CANADA
DEPARTMENT OF MINES
HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

GEOLOGICAL SURVEY, CANADA
W. H. COLLINS, DIRECTOR

MEMOIR 155

Horton-Windsor District, Nova Scotia

BY
W. A. Bell

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1929

Price, 50 cents

No. 2176

CANADA
DEPARTMENT OF MINES
HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

GEOLOGICAL SURVEY, CANADA
W. H. COLLINS, DIRECTOR

MEMOIR 155

Horton-Windsor District, Nova Scotia

BY

W. A. Bell

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1929

CONTENTS

CHAPTER I

CHAPTER II

CHAPTER III

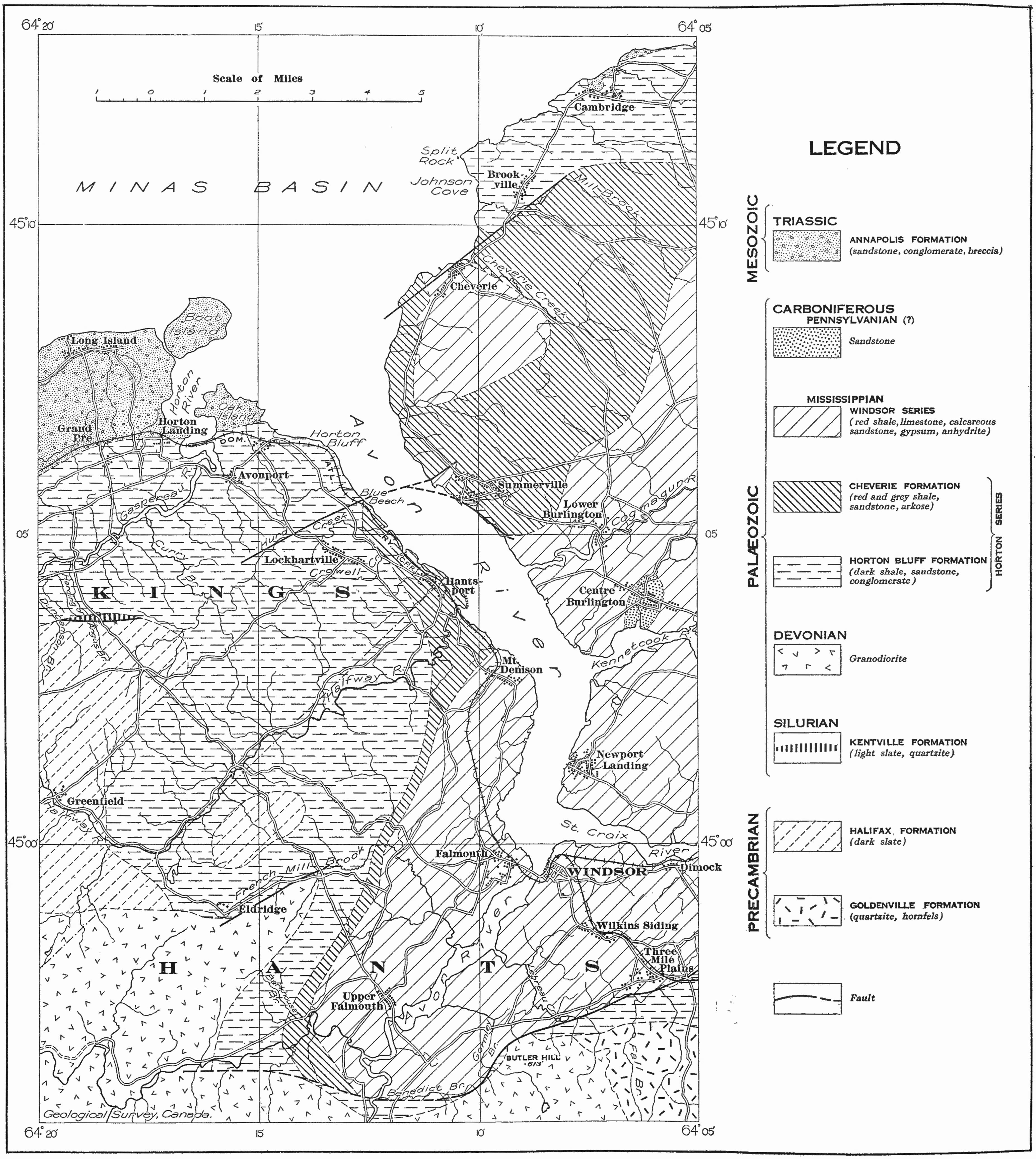
CHAPTER IV

CHAPTER V

CHAPTER VI

CHAPTER VII

Illustrations


64° 20'
15'
10'
64° 05'
Scale of Miles
1 0 1 2 3 4 5
MINAS BASIN
Split Rock
Johnson Cove
Cambridge
Brookville
Mill Brook
45° 10'
Cheverie Creek
Cheverie
Boot Island
Long Island
Horton River
Oak Island
Grand Pre
Horton Landing
DOM.
Horton Bluff
ATL.
Avon River
Avonport
Gaspereau R.
Blue Beach
Summerville
Lower Burlington
Cogmagun R.
05'
Hunt Creek
Curry Br.
RY.
Lockhartville
Crowell Cr.
Hantsport
Centre Burlington
KINGS
Kennetcook R.
Mt. Denison
Halfway R.
Newport Landing
Greenfield
St. Croix River
45° 00'
Falmouth
WINDSOR
Dimock
French Mill Brook
Eldridge
Wilkins Siding
Three Mile Plains
HANTS
Upper Falmouth
Barkhouse Br.
Gormel Br.
BUTLER HILL 613
Benedict Br.
Fall Br.
Geological Survey, Canada.
LEGEND
MESOZOIC
TRIASSIC
ANNAPOLIS FORMATION (sandstone, conglomerate, breccia)
CARBONIFEROUS
PENNSYLVANIAN (?)
Sandstone
MISSISSIPPIAN
WINDSOR SERIES (red shale, limestone, calcareous sandstone, gypsum, anhydrite)
CHEVERIE FORMATION (red and grey shale, sandstone, arkose)
HORTON BLUFF FORMATION (dark shale, sandstone, conglomerate)
HORTON SERIES
PALÆOZOIC
DEVONIAN
Granodiorite
SILURIAN
KENTVILLE FORMATION (light slate, quartzite)
PRECAMBRIAN
HALIFAX FORMATION (dark slate)
GOLDENVILLE FORMATION (quartzite, hornfels)
Fault

70351

Horton-Windsor District, Nova Scotia

CHAPTER I

INTRODUCTION

INTRODUCTORY STATEMENT

The present investigation was concerned primarily with a detailed faunal study of the Windsor series, of Carboniferous age, in the type area in the vicinity of Windsor, Nova Scotia. The underlying purpose was twofold: (1) to so illustrate and describe the faunas that they might be readily identifiable in other localities; (2) to fix more precisely than heretofore their stratigraphic position. The importance of this marine series is paramount in the unravelling of the stratigraphy of the great accumulations of deposits that make up the Carboniferous rocks of eastern Canada, and the present research was planned as a fundamental basis for future studies that might prove of great economic as well as of scientific value.

Since the commencement of this investigation the discovery of rock salt in a Windsor formation at Malagash, the resultant hope of the ultimate discovery of potash, as well as the more intensive development of the gypsum content of the series, has brought the Windsor series to the fore as an economic asset to the province second only to the productive coal measures. Hence the publication of further knowledge concerning it was rendered still more expedient.

The field work was mainly undertaken during the summer months of 1912 and 1913.

ACKNOWLEDGMENTS

The writer is particularly indebted to Professor Charles Schuchert of Yale University for constant inspiration and supervision. As Dr. Schuchert had previously visited the type localities on several occasions, the value of his criticism was greatly enhanced. The Peabody Museum collection of Windsor fossils was generously placed at the writer's disposal.

Thanks are also due to Mr. J. E. Hyde of Western Reserve University, Ohio, for suggestions made in the field during the field work of the first summer.

Although the work was interrupted during the war, the writer was privileged when in England to study the collections of the late A. Vaughan that are preserved in the Sedgwick Museum, Cambridge, and the many courtesies extended him by Professor J. E. Marr of Cambridge University are held in grateful remembrance. Particular pleasure was derived, and benefit received, from direct field observations on the rocks

and contained faunas of Lower Carboniferous age in the vicinity of Settle, Yorkshire, and in Westmoreland, under the admirable guidance of Professor E. J. Garwood of University College, London, who at the sacrifice of his own pressing affairs cordially exerted himself in the writer's behalf.

LOCATION AND AREA

The town of Windsor lies on the estuary of Avon river some 35 miles in a direct line northwest of Halifax. The district under discussion embraces land on either side of the Avon estuary, and faces north on Minas basin, the most southern prolongation of the headwaters of bay of Fundy. The area examined measures roughly 20 miles in a north-south direction by 12 miles in an east-west direction, or about 240 square miles. Communications are readily secured by means of the Dominion Atlantic branch of the Canadian Pacific railway. This railway connects Halifax with Windsor, continues northwards through the district to the town of Wolfville, and thence westerly via Annapolis valley and Digby to Yarmouth. Boat connexions are available at Yarmouth for Boston, and at Digby for St. John. A branch railway running eastwardly from Windsor connects with the Montreal-Halifax line of the Canadian National railways.

REGIONAL RELATIONS

Geologically the district forms a part of what may be termed the Canadian Appalachian system, since it is a northern extension of the Appalachian province of the eastern United States. In Canada this belt of folded Palæozoic rocks has a width of about 375 miles and is bounded on the northwest by the fault system of St. Lawrence valley, which delimits it from the flat-lying Palæozoics and crystalline rocks of the Canadian shield. To the southeast it sinks beneath the waters of the Atlantic, but in Palæozoic times, an old Appalachian land of Acadia lay in this direction, of which the southern half of the Nova Scotian peninsula, which is underlain almost exclusively by Precambrian rocks, may be considered a remnant.

PREVIOUS WORK

To the early settlers the attraction of Windsor district lay in its extensive estuarine flats that, when dyked and drained, would yield rich agricultural harvests with a minimum of labour. Yet the very name of the old French village, "Les Mines" or "Minas" as it was later known to the English, was connected with the supposed mineral wealth of the surrounding country.[1] The extensive outcrops of gypsum along the very shore of the Avon estuary were so readily accessible to the boats trading

[1] Public Documents of the Province of Nova Scotia, Halifax, 1869, pp. 45-46.

there that these deposits were worked as early as the beginning of the nineteenth century, as recorded by Haliburton. But it was not until 1826, when the reputed wealth of iron ore led Francis Alger, the mineralogist, to cross over from Boston to investigate the deposits in Annapolis county, that an attempt was made to interpret the geology of the district.

Alger,[1] in the course of his mineralogical work in Annapolis valley, recognized three formational groups, namely, greenstone, red and white sandstone, and clay slate. No conclusions were advanced, however, as to their relative stratigraphic position. In 1828-1829, Jackson and Alger[2] presented a threefold classification embracing all the rocks of the province. The granite was regarded as primitive, and older than the clay slate. The latter, including both barren and fossiliferous slates, was embraced in a transition clay slate group, and the remaining unmetamorphosed rocks were considered of still later age and lumped together in a red sandstone group. Their younger age was inferred from the contained plant remains, which suggested recent vegetation, and from the fact that their strikes and dips did not conform to those of the slates. Individual beds in this sandstone group are differentiated, as it is noted that "beds of gypsum of practical worth occur near the head of the Basin of Minas, in the vicinity of the Shubenacadie river, where also occurs a large bed of limestone, containing the relics and impressions of marine shells," and that "much larger and more valuable beds of gypsum occur in the county of Hants, where first explored in the vicinity of Windsor about thirty years ago." The topography characteristic of the gypsum rocks is commented upon as follows:

> "The gypsum in the vicinity of Windsor, abounds in those conical or inverted funnel-shaped cavities, supposed to have originated in the solution of rock salt which has been imagined once to have occupied those spaces. No salt, however, or traces of its existence, were discoverable, and if any exists it is unknown to the inhabitants."

An interesting reference is made to the arkose (belonging to the Cheverie formation of this report) which outcrops on a branch of St. Croix river, in which it is classed as a "siliceous breccia passing into greywacke."

Gesner[3] in 1836 co-ordinated the results of Jackson and Alger by dividing the province into four geological divisions, with boundaries running generally southwest-northeast, viz., from south to north:

(1) Primary or granite district.
(2) Clay slate district.
(3) Red sandstone district.
(4) Trap district.

The first serious attempt was then made to differentiate between rocks of the red sandstone district. This was done with considerable success as regards relative position in Pictou district, where from the base upwards Gesner recognized the old red sandstone, mountain limestone, coal measures, and the new red sandstone, but with less fortunate results elsewhere. Thus the gypsum and limestone of Windsor area were considered as a part of the red marl of Annapolis valley, and as belonging to the new red sand-

[1] Alger, F.: Am. Jour. Sci., vol. 12, pp. 227-232 (1827).
[2] Jackson, C. T., and Alger, F.: Ibid., vol. 14, pp. 305-330; vol. 15, pp. 132-160, 201-217 (1828-1829).
[3] Gesner, A.: "Remarks on the Geology and Mineralogy of Nova Scotia", Halifax, 1836, 272 pp.

stone. Moreover, this error was carried to Nappan, Cumberland county, where Gesner stated[1] that "the Coal Measures are covered by the red marl group, including limestone and gypsum" and that "several species of fossil shells and other marine organic remains were discovered in the quarries a short distance from Nappan bridge. They belong to classes contained in the magnesian limestone, i.e., the Permian, of Great Britain, and, therefore, clearly show that this limestone is not the Carboniferous or Old Mountain, as has been supposed by Messrs. Smith and Brown". The earlier correct conclusion of R. Brown that is thus refuted by Gesner was reported in 1829 in Haliburton's "History". Gesner still further added to the confusion thus created by assigning a still later age to the fossiliferous limestone of Economy (which like the Nappan beds carries a Windsor fauna), for he remarked[2] that "the organic remains appearing in the limestone of Economy are sufficient to determine its relative age, and there can be little doubt that it is of similar formation to the Lias [i.e., early Jurassic] of other countries."

In 1841 William Logan visited Nova Scotia fresh from his work in South Wales where he had so ably established the true relations of *Stigmaria* underclays. His recognition of the same phenomena in the Nova Scotia coal fields was an important landmark in the geology of the province. It was during this visit that he made his famous discovery of footprints *(Hylopus logani* Dawson) at Horton bluffs, formerly supposed to be reptilian, but now regarded as amphibian. Logan also collected at that time some fossils at Windsor, which he submitted to De Verneuil and others for identification. These authorities regarded them as equivalent in age to the Permian of Russia, and Murchison in 1843, in his Presidential Address before the Geological Society of London, declared the gypsiferous series of Nova Scotia to be of Permian age.

Sir Charles Lyell, however, visited Nova Scotia in 1842, and his conclusion that the gypsiferous series was pre-Coal Measure, and Lower Carboniferous in age, was published in his "Travels in North America", 1843. Lyell likewise recognized the association with the gypsiferous formation of plant-bearing shales carrying *Lepidodendra* and *Calamites*.

In regard to the origin of the gypsum itself, Lyell states:[3]

"Yet I do not believe that the gypsum has filled rents, for it has all the appearance of having been an original and integral part of the stratified series, formed contemporaneously with the beds of red marl and marine limestone. If we endeavour to account for the origin of the gypsum by the subsequent conversion of carbonate into sulphate of lime, we encounter this difficulty, that beds of limestone full of fossils are intimately associated with the gypsum and yet have undergone no alteration. I saw nowhere any passage from the one to the other even at points where the gypsum and limestone alternate. On the other hand, there are abundant proofs in various parts of Nova Scotia of the intrusion of trappean rocks of contemporaneous origin with the Lower Carboniferous strata so that I have little doubt that the production of gypsum in the Carboniferous sea was intimately connected with volcanic action, whether in the form of heated vapours, or of hot mineral springs or any other kind of agency accompanying submarine volcanic eruptions. To the influence of the latter I also ascribe the remarkable mineralogical difference between the inferior Carboniferous rocks of Nova Scotia and those of the coal fields of the United States which are free from trappean rocks."

[1] Gesner, A.: Op. cit., p. 147.
[2] Gesner, A.: Op. cit., p. 125.
[3] Lyell, C.: Travels in North America in the years 1841-42," 1st ed., 1843, p. 214.

It is difficult to understand what trap rocks Lyell had in mind unless it were those of the Triassic, as basic intrusions of Lower Carboniferous age are not present in western Nova Scotia and are only locally present elsewhere. It is probable, therefore, that Lyell included most of Gesner's red marl group in the Lower Carboniferous series in spite of the fact that he had recognized a red sandstone series at Salmon river as lying unconformably above the Coal Measures. Lyell's observations on the relative age of the gypsum series were confirmed by R. Brown in 1843 for the Cape Breton areas, and Logan in 1844, after an examination of the Minudie section, came to a like decision. Gesner, however, for some time maintained his original attitude, although Dawson in 1843 and in 1845 advanced additional field evidence for the true relative position of these strata.

Although the Lower Carboniferous series was thus well established, little was known of the significance of the sandstones lying above the Coal Measures, until Dawson in 1847, in a paper to the Geological Society, London, assigned the Salmon River beds that had been noted by Lyell, to the Triassic or New Red Sandstone, and traced their distribution about the bay of Fundy. In an appendix to the same paper, Dawson differentiated the gypsiferous formations into an Upper marine formation (later known as the Windsor series) and an estuarine or lacustrine plant-bearing formation (later classified as the Horton series). Thus there were fixed at this time in their proper stratigraphic relations the major units of the late Palæozoic. The remaining work on these rocks was to deal chiefly with the description of the faunas and floras. Dawson in 1847[1] makes mention of an horizon at Horton bluffs with fossil trees in situ. In the same year[2] he proposed an origin for the gypsum similar to that of Lyell, by

"the action of sulphuric acid, conveyed by the rivers into estuaries of small extent, the waters of which, from the abundance of marine fossils, must have been rich in carbonate of lime. . . The acid may have been derived from the oxidation of iron pyrites, which is very abundant in the older formations. . . . There is also good evidence that beds of gypsum were deposited in trough-shaped hollows of small extent. . . . If we suppose the supply of acid to be intermittent this would account for the alternation of gypsum and of shell limestone."

The first edition of "Acadian Geology" was published in 1855. Here Dawson gathered together systematically the results already obtained and accompanied them with a geological map of the province. The main stratigraphic units of the lowland belt are now well established and described, but in the mapping of them the Triassic only is separated. The metamorphic rocks of the uplands are still largely undifferentiated, as the fossiliferous slates are classed together as Devonian and Upper Silurian on the basis of Arisaig fossils submitted to Hall, and the unfossiliferous slates and quartzites of the Meguma series (now regarded as of late Precambrian age) are considered as probably Lower Silurian. The formation of postglacial alluvium by means of tidal action in Bay of Fundy region is explained, and interesting conclusions are drawn as to the inter-relationships of carbon, iron, and sulphur, in the deposits. A bacteriological study

[1] Dawson, J. W.: Quart. Jour., Geol. Soc., London, vol. 4, p. 59 (1847).
[2] Dawson, J. W.: Proc. Roy. Soc., Edinburgh, vol. 2, pp. 140-141 (1847).

of these deposits would be a valuable supplement to Dawson's observations. The drift is recognized as a glacial formation, assigned to a late Tertiary age, and the hypothesis advanced is that of ice floes in a subarctic sea, by which agency boulders were deposited, particularly when the land was subsiding, and stratified drift and " boar backs " formed as littoral deposits on a rising sea bottom.

In 1860, in a supplementary chapter to "Acadian Geology," some advance is made in differentiating the metamorphic rocks. The New Canaan *Dictyonema*-bearing slates are here considered as of Niagaran age after a determination of the fossils by Hall. In the same chapter there is a short description of the characteristic fossils of the Horton series, which later, in 1863, is much amplified in a " Synopsis of the Flora of the Carboniferous Period of Nova Scotia."

The first attempt to subdivide the Windsor series on the basis of faunal content was made by C. F. Hartt in 1867. The main fossiliferous limestones were believed to lie in the following descending order:

Stewiacke limestone
= Maxner limestone of subzone B of this report.

Windsor limestone
= Miller limestone of subzone B of this report.

Kennetcook limestone
= Member of subzone E of this report.

Oolitic fossiliferous limestone
= Member of subzone C of this report.

Avon limestone
= Member of subzone D of this report.

But the difficulties of the problem are well stated by Hartt as follows: [1]

"The question naturally arises as to the relative position of these beds, but this is one which it seems impossible to settle from the Windsor section, and I have seen no localities elsewhere, where their relations to one another were distinctly exhibited. . . These carboniferous limestones wherever they occur are much disturbed and broken up, while the disintegration of the intercalated soft marly strata and gypsum beds, adds to the obscurity of the exposures."

