

GLACIAL DEPOSITS OF INDIANA.

I.

GLACIERS AND THEIR ACTION.

A glacier is a body of ice, which, although solid, flows over a part of the earth's surface. It has been clearly demonstrated that ice in the form of a glacier, no matter how rigid it may appear, has a current similar to that of water. In other words, ice will form a solid stream, so to speak, which will slowly but steadily creep down an inclined plane, and if this ice-stream be very deep, so as to give it great weight, it will overthrow, grind up and bear away whatever obstacle opposes it.

Glaciers are formed by the accumulation of snow, which, by pressure and crystallization, is turned into ice. Thus, wherever the snowfall in winter is greater than can be melted in summer, the snow grows deeper year by year until at length by its own weight, and by partial surface melting it is compressed into a sheet of ice enormously thick. Now if the surface upon which this sheet rests is inclined, the ice flows and we have a glacier. In the Alps there are glaciers from five hundred to over six hundred feet in vertical depth, slowly flowing down the mountain sides. But it does not require steep mountain slopes for the making of glaciers; a comparatively gentle inclination of the surface of the ground is sufficient if the ice be thick enough and other conditions be favorable to motion.

The general form of a glacier is that of a wedge, the edge resting on the lowest point of the surface occupied, the thick end resting on the highest point of the same. Of course the motion of a glacial stream will be in some proportion to the slope of this surface, but the thickness of the great end of the wedge must have much to do with the force of the current. If we adopt the theory of Tyndall, or that of Mosely, or that of Croll, or any other, we must see that gravitation directs the course of the glacial movement just as it does the flow of water; for it can not matter

whether fracture and regelation, as Tyndall claims, or expansion and contraction by changes of solar heat, as Canon Mosely theorizes, or molecular motion generated by the conducting of heat through the mass, as Dr. Croll maintains, is the agent of motion, the fact remains that the glacier, if very thick at its upper end, would flow over a surface of comparatively slight inclination, and its destructive force would be, in a way, proportional to such thickness. Fluidity must be regarded as a property of water, even when the water is in the form of the brittlest ice. It makes but little difference what is the cause of this strange, slow fluidity of ice, it is sufficient for the purpose of the study of the Drift phenomena that the fluidity exists, and that it is sufficient to generate, under certain conditions, a force absolutely incalculable.

It is well for us to bear in mind, at every step of our discussion, that the ice of glaciers is not identical with the ice frozen under ordinary circumstances, nor is the one equivalent to the other. Snow compressed into a mass of glacier-ice is not perfectly crystalline and solid, but peculiarly laminated and porous in its texture, capable of absorbing at times a great quantity of water throughout its body, thus admitting of expansion by the very force of congelation. Moreover, the smallest movement of this sort repeated, at comparatively long intervals, during countless centuries, would thrust a body of ice, no matter how thick, over a long surface distance.

Long and careful study of the phenomena of existing glaciers has resulted in establishing not only the flowing motion of ice, but many of the effects produced thereby, one of the most notable being the *moraine matter* brought down to the glacier's terminus, or collected along its sides. These masses of *moraine matter* consist of worn and striated fragments of stone, of all sizes, from giant boulders down to tiny pebbles and infinitesimal grains of sand, together with earthy matter of great variety. A body of this character collected at the foot of a glacier is called a *terminal moraine*; if at the glacier's side it is called a *lateral moraine*.

A striking and easily recognized feature of moraine boulders and pebbles, of whatever size, is the peculiar surface-planing caused by the glacier having dragged or pushed them over other stone surfaces, or the like. These ground and scratched faces, once seen and fixed in the memory, serve to identify glacier stones wherever found, whether the stones be boulders, pebbles, or rocks in place over which the glacier has passed. Indeed, the floor upon which an ice-river has flowed is always engraved with the unmistakable sign manual of the glacier—fine *striae* parallel with the direction of the current.

