Palæozoic Formations in the Light of the Pulsation Theory.

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I. THE LOWER CAMBRIAN PULSATION

The essentials of the Pulsation theory have been given in several previous communications.[1] The theory is an explanation of the observed phenomena of progressive overlap, followed by regressive off-lap, each of which represents one of the minor divisions of the geological systems, such as the Lower Silurian, which is a transgressive series, and the Middle Silurian which is a regressive series. As these phenomena of overlap and off-lap have occurred more or less simultaneously on all the lands, they cannot be referred to epeirogenic movements, that is, local sinkings and risings of continental masses. It is only the general rise of the sea-level, which would produce simultaneous flooding of the geosynclines and low districts of all continents, while a sinking sea-level would produce a corresponding pancontinental retreat of the sea. It is these two, the rising, and the succeeding falling sea-level, which together constitute an individual pulse-beat, and it is probable that the period of duration of such a pulse-beat is between 20 and 30 million years.

In the discussion of the subject before the Geological Society of China, it was suggested that a more normal sub-division of the Palæozoic, than the one now in use, is desirable, one more in conformity with the phenomena of

1 16th International Geol. Congress, Washington D. C. July 1933. University of California Lecture Berkely Sept. 1933; Joint meeting of the Geol, Soc. of China and Peking Soc. of Nat. History, Oct. 1933; 10th annual meeting of Geol. Soc. of China Nov. 1933.

the pulse-beat, and that hence the Palæozoic should be divided into systems, each one of which represents a transgressive series constituting the lower, and a regressive series, constituting the upper portion. This would require the removal of a third of each of the older systems, and the combination of two adjoining ones into a new one. Thus the old Upper Silurian which represents a transgressive, and the old Lower Devonian which represents a retreatal series, constitute a single pulsation, and would on this new basis have to be united into a distinct and new system of the Palæozoic. Similar changes would have to be made in other systems to harmonize them with the phenomenon of pulsation.

The significance of the pulsations in the development of the Palæozoic systems and their faunas, requires emphasizing, as it may not at first be very apparent.

With the beginning of a pulsation, the sea advances uniformly over the continents, wherever these are sufficiently low to permit marine ingression, when the oceanic level rises. Such transgression is most pronounced in the geosynclines and over the continental shelves, and proceeds from all oceans simultaneously if the rise is a uniform one, or if the continental masses are situated within reach of the rising waters. With separate continents, scattered over the surface of the earth as they are today, transgression affecting all of them could only be brought about by a general rise in the sea-level, such as would be produced were the ocean floor to swell and so lift the entire body of water above it.

If on the other hand the present continents were united in a single continental mass in Palæozoic time, as is postulated by the theory of continental drift, an alternative cause might be assigned for the transgressive and regressive movements. This is the periodic acceleration and subsequent retardation in the earth's rotation, as suggested some years ago by Dr. J. S. Lee. If it may be assumed that the united continental mass occupies one polar hemisphere, with the pole somewhere in the center of this land mass, and the equator marking in general the outer border of the land, then it becomes apparent that a retardation in the earth's rotary movement and the resultant poleward flow of the oceanic waters would produce transgression over the polar hemisphere of land, while an increase in the rate of rotation which would draw the oceanic watars towards the equator, would produce a regressive movement of the waters on the continental hemisphere.

These movements it must be observed can take place simultaneously on all the lands only if these are united in a single polar hemisphere. If they are distributed as now on both sides of the equator, transgression in the polar, would be accompanied by regression in the equatorial regions and conversely, regression in the polar regions is accompanied by transgression in the equatorially situated lands.[1]

So far as facts are known, transgression and regression have affected the continents essentially in a uniform manner. Therefore we must either postulate a universal rise and fall of the sea-level or the concentration of all the lands within a single polar hemisphere; in which case either the general rise followed by a fall of the sea level, or a retardation followed by acceleration of the earth's rotation, would produce the phenomenon designated a pulsation.

When we translate the physical phenomenon of sea-transgression into its effect upon the migration of marine faunas, we are confronted, at the outset, with the problem of distinctive faunal groups. If we deal with partially is-

1 Geosynclines on the equator require special consideration.

olated ocean basins, only sufficiently connected to be affected by the general rise and fall of the oceanic level, we would expect to find that the invading faunas from the several oceanic bodies were each more or less distinct from the other, this being the more pronounced, if the different oceanic bodies existed in different climatic zones. But even if the continents were all concentrated into a single polar hemisphere with the margins more or less falling in the equatorial region, we could understand the existence of distinct faunal groups, along different parts of the continental border, separated by discontinuity of the continental shelves, which at that early time must at best have been narrow, and developed mainly where the rivers from the geosynclines poured into the sea, producing a submerged coastal shelf. Under such circumstances uniformity in the faunal elements would only exist in the pelagic types, while considerable diversity might be found in the groups restricted to the littoral benthos of the various isolated portions of the continental shelf. This would account for distinctive faunal assemblages in the invading oceanic bodies from the various oceanic regions, and the distinction would be pronounced in the proportion in which intermingling of faunas along the continental borders, either in the mero-planktonic or the adult benthonic stage, would be prohibited. (See pl. I)

The phenomenon of a transgressing sea with accompanying vast progressive increase of the littoral realm, which the marine organisms may occupy, would be characterized by an expansive evolution of that fauna, since a free play in developmental tendencies is allowed, and the lessening of the struggle for existence would favour even the persistance of less adaptable types. Moreover, the variety of local habitats, successively opened by the transgression, would bring into play diverse stimuli, under the action of which otherwise dormant characteristics might be developed. In this wise the more or less limited faunas at the beginning of the transgression would become widely diversified during its progress, and since the whole period of a single transgression covers a time interval of some ten million years or more, it would come to pass that the transgressive series of deposits, near the acme of development, at the period of maximum sea expansion, would enclose a rich and diversified fauna. This in itself would represent a more or less coherent unit, widely recognizable, wherever the transgressive series from one source invaded the land, but more or less distinct from the fauna of the contemporaneously invading seas from another isolated portion of the continental shelf. When two such invading seas from opposite directions meet, there would of course be an intermingling of faunal elements whose evaluation, with respect to their original source, would become a subject of speculation. But if there is no such meeting of simultaneously transgressing seas, the benthonic faunas would show many distinctive forms peculiar to each, though the pelagic elements of the faunas might be identical. Thus, while the corals, benthonic brachiopods, most mollusks, trilobites and crinoids are apt to be distinct, the foraminifera, graptolites, and perhaps goniatites, if they have appeared, might show identity of species.

When the regression of the sea begins, the littoral area becomes progressively restricted, with the result that there commences a process of progressive extermination of the benthonic types, and with the narrowing of the field of occupancy comes the development of a more hostile environment, and a sharpening of the struggle for existence.

Under such circumstances further modification in special directions would take place in the surviving types, and thus the fauna decreases numerically and at the same time becomes modified varietally.

Physically the evidence of regression may be found in the replacement of pure water sediments by clastic deposits, and these of themselves are inimical to the existence of many of the formerly widespread organic types. Thus while the fauna of the retreating or off-lapping series would still show marked relationship to that of the transgressing series, it would become sufficiently distinct to permit ready separation from the preceding one. Finally by the time that the retreat has been complete and the littoral zones have become narrowed to the continental shelves, the struggle for existence would have reached its most intense stage, and consequently the modification of the few surviving types, which takes place, would become proportionately pronounced. By the time then that the new pulsation begins, and renewed transgression takes place, most of the older forms would have become exstinct, and the spreading faunas would have a distinctive complexion of their own, more markedly different from that of the preceding retreatal fauna than that one is from its antecedent transgressive fauna.

It is thus apparent that faunally the deposits of a single pulsation, that is the transgressive and regressive series, form a related group of units, distinctive from that of either the preceding or succeeding pulsation. This leads to the inevitable conclusion that the natural division of the systems must be based on the pulsations, each system comprising a lower or transgressive series, and an upper or regressive series.

As is well known, the present classification gives each system one complete and one half pulsation, and therefore includes a part of a distinctive faunal system, either as its lower, or as its upper portion. Thus while the Lower and

Middle Silurian form one cyclic series of deposits and one waxing and waning faunal group, the Upper Silurian is the lower half of the succeeding cycle of deposition with its new waxing fauna. The remainder or upper portion of that cycle, with the waning faunal element, is seen in the Lower Devonian of the present classification. The Ordovician of the present classification on the other hand, begins with the retreatal or upper half of the cycle of deposition with a waning faunal group, while the succeeding Middle and Upper Ordovician represent the deposits of a complete cycle and the corresponding waxing and waning faunas and therefore a complete pulsation.

When we propose to base our classification on the phenomena of pulsation with the accompanying sediments and faunas, it behoves us to scrutinize with marked care the older systemic divisions, to see how far they and their current three-fold divisions permit incorporation into the new pulsation systems. At the very outset we are met with a baffling case in the divisions of the Cambrian system, which do not appear to admit combination into pulsation systems.

It is a matter of general knowledge that few of the current systems present such striking faunal differences between their successive divisions, as does the Cambrian of current usage. The faunal difference between the Lower and Middle Cambrian is almost complete, very few types extending across. Their most marked differences are seen in their leading faunal elements i.e. the trilobites.

In each of the several faunal provinces, into which the Lower Cambrian can be divided, the faunas are distinct from those of the others and in each the fauna of the Lower Cambrian is entirely distinct from that of the Middle Cambrian. Thus in the Lower Cambrian of the Atlantic Province, the leading trilobites are *Holmia* and *Callavia* etc, while the Middle Cambrian is characterized, above all, by *Paradoxides*, *Agnostos* and *Solenopleura*. It is true the *Protolenus* Beds have been put by some at the base of the Middle, and by others at the top of the Lower Cambrian, but that is a matter of classification and does not affect the general proposition, since *Protolenus* is confined to that particular horizon, and is distinct from other forms. Again the Upper Cambrian fauna is markedly distinct, with its *Olenus*, *Ctenopyge*, *Peltura* etc. It is true that *Agnostus* also occurs in the Upper Cambrian, but it is represented by distinct species and is moreover one of the very few generic types in common between the two. This genus may possibly have been a member of the pelagic fauna.

In the Appalachian Province, the Lower Cambrian is characterized primarily by the trilobite *Olenellus*, best known from the Northern Appalachian deposits, but also reported from the Shady formation of the Appalachian Mountains in Tennessee. Besides this genus, other trilobites of the genera *Mesonacis*, *Bonnia*, *Kootenia*, *Neolenus* etc. are found. Again the Middle Cambrian of this province is quite distinct, its characteristic trilobites being of very specialized and still little known genera. There is reason for believing that these faunas have a Boreal origin for we find them again in the Paleo-Cordilleran geosyncline, where the Lower Cambrian is characterized by various species of *Ollenellus*, and *Mesonacis* and the Middle by *Olenoides* types of trilobites etc.

Finally the Lower Cambrian Indo-Chinese Province is characterized by the trilobite *Redlichia*, wholly distinct from the types of the other known provinces. Dr. Sun suggested that the *Blackwelderia* and *Drepanura* faunas of the higher Cambrian may also be of Indian origin. (See map plate I)

In my provious communications I have united the Lower and Middle Cambrian in a single pulsation of which the Lower was made the transgressive and the Middle the regressive phase. But as we have seen, if these divisions harmonized with the characters of the normal Pulsation Series the fauna of the Middle Cambrian should bear a relationship to that of the Lower, at least generically, the chief modification in the fauna being one of reduction in the number of species and the progressive, not sudden, modification of the survivors. This is certainly not the case when we compare the Middle Cambrian fauna with the Lower, for in all the provinces, the Middle Cambrian shows a remarkable and almost complete faunal distinctness from the Lower. Nor can we assert that there is any marked relationship between the two. Moreover, in a regressive series, such as the upper half of a pulsation group represents, the beds should have a lesser areal extent than those of the preceding transgressive series. Though this is true of the Middle Cambrian in some sections, we find the rather remarkable fact, that in most sections the Middle Cambrian itself presents a transgressive series, and that it frequently over-laps the Lower Cambrian. Again, where the Middle Cambrian succeeds the Lower, there is often a marked disconformity between the two, such being known in the Appalachian region and recognized in East China. That the Middle Cambrian frequently over-laps the Lower is a well-known fact. In St. John, New Brunswick, the Cambrian begins with the Protolenus Bed followed by the Paradoxides Beds. In the classical section in Bohemia the Paradoxides Beds alone represent the Cambrian, and in many places in the Rocky Mountains, the Middle Cambrian rests upon the Archæan, or on the Sinian Belt Series.

These facts clearly demonstrate that the Middle Cambrian cannot be included with the Lower as the negative phase of a single pulsation, but represents in fact a separate and distinct pulsation of its own. Nor can we refer the Lower Cambrian to a single transgressive phase of the initial pulsation, for where the sections are complete we find that the upper part of the Lower Cambrian has the physical characters of a retreatal series. We are therefore constrained to regard the old Lower Cambrian as representing a single pulsation unit, comparable to the pulsation units of later Palæozoic time and therefore entitled to distinct systemic rank.

We may note several of the Lower Cambrian sections in the regions of their more complete development.

APPALACHIAN PROVINCE.

In the Southern Appalachians of North America, the Palæozoic Series begins with the great Chilhowee group of continental clastics, of which the Unicoi sandstone of Eastern Tennessee presents a monotonous succession of sandstones with basal conglomerates, whose characteristics and thickness vary from place to place, the range of the latter being from 1550 to 8,000 ft. Some arkosic material occurs in the lower part, but the great mass of the formation consist of rather light-coloured quartzites, often showing cross-bedding, and here and there some micaceous sandstones. In addition to the well-rounded pebbles, there are coarse angular blocks, probably derived from local sources. No fossils whatever have been found in this series and it may in part be referable to the Sinian, or it may represent continental basal eds of the Cambrian.

This series of sandstones is succeeded by the Hampton series, with a minimum thickness of about 1400 feet and a maximum of about 4250. The formation consists predominantly of bluish-grey rocks including slates, shales and to a lesser degree sandstones, and it also varies in lithological character and thickness from place to place. Its terminal member is known as the Murray shale and from beds referred to this division Olenellid trilobites and the phyllopod *Isoxys chilhoweana* Walcott have been collected, though it is not absolutely certain that they are referable to this horizon. It has been suggested that this shale also may be in part of Sinian age.

This shale is again succeeded by the great Erwin quartzite or sandstone, which ranges in thickness from several hundred to more than 1,000 ft. This in other sections appears to be represented by the Hesse and Antietam sandstone formations. In general this series consist of heavy red to white quartzites and sandstones with poorly preserved trilobite fragments in some sections.

The next succeeding series is the Shady formation, at least 1,000 feet thick and perhaps twice that thickness. This is the Calcareous Series and marks the maximum transgression of the Lower Cambrian Sea. In some nearer shore areas, the limestones are more argillaceous, and shales more often occur. In these beds fossils are abundant and a succsssion of distinctive zones has been recognized. The lowest of these is the *Bonnia* zone characterized by the trilobite of that name. This is followed by the zone of *Olenellus thompsoni* (Hall) which, besides that species of trilobite contains other trilobites as well as large phyllopod and merostome crustaceans, gastropods, cystids, worms trails, and algæ. The third zone is characterized by *Archæocyathids* while the fourth, known as the *Nisusia* zone, is characterized by the brachiopod of that name, but also includes the trilobites *Bonnia*, *Olenellus*, *Neolenus*, etc and other brachiopods of the genera *Kutorgina, Paterina, Acrotreta* and the gastropod *Scenella.*

The terminal formation of the Lower Cambrian of this section is the Rome Series which consists of more than 1,000 feet of sandstone and shales often brilliantly coloured and characterized by suncracks and ripple marks. A few impure limey beds are present and here some fossils have been found including *Olenelloid* trilobites in the lower part. This clearly represents the retreatal phase of the series, and it and the succeeding hiatus or emerging phase, mark the negative portion of the Eo-Cambrian pulsation.

In Eastern Tennessee the beds succeeding the Rome formation vary considerably. In general the name Conasauga shale is applied to the series in the vicinity of the Tennessee River. The thickness of this shale varies very greatly. Thus while in the Cleveland folio (east of 85° and north of 35°) east of the southern railway[1] it ranges from 1,100 to 6,000 ft. West of that railway it ranges from 500 to 1,600.

In the Kingston folio, (west of 84°30′ and south of 36°) which represents the belt still further west the thickness has dwindled to between 300 and 500 ft.

In general, as the Conasauga dwindles, the thickness of the Rome increases. As a formation the Conasauga is placed in the Upper Cambrian while the great Knox dolomite which succeeds it, is placed in the Ozarkian. The Conasauga begins with oolitic limestone and it is possible that some of these may be referable to the Middle Cambrian, which is otherwise absent. In the Knoxville folio

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1 The railway extends from Knoxville north-east to Morristown before it changes its course through the mountains; and south-west to Athens and Cleveland. and thence into Georgia.

however, (east of 84^0 and south of 36^0) which represents the more central belt in the geosyncline, the series which succeeds the Rome (the latter with a maximum of 950 ft) is more varied. Immediately above the red, green, yellow and brown shales of the upper Rome, follows the massive dark-blue Rutledge limestone from 350-450 feet thick with *Dolichometopus productus* at its vase. Above this lies the Rogerville shale 180-220 ft thick, a bright green clay shale with a limestone bed. These 2 formations together have been referred to the Middle Cambrian which thus has a thickness varying from 530-670 ft. Then follows another massive dark-blue limestone 350-550 ft thick and called the Maryville limestone which is often referred to the Upper Cambrian. The succeeding beds, which separate this series from the Knox dolomite is called the Nolichucky shale. It is more or less calcareous, with some limestone beds with a thickness of 450-550. This is also referred to the Upper Cambrian.[1]

In Central Alabama[2], the Rome or Montevello formatian is only partly exposed, but since in the not distant Rome quadrangle, it is underlain by the Shady or Beaver limestone, it is probable that that formation also occurs in the more southwestern region. The exposed portion of the Rome is at least 1,000 ft and its thickness may be much greater. In this region it consists predominantly of stiff greenish shale, yellow flaky shale and red shale, but it includes thin layers of impure limestone, thin cherty layers,

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1 R.S. Bassler Index of Ordovician and Silurian Fossils Pt. 2, U.S. National Museum Bnll. 92, 1915. Correlation Table Pl. I. Butts, Stose and Jonas. Guide 3. 16 th Int. Geol. Congress.

2 Geol. Atlas of U.S. Bessemer-Vandiver folio of Alabama by Charles Butts No. 221, 1927 Long. 56°30'-87° W. Lat. 33°.15'-33°.30' N,

thin layers of brown rotten sandstone, which is normally calcareous, thin bands of quartzite and beds of fine-grained calcareous sandstone as much as 20 or 30 ft thick. It is decidedly variegated in colour.

The following fauna has been cllected from this region.

Micromitra (*Paterina*) *major* Walcott, *Micromitra* (*Paterina*) *williardi* Walcott, *Micromitra* (*Iphidella*) *pannula* White, *Obolus smithi* Walcott, *Wimanella shelbyensis* Walcott, *Olenellus thompsoni* Hall, *Paedeumias transitans*, *Wanneria halli* Walcott,

The *Olenellus* has been found up to within 200 ft of the top of the formation, and as it is the most distinctive index fossil of the Appalachian Lower Cambrian, the age of the Rome formation is thus definitely established. Some doubt has been expressed about the upper 200 ft and the possibility of their being referable to the Middle Cambrian is mentioned by Butts. Where the series is followed by a disconformity showing complete emergence, the whole Rome formation must be regarded as representing the retreatal phase of the Lower Cambrian pulsation.[1]

That the hiatus which succeeds the Rome is a reality, is shown in the variable character and age of the formations which overlie it. Thus in the Birmingham and Shades Valley of Alabama (Northwest part of Bessemer sheet) the Rome is followed by the Conasauga Shale of Upper Cambrian age, while in the Cahaba Valley, 12 miles southeast (In reality 3 or 4 times that, if the folds are considered) the lower members of the Knox dolomite, that is the Ketona dolomite, which in the other sections overlies the Conasauga, rests directly on the Rome.

1 In some sections however, sandy beds with Middle Cambrian fossils occur which mark the transgressing portion of that series.

About 16 miles SW along the strike in the Cahaba Valley (throughout which valley, on the Bessemer and Vandiver quadrangles, the Conasauga is absent) it is said suddenly to appear on Six Mile Creeck, 10 miles SW of Montevello, while between it and the overlying Ketona dolomite (here 275 ft. thick only) appears the Briarfield dolomite with *Cryptozoon proliferum*, 1,250 ft. thick. This is the only place where the Briarfield has been observed and one cannot but wonder if it is not a higher dolomite repeated by faulting.

The Conasauga limestone which disconformably overlies the Rome has a thickness of 1,600 to 2,000 ft. in Northeastern Alabama and consists largely of thin-bedded dark-grey, finely crystalline limestone, interbedded with calcareous shales, the latter sometimes not exceeding 1/10 of the mass. The fossils obtained from it in the Birmingham Valley indicate an Upper Cambrian age, and its equivalency to the Nolichucky shale of the Knoxville Tennessee region and possibly a part of the Maryville limestone. Southeast of the Cahaba coal field however, where some of the so-called Conasauga is preserved (it is absent in the Cahaba Valley of the Bessemer-Vandiver and Birmingham quadrangles) some Middle Cambrian fossils have been obtained and the formation is also equivalent to the Rogersville and Rutledge limestone of the Knoxville region.

The Conasauga of the Birmingham Valley however, must be regarded as the early transgressing member of the Upper Cambrian Lower Ordovician (Cambrovician) pulsation and while it is probable that some Middle Cambrian was present here also, this has been eroded before the Upper Cambrian transgression. This indicates that the Middle Cambrian represents an independent pulsation, characterized by advance and retreat, though apparently in this region the land stood too high for the Mid-Cambrian Sea to linger long.

In eastern Pennsylvanian,[1] York and Lancaster Counties, the Lower Cambrian has been studied in some detail. Although the strata are very strongly folded and disturbed, the sequence as measured by Dr. Stose and Miss Jonas seems to have been well determined. The series begins with the Chickies quartzite, which has the Hellam conglomerate member, of variable thickness, at its base, marking the beginning of Cambrian sedimentation in this region. Because of the strong folding, a certain amount of metamorphism has taken place, but the character of the rock is still recognizable. The Hellam conglomerate, about 50 ft. thick, and consisting of schistose sandstone with small pebbles of glassy quartz, is followed by about 400 ft. of quartzites and quartzitic schists. The only organic remains found are the worm borings, referred to *Scolithus linearis*.

It is followed by the Harpers schist, about 1,500 ft. in thickness, which consists of sandy micaceous schists, with some harder beds of quartz and thin bedded quartzites. No. fossils have been obtained from it.

The next succeeding member is the Antietam quartzite, about 150 ft. thick and consisting of quartzite and quartzite schist. This in sections further north has furnished fragments of *Olenellus* and shells of *Obolella*. These indicate Lower Cambrian age.

Then follows the Vintage dolomite, a dark-blue granular dolomite, more or less impure and having a thickness of approximately 300 ft. In the Lancaster Valley, the forma-

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1 F. Bascom and G. W. Stose. Coatsville-West Chester folio. U.S. Geol. Atlas. No, 223, 1932. Long. 76° W Lat. 40° N. Exposures chiefly in the northwestern part of the folio.

tion has furnished trilobites, shells and cystid plates of Lower Cambrian age.

The Kinzers formation, which comprises about 150 ft. of micaceous limestone, interbedded with calcareous mica-schist and with the *Olenellus* fauna, separates the Vintage from the Ledger dolomite, which marks the maximum of Lower Cambrian transgression in this section. This Ledger formation has a thickness of about 600 ft. and is generally pure carbonate rock. No organic remains are preserved, because of the rather strongly crystalline characters of the rock, but it is still regarded as of Lower Cambrian age. The series is succeeded by the Elbrook limestone, with an estimated thickness of 500 ft. and in character a fine-grained partly dolomitic marble. It contains no fossils, but the typical Elbrook of the Lancaster Valley etc. is referred to the Middle Cambrian. The correlation of the present limestone with it, however, is based wholly on superposition. This limestone series is followed disconformably by the Conestoga Limestone, which in the Lancaster Valley has furnished some fossils probably of Chazy age. There is thus evidently a very pronounced hiatus. The Vintage, Kinzers and Ledger formations are tentatively correlated by Resser with the Shady formation of the generalized section. (Loc. cit. p. 747).

About 2 degrees west, on the same parallels, in the Mercersburg-Chambersburg area (Geol. Atlas U.S. Folio 170) the Cambrian is represented by the following formations in descending order.

Super-Formation. Beekmantown and Stonehenge limestone of Lower Ordovician age . . . . . 2250-2300 ft.

Cambrian Series.

Upper Cambrian. Conococheague
Limestone 1635 ft.

Middle Cambrian. Elbrook formation		3000 ft.
Lower Cambrian		
3	Waynesboro formation	1250 ft.
2	Tomstown Limestone	1000 ft.
1	Antietam sandstone (only partly exposed)	

The Antietam has been tentatively correlated by Resser,[1] with the Erwin quartzite of the generalized Appalachian section, as previously given, in which that sandstone is preceded by the Hampton formation and the Unicoi Series, the latter probably, and the Hampton possibly, being referable to the Sinian (Beltian of American usage).

The Tomstown limestone is composed largely of limestone, both massive and thin-bedded, in part cherty, with some shale interbedded near the base. Among the characteristic fossils are *Salterella, Kutorgina* sp. and fragments of *Olenellus.* Apparently this limestone is the equivalent of the Vintage, Kinzers and Ledger limestones and dolomites farther east and of the Shady formation of the generalized section.

The next succeeding formation, the Waynesboro has a thickness of approximately 1250 ft. and consists of a series of sandstones and purply shales, with a very siliceous gray limestones at the base and some dark-blue to white subcrystalline limestones and dolomites in the middle, which pass upwards into mottled sandstones and dark purple siliceous shales at the top. *Lingulella* sp. had been found at the top but is inconclusive as to age. Stose has tentatively put the formation into the Middle Cambrian, of which it might represent the transgressive series, but it is more likely that it represents the regressive series of the Lower formation and so is equivalent to the Rome formation of

1 Bull Geol. Soc. of America. Vol. 44, No. 4, p. 747.

the more southerly sections. This is the correlation adopted by Butts.

The overlying Elbrook formation is a very thick series 3000 ft. more or less of gray to light-blue shaley limestone and calcareous shale. Shaley members appear to predominate and even the limestone weathers into shales. Near the middle however, are massive beds of dolomite and very siliceous or quartzitic limestones that weather into porous sandstones. The very few fossils found are fragments of trilobites which suggest Middle Cambrian.

The succeeding Conococheague limestone of Upper Cambrian age, is 1635 ft. thick, and begins with a basal conglomerate and siliceous beds, indicating a disconformity. The typical basal conglomerates consist of rounded limestone pebbles one inch or more in size, in a matrix containing numerous coarse grains of vitreous quartz. In addition to this there is an "edgewise conglomerate" in which the fragments are long and slender limestone fragments, tilted at various angles and embedded in a calcareous matrix. This type of rock well-known in China as "Wurm-kalk" is due to the breaking and gliding of thin limestone beds shortly after their formation and before the higher beds are laid down i.e. subaqueous solefluction.[1] It is thus a contemporaneous and intra-formational structure. This formation represents the transgressive series of the Cambrovician.

Farther to the northeast in New Jersey the Palæozoic begins with the Hardyston quartzite, which lies unconformably on, and often in hollows of, the crystalline rock. It varies considerably in composition and in thickness, ranging from a few feet to 200 ft. or more. Primarily it is a conglomerate or quartzitic rock, containing pebbles of quartz,

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1 Grabau. Principles of Stratigraphy p. 784.

feldspar, granite, gneiss and slate, but it may locally be a calcareous sandstone. It is essentially, though not always, an arkose, so pronounced in some localities that it is almost indistinguishable from a coarse granite. Beds of slate occur in the upper part. In the upper calcareous portion, fragments of *Olenellus* suggestive of *O. thompsoni* have been found, indicating its Lower Cambrian age, or else a reworked deposit of Lower Cambrian enclosed in the succeeding formation.

The sandstone grades up through strata of arenæeous limestone or calcareous sandstones and shales into the Kittatinny llmestone, 2700 to 3000 ft. thick, which in turn is separated by a disconformity from the over-lying Jacksonburg limestone of Trenton age.

Characteristic Upper Cambrian fossils including *Dicellocephalus newtonensis* and other trilobites have been found, while at the very summit, some remnants of Beekmantown beds with *Dalmanella wemplii* and *Isotelus canalis* and other species have been found.

Disconformably above this, resting sometimes on the Beekmantown and sometimes on the Cambrian portion, is the limestone of Trenton age.