As to the age of the fauna, Hartt quotes the opinions of J. S. Newberry, and of Meek, both of whom were impressed with the Permian aspect of many of the species. Newberry pointed out their resemblance to those from the Permo-Carboniferous of Kansas, and Meek was of the opinion that " taking the whole group of Windsor mollusca, including the lamellibranchs, any one familiar with the shells of the western Coal Measures and Permo-carboniferous beds, would, upon palæontological grounds alone, be very strongly inclined to refer the Windsor rocks at least to the upper Coal Measures." In face of their well-established position below the Coal Measures, he suggested that they might be a " colony " of Permian forms in the Carboniferous sea. Dawson likewise, in an explanatory note to Hartt's paper, remarked that some of the Windsor beds " may be coeval with the Coal Measures," but that " the supposed Permo-carboniferous facies applies to the upper members of the Windsor limestones more especially."

[1] Hartt, C. F.: Can. Nat., new ser., vol. 3, p. 221 (1867).

In regard to Hartt's conclusions, it may be stated that his correlation of certain of the Avon River beds exposed south of the D. A. R. bridge, with the *Phillipsia*-bearing limestones at the mouth of Kennetcook river, is unquestionably in error, as there is little in common either lithologically or faunally.

In 1868 the "Acadian Geology" appeared as a second edition, in which the fauna of the Windsor series receives much fuller treatment, eighty-seven species being noted, among which are fourteen brachiopods formerly described by Davidson in 1863.[1] Hartt's subdivisions of the series are accepted and grouped as a Lower and an Upper series, as follows:

Lower Carboniferous

Upper series	*Productus* limestone = Stewiacke limestone, Hartt.
	Aviculopectan limestone = Windsor limestone, Hartt.
	Zaphrenntis or *Phillipsia* limestone = Kennetcook limestone, Hartt.
Lower series	Crinoidal limestone = Oolitic fossiliferous limestone, Hartt.
	Spirifer limestone = Avon limestone, Hartt.

Dawson regards a marine limestone occurring in Cumberland county as being still younger and possibly coeval with the base of the Upper coal formation. In addition, the Lower Carboniferous coal formation (Horton series) is described from the standpoint of the contained flora, of the fish remains, of the Entomostraca, of supposed worm trails, etc., and the beds occurring at Horton, on the basis of these fossils, are considered as equivalent in age to the Albert series of New Brunswick.

The later publications of Dawson add little to the knowledge already acquired of the geology of Windsor district. In 1873, the flora of the Horton series receives fuller treatment in "Fossil Plants of the Lower Carboniferous and Millstone Grit Formations of Canada." In 1875, attention is drawn to some of the more obscure markings preserved in these rocks under the title "Impressions and Footprints of Aquatic Animals and Imitative Markings on Carboniferous Rocks." Dawson's speculations to the effect that some of these markings were produced by limuloid crustaceans, trilobites, fish fins, etc., are too hypothetical for acceptance. *Phillipsia,* for instance, does not occur in these beds, as stated, but is confined to the marine Windsor series.

In 1879, Honeyman,[2] who had gained some distinction by his enthusiastic study of the Silurian rocks of Arisaig, visited Windsor district. The pre-Carboniferous slates were divided by him into two formations, the *Greenfield* of Upper Cambrian age, and the *Wolfville* of Lower Silurian age. In the Wolfville he placed practically all of the slates within the confines of the district, including those of Wolfville ridge and a great part

[1] Davidson, T.: Quart. Jour. Geol. Soc., London, vol. 19, pp. 158-175 (1863).
[2] Honeyman, D.: Trans. Nova Scot. Inst. Sci., vol. 5, pp. 21-31 (1879).

of those of Black river now generally recognized as belonging to the Halifax formation (uppermost member of the Precambrian Gold-bearing or Meguma series). The Greenfield apparently included a western portion of the same slate, which appeared to him to correspond more closely in lithological characters with the slates in the vicinity of Halifax. He did not accept an Upper Silurian age for the *Dictyonema websteri* beds, but was inclined to regard them, as well as the quartzites of Whiterock, as Lower Silurian. The drift deposits he held to be post-Pliocene, but he had a conception of the drastic denudation accomplished during the retreat of the ice by the agency of a Champlain sea, as he thought it necessary to fill up the valleys during the period of ice advance, in order to have highways of transportation for the distribution of boulders from the north. The present topography was consequently established in Champlain time. His conclusions regarding the local geography of late Palæozoic times were of the conventional type then prevalent, as evident from the following statement:[1]

"Conditions similar to those now existing in the bay of Fundy seem then to have prevailed. Conditions rather favourable to the denudation of shores, than for the accumulation of littoral deposits. The first littoral check given to the sweep of the waters seems to have been the pre-Carboniferous rocks of Wolfville, which seem to have been a cape of the Carboniferous period. This seems to have been favourable to a coarse sandy accumulation (grit) while at the same time the Cobequids had a shingle shore (conglomerate)."

A similar sea and shore are invoked for Triassic times, a view more definitely advanced in 1881 by Gilpin,[2] who ascribed Triassic sedimentation to tidal action in bay of Fundy, in a manner "closely analogous to that now going on outside our dyked lands."

In 1883, Dawson, in a "Preliminary Notice of New Fossils from the Lower Carboniferous Limestones of Nova Scotia and Newfoundland," described several new species from the Windsor series. The Newfoundland beds from their fossil content were considered to be synchronous deposits.

In 1890, Hugh Fletcher commenced the geological mapping of the district. He immediately, though wrongly, referred the Horton series to the Devonian, as lithologically and structurally he believed they were equivalent to certain rocks in Cape Breton and eastern Nova Scotia previously assigned by him to the Devonian. This correlation later became involved in a prolonged controversy that arose regarding the correlation of various Carboniferous formations within the Maritime Provinces. Fletcher in 1890[3] regarded the contact of the "Devonian" strata at Cheverie with the Carboniferous Limestone formation as unconformable. This contact, as will be stated later on, lies in a faulted belt. The geological formations of the district enumerated by Fletcher in 1894 belong to the Triassic, Carboniferous Limestone, Devonian, Silurian, and Lower Cambrian periods. In the same year, the contact between the Carboniferous Limestone and the "Devonian" is stated to be a "mineralized zone," on account of the manganese content, an observation that has stood the test of all later field work.

[1] Honeyman, D.: Op. cit., p. 28.
[2] Gilpin, A.: Trans. Nova Scot. Inst. Sci., vol. 5, p. 285 (1881).
[3] Fletcher, H.: Geol. Surv., Canada, Ann. Rept., new ser., vol. V, pt. 1, p. 59A.

A reference is also made to the soft sandstones at Burlington (of probable Pennsylvanian age) that overlie the Carboniferous Limestone of Kennetcook river.

In 1899, A. S. Woodward, to whom fish remains from the Horton formation had been submitted, pronounced them unequivocally Carboniferous. The same year both Kidston and David White confirmed Dawson's assignment of the Horton flora to a basal position in the Carboniferous system. H. M. Ami, in 1899, in a paper "On the Subdivisions of the Carboniferous System in Eastern Canada," placed the Windsor series in a Meso-Carboniferous group as the basal member, and although the Horton series is not mentioned specifically, there is little doubt that Ami erroneously considered it at that time a part of the Riversdale, which, with the Union, was placed in an Eo-Carboniferous group. Thus, in the following year, 1900, Ami writes in his "Synopsis of the Geology of Canada":[1]

"In the Eo-Carboniferous I would also place the Horton formation which, throughout the Bay of Fundy trough, consists of black and grey carbonaceous and calcareous shales, etc., overlying granitic sandstones and marls, etc., which latter series constitutes a separate formation in the Wolfville and Horton districts. The name *Gaspereau formation* is suggested for these granitic sandstones of the Avon River valley and from Angus brook in the Gaspereau valley in Kings county, Nova Scotia."

This attempt of Ami to further subdivide the Lower Carboniferous was justified, but unfortunately his Gaspereau formation thus defined would include not only the arkosic strata lying at the base of the Horton Bluff formation in Gaspereau Valley region, but as well the arkose and shales overlying the Horton Bluff formation. It was undoubtedly the latter group particularly that Ami wished to differentiate, but he erred in considering these arkoses so well exposed in the Horton Bluffs section as lying at the base of the dark Horton Bluff shales instead of above them.

Fletcher in 1900 definitely assigns the Horton formation to a place in the American Hamilton group, to which he adds that "the relation of the Horton to the beds immediately overlying the Silurian has not yet been worked out."[2] In 1901 a geological sketch map of parts of Hants and Kings counties was issued by the Geological Survey, on the basis of surveys by Fletcher and Faribault, on which the following formational units are distinguished—Triassic, Carboniferous Limestone, Devonian (Horton), Silurian (and Cambro-Silurian?), Lower Cambrian (Graphitic Slate series), and Igneous. The arkose of the Cheverie formation (formerly placed at the base of the Horton by Ami) is here included in the Carboniferous Limestone, but the upper red shales of the same formation at Cheverie are included in the Horton Devonion. Faribault, however, in the Windsor sheet[3] published in 1909, includes the basal arkoses of the Cheverie formation in like manner with the "Devonian".

E. Haycock in 1901 contributed one of the few papers on the physiography of the district. In his endeavour to trace historically the development of Gaspereau valley, he concludes that it antedated the Horton in age,

[1] Ami, H. M.: Trans. Roy. Soc. Canada, 2d ser., vol. 6, p. 210 (1900).
[2] Fletcher, H.: Trans. N.S. Inst. Sci., vol. 10, p. 242 (1900).
[3] Geol. Surv., Canada, Serial Sheet 73.

having been established by a slow, faulting movement along its present northern margin, with a resultant maximum vertical displacement of some 2,500 feet.

The same year R. A. Daly[1] made a broad analysis of the physiography of the province, comparing and dating the major topographic features with those of New England and the Appalachian country in general. Two peneplains were recognized coinciding with surfaces that are well preserved in the Southern Upland and in the Carboniferous Lowland respectively. Both were held to be of subaerial origin, the products of two main cycles of erosion, the one culminating in the Cretaceous, the other in Tertiary time. The younger or Tertiary was only developed on the softer, unmetamorphosed rocks and its present modification was due to renewed differential movements in late Tertiary times that resulted in the carving of the present valleys and finally in the submergence of the lower valleys of these rivers and the initiation of an estuarine topography and of a ria coast. Later post-glacial differential movements in Post-Champlain time resulted in the uplift of such marine plains as that of Middleton.

Ami[2] in 1902, after a study of *Dictyonema websteri* Hall, came to the decision that this species was a close ally of *D. flabelliforme* Eichwald, and consequently he assigned the slates containing this graptolite to the Upper Cambrian. This procedure met with criticism from H. S. Poole, and was refuted by Ruedemann[3] in 1905, who positively identified *D. websteri* Hall with *D. retiforme* Hall, a Niagaran graptolite.

The Gold-bearing division of the metamorphic strata received further descriptive treatment in 1904 when J. E. Woodman[4] proposed the nomenclature now in use, i.e., Meguma series for the entire group, Goldenville formation and Halifax formation for the lower and upper divisions respectively. Reasons for regarding the Meguma series as Precambrian in age had previously been advanced by Van Hise in 1894-1895

Lambe[5] in 1908, after a comparative study of the fossils from the Albert series of New Brunswick and the Horton series, regarded the two series as nearly synchronous Lower Carboniferous deposits. Later, in 1910,[6] after a revision of the Palaeoniscid fish remains, he confirmed this conclusion and placed them in a position equivalent to the Calciferous Sandstone series of Midlothian and West Lothian, Scotland.

Schuchert, in his "American Fossil Brachiopoda," 1897, lists brachiopods from the Windsor series, assigning them to an Upper Carboniferous age. Later, in 1910,[7] he included both the Horton and Windsor series in his emended Mississippian System, stating that the highest beds at Windsor were seemingly Keokuk in age, but that they might be somewhat younger, and this Mississippian age of the series was supported by J. W. Beede for the Magdalen Islands faunas.[8]

[1] Daly, R. A.: Bull. Mus. Comp. Zool., Harvard College, Geol. Ser., vol. 5, No. 3, pp. 73-104 (1901).
[2] Ami, H. M.: Trans. N.S. Inst. Sci., vol. 10, pp. 447-450 (1902).
[3] Ruedemann, R.: Trans. N.S. Inst. Sci., vol. 11, p. xlvii (1905).
[4] Woodman, J. E.: Am. Geol., vol. 33, p. 368 (1904).
[5] Lambe, L. M.: Geol. Surv., Canada, Sum. Rept. 1908, p. 177.
[6] Lambe, L. M.: Geol. Surv., Canada, Cont. Can. Pal., vol. 3, pt. V, p. 14 (1910).
[7] Schuchert, C.: Bull. Geol. Soc. Am., vol. 20, p. 551 (1910).
[8] Beede, J. W.: N.Y. State Mus., Bull. No. 149, p. 161 (1911).

Sidney Powers[1], in 1916, in a regional study of the Triassic rocks, included the Triassic strata in Wolfville district as a part of his Annapolis formation. Ami had previously designated these rocks the Grand Pré formation. Powers, furthermore, divided the Annapolis formation into two members, the Wolfville sandstone below, and the Blomidon shale above. The evidence bearing on the correlation is reviewed and these beds are assigned a position equivalent to the Newark group of the eastern United States or to the Lettenkohle of Germany, one of the formations of the Triassic.

[1] Powers, S.: Jour. Geol., vol. 24, p. 6 (1916).

CHAPTER II

STRUCTURE AND PHYSIOGRAPHY

LOCAL STRUCTURE

As the bedrock is the material out of which the major land-forms are sculptured by the play of the external forces of nature, a consideration of its component units in relation to their attitude, and their competence as structural materials, is of initial value in physiographic interpretation. In Windsor district these units with their dominant characters are tabulated on a later page.

FAULTING

Normal faults with small, stratigraphic displacements affect the Carboniferous and Triassic formations with but little present topographic expression, except along the shorelines where they commonly are the loci of local drainage gullies. They may be seen to best advantage along the Cambridge shore where small downthrows to the north rarely exceeding 25 feet occur. Similar small slips are displayed in the section at Horton bluffs.

Normal faults with low angles of hade, and thrust faults of unknown hade, both accompanied by wide brecciated zones, are much more important. Of these the Butler Hill fault, the Cheverie fault, the Blue Beach fault system, and the Summerville fault system are of major interest. The Butler Hill fault limits the lowland south of Windsor. It trends about 30 degrees north of east from Avon river to Threemile plains, a distance of 7 miles, and brings the granite mass of Butler hill in approximate contact with gypsum that lies about the middle of the Windsor series. Thus the downthrow is to the north. West of Avon river the fault enters the granite country; eastward of Threemile plains it extends beyond Windsor district at least as far as St. Croix river and probably several miles beyond. The stratigraphic throw varies in amount at different places and in Windsor district certainly exceeds 1,000 feet and probably is in the neighbourhood of 2,000 feet. It finds topographic expression in the abruptness of the slopes between the Carboniferous lowland and the Precambrian upland in the southern, as contrasted with the more graded slopes in the western, part of the district, as well as in the location for several miles along its course of Lebreau creek.

The Cheverie fault has a much less stratigraphic throw, but it is accompanied by intense local brecciation. It trends about north 50 degrees east from the Avon shore south of Cheverie point to the vicinity of Brookville, a distance of 3 miles, beyond which it could no longer be traced on account of the presence of glacial drift. The brecciation involves basal beds of the Windsor series, Cheverie strata, and upper beds of the Horton formation, but the maximum vertical stratigraphic displacement probably does not exceed a few hundred feet. It seems probable, however, that deformation took place along more than one plane, and that a thrust fault, for instance, may be located at Johnson cove, but is now effectively concealed under a mantle of drift. The whole disturbed zone forms a low depression partly occupied by Mill brook.

The Blue Beach fault, well exposed in the Horton Bluffs section, trends about north 30 degrees east. As it affects strata of the Middle Horton and basal beds of the Cheverie only, the stratigraphic throw can not be more than several hundred feet. It is a complex of several planes of movement and is closely related to, if not an extension of, the Summerville disturbed belt that occupies the opposite shore of Avon river for 2 miles southward from the most northerly wharf at Summerville. The thrust nature of the movement at the latter place is quite evident, as gypsum of the Windsor series is seen at several places in the shore bluffs to underlie black shales of the older Horton formation.

A further series of faults of extreme importance stratigraphically, but with little or no direct topographic expression, affect the strata of the Windsor series. These are thrust slides that divide the Windsor mass of sediments into a series of " slices " inclined at high angles to the south. Where the slip planes are closely spaced, there results an isoclinal structure, but where more widely spaced, as in the more competent upper beds of the series, intervening, closed, or even open symmetrical folds may occur. This is exemplified in the southern part of the district, in the vicinity of Windsor, by such open synclines as that of Maxner point on Avon river 1½ miles southwest of Windsor, which affects a bottom member of the series, or that of St. Croix river a mile east of Windsor, where limestone occupying an upper stratigraphic position in the series forms the base of a synclinal hill.

All of the above faults are of post-Windsor age; but another fault of greater antiquity and of equal stratigraphic interest is inferred to be present at Harding (or Angus) brook, coinciding with the plane of contact between Silurian slates, bearing *Dictyonema websteri* Hall, and banded slates of the Halifax formation. The evidence is discussed in detail under the section dealing with the Silurian. Its extension can not be traced far to the westward owing to lack of outcrops in Gaspereau valley, and, as the fault-plane was truncated by pre-Horton denudation, it is overlapped to the eastward by Horton Carboniferous sediments.

FOLDING

Folds affect both the Carboniferous and Precambrian rocks. Such flexures are exemplified in the western half of the district where several anticlines, namely, the Wolfville anticline, Five Points anticline, Grey Mountain anticline, and Eldridge anticline, occur in association with corresponding synclines, Gaspereau syncline, Halfway syncline, French Mill Brook syncline, and Avon River syncline. Of these, the Eldridge anticline is complicated by a fault that steepens its northern face, but which could not be traced with sufficient definition for mapping. The other flexures have resulted from broad, unmodified folding movements. The reflex of this folding on the topography is apparent in the boundary of lowland and upland; lowland synclinal valleys are projected into the upland as embayments, and major anticlines form upland ridges locally designated "mountains", e.g., Gray mountain. This relation has given rise to the mistaken impression, commonly current in the literature, that these lowland embayments or valleys are a reproduction of an original marine shoreline topography of deposition.

A second type of folding of a minor order has deformed the soft Windsor strata. Commonly these folds are recorded in the topography by small, synclinal hills of limestone.

The date of folding of the Carboniferous strata was pre-Triassic, as evidenced by the unconformable contact and attitude of the Triassic beds. Contacts of basal Pennsylvanian strata with Windsor beds elsewhere in the province indicate no appreciable folding movements in the interval between the Mississippian and Pennsylvanian periods. But at Parrsboro, only 20 miles north of Windsor district, there is recorded a folding disturbance of early Pennsylvanian time, as the Parrsboro formation of late Riversdale age lies with marked angular unconformity upon the Harrington River formation of early Riversdale age and both divisions of the Riversdale were deposited in Pottsville time. Although Riversdale folding does not seem to have been widespread throughout the province, but to have been confined to a local belt bordering the Cobequid crystalline axis, it seems scarcely possible that the Windsor sediments of Windsor district escaped the movement. But whether Horton and Windsor strata of the latter district were mainly deformed at the time of the Riversdale disturbance is not known as later Pennsylvanian folding movements are recorded at various localities in Nova Scotia.

The thrust slides of the Windsor series and such underthrusts to the north as those at Summerville and Cheverie may have originated at the time of the major folding or subsequently at a time of major normal faulting. The Pennsylvanian sedimentary basins of Nova Scotia are commonly bounded by normal faults of low hade and great magnitude and it is reasonable to infer that such faults as the Butler Hill fault were likewise of post-Pennsylvanian age. At the time of such faulting adjustment of such a plastic series as the Windsor might readily be affected by thrust slipping. It is a commonplace observation in Nova Scotia to note that the gypsum areas are frequently cut and bounded by faults, whereas neighbouring areas underlain by less plastic strata are unbroken. The extreme plasticity of gypsum has caused it when under differential pressure to force its way into surrounding sediments and the resulting faults are commonly accompanied by widespread brecciation. Volumetric expansion consequent upon a change from anhydrite to gypsum has likewise been a factor in deforming adjacent beds. Northward axial dips, of folded Carboniferous strata, in the northern part of the Horton-Windsor district, are contrasted with southward axial dips in the south and this is probably a result of the presence of the resistant crystalline mass of the Cobequid ridge, which acted as a buttress against the movements of the softer Carboniferous strata south of it, resulting in overturning of folds to the southeast.

LOCAL TOPOGRAPHY

The greater part of Windsor district is a low-lying, undulating surface with elevations below 200 feet. It is dissected by a number of shallow valleys, *e.g.*, the Avon, Gaspereau, St. Croix, Kennetcook, and Cogmagun, whose lower courses have been submerged, greatly widened, and converted into tidal estuaries with bordering flat marshlands. This lowland surface is continuous with, and quite evidently an integral part of, the Carboniferous and Triassic lowland tract of Minas basin that extends eastward to Truro and beyond, and westward up Cornwallis-Annapolis valley. To the south and southwest, however, the surface progressively rises, now abruptly, now less so, but ever with high gradients, to an upland surface, 500 feet or more in elevation, locally known as the Uniacke and South mountains. This highland is, however, only the northern border of the southern upland that flanks the whole southern half of the peninsula and that includes the main watershed of the province.

