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VI. Early Cambrian Stratigraphy in the North American Cordillera, with Discussion of Albertella and Related Faunas.

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INTRODUCTION.

In 1913, Schofield first noticed the presence near Elko, British Columbia, of fossils immediately superjacent to a great series of rocks (the Galton) generally assigned to the Pre-Cambrian. Together with Mr. Schofield the writer visited the locality during the latter part of the same field season and secured fossils from four closely related horizons in the basal layers of the Burton formation in the immediate vicinity of the Burton mine, about 2 miles northwest of the town of Elko, British Columbia.

Schofield has called attention to this discovery in a review of the Pre-Cambrian rocks of the northern Cordillera.[1]

In adjoining areas the Galton series is mantled by the Devonian[2], and Willis[3] found the Carboniferous resting unconformably upon a similar series of rocks in northern Montana, so that the importance of the discovery at Elko depended largely upon the age of the fossils. This is particularly true for the reason that the Pre-Cambrian age of the underlying beds has been called in question.[4] That the upper and best represented of the faunas secured by Schofield and myself should happen to

[1]Geol. Surv. Can., Museum Bull. No. 2, 1914, pp. 79-91.
[2]Idem, p. 83.
[3]Bull. Geol. Soc. America, vol. 13, 1902, p. 325.
[4]Daly, R. A.: Geol. Surv., Can., Memoir No. 38, 1912, pp. 174-178.

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be referable to the *Albertella* fauna, a zone which appears to occupy a debatable position between the Lower and the Middle Cambrian, is fortuitous and it will be necessary to preface the discussion of the age of the Burton formation by a general review of our present knowledge concerning the *Albertella* fauna, the Pioche formation, the relations of the basal Cambrian to the Pre-Cambrian rocks, and the boundary between the Lower and the Middle Cambrian in the Cordilleran region.

THE BASAL CAMBRIAN AND ITS RELATIONS TO THE PRE-CAMBRIAN.

The formations referred to the Pre-Cambrian in the Cordilleran region have already been described and correlated in detail.[1] In this review Schofield[2] has outlined the diastrophic criteria for the separation of the Burton formation (Cambrian) and the Roosville (Pre-Cambrian). In the following pages will be given a fairly detailed account, mainly from a palæontologic standpoint, of the beds composing the basal Cambrian in the various districts and of their relations to the Pre-Cambrian. Of the sections described the writer has visited those in British Columbia, Idaho, and Utah, with the single exception of the one at Yellowhead pass, and has drawn largely upon his unpublished field notes for the data which follow.

The various districts are arranged in an order comparable with the successive stages in the advance of the Lower-Middle Cambrian sea upon the Cordilleran region, as follows: California, Nevada, Arizona, Utah, Idaho, Montana, and British Columbia.

California, Inyo County, Waucoba Springs.—The Lower Cambrian occurs east of Waucoba Springs, on the Saline Valley road, east of the Inyo range, Inyo county, California,[3] as a series of limestones, arenaceous limestones, shales, and sandstones, 5,670 feet thick, without observed upper or lower limits, and within which the genus *Olenellus* and its immediate

[1]Schofield, S. J.: Geol. Surv., Can., Museum Bull. No. 2, pp. 79-91.
[2]Idem, p. 84.
[3]Walcott: Smithsonian Misc. Coll., vol. 53, No. 5, 1908, pp. 185–188.

allies have a range of 4,900 feet. This section and the one at Barrel Spring, Nevada, exhibit the greatest known development of fossiliferous Lower Cambrian.

Nevada, Silver Peak, Barrel Spring.—The Lower Cambrian limestones, shales, and quartzites in the vicinity of Silver Peak, Nevada, appear to have an exposed thickness of 6,250 feet,[1] without upper and lower limits, and are much like those east of Waucoba Springs, California, with the exception of the interruption of the middle of the section by a mass of andesite 750 feet thick. The genus *Olenellus* and its congeners (the Mesonacidæ) appear to have a vertical distribution in this section of about 5,300 feet. If there is no duplication in either this section or the one near Waucoba Springs, California, these vertical distributions for the Mesonacidæ of 5,300 and 4,900 feet, respectively, are of great importance and indicate clearly that, in the absence of ample diastrophic criteria, there is little justification for assigning to the Pre-Cambrian any of our basal quartzitic series, no matter how thick they may be. Such occurrences can also be interpreted as indicative of the relatively quiescent conditions which obtained in the ocean covering the southwestern portion of the continent during the time required for the general northeasterly advance of the overlapping portion of the same body of water. Traces of organic life are conspicuously absent from the major portion of the sediments resulting from this encroachment, but favourable habitats in the new sea areas appear to have shared the biota of the ocean to the southwest.

Nevada, Highland Range.—The basal quartzite series is succeeded in the Highland range of Nevada by the Pioche formation which is stated[2] to be 170 feet thick. A limestone in the section at Bennet Springs[3] carries a fauna which is to be compared directly with the fauna assigned to the Pioche at Pioche (See page 120.) As is explained on page 122, in the discussion of the Pioche formation, Mr. Walcott has called attention to the relative positions in these faunas of the *Olenellus* horizon and the horizon indicated by the other fossils, and to the fact that in the early collections from the Big Cotton-

[1] Walcott: Smithsonian Misc. Coll., vol. 53, No. 5, 1908, pp. 188–189.
[2] Idem, No. 1, 1908, pp. 11–12.
[3] Walcott: Mon. U. S. Geol. Survey, vol. LI, 1912, p. 189.

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wood Canyon, Highland Range, and Eureka District sections the two horizons were not separated by the field observers.[1]

The Lower Cambrian is represented by at least the lower portion of the Pioche formation (see page 121) but the relation of the underlying quartzite series, which has an exposed thickness of 350 feet,[2] to the Pre-Cambrian is unknown. Over 1,000 feet above the layers with *Olenellus* in the Highland Range section, occurs a fauna, No. 21 of the section,[3] which can be correlated with that of the Middle Cambrian portion of the "Pioche" in Big Cottonwood canyon and can be assigned to the Spence shale horizon[4] in northeastern Utah and Idaho and to the *Ogygopsis* zone of the Stephen formation in British Columbia. These faunas are discussed more fully in the section on the Pioche formation, pages 120-125.

Nevada, Pioche.—The most thorough discussion of the stratigraphy near Pioche, Nevada, is furnished by Pack[5] who gives the following section[6]:—

1. Limestone	800	feet.
2. Shale [= *Zacanthoides typicalis* zone]	75	"
3. Limestone	600	"
4. Shale [= Pioche formation]	400	"
5. Quartzite	1500	"

The town of Pioche lies in the northwestern portion of a pitching anticlinal[7] which has been considerably disturbed by faulting, but in which there is a general concentric arrangement of the shale and limestone formations about the quartzite. Both shale horizons carry well developed faunas, that of the lower (400 feet) being the one quoted on page 120, and generally ascribed to the Pioche formation.

[1] Walcott: Bull. U. S. Geol. Survey, No. 81, 1891, p. 319.
[2] Idem, No. 30, 1886, p. 33.
[3] Idem, p. 34.
[4] The name Spence has been carried southward to the House range (Smithsonian Misc. Coll., vol. 53, No. 5, 1908, p. 183) where the rocks to which the name has been applied carry a fauna more closely analogous to that in the shales forming No. 21 of the Highland Range section, but no name has as yet been applied either to these shales or to the Middle Cambrian shale outcropping near the mines in the Ely mountains near Pioche (No. 2 of the above section).
[5] School of Mines Quarterly, vol. XXVII, 1906, pp. 285–312.
[6] Idem, p. 295.
[7] Idem, pl. II, between pp. 290 and 291.

The interpretation of such a fauna as properly belonging to the Lower Cambrian has, in addition to any doubt which might be occasioned by the association itself, been clouded by the reported occurrence[1] in "the Ely mountains, just east of the Highland range", and, therefore, very near Pioche, of a Middle Cambrian shale (2 of the section, page 96) carrying several species identical with those in the "Lower Cambrian." Pioche lies on the north slope of the Ely mountains and the literature has thus come to indicate the presence near Pioche of two shales of more or less indefinite position, and with comparable faunas, the one referred to the Lower, the other to the Middle Cambrian[2].

F. J. Pack[3] was the first to point out the relationship between these two shales, their typical outcrops being given as 5 or 6 miles apart and separated by a stratigraphic interval of 1,000 feet.

The two localities may be closely defined as follows: (1) the shale which has been referred to the Lower Cambrian (4 of the section page 96) and for which the name "Pioche" was proposed[4] outcrops southeast of the town of Pioche on the road to Panaca, Nevada;[5] (2)the shale which has been referred to the Middle Cambrian outcrops in the dumps of the Abe Lincoln, Chisholm, and Half Moon mines west and northwest of Pioche.[6] The second outcrop is upon the western flank of the anticline, the first upon the east.

As thus defined the lowest shale (4 of section) represents the Pioche formation and appears to be divisible (see pages 121-123) into a basal *Olenellus gilberti* zone, and an upper portion or *Crepicephalus* zone which is believed to be Middle Cambrian in age and is in this paper (see page 127) correlated with the *Albertella* fauna in Montana and British Columbia and the Burton formation in southern British Columbia. The upper shale

[1] Walcott: Bull. U. S. Geol. Survey, No. 30, 1886, p. 35.
[2] Cf. localities 31 and 31a, Mon. U. S. Geol. Survey, vol. LI, 1912, p. 192.
[3] School of Mines Quarterly, vol. XXVII, 1906, pp. 292 and 294–296.
[4] Walcott: Smithsonian Misc. Coll., vol. 53, No. 1, 1908, pp. 11-12.
[5] "On the east side of the anticlinal arch at Pioche:" Bull. U. S. Geol. Survey, No. 30, 1886, p. 35.
"Southeast of Pioche on the road to Panaca, Utah:" Smithsonian Misc. Coll., vol. 53, No. 1, 1908, p. 11.
"Southwest of Pioche on the Panaca Road:" Idem, No. 5, 1908, p. 184.
[6] "In the Ely Mountains just east of the Highland Range, owing to mining operations:" Bull. U. S. Geol. Survey, No. 30, 1886, p. 35.

