Chapter 23. Palaeontology of the Cambrian System in the North-West Highlands

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In the present chapter an account will be given of the organic remains which have been obtained from the several subdivisions of the Cambrian series in stratigraphical order, beginning with the oldest members.

Lower Cambrian

Lower and Upper Quartzite

In the lower quartzite organic remains are so rare that they have been met with only at one place. They consist of the cylinders of sand known as "pipes", and named *Scolithus linearis* (Haldeman). These are attributable to burrowing annelides, and they not only indicate the presence of such animals during the deposition of the quartzite, but also of sufficient organic matter having been mixed with the sand where they occur to furnish nourishment to the worms.

In the upper zone of the quartzite these cylinders become so numerous as to have gained for it the title of "The Pipe-rock". But, besides their great abundance, they vary so much in form and mode of occurrence (probably indicating that they were produced by different species of annelides) that different forms of them appear in a definite chronological order. Hence successive sub-zones of the "pipe-rock" have been mapped out by means of them.

The beds of the lowest sub-zone (I) are characterised by "small pipes", about one-eighth of an inch in diameter, which pass up through the somewhat massive beds of white or pinkish granular quartzite at right angles to the bedding planes, and end on the upper surface of the beds in small cup-shaped hollows, from a quarter to half an inch across the mouth.

In Sub-zone II the "ordinary pipes" are larger, often reaching half an inch in diameter, while those of the underlying zone disappear.

Sub-zone III is characterised by "trumpet pipes", the *Arenicolites* of Salter. In these the cylinders, when followed to the surface of the bed, are found to end at the bottom of cup-shaped depressions, which sometimes measure two inches across. Seen in section, the cylinder can be observed to stand up a little into the bottom of the cup, while the layers of the quartzite, which are comparatively thin in this sub-zone, are attenuated and bent downwards as they approach the cylinder in such a manner as to suggest the operations of a worm, plentifully provided with chetae, which left the voided cylinder behind as it sank down into its burrow. An inverted cone-within-cone structure is thus produced, simulating that of a primitive orthoceratite, for which, indeed, these relics were at first mistaken. Two forms of " trumpet pipes", a larger and a smaller, are distinguishable in the field, sometimes associated together and sometimes separately. These trumpet pipes do not occur in all the beds of the sub-zone; but the ordinary " pipes", like those of Sub-zone II., are to be found throughout the zone, and are by far the most abundant. In addition to these worm-casts, a small hollow conical calcareous fossil, named *Serpulites Maccullochii* by Salter after its first discoverer, and now supposed to belong to the tubicolar ann elides, was found by Mr. H. M. Cadell in the rocks at the top of this sub-zone in the Reay Forest, near Loch Stack, in Sutherlandshire. This fossil is found associated with *Olenellus* on a higher horizon; the genus is characteristic of the Lower Cambrian rocks.

In Sub-zone IV only the ordinary "pipes", like those of the lower zones, occur, but they are exceedingly numerous and conspicuous, owing to several concurring circumstances. The strata are thinly bedded, and the bands are usually of red and white colour in rapid alternation, while the "pipes" are usually wholly white. The dragging downwards and attenuation of the layers as they approach the cylinder is also very conspicuous at all depths, a circumstance which, together with the cup-shaped depressions, proved to be of great service in distinguishing whether the beds are in their natural order or inverted in those areas in which the rocks have been greatly disturbed.

Sub-zone V — The pipes are here somewhat larger in diameter than those of the underlying sub-zones, but they are otherwise of the ordinary type. As the beds are massive and the grains large and well rounded, the rock is often

comparatively uncompacted and less of a quartzite than the others. Its general colour if often red or purple, while the pipes in it are white. Sometimes the matrix is discoloured or bleached for a short distance round the pipes. A similar decolouration takes place round the burrows of the recent lobworms on our shores. One bed, which lies at the very top of the quartzite, and which probably belongs more properly to the overlying fucoid-beds, as it is mixed with a good deal of shaly material, contains "pipes" measuring sometimes nearly an inch across.

In America *Scolithus linearis* occurs in Cambrian rocks chiefly in connection with the *Olenellus* zone.

"Fucoid Beds"

In this zone *Scolithus* continues to occur, but the most characteristic worm casts are those which lie along the bedding planes of the shales, and are known under the name of *Planolites* (Nicholson). It is these flattened casts that have been mistaken for the remains of fucoids, and from which the name of the zone has been derived. Where alternations of sandy and shaly strata occur, abundant evidence is procurable that these casts, as well as those known as *Scolithus,* were made by some worm-like animal, which brought up the sand of the casts from beds underlying the shales in which they actually occur. They cannot, therefore, have been formed by sand filling in the burrows from above. In addition to these annelides, the muds and calcareous sediments of this zone appear to have been so well fertilised by the plankton as to support several other organisms. Among these, certain forms, which are individually abundant, have been mistakenly classed among the pteropods, but may with more reason be regarded as tubicolar annelides. They belong to the genera *Salterella,* of which three specimens are represented, and *Coleolides,* represented by a single species. Two species of *Hyolithes* also occur, an organism which probably links the worms with the hingeless brachiopods. Boring annelides also appear to have made sinuous tunnels in the thickened portions of the dead or discarded tests of trilobites.

