Vol. I. *No. VI.*

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DR. GEORGE M. DAWSON, D. S., F. G. S., &c.,

Assistant Director of the Geological Survey of Canada.

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BY DR. GEORGE M. DAWSON, D. S., F. G. S., F. R. S. CAN., ASSOCIATE R. S. M., AND ASSISTANT DIRECTOR OF THE GEOLOGICAL SURVEY OF CANADA.

(READ BEFORE THE CHICAGO ACADEMY OF SCIENCES JUNE 9, 1885, BY H. A. JOHNSON, M. D., F. R. M. S.)

In a paper read before the Academy in January, 1884, and printed in the bulletins of the Academy (vol. i, No. 4), H. A. Johnson, M. D., and B. W. Thomas, F. R. M. S., gave the results of an investigation by them of microscopic organisms in the boulder clay of Chicago and vicinity. This paper refers principally to certain remarkable bodies first found by these gentlemen in 1865–66–67, in specimens of the clay through which the lake tunnel, which supplies the city of Chicago with water from Lake Michigan, was being constructed. On the completion of the tunnel large numbers of the same bodies were observed in the filtrate from the city water supply, and which were subsequently proved to be identical with organisms described in 1871 by Sir J. W. Dawson from the Devonian shales of Kettle Point, Lake Huron. They have since been observed in the Devonian rocks of a number of widely separated localities, and are now believed by Sir J. W. Dawson to be macrospores of rhizocarps.* In accordance with this view the generic name of *Protosalvinia* is proposed by Dawson in the paper above referred to instead of *Sporangites*, which term is, however, still used in this paper. Properly speaking, this term would apply to the *Sporangia* containing these macrospores, and which are absent in the specimens in question. Mr. Thomas, in a note to the paper first quoted, refers to the additional discovery in boulder-clay from Minnesota, sent to him by Prof. N. H. Winchell, of several species of *Foraminifera*, evidently derived from the Cretaceous rocks of that region. Since

*Proc. A. A. A. S., 1883, and Can. "Record of Science," vol. i. See also paper by Mr. J. M. Clarke, American Journal of Science, vol. xxix, p. 284.

this announcement Mr. Thomas has mounted for the microscope and examined many samples of boulder-clays from various places, and has favored me from time to time with a number of his preparations. He has also kindly prepared and mounted specimens of several boulder-clays and allied materials collected in Manitoba and the Saskatchewan region. At his request the notes made by me on these last and on a few of those first mentioned are here offered. This paper must, however, be understood to be merely of a preliminary and general character, being based on the examination of less than one hundred microscopic preparations. It may, it is hoped, be supplemented later by a more detailed report, including the discussion of a larger suite of specimens, from a greater number of localities.

The microscopical investigation of these boulder-clays has resulted in the discovery of many objects which, while evidently of organic origin, are very difficult to name or classify, and require comparison with a wide range of bodies and reference to many works for that purpose. Mr. Thomas has also found that even in the case of those clays with which he is most familiar, each new lot of preparations mounted is almost sure to show forms not before observed, and that the field is an ever-widening one.

It is now, therefore, proposed merely to denote the classes of objects so far observed in the various boulder-clays, and when possible the genera to which the organisms belong, without attempting to catalogue them specifically. Neither is it here intended to enter into any further discussion as to the nature of the Macrospores occurring in some of the clays.

It should also be stated that most of the objects on the many slips examined, have been indicated by maltwood markings by Mr. Thomas, a circumstance greatly reducing the amount of labor involved in going over the material.*

BOULDER-CLAYS OF CHICAGO AND VICINITY.

The preparations examined representing the boulder-clay of Chicago and vicinity are as follows: From Chicago lake tunnel, 86 feet down, 5 slides; North Chicago boulder-clay, 60 feet down, 11; North Chicago clay, 64 feet down, 2; North Chicago, 65 feet down, 10; corner of Washington and Clark streets, eight feet down, 1; or 29 in all. These are so similar in their general characters and the class of objects which they present that they may be considered together.