(2 of section, page 96) carries a fauna which has been referred to the Spence (Middle Cambrian) in the House range (see page 96) and which is to be correlated directly with No. 21 of the Highland Range section. The Middle Cambrian faunas of the two shales bear more or less striking resemblances to each other. Gilbert, who was the first to describe the district,[1] appears to have had little doubt as to the unity of the different shales (2 and 4 of section, page 96), and attempted to account by faulting for their presence near the mines. Pack's description[2] of the two formations (their occurrence and their metamorphism, particularly the obliteration of bedding planes in both the quartzite and limestone, the pockety nature of the upper shale outcrops and their variation in thickness from 4 to 100 feet in distances of half a mile, the fact that many of the ores of the district occur as "bedded deposits" along fault planes in the upper shale formation, etc.) also bears internal evidence of the possibility that the two formations may be the same.

The relations between the two shale series and their correlation is further discussed in the section on the Pioche formation, pages 120-125.

Arizona, Grand Canyon.—The sediments overlying the Pre-Cambrian in the Grand Canyon region have been referred to the Tonto group and placed in the Middle Cambrian.[3] They are stated[4] to have been deposited upon an erosion surface[5] transecting at least 13,000 feet of strata and cutting deeply into the Archæan. This pre-Tonto series consists of limestones and shales remarkable for their lack of metamorphism, but the evidence of an unconformity so profound as the one by which they are separated from the Cambrian leaves little question as to the correctness of their reference to the Pre-

[1] U. S. Geog. Surveys West 100th Meridian, vol. III, 1875, pp. 257–261.
[2] School of Mines Quarterly, Vol. XXVII, 1906, pp. 291–292 and 294–296.
[3] Walcott: Smithsonian Misc. Coll., vol. 53, No. 5, 1908, p. 167.
[4] Walcott: American Jour. Sci., 3d. ser., vol. XXVI, 1883, p. 440.
[5] The unconformity at the base of the Cambrian involves erosion and the line will frequently be spoken of as a plane of erosion or an erosion surface. It is to be understood, however, that the Cambrian might be in contact with several or even all of the underlying Pre-Cambrian formations through depositional or other causes without postulating a period of erosion so intense as actually to have removed the missing strata. And such an explanation is favoured by the continental origin assigned to the Pre-Cambrian by such observers as Barrell (Jour. Geol., vol. 14, 1906, pp. 553–568).

Cambrian. No Lower Cambrian fossils have been found in the Tonto, the lowest horizon represented being the lower portion of the Middle Cambrian.

Utah, House Range.—No Lower Cambrian fossils, with the exception of annelid trails and trilobite ? tracks (*Cruziana*), have been found in the House range in western Utah, though that section is only 100 miles distant from Pioche, Nevada, where the Lower Cambrian Pioche formation is so typically developed. The base of the section is formed of a series of unfossiliferous quartzitic sandstones and arenaceous shales 1,500 or more feet in thickness, conformably overlain by arenaceous limestones of Middle Cambrian age. In view of the proximity to Pioche there appears to be no reason for doubting the reference of the quartzitic series to the Lower Cambrian, but the Pre-Cambrian appears to be unrepresented. The horizon of the Spence shale is well represented in the House range 200 feet above the quartzitic series.

Utah, Oquirrh Range.—The first reference to the Cambrian of the Oquirrh range is by Howell[1] who mentions Primordial "shale carrying several species of trilobites and *Discina*," and it is probable that this material furnished the species for which White[2] proposed the name *Olenellus gilberti*. Emmons[3] found a fauna in 100 feet of greenish yellow clay slates immediately overlying a quartzite series which is not listed as containing *Olenellus* and which is apparently referable to a higher horizon, the *Bathyuriscus productus* zone (see page 101). Walcott[4] mentions a shale in the Oquirrh range as carrying both of these faunas (*Olenellus gilberti* and *Bathyuriscus productus*) but in 1891[5] he credits the collection to the Wheeler (100th Meridian) Survey and states that it probably represents an artificial mixing of the collections from two distinct zones similar to that described for Big Cottonwood canyon (page 101) and Pioche (page 121). The shale near Ophir City in the Oquirrh range is thus apparently the lithologic, stratigraphic, and faunal equivalent of the Pioche shale in the Big Cottonwood Canyon section.

[1] U. S. Geog. Surveys West 100th Meridian, vol. III, 1875, pp. 237–238.
[2] Idem, vol. IV, 1877, pp. 45–46.
[3] U. S. Geol. Expl. 40th Parallel, vol. II, 1877, pp. 443–444.
[4] Bull. U. S. Geol. Survey, No. 30, 1886, pp. 39–40.
[5] Idem, No. 81, 1891, pp. 319–320.

Utah, Wasatch Mountains.—The sedimentation in the different portions of the Wasatch mountains varies so greatly that the individual sections will be described in detail. The Bear River plateau or range, with the Blacksmith Fork, Utah, section upon its western flank and the Mill canyon, Idaho, section upon the east, is also to be included in the northward extension of the Wasatch mountains though it lies to the east of the Wasatch mountains proper and is separated from that range by a pronounced depression.[1] The Wasatch Canyon, Ogden Canyon, and Big Cottonwood Canyon sections occupy positions along the north-south line formed by the western escarpment of the Wasatch mountains. In the southern portion (Big Cottonwood canyon) *Olenellus* occurs in siliceous shales at the top of the quartzitic series (see below); 70 miles to the north (Wasatch canyon), and in the Bear River range immediately to the east (Blacksmith Fork and Mill canyon) conditions favouring the deposition of sandstone appear to have continued into the Middle Cambrian and the upper portion of the quartzitic series, here named the Brigham quartzite, is referable to the Middle Cambrian.[2] (See also the summary statement, pages 110-111).

Utah, Wasatch Mountains, Big Cottonwood Canyon.—An unfossiliferous quartzite 1,000 to 1,500 feet thick, conformably overlain by arenaceous shales containing *Olenellus*, itself rests with angular unconformity upon an almost similarly metamorphosed quartzite, slate, and conglomerate series approximately 10,000 feet thick, the erosion surface being so uneven that in places the upper quartzite series even rests on a much older gneiss and schist series which has been referred to the Archæan.[3] Here the weight of evidence would seem to be in favour of a Pre-Cambrian age for the quartzite, slate, and conglomerate series, and a Lower Cambrian age for the upper quartzite series.

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[1] The classic reports on the geology of the Fortieth Parallel by King, Hague, and Emmons, with their accompanying atlas, still contain the only comprehensive description and delineation of the geology of the area included within this mountain system.

[2] Middle Cambrian fossils have been found in the Brigham quartzite in Mill canyon only (see p. 102), but there as well as throughout the area the quartzite series is immediately overlain by beds similar both in lithology and faunal content, and the generalization would appear to be applicable.

[3] Blackwelder: Bull. Geol. Soc. America, vol. 21, 1910, p. 523.

The overlying shale series is the stratigraphic, lithologic, and faunal (?) equivalent of the Pioche formation in Nevada, and like that formation (see page 122) its first description[1] listed fossils collected from Lower and Middle Cambrian zones a hundred or more feet apart. This mistake was corrected in 1891[2] when the formation was divided into two zones, a lower one with *Olenellus* which for convenience of description we shall call the *Olenellus gilberti* zone of the Pioche formation, and an upper one with "*Lingulella ella, Bathyuriscus producta,*" etc., which for similar reasons will be called the *Bathyuriscus productus* zone of the Pioche formation. In Big Cottonwood canyon, therefore, this unit is lithologic and includes both Lower and Middle Cambrian horizons. Indeed it includes the only Lower Cambrian forms so far discovered in the section and the placing below it of the line between the Lower and Middle Cambrian would remove from the underlying beds the very fossils upon which their age is predicated. For this reason that boundary is believed to be correctly assigned to a position above the *Olenellus gilberti* zone and it may be expected that subsequent work in the district will show this lower horizon to be properly separable as a lithologic member of the Pioche, more closely related to the underlying quartzite than to the overlying shale (see pages 124-125). Hintze[3] has proposed the term Alta shale for the strata between the quartzite and the "Ordovician" limestone to which he has applied the term Maxfield. The discovery, by Mr. F. B. Weeks and the writer,[4] of Middle Cambrian fossils in the type section of this limestone obliterates the "hiatus" at the top of the "Alta" and leaves that name so nearly the equivalent of the Pioche as hardly to warrant its adoption.

Utah, Wasatch Mountains, Ogden Canyon.—The basal quartzite in Ogden canyon, Utah, is an apparently conformable series about 1,000 feet thick, which rests on gneisses and schists referred to the Archæan and is itself overlain by shales containing fossils that have been referred to the Middle Cambrian. Black-

[1] Walcott: Bull. U. S. Geol. Survey, No. 30, 1886, p. 39.
[2] Idem, No. 81, 1891, p. 319.
[3] Annals N. Y. Acad. Sci., vol. XXIII, 1913, pp. 104, 105.
[4] Unpublished notes.

welder[1] discusses the stratigraphy and structure in the Ogden Canyon region, correlating the shales immediately above the quartzite with the "Middle Cambrian [portion of the] Pioche." The Langston limestone[2] is not present in the measured section, and while *Olenellus* was not secured from the layers immediately above the quartzite the succession appears to correspond more closely with that in the Big Cottonwood Canyon section less than 50 miles to the south than in the Bear River range to the northeast.