In analysing this topography of Windsor district, one well-marked peneplain is presented coinciding with the surface of this upland. Its superior elevation, in conjunction with the structural field evidence, indicates that it is older than the present lowlands, which latter may, therefore, be considered as a broad valley carved in the softer rocks out of its mass. The chief characters of the upland will briefly be considered.

SOUTH MOUNTAIN PENEPLAIN

Starting from the Gaspereau lowland at the limit of the high tidal line and ascending one of the streams draining South mountain, *e.g.*, Harding (or Angus) brook, one is impressed by the youthful, ravine-like character of the valley. Rock outcrops are abundant along the stream channel, and ledges of fresh rock outcrop in the steep banks on either hand. The valley itself is narrow, and but little wider than the channel, even at times of least water flow. On ascending higher, the water cascades over a low fall. From here up, there is a radical change. The valley broadens out into a very shallow, swampy depression with low, mature slopes. Rock outcrops are practically absent except where the small, meandering channel has washed away the glacial drift. The boggy nature of the ground favours the growth of dense groves of black alder, rendering further progress difficult. The traveller has, in fact, reached the upland, peneplaned surface of South mountain. Further travelling through the bush and along the roads of this upland fails to discover any exception to the monotonous rolling surface. Only when granite is encountered does the ground rise to rounded hills several hundred feet above the general level, such as that of Butler hill, 613 feet. Bogs, small lakes, and ponds are everywhere abundant.

The underlying rock, wherever exposed, consists of highly inclined slates or quartzites, or of irregular masses of granite. The sediments belong to the Precambrian Gold-bearing or Meguma series, and a glance at the geological map of the province will show that these hard crystalline rocks are co-extensive with the upland surface itself. These sediments are closely folded into a series of long anticlines and synclines pitching at moderate angles and trending generally northeast-southwest, but with the axial line somewhat concave towards the Atlantic. Yet these great flexures are at the present time truncated everywhere by the upland surface, so that their restoration would yield a hypothetical constructional topography towering thousands of feet in height above the present peneplain. The quartzite series of the Meguma is massively bedded and it is consequently a very resistant rock. Yet it is subdued into low, rolling belts little higher than the adjacent belts of slate. The granite is still more resistant and it does indeed rise to higher elevations, but likewise with a very subdued aspect. As the mass of quartzite, or the Goldenville formation as it is called, is older than the slates of the Halifax formation, its highest levels occur in the anticlines, and the greater breadth and extent of its outcrop is a good indication of the vast amount of denudation that must have taken place before the last peneplanation that gave its present surface.

As this surface is so unrelated to the presence of such highly tilted rocks of varying degrees of hardness, it might well have had an extension much beyond its present limits. Certainly the youthful slope connecting the lowlands with the upland suggests that it passed over the whole of Windsor district. It seems to have included as well the present summit level of North mountain, a trap ridge of about 700 feet elevation, that extends uninterruptedly for more than 100 miles along the south shore of bay of Fundy and is removed from the main mass of South mountain by a valley less than 10 miles wide. The summit trace of this ridge as seen against the sky is likewise independent of the attitude of the trap, which is made up of a number of distinct stratified flows that slope at an angle of some 10 degrees northwards under the bay. Ten to 15 miles north of North mountain, there is another peneplained surface, with elevations of 1,050 to 1,250 feet, developed on the crystalline complex of Cobequid mountain, that runs as an upland ridge through Cumberland and Colchester counties. Some 35 miles north of North mountain, a similar peneplain is developed on the crystalline complex of Caledonian mountains in New Brunswick (1,000 to 1,200 feet). That these outlying surfaces are likewise remnants of a common peneplain that includes the South Mountain upland surface has been suggested,[1] although the evidence is not conclusive. The degree of probability of such a widespread extension would be more accurately gauged if one could definitely fix the origin of the peneplain. If it is a resultant of fluvial denudation, as postulated by Daly, it would necessarily be of great extent and might even be readily correlated with such far distant peneplains as those of New England and elsewhere in the American Appalachians. Barrell, however, has presented evidence that the so-called peneplain of New England east of Green mountains, Vermont, is actually a series of dissected piedmont terraces.[2] Moreover, he has traced these terraces over such a length of country from north to south that they might well have representatives in Acadia. Unfortunately there are three fundamental unfavourable factors that pre-

[1] Daly, R. A.: Bull. Mus. Zool., Harvard Coll., vol. 88, pp. 82-83 (1901).

[2] Barrell, J.: Bull. Geol. Soc. Am., vol. 24, pp. 688-696 (1868). *See also* "Physiography of Nova Scotia," by J. W. Goldthwait. Mem. 140, Geol. Surv., Canada; this memoir was published subsequent to the writing of the present memoir.

vent a comparable analysis of the peneplained surfaces of Nova Scotia. These are the timbered nature of the upland country, the lack of topographically contoured maps, and an unfavourable relation of axial trend of the rocks to the Atlantic.

Returning to the southern upland surface, there are modifying features that must be considered. Another glance at the map will confirm the ubiquitous presence of innumerable lakes, ponds, and bogs, and field observations will prove the presence of many hills and ridges unrelated to the rock floor, as well as a disordered condition of the drainage inconsistent with the present level of the upland. Countless boulders, scratched and polished surfaces of rock, and the heterogeneous or stratified nature of the drift composing these hills betray the agent that brought about this alteration of the peneplain as a glacial one. There is no evidence, however, that the partial glacial cycle was sufficiently long or of such a character as to produce pronounced regional erosion. It removed, it is true, practically all traces of a residual soil, and scratched and polished the underlying rock, and erosion was intensified along preglacial valleys that trended in the general direction of its path, thus strengthening the ria nature of the Atlantic coast-line. The most pronounced effects, however, were left as a heritage during the retreat of the ice, when moraines, drumlins, and eskers were left stranded as obstructions to the modifying agents of the next regime.

MINAS LOWLANDS

There are few elevations in the lowlands, within Windsor district, exceeding 200 feet, and these higher elevations fall on the slopes bordering South mountain, which are developed mainly on the Horton series, the basal member of the Carboniferous. In general, the elevations of the Horton strata exceed those of the Windsor series, which comprises much softer rocks rarely exceeding altitudes of 100 feet. It is apparent, therefore, that in so far as Windsor district is concerned, there is an intimate dependence of the lowland topography on the underlying rock. The surface may perhaps be classified as old mature, as the slopes are well graded and the relief is subdued.

The lack of a contoured map of Windsor district makes it impossible to decide whether some of the higher elevations in this lowland tract are so co-ordinated as to lie on a definite peneplain that may have been developed on the Carboniferous rocks below the level of the South Mountain peneplain. The slopes in the western and southern parts of the district are clearly graded in conformity with the bedrock. There is, however, an area in the eastern part of the district, in Kempt township, lying in the neighbourhood of 150 feet elevation, in which the surface is a low, rolling plain, little dissected, that truncates disturbed folded beds of differential thickness. Moreover, similar well-developed tracts occur in Cumberland county and elsewhere in the province with elevations approximating 200 feet. It is not improbable, therefore, that Windsor district is a dissected portion of an extensive peneplain of whatever origin, coincident with part of, or with the whole, Carboniferous lowland of the Maritime Provinces. A more pronounced dissection in the southern and western parts of Windsor district is readily explicable, as it is the basin area of Avon and St. Croix rivers, and is underlain dominantly by soft rocks of the Windsor series.

Limestone, gypsum, and soft, red, argillaceous shales and marls make up the Windsor series. Of these, the shales are most readily denuded, and where overlain by limestone, the latter forms synclinal hills. As the folding of this weakly competent series has been in the nature of small flexures with rather steeply inclined axial pitches, where shale is dominant these hills are in some cases oval-shaped or drumlin-like, necessarily of low elevation, as the thickness of the individual limestone members never exceeds 100 feet.

The thick zones of gypsum locally give rise to a topography characterized by deep, funnel-shaped sink-holes and larger depressions with no surface drainage outlet. Rarely they assume a definite alignment, and occasionally this may be correlated with underground drainage channels. The subsidence, therefore, has resulted either from undermining by the groundwaters which have dissolved out channels for themselves, or by vertical solution along pre-existing joints and lines of weakness and slumping in of the mouths of these fissures. Typical karst topography is not developed in Windsor district, although it is present on a small scale in some parts of the province.

ESTUARINE PLAINS

There is another important element in the landscape, that bears an alien relation to the above topography. This is the tidal marsh whose plains border certain portions of the Avon estuary and its tributaries. They are plains of aggradational, in contrast with planes of denudational, origin. They are directly a product of the estuary as the present valleys containing them are entrenched within the older topography of the district, and the estuaries are simply their drowned lower courses.

The estuarine plains occur at the heads of the estuaries and at the mouths of tributary stream valleys. In Windsor district the most extensive are: (1) the Grand Pré meadows lying at the mouths of Gaspereau and Cornwallis rivers; (2) dyked marshland for 5 or 6 miles along Avon river above Windsor; (3) along the lower course of St. Croix river, with minor strips along Kennetcook and Cogmagun rivers. The most of this marshland has long been dyked by artificial embankments and converted into rich hay meadow. The width of the tracts is variable according to the size of the streams and their meanders, the characteristics of the adjacent shoreline, the tidal range, etc. The latter at Windsor averages about 20 feet for the neap, and 30 feet for the spring, tides.[1] According to Haliburton, the Grand Pré and adjacent dyke land alone comprise some 4,000 acres.

The tidal origin of these extensive marshes is evident from their present growth, from their localization along meander bends or elsewhere upon favoured, antecedently flat-lying bottoms of stream valleys, and from the relations they hold to areas of wave erosion. The wave erosion of the soft, calcareous Triassic sandstone of Minas basin is particularly rapid, with the

[1] Haliburton, T. C.: "An Historical and Statistical Account of Nova Scotia," Halifax, 1829, p. 102.

result that much sediment is worked over by the tides. Marsh formation at the head of bay of Fundy and in the tributary Avon estuary is especially prominent. Mechanical analysis of the muds reveals an origin from adjacent Triassic and Carboniferous arenaceous beds, in that the proportion of clay rarely exceeds 15 per cent and may be as low as 5 per cent, whereas the great bulk is very fine sand or siliceous silt.[1] The chocolate-brown colour itself is inherited, as it is furnished by the unaltered iron hydroxide derived from the Triassic and Carboniferous rocks. Tidal deposition and marsh formation proceed, therefore, hand in hand, as the tidal current loaded with sediment strives to grade its profile in a manner analogous to a river. The resulting surface of equilibrium is in consequence continually shifting in sympathy with changes of the shoreline, changing range of tidal level, etc. It is not infrequent, for this reason, to see salt marsh in the process of rapid undercutting by the present waves.

Certain features commonly associated with such marshes have been advanced as evidence of subsidence, and subsidence has commonly been accepted as a prominent casual factor in their formation. For example, Ganong has advanced the following three arguments for subsidence: (1) submerged trees; (2) peat bed 20 feet thick under 80 feet of marsh at Aulac (after Chalmers, 1885); (3) marsh mud underlain by post-glacial clay. Nos. 1 and 3 fall into the same category, but in some instances there is no necessity of implying subsidence in order to explain the facts. That normal undercutting may be effective in bringing about local features of this category was pointed out by Hamilton in 1868.[2] All submerged stumps observed by the writer in Windsor district—and they are common off Oak and Long islands, in an area landward of shifting bars—were above low tidal level and may testify to nothing more than normal marine transgression. It is even quite possible through local changes in the range of tide in co-ordination with the change of shoreline, where tidal ranges are normally high, as in Fundy basin, that terrestrial surfaces such as submerged forest soils, peat beds, etc., might be submerged several feet below the level of low tide. Where former terrestrial surfaces, however, are deeply embedded below low tide, as instanced by the Aulac marsh, it seems necessary to postulate progressive subsidence contemporaneously with tidal deposition as suggested by Dawson[3] and recently elaborated by D. W. Johnson.[4]

---

[1] Ganong, W. F.: Bot. Gazette, vol. 36, pp. 161-186 (1903).
[2] Hamilton, P. S.: Trans. Nova. Scot. Inst. Nat. Sci., vol. 2, pt. 2, pp. 94-99 (1870).
[3] Dawson, J. W.: "Acadian Geology", 2nd ed. 1868, pp. 28-31.
[4] Johnson, D. W.: "The New England-Acadian Shoreline," 1925, pp. 517-587.

CHAPTER III

SEDIMENTARY GEOLOGY

INTRODUCTION

The purpose of the present chapter is to present a broad general description of the various stratigraphic units into which the rocks of Windsor district may be divided, to outline their local distribution and regional relations, and to summarize briefly the data on which their correlation is based. Thicknesses where given are only approximate estimates, a circumstance rendered unavoidable by the isolation and incompleteness of the outcrops, by the presence of many small faults or folds, and by the terrestrial nature or peculiar facies of the sediments. In their calculations, horizontal distances across the strikes were computed from stadia surveys by means of a telemeter, and the dips and strikes were checked with great frequency. The results are believed to err in the direction of too small, rather than too great, amount.

The formational names employed have, with one exception, already entered into the literature through the usage of previous authors. For the present the designation "Windsor series," as used by Dawson for the marine Carboniferous, is preferred to the term "Windsor formation" as has been proposed by Ami. However, if a "formation" be regarded chiefly as a mappable unit, there would be little objection to its application in this particular district, as it would be almost impossible to map with any accuracy the two major faunal zones into which the Windsor series may be divided. Moreover, the series as a whole is a well-defined lithological unit that was deposited under similar geographic conditions. The stratigraphic succession is tabulated as follows.

Table of Formations

Era	Period	Formation	Lithological character	Thickness	Correlation
				Feet	
Cenozoic	Recent		Stream gravels, modified glacial drift, residual soils, tidal alluvium	0-?	
		Unconformity			
	Pleistocene		Boulder clay, stratified drift	0-60+	
		Unconformity			
Mesozoic	Triassic	Annapolis	Salmon-red grits and sandstones	1,000 +	Newark (U.S.A.) Lettenkohle (Germany)
		Unconformity			
Palæozoic	Pennsylvanian or Upper Mississippian		Soft grey sandstone, weathering buff-yellow	17+	Westphalian (?)
		Unconformity			
	Upper Mississippian or Tennesseean	Windsor series	Brick-red argillaceous shale, grey limestone, gypsum, and anhydrite	1,550 1,100±	Visean (England, Belgium) Chester gp. (in part) + Ste. Genevieve (?) U.S.A.
		Disconformity			
	Lower Mississippian or Waverlyan	Cheverie	Grey arkose, red shale	600	
		Disconformity			
		Horton Bluff	Dark grey arenaceous and argillaceous shales, grey feldspathic sandstones and grits	1,000–3,400	Kinderhookian Pocono (U.S.A.)
		Unconformity			
	Silurian	Kentville	Green-grey slates	?	Niagaran
		Disconformity			
Precambrian		Halifax	Dark green-grey banded slates	2,500±	?Avalonian (in part) (Newfoundland)
		Goldenville	Finely granular quartzite	?	

PRECAMBRIAN

GOLDENVILLE AND HALIFAX FORMATIONS

Introduction

The southern half of the peninsula of Nova Scotia is built of an immense accumulation of arkosic quartzites and slates, estimated as fully 28,000 feet[1] above an horizon whose position relative to the real base is unknown. These rocks are closely folded in long, moderately pitching flexures parallel to the trend of the Gaspe Appalachian axis, have a marked regional cleavage, and are intruded by one or more batholiths of granite of Devonian age. Subsidiary domal folds located on the major anticlines in many cases carry auriferous quartz ore-bodies, an economic factor that has accelerated the detailed investigation of the rocks by geologists.

Their efforts have led to the division of the Meguma series, as it has been called, into two lithological formations, the Goldenville below and the Halifax above, conformable one to the other, but over large areas showing an abrupt change of facies from a dominantly quartzitic, to an almost pure pelitic, phase. The most salient physical character of the Goldenville formation, in relation to its thickness of more than 16,000 feet, is the monotonous uniformity of the facies, as the development of conglomerate is almost negligible, and the amount of interbedded greenish slate so meagre as not to exceed 5 per cent of the whole.[2] The Halifax formation, on the contrary, supposedly exceeding 10,000 feet in thickness, is characterized by its lack of quartzite, and is an equally monotonous succession of dark slates, frequently graphitic in nature. A modification of this facies, less widespread geographically, and especially characteristic of the western half of the province, is a series of finely banded slates or argillites, that are believed to occupy a basal position in the Halifax formation.

Local Descriptive Geology

Both the Halifax and Goldenville formations have representatives in the marginal uplands of Windsor area. They are widely separated from one another in location by an intruded granite batholith, and by a down-faulted, bay-like prolongation of the Lower Carboniferous formations that extends into this granitic area along Avon River valley.

The smaller of these areas is underlain by the Goldenville quartzite division, and occurs as a wedge-shaped mass in the southeastern corner of the area, forming part of the southern upland. Outcrops may be seen in Fall brook in the vicinity of the reservoir of the Windsor waterworks. Eastward, these rocks may be traced into the much more extensive areas of Rawdon and Uniacke. Westwards and southwards, they are abruptly cut off by the coarsely crystalline biotite granite of the batholithic intrusion.

[1] Prest, W. H.: Geol. Surv., Canada, Ann. Rept., vol. IX, pt. M, p. 83 (1898).
[2] Woodman, J. E.: Am. Geol., vol. 34, p. 18 (1904).

Those rocks that, near the waterworks reservoir, rise unconformably from beneath basal conglomerate of Lower Carboniferous Horton age, are clearly a metamorphosed product resulting from their close proximity to the loci of the granitic intrusion. They are imperfectly schistose, of a dark grey colour, exhibiting on a fresh fracture surface abundant shining lamellæ of altered prismatic crystals of iolite of a dark brown colour. Near the weathered surface the alteration of this mineral has proceeded much farther, its pronounced foliation is lost, it becomes dull and greasy, and gives a spotted appearance to the rock. As this softer product of iolite alteration is readily eroded, the weathered surface of the rock is conspicuously pitted. The rock may be defined as a cordierite hornfels. Further evidence of its metamorphic nature is occasionally preserved on weathered faces in the form of faint colour banding, and in traces of minute cross-bedding. This fact, as well as the composition of the contact mineral iolite, would trace its origin to the alteration of slate bands in the quartz arkose by means of hypothermal action consequent on the intrusion. The attitude of the beds is at first nearly horizontal or with slight northerly dip, but they soon dip moderately southward and are overlain by blue-grey, finely granular, pyritized quartzitic arkose, or " whin " as it is locally called, of typical Goldenville aspect. The correlation of these rocks with the Goldenville is based on the presence of this overlying mass of " quartzite."

The second area of Precambrian rocks in Windsor district is occupied by Halifax strata. It lies along the western upland margin, mainly on the divide between Gaspereau and Halfway rivers, but with a small outlier on the next southerly divide that separates Halfway river from Mill branch of the Avon. These are but the present marginal portions of a great mass that extends for 6 or 7 miles westward until it suffers abrupt truncation and isolation by the batholithic invader. Black river immediately west of Windsor district has furnished the most complete section of the Halifax slates within the province, a fact that lends greater interest to the relations of this formation within the present area.

The rocks are exposed by two short tributaries of the Gaspereau, Duncanson brook and Harding (or Angus) brook, that deeply notch the upland for a short distance in their course. The section of Harding (or Angus) brook is of particular interest, as beds undoubtedly equivalent to some of those of Black river and regarded as typical Halifax slates are in contact with slates bearing *Dictyonema websteri* Hall. Disregarding the contact beds for the moment, and postponing their discussion to that of the Silurian, the remaining rocks dip steeply at a high angle to the north and have a cleavage fissility developed at a high angle to the south. The average strike is north 65 degrees east, dip 82 degrees north, which would yield a thickness of exposed rock of 2,500 feet. Below this level stratigraphically, the exposures are few and isolated, but individual beds of quartzite, several feet thick, come in, which yield locally abundant material to the overlying glacial drift.

Viewed as a whole, the rocks form a uniform sequence of fine, quartzitic, chloritic, and micaceous slates of a prevailing dark green-grey colour, but with a marked rhythmic banded appearance due to rapid alternation of dark carbonaceous micaceous layers with lighter siliceous bands. The siliceous layers are commonly minutely crossbedded. Abundant cubical crystals of pyrite occur, particularly along the bedding planes of the light siliceous bands. The scale of rhythmic banding is indicated in Figure 1.