So far as appears here, the series is a continuously transgressing one to the Beekmantown, but there can be little doubt that it is not a complete series. No Middle Cambrian has been found, although it is generally thought to be included in the series. It is more likely however, judging from the other sections, that there is a pronounced disconformity above the Hardyston quartzite and that the Kittatinny represents primarily the transgressive series of the Upper Cambrian-Lower Ordovician pulsation (Cambrovician) of which a little of the retreatal or Beekmantown series remains. Bassler and Ulrich on the other hand, place the entire Kittatinny into the Ozarkian and Canadian, and in adjoining districts, they separate the Allentown limestone below as Lower Ozarkian and the Copley limestone above as of Canadian or Beekmantown age, holding that there is a considerable hiatus between the two. They also recognize a hiatus between the base of the Kittatinny limestone and the Hardyston, this covering the Middle and Upper Cambrian.[1]

In the Lehigh Valley, the lower portion or Allentown Limestone, contains *Cryptozoon* while *Lingulella* cf. *acuminata* has been found in the upper part. It must be remembered that the existence of a hiatus in the middle portion of the Kittatinny is based on theoretical grounds, since Ulrich does not find representations of his intermediate members. This subject will be discussed, in a later paper.

The early Palæozoic strata of the Northern Appalachians are very much disturbed and their true order of superposition has only recently been worked out with any degree of accuracy. Formerly it was held that all the slates in the area between the Green Mountains and the great fault line east of Lake Champlain were of Lower Cambrian age, and presented in general a regular succession, somewhat complicated by folds and minor faults. Recently however Keith has determined the existence of a series of important over-thrusts from the east parallel to the great over-thrust at Lake Champlain. These divide the area into a series of north-south strips, which over-ride one another, greatly decreasing the original width. In age these beds are now known to range from the Lower Cambrian to the Lower

1 Ulrich. Revision, p. 644. Bassler, Correlation table. Bull. U.S. National Museum 92, Pl. I.

Ordovician. The succession as now recognized east of the Champlain fault is shown in the table.[1] The chief anomalous features of this section is a series of disconformities or even unconformities, of which those between the Lower and Middle Cambrian and between the Middle and Upper, are quite in harmony with the theory of 3 distinct pulsations but the disconformity reported in the Lower Cambrian and the slight unconformity, not much more than a disconformity, between the Upper Cambrian and the Lower Ordovician present anomalous features, which do not appear to harmonize with the conception here discussed, and which therefore need careful consideration and explanation. This is especially the case with the Cambro-Ordovician break. According to Longwell, the Lower Ordovician "starts with a remarkably coarse conglomerate, laid unconformably across various Cambrian formations. Although no sharp pre-Ordovician folds are recognized, considerable warping and erosion must have occurred in late Cambrian time to produce the striking unconformity with the Lower Ordovician and to make possible the large assortment of rock types in the basal conglomerate. In contrast with the limestone in the west the Lower Ordovician strata in the Middle belt consist entirely of clastic sediment." We will return to the discussion of this feature in a later paper.

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1 Chester R. Longwell. Eastern New York and Western New England. Guide Book I, 16th International Geol. Congress p. 64, *et seq.*

Table of the Succession of the Lower Palæozoic in the Slate belt of north-western Vermont

	Feet	Meters
Lower Ordovician.		
Maximum thickness	3,500 ft.	1,067
Conglomerate	0 to 30	0 to 9
Mild unconformity or disconformity		
Upper Cambrian		
Highgate Slate	0 to 300	0 to 91
Marble (horizon uncertain)	0 to 400	0 to 122
Dolomite with abundant intraformational breccia locally	0 to 500?	0 to 52 ?
Mill River Conglomerate	0 to 15	0 to 5
Disconformity		
Middle Cambrian.		
St. Albans Slate of local development	0 to 200	0 to 61
Disconformity		
Lower Cambrian		
Milton Dolomite	30 to 250	9 to 76
Colchester Slate with limestone reefs	0 to 200	0 to 61
Disconformity (?)		
Mallett Dolomite. Very sandy	50 to 800	15 to 284
Winoosky Red dolomite (marble)	250	76
Vermont Quartzite (base not exposed)	300	91

The basal Cambrian quartzite is more commonly a sandstone and is the Red Sand Rock of the earlier writers. Its colour is chiefly red, but contains white and variously coloured beds. Near the top dolomite beds appear, the series grading into the overlying formation. In the sandstone ripple-marks, mud-cracks and other structures indicating continental origin are common. Farther east where it rests unconformably on the crystalline rocks, the quartzite has a maximum thickness of about 800 feet. It is possible that the greater part of the series is of sub-aerial origin like the sands of the Yellow River Plain. This is also suggested by the red colour.

The calcareous beds near the top mark the encroachment of the sea, and here Lower Cambrian trilobites have been found.

The succeeding dolomites are compact fine-grained and dominantly pink and mottled in the lower part. Here are also found intra-formational breccias while the bedding planes are wavy and irregular. These beds contain *Salterella pulchella*, *Nisusia festinata*, and *Ptychoparia adamsi*, all characteristic of the Lower Cambrian of this province. Upward the dolomites become thicker bedded and contain considerable amounts of sand, with several beds of quartzitic sandstones. At the base of the gray dolomite, are several beds of quartzitic sandstone and rounded grains of glassy quartz, apparently of eolian origin are scattered throughout it. In addition there is considerable intraformational conglomerate with pebbles of sandstone. Quartz geodes and veinlets of quartz are also common. The fossils obtained from this higher dolomite are *Paterina swantonensis*, *Salterella pulchella*, *Hyolithellas micans*, *Ptychoparia adamsi*, and *Olenellus thompsoni*.

Apparently no positive structural evidence of a break between this dolomite and the over-lying slates is recognized other than the sandy character of the beds near the contact, and the very variable thickness shown by both of them.[1] Normally the slate is fine-grained, but there are numerous large limestone lenses, as much as 100 ft. (30 meters) in length. The fauna recorded from these beds also appears anomalous suggesting a mixture of Lower and Middle Cambrian fossils. The list is as follows.

1. *Kutorgina cingulata* (Billings)
2. *Nisusia festinata* (Billings)
3. *Swantonia antiquata* Walcott
4. *Microdiscus parkeri* Walcott
5. *Mesonacis vermontana* (Hall)
6. *Olenellus thompsoni* (Hall)
7. *Olenellus thompsoni* var *crassimarginatus* Walcott
8. *Olenoides marcoui* Whitfield
9. *Paedeumias transitans* Walcott
10. *Bathynotus holopyga* Hall
11. *Ptychoparia adamsi* (Billings)
12. *Pt. vulcanus* (Billings)
13. *Protypus hitchcocki* Whitfield
14. *Protocaris marshi* Walcott

No. 8 of this series, *Olenoides marcoui* is a surprising element of this fauna, since this genus is most characteristic of the Middle Cambrian division, as are the other related genera with large spinose pygidia. The presence however of *Olenellus thompsoni* and probably also *Mesonacis vermontana* indicate typical Lower Cambrian. Either then, we must consider that forms of the type of *Olenoides marcoui* range from the Lower to the Middle Cambrian, or else that the occurrence of this form in the slates of the Parker quarry, indicates the existence there of fault blocks of Middle Cambrian age. It might also be questioned

1 Resser does not recognize a break in his correlation table. Guide Book 29, XVI Int. Geol. Congr. Pl. I.

whether this slate series may not actually represent Middle Cambrian beds, in which are included masses of Lower Cambrian limestones and slates. This problem must for the present remain unsolved.

The succeeding dolomite is partly sandy and conglomeritic in its basal portion, thick-bedded in the lower and thin-bedded in the upper part. Its exact age is not known as no fossils have been obtained.

The next higher slate bed, which ranges in thickness from 0 to 200 ft. is recognized as of Middle Cambrian age, its guide fossils being the trilobites *Centropleura*[1] and *Elix*. In its absence the Upper Cambrian lies directly on the preceding bed unless it too is absent. When present there is a basal conglomerate, containing huge masses and angular slabs of limestones and dolomites, derived from the underlying beds

The presence in a younger formation of huge masses of an older rock-mass of such dimension, and in such positions as to suggest stratigraphic continuity, is not unknown, and is especially marked in regions where the newer rock is built against an erosion cliff of the older. It might be profitable to examine the limestone masses in the slate beds with this idea in mind. If this series can be referred to the Middle Cambrian with inclusions of Lower Cambrian, the disconformity between it and the sandy grey dolomite is accounted for.

At Bic, in Quebec, pebbles in a conglomerate of Upper Cambrian age have furnished *Callavia bicensis* W, *Micromitra nisus* W. and *Botsfordia cœlata* W.

The northeastern-most portion of the Appalachian geosyncline as exposed on the American continent is shown in

1 Formerly identified as *Paradoxides* cf. *harlani*

the western part of Newfoundland and the eastern border of Labrador, that is, on opposite sides of the Straits of Belle Isle, and southward in Newfoundland on the Gulf of St. Lawrence. These sections were measured in great detail by Logan in 1861 and again in 1862.[1]

At Bonne Bay, near the center of the west coast of Newfoundland, the Cambrian rests directly on the old Laurentian gneiss. The basal beds are concealed for about 230 ft. and these may correspond to the red and grey sandstones of L'Anse au Loupe further north. Slates and quartzites continue up to 605 ft. above the base, these constituting division A. Then light-grey limestones in beds from 1 to 3 inches, interstratified with blackish-blue slightly calcareous shales follow, these containing *Mesonacis vermontana* and other trilobites. There are 80 feet of these limestones and they are followed by arenaceous shales, granular quartzites totalling 376 ft., and finally by 27 ft. of grey arenaceous dolomite, with reddish quartzite and arenaceous shale, especially towards the top. In these beds, *Paterina labradorica*, *Mesonacis vermontana* and other trilobites and *Salterella* are found. This and the preceding constitute division B, with a total thickness of 483 ft. In the Anse au Loupe limestone of L'Anse au Loupe Labrador, Straits of Belle Isle, beds probably of this horizon, with *Olenellus logani* and *Pædeumias transitans* have been found.

Division C begins with a quartzite series interbedded with shales in the bottom, dolomites in the middle, and shales near the top the whole having a thickness of 400 ft. This is followed by limestones, with *Mesonacis vermontana*, *Salterella* etc. 20 ft. thick, with a thick bed

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1 Geology of Canada p. 865

composed almost equally of limestones and shales near the middle, the whole with a thickness of 82 ft. Dolomites, shales and limestones follow, bringing the whole thickness of the division up to 623 ft., all of which apparently belong to the Lower Cambrian, that series thus having a thickness of 1711 ft. Three hundred feet more of quartzites, limestones and dolomites follow, though fully ½ of the series is concealed. The age of these beds is undetermined for lack of fossils. It may be Middle or Upper Cambrian or belong even to the Lower Ordovician. Higher Ordovician beds follow.

East Greenland:[1] Lower Cambrian rocks are now known to be included ln the beds described by Nathorst in 1901, and by Koch in 1929. Koch was the first to collect the Cambrian fossil. The area lies on the borders of Lyell and Andreé Land, and on Ymer and Ella Islands, the most important localities being on Geology Fjord. (approximately Longitude 20°-25°W., Latitude 71°-74° N. The formations occur in a series of apparently very regular anticlines and synclines with a general north-south strike and a moderate amount of faulting. They were divided by Poulsen in 1929 as follows.[2] (In descending order.

Lower Ordovician (Middle Ordovician of usual classification)

Narwhale Sound Formation

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1 Chr. Poulsen. The Lower Cambrian faunas of East Greenland. Meddelelser om Grönland. Udgivne af Kommissionen for Videnskabelige Undersogelser I Grönland. Copenhagen 1932.

2 Poulsen, Chr. Meddelelser om Grönland Vol. 74, 1930, pp. 306-309.

Upper Canadian (Lower Ordovician.)
Cape Weber Formation
Upper Ozarkian (Lower Ordovician?)
Cass Fjord Formation
Upper Cambrian? (Possibly Middle Cambrian)
Dolomite Formation
Hyolithes Creek formation

Disconformity and hiatus.

Lower Cambrian
Ella Island formation
Bastion formation
Spiral Creek formation
Tillite Canyon formation
Disconformity
Pre-Cambrian (Sinian?)
Cape Oswald formation
Eleonore Bay Formation

In some sections the series is unconformably overlain by the Old Red Sandstones, referred to the Devonian. The Lower Cambrian fossils were obtained from the Bastion and Ella Island formations. The fossils of the Bastion formation are confined to a series of glauconitiferous shales in the uppermost part and are usually very poorly preserved. In Hyolithes Creek, these glauconite shales contain thin limestone beds and concretions from which the majority of the fossils of this division have been obtained. They comprise the following species.

Brachiopoda
Lingulepis prisca Poulsen
Obolella congesta Poulsen
Botsfordia cælata (Hall)

Pelecypoda

Fordilla troyensis Barrande

Gastropoda

Discinella micans (Billings)
Helcionella cingulata Cobbold?
Helenia bella Walcott
Hyolithellus micans Billings
Orthotheca bayonet Matth. var groenlandica Pouls.
Orth.- bayonet var. longa Pouls.
Orth.- communis (Bill.)
Orth.- cfr. fistula (Hall)
Hyolithes americanus Bill.
H. billingsi Walcott
H. similis Walcott?
H. mutatus Poulsen
Hyolithes sp.

Trilobita

Olenellus sp.
Mesonacidæ indet.

Ostracoda

Bradoria sp.

The Ella Island formation consists of relatively thin beds of more of less pure gray limestones. Some of them are developed as intra-formational conglomerates with very small pebbles of dark-gray limestone. These beds alternate with thin layers of gray very fine-grained calcareous sandstones which are beautifully cross-bedded, the whole representing near shore or emergent conditions. This phase evidently belonged to the retreatal portion of the Lower Cambrian pulsation. Fossils are confined to the limestones and are fragmentary and frequently worn, and so further support the idea of an emergent series. The fossils found in this formation are the following.

Rhizopoda
Lagena sp.
Archæocyathida
Spirocyathus cfr. atlanticus (Billings)
Vermes?
Scolithus linearis Haldeman
Brachiopoda
Paterina mediocris Pouls.
Kutorgina reticulata Pouls.
Billingsella?
Pelecypoda
(Gen. & sp. indet)
Gastropoda
Discinella micans (Billings)
D. brastadi Pouls.
Hyolithellus micans Bill.
Cephalopoda
Salterella rugosa Bill.
Trilobita
Olenellus simplex Pouls.
O.(?) curvicornis Pouls.
Olenellus? sp. 1.
Olenellus? sp. 2.
Wanneria nathorsti Pouls.
Wanneria ellæ Pouls.
Pædeumias hanseni Pouls.
Pædeumias tricarinatus Pouls.
Mesonacidæ indet.
Proliostracus strenuelliformis Pouls.
Proliostracus rosenkrantzi Pouls.
Proliostracus liostracoides Pouls.
Proliostracus noe-nygaardi Pouls.

Bonnia groenlandica Pouls.

Corynexochus sp. indet.

Though to a large extent represented by new species 8 of the 33 specifically identified forms from the two formations, or 24.3 per cent, occur in the Appalachian geosyncline farther south and three or 9.1 per cent, in the north Scottish extension of the geosyncline. Seven on the other hand, have also been reported from beds of the Caledonian geosyncline, but these are all Hyolithids, with the exception of the rather doubtful *Fordilla troyensis* reported from Sweden, *Discinella brastadi* of Mjösen; *Botsfordia caelata*, from the same section, and the ubiquitous *Scolithus linearis*. Taking however, the general character of the fauna, especially the occurrence of *Olenellus*, *Paedeumias* and *Wanneria*, the close association of these deposits with the Appalachian geosyncline farther south is apparent. *Wanneria* has also been reported in association with *Callavia* at Comley in England, but is more characteristic of the other geosynclines.

In north-western Greenland, Lower Cambrian fossils have been found, south of Humboldt glacier on Kane Basin.[1] Here the strata are nearly horizontal. The lowest formation is the Wulff River formation, from 20 to 40 meters in thickness and known only from Inglefield land, on both sides of Wulff River, approximately Longitude 68^{0} W. Latitude 79^{0} N. It lies disconformably, on 80 or more meters, of Sinian Rocks, consisting in descending order of dolomites, white sandstones and red sandstones, these in turn resting unconformably upon the old syenite. The Wulff

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1 Chr. Poulsen. The Cambrian, Ozarkian and Canadian faunas of northwest Greenland, Jubilæumsekspeditionen Nord om Grönland. 1920-23, No. 2, Kopenhagen 1927, pp. 237-343 with 8 plates and map and sections.

River formation, consists of from 20-40 meters of green glauconitic sandstone alternating with more or less coarse conglomerate and in some places thin limestone beds.

The conglomerates contain numerous pebbles of diabase, pebbles of pure quartz, and small pebbles of dark brown sandstone, which contain fossils of an older formation. The fossils of the Wulff River formation, are mainly in the limestone. The following have been recorded.

BRACHIOPODA

Paterina lata Poulsen
Obolus? sp.
Bostsfordia caelata (Hall)
Acrothele? pulchra Poulsen

CEPHALOPODA

Salterella expansa Poulsen
Salterella sp.

TRILOBITA

Callavia breviloba Poulsen
Olenellus arcticus Poulsen
Olenellus? sp.
Strenuella grönlandica Poulsen.

This fauna is correlated by Poulsen with both the Bastion and Ella Island formations of East Greenland.

The Cape Kent formation rests upon the Wulff River, with perhaps a small hiatus, and is disconformably succeeded by the Middle Cambrian Cape Wood formation, which begins with a conglomerate. The Cape Kent formation consists of from 10-20 meters of yellowish white, almost pure oolitic limestone. The fauna is composed exclusively of pteropods and trilobites, with the following 26 species determined.

PTEROPODS

Hyolithes billingsi Walcott.

TRILOBITA

Olenellus (sensu latu) *grönlandicus* Poulsen.
,, ,, *kentensis* Poulsen
,, ,, sp. ind. (two or three species)
Dolichometopsis resseri Poulsen
,, *septentrionalis* Poulsen
,, *minuta* Poulsen
Kochiella tuberculata Poulsen
,, *propinqua* Poulsen
,, *arcana* Poulsen
,, *gracilis* Poulsen
Inglefieldia porosa Poulsen
,, *planilimbata* Poulsen
,, *groenlandica* Poulsen
,, *thia* (Walcott)
,, *inconspicua* Poulsen
,, *affinis* Poulsen
,, *discreta* Poulsen
Chancia venulosa Poulsen
Solenopleura grönwalli Poulsen
,, *similis* Poulsen
,, *bullata* Poulsen
,, *borealis* Poulsen
Crepicephalus cfr. *cecinna* Walcott.

The genus *Kochiella* Poulsen and the closely related genus *Inglefieldia* Poulsen connect this fauna with the Mount Whyte formation of British Columbia and Alberta and show that these types are of Boreal origin. The Cape Kent formation is higher than any exposed in east Greenland. It is correlated by Poulsen with the Protolenus fauna of the Atlantic-Caledonian province, but that is probably erroneous, for in spite of the presence of *Dolychometopsis* Poulson a relative of *Poliella*, this fauna is probably still to be classed as Lower Cambrian, whereas the Protolenus is referable to the Middle Cambrian.

The location of these deposits in northwest Greenland suggests that they lie within the connecting belt of the Boreal sea between the Appalachian and the Palæo-Cordilleran geosynclines.

The North Scottish Section. The last of the sections of the Appalachian geosyncline is that shown on the northwest shore of Scotland, where, the beds are exposed in the Durness region, in Loch Eriboll, and Loch Maree, and elsewhere. The Torridon sandstone of Sinian age, usually underlies the Cambrian rocks at a slightly different angle, there being thus a minor unconformity between the Sinian and the Cambrian. In some sections, the latter may rest directly upon the Lewisian gneiss. The section in descending order is as follows, according to Peach and Horne.[1]

Durness Limestone Series	1500 ft.
VII. Durine Group	
VI. Croisaphuill Group (Croispol Group)	
V. Balnakiel Group	
IV. Sangomore Group	
III. Sailmhor Group	
II. Eilene Dubh Group	
I. Ghrudaidh Group (Grudie Group)	
Eriboll Quartzite Series	
Serpulite grit	30 ft.
Fucoid Shale	40—50 ft.
Pipe Rock	300 ft.
Basal sandstone and conglomerate	200 ft.

1 B. Peach and G. Horne, the Geological structure of the northwest Highlands of Scotland 1907.

Unconformity

Sub-formation: Lewisian gneiss or Torridon Sandstone

The pipe-rock is so called because it is traversed by numerous vertical tubes or pipes, which appear to be ancient worm borings. In the Fucoid Shale, *Paterina labradorica* and other fossils characteristic of the Lower Cambrian of the Appalachian are found.

The Serpulite grit contains *Salterella maccullochi* (Salter), *Olenellus lapworthi.* Peach, *Olenellus? gigas* Peach, *Olenellus reticulatus* Peach and *Olenelloides armatus* Peach.

The Ghrudaidh limestone which succeeds, contains 3 species of *Salterella*. *S. maccullochi* (Salter), *S. pulchella* Billings and *S. rugosa* Billings. These *Salterella* still indicate Lower Cambrian age and are distributed in 2 bands, one at the base and one about 30 ft. above it. The upper part is mottled dolomite.

The succeeding Eilene Dubh Group consists of fine-grained white flaggy limestone. No fossils have been obtained from it except so called worm casts, but intraformational conglomerates are frequent. Within the Eilene Dubh group, there is a disconformity marked by a bed of conglomerate with worn pebbles of limestone, generally less than an inch in diameter, the bed varying in thickness from an inch to a foot. The underlying bed is slightly irregular, showing an erosion surface. It is exposed at low tide on Eilene Dubh (Black Island) and can be traced along the low neck and for some distance along the Kyle of Durness.[1]

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1 A.W. Grabau, Bull. of Geol. Soc of America, Vol. 27, pp. 562-563. 1916.

Another irregular contact is found about 125 ft. higher along the Kyle of Durness. Here the dolomite shows an irregular solution surface, with a covering of horizontally bedded calcilutytes. No fossils have been recorded from the higher Eilene Dubh Series, but from the succeeding Sailmhor Group, typical Lower Beekmantown fossils have been obtained. Here it is evident that the Lower Beekmantown or possibly some late Upper Cambrian rests directly and disconformably on the Lower Cambrian, as appears to be the case in the west Newfoundland region. This will be more fully considered later.

In Loch Maree, in the Northwest Highlands, the Serpulite grit, shows the following divisions in descending order.[1]

SERPULITE GRIT.

7)	Blue clay and sandy shale, full of small vertical worm casts, with fragments of *Olenellus gigas* and *Olenellus lapworthi*.	18 ft.	0 inch
6)	Shale with well preserved brachiopods *Acrothele subsidua*. .	0	9
5)	Dark flaggy or platy shale, with fragments of *Olenellus* at the base.	2	10
4)	Yellow ferruginous dolomitic band, with conchoidal fracture .	0	7
3)	Pisolitic iron stone, with remains of trilobites and echinoderms. .	0	2

1 B. N. Peach and J. Horne. Chapters on the geology of Scotland. Oxford University Press. 1930.

2)	Hard ferruginous dolomitic band, the bottom film crowded with carapaces of *Olenellus*.	0	3½
1)	Soft-jointed cleaved clay shale, the top-most seam yields occasional complete specimens of *Olenellus* and fine examples of *Olenelloides armatus*. The lowest 2 inches are crowded with disjointed and broken segments of *Olenellus*. This band is termed the *Olenellus* shale.	0 ft.	11 inches

Summary of the Lower Cambrian of the Appalachian Geosyncline

From Alabama northeastward to western Newfoundland and Labrador, E. Greenland and North Scotland, the Lower Cambrian is well developed and contains a fauna which is an essential unit in which *Olenellus* is the leading trilobite, while *Kutorgina*, *Paterina* etc. are leading brachiopods and *Salterella* the pelagic mollusk. In all sections, where the sequence is well ascertained, the series begins with sandstones, often of continental type (and possibly of Sinian age), and shows its maximum in calcareous development of greater or less thickness. A retreatal series is very generally shown by succeeding sandstones, of which the Rome is typical, which in some cases marks actual emergence. Such actual emergence is also shown by the disconformity which separates the Lower Cambrian from the succeeding beds. These in some sections are Middle Cambrian, in others Upper Cambrian and in still others Lower Ordovician. Frequently also erosion has affected the beds of the Lower Cambrian, so that some of the emergent members may be entirely removed. No case is positively known where the Lower and Middle Cambrian show continued deposition, though in Vermont *Olenoides*, a form suggestive of Middle Cambrian affinities, has been reported in association with *Olenellus*. In this section, however evidence of emergence at the end of the Lower Cambrian is also seen. Thus so far as the Appalachian Province is concerned the Lower Cambrian represents a complete pulsation and shows a distinctive fauna, the origin of which is probably chiefly a Boreal one.

THE PALAEO-CORDILLERAN GEOSYNCLINE

This ancient and long continued geosyncline near the western border of North America, was already very prominent in Sinian time, for it is here that some of the thickest beds of the Sinian Series, i.e. the *Belt terrane* (30,000 ft. thick) the Uinta quartzite (14,000 ft.) and the Grand Canyon series (12,000 ft. plus) were deposited. It is here also that we find the greatest development of the Cambrian strata, but the remarkable fact must be noted, that the Middle Cambrian is far more extensively developed here than the Lower Cambrian, which is the reverse of that seen in the Appalachian geosyncline, where the Lower Cambrian is well developed and the Middle scarcely at all. It is because of this that Resser has chosen the Appalachian section to represent the standard of the Lower Cambrian and the Rocky Mountains as furnishing the type for the Middle Cambrian,[1] this series here reaching a thickness of 6,000 ft. or over. It is true that in many sections the Lower Cambrian is enormously developed as to thickness, this reaching 4,000 ft. or more, but the great mass of this consists of clastic material, mostly sandstones representing either subaerial or shallow water deposits. The Middle Cambrian on the other hand is very largely developed in calcareous facies.

In a general way the Palæocordilleran geosyncline extended over the region of the present Canadian Rockies, where the area of sedimentation had an original width of 100 miles or more. This however, included the geosyncline and the area of the marginal plain, covered by these sediments. Southward we may trace the course of this ancient geosyncline through the Great Basin region of Utah and Nevada, with the Wasatch Mountains forming the region of the marginal plain, and the Sierra Nevada, that of the Old Land, the distance between the two being some 8^0 of longitude or approximately 400 miles. Since these strata have been more or less intensively folded the width was originally vastly greater. How much of this belonged to the actual geosyncline and how much to the broadly flooded marginal plain, cannot now be determined with any degree of certainty. As may be seen from the new geological map of the United States, Cambrian strata are well developed in South-western Nevada and the adjoining portion of California, as far south of the Mohave desert. Eastward they appear at intervals in the Basin Ranges of southern and eastern Nevada and western Utah to the Wasatch Mountains, near Salt Lake City, and northward beyond the State line.

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1 I have elsewhere proposed the group name *Albertan* for this series.

Within this portion of the geosyncline, the Palæozoic strata were apparently folded at the end of that era with the accompanying migration of the geosyncline. Such folding apparently did not occur to any marked degree in the northern or Canadian region where the Mesozoic of the Cascade River region rest concordantly though disconformably on the late Palæozoic.[1] Here the folding apparently all belongs to the late Cretaceous or Rocky Mountain period and hence there are no actual unconformities recognized between the several formations involved. Resser (1933 page 742) calls attention to the distinctness in character between the northern and the southern region, considering that the region north of the Beltian area of Montana and Southern Canada, represents deposits in geosynclinal troughs and today occur as great mountain ranges, "on the other hand, south of Montana (except in the Great Basin) the Cambrian deposits fringe Archæan areas, which were first low monadnocks, that maintained their relative elevation, finally becoming the cores of the present ranges." There is, in his opinion, no essential difference between the deposition of the Cambrian and of the later beds which also were deposited between the same positive elements of the Archæan basement. Here, during the Rocky Mountain movement, the Palæozoic strata were tilted rather than folded.

While this is true for the Rocky Mountains proper, it is otherwise, as he implies, for the Great Basin, where the folding of the Palæozoic, preceded the deposition of the later beds. This would imply that the northern region was

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1 P. E. Raymond and Bradford Willard. A Structure Section across the Canadian Rockies. Journal of Geology Vol. 39, No. 2, p. 102.

not involved in the old Palæo-cordilleran geosyncline, or the Palæo-cordilleran geosyncline of this region was merged without disturbance of the strata into the Cordilleran of Mesozoic and later time. Even during the later folding, most of the region east of the Columbia River was only moderately disturbed, except by thrust faults. In consequence the outcrops of the Cambrian strata, at least in most of this region, are either gently tilted or still almost horizontal, thus forming a sharp contrast with the Cambrian strata of the Appalachian geosyncline, which are often intensely folded. We will consider first the lower Cambrian strata of the northern region.

In general, the succession is as follows in descending order.

Super-formation—Middle Cambrian Ptarmigan formation.

Disconformity

Lower Cambrian.

Mount Whyte formation. chiefly limestones.
Saint Piran formation, mostly sandstones and quartzites
Lake Louise Shale.
Fort Mountain quartzite

Disconformity

Sinian Series.

Hector Shale
Coral Creek quartzite

The Fort Mountain quartzite varies very greatly in thickness, but is generally a massive-bedded compact gray quartzite with a basal conglomerate, which may reach a thickness of 50 ft. or more.