Utah, Wasatch Mountains, Wasatch Canyon.—At the mouth of the first small canyon south of Wasatch canyon, 5 miles north of Brigham, Utah, the Spence shale is well developed and the succession is in every way comparable with that in the Bear River range (Mill canyon) to the northeast.

Utah, Blacksmith Fork.—The basal quartzite series has an exposed thickness of 1,000 or more feet without observed unconformity, and grades upward into a series of massive limestones to which the name Langston has been applied.[2] The line between the Langston and the underlying Brigham is here drawn 500 feet down in this gradational series, while at Malade and on Mill creek in the Bear River range, Idaho, localities within 45 miles of the section in Blacksmith Fork, the Langston is very thin, sharply set off from the underlying quartzite, and crowded with fossils referable to the Middle Cambrian. In the Blacksmith Fork section no fossils were found in the Brigham quartzite, but that formation, in the Mill Canyon section, has yielded fossils upon whose basis the Brigham quartzite has been referred, at least in part, to the Middle Cambrian.[3]

Idaho, Bear River Range, Mill Canyon Section.—The sedimentation in the Mill Canyon section of the Bear River range is closely comparable with that at Blacksmith Fork in the southern portion of the same range, see above. The Middle Cambrian Brigham quartzite is clearly to be distinguished from the overlying Langston limestone, however, and the latter formation is here only 25 or more feet thick and abundantly fossiliferous. As in the Blacksmith Fork section it is conformably overlain

[1] Bull. Geol. Soc. America, vol. 21, 1910, pp. 526 and 534–539.
[2] Walcott: Smithsonian Misc. Coll., vol 53, No. 5, 1908, p. 198.
[3] Mon. U. S. Geol. Survey, vol. LI, 1912, p. 153.

by the Middle Cambrian Spence shale which is of interest in this connexion because of the similarity in lithologic position between it and the Pioche formation. The error resulting from admixture of Lower and Middle Cambrian forms in the lists of fossils credited to the Pioche formation (see pages 122-123) has been perpetuated for years and has still further accentuated the resemblance of the Pioche to the Spence. The presence of *Olenellus* in the Pioche has been the "insurmountable" barrier to this correlation, but the division of the Pioche into two zones referable to the Lower and Middle Cambrian respectively permits the true correlation of the Spence with the upper or *Bathyuriscus productus* zone. See the discussion of the Pioche formation on pages 120-125.

Idaho, Malade.—In Two Mile canyon, southeast of Malade, Idaho, the relations of the Langston limestone to the Brigham quartzite closely approximate those in the Mill Canyon section of the Bear River range. The limestone is much thinner, however, only 5 or 6 feet, and is very fossiliferous, thirty species having been identified.[1] Of these *Oryctocephalus* is perhaps the most interesting in this connexion, because of the very limited stratigraphic distribution of this most striking form. It has been found not only in the Langston limestone and the overlying Spence shale at Malade, in the Spence in Mill canyon, Idaho, and in the Stephen formation on Mount Stephen, British Columbia, all localities which appear to be referable to one remarkably uniform though widespread Middle Cambrian horizon, but it was included in the collections which have been assigned to the "Lower Cambrian" Pioche formation. This occurrence has been used on page 124, as an argument for the correctness of the proposed division of the Pioche.

Montana, Big Belt and Little Belt Mountains.—The lowest rocks referred to the Cambrian in the Big Belt and Little Belt mountains of Montana are the Flathead sandstones which are stated[2] to carry fossils in the lowest horizons "comparable with the oldest part of the Middle Cambrian fauna as the latter occurs a short distance above the *Olenellus* horizon in Utah and Nevada.''

[1] Walcott: Smithsonian Misc. Coll., vol. 53, No. 5, 1908, pp. 198-199.
[2] Walcott: Bull. Geol. Soc. America, vol. X, 1899, pp. 209-245.

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If this correlation is correct the fauna of the Flathead would appear to be quite closely comparable to that of the shales in the Dearborn River section which are also believed to be referable to the base of the Middle Cambrian (See the discussion of the age of the *Albertella* fauna, pages 118-120). Differences of metamorphism between the Flathead and the underlying formations are marked and the two series are separated by an unconformity which brings the Cambrian Flathead into contact not only with many of the different units into which the Pre-Cambrian has been divided but with the Archæan as well. Here, as in the Grand Canyon region of Arizona, the Pre-Cambrian age of the lower series would seem to be demonstrable, though the overlying rocks can not be proven to have been deposited earlier than the Middle Cambrian.

Montana, Dearborn River Section.—An unfossiliferous sandstone 150 feet thick separates a superjacent shale carrying an assemblage of fossils to which the name *Albertella* fauna has been given, from underlying shales having apparently the same strike and dip as the base of the sandstone, but which appear, when traced on the strike, to occupy an unconformable relation. The upper shale and sandstone are referred to the Lower Cambrian by Walcott,[1] the underlying shales being referred to the Pre-Cambrian. The Pre-Cambrian age of these underlying shales seems to be well attested by sections measured by Mr. Walcott at many other points in this area of Beltian rocks. The overlying shale and sandstone, however, occupy lithologic positions exactly analogous to those of the Wolsey shale and Flathead sandstone in the Little Belt Mountains section, 100 miles to the east. There both the Wolsey and the Flathead carry well developed Middle Cambrian faunas, and while that of the Wolsey is noticeably different from the *Albertella* fauna found in the Dearborn River section, the fossils occurring in the underlying Flathead in the Little Belt Mountains are described by Mr. Walcott as comparable with the oldest part of the Middle Cambrian fauna (see page 103). This, the *Albertella* fauna is now believed to represent, see pages 116-120.

[1] Smithsonian Misc. Coll., vol. 53, No. 5, 1908, p. 203.

Montana, Phillipsburg District.—The Pre-Cambrian rocks are separated from a quartzite series correlated with the Flathead by an unconformity involving angular discordance, yet[1] "difficulty will often arise in exactly defining the limit between the Flathead and the Spokane (Pre-Cambrian). A sharp boundary can be drawn only where the unconformity is visible, or where the Flathead rests on shaly Spokane strata and the contact is marked by an abrupt lithologic change." No fossils were obtained from the upper quartzite series ("Flathead") and it can not be referred with certainty either to the Lower or Middle Cambrian.

British Columbia, Elko.—The Pre-Cambrian rocks about two miles northwest of the town of Elko, British Columbia, are overlain without angular unconformity by a transitional sandstone, sandy limestone, and shale series to which the name Burton formation has been applied.[2] The formation is readily divisible into a basal sandstone member 20 feet thick, and an upper shale member about 40 feet thick, but the faunas which have been secured from these beds all appear to be referable to the early Middle Cambrian. They are correlated with the *Albertella* fauna and, more or less tentatively, with the *Crepicephalus* zone of the Pioche formation. (See page 126 and the section on the Burton formation, pages 125-128).

British Columbia and Alberta, Mount Bosworth Section and Bow River District.—The base of the section along the main line of the Canadian Pacific railway in British Columbia and Alberta is composed of a clastic series to which McConnell early[3] applied the term Bow River series or Bow River group. It is several thousand feet thick and has been recently described[4] as including 2,500 feet of Pre-Cambrian at the base. Frequent variations in the sedimentation and the presence of conglomerates at many places in the section,[5] however, complicate the proposed separation. The Cambrian rocks of the Bow River district have

[1] Emmons and Calkins: Prof. Paper, U. S. Geol. Survey, No. 78, 1913, p. 51.
[2] Schofield: Geol. Surv. Can., Museum Bull. No. 2, 1914, p. 82.
[3] Ann. Rept. Geol. and Nat. Hist. Survey Canada for 1886, Part D, 1887, pp. 29 D-30 D.
[4] Walcott: Smithsonian Misc. Coll., vol. 53, No. 7, 1910, p. 428.
[5] McConnell: Ann. Rept. Geol. and Nat. Hist. Survey Canada for 1886, Part D, 1887, p. 30 D; and Daly: Geol. Survey Canada, Memoir No. 38, 1912, p. 176.

recently been subdivided by Walcott[1] who places the boundary between the Bow River group and the overlying Castle Mountain group[2] below a 20-foot bed of interbedded arenaceous limestones and siliceous shales (the *Olenellus canadensis* zone) forming the base of the Mount Whyte formation. The correlation of the top of this bed with the upper boundary of the Bow River group would make that group synonymous with the Lower Cambrian, at least so far as their upper limits are concerned, and would permit the relegation to the Middle Cambrian of the upper portion of the Mount Whyte in spite of the inclusion within that horizon of fragments which appear to be referable to *Olenellus*. The correctness of this reference is indicated (a) by close faunal affinities between the underlying Bow River group and the 20-foot bed in question and (b) by the presence just above that horizon of the *Albertella* fauna (see pages 116-120), a striking assemblage which is here known, in its typical expression, only from two drift blocks. One of these loose fragments weighing several tons has been thoroughly tooled by both Mr. Walcott and the writer without discovering the smallest fragment referable to *Olenellus*. The absence of this genus in strata so widespread (Montana and British Columbia, page 113) and so minutely studied, here possesses special significance since these layers appear to be interbedded between strata carrying *Olenellus* and supports the impression that the occasional appearance in the Mount Whyte of fragments referable to the latter genus is to be explained by the recurrence of a lingering type.

