4	1·1	2·5	1·46	18·3
Oldest (Günz) Glaciation			Tyszki (6)	0·5	5·0	5·5	0·20	0·7
			Brzozówka (17)	6·7	2·4	9·1	2·72	5·7
			Debły (18)	2·9	1·1	4·0	3·04	4·0
			Borowie (22)	2·6	2·5	5·1	1·36	9·5
			Luszawa 8 (24)	0·8	1·7	2·5	1·00	16·4

TABLE 3. Heavy minerals associations in boulder clays (mean values for the fraction 0·25 - 0·1 mm)

Glaciations and stages			Localities (name and number from Fig. 1)	Percentage of				Transparent minerals; quantitative percentage														Weathering index resistant: :non-resistant
				Heavy minerals total	Opaque minerals	Glauconite	Transparent minerals	A	Ap	B	Z	D	E	Gr	P	R	St	Sy	T	Chl	And	
								%														
Southern-Polish (Cracovian, Mindel) Glaciation	third stage		Tyszki (6)	1·15	40·2	6·0	53·8	26·0	0·4	15·4	2·4	2·0	6·4	31·0	2·2	2·0	2·8	0·8	6·0	3·2	—	0·72
			Grzybowo (9)	1·68	38·0	3·0	59·0	27·0	1·0	14·0	8·0	2·0	6·0	31·0	6·0	1·0	1·0	—	2·0	—	1·0	0·82
			Świercze (10)	1·00	44·7	9·5	45·8	21·7	0·3	7·2	3·1	2·5	5·8	39·0	2·5	3·7	4·2	1·5	4·1	4·3	—	1·48
			Popielżyn (11)	0·85	52·5	10·4	37·0	27·1	1·2	21·7	1·9	3·6	6·1	30·1	2·0	3·1	2·9	1·5	4·2	4·5	—	0·91
			Brzozówka (17)	1·30	30·1	12·6	57·3	32.4	0·6	12·6	3·0	2·0	5·1	31·3	2·3	1·7	3·3	0·6	3·6	1·4	0·1	0·84
			Jadwigów (13)	0·96	64·5	0·7	34·8	12·7	0·5	13·3	10·9	3·5	5·7	32·2	3·2	4·9	6·0	0·3	2·5	4·3	0·2	1·53
			Łęczyca (14)	0·83	57·2	2·3	40·5	21·4	0·6	10·7	10·4	2·3	7·8	32·0	2·2	3·1	3·2	0·8	3·4	1·6	0·1	1·30
			Widawka (15)	0·92	34·5	5·5	60·0	21·5	0·5	6·5	19·5	3·5	2·5	23·5	3·5	4·5	7·0	1·0	6·5	—	—	1·93
	second stage	younger phase	Łęczyca (14)	0·57	70·8	1·8	27·4	20·8	0·2	7·0	6·0	3·2	8·6	36·0	2·8	4·0	4·5	0·6	3·0	3·7	0·2	1·36
			Widawka (15)	0·83	40·8	5·4	53·8	19·2	0·8	8·6	23·4	2·4	3·6	22·8	2·2	7·2	2·6	—	7·0	—	—	1·99
			Dobiesz (19)	0·96	67·8	5·0	27·2	19·4	0·6	11·2	3·3	2·3	6·9	35·9	1·4	3·9	4·7	0·7	5·4	4·6	0·1	1·24
			Borowie (22)	0·89	49·3	4·3	46·4	28·0	1·7	9·7	4·3	2·0	4·7	37·3	2·0	1·7	1·7	1·0	5·3	0·3	0·3	1·21
			Ferdynandów (23)	0·93	27·7	7·0	65·3	21·3	—	12·3	10·3	2·7	2·3	28·7	1·4	7·0	4·0	0·3	9·7	—	—	1·70
			Serniki A (25)	1·07	27·8	6·9	65·3	17·6	0·7	8·4	12·9	2·3	3·3	34·6	1·6	4·1	4·4	0·3	9·7	—	0·1	2·21
		older phase	Brzozówka (17)	0·98	39·8	11·2	49·0	25·4	1·4	10·8	6·2	4·2	5·8	27·6	4·6	4·0	2·0	1·0	5·4	1·4	—	1·06
			Widawka (15)	0·87	44·0	6·5	49·5	19·5	0·5	8·0	25·0	1·0	1·0	29·0	1·5	7·5	4·5	—	4·0	—	—	2·33
	first stage		Tyszki (6)	1.71	37.0	19·2	43·8	32·1	0·5	15·0	2·2	3·5	8·3	22·5	2·8	3·0	2·0	1·1	5·2	2·5	0·1	0·66
			Grzybowo (9)	1·46	33·4	2·4	64·2	24·0	0·6	12·4	5·6	2·4	6·4	36·0	3·2	3·0	1·4	0·2	2·2	2·4	0·2	1·05
			Popielżyn (11)	1·03	45·0	8·2	46·8	26·2	—	24·3	2·5	1·8	5·7	24·7	2·0	1·8	2·5	1·5	2·5	4·5	—	0·62
			Piaski (12)	0·80	42·4	5·4	52·2	28·8	0·2	8·8	1·5	2·1	8·0	36·2	2·3	2·3	2·7	1·7	4·0	1·6	—	1·04
			Dębe Małe (21)	1·17	43·5	2·5	54·0	24·0	—	7·0	10·8	1·2	4·5	39·5	1·8	4·2	3·0	0·5	1·5	2·0	—	1·57
Oldest (Günz) Glaciation			Tyszki (6)	1·85	79·0	9·6	11·4	18·0	0·2	10·4	4·6	5·4	6·0	27·6	2·2	1·8	2·8	0·6	6·4	14·0	—	0·98
			Brzozówka (17)	0·82	61·3	7·3	31·4	15·0	1·3	10·7	5·3	3·7	2·0	35·0	3·3	3·3	5·7	1·4	5·3	8·7	—	1·45
			Borowie (22)	0·95	37·4	11·9	50·7	31·7	0·6	10·3	3·4	2·6	4·4	32·4	3·1	2·9	2·3	0·6	4·1	1·3	—	0·99
			Serniki C (25)	1·04	25·5	6·8	67·7	27·5	1·0	10·8	4·2	2·7	3·0	34·3	1·8	5·0	3·2	—	4·5	1·5	0·5	1·19

Explanation of symbols: A — amphiboles, Ap — apatite, And — andalusite, B — biotite, Chl — chlorites, Z — zircon, D — disthene, E — epidote, Gr — garnets, P — pyroxene, R — rutile, St — staurolite, Sy — sillimanite, T — tourmaline

TABLE 4. Petrographical composition of boulder clays (mean

Glaciations and stages			Localities (name and number from Fig. 1)	Scandinavian rocks					Limestones
				Crystalline rocks	Paleozoic limestones	Dolomites	Sandstones and quartzites	Northern quartzes	
Southern – Polish (Cracovian, Mindel Glaciation)	Third stage		Szurpiły (2)	38·1	43·4	—	5·3	4·8	5·2
			Krasnopol (3)	30·7	30·3	5·6	7·6	2·8	15·7
			Sokółka (4)	31·1	27·6	7·0	5·6	2·6	20·1
			Kruszyniany II(5)	33·4	37·6	0·2	4·2	2·5	6·7
			Kruszyniany V(5)	34·0	37·6	0·4	5·9	2·7	6·0
			Grzybowo (9)	39·3	34·0	—	14·9	1·2	—
			Świercze (10)	31·2	34·6	1·0	7·8	2·6	1·9
			Popielżyn (11)	30·4	33·1	0·6	11·2	3·4	2·4
			Brzozówka (17)	33·8	40·1	1·6	4·5	3·5	1·4
			Jadwigów (13)	36·5	44·4	0·4	4·7	6·7	2·5
			Domaniewice (16)	42·4	45·6	0·1	3·2	4·0	0·8
			Łęczyca (14)	39·0	43·4	0·1	4·8	5·2	3·6
			Widawka basin (15)	41·0	41·1	—	5·3	1·9	3·1
	Second stage	Younger phase	Łęczyca (14)	42·2	36·9	—	4·6	4·8	8·8
			Widawka basin (15)	37·1	30·9	—	5·5	4·0	7·3
			Debły (18)	40·8	33·4	—	6·3	2·9	10·5
			Dobiesz (19)	33·7	31·2	0·3	10·1	11·8	4·9
			Borowie (22)	41·3	38·0	0·5	5·8	4·2	4·8
			Ferdynandów (23)	42·4	27·3	—	8·2	4·0	9·1
			Luszawa 7 (24)	43·5	37·9	2·8	4·0	7·9	1·4
			Serniki A (25)	46·1	39·9	—	2·8	3·1	4·3
		Older phase	Kruszyniany (5)	35·4	35·7	—	4·8	2·5	6·1
			Brzozówka (17)	34·4	35·8	2·0	3·6	3·5	1·3
			Debły (18)	40·8	39·6	3·5	3·3	6·0	3·0
			Serniki B (25)	40·1	40·0	—	5·3	2·8	7·5
			Widawka basin (15)	35·4	33·4	—	5·9	2·1	4·9
	First stage		Kruszyniany (5)	37·4	44·5	—	5·6	2·9	2·3
			Grzybowo (9)	30·5	38·3	0·3	11·8	2·0	2·9
			Popiełżyn (11)	31·6	38·8	1·4	10·2	3·2	2·9
			Piaski (12)	38·9	46·2	0·4	4·9	2·8	2·2
			Dębe Małe (21)	36·7	44·6	1·3	8·0	3·3	3·0
			Luszawa 7 (24)	35·9	49·2	0·8	2·9	3·8	1·8
			Luszawa 8 (24)	35·0	55·5	0·2	2·2	2·7	2·1
Oldest (Günz) glaciation			Tyszki (6)	34·3	25·0	0·3	12·0	5·9	0·6
			Stojadła (20)	43·6	38·7	—	7·0	5·1	2·1
			Borowie (22)	41·8	37·0	0·7	6·1	4·3	3·9
			Serniki C (25)	39·1	33·7	—	5·1	2·0	14·5
			Brzozówka (17)	35·8	43·3	—	1·4	7·5	6·0
			Debły (18)	34·7	30·1	0·8	3·9	10·8	3·8

values for the fraction 5 - 10 mm)

Particles of local rocks						Petrographical coefficients*		
Sandstones	Tertiary quartz	Flints	Lydites and hornstones	Mudstones	Others	O/K	K/W	A/B
3·3	—	—	—	—	—	1·13	0·98	0·90
1·7	—	1·2	—	—	4·5	1·30	0·93	0·87
3·2	—	0·8	—	—	2·0	1·21	1·03	0·90
0·6	0·1	9·0	—	4·9	0·7	1·19	0·97	0·95
1·5	0·2	7·0	—	3·8	0·4	1·20	0·97	0·90
3·5	—	—	—	6·4	0·8	1·26	1·17	0·62
3·1	0·2	0·4	—	16·7	0·4	1·31	0·96	0·88
4·1	0·2	0·4	—	13·0	1·3	1·30	1·03	0·75
5·0	0·1	0·6	0·2	8·0	1·4	1·22	0·94	0·96
2·5	0·2	0·2	0·2	0·2	2·3	1·17	0·98	0·94
1·5	0·1	0·5	0·4	1·0	0·5	1·06	1·02	0·94
1·5	0·7	0·4	0·2	0·1	0·9	1·11	1·04	0·90
3·1	2·3	0·6	0·1	—	1·6	1·10	1·06	0·87
0·6	0·6	0·7	0·5	0·2	0·3	0·97	1·19	0·78
2·6	5·7	2·5	0·3	—	4·2	0·90	1·34	0·68
3·3	—	—	—	—	2·8	0·93	1·32	0·67
2·7	2·5	0·9	0·8	0·1	0·9	0·94	1·42	0·59
0·7	0·5	1·7	0·1	0·5	1·9	0·97	1·18	0·75
5·9	1·9	0·9	—	—	0·2	0·79	1·62	0·53
0·2	—	1·0	0·3	0·1	0·7	0·86	1·27	0·74
2·1	—	0·3	—	—	1·1	0·87	1·25	0·75
1·0	0·1	9·3	—	4·8	0·3	1·07	1·08	0·83
4·6	0·2	0·2	0·1	12·9	1·5	1·01	1·11	0·83
3·0	0·8	—	—	—	—	0·99	1·09	0·86
1·0	0·6	0·1	0·2	1·4	0·9	1·05	1·06	0·86
4·0	7·2	2·1	0·2	—	4·6	1·07	1·09	0·81
1·2	—	1·3	—	4·7	—	1·27	0·93	0·98
4·0	0·1	0·2	—	9·2	0·6	1·57	0·85	0·88
3·3	0·3	0·3	—	7·4	0·8	1·49	0·89	0·91
2·7	0·5	0·2	0·1	0·1	1·1	1·22	0·92	0·96
1·2	0·3	0·5	0·2	0·3	0·6	1·36	0·88	0·99
0·2	0·3	0·2	0·2	3·2	0·5	1·30	0·82	1·15
1·0	—	0·3	0·2	0·3	0·6	1·50	0·69	1·36
1·9	0·1	1·2	—	1·8	17·0	0·98	1·52	0·51
0·7	—	0·5	0·7	—	1·5	0·95	1·26	0·69
1·2	0·4	1·6	0·1	0·9	1·0	0·95	1·24	0·73
1·0	0·8	0·3	—	—	3·3	0·95	1·25	0·73
6·0	—	—	—	—	—	0·89	1·12	0·89
3·8	3·2	2·7	0·3	1·3	6·5	0·81	1·51	0·62

* O/K=sedimentary rocks/crystalline rocks, K/W=crystalline rocks/Paleozoic limestones, A/B=non-resistan rocks/resistant rocks.

with prevailence of the first ones, the reflection of which can be found in the values of coefficients K/W, fluctuating between 1·12 and 1·52. With regard to the frequency the third place have Scandinavian sandstones, northern quartz or local limestones. The quantity of the sandstones decreases regularly in southern direction, while the frequency of northern quartz increases (Table 4). Local limestones appear in different quantities, the highest share of which occurs in eastern Poland (Cretaceous substratum). This latest property confirms the supposition about the influence of local bedrock on the lithology of boulder clays, advanced on the basis of their calciferousity. Despite this petrographic variability the clays of the oldest Glaciation stand out with the homogeneity of the values of petrographical coefficients (Table 4). In this way the value of O/K index changes from 0·81 to 0·98; its values decrease southwards. A/B coefficent fluctuates from 0·51 in the North, to 0·73 in the South (in foreland of Lublin Upland).

The relative homogeneity of the oldest boulder clay is accordingly an important feature defining generally its stratigraphical lithotype — for the oldest glaciation.

The full lithological characteristic of the oldest boulder clay — connected with detailed elaboration of the key cross-section of quaternary deposits — permits among others to verify the courses of the limits of the Podlasie Glaciation. Serniki on the Wieprz River represent the southern most cross-section, where the appearance of boulder clay of this age has been confirmed (Fig. 1). It lies here on the bottom of the preglacial valley of the Wieprz River. Apart of these the oldest clay appears in Borowie (the foreland of Lublin Upland), in Debły, Brzozówka and Stojadła (near Warsaw). All these profiles are situated beyond the reach of the Podlasie Glaciation as defined up to now.

BOULDER CLAYS OF THE SOUTHERN-POLISH GLACIATION (CRACOVIEN)

Boulder clays of the Southern Polish Glaciation were examined in 31 representative profiles (Fig. 1, 2). Between the deposits of the Mazovian (Mindel-Riss) and Cromerian (Günz-Mindel) interglacials appear four stratigraphical horizons of boulder clays of which certain bipartite (Fig. 2). The two middle horizons were reckoned among deposits of two phases of the same stage i.e. middle or second stage. The lowest and highest clays have been defined as corresponding with the first and third stage. Between clays of all three stages appear lacustrine and fluvial deposits interpreted as interstadial [2, 3, 9, 10, 24, 28 - 31, 35 - 37, 44, 49, 50, 53, 55 - 57, 59, 60, 63, 64, 66, 73]. The idea of the tripartite character of the Southern Polish Glaciation is not a new one. Such a stratigraphical division has been lately presented by E. Rühle [53] and S. Z. Różycki [49, 50]; in the neighbouring countries by K. Richter [48], W. A. Chepulite [8] and V. P. Vonsavichyus [73].

FIRST BOULDER CLAY (FIRST STAGE) OF THE SOUTHERN-POLISH GLACIATION

The oldest stage of the Southern Polish Glaciation is represented by one boulder clay, which was confirmed in nine among the examined profiles. Clays of this stage reach their southernmost position East of Vistula River (Ferdynandów on lower Wieprz River). In the neighbourhood of Warsaw as well as in the Płock Basin this clay has not been found south of the Vistula valley.

The boulder clay of this stadial is generally more rich in sandy fractions but poorer in aleuritic and clayey material than clays of the previous glaciation (Table 1). The permanent contents of colloidal clay (diameter below 0·002 mm) calls attention. It amounts to 21·5 - 22·0% irrespectively of the region. The mode appears usually in the fraction of 0·25 - 0·1 mm in diameter.

Carbonate contents in this clay is several times bigger than in the oldest one and amounts from 11·7% in the foreland of Lublin Upland, to 19·7% in northern Mazovia. In the clay of the Płock Basin, originating from the Cracovian Glaciation calciferousity is similar (Table 2). Whereas in clays of the Podlasie Glaciation the calciferousity increased southwards, in this boulder clay we deal with a decrease of quantity of carbonates in the same direction. This phenomenon accompanies an increase of freshness of mineral particles. Among others this is expressed well by the index of feldspars, of which the value grows regularly smaller in Southern direction — irrespectively of region. This is the result of an increase of the frequency of plagioclases of a smaller weathering resistance with a parallel decrease of the K-feldspars share. The weathering coefficient of heavy minerals shows as well a decrease of value to the South, but still clearer from East to West (Table 3). In the same direction the contents of amphiboles and epidotes increases and the quantity of zircons decreases. Although the main component in the association of heavy minerals remained the garnets (up to 40%) this means that the frequency of amphiboles which does not drop below 24%, increased. In general it may be said that in this boulder clay the heavy fraction contains a higher share of resistant minerals, but besides there appear more components of scandinavian igneous rocks. At last, the quantity of such minerals as biotite and zircon changes very irregulary in a very wide scope. These facts may point to a larger heterogeneity of parent material of this boulder clay.

In the gravel fraction the crystalline rocks particles and paleozoic limestones dominate again, but these last ones prevail in quantity establishing up to 46% of all gravels. On the third place the scandinavian sandstones are deciding, which form 5 - 12% of the fraction of 5 - 10 mm in diameter. On the other hand northern quartz have a very law frequency (only 2·0 - 4·8%). Among the particles of local rocks, beside a small contents of limestones, attention calls the large percentage of mudstones (up to 9·2%). The petrographical coefficients of this boulder clay characterize a large values of O/K (1·13 - 1·57) and an imperceptibly larger values of A/B (0·87 - 0·99) than of K/W (0·85 - 0·98). The coefficients K/W and A/B show an exceptional large similarity, even in profiles placed in completelly different regions (Table 4).

BOULDER CLAYS OF THE SECOND STAGE OF THE SOUTHERN-POLISH GLACIATION

Boulder clays of the second stage appear in 11 of the examined profiles. Moreover, clay of an older phase were ascertained only in some profiles and possesses small thickness (maximally 7 m). The clay of a younger phase, however, is more spread and is characterized by a great thickness, often of more than 20·0 m. The southernmost localities having this clay are found on Widawka River (in the basin of middle Warta), on the mouth of Pilica into the Vistula and on the lower Wieprz.

The mechanical composition of these clays is marked with the predominance of sandy fractions on aleuritic material, with a very unequal contents of colloidal clay. This finds its expression particularly in younger clay whereas the older clay contains much more aleuritic material (Table 1). In both these clays and especially in the older one an important feature is a negligeable frequency of gravels. In the second stage of the Southern Polish Glaciation already takes place a clear regional differentiation in the graine size composition of clays. whereas older horizons of clays rather showed only changes in meridional direction.

Carbonate contents in clays of the second stage is several times lower than in clays of the first stage. This refers especially to the clay of older phase (Table 2). Certain regional differncies are marked here. Namely the foreland of Lublin Upland and the zone of Kuyavian-Pomeranian anticlincrium have much more calcareous clays than the Warsaw Basin.

The frequency of feldspars is exceptionally low (below 6·0%), beside the plagioclases are clearly less frequent than the K-feldspars. This fact is reflected in large values of feldspar index. Simultaneously a certain quantitative regularity is disclosed, namely, in one region the values of feldspars index are very similar. The association of heavy minerals expressed by the weathering coefficient shows a regularity of the same kind (Table 3). The spacious analysis of the values of this last coefficient reveals, that in every of the examined regions the frequency of resistant minerals increases in meridional direction. Heavy fraction contains as main components the garnets and amphiboles, but in several regions, e.g. in the basin of Widawka River, appear zirkons instead of amphiboles. Boulder clays of the second stage are above all characterized by a larger contents of tourmalines, especially in eastern Poland (up to 10%).

Principal feature of petrographical composition of gravels is an insignificant predominance of occurrence of crystalline rocks over paleozoic limestones particles (Table 4). The significance of local limestones is more important. Their frequency is more than twice as large as in both of the oldest clays. It is difficult to notice some regular, regional variability in contents of different kinds of gravels. This again is in disagreement with the huge homogeneity of values of petrographical coefficients (Table 4). This time the homogeneity concerns all three presented indices.

BOULDER CLAYS OF THE THIRD STAGE OF THE SOUTHERN-POLISH GLACIATION

Boulder clay of this stage appear in the examined profiles most commonly (Fig. 1 and 2), showing besides the largest thickness among all clays of the Southern-Polish Glaciation (often of more than 30 m). The anomaly in the all-Poland scale, which is the boulder clay from Łęczyca profile, having a thickness of about 150 m ought to be mentioned here (Fig. 4). This large thickness of clays in connection with a significant bigger frequency of coarse-particle fractions can prove about large thickness of the ice sheet. In other words, in the third stage the biggest transgression of inland-ice probably took place. This supposition is therefore the more essential because immediately after the third stage of this glaciation intensive degradation processes acted, despite which such thick layers of boulder clays were preserved.

The already mentioned sandiness of the youngest boulder clay of the discussed glaciation causse, that the finegrained sand is dominating in granulometric distribution. Besides, this clay contains much less clayey material than the older ones. Grain-size distribution shows however a clear regional differentiation. And so e.g. in the Płock Basin the clay of this age is decidedly clayey (Table 1), whereas in the drainage basin of Widawka River the aleuritic fractions dominates and in the remaining area dominate the sandy fractions already mentioned.

The calciferousity is again large but decreases from about 20% of CO_3Ca in northern Mazovia to about 13% in southern Mazovia (Table 2). The regions of Płock Basin and the Kuyawian-Pomeranian anticlinorium show here a significant peculiarity i.e. a lower calciferousity.

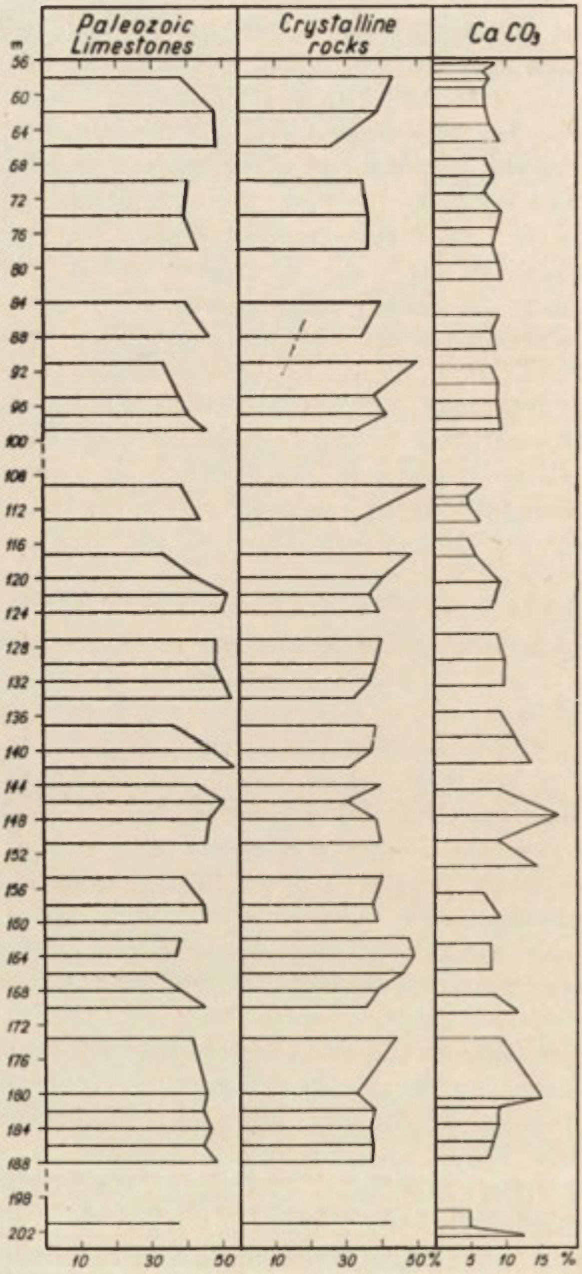

Fig. 4. Variability of certain petrographic components in the boulder clay of third stage of Southern-Polish Glaciation (Q_2c), from Łęczyca-profile

Among the feldspars a regular decrease of quantity of plagioclases is marked in southern direction. This feature also reflects the regional differentiation, a similar kind as the calciferousity. The general frequency of feldspars is higher than in the older tills of the same glaciation. The southward increase of numbers of resistant minerals is marked very clearly in the heavy fraction (Table 3). This can be ascertained especially in the statement of the values of weathering coefficient. Beside a little smaller quantity of amphiboles and garnets, the characteristic feature of the heavy fraction is her enrichment in epidotes and pyroxene, and especially in biotite. The presence of a larger quantity of minerals little resistant on weathering proves about the freshness of boulder clay of this stage.

The petrographical coefficients of the youngest clay of the Southern-Polish Glaciation have also very similar values. The characteristic distribution of these coefficients is a clearly bigger value of O/K than of K/W and A/B; besides the coefficient K/W has insignificant higher values than A/B (Table 4). In the gravel material the paleozoic limestones dominate over crystalline rocks, but there are profiles where the proportions are opposite. In both these cases however. the quantitative difference is very small. Among other components the presence of dolomites in nearly all profiles and a clear domination of mudstones in local materials draws the attention. The Scandinavian sandstones decrease their frequency quickly in southern direction. In the same direction the number of northern quartz increases (Table 4).

In the mentioned clay from the Łęczyca profile a regular rhythm of changes in the petrographic and mineralogical composition is ascertained. This rhythm depends e.g. on a many-fold increase of paleozoic limestones contents in the layers of clay of a stable thickness of about 9 - 10 m. In all these clay layers there appears an increase of quantity of limestones of a similar value — in the top part it is about 8% and in the lower part about 15 - 17% (Fig. 4). It may be suggested that this cyclical changes of the petrographical composition of boulder clay having such a large thickness (about 150 m) reflect the dynamical structure of inland-ice i.e. these rhythmical changes are the traces of layers of ice in the continental glacier.

LITHOLOGICAL PROPERTIES OF STRATIGRAPHICAL LITHOTYPES OF THE BOULDER CLAYS

A test of methodical estimation of different lithological properties has been presented in other paper. It has been done from the point of view of their usefulness for stratigraphical, regional or genetic-facial systematics as well [61]. In this place certain conclusions to which the above presented factographical material authorizes may be noticed.

Above all they confirm earlier observations of the authors, concerning the meaning of different lithological properties in characterizing boulder clays. The conclusion that petrographical coefficients allow for a correlation of stratigraphical lithotypes even among different regions is one of the most important. On the other hand the analysis of mineral composition (especially of the heavy fraction) makes such a correlation possible but only in the limits of one region. The interregional correlations are possible on this basis only in some horizons of boulder clays as for example in the oldest and youngest clays of the Southern-Polish Glaciation. It may be added here, that boulder clays of the Middle-Polish Glaciation allow for a similar comparison in an even smaller degree. The mineral composition as well as the frequency of particles of local rocks in the gravels characterize well the regional lithological types and permit to define accurately the way of movement of the inland-ice.

Grain size distribution and calciferousity are properties which excellently distinguishe the lithological character of boulder clays in different regions. On the other hand. inside of the regions, they can establish a criterion for the stratigraphical separation of different clay horizons. These observations are illustrated exemplary by the added tables and figures (Table 1 - 4 and Figures 1 - 4). A restriction ought to be made here, that an effective use of both last properties for the stratigraphy of Pleistocene can only take place after preparing of key-papers, this means that the mean grain size distribution or calciferousity of clays in the assumed region as well as direction and scale of quantitative changes in the examined features ought to be defined. Such was exactly the chief task of the work of which a small part was presented above.

Boulder clays of the two older glaciations above discussed in stratigraphical order have a series of lithological features, which may be presented shortly as follows:

1. The common property of the grain size distribution of the characterized boulder clays is the small contents of gravel material. Exception here are the clays of Podlasie Glaciation and the first and the last clay of Southern-Polish Glaciation, where there appears a larger quantity of gravels. The enrichment in coarse material however concerns only profiles situated in the northern part of the examined territory. Further south the coarse detritus of rocks undergoes a quick crushing.

2. The grain-size distribution of basal boulder clays is a very sensitive criterium for the estimation of the influence of local bedrocks on their lithology. The conclusions of this kind however, ought to be confirmed by an analysis of calciferousity and of an association of local rock particles in the gravel fraction, as e.g. for the oldest boulder clay.

3. With exception of the clay of the first stage of Southern-Polish Glaciation, in all other K-feldspars dominate over plagioclases. The general contents of feldspars is bigger in two oldest boulder clays.

4. The main components of the heavy fraction are garnets and amphiboles. In certain regions (i.e. Płock Basin, drainage basin of the Widawka River) zircons and biotite can play a significant role.

5. For the boulder clay of the Podlasie Glaciation characteristic is an at least several times larger frequency of chlorites, than in the younger clays of the same region.

6. The petrographical composition of gravel fraction allows to differentiate boulder clays with regard to the stratigraphy. Among the rock-particles of Scandinavian origin the crystalline rocks and paleozoic limestones, which form together 80% of all gravels, dominate. In the local materials once dominate limestones, once mudstones.

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AN ATTEMPT OF BOULDER CLAY CLASSIFICATION FROM NW POLAND BY MEANS OF MINERALOGICAL AND CHEMICAL INVESTIGATIONS

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Boulder clays though potential leading levels in the stratigraphy of Quaternary sediments have been hardly examined. The criterium of colour, used up to now, as index of their age is practically of little importance, as shown by R. Blachowski [1] and stressed by B. Krygowski [8] and A. Karczewski [6]. In the Polish geomorphic literature of recent years we can find cricumstantial papers referring to boulder clays. Let us only mention such items as B. Krygowski [9, 10], A. Falkiewicz [2], A. Karczewski [5, 6], A. Kostrzewski, B. Krygowski [7], A. Stankowska [12], U. Wesołowska [14], K. Łydka, M. Turnau-Morawska [11], J. Trembaczowski [13]. These papers include all the problems concerning the structure and texture of boulder clay or deal only with special questions. In this paper special importance is given to the analysis of some mineral and chemical features of the rock. The authors assume that because of great differences in the age of various boulder clay horizons there must be differrences in the degree of their "ageing". It is supposed that the processes causing the ageing of clay are especially distinct in the case of secondary minerals, i.e. those building the clay fraction of boulder clays.