The movement of a glacier may, and often does, load the ice-surface with stones, dust and other detritus, either by ploughing under the same, or by receiving them as they fall from the slopes on the side.

II.

THE GLACIAL PERIOD, ITS EXTENT AND EFFECT.

At the close of what geologists call the Tertiary age, there came a great change in the earth's atmospheric temperature, by which a large part of the northern hemisphere was subjected to a frigidity quite as great, perhaps, as that which now exists in the arctic regions. This polar condition crept on slowly, it is thought, until at length, in America and Europe, the desolation of almost unbroken snow and ice reigned supreme. What length of time was required to bring about this climatic change can only be conjectured. Enough evidence appears, however, to make it quite certain that a sub-tropical temperature, and a *fauna* and *flora* generated thereby, were banished from our hemisphere, while a boreal winter set its grip of ice upon everything.

In all Northern Europe and America snow accumulated year by year, and century by century, until its own weight compressed the mass into glaciers of scarcely imaginable thickness and area, and beside which the ice-fields of Greenland are insignificant. As the winter grew colder and colder, the summer grew feebler, and there is plenty of evidence showing that a boreal *fauna* and *flora* crept far southward to usurp the places of those animals and plants that had lately flourished in a balmy air and a warm, kind soil.

The enormous proportions of the glacial accumulation may be somewhat measured by the fact that the flowing was strong enough to urge ice-currents over considerable ranges of hills in Europe. Indeed, all over Northern and Central Europe the great rock floor, underlying what is called the Drift, is found to be polished, grooved and striated in the unmistakable pattern of glacial effects. The direction of these grooves and *striae* register the course of the monstrous ice floods, and the morainic stuff, heaped in vast beds all over the region affected, tells the rest of the story so fraught with tragedy—an age of frigid desolation, interspersed with obscurely marked periods of relaxation and warmth.

Throughout the Drift area the physical features vary but little. Above the striated floor-rocks the worn and peculiarly flattened boulders and pebbles, the heaps and ridges of sand and gravel, and the vast mass of bluish clay or till, accompany the glacial matter and make almost the whole of its bulk.

In Europe geologists have studied the Drift in immediate connection with still existing and active glaciers, and have found everything to satisfy the conditions of the "ice theory," or the theory of the glacial origin of the Drift deposits.

In America the Drift lies over a vast irregular area, as yet very indefinitely outlined in the north, but pretty accurately defined along the

southern boundary throughout a large part of its extent. From the highlands of Canada an enormous glacier (or rather a series of glaciers) appears to have descended into the region south of the great lakes, overwhelming with morainé matter a large part of the United States, from the Atlantic to the Pacific.

An examination of this Drift or moraine matter shows it to consist, in a large degree, of silicious *debris*, brought from a region of granite, gneiss, green-stone, quartzite and various other metamorphic or igneous rocks quite foreign to the area covered by the mass. Nor is it difficult to see, in a general way, that much of this matter has been transported from the Canadian highlands, where the granitic and other crystalline rocks are found in place, their surfaces torn, worn and shattered by the glacial action.

III.

SUPERFICIAL DESCRIPTION OF THE DRIFT DEPOSITS OF INDIANA.

The mass of matter, very appropriately named Glacial Drift, which is probably the most important, and certainly the least understood geological feature of Indiana, is in the form of an irregular wedge, its thick end to the north, its edge, or thin end, to the south, the former resting against Michigan, the latter disappearing in a sort of fringe along the Ohio River. Of course this description is of the most general nature, but the student must bear in mind the peculiar shape and position of the mass in order to have a ready understanding of such particular features as are hereinafter discussed.