Echinoderms are represented by some minute fragments showing the microscopical structure of their plates and ossicles, which. together with debris of shells and trilobites, form nuclei round which pisolitic structures have been built up in certain dolomitic bands. The original carbonates in these beds have in some cases been replaced by iron-ores, as is observed in specimens from certain bands first discovered by Mr. Horne in the Achnashellach Forest, which Mr. Teal' has found to present characters similar to those of some ironstones that have replaced Carboniferous limestones in Wales and Cumberland. The echinodermal remains are provisionally referred to the genus *Eocystites* (Billings)

Brachiopods are represented by the hingeless forms *Paterina* (*Kutorgina*) *labradorica* and *Acrothele subsidua,* the former being one of the simplest and most primitive known types, representing an early stage in the development of all the higher forms. Both of these species are found in the *Olenellus*-zone of America, the former in Newfoundland and Canada, the latter occurring plentifully with *Olenellus Gilberti* at Pioche, Nevada, and in association with Middle Cambrian fossils at Antelope Springs.

Gasteropods are represented by a badly-preserved form, probably a *Murchisonia,* found near Tokavaig, in Skye, and by *Helenia bella,* a curved tube open at both ends, doubtfully referred by Walcott to the *Dentalidae.* This organism also occurs together with *Holmia* (*Olenellus*) *Broggeri,* at Manuels Brook, Conception Bay, Newfoundland. Arthropods are represented by *Aristozoe rotundata,* and a species of *Nothozoe,* among the *Phyllocaridea,* which are also met with in the *Olenellus* zone of America.

The trilobites, however, are the most characteristic feature of this horizon in the Cambrian series. The genus *Olenellus* of Hall is here represented by five species and varieties closely allied to *O. Thomsoni* and *O. Gilberti,* the forms which mark the Georgian Terrane or *Olenellus*-zone on the east and west side of North America respectively. The genus *Olenelloides* was made to hold a primitive trilobite in almost vermiform aspect, highly armed with spines, and resembling larval stages of *Olenellus,* but evidently in adult condition. The same genus appears also abundantly in certain dolomitic beds along with *Olenellus.* A small fragment of trilobite, which suggests close affinities with *Conocoryphe,* has likewise been found, but in too imperfect a state to allow of a determination to which of the sub-genera it should be assigned. With the exception of one or two forms which have only as yet been found in the North-West Highlands, the whole assemblage of fossils from the Fucoid-beds of Sutherland, Ross, and Skye is almost identical with that found in the *Olenellus*-zone of North America.

"Serpulite Grit"

In this zone worm-casts of the nature of *Scolithus* form still a characteristic feature. They are of various kinds, the most conspicuous being "pipes", which sometimes attain a diameter of nearly an inch. These can he traced through the rock vertically for a length of more than a yard, until they end on the upper carious weathering surface of the grit in cup-shaped depressions measuring several inches across. These pipes are sometimes contracted at regular intervals in such a manner as to suggest that the contractions are due to the peristaltic action of the intestine of the worm. Sometimes the part between the "pipe" and the surrounding matrix has been filled in with sand containing more carbonate than either of them, so that on a weathered face of the rock the "pipe" is seen in the middle of a hollow tube. Smaller pipes, which in one layer appear to be more calcareous than the matrix of the bed, may be observed to have weathered out so as to leave the rock honey-combed with their hollow casts. The small tubicolar *Salterella,* the *Serpulites Macullochii* of Salter, first discovered by Macculloch from this band, to which it gives the name, occurs in myriads in certain layers, and is usually to be found scattered more or less through. out the whole of the zone.

Of higher organisms in the Serpulite Grit, the head shield of *Olenellus Lapworthi* was found in the Dundonnell Forest, and an orthoceratite is said to have been obtained at Eireboll in Sutherlandshire. Professor Lapworth records the finding of *Orthoceras* and Linguloid shells (?) in the dolomitic carious-weathering beds at the top of the zone in Eireboll, but he regards them as the basement beds of the Durness Limestone.<ref>*Geol. Mag.,* vol. x., new ser., p. 126, 1883.</ref>

The Durness Limestone or Dolomite

Grudhaidh Group (in part)

The first 30 feet of this sub-division of the Durness Dolomite are here claimed to belong to the Lower Cambrian or *Olenellus* zone, because of the occurrence in them of two thin but remarkably persistent layers which are usually crowded with two species of *Salterella* (*S. rugosa* and *S. pulchella*), forms also found in the *Olenellus*-zone of America. One of these layers lies immediately above a few feet or inches of a dark carbonaceous shaly limestone which forms the base of the Durness Dolomite, and in which *Salterella* is also occasionally found. The other layer is met with about 30 feet further up. Besides the fossils just mentioned, worm-casts (*Planolites*) also occur, but less abundantly than in some of the higher layers of the sub-division.