In the Mount Assiniboine region, it has a thickness of 526 ft. In the Lake Louise section, where the base is not exposed, it is 1000 ft. or more, 940 ft. being shown on the north face of Fairview Mountain above Lake Louise. The colour locally becomes purplish, but is largely gray, rather coarse-grained below, and finer grained at the top, where some slight cross-bedding has been reported. A small amount of shale also occurs in it. No fossils have been reported from any of the sections, and the formation seems to be largely if not wholly of continental origin.

The *Lake Louise shale* which succeeds it is never a very thick formation. In the type region of Lake Louise, it has a thickness of 105 ft. or 32 meters and consists of hard grey siliceous shale, with the following fauna.

Micromitra (*Iphidea*) *louise* Walcott
Cruziana.
Annelid trails.

The last two stamp it as a very shallow water formation with occasional emergence. In the Mount Assiniboine section it is only 70 ft. thick, and is also a dark siliceous shale. In the famous Mount Bosworth section, the Lake Louise shale is either absent or not exposed, while in the Ptarmigan Peak section it is 28 ft. thick and contains *Cruziana* and *Planolithes.*

The Lake Louise Shale is succeeded by another great sandstone formation the *St. Piran* quartzite. In the Lake Louise section, where this quartzite rests upon 105 ft. of that shale it has a thickness of 2,632 ft. or 802.2 meters. At the base there are some shaley interbeddings, after which there are some 550 ft. of sands and gray and purplish quartzites, the upper with *Scolithus* borings. Then follow fossiliferous sandstones and shales, with *Scolithus* sp., *Orthotheca* sp, *Mesonacis gilberti* (Meek) and *Olenellus canadensis* Walcott. The upper two thirds of the series consists of gray quartzites alternating with thin beds of siliceous shale.

In the Mount Assiniboine region, it has a thickness of only 125 ft, with fragments of *Olenellus* in the lower part. In the Ptarmigan Peak section, the thickness is 785 ft. and here in the thin-bedded light grey quartzite, which forms the lower 3rd, *Scolithus* occurs in immense numbers, and in many layers varying from 2 inches to 2 ft. in thickness. Somewhat higher *Mesonasis gilberti* is found and the remaining two-thirds of the section consist of quartzitic sandstone, which near the top become cross-bedded.

In Mount Bosworth 503 ft. of the St. Piran is exposed, and here fragments of *Olenellus canadensis ?* are found in the basal portion together with *Hyolithes* and annelid trails and *Scolithus*. In the sandstones succeeding, to within 68 ft. of the top, these same fossils are found with the addition of 2 species of *Ptychoparia*. The upper 68 ft. are made up of alternating shales and sandstones apparently without fossils.

In Vermilion Pass, on the Continental Divide between British Columbia and Alberta, the St. Piran has a thickness of 2,300 ft. It rests on the Lake Louise Shale and is followed by the Mt. Whyte. It contains *Wanneria? gracile* Hall, *Obolella vermilionensis* W. and *Orthotheca adamsi* W.

As seen from these sections, the fauna of the St. Piran formation is a typical Lower Cambrian one, but with few species. The trilobites are represented only by *Olenellus canadensis* Walcott, *Mesonacis gilberti* (Meek), and *Wanneria gracile* Hall, together with undetermined species of *Ptychoparia*. The pelagic pteropods are represented by *Orthotheca* and *Hyolithes*, while the worm boring (*Scolithus*) occurs in many strata. Brachiopods are rare, but *Obolella* has been recorded.

The Mount Whyte Formation

I. *Mount Assiniboine Section* (Walcott, V. p. 297[1]) The St. Piran is the last of the quartzites, the succeeding Mount Whyte formation being a calcareous one. The greatest development of this formation appears to be in the *Mount Assiniboine section,* where it begins with nearly 200 ft. of grey to black siliceous shale, followed by 300 ft. or more of calcareo-arenaceous green shales, in which the only fossil observed is the cystoid *Gogia prolifica* of the family *Aristoeystidæ.* More siliceous shales follow, but near the top the series becomes calcareous, terminating in a 23 ft. bed of oolitic limestone, with a rich fauna, composed of the following species. (62 w.)

Archæocyathidæ.

1. Archæocyathus atreus Walcott

Brachiopoda

2. Kutorgina cf. cingulata (Billings)
3. Paterina labradorica (Billings)
4. Jamesella lowi Walcott
5. Acrotreta sagittalis taconica Walcott

Gastropoda etc.

6. Helcionella elongata Walcott.
7. Scenella varians Walcott.
8. Hyolithes billingsi Walcott

Trilobita

9. Crepicephalus cecinna Walcott
10. Kochiella cleora (Walcott)
11. Ptychoparia gogensis Walcott

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1 This refers to the Volumes of Cambrian Geology and Palæontology in the Smithsonian Miscellaneous collections vols. 53, 57, 64, 67, and 75 respectively.

12. Pt. skapta Walcott
13. Dorypyge damia Walcott

This is a fauna of rather remarkable composition, and one that can not readily be considered as typical Lower Cambrian. Indeed both the *Crepicephalus* and *Dorypyge* are types referable to the Middle Cambrian and to that division the upper limestone of the Mount Whyte formation may perhaps be related. The lower part however, has an undoubted Lower Cambrian fauna and if a division is necessary, the dividing line must be placed somewhere within the formation, and this is probably within some of the sandstone members. It is true that the brachiopods of this fauna as well as the gastropods range widely through lower beds but the trilobites with 2 exceptions do not occur below, these being *Crepicephalus cecinna* which also occurs in one of the highest beds of the Mount Whyte of Ptarmigan Peak (1 c) and the other in an upper bed (1 b) of the Mount Bosworth Section.

II. *Ptarmigan Peak Seetion.* (Walcott V, p 278) In Ptarmigan Peak. the Mount Whyte formation has a thickness of 342 ft. and here the lowest thin-bedded more or less calcareous sandstone 17 ft. thick (No. 4), contains a typical Lower Cambrian fauna including the trilobites *Olenellus canadensis* Walcott, *Mesonacis gilberti* (Meek) and *Bonnia fieldensis* (Walcott). The first 2 of these are also characteristic of the St. Piran formation. Above this comes (No. 3) a fine-grained, gray-green arenaceous shale with fragments of trilobites, and it is possible that here is the contact between the lower and upper Mt. Whytet the fragments of trilobites representing the products of ware action in shallow water indicating, if not a disconformity, at least an oscillation of the sea level. The next succeeding 57 ft. of arenaceous shale (No. 2), alternating with thin beds of greenish and brown sandstone, with the casts of annelid trails and borings, contains *Ptychoparia cleadas* Walcott and *Olenopsis crito* Walcott. The former also occurs in the upper part of the Bosworth Section (horizons 1 b, and 2) but the other is so far unknown elsewhere. Above this follows (1 c) 135 ft. of calcareous beds, near the middle of which (62 ft. from the base) occur numerous fragments of trilobite tests, so much broken that even the species and genus cannot be recognized. In the upper oolitic beds, at the top of 1c, again occurs a fauna, including species suggestive of the higher beds of the preceding section i. e. *Nisusia (Jamesella) lowi* Walcott, *Wimanella catulus* Walcott (not known elsewhere) *Hyolithes billingsi* Walcott, *Ptychoparia cercops* Walcott, and *Crepicephalns cecinna* Walcott.

After this follow (1b) 62 ft of fissile limestcne and shale and above it (1a) 28 ft. of dark bluish limestone, with *Lingulella* sp *Wimanella?* sp. *Ptychoparia cilles* Wal. and *Crepicephalus chares* Walcott. This is the top of the Mount Whyte formation.

It is possible that a dividing line may be drawn where the bed with trilobite fragments suggest a disconformity in horizon 1c. The fossils of the uppermost bed contain two wide-spread species *Jamesella lowi* and *Hyolithes billingsi* Walcott. which are characteristic of the upper Mt. Whyte formation of other sections. *Ptychoparia cercops* also occurs in horizon 3 of the Ross Lake Section (VIII) with widespread Mt. Whyte mollusks and brachiopods, but associated with it is *Crepicephalus cecinna,* a species in which the pygidium is prolonged on either side into a long flattened slender and slightly diverging spine of approximately the same length as the axial lobe. The species as Walcott says is closely related to *C. upis* of the Upper Cambrian Gallatin limestone of Montana and to *C. lilliana* from strata referred to the upper zone of the Lower Cambrian of Nevada. Such forms certainly seem out of place in the Lower Cambrian.

Crepicephalus chares Walcott, which occurs in the highest beds was originally described from the Ptarmigan formation,[1] on the peak of that name, and is therefore a typical Middle Cambrian form. It is characterized by having the entire plural portion prolonged into the terminal spine on either side. *Ptychoperia? cilles* Walcott was likewise described from the Lower Ptarmigan formation[2] of Ptarmigan Peak. This may make it necessarv to place the dividing line between the basal *Olenellus* bed and the highest limestone of the Mount Whyte formation. If it were not for the fact that *Ptychoperia cercops* which occurs with *Crepicephalus cecinna*, is associated in its other occurrences (Bed 3 of the Ross Lake, Section VIII) with many typical species characteristic of the lower horizon, the problem would not be so difficult. If a part of the Mt. Whyte formation is to be referred to the Middle Cambrian, which I would not favor, we may tentatively place the dividing line between these two layers, selecting the beds with trilobite fragments below the *Crepicephalus cecinna* beds, *i. e.* the lower part of division 1 c of Walcott's section.

III. *Castle Mountain Section.* (Walcott. V p. 274) In the Castle Mountain section the base of the Mount Whyte formation, which has a total thickness of only 248 ft., consists of shaly sandstones and shales, 57 ft. in thickness (division 1f of Walcott's section) and with interbedded thin layers of sandstone, which contain many fragments of

1 Walcott Cambrian Geology and Palæontology Vol. 4, page 35.
2 *Ibid.* page 32

Olenellus. This rests directly upon the quartzitic sandstones of the St. Piran formation, in which fragments of *Olenellus* also occur. Next come 27 ft. of thin-bedded sandstone (division 1e) with coarse annelid trails and mud cracks on the surface of many of the layers. Then follow 6 ft. of oolitic and sometimes shaly sandstone, becoming more sandy in the lower part (division 1d) and these are succeeded by gray and dirty-brown thin-bedded sandstones 32 ft. in thickness, (division 1c). These are said to contain a typical upper Mount Whyte fauna, similar to that which appears at this horizon in the Mount Bosworth and Mount Stephen sections, and we may draw the dividing line between the lower and upper Mt. White formations at the base of this bed. The next succeeding 96 ft. of thin-bedded limestones (division 1b) includes many indeterminate fragments of trilobites and the highest 40 ft. of the formation (1a) has furnished undescribed trilobites. The succeeding Ptarmigan formation carries the *Albertella* and *Dorypyge* fauna, which is wholly distinct. If the whole of the Mount Whyte formation in this section is of Lower Cambrian age, the difference between the thickness here, and that of the Mount Assiniboine, section exclusive of the upper 3 divisions, is nearly 500 ft. and this may be due to off-lap during the retreat of the Lower Cambrian Sea and in part to subsequent erosion. If we separate the uppar part of the Mt. Whyte formation of the Ptarmigan Peak section, the part referable to the Lower Cambrian is only about 180 ft.

IV. *Mount Stephen Section.* (Walcott V p. 317) Turning new to the Mount Stephen section, we find the Mount Whyte formation 315 ft. thick. It begins with a bluish black and gray limestone 18 ft. thick (division 6) which rests directly on the quartzites of the St. Piran formation

This contains a rich fauna, including the following species (Hor. 35f).

Brachiopoda.

Iphidella pannula (White)[1]
Acrotreta sagittalis taconica Walcott[1]
Kutorgina cingulata Billings[1]
Nisusia festinata (Billings)[1]

Gastropoda etc.

Hyolithes billingsi Walcott[1]
Scenella varians Walcott.[1]

Trilobita

Agraulous charops Walcott
Ptychoparis cuneas Walcott
P. pia Walcott
P. cleon Walcott
P. thia Walcott
Olenellus canadensis Walcott.

This is succeeded by 102 ft. of gray siliceous shale (division 5) with *Hyolythes billingsi* Walcott, *Scenella varians* Walcott 2 species of *Ptychoparia* and *Kochiella agnesensis*.[2]

The next succeeding division (No 4) consists of 32 ft. of brownish quartzitic sandstone and contains *Olenellus* fragments, *Microdiscus* sp., *Ptychoparia?* sp., and *Bonnia* sp. Next come (division 3) 52 ft. of thin-bedded, dark bluish grey limestone, with interbedded siliceous shales. The fossils occur near the top and near the base. These in the following list are marked t. and b., corresponding to Walcott's loc. 57e and 58s respectively.

1 Also in Lower Cambrian of Appalachian province.

2 Originally described as *Olenopsis? agnesensis* Walcott, Cambrian Geology and Palæontology Vol. II, p. 242, Pl. XXXVI. fig. 2.

Brachiopoda

Acrotreta sagittalis taconica Walcott (t and b)
Acrothele clitus Walcott (b and t)
Paterina labradorica (Billings) var. (b)
Iphidella pannula (White) b

Gastropods etc.

Scenella varians Walcott (b and t)
Helcionella elongata Walcott (b)
Stenotheca elongata Walcott var. (t)

Trilobita

Poliella[1] primus Walcott (b and t)
Olenellus canadensis Walcott b
Olenellus fragments t
Ptychoparia pia (t) and other species b

Division 2 condists of 108 ft. of gray siliceous shale, with interbedded gray fossiliferous limestone in the upper portion. In the shale of the central portion, the following fossils were found. Cystid plates, *Paterina* sp, *Acrotreta sagittalis taconica* Walcott, *Nisusia* (*Jamesella*) *lowi* Walcott, *Hyolithellus* sp. *Scenella varians* Walcott. *Olenellus canadensis* Walcott.

The highest member (No 1), consists of thin-bedded, bluish-black and grey limestone and from this and the interbedded limestones at the top of No 2, the following forms have been obtained. (58k)

Brachiopoda

Acrotreta sagittalis taconica Walcott
Nisusia (Jamesella) lowi Walcott

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1 Subgenus of *Bathiuriscus.* The species of this subgenus are usually confined to the Middle Cambrian, except *P. primus* which occurs with *Olenellus* (Walcott, Camb. Geol. and Pal. Vol. 3, page 352)

Gastropoda etc.

Helcionella elongata Walcott var.
Scenella varians Walcott
Hyolithes billingsi Walcott

Trilobita

Kochiella agnesensis Walcott
Ptychoparia clusia Walcott
Ptychoparis thia Walcott
Crepicephalus celer Walcott
Polyella primus Walcott

If we now consider this fauna as a whole, we find that most of the species have a wide range, being generally absent only from bed No. 4, which is a sandstone in which the fossils are imperfect or fragmentary. Those that range through the entire 315 ft. of the Mount Whyte of this section are

Brachiopoda

Actrotreta sagittalis taconica Walcott (except 4 & 5)

Gastropods etc.

Scenella varians Walcott (except 4)
Hyolithes billingsi Walcott (except 2, 3, 4)

Trilobita[1]

Olenellus canadense Walcott (except 2, 4, 5)
Polyella primus Walcott (except 2, 4, 5, & 6)

These may therefore be considered the index fossils of this formation. It is quite evident that in this section, the Mount Whyte formation is a unit and referable to the Lower Cambrian. Moreover, it appears to be directly succeeded by the Cathedral formation, a massive dolomitic

1 Crepicephalus celer which occurs in this fauna is described from a cephalon only and may not be of this genus.

limestone 1,680 ft. in thickness. The Ptarmigan formation, which in other sections separates the two, appears to be wanting here or induded in the overlying limostone. If absent, it would appear that we have here a case of overlap of Middle Cambrian strata and this together with the absence of the higher Mount Whyte beds, strongly suggest a disconformity, and therefore the unity of the Lower Cambrian pulsation.

V. *Mount Temple Section* (Walcott V. p. 301). In this section, the Mount Whyte formation is only 171 ft. thick. It rests on the St. Piran quartzites and is overlain by massive-bedded limestones, the age of which is not given. The series begins with 7 feet of reddish-brown and grev sandstones, with some calcareous layers almost made up of fragments of *Olenellus* (No. 7). 3 ft. of greenish slale (No. 6), follow, and then 23 ft. of coarse reddish and gray calcareous sandstone, with numerous fragments of *Olenellus* (5). After this 5.5 ft. of cross-bedded grey sandstone (4) and 3.5 ft. of thin-bedded arenaceous limestone (3) follow. These are succeeded by 107 ft. of greenish, arenaceous and siliceous shales in massive beds (2), from which various species of *Obolus* have been obtained. The formation is terminated by (b) 22 ft. of thin-bedded impure bluish-gray limestone. Since only *Obolus* has been obtained from the shales of No. 2, it is impossible to determine its age, but as this genus is more characteristic of the upper Mt. Whyte and higher beds though also found in the lower Mt. Whyte it is possible that these may represent the higher division if not Middle Cambrian, in which case, the line of division might perhaps be drawn at the top of the cross-bedded sandstone (4) that marking a physical line of disconformity. This would reduce the thickness of the lower portion to less than 40 ft.

VI. *Lake Louise Section.* (Walcott V, p. 302). In this section where the St. Piran has a thickness of 2,632 ft, the Mount Whyte which succeeds it, is 458 ft. thick, and is in turn followed by massive limestones of which about 500 ft. have been referred to the Ptarmigan formation. The Mount Whyte begins with 72 ft. of brownish and gray sandstones, with shale partings (1 e) which contains the index species *Scenella varians* Walcott, and species of *Orthotheca, Ollenellus* and *Bonnia.* It is followed by 115 ft. of thin-bedded arenaceous gray limestone (1 d) with numerous small concretions, and with fragments of *Olenellus* throughout.

Succeeding this is (1 c), 64 ft. of greenish siliceous shales, with the following fauna in the lower 2 ft- *Lingulella* sp, *Iphidella wapta* Walcott, *Obolus parvus* Walcott, *Acrothele clitus* Walcott, *Hyolithes billingsi* Walcott ? *Kochiella agnesensis* (Walcott), *Ptychoparia carina* Walcott, *Pt. perola* Walcott, and *Polyella primus* Walcott.

Of this list only the trilobite *Kochiella agnesensis* and the pteropod *Hyolithes billingsi* are found in the Mount Whyte fauna of Mount Stephen, the first in the shales 60 ft. or more from the base, and at the top, the other at various levels throughout.

The question then arises, should these beds still be considered of Lower Cambrian age? or should they be placed in the Middle Cambrian, which would make *Kochiella agnesensis* one of the few species which continues from the Lower into the Middle Cambrian. In the succeeding 104 ft. of shales, interbedded limestones and sandstones (1 b and 1 a) only annelid trails and trilobites tracks have been found, and these indicate shallow water if not actual continental beds and may mark a line of physical disconformity.

The highest member of the Mount Whyte formation of this section (1) consists of 103 ft. of oolitic, banded, and dolomitic limestones in alternation. These are correlated with the similar beds of the Mount Stephen section in which the *Scenella varians* fauna is found, and beds in the upper part of the Mount Boswell section, which carry the *Kochiella agnesensis* fauna.

VII. *Mount Schaffer Section.* (Walcott V p. 305). This section shows only a portion of the Mount Whyte formation, of which only about 160 ft. is exposed. It is succeeded by thin-bedded arenaceous limestone, probably of the Ptarmigan, above which lie the heavy-bedded Cathedral limestones.

The lower 120 ft. of the exposed portion consists of various sandstones often of brown colour and with fragments of *Olenellus* throughout the greater part (divisions 3 to 6). Then follows (division 2) 15 ft. of grey arenaceous thin-bedded limestone with finely oolitic and pure limestones. From this division the following fauna (61 d) was collected.

Brachiopoda

Paterina labradorica (Billings)
Iphidella pannula (White)
Acrotreta sagittallis taconica Walcott
Jamesella lowi Walcott.

Gastropods etc.

Scenella varians Walcott.
Pelagiella sp.

Trilobita

Corynexochus senectus (Billings)
Agraulus unca Walcott

Mesonacis gilberti (Meek)
Ptychoparia lux Walcott.
P. sp.
Zacanthoides sp.

Other Crustacea.
Shafferia cisina Walcott

This is a typical Mount Whyte fauna of Lower Cambrian affinities and contains no forms dissonant with that classification.

The highest beds (1) consists of 20 ft. of gray arenaceous and siliceous limestone with irregular cherty stringers in the line of bedding. No fossils have been reported from it.

VIII. *Ross Lake Section.* (Walcott V p. 306). Here the full thickness of 248 ft. of the Mount Whyte formation is exposed between the St. Piran sandstone below and the Ptarmigan limestones above. 6 subdivisions are recognized in the Mount Whyte. The lowest (No. 6) is a calcareous sandstone 27 ft. in thickness and carries typical Lower Cambrian trilobites (63 l).

Bonnia fieldensis Walcott
Olenellus canadensis Walcott
Olenellus fragments.

The next higher division (No. 5) consists of 85 ft. of greenish, drab and buff-coloured siliceous shale with thin limestone partings. *Micromitra* and *Ptychoparia?* have been obtained. The next 70 ft. of shale and sandstones (No. 4) have furnished no fossils, except annelid trails and tracks of trilobites.

In horizon 3 however, which consists of 18 ft. of gray finely oolitic limestone, the following fauna has been found in the lower part. (63 k).

Brachiopoda

Jamesella lowi Walcott

Gastropoda etc.

Pelagiella sp.
Helcionella elongata Walcott
Scenella varians Walcott
Hyolithes billingsi Walcott.
Ptychoparia cercops Walcott
P. pia Walcott
Kochiella agnesensis Walcott

This fauna is entirely comparable to, though less abundant than, that of the upper beds of the Mount Stephen section, where the thickness is only a little greater.

IX. *Mount Bosworth Section.* (Walcott V, p. 313) In this section the Mount Whyte formation is 390 ft. thick and is limited below by the St. Piran and above by the Ptarmigan. Six divisions are recognized, but the upper 3 are grouped as a unit under No. 1.

In this section the Mount Whyte begins with 20 ft. of limestones and inter-bedded shales (No. 4) which have furnished a considerable fauna, with the following species. (35 h)

Brachiopods.

Nisusia festinata (Billings)

Gastropods etc.

Scenella sp
Hyolithellus sp.

Trilobita

Ptychoparia pia Walcott
P. (Inglefieldia) thia Walcott
Bonnia fieldensis Walcott

Olenellus canadensis Walcott

Mesonacis gilberti Meek.

The next division (3) consists of 115 ft. of siliceous shales, with few interbedded thin layers of sandstones. It has furnished no fossils. But the overlying bed of sandstone (No. 2) 31 ft. thick, has furnished (58 u).

Hyolithes sp.

Ptychoparia cleadas Walcott.

The upper division (1) is 224 ft. thick and is wholly calcareous. In the Lower 60 ft. (1 c) a fauna (57 q) is found comprising.

Ptychoparia adina Walcott

Crepicephalus? celer Walcott

This last is a form which also occurs in the upper bed (No. 1) of the Mount Stephen section. It is rather remarkable for this horizon, since the extremities of the pleural lobe are produced in flat tapering cuneate appendages terminating in acute points and the posterior border of the pygidium is deeply emarginate. This species differs from the typical forms of *Crepicephalus* and probably represents a distinct genus. It must be regarded as one of the advanced forms of Lower Cambrian trilobites.

The next 44 ft. of oolitic limestone (1 b) contains a more extensive fauna (57 s). This includes:

Brachiopoda

Jamesella lowi Wallcot

Acrotreta sagittalis taconica Walcott?

Trilobita

Eodiscus sp.

Agraulus sp.

Ptychoparia cleadas Walcott

Kochiella agnesensis Walcott

Kochiella cleora Walcott

The series is terminated by 120 ft. of thin bedded bluish grey slightly arenaceous limestone (1 a) which contains numerous annelid trails and borings, but has furnished no other fossils.

This is probably the true summit of the Lower Cambrian, although from the occurrence of *Crepicephalus? celer*, one might be tempted to consider division 1 as referable to the Middle Cambrian. That however, would involve the ranging of too many of the normal late Lower Cambrian species into the Middle Cambrian.

X. *Bow Lake Section* (Walcott V, p. 325). This section is chiefly remarkable for the great thickness of the Mount Whyte formation which is here 762 ft. thick. It rests on the St. Piran and is succeeded by the Ptarmigan, with the *Albertella* fauna. The series is divided into 20 divisions 10 of which are calcareous, these aggregating a total of nearly 450 ft. 7 of the division are shale generally alternating with the limestones, and these have an aggregate thickness of slightly over 150 ft. The remainder is made up of sandy beds, either with calcareous or with shaly partings and these occur at the base or below the Middle. *Nisusia* and *Hyolithes* have been reported from one of the higher limestones (No. 4) but otherwise the section has furnished no fossils.

XI. *Siffleur River Section* (Walcott V, p. 333). This is one of the thinnest sections of the Mount Whyte formation, this being only 140 ft. thick. It rests on the St. Piran quartzites and is followed by the Ptarmigan formation with *Albertella*. The section begins with 16 ft. of oolitic limestones (1 b), while its upper part (1 a) is formed of 124 ft. of calcareous shales, with thin layers of limestones. The lower division (1 b) has furnished a meagre fauna, (65 n), which is however, characteristically Lower Cambrian. It includes:

Hyolithes sp.
Scenella sp.
Olenellus cf. thompsoni (Hall)
Bonnia sp.

This concludes the survey of the detailed sections of the Mount Whyte formation, and it is probable that the whole series is to be referred to the Lower Cambrian, though it would be desirable if we could exclude from this the beds with *Crepicephalus cecinna* and *Dorpyge damia.* Both of these forms are more at home among the Middle Cambrian faunas. Unfortunately however, these same beds include so many brachiopods and mollusks which range throughout the Mount Whyte, that it seems impossible to separate them from the lower divisions. Reluctantly we must then conclude that *Crepicehalus cecinna* and *Dorypyge damia* are advance forms of a fauna which returns in force in Middle Cambrian time though in other species. They may be of "southern" origin. Even with this inclusion we find the Lower Cambrian fauna wholly distinct from the Middle, and though genera recur, the species are largely distinct.

It must be confessed that there is no marked physical evidence of a retreating sea at the end of Lower Cambrian time and although there is a very great variation in the thickness of the Mount Whyte Formation, there is in many sections a marked similarity in faunas of the higher beds, suggesting that this horizon is rather constant. Neverthe-less, there are formations, in which the higher beds carry a typical *Olenellus* fauna and this may mean that the highest beds of the Mount Whyte formation, preserved in some sections, are wanting in others, either due to off-lap or because of sub-sequent erosion, after the retreat of the Lower Cambrian Sea. It is possible that the variable thickness of the overlying St. Piran formation, if that is accurately recorded, is to be explained by over-lap in the Middle Cambrian Sea.

None of these physical feature ares however, conclusive, and we are compelled therefore to rely entirely upon the sudden change in fauna for the determination of a hiatus between the Middle and Lower Cambrian, and this acknowledged sudden change is certainly not capable of explanation in any other way.

XII. *Robson Peak Section* (Walcott V. p. 362). Robson Peak is one of the most remarkable of the many striking peaks of the Canadian Rockies, terminating in a pyramid of almost artificial appearance, the summit of which rises to a height of 12,972 ft. or 3,953.8 meters above sea level or 9,752 ft. 2,972.4 meters above the level of Lake Kinney at its base. But the remarkable fact is that this great peak is carved almost entirely out of horizontal[1] Cambrian and early Ordovician strata and that its flanks represent a continuous section from the Lower Cambrian to the Lower Ordovician. The district in which the sections are exposed, lies partly in British Columbia and partly in Alberta, Canada.

The base of the section shown in the slightly upturned strata on one side of the peak, is formed by the Miette formation of Sinian (Beltian) age. This consists of 2,000 ft. of massive-bedded gray sandstones with thick beds of gray and greenish siliceous shale. It is separated by a disconformity from the Lower Cambrian. The latter comprises the following members in descending order.

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1 It represents the central part of a broad syncline.

Superformation Middle Cambrian		
Chetang formation.	900 ft.	(274.3 meters)
Lower Cambrian		
Hota Formation calcareous	800 ft.	(243.8 meters)
Mahto Formation chiefly sandstones	1,800 ft.	(548.7 meters)
Tah Formation, chiefly shales	800 ft.	(243.8 metres)
McNaughton Formation, sandstones	500+ft.	(152.4+meters)
Disconformity		
Subformation; Sinian Miette Formation, sandstones	2,000+ft.	(609.6+meters)

The McNaughton, Tah and Mahto formations have furnished no fossils, but the Hota formation, which consists of 800 ft. of massive-bedded arenaceous limestone, contains *Olenellus* fragments in various divisions at one of which (61 s) 300 ft. from the top the species could be identified as *O. canadensis* Walcott. This is the only species also known from the lower Mount Whyte and St. Piran formations. At another locality however (61, k), a considerable fauna is found in an interbedded band of dark shale. This includes the following.

Brachiopoda.

