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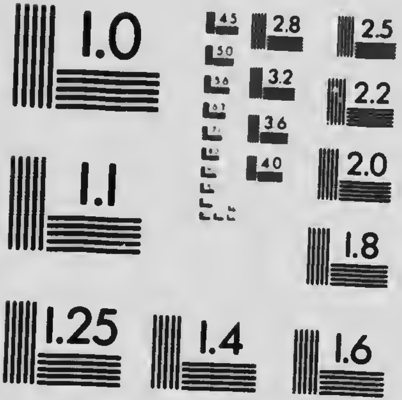


McGILL UNIVERSITY

PAPERS FROM THE DEPARTMENT

OF

GEOLOGY.

No. 16.—The Theory of the Formation of Sedimentary Deposits.

BY

ALFRED W. WILSON, Ph. D.

[Reprint from the Canadian Record of Science, Vol. IX., No. 2, for July, 1903.]

Montreal, 1904.

"Reprinted from the Canadian Record of Science, Vol. IX., No. 2, for July, 1903, issued December, 1903."

The Theory of the Formation of Sedimentary Deposits.[1]

A Deductive Study in Geology and Its Application.

By Alfred W. G. Wilson, McGill University, Montreal.

After the completion of the study of the geology of any considerable superficial area of the earth's crust the geologist usually attempts to interpret the various form-

1 The discussion is confined chiefly to the sub-aqueous deposits.

ations which he has found within the district under discussion—to read the history told by its fauna or flora, whether of land or sea—and upon this foundation to construct a more or less elaborate account of the history of the region and to outline the various changes that it has undergone. There are many well recognized and generally accepted criteria, for the most part based on the study of present geologic process, by which the history of any region may be inferred from the nature of the deposits found within or adjacent to its boundaries, and from the character of the fossil remains which they contain. A primary pre-requisite to the interpretation of any sedimentary series must necessarily be a knowledge of the conditions under which the given series may be produced. The formation of sedimentary deposits under what may be termed normal conditions is a function of many varying factors and it not infrequently happens that similar formations may be produced in two localities at the same time, or in the same locality at different times, by a totality of conditions in each locality, although the factors contributory to their production were not precisely alike in the two places, or at the two different times.

The general conception of the origin of sedimentary deposits, and of the relations of the various types of deposits to each other, which is set forth in this paper, is one which has been long and widely entertained. In restating what has so long been generally held, the writer has but repeated the work of others. The method of presentation varies somewhat from that usually adopted in that it is deductive rather than inductive. The paper is offered rather as an illustration of the application of the deductive method to geologic problems than as a direct contribution to our knowledge. In the latter part of the paper direct application of the inferences from the study is made to two minor problems of local interest. In the present paper the writer attempts to present the subject in a systematic manner, and in so doing to lay special emphasis upon certain processes of formation of sedimentary deposits which, though apparently departures from the normal method of formation, have apparently been the dominant processes in the growth of our greater sedimentary formations. The problem of the formation of sedimentary deposits (chiefly aqueous), is considered from a deductive standpoint, but it is based upon studies, more or less defective as to detail, of present geologic processes as they are in progress in our Great Lakes and elsewhere. First assuming certain elementary conditions of general occurrence in the formation of sedimentary deposits, the effects of variation in either of these factors, singly, or in both simultaneously, are considered. Later, secondary factors—since they are less important or are less widespread in their operation—are introduced, and a very few of the many complications which they would produce in the nature of the resulting deposits are considered. Naturally it will be found that the increase in the number of variant factors results in an increased complexity of product, and it is under the operation of these complex conditions that similar results may be produced by processes which are not exact equivalents.

FIGURE 1.