From the palaeontological evidence which has now been stated, it may be concluded that the groups of strata from the middle of the "Pipe-rock" up to the top of the first thirty feet of the Grudhaidh Dolomite should be classed as Lower Cambrian, seeing that they enclose a fauna identical with that of the *Olenellus* zone so well developed in North America. How much more of the rest of the Durness Dolomite may belong to the same subdivision cannot be determined owing to the paucity or absence of organic remains. As to the quartzite beneath the trumpet pipes (Subzone III of the "Pipe-rock") though no other fossil evidence beyond the occurrence in it of *Scolithus linearis* has hitherto been forthcoming, yet, for the sake of convenience, all the sub-zones down to the base are provisionally regarded by the Geological Survey as part of the Lower Cambrian series.

From the study of the fossils of the Durness Limestone, Salter pointed out, as early as 1859, that the biological affinities are more closely linked with American than with European forms, and all subsequent observation has confirmed his opinion. This curious relationship, so distinctly traceable among the fossils of the Lower Cambrian zones of the North-West Highlands, continues to be visible in the rest of the Cambrian succession of that region. Not only are the fossils identical on the two sides of the, Atlantic, but the sediments in which they have been preserved present a remarkable similarity, as if the North American and Scottish Cambrian rocks were deposited under similar, if not identical, physical conditions, and as part of one and the same geological and zoological province.

Middle and Upper Cambrian. Durness Dolomite

I Grudhaidh Group

The portion of this group which overlies the upper *Salterella*-bearing band above described, in the absence of definite fossil evidence, is here included in the Middle Cambrian series. It consists in great part of mottled dolomite, the mottling being due to the great abundance of worm-casts of the nature of *Planolites*. A conspicuous band with oolitic structure lies about the middle of the group. In this band, while the oolitic grains are generally calcite or dolomite, in one seam they may often be seen to have been preserved in silica, which has probably replaced the original carbonate. Thin slices of both these types of oolite have been prepared and microscopically examined, but no organic structures have been observed in them. In Assynt one of the uppermost beds of the group displays worm-casts, which have sometimes been replaced by silica. With the exception of *Planolites,* no fossils have as yet been obtained from this part of the series of strata, and as by far the greater part of the rocks of the group show evidence that their component materials passed through the digestive system of worm-like creatures, they must have once been in the state of a finely-divided calcareous mud or sand, which was probably derived from both the calcareous and siliceous organisms of the plankton.

II Eilean Dubh Group

The only fossils obtained from this group are of the nature of worm-casts, which, in marked contrast to the other sub-zones, are few in number and confined to one or two beds. This paucity may be due to the original absence of calcareous organisms larger than those which constituted the greater part of the plankton, for though the component strata of the group are everywhere more or less magnesian and often dolomitic, yet they always present a fine-grained and thinly-bedded character, indicating that their original condition was that of fine mud. If any larger forms contributed to the substance of the rock, they appear to have been reduced to a fine calcareous powder.

A close examination of the strata in the field has disclosed the interesting fact that some of them have here and there "set" or solidified on the sea-floor, and have afterwards, while the deposition of the series was still going on, been broken up in places or brecciated, the interstices being filled in with a matrix of similar composition to the dislocated layers, while the overlying and underlying sediments have been undisturbed.

Siliceous organisms seem to have contributed to the building up of this group, for in the Assynt region layers of chert nodules have been found on several horizons, and also continuous layers of chert, some of which attain a thickness of more than two feet. Oolitic structures appear in the cherts of this group in Skye. These have been cut and submitted to Dr. G. J. Hinde for microscopic examination, but he *was* unable to detect any undoubted organic structures in them. The cherts from this group are less granular in texture than those which have replaced the calcite of the oolites of the Grudhaidh Group.

III Sail Mhor Group

This group consists of coarsely-granular dolomites charged with worm-castings, which are often of a different colour from the matrix, so as to have earned for it such names as "The Mottled Group" and "Leopard Stone", the latter being that by which it is locally known. That siliceous organisms contributed material towards the building up of this group of strata also, is indicated by large nodules of chert which occur plentifully along certain layers near the base. Some of these resemble the "Paramoudras" of the chalk in being arranged vertically above each other. It is clear that the silica replaced the calcareous mud which constituted the limestone before its compression and consolidation, for the lines dividing the layers are seen to run continuously into the chert from the limestone, while thin layers extend from the limestone and penetrate into the edges of the siliceous nodules. The silica became consolidated into chert prior to the compression of the calcareous mud through the weight of the accumulating sediment, so that the part of each layer now represented by chert is much thicker than that still represented by limestone. Certain siliceous hollow rods in this group may possibly be remains of sponges, like the *Rhabdaria* of Billings, which possibly contributed to the formation of the nodules. But the greater proportion of the silica was probably derived from the plankton, and most probably from diatoms, as unicellular plants doubtless formed the chief support of the oceanic animal life during the Cambrian period as they do at the present time. Radiolaria may likewise have shared in the formation of the chert; they are certainly among the oldest fossils known. The opinion that the limestone mud was not a mere chemical precipitate from sea-water, but a kind of organic calcareous ooze, is perhaps strengthened by the fact that when the calcareous rocks of this group are broken they emit a strongly fetid odour, and when dissolved leave a residue of carbon. The researches of Dr. G. J. Hinde have shown that cherts examined by him from nearly all the great geological formations from all parts of the globe have had an organic

origin. A strong presumption is thus raised that most of the cherts in sedimentary rocks have been produced from organic silica.

