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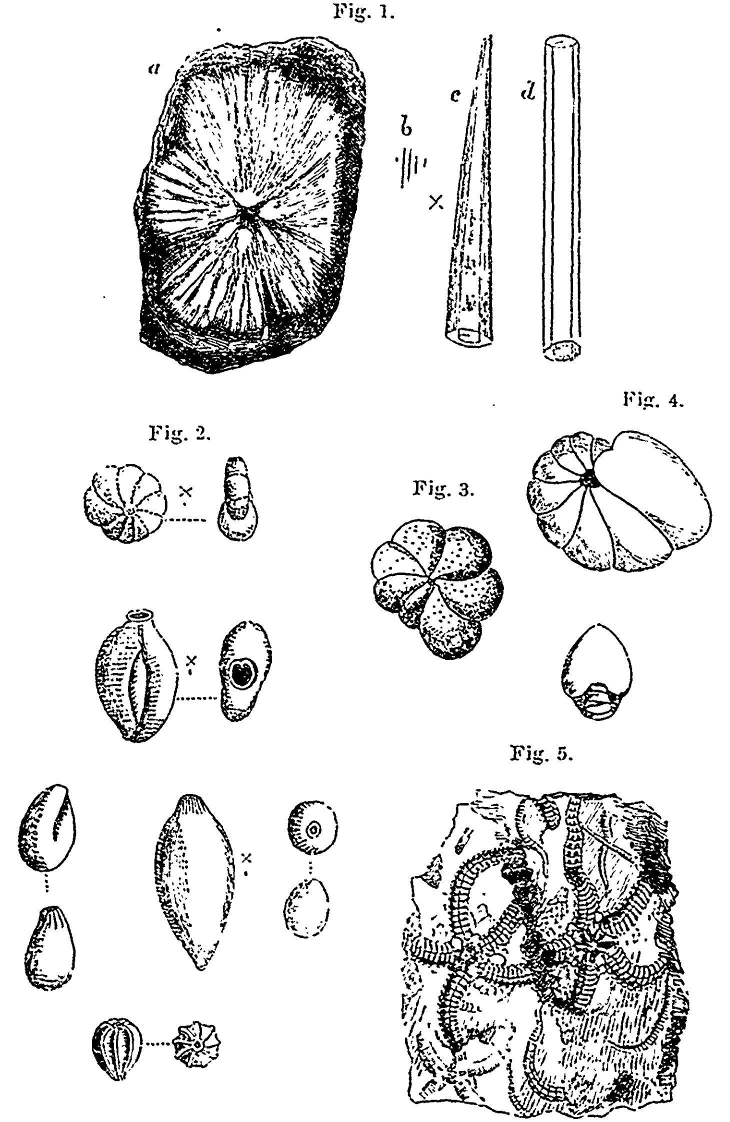

Fig. 1. *Tethea Logani*, Montreal, (*a*) Mass of Spicules in clay; (*b c d*) Spicules, (natural size and magnified.)

Fig. 2. Group of Common Foraminifera from Montreal. (magnified.) *Polystomella crispa; Quinqueloculina seminulum; Polymorphina lactea*, two varieties; *Entosolenia globosa* and *E. costata*.

Fig. 3. *Truncatulina lobulata*. (magnified.)

Fig. 4. *Nonionina scapha*.—Var. *Labradorica*. (magnified.)

Fig. 5. *Ophioglypha Sarsii*, Duck Cove, St. John, N. B.

THE

CANADIAN NATURALIST

AND

Quarterly Journal of Science.

THE POST-PLIOCENE GEOLOGY OF CANADA.

By J. W. Dawson, LL.D., F.R.S., F.G.S.

PART II.—LOCAL DETAILS.—(*Continued.*)

5. *Lower St. Lawrence—South Side.*

The Report of the Geological Survey of Canada (1863), includes all that is yet known of the Post-pliocene formations at Gaspé, and thence upward to Trois Pistoles. According to this Report, the Boulder-clay and overlying sands and gravels are extensively spread over the Peninsula of Gaspé. On the Magdalen River they have been traced up to a height of 1600 feet above the sea, though marine shells are not recorded at this great height. Terraces occur at various elevations, and in one of the lower at Port Daniel, only fifteen feet above the sea, marine shells occur. On the coast westward of Cape Rosier, terraces occur at many places, and of different heights, and marine shells have been found ninety feet above the sea. I have not had opportunities to examine these deposits to the eastward of the place next to be mentioned.

Trois Pistoles.—At this place one of the most complete and instructive sections of the Post-pliocene in Canada, has been exposed by the deep ravine of the river, and by the cuttings for the Intercolonial Railway. The most important terrace at the mouth of the Trois Pistoles River, that in which the railway cutting has been made, is about one hundred and fifty feet above the level of the sea, and is composed of clay capped with sand and gravel. At no great distance inland, there rises a second terrace one hundred and sixty feet higher than the first, or about three hundred and ten feet above the sea. In some places the front of this terrace is cut into two or more. It consists of clay capped with sand and gravel, with some large stones and Laurentian boulders. Still farther inland is a third terrace, the height of which was estimated at four hundred to four hundred and fifty feet.

In the first mentioned of the above terraces, a very deep railway cutting has been made, exposing a thick bed of homogeneous clay of a purplish gray colour and extremely tenacious. It contains few fossils; and these, as far as I could ascertain, exclusively *Leda truncata*. It is, in short, a typical Leda clay, and its thickness in this lower terrace can scarcely be less than one hundred and twenty feet. As the inland terraces are probably also cut out of it, this may be less than half of its maximum depth. Under the Leda clay a typical Boulder-clay had been exposed at one place in digging a mill sluice. It seemed to be about twenty feet thick, and rests on the smoothed edges of the shales of the Quebec group.

Though the Leda clay at the Trois Pistoles seems perfectly homogeneous, it shows indications of stratification, and holds a few large Laurentian boulders, which become more numerous in tracing it to the westward. A short distance westward of Trois Pistoles, it is seen to be overlaid by a boulder deposit, in some places consisting of large loose boulders, in others approaching to the character of a true Boulder-clay or associated with stratified sand and gravel. We thus have Boulder-clay below, next Leda clay, and above this a second Boulder drift associated with the Saxicava sand, and apparently resting on the terraces cut out of the older clays. This is the arrangement which prevails throughout this part of Canada. It is modified by the greater or less relative thickness of the Boulder-clay and Leda clay, by the irregular distribution of the overlying sands, and by the projection through it of ridges of the underlying rocks.

The section at Trois Pistoles may be represented as follows in descending order:

1. *Sand and Gravel*, capping the terraces cut in the previous deposits, and forming slight ridges or eskers in some of the lower levels. It contains on the lower terraces a few shells of *Leda* and *Tellina*. At the bottom of this deposit there are seen in places many large boulders of Laurentian and Lower Silurian rocks, resting on the Leda clay below.
2. *Leda Clay*, exposed in the railway cutting and seen also in the edge of the second terrace. Thickness one hundred and twenty feet or more. It holds a few large boulders and shells of *Leda truncata*—the latter uninjured and with the valves united.
3. *Boulder clay*, or hard gray till, with boulders and stones. Seen in a mill-sluice near the bridge, and estimated at twenty feet in thickness, at this place; though apparently increasing in thickness farther to the westward.
4. *Shales* of Lower Silurian age, seen in the bottom of the River near the bridge. They are smoothed over, but show no striæ, though they have numerous structure lines which might readily be mistaken for ice-striæ.

To the eastward of the mouth of Trois Pistoles River, the first terrace above-mentioned is brought out to the shore by a projecting point of rock. In proceeding westward toward Isle Verte, it recedes from the coast, leaving a flat of considerable breadth, which represents the lowest terrace seen on this part of the St. Lawrence, and is elevated only a few feet above the sea. This flat is in many places thickly strewn with large boulders, probably left when it was excavated out of the clay. In proceeding westward the first or railway terrace of Trois Pistoles, inland of the flat above mentioned, is seen to consist of Boulder-clay, either in consequence of this part of the deposit thickening in this direction, or of the Leda clay passing into Boulder-clay. It still, however, at Isle Verte, contains a few shells of *Leda truncata* in tough reddish clay holding boulders.

Rivière-du-Loup and Cacouna.—The country around Cacouna and Rivière-du-Loup rests on the shales, sandstones, and conglomerates of the Quebec and Potsdam groups of Sir W. E. Logan. As these rocks vary much in hardness, and are also highly inclined and much disturbed, the denudation to which they have been subjected has caused them to present a somewhat uneven surface. They form long ridges running nearly parallel to the coast, or north-east and south-west, with intervening longitudinal valleys excavated in the softer beds. One of these ridges forms the long reef off Cacouna, which is bare only at low tide; another, running close to the shore, supports the village of Cacouna; another forms the point which is terminated by the pier; a fourth rises into Mount Pilote; and a fifth stretches behind the town of Rivière-du-Loup.

The depressions between these ridges are occupied with Post-pliocene deposits, not so regular and uniform in their arrangement as the corresponding beds in the great plains higher up the St. Lawrence, but still presenting a more or less definite order of succession. The oldest member of the deposit is a tough Boulder-clay, its cement formed of gray or reddish mud derived from the waste of the shales of the Quebec group, and the stones and boulders with which it is filled partly derived from the harder members of that group, and partly from the Laurentian hills on the opposite or northern side of the river, here more than twenty miles distant. The thickness of this Boulder-clay is, no doubt, very variable, but does not appear to be so great as farther to the eastward.

Above the Boulder-clay is a tough clay with fewer stones, and above this a more sandy Boulder-clay, containing numerous boulders, overlaid by several feet of stratified sandy clay without boulders; while on the sides of the ridges, and at some places near the present shore, there are beds and terraces of sand and gravel, constituting old shingle beaches apparently much more recent than the other deposits.

All these deposits are more or less fossiliferous. The lower Boulder-clay contains large and fine specimens of *Leda truncata* and other deep-water and mud-dwelling shells, with the valves attached. The upper Boulder-clay is remarkably rich in shells of numerous species; and its stones are covered with Polyzoa and great Acorn-shells (*Balanus Hameri*), sometimes two inches in diameter and three inches high. The stratified gravel holds a few littoral and sub-littoral shells, which also occur in some places in the more recent gravel. On the surface of some of the terraces are considerable deposits of large shells of *Mya truncata*, but these are modern, and are the 'kitchen-middens' of the Indians, who in former times encamped here.

Numbers of Post-pliocene shells may be picked up along the shores of the two little bays between Cacouna and Rivière-du-Loup; but I found the most prolific locality to be on the banks of a little stream called the Petite Rivière-du-Loup, which runs between the ridge behind Cacouna and that of Mount Pilote, and empties into the bay between Rivière-du-Loup and the pier. In these localities I collected and noticed in my paper on this place* more than eighty species, about thirty-six of them not previously published as occurring in the Post-pliocene of Canada.

We have thus at Rivière-du-Loup indubitable evidence of a marine Boulder-clay, and this underlies the representative of the Leda clay, and rests immediately on striated rock surfaces—the striæ running north-east and south-west.

The Cacouna Boulder-clay is a somewhat deep-water deposit. Its most abundant shells are *Leda truncata*, *Nucula tenuis*, and *Tellina proxima*, and these are imbedded in the clay with the valves closed, and in as perfect condition as if the animals still inhabited them. At the time when they lived, the Cacouna ridges must have been reefs in a deep sea. Even Mount Pilote has huge Laurentian boulders high up on its sides, in evidence of this. The shales of the Quebec group were being wasted by the waves and currents; and while there is evidence that much of the fine mud worn from them was drifted far to the south-west to form the clays of the Canadian plains, other portions were deposited between the ridges, along with boulders dropped from the ice which drifted from the Laurentian shore to the north. The process was slow and quiet; so much so that in its later stages many of the boulders became encrusted with the calcareous cells of marine animals before they became buried in the clay. No other explanation can, I believe, be given of this deposit; and it presents a clear and convincing illustration, applicable to wide areas in Eastern America, of the mode of deposit of the Boulder-clay.

A similar process, though probably on a much smaller scale, is now going on in the Gulf. Admiral Bayfield has well illustrated the fact that the ice now raises, and drops in new places, multitudes of boulders, and I have noticed the frequent occurrence of this at present on the coast of Nova Scotia. At Cacouna itself, there is, on some parts of the shore, a band of large Laurentian boulders between half tide and low-water mark, which are moved

* *Canadian Naturalist*, April, 1865.

more or less by the ice every winter, so that the tracks cleared by the people for launching their boats and building their fishing-wears, are in a few years filled up. Wherever such boulders are dropped on banks of clay in process of accumulation, a species of Boulder-clay, similar to that now seen on the land, must result. At present such materials are deposited under the influence of tidal currents, running alternately in opposite directions; but in the older Boulder-clay period, the current was probably a *steady* one from the north-east, and comparatively little affected by the tides.

The Boulder-clay of Cacouna and Rivière-du-Loup, being at a lower level and nearer the coast than that found higher up the St. Lawrence valley, is probably newer. It may have been deposited after the beds of Boulder-clay at Montreal had emerged. That it is thus more recent, is farther shown by its shells, which are, on the whole, a more modern assemblage than those of the Leda clay of Montreal. In fossils, as well as in elevation, these beds more nearly resemble those on the coast of Maine. It would thus appear that the Boulder-clay is not a continuous sheet or stratum, but that its different portions were formed at different times, during the submergence and elevation of the country; and it must have been during the latter process that the greater part of the deposits now under consideration were formed.

The assemblage of shells at Rivière-du-Loup, is, in almost every particular, that of the modern Gulf of St. Lawrence, more especially on its northern coast. The principal difference is the prevalence of *Leda truncata* in the lower part of the deposit. This shell, still living in Arctic America, has not yet occurred in the Gulf of St. Lawrence, but is distributed throughout the lower part of the Post-pliocene deposits in the whole of Lower Canada and New England, and appears in great numbers at Rivière-du-Loup, not only in the ordinary form, but in the shortened and depauperated varieties which have been named by Reeve *L. siliqua* and *L. sulcifera*.

Of *Astarte Laurentiana*, supposed to be extinct, and which occurs so abundantly in the Post-pliocene at Montreal, few specimens were found, and its place is supplied by an allied but apparently distinct species, to be noticed in the sequel, which is still abundant at Gaspé and Labrador, and on the coast of Nova Scotia.

It must be observed that though the clays at Rivière-du-Loup are more recent than those of Montreal, they are still of considerable antiquity. They must have been deposited in water perhaps fifty fathoms deep, and the bottom must have been raised from that depth to its present level; and in the meantime the high cliffs now fronting the coast must have been cut out of the rocks of the Quebec group.

The order of succession of beds, as seen in the banks of the Little Rivière-du-Loup, may be stated as follows, in descending order:

1. Large Loose Boulders, mostly of Laurentian rocks, seen in the tops of ridges of rock and gravel. One angular mass of Quebec group conglomerate was observed ninety feet in circumference and ten to fifteen feet high. Near it was a rounded boulder of Anorthosite Felspar from the Laurentian, 13 feet long.
2. Stratified sand and gravel resting on the sides of the ridges of rock projecting through the drift. Thickness variable.
3. Stratified sandy clay and sand with *Tellina Grœnlandica* and *Buccinum*. 10 feet.
4. Gray clay and stones. *Rhynconella psittacea*, and *Terebratulina Spitzbergensis*, &c. 1 foot or more.
5. Gray clay with large stones, often covered with Bryozoa and Acorn-shells. *Tellina calcarea* very abundant, also *Leda truncata*. 3 feet.
6. Tough, hard, reddish clay, with stones and boulders, passing downward into Boulder-clay, and holding *Leda truncata*. 6 feet or more.

It was observable that the boulders were more abundant on the south side of the ridges than on the north; and between Rivière-du-Loup and Quebec there are numerous small ridges and projecting masses of rock rising above the clays, which generally show the action of ice on their N. E. sides; while the large boulders lying on the fields are seen to have their longer axes N. E. and S. W.

At the Petite Rivière-du-Loup the surface of the red clay (No. 6 above) was observed to have burrows of *Mya arenaria*, with the shells (of a deep-water form) still within them.

VI.—*River St. Lawrence above Quebec, and Ottawa Valley.*

Quebec and its Vicinity.—The deposits at Beauport, near Quebec, were described by Sir C. Lyell in the Geological Transactions for 1839; and a list of their fossils was given, and was compared with those of Montreal in my paper of 1859. As exposed at the Beauport Mills, the Post-pliocene beds consist of a thick bed of Boulder-clay, on which rests a thin layer of sand with *Rhynconella psittacea* and other deep-water shells. Over this is a thick bed of stratified sand and gravel filled with *Saxicava rugosa* and *Tellina*. In a brook near this place, and also in the rising ground behind Point Levi, the deep-water bed attains to greater thickness, but does not assume the aspect of a true Leda clay. Above Quebec, however, the clays assume more importance; and between that place and Montreal are spread over all the low country, often attaining a great thickness, and not unfrequently capped with the Saxicava sand. At Cap a la Roche the officers of the Geological Survey have found a bed of stratified sand under the Leda clay. The Beauport deposit is evidently somewhat exceptional in its want of Leda clay, and this I suppose may have been owing to the powerful currents of water which have swept around Cape Diamond at the time of the elevation of the land out of the Post-pliocene sea. The layer of sand at the surface of the Boulder-clay is evidently here the representative of the Leda clay, and affords its characteristic fossils, while the stones projecting above the Boulder-clay are crusted with Bryozoa and Acorn-shells. At St. Nicholas, there is a sandy Boulder-clay, not unlike that of Rivière-du-Loup, which has afforded some very interesting fossils. It is stated in the Report of the Survey to be one hundred and eighty feet above the sea.

Montreal.—In the neighbourhood of Montreal very interesting exposures of the Post-pliocene beds occur, and with the terraces on the Mountain have been described in my papers of 1857 and 1859. I may here merely condense the leading facts, adding those more recently obtained.

An interesting section of the deposits is that obtained at Logan's Farm, which may be thus stated in descending order:

	ft.	in.
Soil and sand,	1	9
Tough reddish clay,	0	$0\frac{1}{2}$
Gray sand, a few specimens of *Saxicava rugosa*, *Mytilus edulis*, *Tellina Grœnlandica*, and *Mya arenaria*, the valves generally united,	0	8
Tough reddish clay, a few shells of *Astarte Laurentiana, and Leda truncata*,	1	1
Gray sand, containing detached valves of *Saxicava rugosa*, *Mya truncata, and Tellina Grœnlandica:* also *Trichotropis borealis*, and *Balanus crenatus;* the shells, in three thin layers.	0	8
Sand and clay, with a few shells, principally *Saxicava* in detached valves.	1	3
Band of sandy clay, full of *Natica clausa*, *Trichotropis borealis*, *Fusus tornatus*, *Buccinun glaciale*, *Astarte Laurentiana*, *Balanus crenatus*, &c. &c., sponges and *Foraminifera*. Nearly all the rare and deep-sea shells of this locality occur in this band,	0	3
Sand and clay, a few shells of *Astarte* and *Saxicava*, and remains of sea-weeds with *Lepralia* attached; also *Foraminifera*, ...	2	0
Stony clay (Boulder-clay). Depth unknown.		

In this section the greater part of the thickness corresponds to the Leda clay, which at this place is thinner and more fossiliferous than usual. Along the south-east side of the Mountain, and in the city of Montreal, the beds have been exposed in a great number of places, and are in the aggregate at least 100 feet thick, though the thickness is evidently very variable. The succession may be stated as follows:

1. *Saxicava Sand.*—Fine uniformly grained yellowish and gray silicious sand with occasional beds of gravel in some places, and a few large Laurentian boulders, *Saxicava*, *Mytilus*, &c., in the lower part. Thickness variable, in some places 10 feet or more.

2. *Leda Clay.*—Unctuous gray and reddish calcareous clay, which can be observed to be arranged in layers varying slightly in colour and texture. Some of these layers have sandy partings in which are usually Foraminifera and shells or fragments of shells. In the clay itself the only shells usually found are *Leda truncata* and a smooth deep-water form of *Tellina Grœnlandica;* but toward the

surface of the clay in places where it has not been denuded before the deposition of the overlying sand, there are many species of marine shells. A few large boulders are scattered through the Leda clay.

3. *Boulder-clay.*—Stiff gray stony clay or till, with large boulders and many glaciated stones, often of the same Trenton rocks which occur on the flanks of the Mountain. It is of great thickness, though it has been much denuded in places, and has not been observed to contain fossils. It is especially thick at the south and south-west sides of the Montreal Mountain.

The Montreal Mountain, like other isolated trappean hills in the great plain of the Lower St. Lawrence, presents a steep craggy front to the north-east, and a long slope or tail to the south-west; and in front of its north-east side is a bare rocky plateau of great extent, and at a height of rather more than 100 feet above the river. This plateau must have been produced by marine denudation of the solid mass of the Mountain in the Post-pliocene period, and proves an astonishing amount of this kind of erosive action in hard limestones interleaved with trap dykes, and which have been ground and polished with ice at the same time that the plateau was cut into the hill. By ice also must the debris produced by this enormous erosion have been removed, and piled along the more sheltered sides of the hill in the Boulder-clay.

With regard to the crag-and-tail attitude of Montreal Mountain, I have to observe that in large masses of this kind reaching to a considerable height, and rising above the Post-pliocene sea, the north-east or exposed side has been cut into steep cliffs, but in smaller projections of the surface over which the ice could grind, the exposed side is smoothed or "moutonnée," and the sheltered side is angular. A little reflection must show that this must be the necessary action of a sea burdened with heavy floating ice.

The most strongly marked terraces on the Montreal Mountain, are at heights of 470, 440, 386, and 220 feet above the sea, but there are less important intermediate terraces. On the highest of these, on the west side of the Mountain, over Cote des Neiges village, there is a beach with marine shells, and on the summit of the Mountain, at a height of about 700 feet, there are rounded surfaces, probably polished by ice, though no striation remains, and large Laurentian boulders, which must have been carried probably a hundred miles from the Laurentian regions to the north-east, and over the deep intervening valley of the St. Lawrence.

I have already, in the first part of this memoir, noticed the striation on rock surfaces at Montreal, and may merely add that it is often very perfect, and must have been produced by a force acting up the St. Lawrence valley from the north-east, and planing all the spurs of the Mountain on that side, while leaving the Mountain itself as a bare and rugged unglaciated escarpment. In the streets of Montreal the true Boulder-clay is often exposed in excavations, and is seen to contain great numbers of glaciated stones, most of which are of the hardened Lower Silurian shales and limestones of the base of the Mountain; and though no marine shells have been found, the sub-aquatic origin of the mass is evidenced by its gray unoxidised character, and by the fact that many of the striated stones at once fall to pieces when exposed to the frost, so that they cannot possibly have been glaciated by a sub-aerial glacier.

At the Glen brick-work, near Montreal, the Leda clay and underlying deposits have been excavated to a considerable depth, and present certain remarkable modifications. The section observed at this place is as follows:

	ft.	in.
1. Hard gray laminated clay, *Foraminifera* and *Leda*, in thin layers	7	0
2. Red layer, in two bands	0	6
3. Sandy clay	1	0
4. Gray and reddish clay	9	0
5. Hard buff sand, very fine and laminated	15	0
6. Sand with layers of tough clay, holding glaciated stones, and very irregularly disposed	4	0
7. Fine sand	1	0
8. Gray sand, with rounded pebbles, and laminated obscurely and diagonally	4	0
9. Fine laminated yellow sand	3	0
10. Gravel	0	4
11. Very irregular mass of laminated sand, with mud, gravel, stones and large boulders	12	0
	56	10

The whole of these deposits except the Leda clay, are very irregularly bedded, and are apparently of a littoral character. They seem to shew the action of ice in shallow water before the deposition of the Leda clay. The only way of avoiding this conclusion would be to suppose that the underlying beds are really of the age of the Saxicava sand, and that the Leda clay has been placed above them by slipping fram a higher terrace; but I failed to see good evidence of this. A little farther west at the gravel pits dug in the terrace for railway ballast, a deep section is exposed showing at the top Saxicava sand, and below this a very thick bed of sandy clay with stones and boulders, constituting apparently a somewhat arenaceous and partially stratified equivalent of the Boulder-clay. A little above this place, at the Brick-works, the Saxicava sand is seen to rest on a highly fossiliferous Leda clay, which probably here intervenes between the two beds seen in contact nearer the edge of the terrace.

Ottawa River.—The Leda clay and Saxicava sand are well exposed on the banks of the Ottawa; and Green's Creek, a little below Ottawa City, has become celebrated for the occurrence of hard calcareous nodules in the clay, containing not only the ordinary shells of this deposit, but also well-preserved skeletons of the Capelin (*Mallotus*) of the Lump-sucker (*Cyclopterus*) and of a species of stickleback (*Gasterosteus*). Some of these nodules also contain leaves of land plants and fragments of wood, and a fresh-water shell of the genus Lymnea has also been found. At Packenham Mills west of the Ottawa, the late Sheriff Dickson found several species of land and fresh-water shells associated with Tellina Grœnlandica and apparently in the Saxicava sand. These facts evidence the vicinity of the Laurentian shore, and indicate a climate only a little more rigorous than that of Central Canada at present. They were noticed in some detail in my paper of 1866 in *The Canadian Naturalist*..

The marine deposits on the St. Lawrence are limited, as already stated, to the country east of Kingston; and the clays of the basin of the great lakes to the south-westward have, as yet, afforded no marine fossils. I have, however, just learned from Prof. Bell, of the Geological Survey, a discovery made by him in the past summer and which is of very great interest, namely that two hundred miles north of Lake Superior the marine deposits reappear. The details of this important discovery will be given in a forthcoming Report of the Geological Survey, and its theoretical significance will be referred to in the concluding part of this memoir.

In the above local details, I have given merely the facts of greatest importance, and may refer for many subordinate points to the papers catalogued in the introduction to this memoir, and to the reports of the Geological Survey of Canada.

PART III.—REVISION OF POST-PLIOCENE FOSSILS OF CANADA.

The list of Post-pliocene fossils published previously to 1856, amounted to only about 26 species. In my papers published between that year and 1863, the number was raised to nearly 80. My lists were tabulated, along with some additional species furnished in MS, in the Report of the Geological Survey for 1863, the list there given amounting to 83 species, exclusive of Foraminifera. In my paper on the Post-pliocene of Rivière-du-Loup and Tadoussac, published in 1865, I added 38 species, and shall be able still farther to increase the number in the present revision, which will afford a very complete view of the subject up to the present time; and though additional species will no doubt be found, yet all the principal deposits have been so carefully explored that only very rare species can have escaped observation. For some of the additional species included in the present list, I am indebted to Mr. G. T. Kennedy of Montreal, Dr. Anderson of Quebec, and other friends, to whom reference will be made in connection with the several species in the catalogue.

SUB-KINGDOM RADIATA.

Class I.—Protozoa.

(1) *Foraminifera.*

Nodosaria (Glandulina) lævigata.

——————————(Var. *Dentalina communis*)

Fossil—Leda clay, Montreal.

Recent—Gulf St. Lawrence, 30 to 300 fathoms, G.M.D.*

This species is very rare in the Post-pliocene, but sometimes of large size and of different varietal forms.

* The initials G. M. D., refer to the List of Foraminifera by Mr. G. M. Dawson in *The Canadian Naturalist*, 1870.

Lagena Sulcata —— (Var. *distoma.*)
——————— (Var. *semisulcata.*)

Fossil—Leda clay, Montreal; Quebec; Murray Bay; Rivière-du-Loup; Portland (Maine.)

Recent—Gulf St. Lawrence, 18 to 313 fathoms, G.M.D.

Rather rare in the Post-pliocene as well as in the recent.

Entosolenia globosa.
—————*costata.*
—————*marginata.*
—————*squamosa.*

Fossil—Montreal, Leda clay; Labrador; Rivière-du-Loup; Murray Bay; Quebec; Portland (Maine).

Recent—Gulf and River St. Lawrence, 20 to 313 fathoms. G. M. D.

Generally diffused in the Post-pliocene, and presenting the same range of forms as in the recent; but not common. I regard the supposed species of *Entosolenia* above named as merely varietal forms.

Bulimina Presli.
————— (Var. squamosa)

Fossil—Montreal, Leda clay; Labrador; Rivière-du-Loup; Murray Bay; Quebec; Portland (Maine).

Recent—Gulf and River St. Lawrence, 10 to 313 fathoms, G. M. D.

Generally diffused in the Post pliocene. In the recent it seems to be a deep-water form. What Parker and Jones call the essentially arctic form *B. elegantissima* is not uncommon, though other forms also occur.

Polymorphina lactea.

Fossil—Montreal, Leda clay; Labrador; Rivière-du-Loup; Murray Bay.

Recent—Gulf and River St. Lawrence, 30 to 313 fathoms. G. M. D.

Not uncommon in the Post pliocene, particularly in the deeper parts of the Leda clay. Less common recent. I observed in the Rivière-du-Loup gatherings a small individual of this species with the internal pipe at the aperture characteristic of Entosolenia, which is also sometimes observed in recent specimens.

Truncatulina lobulata.

Fossil—Leda clay, Labrador; Rivière-du-Loup.

Recent—Gulf St. Lawrence, very common 30 to 50 fathoms.

This species is much less common in the Post-pliocene than in the recent.

Orbulina universa.

Fossil—Leda clay, Montreal; Rivière-du-Loup; Labrador.

This may be regarded as a rare and somewhat doubtful Post-pliocene fossil. It has not yet been recognized in the Gulf of St. Lawrence.

Globigerina bulloides.

Fossil—Rivière-du-Loup.

Recent—Gulf St. Lawrence, more especially in the deeper water, where it is common. It is very rare in the Post-pliocene.

Pulvinulina repanda.

Fossil—Montreal, Leda clay; Rivière-du-Loup; Murray Bay; Labrador; Quebec; Portland (Maine).

Recent—Gulf St. Lawrence, 30 to 313 fathoms, G. M. D.

Somewhat rare both in the Post-pliocene and recent, and of the small size usual in the arctic seas.

Polystomella crispa.—(Var. *Striatopunctata*).
——————— (Var. *Arctica.*)

Fossil—Montreal, Leda clay; Labrador; Rivière-du-Loup; Murray Bay; Quebec; Portland (Maine); St. John, N. B.

Recent—Gulf and River St. Lawrence, 30 to 40 fathoms. G. M. D.

Very common, especially in depths of 10 to 40 fathoms. This is by far the most abundant species in the Post-pliocene deposits, as it is also in all the shallow parts of the Gulf of St. Lawrence at present, and also in the Arctic Seas, according to Parker and Jones. It is the only species yet found in the Boulder-clay of Montreal, and this very rarely.

Nonionina scapha.
———————(Var. *Labradorica.*)

Fossil—Leda clay, Montreal; Rivière-du-Loup; Labrador; Murray Bay; Quebec; St. John, N. B.

Recent—Gulf and River St. Lawrence, 10 to 313 fathoms. Var. *Labradorica* is the deeper water form and is rare in the Leda clay.

Textularia pygmæa.

Fossil—Leda clay, Labrador; Rivière-du-Loup; Quebec; also at Portland (Maine).

Recent—Gulf St. Lawrence, 10 to 30 fathoms.

The Textulariæ are rare and of small size, both in the Post-pliocene and recent.

Cornuspira foliacea.

Fossil—Leda clay, Montreal.

Recent—Gulf St. Lawrence, 16 to 250 fathoms, G. M. D.

This species is rare both fossil and recent.

Quinqueloculina seminulum.

Fossil—Leda clay, Montreal; Labrador; Quebec; Portland (Maine).

Recent—Gulf St. Lawrence, 10 to 313 fathoms, most abundant in shallow water. G. M. D.

This species is by no means common and not usually large in the Post-pliocene. It is more abundant in the clays of Maine than in those of Canada.

Biloculina ringens.

Fossil—Leda clay, Montreal; Labrador; Rivière-du-Loup; Murray Bay; Quebec.

Recent—Gulf St. Lawrence, 30 to 313 fathoms. G. M. D.

Rather rare in the Post-pliocene as well as in the recent.

Triloculina tricarinata.

Fossil—Leda clay, Rivière-du-Loup; Murray Bay; Quebec.

Recent—Gaspé, 30 to 50 fathoms. G. M. D.

Rare both in Post-pliocene and recent, but perhaps more generally diffused in the former.

Lituola and *Saccammina.*

A very few minute sandy forms referable to these genera are found among the finer part of the washings from Riviére-du-Loup.

Euglypha?

A single minute test, apparently identical in form with that of *Euglypha alveolata,* was found in washing the Rivière-du-Loup clays.

In general terms it may be stated that all the species of Foraminifera found in the Post-pliocene still inhabit the Gulf and River St. Lawrence. Several species found in the Gulf of St. Lawrence have not yet been recognized in the Post-pliocene, and these are mostly inhabitants of depths exceeding 90 fathoms, or among the more southern forms found in the Gulf.

On the whole, the assemblage, as in the northern part of the Gulf of St. Lawrence at present, is essentially arctic, and not indicative of very great depths.

The sandy forms which are not uncommon in the Gulf are very rare in the Post-pliocene; but this may be accounted for by the greater difficulty of washing them out of the clay, or possibly their cementing material may have decomposed, allowing them to fall to pieces. As the epidermal matter of shells is often preserved, the last supposition seems less likely. The Leda clays are, however usually very fine and calcareous, so that there was probably more material for calcareous than for arenaceous forms.