The discussion of the basal Cambrian sedimentation in the Mount Robson district (see below) also contains additional notes on the Mount Bosworth section.

British Columbia and Alberta, Yellowhead Pass Region, Mount Robson Section.—In 1901 McEvoy[3] described and mapped the geology in the vicinity of Yellowhead pass, dividing the basal stratigraphic succession into a "Lower Cambrian Bow River series" and an "Upper Cambrian Castle Mountain group"

[1] Walcott: Smithsonian Misc. Coll., vol. 53, No. 5, 1908, pp. 204–217.
[2] McConnell: Ann. Rept. Geol. and Nat. Hist. Survey Canada for 1886, Part D, 1887, pp. 24 D–29 D.
[3] Ann. Rept. Geol. Survey Canada for 1898, vol. XI, 1901, Part D, with map.

which "may include some beds newer than the Cambrian but not distinctly separable from it."[1]

This conception of the stratigraphy and of the relations between this section and that along the main line of the Canadian Pacific railway to the south has been confirmed by the recent discovery[2] of Lower Cambrian fossils in the upper beds of the Bow River series and of drift blocks indicating the Ordovician age of the upper portion of the Robson massif, all of which was mapped by McEvoy as Castle mountain.

The Cambrian strata are divided by Walcott[2] into nine formations, see page 109, but fossil collections were only secured from general horizons in the Hota, Chetang, and Titkana. McEvoy's Bow River series is divided into a Cambrian and Pre-Cambrian sequence, but the thickness of the basal Cambrian sandstones (McNaughton) is described[3] as very uncertain since it is difficult to determine the line of demarcation between them and the unconformably underlying Miette sandstones. Here the lack of knowledge concerning the relations between the two basal sandstone series leaves some doubt as to the Pre-Cambrian age of the Miette, but the Lower Cambrian age of at least a portion of the basal clastics is certain. In this region the *Albertella* fauna is assigned[4] to a position 350 feet below the top of the 900 feet of Chetang limestones, all of which is placed above the Lower-Middle Cambrian boundary. While the *Albertella* fauna is thus separated by a considerable interval from what seems to be the correct position for the top of the Lower Cambrian, the actual data with regard to the distribution of the *Olenellus* fauna in the Hota formation below that boundary are very meagre.[4] On the line of section fragments assigned to the genus occur in the upper layers of this formation on Mahto mountain, a recognized species (*Olenellus canadensis*) was obtained from a horizon placed about 300 feet below the top and an undetermined species near the top of the formation, and the new subfauna with *Callavia*, *Wanneria*, *Holmia*?, and *Olenellus*[5] is assigned to the 800 feet of which this formation

[1] Ann. Rept. Geol. Survey, Canada, for 1898, Vol. XI, 1901, Part D, geological notes on map.
[2] Walcott: Smithsonian Misc. Coll., vol. 57, No. 12, 1913, pp. 327–343.
[3] Idem, p. 339.
[4] Idem, p. 338.
[5] Idem, vol. 57, No. 11, 1912, pp. 309–326.

(the Hota) is composed without observation as to its relations to the upper or lower limits of that formation. Stratigraphic arrangements based solely on apparent stages in the development of the included faunas have been a source of error in the past, but this new subfauna, including *Olenellus* as it does, appears to represent a horizon high up in the Lower Cambrian, even if it may not be as young as the *Olenellus canadensis* fauna of the Mount Bosworth section to the south. If its reference to the Hota is correct it is separated by at least 550 feet of strata from the *Albertella* fauna which does not contain *Olenellus*, either here or in the Mount Bosworth region, where, as has been stated, tons of its enclosing sediment have been worked up in the minutest of detail by both Mr. Walcott and the writer.

The absence in the Mount Robson region of any fossil collections from this 550 foot interval as well as from the 250 feet immediately overlying the *Albertella* horizon, coupled with the fact that in the Mount Whyte formation of the Mount Bosworth section *Olenellus* is also absent from the beds above the position to which the *Albertella* fauna was assigned[1], would appear to lend weight to the assumption that the Chetang limestone and that portion of the Mount Whyte formation down to and including the *Albertella* horizon are to be referred to the same division of the Cambrian. As the writer has intimated in the discussion of the Mount Bosworth section, page 106, he believes the upper portion of the Mount Whyte formation to be Middle Cambrian in age. Mr. Walcott[2] has placed this formation entirely in the Lower Cambrian, but he appears to recognize its kinship with the Chetang, which also carries the *Albertella* fauna, by stating[3] that that fauna occurs at about the same horizon in both the Mount Bosworth and Mount Robson sections. In his table of formations in these two

[1]Walcott: Smithsonian Misc. Coll., vol. 53, No. 5, 1908, pp. 212–215, gives 3 faunal horizons above the *Albertella* horizon in the "Lower Cambrian" Mount Whyte, all without *Olenellus*, the evidence for the statement (p. 203 of the same reference) that that genus "occurs so generally in the Mount Whyte formation, both above and below the *Albertella* horizon" and for the writer's discussion of the possibility of the recurrence of *Olenellus* above the Lower-Middle Cambrian boundary (page 117), being the presence in a different section (the Mount Stephen), though in an apparently similar position, of fragments assigned to *Olenellus*.

[2]Smithsonian Misc. Coll., vol. 53, No. 5, 1908, p. 212. Its reference to the Middle Cambrian in No. 1 of the same volume, page 2, being a typographical error.

[3] Idem, vol. 57, No. 12, 1913, p. 338.

EARLY CAMBRIAN STRATIGRAPHY IN THE NORTH AMERICAN CORDILLERA, WITH DISCUSSION OF ALBERTELLA AND RELATED FAUNAS.

By

Lancaster D. Burling.

Geological Survey, Canada, Museum Bulletin No. 2,
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Contents

districts,[1] however, the Mount Whyte is correlated with the Lower Cambrian Hota formation, presumably upon the basis of the presence in each of the genus *Olenellus* and the absence from the overlying beds in each case of anything referable to that genus. This principle, to which Mr. Walcott has long subscribed, altogether ignores the stratigraphic value of so new and striking an assemblage as the *Albertella* fauna, and places that biota in the Lower Cambrian on Mount Bosworth and in the Middle Cambrian on Mount Robson. The Titkana and Eldon are correlated upon page 343 of the same paper whereas beds at least 1,000 feet above the base of the former unit are stated on page 337 to have yielded a fauna directly comparable with that of the Stephen formation. The Mount Robson Cambrian section, which is 9,200 feet thick, has yielded only seven fossil horizons and three of these are closely related zones with *Olenellus*, consequently the following table can be presumed to give only the major features of the correlation between the Mount Robson and Mount Bosworth sections:—

Correlation of Cambrian Formations in British Columbia.

	Mount Robson district.		Mount Bosworth district.	
Upper Cambrian	Lynx	2,100	Ottertail	1,725+
			Chancellor	2,500+
			Sherbrooke	1,375
			Paget	360+
			Bosworth	1,855+
Middle Cambrian	Titkana	2,200	Eldon	2,728
			Stephen	640+
	Mumm	600		
	Hitka	1,700	Cathedral	1,595+
	Tatay	800		
	Chetang	900		
Lower Cambrian	Hota	800	Mount Whyte	390
	Mahto	1,800	St. Piran	2,705
	Tah	800	Lake Louise	105
	McNaughton	500+	Fort Mountain	2,700

[1] Smithsonian Misc. Coll., vol. 57 No. 12, 1913, p. 343.

These sections differ from those of Walcott[1] in the correlations, in the substitution of the Fort Mountain for the Fairview,[2] and in the addition of the Ottertail and Chancellor formations.[3] The only correlations which can be assumed, from our present information, to have any certainty are (*a*) the equivalence of at least part of both the Hota and Chetang to the Mount Whyte and (*b*) the equivalence of the Stephen to the lower portion of the Titkana. The Mumm, Hitka, Tatay, Mahto, Tah, and McNaughton formations in the Mount Robson district have proven unfossiliferous[4] and this is also true for the Bosworth and Fort Mountain formations near Mount Bosworth.[5]

(See also the section of the *Albertella* fauna, pages 116-120).

Summary.—The data presented in the preceding pages are largely utilized in the discussion oft he boundary between the Lower and Middle Cambrian, pages 112-115, and form the basis also for the discussion of the *Albertella* fauna, the Pioche formation, and the Burton shales, but the following summary statement may be useful:—

In the Big Cottonwood Canyon, Oquirrh Range, and Pioche sections, the only localities northeast of the Highland range from which *Olenellus* has been obtained, the quartzite series is succeeded by siliceous or sandy shales; where the same series grades into limestone in the northern portion of the Wasatch mountains, both the limestone and the overlying argillaceous shale carry Middle Cambrian fossils, and at one point (Mill canyon) this fauna extends into the underlying quartzite. Diagnostic fossils were not discovered at the following localities, but if the above generalization may be applied to this portion of the Cordilleran region, Mill canyon, Idaho, and Blacksmith Fork, East Fork canyon, Geneva, Wasatch canyon, and Promontory point, Utah, all represent sections where the upper part of the quartzite series is of Middle Cambrian age; and this appears to hold for the Onaqui range, 50 miles southwest of Big Cottonwood canyon. With this exception, however, the quartzite series,

[1] Smithsonian Misc. Coll., vol. 57, No. 12, 1913, p. 343.
[2] Walcott: Mon. U. S. Geol. Survey, vol. 51, 1912, p. 131.
[3] Allan, Summary Rept. Geol. Survey Branch, Dept. Mines, Canada, for 1911, 1912, p. 178.
[4] Smithsonian Misc. Coll., vol. 57, No. 12, 1913, pp. 337-339.
[5] Walcott: Mon. U. S. Geol. Survey, vol. 51, 1912, pp. 125-131.

if present at all, is succeeded by siliceous shales and appears to be of Lower Cambrian age in all of the examined sections south and southwest of Ogden canyon, Utah, and north and east of the Highland range, Nevada. These include the Stansbury Range (Muskrat Spring), Oquirrh Range, Simpson Range, Beaver River Range (Cricket Spring), and House Range sections. The basal quartzite series is not exposed in the other sections measured in this area. In the Highland range[1] the basal quartzite series is separated from the *Olenellus gilberti* zone of the Pioche formation by 35 feet of limestone.