In order to check these assumptions it has been decided to examine boulder clay samples of different age. Basing on the latest papers of R. Galon, L. Roszkówna [3] and B. Krygowski [8] samples were taken from vertical geologic profiles in the area of the Middle Polish and Baltic Glaciations (Fig. 1). And so, though samples from the area south of the line of maximum extent of the Baltic Glaciation represent older sediments, Middle Polish at least those taken north of this line do not always belong to the Last Glaciation. This is proved by their geologic situation. In laboratory investigations of these samples of boulder clays special stress was laid on the analysis of heavy minerals, clay minerals as well as of some chemical features, and besides the mechanical composition was stated. The discussed samples of clays were analyzed in the laboratory of Experimental Geomorphology at the Poznań University and partly, too, in the laboratory of Physical Geography of the University in Amsterdam.

Fig. 1. Situation map of research stands (Lucień, Radowice, Rusinów, Brojce, Skwierzyna, Naramowice, Rewal)

Extent of inland-ice according to R. Galon, L. Roszkówna (1961): SW — Warta Stage, L — Leszno Stage, PZ — Poznań Stage, P — Pomeranian Stage

It was the firts problem to find whether, in the case of boulder clays there are any clear relations between the changeability of mechanical composition and the other factors. That such corelation exists was already pointed out [12]. Therefore there is the risk lest differences occurring within contemporaneous clays should exceed proper amplitudes for sediments belonging to different ages. Classifying the whole material hitherto collected it should be stated that there is no equivalent dependence between changes in mechanical composition and the other parameters (Table 1 - 9). Building upon the analysis of samples taken at Lucień, Radowice and Naramowice, as well as Rewal we could think the above statement erroneous. There is a convergence of changes in grain size composition in the composition of clay minerals, in the chemical composition, and also in heavy minerals. On the other hand, the samples from Skwierzyna, Brójce, and above all from Rusinów show all an inverse dependence. Such a state allows to exclude one greatly important factor that makes in tests of fixing the stratigraphy of boulder clays based on mineralogical and chemical investigations difficult.

TABLE 1. Variability of colour and mechanical composition of boulder clays analysed by the authors

Locality	Colour	Mechanical composition (mean values %)			
		>0·1 mm	<0·002 mm	Index of siltness	
Lucień	dark-brown	31·2	32·0	0·47	0·38
		45·8	23·0	0·30	
Radowice	dark-brown	50·8	18·3	0·22	
	dark-brown to black	45·7	23·3	0·30	0·26
Rusinów	brown-red	32·1	32·0	0·47	
	grey-brown	63·5	13·0	0·15	0·31
Brójce	brown-grey	47·5	18·8	0·23	0·23
Skwierzyna	light-brown	56·5	11·8	0·13	0·13
Naramowice	light-brown	56·7	10·6	0·10	0·10
Rewal	brown	51·3	12·3	0·14	
	grey	47·8	14·0	0·16	
	light-brown	60·5	8·1	0·09	0·13
	dark-grey	49·0	15·0	0·17	
	light-grey	60·2	9·0	0·10	

Classifying the results of all analyses in reference to their suitability for stratigraphic purposes it should be stated that the examinations of heavy minerals were least effective (Tables 2 and 3). There are too many factors that decide the differentiation in the composition of primary minerals. Among these factors there are mainly the structure of parent rocks whose detritus is a component of clays. then the profile position the consitency of clay, its environment and some others. The elaboration of the stratigraphy of clays basing on this criterion is very difficult if not even impossible. Hundreds of samples, there being no doubt that they belong to different glaciations, should be analyzed and statistical examinations should be undertaken. A positive result, however, is rather dubious.

Quite different are the results of examining the clayey fraction in which secondary minerals are grouped. Basing upon the analyses of clay minerals and on date of the chemical composition these boulder clays can

TABLE 2. Heavy minerals — superficial composition in %

Locality and depth of sample below ground surface in cm	Zircon	Rutile	Tourmaline	Staurolite	Kyanite	Garnet	Biotite	Amphiboles	Epidotes and others
Lucień									
150	6·4	3·9	3·4	1·0	—	52·2	—	11·7	21·4
270	3·9	3·2	1·1	1·0	0·7	50·2	—	13·9	26·0
350	6·0	2·5	2·4	0·7	—	37·0	—	20·7	30·7
mean	5·4	3·2	2·3	0·9	0·2	46·6	—	15·4	26·0
Radowice									
330	5·2	2·2	2·3	0·5	0·6	30·8	—	22·4	36·0
750	7·2	2·1	1·8	—	—	37·6	—	13·0	38·3
1150	8·2	1·7	1·1	1·3	—	22·0	—	19·9	45·8
1550	4·5	0·7	1·5	1·1	0·5	37·0	—	20·8	33·9
mean	6·3	1·7	1·7	0·7	0·3	31·8	—	19·0	38·5
Rusinów									
100	11·4	7·0	2·6	1·8	0·5	38·3	—	12·8	25·6
200	12·9	8·0	1·0	—	—	37·1	—	4·7	36·3
375	5·8	2·9	4·8	—	0·4	23·5	—	24·7	37·9
mean	10·0	5·9	2·8	0·6	0·3	33·2	—	14·0	33·2
Brojce									
70	4·9	2·2	3·7	—	—	28·6	—	23·2	37·4
150	4·5	2·5	2·8	—	—	29·1	—	22·5	38·6
350	4·8	2·4	2·3	1·3	0·6	38·0	—	18·9	31·7
mean	4·7	2·4	2·9	0·4	0·2	32·0	—	21·6	35·8
Skwierzyna									
100	9·3	5·2	1·0	1·4	—	39·7	—	15·3	28·1
200	12·7	5·1	1·2	—	0·8	38·3	—	13·6	28·3
400	7·2	3·5	1·8	0·8	—	34·0	—	21·5	31·2
mean	9·7	4·6	1·3	0·7	0·2	37·4	—	16·8	29·3
Naramowice									
200	1·4	1·1	1·7	0·6	—	33·1	—	33·1	29·0
300	3·5	1·6	0·4	1·3	—	51·2	—	15·1	26·9
mean	2·4	1·3	1·0	1·0	—	42·2	—	24·1	28·0
Rewal									
mean	6·7	4·4	2·2	0·9	1·0	26·5	0·2	17·6	40·5

be divided into two groups. Samples of clays from Lucień, Radowice and the bottom part of the profile from Rusinów 375 cm sample belong to the first group, Rusinów down to 350 cm, Brojce, Skwierzyna, Naramowice and Rewal to the other (Tables 4 - 9). All considerations of this type of course should exclude samples to the depth of about 200 cm the parent rock there being changed by soil processes. This is made clear by the high values for montmorillonite in the samples: Brojce 70 cm and 150 cm,

TABLE 3. Heavy mineral-groups according to resistance (mean values in %)

Locality	Minerals				Index of weathering*
	extremly resistant	resistant	less resistant	non-resistant	
Lucień	10·9	47·7	26·0	15·4	2·54
Radowice	9·7	32·8	38·5	19·0	2·33
Rusinów	18·7	34·1	33·2	14·0	2·67
Brojce	10·0	32·6	35·8	21·6	2·31
Skwierzyna	15·6	38·3	29·3	16·8	2·53
Naramowice	4·7	43·2	28·0	24·1	2·28
Rewal	13·3	28·4	40·5	17·8	2·37

* According to Kucharenko (L. B. Ruchin 1961).

Skwierzyna 100 cm, Radowice 100 cm and 150 cm. This fact is most probably connected with the high hydrophilic feature of montmorillonite and its downward displacement in the soil profile.

The above division seems to be very helpful for the stratigraphy of boulder clays. Considering the extent of the Baltic Glaciation [3, 8] and the authors own field investigations of the discussed profiles, the clays of the former group should be acknowledged older than the Last Glaciation and of the other group as belonging to it.

While the situation and homogeneity of the clay found at Lucień do not cause any difficulty in the interpretation, the profile at Radowice as a whole may be brought up for discussion. It bottom parts is undoubtedly, built of old clay, but the top of the profile (above the sand lenses) is open to discussion. It may be that two clays occur here the upper one being very little known. In the light of mineralogical and chemical data, however, it does not differ from the other. The geologic situation as well as the character of the deposit do not permit, however, to number this profile among the clays of the Baltic Glaciation. The last of clays of this group is the sediment building the bottom of the profile at Rusinów. It shows features of glacitectonic disturbances and is an alien element of this profile. We may, therefore, suppose that it is an old clay glacitectonically displaced during the Last Glaciation, and later covered by its sediments. It must be stressed that clays building the profile at Rusinów cover crystalline and organic sediments belonging to the Last Interglacial [4].

The boulder clays treated here contain quite a large amount of montmorillonite (10 - 20 percent) and kaolinite (trace — 20 percent), beside illite which is the dominant mineral in all samples. The bottom of the profile at Radowice has also gibbsite in trace amounts (Tables 4, 5 and 7).

TABLE 4. Clay minerals — X-ray data

Locality and depth of sample below ground surface in cm	Illite	Montmorillonite	Kaolinite	Gibbsite	Goethite	Feldspar	Quartz
Lucień							
150	dominant	15 - 20	5	—	trace	—	15
270	dominant	15 - 20	5	—	trace	—	15
350	dominant	15 - 20	5 - 10	—	—	—	5
Radowice							
100	dominant	15 - 20	15 - 20	—	—	—	5
150	dominant	5 - 10	15	—	—	—	5
330	dominant	10	10	—	—	—	10
550	dominant	10	10	—	—	—	10
750	dominant	15	5	—	—	—	15
950	dominant	20	10 - 15	trace	—	—	10
1150	dominant	10 - 15	20	trace	—	—	15
1550	dominant	20	15 - 20	trace	—	—	15
Rusinów							
100	dominant	trace	trace	—	—	—	10
200	dominant	5	trace	—	—	—	15
375	dominant	20	trace	—	—	—	15
Brójce							
70	dominant	20 - 25	5	—	—	—	10
150	dominant	10	trace	—	—	—	10
350	dominant	5	trace	—	—	—	10
Skwierzyna							
100	dominant	5 - 10	15 - 20	—	—	trace	5 - 10
200	dominant	1 - 5	15 - 20	—	—	trace	10
400	dominant	1 - 5	10	—	—	trace	10 - 15
Naramowice							
200	dominant	5	trace	—	—	trace	10
300	dominant	5	trace	—	—	trace	10
Rewal							
670	dominant	trace	trace	—	—	trace	5
840	dominant	1 - 5	trace	—	—	trace	5
890	dominant	1 - 5	trace	—	—	trace	5

These three minerals: montmorillonite, kaolinite and gibbsite show that the weathering process was very advanced. The question arises whether the montmorillonite met here does not come from the rock of the substratum. We suppose however that this montmorillonite is the result of changes of hydromike in the course of the wethering proces. This is the more likely because older clays weathered in conditions favouring the formation of this mineral — in warm period of interglacial time. It may well be that there is a certain amount of mechanic admixture of montmorillonite.

TABLE 5. Clay minerals — DTA data

Locality and depth of sample below ground surface in cm	Illite	Montmorillonite	Kaolinite
Lucień			
270	dominant	large	—
350	dominant	large	—
Radowice			
550	dominant	large	small
950	dominant	large	small
1550	dominant	large	large
Rusinów			
200	dominant	—	—
375	dominant	very small	—
Brojce			
350	dominant	—	—
Skwierzyna			
100	dominant	small	—
400	dominant	small	—
Naramowice			
300	dominant	small	—
Rewal			
670	dominant	very small	—
890	dominant	very small	—

The clays of group one compared with those of group two have a higher index of ion exchange capacity in relation to cations (54, 62 - 66, 25 m-eqv/100 g) and an insignificant lowering of molecular proportion (Tables 6 and 7). The date of chemical composition show negligible differences within the two groups of clays singled out (Tables 8 and 9). And so silica, which is resistant to destruction, as well as alumina and the sum of adsorption and constitutional waters occur in a larger amount in clays of group one. Carbonates, no resistant to weathering are found in smaller amounts.

The above description of clays is strikingly similar to the result obtained by A. Falkiewicz [2]. The named the following clay minerals in the boulder clays from the Warsaw area: hydromike, montmorillonite and kaolinite. Moreover the mean value of ion exchange capacity is also similar to the authors' value (56·26 m-eqv/100 g). The clays described by A. Falkiewicz [2] were certainly formed in the period of the Middle Polish Glaciation or even earlier. This concordance of results is a further argument that qualifies the clays of group one to sediment older than the deposits of the Baltic Glaciation.

TABLE 6. Molecular proportion in clay fraction. Cation-exchange capacity in clay fraction

Locality and depth of sample below ground surface in cm		$SiO_2/Al_2O_3+Fe_2O_3$		m-eqv/100 g	
Lucień					
	150	—		52·87	
	270	2·96	3·04	57·12	57·12
	350	3·11		57·12	
Radowice					
	100	—		57·12	
	150	2·79		51·75	
	330	—		58·87	
	550	3·09	2·99	58·75	
	750	—		61·87	59·60
	950	3·05		54·75	
	1150	—		57·12	
	1550	3·04		66·25	
Rusinów					
	100	—		48·50	
	200	3·21		46·51	
	375	3·21		54·62	
Brojce					
	70	—		58·37	
	150	2·90	2·92	48·50	48·31
	350	2·95		48·12	
Skwierzyna					
	100	2·54		59·12	
	200	—	2·81	53·87	53·81
	400	3·08		53·75	
Naramowice					
	200	—		47·87	47·56
	300	3·18		47·25	
Rewal					
	670			44·00	
	840		3·12	35·50	38·08
	890			34·75	

TABLE 7. The differences between boulder clays

Locality	X-Ray data and DTA data				Cation exchange capacity m-eqv/100 g		Molecular proportion	
	Montmorillonite		Kaolinite					
Lucień	17	16	6	10	57·12	58·36	3·03	3·01
Radowice	14		13		59·60		2·99	
Naramowice		4	trace		47·56	42·82	3·18	3·15
Rewal	2		trace		38·08		3·12	

TABLE 8. Chemical composition of clay fraction in %

Locality and depth of sample below ground surface in cm	H_2O-	H_2O+	SiO_2	Fe_2O_3	Al_2O_3	TiO_3	pH
Lucień							
270	3·39	7·88	53·65	12·88	22·59	1·02	7·7
350	4·42	7·72	56·69	15·68	20·93	1·38	7·7
Radowice							
150	5·75	9·81	53·74	10·00	26·41	1·20	6·7
550	5·42	8·31	56·57	11·33	23·89	1·10	7·8
950	4·75	9·75	55·47	10·85	23·90	1·32	7·7
1550	4·32	15·48	56·90	7·13	27·25	1·18	7·6
Rusinów							
200	4·05	7·38	54·86	9·18	23·17	1·15	7·6
375	5·35	7·18	55·82	13·51	20·94	1·37	7·7
Brojce							
150	5·55	8·28	53·82	13·39	22·98	1·21	7·7
350	5·14	9·92	53·91	12·01	23·35	1·35	7·6
Skwierzyna							
100	5·17	9·49	54·17	17·08	21·30	1·32	7·1
400	5·05	7·35	53·62	15·24	19·87	1·31	7·7
Naramowice							
300	3·93	7·05	54·43	14·74	19·62	1·29	7·6
Rewal							

The clays of group two show a small content of montmorillonite (trace — 5%) and kaolinite (trace) compared with clays of group one (Tables 4, 5 and 7). In samples taken at Skwierzyna the X-ray radiographic analysis showed a large content of kaolinite. At the same time, however, the thermo-differential analysis and the value of exchange capacity (an increase of index while kaolinite should lower it) does not confirm the results of the X-ray radiographic analysis. Therefore it can be assumed that mineral belonging to the chlorite group were erroneously

TABLE 9. Contents of carbonate and humus matter

Locality	Carbonate		Humus matter
	amplitude	mean	mean
Lucień	4·9 - 5·9	5·4	0·15
Radowice	3·6 - 9·1	5·9	1·40
Rusinów	11·1 - 12·2	11·6	
to 350 cm deaper		5·5	0·29
Brojce	4·5 - 6·9	5·8	0·51
Skwierzyna	7·8 - 8·9	8·4	0·22
Naramowice	2·3 - 4·7	3·5	0·12
Rewal	8·0 - 13·9	10·7	0·53

taken for kaolinite, the more so that reflexes of these minerals approximate. This supposition is very probable because chlorites posses a great ion exchange capacity.

Clays of group two have also a lower index of ion exchange capacity in relation to cations — 35·50 to 53·87 m-eqv/100 g (Table 6). Feldspar too, occurs in trace amounts, and being little resitant to weathering it is mainly met in young formations. Further differences between the groups of clays respecting the chemical composition have been described before. Clays of group two should be connected with the Baltic Glaciation.

TABLE 10. Parameters differentiating the boulder clays of variousage

Locality	Age	Minerals (%)				Cation exchange capacity m-eqv/ /100 g
		Montmorillonite	Kaolinite	Gibbsite	Feldspar	
Lucień	The older Glaciations	>15	6	—	—	57·12
Radowice		15	13	trace	—	59·60
Rusinów depear than 350 cm		20	trace	—	—	54·62
Rewal	Baltic Glaciation	<5	trace	—	trace	38·08
Naramowice		<5	trace	—	trace	47·56
Brójce		<5	trace	—	—	48·31
Skwierzyna		<5	?	—	trace	53·81
Rusinów to 350 cm		<5	trace	—	—	46·51

The results of this paper, we suppose, show that further mineralogical and chemical researches especially of secondary minerals may help to find the criterion of stratigraphy of boulder clays (Table 10).

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THE PART PLAYED IN THE DEPOSITS OF TODAY'S VISTULA BY MATERIAL BROUGHT IN BY TRIBUTARIES

GENOWEFA KOCISZEWSKA-MUSIAŁ

1. INTRODUCTION

So far no comprehensive studies have been made as to how far tributary inflow is affecting sedimentological conditions in the channels of large rivers. As a rule examinations of this kind have been undertaken for individual larger or smaller rivers without taking into consideration the group of tributaries which a given river collects along its course. R. D. Russel [5, 6] examined only main stream deposits neglecting the part played by tributary rivers. He took for granted only a slight influence on changes in the petrographical composition of the Mississippi deposits probably caused by tributary inflow. There are instances however when comprehensive studies are involved defining the mineralogical-petrographical composition of such deposits with special attention paid to heavy minerals, that probleme of the mineral composition of deposits in the tributary rivers are often recognized to be of greater importance than those of the alluvia deposited in the main river. And this kind of comprehensive investigations have revealed, that the mineral composition of the material carried by tributary rivers does often differ from what is accumulating in the main channel downstream of the individual inflows. M. I. Icikson [1] holds, that the sampling of deposits in main river channels is of little value unless it is correlated with samples taken from the tributaries of this river.

Examinations made recently of the alluvia of the Vistula were not limited to the main river channel, but simultaneously close attention was given to the alluvial deposits of its tributaries, in an effort to determine the sedimentological conditions which prevail in the Vistula drainage basin. For this purspose samples were collected in 1961 from present Vistula channel, taking in its course from the springs as far as the inflow of the Bug River; these samples were taken at some 5 km intervals. Further, samples were collected in the channels of thirty Vistula tributaries, from the sections nearest their inflow into the Vistula, and this was done in a period when low-water throughout the Vistula drainage area created relatively uniform dynamic conditions.

Her study of the sedimentological conditions in the Vistula drainage basin, as discussed in the present paper, the author has based on the determination of the grain features of the alluvia in both tributaries and main stream, on the abrasion of quartz grains, and on the mineralogical--petrographical composition of the deposits.

2. EFFECT OF GRAIN SIZE OF MATERIAL BROUGHT IN BY TRIBUTARIES UPON GRAIN SIZE OF DEPOSITS IN VISTULA CHANNEL

For determining changes in grain size, sieve analyses were made for 108 samples collected from the Vistula channel and for 28 samples taken from the channels of tributaries. From the grain size histograms shown in Fig. 1 and 2 it was possible to determine interdependences and mutual influences between the tributaries and the main river. The histograms shown in Fig. 1 indicate in per-cent values the mean quantities of grains of individual fractional groups in the samples for the Vistula channel and for the tributaries, listing them in downstream sequence according to the longitudinal Vistula profile. Omitted were the Wapienica and Biała rivers. because they join the Vistula in a section inaccessible for studies of alluvia, i.e. within the extent of the Goczałkowice storage basin.

Observations made in the Vistula channel up- and downstream of the inflow of the successive tributaries revealed, that the Przemsza and the Soła rivers, for all the relatively ample (some 25%, see Fig. 2) 0·4 - 0·5 mm fraction they carry in their lowest sections, do not cause in this grain fraction any perceptible changes in the Vistula channel. The same applies to the groups of the next larger fraction, those of 0·5 - 0·6 mm, 0·6 - 0·75 mm, and 0·75 - 1·0 mm which in the above mentioned two tributaries show a higher concentration than in the Vistula alluvia of this part of the channel, near the mouths of these rivers. While in the tributaries the share of grains of the 0·3 - 0·4 mm and the 0·2 - 0·3 mm fractions is relatively small, the deposits of the main channel downstream of the inflow of Przemsza and Soła show a considerable increase in these two fractions, — no matter what grain sizes the tributaries brought in.

Along similar lines, but with changed proportions in percentage,

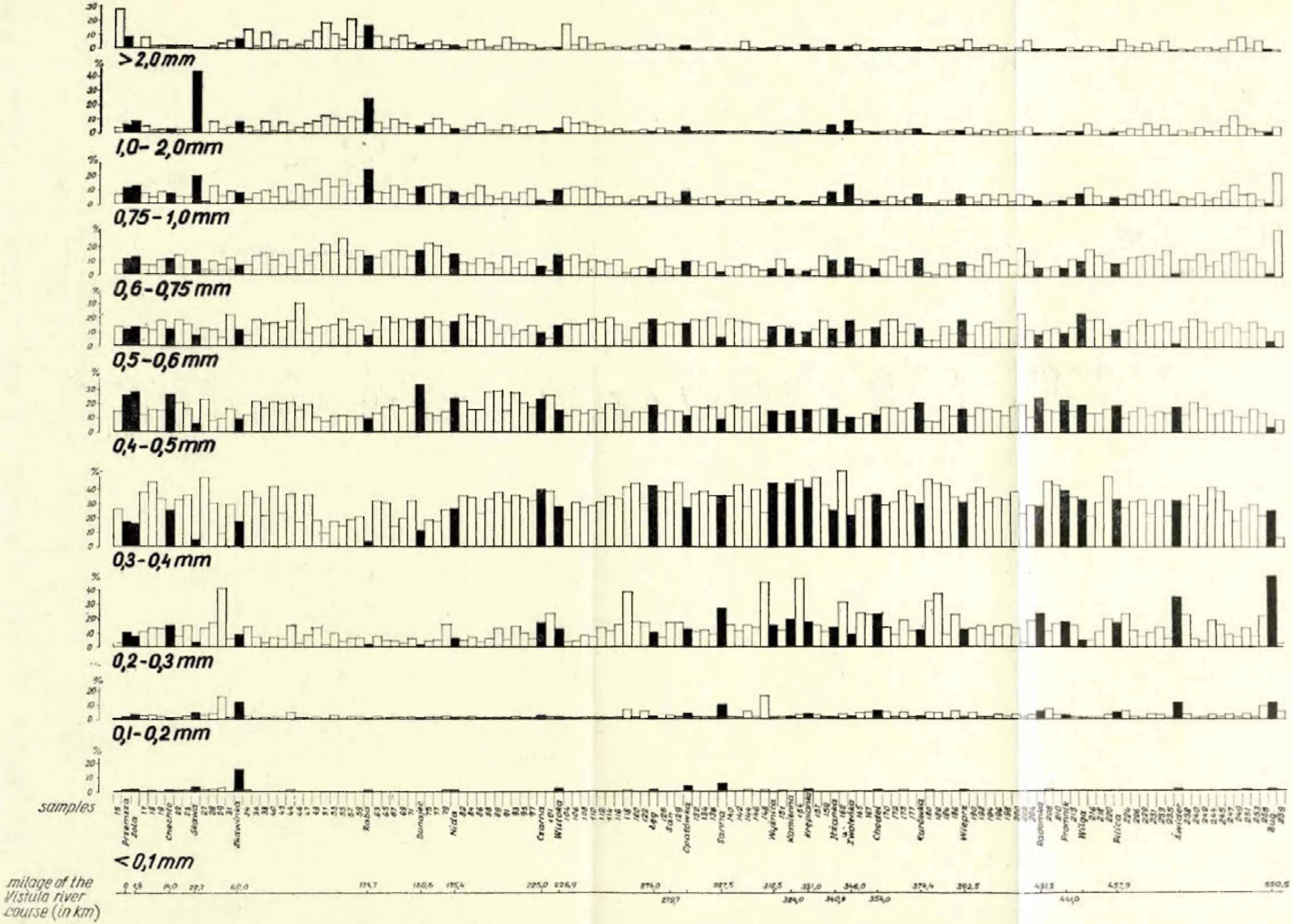

Fig. 1. The grain-size composition of sediments in the Vistula and its tributaries, listed along the longitudinal profile

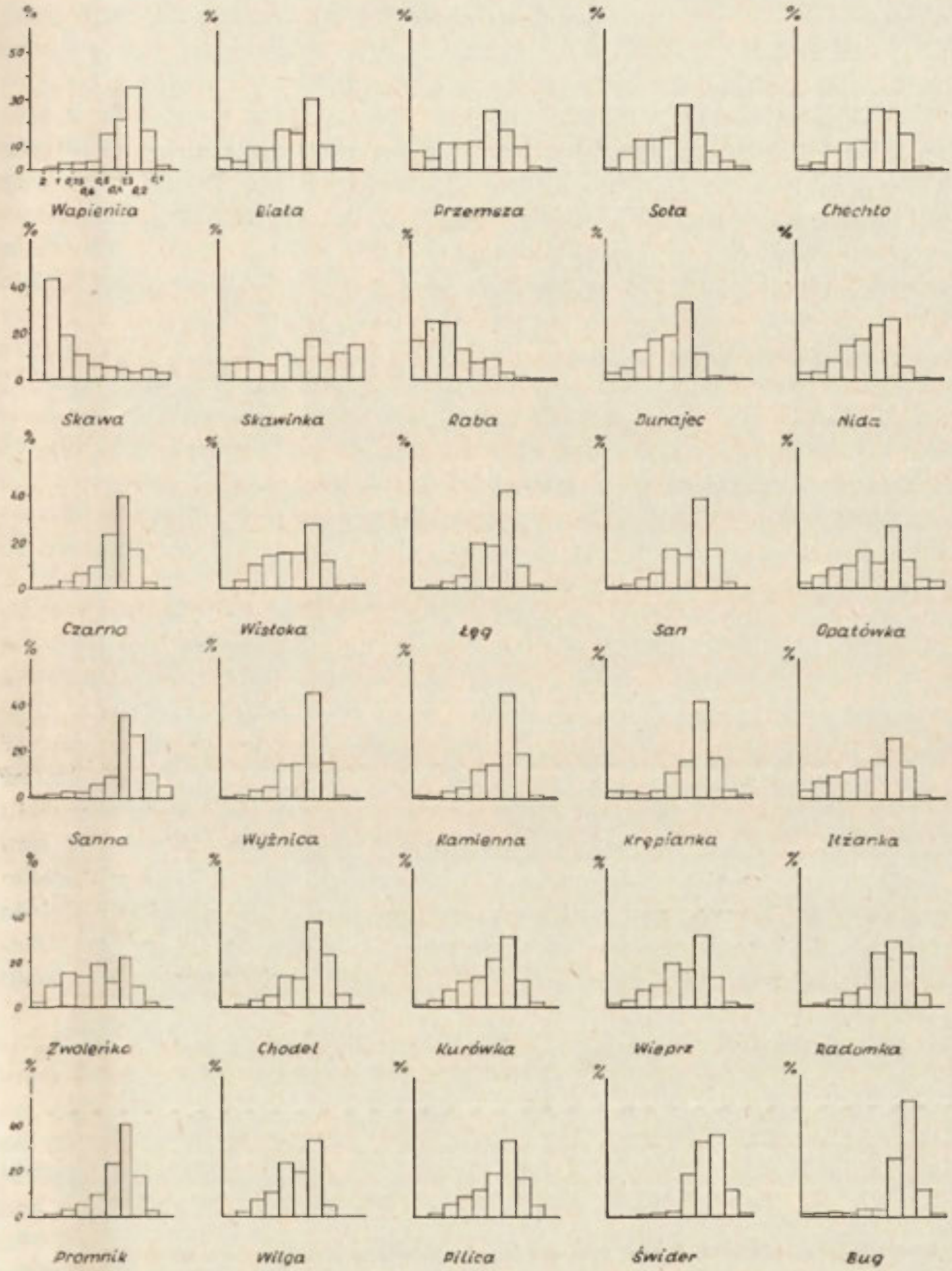

Fig. 2. Histograms of the grain-size composition of samples taken from the Vistula tributaries

appear conditions of grain size downstream of the Chechlo inflow. Worthy of notice is here fraction 0·3 - 0·4 mm, larger quantity of which downstream of the Chechlo inflow does not depend on the material brought in by the tributary. Although Chechlo River carries some 25% of this fraction, its quantity is still about 7% lower when compared with the Vistula alluvia close to the inflow of Chechło River. In the same way no interrelation can be observed between the percentage of medium--grained sands (0·5 - 1·0 mm) and coarse sands (1·0 - 2·0 mm) in the main channel alluvia and the percentage of these fractions in the Chechło River.

The Skawa River carries in its lowest reach a large quantity (some 43%) of coarse-grained sand of the 1·0 - 2·0 mm fraction, but no effect of this inflow can be observed in the main Vistula channel; on the contrary. a sample taken of the Vistula deposits some 2 km below the Skawa inflow shows a complete absence of this fraction. And vice-versa, while the Skawa flow carries little fine-grained sand up to 0·5 mm size, downstream of the inflow of this river the Vistula alluvia show an increase of a dozen or so per-cent of these finer fractions.

The histogram of the grain size composition in the Skawinka river shown in Fig. 2 illustrates distincly well balanced proportions between the individual grain sizes: slight maxima occur only in groups 0·3 - 0·4 mm and in the finest fractions of $<$ 0·1 mm. The greater quantity of silty material in this mountain river is the result of an increased amount of diluvial material originating from slope erosion. These conditions, similar to those for the Skawa river, again do not cause any changes in the grain size composition of the main river alluvia; neither do the 0·1 - 0·2 mm fraction and the silt content of $<$ 0·1 mm which in this tributary are in excess of 10%, cause any noticeable changes in the alluvia of the Vistula channel. And even the coarser fractions, of which there are less than 10% in the Skawinka River, fail to affect the composition of the main river alluvia.