The Foraminifera are very generally diffused in the Post pliocene clays. though much more abundant in some layers than in others. They may easily be detected by a pocket lens, and are usually in as fine preservation as recent specimens, especially in the deeper and more tenacious layers of the Leda clay. They are however, usually most abundant in the somewhat arenaceous layers near the top of the Leda clay, and immediately below the Saxicava sand, and especially where this layer contains abundance of shells of Mollusca. I have nowhere found them more abundant or in greater variety than at the Glen Brick-work, Montreal, on the McGill College Grounds, and at Logan's Farm. At the Glen Brick-work a few worn specimens of Polystomella are contained in the beds underlying the Leda clay and equivalent to the Boulder-clay, which, however, has in general, in the vicinity of Montreal as yet afforded no marine fossils.

In searching for Foraminifera in the clays of Rivière-du-Loup, I have observed in the finer washings several species of Diatomaceæ; among these a species of Coscinodiscus very frequent in the deeper parts of the Gulf of St. Lawrence. But on the whole Diatoms appear to be rare in these deposits. In the Rivière-du-Loup clays I have also observed the pollen grains of firs and spruces.

The nomenclature used above is that of Parker and Jones, in their paper on the North Atlantic Soundings, in the Transactions of the Royal Society. For figures of the species, I may refer to that memoir, and to my previous papers published in the *Naturalist.*

(2) *Porifera.*

Tethea Logani, Dawson.

Leda clay, Montreal. This species has not yet been recognised in a living state, though allied to *Tethea hispida*, Bowerbank, of the coast of Maine. Its spicules in considerable masses, looking like white fibres, are not uncommon in the Post-pliocene at Montreal.

Tethea?

Another silicious sponge is indicated by little groups of small spicules found at the Tanneries, near Montreal, by Mr. G. T. Kennedy, and at Riviere-du-Loup by the author. Its spicules are long and accerate, and much more slender than those of *Tethea Logani*. They resemble those of *T. hispida*, recent on the coast of Maine, and also those of a species of *Polymastia*, dredged by Mr. Whiteaves in the Gulf of St. Lawrence.

Class II.—Anthozoa.

Class III.—Hydrozoa.

No distinct organisms referable to the above groups have yet been found in the Post-pliocene deposits of Canada. As our recent fauna includes no stony coral, and the recent species of the Gulf of St. Lawrence have no parts likely to be preserved other than minute spicules, this is not to be wondered at. In washing the clays for Foraminifera, however, numerous fragments are obtained, which resemble portions of the horny skeletons of hydroids, though not in a state admitting of determination.

Class IV.—Echinodermata.

(1) *Ophiuridea.*

Ophioglypha Sarsii, Lutken.

Fossil—Leda clay, near St. John, N. Brunswick; Mr. Matthew.

Recent—River St. Lawrence, at Murray Bay; also found of large size in deep water in the Gulf of St. Lawrence, by Mr. Whiteaves.

Ophiocoma.

Fragments of a small species of ophiuroid starfish not determinable, have been found in the Leda clay at Montreal, and in nodules at Green's creek.

(2) *Echinoidea.*

Euryechinus drobachiensis, Müller.

Fossil—Leda clay, Beauport; Rivière-du-Loup; Montreal.

This species is rare in the Post-pliocene, but very common in all parts of the Gulf of St. Lawrence at present.

(3) *Holothuridea.*

Psolus phantopus? Oken.

Scales of an animal of this kind have been found in the Leda clay at Montreal. They may belong to *P. phantopus*, or to the species *P.* (*Lophothuria*) *Fabricii*, also found on our coasts.

ON THE ORIGIN AND CLASSIFICATION OF ORIGINAL OR CRYSTALLINE ROCKS.

By Thomas Macfarlane.

(*Continued from page* 312—Vol. V.)

V.—MINERALOGICAL CONSTITUTION.

Having, in the foregoing, adverted to the texture and chemical composition of original rocks, it now becomes necessary to refer more particularly to their mineralogical constitution. In order to continue the analogy which has been shewn to exist between furnace slags and original rocks, it will be well here to refer to those instances which have been observed of the formation of well developed crystals in the cooling of artificial silicates. The rapid manner in which furnace slags are commonly allowed to cool is of course detrimental to the formation of any mineral-like aggregations, but it is sometimes possible to observe in copper furnace slags that, when they have been allowed to solidify in large blocks or cakes, they shew an actynolitic structure in their mass, often closely resemble hornblende rock, and very commonly contain cavities lined with the most beautiful crystals. The formation of pyroxene in slags from iron furnaces has been frequently observed and well authenticated. Nöggerath described augite crystals from the slags of the iron furnace of Olsberg near Bigge in Westphalia. Montefiori Levi analysed augites taken from the slags of the iron furnace at Augreé near Liege. Richter described and examined similar crystals from the iron works of Rufskberg in the Banat; Von Leonhard mentions acicular augite crystals in the iron furnace slags of Skis-hytta in Sweden. F. Sandberger describes similar occurences; and numerous others might here be mentioned. Mitscherlich and Berthier obtained by melting silica, lime, and magnesia together, in a charcoal crucible placed in a porcelain furnace, a mass possessing cleavage corresponding to the faces of augite, and the hollow cavities in which were crowded with the most beautiful crystals of that mineral. These are also of very common occurrence in the lava streams not only of extinct but of active volcanoes; and well-developed augite crystals have not unfrequently been ejected from their craters. Olivine has been observed in the slags of iron furnaces quite as frequently as augite, and it, as well as magnetite, is one of the commonest minerals in streams of basaltic lava. So is leucite, although it has not yet been produced artificially. Mitscherlich observed transparent six-sided tabular crystals of mica, and leaves of it several inches broad, in the cavities of old copper furnace slags near Garpenberg in Dalecarlia. Gurlt also mentions artificially formed mica, and it appears frequently in ancient and modern lava streams. With regard to felspar, Hausmann makes mention as early as 1810, of felspar crystals which had been formed in one of the Mansfield furnaces. In 1834 Herne found similar crystals in the copper furnace of Sangershausen after it had been blown out, and in the iron furnace of Josephshütte in the Hartz, they were also detected. In 1810 the formation of felspar crystals in glass works was first observed; and in 1848 Prechtl gave an account of their occurring in a mass of glass weighing 133½ lbs. which had been melted in the plate glass factory at Neuhaus. They were of various sizes, some an inch in length, with perfectly sharp edges. The formation of sanidine and other varieties of felspar, in lavas of recent age, is a matter of common occurrence. No instance is known of the production of quartz from artificial silicates, nor do those lavas of the present day which are highly siliceous, develope it in cooling. These solidify as vitreous uncrystalline masses, but many lavas of extinct volcanoes in the Andes and the Siebengebirge contain it in well-formed crystals, shewing that it must have crystallized out from the mass of the rock.

The number of minerals which enter into the constitution of rocks is very small compared with the number of the mineral species which are found described in the various treatises on mineralogy. Of the latter there are upwards of six hundred, but the great majority of these are rare minerals, occurring in veins or cavities, and not entering into the constitution of the rocks themselves. The number of minerals which are found in original rocks is still more limited, and if from it if we deduct the sparingly occurring, or so-called accessorial constituents, the number is reduced to twenty minerals, which may be called the essential constituents of original rocks. The following table gives their names and the silica contents of the extreme acid and basic varieties.

Mineral.	*Percentage of Silica.*
Quartz	100 ——
Orthoclase	69 —62.75
Oligoclase	64.25—59.28
Labradorite	55.83—50 31
Anorthite	47.63—42 01
Leucite	58 10—53 50
Nepheline	45.31—43.50
Potash mica	51.73—43 47
Magnesia mica	44.63—36 17
Hornblende	60.60—37 84
Pyroxene	57.40—38.58
Hypersthene	51.35——
Enstatite	56.91——
Diallage	53.71—49 12
Olivine	44.67—36.30
Magnetite	00.00——

The separation of the minerals occurring in rocks into essential and accessorial constituents originated with German lithologists and may perhaps be regarded as arbitrary. In characterising the sixteen minerals just mentioned as *essential* constituents, we have however, to some extent, been guided by their chemical constitution. In the preceding chapter silicic acid, alumina, peroxide of iron, protoxide of iron, magnesia, lime, soda and potash were indicated as the essential chemical constituents of rocks; and only such minerals as contain these substances, and no others, as *essential ingredients*, have been admitted into the table. This mode of selection may perhaps be considered as arbitrary as any other, for it causes the exclusion of the mineral tourmaline, which sometimes appears to deserve the rank of an essential constituent.

Tourmaline, however, contains, besides some of the subtances just mentioned, boracic acid and fluorine, and, in its mode of occurrence, resembles such accessorial or accidental minerals as zircon, apatite, titanite and others. Garnet, corundum, epidote, cordierite and scapolite are rock minerals, containing no other chemical constituents than those above mentioned, but they have been excluded from our list because they resemble the accessorial constituents in the manner of their occurrence.

With regard to these essential minerals it is first to be remarked that the analyses which have been made of them are not, in every case, of such specimens as have actually formed part and portion of some rock species. To obtain pure specimens of the minerals of rocks is often a matter of great difficulty, and well-developed crystals from veins or geodes have been preferred for analysis to the generally amorphous particles of the same species which enter into the constitution of rocks. The composition of these minerals cannot, like that of well-crystallised artificial chemical compounds, be unequivocally expressed by chemical formulæ. Attempts, the most painstaking and persevering, have been made in this direction by mineralogists, and the result has only been to shew that, in the majority of cases, each analysis of the same species demands a different formula for expressing its composition in chemical equivalents. The composition of micas, augites and hornblendes is especially variable, and even with regard to the felspars it has been maintained that those of our list are not distinct or independent species but are mixtures of one with the other or with other supposed species, such as krablite, albite or adularia. It has therefore been considered best here to neglect their various assumed chemical formula and to regard principally their average chemical composition.

Certain differences in the composition of these minerals cause their subdivision into two different classes. The minerals of the first class are mostly silicates of alumina, lime, potash and soda, and *it may be called the felspathic class.* It includes, however, leucite and nepheline, which can scarcely be called felspars, and quartz, which, although of very different composition, nevertheless possesses lithological affinities connecting it closely with the acid felspars. The minerals of the second class also contain lime, but alumina and the alkalies are less frequent or absent altogether, being replaced by magnesia and protoxide of iron. They are generally of a more basic nature than the felspathic class, and the purely basic mineral magnetite may be placed, as lithologically related, along with them. The minerals of this class may therefore be called the basic essential constituents of rocks. We have thus the following classification of these essential rock minerals.

Class 1st.—Felspathic—Quartz, Orthoclase, Oligoclase, Labradorite, Anorthite, Leucite, Nepheline.

Class 2nd.—Basic—Potash mica, Magnesia mica, Hornblende, Pyroxene, Diallage, Enstatite, Hypersthene, Olivine, Magnetite.

The extent to which these minerals enter into the constitution of original rocks will be best seen by repeating here the general view given of the families of rocks, placing at the head of each column the names of the principal constituents.

Table II.

General View of the Mineralogical Constitution of the families of Original Rocks.

	Basic Rocks.	*Basous Rocks*	*Neutral Rocks*	*Siliceous R'ks*	*Silicic Rocks.*
Felspathic Min'ls	Anorthite.... Nepheline...	Oligoclase. Labradorite. Anorthite. Nepheline.	Orthoclase. Oligoclase.	Quartz Orthoclase. Oligoclase.	Quartz. Orthoclase.
Basic Minerals..	Pyroxene.... Olivine...... Magnetite...	Mag: mica. Hornblende. Pyroxene. Olivine.	Mag: mica. Hornblende.	Mag: mica.	Pot: mica.
I. Coarse and small-grained.	Anorthosite..	Greenstone.	Syenite.	Granitite.	Granite.
II. Schistose....	Basic schist..	Greenstone schist.	Syenitic schist.	Gneiss.	Gneissite.
III. Slaty.......	....	Greenstone slate.	Clay slate.	Siliceous slate.	Silicic Slate.
IV. Porphyritic..	Augitic porphry.	Greenstone porphry.	Melaphyre.	Porphyrite.	Porphyry.
V. Variolitic....	....	Variolite.	Var. basaltite	....	Spherulyte.
VI. Fine grained	Anhydrous basalt.	Trap.	Basaltite.	Eurite.	Felsite.
VII. Trachytic..	Nephelinite.	Dolerite.	Andesite.	Trachyte.	Rhyolite.
VIII. Volcanic..	Nephelinite lava.	Doleritic lava	Andesitic.	Trachytic lava.	Obsidian.

It will be observed from this table that a certain degree of consistency is observed by the essential minerals in entering into the constitution of original rocks. Such acid minerals as quartz and orthoclase never occur in the basic rocks; nor, on the other hand, do we find augite or labradorite entering into the composition of siliceous granites or trachytes. Towards the basic extreme of chemical composition in rocks, the siliceous minerals diminish or disappear, and, towards the acid extreme, basic minerals act in the same way. This behaviour alone is sufficient to shew that the mineralogical constitution of a rock is not the result of accident, but mainly the consequence of the chemical nature of the plastic magna from which it resulted, an inference which is borne out by the varying composition of the minerals themselves.

It will be seen that at the heads of the columns the minerals have been arranged according to the classification already given. Now it would appear, with regard to the members of each of the classes which we have distinguished, that not only do they resemble each other in chemical composition but they seem to replace each other when they enter into the composition of original rocks. That is to say, the increase, in quantity, of one of them in a rock is generally accompanied by a decrease on the part of another member of the class, and generally of that member which most closely approaches the first in chemical composition. This appears to be well borne out by the table, and numerous examples of such substitutions might be cited. Thus hornblende replaces mica in granitite forming syenite; oligoclase replaces orthoclase in the passage from syenite to diorite; and diallage replaces pyroxene in that species of greenstone called gabbro. There are thus formed gradual transitions from one rock species to another in mineralogical constitution as well as chemical composition. In the subjoined table (III) the nature and manner of these transitions are exhibited. It will be seen that the distinctions already made as to the orders and families of rocks are kept steadily in view while at the same time an attempt is made to give a systematic arrangement of the different species of original rocks and their mutual relations.

III.—Table showing the Mineralogical Constitution of the Species of Original Rocks.

	Basic non-felspathic Rocks.	*Basic Rocks.*	*Basous Rocks.*	*Neutral Rocks.*	*Siliceous Rocks.*	*Silicic Rocks.*	*Silicic non-felspathic Rocks.*
Silica Contents.		Below 49 p. c.	49 to 56 p. c.	56 to 63 p. c.	63 to 70 p. c.	70 p. c. & upw'ds.	
Essential felspathic constituents.		Saussurite. Anorthite. Nepheline.	Oligoclase. Labradorite.	Orthoclase. Oligoclase.	Quartz. Orthoclase. Oligoclase.	Quartz. Orthoclase.	Quartz.
I. Coarse & small-grained							
with no basic constituents			Noryte.	Miassyte.		Granitelle.	Quartzyte.
" Mica			Mica diorite.	Syenite.	Granityte.	Granite.	Greisen.
" Hornblende	Amphibotyte.	Corsyte.	Diorite.		Hornb. Granityte.		
" Pyroxene	Pyroxenyte.	Eukryte.	Diabase.				
" Diallage or Smaragdite	Omphazyte.	Euphotide.	Gabbro.				
" Hypersthene			Hyporyte.				
" Enstatate		Protobastyte.					
" Olivine	Dunyte.						
" Magnetite	Magnetite.						
II. Schistose							
with no basic constituents						Granulite.	Quartz schist
" Mica				Syenite schist.	Gneiss.	Gneissyte.	Mica schist.
" Hornblende	Hornb. Schist.		Diorite schist.		Syen. gneiss.		
" Pyroxene			Diabase schist.				
III. Slaty		Green slate.	Aphanite slate.	Argillyte.	Siliceous slate.	Felsitic slate.	
IV. Porphyritic.							
with no basic con. develop.				Melaphyre.	Porphyrite.	Felsitic porphy.	
with Mica separated			Kersantone.	Minette.	Mica porphyrite.	Mica porphyry.	
" Hornblende separated		Anorthite porph.	Diorite porph.	Hornb Melaphyre	Horn. porphyrite.		
" Augite separated		Augitic porph.	Diabase porph.	Aug. Melaphyre.			
V. Variolitic			Variolyte.			Spherulyte.	
VI. Fine-grained.							
Unasso'd with other rocks		Basanyte.	Aphanyte.	Basaltyte.	Euryte.	Felsyte.	
Asso. with dioritic rocks			Dior. aphanyte.				
" diabase "			Diab. aphanyte.				
" basaltic "		Basalt.	Anamesyte.				
VII. Trachytic.							
with no basic constituents				Andesyte.		Rhyolyte.	
" mica and hornblende				Aug. Andesyte.	Trachyte.	Dacyte.	
" Augite		Nephelinyte.	Doleryte.		Aug. Trachyte.		
" Augite and olivine	Lherzolyte.	Oliv. Nephelinyte	Ol. Doleryte.				
VIII. Volcanic.							
Vitreous				Aud. pumice.	Obsidian.	Silicic obsidian.	
Cavernous				Aud. lava.	Pumice.		
Scoriaceous		Neph. lava.	Dol. Lava.				

In preparing table III, the same care has been taken as with those already given to introduce no new terms, and to use the various names of the species only in the sense which at present is generally attached to them by petrologists. In a few instances, where such names have hitherto borne a too general or a more or less indefinite meaning, an attempt has been made to confine their application to one species. The name rhyolite is for instance used in a somewhat more restricted sense than that given it by its originator, and the very vague, generally condemned, but still much used or misused, name, melaphyre, is, as applied to a particular species, limited to those porphyrite rocks which are neutral in chemical composition and in which crystals of triclinic felspars only are developed. In some other cases, where the same species possessed several synonyms, a slightly different signification has been given to one, and generally the least used of them, in order to make it of use in our system. For instance, eurite and felsite have hitherto been synonymous. In our table the latter term is made to indicate the more silicic species of fine grained rocks. Such names of rocks as have been derived from those of minerals have their terminations, in accordance with Dana's suggestion, altered from *ite* to *yte*.

It will be observed that, in table III, the minerals of the felspathic class only are placed at the head of the vertical columns, while the other essential minerals have been placed under each variety of texture on the left hand side. The cause of this arrangement may here be stated. The felspars, being of very constant occurrence in original rocks, and being frequently difficult to determine, have not been much made use of in distinguishing species until quite recently. For instance, oligoclase very often can only be distinguished from orthoclase by an experienced mineralogist, and only an experienced chemist after a minute analysis, can distinguish between oligoclase, labradorite and anorthite in a compound rock. On the other hand the minerals of the other class possess very well marked physical characters, and the presence of one or other of them was readily detected by the earlier petrologists and made use of by them for characterising different rocks. Thus, mica, hornblende and olivine are very widely apart both as regards form, colour, hardness and fusibility. The only two minerals of the second and third classes which are difficult to distinguish from each other are hornblende and augite, and this is only the case in fine grained compound rocks. By giving prominence to each of these non-felspathic minerals and placing their names on the horizontal lines of our table, it becomes possible to shew at a glance the rocks which they form with the felspathic minerals named at the heads of the vertical columns, and the manner in which, by gradually replacing each other, they form the different species of original rocks. Thus it will be observed that among the schistose rocks the most basic is diabase schist; that the latter becomes diorite schist when hornblende replaces pyroxene; that the diorite schist, as its oligoclase is replaced by orthoclase, becomes syenite schist, and, as quartz makes its appearance and increases, syenitic gneiss is produced. At the next step in a silicic direction, mica replaces the hornblende, producing common gneiss, then when the mica disappears, granulite results. If, instead of the mica, the orthoclase disappears, mica schist is developed, and when from the latter rock the mica in greater part is withdrawn, it becomes quartz schist. The other varieties of texture, such as the porphyritic and trachytic, each exhibit a similar series of transitions, the most fully developed being the granular order. In the latter it becomes possible, by means of the peculiar arrangement of our table, to shew the mineralogical nature of each of the species of the complicated family of the greenstones. Diorite, gabbro, hyperyte, diabase and protobastyte rock are shewn to be respectively characterised by hornblende, diallage, hypersthene, pyroxene and enstatite in combination with various felspars. The great majority of original rocks contain some variety of felspar, but there are a few species in which that mineral is absent and which are called non-felspathic rocks. In order as far as possible to shew these also in our table, two columns have been added to it, one at each side. The right hand one shews the silicic, and the left hand the basic rocks void of felspar.

VI.—ACCESSORIAL CONSTITUENTS.

Besides the minerals mentioned in the foregoing chapter as the essential constituents of crystalline rocks, there are others of less frequent and only accidental occurrence, which have been called by *German lithologists the accessorial constituents.* Among these such minerals are not included as are only found in the veins, cavities, or even joints enclosed in rocks. Only those which are found in intimate mechanical union with the essential constituents in the body of the rock itself are regarded as accessorial constituents. They are sometimes made up of the same common chemical components as the essential rock constituents, but much more frequently other and rarer elements enter into their composition. It is indeed almost exclusively from these accessorial minerals that many of the rare simple elements have been derived with which chemists alone have any intimate acquaintance. Thus glucinum, cerium, yttrium, lanthanium, columbium, tantalum, tungsten and zirconium are only found as components of accessorial rock constituents, while other elements, such as sulphur, phosphorus, boron, fluorine, chlorine, tin, copper, lead, chromium and titanium are frequently found in them, which but rarely occur in essential rock constituents. The following is a catalogue of the accessorial constituents of rocks, arranged according to Dana's system, which at the same time indicates briefly their chemical nature.

I. *Native elements.*

Gold.
Silver.
Mercury.
Iron.
Diamond.
Graphite.

II. *Sulphides, &c.*

Molybdenite.
Galena.
Blende.
Magnetic pyrites.
Iron pyrites.
Copper pyrites.
Skuterdite.
Cobaltite.
Leucopyrite.
Mispickel.

III. *Fluorides.*

Fluorite.
Fluocerite.

IV. *Anhydrous Oxides.*

Corundum.
Hematite.
Ilmenite.
Perofskite.
Spinelle.
Gahnite.
Chromite.
Chrysoberyl.
Tinstone.
Rutile.

V. *Anhydrous Silicates.*

1. Bi silicates.
Aegirite.
Acmite.
Spodumene.
Crocidolite.
Beryll.
Eudialite.

2. Uni silicates.
Leucophanite.
Wohlerite.
Phenakite.
Helvine.
Zircon.
Vesurianite.
Melilite.
Epidote.
Saussurite.
Allanite.
Gadolinite.

Mosandrite.
Lievrite.
Cordierite.
Lepidolite.
Scapolite.
Meionite.
Dipyre.
Sodalite.
Haüyn.
Nobean.
Leucite.

3. Subsilicates.
Tourmaline.
Andalusite.
Cyanite.
Topaz.
Titanite.
Staurolite.

VI. *Tantalates, Columbates and Tungstates.*

Pyrochlore.
Tantalite.
Columbite.
Yttrotantalite.
Aeschinite.
Polycrase.
Polymignite.
Mengite.
Wolframite.

VII. *Phosphates.*

Apatite.
Monazite.
Tryphllite.

From this list it will be seen that the accidentally-occurring minerals in crystalline rocks are five times as numerous as the essential minerals. It is scarcely possible to take a general view of the list without noting not only the number of rare elements which are found among their components, but also the preponderance of bases in their composition. The number of subsilicates and unisilicates largely exceeds that of the bisilicates. The rare tantalates, columbates, &c., are exceedingly basic, while no less than ten consist exclusively of anhydrous oxides. Another peculiarity in the composition of the silicates among them is the presence of sesqui-oxides in large quantity. Epidote, lievrite and others are silicates of alumina and peroxide of iron, while andalusite, cyanite, topaz and many others contain the former base in great abundance.

With regard to their distribution among original rocks, it is to be remarked that by far the greater number are native to the coarse-grained and schistose series, and occur in largest quantity in their neutral or siliceous families. Granites and syenites are especially rich in them, a remarkable instance being the zircon syenite of Fredericksvaern in Norway, in which no less than fifty different minerals are found, among whose components there are nine rare elements. These accessorial minerals become less frequent in the porphyritic and trachytic rocks, until among modern lavas very few of them are to be found.

The following statement shews the distribution of the accessorial minerals among the various orders of original rocks:

In coarse and small-grained rocks.

Aegirite.
Aeschinite.
Acmite.
Allanite.
Analcime.
Andalusite.
Apatite.
Apophyllite.
Beryll.
Blende.
Calcspar.
Catapleiite.
Columbite.
Copper pyrites.
Cordierite.
Corundum.
Crocidolite.
Chrysoberyll.
Cyanite.
Diamond.
Epidote.
Eudnophite.
Eukolite.
Fluocerite.
Fluorite.
Gadolinite.
Gahnite.
Galena.
Gold.
Graphite.
Hematite.
Hypostilbite.
Ilmenite.
Iron pyrites.
Lepidolite.
Leucophane.
Magnetic pyrites.
Mengite.
Mercury.
Molybdenite.
Monazite.
Mosandrite.
Phenakite.
Pinite.
Polycrase.
Polymignite.
Prehnite.
Pyrochlore.
Rutile.
Saponite.
Saussurite.
Scapolite.
Silver.
Sodalite.
Spodumene.
Tantalite.
Thorite.
Tinstone.
Titanite.
Tourmaline.
Triphylite.
Tritonite.
Vesuvianite.
Wolframite.
Wöhlerite.
Yttrotantalite.
Zircon.

In Schistose rocks.

Andalusite.
Apatite.
Beryll.
Calcspar.
Cordierite.
Corundum.
Cyanite.
Dolomite.
Fluorite.
Graphite.
Hematite.
Iron pyrites.
Lepidolite.
Molybdenite.
Rutile.
Spinelle.
Staurolite.
Titanite.
Tourmaline.
Zircon.

In Slaty Rocks.

Chiastolite.
Chloritoid.
Damourite.
Dipyre.
Fahlunite.
Ottrelite.
Paragonite.
Sericite.
Staurolite.

In Impalpable rocks.

Hauynite.
Ilmenite.
Iron.
Iron pyrites.
Magnetic pyrites.
Nepheline.
Nosean.
Sapphire.
Titanite.
Zircon.

In Porphyritic rocks.

Apatite.
Calcspar.
Crocidolite.
Delessite.
Epidote.
Fluorite.
Gieseckite.
Halloysite.
Iron pyrites.
Liebenerite.
Titanite.
Tourmaline.

In Trachytic rocks.

Apatite.
Faujasite.
Hauynite.
Hematite.
Iron pyrites.
Leucite.
Melilite.
Nepheline.
Nosean.
Sapphire.
Titanite.
Zircon.

With regard to the origin of these accessorial minerals it may be maintained that by far the greater number of those just mentioned have been developed during the solidification of the rocks containing them, and somewhat in advance of the essential constituents among which they are found. The evidence of this statement will, however, be given in the following chapter.

VII.—ON THE ORDER IN WHICH THE CONSTITUENTS OF ORIGINAL ROCKS WERE DEVELOPED.

It cannot be assumed that, in the slow crystallisation of a rock from igneous fusion, its minerals were all developed at one and the same instant. On the contrary, many of them are found under circumstances which prove that, even after their formation, the mother magna still possessed some degree of plasticity, and many of the constituents of rocks are so associated and surrounded as fairly to lead to the conclusion that a certain order was maintained in their gradual developement.

The well-known phenomena of fractured crystals in original rocks first deserves mention in this connection. Felspar crystals are frequently found in granites, broken in two pieces, these fragments being displaced, and the space between them filled up with granitic substance. This is the case with the orthoclase crystals of the porphyry of Elba and of the quartz poryhyry of Ilmenan; with the sanidine in the trachyte of Drachenfels, and with the tourmaline of the granite of Winkelsdorf in Moravia. These phenomena serve to prove that the solidification of original rocks took place very gradually, and that their crystallisation was in progress long before they became completely consolidated.

Very many of the facts recorded regarding the occurrence of accessorial minerals in rocks go to prove that they were the first to separate from the fluid magma and assume their characteristic forms. Blum has observed that the long tourmaline crystals which occur in the chloritic schists and granites of Aschoffenburg and of Winkelsdorf in Moravia, and which are frequently found fractured, have their separated fragments frequently bent out of their proper direction and cemented together by mica. The proof here seems plain as to the formation of the tourmaline prior to that of the mica.* In the large grained granite of Bergstiege, near Ruhla in Thuringia, Senft has observed that the quartz partly surrounds the tourmaline and wholly surrounds the mica plates, and regards this occurrence as proving that the formation both of the tourmaline and of the mica preceded that of the quartz.† Very many instances have been observed which go to prove the formation of tourmaline prior to quartz, and not a few from which it may reasonably be inferred that it crystallised before both mica and felspar. In connection with the ore deposits of Scandinavia, mention is made of the occurrence of iron pyrites completely enclosed in a crystal of tourmaline. A similar relation has been observed in the case of garnet, which very frequently encloses in its crystals a kernel of magnetite. Garnet is, however, noted for enclosing many other minerals, quartz, mica, iron glance, vesuvian, epidote, copper pyrites, iron pyrites, galena, blende, and especially hornblende varieties, having been found in the interior of its crystals. According to Blum the orthoclase crystals of the porphyrite of the Baranco des las Angustias, on the Island of

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* Zirkel, Petrographie I, C3.

† Die Krystalfinische Felsgementheile, p. 512.

Palma, contain radiating particles of epidote which gradually merge into the mass of the orthoclase. This and similar instances can scarcely be explained otherwise than on the supposition that the formation of the epidote preceded that of the orthoclase. Other facts concerning the occurrence of epidote in syenitic rocks would seem to indicate that the formation of the hornblende preceded or took place contemporaneously with that of the epidote. Senft has observed, near Brotterode, staurolite crystals enclosed in transparent plates of mica, and G. Rose describes both staurolite and cyanite columns as occurring in a similar manner. According to Senft, tourmaline, garnet, staurolite and cyanite are very constant companions of potash mica in crystalline rocks, and most frequently occur bedded in it as well developed crystals, and when separated from the surrounding mass of mica, leave in it an accurately bounded, smooth sided and sharp angled impression of their several forms.*

The order of the formation of the minerals of granite has been a matter of frequent discussion, and the impression prevails that the mica preceded the formation of at least the quartz in that rock. Senft thus gives the result of his observations on this matter: "Potash mica shews itself most frequently associated "with amorphous quartz and with orthoclase; with the first "usually so that it lies imbedded in its mass, which would in-"dicate a later formation for the quartz; with the orthoclase, on "the contrary, frequently so that it appears to sit upon it, so "that one must regard the mica as the newest mineral. How-"ever, there are not wanting examples of the occurrence of mica "sitting upon the quartz, nor of others in which it appears so "evenly intermixed with fresh orthoclase that one must ascribe "to them a contemporaneous origin." †

Senft has also the following remark on the mutual relations of oligoclase and hornblende: "Where oligoclase occurs in very "distinct intermixture with crystals of hornblende, it, for the "most part, surrounds them, and, indeed, often completely encloses "them in its mass. This relation plainly indicates that although "both minerals were produced in one and the same original "magma, nevertheless, the hornblende was the first born, and the "oligoclase was obliged to produce itself out of that part of the "magma remaining after the formation of the hornblende."

* Felsgemengtheile, p. 707.

† Felsgemengtheile, p. 707.

The study of the manner and order of the formation of crystalline minerals in coarse-grained, compound crystalline rocks, has not, on the whole, had that attention which it deserves. On the other hand many of the results obtained in the microscopical examination of fine-grained original rocks have an important bearing upon this subject. Vogelsang* has described with the most painstaking accuracy his observations on the mutual relations of the minerals of many pitchstones, trachytes and porphyries. Mention must first be made of a very interesting phenomenon which he has detected in the microscopical structure of many trachytic and porphyritic rocks. This is called Fluidal-structure, and seems to have been discovered somewhat earlier and independently by E. Weiss.† This term is to be understood to denote such a position of the constituents of a rock relatively to each other, as to allow of the inference being drawn that a movement of the mass either as a whole or in its smallest parts, had taken place while the process of crystallisation or solidification was going on. Eight different illustrations of this phenomenon are given in the beautifully coloured plates accompanying Vogelsang's work. One of these shews a trachytic pitchstone from the Euganean hills magnified 100 times. In a brownish perfectly vitreous matrix there are found yellowish grains of glassy felspar, needles of hornblende and microscopical crystals of magnetite. The whole of the vitreous matrix is, besides, filled with small prismatic crystals which are sharply distinguishable from the dark ground. These, Vogelsang hesitates to declare to be felspars, and in the meantime, for convenience sake, terms them "microlites." These little crystals are quite frequent in many rocks, and it is possible to distinguish light and dark coloured microlites, the former being in all likelihood scapolites or felspars, the latter augites or hornblendes. The figure shews the position of these little crystals in relation to the larger ones above named, and it is easily observed that the former lie with their longest axes parallel to each other except in the neighbourhood of the larger crystals of felspar, hornblende and magnetite, around certain sides of which they crowd more closely than elsewhere. The drawing shews the effect of the

* Beiträge zur Kemetuiss der Feldspath bildung, Haarlem, 1866.