The inorganic material in these clays, as represented by the above preparations, consists largely of quartz sand, in which few well-rounded grains appear, most being sub-angular and many quite angular and unworn. With these is a notable proportion of bottle-green particles of hornblende,

*It should be explained that the material referred to in the succeeding notes is that part of the boulder-clay which is composed of particles of medium size, from which the very fine matter has, as a rule, been separated by decantation. This again has been sized by repeated decantations at intervals of one, two or three minutes. Mr. Thomas states that the greater number of examples of a given form are frequently thus obtained in material of a certain grade of fineness.

with a few of mica and feldspar. Nearly one-half of the entire material is, however, composed of flattened and rounded grains of fine shale, which have a dark brown color and granular texture by transmitted light. One or two of the quartz grains show included crystals, and many hold fluid or gas cavities. The bodies of organic origin most commonly met with are referable to *Sporangites* (*Protosalvinia*) *Huronensis*, Dawson, of the Devonian shales. These are extremely abundant, and the shale particles already described are doubtless derived from the disintegration of the same beds. They are in some instances very well preserved, but are also present in all stages of decay, and in many cases hold a quantity of granular, shaly, or clayey matter in their interiors. Besides these a specimen occurs in the material from the lake tunnel of entirely different character. It is a partly flattened sphere of 0.2 m. m. in diameter, with radiating and concentric structure, brownish color, and very small central cavity, or nucleus. This is similar to some of the bodies from the Devonian rocks described as macrospores by Mr. Clarke in his paper above referred to. Two more bodies of the same class appear in other preparations, but are more nearly transparent, and evidently in a different state of preservation. To one of them a small fragment of the matrix attaches and serves to show that both of these may have come from a lime-stone bed.

Next in abundance to the Sporangites is a class of bodies the true nature of which is very doubtful. Of these at least twelve large fragments were noted in the preparations under discussion, with many smaller and less characteristic pieces. They may be described as spines or spicules, generally cylindrical, but sometimes trough-shaped or triangular in cross-section, averaging about .05 m. m. in diameter, and of pale yellowish brown color. Their structure is very finely granular, and the outer surface more or less roughened, as though from erosion. They are in some cases distinctly tubular, with a small central cavity; others have a thick medullary portion, which is poorly defined, but differs somewhat in texture from the exterior. Some of the fragments terminate in acute points, others have a slightly swollen, rounded end, and one was observed to be doubly terminated and nearly spindle shaped. They appear to be calcareous, but whether this is their original condition, or the result of mineralization, is uncertain. They can scarcely be chitinous, being much paler in color than other specimens of this character met with in some of the preparations. So many organisms may have produced spines or spicules resembling these bodies that it is not yet possible to assign them definitely. They do not appear to be sponge spicules, but as their color and texture is not unlike that of the next class of objects, they may possibly be partly mineralized chitinous setæ of Annelids, derived from some of the subjacent rocks. Their diversity in shape is such that they must either represent several species or belong to different parts of some organism in connection with which several types of appendage of this character were developed. (Fig. 1.)

Among the most interesting bodies found in these clays are certain comblike objects which are regarded as Annelid jaws. Of these, four, all fragmentary, have been observed. They were at first supposed to be teeth from the lingual ribbon of some mollusk, but on more careful examination were found to be unlike the teeth of any mollusk of which figures can be found, and, moreover, to correspond almost exactly in form with some of the Annelid jaws described by Mr. G. J. Hinde from the Silurian and Devonian rocks of Canada.† One of the specimens shows a series of long and curved prongs. (Fig. 2.) Three others apparently belong to a single type, in which a nearly flat plate is armed along one edge with a series of small, close denticles arranged somewhat obliquely to the line of attachment. (Fig. 3.) Like the bodies last described they are of a pale straw color, differing in this respect from Mr. Hinde's specimens, which are said to be shining and black; but this difference may arise from the mode of preservation. They exhibit no reaction with polarized light, and are smooth and not distinctly granular. The ends of the prongs or denticles are worn and roughened as though by use.

Fig. 1 (x130)

Fig. 2 (x130)

Fig 3 (x130)

Organisms from the Chicago boulder-clays.

Other bodies occurring in these preparations in smaller numbers need not be referred to in detail. Two broken specimens evidently represent Ostracoda. They show no well marked sculpture, but a minutely granular structure. The most perfect is .31 m. m. in length. A third specimen, somewhat larger, and also broken, is either a small Sphærium or a very young specimen of some larger shell. All three have adhering to them brownish shaly particles, which appear to indicate their origin, though it must be remarked that the shell substance is very well preserved and fresh-looking. Still another specimen is a broken piece of the edge of a large calcareous shell or carapace, beautifully marked, and possibly that of an ostracod of another species. The remaining objects observed are mere fragments, quite indeterminate in character. Among these are small pieces of a delicate ribbed shell, the ribs being square in cross-section; a rather large chitinous fragment, striated externally, but without any other apparent structure, and one or more pieces of straight tubular siliceous spicules probably belonging to some sponge.