The grain size composition in the Raba River (Fig. 2) contains maximum quantities (some 25%) in the 1·0 - 2·0 mm and 0·75 - 1·0 mm fractions. With regard ot grain sizes in the Vistula channel, these groups in no way affect the grain size composition, neither above nor below the inflow of the Raba River. In the groups of fine-grained sand, on the other hand, which occur in negligible quantities in the Raba alluvia and fail to increase these groups in the Vistula deposits downstream of the Raba mouth, a 10% increase in the 0·3 - 0·4 mm group can clearly be observed in the Vistula channel, compared with the composition seen in samples taken upstream of the inflow of this tributary.

The Dunajec River stands out by its large share (more than 30%) in the 0·4 - 0·5 mm group, although this causes no increase of this group in the Vistula channel. Downstream of the Dunajec inflow there was even observed a decrease by a few per-cent of this fraction, as clearly visible in Fig. 1. Grains of the $>$ 0·5 mm fractions appear in nearly identical shares in the deposits of both Dunajec and Vistula; thus the longitudinal profile of this reach of the Vistula shows no changes in grain size.

In the Nida and Czarna rivers the grain size composition resembles much that of the Vistula. Only downstream of the Nida inflow a marked increase (some 9%) is noticeable in the 0·3 - 0·4 mm fraction, and another downstream of the Czarna mouth in the 0·2 - 0·3 mm fraction and, also, in two groups of coarser grain size.

The Wisłoka River deposits contain some 2% of fractions of the $<$ 0·1 mm size. Below its mouth, the Vistula alluvia show a characteristic decrease of their fine-grained fractions, especially in the 0·2 - 0·3 mm group and also the 0·3 - 0·4 mm group; this is accompanied by an increase in coarse-grained fractions, from 1·0 - 2·0 mm and $>$ 2·0 mm grain size. This phenomenon cannot be caused by material brought in, because the Wisłoka River carries little coarser material; instead it is its flow velocity which, after inflow into the Vistula, causes a disturbance in the river profile and furthers erosion, as indicated by the increase in coarse grains in the fractions mentioned.

In the Łęg and San rivers the grain size composition resembles that of the Vistula alluvia. In spite of this, downstream of their inflow, an increase of some 7 - 8% in the concentration of the 0·3 - 0·4 mm fraction has been determined in the Vistula channel.

The Opatówka River shows, compared with the Vistula, differences in the following fine-grained fractions: $<$ 0·1 mm and 0·1 - 0·2 mm, and among coarser-grained fractions in those of 0·75 - 1·0 mm, 1·0 - 2·0 mm and $>$ 2 mm. However, these differences are only of the order of 2 - 5% and cause no noticeable changes below the mouth of this river.

In the Sanna River a marked predominance in the medium-size groups $<$ 0·1 mm, 0·1 - 0·2 mm and 0·2 - 0·3 mm has been found, and a considerable deficiency in the grain group 0·4 - 0·5 mm and in coarser groups, compared with the Vistula alluvia. However, neither the increased nor the decreased quantities of grain-size groups are reflected in the Vistula deposits (Fig. 1).

The Wyżnica River shows no essential difference in its grain fractions from those of the Vistula, but ahead of its inflow it produces in the main river an increased accumulation, as can clearly be seen from the maximum values of Sample 148 in the fractions of 0·1 - 0·2 mm and 0·2 - 0·3 mm size.

The Kamienna and Krępianka rivers, while carrying similar contents of a number of fractions, affect the main channel downstream of their mouts in different ways: for Kamienna this means an increased accumulation in the 0·2 - 0·3 mm fraction as observed in sample 154, — for Krępianka this increase is less marked, and here the maximum seer in sample 157 refers to the 0·3 - 0·4 mm fraction.

The Iłżanka and Zwoleńka rivers show in their deposits only a small share of the 0·2 - 0·3 mm and the 0·3 - 0·4 mm fractions. In spite of this, downstream of their inflow the Vistula alluvia contain a high concentration of these fine-grained groups. The inverse goes for the coarser grain fractions, from 0·5 to 2·0 mm size. Both these rivers carry a concentration several per-cent higher than the Vistula channel, but no effect of this has been observed in the samples taken from points downstream of their inflow.

Analogous conditions as for Iłżanka and Zwoleńka occur near the inflow of the Kurówka River, partly also where the Wieprz and the Radomka rivers join the Vistula.

Different are the processes observed downstream of the mouths of the Promnik and the Wilga rivers. Their deposits contain little of the $<0{\cdot}5$ mm fractions; even so, the Vistula channel shows a concentration of the $>0{\cdot}5$ mm fractions, although these two tributaries brought in too little to affect the alluvia in the main channel. This indicates, that downstream of these two inflows erosion is taking place in the Vistula channel.

Similar phenomena have been observed downstream of where the Pilica and the Bug rivers join; also noticeable is a slight and little effective accumulation in the Vistula channel downstream of the Świder mouth.

On the whole it can be said, that the grain pattern is much alike in the tributaries and the Vistula, and only by narrow-interval investigations of the grain sizes can the differences within the drainage basin be determined. The correlation of size medians and of coefficients of grain sorting of the alluvia of both the tributaries and the Vistula also indicate a marked similarity in these two features throughout the Vistula drainage basin. In the Vistula channel the grain size medians oscillate between 0·27 and 0·98 mm; among the tributaries highest are these medians for Skawa and Raba — 0·90 mm, and lowest for Bug — 0·27 mm. For all the remaining tributaries the medians lie for the most part between 0·35 mm and 0·50 mm — almost the same as found in the majority of samples taken from the Vistula channel.

The coefficient of asymmetry for the Vistula alluvia varies, from 0·91 to 1·55. Among the tributaries, lowest is this coefficient for Skawinka — 0·85, highest for Raba — 1·30.

The coefficients of grain sorting, after P. D. Trask [7] and A. Hazen [3] show the values: 1·18 - 2·11 and 1·43 - 5·27 for the Vistula alluvia, and similar extreme values: 1·23 - 1·94 and 1·53 - 6·62 for the deposits of the tributary rivers.

As regards grain sorting, the most stabilized section of the Vistula channel is the reach between the points of inflow of the San and the Wieprz rivers. This high degree of sorting led to a concentration of well rounded quartz grains which, in quantity, is here higher than in the adjoining Vistula reaches. Both these phenomena are the result of accumulation which appears to be characteristic in this part of the Vistula channel.

3. CHANGES IN MINERALOGICAL-PETROGRAPHICAL COMPOSITION OF THE VISTULA ALLUVIA CAUSED BY MATERIAL BROUGHT IN BY TRIBUTARIES

The mineralogical-petrographical composition determined in samples of the alluvia from the Vistula and its tributaries and shown in Fig. 3 illustrate the conditions and interrelations observed in the Vistula drainage basin. It should be stressed that, apart from isolated instances when alluvia of tributary rivers contain minor quantities of quartz (like in the Wapienna, Opatówka, Sanna, Kamienna and Krępianka rivers), quartz is dominant in the remaining tributaries and in the Vistula where it constitutes the basic component always exceeding 50% in the samples. Apart from the tributaries enumerated, the other rivers of the whole drainage basin usually contain less quartz grains than the Vistula deposits. The difference is of the order of several to some 15%, combined with increased quantities of other petrographical components like sandstones, quartzites, carbonates, and miscellaneous other rocks.

As to sedimentological age, the alluvia of the tributary rivers are younger than the Vistula deposits; the latter contain material from valley slopes of glacial origin and from rocks of the older substratum, and this is why the Vistula alluvia are rich in other components apart from quartz. The same applies to the "mountain" reach of the Vistula where sandstone grains prevail in the alluvia over quartz grains. The next lower reach of the river, beginning with the region of the Skawinka River, contains definitely quartz-rich alluvia, because even in the fractions of coarse-grained sand of 1 to 2 mm size this component accounts on the average for 70 - 75% of the material.

The above reflections on the part played by quartz in the river alluvia indicate that, compared with its tributaries, the Vistula deposits are much poorer. This must have been caused by the oft-repeated abrasion of the alluvia accumulated in the wide Vistula valley and by the fact, that the river channel is not in contact with the older substratum which would have supplied new rock material to be worked over by the river.

When it comes to further components apart from quartz, feldspars occur in quantities of some 5%; usually the tributaries contain less feldspars in their deposits than the main river. With a situation like this, one can hardly visualize and discuss the share of tributaries in the shaping process of the Vistula alluvia. A further component are crystalline rocks; with the course of the river they increase in importance reaching a share of some 15%. From the Vistula source, down to the inflow of the Kamienna River (km 324 of the Vistula mileage), the crystalline rocks in the tributaries show values lower than the Vistula alluvia. Kamienna, Krępianka and Iłżanka rivers alter these proportions by supplying larger quantities of crystalline rocks. An abruptly higher percentage can also be observed in the Zwolenka deposits, and downstream of its inflow the alluvia of both Vistula and tributaries contain a fairly uniform higher content (in excess of 10%) of crystalline rock fragments. The mouth of the Zwolenka River constitutes a threshold, downstream of which the Vistula alluvia contain a much higher concentration of crystalline rock grains than in the upper river reaches.

A further characteristic component of the alluvia in the Vistula drainage basin are sandstones; particularly worthy of attention are the sandstones of the Carpathian flysch sediments. They are the principal (68%) component of the Wapienica deposits; they also participate markedly (more than 20%) in the deposits of the Soła, Skawa and Skawinka rivers and (in about 15%) in those of Raba and Dunajec. These sandstones are also one of the important components in the deposits of the "mountain" part of the Vistula where they represent 30 - 40% of the 1 - 2 mm grain fraction. In the Vistula alluvia the share of sandstone grains drops abruptly to same 3% at the inflow of the Przemsza river, and farer downstream the Sola, Skawa and Skawinka rivers again raise this share to 10 - 12%. From this part of the Vistula one can perceive, how far tributary rivers affect the petrographical composition in the alluvia of the main river, and this effect can be noticed even farer downstream, below the Dunajec inflow. The content of flysch sandstone grains in the mountain tributaries of the Vistula surpasses that found in the channel of the main river by 17 - 20%; for the Dunajec this difference is some 10%. But the enrichment of the Vistula alluvia below the inflow of these rivers is only about 2%; only downstream of the Soła inflow the increase is some 7% over a distance of about 20 km. The maximum enrichment of the Vistula alluvia is not observed immediately after the inflow of a tributary carrying characteristic sandstone grains,

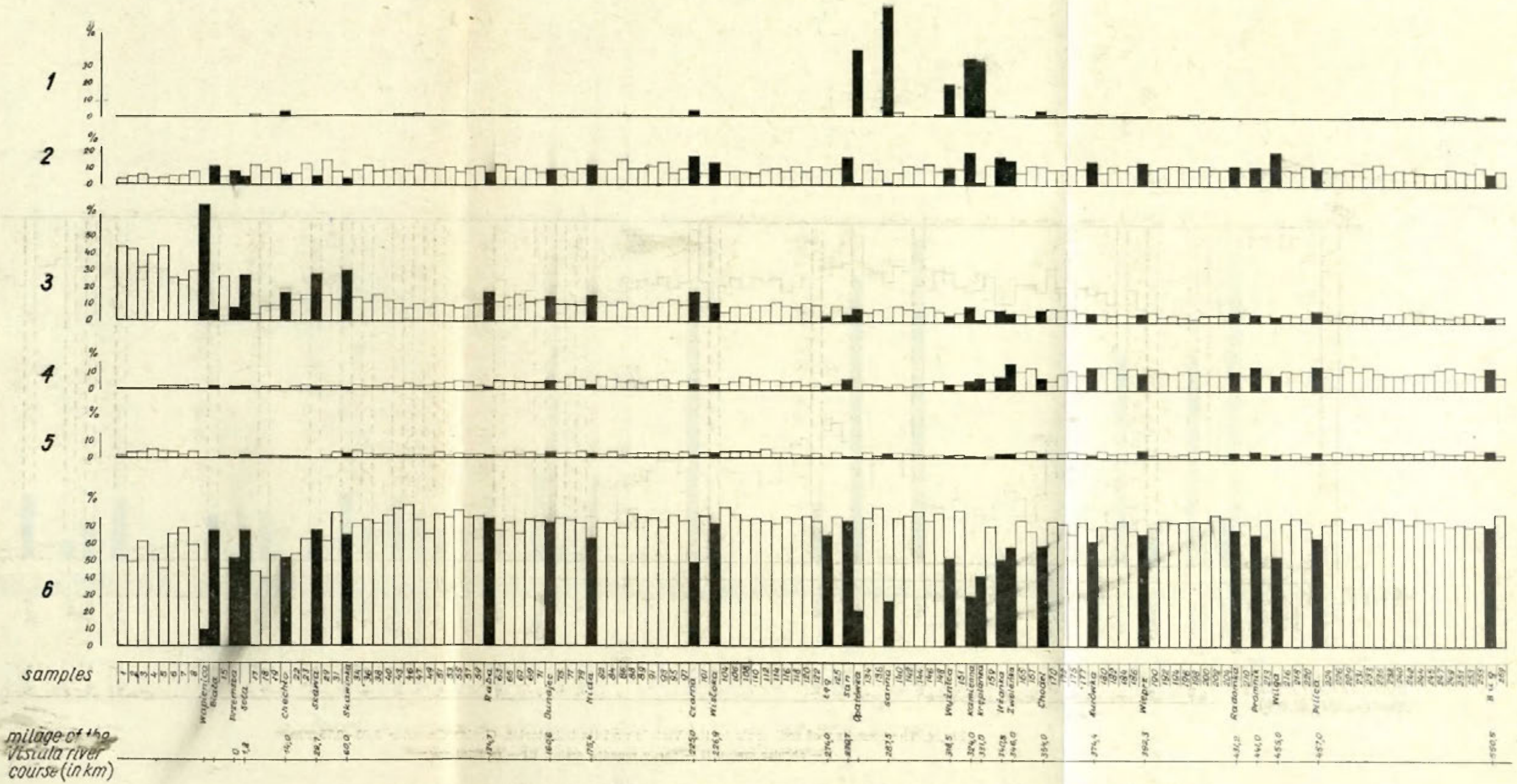

Fig. 3. The share of basic mineralogical-petrographical components in the Vistula and its tributaries. Grains diameter 1 - 2 mm

1 — calcites and carbonate rocks; 2 — quartzites and silica rocks; 3 — sandstones; 4 — cristalline rocks; 5 — feldspars; 6 — quartz

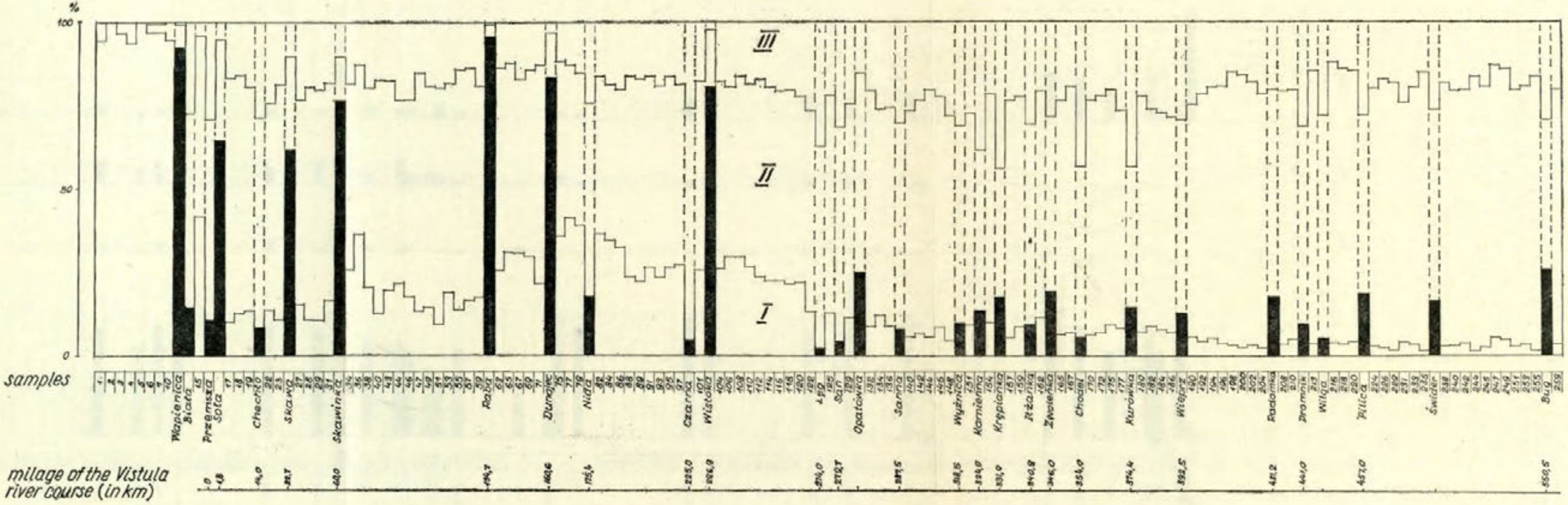

Fig. 4. The rounding of sediments in the Vistula and its tributaries. Grains diameter 0,60 - 0,75 mm.

I — angular grains, II — partly rounded grains, III — rounded grains but this influence is only noticeable in a number of samples spread out over some 10 to 15 km downstream.

Grains of the Carpathian sandstones are carried as far as Warsaw; in the Vistula reach from km 173 (Nida inflow) to km 317 (inflow of Wyżnica) their share in the alluvia is from 2 to 5%, farer on to the region of Warsaw it is about 1%. This far transport is probably due to the fact that sandstone grains attain a certain relative resistance to abrasion. After they reach this stage which depends on the natural properties of sandstone rock and on the dynamics of the environment, the content of sandstone grains in the alluvia is practically uniform for tens of kilometers.

Quartzites and siliceous rocks (the occurrence of grains of these two rock groups has been discussed in a separate paper dealing with the characteristic of Vistula sands), although always present in quantities of about 10%, are no characteristic components of the Vistula alluvia, from which fact one might draw conclusions as to the effect of tributary rivers on the mineralogical-petrographical composition in the main river. Some of these tributaries like Soła, Chechło, Skawa, Skawinka, Raba, Bug and a few others, bring in less quartzite and siliceous rock grains than the Vistula alluvia contain; in others, like Nida. Czarna, Wisłoka, San, Kamienna, Iłżanka, Zwoleńka, Kurówka, Wieprz and Wilga, quartzites and siliceous rocks occur in slightly higher concentrations, often 2 to 5% and, exceptionally 10% higher than in the deposits of the main channel. However, these small differences in favour of the tributaries are of so little importance that it would be impossible to trace an increased concentration of these components in the Vistula downstream of the inflow of these rivers. For a variety of reasons one should not considered one--sidedly concentrations increassed 1 - 2% and sometimes even more; ascribing them to the nearest tributary inflow; one of the reasons is, that the relatively insignificant differences indicated by successive samples taken from the river may be due to inaccuracies in the method how these examinations are made and therefore in keeping with the admissible error limit, or they may be the result of accidental local differences in the composition where the samples have been taken.

Limestones and other carbonate rocks occur in the deposits of the Chechło and Czarna rivers in quantities of about 3%, while in the local Vistula alluvia none have been determined. Much more of these rock fragments are carried by the Opatówka, Sanna, Wyżnica, Kamienna and Krępianka rivers where they account for 20 to 65% of the deposits (Fig. 3). Even so, below the inflow of Sanna, and of Krępianka also, only some 2 - 4% of these carbonates are found in the Vistula channel, and further downstream this figure drops to about 1%. However, it seams that this material is rather derived from erosion in the gap section of this part of the Vistula valley than from tributary deposits.

Attempts of correlating the effect, how Carpathian sandstones and other rocks resistant to abrasion influence the Vistula alluvia, with the effect of the carbonate rocks are out of place. Carbonate rocks are a characteristic component of the alluvia of those rivers which passing carbonate outcrops in their courses carry off this kind of material; and because carbonate rocks are soft and easily broken up mechanically, they are found in the river deposits only for short distances downstream of these outcrops [2]. They do not occur in older alluvia which have been worked over many times by the river, — as is the case in the Vistula alluvia. In the Vistula reach below Warsaw, the carbonate components observed in the successive samples indicate, that here erosion of glacial series is taking place affecting the large quantity of carbonate pebbles of Paleozoic Scandinavian limestones.

Our survey correlating the conditions, under which the principal mineralogical-petrographical components occur in the Vistula alluvia, with those prevailing in the tributaries of this river leads to the conclusion, that no definite effect of the tributaries can be observed in the alluvia of the main river, apart from the minor interdependences discussed involoving, for instance, the Carpathian sandstones. No other traces are noticeable of the effect of tributary rivers upon the main river alluvia, and the mineralogical-petrographical composition of the Vistula deposits is practically immune against the effect of its numerous tributaries, although in the latter the deposits often vary distinctly from those of the main river. One must keep in mind, that it would be rather one-sided to study this problem solely from the viewpoint of the drainage basin of the Vistula because, beginning with the inflow of the Przemsza or, even, somewhat farer upstream, the Vistula is a lowland river incised into older alluvia of considerable thickness. It must be assumed that conditions differ in rivers operating in older formations, but this type of rivers usually run with steeper gradients and higher velocities characteristic of mountain streams [3, 4]. Similar conclusions can be found in a paper by R. D. Russell [6]; still, they are only similar, in the form of assumptions, because this author failed to analyze the composition of the alluvia brought in by tributary rivers.

4. CHANGES IN THE VISTULA DRAINAGE BASIN EXAMINED ON THE BASIS OF QUARTZ GRAIN ABRASION

A further most interesting problem is the abrasion of quartz grains which are part of the alluvia in the Vistula and its tributaries. In the study of abrasion three groups of grains were distinguished: angular, semi-rounded, and well rounded grains, as indicated in Figure 4. For specifying the changes in grain abrasion as they occur in the longitudinal profile of the Vistula, the author studied the group of grains which in the environment of flowing water appear best abraded, i.e. the 0·60 - 0·75 mm fraction.

In the Vistula profile the Wapiennica inflow sets an end to the "mountain" river section in which at present no rounded alluvia exist. Vastly predominant (accounting for 90 - 100%) is here the group of non-abraded angular grains. This angular material is the principal source of the alluvia accumulated in the channel of the "lowland" Vistula. The limiting line at which grain abrasion changes, coincides with a dividing line of flow dynamics. As early as in the Oświęcim Basin the Vistula turns into what is called a "lowland" river, containing in its alluvia relatively well rounded quartz grains. In this abrupt change in grain abrasion some significant part must have been played by the selective transport of material, as well as the inflow of rivers like Biała, Przemsza and Chechło which carry some 30% rounded quartz grains and relatively little angular grains, 10% at the most. Due to these facts and, moreover, to flow dynamics which in this section of the Vistula slackens and tends towards a tranquil sedimentation, as indicated by the low median grain size of about 0·4 mm and a high degree of material sorting which, after Trask, lies within the limits of 1·2 to 1·3, the Vistula deposits show here a considerable share of rounded grains, reaching some 20 - 25%. The effective rounding of the alluvia of this section bounded by the mouths of Przemsza and Skawa, is also enhanced by the small share of angular grains these rivers carry. Nor is the stabilized dynamics of this Vistula section affected by the inflow of the Soła River to such degree as might have been expected from a mountain stream carrying some 65% angular material. The increase in concentration of angular quartz grains downstream of the Soła inflow is negligible, being no more than about 2%. Unfortunately there is no way how to compare this river section with that upstream of the Przemsza inflow, because the Goczałkowice dam causes a break in the profile of the river, and this is why reliable source data are lacking illustrating the effect the Soła River may have upon changes in the grade of abrasion of the Vistula material.

The next Carpathian tributaries, the rivers Skawa, Skawinka, Raba, Dunajec and Wisłoka carry a high percentage of angular grains. First place take the Raba deposits with some 95% angular quartz grains; next come Dunajec with 83%, Wisłoka with some 80% Skawinka with 76% and Skawa with 62%. The angular material brought in by these tributaries is an evidence of how different are their dynamic conditions compared with the remaining tributaries of the Vistula drainage basin; this type of angular material is typical of mountain streams, with steep gradients and high flow velocities. The junction of these tributaries with the main river leaves distinct traces in the shape of major or minor changes in the Vistula alluvia, involving an increased concentration of angular quartz grains downstream of the places where the Carpathian tributaries successively enter the main Vistula channel. Below the Skawa inflow the change is slight, only some 4%; it is greater afterwards, below the inflow of the Skawinka river and the succeeding rivers: ahead of the Skawinka mouth the deposits of the Vistula contain some 17% angular grains, but downstream, 25 km below the inflow, this quantity reaches up to 26% and, in the next sample taken about 8 km below the Skawinka inflow, it reaches values up to 36%.

Of a similar order are the changes caused by the Raba river: before it joins, the Vistula deposits show 17% angular grains; downstream this figure is 25% and in the next downstream sample it is as much as 31%. Where the Dunajec joins the main channel, the angular grains are 21% ahead of the mouth of this river, and 36% in the first downstream sample and 41% in the next one. On the whole, for the entire drainage basin of the upper and middle Vistula, Skawinka, Raba and Dunajec are rivers of high dynamics which near their inflow cause distinct changes in abrasion of the Vistula deposits; these changes, as mentioned above, are of the order of 9 - 19% for Skawinka, 8 - 14% for Raba and 15 - 20% for Dunajec.

The Wisłoka River resembles the Skawa by causing minor changes in grain abrasion, only about 4%. These changes, as far as they occur in the present-day Vistula alluvia for well rounded grains, show less regularity, and a much narrower amplitude than in the group of angular grains. This can be readily understood in view of the fact, that the Carpathian tributaries carry only insignificant quantities of well rounded grains; as a matter of course, therefore, a grain fraction scantily represented in the material brought in by the tributaries cannot markedly affect the grain composition in the main river channel. Fluctuations of a few per-cent either way, encountered in this group. results from relative surpluses or deficiencies with regard to the two remaining types of grain abrasion; they may also be caused by local differences in sample composition or by innaccuracies of the method employed.

The Nida and Czarna rivers, arriving from the Holy Cross Mountains, carry a fairly well rounded quartz material. In the case of Nida, its 25% content of well rounded grains delivered into the Vistula increases slightly the quantity of this type of grains in the Vistula deposits downstream of the Nida inflow.

An interesting section is the Vistula reach between the points where the Łęg and the Wieprz join the main river, because a number of smaller and larger rivers enter the Vistula valley from both sides supplying a considerable quantity of well rounded quartz grains. In the twelve rivers of this region from which samples were analyzed, the quantity of well rounded grains varies from some 16% in Opatówka to 44% in Krępianka, Chodel and Kurówka, and these figures are far in excess of those in the Vistula channel which average 10 - 15%. The changes in well rounded grains as were found in successive samples from the Vistula deposits are of the order of about 5%. Downstream of an inflow there either may be an increase in quantity of well rounded grains, like below the mouths of Krępianka or Chodel, or the inverse may appear: a decrease in well rounded grains, as was noted downstream of the inflow of rivers like Kamienna, Iłżanka, Kurówka and Wieprz. Similar are these interdependences in the percentage of angular grains, where the differences in quantity for successively taken samples vary up to 5%; noteworthy is, that the majority of the rivers mentioned for this Vistula reach show a higher concentration of angular quartz grains than the deposits of the main channel. In spite of this, in most instances downstream of the mouths of these rivers no increase but rather a decrease in angular grains has been determined.

Identical interrelations between angular and well rounded groups of quartz grains can be observed in the next part of the longitudinal profile of the Vistula, from the Wieprz to the Bug inflow. Although the tributaries supply higher percentages of the two groups of grain abrasion, here one also finds, as a rule, that the Vistula channel contains smaller concentrations — proof that the alluvia of the Vistula form their own deposits irrespective of what the tributary rivers bring in.

The grade of abrasion of the deposits of the Vistula drainage basin indicates the part played by tributary inflow upon changes in the composition of the main river alluvia. In view of the fact, that this influence can only be observed downstream of the inflow of the Carpathian tributaries and only for the group of angular quartz grains, one can easily draw conclusions as to the role of other components of the alluwia brought in by rivers of the Vistula drainage basin. The group of angular quartz grains supplied by the tributaries in quantities: 75% (Skawinka) to 80 - 95% (Raba), causes in the main river channel increases of the order from 8% to, at the most, 20%. Other rivers with some 60% angular grains (Soła and Skawa) or even 80% (Wisłoka) cause changes of some 5%. Assuming similar proportions of changes for other components one may conclude, that for the inflow of a component in a quantity of 10 - - 20% the resulting change in the main channel would be of the order of 1 - 5%. When it comes to the mineralogical-petrographical components analyzed in the preceding chapter, the changes noticeable in the main channel are extremely small or outright imperceptible. This is easy to explain because, after all, these components show often only a predominance of a few per-cent in the tributary alluvia and cannot visibly affect the composition in the main river channel. The effect of tributary inflow upon the main channel alluvia can only be definitely noticeable, when the tributaries have unstabilized dynamic conditions and when, apart from their dynamics, they carry deposits differing by some fifty per-cent from those in the main channel. Conditions like these exist mostly in the hydrographical network of the mountain areas. No such effect can be seen in the lowland part of those streams, where dynamic conditions are uniform and the composition of the alluvia in the tributaries and in the main stream are approximately identical. The example illustrating today's deposits in the Vistula channel shows, that changes in alluvial composition appear only as to grain rounding in river reaches downstream of the inflow of the Carpathian tributaries. On the other hand, the mineralogical-petrographical components of alluvia which in the tributaries predominate very little in quantities compared with angular material, give no occasion of observing changes in the Vistula channel; in this respect changes of one or a few per-cent may be due. as mentioned above, to local differences or to inaccuracies of the method applied.

Taking as an example the changes which can be seen in the Vistula channel downstream of points of inflow of Carpathian tributaries, attention should be paid to how sedimentation of the brought-in material is taking place in the river channel. The concentration of angular grains in the Vistula bed is not highest directly after a tributary has joined the river, but it is rather shifted downstream as far as the place of the next sample. It is 2 to 3 km below the tributary inflow that the nearest sample is taken, with the next sample about 5 km farer downstream. Thus it appears, that the maximum concentration of angular grains lies 7 - 8 km below the tributary inflow, and this content is higher than in the preceding sample by some 3% for Wisloka, 5% for Raba and Dunajec, and 10% for Skawinka. This phenomenon, clearly determined downstream of where the different tributaries join the Vistula (Fig. 4), indicates that in fluvial transport a selection is taking place by which angular grains, due to their greater displacement, are carried farer than rounded grains which in shape resemble spheres. Thus, selective sorting is the principal feature brought about by differences in dynamics of the rivers or their individual reaches, and this leads to changes in the proportions of the three distinguished groups of grain abrasion in the longitudinal profile of the Vistula, from its springs down to the inflow of the Bug River.

For the group of well rounded grains the concentration is higher in river reaches which show less steep gradients, good sorting, and less powerful dynamics, — in other words, in parts of the river profile where accumulation predominates. In the Vistula channel this refers to the reaches between the mouths of Przemsza and Skawa and, again, between San and Wieprz. For the remaining parts of the long profile of the Vistula, the channel has rather an erosive character and contains less well rounded grains in its deposits.