† Vogelsang—Philosophie der Geologie und Microscopische Gesteins-studien—Bonn, 1867.

last movement of the mass at the moment of its final solidification. The observer can plainly see that this movement proceeded from right to left, crowded the microlites against the right sides of the larger previously formed crystals, and then carried them past these in the direction of the flow, namely, towards the left. The figure further shews that one large dark coloured crystal of hornblende had been broken into two pieces, and that the smallest of these, after the fracture, had been caused by the motion of the mass to assume a new position against the end of the larger piece. There can be no doubt, says Vogelsang, as to this fact, for each piece possesses a crystalline and a fractured end, and at the latter, in the larger piece, a crystal of magnetite is seen which corresponds exactly to a space visible in the broken end of the smaller piece. The crystal has evidently been broken at this weak place, and the pieces afterwards turned and pressed against each other. Sometimes the felspar crystals in this rock shew a light brown edge round the clear central mass of the crystal. When more strongly magnified, it becomes plain that the brown vitreous matrix has penetrated the crystal in innumerable places by the cleavage planes. In some crystals this only takes place to a certain depth; others are penetrated through and through by the matrix. Fluidal-structure, sometimes closely resembling that just described and sometimes considerably modified, has been observed by Vogelsang in the basalts of Unkel and Obercassel, in the lava of the island of Ischia, in the diabase of Weilburg on the Sahn, in the quartzose trachyte of Campiglia, in the black pitchstone of Zwickau, and in the quartzose porphyry of Wurtzen in Saxony. Another figure gives a representation of a part of the last named rock magnified 200 times. In this example the Fluidal-structure is not indicated by the position of crystals previously developed, but by a varied colouring which corresponds to differences of densities in the vitreous matrix. A similar appearance is frequently visible in window glass when its substance has not been rendered perfectly homogeneous in the manufacture. Through the whole of the matrix of this rock there are scattered very fine black points, but these are found much less frequently in the dark than in the light-coloured portions of the matrix.

Many of the facts observed by the naked eye, concerning the order of the formation of rock minerals, are confirmed by Vogelsang's researches with the microscope. Especially decided is the result as regards magnetite, which is invariably observed to be the oldest formed mineral in the more recent eruptive rocks, all the crystalline constituents of which enclose it. The felspars contained in trachytes, basalts, dolerites, and melaphyres, and the augites and hornblendes of the same rocks, all found the magnetite ready formed when their developement began, and enclosed it as their growth progressed. Even leucite and olivine, which are ordinarily free from foreign enclosures, are found to contain magnetite. On the other hand magnetite is seldom enclosed by quartz, but it is to be remembered that rhyolites very seldom carry the former mineral. In the matrices of many basalts, melaphyres and trachytes, which, in an undecomposed condition, present under the microscope a mass of microlites, the magnetite is found inserted between the needles and determining their limits. The andesite of Lowenburg in Siebengebirge shews, under the microscope, many of these phenomena clearly and distinctly.

In considering the observations that have been made on this subject one cannot avoid remarking that magnetite, tourmaline, and other basic accessory minerals, appear to have been the first to separate from the solidifying magma of crystalline rocks. After the very basic minerals the essential constituents seem to have been formed somewhat in the following order: 1st. Mica; 2nd. Hornblende; 3rd. Felspar; 4th. Quartz. It would, therefore, seem possible to recognise the operation of a definite law in the order of the separation of these minerals from their mother magma, namely, that the minerals of original rocks have crystallised out in the order of their basicity. Some facts, in support of the existence of such a law, are observable in connection with the composition of porphyritic rocks. Not unfrequently the felspar crystals found in these, and which we must suppose, in accordance with facts stated above, to have been produced previous to the solidification of their matrices, have a more basic composition than the latter, or, what amounts to the same thing, the composition of the matrices is more siliceous than that of the whole rock including the crystals. Thus, according to Laspeyres, the felsitic porphyry of Mühlberg, near Halle, enclosing colourless sanidine, oligoclase, quartz and a little mica, contains 72.24 p. c. silica, while the dark greyish green matrix contains 74.41 p. c. Again, the porphyrite of Gänse-Schnabel, near Ilfeld, containing triclinic felspar and other crystals has a silica contents of 64.34 p.c. The homogeneous, nearly infusible matrix of the same rock contains 67.36 p.c. of silica. The labradorite porphyrite of Mühlenthal, near Elbingerode in the Hartz, possesses a black, very fresh and hard matrix, which encloses undecomposed very lustrous crystals of labradorite, and a dark green or black augitic or hornblendic mineral. The labradorite contains 51.11 p.c. silica, while the whole rock, in spite of the presence of the, doubtless more basic, black mineral, contains 57.57 p.c. silica. On the other hand, in many porphyries and rhyolites distinct quartz crystals are developed, which, of course, must be more acid than the enclosing matrix. In spite of this exception, the law above referred to still applies so far as regards the minerals developed in crystalline rocks or separated out from their matrices during solidification.

VIII.—SPECIFIC GRAVITY.

It has been already remarked that in general the specific gravity of original rocks decreases with the increase of silica and increases with the decrease in quantity of the same substance; the most acid rocks are specifically the lightest, the most basic rocks are specifically the heaviest. Abich was the first to call attention to this as exhibited among the volcanic rocks, and to shew the conclusions which might be drawn regarding the silica contents of these rocks from their ascertained specific gravities. Although the same relation has been observed to exist among the granitic and porphyritic rocks, and doubtless runs through all the orders, it has not been found that a certain specific gravity invariably corresponds to a certain degree of silicification or that, for instance, because a syenite containing 59.83 p.c. of silica has a specific gravity of 2,730, a trachyte having the same silica contents will have the same specific gravity. On the contrary we find decided differences as to specific gravity in rocks of similar composition, but belonging to different orders of texture. The following table shews the average specific gravity of the various families of granular, porphyritic and trachytic rocks:

	GRANULAR.	PORPHYRITIC.	TRACHYTIC.
Hypersilicic rocks with over 77 p.c. silica.	Pegmatites below 2.6	Quartz porph. below 2.6	Q. trachyte below 2.57
Silicic. 70 to 77 p.c. silica	Granites.. 2.65 to 2.6	Porphyry... 2.65 to 2.6	Rhyolite ... 2.62 to 2.57
Siliceous 63 to 70 "	Granitites 2.72 to 2.65	Porphyrite.. 2.75 to 2.65	Trachyte... 2.7 to 2.62
Neutral. 56 to 63 "	Syenites.. 2.8 to 2.72	Melaphyre.. 2.8 to 2.75	Andesite ... 2.8 to 2.7
Basous.. 49 to 56 "	Gr'nstones 3.0 to 2.8	Gr. porphyry 2.9 to 2.8	Dolerite.... 2.86 to 2.8
Basic... 42 to 49 "	Anorthosyte 2.9 to 3.	Aug.porphyry 2.7 to 2.9	Nephelinite. 2.6 to 2.86

It will be observed from this table that the specific gravity of granular rocks is generally greater than that of the trachytic rocks which correspond with them in degree of acidity; granites are heavier than rhyolites, and greenstones than dolerites. (The rule does not hold good when applied to the basic rocks, but this may be owing to the facility with which they become decomposed and absorb water, which causes a material diminution of gravity.) The porphyritic rocks seem to occupy a position between the other two series, being neither so dense, relatively, as the granular nor so light as the trachytic rocks. This would seem to indicate that the coarsely granular rocks crystallised more slowly and perfectly than the porphyries and the latter more than the trachytes. This difference in density between rocks having the same percentage of silica is even more observable between trachytic and vitreous rocks. Obsidian has invariably a much less specific gravity than a quartzose trachyte which possesses the same percentage of silica. Thus we have the specific gravity of

Rhyolite from Palmarola	with 74.54 p. c. $Si. O_2$		= 2·529
Obsidian from Lipari	with 74.05	"	= 2.370
Quartz trachyte from Besobdal, Asia Minor,	with 76.56	"	= 2.656
Obsidian from Little Ararat	with 77.27	"	= 2.394

The cause of the difference seems merely to be that while the rhyolites cooled slowly and shrank together to a denser mass, the obsidians are quickly cooled unannealed natural glasses. It is well known that garnet, vesuvianite, orthoclase, labradorite, augite, and olivine have their densities much decreased by being fused and quickly cooled, and the same thing has been remarked with regard to rocks. St. Claire Deville, and Delesse experimented on several rocks, and found that their specific gravities were diminished after fusion. St. Claire Deville's results were as follows:

	Specific Gravities before fusion.	Specific Gravities after fusion.
Vitreous lava from the Peak of Teneriffe......	2.570	2.464
Trachyte from Chahorra....................	2.727	2.617
Basaltic lava from the Peak of los Majorquines	2.945	2.836
Basalt from Pic de Foga, Cape of Good Hope..	2.971	2.879
Granite from Andoux.......................	2.662	2.360

Delesse found the loss to be less with fine-grained and semi-vitreous rocks than with those of a distinctly crystalline character. According to his results, if the rocks experimented on be arranged according to the degree of diminution which their specific gravities undergo in fusion, beginning with those which experience greatest loss, those rocks will be found at the head of the list which are commonly considered to be the oldest in age. Delesse found the following per centages of diminution, the specific gravity of the various rocks before fusion being regarded as = 100.

Granite, granulite and quartz porphyry........	9—11	p. c.
Syenitic granite, and syenite	8— 9	"
Porphyry with orthoclase and oligoclase, with and without quartz........................	8—10	"
Diorite and diorite porphyry..................	6— 8	"
Melaphyre....................................	5— 7	"
Basalt, trachyte, and old volcanic rocks	3— 5	"
Lavas and volcanic rocks......................	0— 4	"

As early as 1841, Gustav Bischof made observations on the comparative volumes of Basalt, Trachyte and Granite in their crystalline, melted, and vitreous conditions, with the following results:

	Volume in vitreous condition.	in crystalline.
Basalt	1	0.9298
Trachyte	1	0.9214
Granite	1	0.8420

	Volume in a fluid state.	in crystalline.
Basalt	1	0.8960
Trachyte	1	0.8187
Granite	1	0.7481

Nothing can be more obvious from these data and experiments than that original rocks in *cooling, solidifying and crystallising*, underwent contraction, increasing thereby their density, and that the amount of contraction was the greater the more thoroughly and coarsely crystalline the rock, and the earlier the dates of its eruption in the geological history of the earth. It is not customary in treating of eruptive rocks usually to entertain any very definite ideas as to their age, but it ought not to be forgotten *that the geological experience of Europe has shewn that they* made their appearance on the earth's surface somewhat in the same order as they occupy in Table III. It would therefore seem that those rocks which have experienced most perfect crystallisation and the greatest amount of contraction or increase of density during that process are the oldest in geological age, that those which have crystallised imperfectly and experienced but a moderate amount of contraction, belong to the middle age of geological history, and that those which have solidified quickly to a semi-vitreous condition, and have experienced in so doing scarcely any contraction, are exactly those which are the most recent, and have been denominated volcanic rocks. Such results ought not to surprise us, but ought rather to be anticipated if the theory of the original igneous fluidity of the globe be well founded. The enormous degree of heat, which only could have occasioned such a condition, could not have disappeared suddenly. A gradual decrease of temperature must have taken place from the time when the solidification of the earth began down to recent geological periods. It follows that this gradually decreasing temperature must have had more or less influence upon the cooling of the various rocks protruded through the earth's crust during different geological ages. Those which appeared in earlier periods must have cooled when the earth's temperature was very high, and must therefore have enjoyed the most favorable conditions for slow and perfect crystallization and great contraction of volume, while on the other hand, those which were erupted in later ages must have appeared at a time when the temperature had much diminished, and consequently they must have solidified much more rapidly, crystallised much more imperfectly, and experienced less increase of density than their predecessors. Thus there can be distinctly traced a very decided connection between the universally accepted theory of the earth's original fluid condition and many of the facts which have been here stated with regard to the density of original rocks.

But although, generally, definite relations can be shewn to exist between the age and texture of rocks, it is not to be supposed that this is invariably the case, that there are no exceptions to the rule. It is not to be forgotten that other conditions besides the temperature of the earth's surface may have exerted their influence. Thus it is frequently the case that veins or dykes of diorite have in the centre a distinctly compound texture, while toward the sides they become almost impalpable. Then again beds of basaltite are often seen to be in the upper part and at the bottom fine-grained and compact, while in the middle they are small-grained and variolitic in texture. It is also frequently to be observed that masses of granite distinctly granular in the centre, assume towards the periphery a schistose texture, the direction of which is most generally parallel to the line of junction with the neighbouring rock. Thus it appears that in the solidification of a rock, the space which it occupied, the pressure to which it was exposed, the temperature of the enclosing rocks at the time of eruption, and the circumstances under which it was erupted, whether, for instance, on land or under water, must have influenced more or less its resulting density as well as its texture.

HISTORY OF THE NAMES CAMBRIAN AND SILURIAN IN GEOLOGY.

By T. Sterry Hunt, LL.D., F.R.S.

It is proposed in the following pages to give a concise account of the progress of investigation of the lower paleozoic rocks during the last forty years. The subject may naturally be divided into three parts: 1. The history of Silurian and Upper Cambrian in Great Britain from 1831 to 1854; 2. That of the still more ancient paleozoic rocks in Scandinavia, Bohemia, and Great Britain up to the present time, including the recognition by Barrande of the so-called primordial paleozoic fauna; 3. The history of the lower paleozoic rocks of North America.

I. Silurian and Upper Cambrian in Great Britain.

Less than forty years since, the various uncrystalline sedimentary rocks beneath the coal-formation in Great Britain and in continental Europe were classed together under the common name of graywacke or grauwacké, a term adopted by geologists from German miners, and originally applied to sandstones and other coarse sedimentary deposits, but extended so as to include associated argillites and limestones. Some progress had been made in the study of this great Graywacke formation, as it was called, and organic remains had been described from various parts of it; but to two British geologists was reserved the honor of bringing order out of this hitherto confused group of strata, and establishing on stratigraphical and paleontological grounds a succession and a geological nomenclature. The work of these two investigators was begun independently and simultaneously in different parts of Great Britain. In 1831 and 1832, Sedgwick made a careful section of the rocks of North Wales from the Menai Strait across the range of Snowdon to the Berwyn hills, thus traversing in a south-eastern direction Caernarvon, Denbigh and Merionethshire. Already, he tells us, he had in 1831, made out the relations of the Bangor group, (including the Llanberris slates and the overlying Harlech grits,) and showed that the fossiliferous strata of Snowdon occupy a synclinal, and are stratigraphically several thousand feet above the horizon of the latter. Following up this investigation in 1832, he established the great Merioneth anticlinal, which brings up the lower rocks on the south-east side of Snowdon, and is the key to the structure of North Wales. From these, as a base, he constructed a section along the line already indicated, over Great Arenig to the Bala limestone, the whole forming an ascending series of enormous thickness. This limestone in the Berwyn hills is overlaid by many thousand feet of strata as we proceed eastward along the line of section, until at length the eastern dip of the strata is exchanged for a westward one, thus giving to the Berwyn chain, like that of Snowdon, a synclinal structure. As a consequence of this, the limestone of Bala re-appears on the eastern side of the Berwyns, underlaid as before by a descending series of slates and porphyries. These results, with sections, were brought before the British Association for the Advancement of Science at its meeting at Oxford, in 1832, but only a brief and imperfect account of the communication of Sedgwick on this occasion appears in the Proceedings of the Association. He did not at this time give any distinctive name to the series of rocks in question. [L. E. & D. Philos. Mag. [1854] IV, viii, 495.]

Meanwhile, in the same year, 1831, Murchison began the examination of the rocks on the river Wye, along the southern border of Radnorshire. In the next four years he extended his researches through this and the adjoining counties of Hereford and Salop, distinguishing in this region four separate geological formations. each characterized by peculiar fossils. These formations were moreover traced by him to the south-westward across the counties of Brecon and Caermarthen; thus forming a belt of fossiliferous rocks stretching from near Shrewsbury to the mouth of the river Towey, a distance of about 100 miles along the north-west border of the great Old Red sandstone formation, as it was then called, of the west of England.

The results of his labors among the rocks of this region for the first three years were set forth by Murchison in two papers presented by him to the Geological Society of London in January, 1834. [Proc. Geol. Soc. II., 11.] The formations were then named as follows in descending order: 1. Ludlow, 2. Wenlock, constituting together an upper group; 3. Caradoc, 4. Llandeilo (or Builth) forming a lower group. The Llandeilo formation, according to him, was underlaid by what he called the Longmynd and Gwastaden rocks. The non-fossiliferous strata of the Longmynd hills in Shropshire were described as rising up to the east from beneath the Llandeilo rocks; and as appearing again in South Wales, at the same geological horizon, at Gwastaden in Breconshire, and to the west of Llandovery in Caermarthenshire;, constituting an underlying series of contorted slaty rocks many thousand feet in thickness, and destitute of organic remains. The position of these rocks in South Wales was, however, to the north-west, while the strata of the Longmynd, as we have seen, appear to the east of the fossiliferous formations.

In the *Philosophical Magazine* for July, 1835, Murchison gave to the four formations above named the designation of Silurian, in allusion, as is well known, to the ancient British tribe of the Silures. It now became desirable to find a suitable name for the great inferior series, which, according to Murchison, rose from beneath his lowest Silurian formations to the north-west, and appeared to be widely spread in Wales. Knowing that Sedgwick had long been engaged in the study of these rocks, Murchison, as he tells us, urged him to give them a British geographical name. Sedgwick accordingly proposed for this great series of Welsh rocks, the appropriate designation of Cambrian, which was at once adopted by Murchison for the strata supposed by him to underlie his Silurian system. [Murchison, Anniv. Address, 1842; Proc. Geol. Soc. III., 641.] This was almost simultaneous with the giving of the name of Silurian, for in August, 1835, Sedgwick and Murchison made communications to the British Association at Dublin on Cambrian and Silurian Rocks. These, in the volume of Proceedings (pp. 59, 60) appear as a joint paper, though from the text they would seem to have been separate. Sedgwick then described the Cambrian rocks of North Wales as including three divisions: 1. The Upper Cambrian which occupies the greater part of the chain of the Berwyns, where, according to him, it was connected with the Llandeilo formation of the Silurian. To the next lower division, Sedgwick gave the name of Middle Cambrian, making up all the higher mountains of Caernarvon and Merionethshire, and including the roofing-slates and flagstones of this region. This middle group, according to him, afforded a few organic remains, as at the top of Snowdon. The inferior division, designated as Lower Cambrian, included the crystalline rocks of the south-west coast of Caernarvon and a considerable portion of Anglesea, and consisted of chloritic and micaceous schists, with slaty quartzites and subordinate beds of serpentine and granular limestone; the whole without organic remains.

These crystalline rocks were, however, soon afterwards excluded by him from the Cambrian series, for in 1838 [Proc. Geol. Soc. II, 679] Sedgwick describes further the section from the Menai Strait to the Berwyns, and assigns to the chloritic and micaceous schists of Anglesea and Caernarvon a position inferior to the Cambrian, which he divides into two parts; viz., Lower Cambrian, comprehending the old slate series, up to the Bala limestone beds; and Upper Cambrian, including the Bala beds and the strata above them in the Berwyn chain, to which he gave the name of the Bala group. The dividing line between the two portions was subsequently extended downwards by Sedgwick to the summit of the Arenig slates and porphyries. The lower division was afterwards subdivided by him into the Bangor group, (to which the name of Lower Cambrian was henceforth to be restricted,) including the Llanberris roofing-slates and the Harlech grits or Barmouth sandstones; and the Festiniog group, which included the Lingula-flags and the succeeding Tremadoc slates.

In the communication of Murchison to the same Dublin meeting, in August, 1835, he repeated the description of the four formations to which he had just given the name of Silurian; which were, in descending order, Ludlow and Wenlock (Upper Silurian), and Caradoc and Llandeilo (Lower Silurian). The latter formation was then declared by Murchison to constitute the base of the Silurian system, and to offer in many places in South Wales distinct passages to the underlying slaty rocks, which were, according to him, the Upper Cambrian of Sedgwick.

Meanwhile, to go back to 1834, we find that after Murchison had, in his communication to the Geological Society, defined the relation of his Llandeilo formation to the underlying slaty series, but before the names of Silurian and Cambrian had been given to these respectively, Sedgwick and Murchison visited together the principal sections of these rocks from Caermarthenshire to Denbighshire. The greater part of this region was then unknown to Sedgwick, but had been already studied by Murchison, who interpreted the sections to his companion in conformity with the scheme already given; according to which the beds of the Llandeilo were underlaid by the slaty rocks which appear along their north-western border. When, however, they entered the region which had already been examined by Sedgwick, and reached the section on the east side of the Berwyns, the fossiliferous beds of Meifod were at once pronounced by Murchison to be typical Caradoc, while others in the vicinity were regarded as Llandeilo. The beds of Meifod had, on paleontological grounds, been by Sedgwick identified with those of Glyn Ceirog, which are seen to be immediately overlaid by Wenlock rocks. These determinations of Murchison were, as Sedgwick tells us, accepted by him with great reluctance, inasmuch as they involved the upper part of his Cambrian section in most perplexing difficulties. When however, they crossed together the Berwyn chain to Bala, the limestones in this locality were found to contain fossils nearly agreeing with those of the so-called Caradoc of Meifod. The examination of the section here presented showed, however, that these limestones are overlaid by a series of several thousand feet of strata bearing no resemblance either in fossils or in physical characters to the Wenlock formation which overlies the Caradoc beds of Glyn Ceirog. This series was, therefore, by Murchison supposed to be identical with the rocks which, in South Wales, he had placed beneath the Llandeilo, and he expressly declared that the Bala group could not be brought within the limits of his Silurian system. It may here be added that in 1842 Sedgwick re-examined this region, accompanied by that skilled paleontologist, Salter, confirming the accuracy of his former sections, and showing moreover by the evidence of fossils that the beds of Meifod, Glyn Ceirog and Bala are very nearly on one parallel. Yet, with the evidence of the fossils before him, Murchison, in 1834, placed the first two in his Silurian system, and the last deep down in the Upper Cambrian; and consequently was aware that on paleontological grounds it was impossible to separate the lower portion of his Silurian system from the Upper Cambrian of Sedgwick. (These names are here used for convenience, although we are speaking of a time when they had not been applied to designate the rocks in question.)

This fact was repeatedly insisted upon by Sedgwick, who, in the Syllabus of his Cambridge lectures, published very early in 1837, enumerated the principal genera and species of Upper Cambrian fossils, many of which were by him declared to be the same with those of the Lower Silurian rocks of Murchison. Again, in enumerating in the same Syllabus the characteristic species of the Bala limestone, it is added by Sedgwick: "all of which are common to the Lower Silurian system." This was again insisted upon by him in 1838 and 1841. [Proc. Geol. Soc. II, 679; III. 548.] It was not until 1840 that Bowman announced the same conclusion, which was reiterated by Sharpe in 1842. [Ramsay, Mem. Geol. Sur. III, part 2, page 6.]

In 1839, Murchison published his *Silurian System*, dedicated to Sedgwick, a magnificent work in two volumes quarto, with a separate map, numerous sections and figures of fossils. The succession of the Silurian rocks, as there given, was precisely that already set forth by the author in 1834, and again in 1835; being, in descending order, Ludlow and Wenlock, constituting the Upper Silurian, and Caradoc and Llandeilo (including the Lower Llandeilo beds or Stiper-stones), the Lower Silurian. These are underlaid by the Cambrian rocks, into which the Llandeilo was said to offer a transition marked by beds of passage. Murchison, in fact, declared that it was impossible to draw any line of separation either lithological, zoological or stratigraphical between the base of the Silurian beds (Llandeilo) and the upper portion of the Cambrian,—the whole forming, according to him, in Caermarthenshire, one continuous and conformable series from the Cambrian to the Ludlow. [Silurian System, pages 256, 358.] By Cambrian in this connection we are to understand only the Upper Cambrian or Bala group of Sedgwick, as appears from the express statement of Murchison, who alludes to the Cambrian of Sedgwick as including all the older slaty rocks of Wales, and as divided into three groups, but proceeds to say that in his present work (the Silurian System) he shall notice only the highest of these three.

Since January, 1834, when Murchison first announced the stratigraphical relations of the lower division of what he afterwards called the Silurian system, the aspect of the case had materially changed. This division was no longer underlaid, both to the east in Shropshire and to the west in Wales, by a great unfossiliferous series. His observations in the vicinity of the Berwyn hills with Sedgwick in 1834, and the subsequently published statements of the latter had shown, that this supposed older series was not without fossils; but on the contrary, in North Wales, at least, held a fauna identical with that characterising the Lower Silurian. Hence the assertion of Murchison in his *Silurian System*, in 1839, that it was not possible to draw any line of demarcation between them. The position was very embarrassing to the author of the *Silurian System*, and for the moment, not less so to the discoverer of the Upper Cambrian series. Meanwhile, the latter, as we have seen, in 1842 re-examined with Salter his Upper Cambrian sections in North Wales, and satisfied himself of the correctness, both structurally and paleontologically, of his former determinations. Murchison, in his anniversary address as President of the Geological Society in 1842, after recounting, as we have already done, the history of the naming by Sedgwick in 1835, of the Cambrian series, which Murchison supposed to underlie his Silurian system, proceeded as follows: "Nothing precise was then known of the organic contents of this lower or Cambrian system except that some of the fossils contained in its upper members in certain prominent localities were published Lower Silurian species. Meanwhile, by adopting the word Cambrian, my friend and myself were certain that whatever might prove to be its zoological distinctions, this great system of slaty rocks being evidently inferior to those zones which had been worked out as Silurian types, no ambiguity could hereafter arise. * * * In regard, however, to a descending zoological order it still remained to be proved whether there was any type of fossils in the mass of the Cambrian rocks different from those of the Lower Silurian series. If the appeal to nature should be answered in the negative, then it was clear that the Lower Silurian type must be considered the true base of what I had named the protozoic rocks; but if characteristic new forms were discovered, then would the Cambrian rocks, whose place was so well established in the descending series, have also their own fauna, and the paleozoic base would necessarily be removed to a lower horizon." If the first of these alternatives should be established, or in other words, if the fauna of the Cambrian rocks was found to be identical with that of the Lower Silurian, then, in the author's language, "the term Cambrian must cease to be used in zoological classification, it being, in that sense, synonymous with Lower Silurian." That such was the result of paleontological inquiry, Murchison proceeded to show by repeating the announcements already made by Sedgwick in 1837 and 1838, that the collections made by the latter from the great series of fossiliferous strata in the Berwyns, from Bala, from Snowdon and other Cambrian tracts, were identical with the Lower Silurian forms. These strata, it was said, contain throughout "the same forms of Orthis which typify the Lower Silurian rocks." It was farther declared by Murchison in this address, that researches in Germany, Belgium and Russia led to the conclusion that the "fossiliferous strata characterized by Lower Silurian Orthidæ are the oldest beds in which organic life has been detected." [Proc. Geol. Soc. III, 641, et seq.] The Orthids here referred to are, according to Salter, *Orthis calligramma*, Dalm, and its varieties. [Mem. Geol. Survey III, part 2, 335–337.]

Meanwhile Sedgwick's views and position began to be misrepresented. In 1842, Mr. Sharpe, after calling attention to the fact that the fossils of the Bala limestone were, as Sedgwick had long before shown, identical with those of Murchison's Lower Silurian, declared that Sedgwick had placed the Upper Cambrian, in which the Bala beds were included, beneath the Silurian, and that this determination had been adopted by Murchison on Sedgwick's authority. [Proc. Geol. Soc. IV, 10.] This statement Murchison suffered to pass uncorrected in a complimentary review of Sharpe's paper in his next annual address (1843). In his *Siluria*, 1st edition, page 25, (1854) he speaks of the term Cambrian as applied (in 1835) by Sedgwick and himself "to a vast succession of *fossiliferous* strata containing undescribed fossils, the whole of which were supposed to rise up from beneath well-known Silurian rocks. The Government geologists have shown that this *supposed* order of superposition was erroneous," &c. The italics are the author's. Such language, coupled with Mr. Sharpe's assertion noticed above, helped to fix upon Sedgwick the responsibility of Murchison's error. Although the historical sketch, which precedes, clearly shows the real position of Sedgwick in the matter, we may quote further his own words: "I have often spoken of the great Upper Cambrian group of North Wales as inferior to the Silurian system, * * * * * on the sole authority of the Lower Silurian sections, and the author's many times repeated explanations of them before they were published. So great was my confidence in his work that I received it as perfectly established truth that his order of superposition was unassailable. * * * * I asserted again and again that the Bala limestone was near the base of the so-called Upper Cambrian group. Murchison asserted and illustrated by sections the unvarying fact that his Llandeilo flag was superior to the Upper Cambrian group. There was no difference between us until his Llandeilo sections were proved to be wrong." [Philos. Mag. IV, viii, 506.] That there must be a great mistake either in Sedgwick's or in Murchison's sections was evident, and the Government surveyors, while sustaining the correctness of those of Sedgwick, have shown the sections of Murchison to have been completely erroneous.

The first step towards an exposure of the errors of the Silurian sections is, however, due to Sedgwick and McCoy. In order better to understand the present aspect of the question it will be necessary to state in a few words some of the results which have been arrived at by the Government surveyors in their studies of the rocks in question, as set forth by Ramsay in the Memoirs of the Geological Survey. In the section of the Berwyns, the thin bed of about twenty feet of Bala limestone, which, (as originally described by Sedgwick) they have found outcropping on both sides of the synclinal chain, is shown to be intercalated in a vast thickness of Caradoc rocks; being overlaid by about 3,300 and underlaid by 4,500 feet of strata belonging to this formation. Beneath these are 4,500 feet additional of beds described as Llandeilo, which rest unconformably upon the Lingula-flags just to the west of Bala; thus making a thickness of over 12,000 feet of strata belonging to the Bala group of Sedgwick. A small portion of rocks referred to the Wenlock formation occupies the synclinal above mentioned. [Memoirs, III, part 2, 214, 222.] The second member, in ascending order, of the Silurian system, to which the name of Caradoc was given by him in 1839, was originally described by Murchison under the names of the Horderley and May Hill sandstone. The higher portions of the Caradoc were subsequently distinguished by the Government surveyors as the Lower and Upper Llandovery rocks; the latter (constituting the May Hill sandstone, and known also as the Pentamerus beds, being by them regarded as the summit of the Caradoc formation. In 1852, however, Sedgwick and McCoy showed from its fauna that the May Hill sandstone belongs rather to the overlying Wenlock than to the Caradoc formation, and marks a distinct paleontological horizon.

This discovery led the geological surveyors to re-examine the Silurian sections, when it was found by Aveline that there exists in Shropshire a complete and visible want of conformity between the underlying formations and the May Hill sandstone; the latter in some places resting upon the nearly vertical Longmynd rocks, and in others upon the Llandeilo flags, the Caradoc proper or Bala group, and the Lower Llandovery beds. Again, in

South Wales, near Builth, the May Hill sandstone or Upper Llandovery rests upon Lower Llandeilo beds; while at Noeth Grug the overlying formation is traced transgressively from the Lower Llandovery across the Caradoc to the Llandeilo. These important results were soon confirmed by Ramsay and by Sedgwick. [Ibid, 4, 236.] The May Hill sandstone often includes, near its base, conglomerate beds made up of the ruins of the older formation. To the north-east, in the typical Silurian country, it is of great thickness and continuity, but gradually thins out to the south-west.

There exists, moreover, another region where not less curious discoveries were made. About forty miles to the eastward of the typical region in South Wales appear some important areas of Silurian rocks. These are the Woolhope beds, appearing through the Old Red sandstone, and the deposits of Abberley, the Malverns and May Hill, rising along its eastern border, and covered along their eastern base by the newer Mesozoic sandstone. The rocks of these localities were by Murchison in his *Silurian System* described as offering the complete sequence. When however it was found that his Caradoc included two unconformable series, examination showed that there was no representative of the older Caradoc or Bala group in these eastern regions, but that the so-called Caradoc was nothing but the Upper Llandovery or May Hill sandstone. The immediately underlying strata, which Murchison had regarded as Llandeilo, or rather as the beds of passage from Llandeilo to Cambrian, and had compared with the north-west parts of the Caermarthenshire sections, (Sil. Sys. 416.) have since been found to be much more ancient deposits, of Middle Cambrian age, which rest upon the crystalline hypozoic rocks of the Malverns, and are unconformably overlaid by the May Hill sandstone. We shall again revert to this region, which has been carefully studied and described by Prof. John Phillips. [Mem. Geol. Sur. II., part 1.]