The probable sources of the organic bodies in these clays is discussed subsequently in connection with those from other places.

† Quarterly Journal of the Geological Society, 1879, p. 370.

BOULDER-CLAYS FROM BLOOMINGTON, ILL., 107 FEET DOWN.

This clay immediately underlies an interglacial deposit of soil and peaty matter with remains of wood, etc.* Of this clay five preparations only have been examined. The coarse material is here chiefly quartz sand, of which by far the larger proportion is sub-angular. There are also a few grains of amethystine quartz, showing sharp conchoidal fracture. Several quartz grains show inclusions, one of very small hexagonal red crystals, probably hematite. Hornblende grains are moderately abundant, but shaly fragments, such as those which make up a large proportion of the material from the Chicago clays, are almost or altogether wanting. A few Macrospores exactly like those previously noticed occur, together with one or two specimens of the pale brownish granular spines, or setæ, found in the Chicago clays. A small, flat, curved, finely-ribbed body in one of the slips resembles part of the edge of a carapace. While therefore not altogether wanting in this clay, organic traces appear to be very scantily represented.

BOULDER-CLAYS FROM MEEKER COUNTY, MINN.

This material is derived from a well shaft sunk in Meeker County, at a depth of about twenty-two feet, and was transmitted to Mr. Thomas by Prof. N. H. Winchell, State geologist of Minnesota. Mr. Thomas has made a large series of preparations from it, a number of which I have had the opportunity of inspecting.

As the Foraminifera contained in these preparations are being named and catalogued by Messrs. A. Woodward and B. W. Thomas, the remarks here given are confined principally to the general character and contents of the clay, with the object of comparing it with those from other localities.

The coarser material from this clay, as it appears in the preparations, is chiefly quartz sand, which is generally sub-angular, though with some well-rounded grains. Hornblende and mica appear in about the usual proportions, and two quartz grains with very beautiful inclusions were noticed, one being probably either hornblende or rutile, the other possibly apatite. A large proportion of the material, however, consists of rounded grains of shale, of gray or greenish-gray color by transmitted light, and not nearly so dark as the shale mixed with the Chicago clays. In specimens boiled in nitric acid, the shaly fragments have become reddish from the oxidation of their iron.

Of organic bodies present in these specimens of Minnesota clay, the *Foraminifera* are most prominent and important. They are evidently derived from the Cretaceous strata, and resemble those found in the western development of these rocks, both specifically and in mode of preservation. *Rotalidæ* and *Textularidæ* are most abundant, though specimens of *Globigerina* and other genera also occur. Next in abundance to the *Foramin-*

*This stratum of soil is about 6 feet thick, and underlies 101 feet of boulder-clay. I do not know the thickness of the clay deposit below the inter-glacial soil, but both the upper and lower clay deposits carry an abundance of glacial-marked boulders.—*B. W. T.*

ifera are remains of *Radiolaria*. Some difficulty was experienced in deciding the true nature of fragments of these bodies at first met with, but the subsequent discovery of numerous and often well-preserved specimens, and the observation by Mr. Thomas that they resist boiling in nitric acid, now leave no doubt as to their character. Several genera and quite a number of species are represented, and it will eventually be possible to determine many of these forms specifically. Most appear to belong to the Polysphæridæ and Cystidæ of Haeckel's classification. The constant occurrence of these bodies with the Cretaceous Foraminifera in the Minnesota preparations and in those from other places, with their absence from materials not equally characterized by the Foraminifera, leaves little room to doubt the common origin of both. Among miscellaneous objects from the Minnesota clay may be mentioned a few fragments apparently identical with the minutely granular spines or setæ described as occurring in the Chicago clays; also two broken portions of stout siliceous spicules, about .026 m. m. in diameter, one smooth, the other tuberculated; both tubular, and probably belonging to some sponge. Lastly, a single specimen of a very curious body, of straggling and irregular form, composed of numerous expansions differing in shape and size and pretty uniformly pitted and connected by narrow, smooth necks. As this is in one of the preparations which has been treated with acid, it must be siliceous. I can only suggest that it may be the siliceous cast of some foraminifer like *Aschemonella catenata* of Norman the arenaceous test of which has been composed of calcareous particles which have left pitted impressions on the cast. Against this is the fact of its small size, it being about .2 m. m. only in greatest diameter.

BOULDER-CLAY FROM CRETE, SALINE CO., NEB.