Lingulella chapa Walcott.
Lingulella hitka
Mickwitzia muralensis Walcott
Obolella nuda Walcott.
Obolella cf. chromatica Billings

Trilobita

Callavia eucharis Walcott
Callavia perfecta Walcott

Wanneria occidens Walcott
Olenellus truemani Walcott.

Other fossils

Cystid? sp.
Hyolithes sp.
Hymenocaris sp.

This is a remarkable fauna, unknown in any of the other Lower Cambrian beds of the northern Cordilleran region. Moreover, the association of *Callavia* with *Olenellus* is a striking feature. The two species are represented by nearly perfect individuals and these show a very close relationship to *Callavia burri* Walcott, and *Callavia crosbyi* Walcott, both of which are characteristic species of the Lower Cambrian of Braintree near Boston, a locality within the Atlantic or Caledonian Basin. Other species occur in that basin and they are closely related to typical *Holmia*, with which they were originally identified generically.

Mickwitzia muralensis of this fauna differs only in minor features from *M. monilifera* of the Baltic Lower Cambrian, and thus presents another species with Atlantic affinities. Here then we have an example of the intrusion of the Atlantic Lower Cambrian fauna, into the Cordilleran geosyncline, and since this cannot be explained by any cross-continental migration, we must consider that both faunas entered from the Boreal realm. But since these faunas are not generally commingled they could not exist simultaneously, but probably represent different periods of the Lower Cambrian. Then the question arises, is the *Callavia-Holmia* fauna older or younger, than the faunas so far discussed. The answer must be that it is at least an older fauna than the Mount Whyte and probably precedes the fauna with *Olenellus* in the St. Piran formation, though this might follow it very shortly, since *Olenellus*, though of a distinctive species, is actually associated with these forms. That would imply that the horizon of the Mount Whyte formation is absent in this section and that in turn would suggest a marked hiatus between the Hota and the over-lying Middle Cambrian Chetang formation as that is characterized by the *Albertella* fauna and hence represents the Ptarmigan formation.

Sections in the Southern Cordilleran Region.

South of the great Tertiary lava plateaus, in the States of Utah, Nevada and Southern California a number of characteristic sections have been studied, but only a very small portion of this very extensive district has been explored in detail. In the Wasatch Mountains of northern Utah the Middle Cambrian apparently lies directly and disconformably upon the Sinian Rocks, though originally a part of these lower beds were thought to be of Lower Cambian age *Mesonacis gilberti* having been reported from a thin-bedded limestone, on the north side of Big Cottonwood Canyon one mile below Argenta, southeast of Salt Lake City Utah.

One of the best sections of the Cambrian strata, is found in the western part of the State of Utah at House Range, which lies west of Sevier Lake.[1] Other sections are known from Pioche and the Eureka mining district of southeastern Nevada, and in the western part of the Great Basin in California, Nevada, and the Mohave desert in southern California.

XIII. *House Range Utah Section.* (Walcott I. p 184) House Range is one of the fault blocks, that compose the Basin Ranges. It belongs to the eastern series and there-

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1 Approximately Long. 113° 30′ W., and Lat, 39° N,

fore has its fault scarp, more or less eroded, facing westward,[1] and its strata gently dipping to the east. No pre-Cambrian rocks are exposed, the lowest Cambrian being only in part shown. This is the Prospect Mountain formation, a gray and brown quartzitic sandstone in layers 4 inches to 3 ft. in thickness.

Overlying the Prospect Mountain sandstone is the Pioche formation, which consists of 125 ft. of arenaceous shaley layers, with some thicker layers of quartzitic sandstone, and contains annelid trails and *Cruziana*. This therefore represents the shore or even subaerial portion of this shale, which in the type region at Pioche Nevada, is very fossiliferous. Overlying the Ploche shale are the arenaceous limestones and sandstones which form the base of the Middle Cambrian. These at a somewhat higher level, contains a fauna with *Zacanthoides* and *Dorypyge?*

XIV. *Pioche Nevada Section.* This section lies in southeastern Nevada (approximately Long. 114°.25′ west, Lat. 37°.55′ north). On the road from Pioche south to Panaca, is the classical exposure of the Pioche shale. Here it contain the following fauna.

Brachiopoda

Iphidella pannula (White)
Westonia ella (Hall & Whitfield)
Acrothele subsidua White
A. subsidua var. hera Walcott

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1 A photograph of this, copied from Walcott, is given in my Text-book Vol. II, p. 245, fig. 1042. The lower half or more of the view shows the Prospect Mountain quartzite, while the upper part of the Mountain represents Middle Cambrian, the two being separated by the Pioche shale, which is not very evident in the photograph.

Acrothele spurri Walcott.
Acrotreta primæva Walcott
Billingsella highlandensis Walcott.

Gastropoda etc.

Hyolithes billingsi Walcott.

Trilobita

Mesonacis gilberti Walcott.
Zacanthoides levis Walcott.
Crepicephalus augusta
Cr. liliana Walcott
Mesonacis freemonti Walcott.

Cystoidea

Eocystides? longidactylus Walcott[1]

Of these only 3 species, *Iphidella pannula*, *Hyolithes billingsi* and *Mesonacis gilberti* have been found in the northern sections. The first of these also occurs in the Middle Cambrian Stephen formation of Mount Bosworth and Mount Stephen. The second is a wide-spread pelagic type. The 3rd is a typical member of the Mount Whyte formation. Of the others *Billingsella highlandensis* is known from the Waucoba Springs sections, but unknown in the northern section. The others have not been reported from the Lower Cambrian elsewhere. *Westonia ella* is also known from the Stephen shale of the Middle Cambrian. *Zacanthoides levis*, if it belongs to that genus, has its nearest relatives in the Middle Cambrian. Finally the 2 species of *Crepicephalus*, the first with broad pleural spines at the end, the second with narrow and longer spines also appear out of place in a Lower Cambrian fauna. The presence of *Mesonacis* however, gives the fauna a distinctively Lower Cambrian aspect. It is possible that the aberrant part of the fauna is of southern origin, and that

1 These fossils are mostly discribed by Walcott in Bulletin XXX U.S. Geol. Survey.

we have here a commingling of both the Boreal and the southern type.

In the Eureka mining district 135 miles to the northwest, (approximately longitude 116^0 W, and Latitude 39^0 30′ N.) the Pioche shale is 200 ft. thick and contains *Mesonacis gilberti*, *Mesonacis freemonti*, and *Peachella iddingsi* Walcott.

At the south end of the Timpahute Range the Pioche Shale has the following fauna

Jamesella erecta Walcott
Billingsella highlandensis Walcott
Callavia (Pædeumias) nevadensis Walcott
Mesonacis freemonti Walcott
Peachella iddingsi Walcott

XV. *Waucoba Springs Section.* Inyo County California (Walcott I, p. 185)

This is situated in southeastern California close to the Nevada line and has been considered as representing the most typical Lower Cambrian section of western North America. The entire Lower Cambrian is represented by the Silver Peak group, with a thickness of 6,570 ft. Neither the base nor the top however are exposed. The total series is divided into 3 divisions each with a number of subdivisions. The lowest exposed bed (3 d) comprises 450 ft. of shaly and massive sandstones, which besides *Cruziana* has furnished the following fossils.

Archæocyathids

Archæocyathus sp.
Ethmophyllum gracile Meek

Brachiopoda

Mickwitzia occidens Walcott
Obolella sp.

Tramatobolus excelsis Walcott

Gastropoda etc

Hyolithes sp.

Trilobita

Wanneria? gracile.

Next follow 575 ft. of alternating arenaceous limestones, shales and sandstones (3 c). 275 ft. from the base *Archæocyathus* is very abundant. The next series (3 b) comprises argillaceous and sandy shales with few thin limestone beds 200 ft. thick, and carrying *Tramatobolus excelsis* and *Obolella* sp. 160 ft. from base.

The upper part of this division (3 a,) consists of 360 ft. of sandstones and shales with some interbedded limestone which also forms the summit of the division. 430 ft. from the base, numerous fragments of *Olenellus* have been found.

The next division consists of 2,755 ft. of more or less sandy beds. It begins with 790 ft. of quartzitic sandstone (2k) with annelid trails on the surface of the layers.

The next division (2j) consists of 485 ft. of quartzitic sandstones with *Scolithus* and with interbedded shales, in which have been found *Billingsella highlandensis*, and the trilobite *Mesonacis freemonti*. Then follow 430 ft. of alternating shales and quartzites with *Scolithus*, *Salterella* and *Olenellus* fragments. The remainder of this division 2h-2a inclusive, 1050 ft. in thickness, consists of shales sandstones and limestones of various combinations, sometimes with fragments of trilobites and in the upper part, with annelid trails and *Cruziana*. The highest division No. 1 has a thickness of 1,040 ft. and is mainly calcareous. It begins with 340 ft. of arenaceous limestones (1 d) in which *Holmia*, and *Salterella* occur 105 ft. above the base. Then follow 175 feet of limestones (1c and 1b) from which no fossils have been reported and the series terminates with (1a) 525 ft. of compact limestone with concretions. 50 ft. from the bottom, sections of calcareous brachiopds and a large *Orthotheca* like shell have been found.

XVI. *Barrel Springs Section* (Walcott I, p. 188)

This section is 16 miles south of the town of Silver Peak, Nevada and represents the same series as that shown in Waucoba springs. The total series exposed is 6,250 ft. and all of its belongs to the Lower Cambrian. Neither base nor top is shown and hence the complete thickness is unknown. 13 subdivisions have been recognized, of which the lowest exposed portion (No. 13) consists of 180 ft. of siliceous buff limestone, from which no fossils have been recorded. This is followed by (12) 222 ft. of massive quartzite, shaly in places, which contains *Nevadia weeksi*, and *Holmia rowii*. This, until recently, was regarded as the oldest fauna known, with the earliest of trilobites. (See Walcott. Cambrian Geol. and Pal. Vol. IV p. 431). This is borne out by the section, since with the exception of unidentified fragments of Olenelloid trilobites, about 1,000 ft. higher, no other trilobites are known, in the next 3,322 ft, which is composed of a great mass of siliceous and "coral" limestone (No. 11) 1349 ft, followed by 904 ft. of quartzites (No. 10), 238 ft. of calcareous shales (No. 9); 81 ft. of massive limestone (No. 8); and the whole capped by a flow of andesite 750 ft. in thickness. According to Resser (Bull G. S. A. Vol. 44, p. 748) "recently grave doubt of the early age of this zone has arisen, a survey indicating that it really belongs close to the *Olenellus* zone."

Above the andesite follow 460 ft. of green calcareous shale, with bands of limestone at the top (No. 6). This contains *Salterella* sp, *Wanneria? gracile* Walcott, *Olenellus claytoni* Walcott. Other green shales and limestones follow capped by massive blue limestone (Nos. 4 & 5) the total aggregating 629 ft. Then follow (No. 3) 390 ft. of calcareous shales, arenaceous toward the top, with a rich fauna of the following species.

Archæocyathids

Archæocyathus? sp.

Brachiopoda

Kutorgina cingulata (Billings)
K. perugata Walcott.
Siphonotreta? dubia Walcott.
Acrotreta claytoni Walcott.
Acrothele spurri? Walcott.
Swantonia weeksi Walcott.
Swantonia? sp.

Gastropoda etc.

Helcionella cf. elongata (Walcott)
H. cf. rugosa Hall

Cephalopoda

Salterella sp.

Trilobita

Ptychoparia sp.
Olenellus argentus Walcott
Mesonacis gilberti. (Meek)
Wanneria? gracile Walcott.

In the next succeeding 206 ft. of sandy shales and sandstones No. 2, fossils are scarce or absent, but from the terminal thin bed of limestone the following fauna has been recorded.

Brachiopoda

Paterina prospectensis Walcott.

Jamesella amii Walcott

Gastropoda etc.

Scenella sp.

Trilobita

Agraulus? sp.

Mesonacis gilberti (Meek)

The section is terminated by 737 ft. of massive blue mottled limestone, with 50 ft. of sandy limestones in the middle of the series (No. 1) *Archæocyathus* and allied forms occur throughout this limestone.

XVII. *Bristol Hill Section.* (Iron Mountain) Near Cadiz, California.

(Approximately Longitude 115° 35′ W, Latitude 34°, 38′ N). This section in the Mohave desert of San Bernardino County in Southern California, about 50 miles southeast from the Nevada-Arizona line, is the southernmost section of these Cambrian strata known. It probably represents the western part of the Palæo-Cordilleran geosyncline and since throughout Arizona only the Middle and Upper Cambrian is known, it probably also marks the southern extent of the invading sea from the north. It is of course possible that there was an opening to the Pacific west of this section, in which case the Bristol Mountain formations must be regarded as representing the eastern border of that geosyncline, but at present no Cambrian strata are known from this part of California. If, as indicated by the present known sections, the geosyncline was closed to the invading sea on the south, the Lower Cambrian fauna of this region, must be entirely of Boreal origin. If on the other hand, as Resser suggests, the *Crepicephalus* element is of southern origin, a connection must have existed, perhaps across Arizona, the record of which was again eroded before the deposition of the Middle and Upper Cambrian.

The Bristol Mountain section,[1] first discovered by Darton, begins with 470 ft, (143.3 meters) of quartzites, which rests unconformably on an eroded granite surface. Above this occur 22 ft. (6.7 meters) of fine-grained arenaceous shale, containing thin beds of sandstone. These shales contain an abundant fauna of the following species.

Brachiopoda

Paterina prospectensis Walcott.

Trilobita

Mesonacis freemonti Walcott.
M. bristolensis Resser.
M. insolens Resser
Pædeumias nevadensis Walcott
P. clarki Resser

This is a typical Lower Cambrian fauna of Boreal origin.

These beds are succeeded by 25 ft. (7.6 meters) of blue to black, unfossiliferous nodulous limestone which is also referred by Resser to the Lower Cambrian. It is followed disconformably by 120 ft. (36.6 meters) of brown or black arenaceous shales, which about 12 ft. above the base has furnished 2 Middle Cambrian trilobites.

Dolichometopus? lodensis (Clark)
D. productus (Hall & Whitfield)

The latter, generally known as *Bathyuriscus productus*, is a wide-spread Middle Cambrian species, in Utah, Nevada,

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1 Charles E. Resser. Cambrian fossils from the Mohave desert. Smithsonian Miscellaneous collection. Vol. 81, No. 2, Washington 1928.

and Arizona (Coconino County). It has also been found in shaly sandstones near Rogersville and Bays Mountain Tennessee, southeast of Knoxville, in strata erroneously referred to the Rome formatisn, and in the Conasauga limestone above the Rome in Floyd County, Georgia. This suggests that it is of early Middle Cambrian age and probably derived from the south, though Resser may be correct in suggesting that it too is of northern origin.

The Middle Cambrian beds of this section are disconformably succeeded by limestone of Mississippian age.

This concludes our survey of the Lower Cambrian of the Cordilleran province. In Table II the distribution of the faunas so far as recorded is given.

LOWER CAMBRIAN OF THE ATLANTIC OR CALEDONIAN PROVINCE

If we accept the hypothesis of the former continuity of the Eur-African and American continents, we remove the Atlantic as a center of faunal evolution and the center of the Atlantic or Caledonian faunal province must therefore also be placed somewhere in the region of the present Boreal realm. As previously suggested, when we postulate a former discontinuity of continental shelves, and therefore interruptions of the littoral district, which was probably the permanent home of these organisms, we can understand the distinctness of the faunas of the various provinces. That they were not absolutely distinct is shown by the occurrence of trilobites referred to the genus *Holmia*, and others of the genera *Paedumias* and *Callavia* in Lower Cambrian strata of the Palæocordelleran province, and also by the occurrence of similer brachiopods and gastropoda. On the whole however. the faunas of these provinces are strikingly distinct and unless we can postulate a marked difference in age between them which does not seem likely, we must explain this difference by isolation in distinct parts of the continental shelf.

The deposits of this region are now known from Eastern New Foundland, Cape Breton and Eastern Massachussettes on the American side, and from England and Wales, the Baltic region, and Poland on the European side. In the following maps and diagrams an attempt is made to show the former and present position and character of these and the Appalachian deposits (Figs. 1—3).

Before preceding to the discussion to these individual regions, we may give Resser's zoning of the Lower Cambrian of this province.

Superformation.

Protolenus beds (*Referred here to Middle Cambrian*)

	Formational unit	Faunal zone
Lower Cambrian	*Callavia beds*	Callavia
	Holmia beds	(Conchostraca)
		Holmia kjerulfi
	Acrothele beds	Acrothele prima
	Obolella beds	Obolella groomi
	Volborthella beds	Volborthella
	Platysolenites beds	Platysolenites
	Discinella beds	Discinella holsti
	Quartzites beds	———

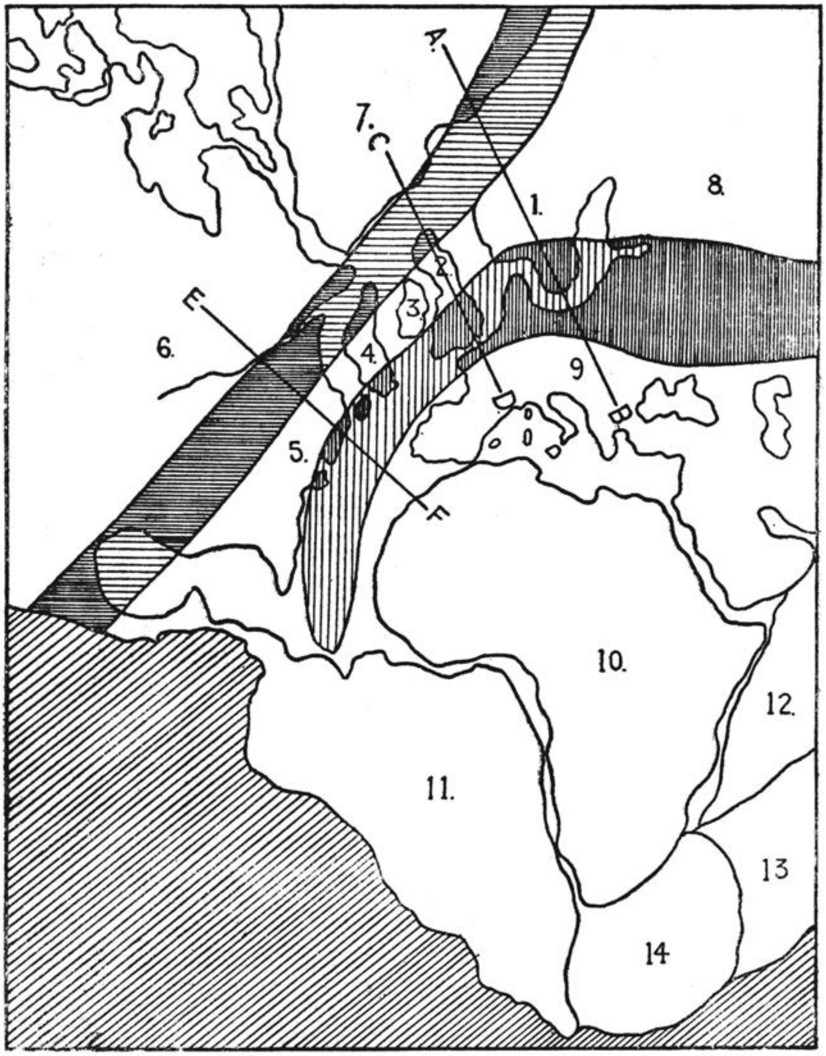

Fig. 1. Map of a portion of Palæozoic Pangæa or the united continents, with the geosynclines, in Lower Cambrian time.

Vertical lining: Atlantic-Caledonian geosyncline. *Horizontal lining:* Appalachian geosyncline.

The portions of the present lands, included in the geosynclines and covered by the Lower Cambrian Sea, is darker. (The East Iberian Peninsula is not included, as there is some doubt of the Lower Cambrian age of the deposits of Villa Boim).

Diagonal lining: Pan-Pacific Ocean. A-B, C-D, and E-F, lines of section I.

The various land masses of today are numbered as follows: 1. Scandinavia 2. England and Scotland 3. Ireland 4. New Foundland 5. Southern Appalachia 6. Central North America (Mississippia) 7. Greenland. 8. Eastern North Europe. 9. South Europe 10. Africa 11. South America 12. India 13. Australia (represented too large) 14. Antarctica. Many of the lands are represented larger than they are today to eliminate the compression due to folding.

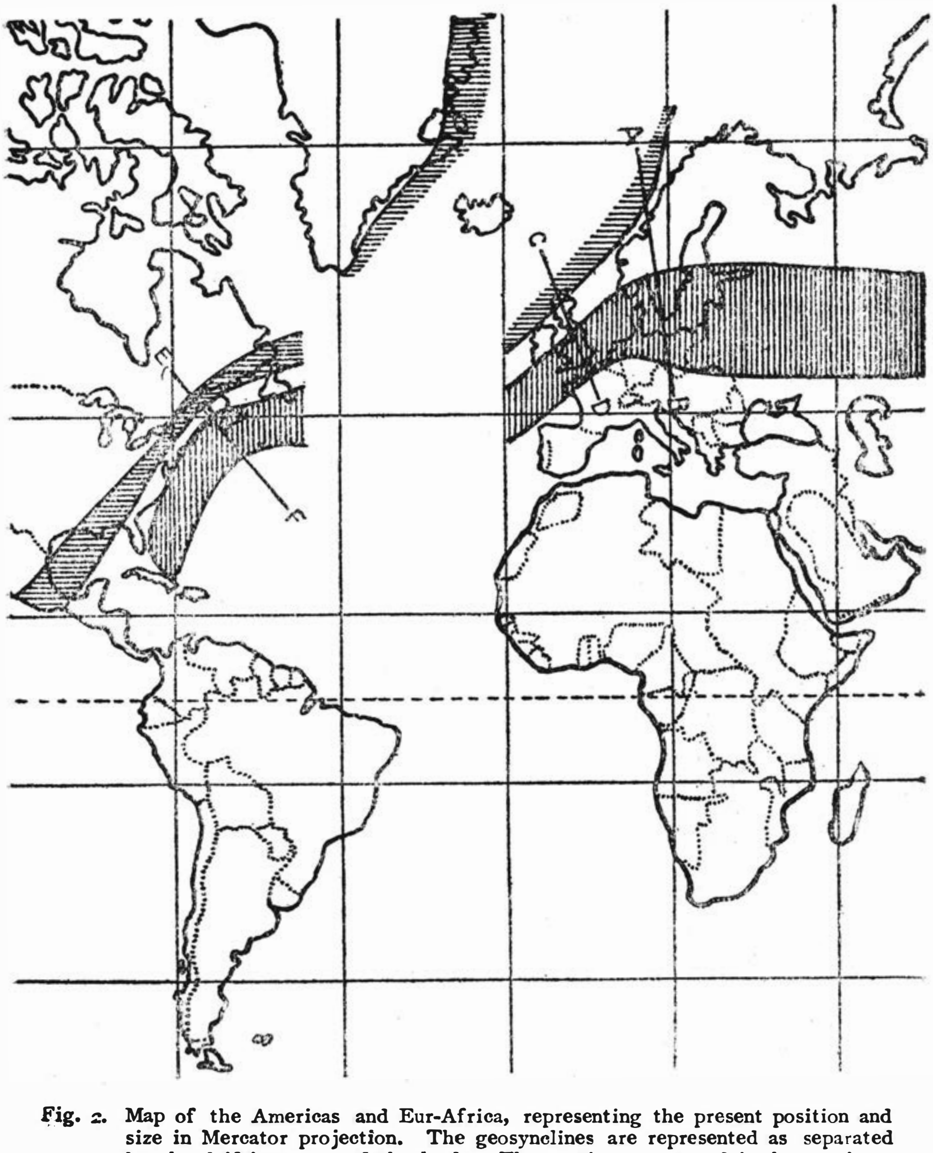

Fig. 2. Map of the Americas and Eur-Africa, representing the present position and size in Mercator projection. The geosynclines are represented as separated by the drifting apart of the lands. The portions preserved in the continent are not differentiated.

A. B. and *C. D.* Lines of section II. (combined)

E. F. Line of section III.

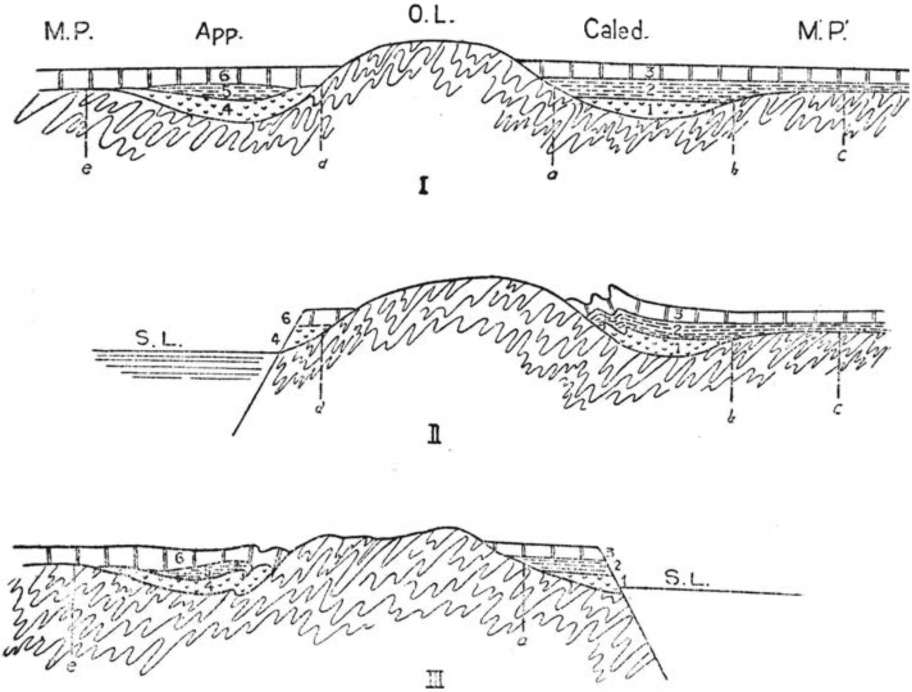

Fig. 3. Sections along the lines, shown on the maps fig 1 and 2.

I. Section restored, showing the original conditions of the geosynclines in Cambrian time, before the separation of the continents. More or less combined from the 3 sections A-B, C-D, and E-F on Fig 1.

O.L. Old Land of Appalachio-Cadedonia.

App Appalachian geosyncline.

Caled. Caledonian geosyncline.

M. P. Marginal Plain of Appalachian geosyncline.

M'.P'. Marginal Plain of the Caledonian geosyncline.

1. Lower Cambrian, *Holmia* Beds. 2. Middle Cambrian, *Paradoxides* Beds. 3. Upper Cambrian, *Olenus*-Tremadoc-Lower Ordovician beds, all in Caledonian geosyncline. 4. Lower Cambrian, *Olenellus* beds. 5. Middle Cambrian, *Dolychometopus beds*. 6. Upper Cambrian. *Crepicephalus* and Lower Ordovician beds. 4-6 in Appalachian geosyncline.

a. Over-lapping Middle Cambrian and later beds on Old Land, as in St. John New Brunswick. *b.* Over-lap of *Protolenus* Beds, as at Lausitz Mountains. *c.* Great over-lap of Middle Cambrian and later strata on the marginal plain, as in Bohemia. *d.* Disconformable super-position of Upper Cambrian and Lower Ordovician on the

Characteristic Section

Section I. Manuels Brook Newfoundland. On the Avalon Peninsula of S. E. Newfoundland, the Cambrian beds have long been known from Manuel's Brook and Conception Bay. The total thickness of the Lower Cambrian, excluding from this the *Protolenus* beds, is not over 60 feet. Resting upon the old rocks is a series of conglomerates 18 ft. in thickness. At the Falls of the brook "It constsis of well-rounded boulders and pebbles apparently derived from the adjacent pre-Cambrian, with the interstices between them filled with sand. It is coarsest at its base, where some of its boulders are said to measure as much as 12 ft. in diameter (Dale) and grades upward through 3 ft. of limy sandstone into a shaly pyritiferous pink and

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Lower Cambrian as in North Scotland, west New Foundland, and many other parts of the Appalachian geosyncline, where the Middle Cambrian is only preserved in the center of the geosyncline. *e.* Extensive over-lap of Cambrian and Lower Ordovician on the marginal plain, as in many parts of Canada and the United States.

II. Section along the line A-B or C-D on Fig. 2, showing approximately the conditions as they exist today, after the separation of the lands and the birth of the Atlantic Ocean.

S. L. Sea-level of North Atlantic Ocean. 1, 2, 3, the strata of the Caledonian geosyncline, folded in the British region. 4. Lower Cambrian; 6. Upper Cambrian and Lower Ordovician in disconformable relation to the Lower Cambrian, and little disturbed at North Scotland. (d). *b.* Position of Lausitz Mountains; *c* Bohemia. In both plases, Middle Cambrian overlaps Lower.

III. Section along the line E-F on Fig 2, showing approximately the present position, after the separation of the continents and the birth of the Altantic.