5. SEDIMENTATION PROCESSES DISTURBING PRESENT LONGITUDINAL PROFILE OF THE VISTULA

There remains to be discussed the phenomenon of the numerous maxima encountered in the main river channel down- and upstream of the inflow of tributaries. As was shown in our analyses of grain size distribution, these maxima do not result from any particular grain group having been brought in a by a definite tributary, but they are rather caused by the conditions of sedimentation prevailing in the drainage basin. Such maxima develop due to a disturbance in the dynamic equilibrium in the main river, resulting from some particular lateral inflow. In the river profile this disturbance in equilibrium finds its expression in processes of accumulation or erosion; these processes affect the close neighbourhood of that inflow which has caused in the main channel the disturbance mentioned.

To give an example: in the upper and middle reach of the Vistula, downstream of the mouths of the tributaries: Dunajec, Wisloka, Wyżnica, Krępianka, Zwoleńka, Chodel, Wieprz and Bug, one observes an intensified erosion, noticeable each time for a distance of a few to several score kilometres. Thus, the Wisłoka inflow is followed by a reach of 35 km in which erosional phenomena can be easily observed because no exterior factors (no tributaries join here the river) can cause any of the changes observed. In the alluvia downstream of the inflow of the tributaries mentioned, this erosion can be recognized by a decrease in the share of the following fine-grained fractions: 0·1 - 0·2 mm, 0·2 - 0·3 mm, and 0·3 - 0·4 mm, and by an increase in the coarse-grained fractions of sand and gravel in the fractions: $>$ 2·0 mm, 1·0 - 2·0 mm, 0·75 - 1·0 mm, 0·6 - 0·75 mm and. sometimes, even smaller fractions.

Downstream of places where tributaries join the Vistula, increases have been observed in the Vistula channel for the following rivers and given fractions: for Dunajec — for 0·6 - 2·0 mm, for Wisloka — 0·5 - 2·0 mm and $>$ 2·0 mm, for Wyżnica and Zwoleńka — 0·4 - 2·0 mm, for Krępianka — 0·4 - 1·0 mm, for Chodel — 0·4 - 0·75 mm, for Wieprz — 0·75 - 2·0 mm and $>$ 2·0 mm, for Bug — 0·5 - 2·0 mm.

By water carried by these tributaries the water level in the Vistula channel is lifted and forms some sort of "steps" which locally raise the base of erosion and cause an increase in accumulation in the river section upstream of the inflow of each of these tributaries. A further feature of this process is an increased concentration in the group of fine-grained fractions just ahead of each inflow; for the Dunajec river, for instance, this is seen for grain size 0·3 - 0·4 mm in sample 71, taken from the Vistula alluvia upstream of the mouth of this river. This shows, that every tributary is apt to cause changes in the main river channel ahead of, and below, its inflow, expressed by accumulation upstream of the rise of the water level at the junction, and erosion downstream of it.

A second group of tributaries are those which lead to increased accumulation of deposits below their mouths. This process is expressed by an increase in the fine-grained fractions, combined with a decrease in the coarser grain fractions. To this group of tributaries belong: Przemsza with increases for the 0·2 - 0·4 mm fraction, Skawa and Nida — for 0·3 - 0·5 mm, Skawinka and Raba — for 0·2 - 0·4 mm, Czarna — for 0·2 - 0·5 mm, San, Kamienna and Iłżanka — for 0·2 - 0·4 mm, Sanna — for 0·2 - 0·3 mm, Kurowka — for 0·1 - 0·4 mm, Radomka — for 0·1 - 0·2 mm and 0·3 - 0·4 mm, Pilica and Swider — for the 0·1 - 0·3 mm fraction.

6. SUMMARY

The preceding chapters brought a description of the sedimentary conditions prevailing in the drainage basin of the upper and middle Vistula, based on differences of grain size distribution, changes in mineralogical-petrographical composition, and features of grain abrasion of the alluvia of this river. The author's studies show, that for grain size and mineralogical-petrographical composition the properties are much alike. However, this similarity in the properties of the tributaries and the main river prevents, to a certain extent, their mutual interaction and their effecting perceivable changes in the regime of these rivers.

From the grain rounding features which differ in the individual tributaries and in the different reaches of the Vistula, one can observe the changes in the main river which occur downstream of inflows bringing in greater quantities of different components. As has been shown above, this also reflects upon conditions ruling the whole drainage basin, and upon the limited way how the tributaries can affect these conditions; this effect can only be observed in cases, when the differences in the deposits brought in by tributaries and those accumulated in the Vistula channel are very impressive.

Here it should be emphasized. that in the Vistula drainage basin the part played by tributary rivers is limited to processes which control the forms of deposit sedimentation, not to changes in the composition of the accumulated alluvia. The changes noticeable from differences in grain features are brought about by differences in the dynamics between the tributaries and the Vistula. The longitudinal profiles of the tributaries are not continued in the gradient of the Vistula; at their inflow they meet with a different longitudinal profile in the main channel, and for a relatively short distance they disturb, in a manner more or less noticeable, the equilibrium in the Vistula flow. A variety of seasonal elements also contribute to these disturbances. At some distance farer downstream, the tributaries lose their specific features, and henceforth the Vistula waters continue as if no tributaries had joined the main river.

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VI. ARCHAEOLOGY

ENSEMBLES MICOQUO-PRONDNIKIENS EN EUROPE CENTRALE

Waldemar Chmielewski

Les ensembles traités ci-dessous proviennent en majeure partie des gisements bien connus. La grotte Jama à Piekary I fut fouillée par G. Ossowski dans les années 1880. L'outillage lithique de la grotte Okiennik à Piaseczno est un des mieux connus parmi les gisements archéologiques du pléistocène en Pologne, grâce à l'ouvrage de L. Kozłowski [12]. Les matériaux de la grotte Ciemna à Ojców dont une partie fut mentionnée par W. Antoniewicz en 1928 [1], ont été largement traités et illustrés dans l'ouvrage de S. Krukowski [13]. Le gisement bien connu de Vogelherd [15] en Bavière contenait un niveau qui peut être considéré comme micoquo-prondnikien. En Slovaquie le site Zamarovce [2] a livré en 1928 des outils d'un type spécial, nommés en Pologne „prondnik" (d'après S. Krukowski). C'est lui qui dans le traité sur le paléolithique en Pologne [13] publia des nouvelles observations sur les gisements Piekary I et III.

La tentative de ranger une partie de ces gisements en un groupe culturel, nommé „prondnikien", ne se trouve que dans l'ouvrage cité de S. Krukowski. Deux industries y font partie: celle de Skała du gisement Piekary III et celle de Ojcow de la couche 5 de la grotte Ciemna. S. Krukowski a déduit que les matériaux d'Okiennik présentent un mélange mécanique de différents ensembles provenant d'époques et de civilisations différentes. D'autres, comme Piekary I et la grotte Ciemna, couche 6, auraient été des fragments d'ensembles assez fortement mélangés. Les sources mentionnées ont trouvé une classification différente dans d'autres travaux; Okiennik fut considéré comme gisement de la civilisation micoquienne [1, 12], Vogelherd comme appartenant à l'Acheuléen supérieur [15], Piekary I au Moustérien [12], Zamarovce à l'Aurignacien [12. 17], ou bien au Széletien [14].

De 1962 à 1966 l'auteur et Mme T. Madeyska-Niklewska ont fait des fouilles à l'abri Wylotne à Ojców ce qui leur permit de découvrir 3 niveaux avec des prondniks, bien séparés stratigraphiquement. L'analyse d'une partie (ca 1/8) des outillages lithiques provenant de ces niveaux et leur comparaison avec les ensembles cités suggèrent, distinction d'un groupe culturel qui se développait en Europe centrale, dans la phase initiale de la dernière période froide (Würm; G. IV). On a propose pour ce groupe le nom de „civilisation micoquo-prondnikienne" [6, 7, 9]. La justification de son existence par l'analyse des traits qui la distinguent des autres civilisations de la même époque et l'examen de ses éléments font l'objet de ce traité.

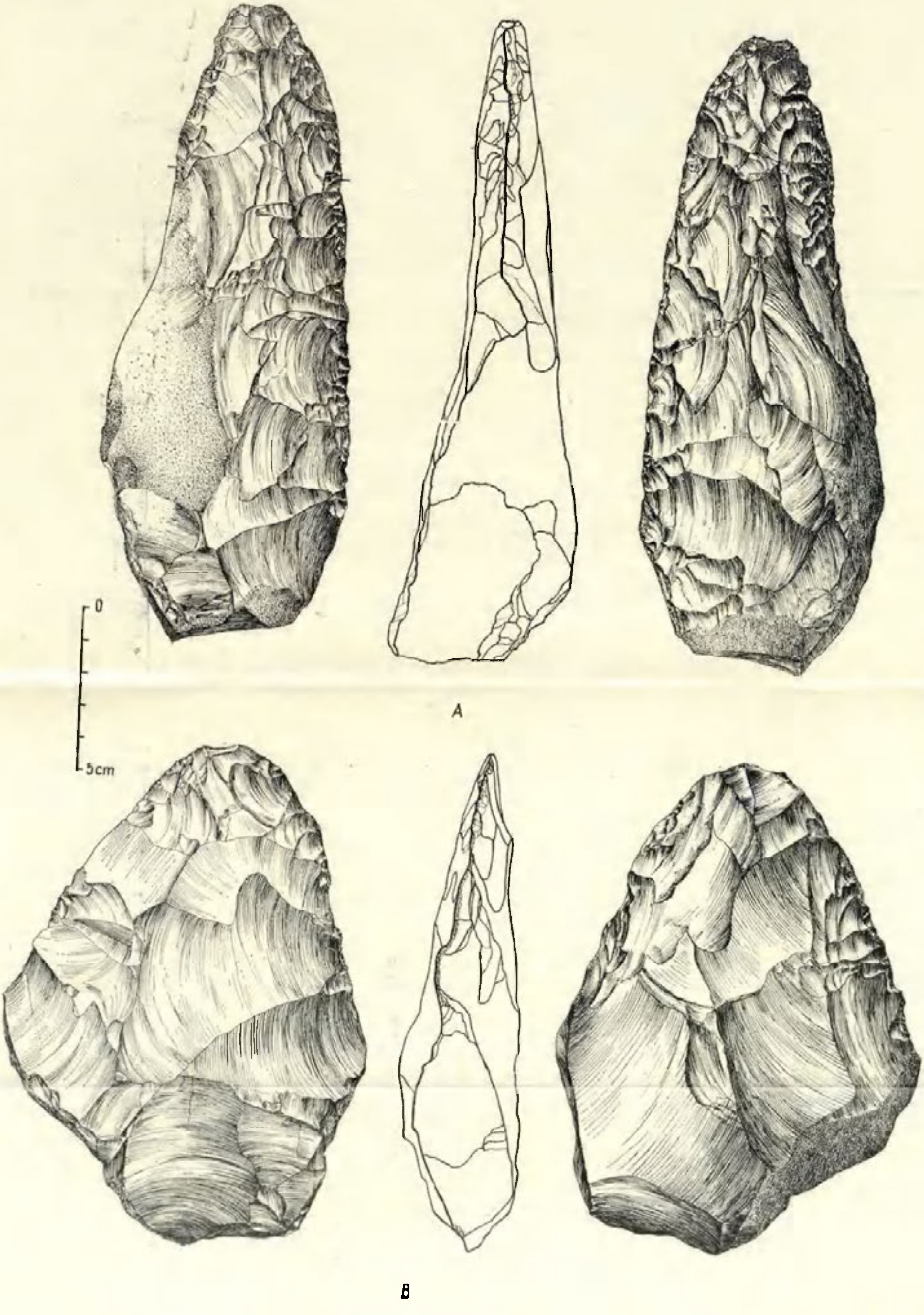
CARACTÉRISTIQUE DES ENSEMBLES MICOQUO-PRONDNIKIENS

F. Bordes, se servant de sa propre méthode typologique et statistique, a démontré la différentiation du complexe moustérien de l'Europe occidentale, en y distinguant 5 groupes culturels [4, 5]. Cette méthode est également très utile en dehors des territoires de l'Europe occidentale et constitue une base méthodique principale de ces considérations.

Les outillages lithiques des gisements datant de la phase initiale de la dernière période froide se ressemblent du point de vue typologique, cependant les proportions du nombre des outils découverts sont différentes. Ceci constitue la base de distinction des groupes culturels. La technique lavalloisienne ou le manque de celle-ci dans l'outillage lithique sont un critère supplémentaire de la classification.

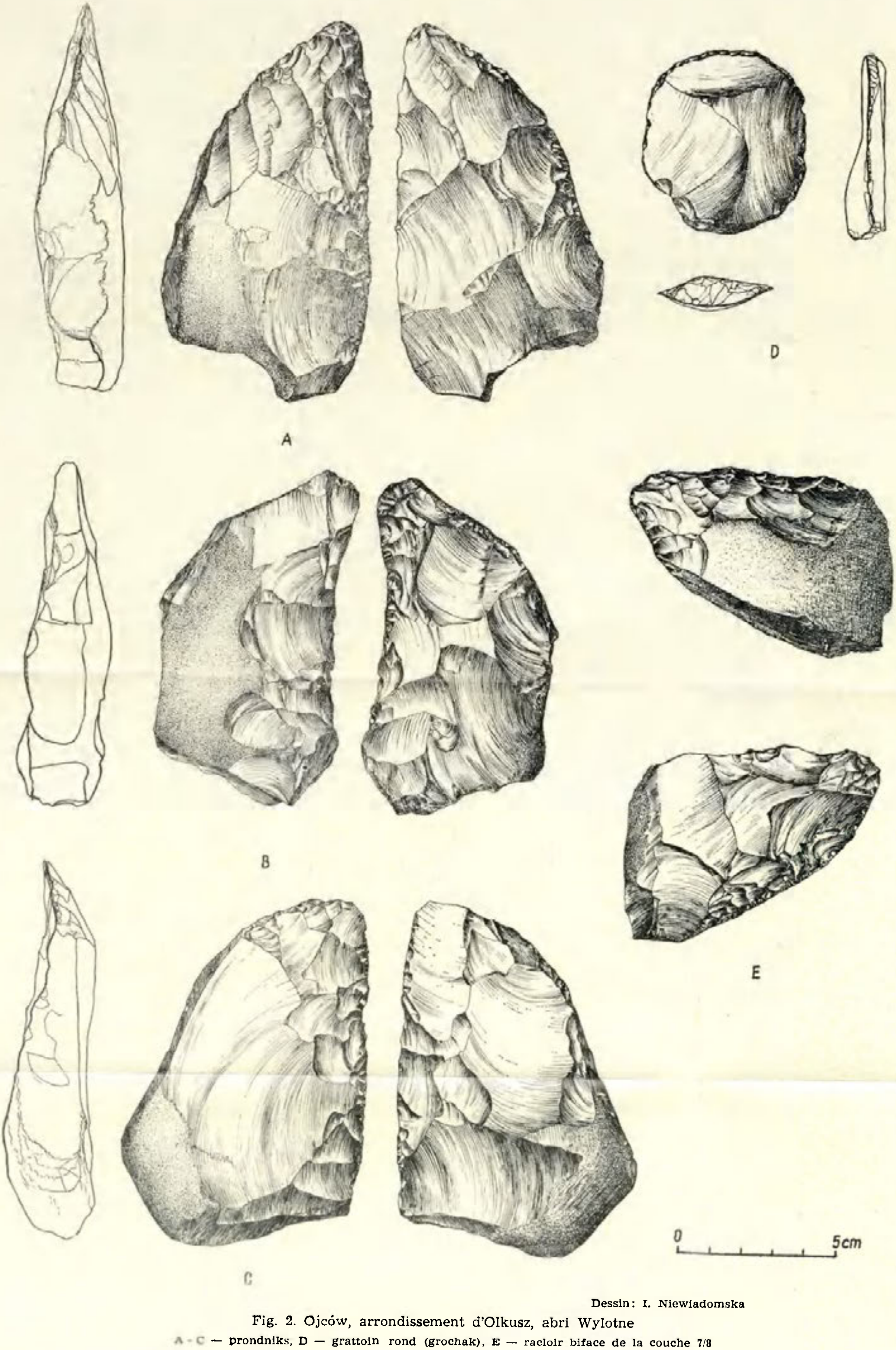
Les ensembles nommés micoquo-prondnikiens ne font partie d'aucun groupe moustérien de l'Europe occidentale. Le trait qui les caractérise est la présence dans leur inventaire lithique d'un outil d'un type tout particulier à retouche bifaciale, pareille à celle des bifaces, dénommé prondnik par les préhistoriens polonais. Je considère cet outil comme biface d'un type particulier. Ses traits caractéristiques sont les suivants: une retouche bifaciale plate, parfois partielle si l'outil a été fait sur un éclat; un bord est droit, rarement un peu concave, et fait avec le bord opposé un tranchant fin et perçant à l'extrémité distale. Le bord arqué passe dans sa partie proximale en un dos épais atteignant la moitié ou les 2/3 de la longueur de celui-ci. Les talons des prondniks sont pour la plupart gros et bien souvent couverts de cortex. Les pièces des ensembles plus récents sont souvent retouchées à la surface et aussi aux talons (Fig. 2-A. B, C; 3-A, B, C, D; 4-B).

En suivant le développement des prondniks on peut apercevoir la naissance de leurs variétés et les procédés techniques appliqués pendant la fabrication ou la réparation de ces outils. La réparation consistait à enlever du sommet de l'outil, d'une de ses faces, mais toujours près de son



Dessin: I. Niewiadomska

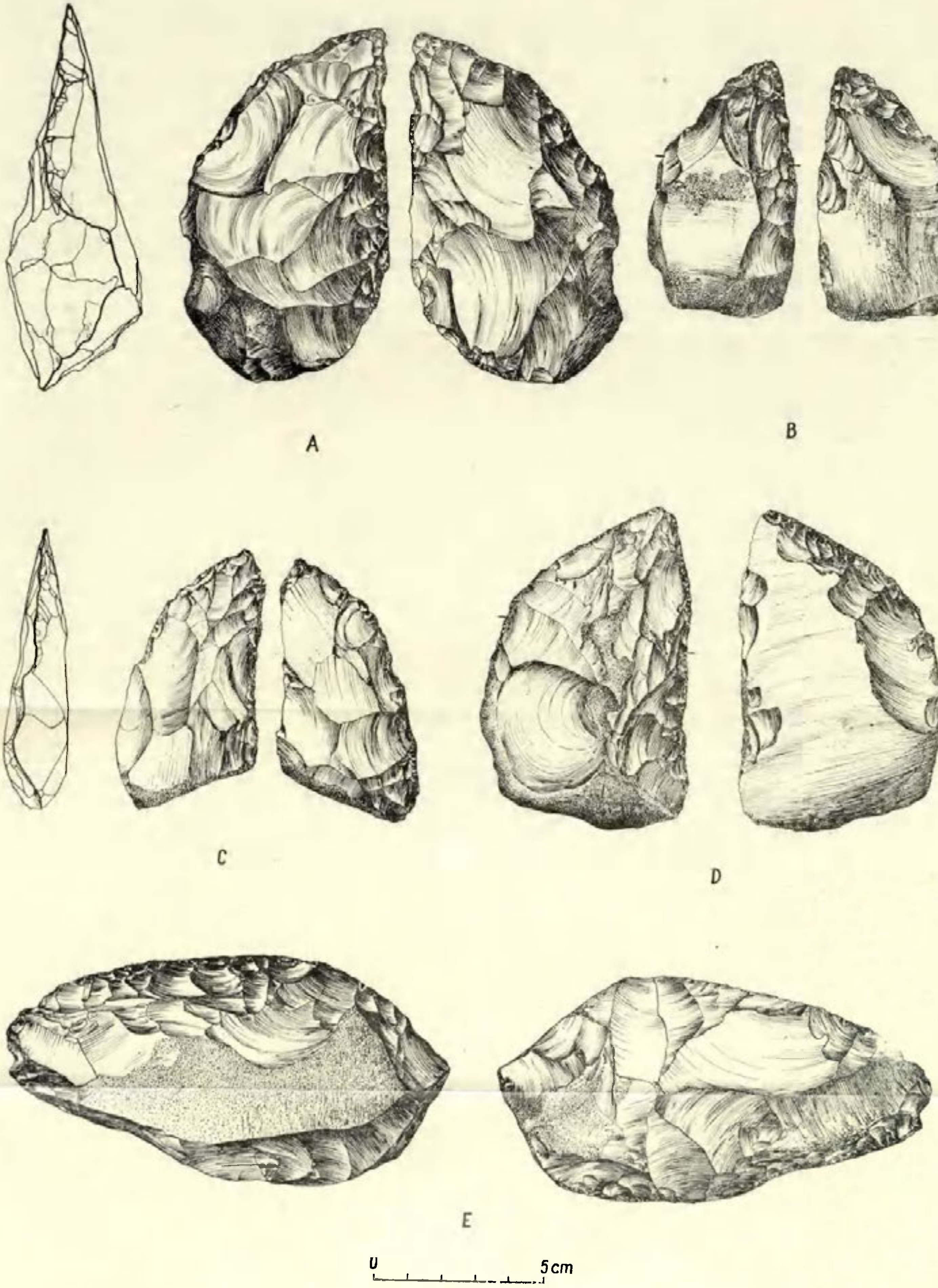
Fig. 1. Ojców, arrondissement d'Olkusz, abri Wylotne
Bifaces de la couche 7/8



Dessin: I. Niewiadomska

Fig. 2. Ojców, arrondissement d'Olkusz, abri Wylotne

A - C — prondniks, D — grattoin rond (grochak), E — racloir biface de la couche 7/8



Dessin: I. Niewiadomska

Fig. 3. Ojców, arrondissement d'Olkusz, abri Wylotne

A - D — prondniks, **E** — racloir biface, type Quina de la couche 7/8

TABLEAU 1. Caractéristiques typologiques des ensembles micoquo-prondnikiens de l'abri Wylotne à Ojców

Caractéristiques typologiques	Couche					
	5		6		7/8	
	n	%	*n*	%	*n*	%
1 — Éclats Levallois typiques	1	0,362				
2 — „ Levallois atypiques					1	2,22
3 — Pointes levalloisiennes					1	2,22
4 — „ levalloisiennes retouchées	1	0,362				
5 — „ pseudo-levalloisiennes			1	1,04		
6 — „ moustériennes						
7 — „ moustériennes allongées						
8 — Limaces	1	0,362				
9 — Racloirs simples droits	6	2,20	6	6,25	1	2,22
10 — „ simples convexes	13	4,72	6	6,25	3	6,66
11 — „ simples concaves	1	0,362	1	1,04		
12 — „ doubles droits			2	2,09		
13 — „ doubles droit-convexes	3	1,08	1	1,04	1	2,22
14 — „ doubles droit-concaves						
15 — „ doubles biconvexes	1	0,362				
16 — „ doubles biconcaves						
17 — „ doubles convexe-concaves	3	1,08	2	2,09		
18 — „ convergents droits	2	0,725				
19 — „ convergents convexes	9	3,26	3	3,12	1	2,22
20 — „ convergents concaves						
21 — „ déjetés	18	6,26	5	5,25	4	8,90
22 — „ transversaux droits	6	2,18	2	2,09		
23 — „ transversaux convexes	8	2,9	4	4,18		
24 — „ transversaux concaves						
25 — „ sur face plane	8	2,9	1	1,04	1	2,22
26 — „ à retouche abrupte						
27 — „ à dos aminci	6	2,18			1	2,22
28 — „ à retouche biface	15	5,44	5	5,21	4	8,90
29 — „ à retouche alterne	8	2,9	4	4,18	1	2,22
30 — Grattoirs	8	2,9	3	3,12	1	2,22
31 — Grattoirs atypiques	10	3,62				
32 — Burins	10	3,62	3	3,12		
33 — „ atypiques						
34 — Perçoirs	4	1,45	2	2,09		
35 — „ atypiques			1	1,04	2	4,44
36 — Couteaux à dos	9	3,26	3	3,12	1	2,22
37 — „ à dos atypique	4	1,45				
38 — „ à dos naturel	5	1,81	3	3,12	1	2,22
39 — Raclettes	23	8,35	4	4,18	5	11,6
40 — Éclats tronqués						
41 — Tranchets	7	2,54	3	3,12	3	6,66
42 — Encoches	29	10,05	17	17,71	7	15,58
43 — Denticulés	23	8,35	5	5,25	1	2,22

Tab. 1 (cont.)

Caractéristiques typologiques	Couche					
	5		6		7/8	
	n	%	*n*	%	*n*	%
44 — Pointes burinantes alterne	7	2,54	1	1,04	5	11,6
45 — Retouches sur face plane	12	4,35	3	3,12		
46 — „ abruptes épaisses	(234)	(46)	(89)	(48)	(38)	(46)
47 — „ alternes épaisses						
48 — „ abruptes minces	7	2,54	4	4,18		
49 — „ alternes minces						
50 — „ bifaces	5	1,8				
51 — Pointes de Tayac						
52 — Triangles à encoche	4	1,45	1	1,04		
Total	276	100	96	100	45	100

TABLEAU 2. Caractéristiques techniques des ensembles micoquo-prondnikien de l'abri Wylotne à Ojców

Caractéristiques techniques	Couche		
	5	6	7/8
Bifaces			
Micoquiens	5	1	2
Cordiformes	5	2	3
Subtriangulaires	6	8	—
Lagéniformes	—	—	2
Partiels	2	2	—
Total	18	13	7
Discs	5	1	1
Prondniks	13	10	6
Total	36	24	14
Nuclei			
Initials à un plan de frappe	3	1	1
Prismatiques à un plan de frappe	8	3	6
À un plan de frappe usés	4	1	—
Discoides	4	2	—
À deux plans de frappe	4	2	1?
Globuleux	6	—	—
Informes	7	1	2
Total	36	12	10
Èclats, fragments des outils et outils initials			
Facetté	120 (10)	30 (2)	—
Lisse	88 (4)	22 (1)	4
À talon non préparé	33	12	2
À talon oté	85	6	2
Èclats de taille	81	19	5
Fragments	248	37	7
Fragments des outils	72	8	3
Outils initials	5	9	7
Total	732	143	30

TABLEAU 3. Indices et groupes caractéristiques des ensembles micoquo-prondnikien de l'abri Wylotne à Ojców

Indices	Couche		
	5	6	7/8
	%		
Indice acheuléen total	17,7	30,12	33,9
„ de couteax à dos	4,9	3,13	4,44
„ de bifaces	11,35	21,3	30,8
„ de prondnik	41,9	43,4	46,0
„ de racloirs	39,2	43,9	37,8
„ charentien	9,8	12,53	6,67
„ de cryoturbation	46,0	48,0	46,0

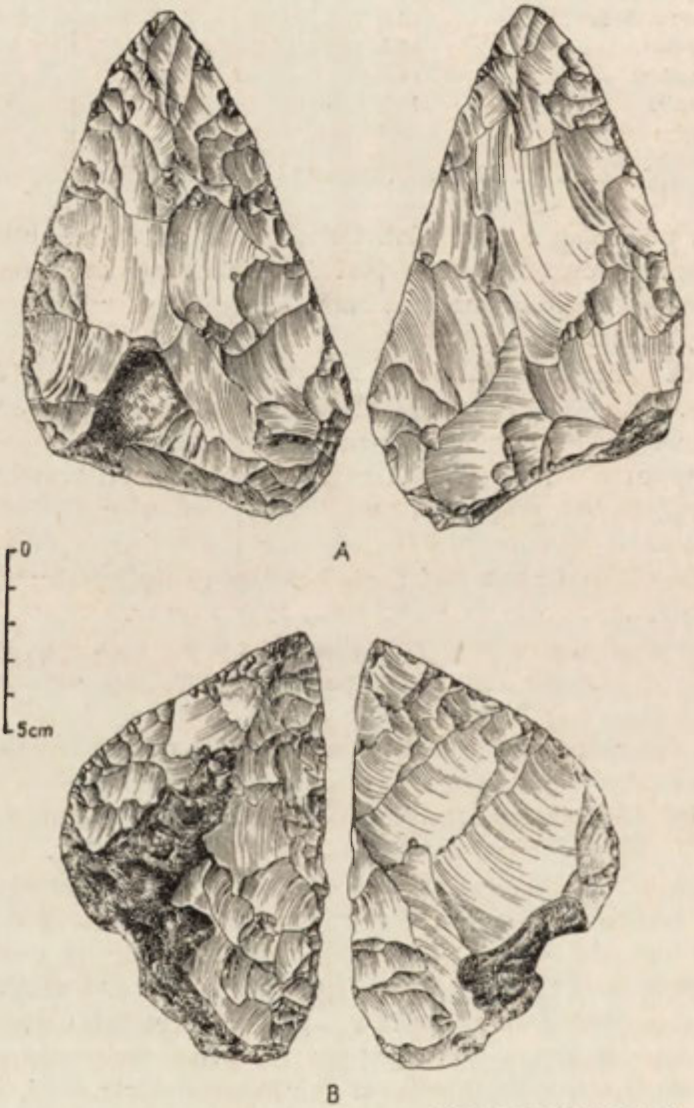
bord droit. une lame ou un éclat. Cette technique est semblable à celle de la fabrication du burin et surtout du burin plat. Les prondniks avec les traces de cette technique sont caractéristiques pour les sites plus récents [11] (Fig. 2-C).

Il y a des prondniks fabriqués sur de grands et moyens éclats, plus ou moins retouchés sur la face plane (Fig. 3-B, D). Parfois ils ressemblent beaucoup aux racloirs convergents déjetés. Pourtant ce ne que les formes des deux types d'outils qui sont pareilles et particulièrement lorsqu'on les regarde dans une projection horizontale. Vus de profil, les prondniks sont plus élancés que les racloirs, et leurs extrémités distales sont toujours perçantes. Une autre différence consiste en un traitement du matériel brut différent; l'axe de l'éclat dans le cas du racloir convergent déjeté est perpendiculaire ou bien oblique au bord plus long et retouché de celui-ci, tandis que l'axe du prondnik est le plus souvent parallèle à son côté droit.

A part des prondniks le trait caractéristique des ensembles micoquo--prondnikiens est l'existence d'une quantité considérable d'outils retouchés sur les deux faces: les bifaces et les racloirs. Parmi ces derniers l'indice des racloirs, type Quina, est toujours élevé (Fig. 1, 2-D; 3-E).

Dans les ensembles plus anciens on trouve encore des séries d'outils d'un type caractéristique que S. Krukowski a nommés „grochakis". Ce sont des éclats auquels on donnait une forme ronde ou ovale par une retouche de type différent (Fig. 2-D; 7-E, F; 8-B). On différencie trois variétés de grochakis en raison du type de la retouche. Les spécimens présentant sur leur pourtour de fines retouches continues ressemblent aux raclettes. La seconde variété a l'air d'un grattoir rond, la retouche semiabrupte de la troisième variété ne la distingue pas des racloirs. C'est pourquoi les grochakis seront dénommés par la suite „grattoirs ronds", ou „racloirs ronds".

Les autres outils apparaissant dans les ensembles micoquo-prondnikiens sont les mêmes que ceux connus du Moustérien. Pour s'orienter dans les proportions de leur apparition on a donné sur le tableau I une liste type, le nombre et le pourcentage de chaque type par rapport à la totalité des outils de chacune des 3 séries provenant de l'abri Wylotne



Dessin: I. Niewiadomska

Fig. 4. Ojców, arrondissement d'Olkusz, abri Wylotne

Biface cordiforme (A) et prondnik (B) de la couche 5 à Ojców. On a pu présenter sur cette base des données sous forme des diagrammes d'une manière analogue à celle de M. F. Bordes et d'autres auteurs (Fig. 5).