At the present time it is generally conceded that all the great sedimentary formations were laid down around the margins of great ocean bodies and upon a gradually sinking land surface. In the generally accepted hypothesis of the formation of sedimentary deposits along the margin of a slowly sinking land area what may be termed the normal distribution of material, supplied by the waste of that land area and by which the sedimentary formations are built up, will be the formation of arenacious deposits (including, for convenience in discussion, the coarser varieties, breccias and conglomerates), at or near the shore line. As distance from the shore line increases (temporarily assuming a gradually deepening of the water seaward) these arenacious materials will grade gradually through areno-argillaceous to argillaceous, and thence through argillo-calcareous to calcareous, as the distance from the shoreline increases. In Figures 1, 2, and 3 (omitting zones of transition) A represents the sinking oldland upon which the sediments are being laid down and from which the detritus is derived, B represents the arenaceous zone, C the argillaceous, and D the calcareous, the relatively narrower transition zones between B and C, and between C and D, being conveniently represented by lines. During the course of time these deposits become more or less coherent, according to the conditions to which they may be subjected. In the subsequent discussion these separate zones of deposition may be referred to as the sandstone, the shale or the limestone zone, it being, however, recognised that there are also zones of transition between adjacent pairs.

It would seem that any given stratum must have three synchronous members, each merging gradually into the adjacent member or members. The beds composed of strata, which have been deposited successively must also each consist of these three members. The fact that the thickness of the stratum must, in each of the zones, be dependent upon the amount of material present must necessarily lead to the recognition of the other fact that under certain conditions of supply a stratum of considerable thickness might be laid down in one zone, while the strictly synchronous equivalent in either of the other zones might be represented by a very small amount of deposit, or by *none at all.* Through the operation of certain imperfectly understood causes, probably climatic, directly or indirectly, strata are found grouped together into beds, and it is conceivable, though *not always prob-*

able, that strictly synchronous beds may be found in each of the three zones though the thickness *may vary considerably and the strata of some beds may not have synchronous representatives in the other beds.*

During the time of the formation of any given bed (or group of beds formed within a given small interval) the forms of life existing at that time will be distributed over the surface of that bed, each in its appropriate locality, the sand-loving forms in the sand zone, the mud-loving forms in the areas which afterwards become shale, and the forms which thrive best in deeper or clearer water, beyond. At the transition zones where there is a merging of conditions there will be a merging of forms. It may happen also that a form normally a habitant of one zone is accidently carried to anoth r. These may be regarded as accidents in the normal distribution. Occasionally a form migrating from one zone to another will, in the process of its migration, take on different features because of its environment, eventually undergoing such changes that it would be classed as a species different from the descendants of its parent forms which remained in the original habitat. Some few forms may exist in all three zones, and fossil forms of these types will be of special value in the correlation of beds of different zones. It must be noted, however, that in the study of fossil forms which are found common to all three zones the question whether the forms have migrated during the course of time from one zone to another must be considered, and the beds in which such similar forms are found need not necessarily be of the same age, but may be successively older or younger than the bed in which the like forms are found.

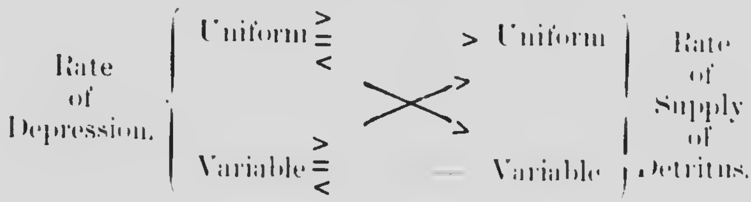
In the production of a series of deposits the final product is the function of many varying factors. The two most important of these factors, and which for this reason may be termed primary factors, are the *Rate of Depression of the Land* and the *Rate of Supply of Detritus.* Such a factor as the *Character of the Material* may, by contrast, be considered of secondary importance, while the factors which determine the character of the material as to kind (source) and as to condition (processes of erosion and transportation) may be regarded as factors of a third order. It is easily seen that factors of a fourth or even higher order are in constant operation in the actual formation of sedimentary deposits, and that the complete consideration of the history of an area involves the consideration of diverse and complex factors; and although the final result of the operation of these factors is apparent, the share to be assigned to each is often indeterminate.