Taking this vast wedge of matter, then, and beginning our examination in the neighborhood of its southern limit, or edge, we find it more or less obscurely outlined and its constituent parts passing by insensible gradations into the clays formed of decomposed rocks. Proceeding northward, mere superficial observation discovers that the Drift mass grows thicker and an occasional boulder is seen, while here and there a bed of smooth gravel appears along with deposits of sand. Upon examination the boulders prove to be rounded, scoured and scratched blocks of granite, gneiss, greenstone and other igneous or metamorphic rock, and the pebbles of the gravel are simply minute boulders of the same materials. The sand, when carefully studied, appears to be composed mostly of particles of quartz, feldspar, mica and other silicious crystals, evidently the result of a grinding up of igneous rocks.

Bluish or smoky gray colored clay is next discovered and at once becomes the chief component of the Drift mass, growing thicker step by step, as we go northward, save where water and other agents have thinned or removed it. Another very notable fact is the increase in the number

of boulders apace with our progress toward the northern end of the wedge. This gray-blue clay, or boulder till, is a mass of pulverized rock sometimes quite appreciably calcareous, but often almost wholly silicious, as if it were a grist of granitic rocks ground between some monstrous upper and nether millstone and poured out upon the surface of our State. From Middle Indiana northward ridges and hills of gravel and sand, and vast accumulations of boulders, appear at irregular intervals. Sand, heaped in hillocks and eccentric waves, covers a large area in the northern quarter of the State. Under all this, however, lies the boulder till, or blue-gray clay, which, as I have said, grows thicker gradually, in a general way, as we approach the northern limit.

Nearly all the principal valleys of Indiana lie so that their water-flow is from northeast to southwest, and are trenches cut by some agency, not only through the Drift mass, but often through parts of the underlying paleozoic rocks as well. Leading into these valleys from all directions smaller streams cut the land surface into irregular areas, and expose very interesting sections of the Drift mass. Along most of the water courses, large and small, the glacial materials have been assorted at certain points and re-arranged in terraces of stratified sand, gravel and water-worn fragments of stone.

In the northern part of the State, especially between Lake Michigan and the southern limits of the Kankakee and Yellow River valleys, the boulder clay has a large number of deep basins filled with water, forming beautiful little lakes.

The outcroppings of stratified rock decrease in number and thickness as we go northward from the Ohio River, until at length the Drift mass becomes so thick that even the largest streams have not cut through it, and there, of course, no paleozoic deposits are exposed.

Between the Kankakee River and Lake Michigan a large area is covered with sand, identical with that of the famous "Hoosier Slide" hills at Michigan City, and the old shore-lines of the lake are easily traceable practically parallel with the present one.

Bearing in mind the foregoing general sketch of the surface features most characteristic of our Drift deposit, the student will be able to understand the correlation of the details which follow.

IV.

SECTIONS AND BORINGS, SHOWING THE INTERIOR OF THE DRIFT DEPOSITS.

Wherever streams of water have worn a deep channel into the Drift, and wherever wells have been sunk into or through the same, there have been disclosed marked peculiarities of deposition. In cutting through the boulder till, which is usually a most solid and refractory substance,

strata or intercalated beds of gravel and sand are found, not in persistent sheets, but usually lenticular, or in some eccentric form of deposition, curiously gripped in the surrounding clay. Some of these sand and gravel masses would seem of great extent, however, serving as vast sponges to hold the water caught between the beds of impervious till. All through the Drift mass boulders of every size (from tons in weight to pebbles of the size of a pea) are found, having worn faces whose striæ are usually parallel to their longer axes. In many places the deposits are curiously curved and otherwise contorted, a condition which shows very plainly wherever the clay, gravel and sand are stratified to some extent.

Boulder till is quite variable in the relative proportion of its constituent parts. While many sections show homogeneous gray or bluish clay, with only here and there pebbles and boulders, other sections disclose almost every degree of mixture between pure clay, obscurely stratified gravel beds and so-called boulder dykes. The farther we go north in Indiana, speaking with reference to a general average, the greater becomes the admixture of boulders, pebbles and angular fragments of rock in the till, especially toward its surface, and the more extended become the intercalated strata of sand and gravel, while, at the same time, the number of basins containing water increases, both at the surface and within the mass.