Calcareous organisms larger than could be provided by the plankton also occur as fossils in this group, preserved in the form of calcite, but they are few in number. Many more may have once existed, but, if so, they have been destroyed during the process of dolomitisation and the production of the coarsely crystalline texture which characterises the rocks of the group. The gasteropods are represented by a single specimen of *Murchisonia,* not sufficiently well preserved for specific identification, and by two species of *Pleurotomaria,* (*P. Ramsayi* and *P. Etna*) of a type found in the "Calciferous" rocks of Newfoundland and Mingan Islands in Canada. The former presence of cephalopods is proved by the occurrence of at least two forms probably belonging to different species, with oval section, slight curve of the cone, closely-set septa, and wide endogastrie siphuncles. These have been provisionally placed in the genus *Cyrtoceras,* though they seem to have strong affinities with such primitive types as *Endoceras* and *Piloceras.* The arthropods are represented by part of the epistome of a large asaphoid trilobite which is almost identical with that of *Asapleas canalis* (Conrad), a fossil of the Calciferous horizon of Newfoundland. Thus the evidence of the fossils, scanty and imperfect though it be, shows a strongly-marked American facies in the fauna of this group.

IV Sangomore Group

This group is composed chiefly of granular dolomite, but towards the top one or two thin bands of fine-grained limestone make their appearance in the Durness district. Bands of chert also occur chiefly towards the base of the group, one of which at Durness is 5 feet thick. Some of the beds are oolitic, and in one case the oolites are preserved in crypto-crystalline silica, but no organic structures have been observed in them. No fossils have been found. Their absence from the dolomites, which are more coarsely crystalline in this than the two preceding groups, might be accounted for by the amount of reconstruction which the rocks have undergone, but this explanation would not hold for the fine-grained limestones, from which fossils are also absent.

V Balnakiel Group

This group consists of alternations of dark and lighter coloured line-grained limestones not much marked by worm-tracks, including nodules and thin bands of black chert. This association of sediment points to the still-continued deposition of minute calcareous and siliceous organisms. A few of the beds only have been dolomitised. Some of the limestones are highly fossiliferous, and it is from this and the overlying group that most of the fossils of the Cambrian series of the North-West Highlands have been obtained. As these organisms are for the most part common to the two groups, the whole fauna will here be treated as one.

VI Croisaphuill Group

The rocks of this group are much more varied than those of the preceding one. Towards the base they consist chiefly of massive beds of dark-grey limestone, full of worm-casts, which are now chiefly represented by dolomite, so that they stand out in matted masses on the weathered surface of the rock, the limestone matrix having yielded to solution more readily than the dolomite. Such rocks are highly fossiliferous, but where bands of granular dolomite make their appearance fossils are rarely or never met with. The lower part of the group is marked by several layers of small chert nodules. The middle portion is made up chiefly of unfossiliferous granular leaden-coloured dolomite, with a few light-coloured bands of fossiliferous limestone full of worm-casts. The upper part, consisting of massive sheets of fossiliferous limestone full of worm-casts preserved in dolomite, resembles the lower sub-division.

Thus up to the very top of the Cambrian series of Sutherland and Ross impressive evidence is supplied by the abundance of worm-casts that the rocks must have accumulated in the state of fine mud or ooze, probably mainly derived from the minute organisms of the plankton. The fact that the worm-casts in the two upper groups of the series are for the most part preserved in dolomite, while the matrix remains a limestone, suggests that either the worms were selective as to their food or that their gastric juices had the effect of predisposing the casts to be dolomitised under the influence of magnesian solutions more readily than the surrounding mud.

The fossils now to be more specially noticed are usually preserved in orbicular silica and filled in with calcite, and their microscopic structure has been entirely obliterated. They are, moreover, generally incomplete and seldom show their external markings — a condition probably referable chiefly to decomposition, solution, and disintegration prior to their being embedded. That their imperfection cannot be attributed to actual abrasion on the sea-floor appears to be placed beyond doubt by the condition of some of the fossils. Thus the valves of lamellibranchs are often found attached and in the position in which the shell lived, though part of the organism has been removed, obviously through solution. In most cases the septa and walls of chambered shells have been wholly or in part dissolved away, so as to leave only the more massive structures of the siphuncles, and worm-castings are often found within the chambers where the septa have been preserved. These features seem to indicate that the accumulation of the calcareous mud in which the fossils were embedded was so slow that there was time for the solution of part of an organism before the whole of it was covered up. Indeed, there is good reason to believe that a great many organisms totally disappeared by this process, for in some of the layers of the Croisaphuill group near Durness the massive opercula of certain species of *Maclurea* occur in abundance, while the shells belonging to them have not been observed.

