

Mieczysław Klimaszewski.

O kilku problemach glacialnych w Polsce.

Some problems of the glaciation in Poland.

The last decennary is a period of awakened interest in the Diluvian problems in Poland. A series of publications concerning this epoch so long neglected were issued, treating of the large and but little known Polish soils. They offer new notions and theories as to the number and limits of the glaciations, as well as of their bearing on the substratum and on the actual scenery. In the course of time, due to the progress of the investigations and the improvement of the methods, these ideas have undergone some changes. Thus, when in the year 1922, Limanowski [15] endeavored to lay the foundation to the theory of two glaciations in Poland (L_3 and L_4), on the base of the situation of the older ground moraine in the Eem formation, considered as belonging to the second Interglacial, which belief has of late been strongly shaken [23], the scientists, Lewiński J. [14], Szafer W. [31], Makowski A. [16] (yet earlier, Ludomir Sawicki [29] had expressed it in the form of conjecture [29]), all admitted three glaciations. The difference cardinally lies in this, that the first investigators, Szafer, Sawicki, Lewiński, Pawłowski, Rydzewski, consider the moraines of Pojezierze as terminal moraines of the latest, independent and eparate glaciation, while Lencewicz [11], Wołosowicz [35], Limanowski [15] define them as stadial ones. Finally, the question was resolved in favour of the first by the discovery of the undeniable Interglacial in Żoliborz.

In the year 1930 was stated one more transgression of the ice-sheet, thus confirming the existence of four glaciations on our soils (Szafer [32, 34]).

Prof. W. Szafer has obtained these results by way of the stratigraphical method which leads to the discovery of Interglacials and Interstadials. It consists on the investigations of flora and fauna preserved in loams and peats of the Diluvian and

Postdiluvian period. In regard to the flora found in peat layers the method of pollen analysis is of the greatest importance [5].

Making use of his own results and those of other investigators, Szafer has published in 1928 «A sketch of the stratigraphy of Polish Diluvium on floristic base», discerning three glaciations and two unquestionable interglacials. His last year discoveries permitted him to distinguish four glacial periods.

The oldest of them is called Jaroslavian, and after this come the already adopted: Cracovian, Varsovian I, and Varsovian II with between them the Interglacials: Sandomirian, Mazovian I and Mazovian II.

Szafer was led to admit the existence of this oldest glaciation by the character of the interglacial flora preserved in a layer of peat with the ground moraine Cracovian at the top. At the bottom we find the flora of cold climate with *Betula nana* and some other arctic plants, higher up appears the flora of the warmer period: pine, willows, larch etc., and last comes the flora of the completely warm period: beech-trees, elms etc. The upper parts of the peat, where probably a new cold period layer should occur, these were destroyed by the advancing ice-sheet (Cracovian). As here the cooling down towards the bottom is visible, one must accept that it was caused by the ice-sheet, during the regression of which, the above discussed peats were formed in a lake, but no ground moraine was discovered. If the glaciation reached up to the Carpatian Mts, the erratics, found high up in the region of the Carpatian foot-hills, would belong to it, according to Szafer.

He is not alone in his opinion of the existence of four glaciations in Poland. Much earlier, for in the year 1909, W. Kuźniar [10] established with great certainty the invasion of two ice-sheets in the environs of Cracow, having found two moraines superposed, the older one strongly destructed and obscured by the subsequent ice-sheet, which also left a moraine in the form of gravel, sand, loam with crystalline northern material. Between these moraines he found the bones of a mammoth and a European bison from the interglacial period (Ludwinów).

Pawłowski St., investigating the Diluvian formations in the basin of the river Mlecza [21], supposes, though doubtfully enough, the existence of two glacial epochs at the border of the Carpatian Mts.

It is only when studying the terraces in the valley of the river Wisłoka [22], that he ascertains the invasion of two ice-sheets, which extended as far as the Carpatians and defines them by the name of Carpatian and Subcarpatian glaciation [24].

In Upper Silesia, Michael [18], distinguishing three ground moraines superposed and divided by interglacial formations, admits as many glaciations, the oldest of which must be reckoned as the glaciation Günz (Jaroslavian). Zeuner, when investigating the Nissa terraces, admits the existence of 7 cold periods, grouped in three glaciations with oscillations. The researches of Polish geologists [16, 17], carried on in the region of the Polish coal basin, confirm the supposition of Michael, however the lack of definite proofs in other parts of Poland, kept them back from positively admitting the glaciation Jaroslavian (L_1 , Günz). Czarnocki J. finds, in the central part of the Świętokrzyskie range [1, 2], under the moraine of the glaciation Cracovian (L_3), interglacial formations such as banded-loam, loess-mud and sands, containing at the base a layer of gravel, boulders of quartzite and of sandstone embedded in clay. In the opinion of Czarnocki, they are remnants of the oldest glaciation « L_2 relatively L_1 ». Lewiński J. equally supposes, on the ground of facts gathered near Piotrków (local moraine) [12] and Warsaw (preglacial) [13], the existence of a glaciation older than the Carpatian one (Cracovian-Mindel), extending to the environs of Warsaw [14].