Considering now the two primary factors, *Rate of Depression* of the Land and *Rate of Supply* of detritus, we find that the former may be *uniform*, while the latter is either *uniform* or *variable*, or the rate of depression may be *variable*, while the rate of supply of detritus is either *uniform* or *variable*. In each of the four possible relations one of three results must obtain, according to the inter-relations existing between the two factors. The ocean over the area of deposition may be *gradually deepening*, may retain a *constant depth*, or it may be becoming *gradually shallower*. In the first case, for convenience in discussion, the rate of depression will be said to be *greater than the rate of supply of detritus*, in the second *to equal it*, and in the third *to be less than it*. The first six of this series of twelve possible relationships which may thus exist between these two factors may be tabulated thus:—

1. The uniform Rate of Depression may be greater than the Rate of Supply of Detritus which is uniform.
2. The uniform Rate of Depression may be greater than the Rate of Supply of Detritus which is variable.
3. The uniform Rate of Depression may be equal to the Rate of Supply of Detritus which is uniform.
4. The uniform Rate of Depression may be equal to the Rate of Supply of Detritus which is variable.
5. The uniform Rate of Depression may be less than the Rate of Supply of Detritus which is uniform.

6. The uniform Rate of Depression may be less than the Rate of Supply of Detritus which is variable.

The remaining six relationships, when the Rate of Depression is not uniform but variable, may also be tabulated in a similar way: or all twelve relationships may be indicated graphically, thus:—



When there is uniform rate of depression and uniform rate of supply of detritus, the rate of the latter being less than the rate of depression, the seaward zones will gradually encroach upon the shoreward zones, the materials of the shale and sand zones will become commingled, and it may even happen that the limestone will be deposited directly upon what was the oldland surface. In this latter event the lower beds would be apt to become calcareous grits or conglomerates. Such conditions seem to have existed at one time in the vicinity of Kingston Mills, Ontario, where a calcareous conglomerate of Black River age, carrying angular quartz fragments, casts of a Cameroceras, and fragments of crinoid stems is found resting directly upon an Archean red granite.[1] Similar conditions seem to have existed in the Hudson Bay Basin during a portion of Devonian time. Parks describes the occurrence of certain Devonian corals in the basin of the Moose River with their bases attached to an Archean boss.[2] In the instance cited the boss of Laurentian gneiss probably formed an island in the Devonian sea at some distance from the shore of the oldland. The rate of depression was slow enough for the formation of a sandstone conglomerate near the shore.

1 Wilson, Phys. Geol., Central Ontario, Can. Inst., Trans., Vol. VII., p. 118.
2 Parks in Report of the Bureau of Mines, Ontario, 1899, p. 188.

Where the rate of depression is equal to the rate of supply of material, whether each is uniform, or whether they vary, provided they vary by the same amount and in the same sense, there will be a uniform shoreward overlap of the zones of deposition. (Figure 1.) Such an equality between the two primary factors seems to have existed in many localities during the periods of deposition of the various sedimentary deposits as we find a gradual encroachment of the limestone upon the shales and of the shales upon the sandstones.

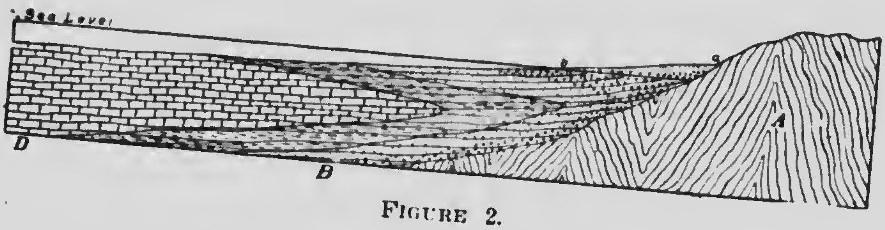


FIGURE 2.