The Drift appears in places to be parted by a stratum, or strata of ancient soil, in which are found vegetable remains more or less preserved, consisting of tree-trunks, branches and roots, belonging to what have been large forest trees. Wells sunk through the blue boulder till from thirty to sixty feet, in Newton County, reached a vegetable mold not unlike rotten leaves reduced to fine powder.

While it has been asserted by geologists generally that our Drift clay or till is not stratified, I have noted in many railroad excavations made through it a tendency toward cleaving along horizontal or waving lines of separation, especially where the till was quite dry.

One striking feature of the superficial deposits of the Drift is the situation of the cleanest gravel on the north side of the hills and ridges. In fact, it is a rule, with comparatively few exceptions, that a section drawn north and south through a Drift hill will disclose the coarse gravel and boulders heaped in a more or less wedge-shaped mass against the north or northeastern side of the elevation, the rest of which will be sand and till. Furthermore, beginning with the northmost line of the section, the coarsest part of the gravel will come first, and its pebbles will grow finer as you pass southward across the cutting until it becomes sand, and you find the clay against which it lies. Of course this is not always the case, and many modifications of the rule will be discovered, owing to recent or comparatively recent erosions and other disturbances; but every observer will admit the larger fact to be the rule itself. Even where conical hills or

knobs of gravel are found, as is often the case, standing quite isolated on our level table lands, a section of each will generally show a gradation in the gravel, the pebbles diminishing in size along a line from north to south, or from northeast to southwest, the south side passing into sand.

Between practically horizontal sheets of the boulder till of Indiana, basins or underground lakes of fresh water exist in many places, and when these are tapped by borings the water will often flow as an artesian fountain above the surface. I mention this well-known feature here as the best proof of the impermeable nature of the clay, and to call the reader's attention to a fact which at another place will be found of peculiar interest in connection with a study of the manner in which our Drift has been deposited. These underground pockets of water are, as a rule, similar in every way to the small deep lakes that dot the surface of Northern Indiana, save that the subterranean basins have been filled with sand and gravel in which the water is held, as in a sponge.

I have found cross sections of the terraces along our rivers to show a simple enough re-arrangement of Drift materials caused by the action of the water, as the streams gradually decreased in volume, subsequent to the withdrawal of the glaciers, while the loess, bluff or lacustral deposits indicate the bottoms of comparatively recent fresh water lakes over a large area of our State.

The cuttings of the Louisville, New Albany & Chicago Railroad from New Albany on the Ohio River, to Michigan City on Lake Michigan, give a key to many of the most interesting problems connected with the Drift. The student may note, as he follows this line from the southern to the northern border of the State, how, from a fringe of doubtful glacial *debris*, the mass of superimposed materials thickens over the rocks in place, until at length the excavations no longer reach deep enough to sever the boulder clay. It requires no practiced eye to recognize the flat, monotonous billows of the glacial table-lands as soon as they are reached. The whole country, from within thirty miles of the Ohio River to the valley of the Kankakee, presents the appearance of having been heaved into long low waves; but erosion, in fact, and not upheaval, has formed this rolling surface, and each billow is found to be simply a barrier of Drift between two drainage beds.

A feature of the Drift not easily observable, save by the use of the level or the barometer, is a series of waves or swells of the surface, made on a grand scale, and running, in a general way, east and west without any apparent reference to the valleys of erosion. These, as we shall see further on, are due to what may be called forward and backward steps of the glacier or glaciers during the vacillations of climate between the beginning and the end of the ice period.

V.

SPECIAL FEATURES OF THE DRIFT.