S. L. Sea.level of the Atlantic on the American coast. 1, Lower; 2, Middle; 3. Upper Cambrian and Lower Ordovician, on the Atlantic coast as at Manuel's Brook N. F. These are remnants of the Caledonian geosyncline. 4 Lower Cambrian, 5 Middle Cambrian, 6 Upper Cambrian and Lower Ordovician of the Appalachian geosyncline, all in disconformable contact and extensively folded.

a. Overlap of the Middle Cambrian *Protolenus* and *Paradoxides* beds at St. John New Brunswick. *e.* Extensive overlap of the Upper Cambrian and Lower Ordovician in Canada and the United States.

blue limestone containing great numbers of what are probably pteropods."[1]

Succeeding these beds are olive-gray shales mostly concealed, with some red shales and limestones higher up, followed by 34 ft. of hard olive shale which apparently belong to the horizon of *Metadoxides* (*Catadoxides*) *magnificum* Matthew, which normally belongs above the *Protolenus* zone and is here included with the Middle Cambrian.

The contact between these and the underlying beds is regarded by Dale as a disconformable one, while Howell (*loc, cit*, p. 25) describes it "as certainly a very uneven one; but the beds seem sometimes to grade into each other". If this disconformity exists, it represents the hiatus between the Lower and Middle Cambrian elsewhere recognized. The total thickness probably is not over 25 ft. and near the middle it contains a limestone of pinkish colour (Smith Point Limestone). The fauna reported by Walcott from the beds of this section, chiefly the limestones, is as follows.

Brachiopoda

Paterina labradorica (Billings)
Obolella atlantica Walcott

Gastropoda etc.

Scenella reticulata Billings
Helcionella rugosa (Hall)
H. rugosa var. acutacosta (Walcott)
H. rugosa var. erecta (Walcott)
H. rugosa var. levis (Walcott)
H. rugosa var. paupera (Billings)

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1 B. F. Howell. The faunas of the Cambrian Paradoxides Beds of Manuels Newfoundland. Bull, of American Pal. Vol. XI, 1925, No. 43, pp. 24-25

Straparollina remota Billings
Platyceras primævum Billings
Helenia bella Walcott
Hyolithes impar Ford
H. princeps Billings
H. quadricostatus Shaler & Foerste
H. similis Walcott
H. terranovicus Walcott
Hyolithellus micans Billings
H. micans var. rugosa Walcott
Coleoloides typicalis Walcott

Trilobita

Microdisus helena Walcott
M. bellimarginatus Shaler & Foerste
Callavia bröggeri Walcott
Avalonia manuelensis Walcott
Ptychoparia? attleborensis Shaler & Foerste
Agraulus (Strenuella) strenuous Billings
Agraulus (Strenuella) strenuous var. nasutus Walcott
Solenopleura bombifrons Matthew
S. harveyi Walcott
S. howleyi Walcott

Section II. Hanford Brook St. Martins New Brunswick. 30 miles northeast of St. John's New Brunswick, the Lower Cambrian, here known as the Etcheminian, has a thickness of 1200 ft. and rests unconformably on the older rocks which in this region is a great series of ancient volcanics. The succession in detail is as follows (In descending order).

Superformation.

Middle Cambrian beds

Lower Cambrian beds (Etcheminian)

3. Concealed beds . . . . 320 ft.

2c.	Purplish sandy shales, with a few bands of greenish shale, with *Scolithus*	300 ft.
2b.	Soft purplish-red shales, with green glauconite grains, the upper part firmer and more sandy. Greenish-grey layers interspersed, especially towards the base. It contains *Platysolinites*, *Obolus*, *Volborthella*	175 ft.
2a.	Purplish-red conglomerate, more friable than 1a.	135 ft.
1c.	Purplish-red sandstone, with greenish layers. Remains of seaweeds (*Phycodella*) animal tracks, (*Psrammichnites* and *Helminthites*) and worm burrows (*Arenicolites*) etc.	240 ft.
1b.	Grey and purplish flags and sandstones with worm casts, seaweeds (*Palæochorda* and *Buthotrephis*) and numerous spicules of sponges	70 ft.
1a.	Coarse purplish-red conglomerates. . . .	60 ft.

Unconformity.

Subformity

Pre-Cambrian. Coldbrook Group of anygdaloidal greenstone.

Among the fossils of this series only a few have been positively identified. These include.

Obolella nitida Ford
Acrotreta gemma Billings
Lingulella cælata (Hall)
Hyolythellus micans Billings
Coleolides typicalis Walcott
Hyolithes americanus Billings

At St. John New Brunswick, the entire Etcheminian is wanting, the Cambrian beginning with about 150 ft. of red and greenish shales resting with a basal conglomerate upon the older beds and followed by the St. John quartzite, which probably corresponds to the *Protolenus* horizon, here placed at the base of the Middle Cambrian.

A much greater development is found of Cape Breton Island.[1] On Mira Bay on the eastern coast Mathew found from 3,000 to 5,200 ft. of the Etcheminian beds mostly argillutites and in part red. These rest with a basal conglomerate on the older rocks. Traced westward, the section decreases apparently by overlap, until at East Bay on Bras d'Or Lakes, 20 miles further west, only 500 ft. of Etcheminian occurs. In both localities there seems to be an erosion interval between the Etcheminian and the overlying Middle Cambrian, this perhaps accounting in part for the difference in thickness, though most of that is undoubtedly due to progressive westward overlap, and failure of the lower beds.

Section III Eastern Massachusetts. In the region around Boston, a considerable thickness of argillaceous and calcareous strata is referable to the Lower Cambrian, but they are nowhere in undoubted contact with the Middle Cambrian *Paradoxides* Beds. The more prominent of these sections are at East Point Nahent, Mill Cove Weymouth and North Attleborough. In the former, the chief formation is of white limestone almost of marble, interbedded between basaltic or diabasic flows. In the Weymouth region near Braintree, the exposures consist of purplish shale less than 100 ft in thickness and showing no relation to other beds

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1 G. F. Mathew Report on the Cambrian Rocks of Cape Breton. Canadian Geol. Survey Ottawa 1903.

since they crop out through a glacial sand plain In North Attleborough further south, there are beds of slates and pinkish limestones the thickness of which has been estimated at 2,000 ft. though that may be excessive.[1] Other localities in which fossils have been found are in Rowley and Topsfield Massachusetts. From various portions of the harbour fossil-bearing Lower Cambrian rocks have been obtained, either underlying the harbour or belonging to glacial drift. To the latter category probably belong a number of boulders of red limestone, found by Dr. Thomas A. Watson at Cohasset and Nahant. These contain a typical Lower Cambrian fauna which I described in 1900,[2] and recognized as identical with the fauna of the Smith Point limestone of Newfoundland to which the boulders also corresponded lithologically. I then suggested that these boulders were carried by the Pleistocene ice from this distant northern locality. In the following table, the species from some of these localities are listed.

The localities are as follows.

a. North Attleborough Massachusetts, Stations 1, 2, 3.

b. Glacial boulders from various parts of the coast.

c. White limestone of Nahant.

d. Red slates and limestones from Mill Cove Weymouth.[3]

e. Dark purplish slates of Pearl Street, North Weymouth.[3]

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1 N. S. Shaler and A. Foerste, Bull Museum of Comparative Zoology Cambridge, Vol. XVI, No. 2.

2 A. W. Grabau. Palæontology of the Cambrian Terranes of the Boston Basin. Occasional paper of the Boston Society of Natural History. Vol. IV, Part III, pp. 601-694, Pls. 31-38

3 Henry T. Burr. A new Lower Cambrian Fauna from Eastern Massachusetts. American Geologist Vol. 25, pp. 41-50, 1900

	a	b	c	d	e
Brachiopoda					
1. Iphidea bella (?)	—	—	—	×	
2. Obolella crassa	×	—	—	×	
3. Obolella atlantica	×	—	—	—	×
4. Acrothele woodworthi	—	—	×		
Pelecypoda					
5. Fordilla troyensis (?)	×				
6. Lamellibranch (?)	×				
Gastropoda					
7. Scenella reticulata	×				
8. Scenella (?) sp.	—	×			
9. Platyceras primævum	×	×			
10. Platyceras deflectum	—	×			
11. Watsonella crosbyi	—	×			
12. Raphistoma attleborensis	×	×			
13. Straparollina remota	—	×	—		
14. Stenotheca (Helcionella) abrupta	×	×	×		
15. Stenotheca (Helcionella) curvirostra	×	×			
16. Stenotheca (Helcionella) pauper	×	×			
17. Stenotheca (Helcionella) levis	—	×			
Hyolithidæ etc.					
18. Hyolithes princeps	—	—	×		
19. H. excellens	—	—	×		
20. H. quadricostatus	×				
21. H. americanus	×	—	×		
22. H. billingsi	×				
23. H. searsi	—	—	×		
24. H. communis	?	—	×		
25. Hyolithes impar	—	—	×		
26. Orthotheca cylindrica	×	×	×	×	

Continued	a	b	c	d	e
27. O. emmonsi	×	?	×		
28. O. (?) foerstii	×	×			
29. Hyolithellus micans	×	×			
30. Urotheca pervetus	—	—	—	—	×
31. Salterella curvatus	×				
Crustacea					
32. Aristozoe (?)	×				
33. Callavia burri	—	—	—	—	×
34. Callavia crosbyi	—	—	—	—	×
35. Olenellus? walcotti	×				
36. Microdiscus bellimarginatus	×				
37. Microdiscus lobatus	×				
38. Microdiscus, cf. M. helena	—	—	—	—	×
39. Strenuella strenua	×	×	—	—	×
40. Ptychoparia (?) attleborensis	×				
41. trails.	—	—	—	—	×

The European Sections

The Caledonian geosyncline of North-western Europe, may be regarded as the eastern extension of the Atlantic geosyncline of America, these being now separated by 35° or more of latitude. The Welsh and Western England sections as well as those of Scandinavia represent the western or Old Land portion of the geosyncline, while the North German and Polish regions represent the broadly flooded marginal plain. In the former, the deposits are partly clastic where the land was high, partly they occur in thin over-lapping wedges. In the region of the marginal plain, they too are represented by the thinner deposits and also by successive over-lapping beds, but these extend much farther.

We will take the sections in general from west-eastward.

Section V. Wales. Here the Lower Cambrian Carfai and Lower Harlech consists entirely of clastic beds, the greater part of which is of continental origin, though some *Olenellus* and *Lingulella ferruginea* have been found. The thickness ranges from 450 to 1200 meters (1500-4000 ft.) and comprises an alternation of coarse grey-wacks and red or vari-coloured shales. Much volcanic material also occurs. Worm-tubes (*Scolithus*) are however, not uncommon. In the northern part of North Wales, the series is of less thickness and consists chiefly of variegated shales with thin layers of fine-grained sandstone. The Middle Cambrian Solva and Menevian succeed with a thickness up to 830 meters (2767 ft.).

Section VI. The Midland District. In the Midland districts of England, the sections are often very incomplete, parts of the Middle and Upper Cambrian being locally wanting, and Ordovician or Silurian rests disconformably on Middle Cambrian. The total thickness is not over 400-600 meters. (1300-2000 ft). It begins everywhere with conglomerate and quartzites, the pebbles generally composed of the underlying pre-Cambrian rocks. The upper part of the quartzite and sandstone series is glauconitic and includes limestone beds. In these and the intercalated quartzites, *Hyolithes*, *Kutorgina cingulata*, and other Lower Cambrian fossils have been found. Higher up are two limestone bands the lower with *Callavia callavii*, the upper with *Protolenus*, *Microdiscus bellimarginatus* and *M. lobatus*. This latter apparently represents the Protolenus zone. The succeeding *Paradoxides* beds are sometimes separated from the Lower Cambrian by a disconformity. The total thickness of the Lower Cambrian does not exceed 150 meters or about 500 ft, while the Middle Cambrian may reach a thickness of 600 meters or 2000 ft.

It should be noted here that the *Protolenus* zone, which I would place at the base of the Middle Cambrian has a wide distribution, extending from England eastward to the Lausitzer Mountains on the northern border of Bohemia and still farther east into Poland, whereas it is wanting in Sweden. This I hold marks the transgression of the Middle Cambrian Sea, which becomes even more extensive in the succeeding stages as shown by the overlapping *Paradoxides* Beds of Bohemia. I would place the great disconformity which marks the Lower Cambrian retreat below the *Protolenus* zone.

In the Malvern Hills of West England, (Long. 2° 20′ W, Lat. 52° 52′ N) the succession of formations is as follows in descending order.[1]

D. Bronsil Shales

4.	*Upper gray shales* with *Dictyonema sociale*, *Parabolinella* etc.	500 ft.
3.	*Coal Hill Band.* Gray shales, with interbedded diabase with *Dictyonema sociale* the shales having a thickness of about 100 ft.	250 ft.
2.	*Lower Gray shales*, with *Lingulella* and *Tomaculum problematicum* Groom (Thought to be trilobite eggs)	250 ft.
1.	*Lower shales*, with "Middle" igneous band; shales with intercalated basalts. A few imperfect *Lingulellas* have been found	300 ft.

1 Theodore Groom. The sequence of the Cambrian and associated beds of the Malvern Hills. Quarterly journal of the Geol. Soc., Vol. 58, pp., 89-135, 1892.

C. WHITE—LEAVED—OAK SHALES

These are chiefly dark shales and divisible into the following series:

4. *Upper Black shales* with *Sphærophthalmus alatus* Boeck, *Ctenopyge bisulcata* Phillips, and *Agnostus trisectus* Salter. 150 ft.

3. *Upper White Leaved-Oak Igneous Band.* Olivine basalts, interbanded with dark shales, often bleached white. *Sphæropthalmus alatus* Boeck, common. Basalts about 200 ft. thick. 300 ft.

2. *Lower Black shale.* With *Sphæropthalmus alatus* Boeck, *Ctenopyge bisulcatus* Phillips, *Ct. pecten* Salter, *Peltura scarabæoides* Wahlenberg 250 ft.

1. *Lower White-Leared-Oak Igneous Band.* Coarse glauconitic quartzose grits and black shales interbedded with sills of basaltic rock; (about 100 ft. of basalts). The only abundant fossil is an ostracod, *Polyphyma lapworthi* Groom. 150 ft.

Hiatus and Disconformity

B. HOLLYBUCH SANDSTONE.

This consists of the following members in descending order.

b. *Massive sandstones*

3. Green sandstones, containing *Scolecoderma antiquissima*, with a zone of dark-green sandstone and thin conglomerate layers, dark-gray quartzite, and light-grey sandstone, with

S. antiquissima, (Salter), *Paterina phillipsi* (Holl), *Acrotreta sagittalis* Salter?, *Hyolithes fistula* (Holl), *H. primaevus* Groom, *H. malvernensis* Groom, etc. about 650 ft.

2. Gray, dark-gray or black sandstones and quartzites, alternating with green and dark-green sandstones and a thin impure, limestone near the base, contains *S. antiquissima* Salter, about 400 ft.

a. *Flaggy and shaly sandstones*

1. Flaggy and shaly green sandstones with one or two thin calcareous layers and a thin impure limestone, passing up into more massive gray or green sandstones, and grading down into the underlying Malvern quartzite. The fossils found are: *Paterina phillipsi* (Holl), *Acrotreta sagittalis* (Salter), *Obolella groomi* Matley, *Scolecoderma antiquissima* Salter. 75 ft.

A. MALVERN QUARTZITE.

Compact quartzite to coarse conglomerate, with fragments of white quartz, metamorphic quartzites, felsites, rhyolites? granites and granophyres. The fossils are:
Paterina phillipsi (Holl)
Obolella groomi Matley
Hyolithes primævus Matley
Orthotheca fistua (Holl)
Glauconite casts of foraminifera

All the fossils of the Malvern quartzite also occur in the Hollybush sandstone and with the exception of *Scolecoderma antiquissima* and several new species of *Hyolithes* as well as the questionably identified *Acrotreta sagittalis*, all the Hollybush sandstone species, also occur in the Malvern quartzite, while none occur in the White-Leaved-Oak shales, except *Obolus* (*Bröggeria*) *salteri* Holl. Walcott (Cambrian Brachiopoda p. 236, ref. 304 g,) refers the Hollybush to the Upper Cambrian (see also page 135) but this is certainly not borne out by the list of species given by Groom, and according to which the Hollybush sandstone, both the shaly and the massive series, are referable to the Lower Cambrian This is also shown by the gradation of the Malvern sandstone into the Hollybush sandstone, and the abrupt change from the Hollybush to the White-Leaved-Oak shale. According to Groom "The striking contrast between the Hollybush sandstone and the White-Leaved-Oak, seen everywhere, even along the line of contact, and the circumstance that along the greater part of this junction, the Hollybush sandstone is the dark type, supposed to characterize a low horizon in the formation, suggest that beds are missing along the line of contact, owing either to unconformity [disconformity] or faulting."[1]

The White-Leaved-Oak shales are clearly Upper Cambrian and the Bronsil shales are Tremadoc. This cuts out the Middle Cambrian entirely and separates the Lower and Upper Cambrian by a great disconformity or fault.

The Comley District which is situated in Western Shropshire England (approximately in the region of Long. 2° 30′ W, Lat. 52° 30′ N) contains one of the best known sections though the exposures in the Comley quarry and surrounding regions are very inadequate, and the development of the Lower Cambrian is extremely slight. The total thickness is only 483 ft, almost the whole of which

1 Groom. loc. cit. page 104.

is sandstone. The succession according to Cobbold[1] is as follows in descending order.

SUPERFORMATION Middle Cambrian Paradoxides Beds.

Disconformity with erosion down to beds Ab_4.

LOWER CAMBRIAN

Ad *Lapworthella limestone* . . . . 0.5 ft.
Calcareous and phosphatic granular material, with a fauna mostly of distinct species, including the cephalopod ? *Lapworthella nigra* and the ubiquitous *Hyolithellus micans* which passes into the Middle Cambrian. (For full fauna see Table III).

Ac_5 *Protolenus limestone*. . . . . 0.5 ft.
Black to gray compact, phosphatic limestone with the Protolenus fauna, mostly of forms not found in the lower horizons although a few occur as shown in Table III.[2]

Ac_4 *Strenuella limestone*. . . . . 0.75 ft.
Gray—to red-purple gritty limestone with phosphatic inclusions, characterized by several species of *Strenulla*, *Microdiscus lobatus* and *M. speciosus* and fragments of *Callavia* cf. *calavii* which also occur in the *Protolenus* bed.

Ac_3 *Microdiscus bellimarginatus limestone* . 1.75 ft.
Gray and pinkish limestone with much phosphate in places. Contains a

1. Edgar S. Cobbold. The Cambrian horizon of Comley. Quart. Journ. Geol. Soc. Vol. 76, 1921, pp. 325—386, 4 plates.
2. The status of this fauna will be more fully discussed in a subsequent paper.

typical Lower Cambrian fauna with *Paterina labradoriea*, *Eodiscus bellimarginatus*, *Collavia cobboldi* and fragments of *C. callavii* besides besides others given in Table III.

Ac_2 *Olenellus limestone* . . . . 2.5 ft.

Purple nodular limestone, with several varieties of *Micmacca elipsocephaloides*, *Microdiscus atteborensis*, *Callavia callavii*, and *C. cartlandi*, as well as *Paterina labradorica* and other species.

Ac_1, Ab_4, Ab_3, Ab_2, Ab_1 } *Lower Comley sandstone* . . . . 477 ft.

Various froms of greenish to reddish sandstones with some nodular calcareous beds, with conglomerate beds at the base. It includes the *Callavia* sandstone at the top, the *Holmia*sandstone at the middle and the *Obolella groomi* beds. (Ab_1 27 ft. thick) at the base.

The fauna is similar to the overlying beds except in the basal series, which contains many new species as given in Table III.

Aa *Wrekin quartzite*. . . . . 22 ft.

Yellow quartzite grading down into compact blue quartzite, conglomeratic at the base.

The Wrekin quartzite is correlated with the Malvern quartzite of the Malvern Hills and the Park Hill quartzite of Nuneaton. The Lower part of the Lower Comley sandstone is correlated with the Hollybush sandstone of the

Malvern Hills and the Tuttle Hill quartzite of Nuneaton. The Olenellus limestone is correlated with the Camp Hill quartzite of Nuneaton.

On the opposite shore of the geosyncline, in the Iberian Peninsula and in Brittany, the evidence of the existence of Lower Cambrian beds is found. In Eastern Portugal, at Monte de Valbon, Northeast of Villa Boim, Province of Alemtig (Long. 7° 15′ W., Lat. 38° 50′ N) a series of strata has has been found which contain numerous Middle Cambrian fossils, including *Paradoxides*, and the following brachiopods, which are referred by Walcott to the Lower Cambrian.

Acrothele villaboimensis Delgado.
Delgadella lusitanica (Delgado)
Lingulella delgadoi Walcott.[1]

Fordilla troyensis is also reported and questionable species of *Olenellus*, but with the exception of characteristic species of *Paradoxides* (*P.* aff. *abenacus*, *P.* aff. *spinosus*, *P.* aff. *tessini*), the fossils are mostly new and unknown in Lower Cambrian strata elsewhere. The question then arises, are the brachiopods reported referable to the Lower as Walcott considers, or should they be regarded as Middle Cambrian species. If the latter, then it is probable that this region was not covered by the Lower Cambrian Sea. (In Figs. 1 and 2, this region is not included in the geosyncline, but in Pl. I it is included).

In Brittany, on the northwest coast of France, the Cambrian rest unconformably and transgressively on the

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1 J. F. N. Delgado 1904. Faune cambrienne du Haut Alemtejo. Communicatoes de Commissas de Servico Geologico de Portugal tome 5 fasc. 2, pp. 307-374; with plates.

folded and eroded pre-Cambrian. Both in Brittany and Normandy, the Cambrian is very incomplete and almost unfossiliferous, sometimes absent altogether. Red conglomerates followed by red shales and arkoses usually represent the Lower Cambrian followed by shales, quartzites and limestones of Middle Cambrian age. *Archæocyathids* and *Ptychoparia* have been obtained from some of the higher beds, but their exact position is not noted. Many volcanic rocks also occur and this region evidently marks the shore facies, there being a complete absence of the Cambrian in the Central Plateau. On the other hand, in the Montagne Noire of Southern France, the Lower Cambrian seems to be represented by sandstones with *Kutorgina*, followed by the *Paradoxides* beds. The entire Cambrian series, of which the fossiliferous beds are mainly represented by the Middle Cambrian, has a thickness of about 2,000 meters or 6,700 ft. It is at present impossible to determine the exact palæogeographic relationship of these Lower Cambrian beds. They may have been deposited in a Mediterranean geosyncline in which the *Paradoxides* beds of this section as well as those of Sardinia, with the overlying *Olenopsis* beds were deposited.

Section VII. The Southern Norway Sections. In Southern Norway i.e. the Christiana or Oslow region, the Lower Cambrian is absent, the Middle Cambrian resting with a basal conglomerate upon the old rock, both Upper and Middle Cambrian having here a thickness of 75 meter or 250 ft.

Farther north however, in the region of Lake Mjösen (approximately Long. 11^0 E. Lat. 60^0 30′ north) the Lower Cambrian has a thickness of 60 meters or about 200 ft. Here the succession is as follows in descending order.

Western Facies

Superformation: 1c-d. Alum shales of the Middle Cambrian

Disconformity

Lower Cambrian 60 meters, 200 ft.

1bβ. Green shales and limestones with *Strenuella linnarssoni*

1bα. Green shales, with *Holmia kjerulfi*

1aβ. Green shales, with *Volborthella tenuis.*

1aα. Basal calcareous sandstone, with *Discinella holsti*

Disconformity

Sinian quartzites

Eastern Facies

Superformation. Middle Cambrian. Alum Shales.

Lower Cambrian about 60 m. (200 ft.)

1bβ. Green shales and limestones with. *Strenuella linnarssoni*

1bα. Green shales with *Holmia kjerulfi*

1aβ. Sandstones with *Platysolenites antiquissimus.*

1aα. Basal sandstones and conglomerates.

Disconformity

Quartzites of Pre-Cambrian.

At Trömton, the Middle Cambrian is disconformably preceded by sandy *Strenuella* limestone below which lies gray *Holmia* shale, which in turn rests upon older quartzites.

In Ustaoset the section is as follows in descending order.

ORDOVICIAN PHYLLITES

Disconformity

MIDDLE-UPPER CAMBRIAN ALUM SHALES

Disconformity and great hiatus

MIDDLE CAMBRIAN? Sandstones and conglomerates 1.05 m.
Disconformity.

LOWER CAMBRIAN.
Limestone and lime sandstone with *Strenuella linnarssoni, Torellella lævigata, Hyolithes, Nisusia* etc. 0.70 m.
Shaly sandstones and conglomerates
Disconformity

TELLEMARK FORMATION

At Finse the following beds are shown

3 Altered Alum shale, with *Dictyonema flabelliforme*
Disconformity and great hiatus.

2 Basal conglomerate, with *Torellella lævigata* (Lower Cambrian)
Unconformity.

1 Red granite etc.

The irregularity of the shore line which is here indicated by the lesser development of the Lower Cambrian basal beds, in the Oslow region, than in the Mjösen region farther north, is probably due to post-Lower Cambrian erosion, before the overlap of the Middle Cambrian series occurred.

VIII. *The Southern Sweden Section.* The Swedish sections have been studied in more detail than others in this region, but they are developed in only very slight thickness. The Lower Cambrian of the Andrarum section of Scania in Sweden[1] has a total thickness of 103 meters

1 J. C. Moberg. Guide for the principal districts of Scania. Geol. Fören. i Stockholm. Förhandl. Vol. 32, Heft I, Jan. 1911

(345 ft.). It begins with 100 meters of basal sandstone, without fossils, which however, are referred to the zone of *Schmidtiellus torelli* Mbg. found in equivalent beds at Simrishamn, where these underlie the graywacks with *Holmia kjerulfi* Linrs.

The basal sandstone is succeeded by from 1-2 meters of graywacke shales, with *Holmia kjerulfi*, *Ellipsocephalus nordenskiöldi* Linrs, (the most common fossils) *Arionellus primævus* Brögger, *Hyolithes* sp, and *Lingulella nathorsti* Linrs. This is succeeded by phosphoritic limestones of slight thickness, at times replaced by light gray shales, or dark quartzite-like sandstone, which also contains phosphorite. Fossils are rare, a Lingulid having been found in the limestone and *Lingulella* and *Acrothele bellapunctata* in the sandstone. This bed is often wanting, and the entire series is separated by a disconformity from the overlying Middle Cambrian beds, which begin with alum shales, referred to the *Paradoxides oelandicus* zone.

In the Kinnekulle, on Lake Venern, the Cambrian has a total thickness of 177.3 ft. It rests on granite, which was more or less decomposed, probably before the Cambrian transgression, and begins with the so called *Mickwitzia* sandstone, which contains *Mickwitzia monilifera*, *Medusites lindströmi*, *M. favosus*, *M. radians*, besides the raised trail casts on the under side of the sandstone, known as *Eophyton*. The sandstone moreover contains wind-worn pebbles or "dreikanter", showing that it was a wind-blown deposit in pre-Cambrian time.

This is succeeded by the *Lingulella* sandstone 20 meters (65.6 ft.) in thickness. Then follows a disconformity, and 6.4 meters (21 ft.) of Middle Cambrian, above which in turn, after another disconformity lies the Upper Cambrian 15.6 meters (51.17 ft.). Then follows the *Ceratopyge* limestone, 2 meter or 6.5 ft. in thickness.[1] In the Dalarne, Jämtland and Oeland region, the Middle or Upper Cambrian or even the Lower Ordovician rest directly on the old crystalline rocks.

IX. *Esthonia.* At Reval, on the coast of Esthonia the beds with *Mickwitzia monilifera* and *Medusites lindströmi* are underlain by an unfossiliferous blue clay, which at St. Petersburg is 100 meters in thickness and passes downward into basal sands, which rests unconformably upon the gneiss and granites. This clay represents an older portion of the Lower Cambrian than that shown in Sweden, where there is progressive over-lap, the basal sand rising in all cases in the series, so that in the north-westernmost region, the beds with *Holmia kjerulfi*, eventually rest upon the basal beds. The former belong above the *Mikwitzia* horizon and are absent in the Esthonian and Russian regions. The Lower blue clay is referred to the horizon of *Mesonacis mickwitzi*.

It is evident, that only a very small portion of the Lower Cambrian Sea transgressed across southern Sweden and the Esthonian border of the Finnish old land, the deposits nowhere being of very great thickness and mostly of clastic character. On the other hand due south on the northern border of Bohemia in the Lausitzer Mountains, the Protolenus beds are the lowest beds of the Cambrian, resting directly on the older rocks. Between these two points then, in North Germany, must have been the deeper portion of the geosyncline, though this region is generally assumed to carry no Cambrian deposits, especially since

1 A. W. Grabau. Bull. Geol. Soc. America. Vol 27, p. 588, 1916.

the Cambrian is wholly absent in the Hartz. Von Bubnoff[1] however, concludes that under the North German low plain, there must be Cambrian developed to a much more complete degree than in Scania. If this is not the case, it would seem that the connection between the Polish and the British region was an exceeding slight one and repeatedly interrupted.