La comparaison des diagrammes cumulatifs des 3 séries de l'abri Wylotne démontre leur conformité interne et leur ressemblance, tandis que la comparaison avec les diagrammes des ensembles du Moustérien de tradition acheuléenne et du Micoquien avec une technique levalloisienne accuse des différences considérables typologiques et statistiques entre les ensembles micoquo-prondnikiens et les deux groupes culturels de l'Europe occidentale (Fig. 6).

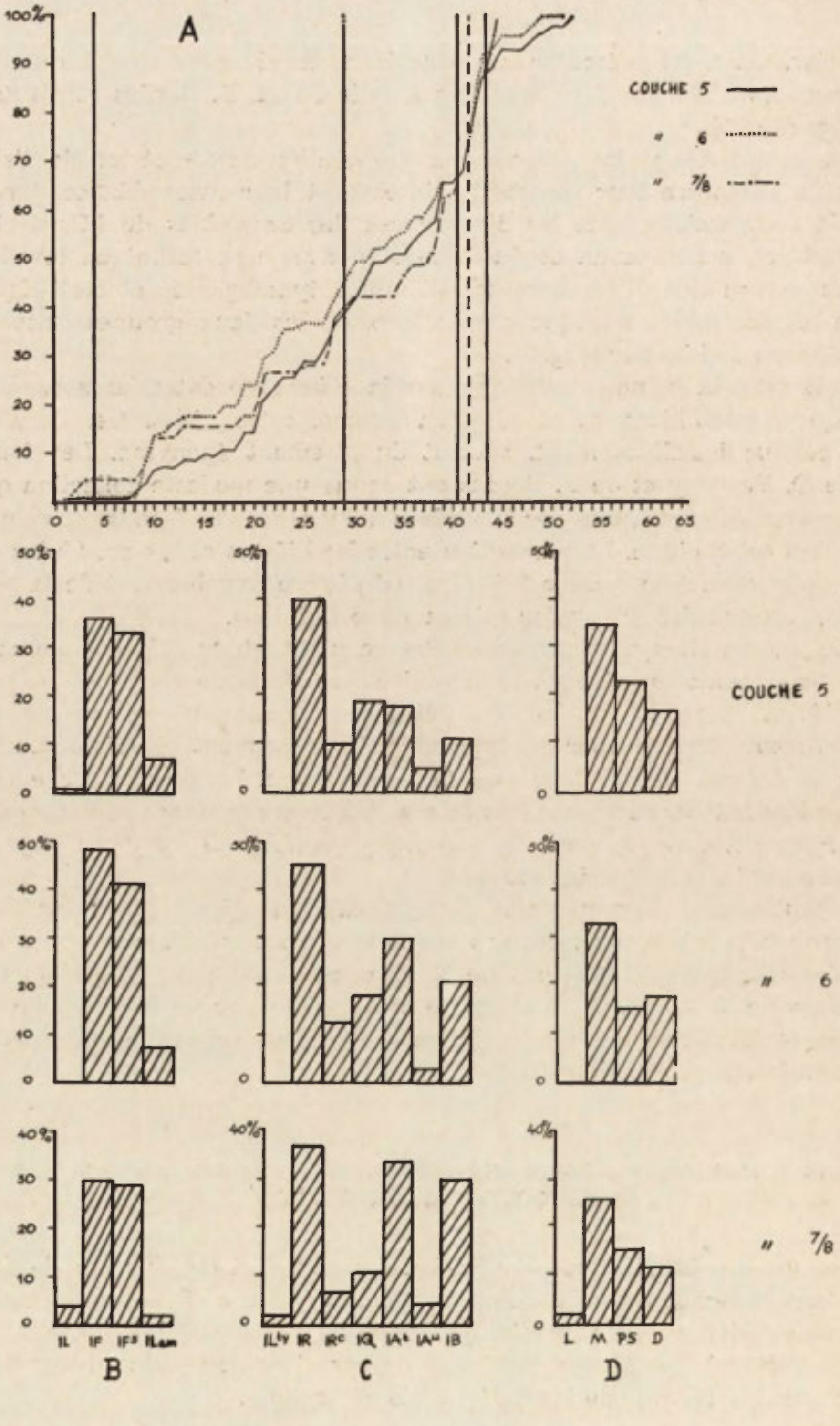
Cela vaut la peine de réfléchir sur la différence entre les ensembles micoquo-prondnikiens et ceux qu'on nomme micoquiens. Ces derniers sont connus insuffisamment, surtout du gisement éponyme. Les fouilles de D. Peyrony et de F. Bordes ont donné une modeste collection que j'ai en l'occasion pu examiner à Bordeaux. J'y ai trouvé 4 petits prondniks dont l'un est typique. La proportion entre les bifaces et les prondniks est dans cette collection comme 3 à 1 ce qui diffère sensiblement de la proportion connue des ensembles micoquo-prondnikiens.

Les autres sites micoquiens en France n'ont qu'un élément commun avec les ensembles micoquo-prondnikiens de l'Europe centrale: ce sont les bifaces. Dans l'évolution du Micoquien occidental les prondniks n'aboutirent pas à former un type spécial. Ils peuvent parfois accompagner les bifaces comme leur variété insignifiante. Le substrat acheuléen se manifestant par le groupe des bifaces est commun pour les deux groupes. Pour cette raison dans le nom des ensembles de l'Europe centrale le composant micoquien fut souligné.

Il faut encore ajouter que de plus grandes analogies se font voir entre les ensembles micoquiens des grottes de la France méridionale et les ensembles micoquo-prondnikiens de la Pologne qu'avec les ensembles micoquiens de la France septentrionale caractérisés par un indice élevé de technique levalloisienne. Cet indice dans les séries micoquo-prondnikiens est bien faible, proche de zéro.

CERTAINES TENDANCES DANS L'ÉVOLUTION DE LA CIVILISATION MICOQUO-PRONDNIKIENNE

Les gisements micoquo-prondnikiens se groupent en plus grande densité dans la région du Jura Polonais. C'est là qu'on a découvert quelques ensembles bien repérés stratigraphiquement (Ojców: l'abri Wylotne, la grotte Ciemna). Le proche voisinage de ces sites permet d'utiliser dans les études les données de la stratigraphie géologique.


A
COUCHE 5
" 6
" 7/8
100%
90
80
70
60
50
40
30
20
10
0
5
10
15
20
25
30
35
40
45
50
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60
65
50%
40
30
20
10
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COUCHE 5
" 6
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IL
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Les données présentées sur le Tableau 1, concernant les trois ensembles de l'abri Wylotne nous montrent une certaine stabilité de leur outillage. Ceci se rapporte particulièrement au groupe des racloirs. Dans celui des bifaces et prondniks on observe une diminution progressive du nombre de ces outils dans les séries plus récentes. C'est l'inverse pour les outlis du type paléolitique supérieur (grattoirs, burins, perçoirs et couteaux).

La grotte Ciemna à Ojców contient dans ses couches deux ensembles micoquo-prondnikiens. Celui qui est plus ancien provenant de la couche 6 (d'après S. Krukowski ce qui correspond à la couche 8 d'après le numérotage de S. Kowalski) n'est pas nombreux. Son biface subtriangulaire massif et les prondniks tout aussi massifs démontrent une forte ressemblance avec l'outillage de l'ensemble provenant du contacte entre la couche 7 et 8 de l'abri Wylotne. On peut conclure de l'analyse des coupes de nombreux gisements du Jura Polonais que l'ensemble de la grotte Ciemna (provenant de la couche 5 d'après S. Krukowski, de la couche 6 d'après S. Kowalski) est le plus jeune. Les ouvrages publiés jusqu'à présent font nous connaître que cet ensemble ne contenait pas un seul biface, ni grattoir rond, tout en contenant un grand nombre de tels outils comme les burins et les prondniks. Ceci témoigne que cet ensemble se distingue des autres ensembles connus de la civilisation micoquo-prondnikienne. Ce fait pourrait être causé par une différence d'âge entre les ensembles comparés, ou bien montrer également la différenciation interne de la culture micoquo-prodnikiennes. Il faut souligner aussi que l'ensemble plus récent de la grotte Ciemna n'atteint pas la limite supérieure d'âge des ensembles moustériens de l'Europe occidental. Ceci rend difficile toutes les considérations sur les héritiers éventuels de la civilisation micoquo-prondnikienne.

L'assemblage lithique de la grotte Okiennik à Piaseczno compte quelques milliers de spécimens, et, il n'y a pas longtemps, il était le plus riche en Pologne. Le remplissage de cette grotte n'atteignait que dans quelques endroits une épaisseur de 80 cm. Pour cette raison les informations qu'il aurait apparu dans le niveau loessique n'ont pas de grande

Fig. 5.

A. Diagrammes cumulatifs des 3 séries de l'abri Wylotne. Les chiffres en bas du diagramme concernent les types des outils d'après la liste du tableau 1

B. Indices technologiques de ces mêmes séries: IL — indice de la technique levalloisienne, IF — indice total de facettage des talons d'éclats. IF^s — indice de facettage des éclats sans talons dièdres, ILam — pourcentage des lames

C. Indices typologiques: IL — indice des types levalloisiens, IR — indice des racloirs, IR^c — indice des racloirs charentiens, IQ — indice des racloirs, type Quina, IA^t — indice das types acheuléens, IA^u — indice des couteaux à dos, IB — indice des bifaces et des prondniks.

D. Indices de civilisation: L — levalloisienne, M — moustérienne, PS — indices des formes caractéristiques du paléolithique supérieur, D — indices des denticulés.

valeur. Ce fait ainsi que la richesse de ce gisement ont fait suposser S. Krukowski qu'il présente un mélange de plusieurs ensembles. Du point de vue de la typologie et du nombre de l'outillage la couche 5 de l'abri Wylotne correspond parfaitement à celui d'Okiennik. Cette couche

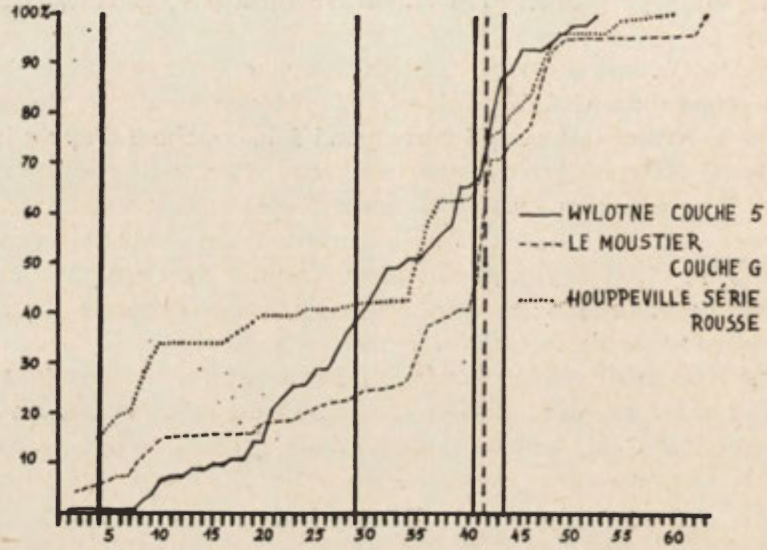

Fig. 6. Comparaison des diagrammes cumulatifs de l'ensemble micoquo-prondnikiens de la couche 5 de l'abri Wylotne, de l'ensemble moustérien de tradition acheuléenne de la couche G du Moustier ainsi que de l'ensemble micoquien de Houppeville. Les deux derniers diagrammes d'après F. Bordes, 1954. Le diagramme de Houppeville présenté sans les éclats et les lames levalloisiens

5, mince, très abondante en outils, provient probablement de même période (Fig. 7). Dans le proche voisinage d'Okiennik se trouve l'abri de Dziadowa Skała (la Roche des Mendiants), près de Skarżyce. Elle a un coupe géologique bien développé [8]. Cet abri est pauvre en outillage lithique. Un nucléus provenant de la couche datant de la phase initiale de la dernière période froide ressemble beaucoup à ceux d'Okiennik.

Deux derniers ensembles micoquo-prondnikiens découverts jusqu'à présent en Pologne provienent des gisements Piekary I et III. Probablement les deux ensembles se complètent mutuellement étant le vestige de l'activité du même groupe d'hommes qui habitaient l'abri Jama et campaient également dans la proximité de l'abri, sur la terrasse de la Vistule. Dans les deux ensembles apparaissaient des bifaces, des prondniks, des grattoirs ronds et des burins, ce qui semble montrer une grande ressemblance de ces ensembles aux outillages connus de l'abri Wylotne.

Une certaine différence entre eux consiste dans la présence relativement nombreuse de bifaces triangulaires à Piekary.

Une très forte proportion d'outils bifaces: de bifaces et de prondniks, dans la couche la plus inférieure de l'abri Wylotne suggère que la civilisation micoquo-prondnikienne pourrait dériver d'un fond acheuléen interglaciaire. Les bifaces de cet abri auraient pu se trouver dans n'importe quel ensemble de l'Acheuléen supérieur (Fig. 1). Les bifaces et les racloirs du site Cracovie-Wawel ont maints traits caractéristiques communs avec les ensembles micoquo-prondnikiens, et leur âge interglaciaire, bien qu'il ne soit pas prouvé, est très probable [16]. Dans les col-

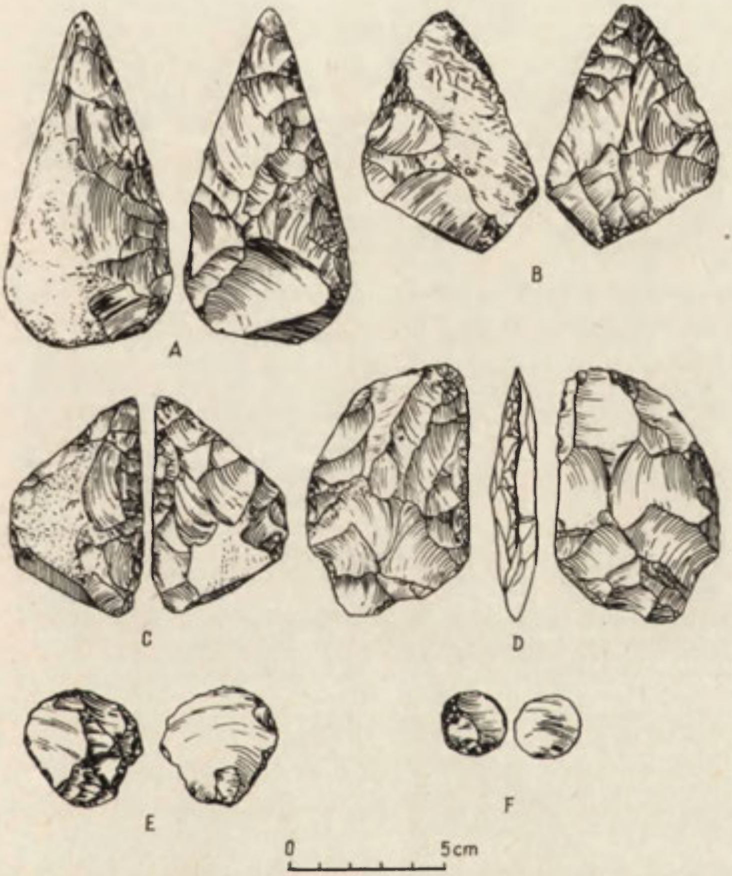

Fig. 7. La Grotte Okiennik à Piaseczno, arrondissement de Zawiercie

A - B — bifaces, C - D — prondniks, E - F — grattoirs ronds (grochakis) d'après S. Krukowski [13] lections non publiées de A. Jura, de Zwierzyniec à Cracovie, se trouvent des outils du type acheuléen, et leur âge interglaciaire, dans la lunière des recherches y faites par L. Sawicki, est également vraisemblable. Les deux sites de Cracovie prétendent de représenter les ancêtres des ensembles micoquo-prondnikiens en Pologne.

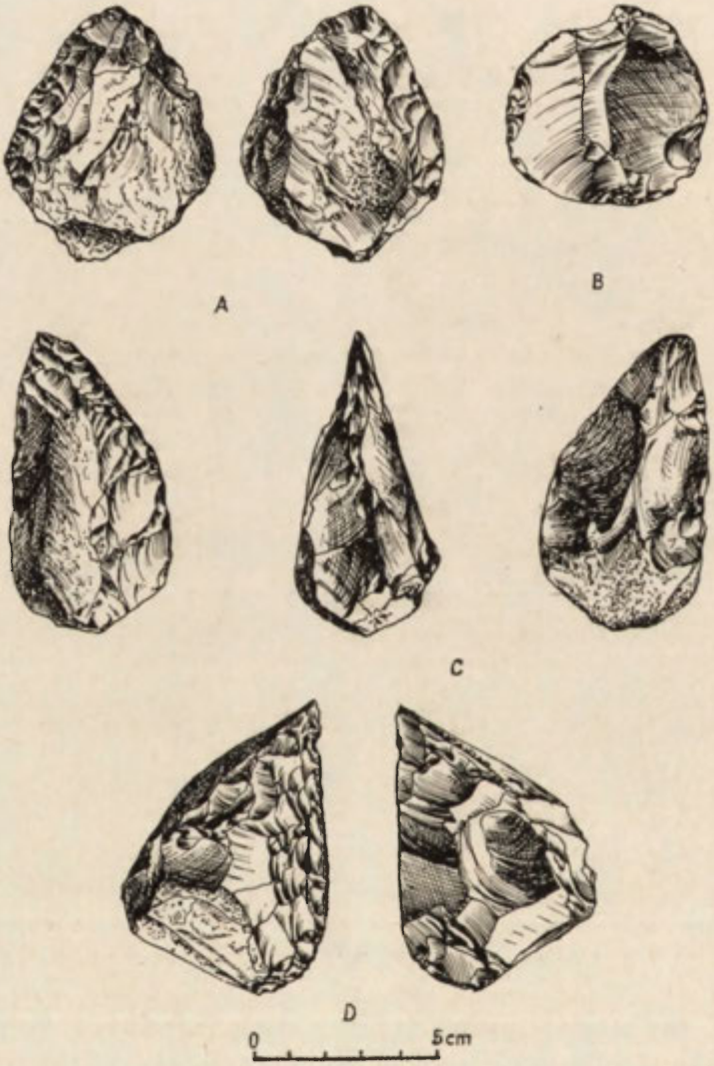

Fig. 8. Choix d'outils caractéristiques de l'ensemble micoquo-prondnikien de Vogelherd (Bavière)

A — biface cordiforme, B — grattoir rond, C - D — prondniks d'après G. Riek [1]

EXTENSION DES ENSEMBLES MICOQUO-PRONDNIKIENS

La grande densité des sites de cette civilisation dans la région du Jura Polonais suggérait sa limitation territoriale. Cependant on peut maintenant démontrer que le territoire où apparaissent les ensembles micoquo-prondnikiens est bien plus vaste. La distinction du prondnik

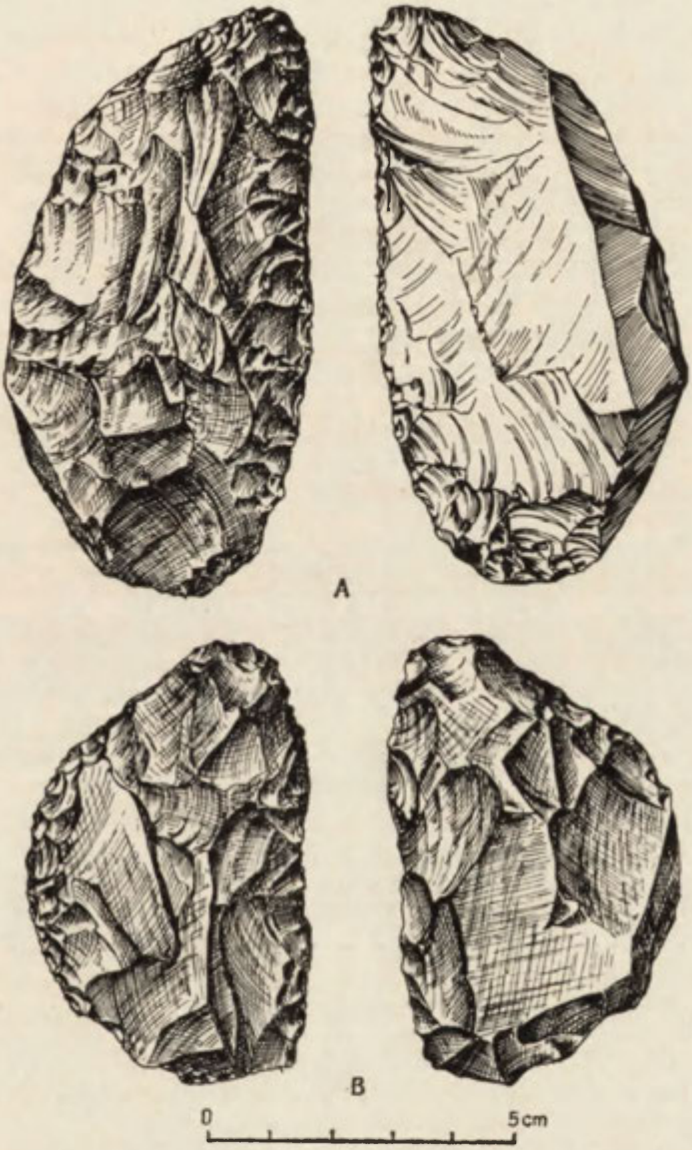

Fig. 9. Prondniks du site Zamarovce (Slovaquie) d'après J. Skutil [17]

comme type d'un outil caractéristique ainsi que les données typologiques et statistiques, publiées ici, permettent de discerner les ensembles considérés et eo ipso de fixer l'étendue de la civilisation en question.

L'ensemble du gisement Vogelherd (en Bavière), publié par M. G. Riek, démontre une ressemblance frappante aux outillages polonais, sur quoi cet auteur a tiré l'attention en le comparant à celui de la grotte Okiennik [15]. Outre les deux spécimens de prondniks et un biface cette petite série de 31 pièces contenait un grattoir rond (grochak) typique (Fig. 8).

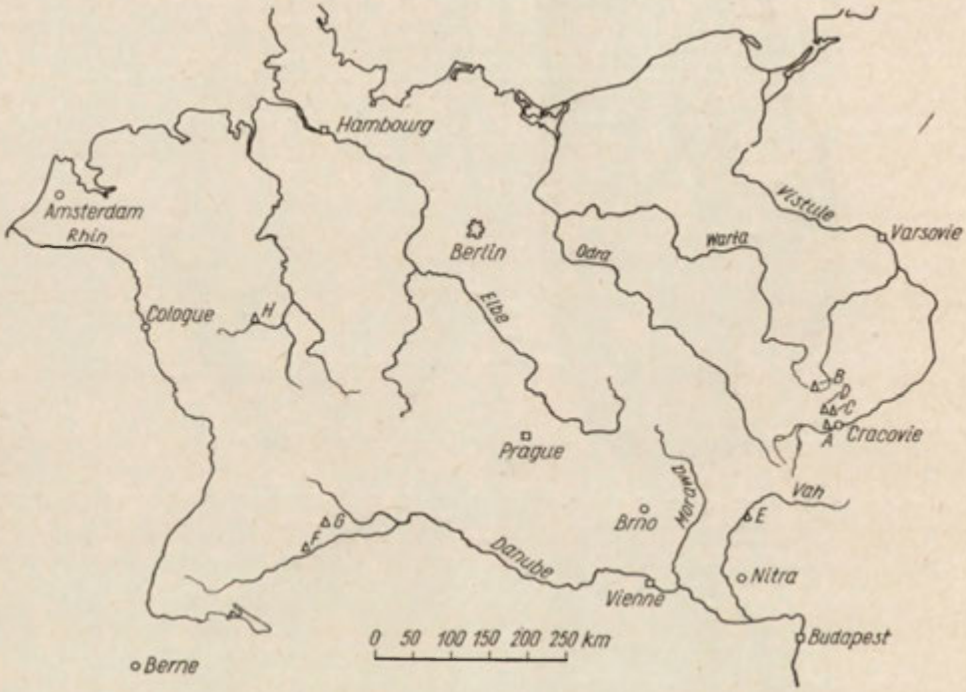

Fig. 10. Carte des sites micoquo-prondnikiens en Europe centrale

A — Piekary I et III, B — Grotte Okiennik à Piaseczno, C — Grotte Ciemna à Ojców, D — abri Wylotne à Ojców, E — Zamarovce, F — Vogelherd, G — Hohler Stein, H — Buhlen

De Bavière provient encore un ensemble micoquo-prondnikien, notamment celui de Hohler Stein, près de Böhmfeld. Il fut présenté en 1966 par M. W. Taute au Congrès des Sciences Pré- et Protohistoriques à Prague. Cet ensemble est proche de celui de Vogelherd et ressemble beaucoup aux outillages de l'abri Wylotne à Ojców.

Récemment M. G. Bosiński a écrit un article sur la technique de réparation des prondniks, observée sur les spécimens trouvés dans le site

Buhlen, en Hesse. Ce procédé technique était très fréquent chez les créateurs de plus récent ensemble de la grotte Ciemna. Probablement Buhlen et le site polonais représentent la phase évolutive tardive de la civilisation considérée.

Dans la série du site Zamarovce, au bord du Vah, se trouvent deux prondniks dont l'un est typique (Fig. 9). Leur situation stratigraphique dans la coupe de la briqueterie d'où ils proviennent, malheureusement n'est pas connue. Sur ce site apparurent des outils du paléolithique supérieur. Pour cette raison les préhistoriens tchécoslovaques attribuèrent les prondniks au Szélétien. Les deux spécimens sont très typiques, et on ne trouve pas de semblables dans les assemblages lithiques szélétiens. C'est pourquoi l'auteur suppose qu'ils représentent un fragment d'un certain ensemble micoquo-prondnikien du territoire slovaque.

Aux sites mentionnés des territoires voisins s'ajoutent 8 ensembles du Jura Polonais et aussi quelques trouvailles isolées des environs de Cracovie et des alentours de Ojców qui ne furent pas considérés ici (Fig. 10). La totalité constitue un nombre considérable de 12 ensembles connus jusqu'à présent. Ils forment un groupe homogène ce qui justifie de les considérer comme unité culturelle hautement développée du paléolithique moyen.

Prenant en considération les données statistiques et typologiques discutées sommairement plus haut, la classification chronologique des ensembles micoquo-prondnikiens se présente comme dans le Tableau 4.

TABLEAU 4

Ensembles micoquo-prondnikiens supérieurs	Grotte Ciemna, couche 5; Buhlen
Ensembles micoquo-prondnikiens inférieurs	Abri Wylotne, couche 5 Grotte Okiennik, Vogelherd, Piekary I et III, Hohle Stein, Zamarovce? Abri Wylotne, couche 6 Abri Wylotne, couche 7/8 Grotte Ciemna, couche 6
Ensembles acheuléens tardifs avec des éléments micoquiens	Cracovie - Wawel? Cracovie Zwierzyniec Klausen

La séquence, ainsi déterminée, des ensembles culturels micoquo-prondnikiens par rapport à la stratigraphie géologique et aux changements du climat de la première phase de la dernière période froide est considérée dans l'ouvrage de Mme T. Madeyska-Niklewska.

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SITUATION STRATIGRAPHIQUE DES ENSEMBLES MICOQUO-PRONDNIKIENS

TERESA MADEYSKA-NIKLEWSKA

Comme il résulte de l'article de W. Chmielewski publié dans ce volume, les ensembles micoquo-prondnikiens sont connus de quelques grottes dans la région du Jura Polonais ainsi que dans la grotte Vogelherd dans le Jura Souabe.

Dans la partie méridionale du Jura Polonais, dans la vallée de la Vistule se trouve la station paléolithique Piekary [11]. Aux environs de Ojców — la grotte Ciemna, dans la vallée du Pradnik [9, 10] et l'abri Wylotne, exploré dernièrement [12], dans la vallée du Sąspówka. Dans la partie septentrionale du Jura Polonais la station dans la grotte Okiennik, près de Skarżyce, est connu depuis longtemps [6, 11].

Les profils des stations mentionnés ne sont pas toujours une base suffisante pour fixer la position stratigraphique des ensembles considérés. Parfois on ne peut obtenir des données plus détaillées sans avoir comparé les ensembles d'autres grottes ayant des profils de sédiments mieux développés et plus différenciés.

Le plus important station est l'abri Wylotne, qui possède trois ensembles micoquo-prondnikiens provenant des époques différentes. Malheureusement la coupe des dépots de cette station est relativement pauvre et partiellement détruit par les déformations dans le système primordial des couches. La situation stratigraphique des ensembles micoquo-prondnikiens de cet abri peut être fixée sur la base de comparaisons avec deux autres stations provenant des grottes situées dans le voisinage (Fig. 1, W, K, N), notamment de la grotte Koziarnia et de la grotte Nietoperzowa [1, 3 - 5, 12].

Le plus ancien ensemble micoquo-prondnikien de l'abri Wylotne se trouve dans la zone des couches 7 et 8, l'ensemble moyen à l'intérieur de la couche 6, et le plus recent dans la mince et très noire couche de foyer 5. Tous les trois niveaux se trouvent au-dessus de la série de limons et de sables (stérile du point de vue de l'archéologie) déposés dans l'eau (couche 8), et au-dessus d'une série de dépôts de loess et d'éboulis.