We have already seen that lenticular beds of sand and gravel, strata of ancient soil and "pockets," or subterranean basins of water, are found hermetically sealed up in the body of the blue bowlder clay of the Drift. These features have puzzled the minds of geologists not a little, and by some they have been considered inexplicable in connection with the glacial theory. At first glance it would seem quite impossible to account for a stratum of soft black muck and loam found intercalated between thick beds of Drift clay, especially when this soil contains roots, branches and even trunks of trees showing little evidence of any crushing or grinding force such as we must look for in connection with the glacial action. This soil and muck, deep buried under a vast mass of the clay, and resting on another mass equally thick, can not be the result of a mere accident, but must be due to some law. So, with regard to the beds of sand and gravel and the subterranean lakes of the Drift; they owe their origin to perfectly explicable and normal forces acting consistently with, and, so to speak, parallel with the great glacial movements.

In the course of my studies of the surface and subterraneous waters of the Drift, I have noted the following facts:

1st. Springs of water rising *vertically*, or practically so, from Drift deposits usually come from a great depth, and are more or less impregnated with the salts of iron and other mineral impurities.

2d. Flowing wells whose water comes from natural reservoirs in the Drift clay are usually strongly impregnated with iron which oxidizes upon exposure to the air.

3d. Wells bored or dug in the Drift, and whose water does not rise in the bore, are, as a rule, comparatively free from iron and other mineral impurities, but they may contain, occasionally, vegetable impurities, or rather impurities of a vegetable origin.

In connection with the above-named general facts I have noted that, in certain localities, gas generated by decomposing vegetable matter has been met with in the Drift. This, indeed, would be expected where forests lie mouldering in the grip of the clay. But the sudden exit of this gas when reached by a bore shows how impervious, to even the subtlest element, is the bowlder clay. So when water gushes with great force out of a bore we know that the liquid has been safely sealed in the clay reservoir.

Now, when we are told, and with an overwhelming show of evidence, that all this Drift mass has been the result of glacial action, we immediately ask—how can it be that a glacier, or any number of successive glaciers could have formed in the body of its deposits these pouches of water,

these strata of soil and vegetable matter, and these lens-shaped intermediate pockets of sand and gravel? Such questioning is pertinent, and is not at all based on idle curiosity. A great deal depends upon a correct response. The most usual, and, withal, the most plausible answer is the the general one which accounts for these special features of the Drift by assuming that there have been many advances and retreats of the great ice flood over the area of our glacial deposits, and that the sorting action of water, the glacial movements and their attending accidents, have given the grand mass its peculiarity of composition. But the practical minded inquirer at once interposes the objection which arises on the face of the proposition. "How could a glacier, upon returning to its abandoned field, pass over the mass of its deposits without bearing it all away as it bore away the solid rocks in the first place?" If this question can be answered the rest of the explanation would seem to be quite easy; for if we can account for a stupendous glacier passing over a mass of morainic matter left by a former one without entirely removing the mass, then we can see how sand, gravel, soil, and even water, could be caught between the clays of the two glaciers and thus be left hermetically sealed in the deposits as we now find them.

We have already considered the nature of glaciers and the flow of ice in a general way, but in order to solve the problem now in hand we must take a comprehensive view of the conditions which must have attended the formation of glaciers sufficiently grand to bring about the effects observable in our Drift area. Such intense and prolonged cold (extending over many centuries, perhaps many hundreds of centuries) as would attend the formation of ice thick enough to fill the conditions of the great glacial problem, would freeze the crust of the earth to the solidity of adamant many feet deep. We are not left to mere reasoning or conjecture in this. In many northern regions the earth is now frozen to a great and unknown depth. It could not be otherwise. If thirty or forty days of weather with the temperature varying between the freezing point and ten degrees below zero will solidify the ground to a depth of two feet, as is often the case now in our State, how deep would continuous boreal winter for twenty thousand years solidify it? Of course the process of the descent of frigidity into the earth would depend upon some mathematical ratio which would at length practically vanish, but there can be no doubt that a vast period of arctic cold would affect the crust of the earth to a great depth. This proposition conceded, we may proceed to inquire into its effect upon the Drift deposits.