X. *Poland Section.* In that portion of Poland bounded by the Vistula on the east and the Pellica on the north and west (approximately 20^0-22^0 east, and 50^0 30′-51^0 30′ north,) with Kielce approximately as the center, a rather complete series of Cambrian including Lower, Middle and Upper, as well as Ordovician, Silurian and Devonian and even Dinantian strata are exposed, though there are many disconformities. The Lower Cambrian shows the following succession in descending order.

Superformation. Protolenus zone, with an abrupt change in fauna.

Disconformity?

Lower Cambrian

3. Sandy shales, with "fucoids" but with a scarce marine fauna comprising *Holmia* sp, *Strenuella primæva, Strenuella kiaeri, Hyolithes* sp. This seems to correspond to 1. b, β of Sweden.

2. Olive green and yellow shales with sandstones containing a rich fauna, including

Holmia kjerulfi,
Holmia walcotti,
Kjerulfia lagowiensis,
Strenuella polonica,
Strenuella primaeva,

1 Geologie von Europa Vol. 2, Part I, p. 672.

Conocoryphe vistulæ
Hipponicharion eos,
H. subquadratus,
H. gracilis,
Beyrichina lingua,
B. depressa,
Lingulella sp.
Obolella rotundata
Mickwitzia kjelcensis,
Helcionella rugosa,
Hyolithes variabilis,
H. complanatus,
H. trigonale,
Torellella laevigata,
Cruziana.

This comprises many endemic forms, but the equivalency with zone 1 bα of Scandinavia is apparent.

1. Dark-green shales, with quartzite layers. Contains *Holmia* sp, *Torellella lævigata*, *Hyolithes zbelutkensis*, *Volborthella* cf. *tenuis*. This corresponds to the Scandinavian zone la, with *Schmidtiella torelli*.

This is the last of the sections in Europe in which Lower Cambrian beds are exposed, and the question arises what is the source of the Lower Cambrian faunas of this and of the American Atlantic coast. If the Atlantic had been in existence at that time we might assume that ocean to have been the source of the faunas, in which case we must extend a narrow Caledonian land mass from Newfoundland to Ireland, the Scottish Highlands and Norway, north and west of which lay the sea with the *Olenellus* fauna, and to the south of it the *Holmia-Callavia* ocean. If however, the Old and New World were in contact, and the present outcrops are separated parts of parallel geosynclines, the Caledonian on the southeast, the Appalachian on the northwest, we must seek for the source of the fauna in another water body, since it is evident that it could not develop in a geosyncline, which was only flooded for a short time, and in which the characteristic faunas appear in the lowest marine beds. There seems no escape from the conclusion that this fauna must also be of Boreal origin, but so far removed from the *Olenellus* fauna, that little or no intermingling could take place. This would imply that the continental shelf, which bordered the lands, was discontinuous. The only region known, which could possibly supply such a distinct fauna, is that portion at present bordering the shore of northern Siberia. We know that the Irkutsk Basin was flooded in Cambrian time and that thick Lower Cambrian deposits were formed there, but unfortunately we have practically no record of the faunas of these beds. In previous publications, I have referred this to the *Ollenellus* sea, largely because of its Boreal connection, but it now seems more likely that the continuation extending across western Siberia and eastern Russia, joined this body to the Caledonian geosyncline now only known from sections as far east as Poland. This connection must have been across some portions of the Urals, with which we are not yet familiar or else the deposits formed there were eroded again in post Cambrian pre-Devonian time. (see map. Pl. I)

We will next consider one or more of the characteristic Lower Cambrian sections of the Irkutsk Basin of Siberia.

The Irkutsk Basin

This great Siberian Palæozoic area lies between the Yenissei River on the west, (approximately 90° Longitude) and the Lena River on the east, (approximately 125° Longitude). Its southern border is in the region of Lake Baikal and Irkutsk on the Trans-Siberian Railway, (approximately Long. 104° 30′ East and Lat 42° 30′ N). The region was surrounded in early Palæozoic time by a continuous horse-shoe shaped band of old land next to which on the inside was a geosyncline, the strata of which are now more or less folded over to the center of the basin.[1] Near the center of the basin, they are less disturbed and exposed on the banks of the Angara and other rivers which have transected them. The formations range from the Sinian to the Silurian and these are disconformably succeeded by very late Permian continental beds.

A nearly complete section of the Lower Cambrian has recently been measured by S. Obrutschew Jr. along the Angara River, between the cataracts and the Yenissei. Here the Lower Cambrian with a thickness ranging from 3,210 to 4,130 meters (10,700-13,767 ft.) is separated from the Sinian Beds by a fault and hence probably does not show the beginning of the series. The total succession of the Lower Cambrian as summarized by W. A. Obrutschew in his Geologie von Sibirien (p. 86) is as follows.

Upper Division. (930-1130 meters)

9. Red series of Mount Totschilnaja. Thick-bedded, red, yellow and gray sandstones, lilac coloured at the base, and violet and green marls and thin-bedded sandstones. 200 m.

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1 These folds are reported by Suess, though Obrutschew has questioned their existence and therefore the correct interpretation of the margins of these basins as a series of geosynclines.

Covered Interval

8.	Red series of Kokuisk		530 m.
	e. gray dense dolomites	70 m.	
	d. red dolomitic sandstone	10 m.	
	c. green yellow and lilac dolomites with marl layers.	100 m.	
	b. Red heavy - bedded sandstones	250 m.	
	a. Gray sandstones, with quartzites below	100 m.	

Covered Interval

7.	Red Series of Bykowsk		200-400 m.
	c. Gray dense dolomite	50-100 m.	
	b. Red sandstones with conglomerates of dolomite shale and red iron-stone at the base	100-200 m.	
	a. Black dolomites, gray limestones and graphite shales.	50-100 m.	

Lower Division. (2280-3000 meters)

6.	Dschur River Series. Gray and white limestones and dolomites mostly with Stromatopora.	375 m.
5.	Wanitschkow River Series. Gray and yellow shales, with yellow red and varied coloured quartzites	200-1000 m.
4.	White and gray dolomites of Mandscha	500 m.

3.	Shantar Shales. Black and soft shales with concretions of limestone, carbonaceous in the upper part, with carbonaceous limestone	152-200 m.
2.	Terinsk Rapids Series. Black soft shales, dolomites and limestones, partly with *Stromatoporas*	205 m.
1.	Grebenski-byk series. Gray and white dolomites mostly with Stromatoporas, and black thin-bedded coaly shales and coaly limestones	750 m.

Fault

Sinian Beds.

The Middle Cambrian of this region, which has a thickness of 700 meters is mostly calcareous and dolomitic. It is separated from the Lower Cambrian outcrops by a covered interval.

Although the base of this section is not exposed, it is nevertheless recognized as a transgressive series over the Sinian. The middle portion of this enormous series is largely calcareous, consisting of 500 meters of dolomites below and 375 meters of dolomite above. But between the two lie from 200-500 meters of shales and sandstones, indicating a period of oscillation. The upper 930 to 1130 meters is clearly a retreatal series. Red sandstones predominate while the calcareous beds aggregate only from 370 to 470 meters or a little over 40 per cent of the total. Again the enormous thickness of this Lower Cambrian series, assuming that the measurements are correct and that there is no repetition by faulting or folding, is remarkable. Even without the incomplete basal portion, the series aggregates from 3210 to 4130 meters (10, 700-13,767 ft.). It thus represents beyond question a single pulsation unit. When we compare it with the slight development of the Lower Cambrian at Andrarum in Sweden where there are only 335 ft. and this mostly sandstones, or only about 3 per cent of the minimum thickness of the Siberian section (the entire Cambrian there is only 454 ft. thick), we can realize that the Swedish succession represents only the thin wedge of the Lower Cambrian transgression.

Unfortunately, very little is as yet known of the faunas of the Lower Cambrian of these Siberian sections, though more is known of the Middle Cambrian fauna, including that of the Protolenus zone. *Kutorgina cingulata* seems to be among the characteristic Lower Cambrian fossils, as is also *Obolella* cf, *chromatica*. Both of these have been obtained from the Lower Cambrian of the Atlantic province, though the first is more characteristic of the Appalachian province.

At Krasnoiarsk on the left bank of the Yenissei River, (approximate Longitude 55^0 30′ N). A series of red shales, the *Katscha beds* are exposed on the river of that name. These have been referred to the Upper Cambrian by Obrutchew, though Bogdanovitch had classified them as Devonian or Silurian. They are unconformably succeeded by the Ursa continental beds (Dinantian). A few thin beds of limestone are intercalated in the Katscha series, but no fossils have been found in them.

On the opposite bank of the Yenissei, above the village of Torgoshino, from 10-15 meters of limestone, the *Torgoshino beds*, rest unconformably on the strongly folded pre-Palæozoic series. From these beds two trilobites *Dorypyge slatkowskii* and *Solenopleura sibirica* have been obtained, besides a large number of species of Archæocyathids 11 of which are of Sardinian species and 4 of which are new. *Kutorgina* sp, is the only brachiopod reported from these beds. If there is no fault along the Yenissei River, these beds pass under the Katscha series on the opposite bank. Their age however, is not older than Middle Cambrian and an early Ordovician age is not excluded. In any case they represent an over-lap of the later over the Lower Cambrian beds.

Fossiliferous Middle and Upper Cambrian beds, including those of the *Protolenus* zone, have been reported from many districts in Siberia, but as yet the Lower Cambrian fauna is very little known. That the marginal rim was not unbroken throughout the whole of Cambrian time is shown by the occurrence of Middle Cambrian in the upper reaches of the Ob and Tom Rivers, and apparently by the occurrence of Upper? Cambrian along the slopes of the Tianshan as indicated by collections obtained by the Sino-Swedish expedition.

Summary of the Atlanto-Caledonian geosyncline and the Siberian extension

There seems little doubt that the East American Atlantic, and west European Caledonian Lower Cambrian deposits were parts of the geosyncline which was continuous when Europe and North America were still in contact. This geosyncline, which was of course broader than the present area occupied by these strata, was separated by a continuous Caledonian land-mass from the Appalachian geosyncline. This land mass on the European side, is now represented by the old rocks of Scandinavia, north of the Lower Cambrian area, by the old rocks of Northern England, the Highlands of Scotland, and the entire mass of

Ireland, and on the American side by the rocks between the eastern and western borders of Newfoundland and between the Boston (Massachusetts), and Albany-Troy (New York) region of New England. This land mass was of course much wider than the area it now occupies, since it has been subjected several times to intensive folding. In like manner, the two geosynclines were much wider than the area occupied by the rocks today, for we must eliminate the effects of the Appalachian folding in the one case and the Caledonian folding in the other. The latter is chiefly seen in the Cambrian deposits of England and Wales and in those of Eastern Newfoundland and Eastern Massachusetts. In the portion of this geosyncline now on the continent of Europe, very little if any folding has taken place and hence the present extent reveals nearly the former transgression of the Lower Cambrian Sea, except where post Lower Cambrian erosion has removed some of the strata.

Beyond the Baltic borders nothing is known of these older strata as they are covered by much more recent deposits. In only one area in Poland (Polnisches Mittelgebirge) between Warsaw and Krakow, have these strata again been brought to the surface and there we have the typical Lower Cambrian of this geosyncline. Beyond this however, nothing is known until we come to the North Siberian or Irkutsk Basin. No Cambrian strata are known from the Urals, where Devonian and possibly late Silurian beds rest directly upon the crystalline formations.

Since however, these mountains had one elevation in early Palæozoic time, it is quite possible that Cambrian strata, which once may have existed here, could have been removed by erosion, and their eroded edges covered by overlapping Devonian and later strata.

Unless we can connect the deposits of the Caledonian geosyncline with those of the Irkutsk Basin, we have no recognized source of that fauna, unless indeed we must postulate the existence of an Atlantic at that time, as a center of faunal evolution. Though we are not yet certain, that the Lower Cambrian fauna of the Siberian Basin is of the type known from the Caledonian geosyncline, we may so infer from the fact that the known Middle Cambrian fauna of that province shows a close relationship to the corresponding fauna of western Europe and Eastern America, which we refer to the Caledonian geosyncline. The distinctness of this fauna from that of the Palæo-Cordilleran and Appalachian geosynclines, indicates that the continental shelf of this portion of the Boreal Sea was isolated from the corresponding North American shelf on which the *Olenellus* fauna had its home. In Table III will be found a summary of the fauna of the Lower Cambrian of this province.

THE LOWER CAMBRIAN OF THE INDO-CHINESE GEOSYNCLINES

In the East Cathaysian geosyncline of China as far north as Manchuria and in the Himalayan geosyncline and in southern Australia, the Lower Cambrian contains a wholly distinct fauna, which is characterized by the trilobite *Redlichia*. Several sections may be briefly considered.

Salt Range. In the Punjab and Salt Range district of India, the lowest known beds represent some 1500 ft. of sands, shales, and marls (Salt marl) with beds of rock salt and deposits of gypsum (Khewra group). The next succeeding series, with a thickness of 450 ft. is known as the Purple Sandstone and is of dark red colour, marked by ripple-marks, cross-bedding etc, these features indicating a non-marine origin. Formerly these beds were classed as pre-Cambrian in age, because they are succeeded by Lower Cambrian strata, in apparent conformable relation. It is now however, generally believed that these salt-bearing beds are of Tertiary age and that the Cambrian and later strata have been thrust over them.

The Cambrian begins with the Purple Sandstone followed by the *Neobolus* beds or the *Khussak group* about 100 ft. thick and capable of the following sub-division in descending order.[1]

5. Zone of *Redlichia noetlingi*
   Black micaceous clay slate, with *R. noetlingi*, *Lingulella wannecki*, *Hyolithes* sp. etc.
4. Zone of *Neobolus warthi*, red micaceous arenytes and lutytes, with the peculiar brachiopods, *Neobolus warthi*, *N. wynnii*, *Discinolepis granulata*, *Schizopholis rugosa*, *Lakhminia linguloides*, *L. squama*, *Lingula kiurensis*, *L. warthi*.
3. Upper annelid sandstone.
   Glauconitic arenyte, with alternations of thin softer beds. Contains *Orthis* (*Wynnia*) *warthi* and *Hyolithes wynnii*.
2. Zone of *Hyolithes wynnii*. Blackish red arenyte and lutyte with *H. wynnii*, fragments of trilobites etc. 10 ft.
1. Lower annelid sandstone,
   Glauconitic arenyte, alternating with thin beds of softer arenyte and carrying *Obolella*, *Hyolithes* and annelid tracks. 50 ft.

This series is succeeded by the Jutana group or Magnesian Sandstone, 250 ft. of alternating arenytes and dolomites carrying *Helcionella rugosa*, *Schizopholis* sp. etc.

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1 Walcott refers some of these beds to the Middle Cambrian, inferring apparently a complex structure.

This is still classed as Lower Cambrian and is succeeded by the Middle Cambrian Bhagenwalla group of red shales with salt pseudomorphs, 450 ft. thick.

Upon this rests disconformably the Upper Carboniferous glacial tillite of the Talchir group.[1]

Australia and Tasmania. Lower Cambrian rocks are also known from South Australia and Tasmania especially the Peninsula of York.[2] *Redlichia* is also found and the series is in Australia disconformably succeeded by the *Archæocyathid* limestone, probably of Middle Cambrian or much younger age.

China. In the East Cathaysian geosyncline the Lower Cambrian consists of a variable series of red shales and clay, characterized throughout by *Redlichia chinensis.* In Tongking, the Lower Cambrian has been subdivided into the following zones in descending order.

4. Zone of *Redlichia carinata* Mansuy
3. Zone of *Palæolenus douvillii* Mansuy
2. Zone of *Acrothele orbicularis* Mansuy
1. Zone of *Redlichia chinensis* Walcott.

The section given for Yunnan by Deprat, is as follows.

Superformation. Ordovician?

Disconformity

Lower Cambrian.

8. Yellow shale	30 meters
7. Green concretionary marls.	10 „

1 F. Noetling. Records of the Geölogical Survey of India. Vol. XXXVII part III 1894. Also K. A. Redlich, The Cambrian fauna of the eastern Salt Range. Palæontologia Indica, New Series, Vol. I, 1899. with full literature reference.

2 Etheridge. Proceedings Royal Society Tasmania 1882-1883. Also Transactions of the Royal Society of South Australia. Vol. XIII, page 10.

6. Green shaly sandstones with *Redlichia, Palæolenus* etc.	70	meters
5. Sandstone without fossils	40	,,
4. Reddish and yellow marly shales with *Redlichia, Obolus, Aristozoe* Phyllocarids etc.	100	,,
3. Greenish shaly sandstones with *Acrothele*	20	,,
2. Crumbly marl shales with *Redlichia*	80	,,
1. Green arkosic sandstone, base not exposed		

There are thus some 300 meters (1000 ft.) of fossiliferous strata and the basal arkosic sandstone would add another 300 meters wherever fully developed. The Salt Range section lies 1,700 miles (2700 k.m.) to the west.

Shantung. 1,300 miles (2100 k.m.) to the northeast in Shantung, the Manto shale series represents the same succession and this can be traced north into Manchuria. In Shantung the Manto shale is from 150 to 175 meters (500 to 580 ft.) thick and it rests disconformably on the Sinian or unconformably on the older rock. Succeeding it, is the Changhia limestone of Middle Cambrian age, the two being probably separated by a disconformity. The leading fossil everywhere in the Manto shale is *Redlichia chinensis* and associated with it is *Ptychoparia* sp. *Helcionella rugosa* var *chinensis* and *Obolella asiatica.*

Shansi. In southern Shansi, 50 li north of Chishanhsien, the following section was measured by Pere Teilhard de Chardin and C. C. Young.[1]

Superformation.

Cambro-Ordovician limestone, forming the mountain range.

Probable disconformity.

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1 Bulletin of Geol. Soc. of China Vol. X, p. 179 et seq.

Lower Cambrian

6. Red shales, interbedded with several thin layers of fossiliferous upper limestone	5 meters
5. Red shale	20 meters
4. Middle Limestone, Fossiliferous	2 meters
3. Red shales	15 meters
2. Lower limestone several layers or lenses fossils are trilobites only	20 meters
1. Quartzite and consolidated arkose	2 meters

Unconformity

Subformation: Archæan-gneiss etc.

Beds 4 and 6 are very largely composed of a *Hyolithid*-like organism, which Pere Teilhard has named, *Biconulites grabaui* and which, though simpler in character recalls some of the detailed structure of *Salterella*. The other fossils from these linestones have not yet been studied.

Manchurian Provinces of China. In southern Manchuria, between Moukden and Lushan, the Lower Cambrian is well exposed and a number of sections made by various individuals are published by Yabe and Osaki.[1]

What appears to be a complete section is exposed at Lienliwan along the Tai-Tsu-Ho, opposite Hsiao-Hsuan a short distance south of Moukden. In descending order.

Superformation Middle Cambrian Limestone

Disconformity?

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1 H. Yabe and K. Osaki, *Girvanella*, in the Lower Cambrian of South Manchuria. Science Reports of the Tohoku-Imperial University, 2nd series Geology Vol. XIV. No. 1, pp. 79-83, Pl. XXV, 1930.

Lower Cambrian.

23. Gray micaceous sandstone.
22. Grayish-green micaceous sandstone with a thin bed of greyish white crystalline limestone.
21. Brown micaceous sandy shale
20. Pisolitic limestone, composed of *Girvanella manchurica*. Y. & O.
19. Green shale
18. Brown shale, with marl balls.
17. Red shale
16. Brown shale with marl balls
15. Gray oolitic limestone with *Ptychoparia aclis* Walcott
14. Brown shale
13. Gray oolitic limestone with green spots.
12. Brown micaceous sandy shale
11. Brown to red marl, with 2 or 3 thin layers of fossiliferous marls intercalated.
10. Brown siliceous marl, with *Redlichia nobilis.*
9. Black limestone.
8. Banded platy marl, alternately grayish yellow and bluish-gray in colour.
7. Red marly shale
6. Yellow marl
5. Black limestone, with numerous calcite veinlets and becoming platy upwards.
4. Marly shale, either dark gray or grayish yellow, and with small limestone nodules arranged in layers and increasing in number upwards; contains *Redlichia chinensis* Walcott.
3. Black limestone
2. Grayish yellow shale, bluish gray shale and light-red marl in alternation.

1. Red shale and red sandstone in alternation, with a thin calcareous sandstone, occasionally with a conglomerate in basal part.

Diconformity or Unformity?

Subformation:

Pre-Cambrian quartzites (Sinian?)

Another more satisfactory section because the thicknesses are given was measured at Chin-Chia-Cheng-Tzu. Fu Hsien, in the southern part of the area; in decending order.

Superformation. Middle Cambrian Limestone

Disconformity?

Lower Cambrian

16. Red or yellowish brown micaceous sandstone, intercalated with lenticular limestone, about	100 meters
15. Reddish, purple shale and oolitic limestone, with *Ptychoparia aclis* Walcott, *P. impar* Walcott, *Redlichia nobilis* Walcott. *Helcionella* and brachiopods	40 meters
14. Grayish white or reddish brown marl, about	15 meters
13. Oolitic limestone and limestones made of *Girvanella manchurica* Y. and O.	6 meters
12. Grayish-white or reddish-brown marl with trilobites in fragments, about	15 meters
11. Oolitic limestone, about	3 meters
10. Yellowish green shale, about	10 meters
9. Black limestone with brown spots, about	50 meters

8.	Yellowish green shale intercalated with limestone containing trilobites, about	20 meters
7.	Black limestone about	20 meters
6.	Reddish purplish shale with *Redlichia chinensis* Walcott	25-50 meters
5.	Green shale and nodular limestone, about	3-10 meters
4.	Reddish-brown crystalline limestone about	10 meters
3.	Black limestone about	150-200 meters
2.	Black platy marly limestone, about	100 meters
1.	Marly shale and siliceous sandstone thickness unknown?	
Total Lower Cambrian exclusive of bed I.		567-650 meters

Summary of the Indo-Chinese district.

So far as the Lower Cambrian of this province is now known, it is wholly distinct from any of the others, and clearly represents a transgression from an isolated portion of the ancient sea. These waters entering Asia by the Burma Straits, penetrated throughout the Himalayan geosyncline, to the Salt Range and beyond into Persia. A second branch extended northeastward through the East Cathaysian geosyncline north into Manchuria, but there was no connection with the Irkutsk Basin or any other water body. That the sea retreated at the end of Lower Cambrian time and returned in Middle Cambrian time is shown by the abrupt change in fauna rather than by any marked evidence of a disconformity at present known. Not a single species extends from the Lower into the Middle Cambrian. The fauna of this province is summarized in Table IV.

TABLE I

LOWER CAMBRIAN FAUNAS OF THE APPALACHIAN GEOSYNCLINE

In Columns 1-7, the successive formations of the *Southern Appalachians* in Georgia, Albama and Tennessee are given. They include the following from the base up.

Col. 1 Nichol's shale
Col. 2 Nebo sandstone
Col. 3 Murray shale
Col. 4 Hesse sandstone and Erwin quartzite
Col. 5 Apison shale
Col. 6 Beaver or Shady limestone
Col. 7 Rome Sandstone, including Montevallo sandstone and Weissner quartzite.

Cols 8-13 represent the localities in the *Middle Appalachians*, that is in Virginian Maryland, Pensylvania and New Jersey.

Cols 8-11 represent, the successive formation as follows from the base upward.

Col. 8 Chickies quartzite
Col. 9 Harpers and Antietam formations.
Col. 10 Tomstown limestone and Kinzer's shale. Shady limestone.
Col. 11 Waynesboro sandstone = Rome sandstone
Col. 12 Represents the Lower Cambrian localities in York, Lancaster and Cumberland counties Pennsylvania. The horizons not differentiated.

Col. 13 Represents the localities in Washington Co. Maryland and Rockbridge Co. Virginia, with the horizons not differentiated.

Cols 14-18 represent the *Northern Appalachians* of Eastern New York, Vermont, Ontario, Quebec, West Newfoundland, and Labrador.

Col. 14 Locality at Troy and other localities in Rensselaer Co. New York, as well as those of Washington Co, Columbia Co. and Duchess Co, New York.

Col. 15 Vermont Localities, including Parker's quarry at Georgia, the outcrops at Swanton and at Highgate Springs all in Franklin Co, also those of Rutland Co.

Col. 16 Pebbles or boulders in younger conglomerates at Bic and other localities in Quebec.

Col. 17 Lower Cambrian beds of Bonne Bay Western Newfoundland.

Col. 18 Cambrian beds of L'Anse au Loupe and other localities on the Labrador Coast of the Straits of Belle-Isle.

Col. 19 Bastion formation of Eastern Greenland.

Col. 20 Ella Island formation Eastern Greenland

Col. 21 Lower Cambrian of Northwest Scotland especially the Serpulite grit.

Col. 22 Also in Lower Cambrian Cordilleran Geosyncline

Col. 23 Also Lower Cambrian of Caledonian Geosyncline

Col. 24 Also in the Middle Cambrian.