This material, Mr. Thomas informs me, was obtained from a single small excavation. It was forwarded to Mr. Thomas by Prof. G. D. Swezey, and is described by him in a letter to Mr. Thomas as a blue clay underlying the loess. The inorganic matter in the preparations made from it consists largely of fine angular and sub angular quartz grains, with a small proportion of green hornblende and much shale or earthy limestone in little particles which differ in color and texture. It is extremely rich in organic forms, chiefly Cretaceous Foraminifera, so much so that it seems probable that it is largely composed of the debris of the Niobrara division of that formation, and that a complete study of its contents would practically include that of all the forms occurring in the chalky limestone of that stage. The present notice of it must therefore be considered as of the most general and preliminary character only. Of this material a suite of thirty-one preparations has been examined, and in an enumeration of about one hundred of the best preserved forms, nearly fifty per cent belong to the *Textularidæ*, the remainder being made up in nearly equal proportions of *Globigerinidæ*, *Rotalidæ*, miscellaneous *Foraminifera* of other families, and *Radiolarians*,

resembling, and in some cases identical with, the Minnesota species. Fragments of calcareous prisms from the shell of *Inoceramus* and in the finer matter specimens of *Coccoliths* and *Rhabdoliths* also occur; all resembling in every respect similar bodies found in the Niobrara rocks of Nebraska and Manitoba.*

Many of the Foraminifera are completely filled with calcite, while others are still partially hollow, and yet others are filled partly with calcite and partly with black carbonaceous or bituminous matter. Of objects of an unusual character two may be specially referred to. A rod-like body about .2 m. m. in length, narrowed near the middle, though broken at one end, and marked by numerous pits in linear series. This may be a small spine from some *Echinoderm.* Also a hollow conical tooth or spine, evidently that of a fish, also broken, but still .25 m. m. in length.

BOULDER-CLAY FROM A WELL AT ROSENFELD, MANITOBA.

This material, sent to me under the name of "Hard-Pan," was obtained at a depth of 135 feet, in a well bored by the Canadian Pacific Railroad Company at Rosenfeld, Manitoba. It formed, mixed with gravel and boulders, a layer of eighteen feet in thickness, below the post-glacial alluvial deposits of the Red River Valley and resting on a Silurian shale. As the well was bored with an ordinary percussion drill, it is possible that some matter from the alluvial deposits above referred to may have been mixed with the specimen of "hard-pan," but so far as examined these alluvial deposits do not hold any organic forms. Numerous small particles of steel from the edge of the drill occur in the six preparations representing this clay.

The inorganic constituents are coarse in texture; quartz grains, of which nearly one-half are perfectly rounded, as usual predominating. Bottle-green hornblende is moderately abundant as are also fragments of feldspar and limestone, but shaly materials are almost altogether wanting. Bodies of organic origin are rather scarce, Foraminifera, however, being most common, and a Textularia of the type of *T. globulosa* is characteristic. A few Rotalidæ are also present, with broken chambers of other Foraminifera. The examination of a greater quantity of the material would doubtless lead to the discovery of all the ordinary Cretaceous types.

BOULDER-CLAY FROM THE SOUTH SASKATCHEWAN RIVER TEN MILES EAST OF THE MOUTH OF THE SWIFT CURRENT.

This and the two following localities in the Canadian northwest territory are represented by specimens collected by Mr. R. G. McConnell. The three localities lie between the 106th and 108th meridians, and represent a portion of the great drift-covered area of the northern plains. The material from this place is, as usual, largely siliceous, but there is a larger proportion

*See a paper by the writer in the Canadian Naturalist, 1874.

than common of coarse, thoroughly-rounded quartz grains. Hornblende and other crystalline minerals from the Laurentian or Huronian are also present, and there is a notable quantity of amethystine quartz in angular fragments. Comminuted gray shale, very finely ground, is moderately abundant. Bodies of organic origin are not frequent. In pretty carefully examining a series of six preparations, about ten only were met with. These are *Textularia* and rotaline *Foraminifera*, with one very small *Globigerina* and a couple of *Radiolarians*; one very perfect, oval and .09 m. m. longest diameter. (*Haliomma?*) A fragment was also found of bony substance, showing haversian canals and probably portion of a ganoid scale. There is also in these preparations a number of rounded and flattened grains, nearly transparent, though in some cases with a more opaque central spot, and surface minutely and regularly roughened. These were eventually determined by comparison to be fragments of some pearly shell, probably that of *Unio*, a form quite abundantly represented in the Cretaceous and Laramie rocks of the region. The appearance of an opaque nucleus in some examples appears to result from the non-penetration of the mounting medium to the centre of the larger grains.