When the glacial period began in Indiana, no Tertiary deposits had been laid down upon our Carboniferous rocks, for, as we have seen, there is no good evidence of the Tertiary formations here. The *fauna* of the Carboniferous seas consisted of marine forms, and in a large degree the *genera* were those having a very deep water habitat. As the seas became shal-

low, at length the marine life disappeared. At the beginning of the Ice age, there must have existed in Indiana the broken remnants, so to speak, of the Carboniferous sea—a sea at that time full of sandy, desolate islands, upon which, in places, a scant vegetation may have begun to appear. Far northward, the mountains of Canada were already covered with snow, and year by year a boreal temperature was creeping southward, on account of a far withdrawal of the deep seas and great changes in their climate-controlling currents. It is not probable, I think, that the Canadian mountains were very high; indeed, they must have been low enough to be finally overwhelmed by the awful accumulations of snow and ice north of them, for it is plain that the great glacier flowed over them instead of simply running down their sides.

It is impossible to determine how often the ice has flowed over and retreated from the area now covered by the Drift, but to my mind there is the best evidence that the alterations have been many, and between a great extreme of cold on one hand and a sub-arctic temperature on the other hand. In other words, while the frigidity during glacial action was incalculably powerful, the intervals of recession were, as a rule, far from tropical, as we now understand the word.

Let us try to get a view of the surface condition of our Drift area after the withdrawal of the first great glacial agent. The highlands of Canada have been largely demolished, the basins of the lakes have been scooped out of the paleozoic rocks and are filled with solid masses of ice covered over with glacial *debris*, and the surface of nearly four-fifths of Indiana is covered with an immense Drift deposit.

I have said that the great lake basins were left full of solid ice, when the glacier had retreated far northward, and that the surface of this ice was covered with a coating of Drift material. The same statement is applicable to innumerable small basins left in the glacial clay, just such basins, in fact, as the retreat of the last glacier left filled with ice and covered with sand, gravel and boulders, and which later basins are now the beautiful little lakes of Northern Indiana.

But how, if these basins were solidly filled with ice, did they come to be covered with a layer of sand, gravel and boulders? The question is easily answered. As the foot of the great glacier receded northward a constant flow of water was caused by its melting, the washing force of which carried forward fine sand and gravel and icebergs, as well, loaded with morainic matter which was distributed over the surface upon which the water flowed. Now, it is apparent, from the very nature of things, that a vast deep basin, in the frozen crust of the earth, filled with a solid lump of ice, would be very slow to melt, and that the glacier overlying it would retreat on the line of the basin's rim and leave a great tower of ice; in the form of a cone, marking the site. This cone would rapidly melt down to the basin's level and then the currents from the still retreating

glacier would flow across it, depositing its sand, gravel and (by means of floating bergs) boulders and rock fragments. Then we have the following conditions: The crust of the earth is frozen to a profound depth below the ice which fills the lake basins, while upon the ice is deposited a thick mass of Drift material, transported there by water and icebergs. One instantly sees how great a time it would require to melt a vast cake of ice under such conditions. Indeed, before this melting is accomplished the glacier returns and flows over the whole area again. But the very circumstances which cause a return of the glacier necessarily operate to re-congeal such parts of the Drift as have been thawed, so that the surface over which the second glacier flows is rendered as hard as were the paleozoic rocks upon whose surface it first cut its lasting autograph. This mass of sand, gravel and boulder-clay, frozen to adamantine solidity, must have been a very refractory substance for a glacier to grind down. Indeed, the second glacier had a more stubborn material to overcome than had the first. So we can readily see how each retreat of the glacier left deep basins full of ice in the surface of the Drift, and how each return of the glacier buried these basins of ice deep under another mass of till. Hence, all through the grand body of our glacial deposits, we find the hermetically sealed "pockets" of water which represent the imprisoned ice-cakes now melted in the buried basins. The lenticular beds of sand and strata of soil and muck are to be accounted for upon the same grounds. When the time between the retreat and return of the glacier was long enough, no doubt vegetation was generated upon favored areas of the Drift, and a soil was formed which, when it chanced to be on low places, was covered up when again the glacier appeared.