In the Grand Canyon, Big Cottonwood Canyon, Phillipsburg, Mount Bosworth, and Mount Robson sections, variations in the degree of metamorphism between the Cambrian and Pre-Cambrian are so slight as to make this criterion of little value. At Elko only is there a pronounced difference.

In the Grand Canyon, Big Cottonwood Canyon, and Phillipsburg sections the unconformity between the Cambrian and Pre-Cambrian involves angular discordance; in the other sections unconformity can be proven only by overlap, basal conglomerates, etc.

The Cambrian and Pre-Cambrian systems both appear to be represented in the Grand Canyon, Big Cottonwood Canyon, Dearborn River, Phillipsburg, Elko, Mount Bosworth(?), and Mount Robson (?) sections; in Ogden canyon and in the Big Belt and Little Belt mountains the Cambrian rests on the Archæan.

The Pre-Cambrian does not appear to be represented in the Highland Range, Pioche, House Range, Wasatch Canyon, Blacksmith Fork, Mill Canyon, and Malade sections.

The Lower Cambrian is not represented by fossil evidence in the Blacksmith Fork, Malade, Wasatch Canyon, Mill Canyon, Big Belt and Little Belt Mountains, Dearborn River, Phillipsburg (?), and Elko (?) sections.

The relations of the Lower Cambrian to the over- and underlying strata do not appear to have been observed in the Waucoba Springs or Silver Peak sections.

[1] Walcott: Bull. U. S. Geol Survey, No. 30, 1886, p. 33.

THE BOUNDARY BETWEEN THE LOWER AND MIDDLE CAMBRIAN.

The Lower Cambrian has, by general usage, been defined as the time interval dominated by the *Olenellus* fauna, beginning with its earliest advent and ending with its final disappearance. Such a definition for the upper limit has been called in question[1] and, as has been outlined on page 106, the Mount Bosworth and Mount Stephen sections in British Columbia appear to represent environments of so favourable a nature that *Olenellus*, or the local representative of that genus, there became temporarily immune and did not share the timely oblivion to which the other members of the group appear to have been doomed.

Chamberlin and Salisbury[2] suggest the possibility that *Olenellus* in the west may be contemporaneous with *Paradoxides* in the east, but Walcott has shown[3] the latter genus to be the probable derivative of a line of *Olenellus* ancestors including *Nevadia*, *Callavia*, *Holmia*, and *Wanneria*. Schuchert[4] would separate the two divisions and give them systemic rank, a conclusion reached from a study of the relations for the continent as a whole; Ulrich[5] would not.

Prior to 1905 the last traces of the genus *Olenellus*, the top of the quartzitic sandstone series, and the top of the Lower Cambrian were supposed, for the Cordilleran region at least, to be synonymous, indeed this condition appears to hold for Nevada and Utah as far north as Big Cottonwood canyon in the Wasatch range just south of Salt Lake City. Between this point and the Upper Columbia lakes[6] nearly 700 miles to the north in British Columbia, however, *Olenellus* is unknown, and the only palæontologic evidence for the presence of the Lower Cambrian throughout this distance is the reference to that period of the *Albertella* fauna in the Dearborn River section of central Montana. That the Lower Cambrian and a con-

[1] Ulrich: Bull. Geol. Soc. America, vol. 22, 1911, p. 619.
[2] Text book of Geology, vol. II, 1907, p. 245.
[3] Smithsonian Misc. Coll., vol. 53, No. 6, 1910, p. 249.
[4] Bull. Geol. Soc. America, vol. 20, 1910, p. 483.
[5] Idem, vol. 22, 1911, pp. 625–627.
[6] Dawson: Ann. Rept. Geol. Survey, Canada, for 1885, vol. 1, 1886, p. 156B, refers rocks at this locality to the Cambrian, but states that the included fossils were not determined even generically. They are preserved in the collections of the Victoria Memorial Museum and have been identified by the writer as *Olenellus*.

siderable portion of the Middle Cambrian seas were continuous between Nevada and British Columbia there can be little doubt. Apparently synchronous deposits occur in the Lower Cambrian of California, Nevada, Utah, British Columbia, and Alberta, though in the latter region limestone forming conditions obtained long before the actual disappearance of *Olenellus*, an event which is not believed by the writer to have been contemporaneous with the close of the Lower Cambrian (see page 112). The *Albertella* fauna crosses the interval between Gordon creek, Montana, and Mount Bosworth, British Columbia, a distance of 300 miles, with only a modicum of change; and the Spence-Stephen-Titkana fauna of the Middle Cambrian, though characterizing different lithologic facies and occupying different positions with respect to the basal clastics in the areas where it has been discovered, still preserves its identity through the 1,100 miles separating the Highland range of Nevada from the Mount Robson district of British Columbia and Alberta. This broad expanse of water was bounded on the east in northern Utah, southeastern Idaho, and central Montana by land areas whose submersion was gradual and upon whose Pre-Cambrian shores the sea matured from Lower to Middle Cambrian in age before it was able to mantle the Pre-Cambrian regolith.

Without going into a discussion of the problems involved in the satisfactory solution for the continent as a whole of the true relations of the Lower to the Middle Cambrian, we may base our conclusion that the Cordilleran region offers a very close approximation to a gradual transition between these two units upon the following grounds: (*a*) the Mesonacidæ, or *Olenellus*-like genera, are everywhere represented in the uppermost layers of the Lower Cambrian by *Olenellus* (s.s.) or the latest [1] if not the highest exponent of the group for which it has long been considered typical, the importance of the apparent annihilation of this genus over so large an area being tempered by the presence of a recurrent(?) species in the Mount Stephen section of British Columbia; (*b*) in the Mount Robson region the upper portion of the rocks referred to the Lower Cambrian contains representatives of all of the genera (*Callavia*,

[1] Walcott: Smithsonian Misc. Coll., vol. 53, No. 6, 1910, p. 248.

Wanneria, and *Holmia*) that have been placed[1] upon the theoretical line of evolution between the primitive *Nevadia* and the Middle Cambrian Paradoxidæ; (*c*) there is widespread evidence of a transition fauna (the *Albertella*) between the Lower and the Middle Cambrian, a fauna distinct from its predecessors in the region and so closely united with those which follow that it has in this paper been referred to the Middle Cambrian, but whose very presence betrays a kinship between the two divisions of the Cambrian which is only emphasized by the apparent recurrence in younger strata of a surviving member of the illfated Mesonacidæ; and (*d*) nowhere have unconformable relations between the two units been observed. To be sure there is evidence of a gradual encroachment upon an eastern land mass of the waters of a great Lower-Middle Cambrian sea which appears to have been continuous from Nevada to British Columbia, but the slowness of the approach effectually barred the Mesonacidæ from participating in the march upon the promised land and reserved to their descendants the peopling of shores not 50 miles away.

In California and Nevada the Lower Cambrian arenaceous series contains large quantities of calcareous and argillaceous matter, and *Olenellus* and its congeners there yield our only record of their existence during a period long enough for the deposition of a mile or more of strata. Here the time interval necessary for the gradual spread of the Lower Cambrian sea upon the western portion of our continent was spent under conditions of more or less stable equilibrium and the deposits have yielded representatives of the Mesonacidæ ranging from the most primitive (*Nevadia*) to the most highly specialized (*Olenellus* s.s.)[2] Elsewhere in the United States portion of the Cordilleran region the members of this group appear to be confined to *Olenellus* (s.s.) and occur only in the upper thin-bedded layers of a highly arenaceous series referred to the Lower Cambrian,[3] as if the waters in or by which these sediments were deposited proved so inhospitable that the life which teemed

[1] Walcott: Smithsonian Misc. Coll., vol. 53, No. 6, 1910, p. 249.
[2] Idem.
[3] The Middle Cambrian age of a lithologic equivalent of this series has been described, p. 102.

in the contemporaneous seas of Nevada and California held back until the very last. Farther north, in British Columbia, however, the genus ranges sparingly through the upper 500 feet of a similar clastic series and then occurs in great profusion in the lower 20 feet of an overlying transitional formation.

Here the true Lower-Middle Cambrian boundary from a diastrophic standpoint would appear to lie just above this clastic series, but the profusion of Lower Cambrian forms in the overlying 20 feet[1] suggests the drawing of the boundary above that stratum, and the correctness of this interpretation appears to be attested by the occurrence, in the immediately overlying beds, of the Middle Cambrian *Albertella* fauna with its host of new types (See pages 118-119).

A similar delineation of the boundary between the Lower and Middle Cambrian has been made in Big Cottonwood canyon, Utah, in the belief that where so distinctive a Lower Cambrian form as *Olenellus* occurs just above a quartzitic series, even in transitional beds, and is neither associated with nor preceded by forms characteristic of the Middle Cambrian, we are not doing violence to the principles to which we subscribe (pages 119-120) when we suggest that the divisional boundary between the Lower and Middle Cambrian be drawn above the horizon characterized by that genus.