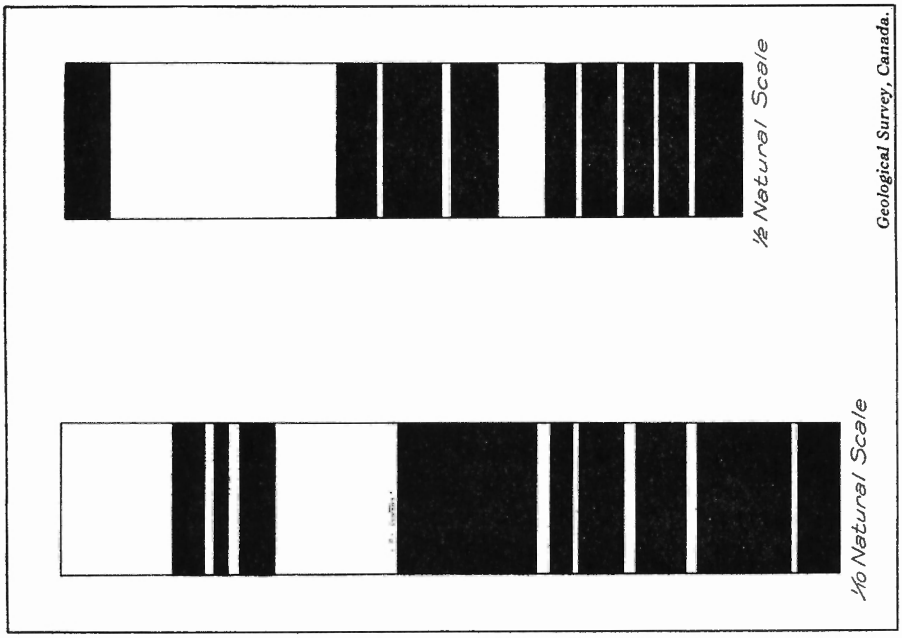


Figure 1. Typical rhythmic banding in Precambrian Halifax slates, Duncanson brook.

Conditions of Deposition

Sufficient work has not yet been done in connexion with the Meguma series in recording the textural features, e.g., ripple-marks, crossbedding, channelling, size, and form of grain, etc., to formulate convincing conclusions regarding conditions of deposition.

Former writers have tacitly assumed a marine origin for these sediments. That there is a possibility of a continental fluvial origin in whole or in part is suggested by such facts as: (1) the vast thickness of sediments (28,000 to 35,000 feet); (2) the preservation throughout of a remarkable uniformity along an elongated belt of geosynclinal outline, at least 250 miles in length, and whose direction coincides with the orogenic trends of the region; (3) the sudden local changes in continuity and thickness of individual strata in contradistinction to the general uniformity; (4) the arkosic nature of the quartzites; (5) the small content of calcareous matter; (6) the presence of crossbedding of a current rippled type; and finally (7) the unsorted nature of some of the clastic material. Perhaps the strongest arguments that may be advanced for a marine origin of the deposits are the almost negligible presence of conglomerates and the graphitic nature of large bodies of slate, comparable to that of the Animikian slates of Lake Superior region. Until more data are accumulated either from a study of the inherent characteristics of the sediments or from the discovery of reliable external testimony concerning the geographic and topographic conditions prevailing at the time of deposition, it would be temerity to judge between the two hypotheses of a marine origin on the one hand or of a fluvial origin on the other.

Whatever the environment, the determining factor of such concentration and preservation of huge masses of detritus must have been the differential warping of the land areas or immediate sea troughs coterminous with a mountainous topography.

As to the location of these mountains, the evidence is not sufficient to weigh between a northerly or southerly derivation of the detritus. The presence of some conglomerate in the western part of the peninsula and the lack of correlation with the Precambrian of New Brunswick would favour a southerly origin and the location of the mountains in old Appalachia. If the Meguma series prove synchronous with a part of the Avalonian series of Newfoundland, as has been frequently suggested,[1] there were mountain-making movements in adjacent regions, with batholithic and volcanic igneous invasions in early later Precambrian times.[2] Similar orogeny at this time is reported for Maryland and Virginia.[3] Thus the conditions would be especially favourable to the formation and preservation of great fluvial or of marine deltaic deposits comparable with those existing towards the close of the Palæozoic in the same region.

Of the Newfoundland Avalonian sediments, the Momable slates 2,000 feet in thickness are lithologically very like the Halifax slate. Buddington considers them as of marine origin on the basis of their carbon content, assuming the necessity for a permanent water-level. This assumption is open to the criticism that it neglects the important factor of climatic control in relation to the carbon content of continental sediments. In such deposits the groundwater level, atmospheric humidity, and temperature, the amount and distribution of rainfall, the character and extent of the living vegetation, the character of the rocks supplying the debris, are all of extreme importance.

The evidence afforded by ripple-marks has hitherto been largely neglected. In Windsor area the outcrops are confined to the stream-cuts, and the observer must deal only with cross-sections of the strata. A noticeable feature throughout the whole depth of the banded slates exposed is the presence of minute crossbedding in the light-coloured or more siliceous bands of the slates, expressed in the form of finely laminated truncated lenses. The lamination is often exceedingly minute and barely visible to the naked eye. This phenomenon is explicable by the rapid travelling of current ripples, with probable contemporaneous rapid deposition of sediment from above.[4] Such an ubiquitous occurrence of current

[1] Murray, A.: Geol. Surv., Newfoundland, Rept. for 1868, p. 167; Walcott, C. D.: U.S. Geol. Surv. Bull. No. 81, p. 262 (1891); Van Hise, C. R.: Ann. Rept., U.S. Geol. Surv., pt. I, p. 811 (1894-95); Matthew, G. F.: Proc. and Trans., Roy. Soc. Canada, 3rd ser., vol. 12, sec. IV, p. 125 (1908).
[2] Buddington, A. F.: Jour. Geol., vol. 27, pp. 456-486, 477 (1919).
[3] Keith, A.: Am. Geol., vol. 10, pp. 362-368 (1892).
[4] Bucher, W. H.: Am. Jour. Sci. (4), vol. 47, p. 156 (1919).

rippling is a common feature of river alluvium, but occurs also in marine deposits. The occurrence in the Halifax slates is strikingly analogous to its occurrence in the banded shales in the upper part of the Horton Bluff formation, an undoubted continental deposit.

Correlation

The unfossiliferous, banded, pyritized slates and arkosic quartzites of Windsor district are correlated with the Meguma series on the basis of field relations as well as mutual lithological and structural characters. The Meguma series itself is referred to the Precambrian on the basis of greatest probability only. Its floor is unknown, and the next overlying formation that is unquestionably unconformable to it, is of Lower Carboniferous age. For, although the Silurian has been stated, on the grounds of a comparative analysis of the tectonic axes, to hold an obligatory unconformable position,[1] such a relation has never been established, and the field evidence has led to a contrary conclusion.[2]

Previous opinions regarding the age of the series have fluctuated from Lower Silurian to Precambrian.[3] The chief arguments in favour of a late Precambrian age may be summed up as follows:

(1) Entire absence of any recognizable Palæozoic fossils. The obscure, so-called, organic remains that have been reported are without any diagnostic value.[4]

(2) The great thickness and uniformity of the deposits for which there is nothing comparable in any of the Eopalæozoic formations of the Maritime Provinces or of the Appalachian area.

(3) The inherent distinction from the highly metamorphosed crystalline complex of the older Precambrian rocks of New Brunswick and of Cape Breton.

(4) The lithological resemblance to the late Precambrian Avalonian deposits of southeastern Newfoundland. Although the hypothetical extension of the Meguma geosynclinal axis clears Cape Breton, owing to its easterly deflexion, it might be expected to resume a northeasterly trend and to strike southernmost Newfoundland.

(5) The deposits represent the waste of extensive mountains, a factor that is strongly suggestive of late Precambrian time. The Torredonian in Scotland and the Animikian of interior America, furnish examples of analogous sedimentation, the former perhaps dominantly continental and the latter marine.

---

[1] Woodman, J. E.: Bull. Geol. Soc. Am., vol. 19, p. 108 (1908).
[2] Faribault, E. R: Geol. Surv., Canada, Sum. Rept. 1909, p. 151; Malcolm W.: Geol. Surv., Canada, Mem. 20E, p. 75 (1912).
[3] Malcolm, W.: Op. cit., pp. 71-76.
[4] Woodman, J. E.: Bull. Geol. Soc. Am., vol. 19, pp. 99-112 (1908).

SILURIAN

KENTVILLE FORMATION

Regional Relations

The famous Silurian section at Arisaig lies some 80 miles west-northwest from Windsor district. It there comprises 3,800 feet of marine fossiliferous shales and sandstone, with a few beds of impure limestone. The faunal aspect is European rather than American, the formations ranging in age from Lower Llandovery to Ludlow.[1] Areas of as yet undifferentiated Silurian occur in the metamorphic complex of the Cobequid upland that extends westward from Arisaig region for 100 miles, forming the height of land between Minas basin and Chignecto bay.

West of Windsor district, and south of Kentville, at Beach Hill and New Canaan, there is a small area of fossiliferous Silurian fawn and dark-coloured slates, rising from the Triassic lowland and bordering the Halifax slates and Devonian granites of the upland to the south. The contact relations of these beds to the dark Halifax slates referred to the Precambrian is still a mooted question, as they have undergone similar metamorphism. At the eastern border of this Silurian area, at the mouth of Black river at Whiterock, a massive pink quartzite member, folded in a syncline that here forms the bed of Gaspereau river, rests disconformably upon the banded Halifax slates. This quartzite is separated by a zone of fawn-coloured argillites from a similar higher quartzitic member. These beds have failed hitherto to yield fossils or certain evidence of their relation with the Beech Hill Silurian slates.

Local Description

The Silurian rocks of Windsor district are an extension of Gaspereau area outlined above. They outcrop in a very narrow belt on the slope of the Gaspereau divide immediately to the east of the Whiterock quartzite of Black river. The exposure is a bare hundred yards in width and is due to the stripping back of the basal Horton Bluff beds from the Silurian-Halifax contact.

The strata are dark green to greenish purple, or variegated green and purple argillites. The relation to the Whiterock quartzite was not determined, as the evidence indicated a faulted contact between the Silurian here exposed, and the Halifax and overlying Whiterock quartzites. The latter would, however, seem to be a basal member of the *Dictyonema* series.

The Silurian-Halifax Contact

In Harding (or Angus) brook the Silurian beds are exposed for 200 feet. They outcrop from beneath the basal member of the Horton Bluff formation, which is virtually a breccia of their fragments. They consist of dark greenish grey, to variegated green and purple, micaceous, arenaceous

[1] McLearn, F. H.: Am. Jour. Sci. (4), vol. 45, pp. 133-135 (1918).

slates with thin beds of smooth, more argillaceous slate. The strike is seemingly about north 40 degrees east, dip 35 degrees south. The beds nearest the Precambrian Halifax contact have a cleavage nearly parallel to the bedding, and yield *Dictyonema websteri* Hall (= *D. retiforme* Hall). The interval separating them from typical banded pyritous slates of the Halifax formation is only 25 feet. No pyrite was observed in the Silurian beds. The strike of the Halifax slate is about north 60 degrees east, dip 75 degrees south, with cleavage fissility at a high angle to the south. In several instances where the minute crossbedding in the Halifax beds was studied there were evidences of abnormal truncation, and this relation held good until an anticline followed by a sharp syncline brought about a northerly dip.

Duncanson brook lies two-thirds of a mile to the west of Harding (or Angus) brook. Here some of the beds that are exposed beneath the Carboniferous contact for 100 yards are superficially very similar to the *Dictyonema* beds. No fossils, however, were obtained, and it was noted that there was here a marked discordance of the fissility to the bedding planes, accompanied by the significant fact that the bedding planes are inclined to the south 10 degrees to 30 degrees more steeply than the fissility planes. Twenty feet distant, typical dark Halifax slates dip southward about 55 degrees, and in the intervening space there is a lithological transition from the dark, to green and purple, shades of colour. Furthermore, it was noted that the basal Horton Bluff beds were dominantly made up of these greenish and purplish slates, which suggests that the lighter colours may be explained by pre-Horton oxidation and weathering. The beds all trend in general about east northeast-west southwest. Abnormal truncation of crossbedded laminæ was observed at one place in the southerly dipping slates, as in Harding (or Angus) brook.

In the light of these facts, doubt is expressed as to the correlation of these light-coloured beds of Duncanson brook with the nearby *Dictyonema*-bearing beds of Harding (or Angus) brook. At the same time it is clear that undoubted Silurian beds, as in Harding (or Angus) brook, owe their present position to faulting in pre-Horton times. Overturning of the slates of the Halifax formation involved in the fault drag zone has given rise to a local southerly dip, as attested by abnormally truncated lamellæ of ripple crossbedding, and suggested in Duncanson brook by an abnormal relation of the fissility to the bedding planes. The trend of the fault is seemingly about east-west, which continued westward would pass stratigraphically above the Whiterock quartzite. The broader problem of the relation of this quartzite to the *Dictyonema* beds and of the amount and extent of this pre-Horton faulting will remain in abeyance upon detailed stratigraphic work in the larger Silurian area to the west.

Conditions of Deposition

The presence of the graptolite *Dictyonema websteri* Hall (= D. *retiforme* Hall) definitely establishes these slates as of marine origin. The clastic nature of the material and absence of limestones, taken in conjunction with the character of the Silurian elsewhere in the province, attest close proximity to shorelines and clastic deposition of muds and sand.

The affinity of the characteristic graptolite with *D. retiforme* Hall from the Niagaran, and the reported occurrence of *Favosites hisingeri* E. and H., *F. pyriformis* (Hall), and *Heliolites* cf. *elegans* Hall, in associated beds at New Canaan, would seem to indicate sea connexions with the Appalachian region of North America in Rochester time. As these fossils, however, are long-ranging cosmopolitan types, they are poor indices of the seaways of the times.

Correlation

Considering Windsor district alone, the correlation of these slates is founded on the abundant presence of *Dictyonema retiforme* (Hall), a species that occurs in the Rochester of New York state, and at Hamilton, Ontario. The slates of New Canaan district to the west are stated by Dawson to be closely associated. Of the few fossils known from that locality, the following remarks might be made. *Favosites hisingeri* E. and H. is a cosmopolitan species that is found in various localities in the Cataract and Niagaran of the United States and Canada, and is probably represented synonymously by *F. hispidus* Rominger from the Lake Huron Niagaran. *F. pyriformis* (Hall) is a Rochester-Niagaran species common in New York and Lockport, etc. A *Heliolites* closely allied to, if not identical with, *H. elegans* Hall also occurs, which is another common Niagaran form in the Appalachian and Mississippian regions.

CARBONIFEROUS

REGIONAL RELATIONS

The Carboniferous rocks that underlie the lowlands of Windsor district are but a part of a much more extensive detrital mass that stretches from the uplands of Nova Scotia in the southeast to the interior uplands of New Brunswick in the northwest. Seaward, Northumberland strait and the gulf of St. Lawrence occupy a still greater tract of this former basin of sedimentation. Inland from the present coastal belt, which roughly outlines in plan a semicircular arc facing Northumberland strait, the lowland terminates in a series of embayments of variable width separated by relatively narrow divides of pre-Carboniferous rock. The simplicity of this arrangement is interrupted, however, along the southern border of the region. In general, the Cobequid upland delineates the change in character. To the south of it, the strata, in contrast with the almost flat-lying sediments of the north, show the effects of deforming stresses, locally severe, although this has rarely proceeded to such an extent as to produce metamorphism. It is in this relatively more disturbed southern belt of Carboniferous rocks that Windsor area is included. It should be clearly borne in mind that the above relations have a broad application only to the distribution of the mass of Carboniferous sediments as a whole, and that there was by no means continuous sedimentation over the whole area at any one time.

Differential uplift was intensified in the Maritime Provinces at several distinct times during the Carboniferous period, giving rise to local unconformities and to the establishment of contemporaneous secondary basins of deposition within the main lowland.

Carboniferous rocks underlie the major part of Windsor district and assume superficially the aspect of an embayment projecting into the southern upland of Nova Scotia, this embayment being a gulf-like extension of a larger basin that includes and surrounds the present Minas basin. That this bay-like area is not inherited from an original coastal feature existing during the time of sedimentation is evident from the relations of its borders. To the south, the limit of this embayment is a faulted one, resulting in the preservation on the upland side of a very narrow remnant of the original contact with pre-Carboniferous rocks. Westward, the contact plane is warped by southwesterly-northeasterly trending anticlinal and synclinal flexures that determine the sinuous trend of the upland in this direction. To the north, the deposits are overlain unconformably by Triassic sediments. The district is bisected by the estuary of Avon river in a direction oblique to the trend of the orogenic axes.

Three well-marked formations of the Carboniferous can be recognized within the confines of the district, with a meagre representation of a fourth in a narrow area along Kennetcook river. These in ascending order are the Horton Bluff formation, the Cheverie formation, the Windsor series, and a sandstone of possible Pennsylvanian age.

HORTON BLUFF FORMATION

Distribution

The Horton Bluff formation outcrops in a low anticlinal belt whose axis runs from the headwaters of Curry brook in Horton township northeasterly through Kempt township to Walton and beyond. It may be designated the Walton anticline, although it is more strictly a small anticlinorium. The best exposures of the higher beds occur in the shore bluffs of Minas basin in Kempt township from the vicinity of Cambridge to Split Rock, in Horton bluffs of Avon river, in Hurd creek, Crowell creek, and Reed brook. Outcrops of basal beds with good exposures of the contact on pre-Carboniferous rocks may be best seen in Duncanson brook and Harding (or Angus) brook, tributaries of Gaspereau river, and in Fall brook south of Windsor. Sections of intermediate beds are present in nearly all the brooks that cut back into the upland on the western border of the area.

Lithology

Broadly the Horton Bluff formation may be divided for the sake of convenience into a basal feldspathic sandstone or arenaceous member, which carries rare faunal remains, and an upper argillo-arenaceous shale member with abundant ostracoda and fish scales at various horizons. In the latter, the more purely argillaceous and ostracod-bearing beds occur in a basal member, and the top member has many thin beds of feldspathic quartzite.

Basal Member

The feldspathic strata at the base of the lowest member of the Horton Bluff formation flank the slopes of the bordering uplands, and as the dip of the contact surface averages about 10 degrees, these beds enter very little into the composition of the old mature topography of the upland surface itself. Outcrops occur, however, in a broad belt in those stream gullies that drain the western upland, such as Harding (or Angus) brook, Duncanson brook, Curry brook, Halfway river, and Barkhouse brook. The conditions are otherwise along the southern borders of the field where the upland rises steeply and a bare remnant of the steeply dipping basal Horton Bluff beds is preserved on the upthrow side of the fault that limits the Carboniferous basin in this direction.

The composition of the basal contact beds is in direct relation to that of the underlying rock. Where the latter is slate, as in the area north of Mill branch of Avon river, the Lowermost Horton bed of several feet thickness is a breccia consisting of angular or sub-rounded fragments of the underlying rocks embedded in a paste of the same material and with but occasional waterworn pebbles from distant localities. These underlying slates show the effects of weathering for several tens of feet—weathering that took place before the Horton was laid down, as it is reflected in the colour of the material included in the Horton breccia. The effect of weathering was to oxidize the iron and to remove the carbon so that purplish or reddish shades of colour were produced.

Where the composition of the underlying rock is that of a granite, as in Gormley brook to the south of Windsor, the basal Horton deposit is composed so dominantly of its disrupted minerals that it is sometimes difficult to fix its exact contact with the underlying granite. Above the thin sheet of basal breccia the stream-deposited feldspathic grits and arenaceous shales, so characteristic of the formation, were laid down. The coarser beds may be considered megascopically in several groups.

(1) *Feldspathic Quartz Conglomerate Group.* Light grey, rarely reddish in colour. Matrix: dominantly angular, transparent quartz 2 to 7 mm. in diameter; secondarily, rounded flakes of dark slate; sparingly, flakes of pearly lustrous muscovite (possibly in part a vermiculite from alteration of biotite), the interspaces are filled with white or grey kaolin. Pebbles comprise: (a) vein quartz up to 5 cm. diameter common, with fracture facets but well rounded corners; (b) fine, granular, grey quartzite common, usually more rounded than the vein quartz, occasionally approaching prolate spheroids, attain diameters of 6 cm. to rarely 15 cm., generally less than 6 cm.; (c) dark arenaceous to finely siliceous slate from the underlying Halifax formation, commonly less than 3 cm. diameter; (d) rarely angular fragments of pink or grey feldspar. There are, however, many gradations of texture and composition dependent on the relative abundance of each of these constituents. When the quartz is very abundant in the matrix, together with a minimum of kaolin, secondary recrystallization has frequently produced a true quartzite. Small, nodular pyrite masses are not uncommon, and the weathered rock commonly presents a rusty, spotted appearance as a result of their oxidation.

(2) *Feldspathic Quartz Grits.* Grain 2-6 mm. Do not differ essentially from the above except in the absence of water-worn pebbles. Where kaolin is abundantly present, the rock is friable. When it is sparingly present the rock is quartzitic and very hard and compact.

(3) *Ironstone Intraformational Conglomerate.* Consisting of ironstone nodules of concretionary origin, embedded in a feldspathic quartz matrix. A very local phase.