Finally Premik J. states in the basin of the medial course of the rivers Warta, Widawka and Proсна [26, 27], the thrice repeated transgression of the ice-sheet, «which is testified by the presence of three moraines divided by two Interglacials». Of the moraine of the oldest glaciation remnants alone are left in the form of sharp-edged blocks of sandstone, chert and rocks of northern proveniency. In the opinion of Premik, the glaciation, belonging to this moraine, «extended, far on to the south, beyond our region, probably as far as the Carpatians». The second and next one (Cracovian) reached equally the Carpatian border, then appeared the so-called middle Polish glaciation (Varsovian I) and the last Baltic glaciation (Varsovian II).

Therefore we see that the existence of the fourth glaciation, particularly after the testimony given it by Szafer, is unquestionable and that we must continue our efforts to establish the repartition of this glaciation on our soils.

But was this glaciation really the first one? In the preceding epochs and periods were not our soils invaded by equally large ice-tongues from the North and, after a certain period of time, will not the same occur again? In order to answer these questions we must consider the cause of the glaciations. At present it is recognized that the glaciations occurred owing to changes in the situation of certain astronomical elements (Pillgrim, Milankowicz). Not so long ago (1924) W. Köppen and A. Wegener [6] presented on the ground of the calculations of Milankowicz the astronomical division of the Diluvian epoch. The work of Milankowicz is based on periodical changes taking place in the disposition of three astronomical elements:

alterations in the inclination of the ecliptic among the utmost values 22° — $24\frac{1}{2}^{\circ}$ in a period of above 49,000 years,

alterations in the length of the perihelium in a period of 20,700 years (it means that at this time the perihelium circles about all the seasons of the year,

and finally, changes of eccentric of the way of the earth in a period of 91,800 years.

These changes provoke differences in the insolation of various areas of the earth and therefore in the supply of heat from the sun.

Milankowicz has traced on this base the curve of the radiation for a period of 650,000 years. Minima of radiation indicate periods of cold, viz. glaciations. According to Milankowicz there were four double glaciations, divided by Interstadials of the length of 40,000 years; the interglacial periods were characterized by a remarkably longer time of duration (I intergl. = Sandomirian: 75,000 years; II intergl. = Mazovian I: 200,000; III intergl. = Mazovian II: 72,000 years). Thus we should have absolute numbers for interglacial and glacial periods which in the Diluvium reigned in Poland and North Europe for 650,000 years backwards. By way of further calculations this curve can be lengthened backwards and onwards. Therefore, in the Tertiary and before, there might have been glaciations, the traces of which were completely destroyed by the oceans, if, naturally, there were no peculiar conditions preventing their formation (deep seas, warm currents). One may define similarly the future ice-period. Milankowicz supposes that after a lapse of 10,000 years, the longest season of the year in our country will be winter, and summer

the shortest, which of course will bear relatively on the climatic conditions. These conjectures as to the periodical return of glaciations are confirmed again by prof. Szafer [33].

Characterizing the interglacial periods in relation to the kind of plants succeeding each other and to their proveniency, Szafer distinguishes in each Interglacial the following climatic phases: the arctic phasis, the cold one from the period of regression of the ice-sheet, and subsequently the warm phasis, which slowly enters the period of a temperature warmer than the actual one, namely «the climatic optimum». Then follows «the spoiling» of the climate and again comes the ice-period. Such were the relations in the three interglacial periods, which we have examined.

The studies concerning the Diluvium are not limited only to ice-periods, they embrace also the time which elapsed since the regression of the ice-sheet in Poland till the actual alluvial epoch. And we see again on the ground of stratigraphical studies that at the time of regression of the ice-sheet, there reigned a period of cold climate (arctic phasis), followed by a warm one. In the neolithic period was attained the climatic optimum testified by a great many floristic facts (hazel in profusion, higher upper limit of leafy trees). Nowadays we live in the period of «the spoiling» of climate, its cooling, the period preceding a new glaciation, therefore the decline of the Interglacial.

The cooling progresses quickly enough. It is shown among others (climatic facts for inst.) by the descent of fir-tree and spruce in the Carpatians, therefore, the lowering of the upper limit of the forest. In the environs of Suwałki one can observe actually the migration of the spruce to the South.

Considering as probable the advance of the ice-sheet on our soils, it is a question of great interest whether it will come on rapidly, all of a sudden, scarcely wanting a few decennaries to form a mighty ice-sheet, or will it rather happen by way of a slow cooling down of the climate in regions the which the ice-sheet will some day occupy (Milankowicz).

Nowak J., who considers rather the first supposition as more probable [20], thinks that the formation of an ice-sheet in northern Europe should not require more than about 4° less than the average temperature.