In our opinion the sudden and widespread introduction of so characteristic a biota as the *Albertella* fauna was an event of far more importance than the ultimate extinction of the Mesonacidæ, and the Lower-Middle Cambrian boundary has been drawn below that horizon. When the absolute disappearance of the preceding biota or of any one type is not considered a necessary corollary to the inauguration of a new period, inconsistencies which appeared to be difficult of explanation no longer vex us but give way to new problems, and the delimitation of the boundaries between the stratigraphic units becomes one of increasing complexity because of the substitution of the proper valuation of a debatable series of diastrophic and organic phenomena for a simple yes or no.

[1] Walcott: Smithsonian Misc. Coll. vol. 53, No. 5, 1908, pp. 214–215.

THE ALBERTELLA FAUNA.

The *Albertella* fauna has had an interesting history. It was first discovered in 1905 by Mr. C. D. Walcott [1] in a shale 75 feet above a quartzitic sandstone on Gordon creek, 6 miles from the south fork of Flathead river, Ovando quadrangle (U. S. Geol. Survey), Powell county, Montana. In 1907, drift blocks up to several tons in weight were discovered on the south slope of Mount Bosworth about 500 feet northwest of the main line of the Canadian Pacific railway between Hector and Stephen, British Columbia.[2] The duplication between these drift blocks and the original locality in Montana is nearly perfect, specimens from the two localities containing at least four identical species and being almost interchangeable. At the time the drift blocks were discovered their horizon in the section could not be located and subsequent attempts have likewise proven futile. The fossiliferous shale carrying the *Albertella* fauna, an assemblage of more than a dozen species, is at least 4 feet thick, yet the only trace of its presence in the measured sections is a fragment of one specimen referred to the genus from which the fauna derives its name. On Mount Stephen, 8 miles away, the beds with which the *Albertella* fauna is correlated, and which themselves contain fragments referable to the genus, are overlain and underlain by *Olenellus*, and the *Albertella* fauna was, therefore, assigned to the Lower Cambrian.[3]

In a recent publication Walcott[4] mentions finding the *Albertella* fauna in the Mount Robson region of British Columbia, 150 miles north of the main line of the Canadian Pacific. Curiously enough the fauna was there also found in drift blocks, though their horizon was located in the measured section. It is described as occurring 550 feet above the top of the Lower Cambrian in the Chetang limestone, yet the apparently contradictory statement is made[5] that it "occurs at about the same horizon in the Mount Bosworth section" where it has been referred to the Lower Cambrian. A large part of the discussion of the basal

[1] Mon. U. S. Geol. Survey, vol. 51, Pt. I, p. 168, locality 4v.
[2] Idem, p. 197, locality 35c.
[3] Walcott: Smithsonian Misc. Coll., vol. 53, No. 5, 1908, pp. 203 and 214
[4] Smithsonian Misc. Coll. vol. 57, No. 12, 1913, p. 338.
[5] Idem.

Cambrian sedimentation in the Mount Bosworth and Mount Robson regions of British Columbia, see pages 105-110, relates to the occurrence of this fauna. In neither of these sections is the *Albertella* fauna found below *Olenellus*, and as has been outlined on the pages just referred to the occurrence of the latter genus above an *Albertella* in the Mount Stephen section seems to argue rather for the recurrence in the basal Middle Cambrian of a surviving member of the Mesonacidæ than for the Lower Cambrian age of a fauna so distinct from its predecessors as the one in question.

The collections from China which have so recently been described[1] contain a representative of the genus *Albertella*, to which the specific name *pacifica* has been applied.[2] It is to be distinguished from the species of *Albertella* described for the Cordilleran region by the presence upon its posterior margin of four instead of two spines, but it is referred to the genus without hesitation by Mr. Walcott. It occurs 1,000 feet above a white quartzite in a low bluff on the shore of Tschang-hsing-tau island, in Liau-tung, Manchuria, and is the highest horizon from which fossils were obtained. Its resemblance to *Albertella* and its reference to a position well up in the Middle Cambrian appear to warrant its inclusion in the present discussion.

The field relations of the horizon of the *Albertella* fauna may be summarized as follows: (*a*) In the Dearborn River section of Montana and at Elko, British Columbia, it is without close relations to known faunal horizons and occurs in a shale series conformably overlying a basal sandstone; (*b*) on Mount Bosworth it was found in the drift but was referred to the Lower Cambrian because of the presence in a section 8 miles away (Mount Stephen) of *Olenellus* fragments both above and below its correlated horizon, a siliceous shale interbedded in a gradational sandstone, shale, and limestone series; (*c*) in the Mount Robson region it occurs in the section 350 feet down in a 900 foot formation described[3] as composed of "bluish grey thin

[1] Walcott: Research in China, vol. 3, 1913, pp. 1–276.
[2] Idem, p. 106, pl. 12, fig. 3.
[3] Walcott: Smithsonian Misc. Coll., vol. 57, No. 12, 1913, p. 338.

bedded limestone" and referred to the Middle Cambrian; and (*d*) in China it occurs well up in the Middle Cambrian.

The affiliations of the species constituting the *Albertella* fauna are nearly all with those of the Middle Cambrian. The fauna abounds in types not found in the Lower Cambrian, and while several of them are undescribed the following list of described species will be sufficient for the purposes of our study:—

Described Species of Albertella Fauna.

——	Mount Bosworth.	Dearborn river.
	British Columbia.	Montana.
Micromitra (*Paterina*) *wapta* Walcott	X	
Micromitra (*Iphidella*) *pannula* (White)		X
Obolus parvus Walcott	X	
Obolus (*Westonia*) *ella* (Hall and Whitfield)		X
Acrothele colleni Walcott	X	X
Acrothele panderi Walcott		X
Wimanella simplex (Walcott)	X	X
Olenopsis agnesensis Walcott	X	
Olenopsis americanus Walcott		X
Albertella bosworthi Walcott	X	
Albertella helena Walcott	X	X
Bathyuriscus productus (Hall and Whitfield)		X

Micromitra (*Iphidella*) *pannula* has been identified from forty-one Cambrian localities[1] of which ten have been referred to the lower division of that system. Three of these are from the Pioche formation and one from the *Albertella* fauna. *Micromitra* (*Paterina*) *wapta*[2] and *Obolus parvus*[3] are confined to beds to which the *Albertella* fauna has been referred in British Columbia. *Obolus* (*Westonia*) *ella*[4] has been found at 55 different localities, yet only three are referred to the Lower Cambrian and they are all referable to the "Pioche" or *Albertella* faunas. *Acrothele colleni*[5] has been found only in the Stephen formation, in the beds to which the *Albertella* fauna was referred in British Columbia, and in the upper part of the shale which carries the *Albertella*

[1]Walcott: Mon. U. S. Geol. Survey, vol. 51, 1912, pp. 363–364.
[2]Idem, p. 357.
[3]Idem, p. 408.
[4]Idem, pp. 457–458.
[5]Idem, pp. 641–642.

fauna on Dearborn river, Montana. *Acrothele panderi*[1] and *Wimanella simplex*[2] are confined to the *Albertella* fauna. *Olenopsis agnesensis*[3] and *O. americanus*[4] are the coordinate representatives in correlatable beds of a genus which has not hitherto been identified in North America but which Mr. Walcott[5] refers to the Lower Cambrian on the basis of the "Lower Cambrian" age of the *Albertella* fauna and describes as "a form intermediate between *Holmia* (restricted) and *Paradoxides*[6] or * * * descendant from the *Holmia* type of the Mesonacidæ." *Albertella bosworthi* and *A. helena* are described by Mr. Walcott[7] as representing most interesting types of the Paradoxidæ which "should first be compared with the genus *Zacanthoides* which, in the British Columbia section, is first met with in strata 2,000 feet above the beds in which *Albertella* occurs." *Bathyuriscus productus* is the representative of a genus typical of the Middle Cambrian in the Cordilleran region. It occurs in the Spence and Stephen formations and is one of the two species mentioned by Mr. Walcott[8] as characteristic of the upper or Middle Cambrian portion of the Pioche formation.

With the single exception of *Micromitra* (*Iphidella*) *pannula*, therefore, none of the twelve described species of which this fauna is composed are known to occur in rocks older than the horizon under discussion. Moreover, two of the types (*Albertella* and *Olenopsis*) seem to be derived from the old and to be prophetic of the new, and the remainder are either confined to the *Albertella* fauna or are typically to be referred to the Middle Cambrian.

The problem before us does not seem sufficiently complicated to require a discussion of the principles governing the delimitation of stratigraphic units, since, by its attitude toward both of the elementary lithologic and organic propositions (*a*) that

[1]Walcott: Mon. U. S. Geol. Survey, vol. 51, 1912, p. 652.
[2]Idem, p. 748.
[3]Walcott: Smithsonian Misc. Coll., vol. 57, No. 8, 1912, p. 242.
[4]Idem, p. 243.
[5]Idem, p. 239.
[6]The writer does not share this view of the phyletic relations of *Olenopsis*, but believes with Mr. Walcott that it is probably descendant from the Mesonacidæ.
[7]Smithsonian Misc. Coll., vol. 53, No. 2, 1908, p. 18.
[8]Bull. U. S. Geol. Survey, No. 30, 1886, p. 39.

a gradational series of beds in which the transition is from the more clastic to the less should be included with the younger, and (*b*) that the introduction of new faunas, even of new types in faunas preserving more or less of their original character, is a phenomenon attending the inception rather than the decline of stages in the earth's history, the *Albertella* fauna seems to have achieved the right to be classed with the Middle Cambrian.