If the rate of depression is uniform or variable but less than the rate of supply of detritus, there will be a continuous overlap, but in the opposite sense, i.e., seaward, and it may even happen that a series of land deposits overlying the older marine deposits may be formed. (Figure 2, ab.) These conditions are also frequently represented in the palaeozoic and later sediments of central North America and elsewhere. In Ontario and New York the conditions cited in the two previous paragraphs seem to have existed until the close of the Trenton, when there was a gradual shallowing of the water (accompanied probably by climatic changes), as indicated by the overlap of the Utica shales upon the Trenton limestones. This shallowing continued for a considerable length of time, so that during the Medina we find there were, in certain areas, broad tidal flats on which more or less arenaceous deposits were laid down. The fact that the argillaceous beds are separated by layers of more or less arenaceous material indicates that there were slight oscillations in the operation of one or other of the two primary factors concerned in their deposition. Whether, under these conditions of a more rapid rate of supply of detritus than rate of depression, it happened that a series of land deposits, the shoreward extension of the sandstones, was formed, is at present doubtful. It seems, however, that when there were such broad sandy tidal flats as existed during the Medina, dry at least at low water, as shown by the mud cracks, that the lighter siliceous sands may have been blown up on the beach in the form of sand dunes, leaving the heavier ferruginous sands as a residuum. Such a suggestion may possibly account for the single band of grey sandstone, usually called the grey band which extends across Ontario from Niagara Falls to near Collingwood. This band caps the Medina deposits, and is a fine textured compact sandstone, with an average thickness of about twelve feet. It is traceable from east of the Niagara gorge to Hamilton, and thence northward it is seen at intervals from Flamborough West to Nottawasaga, varying in thickness from ten to twelve feet, but preserving a nearly uniform lithological character. On lot 24, concession 10, of Nottawasaga, the maximum thicknesss of thirty-five feet is reached. West of the townships of Nottawasaga and Collingwood the grey band is wanting and the Clinton is found in several places to rest directly upon the red and green shales of the Medina. Where the surface of the band is uncovered (and it may be seen in many places, as the softer overlying Clinton has been eroded away) it presents a peculiar undulating surface quite comparable to that found at the present day in localities from which a sand dune has recently migrated. In one locality at least, in a cutting transverse to the grey band, by which a roadway ascends the Niagara escarpment, near Grimsby, the band shows excellent cross bedding on a very much larger scale than is usually seen in typical water laid deposits of similar texture. (See figure 3.) The occurrence of this large scale cross bedding, the undulatory character of its surface, the irregularity of its thickening, and the fact that westward of the Niagara escarpment, near Collingwood, the beds, which further east and south overlie the band, are found to rest directly on the red shales and sandstones of the Medina,[1] suggest that this grey band may be an old sand-dune belt subsequently evened off by the Clinton sea—the landward[1] extension of the Medina beds found

The top of the "Grey Band near Grimsby, Ontario, showing cross-bedding. The hammer is leaning against the lowest member of the Clinton, and rests upon the top of the Medina.

FIGURE 3.

. ..er west beneath the overlying Clinton and Niagara. ntario a very few fossils have been found in the band but whether their position was such as to indicate that the band must have been formed under water is unknown. Modern forms are frequently found in modern sand-dune

1 The sandstone has not yet been examined microscopically to determine th character of the grains.

belts along the seashore, and along the lake shores (Ontario and Erie):—we should expect the supposed dune belt to carry fossils in its upper portion since it was manifestly transgressed by the ocean.

During the course of time the rate of depression may vary to the opposite sense, i. e., the land may begin to rise. Under these circumstances the landward end of the strata previously deposited will be subjected to erosion. During a subsequent depression the new deposits would rest unconformably upon them, while further seaward, where the earlier deposits had not emerged, there would be structural conformability. Such conditions seem to have existed during a portion of Palæozoic time in eastern and central North America, where, in the east, unconformities are found between the various formations making up the Palæozoic series, while further west the various members of the whole series are found with the younger conformably overlying the older, indicative of the fact that there was here continuous deposition.

Relatively slight variations of either factor, alone, or of both in opposite senses willl produce interdigitation of the three principal members along the lines of the transition zones.

The individual consideration of the remaining combinations is unnecessary as the final results will be similar to those produced by the variations already considered. Inequalities in the supply of material in the different zones to synchronous portions of the same bed (or series of beds), will lead to many irregularities in the thickness of the bed in its different parts. The final product may thus be very complex, though the general principles will still be applicable.