Siliceous sponges are represented in the two uppermost Cambrian groups by the genera *Archmoscyphia* (Hinde) and *Calathium* (Billings), and by the doubtful forms *Rhabdaria* and *Trichospongia* of Billings. These fossils present no exception to the rule that the organisms were imperfect before they were covered over with succeeding sediments. Only fragments have been preserved, and usually those parts lying towards the base of the forms. Moreover, after being embedded, the original silica of the spicules has been removed, and the structures have been filled in with orbicular silica and calcite, so that the microscopic structure of the organisms is now quite obliterated. The abstracted silica may have furnished some of the chert of the nodules, as Dr. Hinde found remains of sponges in some of the nodules from this horizon at Durness. Most of the species of *Archceoscyphia* and *Calathium* are found in the "Calciferous" rocks of Newfoundland and Canada, where they are associated with *Rhabdaria* and *Trichospongia.*

Only one specimen of what appears to be a coral has as yet been observed, but it is not sufficiently well preserved even for generic identification.

Hinged brachiopods are represented by *Camarella antiquata* (Billings), and *Orthisina festinata* (Billings), which occur in the *Otenellus*-zone of America; *O. grandaeva* (Billings), a "Calciferous" form found in anada, and *O.* (*Orthis*) *striatula* (Hall), also an American form.

The only lamellibranchs that have been found belong to the genus *Euchasma* of Billings, a form allied to *Conocardium.* In addition to his *E. Blumenbachii,* which he obtained from the "Calciferous" rocks of Newfoundland and from the Mingan Islands, several varieties have been met with in the two uppermost groups of the Durness Limestone, which link that genus by almost insensible degrees to his genus *Eopteria,* founded on a form obtained from beds of the Quebec group at Port au Choix, Newfoundland. Billings, however, recogbised the near relationship of the two genera, and was doubtful if *Eopteria* would stand as an independent genus.

Gasteropods are perhaps the most characteristic and abundant members of the fauna of the two uppermost groups. The peculiar primitive euomphalid genera *Maclurea* (Lesueur), and *Ophileta* (Vanuxem), are especially prominent. The first-named genus is represented by at least five species, which can be identified from the remains of the shells themselves. Four of them are the most common shells of certain sub-zones of the Calciferous rocks of Newfoundland and Canada, while a fifth, M. *Peachi,* has as yet been found only at Durness and Skye, though opercula almost identical with those of this species are figured by Billings, and are said to occur together with some of the other species above referred to at Cape Norman in Newfoundland.<ref>Geology of Canada (Palaeontology), Vol. I., p. 243, fig. 228, 1861–1865.</ref> Besides the operculum of *M. Peachi,* four other distinct forms of opercula are also present. These range from flat types like that of *Maclurea matutina* (Hall), figured by Billings<ref>Geology of Canada, p. 115, fig. 24, 1863.</ref>, through those like *M. Peachi,* figured by Salter, to highly elongated and slipper-shaped species, with only a very slight spiral curve. These different types do not occur at random throughout the two groups of strata, but each seems to be restricted to particular beds, where it occurs in profusion. There appears, therefore, to be a probability that these rocks could be subdivided into distinct palaeontological zones by means of these and other fossils, though the task has not been attempted by the Geological Survey. Several species of *Ophileta* occur besides the *O. ampacta* of Salter. Some of these can be identified with species found in the Calciferous rocks of Newfoundland, while one at least appears

to be new to science. Two species of whorled shells, loosely coiled in a flat spiral, have been provisionally placed in the genus *Euomphalus,* while several forms belonging to an allied family, the *Turbinidae,* have been classed with the genus *Oriostoma* (Lindstrom) (*Omphalotrochus,* Meek). One of these, *O.* (*Pleurotomaria*) *Calphurnia* of Billings, is met with in the rocks of the Quebec group of Cape Norman. Three other species, nearly related to it, and which can be connected with it by intermediate forms, also occur. It is an interesting and highly suggestive fact that hemispherical bodies, preserved in orbicular silica, appear in numbers on the same slabs of stone with many of these fossils. One of these bodies was actually found lying at the mouth of a shell in such a manner as to suggest that it is the operculum. If this suggestion be confirmed, it would point to the inference that we are dealing here with primitive types possessing massive calcareous opercula. In the case of *Maclurea,* no great stretch of the imagination is needed to conceive that this form may not be far removed from an actual bivalve shell.