THE PIOCHE FORMATION.

The Pioche formation was first described in 1908[1] when Pioche, Nevada, was cited as the type locality and it was stated to carry the Lower Cambrian *Olenellus* fauna. Later in the same year[2] it was described for the House Range section of western Utah and accompanied by a list of the fossils at Pioche, an assemblage which is compared in the following table with a list first published in 1886.[3]

Fauna of strata ("2, 3, and 4"?) resting on the quartzite at Pioche, Nevada, 1886.[4]	Fauna of the Pioche formation at Pioche, Nevada, 1908.[5]	Fauna of the Pioche formation at Pioche Nevada, 1912.[6]
Eocystites?? longidactylus...	Eocystites? longidactylus.	.....
Lingulella ella.....	Obolus (Westonia) ella....	.....
Kutorgina pannula.....	Micromitra (Iphidella) pannula.....	Micromitra (Iphidella) pannula.
Acrothele subsidua.....	Acrothele subsidua.....	Acrothele subsidua.
	Acrothele subsidua hera..	Acrothele subsidua hera.
	Acrothele spurri.....	Acrothele spurri.
Acrotreta gemma.....	Acrotreta primæva.....	Acrotreta primæva.
Orthis highlandensis.....	Billingsella highlandensis..	Billingsella highlandensis..
Hyolithes billingsi.....	Hyolithes billingsi.....	Hyolithes billingsi.
Olenellus gilberti.....	Olenellus gilberti.....	Olenellus gilberti.
Olenoides levis.....	Zacanthoides levis.....	Zacanthoides levis.
Crepicephalus augusta.....	Crepicephalus augusta.....	Crepicephalus augusta.
Crepicephalus liliana.....	Crepicephalus liliana.....	Crepicephalus liliana.
		Olenoides sp.
		Ptychoparia sp.
		Oryctocephalus primus.

[1]Walcott: Smithsonian Misc. Coll., vol. 53, No. 1, 1908, pp. 11–12.
[2]Idem, No. 5, 1908, p. 184.
[3]Walcott: Bull. U. S. Geol. Survey, No. 30, 1886, p. 35.
[4]Idem.
[5]Smithsonian Misc. Coll., vol. 53, No. 5, 1908, p. 184.
[6]Mon. U. S. Geol. Survey, vol. LI, 1912, p. 192.

The list quoted in the first column has been copied and recopied with little or no modification until 1912[1] when examination of the original material in the collections of the U. S. National Museum resulted in the withdrawal from the list of *Obolus (Westonia) ella* and *Eocystites? longidactylus* and the insertion of *Olenoides* sp., *Ptychoparia* sp., and *Oryctocephalus primus*. Why the latter species, which was described in 1886[2], has not been included in previous lists is more or less of a mystery. Its presence is important, see page 103.

In the following discussion of the beds in question the term Pioche formation will be used though it was not so applied until 1908, see page 120. It will be shown that this formation is divisible into two zones: (1) a lower, characterized from eastern Nevada to northeastern Utah by the trilobite *Olenellus gilberti*, which will be called the *Olenellus gilberti* zone and assigned to the Lower Cambrian; and (2) an upper, which, from the collections at our disposal, appears not to belong to the same portion of the Middle Cambrian in the different sections from which the Pioche has been identified. In the Big Cottonwood Canyon and Oquirrh Range sections this upper zone will be called the *Bathyuriscus productus* zone and correlated with the Spence-Stephen-Titkana fauna; at Pioche and in the Highland range (Bennett Spring) it will be called the *Crepicephalus* zone and tentatively correlated with the *Albertella* fauna and the Burton formation.

The rocks of the Pioche formation as they were first described for the Big Cottonwood Canyon section of Utah[3] were given a thickness of 250 feet and listed as carrying the following fauna: "*Cruziana* sp., *Lingulella ella*, *Kutorgina pannula*, *Hyolithes billingsi*, *Leperditia argenta*, *Olenellus gilberti*, *Ptychoparia quadrans*, and *Bathyuriscus productus*."

The commingling of Lower and Middle Cambrian types exhibited by this fauna was first admitted by Walcott in 1891[4] and the presence of the error has been noted[5], but there appears

[1] Mon. U. S. Geol. Survey, vol. LI, 1912, p. 192.
[2] Walcott: Bull. U. S. Geol. Survey, No. 30, 1886, p. 210.
[3] Idem, pp. 38–39.
[4] Idem, No. 81, 1891, p. 319.
[5] *e.g.*: Mon. U. S. Geol. Survey, vol. LI, 1912, p. 189.

to have been no recognition of the fact that in the original reference [1] a similar condition was acknowledged to exist in the Highland Range and Eureka District sections. Indeed the writer's attention was only called to this fact after his curiosity had been aroused by noticing that the collections at the three localities (Big Cottonwood canyon, Pioche, and in the Highland range) were all made by the same field observers (C. D. Walcott and "J.E.W.") during the same field season at a time (1885) when the *Olenellus* fauna was believed by Mr. Walcott to be of Middle Cambrian age.[2]

A strong intimation of the fact that the *Olenellus* horizon was to be distinguished from that of the other fossils in both the Highland Range and Big Cottonwood Canyon sections was, however, given by Mr. Walcott five years earlier[3] when he said: "In both sections *Olenellus* comes first, and then *Lingulella ella*, *Bathyuriscus producta*, etc." Here Mr. Walcott does not refer specifically to the collection from Pioche but on page 35 of the same work he states that the "Pioche fauna was secured from beds 2, 3, and 4 of the section in the Highland Range," where they have a combined thickness of 131 feet[4] and four of the species occurring at Pioche are stated[5] to occur also, though they are not so listed, in corresponding beds in the Highland Range section. The applicability to the Pioche collection of the remarks concerning the adjoining Highland range is, therefore, clearly shown.

Two shale series have been identified in the vicinity of Pioche (see pages 96-98). The first collection from the lower shales, or the one to which the term Pioche formation has been applied, included two species of *Olenellus* only, and nowhere in their discussion of this fauna do either Gilbert[6] or White[7] give the slightest indication that species representing other genera were included in the collections. This only corroborates

[1] Walcott: Bull. U. S. Geol. Survey, No. 81, 1891, p. 319.
[2] Idem, No. 30, 1886.
[3] Idem, p. 39, section 76.
[4] At Pioche the thickness is given as 210 feet: Walcott, Smithsonian Misc. Coll., vol. 53, No. 1, 1908, p. 11; and 400 feet: Pack, School of Mines Quarterly, vol. XXVII, 1906, p. 295.
[5] Walcott: Bull. U. S. Geol. Survey, No. 30, 1886, p. 35.
[6] U. S. Geog. Surveys West 100th Meridian, vol. III, 1875, pp. 182–183.
[7] Idem, vol. IV, 1877, pp. 7 and 44–48.

the suggestion that the Pioche formation at Pioche includes two faunas, a lower zone with *Olenellus* discovered by the Wheeler Survey, and an upper zone with *Crepicephalus* which was mingled with the lower faunas by the subsequent collectors. Even this conclusion may be wrong, however, and we should be loth to adopt it if it had not already been forecasted by Mr. Walcott (see page 122).

At Pioche, *Olenellus gilberti* is still typical of the lower zone and that horizon may for convenience receive the same name as in the Big Cottonwood section (the *Olenellus gilberti* zone); the Middle Cambrian horizon may be called the *Crepicephalus* zone from its typical fossil. It is separated by 600 feet of limestone from what has been described as a distinct though unnamed upper shale series (see page 96) which can be definitely correlated with the *Bathyuriscus productus* zone of the Pioche formation in Big Cottonwood canyon. (See the section on the stratigraphy at Pioche and in the Highland range, pages 95-98.)

In the Highland Range and Pioche sections, therefore, the Pioche formation does not appear to include faunas so distinct as those comprised in the same formation in Big Cottonwood canyon (the Lower Cambrian and the Spence-Stephen) unless there is a duplication in the Highland Range section or the two shales at Pioche are of the same age. Locally, that is between sections 50 miles or less apart, the Spence shale exhibits marked variations in both the number and the types of species of which it is composed, differences hardly less pronounced than those (*a*) between the fauna of No. 21 of the Highland Range section and that of the Middle Cambrian portion of the "Pioche shale" in the Big Cottonwood Canyon section, or (*b*) between the two Middle Cambrian shales near Pioche—the one southeast of the town on the road to Panaca where the apparent inclusion of an underlying *Olenellus* horizon has complicated its age relationships, and the other typically exposed in the mine dumps west of Pioche in the Ely mountains. The equivalent of the Spence in the British Columbia section, the Stephen, is, however, separated by nearly 1,600 feet of strata from the Mount Whyte, to which the *Albertella* fauna

is referred and with which the Pioche has been compared,[1] yet in the Big Cottonwood Canyon and Oquirrh Range sections of Utah, the original collections appear to have mingled Pioche and Spence types (see page 121). Elsewhere, if we except the House range of Utah where the reference of a shale to the Pioche[2] is not based on fossil evidence, the two shales are not represented in the same section. Interesting, therefore, as the possibility of the suggested duplication may be, and the presence of *Olenoides*, *Zacanthoides*, and *Oryctocephalus* (the latter particularly, see page 103) in the lower shale at Pioche tends still further to suggest its contemporaneity with the Spence, and, therefore, with the upper shale at Pioche, we must await the carrying out of detailed work upon these basal rocks in Nevada, contenting ourselves for the present with the suggested division of the lower shale (the Pioche) into two zones and the tentative correlation of the upper or *Crepicephalus* zone with the *Albertella* fauna and with that of the Burton formation.