What then was the value and the significance of the Silurian sections of Murchison, when examined in the light of the results of the Government surveyors? The Llandeilo rocks, having throughout the characteristic Orthis so much insisted upon by Murchison, were shown to be the base of a great conformable series, and to the eastward, in Shropshire, to rest on the upturned edges of the Longmynd rocks; while westward, near Bala, they overlie unconformably the Lingula-flags, and in the island of

Anglesea repose directly upon the ancient crystalline schists. According to the author of the *Silurian System*, there existed beneath the base of the Llandeilo formation a great conformable series of slaty rocks into which this formation passed, and from which it could not be distinguished either zoologically, stratigraphically or lithologically. The sequence, determined from what were considered typical sections in the valley of the Towey in Caermarthenshire, as given by Murchison, for several years both before and after the publication of his work, was as follows: 1. Cambrian; 2. Llandeilo flags; 3. Caradoc sandstone; 4. Wenlock and Ludlow beds; 5. Old Red sandstone; the order being from north-west to south-east. What then were these fossiliferous Cambrian beds underlying the Llandeilo and indistinguishable from it? Sedgwick, with the aid of the Government surveyors, has answered the question in a manner which is well illustrated in his ideal section across the valley of the Towey. The whole of the Bala or Caradoc group rises in undulations to the north-west, while the Llandeilo flags at its base appear on an anticlinal in the valley, and are succeeded to the south-east by a portion of the Bala. The great mass of this group on the south-east side of the anticlinal is however concealed by the overlapping May Hill sandstone,—the base of the unconformable upper series which includes the Wenlock and Ludlow beds. [Philos. Mag. IV, viii, 488.] The section to the south-east, commencing from the Llandeilo flags on the anticlinal, was made by Murchison the Silurian system, while the great mass of strata on the north-west side of the Llandeilo, (which is the complete representative of the Caradoc or Bala beds, partially concealed on the south-west side,) was supposed by him to lie beneath the Llandeilo, and was called Cambrian; (the Upper Cambrian of Sedgwick). These rocks, with the Llandeilo at their base, were in fact identical with the Bala group studied by the latter in North Wales, and are now clearly traced through all the intermediate distance. This is admitted by Murchison, who says: "The first rectification of this erroneous view was made in 1842 by Prof. Ramsay, who observed that instead of being succeeded by lower rocks to the north and west, the Llandeilo flags folded over in those directions, and passed under superior strata, charged with fossils which Mr. Salter recognized as well-known types of the Caradoc or Bala beds." [Siluria, 4th ed., p. 57, foot-note.]

The true order of succession in South Wales was in fact: 1, Llandeilo; 2, Cambrian (= Caradoc or Bala); 3, Wenlock and Ludlow; 4, Old Red sandstone; the Caradoc or Bala beds being repeated on the two sides of the anticlinal, but in great part concealed on the south-east side by the overlapping May Hill or Upper Llandovery rocks. These latter, as has been shown, form the true base of the upper series which, in the Silurian sections, was represented by the Wenlock and Ludlow. Murchison had, by a strange oversight, completely inverted the order of his lower series, and turned the inferior members upside down. In fact, the Llandeilo flags, instead of being, as he had maintained, superior to the Cambrian (Caradoc or Bala) beds, were really inferior to them, and were only made Silurian by a great mistake. The Caradoc, under different names, was thus made to do duty at two horizons in the Silurian system, both below and above the Llandeilo flags. Nor was this all, for by another error, as we have seen, the Caradoc in the latter position was made to include the Pentamerus beds of the unconformably overlying series. Thus it clearly appears that with the exception of the relations of the Wenlock and Ludlow beds to each other and to the overlying Old Red sandstone, which were correctly determined, the Silurian system of Murchison was altogether incorrect, and was moreover based upon a series of stratigraphical mistakes, which are scarcely paralleled in the history of geological investigation.

It was thus that the Lower Silurian was imposed on the scientific world; and we may well ask with Sedgwick, whether geologists "would have accepted the Lower Silurian classification and nomenclature had they known that the physical or sectional evidence upon which it was based had been, from the first, positively misunderstood." Feeling that his own sections were, as has since been fully established, free from error, Sedgwick naturally thought his name of Upper Cambrian should prevail for the great Bala group. Hence the long and embittered discussion that followed, in which Murchison, in many respects, occupied a position of vantage as against the Cambridge professor, and finally saw his name of Lower Silurian supplant almost entirely that of Upper Cambrian given by Sedgwick, who had first rightly defined and interpreted the geological relations of the group.

In a paper read before the Geological Society in June, 1843, [Proc. Geol Soc. IV, 212-223] when the perplexity in which the relations of the Upper Cambrian and Lower Silurian rocks were involved had not been cleared up by the discovery of Murchison's errors in stratigraphy, Sedgwick proposed a compromise, according to which the strata from the Bala limestone to the base of the Wenlock were to take the name of Cambro-Silurian; while that of Silurian should be reserved for the Wenlock and Ludlow beds, and for those below the Bala the name of Cambrian should be retained. The Festiniog group (including what were subsequently named the Lingula-flags and the Tremadoc slates) would thus be Upper instead of Middle Cambrian, the original Upper Cambrian being henceforth Cambro-Silurian; it being understood that, wherever the dividing line might be drawn, all the groups above it should be called Cambro-Silurian, and all those below it Cambrian. This compromise was rejected by Murchison, who in the map accompanying the first edition of his *Siluria*, in 1854, extended the Lower Silurian color so as to include all but the lowest division of the Cambrian; viz., the Bangor group. When, however, the relations of Upper Cambrian and Silurian were made known by the discoveries of Sedgwick and the Government surveyors, this compromise was seen to be uncalled for, and was withdrawn in 1854 by Sedgwick, who re-claimed the name of Upper Cambrian for his Bala group.

In June, 1843, Sedgwick proposed that the whole of the fossiliferous rocks below the horizon of the Wenlock should be designated Protozoic, and on the 29th of November, 1843, presented to the Geological Society an elaborate paper on the Older Paleozoic (Protozoic) Rocks of North Wales, with a colored geological map. This paper, which embodied the results of the researches of Sedgwick and Salter, was not, however published at length, but an abstract of it was prepared by Mr. Warburton, then president of the society, with a reduced copy of the map. [Proc. Geol. Soc. IV, 212 and 251-268; also Geol. Jour. I, 5-22.] In this map of Sedgwick's three divisions were established, viz., the hypozoic crystalline schists of Caernarvonshire, the "*Protozoic*," and the "*Silurian*." On the legend of the reduced map, as published by the Geological Society, these latter names were altered so as read "*Lower Silurian (Protozoic)*" and "*Upper Silurian*." These changes, in conformity with the nomenclature of Murchison, were, it is unnecessary to say, made without the knowledge of Sedgwick, who did not inspect the reduced and altered map until it was appealed to as an evidence that he had abandoned his former ground, and had recognized the equivalency of the whole of his Cambrian with the Lower Silurian of Murchison. The reader will sympathize with the indignation with which Sedgwick declares that his map was "most unwarrantably tampered with," and will, moreover, learn with surprise, that an inspection of the proof-sheets of Warburton's abstract of Sedgwick's paper was refused him, notwithstanding his repeated solicitations. The story of all this, and finally of the refusal to print in the pages of the Geological Journal the reclamations of the venerable and aggrieved author, make altogether a painful chapter, which will be found in the Philos. Magazine, for 1854 [IV, viii, pp. 301-317, 359-370, and 483-506] and more fully in the Synopsis of British Paleozoic Rocks, which forms the introduction to McCoy's British Paleozoic Fossils.

In connection with this history it may be mentioned that in March, 1845, Sedgwick presented to the Geological Society a paper on the Comparative Classification of the Fossiliferous Rocks of North Wales and those of Cumberland, Westmoreland, and Lancashire; which appears also in abstract in the same volume of the Geological Journal that contains the abstract of the essay and the map just referred to. [I, 442.] That this abstract also is made by another than the author is evident from such an expression as "the author's opinion seems to be grounded on the following facts, etc.," (p. 448) and from the manner in which the terms Lower and Upper Silurian are applied to certain fossiliferous rocks in Cumberland. Yet the words of this abstract are quoted with emphasis in Siluria [1st ed., 147] as if they were Sedgwick's own language recognizing Murchison's Silurian nomenclature.

II.—Middle and Lower Cambrian.

Investigations in continental Europe were, meanwhile, preparing the way for a new chapter in the history of the lower paleozoic rocks. A series of sedimentary beds in Sweden and Norway had long been known to abound in singular petrifications, some of which had been examined by Linnæus, who gave to them the name of *Entomolithi*. They were also studied and described by Wahlenberg and by Brongniart, the latter of whom, from two varieties of the *Entomolithus paradoxus*, Linn, established in 1822 two genera, *Paradoxides* and *Agnostus*. In 1826 appeared a memoir by Dalman on the Palæadæ or so-called Trilobites; which was followed, in 1828, by his classic work on the same subject. [Uber de Palaeaden oder so-genanten Trilobiten, 4to. with six plates, Leipsic.] In these works were described and figured, among many others, two genera—*Olenus*, which included *Paradoxides*, Brongn, and *Battus*, including *Agnostus* of the same author. Meanwhile, Hisinger was carefully studying the strata in which these trilobites were found in Gothland, and in the same year (1828) published in his *Anteckningar*, or Notes on the Physical and Geognostical Structure of Norway and Sweden, a colored geological map and section of these rocks as they occur in the county of Skaraborg; where three small circumscribed areas of nearly horizontal fossiliferous strata are shown to rest upon a floor of old crystalline rocks, in some parts granitic and in others gneissic in character. The section and map, as given by Hisinger, show the succession in the principal area to be as follows, in ascending order: 1. granite or gneiss; 2. sandstone; 3. alum-slates; 5. orthoceratite-limestones; 4. clay-slates. By a curious oversight the colors on the legend are wrongly arranged and wrongly numbered, as above; for in the map and section it is made clear that the succession is that just given, and that the clay-slates (4), instead of being below, are above the orthoceratite-limestones (5).

In 1837, Hisinger published his great work on the organic remains of Sweden, entitled *Lethæa Suecica* [4to. with forty-two plates.] In this he gives a tabular view, in descending order, of the rock-formations, and of the various genera and species described. The rocks of the areas just noticed appear in his fourth or lowest division, under the head of *Formationes transitionis*, and are divided as follows:

a. Strata calcarea recentiora Gotllandiæ.
b. Strata schisti argillacei.
c. Strata schisti aluminaris.
d. Strata calcarea antiquiora.
e. Strata saxi arenacei.

The succession thus given was however erroneous, and probably, like the mistake in the legend of the same author's map just mentioned, the result of inadvertence, *the true position* of the alum-slates (c) being between the older limestone (*d*) and the basal sandstone (*e*). This is shewn both by Hisinger's map of 1828, and by the testimony of subsequent observors. In Murchison's work on the Geology of Russia in Europe, published in 1845, there is given (page 15 et seq.) an account of his visit to this region in company with Prof. Loven, of Christiania; which, with figures of the sections, is reproduced in the different editions of Siluria. The hill of Kinnekulle on Lake Wener, is one of the three areas of transition rocks delineated on the map of Hisinger above referred to. Resting upon a flat region of nearly vertical gneissic strata, we have, according to Murchison: 1. a fucoidal sandstone; 2. alum-slates; 3. red orthoceratite-limestone; 4. black graptolitic slates; the whole series being little over 1000 feet in thickness, and capped by erupted greenstone. Above these higher slates there are found in some parts of Gothland, other limestones with orthoceratites, trilobites and corals, the newer limestone strata (*a*) of Hisinger; the whole overlaid by thin sandstone beds. These higher limestones and sandstones contain the fauna of the Wenlock and Ludlow of England; while the lower limestones and graptolitic slates afford *Calymene Blumenbachii*, *Orthis calligramma*, and many other species common to the Bala group of North Wales. The alum-slates below these however, contained, according to Hisinger, none of the species then known in British rocks, but in their stead five species of *Olenus* and two of *Battus* (*Agnostus*.)

In 1854, Angelin published his *Palæontologica Scandinavica*, part I, *Crustacea formationis transitionis*, [4to. forty-one plates] in which he divided the series of transition rocks above described by Hisinger into eight parts designated by Roman numerals, counting from the base. Of these I was named *Regio Fucoidarum*, no organic remains other than fucoids being know therein; while the remaining seven were named from their characteristic genera of trilobites, which were as follows, in ascending order; certain letters being also used to designate the parts: II. (A) Olenus; III. (B) Conocoryphe; IV. (BC) Ceratopyge; V. (C) Asaphus; VI. (D) Trinucleus; VII. (DE) Harpes; VIII. (E) Cryptonymus. In the *Regio Olenorum* (II) was found also the allied genus *Paradoxides*. With regard to the characteristic genus of Regio III., the name of *Conocoryphe* was proposed for it by Corda in 1847, as synonymous with Zenker's name of *Conocephalus* (*Conocephalites*) already appropriated to a genus of insects.

Meanwhile, the similar crustaceans which abound in the transition rocks of Bohemia had been studied and described by Hawle, Corda and Beyrich, when Barrande began his admirable investigations of this ancient fauna and of its stratigraphical relations. He soon found that beneath the horizon characterized by fossils of the Bala group (Llandeilo and Caradoc) there existed in Bohemia a series of strata distinguished by a remarkable fauna, entirely distinct from anything known in Great Britain, but closely allied to that of the alum-slates of Scandinavia, corresponding to Regiones II. and III. of Angelin. To this he gave the name of the first or primordial fauna, and to the rocks yielding it that of the Primordial Zone. Resting upon the old gneisses of Bohemia appears a series of crystalline schists designated by Barrande as *Etage A*, overlaid by a series of sandstones and conglomerates, *Etage B*, upon which repose the fossiliferous argillites of the primordial zone or *Etage C*. The rocks of the Etages A and B were by Barrande regarded as azoic, but in 1861, Fritsch of Prague, after a careful search, discovered in certain thin-bedded sandstones of B, the traces of filled-up vertical double tubes; which, according to Salter, [Mem. Geol. Sur. III., 243] are probably the marks of annelides, and are identical with those found in the rocks of the Bangor or Longmynd group in Great Britain; which will be shown to belong to the primordial zone. It is, therefore, probable that the Etage B, which apparently corresponds to the Regio Fucoidarum or basal sandstone of Scandinavia, should itself be included in the primordial zone. It may here be noticed that it is in the crystalline schists of A that Gumbel has found *Eozoon Bavaricum*. To the Etage C in Bohemia, Barrande assigns a thickness of about 1200 feet, and to this his first fauna is confined, while in the succeeding divisinos he distinguished a second and a third. The second fauna, which characterizes Etage D, corresponds to that of the Bala group; while the third fauna, belonging to the Etages E, F, G and H, is that of the May Hill, Wenlock and Ludlow formations of Great Britain.

This classification of the ancient Bohemian faunas was first set forth by Barrande in 1846, in his *Notice Preliminaire*, in which he declared that the first fauna was below the base of the Llandeilo of Murchison, unknown in Great Britain, and, moreover, "new and independent in relation to the two Silurian faunas (his second and third) already established in England." This opinion he reiterated in 1859. These three divisions form in Bohemia an apparently continuous series, and being connected with each other by some common species, Barrande was led to look upon the whole as forming a single stratigraphical system;

and finally to assert that these three independent faunas "form by their union an indivisible triad which is the Silurian system." [Bul. Soc. Geol. de Fr. II, xvi, 529-545.] Already, in 1852, in his magnificent work on the Silurian System of Bohemia, Barrande had given to the strata characterized by his first fauna the name of Primordial Silurian. It is difficult to assign any just reason for thus annexing to the Silurian,—already augmented by the whole Upper Cambrian or Bala group of Sedgwick, (Llandeilo and Caradoc)—a great series of fossiliferous rocks lying below the base of the Llandeilo, and unsuspected by the author of the Silurian system; who persistently claimed the Llandeilo beds, with their characteristic second fauna, as marking the dawn of organic life.

Up to this time the primordial paleozoic fauna of Bohemia and of Scandinavia was, as we have said, unknown in Great Britain. The few organic remains mentioned by Sedgwick in 1835 as occurring in the region occupied by his Lower and Middle Cambrian, on Snowdon, were found to belong to Bala beds, which there rest upon the older rocks: nor was it until 1845 that Mr. Davis found in the Middle Cambrian remains of Lingula. In 1846, Sedgwick, in company with Mr. Davis, re-examined these rocks, and in December of the same year described the Lingula-beds as overlaid by the Tremadoc slates and occupying a well-defined horizon in Caernarvon and Merionethshire, beneath the great mass of the Upper Cambrian rocks. [Geol. Jour. II, 75, III, 139.] Sedgwick, at the same time, noticed about this horizon certain graptolites and an Asaphus, which were supposed to belong to the Tremadoc slates, but have since been declared by Salter to pertain to the Arenig or Lower Llandeilo beds, the base of the Upper Cambrian. [Mem. Geol. Sur. III, 257, and Decade II.]

This discovery of the Lingula-flags, as they were then named, and the fixing by Sedgwick of their geological horizon, was at once followed by a careful examination of them by the Government surveyors, and in 1847, Selwyn detected in the Lingula-flags, near Dolgelly, in Merionethshire, the remains of two crustacean forms, the one a phyllopod, which has received the name of *Hymenocaris vermicauda*, Salter, and the other a trilobite which was described by Salter in 1849 as *Olenus micrurus*. [Geol. Survey, Decade II.] A species of Paradoxides, apparently identical with *P. Forchhammeri* of Sweden, was also about this time recognized among specimens supposed to be from the same horizon. It has since been described as *P. Hicksii*, and found to belong to the basal beds of the Lingula-flags,—the Menevian group.

Upon the flanks of the Malvern Hills there are found resting upon the ancient crystalline rocks of the region, and overlaid by the Pentamerus beds of the May Hill sandstone (originally called Caradoc by Murchison) a series of fossiliferous beds. These consist in their lowest part of about 600 feet of greenish sandstone, which have since yielded an *Obolella* and *Serpulites*, and are overlaid by 500 feet of black schists. In these, in 1842, Prof. John Phillips found the remains of trilobites, which he subsequently described, in 1848, as three species of Olenus. [Mem. Geol. Survey II, part 1, 55.] These black shales, which had not at that time furnished any organic remains, were by Murchison in his Silurian System (p. 416) in 1839 compared to the supposed passage-beds in Caermarthenshire between the Llandeilo and the Cambrian (Bala) rocks; which, as we have seen, were newer and not older strata than the Llandeilo flags. From their lithological characters, and their relations to the Pentamerus beds, these lower fossiliferous strata of Malvern were subsequently referred by the Government geologists to the horizon of the Caradoc proper or Bala group; nor was it until 1851, that their true geological age and significance were made known. In that year, Barrande, fresh from the study of the older rocks of the continent, came to England for the purpose of comparing the British fossils with those of the primordial zone, which he had established in Bohemia and Scandinavia, and which he at once recognized in the Lingula-flags of Sedgwick and in the black schists at Malvern; both of which were characterized by the presence of the genus *Olenus*, and were referred to the horizon of his Etage C. This important conclusion was announced by Salter to the British Association at Belfast in 1852. [Rep. Brit. Assoc., abstracts, p. 56, and Bull. Soc. Geol. de Fr. II, xvi, 537.] Since that time the progress of investigation in the Middle and Lower Cambrian rocks of Wales has shown a fauna the importance and richness of which has increased from year to year.

The paleontological studies of Salter, while they confirmed the primordial character of the whole of the great mass of strata which make up the Middle Cambrian or Festiniog group of Sedgwick, (consisting of the Lingula-flags and the Tremadoc slates,) led him to propose several sub-divisions. Thus he distinguished on paleontological grounds between the upper and lower Tremadoc slates, and for like reasons divided the Lingula-flags into a lower and an upper portion. For the discussion of these distinctions the reader is referred to the memoirs of the Geol. Survey [III, 240-257.] Subsequent researches led to the division of the original Lingula-flags into three parts, an upper and a middle, to which the names of Dolgelly and Maentwrog were given by Mr. Belt, and a third consisting of the basal beds, which were separated in 1865, by Salter and Hicks, with the designation of Menevian, derived from the ancient Roman name of St. David's in Pembrokeshire. It was here that in 1862, Salter found *Paradoxides* with *Agnostus* and *Lingula* in fine black shales at the base of the Lingula-flags, resting comformably on the green and purple grits of the Lower Cambrian or Harlech beds. The locality was afterwards carefully studied by Hicks, and it was soon made apparent that the genus Paradoxides, both here and in North Wales, was confined to a horizon below the great mass of the Lingula-flags; which, on the contrary, are characterized by numerous species of Olenus. These lower or Menevian beds are hence regarded by Salter as equivalent to the lowest portion of the Etage C of Barrande.

Beneath these Menevian beds there lies, in apparent conformity, the great Lower Cambrian series, frequently called the bottom or basement rocks by the Government surveyors; represented in North Wales by the Harlech grits, and in South Wales, near St. Davids, by a similar series of green and purple sandstones, considered by Murchison, and by others, as the equivalent of the Harlech rocks. They were still supposed to be unfossiliferous until in June, 1867, Salter and Hicks announced the discovery in the red beds of this lower series, at St. Davids, of a Lingulella, very like *L. ferruginea* of the Menevian. [Geol. Jour. XXIII, 339; Siluria 4th ed. 550.] This led to a farther examination of these Lower Cambrian beds, which has resulted in the discovery in them of a fauna distinctly primordial in type, and linked by the presence of several identical fossils to the Menevian; but in many respects distinct, and marking a lower fossiliferous horizon than anything known in Bohemia or in Scandinavia.

The first announcement of these important results was made to the British Association at Norwich in 1868. Further details were, however, laid before the Geological Society in May, 1871, by Messrs. Harkness and Hicks, whose paper on the Ancient Rocks of St. David's Promontory appears in the Geological Journal for November, 1871. [XXVIII, 384.] The Cambrian sediments here rest upon an older series of crystalline stratified rocks, described by the geological surveyors as syenite and greenstone, and having a north-west strike. Lying unconformably upon these, and with a north-east strike, we have the following series, in ascending order: 1. quartzose conglomerate, 60 feet; 2. greenish flaggy sandstones, 460 feet; 3. red flags or slaty beds, 50 feet, containing *Lingulella ferruginea*, besides a larger species, *Discina*, and *Leperditia Cambrensis*; 4. purple and greenish sandstones, 1000 feet; 5. yellowish gray sandstones, flags and shales, 150 feet, with *Plutonia*, *Conocoryphe*, *Microdiscus*, *Agnostus*, *Theca* and *Protospongia*; 6. gray, purple and red flaggy sandstones, with most of the above genera, 1500 feet; 7. gray flaggy beds, 150 feet, with *Paradoxides*; 8. true Menevian beds, richly fossiliferous, 500 feet. The latter are the probable equivalent of the base of Barrande's Etage C, and at St. David's are conformably overlaid by the Lingula-flags; beneath which we have, including the Menevian, a conformable series of 3370 feet of uncrystalline sediments, fossiliferous nearly to the base, and holding a well-marked fauna distinct from anything hitherto known in Great Britain or elsewhere.

The Menevian beds are connected with the underlying strata by the presence of *Lingulella ferruginea*, *Discina pileolus*, and *Obolella sagittatis*, which extend through the whole series; and also by the genus Paradoxides, four species of which occur in these lower strata; from which the genus Olenus, which characterizes the Lingula-flags, seems to be absent. To a large tuberculated trilobite of a new genus found in these lowest rocks the name of *Plutonia Sedgwickii* has been given. Hicks has proposed to unite the Menevian with the Harlech beds, and to make the summit of the former the dividing line between the Lower and Middle Cambrian, a suggestion which has been adopted by Lyell. [Proc. Brit. Assoc. for 1868, p. 68, and Lyell, Student's Manual of Geology, 466–469.]

Both Phillips and Lyell give the name of Upper Cambrian to the Lingula-flags and the Tremadoc slates, which together constitute the Middle Cambrian of Sedgwick, and concede the title of Lower Silurian to the Bala group or Upper Cambrian of Sedgwick. The same view is adopted by Linnarsson in

Sweden, who places the line between Cambrian and Silurian at the base of the Llandeilo or the second fauna. It was by following these authorities that I, inadvertently, in my address to the American Association for the Advancement of Science in August, 1871, gave this horizon as the original division between Cambrian and Silurian. The reader of the first part of this paper will see with how much justice Sedgwick claims for the Cambrian the whole of the fossiliferous rocks of Wales *beneath* the base of the May Hill sandstone, including both the first and the second fauna. I cannot but agree with the late Henry Darwin Rogers, who, in 1856, reserved the designation of "the true European Silurian" for the rocks *above* this horizon. [Keith Johnson's Physical Atlas, 2nd ed.]

The Lingula-flags and Tremadoc slates have been made the subject of careful stratigraphical and paleontological studies by the Geological Survey, the results of which are set forth by Ramsay and Salter in the third volume of the Memoirs of the Geological Survey, published in 1866, and also, more concisely, in the Anniversary Address by the former to the Geological Society in 1863. [Geol. Jour. XIX, xviii.] The Lingula flags (with the underlying Menevian, which resembles them lithologically) rest in apparent conformity upon the purple Harlech rocks both in Pembrokeshire and in Merionethshire, where the latter appear on the great Merioneth anticlinal, long since pointed out by Sedgwick. The Lingula-flags, (including the Menevian) have in this region, according to Ramsay, a thickness of about 6000 feet. Above these, near Tremadoc and Festiniog, lie the Tremadoc slates, which are here overlaid, in apparent conformity, by the Lower Llandeilo beds. At a distance of eleven miles to the north-west, however, the Tremadoc slates disappear, and the Lingula-flags are represented by only 2,000 feet of strata; while in parts of Caernarvonshire, and in Anglesea, the whole of the Lingula-flags and moreover the Lower Cambrian rocks, are wanting, and the Llandeilo beds rest directly upon the ancient crystalline schists. In Scotland and in Ireland, moreover, the Lingula-flags, are wholly absent, and the Llandeilo rocks there repose unconformably upon grits regarded as of Lower Cambrian age. Thus, without counting the Tremadoc slates, which are a local formation, unknown out of Merionethshire, we have (including the Bangor group and Lingula-flags,) beneath the Llandeilo, over 9,000 feet of fossiliferous strata, which disappear entirely in the distance of a few miles. From a careful survey of all the facts, the conclusion of Ramsay is irresistible, that there exists between the Lingula-flags and the Llandeilo not merely one, but two great stratigraphical breaks in the succession; the one between the Lingula-flags and the Lower Tremadoc slates, and the other between the Upper Tremadoc slates and the Lower Llandeilo.

This conclusion is confirmed by the fact that there exists at each of these horizons a nearly complete paleontological break. The fauna of the Tremadoc slates is, according to Salter, almost entirely distinct from that of the Lingula-flags, and not less distinct from that of the so-called Lower Llandeilo or Arenig rocks, (the equivalents of the Skiddaw slates of Cumberland). Hence, says Ramsay, it is evident "that in these strata we have three perfectly distinct zones of organic remains, and therefore, in common terms, three distinct formations." The paleontological evidence is thus in complete accordance with that furnished by stratigraphy. We cannot leave this topic without citing the conclusion of Ramsay that "each of these two breaks necessarily implies a lost epoch, stratigraphically quite unrepresented in our area; the life of which is only feebly represented in some cases by the fossils common to the underlying and overlying formation." In connection with this remark, which we conceive to embody a truth of wide application, it may be said that stratigraphical breaks and discordances in a geological series, may, *à priori*, be expected to occur most frequently in regions where this series is represented by a large thickness of strata. The accumulation of such masses implies great movements of subsidence, which, in their nature, are limited, and are accompanied by elevations in adjacent areas, from which may result, over these areas, either interruptions in the process of sedimentation, or the removal, by sub-aerial or sub-marine denudation, of the sediments already formed. The conditions of succession and distribution, it may be conceived, would be very different in a region where the period corresponding to this same geological series was marked by comparatively small accumulations of sediment upon an ocean-floor subjected to no great movements.

This contrast is strikingly seen between the conformable series of less than 2,000 feet of strata which in Scandinavia are characterized by the first three paleozoic faunas (Cambrian and Silurian) and the repeatedly broken and discordant succession of more than 30,000 feet of sediments,* which in Wales are their paleontological equivalents. It must, however, be considered that in regions of small accumulation where, as in Scandinavia, the formations are thin, there may be lost or unrepresented zoological epochs whose place in the series is marked by no stratigraphical break. In such comparatively stable regions, movements of the surface sufficient to cause the exclusion, or the disappearance by removal, of the small thickness of strata corresponding to an epoch, may take place without any conspicuous marks of stratigraphical discordance.

The attempt to establish geological divisions or horizons upon stratigraphical or paleontological breaks must always prove fallacious. From the nature of things, these, whether due to non-deposition or to subsequent removal of deposits, must be local; and we can say, confidently, that there exists no break in life or in sedimentation which is not somewhere filled up and represented by a continuous and conformable succession. While we may define one period as characterized by the presence of a certain fauna, which, in a succeeding epoch, is replaced by a different one, there will always be found, in some part of their geographical distribution, a region where the two faunas commingle, and where the gradual disappearance of the old before the new may be studied. The division of our stratified rocks into systems is therefore unphilosophical, if we assign any definite or precise boundaries or limitations to these. It was long since said by Sedgwick with regard to the whole succession of life through geologic time, —that all belongs to one great *systema naturæ*. [Philos. Mag. IV. viii, 359.]

We have already noticed that Barrande, as early as 1852, gave the name of Primordial Silurian to the rocks which, in Bohemia, were marked by the first fauna; although he, at the

* The Longmynd rocks in Shropshire are alone estimated at 20,000 feet; but their supposed equivalents, the Harlech rocks of Pembrokeshire, have a measured thickness of 3,300, while the Llanberris and Harlech rocks together, in North Wales, equal from 4,000 to 7,000 feet, and the Lingula-flags and Tremadoc slates, united, about 7,000 feet. The Bala group in the Berwyns exceeds 12,000 feet, and the proper Silurian, from the base of the Upper Llandovery or May Hill sandstone, attains from 5,000 to 6,000 feet; so that the aggregate of 30,000 feet may be considered below the truth. [Mem. Geol. Survey, III, part 2, pages 72, 222, and Siluria, 4th ed. 185.]

same time, recognized this as distinct from and older than the second fauna, discovered in the Llandeilo rocks, which Murchison had declared to represent the dawn of organic life. Into the reasons which led Barrande to include the rocks of the first, second and third faunas in one Silurian system, (a view which was at once adopted by the British Geological Survey and by Murchison himself,) it is not our province to inquire, but we desire to call attention to the fact that the latter, by his own principles, was bound to reject such a classification. In his address before the Geological Society in 1842, (already quoted in the first part of this paper,) he declared that the discussion as to the value of the term Cambrian involved the question "whether there was any type of fossils in the mass of the Cambrian rocks different from those of the Lower Silurian series. If the appeal to nature should be answered in the negative, then it was clear that the Lower Silurian type must be considered the true base of what I had named the protozoic rocks; but if characteristic new forms were discovered, then would the Cambrian rocks, whose place was so well established in the descending series, have also their own fauna, and the paleozoic base would necessarily be removed to a lower horizon."

In the event of no distinct fauna being found in the Cambrian series, it was declared that "the term Cambrian must cease to be used in zoological classification, it being, in that sense, synonymous with Lower Silurian." [Proc. Geol. Soc. III, 641 et seq.] That such had been the result of paleontological inquiry Murchison then proceeded to show. Inasmuch as the only portion of Sedgwick's Cambrian which was then known to be fossiliferous, was really above and not below the Llandeilo rocks, which Murchison had taken for the base of his Lower Silurian, his reasoning with regard to the Cambrian nomenclature, based on a false datum, was itself fallacious; and it might have been expected that when the government surveyors had shown his stratigraphical error, Murchison would have rendered justice to the nomenclature of Sedgwick. But when, still later, a farther "appeal to nature" led to the discovery of "characteristic new forms," and established the existence of a "type of fossils in the mass of the Cambrian rocks, different from those of the Lower Silurian series," Murchison was bound by his own principles to recognize the name of Cambrian for the great Festiniog group, with its primordial fauna, even though Barrande and the government surveyors should unite in calling it Primordial Silurian.

He however chose the opposite course, and now attempted to claim for the Silurian system the whole of the Middle Cambrian or Festiniog group of Sedgwick, including the Tremadoc slates and the Lingula-flags. The grounds of this assumption, as set forth in the successive editions of Siluria from 1854 to 1867, and in various memoirs, may be included under three heads: first that the Lingula-flags have been found to exist in some parts of his original Silurian region; second, that no clearly-defined base had been assigned by him to his-so-called system; and third, that there are no means of drawing a line of demarkation between these Middle Cambrian formations and the overlying Llandeilo.

With regard to the first of these reasons, it is to be said that the only known representatives of the Lingula-flags in the region described by Murchison in his *Silurian System* are the black slates of Malvern; and some scanty outliers which, in Shropshire, lie between the old Longmynd rocks and the base of the Stiperstones. The former were then (as has already been shown) supposed by him to belong to the Llandeilo, or rather to the passage-beds between the Llandeilo and Cambrian (Bala); while with regard to the latter, Ramsay expressly tells us that they were not originally classed with the Silurian, but have since been included in it. [Mem. Geol. Sur. III, part 2, page 9; and 242, foot-note.]