In the previous discussion it has been tacitly assumed that the material supplied from the oldland area is of such a nature that all three zones, including their transition phases, will receive each its quota of deposit. Material suitable to fulfil this condition will normally be supplied by an oldland area whether it be a region of metamorphosed rocks, such as we find in the great Archean areas of Canada, or by an oldland area consisting of sediments deposited at some preceding time, but subsequently uplifted. In this latter case there may be temporary irregularities in the supply of material for any one or two of the different zones, and it is quite probable that the coarser material in its *(n + 1)th.* transportation, assuming that the sedimentary beds supplying it represent the *nth* series of beds of which it has formed a part, will be in a somewhat finer state of division. Hence that material which in the *nth* series of sedimentaries occurs in the shore zone, may in the *(n + 1)th* series be found in part, at least, in the two outer zones. Quite frequently also, material derived from beds formed in a preceding cycle of deposition will retain in its new position, certain characteristics (of color, form, structure, content) which make it possible to recognize that it belonged to a preceding cycle of sedimentation. On the other hand, it will often lose these characteristics, and then it will be impossible to infer the number of cycles of sedimentation through which it has passed to its present resting place.

Directly or indirectly, the materials which go to form the sub-aqueous deposits are derived chiefly from the waste of the land. In the case of the limestones of various types and, in part, of some of the shales, the material of which they are composed is less often a direct derivative of the waste of the oldland, more frequently it is a secondary product due to the intervention of organic life or to chemical action. In the previous discussion reference was made to the normal existence of a zone in which limestone would be formed. When we consider the usual manner of the formation of this limestone it became necessary to *modify*, to a certain extent, our primary theoretical concept. Along the margin of the land within the zones of deposition of sands and shales, the materials being deposited, are, to a large extent, inimical to the existence of abundant organic life, but in the clearer waters beyond these zones, provided there is a sufficient food supply, various forms will normally, be more abundant. These types, by the growth of their hard parts and the subsequent comminution of these, transfer the lime from a solution of calcareous compounds in the sea water to the ocean floor to eventually form limestones. Again, under certain conditions the calcareous materials are deposited without the intervention of organic forms. For the formation of limestone beds in these ways *deep* water is thus *not always essential* (and, in the former case, beyond a certain maximum depth, fixed by the depth of water at which a fauna can thrive, detrimental). So long as the lime-producing forms are not hindered in their growth by deleterious material or lack of food supply, they will continue to grow. Hence, under favourable conditions, there will be frequently formed off-shore reefs, usually chiefly of corals, but many other forms will also thrive here, *e.g.*, Barrier reefs of Australasia. These reefs may also be covered with comparatively shallow water, and the older parts might in places be exposed. Under these conditions, the action of the wind and waves will lead to the comminution of the materials of which they are composed and the formation of all the various types of limestone rock, included within the types recently designated calcirudite, calarenite, calcilutite by Grabau.[1] The distribution of these various types of rock will bear the same relation to their source, the coral reefs, as does the normal distribution of sedimentary formations to their source, the oldland. Such conditions seem to have prevailed during the period of the formation of the Silurian and the Devonian limestones in New York and elsewhere.

Still another secondary consideration now suggests itself. If the supply of material detrimental to the existence of a great abundance of organic forms diminishes or

[1] Bull. Geol. Soc. Amer. Vol. XIV., 1903, p. 349.

ceases, other conditions remaining constant, one naturally expects that the forms will spread from many centres outward, or towards the land at least, and that during the continued depression of that land area the sea may transgress upon it and the material formed by the comminution of the hard parts of these organic forms will form a series of deposits resting directly upon the oldland. Such formations are now being formed along parts of the Florida coast at the present day. It seems quite probable that such also, on a somewhat greater scale, may have been the condition of affairs during Devonian time when the corals, which Parks found with the bases attached to an Archean boss, were living in the Hudson Bay basin, and such was the case in many other localities. In the case of the example cited as occurring at Kingston Mills, the fragments of the crinoid stems are sometimes several inches in length. The pebbles of the conglomerate with which these and the Camoceras casts are associated vary in size up to about two inches in diameter, and the fossils are found in the beds not only quite close to the Archean, but also in the upper beds some distance above it. That under these conditions the forms were not comminuted suggests that here at least the water must have been comparatively quiet, and hence we may draw the not unnatural inference that the waters were moderately deep. The calcareous material was probably derived from the comminution of organic forms elsewhere, or it may be in part a chemical precipitate.