(4) *Feldspathic Sandstone.* Grain 0·1-0·5 mm. Colour usually light grey, but locally pink or terracotta. Crossbedding usually prominently developed, but, locally, fine-grained massive or ribbon-banded varieties occur.

Accompanying these grits and soon becoming dominant are micaceous-arenaceous shales of a finer texture, with abundant imprints of broken and torn plant debris, and with rough, uneven bedding surfaces due to cross-bedding and current rippling. Exposed surfaces of beds of this character commonly show these ripples well preserved with wave lengths of 2 to 3 inches. Elsewhere, the bedding planes may present a smoothly washed appearance, or they may have a scalloped aspect imposed by a compound type of rippling. Such strata are excellently well exposed in Harding (or Angus) brook.

The thickness of these feldspathic arenaceous beds of the lower Horton Bluff varies from 600 feet or less in the south to fully 2,000 feet in the north.

Middle and Upper Members of the Horton Bluff Formation

The peculiarity of the succeeding beds of the Horton Bluff formation lies in the presence of many beds of laminated, finely arenaceous silts and argillaceous shales, with which are associated thin ironstone bands, ironstone concretions, abundant spheroidal calcareous concretions, and occasional thin argillaceous limestones with a cone-in-cone structure. Certain beds are abundantly rich in leperditoid and beyrichoid ostracods, *Spirorbis*, or the scattered scales and dermal bones of palæoniscid fishes. The remains of the latter especially are locally so abundant in several instances as to comprise thin " bone beds " made up almost entirely of their debris. The softer, more argillaceous, ostracod-bearing beds have a more restricted vertical distribution, and are mainly confined to the middle Horton Bluff member. The succeeding beds of the upper member of the Horton Bluff formation comprise a thick accumulation of finely siliceous, micaceous, arenaceous groups in alternating association with more argillaceous beds or, at higher horizons particularly, with thin quartzites or feldspathic sandstones. The latter occur in heavier beds near the top of the formation, and have been locally quarried for building purposes. Much of the siliceous silty strata is finely interbanded with thin argillaceous laminæ, but there are thick interbeds of non-laminated, or but poorly laminated, argillo-arenaceous deposits, not uncommonly carrying limestone concretions, that break with a characteristic hackly fracture, and weather in many cases to light greenish and buff yellow or variegated colours. An extraordinary feature presented by these beds on their exposed bedding surfaces is a polygonal system of cracking that might readily be mistaken for true suncracking. Careful inspection, however, revealed the presence of carbonaceous traces of a dichotomously branching system of rootlets, and not uncommon association with upright tree stems, denoting that these shales are fossil soils.

Biological Features

The buried forests and soils of the Horton Bluff formation are of extreme interest, not only on account of their very early Carboniferous age and of the light they shed on the plant ecology of those times, but as well on account of the testimony they afford to the environmental conditions of deposition. A striking feature of these soils in contrast with the Stigmarian underclays so prevalent in association with coal seams in the Upper Carboniferous of Nova Scotia and elsewhere, is the large percentage of arenaceous matter. They are dominantly micaceous, siliceous silts, with a subordinate amount of clay. Calcium carbonate, in common with Coal Measure soils, is only a very minor constituent.

Although these soil beds are particularly characteristic of the upper member of the Horton Bluff formation, where they may be observed in their best development, they are by no means confined there, as they are common throughout the whole formation. Many of the finer arenaceous beds at the base of the formation are penetrated by abundant oblique and vertical rootlets, and upright stems may be occasionally observed in similar beds. Moreover, siliceous strata, interbedded with the laminated ostracod-bearing shales of the middle member of the Horton Bluff, are seen commonly to present the same phenomena. It is, therefore, a widespread character both vertically and laterally, and is eminently characteristic of the whole deposit. This is made clear from the following résumé of certain field observations.

From the shore of Minas basin north of Cambridge post office westward to Split rock, a distance of some 5,000 yards, there are excellent exposures of upper Horton Bluff strata that lie above ostracod-bearing shales of the middle Horton Bluff to the eastward. In this distance fifty-six well-marked soil groups were noted, seven of which had associated with them abundant upright plant stems. Several additional soil groups were included in the ostracod-bearing division below.

In the Horton Bluff section the lowest beds exposed are ostracod-bearing shales of the middle member, and lying above them are strata of the upper member much less disturbed than those at Cambridge, but exposed less favourably to observation on account of the rapid undercutting action of the waves that enforces vertical cliffs. Close inspection of the beds, however, revealed the abundant occurrence of rootlets in situ, and two well-marked horizons were noted with upright stems. In one plot 120 feet by 15 feet, ninety-six such stems were counted contained in the basal 1 foot of a 6-foot soil bed.

Again, in the basal Horton Bluff beds of Curry brook, six well-marked soil beds were seen, as well as many scattered occurrences of rootlets in situ, and similar observations were made in Harding (or Angus) brook, where three excellent soils were observed. In the neighbourhood of the hamlet of Lower Horton, exposures are few, and yet several fossil soils were noted and one good horizon with upright stems resting on a thin carbonaceous substratum, a matter of unusual interest as foreshadowing phenomena that were to become so common in the Coal Measures.

Similar testimony of the ubiquitous occurrence of soils was gathered from the southern marginal exposures in Barkhouse brook, and in Fall brook south of Windsor.

The taxonomic position of these upright stems and rootlets is doubtful. As regards the rootlets, their casts and imprints are indistinguishable from the rootlets of *Stigmaria ficoides* of the Coal Measures. In this respect, therefore, the Horton soils possess the distinguishing feature of the Coal Measure soils. That *Stigmariae* were in direct continuity with certain upright stems of *Sigillaria* and functioned as roots has been verified from direct observations. That *Lepidodendron* was similarly "rooted" is generally believed, but has not been so well established. In this connexion it is an interesting fact that no creeping or horizontal rhizomes were found anywhere in the Horton Bluff formation comparable with those in the Coal Measures, in spite of the ubiquitous presence of appendages or rootlets that are seemingly indistinguishable from the rootlike appendages of *Stigmaria*. This is all the more peculiar as *Stigmaria* lends itself so readily to preservation, is one of the commonest fossils in the Coal Measures, and should be preserved as readily as the smaller rootlets. Another fact of interest here is that several upright stems whose diameters were comparable with the largest of any of those observed had directly attached, rootlet-like appendages, some of which branched dichotomously, while all the stems observed were preserved *within* typical soil beds, a fact in harmony with the preceding. That these stems and rootlets if lycopodian belonged to *Lepidodendron* seems a safe inference, as Sigillarian remains, if they occur at all in the Horton Bluff formation, are exceedingly rare, whereas debris of the type of *Lepidodendron corrugatum* Dawson practically has a monopoly of the preserved lycopod flora. As the stems, however, were directly rooted by means of underground upright stems that sent off dichotomously branched rootlets without the interposition of creeping Stigmaria-like rhizomes, it seems more probable that they are pteridospermous. One of the stems of a diameter of 22·5 cm. had attached appendages of varying size from 1·5 to 6 mm. diameter, whereas another of 30 cm. diameter, had attached rootlets of 25-35 mm. diameter.

The surface of certain thin quartzite beds overlain by argillaceous beds have large, fucoidal-like, raised casts of organic origin resembling branching fucoids and from 10 to 15 mm. in diameter. The branching is dichotomous, and it is possible that these may represent branching roots similar to those above mentioned.

Throughout the formation there is abundant broken and comminuted plant material. Larger fragments of the drift flora are quite common, but of poor quality. They are almost exclusively either impressions of the outer cortex of *Lepidodendron corrugatum* Dawson, representing different layers according to the state of decortication, or of broken foliage and stipes of the pteridosperm *Aneimites acadica* Dawson. In the upper beds megaspores (*Spongites glabra* Dawson) 1 mm. to 2 mm. in diameter are very abundant at certain horizons. A single specimen of *Asterocalamites* cf. *scrobiculatus* Schlotheim was found as a drift fragment presumably from the upper member.

The fauna is practically restricted to ostracod crustaceans and to the scales, spines, or dermal bones of fish. The former have a more local and restricted distribution and are confined largely to certain argillaceous strata in the middle member of the formation, being abundant in some of the laminated shales or in some of the accompanying ironstone or calcareous concretions. In such beds the following ostracods were noted:

Jonesina nova-scotica (Jones)—a beyrichoid allied to *Beyrichia gibberosa* or *B. colliculus* Eichwald from Russia.

Kirkbyina sp.—a larger and more quadrate form than *Kirkbyina reticosa* (Jones and Kirkby), very abundant throughout the ostracod zone.

Kirkbyina cf. *scotoburdigalensis* (Jones and Kirkby).

Carbonia cf. *pungens* Jones and Kirkby.

Isolated scales of palæoniscids are abundant and at certain horizons extremely so, forming by their accumulations thin "bone beds." Their type of sculpturing assigns them with most probability to the genus *Elonichthys*. They resemble in form *E. brownii* (Jackson) from the Albert beds of New Brunswick, but possess non-serrate margins. Among the isolated dermal plates the maxillæ are most readily recognizable. They have the oblique suspensorum characteristic of the Palæoniscidæ and one form agrees in contour with the genus *Rhadinichthys*. Judging from the paucity of remains of other groups, the Palæoniscidæ would seem to have suffered little competition. An occasional stray tooth of a rhizodont, *Strepsodus*, testifies to the presence of the fringe-finned ganoids, and more powerful contemporaries are represented by occasional selachian spines, e.g. *Stethacanthus* and *Ctenacanthus*.

Textural Features

Current ripple-marking is a prominent feature throughout the whole of the Horton Bluff formation, but particularly so in the basal and upper members. The average wave length, or distance from crest to crest, is 5 to 8 cm., and the amplitude or height of crest above the furrow 1 to 2 cm. Occasionally, however, wave lengths of 60 cm. have been observed with an amplitude of 8 cm. The ridges are commonly arranged in a fairly regular parallel series, although frequent anastomoses are the rule. The asymmetrical form is much more prominent in the large ripples than in the more prevalent smaller ones. The results of twenty-seven observations are expressed diagrammatically in Figure 2.

Confirmatory evidence of the prominence of rippling is afforded by the presence of minute crossbedding characteristic of much of the finer siliceous and arenaceous material of the middle and upper members of the Horton Bluff formation.

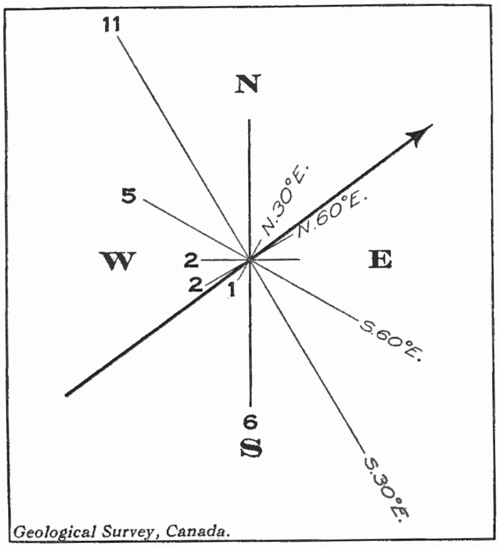


Figure 2. Directions of current ripples in Horton Bluff formation.

Crossbedding on a larger scale is present in the coarser sandstone members with a fairly definite pattern, with the steeper planes truncated and dipping dominantly in northerly directions. They are not, therefore, essentially different from the minute crossbedding structures of the finer siliceous beds and both are probably the effects of the travelling of current ripples.

Channelling phenomena are not a marked character of the Horton Bluff formation in contradistinction to their importance in the succeeding formation. The heavy arkosic grits, however, in the basal portion commonly rest with uneven surfaces on softer shale beds below.

Desiccation, or sun-cracking, is likewise rarely observed, but there are abundant bedding planes that exhibit, on weathering, a cracked surface strongly simulating true sun-cracks. The true nature of this peculiar feature was not evident until the ubiquitous presence and nature of the soil beds was established. It was then recognized that the cracking was a weathering phenomenon peculiar to a great number of typical soil beds. Traces of carbonaceous matter still remaining testify to this fact. Accentuation of the former courses of dichotomously branched rootlets as the result of differential weathering has given the appearance of desiccation fissures of which the pseudo-filling varies from 3 to 30 mm. in width and the intervening polygons are commonly about 25 cm. diameter.

Depositional Environment

Above were outlined some of the main characters of the Horton Bluff formation. True marine conditions of deposition are readily excluded as incongruous with a widespread extension both laterally and vertically of rootlets and erect stems of plants in situ. The absence of marine fossils, the general poverty of lime, the presence of angular quartz grits, the absence of shore conglomerate, of rills, of tidal channels, the general uniformity of current ripples throughout a high vertical and wide lateral range, speak almost as strongly against a swampy estuarine facies. Comparisons have frequently been made in discussions of the origin of these deposits with the estuarine muds now being laid down in the Bay of Fundy estuary. Even neglecting the evidence of vegetation in situ, the comparison is not an apt one. The muds of the bay abound in marine life such as small, shrimp-like crustaceans, mollusca, barnacles, etc.; the exposed mud-flats are characterized by numerous rills and tidal channels. Moreover, subaerial exposure is confined to the narrow limits determined by the height of the tides and effective wave strength. The presence of stumps of trees in situ above the present low tidal shoreline is explicable in some instances by the rapid cutting back of headlands, the formation of barrier beaches, and the flooding of previously fluvial or low-lying swamps by the high tides, changes in tidal level due to shifting shore-lines, etc. To bring about the preservation of a successive series of such buried swamps would entail a delicate balance of subsidence and deposition probably rarely present. Excess of subsidence would bring about sea transgression and more normal marine conditions. Stability or deficiency of subsidence would tend to localize temporary deposition in protected lowlands similar to the conditions existing at the present time.

Considering the accumulations possible under continental conditions, there is nothing in the Horton Bluff formation remotely akin to glacial tills, and equally nothing in the form of rounded sand grains, sand-etched pebbles, dune drift, playa salt deposits, oxidized minerals, etc., to suggest desert deposition. Likewise there is a lack of evidence of torrential action such as might exist along the base of mountain slopes in a climate subject to excessive seasonal concentration of rainfall. There remains, therefore, for consideration, a lacustrine vs. a fluviatile origin. With regard to the former, there are some beds in the Horton Bluff formation, such as the ostracod-bearing laminated shales, and the associated thin fish beds, that must have been laid down in bodies of water that persisted for long intervals of time and were, therefore, lacustrine in nature, but the bulk of the deposits have clearly been exposed subaerially under conditions favourable to the growth of vegetation. The presence of temporary localized or even widespread sheets of water is, however, a phenomenon common to flood-plains of rivers and quite consistent with a fluviatile origin, whereas widespread distribution of current rippling, ill assortment of material as attested by the association of mica, quartz, and kaolin, of argillaceous with arenaceous matter, and angularity of quartz grains, are characters forming an ensemble inconsistent with a lacustrine or continuous water cover. A fluviatile environment under a pluvial climate is postulated, therefore, as the one most consistent with all the facts. The presence of the beyrichoid ostracod *Jonesina* may appear unfavourable to the fluvial or lacustrine origin of the particular sediments in which it is found, but the remaining evidence is so overwhelmingly in favour of a freshwater deposition that it is believed that a freshwater adaptation of this species must be accepted.

The large content of carbon preserved as plant debris, the dominantly unoxidized condition of the iron present, the association of feldspathic with much carbonaceous material and with soil beds, the absence of sun-cracking, all testify against prolonged subaerial exposure to a dry atmosphere. The level of the groundwater was accordingly high even in the arenaceous beds, and at times lacustrine conditions prevailed temporarily. The climate is accordingly judged to have been a temperate insular one. At the beginning of deposition, erosion was perhaps more active on account of the greater relative elevation of the headwaters, but during the deposition of several thousand feet of sediments all variations may be reasonably explained by normal shiftings of streams, slight changes in the concentration of rainfall, or by a variable rate of uplift of the area under erosion relative to a subsiding basin of deposition.

That such differential movement must be invoked is evident from the very fact of the accumulation and preservation of several thousand feet of terrestrial sediments. Stability would determine ultimate erosion and eventually marine deposition. The abundant supply of debris of similar character and derivation through a long period of time is further proof of such a relation. Barrell[1] has pointed out the fact that the rate of deposition in such a case is a function of the rate of subsidence rather than of the rate of erosion, as the excess of sediment is carried farther downstream and finally deposited under marine conditions. Geosynclines either intermontane in position or bordering uprising continental masses, have been, and still exist as, the favoured loci of thick clastic deposition, and as differential warping or isostatic adjustments continually depress them beneath levels of stream and of marine base level, their position ensures their survival for long eras of time. In the present case the geosynclinal basin, trending generally in a southwest-northeast direction, was probably bounded by higher uprising areas both to the southeast and northwest.

Source of Material

Two convergent lines of evidence fix the source of material of the Horton Bluff sediments in upland masses lying in a general southwesterly direction. The mineralogical composition of the sediments, as expressed in angular translucent quartz grains, slate particles and pebbles, kaolinite, occasional fragments of fresh feldspar crystals, quartzite pebbles, and abundant flakes of muscovite, points to the great belt of the Devonian granite batholith and of the Halifax and Goldenville Precambrian rocks, that stretches for 120 miles to the southwest before it dips into the present sea. Wherever the basal Horton contact is exposed, the lowermost material is directly derivable from the underlying rocks. The source of the silvery,

[1] Barrell, J.: Bull. Geol. Soc. Am., vol. 28, p. 786 (1917).

pearly-lustred mica that is so abundant throughout the formation may be found in altered biotite from the coarse biotite-granite intrusive, but muscovite is a very abundant ingredient in the Halifax slates and muscovite-granites occur farther west.

The second line of evidence has its greatest interest in its very fact of correspondence. It is presented by the alignment of the current ripples which, as shown under the discussion of ripples, points to the dominance of southwesterly currents.

The Upper Contact

Although the overlying Cheverie formation as a whole forms a distinct unit in that it reflects the effects of important modifications in the environment of the basin in which the two deposits were laid down, it can not everywhere be clearly delineated from the Horton Bluff formation. This is due in large measure to the initiation of thick beds of feldspathic sandstone late in upper Horton Bluff time, so that the passage into the Cheverie is seemingly transitional. Yet the arrival of heavy arkose and the deposition of red muds in the Cheverie clearly testify to important tectonic and climatic changes at the close of the Horton Bluff epoch.

Correlation

Stratigraphically, the Horton Bluff lies unconformably above granites that elsewhere intrude sediments of Oriskanian age, and it is overlain by the Cheverie formation and by marine limestones that carry " Mountain Limestone " fossils. It is the contained plant and animal remains that permit of fixing its position more precisely within this great interval of mid-Devonian to upper-Mississippian time.

The plant evidence has been admirably summed up by David White.[1] *Aneimites acadica* Dawson is of the same genus as *A. bellidula* of the Arctic province, and is closely allied to *Triphyllopteris virginiana* of the Pocono in Virginia. This genus is eminently characteristic of the early Mississippian. *Lepidodendron corrugatum* Dawson is closely related to the Pocono species *L. scobriforme* and to the Arctic type *L. glincanum* Eichwald, and the Archaeosigillarian type of scar typical of these species is likewise a feature of the early Mississippian and an inheritance from the Upper Devonian. The appearance of *Asterocalamites* cf. *scrobiculatus* Schlotheim in the upper part of the formation indicates the arrival of a type characteristic of middle and late Mississippian time.

The important testimony of the fish remains lies in the presence of the palæoniscid genera *Elonichthys* and *Rhadinichthys,* which alone would establish a Carboniferous age of the deposits. Thus A. S. Woodward[2] to whom material from Horton bluffs had been submitted, stated that " The Horton fossils are certainly Carboniferous but are not enough to determine whether Upper or Lower ".

The ostracods in like manner clearly indicate a Carboniferous age. The most abundant, *Kirkbyina* sp., falls in a Carboniferous genus created

[1] White, D.: Geol. Surv., Canada, Guide Book No. 1, 12th Intern. Geol. Congress, 1913, pp. 144-146.
[2] Geol. Surv., Canada, Ann. Rept., new ser., vol. XII, p. 203A (1902).

by Ulrich and Bassler to include *Primitia*-like carapaces. *Jonesina nova-scotica* (Jones) is a form very similar to *Beyrichia colliculus* Eichwald from the Lower Carboniferous of Russia, whereas the remaining species have their nearest allies among species occurring in the Calciferous Sandstone and Limestone series of Scotland.

A Mississippian age is thus well established for the Horton Bluff formation, and the abundant presence of *Archaeosigillaria* would place it in early Mississippian time and probably not later than Kinderhookian.

CHEVERIE FORMATION

Distribution

The Cheverie formation is of limited extent in this area. Near Hantsport about 250 feet of its basal beds outcrop along the shore of the Avon estuary, dipping at low angles to the eastward. To the north at Blue beach, these strata are faulted against the Horton Bluff formation. To the south they appear again in Halfway river, but are then separated by glacial drift for a distance of a mile from basal anhydrite of the succeeding Windsor series that outcrops at Aberdeen beach near mount Denison.