The Llandeilo beds were by Murchison distinctly stated to be the base of the Silurian system [Sil. Sys. 222.]; and it was farther declared by him that in Shropshire, (unlike Caermarthenshire,) "there is no passage from the Cambrian to the Silurian strata," but a hiatus, marked by disturbances which excluded the passage-beds, and caused the Lower Silurian to rest unconformably upon the Longmynd rocks. [Ibid, 256; and plates 31, sections 3 and 6; 32, section 4.] But in *Siluria* [1st. ed. 47] the two are stated to be conformable; and in the subsequent sections of this region, made by Aveline, and published by the Geological Survey, the evidences of this want of conformity do not appear. Murchison at that time confounded the rocks of the Longmynd with the Cambrian (Bala) beds of Caermarthenshire and Brecon. [Sil. Sys. 416.] Hence it was that he gave the name of Cambrian to the former; and this mistake, moreover, led him to place the Cambrian of Caermarthenshire beneath the Llandeilo. It is clear that if he claimed no well-defined base to the Llandeilo rocks in this latter (their typical region), it was because he saw them passing into the overlying Bala beds. There was, in the error by which he placed *below* the Llandeilo, strata which were really *above* them, no ground whatever for afterwards including in his Silurian system, as a downward continuation of the Llandeilo rocks (which are the basal portion of the Bala group), the whole Festiniog group of Sedgwick; whose infra-position to the Bala had been shown by the latter long before it was known to be fossiliferous.

It was however claimed by Murchison that no line of separation can be drawn between these two groups. The results of Ramsay and of Salter, as set forth in the address of the former before the Geological Society in 1863, and more fully in the Memoirs of the Geological Survey [vol. III. part 2] published in 1866, with a preface by himself, as the director of the Survey, are completely ignored by Murchison. The reader familiar with these results, of which we have given a summary, finds with surprise that in the last edition of *Siluria*, that of 1867, they are noticed in part, but only to be repudiated. In the five pages of text which are there given to this great Middle Cambrian division, we are told that the distinction between the Lower Tremadoc and the Lingula-flags "is difficult to be drawn," and that the Upper Tremadoc slate passes into and forms the lower part of the Llandeilo, "into which it graduates conformably." (Siluria, 4th ed. p. 46.) In each of these cases, on the contrary, according to Ramsay, there is observed "a break very nearly complete both in genera and species, and probable unconformity;" the evidence of the paleontological break being furnished by the careful studies of Salter; while that of the stratigraphical break, as we have seen, leaves no reason for doubt. [Mem. Geol. Sur. III, part 2, pages 2, 161, 234.] The student of *Siluria* soon learns that in all cases where Murchison's pretensions were concerned, the book is only calculated to mislead.

The reader of this history will now be able to understand why, notwithstanding the support given by Barrande, by the Geological Survey of Great Britain, and by most American geologists to the Silurian nomenclature of Murchison, it is rejected, so far as the Lingula-flags and the Tremadoc slates are concerned, by Lyell, Phillips, Davidson, Harkness and Hicks in England, and by Linnarsson in Sweden. These authorities have, however, admitted the name of Lower Silurian for the Bala group or

Upper Cambrian of Sedgwick; a concession which can hardly be defended, but which apparently found its way into use at a time when the yet unravelled perplexities of the Welsh rocks led Sedgwick himself to propose, for a time, the name of Cambro-Silurian for the Bala group. This want of agreement among geologists as to the nomenclature of the lower paleozoic rocks, causes no little confusion to the learner. We have seen that Henry Darwin Rogers followed Sedgwick in giving the name of Cambrian to the whole paleozoic series up to the base of the May Hill sandstone; and the same view is adopted by Woodward in his Manual of the Mollusca. The student of this excellent book will find that in the tables giving the geological range of the mollusca, on pages 124, 125 and 127, the name of Cambrian is used in Sedgwick's sense, as including all the fossiliferous strata beneath the May Hill sandstone. On page 123 it is however explained that Lower Silurian is a synonym for Cambrian, and it is so used in the body of the work.

The distribution of the Lower and Middle Cambrian rocks in Great Britain may now be noticed. The former, or Bangor group, to which Murchison and the Geological Survey restrict the name of Cambrian, and which they sometimes call the Longmynd, bottom or basement rocks, occupy two adjacent areas in Caernarvon and Merionethshire; the one near Bangor, including Llanberris, to the north-east, and the other, including Harlech and Barmouth, to the south-east of Snowdon; this mountain lying in a synclinal between them, and rising 3571 feet above the sea. The great mass of grits or sandstones appears to be at the summit of the group, but in the lower part the blue roofing-slates of Llanberris are interstratified in a series of green and purple slates, grits and conglomerates. (Some of the Welsh roofing-slates are however supposed to belong to the Llandeilo). [Mem. Geol. Survey III, part 2, pages 54, 258.] The Harlech rocks in this north-western region are conformably overlaid by the Menevian, followed by the true Lingula-flags, or Olenus beds, of the Middle Cambrian. Upon these repose the Tremadoc slates, which are not known in the other parts of Wales. The third area of Lower Cambrian rocks is that already described at St. David's in Pembrokeshire, about 100 miles to the south-west; and the fourth, that of the Longmynd hills, about sixty miles to the south-east of Snowdon. The rocks of the Longmynd, like those of the other Lower Cambrian areas mentioned, consist principally of green and purple sandstones with conglomerates, shales and some clay-slates. They occasionally hold flakes of anthracite, and small portions of mineral pitch exude from them in some localities. The only evidence of animal life yet found in the rocks of the Longmynd are furnished by worm-burrows, the obscure remains of a crustacean, (the *Palæopyge Ramsayi*,) and a form like *Histioderma*. This latter organic relic, with worm-burrows, and the fossils named *Oldhamia*, is found on the coast of Ireland opposite Caernarvonshire, in the rocks of Bray Head; which resemble lithologically the Harlech beds, and are regarded as their equivalents.

Still another area of the older rocks is that of the Malvern hills, on the western flanks of which, as already mentioned, the Lingula-flags are represented by about 500 feet of black shales with Olenus, underlaid by 600 feet of greenish sandstones containing traces of fucoids, with Serpulites and an Obolella. It is not improbable, as suggested by Barrande and by Murchison, that these 1100 feet of strata represent, in this region, the great mass of the Lingula-flags,—and, we may add, perhaps the whole series of Lower Cambrian strata, which in Caernarvonshire and Pembrokeshire underlie them; since these sandstones of Malvern, like those of St. David's, rest upon crystalline schists, and are in part made up of their ruins.

These crystalline schists of Malvern, which are described by Phillips as the oldest rocks in England, and by Mr. Holl are conjectured to be Laurentian, seem from the descriptions of their lithological characters to resemble those of Caernarvon and Anglesea, with which they are, by Murchison, regarded as identical. The crystalline schists of these latter localities are, by Sedgwick, described as hypozoic strata, below the base of the Cambrian., Murchison however, in the first edition of his *Siluria*, adopted the suggestion of De la Beche that they themselves were altered Cambrian strata. In fact they directly underlie the Llandeilo rocks, and were apparently conceived by Murchison to represent the downward continuation of these, upon which he had insisted. This opinion is supported by ingenious arguments on the part of Ramsay. [Mem. Geol. Survey, III, part 2, passim.] I am however disposed to regard them, with Sedgwick and Phillips, as of pre-Cambrian age, and to compare them with the Huronian series of North America, which occupies a similar geological horizon, and with which, as seen in northern Michigan, and in the

Green Mountains, I have found the rocks of Anglesea to offer remarkable lithological resemblances.

It may here be noticed that the gold-bearing quartz veins in North Wales are found in the Menevian beds, and also, according to Selwyn, throughout the Lingula-flags. These fossiliferous strata at the gold-mine near Dolgelly appear in direct contact with diorites and chloritic and talcose schists, which are more or less cupriferous, and themselves also contain gold-bearing quartz veins. [Mem. Geol. Survey, part 2, pp. 42; 45, and Siluria, 4th ed., 450, 547.]

The Table on page 312 gives a view of the lower paleozoic rocks of Great Britain and North America, together with the various nomenclatures and classifications referred to in the preceding pages. In the second column, the horizontal black lines indicate the positions of the three important paleontological and stratigraphical breaks signalized by Ramsay in the British succession. [Mem. Geol. Survey, III, part 2, page 2.] In a table by Davidson in the *Geological Magazine* for 1868 [V. 305] showing the distribution of organic remains in these lower rocks, he gives, as the Festiniog group of Sedgwick, only the Dolgelly and Maentwrog beds of Belt (the Upper and Middle Lingula-flags); and makes of the two divisions of the Tremadoc rocks a separate group; the whole being described as the Upper Cambrian of Sedgwick. This however is not the present grouping and nomenclature of Sedgwick, nor was it his earlier one. So far as regards Middle and Upper Cambrian, this discrepancy is explained by the fact already stated, that in 1843 Sedgwick proposed, as a compromise, the name of Cambro-Silurian for his Bala group, previously called Upper Cambrian; by which change the Festiniog or Middle Cambrian became Upper Cambrian. When the true relation between the Lower Silurian of Murchison and the Bala group was made known, Sedgwick, as we have seen, re-claimed for the latter his former name of Upper Cambrian; but this had meanwhile been adopted for the Festiniog group, in which sense it is still used by Lyell, Phillips, Davidson, Harkness and Hicks. The Festiniog group, or Middle Cambrian, as defined by Sedgwick, however, included not only the whole of the Lingula-flags but the Upper and Lower Tremadoc rocks. [Philos. Mag. IV. viii. 362.]

The only change which I have made in the groupings of the British rocks adopted by Sedgwick and by Murchison, is in separating the Menevian or Lower Lingula-flags from the Festiniog, and uniting it with the Bangor group or Lower Cambrian. In this I follow, with Lyell and Davidson, the suggestion of Salter and Hicks.

In the third column, the sub-divisions are those of the New York and Canada Geological Surveys; in connection with which the reader is referred to a table published in 1863, in the *Geology of Canada*, page 932. Opposite the Menevian I have placed the names of its principal American localities; which are Braintree, Mass., St. John, New Brunswick, and St. John's, Newfoundland. The farther consideration of the American subdivisions is reserved for the third part of this paper. With regard to the classification of Angelin, it is to be remarked that although he designates II as *Regio Olenorum*, and III as *Regio Conocoryphlarum*, the position of these, according to Linnarsson, is to be reversed; the Conocoryphe beds with Paradoxides being below and not above those holding Olenus. The *Regio Fucoidarum* in Sweden has lately furnished a brachiopodous shell, *Lingula monilifera*, besides the curious plant-like fossil, *Eophyton Linnæanum*. [Linnarsson, Geol. Magazine, 1869, vi. 393.]

(The third and concluding part of this paper will appear in the next number of the *Naturalist*.)

Lower Paleozoic Rocks of Europe and North America.

	British sub-divisions.	*North American sub-divisions.*	*Nomenclatures of Sedgwick and Murchison.*	*Barrande's classification.*	*Angelin's divisions.*
14	Ludlow.	Lower Helderberg.	Silurian, *Sedgwick.* Upper Silurian; *Murchison.*	Third fauna including Etages H. G F. E.	VIII. VII. or Regiones E. and DE.
13	Wenlock.	Niagara, Clinton,			
12	Upper Llandovery.	Medina, Oneida.			
11	Lower Llandovery.	Hudson-River, Utica,	Upper Cambrian or Bala group, *Sedgwick.* Lower Silurian, *Murchison.*	Second fauna including Etage D.	VI. V. IV. or Regiones D. C. and BC.
10	Caradoc.	Trenton, Birdseye,			
9	Upper Llandeilo.	Black-River.			
8	Lower Llandeilo.	Chazy.			
7	Upper Tremadoc.	Levis.	Middle Cambrian or Festiniog group, *Sedgwick.* Primordial Silurian, *Murchison.*	First fauna or Primordial fauna, including Etage C, and probably also Etage B.	III. II. I. or Regiones B. and A. and Regio Fucoidarum.
6	Lower Tremadoc.	Calciferous.			
5	Dolgelly.	Potsdam.			
4	Maentwrog.				
3	Menevian.	Braintree & St. John.	Lower Cambrian or Bangor group, *Sedgwick.* Cambrian, *Murchison.*		
2	Harlech.	——— ?			
1	Llanberris.	——— ?			

REMARKS ON THE TACONIC CONTROVERSY.

By E. Billings, F.G.S.

Table *of the Silurian formations of New York and Canada as recognized previously to* 1859.

UPPER SILURIAN.	
16 Lower Helderberg.	
15 Onondaga.	
14 Guelph.	
13 Niagara.	
12 Clinton. 11 Medina. 10 Oneida. }	The Red Sandrock of Vermont was originally placed about here by Dr. Emmons, followed by Adams, Rogers, and others. It was afterwards referred to a horizon near the Potsdam by Dr. Emmons and E. Billings.
LOWER SILURIAN.	
9 Grey sandstone. 8 Hudson River. }	Position of the Taconic rocks and Quebec group according to Prof. Hall and others. At first adopted, but rejected by the Canadian Survey in 1860.
7 Utica.	
6 Trenton.	
5 Black River.	
4 Birdseye.	
3 Chazy. 2 Calciferous. }	Approximate horizon of the Quebec group as decided by Sir W. E. Logan & E. Billings in 1860
1 Potsdam. =	Position of the Red Sandrock of Vermont (nearly) according to Dr. Emmons & E. Billings
TACONIC SYSTEM. =	Position of the Taconic System according to Dr. Emmons.

It frequently happens that a science, such for instance as that of geology, possesses a sort of an aristocracy, consisting of the most talented, learned, active and influential of its devotees. The views of this body of men, on any difficult problem that may present itself, are usually regarded as conclusive, and are quietly adopted by the less distinguished members. Indeed, the opinion of any one of these latter, would be scarcely listened to, provided it should happen to be contrary to the established creed of the dominant party. As a general rule the leading men are right, and yet it will sometimes happen that they are wrong. One of the most remarkable instances on record, is that of the great question in American Geology, relating to the age of the rocks which Dr. Emmons called "The Taconic System." Upon this question nearly all of the leading geologists of North America arranged themselves upon one side, and, as it turned out after more than twenty years discussion, *on the wrong side.* Although they were wrong, yet so overwhelming was the weight of their authority, that for nearly a quarter of a century, Dr. Emmons stood almost alone. He had a few followers, but they were not men who had made themselves sufficiently conspicuous and influential to contend successfully against an opinion that was supported by all the great geologists of the continent in one compact body. In consequence of this powerful opposition, the Taconic theory gradually sank so low in reputation, that it was at length considered to be scarcely worthy of the notice of a scientific man.

During the last thirteen years, a great revolution of opinion has occurred with regard to the views of Dr. Emmons. Although not entirely adopted, they are now considered to be, in a general way, well founded. The opposite theory, that all of those rocks which he placed in the Taconic System are above the Potsdam sandstone, instead of below it, as he maintained, is completely exploded. It is at this moment dead, more so than was the Taconic theory in 1859, the year in which the subject was re-opened. As I understand it at present, some of the Taconic rocks are certainly more ancient than the Potsdam, others may be of the same age, and perhaps some of them more recent. The details are not yet worked out, and judging from the manner in which the strata are folded, broken up and thrown out of their original position by almost every kind of geological disarrangement, I venture to say that no man, at present living, will ever see a perfect map of the Taconic region.

The theory, that the Taconic rocks belonged to the Hudson River group, was an enormous error, that originated in the Geological Survey of New York, and thence found its way into the Canadian Survey. No doubt the mistake was due, in the first instance, to the extraordinary arrangement of the rocks, the more ancient strata being elevated and often shoved over the more recent. Thus, without the aid of paleontology, it was impossible to assert positively that they were not, what they appeared to be, of the age of the Hudson River formation. The attitude of the strata, together with their numerous disturbances, might be explained physically, so as to meet either theory. If, for instance, the trilobites of Vermont and Point Levis, had turned out to be of the age of the fauna of the Hudson River group, the rocks would be to this day called Hudson River. There is no apparent physical arrangement to contradict this view, but rather to support it. I do not consider that originally either the physical geologists, or the paleontologists, were much to blame. With regard to the first, when a geologist finds one rock overlying another, he is obliged to accept that as the natural arrangement. Then as to the fossils, with all our increased knowledge, I doubt that any good paleontologist of the present day, would feel himself justified in deciding against physical appearances, on the few imperfect specimens figured in 1847, on pl. 67, Pal. N. Y., vol. I. Be this as it may the object of this note is to show that while the error originated in New York, it was corrected by the Geological Survey of Canada. Dr. Hunt, in his published Address to the American Association, in August last, indirectly associates Prof. Hall with me in the rectification of the mistake, whereas neither Prof. Hall nor Dr. Hunt contributed any aid whatever, but on the contrary, opposed the change that has been made to the utmost. In this paper I desire simply to claim what belongs to myself, and to do justice to some others, who assisted in the work. I shall discuss the subject under the following heads:

1.—*The Vermont Trilobites.*

In 1859, I had some correspondence with Col. E. Jewett, then residing at Albany, N.Y., on the subject of an exchange of fossils. This gentleman is widely known for the extensive collections he has made, and I have also found him to be a good sound geologist, although he has never published much on the science. It appears that, during the numerous excursions he had made over the disputed territory, he had arrived at the conclusion from his own observations that Dr. Emmons was, upon the whole, correct in his views. He had, on several occasions, urged me to take the matter up and investigate it, but this I could not do for want both of time and of facts. On the 5th of April, 1859, he wrote me a letter, in which he gave an account of what specimens he could send in exchange. After mentioning several species, he says:

"I can spare a good specimen of what Prof. Hall describes as *Olenus asaphoides*, which I got from the upturned slates of Vermont, twenty-five miles north of Burlington and four miles from Lake Champlain. Emmons declares it below the New York system. It is singular that no other fossils of any kind are found in the locality which has furnished several of this trilobite."

Shortly afterwards the trilobite was received by me at Montreal, and I was much surprised to find it a true primordial form, but not an *Olenus*. It seemed to me to be more nearly allied to *Paradoxides* and it appears also that I communicated this opinion to Col. Jewett, for I have a letter from him dated 11th of May, 1859, in which he says:

"Should you have any doubts of the trilobite sent you being a true *Paradoxides*, I will send you others which display more graphically the characters."

After studying the fossil for several days, I showed it to the officers of our Survey, and pointed out that its primordial aspect, indicated a horizon far below the Hudson River group, and perhaps even below the Potsdam sandstone. The subject was much discussed, and Sir W. E. Logan proceeded, soon afterwards, to examine the geological structure of the region in which the trilobite had been found. Thus the re-investigation of the Taconic question was commenced by the Canadian Survey in the spring of 1859. I consider this a very important step, because, for many years, the views of Dr. Emmons had been regarded as constituting a theory so utterly baseless, that none of the leading geologists could be brought to think it worth a single day's work in the field. Sir W. E. Logan, however, was not of that opinion, and after seeing the trilobite, took to the field at once. Although he did not, at first, find any good reason to depart from what had been considered, for more than twenty years, the true arrangement of the rocks in question, yet he continued the investigation, whenever his other duties would permit, until his final decision was given, on the last day of December, 1860, just twenty months after the trilobite was received by me.

Dr. Hunt, in his address, has omitted to make any allusion to my determination of the primordial character of this trilobite in the spring of 1869, or to the investigation which took place in consequence thereof. On the contrary he gives his readers to understand, as will be seen by a quotation further on, that this important point was first determined by Barrande in 1860. One whole year, during which the Canadian Survey was engaged in the investigation, is thus left out of his address.

The circumstances which led to Barrande's giving an opinion are the following. In the latter part of 1859, Prof. Hall described three species of trilobites from the Vermont locality, including the form I had received from Col. Jewett. He made no allusion to their primordial characters, but referred them, wrongly, to *Olenus*, a genus whose horizon he supposed to be at the summit of the Lower Silurian. He referred the rocks in which they had been found to the upper part of the Hudson River group. This is the position he had always assigned to the Taconic rocks of New-York. The Canadian Survey had long before adopted his opinion; and indeed before the discovery of these trilobites no good reasons had been given to prove that it was not correct. Dr. Emmon's views, although they turned out to be, in part, well founded, had never been supported by good clear evidence.

Previously to the month of April, 1860, I believe that the only palæontologists who had studied these trilobites, were Prof. Hall and myself. He considered them to belong to the summit of the Lower Silurian, while I maintained that they were primordial, and that the rocks in which they had been found, were either at the base of the Lower Silurian or perhaps below that horizon.

On the 25th of April, 1860, just one year after I had received the trilobite from Col. Jewett, I sent a copy of Prof. Hall's pamphlet, containing the figures and descriptions, to Barrande, then in Paris. He had previously written me several times requesting me to furnish him with any facts, within my knowledge, that might have a bearing upon his theory of Colonies. I referred him to these three trilobites, as an example of a group of primordial fossils, in rocks which were considered by American geologists to be of the age of the Hudson River formation. On the 28th of May he wrote me, acknowledging the receipt of the pamphlet and of my letter. He agreed with me that the trilobites were primordial forms, and expressed his doubts that the rocks in which they had been found were of the age of the Hudson River formation. On the 16th of July he addressed a letter to Prof. Bronn of Heidelberg, on the subject. In this letter he stated that he had received the pamphlet from me,—that the trilobites were primordial forms, and calls for "new researches and new studies, that may lead to a final and certain solution of this important question." (This letter was published in the Proceedings of the Boston N. H. Soc., Dec. 1860; in the Am. Jour. Sci., March 1861, and in the Can. Nat. Geol., in April, 1861.)

Thus Barrande did in 1860, exactly what I had done in 1859. He decided that the trilobites were primordial, and that there was reason to doubt that the rocks were of the age of the Hudson River formation. In quoting Barrande's opinion, Dr. Hunt first alludes to my description of the trilobites from Point-Levis in August, 1860, and then says :—

"Just previous to this time, in the Report of the Regents of the University of New-York for 1859, Professor Hall had described and figured by the name of Olenus, two species of trilobites from the Slates of Georgia, Vermont, which Emmons had wrongly referred to the genus Paradoxides. They were at once recognized by Barrande, who called attention to their primordial character, *and thus led to a knowledge of their true stratigraphical horizon*, and to the detection of the singular error in Hisinger's book, already noticed, by which American geologists had been misled."

Now it appears to me that any one reading this paragraph would arrive at the conclusion, that Barrande was the first to perceive that the trilobites were primordial forms. On the contrary, I pointed this out to the officers of our Survey one year previously, and my opinion led to the investigation above alluded to.

Barrande's opinion was given in 1860, and was founded on materials that I sent him. Mine was given and acted upon in 1859, and yet Dr. Hunt makes no allusion to it in any part of his Address, although it was well known to him.

2.—*The Point Levis Trilobites.*

In May and June, 1860, a large number of trilobites and other fossils, were discovered in the limestones of Point Levis. I decided that these belonged to a horizon about the age of the

Calciferous and Chazy. On the 12th July I wrote to Barrande on the subject, and informed him that I considered the fossils of the age of those of the base of his second fauna. In August I published figures and short descriptions of the principal species. In this paper the designation "*Hudson River group*" was first discontinued as the name of the formation, and I am happy to state that it has never since been applied to the rocks in question, in any of the publications of our Survey. I had a number of separate copies of my paper printed, and sent one with a letter to each of the following palæontologists and geologists:—M. J. Barrande, Paris; J. W. Salter, Geo. Sur. G. B., London; Dr. B. F. Shumard, St. Louis, Missouri; and Prof. J. M. Safford, Lebanon, Tennessee. All of them agreed with me without any reservation whatever.

Previously to the discovery of these fossils, Prof. Hall had examined the rocks at Point Levis, and had described a number of species of graptolites that had been collected there. In his report he says, "These strata belong to the Lower Silurian series, and are of that part of the Hudson River group which is sometimes designated as Eaton's sparry limestone, being near the summit of the group: they form also the rocks of Quebec."

Dr. Hunt in commenting upon the investigations of Prof. Hall and myself says:—

"The palæontological evidence thus obtained by Billings and by Hall, both from near Quebec and in Vermont, led to the conclusion that the strata of these regions, so much resembling the upper members of the Champlain division, were really a great developement, in a modified form, of some of its lower portions."

Now I object to this mode of stating the matter. It seems to associate Prof. Hall with me in the determination of the age of the rocks in question. Taking this passage, with others that precede it, the reader might suppose that Prof. Hall and I had studied the fossils together, and had arrived at the same conclusion. On the contrary we examined them separately and came to widely different conclusions. He placed them, incorrectly, at the summit of the Champlain group, and I, correctly, at the base.

During the years 1859 and 1860, Sir W. E. Logan made numerous excursions into the disputed territory, and examined a great number of localities, in order to find a clue to the true stratigraphical arrangement. I believe no other physical geologist worked at the problem. I conducted the palæontology throughout. Sir W. E. Logan's final decision was given on the last day of December, 1860, and from that date no one has referred either the Taconic or the Quebec rocks to the Hudson River group.

The Canadian Survey did not originate the Taconic theory, but it exposed and removed from American geology, the enormous error which placed the rocks at the summit of the Lower Silurian. The palæontologists who were consulted by me were, Barrande, Salter, Shumard and Safford, as above mentioned. The others who have made important discoveries bearing upon the subject are the following.

In 1861 Mr. J. Richardson of the Canadian Survey, discovered the Vermont trilobites, at the Straits of Belle Isle and at Bonne Bay, in Newfoundland, in rocks which lie below that part of the Potsdam which holds *Lingula acuminata*.

In the same year the Rev. J. B Perry and Dr. G. M. Hall discovered a new locality of the trilobites, about 1½ miles east of Swanton in Vermont.

Mr. T. C. Weston, of our Survey, collected a nearly perfect head of a species of the same genus at Bald Mountain in New York, in June, 1864.

In July, 1871, Mr. S. W. Ford of Troy, New York, published a short paper in the Am. Jour. Sci., entitled: "Notes on the primordial rocks in the vicinity of Troy, N. Y." This paper was re-published in the Can. Nat. in December 1872. Mr. Ford gave a good description of the rocks of the locality, and announced the discovery of 18 species of fossils, 15 of which were found on comparison to belong to the Taconic fauna. Mr. Ford's paper, with the exception of what Dr. Emmons himself had written, is the most important that has ever been published in the United States on this subject. It consists entirely of original observations, while a large number of the papers that have appeared in the scientific journals, relating to the Taconic rocks, are mere compilations, in which the question is misrepresented, many important facts suppressed, and others presented in a false light.

3.—*Determination of the age of the Red Sandrock of Vermont.*

Intimately connected with the Taconic question, is the determination of the Red Sandrock formation of Vermont. This group of rocks forms a chain of low hills, extending nearly the whole length of Lake Champlain, but, in general, situated several miles inland from the eastern shore of the lake. Dr. Emmons, about thirty years ago, referred this formation to the Medina sandstone. He was followed by other geologists, some of whom included in the formation the Oneida conglomerate and the Clinton. He afterwards came to the conclusion that the rocks in question were about the age of the Calciferous or Potsdam. In his American Geology, published in 1855, he sometimes refers it to the former and sometimes to the latter. The view that it was of the age of the Oneida, Medina and Clinton was, however, maintained by all others. The question was finally determined by the fossils, and to these I shall confine myself. A locality of trilobites had been discovered by the late Prof. Z. Thompson in Highgate, near the boundary line, sometime previously to 1847. He pointed out the place to Prof. C. B. Adams, State Geologist of Vermont, who referred some of the specimens to Prof. Hall. The following is his opinion upon them, as it appears in the "Third Annual Report on the Geology of Vermont," by Prof. C. B. Adams, 1847, p. 31:

"*Letter from* PROFESSOR JAMES HALL, *on certain Fossils in the Red Sandrock of Highgate.*

ALBANY, N. Y., September 17th, 1847.

"MY DEAR SIR,

I have only now received your letter of the 10th instant, on my return from a geological excursion. I examined the fossils and, as far as I can determine they are all of the central portion of the buckler of a Trilobite, with a prominent narrow lobed glabella. The cheeks have been separated at the facial section, so that we have not the entire form of the head. The course of the facial section indicates that it terminated on the posterior margin of the buckler, and the glabella is narrower in front than behind—these two characters are inconsistent with Calymene, Phacops or Asaphus, the common genera, (as well as with several other genera) of our strata, but they belong to Conocephalus and Olenus. I am inclined to regard this fragment as part of a Conocephalus, of which I have not before detected a fragment in our rock. From its isolated character, therefore, I am able to infer little regarding its real geological position. The form known to me most nearly like this one, is in the Clinton group of this State. I regret that more species could not have been found, or that some forms in the preceding strata could not be obtained to compare with others already known.

The meagre information of the two known species of Conocephalus is likewise an objection to any geological inference from the discovery of a species. All we know is that they are found in Graywacke, in Germany, or elsewhere, and the position of Graywacke is too dubious and ubiquitous to be of any importance in such a case.

I regret exceedingly that I am able to give only this meagre and unsatisfactory information, and also that I have not had the satisfaction of seeing the locality.

I shall see you in Boston next week, if I am able to go there, and will there reply more fully to the other part of your letter respecting N. Y. fossils.

I have prepared nothing for our meeting, but am coming to see what others do.

I am very sincerely, yours, &c.

PROF C. B. ADAMS. JAMES HALL."

"[Two specimens only have been obtained of a shell, which resembles Atrypa Hemispherica, of the Clinton group of the New-York system. Prof. HALL informs me that he is disposed to assign both the Clinton group and the Medina sand-stone to one geological period.—C. B. A.]"

It is evident from the above that Prof. Hall did not consider the formation to belong to the Potsdam group, but rather to the Medina or Clinton. In 1861, I examined the locality and published the following note in the Am. Jour. Sci., 2nd series, Vol. XXXII, p. 232:

"*On the age of the Red Sandstone formation of Vermont.*
By E. BILLINGS.

"I have lately been examining a tract of the Calciferous sandrock which lies on the boundary line between Canada and Vermont, on Missisquoi Bay. The rock is exposed here in long parallel ridges, over an area of eight or nine miles in length and from one to three in width. On the east side of the exposure there is a ridge of greyish sandstone which I traced south across the boundary line, after crossing which it soon becomes interstratified with thick beds of rock of a chocolate red or brown color. It is here the typical red sandrock formation of Prof. Adams. Hearing that Dr. G. M. Hall and Rev. J. B. Perry of Swanton had discovered trilobites near this place, I called upon them and they kindly conducted me to the locality. It is above two miles south of the line and one mile or a little more east of the Highgate Springs. The individual fossils are abundant in the red sandstone, but I could find only two species, a small *Theca* and a *Conocephalites*. Of the latter we found only the head, but the specimens are very numerous and some of them well preserved. The species resembles Bradley's *C. minutus*, but is a little larger, and I think quite distinct therefrom. It is a true primordial type, and if we are to be guided at all by palæontology we cannot regard this rock as lying at the top of the Lower Silurian but at the very base of Barrande's Second Fauna, if not indeed a little lower. It is therefore not the Medina sandstone, but a formation somewhere near the horizon of the Potsdam. This accords exactly with conclusions drawn from the evidence afforded by the fossils discovered by our survey at Quebec last year."

In this paper the formation was first referred to the base of the Lower Silurian on the palæontological evidence. The following notice from C. Hitchcock was published shortly afterwards. (See p. 454 of the vol. last cited):

"*Letter from* C. HITCHCOCK, Esq., *on the first observation of the Fossils of the Red Sandstone formation of Vermont.*

"Eds. Silliman's Journal: As a notice of the Conocephalites from the Red Sandrock series in Highgate, Vt., has appeared in your Journal (Second Series, vol. xxxii, p. 232), it is but just to the dead to state who were the original discoverers of this trilobite. By referring to the Third Annual Rept. Geol. Vt., 1847, pages 14 and 31, it will appear that Prof. Z. Thompson conducted Prof. C. B. Adams to Highgate, where both gentlemen procured a large number of these trilobites. They were sent to Prof. J. Hall in 1847 for determination, who gave them the name Conocephalus, the same genus to which Mr. Billings now refers them. At that time the precise position of the Conocephalus was not known. Nor was Prof. Hall able to give more definite information respecting them in 1858 when I showed him the specimens again.

These trilobites are noticed on pages 339 and 340 of our Third Report on the Geology of Vermont, which will be ready shortly for distribution.

Amherst, Mass., Oct. 23d, 1861."

From the above I think it will be evident that I was the first to decide the age of the red sandrock on palæontological grounds. The locality at Highgate is perhaps not exactly of the age of the typical Potsdam, but nearly of that age.]

4.—*Sir R. I. Murchison's Address.*

In a paper entitled "On some points in American Geology," published in the Am. Jour. Sci. 2nd series, vol. xxxi, and in the Can. Nat. & Geol., vol. 6, 1861, Dr. Hunt gave an account of the determination of the age of the Quebec group, and introduced Prof. Hall's researches in such a manner that Sir R. I. Murchison was led to make the following statement in his "Address to the Geological Section of the British Association, at Manchester, Sept. 1861":—

"In an able review of this subject, Mr. Sterry Hunt thus expresses himself:—"We regard the whole Quebec group, with its underlying primordial shales, as the greatly developed representatives of the Potsdam and Calciferous groups (with part of that of Chazy), and the true base of the Silurian system." "The Quebec group, with its underlying shales," this author adds (and he expresses the opinion of Sir W. Logan), "is no other than the Taconic system of Emmons;" which is thus, by these authors, as well as Mr. James Hall, shown to be the natural base of the Silurian rocks in America, as Barrande and De Verneuil have proved it to be on the continent of Europe."