A consideration of the foregoing propositions indicates that a feature which one would expect to find in any series of deposits is a zonal arrangement of the various members. Not only may there be two lithological extremes and a mean of synchronous beds (or series of strata) but during the period of continuous depression and deposition there may be formed a continuous band of each of the lithological types, and each of these bands will be composed of beds and each bed may contain forms successively older or younger than the beds of the same zonal band above and below. When there has been (more or less) continuous depression of the land for a long interval, with (more or less) continuous supply of material suitable for all three zones, then subsequent uplift and erosion over extensive areas, the formation resting upon the oldland surface will normally be a sandstone. The earlier formed portion of this sandstone will naturally carry fossil forms appropriate to the age in which they lived, and the later formed likewise. Ami has recently drawn attention to arenaceous character of the formations resting upon the older rocks, along the axis of the Appalachian system, and to the progressive change in faunas from Cambrian types in New Jersey northward to Ordovician types in Canada, as illustrating the progressive depression of the land areas during the progress of early palaeozoic time.[1]

Further, it must be noted that, although the normal type of deposits would show the threefold lithological grouping, yet irregularities in the supply of material and variations in the character of that which is supplied, variations which will be of very frequent occurrence, will mean that in the field truly *contemporaneous beds in the three zones will be rare,* that *all three types of deposit* may be composed of the *same kinds* of material, a feature frequently seen in the limestone deposits, and, thirdly, that *one or more* of the types may be *completely wanting.*

After a long interval of time during which a succession of deposits has been formed under varying conditions, the sea bottom becomes uplifted, and the new formed rocks are subjected to long continued disintegration, degradation, and dissection. The greater part of the deposits are worn away; fragments only remain here and there, scattered over the area where they were once continuous,

1 Ami, Geo. Soc. Amer., Winter meeting 1902-03, "The Eparchean Formation." See Bull. G.S.A., Vol. 14.

this being especially true along the ancient shore-line which probably emerged first. If the erosion continues long enough, the complete series of products formed under a certain series of uniform conditions may entirely disappear, or, if the uplift is not great enough, only their shoreward ends may vanish.

In either case, their removal must expose the shoreward ends of strata belonging to an earlier cycle of deposition. The later (as regards exposure, earlier as regards deposition) deposits may themselves be also more or less dissected, and the different portions remaining will be thus more or less isolated. Such, indeed, seems to be the relations existing between the limestones belonging to the Trenton area, found in the Province of Ontario on both sides of the Frontenac axis (and in New York State to the south), and some of the associated sandstones which were until quite recently usually designated Potsdam.

Where these fragments of the old beds are distributed along the line of the ancient land from which the material was derived, it will happen that portions of synchronous deposits occur in widely separated districts. For example, a small amount of sandstone might remain in a protected hollow near B (Figure 1.), and all the rest of the deposit be eroded away, as far back as D, where the limestones would form an infacing escarpment, the lower deposits being covered with soil. The limestone, which was synchronous with the sandstone left at B, may carry fossils, while the small remnant of sandstone is destitute of them, or carries forms of a different type, due to the different environment when the forms were living, as suggested in a preceding paragraph.

It may happen that at the base of the cliff the earlier sandstone beds can be found. Now in the cliff alone evidently the limestone is younger than the immediately underlying sandstone. This underlying sandstone may be lithologically identical with that at B, since they come from the same source, and may even contain similar fossils. Still it would be obviously incorrect to say that the two sand-stones were of the same age. This would be equally true were each of the beds represented in the figure a series of similar beds, instead of a single one.