La série aquatique de l'abri Wylotne est pareille à celle qui se trouve dans la base du coupe des sédiments de la grotte Koziarnia, et datant du dernier interglaciaire [3]. Elle détermine la limite inférieure d'âge des ensembles micoquo-prondnikiens. Le début de l'accumulation de la plus basse série du loess récent (couche 4) détermine la limite supérieure d'âge des ensembles de l'abri Wylotne. Le partage du loess récent est

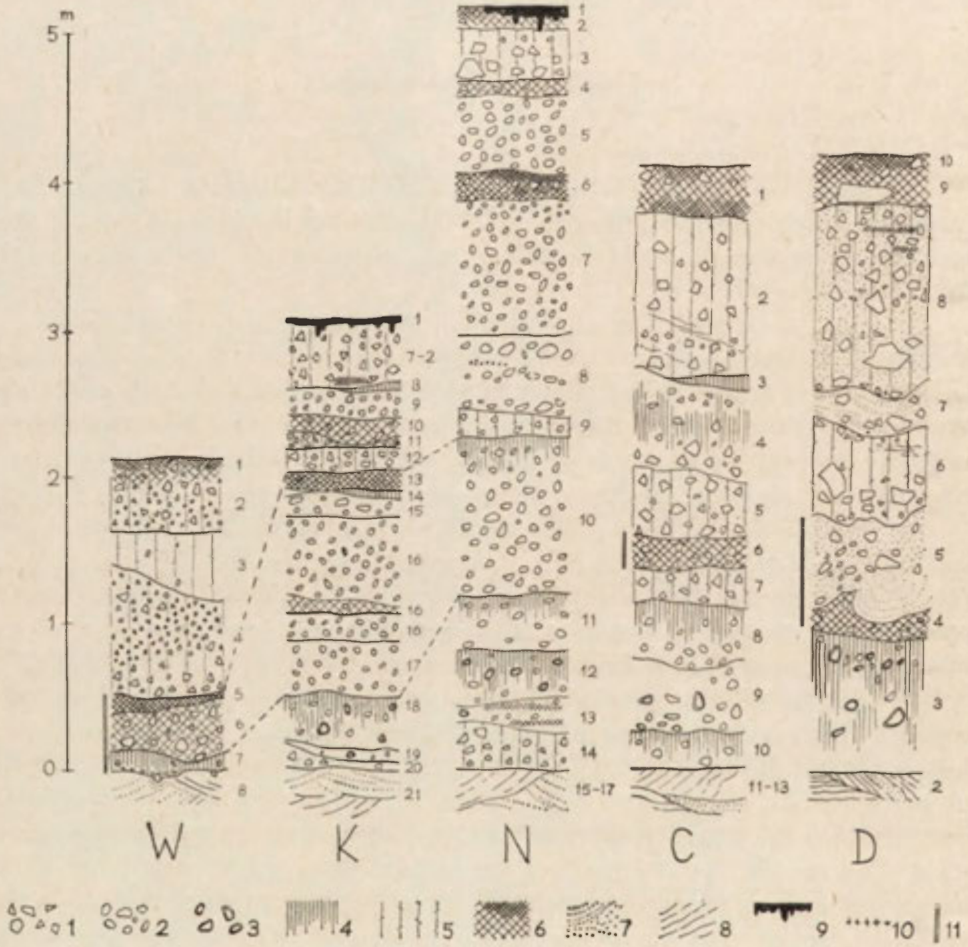

Fig. 1. Coupes schématiques des dépôts des grottes de Jura Polonais: W — L'abri Wylotne [12], K — La grotte Koziarnia [12], N — La grotte Nietoperzowa [12], C — La grotte Ciemna [9], D — La grotte dans la Dziadowa Skala [2]. Le numérotage des couches d'après les auteurs d'ouvrages sur les grottes particulières (repères à la littérature dans le texte).

Explications: 1 — éboulis calcaire aux arêtes vives, 2 — éboulis calcaire arrondi, 3 — éboulis calcaire altéré, 4 — niveaux d'argille brune, 5 — silt clair (loess), 6 — foyers et l'humus, 7 — sables stratifiés et nonstratifiés, 8 — argiles stratifiées, 9 — stalagmites, 10 — niveau à l'industrie paléolithique, 11 — niveau de l'apparition des ensembles micoquo-prondnikiens marqué distinctement aussi bien dans l'abri Wylotne, où les séries de loess et d'éboulis (couche 4 et 2) sont séparées par une période de déformations dans le système des couches et par le silt qui avait rempli les irrégularités (couche 3), qui dans les autres grottes. Les couches d'éboulis et de loess y sont séparées par des dépôts d'éboulis argileuse.

L'apparition des ensembles micoquo-prondnikiens dans l'abri Wylotne correspond donc au début de la dernière période froide (G IV — Różycki 15) qui précède celle de l'accumulation du loess. Dans cette période se manifestent certaines oscillations du climat d'un rang inférieur marquées dans les coupes des sédiments des grandes grottes. On ne peut pas reproduire actuellement la chronologie des trois ensembles micoquo -prondnikiens de l'abri Wylotne par rapport à ces oscillations à cause du dit manque de différenciation des sédiments de cet abri. Le plus ancien ensemble probablement fut abandoné aussitôt que l'eau eut cessé de couler par l'abri. Certains produits de cet ensemble et la partie inférieure de la couche 7 s'enfoncent dans la partie sommitale de la couche 8, et la structure de ces anfractuosités témoigne d'une grande plasticité de la couche 8, probablement à cause de l'humidification de celle-ci. Comme on peut le supposer, en examinant la composition de la couche 7 de l'abri Wylotne, elle correspond sans doute à la couche 18 de la grotte Koziarnia et à la partie supérieure de la couche 11 de la grotte Nietoperzowa et elle pourrait correspondre à la première oscillation chaude du climat, après l'optimum de l'interglaciaire. La colonisation correspondant au plus ancien ensemble micoquo-prondnikien aurait donc eu lieu au temps de la première oscillation froide, après l'optimum de l'interglaciaire.

Le plus jeune ensemble qui repose directement sous la couche 4 de loess provient probablement de la dernière oscillation chaude d'avant la période d'accumulation de loess, et il corresponderait dans ce cas-là à la couche culturelle 13 de la grotte Koziarnia. Cependant il aurait pu naître plus tôt car le caractère de la surface de la couche 5 témoigne de l'existence d'une interruption de sédimentation. Il est également probable que l'âge de l'ensemble apparaissant dans la couche 6 de l'abri Wylotne correspond à celui de la couche 16b de la grotte Koziarnia.

La seconde station paléolithique qui apporte des donées sur l'âge des ensembles micoquo-prondnikiens est la grotte Ciemna [9, 10]. La couche 6 (Fig. 1 C) qui contient l'ensemble micoquo-prondnikien d'outillages a une situation stratigraphique un peu plus élevé que les ensembles de l'abri Wylotne. La couche 6, de même que la couche 7, au-dessous d'elle, ont des traits qui autorisent à situer leur naîssance déjà dans la période de l'accumulation de loess. Ceci est témoigné par la feuillure tranchante des éboulis calcaires, par le manque de traces distinctes d'une altération chimique et également par le caractère loessique du matériel liant. Dans la couche 6 les grumeaux jaune clair du matériel loessique sont éparpillés irrégulièrement à l'intérieur des couches de foyer grises. C'est le plus bas niveau du loess jeune, séparé de la série supérieure de loess (couche 2) par des couches d'éboulis argileuse.

L'ensemble micoquo-prondnikien de la couche 6 de la grotte Ciemna est donc plus jeune que les ensembles de l'abri Wylotne et correspond au début de la période d'accumulation du loess récent inférieur (G IV-2 Różycki 15).

Il y a longtemps que la grotte Okiennik — la troisième station de la civilisation micoquo-prondnikienne, a été explorée [6, 11] et, comme on peut conclure de la littérature, elle avait une coupe sédimentaire exceptionnellement pauvre d'une épaisseur à peine d'un mètre. Les chercheurs n'y ont distingué que trois couches, dont seulement celle du milieu contenait une grande quantité de spécimens paléolithiques en silex, classées maintenant (Chmielewski — l'article dans ce volume) aux ensembles micoquo - prondnikiens. Quant à l'âge de l'ensemble de la grotte Okiennik, on ne peut dire rien de certain en s'appuyant sur la coupe de cette station. Pour fixer son âge présumable on peut comparer son profil à la coupe des sédiments différenciés de l'abri Dziadowa Skała situé à trois kilomètres de la grotte Okiennik [2]. Cet abri était pauvre du point de vue de l'archéologie mais possédait un foyer avec quelques spéciments en silex considérés par l'auteur cité ci dessus comme correspondant culturel de l'ensemble micoquo-prondnikien de la grotte Okiennik. On peut donc supposer que l'âge de la couche 4 de l'abri Dziadowa Skała (Fig. 1D) correspond à l'ensemble d'Okiennik. Elle repose sur une couche d'argile rouge-brun avec des éboulis calcaire fortement altéré, datant du dernier interglaciaire [2, 14]. La limite supérieure d'âge est déterminée par le premier niveau de loess avec des éboulis aux arêtes vives, séparé du loess supérieur par des sables stratifiés mêlés d'argile et d'éboulis calcaire. Nous voyons donc à Dziadowa Skała des limites d'âge des vestiges de l'ensemble micoquo-prondnikien semblables à celles aperçues dans les stations décrits auparavant.

En ce qui concerne les stations polonais des ensembles micoquo-prondnikiens il y a encore ceux de Piekary examinés et étudiés par M. S. Krukowski [11]. Les outillages découverts par lui et classés par W. Chmielewski à la civilisation micoquo-prondnikienne gisaient dans la station de terrasse (Piekary III) et dans l'abri Jama (station Piekary I).

La station Piekary III avec l'ensemble micoquo-prondnikien gisait dans la partie supérieure des alluvions déposées sur un rocher. Sur la surface d'érosion de ces alluvions gît un loess stratifié avec des spécimens du paléolithique supérieur, couvert de loess non stratifié. L'âge de l'ensemble considéré de Piekary correspond donc au début de la dernière

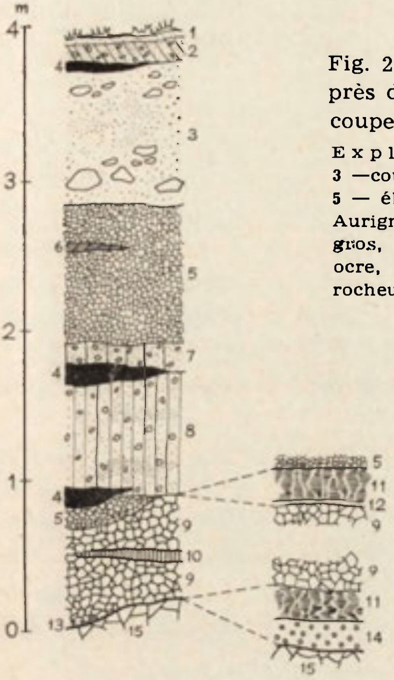

Fig. 2. Coupe de dépôts de la grotte Vogelherd situé près de l'entrée Ouest, complété par des fragments des coupes d'autres places dans la grotte (d'après G. Riek)

Explications: 1 — l'humus, 2 — couche néolithique, 3 —couche d'humus avec éboulis, 4 — couche noire de foyer, 5 — éboulis fin jaune clair, 6 — niveau de Magdalénien, 7 — Aurignacian supérieur, 8 — aurignacian moyen, 9 — éboulis gros, 10 — niveau de l'Acheuléen supérieur, 11 — argile ocre, 12 — Moustérien, 13 — niveau de l'industrie du „fond rocheux", 14 — argile avec des concrétions ferrugineuses, 15 — fond rocheux

période froide (Würm I d'après Krukowski), avant l'accumulation du loess éolien typique.

Il y a encore la grotte Vogelherd dans le Jura Souabe. Elle fut étudiée minutieusement par G. Riek [13]. C'est une station aux couches nombreuses ayant maints niveaux des industrie paléolithiques et plus rècents Fig. 2). L'ensemble décrit par G. Riek comme appartenant à l'Acheuléen supérieur et classé par W. Chmielewski aux ensembles micoquo-prondnikiens, se trouve dans la couche qui abonde en gros éboulis. Elle gît sur une argile ocre-jaune contenant des concrétions ferrugineuses, et provenant d'après l'auteur, du dernier interglaciaire. Au-dessus d'elle, séparée dans quelques endroits, par une argile ocreuse se trouve une autre série d'éboulis. Celle-ci est composée de deux séries de fin éboulis jaune claire (semblable, comme on pourrait le supposer de la description, aux couches 4 et 2 de l'abri Wylotne). La série supérieure contient quelques niveaux de Magdalénien. Ils sont séparés par des dépôts d'argile et d'éboulis contenant des couches aurignaciennes. G. Riek présume que ce niveau de foyer provient de la période ancienne de la première oscillation du froid (Würm I).

Sur la base des observations étant donné présenté ci-dessus concernant la situation des ensembles micoquo-prondnikiens dans les coupes des dépôts de grotte on peut constater que cette civilisation se développait au temps des phases initiales de la dernière période froide. Ses limites chronologiques sont: d'un côté l'optimum du dernier interglaciaire, et de l'autre la phase initiale d'accumulation du loess récent.

Les dépôts des grandes grottes, telles que la grotte Nietoperzowa, la grotte Koziarnia et la grotte Vogelherd, portent l'empreinte de cette période. Près de leurs entrées et également dans les abris rocheux la partie des coupes correspondant à cette période. est d'habitude bien plus mince et peu variée. Les dépôts de cette période sont caractéristique par une altération relativement forte de l'éboulis calcaire et par une quantité considérable d'argile brune ou brunâtre. La série de ces dépôts peut être parfois divisée en des niveaux plus restreints se diffèrent par la composition de l'argile ainsi que par la quantité et le degré de l'altération de l'éboulis [12].

Dans certaines grottes, et surtout dans la grotte Nietoperzowa, à l'intérieur de la partie considérée du profil des dépôts on observe des différences dans la composition de la faune qui ont servi à distinguer quelques unités climato-stratigraphiques d'un rang inférieur [15]. La faune des mammifères minutieusement étudiée [7, 8], et surtout celle des rongeurs de la grotte Nietoperzowa, démonstre sommairement la mutabilité suivante:

Après la domination de la faune forestière interglaciaire (couches 14 - 12) avec le *Clethrionomys glareolus* (Schr.) *L'Apodemus sp.* apparaissent des espèces caractéristiques pour le climat froid. Dans les couches 11 et 10 disparaissent les espèces forestières et aparaissent des espèces de steppe, comme: la *Ochotona pusilla* (Pall.), le cheval (*Equus caballus*) (L), le rhinocèros poilu — *Coelodonta antiquitatis* (Blum), et dans la partie sommitale de la couche 10 même les espèces de la toundra — le *Dicrostonyx torquatus* (Pall.) — très importants dans les niveaux supérieurs.

Le développement de la civilisation micoquo-prondnikienne tombe donc dans la période transitoire, entre le climat chaud du dernier interglaciaire et la période froide et sèche de l'accumulation du loess. C'est alors que sur le territoire du Jura Polonais les forêts mixtes disparaissent en faveur de la steppe qui se transforme ensuite en toundra.

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LE MÉSOLITHIQUE TARDIF EN POLOGNE (AVEC CONSIDÉRATION PARTICULIÈRE DE LA MAZOVIE)

Hanna Więckowska

La période d'après la seconde guerre mondiale a apporté de grandes modifications dans l'étude du mésolithique. Elles embrassent différents territoires, l'Europe et la Pologne y compris.

LA MÉTHODE

Les tentatives actuelles de formuler l'ensemble des problèmes du mésolithique en Pologne sont liées aux modifications de nos manières d'explorer les sites de cette époque, de systématiser et d'interpréter les matériels préhistoriques. Le traité de M. S. Krukowski en est le rudiment [14].

Les sites du mésolithique sont connus dans notre pays, comme on ne l'ignore pas, surtout des terrains sablonneux. On les explore, avec une intensité croissante, à partir de la deuxième moitié du XIX^e^ siècle jusqu'à nos jours.

Les résultats scientifique de la période précédant la seconde guerre mondiale est considérable. On a rassemblé surtout de nombreuses données concernant l'intensification de la colonisation (la découverte d'un très grand nombre de sites), la grandeur des colonies, leur localisation, les cources des matières premières et leur emploi etc. Cependant on résolvait d'une façon simpliste, bien qu'en harmonie avec la science de cette époque — là et conformément à la tendance qui dominait généralement en Europe, les questions liées à la classification des civilisations. Des matériaux, fréquemment trouvés, furent traités comme homogènes du point de vue de la civilisation, et rangés dans la grande, mais pas bien déterminée civilisation du Tardenois, et même parfois ceux qui provenaient des espaces limités, à la civilisation Maglemose, Campigny ou bien Kunda.

Cependant on constata bientôt qu'il fallait tenir compte d'une plus grande différenciation des civilisations du mézolithique [10].

On faisait alors presque exclusivement des explorations superficielles des emplacements. Ceci avait, evidemment, une influence sur les résultats des elaborations, d'autant plus que une nombreuse colonisation du déclin du pleistocène et celle du holocène supérieur, liée aux terrains sablonneux, avait fréquemment laissé des traces d'outillages superposés provenant de différentes civilisations qui d'habitude n'étaient pas séparés stratigraphiquement (le problème de l'âge des dunes et des terrasses). La question de la méthode est liée entre autres à la signalisation des soi-disant croisements de civilisations, notamment une fausse conception de „l'industrie swiderotardenoisienne" s'est répandue le plus et sest maintenue le plus longtemps [1]. Par contre une valeur stable conservent les travaux publiés sur les sites, bien que jusqu'à 1949 les traités sur le mésolithiques ne soient pas nombreux [2].

Les matériaux provenant des explorations superficielles ont été insuffisants pour les conceptions conformes aux postulats de la science. On insista donc dans les dernières années sur un rassemblement systématique de sources provenant de fouilles, pour les mettre à profit surtout dans toutes les constatations concernant la chronologie et les civilisations.

L'appréciation de la pureté des inventaires a pour point de départ la planigraphie et une minutieuse analyse typologique. On est d'accord que les emplacements homogènes quant à la civilisation sont signalés, d'une façon évoquant le moins de restrictions par des amas isolés (concentrations de silex) les plus précieux et comme il s'avère pas rares dans nos conditions. Les matériaux provenant de l'intérieur des concentrations de silex, planigraphiquement fermées, sont traités comme données préliminaires d'une interprétation systématique [3]. Ils rendent exactes les constatations concernant les civilisations, faites sur la base des situations des certaines terrains (les sites „purs" assez fréquents en Pologne, mais ayant des outillages qui ne sont pas rangés en amas serrés) et facli-

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[1] Le bien-fondé de la différenciation de cette industrie a été déjà contesté en 1939 par. K. Jażdżewski (critique de l'ouvrage de C. Engel et de W. La Baune, Kulturen und Völker der Frühzeit im Preussenlande, Königsberg 1936/37) dans *Przegląd Archeologiczny*, t. VI, 1939, p. 308 - 309. Ce problème fut plus largement traité dans l'ouvrage de M. R. Schild et H. Więckowska, Sur l'industrie dite swidero-tardenoisienne.

[2] Comparez l'essai sur l'état des recherches: J. Kostrzewski, Histoire des recherches préhistoriques en Pologne, Poznań, 1949, p. 137 et les suivantes.

[3] Ce procédé n'est pas appliqué généralement par l'archéologie polonaise. Ainsi par exemple M. S. K. Kozłowski, auteur d'ouvrages du domaine de la classification des civilisations du mésolithique ne traite pas ces principes si rigoureusement.

tent la différenciation des ensembles superposés provenant d'époques différentes. En se fondant sur eux, en comparant les amas on distingue des industries nouvelles (si le matériel n'est connu de nulle part), ou bien on augmente le nombre des emplacements faisant partie des industries différenciées auparavant. En suivant cette voie on arrive entre autres à une différenciation des cycles d'industries en s'appuyant sur l'analogie des industries qui se manifeste dans la ressemblance typologique, dans l'apparition commune des mêmes formes d'outils ainsi que dans les proches proportions quantitatives de celles-ci.

PRINCIPES DE CLASSIFICATION CHRONOLOGIQUE ET DE CIVILISATION

La chronologie des inventaires du mésolithique est pour nous un des problèmes difficiles. Pour le moment, les sites suivants font exception: Witów, arrondissement de Łęczyca [2 - 3] et Całowanie, arrondissement d'Otwock [18] où on a réussi à constater la stratigraphie archéologique et à avoir des dates précises (Witów) et des matériaux pour la chronologie relative (Całowanie, en cours d'étude). La grande importance des résultats y obtenus est indiscutable. Cependant les données dont on dispose sont insignifiantes par rapport aux necessités.

La typologie est le critérium fondamental pour fixer l'âge des inventaires du mésolithique, mais des traits, soulignés depuis longtemps, tels que la microlitisation et la géométrisation continuent à occuper leur position (malgré l'existence d'ensembles qui sont dépourvus de ces traits). Il s'agit ici non seulement de ce que nous dit la chronologie des matériaux considérés comme un ensemble homogène de civilisation, mais aussi de certaines formes caractéristiques des outils. Ainsi on a réussi à différencier et à définir plus exactement certains outils jouant le rôle d'indices culturels à l'intérieur des cycles d'industries distingués jusqu'à présent sur le territoire de la Pologne [24]. Ceci se rapporte particulièrement à une lamelle à dos caractéristique, nommée lamelle à dos type Stawinoga (d'apres le site où elle est apparue en grande quantité et diversité, à la lamelle à troncature, type Komornica et aussi à certaines variétés du triangle. Les autres outils ayant la même importance ne furent pas encore exactement définis à cause du manque de grandes séries de ceux-ci (ce qui est une condition de la différenciation des outils — indices culturels, et particulièrement lorsque ces indices proviennent d'ensembles purs et définis).

On attribue un autre rang aux spécimens dont l'importance dépasse les industries déterminées et leurs cycles. Ceci se rapporte aux outils occupant une vaste étendue et apparaissant en grand nombre pendant une époque déterminée et dans les différentes unités culturelles, mais paurant contemporaines les unes aux autres. Si la documentation en est possible, de tels spécimens sont considérés comme éléments interindustriels ayant la valeur d'indices chronologiques [17]. Les trapèzes très répandus au mésolithique supérieur ont, parait-il, une telle importance et sont alliés à lui depuis longtemps. Le moment où ils apparaissent en grand nombre est probablement le tournant de la période boréale et atlantique, accepté comme limite entre le mésolithique inférieur et supérieur [13]. On a également réussi à constater que c'est la présence ou bien le manque de grattoirs (trouvés surtout dans les ensembles plus anciens) et de divers grattoirs irréguliers (ils apparaissent en grande quantité plutôt dans le mésolithique supérieur à la place, parait-il, des grattoirs qu'on ne trouve plus [21, 22, 24] qui est le facteur déterminant l'âge des ensembles. Dernièrement M. S. K. Kozłowski a accepté, mais avec restriction, l'opinion qu'on pouvait considérer les divers grattoirs irréguliers comme élément interindustriel [13]. Il faut constater que cet important groupe d'outils ayant la valeur d'un indice chronologique de civilisation n'a pas encore été examiné minutieusement du point de vue de la typologie. Toutefois on sait qu'il est très différencié dans les inventaires particuliers.

Dans l'étude des matériaux du mésolithique on utilise, mais avec prudence, les résultats obtenus des examens des sites européens (constatations typologiques, chronologiques).

PARTAGE DU MÉSOLITHIQUE

La totalité de ces considérations se rapporte à un bien petit espace, surtout à la Mazovie où on a fait dans les dernières années la majorité des recherches (au bord de la Narew et de la Vistule moyenne) et où on a découvert de nombreux et précieux gisements. En ce moment-ci l'auteur ne tente pas d'étudier les problèmes du mésolithique sur tout le territoire de la Pologne, pour cette raison qu'il manque de bases suffisamment sûres. Néanmoins on peut déjà constater que l'actuelle classification des problèmes et l'élaboration d'un partage chronologique des civilisations ont permis non seulement de profiter en partie des collections polonaises provenant des anciennes recherches mais aussi ont donné une certaine direction aux examens suivants. Dans la lumière des plus récents matériaux provenant du dehors de la Mazovie le schéma se maintient et il est corrigé et documenté conjointement avec l'agrandissement des étendues des unités culturelles distinguées. Toutefois ce n'est pas l'unique schéma. On entreprend également, en s'appuyant sur d'autres critères, de différentes tentatives de résoudre ces problèmes à une plus grande envergure, et même en franchissant les frontières de notre pays [12].

Ainsi, jusqu'à présent deux cycles d'industries ont été le plus exactement esquissés: le cycle de la Narew (Fig. 1) et celui de la Vistule (Fig. 2, 3) avec leurs industries particulières [24]. Cependant tous les deux ont été examinés dans leur phase de développement, tandis que le problème de leur genèse et de leur déclin n'a pas été encore résolu.

Le premier cycle, caractéristique par l'apparition des outils directeurs mentionnés: des lamelles à dos, type Stawinoga, des lamelles à troncature type Komornica, et de grattoirs, se développait déjà dans notre pays à partir du mésolithique inférieur, et certainement depuis l'époque pré-boréale. Les constatations typologiques ne furent confirmées en dates précises que pour le cycle de la Narew; on les a obtenues sur les sites Witów et Całowanie. Un des inventaires purs découverts au cours des fouilles (Wieliszew XI) livra des éléments propres au mésolithique supérieur, entre autres de divers grattoirs irréguliers et des trapèzes d'un type particulier.

Quant au cycle de la Vistule, on a distingué les outils directeurs suivants: des armatures de type Wieliszew, des triangles scalènes (surtout des triangles à deux côtés trés longs), des trapèzes, de divers grattoirs irréguliers et des outils destinés à peu près au même emploi (des racloirs et des spécimens d'un type tout particulier, appelés raclettes [4] un type caractéristique de lamelles à troncature, des grattoirs et des burins d'une quantité et diversité insignifiantes. Le cycle de la Vistule, en ce qui concerne sa partie récente qui tombe au mésolithique supérieur, fut mieux documenté grâce aux matériaux connus.

On compte à ce cycle une série d'inventaires, autant ceux explorés dans les dernières années, que provenant d'anciennes recherches (Wieliszew, arrondissement de Nowy Dwór Mazowiecki, fouille XIII [15], Wistka Szlachecka, arrondissement de Włocławek, fouille III/60 [5], Grzybowa Góra, arrondissement de Starachowice, fouille VI/59), Słochy Annopolskie „Czerwony Borek" I et II, arrondissement de Bielsk Podlaski [19], Janisławice arrondissement de Skierniewice [1], Baraki arrondissement de Kra-

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[4] Les noms d'outils introduits par A. Cheynier, Un outil magdalénien nouveau, à silex à Badegoule, la raclette, BSPF, t. XXVII, 1930, pp. 483 - 488, furent employés dans la littérature polonaise par Mme M. Marczak, Premiers résultats des fouilles faites à Wistka Szlachecka, arrondissement de Włocławek, dans *Sprawozdania Archeologiczne*, t. XVII, 1965, p. 27.

[5] Le site Wieliszew, fouille XIII fut exploré par Mme M. Marczak, Wistka Szlachecka III/60 par M. R. Schild qui ont bien voulu me permettre de profiter de leurs matériaux.

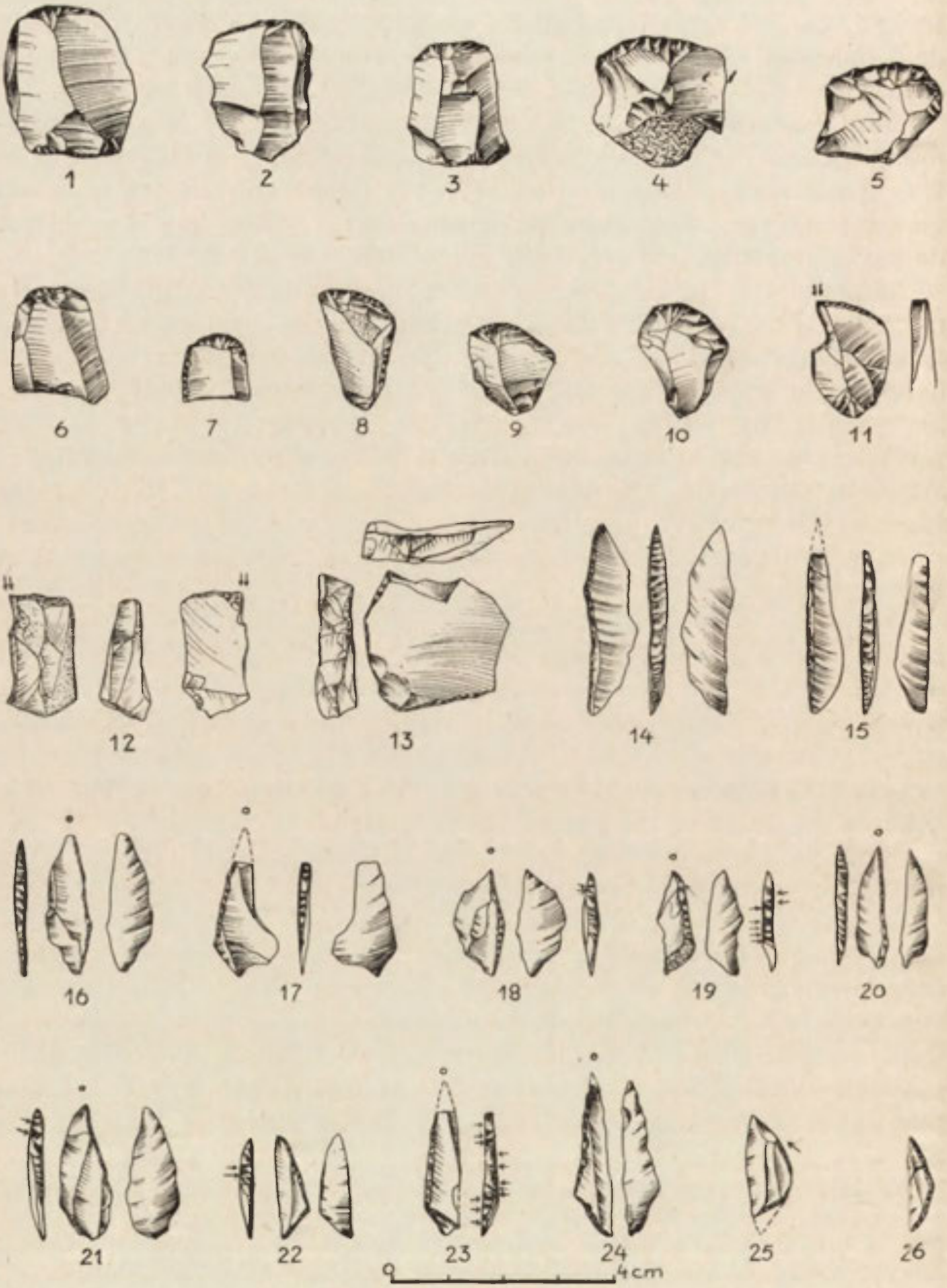

Fig. 1. Cycle de la Narew. Gisement de Stawinoga, arrondissement de Pultusk. Choix d'outils