Table I

Fossils of the Lower Cambrian Beds of the Appalachian Geosycline

	Southern App.							Middle App.						North App.					E.G.					
	1 Nichols sh.	2 Nebo s.s.	3 Murray sh.	4 Hesse etc.	5 Apison	6 Shady etc.	7 Rome Form.	8 Chickies	9 Harpers etc.	10 Tomstown	11 Waynesboro	12 Pennsylvania	13 Md. & Va.	14 Troy NY. Wash. Co.	15 Vermont	16 Quebec	17 Bonne Bay	18 Anse au Loup.	19 Bastion Form.	20 Ella Isl. Form.	21 North Scotland	22 Cordilleran Geos.	23 Caledonian Geos.	24 Middle Cambrian
ALGÆ																								
1. Palæophycus congregatus Billings	|	|	|	|	|	|	|	|	|	|	|	|	|	|	×									
2. Palæophycus incipiens Billings	|	|	|	|	|	|	|	|	|	|	|	|	|	|	×	|	|	×						
ARCHÆOCYATHIDÆ																								
1. Archæocyathus dwighti Walcott	|	|	|	|	|	sp	|	|	|	|	|	|	|	×										
2. Archæocyathus raris Walcott	|	|	|	|	|	|	|	|	|	|	|	|	|	×										
3. Archæocyathus rensselaericus (Ford)	|	|	|	|	|	|	|	|	|	|	|	|	|	×										
4. Archæocyathus profundis Billings	|	|	|	|	|	|	|	|	|	|	|	|	|	|	|	|	|	×						
5. Spirocyathus atlanticus (Billings)	|	|	|	|	|	|	|	|	|	|	|	|	|	|	|	|	|	×						
6. Coscinocyathus billingsi Walcott	|	|	|	|	|	|	|	|	|	|	|	|	|	|	|	|	|	×						
GRAPTOZOA?																								
1. Phyllograptus? cambrensis Walcott	|	|	|	|	|	|	|	|	|	|	|	|	|	|	×									

Table I (*Continued*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
GRAPTOZOA? (cont.)																								
2. Climacograptus? emmonsi Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×									
VERMES?																								
1. Scolithus linearis Haldemann	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	×	—	×			
BRACHIOPODA																								
1. Rustella edsoni Walcott	—	—	—	—	—	—	—	—	—	—	—	×	—	—	×									
2. Micromitra nisus (Walcott)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×								
3. Micromitra scotica Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
4. Paterina bella (Billings)	—	—	—	—	—	—	—	—	—	—	—	×	—	—	×	×	×	—	—	—	—	—	×	
5. Paterina labradorica (Billings)	—	—	—	—	—	sp	—	—	—	—	—	—	—	×	—	×	×	×	—	—	×	×	×	
6. Paterina labradorica var swantonensis (Walcott)	—	—	—	—		—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	×
7. Paterina major Walcott	—	—	—	—	—	—	×																	
8. Paterina willardi Walcott	—	—	—	—	—	—	×																	
9. Paterina lata Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×					
10. Paterina mediocris Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×				
11. Iphidella pannula (White)	—	—	—	—	—	—	×	—	—	—	—	—	—	×	—	—	—	—	—	—	—	×	—	×
12. Obolus prindlii (Walcott)	—	—	—	—	—	—	—	—	—	—	—	—	—	×	×									
13. Obolus smithi Walcott	—	—	—	—	—	—	×																	
14. Lingulella granvillensis Walc.	—	—	—	—	—	—	—	—	—	—	sp	—	—	×	×									
15. Lingulella schucherti (Walcott)	—	—	—	—	—	—	—	—	—	—	—	—	—	×										
16. Lingulella zeus Walcott.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
17. Lingulepis prisca Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×					
18. Bicia (Obolella) gemma (Billings)	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	×	—	×						

Table I (*Continued*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
BRACHIOPODA (cont.)																								
19. Bicia whiteavesi Walcott,	—	—	—	—	—	—	—	—	—	—	—	—	—	×										
20. Kutorgina cingulata (Billings)	—	—	—	—	—	sp	—	—	—	sp	—	—	—	—	×	×	×	×	—	—	—	×	×	
21. Kutorgina reticulata Poulsen	—	—	—	—	—	-	—	—	—	—	—	—	—	—	—	—	—	—	—	×				
22. Obolella atlantica Walcott	—	—	—	—	—	—	cf	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	
23. Obolella chromatica Billings	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	×	×	—	—	—	×		
24. Obolella crassa (Hall)	—	—	—	—	—	—	?	—	—	—	—	×	—	×	×	×	—	×	—	—	—	—	×	
25. Obolella crassa elongata Walcott.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×								
26. Obolella minor (Walcott)	—	—	—	—	—	—	—	—	—	—	—	×	×	×										
27. Obolella congesta Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—		—	—	—	—	×					
28. Botsfordia cælata (Hall)	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	×	×	×	—	—	—	×		
29. Quebecia suessi (Billings)	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	×								
30. Yorkia wanneri Walcott		—	—	—	—	—	—	—	—	—	—	×	—	—	—	×								
31. Yorkia? washingtonensis Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	×		
32. Acrothele subsidua (White)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	×		
33. Acrothele decipiens Walcott	—	—	—	—	—	—	—	—	—	—	—	×												
34. Acrothele nitida (Ford)	—	—	—	—	—	—	—	—	—	—	—	—	—	×										
35. Acrotreta emmonsi Walcott	—	—	—	—	—	sp	—	—	—	—	—	—	—	×										
36. Acrotreta sagittalis taconica (Walcott)	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	×		
37. Nisusia festinata (Billings)	—	—	—	—	—	sp	—	—	—	—	—	×	—	×	×	×	—	×	—	—	—	×		
38. Nisusia festinata transversa (Walcott)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×									
39. Jamesella amii Walcott.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	×		

Table I (*Continued*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
BRACHIOPODA (cont.)																								
40. Jamesella oriens Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×						
41. Wimanella shellwienensis Walcott	—	—	—	—	—	—	×																	
42. Billingsella orientalis (Whitfield)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×									
43. Billingsella salemensis (Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	×								
44. Swantonia autiquata (Billings)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×									
PELECYPODA																								
1. Fordilla troyensis Barrande	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	×	
GASTROPODA etc.																								
1. Scenella varians Walcott	—	—	—	—	—	sp	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	×		
2. Scenella retusa Ford	—	—	—	—	—	—	—	—	—	—	—	—	—	×										
3. Helcionella rugosa (Hall)	—	—	—	—	—	—	×	—	—	—	—	—	—	×	×	—	×	×	—	—	—	×	×	
4. Helcionella elongata Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	×	—	—	—	×		
5. Helcionella cingulata Cobbold?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×					
6. Discinella micans (Billings)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	×				
7. Discinella brastadi Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×				
8. Pelagiella (Platyceras) primævum (Billings)	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	×	—	—	—	—	×		
9. Hyolithes americanus Billings	—	—	—	—	—	—	—	—	—	—	—	—	—	×	×	×	—	—	×	—	—	—	×	
10. Hyolithes emmonsi Ford	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	×	
11. Hyolithes impar Ford	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	×	
12. Hyolithes billingsi Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	×	×	—	—	×	×	
13. Hyolithes princeps Billings	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	?	—	—	—	—	×	

Table I (*Continued*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
GASTROPODA etc. (cont.)																								
14. Hyolithes similis Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	×	
15. Hyolithes mutatus Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×					
16. Orthotheca? communis (Billings)	—	—	—	—	—	—	—	—	—	—	—	—	×	×	×	—	×	—	×	—	—	—	×	
17. Orthotheca? cf. fistula (Hall)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	×	
18. Orthotheca bayonet Matthew var. grönlandicus Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×					
19. Orthotheca bayonet Matthew var. longus Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×					
20. Hyolithellus micans Billings	—	—	—	—	—	—	—	—	—	—	—	—	—	×	×	×	×	—	×	×	—	×	×	
21. Hyolithellus micans rugosa Walcott.	—	—	—	—	—	—	—	—	—	—	—	—	—	×										
22. Helenia bella Walcott.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	×	
CEPHALOPODA																								
1. Salterella pulchella Billings	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	×	×	—	—	×			
2. Salterella rugosa Billings	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	×	—	×	×			
3. Salterella maccullochi (Salter)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
OSTRACODA?																								
1. Leperditia? dermatoides Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	×										
TRILOBITÆ																								
1. Mesonacis vermontana (Hall)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	×	×						
2. Elliptocephala asaphoides Emmons	—	—	—	—	—	—	—	—	—	—	—	—	—	×										

Table I (*Continued*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
TRILOBITÆ (cont.)																								
3. Olenellus thompsoni Hall	—	—	—	—	—	×	×	—	—	×	×	×	×	×	×									
4. Olenellus thompsoni crassimarginatus Walcott	—	—	—	—	—	—	—	—	—	—	—	×	—	—	×	—	×							
5. Olenellus thompsoni rudis Walcott	—	—	—	—	—	—	—	—	—	—	—	×												
6. Olenellus lapworthi Peach & Horne	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
7. Olenellus logani Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	×						
8. Olenellus reticulatus Peach	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
9. Olenellus? gigas Peach	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
10. Olenellus simplex Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×				
11. Olenellus? curvicornis Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×				
12. Olenellus armatus Peach	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
13. Callavia bicensis Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×								
14. Wanneria walcottana (Wanner)	—	—	—	—	—	—	—	—	—	—	—	×												
15. Wanneria halli Walcott	—	—	—	—	—	—	×																	
16. Wanneria nathorsti Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×				
17. Wanneria ellæ Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×				
18. Pædeumias transitans Walcott	—	—	—	—	—	—	×	—	—	×	—	×	—	—	×	×	×	×						
19. Pædeumias tricarinatuso Pulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×				
20. Pædeumias hanseni Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×				
21. Zacanthoides spinosus Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x?							
22. Zacanthoides eatoni Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	×										
23. Olenoides marcoui (Whitfield)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×									
24. Olenoides desiderata (Walcott)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×									

Table I (*Continued*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
TRILOBITÆ (cont.)																								
25. Olenoides fordi Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	×										
26. Olenoides ellsi Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×								
27. Olenopsis roddyi Walcott	—	—	—	—	—	—	—	—	—	—	—	×												
28. Ptychoparia adamsi Billings	—	—	—	—	—	—	—	—	—	—	—	—	—	×	×									
29. Ptychoparia fitchi Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	×										
30. Ptychoparia teucer (Billings)	—	—	—	—	—	—	—	—	—	—	—	—	—	×	×									
31. Ptychoparia miser Billings	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×						
32. Ptychoparia trilineata (Emmons)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×									
33. Ptychoparia meticensis Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×								
34. Ptychoparia subcoronata (Hall & Whitfield)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	cf.								
35. Solenopleura tumida Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	×										
36. Solenopleura nana Ford	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	×						
37. Agraulos redpathi Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×								
38. Polyostracus strenuelliformis Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×				
39. Polyostracus noe-nyggardi Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×				
40. Polyostracus rosenkrantzi Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×				
41. Acrocephalites vulcanus (Billings)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×									
42. Bathynotus holopyga (Hall)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×									

Table I (*Concluded*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
TRILOBITÆ (cont.)																								
43. Corynexochus senectus (Billings)	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	×	×	×	—	—	—	×		
44. Corynexochus brennus Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×								
45. Corynexochus buraris Walcott	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	×								
46. Corynexochus capito Walcott	—	—	—	—	—	—	—	—	—	—	—	×	—	—	×									
47. Corynexochus clavatus Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	×										
48. Bonnia parvulus Billings	—	—	—	—	sp	—	—	—	—	—	—	—	—	—	×	×	—	×						
49. Bonnia busa Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×								
50. Bonnia grönlandica Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×				
51. Protypus hitchcocki (Whitfield)	—	—	—	—	—	—	—	—	—	—	—	—	—	×	×									
52. Agnostus desideratus Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	×										
53. Nicrodiscus parkeri Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×									
54. Microdiscus schucherti Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	×										
55. Goniodiscus lobatus (Hall)	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	×	
56. Eodiscus speciosus (Ford)	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	×	
57. Eodiscus connexus (Walcott)	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	×								
58. Kootenia sp.	—	—	—	—	—	×																		
59. Neolenus sp.	—	—	—	—	—	×																		
OTHER CRUSTACEA																								
1. Isoxys chilhoweeana Walcott	—	—	×																					
2. Protocaris marshi Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×									

TABLE II

LOWER CAMBRIAN FAUNAS OF THE CORDILLERAN GEOSYNCLINE OF WESTERN NORTH AMERICA

In Cols 1-8, the horizons and localities in the Canadian Rockies are given. In Cols 9-12, those of the Utah, Nevada and California region, and in Cols 13 and 14, those of Northwest Greenland. In Cols. 15-17 the occurrences in other geosynclines and horizons are given. The following are the localities and horizons in ascending order.

Cols 1 Lake Louise Shale 3500 ft. below the Middle Cambrian.

Col. 2 Saint Piran sandstone of the Lake Louise Sections Bed 1f 2080 ft. below the Mount Whyte formation.

Col. 3 Saint Piran sandstone of Vermilion Pass, B.C. about 2050 ft. below the Mount Whyte (60b) and 2300 ft. below Mount Whyte.

Col. 4 Upper 500 ft. of the Saint Piran including.
- d Castle Mountain section 55 ft. below top
- c Ptarmigan Peak section 68-498 ft. below top
- b Mount Bosworth section (1b) 68-378 ft. below top
- a Mount Bosworth section (1c) 378-503 ft. below top.

Col. 5 Upper 300 ft. of Hota limestone, of Robson Peak section.

Col. 6 Lower Mount Whyte formation. Including the following beds.

c Mount Stephen section beds 6, 5, 4.
d Mount Bosworth section, beds 4 & 3.
e Ross Lake section beds 6, 5 & 4?
f Siffleur River section, beds 1b and 1a?
g Mount Schaffer section, beds 6, 5, 4? and 3?
h Mount Temple section beds 7, 6, 5 and 4
i Lake Louise section beds 1e, 1d?
j Mount Assiniboine section, bed 6.
m Ptarmigan Peak section beds 4 and 3?
n Castle Mountain section beds 4 and 1c?

Col. 7 Upper Mount Whyte formation, including the following horizons and locations

c Mount Stephen section, beds 3b, 3a, 2b, 2a and 1.
d Mount Bosworth section beds 2, 1c, and 1a.
e Ross Lake section beds 3, 2 and 1
f Siffleur River section. Probably absent.
g Mount Schaffer section, beds 3? 2 and 1
h Mount Temple section bed 1.
i Lake Louise section beds 1c, 1b, 1a
j Mount Assiniboine section, bed 5.
m Ptarmigan Peak section. beds 2 top? beds 1c, 1b, 1a.
n Castle Mountain section beds 1c? 1b, 1a.

Col. 8 Highest Mount Whyte formation comprising beds 3, 2 and 1 of the Mount Assiniboine section

Col. 9 House Range section and Wasateh Range including the Prospect Mountain sandstone and Pioche formation.

Col. 10 Pioche and Eureka, Nevada, section, including

a the Pioche shale of Pioche Nevada,

b the Pioche shale of Eureka Nevada,

c The Prospect Mountain sandstones of Eureka Nevada, and

d the localities in Lincoln and Esmeralda Counties Nevada.

Col. 11 Silver Springs formation of Nevada and California, including (a) the Wacoba Springs of Injo County Cal., and the localities in Deep Spring Valley and (b), the Barrel Springs section Nevada, and the locality at Bennet Springs.

Col. 12 Lower Cambrian beds of Bristol Mountain, Mohave Desert Cal.

Col. 13 Wulff River formation of Northwest Greenland

Col. 14 Cape Kent formation of Northwest Greenland

Col. 15 Also in Lower Cambrian of Appalachian Geosyncline

Col. 16 Also in Lower Cambrian of Caledonian Geosyncline

Col. 17 Also in Middle Cambrian

Table II

Lower Cambrian Faunas of the Cordilleran Geosyncline

	L.Louise shale	St. Piran Sandstone			Hota Limest.	Mt. Whyte L.	Mt. Whyte U.	Mt. Whyte Top	Utah, Nevada California				Northwest Greenland		Appalachian Geosyncline	Caledonian Geosyncline	Middle Cambrian
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
ARCHÆOCYATHIDS																	
1. Archæocyathus atreus Walcott	—	—	—	—	—	—	—	×									
2. Archæocyathus sp.	—	—	—	—	—	—	—	—	—	—	×						
3. Ethmophyllum gracile	—	—	—	—	—	—	—	—	—	—	×						
BRACHIOPODA																	
1. Mickwitzia occidens Walcott	—	—	—	—	—	—	—	—	—	—	×						
2. Mickwitzia muralensis Walcott	—	—	—	—	×												
3. Paterina labradorica (Billings)	—	—	—	—	—	—	×	×	—	—	×	—	—	—	+	+	
4. Paterina prospectensis Walcott	—	—	—	—	—	—	—	—	—	×	×	×					
5. Paterina charon Walcott	—	—	—	—	—	x?											
6. Paterina lata Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	×				
7. Paterina wapta Walcott	—	—	—	—	—	×	×	—	—	—	—	—	—	—	—	—	×
8. Paterina sp.	—	—	—	—	—	—	×										
9. Iphidella louise Walcott	×																
10. Iphidella pannula (White)	—	—	—	—	—	×	×		×	×	×	—	—	—	×	—	×
11. Obolus (Westonia) whymperi Walcott	—	—	—	—	—	—	×										
12. Obolus (Westonia) ella (Hall & Whitfield)	—	—	—	—	—	—	—	—	×	×	×	—	—	—	—	—	×
13. Obolus parvus Walcott	—	—	—	—	—	×	×	—	—	—	—	—	—	—	—	—	×
14. Obolus domo Walcott	—	—	—	—	—	—	×										

Table II (*Continued*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
BRACHIOPODA (cont.)																	
15. Obolus? sp.	—	—	—	—	—	—	×										
16. Lingulepis rowi (Walcott)	—	—	—	—	—	—	—	—	—	—	—	×					
17. Lingulella chapa Walcott	—	—	—	—	×												
18. Lingulella hitka Walcott	—	—	—	—	×												
19. Lingulella sp.	—	—	—	—	—	—	×										
20. Kutorgina cingulata (Billings)	—	—	—	—	—	×	—	cf	—	—	×	—	—	—	×	×	
21. Kutorgina perugata Walcott	—	—	—	—	—	—	—	—	—	×	×						
22. Obolella nuda Walcott	—	—	—	—	×												
23. Obolella chromatica Billings	—	—	—	—	×	—	—	—	—	—	—	—	—	—	×		
24. Obolella vermilionensis Walcott	—	—	×	—	—	—	—	—	—	—	×						
25. Obolella sp.	—	—	—	—	—	—	—	—	—	—	×						
26. Botsfordia cælata (Hall)	—	—	—	—	—	—	—	—	—	—	—	—	×	—	×		
27. Yorkia wanneri Walcott	—	—	—	—	—	—	—	—	—	×	×	—	—	—	×		
28. Trematobolus excelsis Walcott	—	—	—	—	—	—	—	—	—	—	×						
29. Siphonotreta? dubia Walcott	—	—	—	—	—	—	—	—	—	—	×						
30. Acrothele spurri Walcott	—	—	—	—	—	—	—	—	—	×	×						
31. Acrothele clitus Walcott	—	—	—	—	—	—	×										
32. Acrothele subsidua (White)	—	—	—	—	—	—	—	—	—	×	—	—	—	—	×		
33. Acrothele subsidua hera Walcott	—	—	—	—	—	—	—	—	—	×							
34. Acrothele colleni Walcott	—	—	—	—	—	×	×	—	—	—	—	—	—	—	—	—	×
35. Acrothele? pulchra Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	×				
36. Acrotreta claytoni Walcott	—	—	—	—	—	—	—	—	×	—	×						
37. Acrotreta primæva Walcott	—	—	—	—	—	—	—	—	×	×	—	—	—	—	—	—	×
38. Acrotreta sagittalis taconica Walcott	—	—	—	—	—	×	×	×	—	—	—	—	—	—	×		
39. Nissusia alberta Walcott	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	×

Table II (*Continued*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
BRACHIOPODA (cont.)																	
40. Nissusia alberta var, Walcott	—	—	—	—	—	—	×										
41. Nissusia festinata (Billings)	—	—	—	—	—	×	—	—	—	—	—	—	—	—	×		
42. Nissusia sp.	—	—	—	—	—	—	—	×									
43. Jamesella argenta Walcott	—	—	—	—	—	—	—	—	—	—	×						
44. Jamesella amii Walcott	—	—	—	—	—	—	—	—	—	—	×	—	—	—	×		
45. Jamesella lowi Walcott	—	—	—	—	—	—	×	×									
46. Jamesella erecta Walcott	—	—	—	—	—	—	—	—	—	×							
47. Wimanella inyoensis Walcott	—	—	—	—	—	—	—	—	—	—	×						
48. Wimanella catulus	—	—	—	—	—	—	×										
49. Wimanella? sp.	—	—	—	—	—	—	×										
50. Billingsella bivia Walcott	—	—	—	—	—	—	—	—	—	—	×						
51. Billingsella highlandensis (Walcott)	—	—	—	—	—	—	—	—	—	×	×						
52. Swantonia weeksi Walcott	—	—	—	—	—	—	—	—	—	—	×						
53. Swantonia sp.	—	—	—	—	—	—	—	—	—	—	×						
GASTROPODA etc.																	
1. Scenella varians Walcott	—	—	—	—	—	×	×	×	—	—	—	—	—	—	×		
2. Scenella? conula Walcott	—	—	—	—	—	—	—	—	—	×							
3. Scenella sp.	—	—	—	—	—	×	—	—	—	—	×						
4. Helcionella rugosa (Walcott)	—	—	—	—	—	—	—	—	—	—	×	—	—	—	×	×	
5. Helcionella scenella (Walcott)?	—	—	—	—	—	—	—	—	—	×							
6. Helcionella elongata (Walcott)	—	—	—	—	—	—	×	×	—	—	cf	—	—	—	×		
7. Bellerophon antiquatus Whitfield	—	—	—	—	—	—	—	—	—	×							
8. Platyceras sp.	—	—	—	—	—	—	×										
9. Pelagiella sp.	—	—	—	—	—	—	×										
10. Hyolithes billingsi Walcott	—	—	—	—	—	×	×	×	—	×	—	—	—	×	×	×	

Table II (*Continued*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
GASTROPODA etc. (cont.)																	
11. Hyolithes sp.	—	×	—	×	×	×	×	×									
12. Orthotheca adamsi	—	—	×														
13. Orthotheca sp.	—	×	—	—	—	×	—	—	—	—	×						
14. Hyolithellus cf. micans Billings	—	—	—	—	—	—	×	—	—	—	—	—	—	—	×	×	×
15. Hyolithellus sp.	—	—	—	—	—	×	×	—	—	—	×						
CEPHALOPODA																	
1. Salterella expansa. Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	×				
2. Salterella sp.	—	—	—	—	—	—	—	—	—	—	×	—	×				
VERMES AND TRAILS																	
1. Cruziana sp.	×	—	—	—	—	—	—	—	×	—	×						
2. Annelid trails	×	—	—	×	—	—	—	—	×								
3. Scolithus sp.	—	×	—	×	—	—	—	—	—	—	×						
4. Scolithus linearis Haldemann	—	—	—	—	—	—	—	—	—	—	×	—	—	—	×		
TRILOBITA																	
1. Mesonacis gilberti (Meek)	—	×	—	×	—	×	×	—	—	×	×						
2. Mesonacis fremonti Walcott	—	—	—	—	—	—	—	—	—	×	×	×					
3. Mesonacis bristolensis Resser	—	—	—	—	—	—	—	—	—	—	—	×					
4. Mesonacis insolens Resser	—	—	—	—	—	—	—	—	—	—	—	×					
5. Olenellus cf. thompsoni (Hall)	—	—	—	—	—	×	—	—	—	—	—	—	—	—	×		
6. Olenellus truemani Walcott	—	—	—	—	×												
7. Olenellus argentus Walcott	—	—	—	—	—	—	—	—	—	—	×						
8. Olenellus canadensis Walcott	—	×	—	×	×	×	×										
9. Olenellus claytoni Walcott	—	—	—	—	—	—	—	—	—	—	×						
10. Olenellus arcticus Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	×				

Table II (*Continued*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
TRILOBITA (cont.)																	
11. Olenellus grönlandicus Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
12. Olenellus kentensis Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
13. Olenellus sp.	—	—	—	×	×	×	×	—	—	—	×	—	×	×			
14. Holmia rowi Walcott	—	—	—	—	—	—	—	—	—	—	×						
15. Holmia sp.	—	—	—	—	—	—	—	—	—	—	×						
16. Nevadia weeksi Walcott	—	—	—	—	—	—	—	—	—	—	×						
17. Callavia breviloba Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	×				
18. Callavia eucharis Walcott	—	—	—	—	×												
19. Callavia perfecta Walcott	—	—	—	—	×												
20. Wanneria occidens Walcott	—	—	—	—	×												
21. Wanneria gracile Walcott	—	—	×	—	—	—	—	—	—	—	×						
22. Peachella iddingsi Walcott	—	—	—	—	—	—	—	—	—	×	×						
23. Pædeumias nevadensis Walcott	—	—	—	—	—	—	—	—	—	×	×	×					
24. Pædeumias clarki Resser	—	—	—	—	—	—	—	—	—	—	—	×					
25. Olenopsis crita Walcott	—	—	—	—	—	?	×										
26. Olenopsis leuka Walcott	—	—	—	—	—	×											
27. Kochiella agnesensis (Walcott)	—	—	—	—	—	×	×										
28. Kochiella cleora (Walcott)	—	—	—	—	—	—	×	×	—	—	×						
29. Kochiella tuberculata Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
30. Kochiella propinqua Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
31. Kochiella arcana Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
32. Kochiella gracilis Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
33. Oryctocephalus primus Walcott	—	—	—	—	—	—	—	—	—	×							
34. Dorypyge damia Walcott	—	—	—	—	—	—	—	×									
35. Dorypyge quadriceps (Hall & Whitfield)	—	—	—	—	—	—	—	—	—	×							

Table II (*Continued*)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
TRILOBITA (cont.)																	
36. Ptychoparia gogensis Walcott	—	—	—	—	—	—	—	×									
37. Ptychoparia skapta Walcott	—	—	—	—	—	—	—	×									
38. Ptychoparia cercops Walcott	—	—	—	—	—	—	×										
39. Ptychoparia cilles Walcott	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	×
40. Ptychoparia cleadas Walcott	—	—	—	—	—	—	×										
41. Ptychoparia pia Walcott	—	—	—	—	—	×	×										
42. Ptychoparia carina Walcott	—	—	—	—	—	—	×										
43. Ptychoparia perola Walcott	—	—	—	—	—	×	×										
44. Ptychoparia lux Walcott	—	—	—	—	—	—	×										
45. Ptychoparia adina Walcott	—	—	—	—	—	—	×										
46. Ptychoparia cossus Walcott	—	—	—	—	—	—	×										
47. Ptychoparia cuneàs Walcott	—	—	—	—	—	×											
48. Ptychoparia cleon Walcott	—	—	—	—	—	×											
49. Ptychoparia clusia Walcott	—	—	—	—	—	—	×										
50. Ptychoparia sp.	—	—	—	×	—	×	×										
51. Poliella primus Walcott	—	—	—	—	—	×	×										
52. Inglefieldia porosa Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
53. Inglefieldia planilimbata Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
54. Inglefieldia grönlandica Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
55. Inglefieldia thia (Walcott)	—	—	—	—	—	×	×	—	—	—	—	—	—	×			
56. Inglefieldia inconspicua Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
57. Inglefieldia affinis Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
58. Inglefieldia discreta Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
59. Chancia venulosa Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
60. Solenopleura grönwalli Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	×			

Table II (*Continued*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
TRILOBITA (cont.)																	
61. Solenopleura similis Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
62. Solenopleura bullata Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
63. Solenopleura borealis Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
64. Strenuella grönlandica Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	×				
65. Agraulos slator Walcott	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	×
66. Agraulos charops Walcott	—	—	—	—	—	×											
67. Agraulos unca Walcott	—	—	—	—	—	—	×										
68. Agraulos sp.	—	—	—	—	—	×	×	—	—	—	×						
69. Corynexochus senectus (Billings)	—	—	—	—	—	—	×	—	—	—	×	—	—	—	×		
70. Bonnia fieldensis Walcott	—	—	—	—	—	×											
71. Bonnia sp.	—	—	—	—	—	×											
72. Dolichometopsis resseri Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
73. Dolichometopsis septentrionalis Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
74. Dolichometopsis minuta Poulsen	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
75. Crepicephalus cecinna Walcott	—	—	—	—	—	—	×	×	—	—	—	—	—	cf			
76. Crepicephalus chares Walcott	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	×
77. Crepicephalus augusta Walcott	—	—	—	—	—	—	—	—	—	×	×						
78. Crepicephalus liliana Walcott	—	—	—	—	—	—	—	—	—	×	×						
79. Crepicephalus celer Walcott	—	—	—	—	—	—	×										
80. Crepicephalus sp. Walcott	—	—	—	—	—	—	×										
81. Zacanthoides levis Walcott	—	—	—	—	—	—	—	—	—	×							
82. Zacanthoides sp.	—	—	—	—	—	—	×										
83. Protypus sp.	—	—	—	—	—	×											
84. Microdiscus sp.	—	—	—	—	—	×	×										

Table II (*Concluded*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
OTHER CRUSTACEA																	
1. Hymenocaris sp.	—	—	—	—	×												
2. Shafferia cisina Walcott	—	—	—	—	—	—	×										
CYSTOIDEA																	
1. Gogia prolifica Walcott	—	—	—	—	—	—	×										
2. Eocystites? longidactylus Walcott	—	—	—	—	—	—	—	—	—	×							
3. Eodiscus sp.	—	—	—	—	—	—	×										
4. Cystid plates	—	—	—	—	×	—	×										
PLANTÆ																	
1. Girvanella sp.	—	—	—	—	—	—	—	—	—	×							

(+ signipies related type)

TABLE III

LOWER CAMBRIAN FAUNAS OF THE CALEDONIAN GEOSYNCLINE

In Cols 1 and 2, the localities in Eastern Massachusetts are given. Cols 3 and 4 include those of Eastern Newfoundland. Cols 5—10, represent English localities and horizons, 12, 13 those of Norway, 14—18 those of the Baltic Provinces, 19—21 successive horizons in the Polish Middle Mountains, and the others scattered and in other geosynclines and horizons. The details are as follows

Col. 1 White limestone of Nahant; Shales of Mill-Cove and Pearl St. Weymouth. Limestones and shales of North Attleboro, all in Eastern Massachusetts

Col. 2 Boulders of white limestone from the beach of Massachusetts

Col. 3 Shales below the Protolenus bed in Hanford Brook, New Brunswick.

Col. 4 Beds at Manuel's Brook and Top-Sail Head, Conception Bay and in Smith-Sound, Trinity Bay, Eastern Newfoundland.

Col. 5 Malvern Hills quartzite of Malvern Hills England

Col. 6 Hollybush sandstone of the Malvern Hills England

Col. 7 *Obolella groomi* beds Ab_1 Comley England

Col. 8 Lower Comley sandstone Ab_2—Ac_1, Comley England

Col. 9 *Olenellus* Limestone Ac_2, *Microdiscus bellimarginatus* Limestone Ac_3, and *Strenuella* Limestone Ac_4. Comley England.

Col. 10 *Protolenns* Limestone Ac_5 Comley England.

Col. 11 *Lapworthella* Limestone Ad. Comley England.

Col. 12 *Volborthella* and *Discinella holsti* zone, of Southern Norway.

Col. 13 *Holmia kjerulfi* beds of Lake Mjösen district

Col. 14 *Eophyton* sandstone and Sparagmite beds, *Torellella* zone, Southern Sweden.

Col. 15 Fucoid sandstone, Southern Sweden

Col. 16 *Mesonacis torelli* and *Holmia kjerulfi* zone, Andrarum, and near Lund, Southern Sweden

Col. 17 Drift boulders from Southern Sweden, and Oeland Island Sweden, and from Aland Island Finland

Col. 18 *Mickwitzia* conglomerate and Fucoid sandstone of Esthonia

Cols 19—21 the successive horizons in central Poland in ascending order (*19* = bed I.1, I.2, and I.3; *20* = II.4, and II,5; *21* = II,6, the Protolenus bed. This latter may be referable to the Middle Cambrian).

Col. 22 Villa de Boim, Alemtejo, Portugal.

Col. 23 Also in the Lower Cambrian of the Appalachian Geosyncline

Col. 24 Also in the Lower Cambrian of the Cordilleran Geosyncline

Col. 25 Also in the Middle Cambrian.