The upper part of the formation is well displayed along the same estuary on the eastward shore between Cheverie and Somerville. Approximately 600 feet are there exposed below the Windsor contact, of which a possible 100 feet or more may represent beds of the Hantsport section. Crowell creek and Barkhouse brook also cut through lower strata of the Cheverie formation in their lower courses, with roughly about 300 feet represented in each section. Low dips, pronounced crossbedding, rapid lateral change, and channelling, render computations of strikes and dips and estimates of thickness unreliable. It is not likely, however, that the formation as a whole appreciably exceeds a maximum of 800 feet in Windsor district, and it may be considerably less. Roughly, it may be stated as from 600 to 800 feet maximum.

Textural Features

The basal 300 feet as exposed along Avon river is dominantly composed of grey arkose grits with a subordinate amount of chocolate, or chocolate and green, variegated argillo-arenaceous shale, as well as occasional beds of micaceous-arenaceous shale of a greenish black colour. The dominant constituents of the arkose are angular fragments of translucent quartz up to 15 mm. grain, and angular fragments of crystals of orthoclase of like dimensions. Biotite, somewhat altered but preserving its black colour and some of its elasticity, is in many cases present in flakes up to and exceeding 3 mm., and is frequently in excess of muscovite. The binding material is largely grey kaolinite, which renders the arkose rather friable. Commonly, pebbly lenses may be traced in the arkose with pebbles of vein quartz and of quartzite up to 10 cm. diameter. Slate particles are sometimes present, but are of minor importance. Moreover, the dull brown or chocolate shale is in many places badly assorted with fragments of quartz and feldspar up to 3 to 4 mm. in diameter.

The uppermost strata of the formation as exposed along the Cheverie shore are dominantly purple-red to chocolate argillo-arenaceous shales with occasional thin zones of greenish black micaceous arenaceous shale or of slate-grey argillaceous *Estheria*-bearing shales. The dark shales yield a few plant remains and a limited fauna. The chocolate argillo-arenaceous shales are most commonly non-laminated, weather in a hackly manner, and in many cases contain concretionary nodules of reddish limestone (cornstone or kunkur).

Biological Features

Biologically, the features presented are a repetition of those described for the Horton Bluff formation, but they are here in a restricted development corresponding to the more advanced degree of subaerial exposure. Rootlets in situ are common throughout all the argillo-arenaceous non-laminated or mudstone shales, notwithstanding the fact that the strata are now dominantly red and practically devoid of other organic remains. The traces of rootlets, however, are much less frequent than in the Horton Bluff formation, and are most commonly represented by slight colour distinctions; traces of carbon are of rare occurrence, although not altogether absent. At times, leached contact borders betray the former presence of rootlets in these red beds. Upright stems were observed in one instance and this at the extreme top of the section where, in a plot of purple-red shale 9 by 45 metres, thirty-three stems, of which the largest had a diameter of 16 cm., were counted. All carbonaceous traces had disappeared.

The drift flora is practically restricted to occasional thin bands of greenish laminated shale. The flora so far collected is of too fragmentary and poorly preserved a nature for reliable specific identification. It appears to be more varied than that of the Horton Bluff below. *Aneimites acadica* Dawson is seemingly present, megaspores belonging to a smaller species than those so common in the Horton Bluff are present, and *Eremopteris* sp. and a *Calymmatotheca* cf. *bifida* also occur.

Associated with these plant remains, and present at several horizons in the dark shale bands that lie interbedded with the red shales, are found abundant specimens of *Estheria dawsoni* Jones, and of rarer occurrence is a *Leaia* close to, but possibly specifically distinct from, *L. leidyi* var. *salteriana* Jones. The occasional rare presence of fish scales completes this restricted faunal assemblage.

Structural Features

The phenomenon of current ripples and crossbedding is as widespread in the Cheverie as in the Horton formation. Twenty observations were taken on the trend of ripples, with the results as expressed diagrammatically in Figure 3. Crossbedding of the current type is a pronounced feature in the beds of grit and feldspathic sandstone. Channelling of these grit beds into underlying shales is likewise a marked character. In many cases, torn, angular remnants of shale are included in the arkose, and balls of shale as well as interbedded lenses of similar material occur.

Sun-cracking has been observed in several instances in argillo-arenaceous soil beds. That they are true desiccation cracks is revealed by the infilling of fissures by material from above. Striking features of this cracking are the sandy nature of the beds in which it occurs, the relative great width of the fissures themselves, the fact that the cracked beds have traces of rootlets in situ and thus represent old soils, and the coarse,

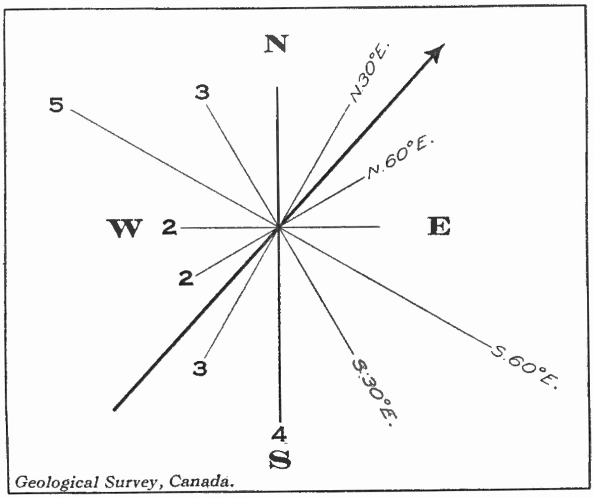


Figure 3. Directions of current ripples in Cheverie formation.

angular nature of the infilling. One such sun-cracked bed is strongly channelled by the grits above, as in a distance of only 25 feet it is entirely removed and replaced by arkose. This sun-cracked bed was greenish grey in colour, but along the Cheverie shore a similar bed was a chocolate brown colour.

Depositional Environment

The same features that denoted a fluvial environment for the Horton Bluff formation are here repeated in accentuated forms. Thus, channelling, sun-cracking, presence of fresh feldspar, little altered biotite, oxidized iron, etc., are dominant properties that give a unity to the deposit and that differentiate the formation as a whole from the underlying one. As the immediate topographical environment has not changed radically, and as the material itself has clearly been derived from the same general land-mass that supplied the Horton Bluff detritus, it is reasonable to look for climatic changes as having mainly controlled the chemical and textural features of the sediments. At the same time it seems necessary to postulate at the close of Horton Bluff time an accentuated or accelerated rise of the positive areas bordering the subsiding or negative basin of deposition in which the Horton deposits were accumulating. Progressive rise of the areas undergoing erosion complementary to subsidence of the basins of deposition throughout the greater part of all Horton time is inferred on account of the long-continued supply of like sediment and any change at the close of Horton Bluff time need not have been more marked than an acceleration or an accentuation of such differential and probably isostatic movements. It is probable, from the amount and freshness of granitic debris making up the bulk of the basal beds, that the uplift of the headwater country that took place at the close of Horton Bluff age was accomplished without destroying the general geographic relations. To what extent these movements contributed directly to the forces inducing climatic change by means of the erection of elevated barriers against prevailing moisture-laden winds is a hypothetical question difficult to consider in the present state of our knowledge.

The initiation of the new climatic order was inimical to the carbonation and hydration of the constituent minerals of the coarse granites that were exposed to weathering along the stream divides. On the other hand, it was favourable to the rapid disruption of this granite into its constituent minerals and for its rapid transportation with little mechanical wear or separation. This would argue for periods of low atmospheric humidity and little rainfall. Strong oxidation and desiccation cracking of the finer material already deposited in the lowlands would be favoured under like conditions. On the contrary, the presence of channels due to tumultuous current action at recurrent intervals in the basal arkose mass, in conjunction with the presence of soil beds at like intervals, would call for periodic pronounced accessions of water flow and a sufficiently high level of the groundwater in the river flats during the intervals to favour a vegetable growth. From the study of present-day climates, it would seem necessary to postulate a warm, temperate, semi-arid type, in order to fulfil all the conditions. During the dry season, extreme diurnal changes of temperature would crumble down the coarsely grained granites exposed on the uplands. On these high divides a much lower water table would perhaps favour a vegetation of pteridosperms. In the wet season of concentrated rainfall, the debris that had accumulated in this manner on the uplands and in the headwaters of streams would be swept tumultuously over the flood-plains of the lower courses, there to inundate and bury great areas that were inhabited by brakes of lowland plants. When the waters had subsided, the coarser material would be dropped progressively farther upstream and finer clays and silts would be deposited downstream, again offering a favourable environment for the invasion of lowland vegetation.

That the temperature was higher than in Horton Bluff times seems very probable, in order to account for the thorough oxidation commonly manifested, for the presence of wide desiccation fissures in soil beds containing much sandy matter, and for the low content of carbon. That true arid conditions were lacking is evidenced by the absence of deposits of alkaline salts, of wind-worn drift, and by the presence of conditions still favourable for an abundant adaptive vegetation. The presence of nodules of red calcium carbonate in the soil beds of the upper part of the formation suggests analogy with the "kunkur" deposits of lime common in the alluvium of the Indo-Gangetic plain, a district subject to semi-arid climatic control. The fact that entombed vegetation, in the loss of its carbon, has at times derived its oxygen from the ferric hydroxide present in the immediate neighbourhood, would speak for a higher groundwater level in the flood-plains at those times. Moreover, larger drift fragments of plants are sometimes present in the coarse arkose grits with the cortex largely converted into coal—additional argument against strong aridity. The accumulated evidence, therefore, is in favour of a temperate semi-arid climate with a seasonal or periodic rainfall.

Source of Material

The fresh granitic debris definitely fixes a source of material in a southwesterly direction, as in the case of the Horton Bluff formation. The evidence furnished by crossbedding and current-rippling likewise supports this conclusion.

Correlation

The Cheverie formation lies above the Horton Bluff formation and beneath the marine Windsor series. It is not, therefore, equivalent to the whole group of rocks for which Ami[1] proposed the term Gaspereau formation as follows:

> "In the Eo-Carboniferous I would also place the Horton formation which, throughout the Bay of Fundy trough, consists of black and grey carbonaceous and calcareous shales, etc., overlying granitic sandstones and marls, etc., which latter series constitute a separate formation in the Wolfville and Horton districts. The name Gaspereau formation is suggested for these granitic sandstones of the Avon River valley and from Angus brook in the Gaspereau valley in Kings county, Nova Scotia."

The Gaspereau formation as thus defined would lie partly at the base of the Horton Bluff formation and would erroneously include the arkose of the Horton Bluffs section (*i.e.,* Cheverie formation). But it is evident that it is the latter series of strata that Ami wished to differentiate as a distinct unit and that he inverted their true stratigraphic position by correlating them with the feldspathic grits that make up the basal portion of the Horton Bluff and that are well exposed in Harding (or Angus) brook. As the Cheverie formation is not present at all in Gaspereau valley, there would be a distinct disadvantage in preserving Ami's nomenclature. Moreover, Faribault has more recently applied the term Gaspereau formation in a quite different sense to denote the Silurian beds to which Ami had earlier given the name Kentville formation.

The stratigraphic position of the Cheverie formation between two Mississippian formations, the Horton Bluff of earliest Mississippian age below and a Windsor series of late Mississippian age above, does not very closely define its position in the Mississippian. The addition to the Horton flora of the genera *Eremopteris* and *Sphenopteris* and the distinct climatic contrast lead to the supposition that the Cheverie lies closer to Windsor than to Horton Bluff time. The local index fossil to this formation, *Estheria dawsoni* Jones, occurs also in the Lower Carboniferous of Scotland. A very important neophyte into the restricted fauna is a *Leaia* closely allied to, if not identical with, *L. leidyi* var. *salteriana* Jones,

[1] Ami, H. M.: Proc. and Trans., Roy. Soc. Canada, 2d. ser., vol. 6, p. 210 (1900).

as *Leaia* is usually regarded in America as a reliable guide to the Pennsylvanian. Although the Cheverie formation is in angular conformity with both the Horton below and the Windsor above, the break between the Horton and the Cheverie is possibly of greater importance than that between the Cheverie and Windsor.

WINDSOR SERIES

Introduction

The Windsor series comprises a group of soft, marine sediments that underlie the lowlands about Avon river and its tributaries. The part of the district occupied by Windsor strata is the western end of a synclinal basin that extends along Kennetcook River valley to Shubenacadie valley and beyond into Brookfield area. Its northern boundary is structurally the Walton anticline whereby Horton Bluff and Cheverie strata underlie the surface. On the south a major fault line is traceable for many miles and sharply limits the Windsor against either Horton or pre-Carboniferous rocks. The western boundary is marked by folded contact with the Horton series.

Estimates of thickness of various members of the Windsor series in Windsor district must be considered as only rough approximations of the true thickness, as, owing to the soft nature of the rocks, exposures are isolated and commonly of poor quality. Close folding, faulting, local overturning, and brecciation render many sections difficult of interpretation. With the reservation, therefore, that the limit of error is probably high, the total thickness of the series in Windsor district is estimated as not less than 1,550 feet.

General Stratigraphy

In composition, the Windsor series comprises a well-defined unit of marine deposits, laid down under peculiarly restricted environmental conditions. There are present four or five distinct stages of calcium sulphate deposits (gypsum and anhydrite), probably none of which is less than 40 feet thick, separated by varying amounts of brick-red argillaceous shale, fossiliferous limestone, thin magnesian sandy shales and oolites. In amount the gypsum may make up almost 20 per cent of the total volume, with red shale 55 per cent and calcareous beds 25 per cent.

The establishment of the sedimentary sequence presented many difficulties. The broken nature of the sections has already been emphasized. The peculiar facies of the deposits, besides favouring the dominance of a few hardy, long-living species, limited the geographic establishment of any peculiar assemblage to very short time intervals. Consequently, there are very few beds that possess an individuality sufficiently distinct for reliable specific recognition over a broad field. The thicker beds of limestone of more normal marine faunal content were of most value. One or more algal bands and thin *Modiola* bands, proved useful in connecting up adjacent fault blocks or affording criteria for normal succession.

Faunally, the series is conveniently divisible into two major zones, each consisting of a number of subzones. The general succession, in descending order, is as follows:

Upper Windsor.	Zone of *Martinia galataea*
Subzone E.	Characterized by *Caninia dawsoni* and *Chonetes politus.*
Subzone D.	Characterized by *Productus semicubiculus.*
Subzone C.	Characterized by *Dibunophyllum lambii and Nodosinella priscilla.*
Lower Windsor.	Zone of *Composita dawsoni*
Subzone B.	Characterized by *Diodoceras avonensis.*
Subzone A.	Basal limestone.

Subzone A is exposed only in section 1, near Cheverie on Avon river. Section 1, in descending order, is as folows:

Section 1

	Feet
(*d*) Gypsum and anhydrite	55±
(*c*) Limestone, platy, reddish, bituminous, cavernous, nodules of manganite	5
(*b*) Limestone, reddish, brecciated, unfossiliferous	13±
(*a*) Quartzite, and grey to reddish arenaceous limestone conglomerate....	22±
Disconformity	

Cheverie formation: greenish grey, arenaceous shale, underlain by brick-red, argillo-arenaceous, non-laminated shale or mudstone with rootlets in situ.

This section is a part of a small Windsor outlier in Kempt township where the Windsor strata are preserved in a secondary syncline within the Walton anticline. The northern limb of this syncline has been underthrust to the northwest against upper beds of the Horton Bluff formation, with the development of much breccia, so that the relations of the gypsum with younger beds of the Windsor are not clear.

The conglomerate of (*a*) has pebbles and nodules of grey and reddish limestone in a matrix of micaceous quartzite. The limestone pebbles may have been derived from the Cheverie formation below, of which the argillaceous members commonly contain small limestone concretions, or they may have been formed contemporaneously with deposition as a result of algal or concretionary action. A species of *Schizodus* is abundant on the top surface of the quartzite, preserved as imprints of attached valves that are spread widely open, an indication of gentle current action.

Subzone B. Two very fossiliferous limestone members occur in this subzone, the Miller limestone and the Maxner limestone. They are separated by red argillaceous shale and gypsum, thin beds of calcareous soft sandstone, calcareous magnesian shale, thin platy limestones, and oolites. The only section, Section 2, containing both limestones, is poorly, and only partly, exposed on Avon river between the Canadian Pacific Railway bridge and Maxner point. Section 2, exposed on Avon river, from the vicinity of Maxner point towards the Canadian Pacific Railway bridge, is as follows:

Section 2

		Feet
Subzone B: (*a*) Maxner limestone—grey, very fossiliferous limestone, massive above; magnesian, yellow-weathering, and cavernous at base..		80±
Subzone A?: Gypsum, with thin bands of calcareous shale and platy limestone (=? Gypsum of (*d*), section 1 subzone A)..		(?)
(*?*) *Faulted contact* (*?*)		
Subzone B:		
(*o*) Gypsum..		(?)
(*n*) Miller limestone; light grey limestone abundantly fossiliferous..		35±
(*m*) Shale, brick-red, argillaceous..		6+
(*l*) Gypsum; with some dolomitic shale..	(?)	35±
(*k*) Shale, brick-red; minor gypsum including one 5-foot bed..	(?)	45±
(*j*) Sandstone, yellow, calcareous..		6
(*i*) Shale, calcareous, green-grey..		4
(*h*) Sandstone, calcareous, yellow..		10
(*g*) Shale, brick-red, minor amount of green..		30±
(*f*) Limestone, oolitic, rare ostracoda..		3
(*e*) Shale, green, calcareous..		3
(*d*) Limestone, grey, platy; *Productus,* ostracoda at base..		4
(*c*) Limestone, yellow, sandy, oolitic..		2
(*b*) Limestone, nodular, greenish grey; and calcareous shale.. ..		3+
Faulted contact		
Subzone C: (*i*) Shale, red, argillaceous, of section 5..		

The Maxner limestone is well exposed above tide at Maxner point in a small syncline about 1 mile southeast of the Canadian Pacific Railway bridge, and may be seen again at low tide in a small island-like mass several hundred yards northwest of Maxner point. The Miller limestone is best exposed in a small quarry at Windsor about 300 yards from the river's edge. Along the line of the strike of the quarry beds it is poorly exposed on the tidal slope at low water. From the latter locality northwards towards the bridge, outcrops at low water reveal beds (*b*) to (*d*) in the crests of three successive anticlines, with the gypsum and shale of beds (*l*) and (*k*) in the intervening synclines. The most northerly outcropping beds in this section are (*b*) and (*c*) which are up-faulted against beds of subzone C, section 5. Minor secondary folds are well seen in the gypsum member that lies beneath the Maxner limestone where thin bands of limestone interstratified with gypsum are much crumpled.

This section does not show clearly the stratigraphical relations of the Miller and Maxner limestone. Those faults of the Avon River sections near the bridges that permit of study are interpreted as upthrows on the south, so that older beds appear successively to the southward. There would appear to be a similar fault separating the Maxner limestone from other beds in the section and on the assumption that the displacement has resulted likewise in an upthrow on the south the Maxner limestone would be assigned as older than the Miller. In a section on Avon river northeast of Newport Landing (or Avondale) wharf there are overturned beds belonging to subzone D that are followed by a concealed interval possibly underlain in part by beds of subzone C and finally followed by gypsum and

Miller limestone with similar strike and dip. If overturning has likewise affected the latter, the Miller limestone would seemingly underlie subzone D without the intervention of Maxner limestone, and the Miller limestone would again appear to be the younger.

An isolated outcrop of fossiliferous limestone, seemingly the Miller limestone, occurs south of Falmouth.

The two limestones, Miller and Maxner, carry a common fauna, but the association as regards relative abundance of individuals of the various species is different. The Maxner limestone is characterized particularly by an abundance of *Diodoceras avonensis* in the upper beds, and by a great abundance of individuals of *Dielasma davidsoni* and of *Composita dawsoni.* The two latter species and other brachiopods are commonly preserved with hollow interiors into which the brachidia project in an excellent state of preservation. The Maxner limestone is also particularly rich in individuals of *Parallelidon hardingi.* The Miller limestone, on the other hand, is characterized by the prominence of bryozoans, aviculopectens, and productids. Secondary coatings of calcite upon the fossils are more prevalent than in the Maxner stone. The following faunal lists permit a comparison of the two assemblages.