The meaning of the above is simply this: that the age of the Quebec group was determined by SIR W. E. LOGAN, as physical geologist; PROF. HALL, as palæontologist, and by DR. T. S. HUNT, as chemist and mineralogist, an arrangement very satisfactory to the latter two gentlemen, but not so to myself. Upon reading the address, I resolved to publish same remarks upon it, but on speaking to Sir W. E. Logan, he thought it best that the matter should be rectified by himself. Accordingly he addressed the following letter to the Editors of the Amer. Jour. Science:

"*Letter from* Sir WM. E. LOGAN, *Director of the Canadian Geological Survey, on Sir Roderick Murchison's reference to the determination of the age of the Quebec Rocks.*

Montreal, November 27, 1861.

"*To the Editors of the American Journal of Science:*

Dear Sirs,—In his address to the Geological Section of the last meeting of the British Association, Sir Roderick Murchison has placed the name of my friend Prof. Hall in such a relation to the Quebec group of rocks, as might lead to the inference that to him was due the credit of having determined its horizon, as adopted by the Geological Survey of Canada. Nothing I am persuaded can be farther from the mind of this distinguished palæontologist than a wish to put forward any claim of this description, as the credit is wholly due to Mr. Billings the Palæontologist of the Canadian Survey.

In 1848 and 1849, founding myself upon the apparent superposition in Eastern Canada of what we now call the Quebec group, I enunciated the opinion that the whole series belonged to the Hudson River group and its immediately succeeding formation; a *Leptæna* very like *L. sericea*, and an *Orthis* very like *O. testudinaria*, and taken by me to be these species being then the only fossils found in the Canadian rocks in question. This view supported Professor Hall in placing, as he had already done, the Olenus rocks of New York in the Hudson River group, in accordance with Hisinger's list of Swedish rocks as given in his Lethæa Suecia in 1837, and not as he had previously given it. But the discovery in 1860 of the Point Lévis fossils enabled Mr. Billings to prove that the rocks of the Quebec group must be placed near the base of the Lower Silurian series instead of at its summit, and it thus became necessary to discover some other interpretation of the physical structure than the one suggested by the visible sequence of the strata.

Although there may be difficulties in regard to detail, the interpretation given in my letter to Mr. Barrande of the 31st December, 1860, will, I am persuaded, turn out to be the right one. Prof. Emmons long ago asserted that the rocks in question in Vermont were older than the Birdseye and Black River formation. In this I now agree with him; while however his interpretation of the structure would make them all older than the Potsdam sandstone, mine would not. But whatever the value of my present interpretation, it might have been some time before I should have been urged to look for it, had it not been for the palæontological skill which Mr. Billings brought to bear on the question. I am, dear Sirs, very truly and respecfully yours,

W. E. LOGAN.'

To the above I shall add two quotations from the last letter I received from Dr. Emmons on the subject of the Taconic system. He was, at the date of this letter, State Geologist of N. Carolina:

"RALEIGH, Feb. 5, 1861.

MR. E. BILLINGS:

"MY DEAR SIR,—I am much obliged to you for your favor of the 30th inst., and especially for the opinions and kind regards which you express. Be assured they are highly appreciated, and the more so seeing that they are rare. I had for years past looked upon the subject with a kind of indifference, until you had expressed to Col. Jewett, opinions favourable to the existence of the lower rocks I had contended for; not indeed that I had any misgivings of the truth of the position I had taken, for that would be impossible from all I had seen, provided there were truth in geology, and that the department were founded on principles. But the real difficulty has always been that geologists would not look at the question at all."

"Be assured that I fully appreciate your kind aid in the matter of the Taconic system, for I think I should have gone down to the grave before it had been acknowledged, except for your active, intelligent, and disinterested labours in the cause."

"Yours truly,

"E. EMMONS."

ON THE GENUS OBOLELLINA.

By E. Billings, F.G.S.

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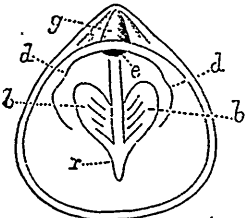

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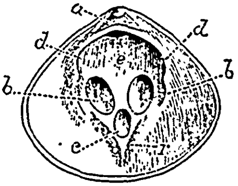

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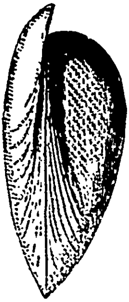

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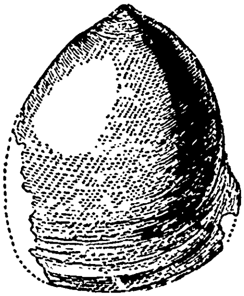

Fig. 1. Diagram of the interior of the ventral valve of a specimen, supposed to be a small individual of *O. Canadensis; bb*, the two large sub-central muscular impressions; *dd*, the groove under the area; *e*, enlargement of the same; *g*, the pedicel groove in the area, on each side of which is a smaller oblique furrow; *r*, the ridge in front of the muscular impressions.

2. *Interior of a dorsal valve; a, the area; c, the pair of small scars* in front of the two larger. The other letters, the same as in Fig. 1.

3. Dorsal view of the original specimen.

4. Side view of the same.

5. Ventral view of the same.

A short notice of this genus was published in the last number of this journal, Dec., 1871. I *now propose* to extend the description, so far as our present material will admit.

(All the figures in this paper are of the natural size.)

Genus OBOLELLINA, Billings.

Generic characters.—Shell, unarticulated, ovate or orbicular, smooth or concentrically striated. Area of the ventral valve with a median groove, on each side of which there is, sometimes, an additional furrow. In the interior of this valve there are two large, ovate, or sub-rhomboidal muscular impressions. They are situated near the centre, but usually (for the greater part) in the posterior half of the shell. They are sometimes obliquely striated or grooved, or obscurely reticulated by both transverse and longitudinal striae. Close under the area there is a fine, but distinctly impressed groove, which curves outwards and forwards, outside of the muscular scars for a greater or less distance towards the front margin. There appears to be an enlargement of this groove, just under the peduncular groove of the area, on the median line, as if for the attachment of a muscle. The large scars are bordered anteriorly, by an elevated margin, which is prolonged forwards, along the median line, in a more or less prominent ridge; this ridge varies greatly in the amount of its developement, in different individuals of the same species, being sometimes almost obsolete.

The area of the dorsal valve varies greatly in size in the different species, and is either flat or with a triangular elevation under the beak like a pseudo deltidium. Beneath the area there is a fine groove, which curves outwards and forwards, as in the ventral valve, with a similar enlargement in front of the beak. There are two large, ovate, sub-central muscular impressions, with a smaller pair in front of, or between them. These latter are situated on or close to the median line, and usually appear as a single scar, but in some specimens are distinctly divided into two, by a longitudinal ridge. Their form varies in different individuals of the same species. The muscular impressions are margined, anteriorly, by an elevated border, which is extended forwards as an obscure ridge, a greater or less distance towards the front.

In the original notice it is stated, that this genus has no cavities in either valve. This holds good for all the specimens of *O. Canadensis* of which the interior has been seen. In *O. Galtensis*, however, while some of the specimens have no cavities, in others, as is shown by the casts of the interior, there is a small one extending a short distance under the larger muscular scar on each side in the ventral valve. In one of our specimens there is a short cone, half-a-line in length, on the edge of the cast of the cavity. No cavities have yet been observed in the dorsal valve. It thus becomes evident, that the existence or non-existence of these cavities, is not always a character of generic value. Whether it be so or not, in any particular instance, depends upon the extent to which the cavities are developed. They may be so small and rudimentary, as not to be even of specific value. Or they may be so large, as to constitute good sub-generic characters. I have some specimens which seem to show that small cavities also exist in species that, with our present knowledge, can only be referred to the genus *Monomerella*. In a general way, therefore, it may be said that these genera are destitute of cavities, but that, exceptionally, they do occur, and that where such is the case, an approach to the genus *Trimerella* is indicated.

I consider that *Obolellina*, *Monomerella* and *Trimerella*, are merely sub genera of a single great genus, of which the first, as it is the most ancient, and the least specialized, should be regarded as the type. They gradually pass into each other, and no doubt as the number of species increases, it will become more and more difficult to draw lines between them.

The Canadian species are *O. Canadensis*, *O. Galtensis* and *O. magnifica*. The second of these, has the muscular impressions in the dorsal valve of the same form and arrangement as those of the first named. The beak of the ventral valve is very large, its length being one-half that of the body of the shell. It is slightly incurved. The area has three furrows, the peduncular and the two lateral grooves. The muscular impressions are rhomboidal rather than ovate, and confined to the central portion of the shell. There are no cavities under the area.

I am informed that it is now proposed to place *O. Galtensis* in one of Prof. Hall's unpublished genera, presently to be noticed, along with the species described in the 20th N. Y. Reg. Rep. p. 368, under the name of *Obolus Conradi*. It seems to me however, that this latter is a *Trimerella*, or rather one of those forms whose position is near the dividing line between *Trimerella* and *Obolellina*. Prof. Hall has figured the cast of the interior of a ventral valve in Pl. 13, fig. 2, of the work cited. Close to the area there are two short obtuse cones, which are continued towards the front, as two rounded ridges, one on each side of the muscular impressions. The latter extend nearly up to the area, and are separated by a small rounded ridge. These characters are all seen in the cast of the ventral valve of *Trimerella*. They do not occur at all in either of the three species of *Obolellina*.

Prof. Hall's fig. 1 represents the cast of the interior of the dorsal valve of his *Obolus Conradi*, showing that the three muscular impressions are completely concealed by two sub-conical projections, just as they are concealed by the cones in *Trimerella*. I have lying before me fifteen casts of the interior of *O. Galtensis*, and in all of them the three scars are entirely exposed as in fig. 6, below. With all due deference, therefore, I think that *O. Conradi* should be classified in *Trimerella* rather than in the same genus with *O. Galtensis*.

6

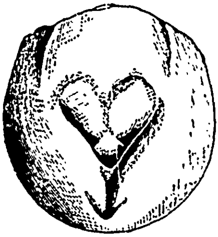

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FIG. 6. The original figure of *O. Galtensis* showing the cast of the interior of the dorsal valve. Compare with Fig. 2. The specimen is imperfect but it shows the casts of the groove *dd*, the two large ovate scars, *bb*, and the smaller pair, *c*, of fig. 2.

8. Dorsal valve of *Obolellina? magnifica*. This was figured in the Report of the Geological Survey of Canada for 1857, published in 1858 as a dorsal valve of *O. Canadensis*. It is, however, a distinct species. The following is the description.

O ? MAGNIFICA, n. sp. Dorsal valve transversely broad ovate; width about one-fourth greater than the length; uniformly and moderately convex; apical angle about 120 degrees; cardinal edges nearly straight, or gently convex for about one-third the length of the shell; sides and front rounded, the latter more broadly than the former. The area seems to be obsolete altogether or merely linear.

The ventral valve is depressed convex with a large beak slightly incurved. Area with a wide triangular peduncular groove; no lateral furrows. Surfaces of both valves concentrically marked with imbricating lines of growth.

In a specimen, which appears to have been about 20 lines in length, the height of the area is nearly 3 lines.

I place this species doubtfully in this genus, because there is in the interior of the dorsal valve, a distinct muscular pit about one line in front of the beak, which does not occur in either of the other two species. In one well preserved specimen this scar is distinctly seen to be divided into two, by a longitudinal ridge. It may be that it represents the small anterior scar (c. fig. 2,) which is certainly variable in form and perhaps, also, in position. In *O. Canadensis*, for instance, the scar, c, is sometimes a distinct ovate pit, as shown in fig. 2, entirely separated from the two larger scars, *bb*. In others all three are confluent, or at least in contact, while in one specimen, c, is represented by two elongated grooves, separated by a rounded ridge, extending backwards between, *bb*. Some of the figures of the English species *O. Davidsoni*, seem to show that a pit, like that of *O. magnifica*, occurs in one of the valves of that species.

O. magnifica occurs in the Black River formation, along with *O. Canadensis*.

A Question of Priority.

About three weeks after the above genus was published, I received a letter from Thos. Davidson, Esqr., F.R.S. Brighton, England, informing me that it had been previously named, by Prof. Hall in a pamphlet of 5 pages, dated March, 1871. On this subject I beg to make a few remarks.

When I was appointed to the office I now hold, in 1856, Prof. Hall was engaged on his 3rd vol. Pal. N.Y., which relates altogether to the Upper Silurian fossils of the State of New York. Sir W. E. Logan gave me to understand that I was not to describe any Upper Silurian fossils until Prof. Hall should have completed his volume. It was also understood, that I should not describe any species which might occur in New York and not in Canada. To do so was thought to be in the highest degree discourteous and un fair. Species that were found in Canada I could describe, although they might be known to occur in New York also. I have never once transgressed these rules for sixteen years. I have compared a number of collections for parties living in New York but have always declined to describe new species, although frequently urged to do so. There is a person at this present time at work on N. Y. fossils, and I have declined to give him any assistance.

It appears that many years ago, Prof. Hall obtained from Galt, a single specimen of the ventral valve of *O. Galtensis*. This species does not occur at all in New York. In the beginning of 1871, Prof. Hall applied to Mr. Selwyn for the loan of the original specimens of *Trimerella grandis*, stating that he wanted them to elucidate some points in the structure of his *Obolus Conradi*. I consented to the loan of them, and Prof. Hall was informed by Mr. Selwyn that the genus was then under investigation by Mr. Davidson, Mr. Dall and myself. Shortly afterwards he applied for specimens of *Kutorgina* and *O. Canadensis*. I declined to lend the latter as I was then using it. In reply he intimated that he had no desire to take any advantage of me, but only to fortify his own position. It turns out, however, that he was then actually working at *O. Galtensis*, intending to make a new genus on a Canadian specimen. He did not inform Mr. Selwyn of this fact. Ten months afterwards, I heard from Mr. Davidson that Prof. Hall had proposed a new genus *Rhynobolus*, on the Canadian specimen before mentioned, and it then became apparent why he wished to borrow *O. Canadensis*. A question now arises, whether or not his pamphlet was regularly published, previously to the 29th Dec. 1871, the date of the publication of my genus.

I have made extensive enquiries in the United States and Canada, among those who would have been the first to have received it, had it been regularly published, and cannot find one who had ever seen it previously to the 29th December, 1871. I have heard from the Directors of six Geological Surveys, from the Smithsonian Institution, the Academy of Natural Sciences of Philadelphia, the New York Lyceum of Natural History, the Boston Natural History Society, McGill College and the Nat. Hist. Soc. of Montreal, besides a number of geologists and professors in colleges where geology is taught. The general opinion is that it was not published in the United States at all.

Then as to foreign countries, the only copy I have any certain account of, is the one sent to Mr. Davidson. Another is noticed in the Journal of the Geological Society for February, 1872, but the exact date of its reception is not mentioned. The case stands thus.

It is admitted by all that the only test of priority is publication. By this term we must understand the placing of a book or pamphlet on sale, so that it may be accessible to the public by way of purchase.

On the other hand, when an author only gives away several copies of his work to his private friends, this is not publication, but private distribution. Should he even send one to a learned society, whose library is private, it would still not be publication. The work would not be accessible to the public.

My genus was openly and fairly published, on the 29th Dec., 1871, in a scientific journal of good standing, and at all times obtainable by purchase.

Prof. Hall's pamphlet was not published, but only privately distributed to a very few parties.

Although the law (that publication in the true sense of the term is the only test of priority,) should, in general, be rigidly enforced, yet in peculiar cases it admits of a considerable amount of flexibility. It should not always be carried out with a strong hand. Circumstances may render it necessary, in order to do justice, that it should be very strictly adhered to as against one of the parties, and more leniently as regards the other. When one of the disputants has proceeded in an irregular manner; has not published his paper in the ordinary way, in a scientific journal or book obtainable by purchase; and when, in consequence of such irregularity, the difficulty to be settled has arisen, he is to blame, and the law should be strictly enforced. If Prof. Hall had brought out his descriptions of *Rhynobolus* and *Dinobolus*, in any of the scientific journals of this continent, in March, 1871, I would almost certainly have seen it before the month of December, and would not have published my genus. This unfortunate collision *would not then have occurred. But instead of following* the regular mode of publication he resorted to private distribution, on a most limited scale; not in America but in England. In consequence of this I knew nothing of his genera, until I was informed of them by Mr. Davidson, in a letter which only reached me on the 17th of Jan., 1872, three weeks after my paper was published. It is not, therefore, my fault but his, that a controversy has arisen. Then as regards the Canadian specimen of *O. Galtensis*, he should, before he instituted a genus upon it, have given Mr. Selwyn notice; but instead of this, although he was informed that I was working at the group of fossils to which it belongs, he said nothing about it. It is not my fault that he concealed this from us. If the species occurred in New-York, as well as in Canada, he would not have been under any obligation to give notice, but as it does not occur in that State the case is quite different. It is said that shortly after his paper was printed a part of the edition was destroyed by fire. That is his misfortune, not mine. He should have had it immediately reprinted. I am informed that it could have been done in less than half a day, and at an expense of only four dollars. Surely the rich State of New York could have afforded that amount. A great deal more might be said upon this subject, but the above is quite sufficient to show that it is not my fault that this difficulty has arisen.

In this case I do not desire that the law of publication should be harshly administered, but I insist that the circumstances are such that it should be strictly carried out. Prof. Hall's pamphlet was not regularly published, according to the strict meaning of the law, and as it is altogether his fault, and not mine, the consequences should fall upon him and not upon me. In the common law, when a loss has accrued, which must be sustained by one out of two individuals, it falls upon the one by whose misconduct or neglect of duty it has been occasioned. The same rule holds good in scientific matters, as well as in the ordinary affairs of every-day life. I bestowed a great deal of investigation on my genus, and no doubt Prof. Hall did the same upon his. As matters have turned out, either his work or mine must be lost. On whom must the loss fall? On the party who is to blame, or or on the party who is not to blame? I do not ask to have the law stretched or executed leniently in my favor. I require no such extension in order to obtain justice. I only desire that it should be strictly adhered to, and not distorted in order to favour the party who has been the cause of all this difficulty.

METEOROLOGICAL RESULTS FOR MONTREAL FOR THE YEAR 1871.

By Charles Smallwood, M.D., LL.D., D.C.L.,
Professor of Meteorology in the University McGill College, Montreal.

The following observations extend over the past year, 1871, and are reduced from the records of the Montreal Observatory, Lat. 45° 30m 17.41s Long. 4h 54m 17s west of Greenwich. The cisterns of the Barometer are 182 feet above mean sea level. The whole of the readings are corrected for any instrumental errors, and the observations of the Barometer are corrected and reduced to 32° F.

Atmospheric pressure.—The highest reading of the Barometer occurred at 10h 30m p.m., on the 25th day of January, and indicated 30,985 inches; the lowest reading was at 2h 25m p.m., on the 18th day of February, and was 29,050 inches, giving a range during the year of 1.935 inches.

The following table has been compiled to show the highest and lowest readings, also the monthly mean and monthly range in inches and decimals of an inch:

Months.	*Highest.*	*Lowest.*	*Mean.*	*Range.*
January	30.985	29.475	30.157	1.510
February	30.549	29.050	29.882	1.499
March	30.422	29.424	29.950	0.998
April	30.316	29.451	29.712	0.895
May	30.261	29.460	29.937	0.801
June	30.149	29.402	29.875	0.747
July	30.267	29.501	29.770	0.766
August	30.301	29.642	29.976	0.659
September	30.386	29.500	30.068	0.886
October	30.504	29.463	29.781	1.041
November	30.456	29.382	29.936	1.074
December	30.462	29.132	29.885	1.330

Temperature of the Air F°.—The highest reading of the Thermometer during the year was on the 13th July and was 95°. The lowest was on the 5th February and was 28° (below zero), giving a yearly range or climatic difference of 123°. The mean temperature for the year was 44.53, which is 2.23 degrees higher than the *Isothem* for Montreal deduced from observations extending over a long series of years.

The first frost of autumn occurred on the 8th September.

The warmest month during the year was the month of July, and the coldest February. The mean temperature of the warmest day was 81.70 on the 13th July, and the mean temperature of the coldest day was 13.73 (below zero) on the 5th February.

The following table shows the monthly mean temperature for 1871, with the amount of rain and snow; the snow in this case is not reduced by melting into water, but is the observed depth in inches on the surface:

Months.	*Mean Temp. in F°*	*Highest Temperat'e.*	*Lowest Temperat'e.*	*Rain in inches.*	*Snow in inches.*
January	11°74	40°1	−20°8	0.427	16.53
February	15°70	46°2	−25°0	0.509	8.36
March	35°25	61°6	17°0	3.059	13.49
April	44°41	68°0	27°1	3.085	
May	58°59	94°5	35°4	1.570	
June	67°52	92°2	45°1	1.298	
July	76°58	95°0	54°1	7.144	
August	70°67	89°6	56°7	3.066	
September ...	57°00	91°0	35°4	1.253	
October.	56°50	83°0	29°7	3.014	0.16
November....	31°60	52°3	− 6°6	1.669	9.20
December	18°50	46°0	−22°9	0.403	26.79

The following table shows the quarterly mean temperature, also the amount of rain and snow in inches for each quarter:

	Months.	*Mean Temp.*	*Rain.*	*Snow.*
Winter Quarter.	December..	24°35	0.203	21.95
	January....	11°04	0.427	16.54
	February...	18°70	0.509	8.36
Quarterly mean...........		18°03	1.139	46.84
Spring Quarter.	March	35°25	3.059	13.49
	April	44°41	3.085	
	May.	58°59	1.570	
Quarterly mean...........		46°08	7.714	13.49
Summer Quarter.	June	67°52	1.298	
	July.	76°58	7.144	
	August....	70°67	3.066	
Quarterly mean...........		69°59	11.507	
Autumn Quarter.	September .	57°00	1.253	
	October ...	56°50	3.014	0.16
	November .	31°60	1.669	9.20
Quarterly mean...........		46°36	5.936	9.36

There were three *cold terms* during the year, one in January, the second in February, and the third in December.

The first was somewhat remarkable for its duration and severity. The temperature was 101^{h} and 20 below zero, and it attained a minimum of 26°8, and the Barometer attained a maximum of 30.985 inches.

The following table will show the variations in temperature and its duration:

22nd January, 1871.

7 a.m.	+7°4	5 p.m.	— 9°0
8 "	—4°1	6 "	— 9°9
10 "	—2°6	7 "	—10°1
12 noon	0°0	8 "	—12°3
2 p.m.	—1°8	9 "	—13°1
3 "	—3°7	10 "	—16°0
4 "	—6°2	12 midnight	—18°4

23rd January, 1871.

2 a.m.	—19°8	3 p.m.	—11°7
4 "	—21°2	4 "	—13°3
6 "	—23°8	5 "	—16°7
7 "	—23°2	6 "	—18°0
8 "	—22°3	7 "	—20°0
9 "	—21°6	8 "	—21°1
10 "	—19°0	9 "	—21°9
12 noon	— 9°2	10 "	—22°1
1 p.m.	— 8°3	11 "	—22°8
2 "	— 7°2	12 midnight	—23°2

24th January, 1871.

2 a.m.	—24°6	12 noon	—14°6
4 "	—25°2	2 p.m.	—13°4
6 "	—26°8	4 "	—10°9
7 "	—25°4	6 "	— 9°0
8 "	—23°3	8 "	— 9°0
9 "	—21°8	9 "	— 9°0
10 "	—19°8		

25th January, 1871.

10 p.m.	—14°2	12 midnight	—16°0

26th January, 1871.

2 a.m.	—17°1	2 p.m.	—14°0
4 "	—19°3	4 "	—14°2
6 "	—22°7	6 "	—15°0
7 "	—22°0	8 "	—13°6
8 "	—21°0	9 "	—12°4
10 "	—17°1	10 "	—11°0
12 noon	—15°1	12 midnight	—10°2

27th January, 1871.

2 a.m.	—10°6	8 a.m.	— 6°0
4 "	— 8°0	10 "	— 3°8
6 "	— 7°0	12.40 "	— 0°0
7 "	— 6°6		

The second cold term occurred on the 4th of February and attained a temperature of —28°. The Thermometer was 52^h 45^m below zero.

The following table contains a record of the observations:

4th February, 1871.

12.15 a.m.	— 0°0	2 p.m.	— 5°2
1 "	— 2°1	2 40 "	— 0°0
2 "	— 8°0	4 "	— 8°0
4 "	—11°6	6 "	— 9°6
6 "	—15°0	8 "	—12°4
7 "	—14°1	9 "	—13°4
8 "	—13°0	10 "	—15°2
9 "	—12°0	11 "	—16°3
10 "	— 8°0	12 midnight	—20°6
12 noon	— 4°0		

5th February, 1871.

2 a.m.	—22°7	2 p.m.	— 2°1
4 "	—26°2	3 "	— 1°4
6 "	—28°0	4 "	— 5°9
7 "	—27°1	5 "	— 7°0
8 "	—25°1	6 "	— 8°0
9 "	—22°3	8 "	—11°4
10 "	—19°2	9 "	—12°0
11 "	—17°0	10 "	—12°2
12 noon	— 9°2	11 "	—11°0
1 p.m.	— 5°3	12 midnight	—11°0

6th February, 1871.

2 a.m.	—10°4	8 a.m.	— 7°7
4 "	—10°0	9 "	— 6°0
6 "	— 9°0	10 "	— 4°0
7 "	— 8°0	11 "	— 0°0

The third cold term of the 21st December set in with somewhat unusual rapidity. The early part of the evening was bright and moonlight, with but light wind from the N. W. The Thermometer attained its zero point at 8.5 p.m. and at 9 p.m. stood at —1°6. Wind N. W.; velocity 4 miles per hour. Barometer 29.632. At midnight the wind freshened and veered to the W., velocity 12 miles per hour, the Barometer slowly rising, and at 11.49 p.m. (one of the signal hours of the War Department at Washington) it stood at —5°5; at 2 a.m. it stood at —10°6; and from that time it fell rapidly and attained a minimum of —22°9. The Thermometer was 34^h below zero.

Below is a table of the observations recorded:

21st December, 1871.

8.05 p.m.	— 0°0	12 noon	— 8°0
9 "	— 1°6	1 p.m.	— 5°1
12 midnight	— 5°5	2 "	— 2°2
2 a.m.	—10°6	4 "	—12°2
4 "	—18°4	6 "	—12°4
6 "	—22°9	8 "	—12°6
7 "	—22°4	9 "	—12°9
8 "	—21°0	10 "	—12°0
9 "	—18°4	12 midnight	—10°0

22nd December, 1871.

2 a.m.	— 5°1	6 a.m.	— 1°0
4 "	— 3°4	7 "	— 0°0

The following table has been compiled to show the number of days in each month on which rain or snow fell, also the number of days without either rain or snow.

Months.	*Days of Rain.*	*Accompanied with Thunder and Lightning*	*Days of Snow.*	*Days without Rain or Snow.*
January	5	..	12	14
February	5	..	10	13
March	8	..	4	19
April	13	..	..	17
May	10	1	..	21
June	13	3	..	17
July	18	5	..	13
August	11	8	..	20
September ...	7	1	..	23
October	10	..	1	20
November ...	6	..	8	16
December ...	3	..	21	7
Total....	109	18	56	200

Rain fell on 109 days; it amounted to 26.507 inches, was accompanied by thunder and lightning in 18 days, and shows a large decrease in the usual annual rain fall.

Snow fell on 56 days, amounting to 74.53 inches on the surface, which is equivalent to about 7.450 inches of rain.

The first snow of autumn fell on the 18th October, and the winter fairly set in on the 29th November, with unusual severity, and somewhat earlier than the usual period, causing severe losses to shipping from foreign ports as also to the river navigation.

The Thermometer first attained its zero point on the 29th November.

The ice left the front of the city on the 8th of April, and the first steamer arrived in port on the 10th day. The last frost of spring was on the 26th of April.

Winds.—The most prevalent wind during the year was the West, the next in frequency the N. E. The most windy month in the year was May, and the least windy month July.

Below is a table showing the direction of the wind for each month and its mean velocity in miles, irrespective of its direction:

Months.	N	NE	E	SE	S	SW	W	NW	*Calm.*	*Veloc'y*
January	0	61	0	0	0	6	19	5	0	4.82
February.....	3	9	0	0	0	19	52	1	0	5.77
March.......	0	26	0	5	4	7	38	7	6	2.86
April........	1	22	0	5	3	14	43	0	2	5.04
May.........	0	39	0	3	0	12	36	0	1	6.89
June	0	20	0	0	3	13	54	0	0	1.84
July	0	17	2	1	0	16	54	2	1	1.84
August	0	23	0	0	9	10	46	5	0	4.55
September...	4	5	1	0	14	7	53	5	1	4.34
October	2	13	1	2	12	23	34	6	0	4.07
November ...	12	19	2	6	5	0	41	4	1	3.84
December ...	0	13	0	1	0	23	48	7	1	4.84

Mean monthly amount of clouds in decimals, a cloudy sky being represented by a whole number (1.00.)

Months.	*Amount.*	*Months.*	*Amount.*
January	0.40	July	0.40
February	0.30	August	0.30
March	0.40	September	0.30
April	0.50	October.........	0.60
May.............	0.30	November.......	0.60
June	0.30	December.......	0.70

There were 138 nights suitable for astronomical purposes during the year.

The aurora borealis was visible at observation hours on 26 nights, and exhibited some grand displays on the 10th and 11th of February, 17th March, 9th of April, 7th of August, 7th of September and the 9th of November.

MONTREAL OBSERVATORY, 30th Jan., 1872.

PROCEEDINGS OF THE
NATURAL HISTORY SOCIETY,

Session 1871–72.

MONTHLY MEETINGS.

1st Monthly Meeting, October 30th, 1871,—Principal Dawson presiding.

A donation of a large collection of fossils from Sir G. Duncan Gibb, Bart., M.A., M.D., F.G.S., &c., &c., having been announced by the Recording Secretary, a special vote of thanks to the donor was passed.

Prof. J. B. Edwards made a communication on an insect larva (?) which he stated perforated filters made of silicated carbon.

Mr. J. F. Whiteaves read a paper entitled "Log of a Deep-Sea Dredging Cruise round the Island of Anticosti." This forms the first part of a report submitted by the author to the Hon. the Minister of Marine and Fisheries for publication, the whole of which it is hoped will appear, with the writer's latest corrections, in an early number of this journal.

A paper by Dr. Anderson, entitled "The Whale of the St. Lawrence," was read by the Rec. Secretary. This will be found at pages 203–208 of the present volume.

The following resolutions having been moved by Dr. Smallwood and seconded by G. L. Marler, were unanimously adopted:

"That this Society desires to convey to the Hon. the Minister of Marine its grateful acknowledgments for the aid afforded to its Scientific Curator in the prosecution of his researches into the fauna of the deeper parts of the Gulf of St. Lawrence during the past summer, and to express its confidence that the results will be found to be useful and creditable to Canada, both in a practical and scientific point of view, and such as to encourage a continuation and extension of similar investigations."

"That this resolution be communicated to the Hon. the Minister of Marine, with the assurance that the Society will do all in its power to enable the important scientific results of the expedition to be worked out, and published as extensively as possible."

A copy of the above resolutions was duly forwarded to the Hon. Mr. Mitchell, to which the following reply was returned:

OTTAWA, Nov. 25, 1871.

SIR,—I have to acknowledge the receipt of your letter of the 3rd instant, informing me that at a meeting of the Natural History Society of Montreal, held on the 30th September last, a resolution of thanks was unanimously carried to myself, for the aid which I had afforded the Scientific Curator of the Society in the prosecution of his researches into the fauna of the deeper parts of the St. Lawrence Gulf during the past summer, and I am gratified to find in the second resolution that the Society have confidence "that the results will be found to be useful and creditable to Canada, both in a practical and scientific point of view, and such as to encourage a continuation and extension of similar investigations." I am gratified also to learn that it is the intention of tho Society to "do all in its power to enable the important scientific results of the expedition to be worked out and published as extensively as possible."

While this action of the Natural History Society is personally very gratifying to me, it is also satisfactory to me to be able to state that the Government, in granting the facilities which your Society asked for during the past season, performed an act which, I believe, commended itself to the intelligence of the country, and I have no doubt that the action of the researches of the Society in the future, directed as they are by intelligence and scientific skill, will always command the use of similar facilities such as those referred to at the command of the Government. It will afford me much pleasure to notice the result of your labours, if furnished therewith, in the annual report of my Department.

I have the honor to be,
Yours, &c.,

P. MITCHELL.

J. F. WHITEAVES, Esq., F.G.S.,
Montreal.

2nd Monthly Meeting, Nov. 29th, 1871.

The Most Rev. the Bishop of Montreal and Metropolitan, Rev. Charles Chapman, M.A., Drs. Eneas, Leprohon, Wilkins and McEachran, and Messrs. T. Wright, W. S. Walker, Alexander Robertson, Thomas Curry, S. B. Scott, H. Mott, N. Mercer, F. W. Hicks, M.A., and J. Dey, B.A., were elected Members of the Society.

Prof. Nicholson's paper "On the Colonies of M. Barrande," was presented; and Mr. Billings gave a popular exposition of Prof. Barrande's views. The article referred to will be found on page 188. Dr. T. Sterry Hunt then made a communication "On the Geological Structure of Mont Blanc." An article on this subject, by Dr. Hunt, entitled "On Arctic Geology," will be found in the American Journal of Science and Arts, for January, 1872.