Szafer has therefore presented the problem of the periodical-

cal advance of the glaciations and has stated that the epoch in which we live is an interglacial period. This problem, till now but little studied, with the exception of Milankowicz, gains in the conception of Szafer a remarkable proof of the frequency and regularity of the glacial phenomena.

Here again we see the very great value of the stratigraphical method, without the adopting of which, accurate researches cannot be thought of, as well in a region formerly glaciated as in a peripheral one, in the vicinity of the ice-sheet, but not covered by it. In the peripheral region to which in Poland belong the Carpatian Mts. which are an obstacle to the front of the ice-sheet the investigations offer great difficulties. The lack of plants remains in the river formations, often well developed in form of gravel, sand and clay, does not permit to define their age and the time of their formation as well as their relation to the phenomena taking place in the North. Here, above all, is important the question of establishing the parallelism of the particular northern glaciations with those of the Tatras [4, 28]. This is possible by way of analitic studies of forms (terraces and levels equalizations) and the stratigraphy of the river and ice deposits, also of their relation to each other in the valley of the Dunajec, which binds the Tatras to the Vistula lowlands. The respective studies are being carried on by the Geographical Institute in Cracow [30] under the direction of prof. J. Smoleński.

The results obtained till today permit us to ascertain the high filling up (130 m above the bottom of the valley) of the valley of the river Dunajec in the period of the blockage of its month near Czchów across the northern ice-sheet (Cracovian; erratics) and the gradual penetration of waters after its regression, which contributed to the formation of some terrace levels.

In the Czarnohora group (Eastern Carpatians) Dr. Świderski has distinguished one glaciation and three stadial periods, which are probably also in relation to the North.

Szafer [33] calls attention to the travertines found in the Carpatians which very often contain remains of plants and animals, and also on the loess formations covering large areas as well in the valleys as in the Subcarpatian ridges and sometimes in the Carpatian ones also [8, 9]. Unfortunately only a very few stations of travertines have been discovered till this day. In the

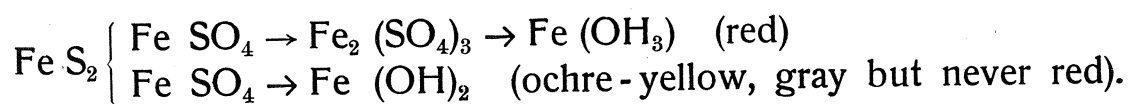
vicinity of Czarny Dunajec the arctic *Betula nana* was found in travertine, in Ganowce (locality in Spiż) appeared an interglacial flora with larch [25], and in Bukowina near Dukla a willow-flora with small leaves was discovered.

Peat-bogs, often met with in the northern part of Poland, occur very seldom in the western Beskids (larger ones only in Podhale [3]), while in the eastern Beskids they attain a very remarkable thickness (about 12 m), appearing even higher up than the upper limit of the forest [34].

Szafer expects however most interesting results from the investigations of fossil peat-bogs in Podolia. They are found, covered with humus, in the so-called «ostoja», depressions, and, not destructed by glaciers, they ought to be natural thermographs of the Diluvian period.

Together with stratigraphical researches, should be carried on geochemical and petrographical ones. The object of the first is the study of the degree of disaggregation of the accumulated formations, the calcination and decalcation of the moraines and their colour, while this last has a remarkable part in the parallelism of the ground moraines.

Namely, the moraines of the glaciation Cracovian are said to be graycoloured and those of the glaciation Varsovian I are red which, according to many investigators, comes from the Old-red of Devon. However, it cannot be considered as quite certain. In the opinion of Kowalski the red or gray colour of the moraine may be the last phasis of the decomposition of three-value iron which, owing to the influence of exterior factors, produces red colour or ochre passing into gray.



In the first case the oxydation is prompt, in the second it is slow.

Consequently, it would not seem really possible to establish the parallelism of the moraines and the definition of their age on the base of colour.

Lately, S. Kreutz has offered a curious conception, namely that gray color comes from the preponderance of calcareous material in the moraine, while red color depends on the preponderance of crystalline material.

More attention is therefore given now to the boulders, blocks for the most part crystalline of Fennoscandia proveniency, left on our soils by the Diluvian glaciations [7, 19, 24, 36].

Their exact petrographical definition and the designation of their place *in situ*, will allow to trace the direction of the ice-sheet and its tongues. By way of the method of calculation of the «moraine indicator», it will perhaps be possible to trace the petrographical limits of the moraines and the corresponding glaciations [24, 14].

The researches effectuated by way of these methods, being in close contact with morphological researches concerning the forms created and left by the ice-sheet, will probably permit, in some time to come, the definition of the number of glaciations as well in central Poland as in the Tatras and Carpatians, their connection with each other, their repartition and their bearing on the substratum and actual landscape.

Geographical Institute in the Jagell. University in Cracow.

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