The genus *Murchisonia* is represented by fourteen species and varieties, which exhibit a great range in form. These have been divided into two sub-genera. Those forms having beaded whorls and simple slit-band form the sub-genus *Hormotoma;* those with sharp. spiral keels are included in the sub-genus *Ectomaria.* Under the first group or *Hormotoma* sub-division come M. (*H.*) *angulocineta, M.* (*H.*) *Anna, M.* (*H.*) *Artemesia, M.* (*H.*) *Alignstina, M.* (*H.*) *linearis,* which are likewise found in the Calciferous rocks of Canada and Newfoundland; also *M.* (*H.*) *bellicincta* and *M.* (*H.*) *gracilis,* which are common forms in the Black River and Trenton groups of America, or the equivalents of the Llandeilo and base of the Bala rocks of Britain. In addition to these species, *M.* (*H.*) *antigua* and *M.* (*H.*) *gracillimo are* as yet only known from the Durness Dolomites.

Of the *Ectomaria* sub-division, *M.* (*E.*) *Adelina* is found in America in the Calciferous group, while *M.* (*E.*) *pagoda is* a Black River form, of which two varieties have been described by Miss Donald from specimens collected at Durness and in Skye. Another form of *Murchisonia* has been met with belonging to a different group, and nearly related to *M. Milleri* (Rogers), which was wrongly named by Hall *M. bicincta.* It appears in the Trenton and Hudson River group of America.

A corresponding variation is found to exist in the species of the genus *Pleurotomaria* preserved in the Balnakiel and Croisaphuill groups of strata. One type has the same characteristics *as Hormotoma,* except that the cone increases more rapidly, in consequence of which the spire is shorter. In fact, these *Murchisonias* and *Pleurotomarias* merge so insensibly into one another that any line drawn between the two genera must be an arbitrary one. Among the forms of *Pleurotomaria* resembling *Hormotoma* a large turgid species has been obtained. Examples of the same type have been found in the Calciferous rocks of Canada and in the Trenton Limestone. A small form, which has been doubtfully placed with *P. gregaria,* also occurs in Durness and Skye, as well as in the Calciferous rocks of the Mingan Islands of Canada.

A second series of the type of *P. calcifera* of Billings, with almost flat spiral and wide umbilicus and of lenticular section like *Raphistoma,* also appears in the Scottish Cambrian fauna. Besides *P. calcifera,* this fauna likewise includes *P. canadensis* and *P. laurentina,* all of which are found in the Calciferous rocks of Canada. This type of shell merges into another in which the spire is higher, giving a trochiform appearance; the umbilicus is wide, and the section of the whorl rhomboidal. The typical species of this group is *P. Etna* (Billings). It is associated with *P. Ramsayi,* and both these species are fossils of the Calciferous rocks of Newfoundland and Canada. *P. Thule,* the species described by Salter from the Balnakiel group at Durness, belongs to this group. Fragments of a large unnamed shell also of the same type is plentiful at Durness. Two other forms, *P. Dryope* (Bill.) and *P.* (*Helicototaa*) *spinosa* (Salter), which appear in the two uppermost groups of the Cambrian formations of the North-West Highlands, are also present in the Black River Limestone on the horizon of the Llandeilo Limestone of Wales.

The cephalopods of the two uppermost groups in the Sutherland succession of strata are of almost equal interest with the gasteropods. They are all of a primitive type, and display a considerable range in form. The characteristic feature of the orthoceratites is the relatively large size of the siphuncle, which is usually supplied with endocones and organic deposits, and is placed laterally. The most conspicuous species in this respect belong to the genus *Piloceras,* which was founded by Salter<ref>Salter, *Quart. Jour. Geol. Soc.,* vol. xxv., 1859, p. 376.</ref> upon the invaginated siphuncles obtained by Charles Peach from these two groups at Durness. This determination was formed under the belief that the fossils constituted the complete shells of a very primitive form of orthoceratite, in which what are now known to be the invaginated endocones were supposed to represent both septa and siphuncle. More complete forms, showing the relation of this complex siphuncle to the septa and outer walls, were subsequently found In America and described by

Whiteaves<ref>Whiteaves, *Bull. Amer. Mus. Nat. Hist.,* vol. i., No. 8, p. 323, pl. xviii. (New York), 1896.</ref>, Billings<ref>Billings. *Geol. of Canada,* Palm. Foss., vol. i., pp. 256–258, fig. 240 (1861–1865).</ref>, and Sir J. W. Dawson<ref>Dawson, *Canadian Naturalist,* New. Ser., vol. a., No. 1.</ref>. Amongst the earlier collections made by the Geological Survey, though most of the specimens consist of the siphuncle only, there are several specimens which show this relation, and which were studied and used by A. H. Foord<ref>Foord, *Cat. Foss. Ceph. Brit. Mus.,* pt. i., figs. 17, 18, 19 (1888).</ref> for the purposes of the British Museum *Catalogue of the Cephalopods,* where some of them are figured. The collections made by the Geological Survey in later years have furnished many more specimens, which prove that, besides the form named by Salter *Piloceras invaginatum,* several others are represented. These differ from that type in the taper and curve of the siphuncle, in the relative distances of the septa from each other, in the obliquity of the ridges left on the outside of the siphuncle where it is clasped by the septa owing to its being always placed laterally on the concave or gastric side of the cone.