Under a system of nomenclature in which formations will be referable to and comparable with lithologic or stratigraphic units, the Pioche formation, from our present knowledge, appears to be an identifiable series of interbedded shales and limestones occupying a transitional zone between true quartzite and limestone series. The two faunas into which the Pioche of the Big Cottonwood section is divisible are, however, separated: (*a*) in the Bear River Range, 100 miles to the north, by several hundred feet of quartzites and limestones; (*b*) in the Mount Bosworth section by 1,600 feet of massive limestones and 350 feet of thin-bedded limestone, sandstones, and shales carrying a new fauna (*Albertella*); (*c*) in the Mount Robson section by 4,350 feet of limestones and shales including the same new fauna; (*d*) in the House range by 205 feet of limestones; (*e*) at Pioche, if the stratigraphy has been correctly solved, by 600 feet of limestone and the *Crepicephalus* zone of the Pioche formation, a horizon comparable with the *Albertella* fauna in the Mount Bosworth section; and (*f*) in the Highland range by 1,100(?) feet of limestones and shales. Such a con-

[1]Walcott: Smithsonian Misc. Coll., vol. 53, No. 5, 1908, p. 171.
[2]Idem, pp. 171 and 184.

dition augurs well for the probable delimitation within the Pioche of lithologic and faunal units to which member names may be applied, but this is left for the investigator who may undertake the critical study of this formation in the light of the new interpretation to which it has been subjected.

THE BURTON FORMATION.

The Burton formation has been named and described by S. J. Schofield[1], who, together with the writer, measured the following section in the slope directly back of the Burton mine about 2 miles northwest of the town of Elko, British Columbia.

Section of Burton Formation Near Elko, British Columbia.

	Section.	Feet.	Fauna.
	Elko limestone (Pre-Devonian, exact age unknown).		
Burton formation (early Middle Cambrian.)	5. Greenish black shales with interbedded limestones, the limestone being in the form of lenses and stringers 1 to 3 inches in thickness and more or less continuous but making up a very small proportion of the strata.	60	In interbedded limestones within 5 feet of the base: *Micromitra* (*Paterina*), *Micromitra* (*Iphidella*) *pannula*, *Obolus* sp., *Acrothele* sp., *Acrotreta* sp., *Agraulos* sp., *Ptychoparia* sp., *Albertella* sp., *Olenoides* sp., *Bathyuriscus* sp., *and Crepicephalus* 2 species.
	4. Massive, dirty grey, sandy limestone.	10	Near top: *Micromitra* sp., *Micromitra* (*Iphidella*) *pannula*, *Agraulos* sp., Trilobite fragments 2 species.
			Near base: *Micromitra* (*Iphidella*) *pannula*, Trilobite fragments 2 species, one suggesting *Olenellus*.
	3. Green micaceous shale, badly sheared.	4	One trilobitic fragment.
	2. Rubbly weathering, calcareous grit, with annelid like borings in top layer.	3	Annelid borings, *Micromitra* (*Paterina*) sp., *Acrotreta* sp., Trilobite fragments 1 species.
	1. Hematite conglomerate.....	1	
	——unconformity——		
	Roosville siliceous metargillite (Pre-Cambrian).		

[1]Geol. Surv., Can., Museum Bull. No. 2, 1914, p. 82.

So far as the writer is aware there are only three reported occurrences of the genus *Crepicephalus* in the beds below or immediately above the line separating the Lower from the Middle Cambrian. First in the Pioche formation of Nevada (page 120), second in a limestone with *Albertella* on Mount Stephen, British Columbia[1], and third in interbedded limestones in a Middle Cambrian shale immediately overlying a quartzite on an island east of Niang-Niang-Kung, Liau-tung, Manchuria.[2] The limits of this paper will hardly permit the inclusion of any further reference to the latter occurrence or to the relations between this shale series and the horizons under discussion. The Middle Cambrian aspect of the fauna of No. 5 of the Burton formation (page 125) was evident at the time its study was undertaken, but the association in the same 1-inch layer of two species of *Crepicephalus* and a representative of the genus *Albertella* suggested the comparison of the Burton formation with the *Albertella* fauna and the Pioche formation, horizons which had both been referred to the Lower Cambrian.

Analysis of the *Albertella* fauna in the other regions from which it has been identified (see pages 118-119) revealed the lack of any necessity for the assumption that its Lower Cambrian age was infallible, and the writer turned his attention to the Pioche. This was shown (pages 121-123) to be divisible into Lower and Middle Cambrian zones respectively, and even to comprise faunas which, at the type locality of the *Albertella* fauna, are separated by 1,600 feet of limestone. At the type locality of the Pioche formation the range of faunas included in that unit does not appear to be so large and the Middle Cambrian horizon, to which the name *Crepicephalus* zone has been applied (see page 123) is to be correlated, at least tentatively, with the Burton formation. The correlation of the Burton formation with the *Albertella* fauna is based largely upon the presence in the former of an *Albertella*, a genus which, according to our present information, is confined in the Cordilleran region to this one horizon. The weight of evidence so largely opposes the Lower Cambrian age of these formations and corroborates their refer-

[1]Walcott: Smithsonian Misc. Coll., vol. 53, No. 5, 1908, p. 213.
[2]Walcott: Research in China, vol. 3, 1913, p. 26, locality 35r.

Correlation of Pioche Formation, Burton Shale, and Albertella Zone.

Pioche, Nevada.	Big Cottonwood canyon, Utah.	Elko, British Columbia.	Mount Bosworth, British Columbia
Zacanthoides typicalis zone (2 of section, page 96) = No. 21 of Highland range.	.... *Bathyuriscus productus* zone..... (= Spence shale horizon in northern Utah).	.....	Stephen formation (*Ogygopsis* zone) = Titkana formation of Mount Robson region (in part).
Pioche formation. *Crepicephalus* zone.....	Pioche formation.	.....Burton formation.	Mount Whyte formation. *Albertella* zone.....
Olenellus gilberti zone.....	*Olenellus gilberti* zone.....	.....	*Olenellus canadensis* zone....

ence to the overlying division of the Cambrian that the Burton formation is referred with some degree of certainty to the Middle Cambrian.

It is hard to resist the impression, however, that the clastic portion of the Burton formation may represent the Lower Cambrian, and while the few species occurring in these lower layers are either unrecognizable or referable to types hitherto unknown, the suggested definition of the Burton formation will not invalidate its future division into shale and sandstone members.

The Burton formation is, therefore, interpreted as a more or less heterogeneous formational unit unconformably overlying the Pre-Cambrian, referable to the early Middle Cambrian, and easily separable into upper and lower members if such a division should be warranted by future work upon the faunas of its basal portion.

SUMMARY.

The *Albertella* fauna has been referred to the Lower Cambrian[1] and this reference has been used as an argument[2] for the systemic designation of such faunas as that containing *Olenopsis* in Sardinia. The *Albertella* fauna is shown in this paper (*a*) to occupy strata transitional between the Lower Cambrian sandstone and the Middle Cambrian limestone forming conditions of the early Cambrian, (*b*) to be unassociated with *Olenellus* though it is apparently interbedded with recurrent representatives of that genus, (*c*) to consist almost overwhelmingly of forms either typical of the Middle Cambrian or confined to the *Albertella* fauna as species of unknown or connecting affinities, and (*d*) to be referable to the Middle Cambrian.

The Pioche formation has been consistently referred to the Lower Cambrian, but it is shown in this paper (*a*) that the faunal lists with which it has been credited represent an artificial

[1]Walcott: Smithsonian Misc. Coll., vol. 53, No. 2, 1908, pp. 21–22.
Idem, No. 5, 1908, pp. 203 and 212.
Idem, vol. 57, No. 8, 1912, pp. 242 and 244.
Mon. U. S. Geol. Survey, vol. LI, 1912, pp. 129–130.
Smithsonian Misc. Coll., vol. 57, No. 12, 1913, p. 343. Referred to the Middle Cambrian on p. 338, see pages 107-109 of this paper for discussion.

[2]Walcott, Smithsonian Misc. Coll., vol. 57, No. 8, 1912, pp. 242 and 244.

mingling of Lower and Middle Cambrian forms, (*b*) that the formation is divisible in the Big Cottonwood Canyon and Oquirrh Range sections of Utah into a true Lower Cambrian horizon with *Olenellus* (the *Olenellus gilberti* zone) and a Middle Cambrian horizon which is called the *Bathyuriscus productus* zone and correlated with the Spence-Stephen-Titkana faunas, and (*c*) that it is probably divisible near Pioche, Nevada, the type locality, into a true Lower Cambrian horizon with *Olenellus* (the *Olenellus gilberti* zone) and a Middle Cambrian horizon with *Crepicephalus* (the *Crepicephalus* zone) which is tentatively correlated with the *Albertella* fauna and the Burton formation.

The Burton formation of Schofield[1] has in this paper received its first palæontologic treatment: its section near Elko, British Columbia, is given, its faunas are listed, and it is correlated with the *Albertella* fauna and referred to the early Middle Cambrian.

The Lower-Middle Cambrian boundary has heretofore been drawn above the youngest beds containing *Olenellus*, irrespective of conflicting diastrophic and organic evidence. It is in this paper redefined and drawn at the base of such horizons as the one containing the *Albertella* fauna, a suggestion which is believed to accord with the principle that the inauguration of major units in the stratigraphic series is more closely related to the phenomena attending depositional expansion and the introduction of new faunas than to the accidental and senile lingering of a decadent type.

[1]Geol. Surv., Can., Museum Bull. No. 2, 1914, p. 82.