Fauna of Miller Limestone	Fauna of Maxner Limestone
Serpula hartti n. sp.	*Serpula annulata* (Dawson)
Fenestella lyelli Dawson	*Fenestella lyelli* Dawson
Septopora primitiva n. sp.	*Septopora primitiva* n. sp.
Batostomella exilis (Dawson)	*Batostomella exilis* (Dawson)
Streblotrypa biformata n. sp.	*Streblotrypa biformata* n. sp.
Polypora schucherti n. sp.	*Polypora schucherti*
Productus lyelli Verneuil	*Productus lyelli* Verneuil
Diaphragmus tenuicostiformis (Beede)	*Diaphragmus tenuicostiformis* (Beede)
Pugnax dawsonianus (Davidson)	*Pugnax dawsonianus* (Davidson)
Pugnax magdalena (Beede)	*Pugnax magdalena* (Beede)
Romingerina anna (Hartt)	*Romingerina anna* (Hartt)
Composita strigata n. sp.	*Composita strigata* n. sp.
Composita windsorensis n. sp.	*Composita windsorensis* n. sp.
Spiriferina verneuili n. sp.	*Spiriferina verneuili* n. sp.
Dielasma davidsoni (Hall and Clarke)	*Dielasma davidsoni* (Hall and Clarke)
Dielasma latum n. sp.	*Dielasma latum* n. sp.
	Dielasma milviformis n. sp.
	Dielasma mesaplanum n. sp.
Cranaena tumida n. sp.	*Cranaena tumida* n. sp.
	Harttella parva n. sp.
	Harttella dielasmoidea n. sp.
Sanguinolites parvus n. sp.	*Sanguinolites parvus* n. sp.
Sanguinolites striatogranulatus Hind	*Sanguinolites striatogranulatus* Hind
Edmondia rudis M'Coy	*Edmondia rudis* M'Coy
Parallelidon hardingi (Dawson)	*Parallelidon hardingi* (Dawson)
Parallelidon dawsoni Beede	*Parallelidon dawsoni* Beede
Leptodesma borealis Beede	*Leptodesma borealis* Beede
Leptodesma dawsoni (Beede)	*Leptodesma dawsoni* (Beede)
Leptodesma acadica (Beede)	*Leptodesma acadica* (Beede)
	Leptodesma ? shubenacadiensis (Dawson)
	Schizodus fundiensis n. sp.
Aviculopecten lyelli Dawson	*Aviculopecten lyelli* Dawson
Aviculopecten subquadratus n. sp.	
Aviculopecten lyelliformis n. sp.	
Pseudamusium simplex (Dawson)	*Pseudamusium simplex* (Dawson)
Modiola dawsoni n. sp.	

Lithophagus poolii (Dawson)	*Lithophagus poolii* (Dawson)
Scaldia sp.	
	Mourlonia ? sp.
	Murchisonia gypsea Dawson
	Murchisonia (Stegocoelia) abrupta n. sp.
Murchisonia (Stegocoelia) compactoidea n. sp.	*Murchisonia (Stegocoelia) compactoidea* n. sp.
	Straparollus minutus de Koninck
Platyschisma ? dubium Dawson	*Platyschisma ? dubium* Dawson
	Euomphalus exortivus ? Dawson
	Cyclonema ? subangulatum Hall
	Holopea cf. *proutana* Hall
Naticopsis howi Dawson	*Naticopsis howi* Dawson
Naticopsis hartti Dawson	*Naticopsis hartti* Dawson
	Bulimorpha maxneri n. sp.
Zygopleura cara (Dawson)	*Zygopleura cara* (Dawson)
Conularia planicostata Dawson	
Orthoceras vindobonense Dawson	*Orthoceras vindobonense* Dawson
	Orthoceras perstrictum Dawson
Stroboceras hartti (Dawson)	*Stroboceras hartti* (Dawson)
Diodoceras avonensis (Dawson)	*Diodoceras avonensis* (Dawson)
	Cypridina acadica n. sp.
Paraparchites gibbus n. sp.	*Paraparchites gibbus* n. sp.
Cyclus subcircularis n. sp.	*Cyclus subcircularis* n. sp.

Subzone C. The beds of this subzone are partly exposed at several localities. On Avon river at Windsor, directly south of the Canadian Pacific Railway bridge, exposures on the tidal slope and partial exposures in the bank yield the following sequence, section 3, in descending order.

Section 3

	Feet	Inches
Subzone C:		
(*w*) Beds of section 9..		
Fault		
Subzone C:		
(*u*) Limestone, platy, grey, oolitic..	?	
(*t*) Limestone, sandy, partly oolitic, grey to yellow, cavernous at base..	7	
(*s*) Shale, green and yellow, sandy..	3	
(*r*) Limestone, oolitic, grey; *Productus* sparingly..	1	8
(*q*) Limestone, dolomitic, sandy, oolitic, yellow..	6	
(*p*) Shale, dark greenish..	2	
(*o*) Shale, brick-red, with minor green..	58	
(*n*) Oolite, with spongiostromid band at top..	2	
Fault		
Subzone C: (*a*) Beds of section 5..	....	

The more northerly fault that limits the beds of (*u*) has resulted in their upthrow against the highest beds of subzone C, which outcrop north of the Canadian Pacific Railway bridge. The total displacement here is perhaps in the neighbourhood of 400 feet. The fault limiting (*n*) at the base of the section has a total displacement of about 100 feet whereby the spongiostromid band has been downthrown against beds (*a*) of the subzone. The beds missing as a result of this latter fault may be seen in section 4, on the tidal slope east of the Windsor wharfs where the following sequence occurs:

Section 4

	Feet	Inches
Subzone C:		
(*n*) Oolite with spongiostromid band at top	3	
(*m*) Concealed	9	
(*l*) Shale, green, calcareous, ribbon-banded; in part concealed	4	8
(*k*) Mostly concealed; in part yellow dolomitic shale	14	
(*j*) Limestone, magnesian, in part oolitic	2	6
(*i*) Concealed	13	
(*g-h*) Limestone, sandy, nodular	(?)	

Southerly of section 3 are outcrops of lower beds of the subzone, forming section 5 exposed south of Canadian Pacific Railway bridge, at tidal slope Windsor.

Section 5

	Feet	Inches
Subzone B: Beds (*b*), (*c*), etc. of section 2	....	
Faulted contact		
Subzone C:		
(*i*) Shale, brick-red, argillaceous	13	
(*h*) Limestone, platy, drab, spongiostromid banding	1	5
(*g*) Limestone, sandy, nodular, fossiliferous corals—*Lophophyllum avonensis, Dibunophyllum lambii*	19	
(*f*) Shale, greenish grey	1	8
(*e*) Limestone, dolomitic, sandy, yellow; with brown oolite	3	
(*d*) Dolomitic shale, soft, yellow	6	
(*c*) Shale, red and green, argillaceous, chiefly red	14	
(*b*) Sandstone, calcareous, platy, deep yellow; *Modiola* band	3	
(*a*) Shale, dolomitic, yellow, decomposed	9+	
Faulted contact		
Subzone C: Beds of section 3		

The nodular beds (*g*) are folded in an anticline followed on the north by a sharp syncline of which the northern limb is overturned, so that the succession from the axis of the syncline to the north is actually descending until beds (*a*) are limited by a downthrow of beds (*n*) of section 3.

The strata of section 5 are also exposed in section 6 in the Canadian Pacific Railway cut at the eastern approach to the bridge.

Section 6

	Feet	Inches
Subzone C:		
(*i*) Shale, brick-red, argillaceous—partly exposed	5+	
Shale, soft, green-grey	2	
(*g*) to (*h*) Dolomite, yellow, argillaceous	0	4
Shale, dolomitic, yellow	1	5
Sandstone, calcareous, soft, yellow	3	
Limestone, magnesian, sandy, with nodules	13	
(*e*) to (*f*) Sandstone and shale, deep yellow, calcareous	7	
Sandstone and shale, decomposed, light yellow	6	
(*d*) Sandstone, calcareous, decomposed, deep yellow	7	
(*c*) Shale, brick-red	9	
Shale, green	5	

		Feet	Inches
(*b*)	Sandstone, deep yellow: *Modiola hartti*..	2	
	Oolitic band..	1	2
	Shale, dolomitic, decomposed, deep yellow (in crush breccia of fault)..	—	
	Faulted contact		
(*o*)	Shale, brick-red (in fault breccia)..	—	
(*n*)	Oolite, with spongiostromid band at top..	1	
(*m*)	Shale, brick-red..	..	

The greater thickness of beds between (*d*) and (*i*) as compared with section 5 is explicable by the absence there of the crushing and slipping that affected those beds in the latter section.

The nodular beds of (*g*) outcrop again in section 7 on the tidal slope near the mouth of St. Croix river, a mile northeast of section 6.

Section 7

		Feet	Inches
Subzone D:			
(*l*)	Yellow, dolomitic silt and shale..	3	
(*k*)	Yellow oolite with *Modiola hartti* and ostracoda.. ..	3	5
(*j*)	Cavernous magnesian limestone..	2	4
(*i*)	Platy, grey limestone with *Martinia galataea*..	6	2
	Platy, grey limestone..	5+	
Subzone C:			
(*v*)	Concealed; in part gypsum..	?425±	
	Yellow dolomitic shale..	?	
Subzone C:			
(*n*)	Oolite with spongiostromid band at top..	2	
(*l*) to (*m*)	Concealed..	7	
	Greenish oolitic dolomitic shale..	2	
(*k*)	Concealed..	14	
(*j*)	Yellow, decomposed, oolitic dolomite..	1	6
(*i*)	Concealed..	11	6
(*h*) to (*g*)	Nodular, grey limestone with rare *Spirifer adonis*.. ..	3	6
	Limestone, shaly..	8	
	Nodular, grey limestone; *Productus*..	2	

The top beds (*v*) of subzone C, represented in section 7 by gypsum and concealed beds, are wholly lacking in the exposures at the Canadian Pacific Railway bridge at Windsor as a result of the fault displacement at the latter locality. The gypsum at this horizon is apparently very thick, perhaps exceeding 100 feet, and has been quarried at several localities. The gypsum beds of Wilkins quarry, a mile south of Windsor, are assigned here. They strike northeasterly to meet St. Croix river near Dimock. It seems probable that the actively quarried gypsum to the southwest, comprising the Eagle Swamp, Fraser, and Meadow quarries, belong likewise to this horizon. The generalized section, section 8, at Wilkins quarry is as follows:

Section 8

		Feet	Inches
Subzone D:			
(*l*)	Ribbon-banded, calcareous shale; ostracoda rare.. ..	3	3
(*k*)	Brown, oolitic limestone. *Modiola* at top..	1	9
(*j*)	Brown to yellow oolite and silty dolomite, cavernous with druses of calcite..	1	9
(*i*)	Platy, blue and brown limestone; *Martinia* in upper 6 feet..	10	
	Platy limestone with abundant *Productus*..	4+	

Subzone C:	Feet	Inches
(w) Largely concealed; in part brick-red shale..	?	
(v) Oolite grey to brown, platy below, somewhat nodular above..	6+	
Concealed..	?	200±
Grey limestone, with minute shells and crinoid stems; also oolitic and nodular limestone..	?	
Concealed..	?	
Gypsum of Wilkins quarry; interbeds of red shale and silty dolomite towards the top; at least one bed of conglomerate with dolomite matrix.. ..	?	

The Wilkins gypsum is exposed again in the Canadian Pacific Railway cut at Dimock and has associated with it thin beds of fossiliferous calcareous shale, arenaceous shale, and a bed 2 feet thick of calcareous conglomerate with well-worn pebbles of quartzites, quartz, and red sandstone up to 5 inches diameter in a calcareous dolomitic matrix. Angular quartz grains are embedded in the matrix. Some of the calcareous, shaly bands are abundantly fossiliferous with Productus, small gasteropods, and ostracods. *Nodisinella priscilla* and *Paraparchites gibbus* occur at several horizons in more easterly outcrops of the same gypsum zone.

Fauna of Subzone C. The fossils derived from subzone C were largely gathered from the nodular beds (*g*). The fauna of the subzone is as follows:

Nodosinella priscilla (Dawson)
Lophophyllum avonensis n. sp.
Dibunophyllum lambii n. sp.
Productus (Linoproductus) lyelli Verneuil
Productus (Linoproductus) semicubiculus n. sp.
Productus subfasciculatus n. sp.
Pustula exigua n. sp.
Diaphragmus tenuicustiformis (Beede)
Allorhynchus hartti n. sp.
Composita obligata n. sp.
Composita windsorensis n. sp.
Composita strigata n. sp.
Spirifer adonis n. sp.
Martinia galataea n. sp.
Dielasma davidsoni (Hall and Clarke)
Harttella gibbosa n. sp.
Sanguinolites niobe n. sp.
Edmondia hartti Dawson
Modiola hartti n. sp.
Spathella insecta (Dawson)
Flemingia dispersa (Dawson)
Paraparchites gibbus n. sp.

Subzone D. This subzone is best exposed at Windsor on Avon river, in section 9, exposed in descending order, proceeding south from Windsor-Falmouth road bridge.

Section 9

Subzone D:	Feet	Inches
(o) Concealed..	?	
(n) Oolite, thinly bedded, brown to yellow, somewhat spongiostromid at top..	5	
(m) Largely concealed; in part brick-red shale..	68	
(l) Dolomite, oolitic, decomposed, greenish and yellow..	1	
(k) Shale, calcareous, arenaceous, greenish, in part concealed..	17	
(j) Limestone, platy, grey..	3	
(i) Shale, calcareous, greenish grey..	2	
(h) Oolite, platy brown, *Modiola hartti* abundant in upper 1 foot..	2	
(g) Dolomite, brown to yellow, lower part cavernous, partly oolitic..	4	5
(f) Limestone, grey, platy; *Martinia galataea* common in upper 6 feet; *Productus* common lower 11 feet. *Avon limestone*..	17	

	Feet	Inches
(*e*) Limestone, platy, grey; minute dark nodules, ostracoda, and small shells..	1	4
(*d*) Limestone, nodular, grey to brown, sandy, *Martinia* and other shells..	5	5
(*c*) Shale, green, argillaceous..	5	
(*b*) Shale, calcareous, rippled..	3	
(*a*) Shale, ribbon-banded, calcareous argillaceous..	2	4
Subzone C:		
(*w*) Shale, green, argillaceous..	8	
Shale, green and red, transition..	1	
Shale, brick-red, argillaceous..	80±	
Faulted contact		
Subzone C: Beds of section 3..	....	

The solid, platy Avon limestone (*f*) outcrops at a number of other localities between Windsor and St. Croix river. Outcrops occur also at Wilkins siding on the Windsor-Halifax branch of the Canadian Pacific railway as indicated in section 8, and the limestone is again well seen near the mouth of St. Croix river about a mile east of Windsor. On the eastern shore of Avon river between Avondale and Kennetcook river scattered outcrops are visible at low tide; the Windsor strata are here broken by faults and in places overturned.

Fauna of Subzone D. The Avon limestone (*f*) and immediately underlying beds have furnished the bulk of the fossils of subzone D. The assemblage is mainly a brachiopod one with the addition of a few mollusca.

Fauna of Subzone D

Productus lyelli verneuil
Productus semicubiculus n. sp
Diaphragmus tenuicostiformis (Beede)
Allorhynchus hartti n. sp.
Composita windsorensis n. sp.
Composita strigata n. sp.
Composita obligata n. sp.
Spiriferina verneuili n. sp.
Martinia galataea n. sp.
Edmondia hartti Dawson
Pseudamusium debertianum (Dawson)
Modiola hartti n. sp.
Spathella insecta (Dawson)
Bellerophon sp.
Conularia planicostata Dawson

Subzone E. The best exposure of this subzone within the district is at the mouth of Kennetcook river where the following sequence was observed:

Section 10

	Feet
Subzone E:	
(*h*) Blue-grey limestone; *Caninia dawsoni* abundant, *Kennetcook limestone*	30
(*g*) Blue-grey limestone with *Bellerophon, Bucanopsis beedii,* and *Martinia galataea. Kennetcook limestone*..	25
(*f*) Blue-grey and dark shaly limestone with *Tabulipora acadica* and *Chonetes politus. Kennetcook limestone*..	20
(*e*) Dark blue-grey limestone. *Kennetcook limestone*..	25
(*d*) Concealed	80±
(*c*) Red and green shale	50±
(*b*) Platy blue limestone..	10±
(*a*) Bituminous, argillaceous, shaly limestone with *Spirifer nox*..	7+
Subzone D:	
(*q*) Red shales, chiefly..	80+
(*p*) Gypsum .. .. ?	40±
Faulted contact	
Subzone D:..	

At low water on the tidal slope of St. Croix river, a mile west of Dimock station, there is an exposure of limestone that belongs to subzone E, but whether it represents a part of (*d*), and (*e*), section 10, or is older than (*a*) of the latter section, is not known. The section at this St. Croix River locality is as follows:

Section 11

	Feet	Inches
Subzone E: Limestone, platy, dense..................	20	
Mainly concealed; in part green, calcareous shale.....	11	
Limestone, nodular, bluish grey, *Zaphrentis minas* common 5 feet from the top..................	16	6

The beds of section 11 strike about north 77 degrees east, dip 13 degrees to south. This strike prolonged westward would carry the beds above Avon limestone beds (*i*) of subzone D, that outcrop in a narrow syncline at the mouth of St. Croix river, a little less than a mile farther west. A concealed interval separates the uppermost platy beds of section 11 from the strata next exposed to the south. The latter are gypsum with interbedded calcareous shales and thin limestones and are exposed in the railway cut at Dimock. They are assigned stratigraphically to (*v*), subzone C. Seemingly, therefore, there is a fault in the concealed ground, which has brought the two subzones in juxtaposition.

The following species were gathered from section 11:

Zaphrentis minas Dawson
Productus lyelli Verneuil
Productus (Avonia) spinocardinatus n. sp.
Buxtonia cogmagunensis n. sp.
Diaphragmus tenuicostiformis (Beede)
Productus avonensis n. sp.
Schellwienella kennetcookensis n. sp.
Composita windsorensis n. sp.
Martinia galataea n. sp.
Diaphorostoma cf. *carleyana* (Hall)
Poterioceras sp.
Oracanthus sp.

In general the faunal assemblage of subzone E is more varied and more normally marine than those which preceded it. A complete list of species follows:

Zaphrentis minas Dawson
Caninia dawsoni (Lambe)
Fenestella lyelli mut.
Tabulipora acadica n. sp.
Crania cincta n. sp.
Schuchertella pictoense n. sp.
Schellwienella kennetcookensis n. sp.
Streptorhynchus cf. *minutum* (Cummings)
Chonetes politus McCoy
Protoniella beedii n. sp.
Productus lyelli Verneuil
Productus lyelli var. b.
Productus semicubiculus n. sp.
Productus cf. *latissimus* Sowerby
Productus spinocardinatus n. sp.
Pustula exigua n. sp.
Buxtonia cogmagunensis n. sp.
Diaphragmus tenuicostiformis (Beede)
Productus avonensis n. sp.
Camarotoechia atlantica n. sp.
Pugnoides ? sp.
Composita windsorensis n. sp.
Composita obligata n. sp.
Spirifer nox n. sp.
Ambocoelia acadica n. sp.
Martinia galataea n. sp.
Martinia thetis n. sp.
Dielasma davidsoni (Hall and Clarke)
Sanguinolites ? sp.
Bellerophon sp.
Euphemus cf. *urei* Fleming
Bucanopsis beedii n. sp.
Diaphorostoma cf. *carleyana* (Hall)
Orthoceras sp.
Poterioceras sp.
Phillipsia eichwaldi Fischer
Oracanthus sp.

Environmental Factors

Certain salient factors enter into the local problem of environment whose effects may be postulated with some degree of probability. Such are abnormally high temperatures combined with shallow waters and aridity, culminating at intervals in salinities wholly inimical to the existence of a bottom animal-life. These, as evidenced from the vertical and horizontal distribution of anhydite or gypsum deposits within the Windsor series, were recurring conditions of widespread extent in the Windsor seas. From the most southwesterly outcrop of the Windsor strata at Mahone bay near Halifax, to outcrops at George bay, Newfoundland, is a distance of 350 miles. About 230 miles north of Mahone bay there is an isolated outlier of gypsum on Tobique river, New Brunswick, so that gypsum-depositing seas prevailed at various places and times over a region of at least 40,000 square miles. The prevalence of oolites at various horizons within the Windsor is considered as a testimony of shallow waters. Basal contacts of the Windsor so far as known record low-lying shores. In Windsor area the lower Windsor sea transgressed over a flat alluvial plain underlain by earlier continental Mississippian sediments without the development of appreciable basal conglomerate. In other areas the lower Windsor sea has similar relations and in still others limestone overlaps upon pre-Carboniferous rocks. Much of the Carboniferous conglomerate formerly mapped as "Lower Carboniferous conglomerate" has since been proved to be either earlier or later in age than the Windsor series. A discussion of calcium sulphate deposition with particular reference to hypothetical conditions permitting of thick chemical deposits in shallow seas is reserved for the chapter dealing with the economic geology of the district.

The times of gypsum or anhydrite deposition were not the only ones that prohibited the establishment of an indigenous fauna. Red mudstones and shales make up nearly one-half of the total mass of the sediments and so far as known are barren of fossils. Extreme muddiness of the waters would be deleterious to animal life and high temperatures would be detrimental to the preservation of such forms as did survive.