Two specimens show a long slit at one side of the invaginated funnel-shaped sheath. The genus *Piloceras* has been recorded from the North-West of Scotland, Canada, and the Eastern States of America only. Four species are found in the Calciferous group of Newfoundland, one in the equivalent rocks of Lachute, near Montreal, and the sixth occurs in the "Bird's Eye" Limestone of Fort Cassin, Vermont, in strata on the horizon of the Lower Llandeilo of Wales.

The allied genus *Endoceras* (Hall) is represented in the North-West Highlands by several forms, but owing probably to the causes already mentioned, for the most part only siphuncles have been preserved, and even these are in a very fragmentary condition. One specimen, in which the outer walls and septa are preserved, shows a gently-tapering smooth cone more than one foot in length, having the septa set at moderate distances from each other, with a large laterally-placed siphuncle which shows organic deposits. Another fragmentary specimen has retained a small portion of the smooth outer wall and a wide, gently-tapering siphuncle with endocone, the siphuncle being almost in touch with the outer wall of the cone. All the detached siphuncles agree in one respect: they exhibit marked obliquely-set annulations on their exterior where the successive septa have merged into the siphuncle, and where in consequence the material of the siphuncle-wall, having been thickened, has longer resisted the dissolving agents than the thin septa. Most of them show endocones, and in one case the intermediate organic deposits between the outer and inner cones appear to simulate septa. Several of the siphuncles closely resemble the corresponding structures of forms found in the Calciferous rocks of Canada, and described and figured by Billings under the names of *Orthoceras Becki, O. — ? O. Montrealense,* and O*. sordidum.*<ref>*Geology of Canada,* p. 121, figs. 35–37 (1863).</ref>

Numerous species of *Endoceras* occur in the "Orthoceras Limestone" of Sweden, which immediately overlies the *Phyllograptus* shales that represent the horizon of the Arenig rocks of Britain.

Certain forms placed by Salter in the genus *Orthoceras* appear in the two uppermost groups of Durness and in Skye. The most common and also the most marked species, *Orthoceras mendax* (Salter), is moderately tapering, strongly annulated, circular *i*n section, with moderately-arched septa and sub-central siphuncle, which measures about one-third of the whole diameter. According to Blake,<ref>Blake, *Brit. Foss. Ceph.,* pt. i., p. 81, pl. iii., fig. i.</ref> the siphuncle shows a central sheath and organic deposits. This form is doubtfully referred by Foord<ref>Foord, *Brit. Mus. Oat. Ceph.,* pt. i., pp. 166–167.</ref> to *Actiaoceras.* From the consideration of these facts, it appears to have close affinities with *Endoceras.* Two species, *O. Priamus*<ref>*Billings, Palaeozoic Foss. Canada*, p. 253, fig. 239.</ref> and *O. Lamarcki,* from the Calciferous rocks of Newfoundland and Canada, figured and described by Billings,<ref>Ibid*.,* Op. cit., pp. 255, 347, fig. 338.</ref> are so much like *O. mendax* in their rate of taper, in their annulations, in their septa, and in the size and position of their siphuncle, that they are evidently nearly allied to that species, if not actually varieties of it. The species figured by Salter from the Durness Limestone as *O. vertebrale* of Hall<ref>Salter, *Quart. Journ. Geol. ,Soc.,* vol. xv., p. 375, pl. xiii., figs,22, 23.</ref> has been shown by Blake<ref>Blake, *Brit. Foss. Ceph.,* pt. i., p. 82.</ref> to belong to *O. mendax* (Salter). The only form that seems really to belong to the genus *Orthoceras* is the *O. pertinens* (Blake), which occurs in both the stratigraphical groups of Durness and also in Skye.

A small fragment, which shows the interior of a siphuncle and a few septa, may possibly belong to a species of the genus *Actinoceras.* It was found in the Balnakiel limestone at Durness. Several slightly-curved forms with elliptical section and closely-set septa from the two uppermost groups of strata have been provisionally placed in the genus *Cyrtoceras.* The variation in form, as well as the position of the siphuncles in these fossils, show them to belong to several species,

though the specimens are all too imperfect for specific identification. The siphuncles are placed close to the side, and usually on the concave or endogastric, but sometimes on the opposite, side. They are wide, and, like most of the forms, they taper rapidly. Although no endocones have been observed, probably owing to the prevalent manner of entombment and preservation, the whole form as well as the large siphuncles bear close resemblance to *Piloceras.* It is evidently a form of the type figured by Salter as doubtfully belonging to the genus *Oncoceras.*<ref>*Quart. Journ. Geol. Soc.*, vol. xv., p. 375, pl. xiii., 1859.</ref>Similar forms are abundant in the rocks at Point Levis, near Quebec.