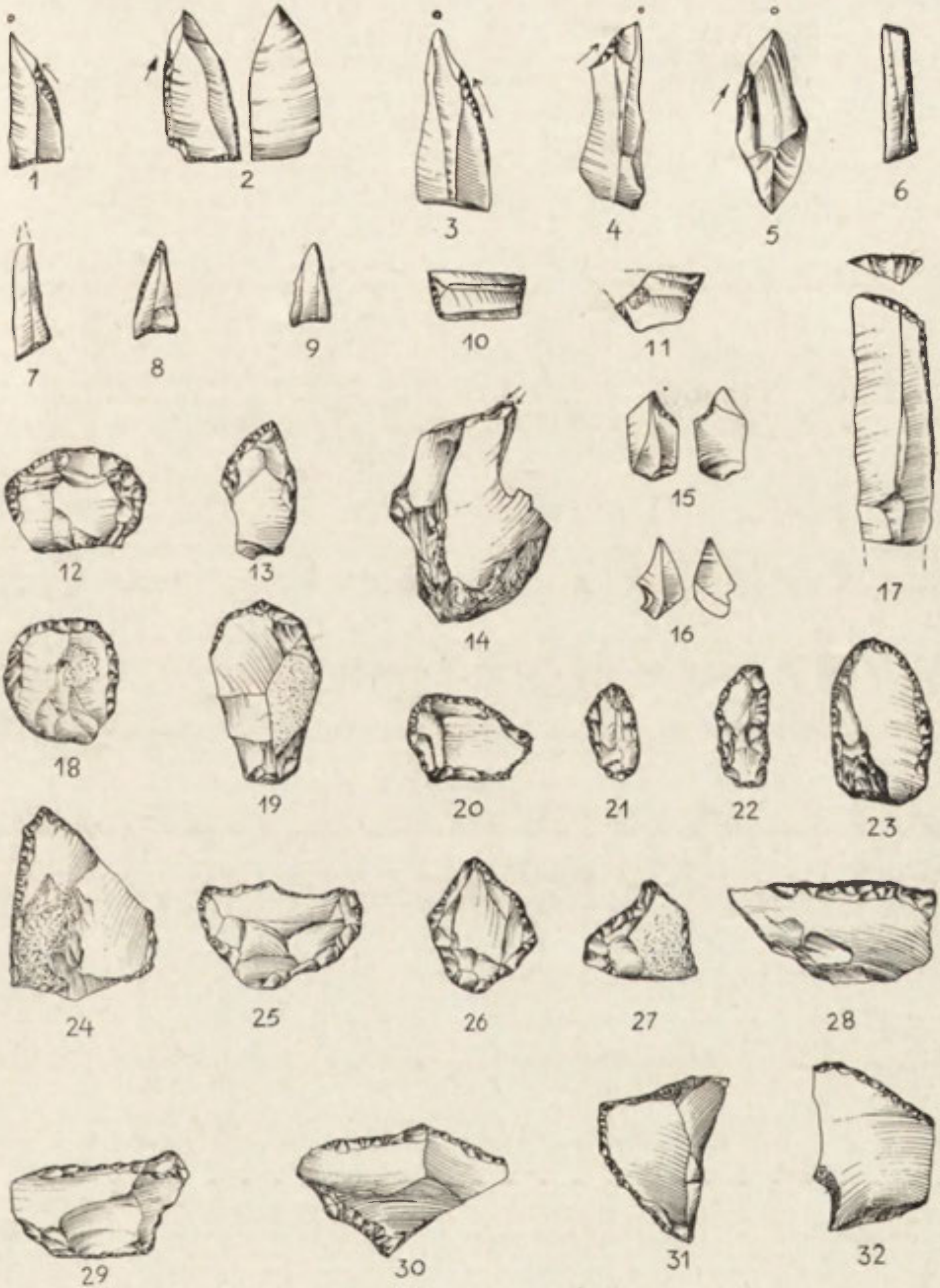

Fig. 2. Cycle de la Vistule. Gisement de Wistka Szlachecka III/60, arrondissement de Włocławek. Choix d'outils

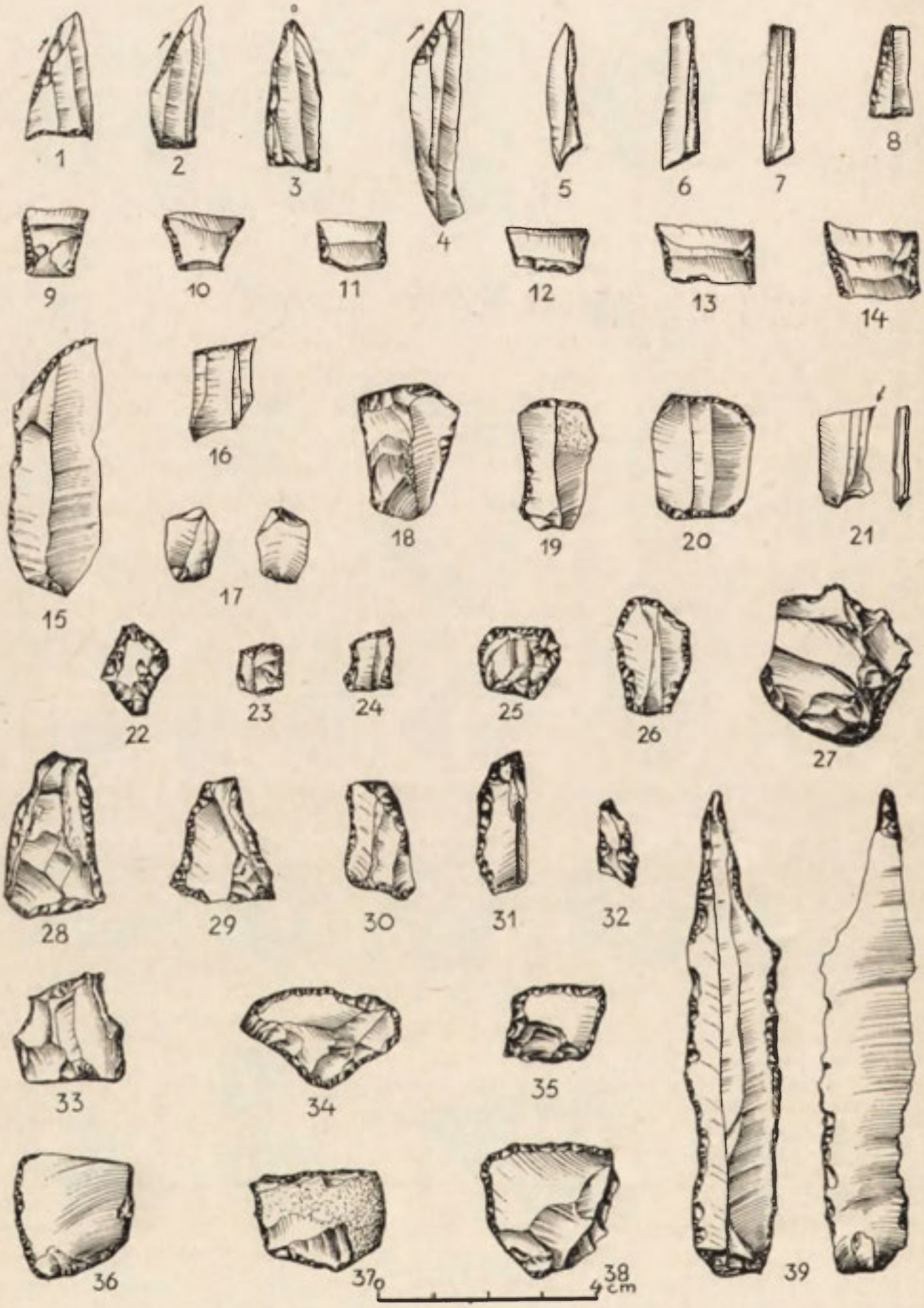

Fig. 3. Cycle de la Vistule. Gisement de Wieliszew XIII, arrondissement de Nowy Dwór Mazowiecki. Choix d'outils

śnik [13], Jawornik-Czarna, arrondissement de Dębica [13], Sośnia, arrondissement de Grajewo et d'autres).

Comme il semble, l'étendue géographique de ce cycle, ainsi que celui de la Narew, est bien vaste. Les sites mentionnés proviennent des voïvodies de: Varsovie, Łódź, Białystok, Kielce et Rzeszów. En outre on observe l'apparition des éléments particuliers, et même une partie du cycle de la Vistule sur de nombreux emplacements connus d'examens de surface de ces terrains ainsi que d'autres voïvodies (entre autres de la voïvodie de Poznań et de Cracovie).

Il faut encore mentionner la civilisation de Pieńki distinguée par M. S. Kozłowski [11, 13]. Pour le moment elle est insuffisamment décrite, et connue des gisements encore peu nombreux (d'abord de la station Świdry Wielkie — l'industrie de Pieńki découverte par M. S. W. Krukowski). Ses traits caractéristiques sont entre autres: de petits triangles scalènes aux côtés allongés, de petites lamelles à troncature, type Komornica, de très nombreux microburins, pour la plupart petits et minuscules, des trapèzes en petit nombre, des racloirs, de divers grattoirs petits. La question à quel point cette civilisation est originale et quel rang elle occupe, demande des études continues. L'essentiel de l'ensemble des problèmes traités ici est le prolongement de sa durée jusqu'à la période atlantique.

LE MÉSOLITIQUE TARDIF. DIVISION

Les cycles mentionnés dont le développement atteint la période atlantique, donc le mésolithique supérieur, ne contiennent pas, semble-t-il, dans leurs formes actuelles des inventaires que l'on pourrait considérer comme appartenant au déclin du mésolithique (exception probable: l'ensemble de Wistka Szlachecka I/63 et III/63 dont il est question ci-dessous). C'est pourtant la dernière phase de cette époque qui donne les plus grandes difficultés à résoudre. On n'a pas encore trouvé de critères précis de classement des ensembles au mésolithique tardif (le manque d'indications provenant des sciences naturelles). et parmi les matériaux obtenus grâce aux fouilles, ce n'est que certains, c'est à dire les plus caractéristiques et incontestablement purs, qui méritent d'être pris en considération. Comme tels sont considérés les matériaux provenant de: Wistka Szlachecka, fouille VI/60 [6] (Fig. 4), Wieliszew, fouille XVI [21, 22] (Fig. 5 : 1 - 23), Wieliszew, fouille XVIIc [23] (Fig. 5 : 24 - 43, Fig. 6). Tous

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[6] Le site Wistka Szlachecka, fouille VI/60 fut exploré par M. R. Schild qui a bien voulu me donner ses matériaux pour les examiner et en profiter.

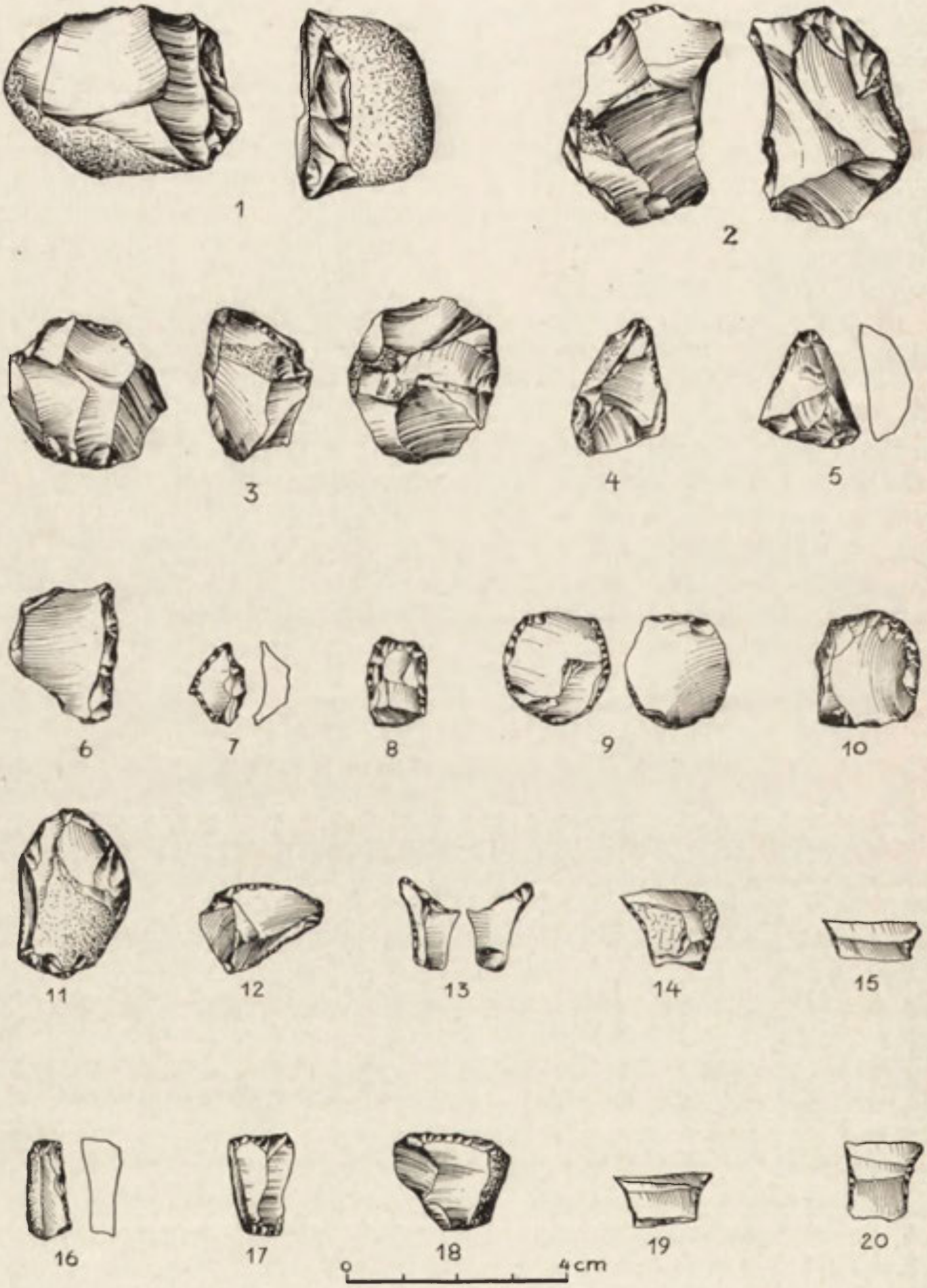

Fig. 4. Gisement de Wistka Szlachecka VI/60. Choix de nucléus et d'outils

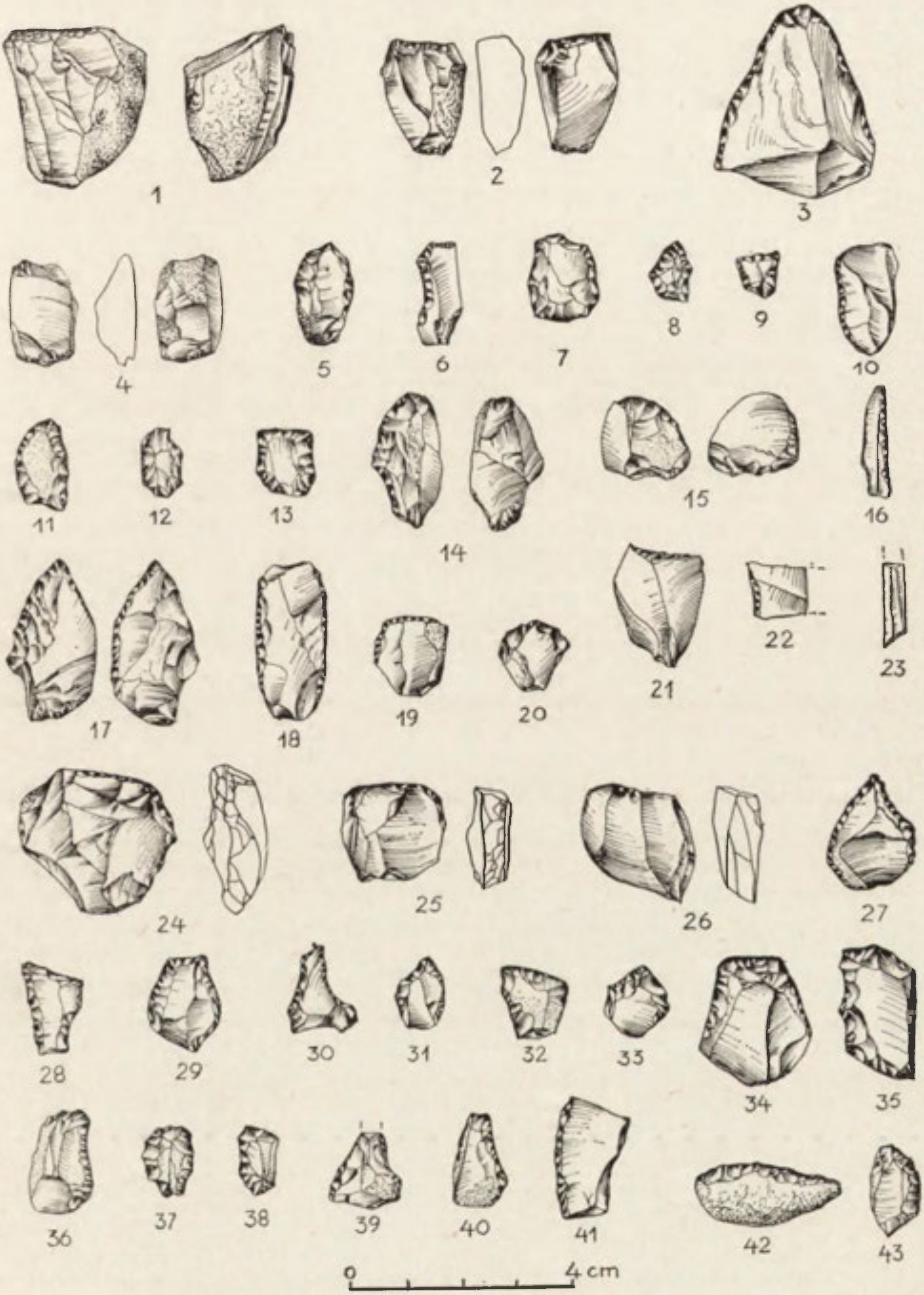

Fig. 5. Dessin 1 - 23 — gisement de Wieliszew XVI; dessin 24 - 43 — gisement de Wieliszew XVIIc. Choix de nucléus et d'outils

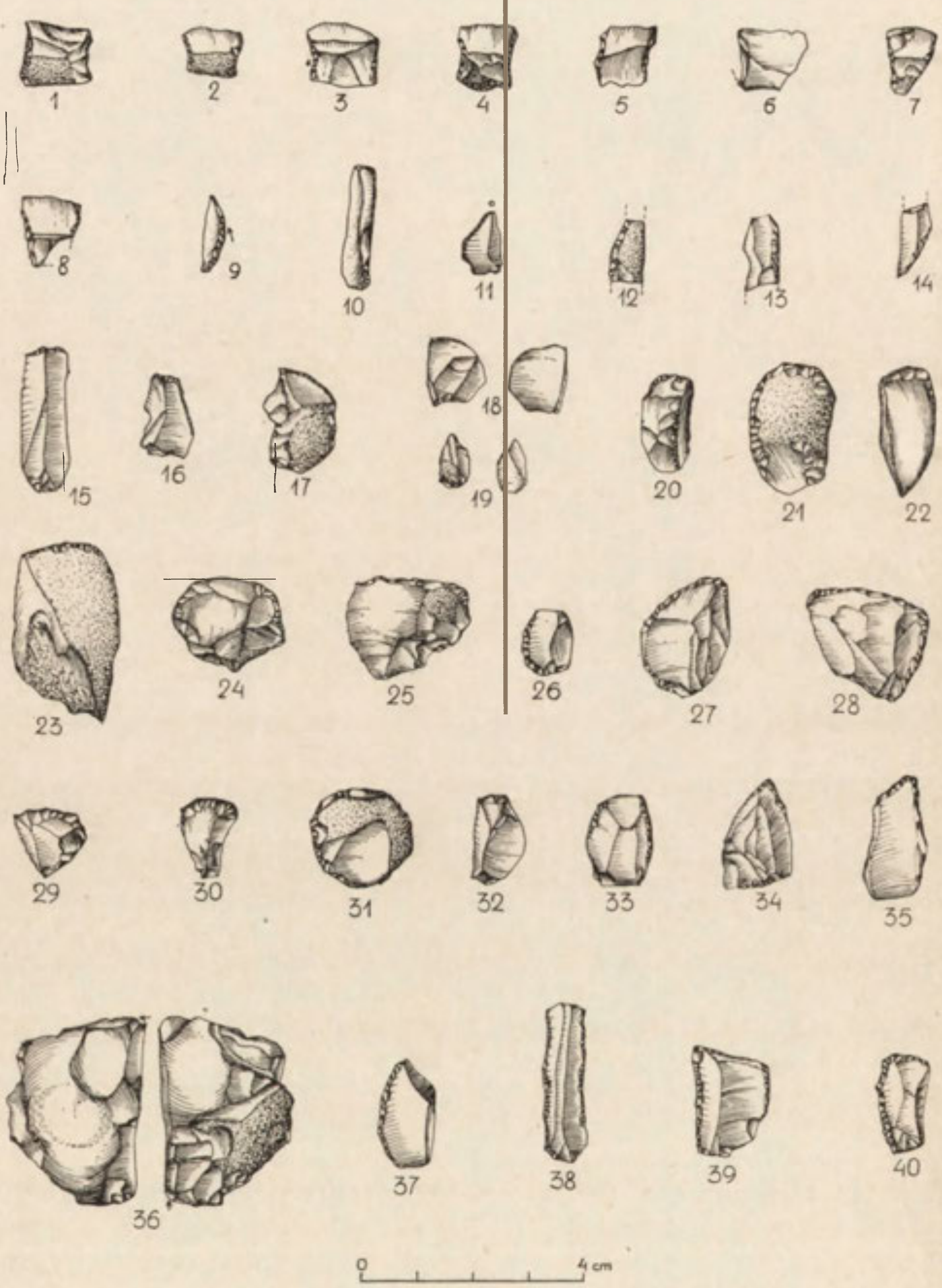

Fig. 6. Gisement de Wieliszew XVIIc. Choix d'outils

ces sites ne sont pas très grands et possèdent une moyenne quantité d'outillages qui formaient sur deux sites (Wieliszew XVI et XVIIc), des amas isolés. Comme supplément fut traité le matériel mésolithique du site Poddebe, arrondissement de Nowy Dwór Mazowiecki, fouille VII [15] avec des outils peu nombreux (site fortement détruit. ensemble incomplet) dont le jeune âge a tiré l'attention de Mme M. Marczak, ainsi que les riches ensembles de Wistka Szlachecka. fouille I/63 et III/63 (une concentration isolée de silex) traités comme correspondants culturels, mais dont la pureté n'est pas certaine.

En classant Wistka Szlachecka VI/60, Wieliszew XVI et XVIIc au mésolithique tardif on a pris en considération leur originalité par rapport aux ensembles faisant partie de cycles bien caractérisés et datés antérieurement: ceux de la Narew et de la Vistule. On aperçoit cette originalité autant dans le genre général des inventaires (on observe dans certains ensembles du mésolithique tardif une microlitisation avancée et une exécution moins soignée des outils) que dans la composition typologique. Dans les inventaires considérés comme plus récents on est frappé par: l'emploi fréquent de pièces esquillées (apparition en grand nombre de pièces esquillées et d'éclats ainsi que d'outils fabriqués de ces éclats), l'indigence d'outillages et de types (de très rares burins!), la supériorité quantitative considérable des divers grattoirs irréguliers. l'apparition de nombreux trapèzes, fréquemment trapus et courts et leur prépondérance absolue sur les autres armatures. Les lames sont rares. Ces traits observés dans les inventaires particuliers en pourcentage et degré différents, sont mis en relief par l'analyse suivante:

Sur chacun des emplacements mentionnés apparaissent, en tant que groupe le plus important, des divers grattoirs irréguliers, en majorité petits et microlithiques, dans une quantité qui constitue environ moitié ou davantage de tous les outils. Dans tous ces inventaires à côté de ces spécimens, des grattoirs (sur l'emplacement Wistka Szlachecka VI/60 aussi de racloirs) et des trapèzes (exception: Wieliszew XVI) d'autres outils apparaissent sporadiquement. De plus, il y a entre eux des différences plus ou moins essentielles. Ainsi:

Le site Wistka Szlachecka VI/60 n'a pas livré de pièces esquillées ni d'outils fabriqués sur elles, observés dans le matériel provenant des deux autres sites. Cette technique de débitage est caracteristique pour l'inventaire de Wieliszew XVI où la part des pièces esquillées, autant par rapport aux nuclei (21 : 1) que par rapport à la totalité du matériel est frappante par sa grandeur.

Les racloirs accompagnant souvent les divers grattoirs irréguliers ne furent pas trouvés dans l'inventaire de Wieliszew XVI mais seulement, en petite quantité, sur Wieliszew XVIIc où on a aperçu d'assez nombreux racloirs représentés faiblement sur les deux autres sites (une partie ces racloirs ont partout des traits intermédiaires entre les racloirs et les divers grattoirs irréguliers).

Les armatures sont représentées dans ces inventaires surtout par les trapèzes, mais dans ce groupe d'outils on observe d'importantes différences. Sur la station Wistka Szlachecka VI/60 les trapèzes constituent environ 18% de tous les outils; ils sont exécutés avec soin et y apparaissent comme uniques armatures; dans l'ensemble Wieliszew XVIIc leur montant est ca. 7%, ils sont exécutés sur des lames provenant de déchets, où bien sur des dechets (leur majorité a des côtés incurvés) et apparaissent en commun avec d'autres types d'armatures avec lesquelles ils constituent environ 12% de tous les outils. Par contre Wieliszew XVI ne livra qu'un seul trapèze, douteux par dessus la marché, et deux autres armatures (en somme environ 3%; ainsi se manifeste une indigence inouie de ces spécimens).

En ce moment il est difficile d'analyser les différences entre les autres outils dont le rôle n'est pas encore précisé.

A l'ensemble Wieliszew XVIIc ressemble le gisement Poddębe VII où en général les mêmes groupes d'outils ont apparu. Les différences entre ces deux sites se manifestent entre certains types de lamelles à dos qui pourtant sont représentées par un petit nombre, ce qui rend difficiles des comparaisons plus précises. Dans l'ensemble Poddębe VII li manque de pièces esquillées et d'outils les accompagnant. Silex provenant de Wistka Szlachecka, fouille I/63 et III/63 méritent une attention particulière. Ils sont classés par Mme M. Marczak au mésolithique tardif sur la base de certains critères mentionnés. A part les traits communs avec les inventaires cités ils démontrent des différences spécifiques qui sont très importantes et caractéristiques. Ceci se manifeste surtout dans l'apparition en grand nombre de divers grattoirs irréguliers, et parmi eux de raclettes qui n'ont apparu dans une telle quantité sur aucun autre site polonais de l'époque du mésolithique. Dans ce site se distinguent également de très courts trapèzes fabriqués sur des éclats ayant des talons arrondis et retouchés. Ce n'est que l'incertitude quant à la pureté de l'ensemble (il y a apparut aussi un matériel représentant une autre industrie du mésolithique et un matériel du début de l'époque du bronze) qui fait hésiter à conclure à quelle civilisation avait-il appartenu. Ainsi, comme le suggère Mme M. Marczak, c'est probablement une nouvelle industrie du mésolithique tardif [7].

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[7] Il existe encore un ensemble intéressant provenant du site Pietrzyków, arrondissement de Września (M. Kobusiewicz, Concentration de silex de l'industrie tardenosienne de Pietrzyków, arrondissement de Września, dans *Fontes Archaeolo-*

Il paraît qu'à l'étape actuelle des recherches. les analogies observées entre les inventaires considérés n'autorisent qu'à la constatation que tous ces sites représentent une phase tardive du mésolithique. Toutefois il serait difficile de se prononcez catégoriquement de quel rang sont les différences entre eux, et particulièrement si elles sont d'ordre chronologique et culturel. Etant donné que ces sites dans leur majorité n'abondent pas en outillages et qu'on n'aperçoit pas distinctement les différences entre eux (le manque ou la présence de types particuliers d'outils et leur part quantitative pourraient être alliés à l'étendue des surfaces examinées ou au nombre des ensembles) il est recommendable de s'abstenir à resoudre la question à quelle industrie et à quel cycle ils appartiennent. A mon avis, il serait difficile de décider aujourd'hui si ces sites sont un chaînon d'autres cycles que le cycle de la Narew et de la Vistule, ou bien s'ils ne font qu'enrichir ceux-ci (par exemple Wistka Szlachecka I/63 et III/63 qui démontrent certaines analogies typologiques avec le cycle de la Vistule). Car il n'a pas été constaté si les indubitables modifications culturelles observées en Pologne, dans la partie tardive du mésolithique ne sont que le résultat de l'évolution des mêmes cycles qui se développaient antérieurement.

M. S. K. Kozłowski prend une autre attitude envers ces problèmes: il va plus loin dans l'interprétation des sources dont on dispose en ce moment-ci et en attribuant une grande importance autant aux matériaux des fouilles qu'à ceux ramassés sur la surface il constate un plus grand nombre de cycles (de civilisations) et suit leur étendue sur tout le territoire de notre pays. Ainsi il distingue pour tout le mésolithique 5 civilisations d'une différente durée et d'une différente étendue territoriale [12]. En outre, tout en voyant dans la période atlantique sur le territoire polonais des sites qui représentent des phases récentes de 3 civilisations faisant part des 4 distinguées par lui qui avaient existées dans le mésolithique inférieur, notamment celles de Komornica, de Janisławice (la première correspond au cycle de la Narew, la seconde à celui de la Vistule) et de Pieńki, il n'attribue qu'a la période atlantique la civilisation

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gici Posnanienses, t. 14, 1963, pp. 1 - 13), malheureusement détruit par la déflation. Il est, parait-il, différent des ensembles cités plus haut (bien qu'on ne puisse admettre avec certitude une homogénéité culturelle) et appartient à la partie récente du mésolithique. Parmi les outils les plus nombreux sont les grattoirs irréguliers, les éclats et les lames tronquées, les grattoirs et les perçoirs sont rares, et il manque tout à fait de burins et de pièces esquillées. Un groupe assez nombreux d'armatures (une dizaine) est représenté surtout par des triangles scalènes: trapus, longs et pas trop longs; un seul trapèze et rhombe apparurent ici. L'emplacement fut inséré par M. S. K. Kozłowski dans la civilisation du Majdan, distinguée par lui, dont il est question plus bas.

de Majdan (nommée par lui auparavant civilisation de Czerwony Borek) qui apparaît et se développe alors[8]. Comme facteur datant M. S. K. Kozłowski cite entre autres des trapèzes, une grande quantité de divers grattoirs irréguliers et un manque de racloirs, des pièces esquillées, des lamellées à troncature basale, des lamelles retouchées aux bords et des microburins. L'auteur fait aussi l'observation que cette civilisation se manifeste dans toute la Pologne et place en elle entre autres 3 des sites considérés: Poddębe VII, Wieliszew XVI et Wieliszew XVIIc. Par contre il classe d'abord l'inventaire de Wistka Szlachecka [11, 13] où les armatures ne sont représentées que par des trapèzes, à la civilisation de Czerwony Borek et ensuite au déclin du mésolithique (fin de la période atlantique) en suggérant l'existence d'un ensemble de sites de ce type. Dans sa conclusion M. S. K. Kozłowski aperçoit „[...] une vole commune de développement des civilisations polonaises du mésolithique supérieur imposée par le courant des trapèzes [...]" (dont l'influence grandit dans le mésolithique supérieur) et l'homogénétité des civilisations. apparente dans la naissance de la plus récente civilisation, probablement contemporaine des premiers agriculteurs. Son inventaire serait constitué des trapèzes, des grattoirs, des racloirs peu nombreux et des pièces esquillées.