In order to illustrate the theory above set forth, let us take Lake Maxinkuckee as an example and suppose that there should come a return of the great glacier from the direction of the northeast. We must remember that before this could happen a long period of intense cold would have to prepare the way by freezing solid all the lakes and rivers and the earth's crust to a great depth. Maxinkuckee would be congealed from surface to bottom, and the great glacier creeping down from its source, and scraping and plowing the granite-like, frozen surface of the ground, would bury the beautiful little lake, like an ice-gem, deep under a mighty mass of moraine clay, sand, gravel and boulders, where it would remain unmelted until the temperature of the surrounding earth rose above freezing point, when it would slowly turn to water and become, not an underground lake, but, by the processes of pressure and solution, a subterranean mass of so-called "water-bearing clay" or "water-sands."

Evidently there were long spaces of time, in the glacial age, during which the ice neither advanced nor retreated, but was held in arrest. No doubt when an advance followed such a pause the glacier overrode its hard frozen terminal moraine, and in this way left large masses of trees

and other matter buried in an uncrushed state, for at every step we must constantly bear in mind the arctic intensity of the cold during these periods of accumulation.

The immense volume of sand which is thrown out of our lakes, even the smaller ones, is proof of the fact that, during the time they were frozen solid, their surface was covered with a coat of Drift which sank when the ice melted.

But the question arises: Why are the waters of *flowing* wells and deep springs, that have their reservoirs in the Drift, nearly always impregnated with salts of iron or other mineral impurities, while the waters of wells that do not flow are usually comparatively pure? The answer must be that flowing wells and springs presuppose, in a general way, that their reservoirs are fed from the surface by filtration through permeable parts of the Drift, and that the water takes up the iron, etc., from the material through which it passes, while the water in wells that are unflowing is not furnished from the surface, or any higher strata of sand and gravel, but really is water from imprisoned ice melted in the body of the Drift-clay. Of course not all flowing wells are iron water, nor impregnated to a great degree with other minerals, but the rule is as I have said. The fact suggests itself, in this connection, that all the porous beds of sand and gravel, intercalated between masses of the Drift clay, were probably full of water, in a frozen state, when they were buried. It must not be understood, however, that I consider this explanation sufficient to compass all the conditions under which water is found in the Drift, but it does seem to me quite applicable to many special problems in that connection which heretofore have not been solved satisfactorily. A number of scientists to whom I have submitted this theory have met me with the question: Why would not a temperature that could cause the retreat of the glacier be sufficient to thaw the Drift and its surface lakes? The answer, it seems to me, would suggest itself at once. Earth frozen, say a hundred feet deep, would require a very long time to thaw, even in a tropical climate. But suppose the Drift and its lakes did thaw out as soon as the glacier had retreated, they would have to freeze up again long before the glacier could return, for it would require an age of arctic cold to cause the accumulation of snow sufficient to form the glacier. Indeed, it can not be doubted for a moment that a temperature warm enough to barely force back superficial ice, no matter how thick, would have comparatively little effect on the earth's crust frozen to a profound depth. Our Drift area must have been a dreary, windy, desolate, frigid waste for a long time after each departure of the glacier. A boreal flora might have appeared and flourished on the surface while yet the ground was frozen for a great way down. However, I can not view the space of time between advances and recessions of the glaciers as being more than the briefest, in a geological sense, so far as most of them are concerned. True, there is some evidence—perhaps sufficient

evidence—of two or three general advances and retreats, which are exceptions.

A great terminal moraine, or tangle of moraines, for the most part well defined, runs across Indiana, somewhat north of the State's center, marking the resting place for a long time of a glacier's foot, or, rather, the feet of glacial lobes. This is traced and described in another place.