Whorled nautiloids are represented by fragmentary remains of several distinct forms, in which the cone shows a very gentle taper and the folds are slightly impressed on one another, so as to present a reniform section. All the specimens in which the exterior is seen show strong ribs. The septa are moderately arched, and in some are closely-set, while in others they stand moderately far apart. The siphuncles, compared with those of the straight and slightly-curved nautiloids in the same strata, are narrow and are placed sub-centrally, usually nearer to the gastric than to the dorsal side, though in the outer whorls the opposite arrangement may sometimes be noticed. The specimens have been too badly preserved for specific determination, but fragmentary though they be, they seem to belong to the genus *Trochdites* of Conrad. Nautiloids of this type, placed in the genus *Nautilus* by Billings, occur in Newfoundland and Canada in the Calciferous sand-rock, associated with an assemblage of fossils similar to that which is found in the two uppermost groups of strata now under consideration in Durness and Skye.

Trilobite remains are extremely scarce in these two groups of the Durness Dolomite, and even when found are so fragmentary and poorly preserved that they can rarely be specifically or even generically identified. Only one species, *Bathyurus Nero* (Billings) has been with certainty determined. It is represented by two detached glabellve, two separate free cheeks, and a pygidium. This form is found in Newfoundland in the Calciferous formation, where it ranges from Beds F to N of Billings' table.<ref>Billings, *Pal. Foss. Canada,* pp. 366–372.</ref> Two pygidea of a trilobite nearly allied to the above also occur in the collection from these zones at Durness.

In the collection made in Skye, a glabella of a trilobite probably belongs to the genus *Solenopleura.* It strongly resembles the corresponding part of *S. tumida* (Wallcott), a form found in the *Olenellus*-zone of America.

Two badly-preserved trunks of a trilobite have been found, showing strongly-marked central axis, with pleura well-grooved and facetted and sharply bent downwards from the fulcra, the distal portions being directed backwards in the anterior segments, and placed either at right angles to the axis or bent slightly forward in the hinder ones. One of the specimens presents 13 free segments, while in the other 14 can be counted. The latter exhibits also the pygidium, which is partially detached and only partly exposed. The central axis, however, shows it to be made up of at least four coalescent segments. The specimen also displays the general form of the glabella and a distended cheek, but these parts are in even a worse state of preservation than the rest of the specimen. The form closely resembles some species of *Conoeoryphe,* and comes near to the *C.* (*Conocephalites*) *Schulzeri* of Schlotheim.

In another specimen the part of a trunk of a trilobite, which is preserved in chert, possesses a well-marked central axis and grooved pleura on the left side, but the distal portions beyond the fulcra have not been preserved, neither are the pleura of the right side to be seen, except close up to the central axis.

The form is only slightly arched. Sixteen free segments can be counted in the fragment. From its very gentle taper, indicated by the lines made by the edge of the central axis and by the row of fulcra being almost parallel, also from the fact that a gap occurs in the series between the most anterior segments and the rest, where the specimen is in a bad state of preservation, the whole trunk may almost certainly be regarded as having originally had more segments than are now to be seen. Such a fragment raises a strong presumption that it belongs to the genus *Paradoxides.*

The only other trilobite remains consist of two large plain glabellae, without furrows and with large nuchal spines. One of them measures more than an inch in length by nearly as much in breadth. The other is about half an inch long, while the spine, which is broken, is quite as long as the glabella, is hollow and oval in section, the long axis of the oval being at right angles to the plane of the body. This type of glabella is found in the genera *Agraulos, Zaeanthoides, Solenopleura, Dorypyge,* and other Middle and Upper Cambrian trilobites.

Thus the whole facies of the trilobites is strongly Cambrian. The horizon of the Balnakiel and Croisaphuill groups is plainly indicated by the fossil evidence to be identical with the strata in Newfoundland from I to N of Billings' table which underlie the dark shales of Table Head, Pistolet Bay, and Cow Head. At the latter locality these shales have yielded an abundant graptolite fauna characteristic of the Arenig rocks.

VII Durine Group

The highest zone of the Durness Limestone is only found at Durness. It consists of grey limestone and chert. The only fossils yet obtained from it are *Murchisonia* (*Hormotoma*) *gracilis* (Hall) and *M.* (*H.*) *gracillima* (Salter). *M. gracilis* is common in the Black River Limestone at Pawquette Rapids, River Ottowa, Canada, which is considered to represent the horizon of the Llandeilo Limestone of Wales. These fossils do not, however, suffice to fix the stratigraphical position of the present group, for they appear abundantly in the underlying Balnakiel and Croisaphuill groups both at Durness and in Skye.

From the palaeontological evidence obtained from the Durness dolomites and limestones which has now been stated, it appears that all the calcareous beds, overlying the *Salterella* dolomites (Lower Cambrian), represent the Middle and Upper Cambrian formations. But owing to the American facies of the fauna it is impossible to correlate the sub-divisions either with the Welsh or Scandinavian succession.