When the exposures are far removed from the oldland shore, and there is very little doubt that the old landward extension of the beds is completely gone, the order of superposition in the cliff, or across country in a region of lightly inclined dips, may be taken as the order of succession. Such a series as that represented by the Medina-Niagara series in Central Ontario and Western New York will serve as a case in point. In areas *adjacent* to the margin of the ancient sea the correlation of the widely separated deposits on lithological or even palæontological grounds must be made with great care. Where lithologically similar deposits carry similar fossils contemporaneity of epoch may generally be postulate[illegible], on the contrary, the forms are not identical, and the deposits are lithologically unlike, they may still be contemporaneous deposits of different zones.

Where a small exposure of rock is found carrying fossils which are normally considered to be characteristic of two different terranes, and as a consequence the beds are inferred to be transitional ones between the two terranes, it must also be recognized that this portion of the bed may mark a transition in a horizontal direction, being but a portion of a synchronous bed of varying members.

Applying these considerations to the correlation of the sedimentary deposits along the margin of the Frontenac axis, so far as the writer is aware, no single bed has been traced through various zones. Whether it is possible to do this is problematical, because of the discontinuity of the outcrops. Inasmuch as this has not been done, there must be a factor of uncertainty in any conclusions which may be reached. There remains, however, the question as to what interpretation does the balance of probabilities tend, a balance upon which, in the incompleteness of the geological record, the solutions of many problems depend.

Because of the uneven character of the floor upon which the sediments are laid down the dips of the beds near the floor are unreliable as criteria with reference to the general dip. Where there is evidence that the sediments are some distance vertically above the crystalline floor the dip may be measured with some degree of certainty that it represents the average dip of the sediments in that locality.

Near Battersea, at which place some of the sandstones are found, the average dip is a little over half a degree to the east of south. What the gradient of the floor upon which they rest may be is not known. It possibly is the same as that of the overlying sediments, it may be even inclined towards them, or what seems to be the more justifiable assumption, it may dip in a similar direction at a somewhat greater angle. If the generally accepted interpretation as to the method of the formation of deposits is correct, the sandstone beds whose shoreward ends are here exposed will gradually merge into argillaceous beds and finally into calcareous members. The argillaceous beds which vertically overlie them will also merge into the limestones further out from the oldland shore. In many of the localities, because of the unevenness of the floor these sandstones are not thick enough to pass over the crystalline ridges, but are limited by them. In some cases at least the sandstones are probably subaerial deposits rather than subaqueous.[1]

In the vicinity of Kingston the limestones are found to rest directly upon the crystallines, which, from their associations probably formed islands in the Palaeozoic sea. Between Kingston Mills and Gananoque there are a number of Archean exposures, some of them several square miles in area. Between them and the main crystalline area to the north the sediments rest in more or

[1] Wilson, Phys. Geol., Central Ontario, Tran. Can. Inst., Vol. VII., p. 159, 1901.

less ellipsoidal basins. Across the basins, though the average depth has been stated to be half a degree because of the unevenness of the floor, the actual inclinations vary considerably. This local variation, combined with the discontinuity of the outcrops, renders exact correlation exceedingly difficult, if not impossible.

In any attempted correlation of widely separated beds by aid of their inclination it must not be forgotten that the beds originally existed, each as a continuous sheet over large areas, *in toto* probably lens shaped, and not only must the maximum inclination or dip be known, but the inclination in the direction of the line between the two beds whose correlation is attempted must be ascertained. The evidence at present available makes even a correlation of this kind in the area under discussion impossible.

With our present available knowledge it cannot be proven that the limestones or argillaceous beds in the one locality are synchronous or contemporaneous with the sandstone in the other; nor can it be proven that the sandstones antedate the limestones, except in the few places where both occur [illegible], in which event it becomes necessary to show that these limestones are also younger than the sandstones elsewhere.

To the writer the possibility that the sandstones in one locality are synchronous with the argillaceous beds and the limestones in another seems more plausible than that they antedate them. This interpretation also obviates the necessity of assuming a time interval of some duration between the deposition of the sandstones and the Black River limestone, during which interval the Calciferous and the Chazy were deposited elsewhere, and during which the non-fossiliferous beds below the Black River and above the sandstone may have been deposited here.