OBSERVATIONS GÉNÉRALES

Pour le mésolithique tardif, en dehors des problèmes de la différenciation des civilisations, on peut tenter d'avancer certaines suggestions générales. Ainsi la particularité de cette époque consiste en une dense colonisation de ce que témoignent les nombreux sites découverts sur les espaces où l'on faisait des recherches (les anciennes vallées. les terrasses et les dunes). Il faut en plus prendre en considération la diversité des sources archéologiques. En faveur de ceci parle non seulement la différenciation du milieu géographique (la particularisation pour cette partie du holocène d'une série de zones géographiques: zone littorale, des forêts continentales du Nord, zone montagneuse meridionale liée à l'Europe centrale et zone de Sud-Est liée aux espaces de la steppe de parc de

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[8] Vide [11 - 13] ainsi que S. K. Kozłowski, Emplacement à Majdan, arrondissement de Kolbuszowa dans la lumière des recherches faites en 1962/63, *Światowit*, t. XXVII, 1966, pp. 109 - 127. M. S. K. Kozłowski nomma cette civilisation d'après l'emplacement Majdan exploré par lui. Les fouilles I et II englobant un vaste terrain (chacune environ 5 ares), n'ont fourni que peu de matériaux surtout dans la deposition secondaire. On en isola des ensembles d'une autre époque deux ensembles du mésolithique tardif (fouille I, ensemble 2 et fouille II, ensemble 2), représentés par un petit nombre d'outils aux traits comme ci-dessous.

l'Europe du Sud-Est) ainsi que les découvertes provenant des différentes partie du pays et des terrains voisinant. En ne se prononcant pas pour le moment, sur la quantité des cycles ainsi que sur leurs dépendances mutuelles génétiques et culturelles par rapport au matériel cité, il faut souligner que sur le territoire de la Lithuanie, de la Lettonie et de la Biëlorussie du Nord-Ouest ont été découverts des sites (Lampédziai, Zemuju-Kaniuku et d'autres) dont les inventaires de silex contiennent les membres suivants: le „postmazovien”, le „russo-sibérien” (caractéristique pour le mésolithique du Nord-Est de la Russie européenne et de la Sibérie) et le „vistulien” [9]. Certains de ces sites proviennent de la fin de la période atlantique. Il faut aussi prendre en considération l'apparition des sites de ce type dans le Nord-Est de la Pologne. Ceci peut être témoigne autant par les découvertes faites au cours des dernières années sur le territoire de Suwałki [25] que par les précédentes se rapportant à la civilisation de Kunda [7]. Il n'est pas exclu que les trouvailles incohérentes de harpons et d'objets en os soient liées aux industries du mésolithique tardif ayant dans leur composition les trois membres mentionnés. Il ne serait aussi pas mal à propos de remarques que le plus certain inventaire de silex, de Kunda, notamment celui du site Kunda-Lammasmägi, bien que plus ancien, possède des éléments spécifiques prononcés, propres aux emplacements mentionnés (le composant postmazovien, russo-sibérien [13]). Il faut également mentionner que B. Gramsch [16] particularisa pour l'espace poméranien dans la période du mésolithique tardif (5500 - 3000 av. J. Chr.) à part d'autres groupes celui de „Płonia” (Płonia près de Szczecin, est le plus important site), ce qui serait aussi lié au problème de la non-homogénéité archéologique de cette période sur les terrains polonais.

PASSAGE DU MÉSOLITHIQUE EN NÉOLITHIQUE

Les examens, faits jusqu'à présent, des emplacements du mésolithique tardif en Pologne ne sont pas une base incontestable (sauf la densité de la colonisation mentionnée plus haut) des conclusions quant à la participation de groupes humains, liés à cette étape de civilisation, au processus des modifications fondamentales, économiques et sociales de l'époque du néolithique.

Les problèmes de la période limitrophe séparant ces deux époques

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[9] R. Schild, critique de l'ouvrage de R. Jablonskyté-Rimantiené, Velyvojo mezolito st'óvykla Lampédziuose, Lietuvos TSR Mosklu Akademijos Darbai, series A, 2, Vilnius 1963, dans *Acta Baltico-Slavica* 4, Białystok, 1966, p. 200 - 206.

sont compliqués, surtout à cause de la difficulté de trouver dans toute l'Europe, y compris la Pologne, des liens entre les sites du néolithique et le lit ancien. Ceci est entre autres le résultat de la méconnaissance du rôle du mésolithique local dans la naissance des civilisations du néolithique. Cependant on remarque dernièrement une autre attitude envers ces problèmes. Ainsi par exemple J. G. D. Clark [4] parle d'un rôle actif et non passif des hommes de l'époque du mésolithique dans l'appropriation des conquêtes du néolithique et dans l'adaptation de leur existence aux conditions nouvelles. Par contre les chercheurs soviétiques (W F. Isayenko [3], R. K. Rimantienie [16], T. J. Telegin [20] parlent déjà en faveur de la naissance des civilisations néolithiques d'une base locale, mésolithique. De même des chercheurs polonais M. K. Jażdżewski [9], M. T. Wiślański [26]) aperçoivent dans les civilisations néolithiques, auxquelles on attribue un développement indépendant (Civilisation des coupes en forme d'entonnoir, des amphores rondes) des affinités avec le mésolithique, surtout en s'appuyant sur des suppositions générales. Il semble toutefois qu'à l'étape actuelle des recherches les liaisons suggérées ne sont pas autant le résultat des analyses des affinités mutuelles que celui des études de l'histoire des civilisations.

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Varsovie

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GEOGRAPHIA POLONICA 17, 1969

LES CIVILISATIONS MÉSOLITHIQUES EN POLOGNE

STEFAN KAROL KOZŁOWSKI

La première synthèse du Mésolithique polonais date d'il y a plus de quarante ans [8]. L. Kozłowski s'est appuyé dans son étude sur des matériaux hétérogènes et de ce fait incertains. Il a aussi adopté et transplanté sur le terrain de la Pologne. sans analyse critique, des conceptions et des divisions culturelles étrangères (le Tardenoisien. le Campignien etc.). Aujourd'hui cette méthode de travail est inacceptable, donc la valeur de cet ouvrage est plutôt historique.

M. Stefan Krukowski, qui a fondé notre science actuelle du Paléolithique polonais. travaillait selon une méthode différente. Il a établi, entre autres. un système d'analyse planigrafique et typologique dans les fouilles. Ce système permet de discerner et d'isoler des ensembles homogènes.

Le système de M. S. Krukowski a joué un grand rôle dans le développement des recherches, et c'est son auteur qu'on doit le niveau actuel des recherches sur le Mésolithique polonais.

Dans les fouilles sur le Mésolithique polonais le plus grand mérite revient cependant aux préhistoriens de la jeune génération. Parmi ce groupe de chercheurs, il y a lieu de citer Mme. M. Chmielewska, Mlle. H. Mackiewicz, Mme. M. Marczak, Mme. H. Więckowska, M. W. Chmielewski, M. B. Ginter, M. M. Kobusiewicz, M. R. Schild et M. J. Trzeciakowski.

L'étude présente concerne le bilan des opinions actuelles de l'auteur sur différents problèmes relatifs au Mésolithique de la Pologne [13].

CHRONOLOGIE

Le caractère spécifique des stations de plein air en terrain sablonneux, où apparaissent d'habitude les matériaux mésolithiques, se manifeste entre autres dans l'absence (hormis quelques exceptions) de dates obtenues par des méthodes adoptées dans le domaine des sciences naturelles. Dans cet état de choses pour etablir un système chronologique du Mésolithique polonais on a du faire appel aux analogies avec les stations bien datées du Nord européen. L'auteur a déjà proposè un projet de division chronologique du Mésolithique de la Pologne [17, 20], il ne présente donc cette fois que les données les plus importantes.

Dans tout un nombre de civilisations de la Plaine Nord européenne on observe certains éléments identiques datant de la même époque; ces éléments sont donc interculturels. Une analyse de la présence de ces éléments dans les civilisations du Nord européen permet de constater certaines règles:

1. Les éléments interculturels apparaissent (ou disparaissent) en même temps, dans toutes les civilisations,
2. Le nombre de ces éléments interculturels augmente (ou diminue) à peu près à la même époque.

De ce fait on peut considérer ces éléments comme indices chronologiques. Cette théorie permet de déduire les conclusions suivantes:
a) Le nombre des grattoirs de type tarnovien [28] (Fig. 1: 6, 13) est assez élevé au Préboréal, il baisse avec le temps (Boréal) et au début de l'Atlantique leur pourcentage devient insignifiant. b) Les grattoirs irréguliers (Fig. 1: 14, 22, 29, Fig. 2: 14, 21, 29, 35) apparaissent vers la fin du Préboréal et à partir de cette époque leur indice augmente au dépens de celui des grattoirs réguliers. Dans les ensembles datant de l'Atlantique l'indice des grattoirs irréguliers dépasse celui des réguliers. c) Les trapèzes apparaissent aux confins du Boréal et de l'Atlantique. Leur indice augmente au dépens des autres microlithes géométriques.

Ces données permettent de diviser le Mésolithique de la Pologne en deux:

1. Le Mésolithique inférieur (Préboréal et Boréal).
2. Le Mésolithique supérieur (l'Atlantique).

Il existe un projet de subdivision de ces deux parties. Le système presenté a été adopté par l'auteur dans cette étude.

FIN DU PALEOLITHIQUE — DÉBUT DU MÉSOLITHIQUE

Le passage de l'extrême fin du Paléolithique au Mésolithique est, en Pologne, une question qui n'a pas encore été étudiée à fond. Au déclin du Pleistocène en Pologne se développait la civilisation sviderienne [28] et tarnovienne. La question est de savoir: quelle était leur évolution dans la période transitoire entre le Pleistocène et l'Holocène et au début de cette dernière époque?

L. Zotz, l'auteur de la conception du „Svidero-Tardenoisien" suggérait que les éléments svideriens se seraient entremêlés avec les groupes „tardenoisiens". M. R. Schild et Mme. H. Więckowska ont démontré [30], que la théorie de Zotz est inapplicable. En effet, on n'a pas découvert jusqu'à présent, ni en Pologne centrale ni en Pologne méridionale, aucun ensemble présentant des éléments caractéristiques du Sviderien à côté d'éléments „microlithiques". Récemment on a signalé la possibilité de la présence, dans la partie nord-ouest de la Pologne, d'ensembles svideriens datés d'Holocène [20]. Ils ne contiennent pas d'éléments „microlithiques". Cette récente phase du Sviderien (Stańkowicze VII? [31] a existé probablement jusqu'au début du Boréal. Au cours du Boréal elle a participé à la genèse des ensembles de type Kunda-Borki [13, 29].

CIVILISATION DE KOMORNICA — (NARVIEN)

La civilisation de Komornica [10, 23] doit son nom à la station éponyme de Komornica, district de Nowy Dwór [33]. Les autres stations classiques (les ensembles homogènes) de cette civilisation sont les suivantes: Stawinoga, district de Pułtusk [24, 27], Wieliszew XI, XII et XVII A, district de Nowy Dwór [34 - 36], Poddębe I, district de Nowy Dwór [36], Całowanie, district d'Otwock [37], Witów, district de Łęczyca [2], Rydno VIII/59, district de Starachowice [4], Majdan I — 1 et II — 1, district de Kolbuszowa [18], Dzierżno, district de Gliwice [5] et Poznań-Starołęka [7]. On a constaté aussi le présence d'éléments typiques pour cette civilisation dans les nombreux matériaux provenant de recherches d'amateur [10, 22].

La civilisation de Komornica occupait la Grande-Pologne, la Basse- et la Haute-Silésie, la Mazovie et la partie ouest de la Petite-Pologne [13].

INVENTAIRE LITHIQUE

Les microlithes géometriques. On constate toujours les formes suivantes: lamelles à dos de type Stawinoga (Fig. 1: 1, 8), lamelles tronquées de type Komornica (Fig. 1: 2, 9), triangles isocèles (Fig. 1: 3, 10), triangles scalènes obtusangles (Fig. 1: 4, 11). Les formes plus rares sont les suivantes: segments de cercle, lamelles tronquées doubles (Fig. 1: 5, 12), trapèzes etc. Les microlithes présentent une retouche abrupte, parfois faite sur enclume. Les lamelles a dos de type Stawinoga sont toujours les plus nombreuses (20 - 50% du nombre total des microlithes) les lamelles tronquées de type Komornica et les triangles scalènes obtusangles y sont moins nombreux (11 - 35%).

Les grattoirs — on constate la présence de grattoirs réguliers et irréguliers. Le groupe de grattoirs réguliers est composé d'un assez grand nombre de pièces très courtes (Fig. 1: 6, 13) — tarnoviens, de grattoires réguliers trapus et de petits grattoirs réguliers. Les grattoires irréguliers sont fréquents dans les ensembles plus récents (Fig. 1 : 14); (1,3$^0/_0$ du nom-

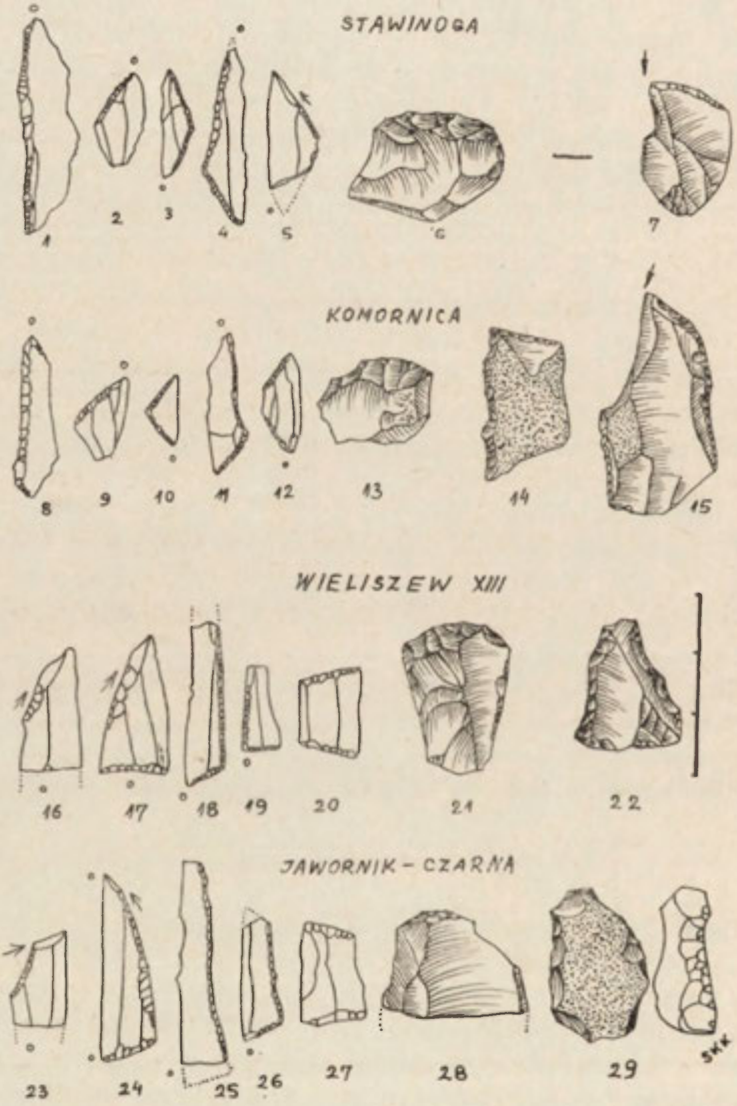

Fig. 1

Civilisation de Komornica: 1 - 7 — Stawinoga, district de Pułtusk; 8 - 15 — Komornica, district de Nowy Dwór

Civilisation de Janisławice: 16 - 22 — Wieliszew XIII, district de Nowy Dwór; 23 - 29 — Jawornik-Czarna, district de Dębica bre total des grattoirs à Komornica; à Wieliszew XI les grattoires irréguliers dépassent en nombres les réguliers).

Les burins — sont peu nombreux, on constate les burins dièdres et sur troncature (Fig. 1: 7, 15).

Il y a lieu de signaler, de plus, la présence de perçoirs, de lames retouchées et de rares tranchets.

Les outils en os et en corne.

Il n'est pas exclu, que les harpons de type 8 (d'après J. G. D. Clark) découverts en Pologne, proviennent des ensembles appartenant à la civilisation de Komornica [16].

CHRONOLOGIE

Pour la chronologie on dispose de trois dates rattachées à la civilisation de Komornica, deux concernant le Mésolithique inférieur (Witów — 6230 av. J. Ch., Całowanie — Préboréal ou Boréal [36]), une — le Mésolithique supérieur (Wieliszew XI — le début de l'Atlantique [36]). En s'appuyant sur ces dates, ainsi que sur l'analyse typologique, on peut établir la chronologie de la civilisation de Komornica. Elle a existé au cours du Préboréal, du Boréal et au début de l'Atlantique [17].

La civilisation en question présente de nombreux éléments d'analogie avec celle de Duvensee, dont le territoire était immédiatement contingu au sien du côté de l'ouest [10]. La civilisation de Komornica appartient aux civilisations du Nord européen. Sa genèse semble être rapprochée de celle de la civilisation de Duvensee.

Les deux amas d'os humains, calcinés par le feu dans la station de Wieliszew XI peuvent faire partie d'une tombe à incinération [36].

ÉLÉMENTS DU TYPE CHOJNICE

On ne trouve ces éléments que dans les inventaires mélangés. Ils apparaissent avec le plus de netteté dans la localité de Nowy Młyn, district de Chojnice [13, 16]. Toutes les stations avec des éléments de type Chojnice sont groupées dans le bassin de la basse Vistule.

INVENTAIRE LITHIQUE

Les microlithes géometriques (la seul forme dont on puisse parler dans ce cas) — les points de type Nowy Młyn, assez grands microlithes à base retouchée, points lancéolés, grands triangles scalènes sveltes etc.

Les outils en os et en corne.

Il existe dans la région occupée par les éléments de type Chojnice deux types de harpon (5 et 7 d'après J. G. D. Clark) datant du Mésolithique. Probablement ces harpons appartiennent à la même civilisation que les éléments de type Chojnice.

CHRONOLOGIE

Au point de vue de la chronologie les éléments de type Chojnice et les harpons de type 5 et 7 sont rapprochés de la civilisation de Maglemose. D'après cette analogie on peut les dater comme cette civilisation (Boréal — début de l'Atlantique), on constate aussi la ressemblance à groupe Gudenaa-Oldesloe.

ENSEMBLES DE TYPE KUNDA-BORKI

Les ensembles de type Kunda-Borki [13] appartiennent à plusieurs civilisations apparentées, encore trop peu étudiées. C'est pourquoi l'auteur ne donne pas à ces ensembles le nom de „civilisation".

Les ensembles de type Kunda-Borki doivent leur nom aux stations éponymes de Kunda-Lammasmägi et celle de Borki (URSS [13, 29]. Les autres stations classiques: Sknyatino, Yelin Bor, Oleńyj Ostrov, Lampédžiai, Zemuïu Kaniuku (URSS). En Pologne on a constaté la présence des inventaires non homogènes [16].

Les ensembles de type Kunda-Borki avaient occupé le partie nord-est de la Pologne, la Lithuanie, la Biélorussie, l'Esthonie et la Russie centrale [1, 16, 29].

INVENTAIRE LITHIQUE

Les pointes — notons, comme formes toujours présentes — les points à pédoncule (Fig. 2: 31) tirant leur origine des points paléolithiques svideriennes [29].

Les microlithes géometriques — les plus nombreuses sont les lamelles de type Borki (Fig. 2: 32, 33). Il y a lieu de citer encore les trapèzes (Fig. 2: 34).

Les grattoirs — on constate la présence de grattoirs réguliers — de type tarnovien (Fig. 2: 36), grattoirs trapus sur lame et des grattoirs irréguliers (Fig. 2: 35). On ne connait pas leur rapports numériques.

Les burins — on observe la présence de pièces dièdres et tronquées. Beaucoup des formes sur cassure.

Enfin il faut mentioner aussi le groupe d'outils macrolithiques (tranchets).

Les outils en os et en corne.

Dans les ensembles de Kunda-Lammasmägi et d'Olénij Ostrov

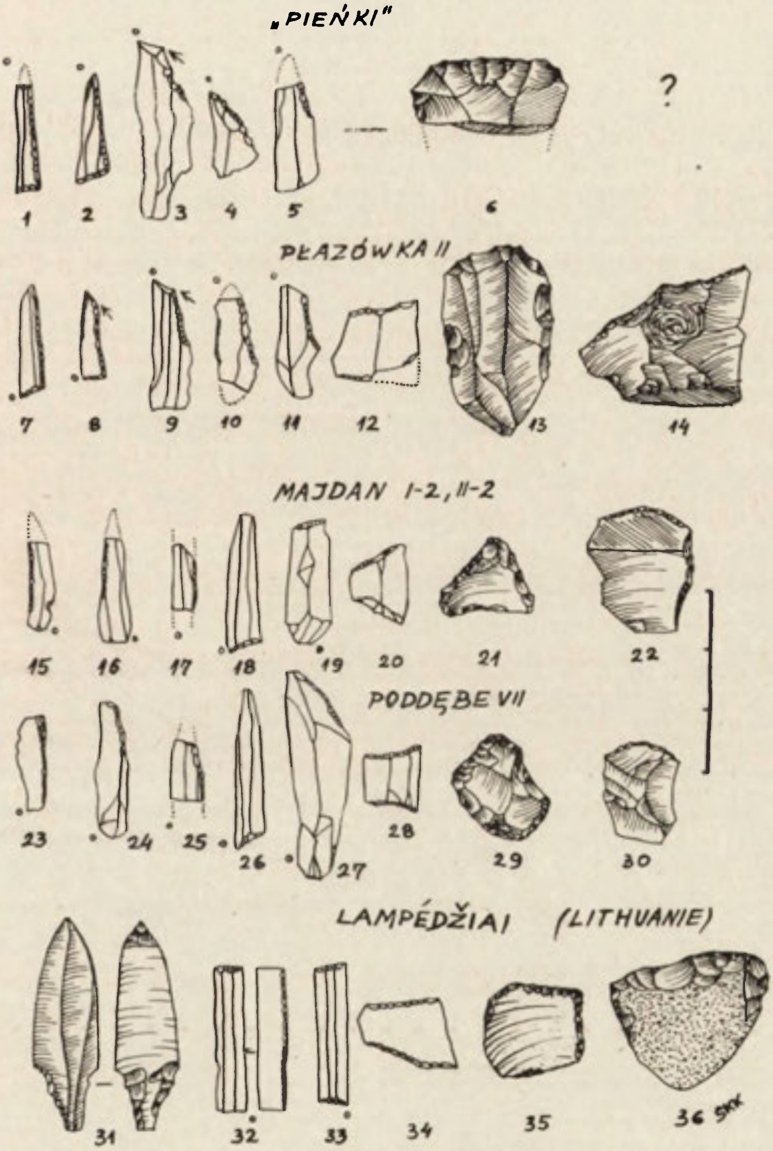

Fig. 2

Civilisation de Pieńki: 1 - 6 — Pieńki, district d'Otwock; 7 - 14 — Płazówka II, district de Kolbuszowa

Civilisation de Majdan: 15 - 22 — Majdan I - 2 et II - 2, district de Kolbuszowa; 23 - 30 — Poddębe VII, district de Nowy Dwór

Ensembles de type Kunda-Borki: 31 - 36 — Lampédziai (Lithuanie) les collections lithiques sont accompagnées d'un certain nombre d'outils en os et en corne. Les plus caractéristiques sont les harpons et les points de type 12 A 13, 16, 17 et 21 (avec une cannelure).

CHRONOLOGIE

Au point de vue de la chronologie la méthode de l'analyse pollinique situe les ensembles de Kunda-Lammasmägi et celui de Sknyatino dans la plus recente partie du Boréal (la date ^{14}C pour Kunda-Lammasmägi = 6735±285 ans B.C.). L'analyse géologique permet de rapporter la station de Lampédziai à l'Atlantique. Les ensembles de type Kunda-Borki ont donc existé au cours de Boréal et pendant l'Atlantique.

La genèse des ensembles de type Kunda-Borki est rattachée à la civilisation svidenenne et aux groupes humains venant du fond de la Russie [13].

Récement on a publié des données sur deux tombes de Giżycko-Perkunowo. On y a découvert les restes de squelettes saupoudrés d'ocre. Ces deux tombes se rattachent, peut-être, aux ensembles de type Kunda-Borki (?) [13].

CIVILISATION DE JANISŁAWICE — (VISTULIEN)

Le nom de cette civilisation [13, 23, 37] tire son origine de la station éponyme de Janisławice, district de Skierniewice [3]. Les autres stations classiques: Jawornik - Czarna, district de Dębica [19], Wistka Szlachecka III/60 et III/63?, district de Włocławek [26, 34], Poręby Dymarskie 2-2-3, district de Kolbuszowa [22], Raniżów, district de Kolbuszowa [22], Czerwony Borek I et II, district de Siemiatycze [31], Wieliszew XIII, district de Nowy Dwór [34], Rydno VI/59, district de Starachowice [4], Baraki, district de Kraśnik, [19]. On constate aussi la présence des éléments typiques pour cette civilisation dans les nombreux matériaux provenant de recherches d'amateur [22].

La civilisation de Janisławice avait occupé la partie est de la Grande-Pologne, la Mazovie, la Podlaquie, la Petite-Pologne, la Lithuanie (?) et la partie nord de la Biélorussie [13].

INVENTAIRE LITHIQUE

Les microlithes géometriques — on observe les formes caractéristiques suivantes: les pointes de type Janisławice (retouche semi-abrupte, technique du microburin, la base cassée intentionellement — Fig. 1: 16, 23, ou retouchée — Fig. 1: 17, 24), les triangles de type Janisławice (Fig. 1: 18, 19, 25, 26) grands ou petits, les lames tronquées. Les trapèzes sont plus rares (Fig. 1: 20, 27). Le nombre des pointes de type Janisławice oscille entre 10 et 58% du nombre total des microlithes. Le nombre des triangles (à l'exception de certains ensembles) varie de 18 à 66%.

Les grattoirs — on observe la présence de grattoirs réguliers (Fig. 1: 21, 28) et irréguliers (Fig. 1: 22,29). Le nombre des grattoirs réguliers dans les ensembles sans trapèzes est à peu près le même que celui des irréguliers; dans les ensembles avec des trapèzes, les grattoires irréguliers gagnent en nombre et finissent par prédominer.

Fig. 3. Principales stations mésolithiques de la Pologne

1 — Poznań-Starołęka, 2 — Pietrzyków, 3 — Holendry Brzezińskie I, 4 - 6 — Wistka Szlachecka III/60, III/63 et VI, 7 — Witów, 8 — Janisławice, 9 — Stawinoga, 10 - 18 — Komornica, Poddębe I et VII, Wieliszew XI, XII, XIII, XVI, XVII A et XVII C, 19 — Pieńki, 20 — Całowanie, 21 - 22 — Czerwony Borek I et II, 23 - 24 — Rydno VI/59 et VIII/59, 25 — Dzierżno, 26 — Czernichów I, 27 — Jawornik-Czarna, 28 - 34 — Majdan I - 1, II - 1, 1 - 2 et II - 2, Płazówka II, Poręby Dymarskie 2 - 2 - 3, Raniżów, 35 — Baraki

Il y a lieu de signaler, de plus, la présence des burins et des microburins.

Les outils en os et en corne.

Les pointes de type Stora Dode (type 21 d'après J.G.D. Clark) avec deux cannelures appartiennent peut-être à cette civilisation (?) [13].

CHRONOLOGIE

La chronologie est basée sur la typologie. On peut rapporter la civilisation de Janisławice à la seconde (première ?) moitié du Boréal aussi bien qu'à l'Atlantique.

La civilisation de Janisławice présente quelques analogies avec celle de Maglemose. Elle appartient aux civilisations du Nord européen.

À Janisławice on a trouvé une tombe appartenant à la civilisation du même nom. C'était une tombe à fosse, où le squelette avait été déposé en position assise, et saupoudré d'ocre [3].

CIVILISATION DE PIEŃKI

La civilisation de Pieńki [12, 13] doit son nom à la station éponyme de „Pieńki" - Świdry Wielkie-Małe, district d'Otwock [12]. Les autres stations typiques de cette civilisation sont les suivantes: Czernichów I, district de Cracovie [9], Płazówka II, district de Kolbuszowa [14] et Holendry Brzezińskie I, district de Konin [32].

Ces stations déterminent l'étude maximale du territoire actuellement connu de cette civilisation (partie est de la Grande-Pologne, Mazovie, Petite-Pologne).

INVENTAIRE LITHIQUE

Les microlithes géometriques — on observe toujours les formes suivantes: petits triangles scalènes (Fig. 2: 1, 2, 7, 8), petites lamelles tronquées de type Komornica (Fig. 2: 4, 5, 10, 11), pointes de type Pieńki (Fig. 2: 3, 9) formées au moyen de la technique de microburin, lamelles à dos. Les pièces isolées sont les suivantes: microlithes à base retouchée, trapèzes (Fig. 2: 12) etc. Les petits triangles, scalènes sont toujours les plus nombreux (35 - 60% du nombre total des microlithes), les lamelles tronquées de type Komornica sont aussi nombreuses (14 - 41%). À côté des microlithes on trouve toujours de nombreux microburins.

Les grattoirs — on constate la présence de pièces peu nombreuses de type tarnovien, des grattoirs réguliers retouchés sur les bords (Fig. 2: 6, 13) et des petits grattoirs irréguliers (Fig. 2: 14). Le nombre des grattoirs réguliers et irréguliers est à peu près égal.

Les burins, les lames rétouchées, les perçoirs sont rares.

CHRONOLOGIE

La chronologie est basée sur la typologie. La civilisation de Pieńki date de la seconde moitié du Boréal et du début de l'Atlantique [13, 17].

La civilisation de Pieńki se rattache sans doute aux civilisations du Nord européen.

CIVILISATION DE MAJDAN

La civilisation de Majdan [11] doit son nom à la station éponyme de Majdan I — 2 et II — 2, district de Kolbuszowa [18].

Les autres stations classiques de cette civilisation sont les suivantes: Wieliszew XVI et XVII C, district de Nowy Dwór [35, 36] Poddębe VII, district de Nowy Dwór [25], Pietrzyków?, district de Września [6].

Ces stations déterminent l'étendue territoriale de cette civilisation, qui avait occupé la Mazovie, la Petite-Pologne et peut-être, la partie est de la Grande-Pologne.

INVENTAIRE LITHIQUE

Les microlithes géometriques — on constate toujours les formes suivantes: lamelles à dos (Fig. 2: 15 - 17, 23 - 25), microlithes à base retouchée (Fig. 2: 18, 26), trapèzes (Fig. 2: 20, 28), plus rarement lamelles tronquées délicates (Fig. 2: 19, 27). Les lamelles à dos sont toujours les plus nombreuses (33 - 50% du nombre total des microlithes). Le nombre des trapèzes et microlithes à base retouchée oscille entre 5 et 38%.

Les grattoirs — les formes régulières (Fig. 2: 22, 30) sont nettement moins nombreuses que les grattoirs irréguliers (Fig. 2: 21, 29), qui sont même quelquefois la seule forme de grattoir.

Les burins sont presque absents.

CHRONOLOGIE

La chronologie est appuyée sur des données typologiques, rapporte la civilisation de Majdan à l'Atlantique.

ENSEMBLES DE TYPE WISTKA SZLACHECKA VI

Les ensembles de type Wistka Szlachecka VI [13] appartiennent peut-être à plusieurs civilisations apparentées. Ils doivent leur nom à la station de Wistka Szlachecka VI, district de Włocławek [36]. Les autres stations ont livré des ensembles semblables.

Inventaire lithique, composé de deux groupes d'outils: des trapèzes et des grattoirs irréguliers. C'est le résultat d'une sorte d'uniformisation culturelle dans le Mésolithique tardif (refoulement des grattoirs réguliers par les irréguliers, refoulement de divers microlithes par les trapèzes). Il n'est pas impossible que les ensembles de type Wistka Szlachecka VI datent de l'époque de l'arrivée des premiers agriculteurs néolithiques sur le territoire de la Pologne [21].

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