Table III

Lower Cambrian Fauna of Caledonian Geosyncline

Locality		No.	COELENTERATA? 1. Medusites lindströmi Linnarsson	2. Medusites gigas	3. Medusites brzechowiensis	TRAILS etc. 4. Arenicolites spiralis Linnarsson	5. Frana tenella Linnarsson	6. Cruziana dispar Linnarsson	7. Eophyton linnaeanum Linnarsson	8. Eophyton torrelli Linnarsson
Middle Cambrian		25								
Cordilleran geosyncline		24								
Appalachian geosyncline		23								
Villa Boime Portugal.		22								
Poland	Div. II—6	21		×	×					
Poland	Div. II 4—5	20		|	|					
Poland	Div. I 1—3	19		|	|					
Esthonia		18		|	|					
Sweden	Boulders	17		|	|					
Sweden	M. torrelli zone	16		|	|					
Sweden	Fucoid s.s.	15		|	|					
Sweden	Eophyton s.s. etc.	14	×	|	|	×	×	×	×	×
Norway	H. kjerulfi zone	13	|	|	|	|	|	|	|	|
Norway	Volborthella zone	12	|	|	|	|	|	|	|	|
England & Wales	Lapworthella L.	11	|	|	|	|	|	|	|	|
England & Wales	Protolenus L.	10	|	|	|	|	|	|	|	|
England & Wales	Limest. Ac 2-4	9	|	|	|	|	|	|	|	|
England & Wales	Lower Comley s.s.	8	|	|	|	|	|	|	|	|
England & Wales	Obolella groomi beds	7	|	|	|	|	|	|	|	|
England & Wales	Hollybush s.s.	6	|	|	|	|	|	|	|	|
England & Wales	Malvern quartzite	5	|	|	|	|	|	|	|	|
Conception & Trinity Bays		4	|	|	|	|	|	|	|	|
Hanford Brook N. B.		3	|	|	|	|	|	|	|	|
Eastern Massachusetts	Boulders	2	|	|	|	|	|	|	|	|
Eastern Massachusetts	Outcrops	1	|	|	|	|	|	|	|	|

Table III (*Continued*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
TRAILS etc. (cont.)																									
9. Scolithus mirabilis Linnarsson	—	—	—	—	—	—	—	—	—	—	—	—	—	×											
10. Scolicoderma antiquissima Salter	—	—	—	—	—	×	—	—	—	—	—	×													
BRACHIOPODA																									
1. Rustella? major Matthew.	—	—	×																						
2. Mickwitzia formosa (Wiman)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×								
3. Mickwitzia monilifera (Linnarsson)	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	×	×							
4. Mickwitzia pretiosoa Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	×											
5. Mickwitzia kjelcensis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×						
6. Paterina bella (Billings)	×	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×		
7. Paterina labradorica (Billings)	—	—	×	×	—	×	—	×	×	×	—	—	—	—	—	—	—	—	—	—	—	—	×	×	
8. Paterina phillipsi (Holl)	—	—	—	—	×	×	×																		
9. Paterina undosa (Moberg)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×								
10. Paterina rhodesi Cobbold	—	—	—	—	—	—	×																		
11. Paterina kingi Cobbold	—	—	—	—	—	—	×																		
12. Paterina minor Cobbold	—	—	—	—	—	—	—	—	×																
13. Paterina minor gibbosa Cobbold	—	—	—	—	—	—	—	—	×																
14. Walcottia lapworthi Cobbold	—	—	—	—	—	—	×																		
15. Walcottia elevata Cobbold	—	—	—	—	—	—	×																		
16. Obolus parvulus Cobbold	—	—	—	—	—	—	—	—	×	×															

Table III (*Continued*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
BRACHIOPODA (cont.)																									
17. Westonia alandensis Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×								
18. Westonia balticus Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×								
19. Westonia bottnicus Walc.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×								
20. Westonia wimani Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×								
21. Lingulella nathorsti Linnarsson	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	×									
22. Lingulella delgadoi Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
23. Lingulella viridis Cobbold	—	—	—	—	—	—	—	—	—	×	×														
24. Lingulella sp.	—	—	—	—	—	—	—	—	—	—	—	—	×												
25. Lingulella (Lingulepis) squamosa Holl	—	—	—	—	—	×																			
26. Delgadella lusitanica (Delgado)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
27. Kutorgina cingulata Bill*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	×	
28. Kutorgina granulata Matthew	—	—	—	×																					
29. Obolella atlantica Walcott	×	—	—	×																					
30. Obolella atlantica comleyensis Cobbold	—	—	—	—	—	—	—	×	×																
31. Obolella atlantica transversa Cobbold	—	—	—	—	—	—	—	—	×																
32. Obolella crassa Hall	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×		
33. Obolella groomi Matley	—	—	—	—	×	—	×																		

*Near Tschurskaia Station, Lena River Siberia

Table III (*Continued*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
BRACHIOPODA (cont.)																									
34. Obolella lindströmi Walcott	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×									
35. Obolella mobergi Walcott	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	×									
36. Obolella rotundata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×						
37. Obolella (Glyptyas) favosa Linnarsson.	—	—	—	—	—	—	—	—	—	—	—	—	×	—	×										
38. Trematobolus insignis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×						
39. Acrothele bellapunctata Walcott	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	×								
40. Acrothele villaboimensis Delgado	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×			
41. Acrothele woodworthi Walcott	×																								
42. Acrothele sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×									
43. Acrotreta eggegrundensis Wiman	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×									
44. Acrotreta uplandica Wiman	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×									
45. Acrotreta uplandica limonensis Wiman	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×									
46. Acroteta sagittalis?	—	—	—	—	—	×																			
47. Acrothyra cf sera (Matthew)	—	—	—	—	—	—	—	—	—	—	×														
PELECYPODA																									
1. Modiomorpha sp.	—	—	—	—	—	×																			
2. Fordilla troyensis Barrande	?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×		
GASTROPODA etc.																									
1. Scenella reticulata Billings	×	—	—	×																					

Table III (*Continued*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
GASTROPODA etc. (cont.)																									
2. Scenella elevata Cobbold	—	—	—	—	—	—	—	—	×																
3. Helcionella rugosa (Hall)	—	—	—	×																					
4. Helcionella rugosa var. comleyensis Cobbold	—	—	—	—	—	—	—	×	×																
5. Helcionella cingulata Cobbold	—	—	—	—	—	—	—	—	x?	×															
6. Helcionella acuticosta Walcott	—	—	—	×																					
7. Helcionella erecta Walcott	—	—	—	×																					
8. Helcionella laevis Walcott	—	×	—	×																					
9. Helcionella pauper (Billings)	×	×	—	×																					
10. Helcionella abrupta (Shaler & Foerste)	×	×																							
11. Helcionella curvirostris (Schaler & Foerste)	×	×																							
12. Discinella holsti	—	—	—	—	—	—	—	—	—	—	—	×													
13. Discinella sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×								
14. Latouchella costata Cobbold	—	—	—	—	—	—	—	—	×	×															
15. Latouchella? striata Cobbold	—	—	—	—	—	—	—	—	—	×															
16. Watsonella crosbyi Grabau	—	×																							
17. Platyceras (Pelagiella) primaevum (Billings)	×	×	—	×																					
18. Platyceras deflectum Grabau	—	×																							
19. Rhaphistoma attleborensis (S. & F.)	×	×																							
20. Straparollina remota Billings	—	×	—	×																					

Table III (*Continued*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
GASTROPODA etc. (cont.)																									
21. Hyolithes princeps Billings	×	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×		
22. Hyolithes excellens Billings	×																								
23. Hyolithes quadricostatus Shaler & Foerste	×	—	—	×																					
24. Hyolithes similis Walcott	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×		
25. Hyolithes billingsi Walcott	x?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	×	
26. Hyolithes impar Ford	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×		
27. Hyolithes searsi Grabau	×																								
28. Hyolithes terranovicus Walcott	—	—	—	×																					
29. Hyolithes (Orthotheca) fistula (Holl)	—	—	—	—	×	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	?		
30. Hyolithes primaevus (Groom)	—	—	—	—	×	×																			
31. Hyolithes degeeri Holm	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	×								
32. Hyolithes (Orthotheca) communis Billings	×	—	cf	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×		
33. Hyolithes malvernensis Groom	—	—	—	—	—	×																			
34. Hyolithes laevigatus Linnarsson	—	—	—	—	—	—	—	—	—	—	—	—	×												
35. Hyolithes americanus Billings	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×		
36. Hyolithes variabilis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×						
37. Hyolithes complanatus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×						
38. Hyolithes trigoniaris	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×						

Table III (*Continued*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
GASTROPODA etc. (cont.)																									
39. Hyolithes zbelutkensis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×						
40. Hyolithes subangularis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×					
41. Hyolithes teretiusculus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	cf					
42. Hyolithes latissimus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×				
43. Hyolithes raphidoplorus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×				
44. Hyolithes (Orthotheca) emmonsi Ford	×	?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×		
45. Hyolithes (Orthotheca) cylindrica Grabau	×	×																							
46. Hyolithes (Orthotheca) foerstii Grabau	×	×																							
47. Hyolithea crassus Cobbold	—	—	—	—	—	—	—	—	—	×															
48. Hyolithes sculptilis Cobbold	—	—	—	—	—	—	—	—	—	×															
49. Hyolithes strettonensis Cobbold	—	—	—	—	—	—	×																		
50. Hyolithes strettonensis brevis Cobbold	—	—	—	—	—	—	×																		
51. Hyolithes (Orthotheca) bayonet Matthew	—	—	—	—	—	—	—	—	—	×															
52. Hyolithes (Orthotheca) bayonet striatus Cobbold	—	—	—	—	—	—	—	—	×																
53. Hyolithes (Orthotheca) compressus Cobbold	—	—	—	—	—	—	—	—	×																
54. Salopiella obliqua Cobbold	—	—	—	—	—	—	—	—	×																
55. Helenia cancellata Cobbold	—	—	—	—	—	—	—	—	×	×	×														

Table III (*Continued*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
GASTROPODA etc. (cont.)																									
56. Helenia bella (Walcott)	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×		
57. Hyolithellus micans (Billings)	×	×	—	×	—	—	—	×	×	×	×	—	—	—	—	—	—	—	—	—	—	—	×	×	×
58. Hyolithellus micans pallidus Cobbold	—	—	—	—	—	—	—	×																	
59. Hyolithellus micans rugosa Walcott	—	—	—	×																					
60. Hyolithellus? sinuosus Cobbold	—	—	—	—	—	—	×																		
61. Torellella laevigata (Linnarsson)	—	—	—	—	—	—	—	—	—	—	—	×	—	×	—	—	×	—	×						
62. Urotheca pervetus Matthew	×																								
63. Coleoloides typicalis Walcott.	—	—	cf																						
CEPHALOPODA																									
1. Volborthella tenuis Schmidt.	—	—	—	—	—	—	—	—	—	—	—	×													
2. Salterella curvatus S. & F.	×																								
3. Salterella bella Cobbold	—	—	—	—	—	—	—	—	—	×															
4. Salterella striata Cobbold	—	—	—	—	—	—	—	—	—	×															
5. Lapworthella nigra Cobbold	—	—	—	—	—	—	—	—	—	—	×														
OSTRACODA, PYHLLOPODA etc.																									
1. Aparchites? andersoni Wiman	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×								
2. Leperditia? lentiformis Cobbold	—	—	—	—	—	—	—	—	×																

Table III (*Continued*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
OSTRACODA PYHLLOPODA etc. (cont.)																									
3. Leperditia cf. solitaria Barrande	×																								
4. Leperditia dermatoides Walcott	—	—	—	—	—	—	—	—	×																
5. Hipponicharion matthewi Wiman	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×								
6. Hipponicharion eos	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×						
7. Hipponicharion gracilis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×						
8. Hipponicharion subquadratus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×						
9. Beyrichina lingua	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×						
10. Beyrichina depressa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×						
11. Beyrichina grevalensis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×								
12. Beyrichina alta	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×								
13. Bradorona nitida	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×								
14. Aristozoe sp.	?																								
15. Escasona? sp.	—	—	—	—	—	—	—	—	×																
16. Bradoria? sp.	—	—	—	—	—	—	—	—	×																
TRILOBITA																									
1. Mesonacis mickwitzi (Schmidt)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×							
2. Mesonacis torelli (Moberg)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×									
3. Holmia kjerulfi Brögger*	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	×	—	—	×						

* Also below Kirkberget, on Shore of Grand Uman Lake Parish of Stensele Lapland Long. 17° E Lat 65° N

Table III (*Continued*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
TRILOBITA (cont.)																									
4. Holmia sp.	—	—	—	—	—	—	—	×																	
5. Olenellus? walcotti Shaler & Foerste	×																								
6. Wanneria sp.	—	—	—	—	—	—	—	×																	
7. Callavia callavei (Lapworth)	—	—	—	—	—	×	—	×	×	x?															
8. Callavia cartlandi (Raw) Walcott	—	—	—	—	—	×	—	—	×																
9. Callavia cobboldi (Raw) Cobbold	—	—	—	—	—	—	—	x?	×																
10. Callavia burri Walcott	×																								
11. Callavia crosbyi Walcott	×																								
12. Callavia bröggeri (Walcott)	—	—	—	×																					
13. Kjerulfia lagowiensis	—	—	—	—	—	—	—	—	—	—	—	—	—	×											
14. Solenopleura bombifrons Matthew	—	—	—	×																					
15. Solenopleura howlyi Walcott	—	—	—	×																					
16. Strenuella strenuus (Billings)	×	—	—	×																					
17. Strenuella strenuus nasutus Walcott	×	—	—	×																					
18. Strenuella polonica	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×						
19. Strenuella primaeva	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	×						
20. Strenuella linnarssoni	—	—	—	—	—	—	—	—	—	—	—	—	×												
21. Strenuella kiari	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	×	×				
22. Strenuella strozlowiensis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×				
23. Strenuella parva Cobbold	—	—	—	—	—	—	—	—	×																

Table III (*Continued*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
TRILOBITA (cont.)																									
24. Strenuella platicephala Cobbold	—	—	—	—	—	—	—	—	×																
25. Strenuella pustulata Cobbold	—	—	—	—	—	—	—	—	×																
26. Strenuella salopiensis Cobbold	—	—	—	—	—	—	—	—	×																
27. Arionellus sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×								
28. Corynexochus parvulus (Billings)	—	—	—	×																					
29. Avalonia manuelensis Walcott	—	—	—	×																					
30. Ellipsocephalus santacruzensis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×					
31. Ellipsocephalus nordenskjöldi	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	×					
32. Ellipsocephalus intermedius	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	×				
33. Ellipsocephalus latus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×								
34. Conocoryphe vistulae	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×						
35. Microdiscus (Eodiscus) bellimarginatus (Shaler and Foerste)	×	—	—	×	—	—	—	—	×																
36. Microdiscus helena Walcott	cf	—	—	×																					
37. Microdiscus comleyensis Cobbold	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	×					
38. Microdiscus emerici	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×				

Table III (*Concluded*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
TRILOBITA (cont.)																									
39. Microdiscus attleborensis (S. & F.)	×	—	—	×	—	—	—	×	×																
40. Microdiscus annio Cobbold	—	—	—	—	—	—	—	—	×																
41. Microdiscus (Eodiscus) speciosus	—	—	—	×	—	—	—	—	×	×	—	—	—	—	—	—	—	—	—	×	—	—	×		
42. Microdiscus (Goniodiscus) lobatus (Hall)	×	—	—	—	—	—	—	—	×	×	—	—	—	—	—	—	—	—	—	—	—	—	×		
43. Protolenus radigasti	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×				
44. Protolenus bodzanti	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×				
45. Protolenus percuni	—	—	—	—	—	—	—	—	—	—	—	—	—		—	—	—	—	—	—	×				
46. Protolenus latouchii Cobbold	—	—	—	—	—	—	—	—	—	×															
47. Protolenus morpheus Cobbold	—	—	—	—	—	—	—	—	—	×															
48. Micmacca? ellipsocephaloides Cobbold	—	—	—	—	—	—	—	—	×																
49. Micmacca? ellipsocephaloides senior Cobbold	—	—	—	—	—	—	—	—	×																
50. Micmacca? ellipsocephaloides spinosa Cobbold	—	—	—	—	—	—	—	—	×																
51. Micmacca? ellipsocephaloides strenuelloides Cobbold	—	—	—	—	—	—	—	—	×																
52. Micmacca? parvula Cobbold	—	—	—	—	—	—	—	—	×																
53. Mohicana clavata Cobbold	—	—	—	—	—	—	—	—	—	×															
54. Mohicana lata Cobbold	—	—	—	—	—	—	—	—	—	×															

TABLE IV

LOWER CAMBRIAN OF THE INDO-CHINESE GEOSYNCLINES

In Cols 1-7 Chinese localities are given. In Cols 8-13, those of the Salt Range and in 14 those of Spiti in the Himalayas. In Col. 15 are given localities in Australia.

Col. 1 Manto Shales, Lower part. On the southeast Houloushan, 2 ½ miles southwest of Yenchuan. Sintai District Shantung Province (Walcott C3)

Col. 2 Central part of Manto shales. West side isolated butte, south of Changhia Shantung, China, (Walcott C20)

Col. 3 Drift block of limestone boulder, 1 mile from Chontonghsin Nanking River South Shensi, China. (Walcott C 32′)

Col. 4 Ferruginous limestone nodules in brown sandy shale, at the top of the Manto Shale, (about 35 ft. above 2.), Changhia, Shantung, China (Walcott C17)

Col. 5 50 li north of Chishanhsien, southern Shensi. Teilhard and Young (Section p. 137 [111])

Col. 6 Manto Shale, various localities in Manchuria, North China (Yabe and Osaki)

Col. 7 Lower Cambrian of Yunnan (Ting and Mansuy) and of Tongking, Indo-China. (Mansuy)

Col. *8–12* Khussak Group of the Salt Range (See Section p. 135 [109])

8, Redlichia beds, *9*, Neobolus Beds, *10*, Upper Annelid sandstone, *Wynnia warthi* zone, *11*, *Hyolithes wynnii* zone; *12*, Lower annelid sandstone.

Col. *13* Jutana group of the Salt Range.

Col. *14* Lower Cambrian of Spiti, bed not located in place.

Col. *15* Lower Cambrian limestone near Wirrialpa Flinders Range South Australia, and Kimberley district West Australia.

Table IV

Lower Cambrian Eauna of the Indo-Chinese Geosynclines.

	Manto Gr. China: Lower	Manto Gr. China: Middle	Manto Gr. China: Drift	Manto Gr. China: Upper	Manto Gr. China: Shensi	Manto Gr. China: Manchuria	Yunnan & Tongking	Khussak Gr. Salt Range: Redlichia bed.	Khussak Gr. Salt Range: Neobolus bed.	Khussak Gr. Salt Range: Wynnia warthi bed.	Khussak Gr. Salt Range: Hyolithes wynnii bed.	Khussak Gr. Salt Range: Lower annelid sandstone.	Jutana Group Salt Range	Spiti India	S. & W. Australia
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ALGÆ															
1. Girvanella manchurica Yabe & Osaki	—	—	—	—	—	×									
BRACHIOPODA															
1. Obolella asiatica Walcott	—	—	×	×											
2. Obolella wirrialpensis Etheridge	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×
3. Obolus? detritus Mansuy	—	—	—	—	—	—	×								
4. Obolus damesi Walcott	—	—	—	—	—	—	×								
5. Obolus cf. chinensis Walcott	—	—	—	—	—	—	×								
6. Billingsella richthofeni Walcott	×	×	—	—	—	—	×								
7. Acrothele matthewi eryx Walcott	—	—	—	—	—	—	×								
8. Acrothele orbicularis Mansuy	—	—	—	—	—	—	×								
9. Lingulella kiurensis Waagen	—	—	—	—	—	—	—	—	×						
10. Lingulella wanniecki Redlich	—	—	—	—	—	—	—	×							
11. Lingula yunnanesis Mansuy	—	—	—	—	—	—	×								
12. Neobolus warthi Waagen	—	—	—	—	—	—	—	—	×						
13. Discinolepis granulata Waagen	—	—	—	—	—	—	—	—	×						
14. Schizopholis rugosa Waagen	—	—	—	—	—	—	—	—	×						
15. Wynnia warthi Waagen	—	—	—	—	—	—	—	—	—	×					

Table IV (*Continued*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
GASTROPODA etc.															
1. Helcionella rugosa (Hall).	—	—	—	—	—	—	—	—	—	—	—	—	×		
2. Helcionella rugosa chinensis Walcott	×														
3. Hyolithes delia Walcott	×														
4. Hyolithes wynnii Waagen	—	—	—	—	—	—	—	—	—	×	×				
5. Biconulites grabaui Teilhard	—	—	—	—	×										
TRILOBITA															
1. Redlichia chinensis Walcott	—	—	—	—	—	×	×								
2. Redlichia nobilis Walcott	×	—	—	—	—	—	×								
3. Redlichia walcotti Mansuy	—	—	—	—	—	—	×								
4. Redlichia noetlingi (Redlich)	—	—	—	—	—	—	—	×							
5. Redlichia forresti (Foord)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×
6. Redlichia carinata Mansuy	—	—	—	—	—	—	×								
7. Ptychoparia yunnanensis Mansuy	—	—		—	—	—	×								
8. Ptychoparia aclis Walcott	—	×	—	×	—	×									
9. Ptychoparia impar Walcott	—	—	—	×	—	×									
10. Ptychoparia granosa Walcott	—	—	—	×											
11. Ptychoparia ligea Walcott	—	×													
12. Ptychoparia (Emmrichella) mantoensis Walcott	—	×													
13. Ptychoparia (Emmrichella) constricta (Walcott)	×														
14. Palæolenus douvillii Mansuy	—	—	—	—	—	—	×								
15. Palæolenus lantenoisi Mansuy	—	—	—	—	—	—	×								
16. Palæolenus deprati Mansuy	—	—	—	—	—	—	×								

NOTE ON PLATE I, PALÆOGEOGRAPHIC MAP OF PANGÆA, In LOWER CAMBRIAN TIME.

This map is drawn in Polar projection, with the North Pole in the region of modern Egypt, where Cambrian strata are entirely wanting. In this projection, the degrees of longitude diverge more rapidly than normal as represented on the globe, and hence the lands between them are progressively enlarged in successively lower degrees of latitude.

In drawing the outlines of the continents an attempt has been made to eliminate the conpression due to post-Cambrian folding.

The deep sea is represented in solid black and the geosynclines and continental shelves by lining. The portions of the smaller lands covered, are represented in darker shades.

CALEDONIAN GEOSYNCLINE. This is represented by horizontal lining and includes the Eastern New England region of the United States and the Maritime Provinces of Canada and Eastern Newfoundland.

In Western Europe it includes the region of Southern England, Southern Norway and Sweden, Estonia and the Polnische Mittelgebirge. Also the southern borders of the Baltic and North Sea, including the Villa Boim region of Portugal, from which Lower Cambrian fossils together with Middle Cambrian fossils have been reported.

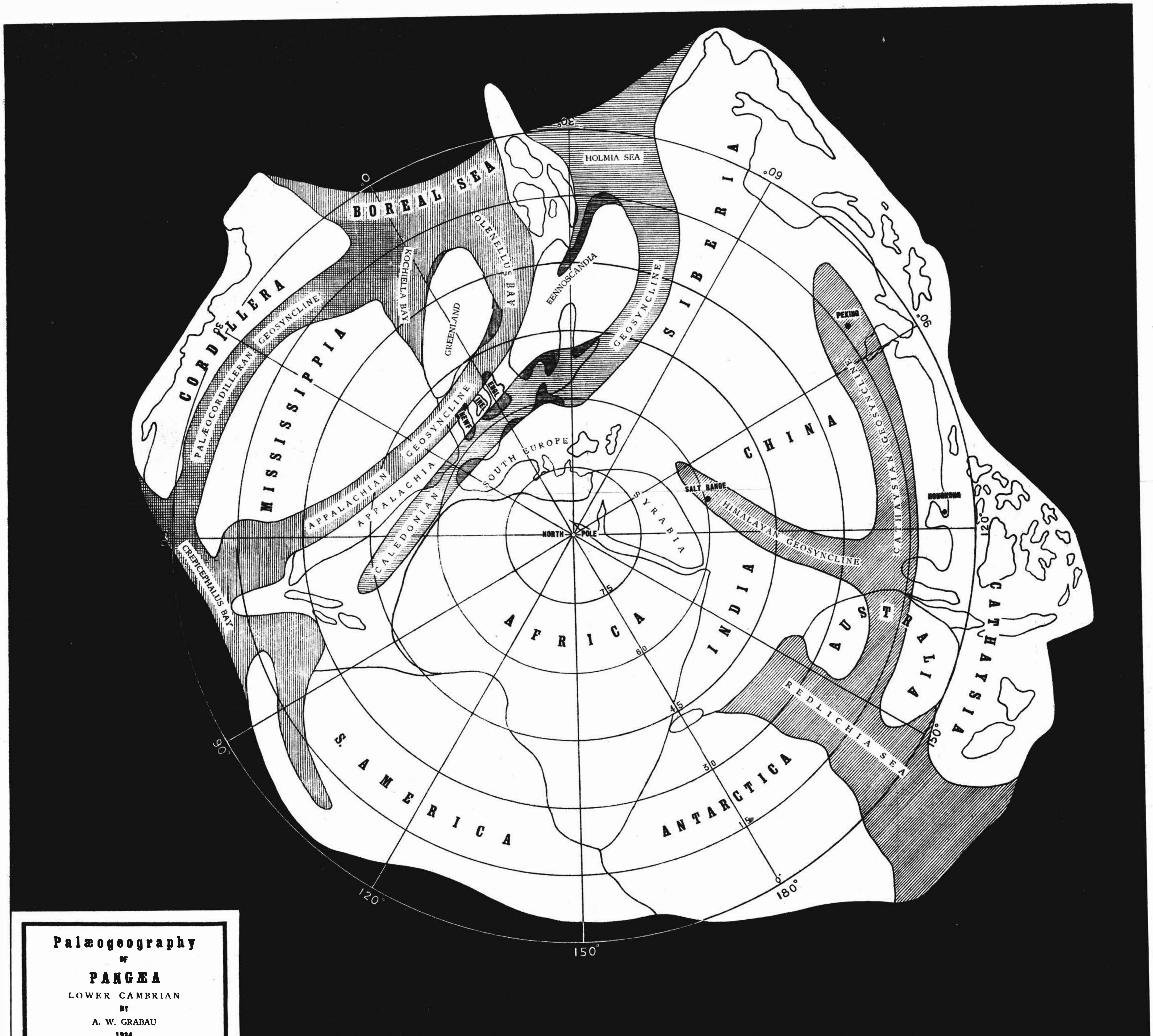
One seemingly anomalous feature should be noted and that is the reported occurrence of *Holmia kjerulfi* in the Arctic regions of Lapland, from below Kyrkberget on the shore of Great Uman Lake, Parish of Stensele Lapland, Long 17^0 E Lat. 65^0 N. (Holm, 1887 Geologiske Föreningens in Stockholm. Förhandlingar. Vol. IX Hafte 7, 1887, p. 512; Walcott Cam. Geol. and Pal. I page 290) This is included in the embayment from the Siberian Holmia Sea.

The Lower Cambrian of the Polnische Mittelgebirge is of the normal type for this geosyncline but many new species occur. The geosyncline is carried across the zone of the Ural Mountains, where there are no Cambrian strata known, but since there was apparently a post-Silurian elevation, followed by erosion, these may have been present and have been eroded before Devonian strata over-lapped them. The connection is made with the Irkutsk Basin of Siberia, which is here called the *Holmia Sea* and is believed to have been the center of evolution of *Holmia*, *Callavia* and the other members of the fauna, though up to date no fossils have been described from these beds. The Lower Cambrian beds are however of enormous thickness, over 4,000 meters and to a large extent calcareous, but nevertheless with a retreatal phase at the top. Apparently the sea lingered here longest and this region may furnish the fossils, showing the evolution of the *Holmia* fauna into the Middle Cambrian *Paradoxides* fauna.

THE APPALACHIAN GEOSYNCLINE. This is represented by vertical lining and covers the Appalachian region of Eastern United States including Western New England, the East Canada region, Western Newfoundland the coast of Labrador, Northern Scotland and the eastern coast of Greenland. In all these the *Olenellus* fauna was typical and the shallow sea which is part of the Boreal Sea, is designated *Olenellus Bay*. The geosyncline is also connected on the south with *Crepicephalus Bay*, the shallow embayment of that part of the pan-Pacific. It is quite probable that at the period of maximum transgression of the Lower Cambrian Sea (Shady limestone period) a connection was formed, allowing some members of the *Crepicephalus* fauna to enter this geosyncline.

PALÆOCORDILLERAN GEOSYNCLINE. This is indicated by crossed vertical and horizontal lines, and opens into the Boreal Sea. The main part of this fauna is of Boreal origin. Between western Greenland and the main land lies *Kochiella Bay*, the bome of the trilobite *Kochiella*, which is so abundantly represented in the west Greenland fauna and well-known in the Palæo-Cordilleran fauna. The connection on the south with *Crepicephalus Bay* was probably established at the period of maximum transgression (Mount Whyte period) allowing the entrance of that trilobite fauna, but if so, the evidence for it was again eroded during the retreatal period at the close of Lower Cambrian time.

THE CATHAYSIAN GEOSYNCLINE. This is shown by diagonal lines. It extends right through the center of Australia, where this fauna is found today, and its home was in *Redlichia Sea*, a water body left after fitting the Antarctic and the Australian lands into their respective positions. The geosyncline extends north to Manchuria and has a western branch, the *Himalayan geosyncline* which extends beyond the Salt Range into Persia. The Old Land of Cathaysia completely shut off the Pacific, where it is probable that the graptolites and cephalopods underwent their early evolution in *Cambrian* time.



Palæogeography
OF
PANGÆA
LOWER CAMBRIAN
BY
A. W. GRABAU
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