BOULDER-CLAY FROM TEN MILES NORTH OF THE SOUTH SASKATCHEWAN, EAST OF MISSOURI COTEAU, TOWNSHIP 21, RANGE 10, WEST OF 3D PRINCIPAL MERIDIAN.

The material in six preparations from this clay differs from the last described only in the much greater quantity of comminuted shaly matter of a reddish-brown tint. Bodies of organic origin are here again scarce. No Foraminifera were found. Two or three broken pieces of minute rod-like pitted objects, very doubtfully referred to small spines of some *Echinoderm*, and evidently dentical in character with that previously described from Saline County, Neb., were detected. Those occurring here are about .015 m. m. in diameter. Another somewhat similar object is rather stouter and with a roughened surface without regular markings. A small broken piece of some chitinous test was also observed, but on the whole this material is very barren.

BOULDER-CLAY FROM THE SOUTH SASKATCHEWAN, FIFTEEN MILES ABOVE THE ELBOW.

In the preparations from this clay—eighteen in number—the sandy material is much finer than in the two last. It is nearly half composed of shaly fragments of brown color, the quartz sand being also rather more angular than usual. It is richer in organic forms than either of the other specimens from the neighborhood of the South Saskatchewan. About half a dozen specimens of Foraminifera were recognized in the preparations, one being probably a small *Discorbina*, others *Textulariæ* and broken chambers of *Globigerinæ*. These are not so well preserved as in some of

the other clays, and in some cases the shell itself appears to have been removed, leaving only a rough cast in calcite. *Radiolarians* are here (so far as the examination of a small quantity of material can be accepted as conclusive) even more abundant than *Foraminifera*, spherical, oval and turbinate forms all being represented, and in some cases in such connection with fragments of the abundant shaly material as to leave no doubt as to their common origin with it. Small, partly rounded prisms from the shell of *Inoceramus* are also present, together with a few pieces of straight hollow siliceous spiculæ, one specimen of a minutely granular spine or seta, with a distinct medullary portion like some previously noticed, and .026 m. m. in diameter, and one of a portion of a body like that previously referred with doubt to an *Echinoderm* spine.

CONCLUSIONS.

In inquiring as to the derivation of the various organic bodies in the clays, it is necessary to consider the situation of each locality with reference to known areas of the older rocks, from the disintegration of which they may have come. The Sporangites so abundant in the Chicago clays have been definitely traced to the shales of the Devonian age, and have doubtless been brought to their present position from outcrops to the northward in the Michigan peninsula. It has already been stated that the bodies supposed to be Annelid jaws may probably have been derived from the same beds, or from others of the Devonian or Silurian rocks of this part of the country. With regard to the remaining bodies no definite statement can at present be ventured, though there is every reason to believe that they might very well have come from the same rocks.

In the clays from Bloomington, in the center of the State of Illinois, Sporangites are again the most characteristic bodies, though much less numerous in correspondence with the greater distance from the shale outcrops. A few other objects associated with these are not dissimilar to those in the Chicago clays.

Meeker County, from which the specimens of Minnesota boulder-clay were derived, is in the southern and central portion of the State, and is underlaid, according to Prof. N. H. Winchell by rocks of the Archæan period, overlain probably, at least in some places, by shales of the Cretaceous. As might be anticipated from the absence of Devonian rocks, both in this locality and the whole region to the north and northeast, Sporangites have not been observed in this clay. While the greater part at least of the organisms are evidently referable to the Cretaceous rocks, the locality lies to the northeast of the generally recognized edge of that formation. Prof. Winchell has, however, proved the existence of a number of outliers of Cretaceous beyond the main area occupied by these rocks, and it is probably from one of these, possibly not remote from the actual position of the clay, that the Foraminiferæ and Radiolariæ have come.

The clay from Crete, Saline Co., Neb., is, as already observed, so rich in Cretaceous forms as to lead to the belief that it is largely composed of the debris of the chalky limestone of the Niobrara stage, and may rest upon or lie very near to the outcrop of these beds. I am not in a position to state whether the geology of the district bears out this conclusion. The map shows at least that Cretaceous rocks underlie this part of the State.