3rd Monthly Meeting, Jan. 29th, 1872.

The Secretary announced a donation of more than 120 volumes of the Zoological Catalogues of the British Museum, from the Trustees of that Institution, to whom a special vote of thanks was unanimously voted.

Prof. G. F. Armstrong, M.A., F.G.S., and Dr. B. J. Harrington were elected ordinary members, and Sir G. Duncan Gibb, Bart., M.A., M.D., LL.D., &c., a corresponding member of the Society.

Principal Dawson made a communication on the Physical Geography of Prince Edward Island. The paper commenced with noticing the form and geographical position of the Island as a crescent-shaped and much indented expanse of undulating and fertile land, more than 100 miles in length, lying in the almost semicircular bend formed by the southern side of the Gulf of St. Lawrence, and separated from the neighbouring coasts of Nova Scotia and New Brunswick by Northumberland Strait. The principal geological formations are the Triassic red sandstones, the almost equally red sandstones of the Upper Carboniferous rocks, which extend across from Nova Scotia and New Brunswick, and appear in limited areas on the West Coast and in Hillsborough Bay. The soil of the Island is almost throughout a fertile red loam, and the beautifully undulating surface, bright green fields contrasting with the red soil, frequent groves and belts of trees, and neat homesteads, give an appearance of beauty and rural comfort not surpassed by any portion of America. The Island is said to be more thickly peopled and more highly cultivated than any other portion of British America of equal extent. Its climate is much more mild and equable than that of Eastern Canada. In July last the horse-mowing machines, which are almost universally used, were to be seen everywhere laying down a crop of hay not to be surpassed in any country, and the wide fields of clean and tall oats presented a magnificent appearance. The potato and turnip are largely cultivated, and wheat to a less extent. In the end of July, however, the author visited a field on the estate of the Hon. Mr. Pope, where a very heavy crop of winter wheat was being cut. The natural fertility of the soil is largely aided by the application to it of mussel or oyster mud obtained in inexhaustible quantities from the old oyster beds of the bays and creeks, by means of dredging machines mounted on rafts in summer and on the ice in winter.

Prince Edward Island possesses excellent sandstone for building, abundance of brick clay, and large deposits of valuable peat. The Coal Formation rocks underlie the whole of the Island, but are probably at a depth too great to permit their profitable exploration at present. Iron, copper, and manganese ores in small quantities occur, but are insufficient for mining purposes. There are beds of useful though impure limestone. Fossil plants, as trunks of coniferous trees and leaves of ferns, occur in great abundance in the beds of the Upper Coal formation, and a few fossil plants occur in the Trias, among them a stem of a cycad, the first discovered in these Provinces. The most remarkable fossil of the latter formation is the large and formidable reptile *Bathygnathus borealis*, an ancient inhabitant of Prince Edward Island, comparable with the great Saurians, which have left their remains in rocks of similar age in the old world. The boulder formation occurs in Prince Edward Island, and in its upper portion includes boulders which must have been drifted from Labrador on the one hand and New Brunswick on the other. Another very remarkable feature of the modern geology is the great extent of sand dunes or hills of blown sand, along the northern coast. For further details the author referred to a report recently prepared by himself and Dr. Harrington, on the geology of this inerest ing and important Province.

After the reading of this paper, Dr. T. Sterry Hunt made some commendatory remarks on its general scope and scientific aspect, and pointed out that in this Island we have an example of two rock formations resting conformably the one on the other, between which a "lost epoch" (the Permian formation) should have intervened, if the succession of rocks had been unbroken. Dr. B. J. Harrington also gave an account of the peat formations of the Island.

Mr. E. Billings read a paper "On some supposed fossils from the Huronian Rocks of Newfoundland."

These supposed organisms, as they are provisionally regarded, belong to two species, or at any rate present two kinds of appearances, but their affinities are at present exceedingly doubtful. A discussion ensued as to the age of the rocks in which these supposed fossils were found, Mr. Billings maintaining (with Mr. A. Murray, the Director of the Geological Survey of Newfoundland), that they are of Huronian age, and Dr. T. Sterry Hunt, that they are of a newer horizon, and belong to the base of the Primordial zone.

4th Monthly Meeting, Feb. 26th, 1872.

Prof. H. A. Nicholson, of Toronto, was elected a corresponding member of the Society.

A paper by Prof. H. A. Nicholson, entitled Sexual Selection in Man, was presented, and Mr. Darwin's views on that subject, with Prof. Nicholson's comments thereon, were explained and illustrated by Principal Dawson. Prof. Nicholson's paper will appear in the next No. of this journal.

A paper entitled "On the Cultivation of Chenopodium Quinoa," was read by Principal Dawson. This we hope to print also in our next number.

Dr. P. P. Carpenter made a communication "On the present condition and causes of the Montreal Death Rate."

SOMERVILLE LECTURES.

The six Annual Lectures of the Somerville Course were duly delivered as follows:

1. Feb. 8th, 1872.—On Mont Blanc, by Dr. T. Sterry Hunt, F.R.S.

2. Feb. 15th, 1872.—A New England Clam-Bake, by Dr. P. P. Carpenter.

3. Feb. 22nd, 1872.—Applied science as illustrated in the processes of Chromo and Photo-Lithography, by Prof. J. B. Edwards, Ph. D., D.C.L., &c.

4. March 7th, 1872.—The elementary principles of Spectrum Analysis, by Prof. G. F. Armstrong, M.A., F.G.S.

5. March 14th, 1872.—On Thermometers and other measures of Heat, by Dr. G. P. Girdwood.

6. March 21st, 1872.—On Fossil Foot-prints, by Principal Dawson, LL.D., F.R.S., &c.

GEOLOGY AND MINERALOGY.

On the Structure of the Palæozoic Crinoids.—The best known living representatives of the Echinoderm class Crinoidea are the genera *Antedon* and *Pentacrinus*—the former the feather stars, tolerably common in all seas; the latter the stalked sea-lilies, whose only ascertained habitat, until lately, was the deeper portion of the sea of the Antilles, whence they were rarely recovered by being accidentally entangled on fishing-lines. Within the last few years Mr. Robert Damon, the well-known dealer in natural history objects in Weymouth, has procured a considerable number of specimens of the two West Indian *Pentacrini*, and Dr. Carpenter and the author had an opportunity of making very detailed observations both on the hard and the soft parts. These observations will shortly be published.

The genera *Antedon* and *Pentacrinus* resemble one another in all essential particulars of internal structure. The great distinction between them is, that while *Antedon* swims freely in the water, and anchors itself at will by means of a set of "dorsal cirri," *Pentacrinus* is attached to a jointed stem, which is either permanently fixed to some foreign body, or, as in the case of a fine species procured off the coast of Portugal during the cruise of the *Porcupine* in the summer of 1870, loosely rooted by a whorl of terminal cirri in soft mud. Setting aside the stalk, in *Antedon* and *Pentacrinus* the body consists of a rounded central disc and ten or more pinnated arms. A ciliated groove runs along the "oral" or "ventral" surface of the pinnules and arms, and these tributary brachial grooves gradually coalescing, terminate in five radial grooves, which end in an oral opening, usually subcentral, sometimes very excentric. The œsophagus, stomach, and intestine coil round a central axis, formed of dense connective tissue, apparently continuous with the stroma of the ovary, and of involutions of the perivisceral membrane; and the intestine ends in an anal tube, which opens excentrically in one of the inter-radial spaces, and usually projects considerably above the surface of the disc. The contents of the stomach are found uniformly to consist of a pulp composed of particles of organic matter, the shields of diatoms, and the shells of minute foraminifera. The mode of nutrition may be readily observed in *Antedon*, which will live for months in a tank. The animal rests attached by its dorsal cirri, with its arms expanded like the petals of a full-blown flower. A current of sea water, bearing organic particles, is carried by the cilia along the brachial grooves into the mouth, the water is exhausted of its assimilable matter in the alimentary canal, and is finally ejected at the anal orifice. The length and direction of the anal tube prevent the exhausted water and the fœcal matter from returning at once into the ciliated passages.

In the probably extinct family Cyathocrinidæ, and notably in the genus *Cyathocrinus*, which the author took as the type of the Palæozoic group, the so-called Crinoidea Tessellata, the arrangement, up to a certain point, is much the same. There is a widely-expanded crown of branching arms, deeply grooved, which doubtless performed the same functions as the grooved arms of *Pentacrinus;* but the grooves stop short at the edge of the disc, and there is no central opening, the only visible apertures being a tube, sometimes of extreme length, rising from the surface of the disc in one of the inter-radial spaces, which is usually greatly enlarged for its accommodation by the intercalation of additional perisomatic plates, and a small tunnel-like opening through the perisom of the edge of the disc opposite the base of each of the arms, in continuation of the groove of the arm. The functions of these openings, and the mode of nutrition of the crinoid having this structure, have been the subject of much controversy.

The author had lately had an opportunity of examining some very remarkable specimens of *Cyathocrinus arthriticus*, procured by Mr. Charles Ketley from the Upper Silurians of Wenlock, and a number of wonderfully perfect examples of species of the genera *Actinocrinus*, *Platycrinus*, and others, for which he was indebted to the liberality of Mr. Charles Wachsmuth, of Burlington, Ohio, and Mr. Sydney Lyon, of Jeffersonville, Indiana; and he had also had the advantage of studying photographs of plates, showing the internal structure of fossil crinoids, about to be published by Messrs. Meek and Worthen, State Geologists for Illinois. A careful examination of all these, taken in connection with the description by Prof. Lovén, of *Hyponome Sarcii*, a recent crinoid lately procured from Torres Strait, had led him to the following general conclusions.

In accordance with the views of Dr. Schultze, Dr. Lütken, and Messrs. Meek and Worthen, he regarded the proboscis of the tesselated crinoids as the anal tube, corresponding in every respect with the anal tube in *Antedon* and *Pentacrinus*, and he maintained the opinion which he formerly published (Edin. New Phil. Jour. Jan. 1861), that the valvular " pyramid " of the Cystideans is also the anus. The true mouth in the tesselated crinoids is an internal opening vaulted over by the plates of perisom, and situated in the axis of the radial system more or less in advance of the anal tube, in the position assigned by Mr. Billings to his " ambulacral opening." Five, ten, or more openings round the edge of the disc lead into channels continuous with the grooves in the ventral surface of the arms, either covered over like the mouth by perisomatic plates, the inner surface of which they more or less impress, and supported beneath by chains of ossicles ; or, in rare cases (*Amphoracrinus*), tunnelled in the substance of the greatly thickened walls of the vault. These internal passages, usually reduced in number to five by uniting with one another, pass into the internal mouth, into which they doubtless lead the current from the ciliated brachial grooves.

In connection with different species of *Platyceras* with various crinoids, over whose anal openings they fix themselves, moulding the edges of their shells to the form of shell of the crinoid, is a case of " commensualism," in which the mollusc takes advantage for nutrition and respiration of the current passing through the alimentary canal of the echinoderm. *Hyponome Sarsii* appears, from Prof. Lovén's description, to be a true crinoid, closely allied to *Antedon*, and does not seem in any way to resemble the Cystideans. It has, however, precisely the same arrangement as to its internal radial vessels and mouth which we find in the older crinoids. It bears the same structural relation to *Antedon* which *Extracrinus* bears to *Pentacrinus*.

Some examples of different tesselated crinoids from the Burlington limestone, most of them procured by Mr. Wachsmuth, and described by Messrs. Meek and Worthen, show a very remarkable convoluted plate, somewhat in form like the shell of a *Scaphander*, placed vertically in the centre of the cup, in the position occupied by the fibrous axis or columella in *Pentacrinus* and *Antedon*. Mr. Billings, the distinguished palæontologist to the Survey of Canada, in a very valuable paper on the structure of the Crinoidea, Cystidea, and Blastoidea (*Silliman's Journal*, January, 1870), advocates the view that the plate is connected with the apparatus of respiration, and that it is homologous with the pectinated rhombs of Cystideans, the tube apparatus of Pentremites, and the sand-canal of Asterids. Messrs Meek and Worthen and Dr. Lütken, on the other hand, regard it as associated in some way with the alimentary canal and the function of nutrition.

The author strongly supported the latter opinion. The perivisceral membrane in *Antedon* and *Pentacrinus* already alluded to, which lines the whole calyx, and whose involutions, supporting the coils of the alimentary canal, contribute to the formation of the central columella, is crowded with miliary grains and small plates of carbonate of line; and a very slight modification would convert the whole into a delicate fenestrated calcareous plate. Some of the specimens in Mr. Wachsmuth's collection show the open reticulated tissue of the central coil continuous over the whole of the interior of the calyx, and rising on the walls of the vault, thus following almost exactly the course of the perivisceral membrane in the recent forms. In all likelihood, therefore, the internal calcareous network in the crinoids, whether rising into a convoluted plate or lining the cavity of the crinoid head, is simply a calcified condition of the perivisceral sac.

The author was inclined to agree with Mr. Rofe and Mr. Billings in attributing the functions of respiration to the pectinated rhombs of the Cystideans and the tube apparatus of the Blastoids. He did not see, however, that any equivalent arrangement was either necessary or probable in the crinoids with expanded arm, in which the provisions for respiration, in the form of tubular tentacles and respiratory films and lobes over the whole extent of the arms and pinnules, are so elaborate and complete.—*Abstract of a paper read before the Royal Society of Edinburgh, by Prof. Wyville Thomson, April 3, 1871. From "Nature."*

On the supposed Legs of the Trilobite, Asaphus platycephalus. By James D. Dana.—(Am. Jour. Sci. May, 1871.) * At the request of Mr. E. Billings of Montreal, I have recently examined the specimen of *Asaphus platycephalus* be-

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* In the last number of this Journal, p. 227, an abstract from the Report of the Committee of the Brit. Association on Fossil Crustacea was published, and this paper should have appeared at the same time. In the March number of the Am. Jour. Sci., Prof. Dana has given a second notice, in reply to Mr. Woodward. We shall publish them both together.

longing to the Canadian Geological Museum, which has been supposed to show remains of legs. Mr. Billings, while he has suspected the organs to be legs so far as to publish on the subject, * has done so with reserve, saying, in his paper, "that the first and all-important point to be decided, is whether or not the forms exhibited on its under side, were truly what they appeared to be, locomotive organs." On account of his doubts, the specimen was submitted by him during the past year to the Geological Society of London; and for the same reason, notwithstanding the corroboration there received, he offered to place the specimen in my hands for examination and report.

Besides giving the specimen an examination myself, I have submitted it also to Mr. A. E. Verrill, Prof. of Zoology in Yale College, who is well versed in the invertebrates, and to Mr. S. I Smith, assistant in the same department, and excellent in crustaceology and entomology. We have separately and together considered the character of the specimen, and while we have reached the same conclusion, we are to be regarded as independent judges. Our opinion has been submitted to Mr. Billings, and by his request it is here published.

The conclusion to which we have come is that the organs are not legs, but the semi-calcified arches in the membrane of the ventral surface to which the foliaceous appendages, or legs, were attached. Just such arches exist in the ventral surface of the Macroura, and to them the abdominal appendages are articulated.

This conclusion is sustained by the observation that in one part of the venter three consecutive parallel arches are distinctly connected by the intervening outer membrane of the venter, showing that the arches were plainly *in the membrane*, as only a calcified portion of it, and were not members moving free above it. This being the fact, it seems to set at rest the question as to the legs. We should add, however, that there is good reason for believing the supposed legs to have been such arches in their continuing of nearly uniform width almost or quite to the lateral margin of the animal; and in the additional fact, that, although curving forward in their course toward the margin, the successive arches are about equidistant or parallel, a regularity of position

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* Q. J. Geol. Soc., No. 104, p. 479, 1870, with a plate giving a full-sized view of the under surface of the trilobite, a species that was over four inches in length.

not to be looked for in free-moving legs. The curve in these arches, although it implies a forward ventral extension on either side of the leg-bearing segments of the body, does not appear to afford any good reason for doubting the above conclusion. It is probable that the two prominences on each arch nearest the median line of the body, which are rather marked, were points of muscular attachment for the foliaceous appendage it supported.

With the exception of these arches, the under surface of the venter must have been delicately membranous, like that of the abdomen of a lobster or other macrouran. Unless the under surface were in the main fleshy, trilobites could not have rolled into a ball.

SUPPOSED LEGS OF TRILOBITES.—Mr. Henry Woodward, of the British Museum, in a reply to the paper by the writer in volume i, p. 320, of the present series of this Journal, supports the view that the supposed legs are real legs. He says that the remark that the calcified arches were plainly a calcified portion of the membrane or skin of the under surface is "an error, arising from the supposition that the matrix represented a part of the organism." But Prof. Verrill, Mr. Smith and myself are confident that there is on the specimen an impression of the skin of the under surface, and that this surface extended and connected with the arches, so that all belonged distinctly together.

Moreover the arches are exceedingly slender, far too much so for the free legs of so large an animal; *the diameter of the joints is hardly more than a sixteenth of an inch outside measure; and hence there is no room inside for the required muscles.* In fact, legs with such proportions do not belong to the class of Crustaceans. Moreover the shell (if it is the shell of a leg instead of a calcified arch) is relatively thick, and this makes the matter worse.

We still hold that the regular spacing of these arches along the under surface renders it very improbable that they were legs. Had they been closely crowded together, this argument would be of less weight; but while so very slender, they are a fourth of an inch apart. Mr, Wooward's comparison between the usual form of the arches in a Macrouran and that in the trilobite does not appear to us to prove anything. We therefore still believe that the specimen does not give us any knowledge of the actual legs of the trilobite. Mr. Woodward's paper is contained in vol. vii No. 7, of the Geological Magazine. J. D. D.

3. NOTE ON THE DISCOVERY OF FOSSILS IN THE "WINOOSKI MARBLE" AT SWANTON, VT.; by E. BILLINGS, F.G.S., Palæontologist of the Geol. Surv. Canada.—A few days ago Mr. Solon M. Allis, of Burlington, Vt., visited our museum and informed me that he had a specimen of the Winooski marble of Swanton which contained some fossils. Since then he has sent it to me. It contains, abundantly, a species of *Salterella*, which I believe to be the *S. pulchella* described in my Pal. Foss., vol. i, p. 18. This marble, both at Swanton and St. Albans, seems to underlie the Geologia slates. It is generally of a reddish, mottled color, but sometimes gray or greenish. The limestone at the straits of Belle Isle, in which *S. pulchella* is found, is also red, gray and greenish; and is, I have no doubt, of the same age. At this latter locality it overlies a red or brownish sandstone, conformably, which holds *Scolithus linearis*. I consider the Belle Isle sandstone to be the "Quartz rock" of the Green mountains of Vermont. In that case, the limestone at Belle Isle occupies, stratigraphically, the position of the Stockbridge limestone as represented by Dr. Emmons in his American Geology, part 2, p. 19. On page 19 of the same work, Dr. E., speaking of the Stockbridge limestone, says: "It is reddish at Williamston and is intimately blended with silex." In his Report on the Second Geological District of New York, in 1838, page 232, he gives a section of the rocks at Burlington combined with one of the strata at Port Kent. He there notices a gray limestone (at Burlington) of which he says:—"It is a stratum, which in Berkshire county, and other parts of the country, has generally been placed among the primary rocks; it is identical with the limestone at the base of Saddle mountain, and which covers more or less of the western flank of the Green Mountains." If the limestone to which he alludes is one of the gray varieties of the Winooski marble, then he is most probably right. I believe Mr. Allis's fossils are the first that have been found in the Winooski marble.

ZOOLOGY AND BOTANY.

DEEP-SEA DREDGING IN THE GULF OF ST. LAWRENCE.—The marine zoology of the deeper parts of the River and Gulf of the St. Lawrence has not been investigated until quite recently. This summer, under the auspices of the Natural History Society of

Montreal, and in consequence of the kindness of the Hon. Peter Mitchell, Minister of Marine and Fisheries for the Dominion (who not only gave me facilities for dredging or board Government vessels, but also caused sufficient rope to be provided for the purpose), depths of from 50 to 250 fathoms were successfully examined. The greatest depth in the Gulf, to the west of the Island of Newfoundland, as given in the Admiralty charts, is 313 fathoms.

The cruise lasted five weeks, the first three of which were spent on board the Government shooner *La Canadienne*, and the remaining two on the *Stella Maris*. The area examined includes an entire circuit round the Island of Anticosti, and extends from Point des Monts (on the north shore of the St. Lawrence) to a spot about half way between the east end of Anticosti and the Bird Rocks. As these investigations were almost necessarily subordinate to the special duties on which the schooners were engaged, in several cases the same ground was gone over twice.

The bottom at great depths generally consists of a tough clayey mud, the surface of which is occasionally dotted with large stones. So far as I could judge, using an ordinary thermometer, the average temperature of this mud was about 37° to 38° Fahrenheit, at least on the north shore. In the deepest parts of the river, on the south shore, between Anticosti and part of the Gaspe Peninsula, the thermometer registered a few degrees higher. Sand dredged on the north shore in 25 fathoms also made the mercury sink to 37° to 38°.

Many interesting Foraminifera and Sponges were obtained, but as yet only a few of these have been examined with any care. A number of Pennatulæ were dredged south of Anticosti; the genus has not been previously recorded, so far as I am aware, as inhabiting the Atlantic coast of America. They were found in mud, at depths of 160 and 200 fathoms, and it seems probable that this species, at least, is sedentary, and that it lives with a portion of the base of the stem rooted in the soft mud. *Actinia dianthus* and *Tealia crassicornis* were frequent in 200 to 250 fathoms. The Echinoderms characteristic of the greater depths are a *Spatangus* (specifically distinct from the common British species), *Ctenodicus crispatus*, *Ophioglypha Sarcii* (very large), *Ophiacantha spinulosa*, and *Amphiura Holbollii*. Marine worms, of many genera and species, were both numerous and fine. Among the more interesting of the Crustacea were *Nymphon grossipes* (?)

and a species of *Pycnogonum*. Several of the last-named crustaceans were taken at a depth of 250 fathoms, entangled on a swab, fastened in front of a deep-sea lead, which was attached to the rope, a few feet from the mouth of the dredge. This circumstance tends to show that the genus is not always parasitic in its habits. The Decapods, Amphipods, &c., at least those of greatest interest, have not yet been identified. Among the most noticeable of the marine Polyzoa are *Defrancia truncata*, and what appears to be a *Retepora*. Not many species in this group were obtained in very deep water, and those procured were, for the most part, of small size. About six species of Tunicates were collected. Being anxious to have Mr. J. Gwyn Jeffreys' opinion upon the various species of Mollusca during his visit to Montreal, I studied these carefully first, and submitted the whole of them to him for examination. Twenty-four species of Testaceous Mollusca were obtained at depths of from 90 to 250 fathoms. Nearly all of these are Arctic forms, and eleven of them are new to the continent of America.

The following are some of the most interesting of the deep-water Lamellibranchiata :—*Pecta grœnlandicus* of Chemnitz, but not of Sowerby; * *Arca pectunculoides* Scacchi; *Yoldia lucida* Loven; *Y. frigida* * Torell; *Neœra artica* * Sars; *N. Obesa** Loven. Among the novelties in the Gasteropoda of the same zone are the subjoined :—*Dentalium abyssorum* Sars; *Siphonodentalium vitreum* Sars; *Eulima stenostoma* Jeffreys; *Bela Trevelyana* Turton*; *Chrysodomus (Sipho) Sarsii* Jeffreys.* Three Brachiopods occur in the Gulf, of which *Rhynchonella psittacea* and *Terebratella Spitzbergensis* are found in about 20—50 fathoms, and *Terebratula septentrionalis* in from 100—250. A few rare shells were obtained in comparatively shallow water; among them an undescribed *Tellina* (of the section *Macoma*), a new *Odostomia*, and *Chrysodomus (Sipho) Spitzbergensis** Reeve. Nor were even the Vertebrata unrepresented; from a depth of 96 fathoms off Trinity Bay, a young living example of the "Norway Haddock" (*Sebastes Norvegicus*) was brought up in the dredge. And off Charleton Point, Anticosti, in 112 fathoms, on a stony bottom, two small fishes were also taken; one, a juvenile wolf-fish

* I am indebted to Mr. Jeffreys for the identification of species to which an asterisk is attached. He corroborates also my determination of the remainder.

(*Anarrhicas lupus*) the other a small gurnard, a species of *Agonus*, probably *A. hexagonus* Schneid.

The similarity of the deep-sea fauna of the St. Lawrence to that of the quaternary deposits of Norway, as described by the late Dr. Sars, is somewhat noticeable. *Pennatulæ*, *Ophiura Sarsii*, *Ctenodiscus crispatus*, several Mollusca, &c., are common to both; but on the other hand, the absence of so many characteristic European invertebrates on the American side of the Atlantic should be taken into consideration. The resemblance between the recent fauna of the deeper parts of the St. Lawrence, and that of the Post-pliocene deposits of Canada, does not seem very close, but our knowledge of each is so limited that any generalisations would be premature.—J. F. WHITEAVES in "Nature."

FISH-NEST IN THE SEA-WEED OF THE SARGASSO SEA.—Extracts from a letter from Professor Agassiz to Prof. Peirce, Superintendent U. S. Coast Survey, dated Hassler Expedition, St. Thomas, Dec. 15, 1871.— * * * The most interesting discovery of the voyage thus far is the finding of a nest built by a fish, floating on the broad ocean with its live freight. On the 13th of the month, Mr. Mansfield, one of the officers of the Hassler, brought me a ball of Gulf weed which he had just picked up, and which excited my curiosity to the utmost. It was a round mass of sargassum about the size of two fists, rolled up together. The whole consisted, to all appearance, of nothing but Gulf weed, the branches and leaves of which were, however; evidently knit together, and not merely balled into a roundish mass; for, though some of the leaves and branches hung loose from the rest, it became at once visible that the bulk of the ball was held together by threads trending in every direction, among the sea-weed, as if a couple of handfuls of branches of sargassum had been rolled up together with elastic threads trending in every direction. Put back into a large bowl of water, it became apparent that this mass of sea-weed was a nest, the central part of which was more closely bound up together in the form of a ball, with several loose branches extending in various directions, by which the whole was kept floating.

A more careful examination very soon revealed the fact that the elastic threads which held the Gulf weed together were beaded at intervals, sometimes two or three beads being close together, or a bunch of them hanging from the same cluster of threads, or they were, more rarely, scattered at a greater distance one from the other. Nowhere was there much regularity observable in the distribution of the beads, and they were found scattered throughout the whole ball of sea-weeds pretty uniformly. The beads themselves were about the size of an ordinary pin's head. We had, no doubt, a nest before us, of the most curious kind; full of eggs too; the eggs scattered throughout the mass of the nest and not placed together in a cavity of the whole structure. What animal could have built this singular nest, was the next question. It did not take much time to ascertain the class of the animal kingdom to which it belongs. A common pocket lens at once revealed two large eyes upon the side of the head, and a tail bent over the back of the body, as the embryo uniformly appears in ordinary fishes shortly before the period of hatching. The many empty egg-cases observed in the nest gave promise of an early opportunity of seeing some embryos freeing themselves from their envelope. Meanwhile a number of these eggs with live embryos were cut out of the nest and placed in separate glass jars to multiply the chances of preserving them, while the nest as a whole was secured in alcohol, as a memorial of our unexpected discovery. The next day I found two embryos in one of my glass jars; they occasionally moved in jerks, and then rested for a long while motionless upon the bottom of the jar. On the third day I had over a dozen of these young fishes in my rack, the oldest of which began to be more active, and promised to afford further opportunities for study.

* * * But what kind of fish was this? About the time of hatching, the fins of this class of animals differ too much from those of the adult, and the general form exhibits too few peculiarities, to afford any clue to this problem. I could suppose only that it would probably prove to be one of the pelagic species of the Atlantic, and of these the most common are Exocœtus, Naucratus, Scopelus, Chironectes, Syngnathus, Monacanthus, Tetraodon and Diodon. Was there a way to come nearer to a correct solution of my doubts?

As I had in former years made a somewhat extensive study of the pigment cells of the skin, in a variety of young fishes, I now resorted to this method to identify my embryos. Happily we had on board several pelagic fishes alive, which could afford means of comparison, but unfortunately the steamer was shaking too much and rolling too heavily, for microscopic observation of even moderately high power. Nothing however, should be left untried, and the very first comparison I made secured the desired result. The pigment cells of a young *Chironectes pictus* proved identical with those of our little embryos.

It thus stands as a well authenticated fact that the common pelagic Chironectes of the Atlantic (named *Chironectes pictus* by Cuvier), builds a nest for its eggs in which the progeny is wrapped up with the materials of which the nest itself is composed; and as these materials are living Gulf weed, the fish-cradle, rocking upon the deep ocean, is carried along as an undying arbor, affording at the same time protection and afterward food for its living freight.

This marvelous story acquires additional interest if we now take into consideration what are the characteristic peculiarities of the Chironectes. As its name indicates, it has fins like hands; that is to say, the pectoral fins are supported by a kind of prolonged, wrist-like appendages, and the rays of the ventrals are not unlike rude fingers. With these limbs these fishes have long been known to attach themselves to sea-weed, and rather to walk than to swim in their natural element. But now that we have become acquainted with their mode of reproduction, it may fairly be asked if the most important use to which their peculiarly constructed fins are put is not probably in building their nest.—*Silliman's Journal.*

PROF. AGASSIZ'S EXPEDITION.—It is probable that I may have been anticipated, as regards part of the present communication. If not, I believe that many of your readers will be glad to learn the objects with which Prof. Agassiz has started, with Count Pourtales and a distinguished band of skilled observers, on a scientific expedition in the United States' surveying ship *Hassler*, and to receive a brief account of what he has already done at St. Thomas and Barbados, at which places he was obliged to touch, in consequence of defects in the vessel or her machinery.

The Expedition was detained some days at St. Thomas, and the time of the Professor and his assistants was devoted chiefly to the collection and preparation of fishes, with a view to the study of the brain, and the breathing and digestive organs. Several boxes full, preserved in alcohol, were at once shipped to the United States, as the first-fruits of the Expedition.

The party arrived at Barbados on December 26, and spent four days there. The first two were devoted by the Professor to examining and studying the large collection of West Indian shells, marine and terrestrial, of corals, sponges, crustacea, semi-fossil shells of the island, made by the Governor, Mr. RAWSON. Of the marine series he wrote in the following terms to Mr. J. G. Anthony, the Curator of the Harvard Museum:—"I am having high carnival. I have found here what I did not expect to find anywhere in the world—a collection of shells in which the young are put up with as much care as the adult, and extensive series of specimens show the whole range of changes of the species, from the formation of the nucleus to the adult." He was particularly struck with the now unique specimen of *Holopus*, lately procured by Mr. RAWSON, which was described by Dr. J. E. Gray in the December number of the "Annals of Natural History," and named by him, from a drawing, *H. Rawsoni*, but which Agassiz, who had seen the specimen of D'Orbigny in Paris, before it disappeared, considers to be a normal specimen of *H. Ranzii*, which had only four, instead of five arms. Count Pourtales recognised among the corals several similar to those which he had obtained by dredging in or near the Gulf Stream, and described in the latest No. (4) of the "Illustrated Catalogue of the Museum of Comparative Zoology at Harvard College," the presence of which on the coast of Barbados serves to indicate the close similarity of submarine life in those two distant localities.

The next two days, or rather the night of the next, and the greater part of the following day, were spent in dredging in the neighbourhood, in a depth of 60 to 120 fathoms, about a mile from the shore, whence Mr. RAWSON has procured his fine specimens of *Pentacrinus Mülleri*. The *Holopus* was found on the opposite side of the island. The results were beyond the expectations, or even the hopes, of the most sanguine of the party. Only dead fragments of the *Pentacrinus* were obtained, but among the abundant spoils were four specimens of a new genus of Crinoid, without arms on the stem, (like *Rhizocrinus ?*) which remained alive, with the arms in motion, until noon on the following day, under the excited observation of the party. A number of deep-sea corals, alive, crustacea, sea urchins of new species, star fish, sponges (crutaceous, jurassic,) and corallines, &c., and a rich harvest of shells, were obtained. Among these was a splendid live specimen of *Pleurotomaria Quoyana*, F and B, of which genus Chenu writes that only one living species, and of that only one specimen, is known. The animal exhibited remarkable affinities, and the artist accompanying the expedition was able to take several sketches of it. A large *Oniscia*, shaped like *O. cancellata* Sow., but with an orange inner lip (*O. Dennisoni?*), some specimens of *Phorus Indicus* Gmel., a magnificent new species of *Latiaxis*, with many exquisite specimens of *Pleurotoma*, *Fusus*, *Murex*, *Scalaria*, and three or four of *Pedicularia sicula* Sw., with innumerable Pteropods and Terebratulinæ, rewarded these "burglars of the deep." The Professor was delighted, and it was with reluctance he abandoned so rich a field in order to secure his passing through the Straits of Magellan at a right season.

Barbados, January 26. —*From "Nature."*

AGASSIZ'S DEEP-SEA EXPLORATIONS.—*More about the trilobites.*—The following letter has been received by Prof. Peirce of Harvard College from Prof. Agassiz, giving interesting details respecting some of the results of the researches of the Hassler Expedition;

"RIO, ON BOARD THE HASSLER, Feb. 12, 1872.