Were fossils present in the sandstone this possibility would be in no way diminished by the fact, even were some of them Potsdam forms. In the locality east of the axis, in the township of Landsdown and elsewhere where the Potsdam types of fossils are found associated with types characteristic of the Calciferous, the portion of the bed in which they occur may justifiably be considered as a transitional phase in a horizontal as well as a vertical direction towards the latter formation. To make the proposed tentative interpretation clearer, Fig. 4 diagramitally represents a portion of an ellipsodial basin in which deposition, accompanied by slow depression of the oldland surface, has been going on for some time. The earlier shore lines are shown in cross-

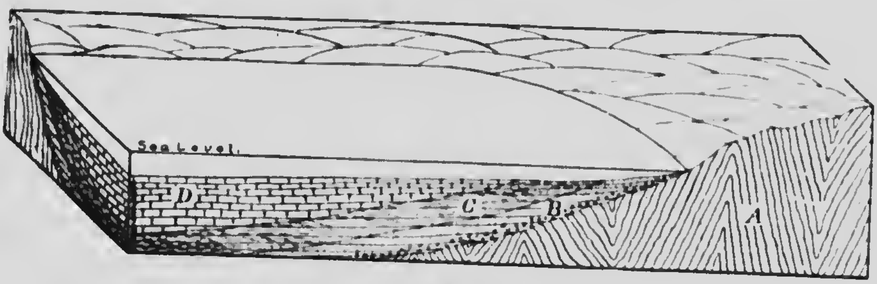


FIGURE 4.

section at the points where the younger strata overlap them to rest upon the crystalline area. Subsequently in the history of the basin the land may rise somewhat, and may be even slightly tilted, and the sea withdraws. During the progress of degradation the greater portion of the sediments are removed; but suppose small remnants of these are still to be found, it can readily be seen that a small portion of the shales or limestones of, say, bed number five might be left along the front of the section of the basin, while towards the back a portion of the sandstone of bed number three remains in a protected hollow among the crystallines. It would be exceedingly difficult, if not impossible, to correlate the two, particularly if they were some miles apart. But since the sandstones beneath the remnant of bed number five are identical in composition with the remnant of bed number three, because formed from the same source, these two which are not synchronous but successive would in the usual practice be correlated. The same would be true if each bed, as shown in the diagram, represented a series of similar beds.

The writer would then suggest that that there is a strong a priori reason for assuming that these beds are contemporaneous with the beds of limestone and argillaceous shales below the Trenton, and probably synchronous with some of them. From the general direction of the dips there is a remote possibility of some of the more distant outliers to the north being synchronous with the lowest beds of the Trenton, but this cannot be proven.[1]

Naturally the question might be asked, would you make all Potsdam contemporaneous with the lower Trenton? Certainly not. Potsdam, as a formational name, was introduced to denote a horizon which is supposed to be geologically older than the Trenton and which possesses certain definite types of fossils, and should be limited in its use to horizons where these two relations are proven to hold. The extension of the term to horizons in areas where the relations do not hold is apt only to lead to confusion. At present in Ontario much that has been classed as Potsdam, particularly on lithological grounds, is probably contemporaneous with limestones referred to later horizons now exposed elsewhere. The Potsdam sandstone undoubtedly should merge into limestone horizontally, unless our ideas of the processes of deposition are incorrect. Where the line of division comes in it would be difficult to say.

1 Wilson, Phys. Geol. Central Ontario. In this paper, on the basis of the above deductions, the writer advanced the views outlined here in more detail. Subsequently Dr. Ami, of the Geological Survey Department, described the Rideau Formation, which is made to include the formations here referred to, but the greater part of which lies to the east of the Frontenac axis, as being the shoreward extension of the Calciferous and Chazy. Dr. Ami's paper (Geol. Soc. Amer., Rochester, 1902.) has not yet come to hand, but the writer understands that the results of his studies on the eastern side of the axis in general confirm the conclusions reached by the writer after a study of the smaller exposures on the west. The latter the writer considers as probably the shoreward extension of the early Black River rather than the Chazy.