The material from Rosenfeld, Manitoba, shows a smaller number of forms, but these are equally characteristic of the Niobrara stage, the outcrop of which, though concealed by alluvial and other deposits, can not be many miles west of the position of the well, and also runs northward along the base of the Pembina escarpment, having been recognized at a point about fifty miles northwest of Rosenfeld on the Boyne River. ("Geology and Resources of the 49th Parallel," p. 78). As there is little probability of the existence of any Cretaceous rocks directly north or to the northeastward of this place, the occurrence of Cretaceous Foraminifera would tend to show that material derived from the northwest had been incorporated with the boulder-clay of this district.

The three localities near the South Saskatchewan may be treated of together, in so far as the origin of their organic constituents is concerned. The general movement of the material composing the glacial deposits of the northern plains in a southwesterly direction has already been demonstrated (see "Quarterly Journal of the Geological Society, 1875," p. 605; "Report of Progress of the Geological Survey of Canada, 1882–84," p. 139), and it would appear that the Cretaceous Foraminifera must also have been carried from the vicinity of the eastern Cretaceous outcrops at a great distance. It is true that the clays here rest on Cretaceous beds, but these are not as a rule calcareous, or such as to yield Foraminifera in the state of preservation of those found in these clays. The Niobrara limestones are not only unknown in the entire district from which the clays come, but their place appears to be taken in this region by the Belly river beds, which are arenaceous and argillaceous. Other organic fragments present in these clays may well have been derived from the Cretaceous or Laramie beds of the immediate neighborhood.

In reviewing the general bearings of the microscopical examination of these boulder-clays, representing as they do a few points only, scattered over a wide area in the central portion of the continent, it would be unwise to endeavor to draw any very definite or too general conclusions. The field appears to be a promising one for future inquiry, and the present paper can be regarded only as in the strictest sense, preliminary. It would appear, however, that of all the organic bodies met with none can be assigned with certainty to the glacial period or era of deposition of the boulder clay itself. The origin of most can be traced unequivocally to the older rocks, from which they have been derived, and incorporated with the boulder-clays. Of all the bodies enumerated the only ones which, on account of their pres-

ence in clays, holding otherwise different sets of forms, may possibly be of contemporaneous origin with them, are siliceous sponge (?) *spicules* and the peculiar spines or setæ several times referred to in the foregoing. To these may be possibly added the Ostracoda from the Chicago clay. While it is therefore probable that the examination of these organic fragments will serve to throw additional light on the direction of transport of material during the Glacial period—a point of particular value over the wide area of the plains, where the soft character of the rock precludes the test of direction of striation—it has so far failed to afford any certain information as to the actual conditions prevailing during that period. The negative evidence, reinforced by the fact that derived bodies have been perfectly preserved, so far as it goes, leads to a belief in the great scarcity of contemporary life. The occurrence of inter-glacial peats and the inclusion of wood and other vegetable matters in the boulder-clays of a number of widely separated localities in the West (see "Vegetable remains in Drift Deposits of the Northwest," by Prof. N. H. Winchell, Proc. A. A. S., 1875; "Report of Progress of the Geological Survey of Canada, 1882–84," p. 144) prove, however, that life was not constantly absent, and it may therefore reasonably be anticipated that further search will eventually lead to the definition in the clays of at least such contemporary organisms as may have been derived from these inter-glacial deposits, and possibly of others strictly contemporaneous with the boulder-clays themselves. The well-rounded character of a considerable proportion of the sand in some of the specimens points to prolonged water action, but there is no means of deciding to what extent in each case previously rounded sand grains have been included in the clays. The comparatively unworn appearance of the majority of the Foraminifera and other delicate objects, on the contrary, indicates rather tranquil conditions of deposit, and negatives the occurrence in the case of these materials of any extensive differential motion in the substance of the clay itself, which would infallibly have destroyed these very fragile organisms. Mr. Hugh Miller, in a carefully worked out paper on "Boulder Glaciation" ("Royal Physical Society, Edinburgh," vol. viii, p. 157), describes a fluxion structure in the Scottish till or boulder-clay, and notes instances of sand grains so shaped and striated as to represent microscopic glaciated boulders which he conceives to have been "slidden along and glaciated in these places in the clay." No confirmation of this observation is afforded by these clays. Though many grains of an elongated shape show what might at first be taken for such striation, it is apparent in almost every case on close examination that the lines are really structural and that the shape of the grains is here, as in ordinary sands, governed to a great extent by the pre-existing cleavage or jointage planes of the material of which they are composed.

The microscopical examination of these boulder-clays bears out the conclusion arrived at from their macroscopic characters that, while largely composed of far-traveled material, they invariably contain a considerable proportion of material of local, or proximately local, origin.