"MY DEAR PEIRCE,—On January 18, Pourtales dredged to a very late hour during the night, the weather being more favorable for this kind of work than it had been at any previous time since we left Boston. As I did not dare to remain exposed to the dew, I missed the most interesting part of the proceedings, about which Pourtales will report himself. The next morning, however, I had an opportunity of overhauling the specimens brought up by the dredge, and to my great delight I discovered among them another of those types of past ages, only found nowadays in deep water. The case is entirely new, as the specimen in question belongs to the Pectinidal, a family the relations of which to earlier geological formations have thus far presented nothing especially interesting or instructive, except perhaps the fact that the type of neither is exclusively cretaceous. I wish had within my reach the means of making a full statement of the facts; but I have not the necessary books of reference, and must in this case trust entirely to my memory.

Among the most remarkable species of Pecten, there is a very small one, figured in Goldfuss under the name of Pecten paradoxus, if I remember rightly, and found in the Lias of Germany, which I have always been inclined to consider as the type of a distinct genus on account of its structural peculiarities. As yet nothing like it has been made known among the living shells. Now among the few specimens dredged on this occasion in 500 fathoms depth, off the mouth of the Rio Doce, there was one living specimen of the same type as the Pecten paradoxus, showing particularly, and very distinctly, the prominent radiating ribs rising on the inner surface of the shallow valve to which the fossil is indebted for its specific name. Like the fossil, the living species is of small dimensions, measuring hardly two-thirds of an inch. I hope I may be able to dissect the animal at some future time, and work out the anatomical character of this exceptional type. With it a few other shells, already known to us, from deep waters, were also found; among them, two beautiful species of Pleurotoma, identical with species found in Florida, off Barbados.

In my first letter to you concerning deep-sea dredging, you may have noticed the paragraph concerning crustacea, in which it is stated that among these animals we may expect "genera reminding us of some Amphipods and Isopods aping still more closely the Trilobites than Serolis." A specimen answering fully to this statement has actually been dredged in 45 fathoms, about 40 miles east of Cape Frio. It is a most curious animal. At first sight it looks like an ordinary Isopod, with a broad, short, flat body. Tested by the characters assigned to the leading groups of crustacea, whether we follow Milne Edwards, or Dana's classification, it can, however, be referred to no one of their orders or families. As I have not the works of the authors before me, I shall have to verify more carefully these statements hereafter, but I believe I can trust my first inspection. The general appearance of my new crustacean is very like that of Serolis, with this marked difference, however, that the thoracic rings are much more numerous and the abdomen or pygidium is much smaller. It cannot be referred to the Podopthalmians of Milne Edwards (which corresponds to the Decapods of Dana) because it has neither the structure of the mouth, nor the gills, nor the legs, nor the pedunculated eyes of this highest type of the crustacea; nor can it be referred to the Tetradecapods of Dana (which embrace Milne Edwards's Amphipods and Isopods), because it has more than seven pairs of thoracic limbs; it cannot be referred to the Entomostraca, because the thoracic are all provided with locomotive appendages of the same kind. But it has a very striking resemblance to the Trilobites; it is in fact, like the latter, one of those types, combining the characteristic structural features of other independent groups which I have first distinguished under the name of synthetic types. Its resemblance to the Trilobites is unmistakable, and very striking. In the first place the head stands out distinct from the thoracic regions, as the buckler of Trilobites; and the large, kidney-shaped facetted eyes recall those of Calymene; moreover, there is a facial suture across the cheeks, as in Trilobites, so that, were it not for the presence of the antennæ, which project from the lower side of the anterior margin of the buckler, in two unequal pairs, these resemblances would amount to an absolute identity of structure. As it is, the presence of an hypostome, in the same position as that piece of the mouth is found in Trilobites, renders the similarity to this extinct type of crustacea still more striking, while the antennæ exhibit an unmistakable resemblance to the Isopods.

In view of the synthetic character of these structural features it should not be overlooked that the buckler of our new crustacean, for which I propose the name of Tomocaris Peircei, extends sideways into a tapering point, curved backward over the first thoracic ring, as is the case with a great many Trilobites. The thorax consists of nine rings, seven of which have prominent lateral points, curved backward, like the pleuræ of Olenus, Lichas, &c. The sixth ring is almost concealed between the fifth and seventh, and is destitute of lateral projections, as is also the ninth. These rings are distinctly divided into three nearly equal lobes by a fold or bend on each side of the middle region, so that the thorax has the characteristic appearance of that of the Trilobites, to which the latter owes its name. The legs are very slender, and resemble more those of the Copepods and Ostracoids than those of any other crustacea. There are nine pairs of them, all alike in structure, six of which, however, the anterior ones, are larger than the three last, which are also more approximated to each other. Besides the legs, there is a pair of maxillipeds attached to that part of the buckler which extends back of the facial suture. These maxillipeds resemble the claw of a Cyclops. All these appendages are inserted in that part of the rings corresponding to the bend of the thoracic lobes; so that, if there exists a real affinity between the Trilobites and our little crustacean, and their resemblance is not simply a case of analogy, we ought hereafter to look to a corresponding position for the insertion of the limbs of Trilobites. I do not remember with sufficient precision what Billings, Dana, and Verrill have lately published concerning the limbs of Trilobites, to say now what bearing the facts described above may have upon the subject, as lately discussed in *The Journal of Science*. But of one thing I am satisfied, since I have examined the Tomocaris Peircei— that Trilobites are not any more closely related to the Phyllopods than to any other Entomostracæ, or to the Isopods. In reality, the Trilobites are, like Tomocaris, a synthetic type, in which structural feature of the Tetradecapods are combined with characters of Entomostracæ and other peculiarities essentially their own.

The pygidium or abdomen of Tomocaris is very like the abdomen of the ordinary Isopods with an articulated oar attached sideways and leaf-like respiratory organs upon the under side. The whole pygidium is embraced between the last curved points of the side of the thorax. Owing to these various combinations, I would expect in Trilobites phyllopod-like respiratory appendages under the pygidium only, and slender, articulated legs, with lateral bristles under the thorax, so thin and articulated by so narrow a joint as easily to break off without leaving more than a puncture as an indication of their former presence. It is impossible to study carefully the synthetic types without casting a side glance at those natural groups, which, without being strictly synthetic themselves, have nevertheless characters capable of throwing light upon the whole subject. And in this connection I would say a few words of Apus and Limulus. If I remember rightly, Milne Edwards considers the shield of Limulus as a cephalothorax in which the function of chewing is devolved upon the legs, while he regards the middle region as an abdomen, and the sword-like tail as an appendage *sui generis*. In the light of what proceeds, I am rather inclined to consider the cephalic shield of Limulus as a buckler homologous to that of the Trilobites, and the middle region as a thorax in which the ring show unquestionably signs of a division into lobes as in Trilobites. The tail would then answer to the pygidium. Apus should be compared with the other crustacea, upon the same assumptions as Limulus.—Ever truly your friend, L. AGASSIZ.

—*From the New York Tribune.*

DREDGING IN LAKE SUPERIOR UNDER THE DIRECTION OF THE U. S. LAKE SURVEY.—Extensive dredgings were undertaken the past season in Lake Superior, from the U. S. steamer

Search, under the direction of Gen. C. B. Comstock, Superintendent of the Lake Survey. Dredging was carried on from the shallow waters, especially along the north shore, down to 169 fathoms, the deepest point known in the lake. In all the deeper parts of the lake, the bottom, as shown both by the dredging and by the soundings executed by the Survey, is covered with an uniform deposit of clay, or clayey mud, usually very soft and bluish or drab in color. Water brought from the bottom at many points was perfectly fresh; that from 169 fathoms gave no precipitate with nitrate of silver. The temperature, everywhere below 30 or 40 fathoms, varied very little from 39°, while at surface (at the time of the observations, during August) it varied from 50° to 55°. The fauna of the bottom corresponds with these physical conditions. In the shallow waters, the species vary with the varying character of the bottom, while below 30 to 40 fathoms, where the deep-water fauna properly begins, the species seem to be everywhere very uniformly distributed. The deep-water fauna, as might be expected from the unfavorable character of the bottom, is meager, and seems to be characterized rather by the absence of many of the shore species than by forms peculiar to itself. Some of the more interesting species occurring in deep water were: *Mysis relicta* Lovén, at various depths from 4 to 159 fathoms; *Pontoporeia affinis* Lindst., at nearly every haul from the shallowest to the deepest; a small undescribed species of *Pisidium*, down to 159 fathoms; several forms of dipterous larvæ, allied to *Chironomus*, down to the same depth; several species of Lumbricoid worms, of the genera *Tubifex*, *Sænuris*, and an allied genus; and a species of *Hydra*, which was found from the shore down to 159 fathoms. Of these, the *Mysis*, *Pontoporeia*, and *Pisidium* are identical with species found by Dr. Stimpson in his dredging in Lake Michigan, a short account of which was published in the American Naturalist for September, 1870. The species of *Mysis* and *Pontoporeia* I am unable to distinguish from specimens from the Lake Wetter in Sweden. In the Swedish lakes, these species were associated with *Idotæa entomon* and *Gammaracanthus loricatus*, marine species, and were supposed by Lovén to have been derived from ancient marine species left in the lake basins by the recession of the ocean. The occurrence of these forms in Lake Superior, so far removed from the ocean, is certainly a very interesting fact in the geographical distribution of species, but one which I will not attempt to discuss in this brief notice. In the shallow waters many interesting species were obtained. Among these was a new species of *Crangonyx*, a genus closely allied to *Gammarus*, and heretofore known only from a few species found in the fresh waters of the old world, which occurred in 8 to 13 fathoms; and at the same depth, species of *Lumbricus*, *Nephelis*, *Procotyla*, *Gammarus*, *Asellus*, *Limnæa*, *Physa*, *Planorbis*, *Valvata*, *Sphærium*, *Pisidium*, etc. A full report will soon be published.

S. I. Smith in Silliman's Journal.

MISCELLANEOUS.

Award of the Wollaston Medal to Prof. J. D. Dana.—Geological Society, February 16.—Mr. Joseph Prestwich, F. R.S., president, in the chair.—The Secretary read the reports of the council, of the Library and Museum Committee, and of the auditors. The general position of the society was decribed as satisfactory, although, owing to the number of deaths which had taken place among the fellows during the year 1871, the society did not show the same increase which has characterised former years. In presenting the Wollaston gold medal to the Secretary, Mr. David Forbes, for transmission to Prof. Dana, of Yale college, Connecticut, the President said:—"I have the pleasure to announce that the Wollaston Medal has been conferred on Prof. Dana, of Yale College, Newhaven, U.S.; and in handing it to you for transmission to our Foreign Member, I beg to express the great gratification it affords me that the award of the Council has fallen on so distingnished and veteran a geologist. Prof. Dana's works have a world-wide reputation. Few branches of geology but have received his attention. An able naturalist and a skilful mineralogist, he has studied our science with advantages of which few of us can boast. His contributions to our science embrace cosmical questions of primary importance—palæontological questions of special interest—recent phenomena in their bearings on geology, and mineralogical investigations so essential to the right study of rocks, especially of volcanic phenomena. The wide range of knowledge he brought to bear in the production of his excellent treatise on Geology, one of the best of our class books, embracing the elements as well as the principles of geology, is well known. His treatise on Mineralogy exhibits a like skill in arrangement and knowledge in selection. In conveying this testimonial of the high estimationin which we hold his researches to Prof. Dana, may I beg also that it may be accompanied by an expression how strongly we feel that the bonds of friendship and brotherhood are connected amongst all civilised nations of the world by the one common, the one universal, and the one kindred pursuit of truth in the various branches of science."—Mr. David Forbes, in reply, said that it was to him a great pleasure to have, in the name of Prof. Dana, to return thanks to the society for their highest honour, and for this mark of the appreciation in which his labours are held in England. It had rarely if ever occurred in the history of the society that the Wollaston medal had been awarded to any geologist who had made himself so well known in such widely different departments of the science, for not only was Prof. Dana preeminent as a mineralogist, but his numerous memoirs on the Crustaceans, Zoophytes, coral islands, volcanic formations, and other allied subjects, as well as his admirable treatise on general Geology, fully testify to the extensive range and great depth of his scientific researches.—The President then presented the balance of the proceeds of the Wollaston donation fund to Prof. Ramsay, F.R.S., for transmission to Mr. James Croll, and addressed him as follows:—"The Wollaston fund has been awarded to Mr. James Croll, of Edinburgh, for his many valuable researches on the glacial phenomena of Scotland, and to aid in the prosecution of the same. Mr. Croll is also well known to all of us by his investigation of oceanic currents and their bearing on geological questions, and of many questions of great theoretical interest connected with some of the great problems in Geology. Will you, Prof. Ramsay, in handing this token of the interest with which we follow his researches, inform Mr. Croll of the additional value his labours have in our estimation, from the difficulties under which they have been pursued, and the limited time and opportunities he has had at his command."—Prof. Ramsay thanked the president and council in the name of Mr. Croll for the honour bestowed on him. He remarked that Mr. Croll's merits as an original thinker are of a very high kind, and that he is all the more deserving of this honour from the circumstance that he has risen to have a well-recognised place among men of science without any of the advantages of early scientific training; and the position he now occupies has been won by his own unassisted exertions. The

President then proceeded to read his Anniversary Address, in which he discussed the bearings upon theoretical Geology of the results obtained by the Royal Commision on Water-Supply and the Royal Coal Commission. The Address was prefaced by biographical notices of deceased Fellows, including Sir Roderick I. Murchison, Mr. William Lonsdale, Sir Thomas Acland, Sir John Herschel, Mr. George Grote, Mr. Robert Chambers, and M. Lartet.—The ballot for the Council and Officers was taken, and the following were duly elected for the ensuing year:—President —The Duke of Argyll, K.T., F.R.S. Vice-Presidents—Prof. P. Martin Duncan, F.R.S., Prof. A. C. Ramsay, F.R.S., Warington W. Smyth, F.R.S., Prof. John Morris. Secretaries—John Evans, F.R.S., David Forbes. F.R.S. Foreign Secretary, Prof. T. D. Ansted, F.R.S. Treasurer—J. Gwyn Jeffreys, F.R.S. Council— Prof. T. D. Ansted, F.R.S., the Duke of Argyll, F.R.S., W. Carruthers, F.R.S., W. Boyd Dawkins, F.R.S., Prof. P. Martin Duncan, F.R.S., R. Etheridge, F.R.S., John Evans, F.R.S., Jas. Fergusson, F.R.S., J. Wickham Flower, David Forbes, F.R.S., Capt. Douglass Galton, C.B.,F,R.S., Rev. John Gunn, M.A., J. Whitaker Hulke, F.R.S., J. Gwyn Jeffreys, F.R.S., Sir Chas. Lyell, Bart, F.R.S., C. J. Meyer, Prof. John Morris, Joseph Prestwich, F.R.S., Prof. A. C. Ramsay, F.R.S., R. H. Scott, F. R.S., W. W. Smyth, F.R.S., Prof. J. Tennant, Henry Woodward.

"Nature," 29th Feb. 1872.

ADDITIONAL NOTE ON OBOLELLINA, &c.—Since the sheet containing my remarks on this genus was printed I have received a letter in which it is stated that Prof. Hall says his paper "was in reality printed in March, 1871, and that he received from twenty-five to thirty copies, from the printer, at that time."— "That he distributed these copies to some learned societies and individuals, having reserved three copies only, and that he sent one to the Geological Society of London, and to other parties whose names he can produce." I do not admit the whole of this statement. I have made extensive enquiries, among the most active and best geologists and naturalists in the United Ststory— men who keep themselves fully informed, as to all books and papers on geology and palæontology published in the country. With a single exception not one of them ever saw, or even heard of the paper until I wrote to them about it. One gentleman, only, sent me a copy on the 12th Feb., 1872, but he did not state when he received it, perhaps, because he did not wish to interfere in the matter. It was probably sent to him after Prof. Hall had seen my paper. The general opinion is that it was not circulated in the United States at all. There is some evidence, of a circumstantial character, to show that the two copies sent to England in September were printed after the month of July with important alterations. The principal objects of requiring a Naturalist to publish, are that others may obtain notice of what species or genera have been named and described; and, also, to afford the public a means of deciding questions of priority without depending upon the word of the author, who is always an interested party. Private distribution is not sufficient for either of these purposes. In this instance all of the six genera, noticed in Prof. Hall's pamphlet, might have been described and published, by as many different authors in the United States in perfect good faith, and without the least suspicion that they had been previously named by any one. Indeed, as he was aware that several were working at the same group, he seems to have concealed his pamphlet from them in order to give them annoyance. How otherwise can we account for the fact, that no copies were sent either to the Smithsonian Institution or to the Canadian Survey?

I am informed that Prof. Hall's genera are to be sustained by two distinguished authors in England. One of them having received a copy of the paper in October, 1871, and knowing that another copy had been sent to the Geological Society of London, about the same time, neither can realize that it was not published. But let us place them in Prof. Hall's position. Suppose that the paper on which they are now engaged relates to a peculiar group of Wenlock fossils. They borrow specimens from the Geological Survey, and are notified by the Director that the palæontologist of the Survey is at work on the same group. Instead of publishing their paper in the Journal of the Geological Society, or in any other scientific journal, they resort to the following extraordinary proceeding. They prepare an abstract of five pages. They send no copies to the Survey, to the Geological Society, to the Royal Society or to any other learned institution in England. They conceal it from the English scientific public altogether. About six months afterwards they send one copy privately to a friend in Russia, and one to the Mineralogical Society there. In consequence of this course, for ten months afterwards not one single member of the Geological Survey, or of the Geological Society, ever hears of the existence of their pamphlet. In the meantime the palæontologist of the British Survey publishes his genus openly and fairly, in the Journal of the Geological Society. Several weeks afterwards he hears from Russia, that it had been previously published in London by the very two gentlemen to whom he had lent the specimens. I cannot believe that British Naturalists in general would consider it right to suppress his work.

I am informed also that Prof. Hall says I have violated the agreement relating to New York fossils, by publishing species found in the United States. This is simply a misrepresentation of the statement of the case. The different Surveys in the United States are quite independant of each other. The Director of any Survey can consult any palæontologist he thinks proper. I have never described a single fossil from any one of the States where Prof. Hall was, at the time, in any way employed. But I have examined a number of species for those Surveys with which he has no connection.

In one of the letters I have received, it is stated with reference to publication, that "No determined rules or laws have been hitherto settled or followed." With the highest respect for the author of this opinion, I cannot agree with him. There are laws which result from the very nature of the circumstances to which they relate. These laws exist perpetually, although not established by legislative enactment, and although they may be disregarded and transgressed by any number of persons. The law of publication is one of these. Every true naturalist feels that such a law does exist, and that it is his duty to observe it. We can scarcely imagine a reason for its non-observance. The loss by fire, urged in this case, is surely not a sufficient excuse, because any scientific journal on the continent would have re-published the pamphlet for Prof. Hall, free of charge. On the other hand, there can be no law in favor of private distribution, for the simple reason that it affords so many facilities for the performance of unfair transactions. If distributed so widely that the requirements of science are satisfied, a book becomes of authority, but this has not been done in the case of Prof. Hall's pamphlet. On the contrary, he seems to have shunned publicity. I am well aware that the law of publication is not always followed. All that I contend for is, that owing to the extraordinary circumstances of the instance under discussion, it should be strictly adhered to.

Waldheimia septigera and Terebratella septata, identical.—TO THE EDITOR OF THE AMERICAN NATURALIST.—Sir,—Having in the course of a too short visit to North America been honored by remarkable kindness and attention on the part of my brother naturalists in this great hemisphere, I am rather disappointed at seeing in your excellent periodical a notice of the Report submitted to the Royal Society of London by my colleagues and myself, on the deep-sea exploration of parts of the North Atlantic, in H. M. S. "Porcupine," during the summer of 1869. The writer of that notice, Mr. W. H. Dall, criticises in what I cannot help considering over severe terms my views "in regard of the specific and generic limits of animals;" and he gives as an instance, "*Waldheimia septigera*" and "*Terebratella septata*," which he states belong to different genera, although I have included both under the same specific name. I do not agree with Mr. Dall in his statement. Having had opportunities of examining the types or original specimens of *Terebratula septigera* (Lovén) at Stockholm, and of *Terebratula septata* (Philippi) at Berlin, and having carefully compared these specimens with the published descriptions and figures, I am convinced that both belong not only to the same genus but to the same species. What seems to have been in the mind of Mr. Dall when he penned his hasty critique was that Professor Seguenza of Messina had referred a species of *Terebratella* from the Sicilian tertiaries to Philippi's species and a species of *Terebratula* found in the same formation to Lovén's species. The former may be the *Terebratella Mariæ* of Mr. Arthur Adams from the Japanese seas; the latter I have ascertained to be rather widely distributed in the North Atlantic.

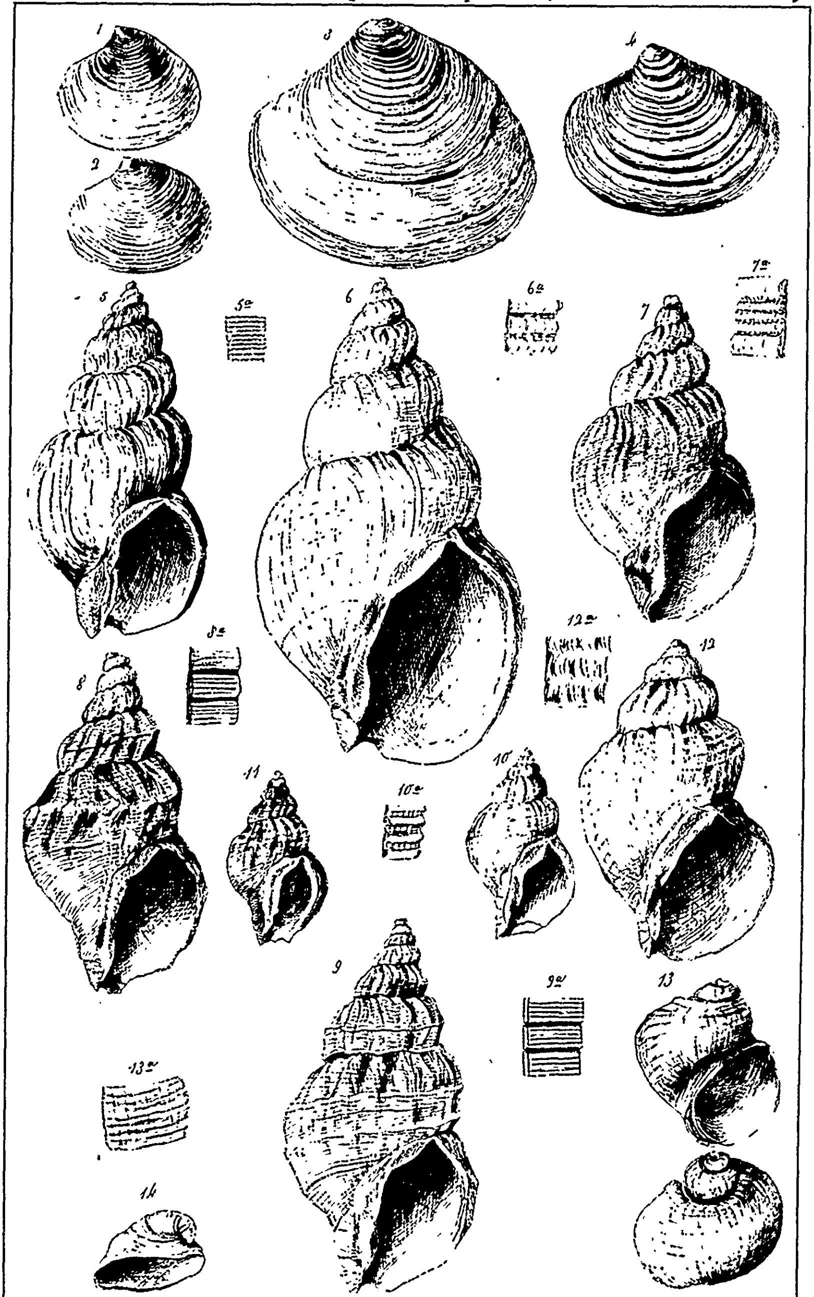
I have the honour to be, Sir,
Your very obedient servant,

J. GWYN JEFFREYS.

Montreal, 6th October, 1871.

Published April, 1872.

Pl. VII. Critical and Rare Post=pliocene Species. (Canadian Naturalist.)



Drawn on Stone, by A.L.D. LEGGO & Co. Lith., Montreal.

IV. POLYZOON, BRACHIOPODS, AND LAMELLIBRANCHIATES

(Post-pliocene—Canada.)

Fig. 1.

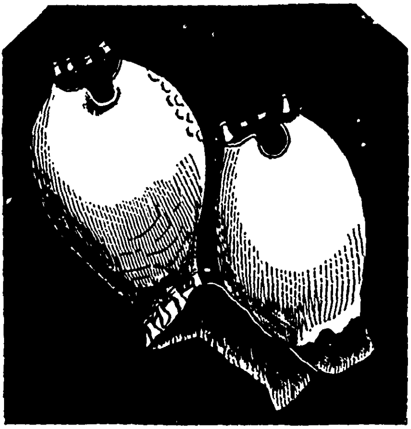


Fig. 2.

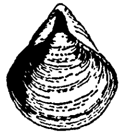
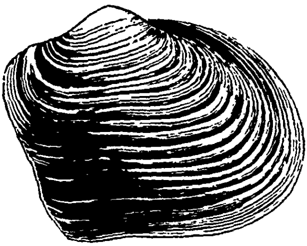


Fig. 3.

Fig. 4.



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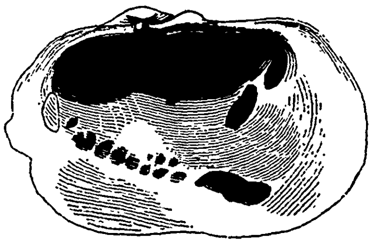

Fig. 5.

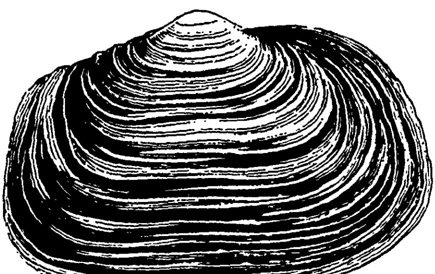

Fig. 7.

Fig. 8.

Fig. 1. *Lepralia quadricornuta*, Montreal (magnified).
Fig. 2. *Rhynchonella psittacea*, Riviere-du-Loup.
Fig. 3. *Terebratella Spitzbergensis*, Riviere-du-Loup.
Fig. 4. *Mya truncata*—Var. *Uddevallensis*—Montreal.
Fig. 5. *Mya truncata*—Var. *communis*—Portland.
Fig. 6. *Panopea Norvgica*, Riviere-du-Loup.
Fig. 7. *Saxicava rugosa*—Var. *Arctica*—Montreal.
Fig. 8. *Astarte Laurentiana*, Montreal.

Fig. 1.

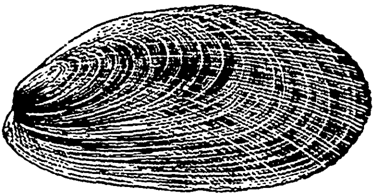

Fig. 2.

Fig. 3.

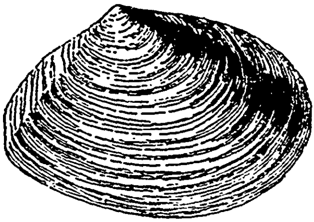

Fig. 5.

Fig. 4.

Fig. 6.

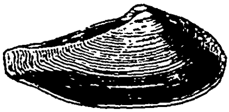

Fig. 9.

Fig. 10.

Fig. 7.

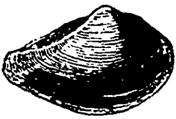

Fig. 11.

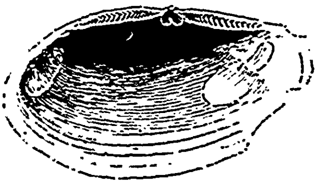

Fig. 8.

Fig. 1. *Modiolaria nigra*, Portland.
Fig. 2. *Mytilus edulis*—(Var. *elegans*)—Montreal.
Fig. 3. *Macoma calcarea*, Riviere-du-Loup.
Fig. 4. *Macoma Grœnlandica*, Riviere-du-Loup.
Fig. 5. *Macoma inflata*, Riviere-du-Loup.
Fig. 6. *Leda pernula*—(Var. *tenuisculata*)—Riviere-du-Loup.
Fig. 7. *Leda pernula*—(Var. *buccata*)—Riviere-du-Loup.
Fig. 8. *Leda minuta*, Riviere-du-Loup.
Fig. 9. *Leda* (*Portlandia*) *glacialis*, Montreal.
Fig. 10. *Nucula expansa*, Riviere-du-Loup.
Fig. 11. *Leda* (*Yoldia*) *limatula*, Riviere-du-Loup.

Fig. 1.

Fig. 2.

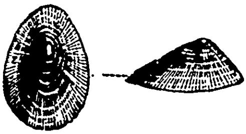

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8.

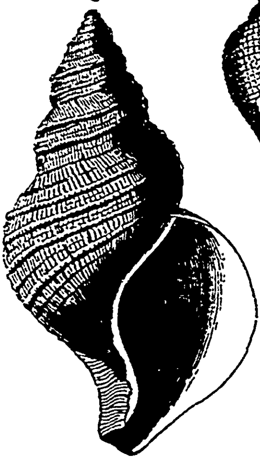

Fig. 10.

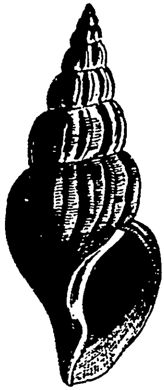

Fig. 9.

Fig. 11.

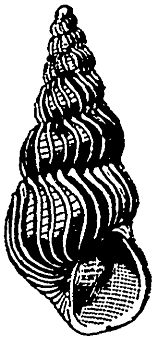

Fig. 12.

Fig. 13.

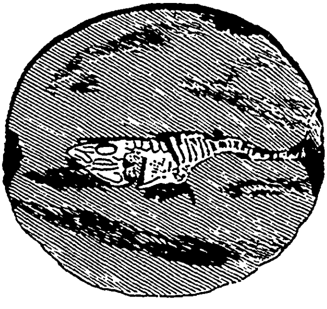

FIG.

1. *Haminea solitaria*, Montreal.
2. *Lepeta cæca*, Montreal.
3. Plates of *Amicula Emersonii*, Montreal.
4. *Trichotropis arctica?* Montreal.
5. *Velutina zonata*, Montreal.
6. *Natica clausa*, Montreal.
7. *Admete viridula*, Montreal.

FIG.

8. *Fusus tornatus*, Montreal.
9. *Fusus tornatus* (Var.), Quebec.
10. *Sipho Kroyeri* (recent specimen, after Packard).
11. *Scalaria Grœnlandica*, Riviere-du-Loup.
12. *Acirsa Eschrichtii*, Quebec.
13. *Gasterosteus*, Green's Creek, Ottawa

EXPLANATION OF PLATE VII.

This plate, drawn on stone under my own direction, is intended to present, as faithfully as possible, the characters of some of the more rare and critical shells of the Canadian Post-pliocene.

Fig. 1. *Astarte Banksii*—A full-grown specimen of the ordinary type. Riviere-du-Loup.

Fig. 2. *Astarte Laurentiana*—An average full-grown specimen. Montreal.

Fig. 3. *Astarte lactea*—Ordinary type. Portland, Maine.

Fig. 4. *Astarte Elliptica*—A specimen with the ribs extending nearer to the ventral margin than usual. Portland, Maine.

Fig. 5. *Buccinum tenue*—Full-grown specimen. Riviere-du-Loup. 5*a*—Sculpture enlarged.

Fig. 6. *Buccinum cyaneum*—Full-grown specimen. Riviere-du-Loup. 6*a*—Sculpture enlarged.

Fig. 7. *Buccinum undulatum*—(Var. of *undatum*)—Immature shell, broken at lip. Riviere-du-Loup. 7*a*—Sculpture enlarged.

Fig. 8. *Buccinum glaciale*—Tuberculated variety. Riviere-du-Loup. 8*a*—Sculpture enlarged.

Fig. 9. *Buccinum glaciale*—Smooth variety. Riviere-du-Loup. 9*a*—Sculpture enlarged.

Fig. 10. *Buccinum ciliatum*—(Fabricius, not Gould)—Smooth variety, somewhat decorticated. Montreal. 10*a*—Sculpture enlarged.

Fig. 11. *Buccinum ciliatum*—(Fabricius, not Gould)—Small but mature specimen. Recent Murray Bay.

Fig. 12. *Buccinum Grœnlandicum*—Adult specimen. St. Nicholas. 12*a*—Sculpture enlarged.

Fig. 13. *Choristes elegans*—(Carpenter)—Adult specimen. Montreal. 13*a*—Sculpture enlarged.

Fig. 14. *Capulus commodus*—Pt. Levi, Quebec.