A rhythmic repetition of red shale and gypsum or anhydrite with fossiliferous calcareous beds is epitomized in the following generalized section:

Subzone E.
- Kennetcook limestone, with cup corals, bryozoans, brachiopods, and trilobites

Subzone D.
- Red shale
- Gypsum, with fossiliferous calcareous bands
- Red shale, etc.
- Avon limestone, with brachiopods

Subzone C.
- Red shale
- Gypsum, with fossiliferous calcareous bands carrying foraminifera and ostracoda
- Red shale
- Dolomitic and calcareous shales, sandy fossiliferous limestone, oolites, *Modiola* and algal bands

Subzone B.
- Red shale?
- Gypsum
- Miller limestone with brachiopods, bryozoa, pelecypods, gasteropods
- Red shale
- Gypsum
- Red shale with some calcareous shale and oolites
- Seeming position of Maxner fossiliferous limestone

Subzone A.
- Gypsum
- Red shale
- Banded brecciated limestone, thin conglomerate and basal sandstone with *Schizodus*

There is no necessity to invoke any more radical change in environmental conditions during the deposition of the fossiliferous members than might have been established by freer communication with the outside sea, which would restore more normal salinities and temperatures. Although there is a strong suggestion that the rhythmic occurrence of similar rock facies in the sequence is a direct reflex of a rhythmic climatic or tectonic oscillation, semi-aridity was the dominant controlling factor throughout the epoch.

Although the thicker calcareous beds are fairly normal in type and with a low percentage of magnesia, many of the thinner beds show an abnormal origin in their oolitic texture, high magnesian content, algal nature, or in the possession of a peculiar restricted faunal assemblage of minute shells comprising several species of gasteropods, lamellibranchs, ostracods, and foraminifera. These beds doubtless represent the more extreme shallowing of the waters, and they are significantly situated in close association with gypsum deposits. They are, however, particularly abundant in the middle Windsor or in the basal member of the Upper Windsor zone. The *Modiola* phases are of interest when compared with similar horizons that characterize the Avonian sequence in England, where they stand in marked relation to disconformities or to diastems.[1]

Correlation

The Windsor series on the basis of its fauna is correlated with the Visean of northern Europe and in general with the Chesterian of the United States. The basis for this reference is outlined in the chapter that deals with the faunal relationships.

PENNSYLVANIAN ? SANDSTONE

At Centre Burlington (or Kennetcook) near the mouth of Kennetcook river, there is a small outlier of sandstone exposing a thickness of about 15 feet, that differs lithologically from any other rock in Windsor district. The sandstone is even-grained, soft, and friable, grey but weathering to a buff yellow. Plant impressions are common but of an indeterminate nature,

[1] Diastems, meaning "intervals" is a term introduced by J. Barrell to indicate those sedimentary breaks "which have a large enough value to be recognized by change in fossils or marked contrast in sedimentation." They are, therefore, minor disconformities. (Barrell, 1917, p. 794.)

although a *Calamites* of the type *C. suckowi* Brongniart, and leaves, and possibly stems, of *Cordaites* are represented. It is probable, therefore, that this sandstone should be assigned to the Pennsylvanian rather than to late Mississippian. As its occurrence was limited to this single outcrop no definite conclusions were reached.

TRIASSIC

ANNAPOLIS FORMATION

Regional Relations

The Triassic rocks of Nova Scotia are confined to Bay of Fundy region, but are preserved today for the most part in that part of the trough lying south of the Cobequid axis. Thus, Minas basin is bordered on both sides by strata of this age, and they continue westward for many miles as a floor to the fertile valleys of Annapolis and Cornwallis rivers. In Windsor district there are stray glimpses along the shore of Minas basin of the marginal deposits of this basin.

Local Descriptive Geology

Just north of the wharf at Avonport, at low tide there may be seen a small outcrop of Horton Bluff shales (mapped by Fletcher as Silurian), and on the same tidal slope unconformable remnants of flat-lying, brick-red, calcareous quartz grits of Triassic age. One thousand feet farther north, some 200 feet of these red beds are exposed in the bluffs of Oak island, dipping several degrees northward. They comprise coarse sandstone grits, with a matrix of sharp, angular, transparent quartz grains and pebbles of slate, quartzite, vein quartz, and arenaceous shale, passing upwards into finer-textured massive sandstones with lenses of conglomerate or of argillaceous material, and with clay balls, the whole markedly cross-bedded. Two miles farther northwards, on Long island, there are still better exposures. Here there are thick beds of massive, strongly cross-bedded, brick-red sandstones as before, the sandstone carrying abundant patches or lenses of pebbles and conglomerate. Associated are interbands 20 feet or less in thickness of chocolate-red, areno-argillaceous shale. The sandstone in places is seen to channel deeply into the shales and has included in itself irregular masses or large balls of the finer beds.

The sharp, angular quartz grains composing the matrix of the grits average up to 7 mm. in diameter. The cement is calcareous and ferruginous. The contained pebbles, ranging in size up to 5 cm., are most commonly bounded by fracture faces, but have well-rounded corners. In composition several lots were found to consist roughly of 60 per cent vein quartz, 12 per cent dark vitreous quartzite, 22 per cent greenish micaceous arenaceous shale, 5 per cent micaceous arenaceous slate with limonite pseudomorphs after pyrite, 1 per cent red felsite or smoky feldspar, gypsum rare.

Across the mouth of the Avon estuary, on the Cambridge shore, the actual contact of the Triassic upon the Horton rocks may be seen in several places. It is a distinct angular unconformity, the strongly folded Horton being abruptly truncated by the contact plane. It is only in detail, with inches as the unit of measure, that one notes many minute channels and a jagged contact with the overlying breccia. The basal several feet of the Triassic is finer in texture than the overlying beds and is in fact a breccia of the underlying shale embedded in a brick-red, argillo-arenaceous matrix. This deposit is then followed unevenly by massive pebbly grits of conglomeratic sandstone like that noted on Oak or Long islands, but in places much coarser conglomerate occurs with boulders up to 1 foot and 2 feet diamter. The most abundant pebbles are green, red, or brown vitreous quartzites with vein quartz second in importance. A few angular blocks occur from the Horton below, and occasional pebbles of gypsum and of a crystalline limestone. The basal breccia with abundant Horton material is very variable in thickness as well as in texture and very badly assorted. Thus, fragments of Horton shale have been noted ranging from a fraction of an inch, associated with large angular blocks up to 18 inches or more.

Depositional Environment

Widespread oxidation, massive conglomeratic beds exceeding 100 feet in thickness, badly assorted material, breccia at the basal contact, marked crossbedding of current type, intraformational channelling, torn remnants of argillaceous material, or clay balls included in beds of grit, constitute together an ensemble so characteristic of terrestrial deposition as to leave no doubt as to the subaerial formation of these beds. The deposit likewise has the earmarks of a fluvial intermontane type in which local alluvium from the highlands bordering the valley was incorporated.

Sufficient data bearing on Triassic sedimentation have not been gathered from the limited exposures in Horton area to throw much light on the climatic conditions prevailing during the time of deposition. In view of the pronounced, widespread oxidation of the iron and the absence of carbon, in conjunction with badly sorted deposition, channelling phenomena, etc., it would seem necessary to postulate semi-arid conditions. The fact that gypsum pebbles have been rolled about and actually preserved, likewise supports this view. On the other hand, the absence of interbedded gypsum or of salt deposits is a strong argument against high aridity. Semi-aridity at this time was indeed a feature of the whole Appalachian region and characterized as well many other areas on the earth's surface.

Source of Material

This is a still more difficult problem of treatment without assembling the evidence from the whole basin of deposition. The basal several feet of breccia is dominantly of local origin, as the debris is readily traced to the Horton shale immediately underlying. On the other hand, the pebbles of the overlying massive conglomeratic sandstone are predominantly dark quartzites that resemble more closely the quartzites occurring in the Cobequid upland or in the Caledonian complex of New Brunswick, than any quartzite in the Precambrian belt to the south. Pebbles of felsite and of a dark, smoky feldspar are likewise not uncommon and these, too, have not a southern aspect. There are, however, slate pebbles with limonite pseudomorphs after pyrite that most probably were derived from the Halifax slates. An unconformity of the Trias on Carboniferous red shale at Lower Economy on the north side of Minas basin has been mentioned by Powers. The basal conglomerate there has subangular pebbles 1 to 3 inches in length, of slate, schist, quartz, and igneous rocks from the Cobequid mountains. This would confirm a local derivation of a large part of the sediment of the basal beds. But the strata above are stated by Powers[1] to be separated from the Cobequids by a post-Triassic fault that runs for some 90 miles from D'Or cape to Truro, with a displacement of 2,000 to 3,000 feet. If such a displacement is actually present it seems as if the Cobequids might have formed a part of the Triassic basin during the greater part of the time of deposition, and that a more extensive and more distant source of supply must be looked for. As the area to the east is underlain by thick Carboniferous deposits, recourse must be had to the metamorphic area of New Brunswick and Maine, or to a part of the old Appalachian land that lay to the east of the present New England coast. The hypothesis of such a derivation might be favoured by the presence of heavy conglomerate beds in the Trias at Quaco, New Brunswick, (450 to 700 feet thick).[2] It is not probable that the Triassic basin extended to the south of the Minas basin much beyond its present limits. The present loci, therefore, of the Fundy borders of the southern upland may not differ radically from the loci of an upland area in Triassic times. Northward-trending streams in the wet seasons would build but alluvial fans in the Triassic valley and contribute their quota of Precambrian slate from the Halifax formation to the main bulk of the Triassic deposits carried down from the New Brunswick highlands of the northwest and the New England highlands to the west.

Correlation

The Acadian Triassic had long been correlated with the New Red sandstone of England by reason of its lithological characters and position above the Coal Measures. Previous to 1847, however, much of the red strata of the Carboniferous, including the Windsor series, were likewise assigned to the New Red. Dawson was the first to differentiate the Trias from the older formations and to define its distribution in Bay of Fundy region. Dawson likewise indicated its probable equivalence to the Newark series of Connecticut and Virginia.

In the Acadian area, very few fossils have been found, but these are fortunately sufficient to determine the correctness of Dawson's conclusions. Miss Ruth Holden,[3] after a careful study of lignitized material from the Triassic of Martin Head, New Brunswick, determined two diagnostic species of plants, *Voltzia coburgensis* Schaur, formerly described by Dawson as *Dadoxylon edvardianum*, and *Equisetum rogersii* Schimper. The former is common to the Lettenkohle and Lower Keuper of Germany, the

[1] Powers, S.: Jour. Geol., vol. 24, pp. 106, 256 (1916).
[2] Powers, S.: Jour. Geol., vol. 24, p. 13 (1916).
[3] Holden, R.: Ann. Bot. London, vol. 27, pp. 243-255 (1918).

latter to the Lettenkohle and to the Virginia Triassic. The discovery of a fauna was made by Haycock, who found fragmentary fish remains in a Triassic marly sandstone overlying the North Mountain basalt at Scott Bay. These were identified by Lambe as probably *Semionotus fultus* (Agassiz), a common Newark form.[1] An *Estheria* also found by Haycock in Triassic boulders within the drift in the vicinity of Kentville is, according to Powers, comparable with *E. ovata* Lea, which is characteristic also of the Appalachian Triassic. In other words, the Acadian Triassic is well established as of late Triassic age.

QUATERNARY DEPOSITS

As the present investigation was concerned with the stratigraphy of the bedrock, attention was paid to the glacial deposits only so far as they were helpful in affording information about the rock of the concealed areas. The great bulk of these deposits is boulder clay, whose thickness was found to vary from 0 to 50 feet or more, being thin on the upland and of maximum thickness over the lowland. The colour is dominantly a chocolate-brown to brick-red, owing to the fact that local red rocks enter so largely into its composition. But on the upland a slate-grey colour was occasionally noted, resulting from the large proportion of locally derived Halifax slate debris. Although a strong clay texture is the characteristic feature, one local instance was noted where the basal deposit was a closely cemented conglomerate consisting of slate and other debris cemented by hydrated hydroxide of iron that was apparently derived from the decomposition of pyrite so abundant in the underlying slate. It is possible that this deposit is of an older glacial epoch than the overlying boulder clay.[2]

The great proportion of the included boulders are readily traceable to local rock outcrops. For example, along St. Croix river about 2 miles southwest of Windsor, a collection of boulders yielded the following content:

	Per cent
Triassic trap and amygdaloid	40
Horton sandstone	30
Felsite, syenite, quartzite, etc., from the Cobequid ridge	20

The Horton sandstone was undoubtedly gathered from the country lying north of Kennetcook and Halfway rivers and south of Minas basin, the trap from North mountain or Five Islands district, and the quartzites and igneous rocks from Cobequid hills that lie some 30 miles to the north. A second lot gathered in the vicinity of Wilkins quarry south of Windsor yielded:

	Per cent
Triassic trap and amygdaloid	43
Horton sandstone	20
Windsor limestone	20
Cobequid quartzites, felsites, etc	13

Several of the Windsor boulders were directly traceable to the outcrop of limestone on Kennetcook river about 5 miles almost due north.

[1] Powers, S.: Jour. Geol., vol. 24, p. 121.
[2] *See also* Prest, W. H.: Trans. Nova Scot. Inst. Sci., vol. 9, pp. 158–170 (1896).

In Curry Brook valley, in the vicinity of the main fork where a tributary enters from the southwest, there is an appreciable percentage of Triassic boulders in the drift. This occurrence is of especial interest as there are no Triassic outcrops within a radius of 4 miles. Moreover, as these Triassic rocks are very soft, it is unlikely they would make up an appreciable proportion of the boulders in the drift at this particular locality, unless they were derived from a direct local source, either from the nearby Gaspereau valley or from Curry valley itself in the near vicinity. As a matter of fact, Curry valley is noticeably broad at this part of its course, supporting the conclusion that it is not improbable that an outlying remnant of Triassic sandstone lies concealed beneath the drift.

More rarely, the boulder clay has intermixed with it stratified sands or gravels. Thus on the shore north of Summerville the following section was noted, in descending order:

	Feet
Boulder clay..	17
Stratified sand and gravel..	3
Boulder clay exposed..	3

Glacial striæ on the basement rocks are rarely seen within the confines of the district, owing to the soft nature of the rocks and the lack of good outcrops. Those noted were as follows:

(1) At the falls, Fall brook, south of Windsor, on Precambrian metamorphic, south 6 degrees east
(2) Near Butler hill, south of Windsor, on Horton conglomerate, south 5 degrees east-south 6 degrees west
(3) Near Lyon brook, West branch Avon river, on granite, south 6 degrees west

RECENT DEPOSITS

The post-glacial deposits comprise the gravel and stream alluvium that forms terraces or lies in the valley bottoms on top of the glacial drift along the present streams, as well as tidal alluvium and beach sands and gravels. An extensive deposit of the former type forms a terrace in the lower Gaspereau valley. A partial section through it at the Wallbrook-Lockhartville road bridge over Curry brook yielded the following:

	Feet
Coarse gravel and shingle..	8
Stratified sands and gravels..	16
Boulder clay..	30
Horton shale..	

Similar terrace deposits border Avon river at Wolfville and elsewhere.

Tidal alluvium has built up extensive flats at the mouths of Gaspereau river, a large part of which has been dyked to form rich meadow land, the historic meadows of Grand Pré. Smaller tracts of similar alluvium border the lower courses of Cogmagun river, Kennetcook river, St. Croix river, and along the upper reaches of Avon river. Moreover, there is a belt of this alluvium of variable width up to 2 miles, exposed at low water bordering the entire coast of the estuary, that of maximum width forming the Cambridge flats off the Cambridge-Cheverie shoreline.

CHAPTER IV

FAUNAL RELATIONSHIPS OF THE WINDSOR SERIES

INTRODUCTION

As interbedded gypsum deposits and red argillaceous shales form so prominent a feature throughout the Windsor series, it is quite evident that the biotic conditions were in general adverse to bottom life, which fact must be borne in mind in a comparative study with other areas. The influence of an abnormal facies will primarily act as a selective agent in the composition of the fauna, favouring either more plastic types, or organisms specialized to that particular environment.

The composition of a faunal assemblage, however, is due not only to the differential effects of the environment, but as well to the barriers set to migration, and to the original faunal composition of the area or areas from which migration is possible. Thus absentees in the Windsor fauna may likewise be absent or poorly represented in the Avonian faunas of the North Atlantic province with which it is allied and with which migratory relations were established. This factor alone might account for the meagre representation of crinoids as mere stem fragments, for the paucity of fish remains, for the absence of echinoderms and of such specialized bryozoans as *Archimedes* and *Lyropora,* while explaining the preponderance of productids and such genera as *Composita.* Yet there are omissions equally conspicuous that were abundantly represented in the Avonian seas of western Europe, of which the corals are the most important. Corals are present in such astonishing numbers and structural variety in the Avonian rocks of England, that they not only are important as rock builders, but they frequently present records by which it is possible to trace the main trends of phylogenetic development, and they have proved to be admirable indices for correlation over wide areas.[1] This profuseness is in striking contrast with the paucity of corals in the Windsor rocks. Here cup corals enter very sparingly in subzone C, although several species manage to establish a small society in the succeeding subzone E, comprising four genera and a meagre five species, so far as recognized. No colonial forms whatever have been met in Windsor district, although *Lonsdalea* occurs in Pictou district. As these cup corals themselves are found in dark argillaceous limestones, the environment was evidently quite distasteful to the class as a whole, and conditions throughout the greater part of the period were even more prohibitive.

As reef corals are conspicuously sensitive to temperature changes and to presence of sediment, their absence from the shallow Windsor seas with

[1] For criticisms of the value of corals in stratigraphic work *See* Carruthers, R. G.: Geol. Mag., Dec. 5, vol. 7, pp. 171–173 (1910).

their shifting salinities is not surprising. Vaughan[1] states that the conditions necessary for vigorous growth of present-day reef-forming corals are as follows: (*a*) depth of water, maximum, about 46 metres (25 fathoms); (*b*) bottom, firm or rocky, without silty deposits; (*c*) water, circulating, at times strongly agitated; (*d*) an abundant supply of small animal plankton; (*e*) strong light; (*f*) temperature, annual minimum not below 18 degrees C., minimum average for the coldest month in the year not lower than about 22 degrees C.; (*g*) salinity between about 27 and 38 parts per thousand. Of these conditions (*c*) and (*d*) would be frequently unfavourable in the Windsor sea, with (*b*) and (*g*) decidedly adverse. Cup corals are more plastic types able to withstand temporary burial and higher temperatures, as according to Vaughan,[2] " the capacity to resist the effects of high temperature and that to resist the effects of burial are brought into relation, and one seems to be the correlative of the other." The only *Zaphrentis* that has been found in the Windsor rocks is of the type *Z. enniskilleni*, an organism whose habitat in the European rocks is closely akin to that at Windsor, that is, bottoms on which were deposited dark argillaceous lime muds.[3]

Among the brachiopods, striking absentees that have a prolific development at this time in the North Atlantic province, are the gigantic *Chonetes*, the only member in the Windsor series of this genus being the very small and smooth-shelled *C. politus* McCoy. This species has abundant individual representatives at a very definite horizon in the Kennetcook limestone, indicating a gregarious habit that is homologous to a similar distribution in the Lower Limestone series of Craigenglen, Scotland. As the gigantic types of the genus in their extravagant abundant development foreshadow racial decay, they were doubtless forms totally unfitted to adaptation to a hostile environment.

In general, the Windsor fauna is characterized in its composition by the abundance of pelecypods in contrast with the fauna of the normal Avonian, which is essentially a coral-brachiopod one. The Scottish and Northumberland facies of the Avonian, however, is dominantly a muddy one with thin, intercalated limestones in the Visean period, and there, as might be expected, pelecypods and gasteropods enjoy likewise a major rôle. In composition, the molluscan fauna of this Bernician (Visean) fauna is closely akin to that of the Windsor limestone, with several species in common.

The richness of pelecypods in such a pure limestone as that of the Maxner seems explicable only on the supposition that the salinities of the waters and the lack of currents were unfavourable to any but the most hardy forms of life. The lower part of this limestone, which is sandy, contains pelecypods almost exclusively, but the purer upper beds are crammed as well with individuals belonging to two or three species of *Composita* and *Dielasma*. These shells lie without orientation in remarkable preservation as veritable shell heaps. There is among them a large percentage of young, immature specimens. Their burial was assured

[1] Vaughan, T. W.: Smith. Rept. for 1917, p. 215.
[2] Vaughan, T. W.: Op. cit., p. 202.
[3] Garwood, E. S.: Quart. Jour. Soc. Geol. London, vol. 68, pp. 509-510 (1912).

by quiet waters as the haphazard arrangement of the shells (*See* Plate XXXVI) and the remarkable preservation of the most fragile internal spires or loops, coupled with the fact that the interiors are as a rule hollow or filled with secondary minerals, implies clear waters and a distinct dearth of currents. The latter factor may be correlated with an absence of oolites in these beds. The Miller limestone phase represents perhaps a greater shallowing of the waters with consequent diagenetic changes, but the conditions otherwise were not radically different from those that prevailed during the deposition of the Maxner limestone. The fauna of the Kennetcook limestone of upper Visean age is more normally marine than any that preceded it.

DWARFING

Shimer[1] has cited the Windsor fauna as a typical example of the dwarfing of individuals as a result of an unfavourable environment. The evidence as presented appears to the writer inconclusive, for the reason that the units of the fauna were not compared with specifically identical units from more favoured localities, and small individuals, as noted by Shimer himself, may not necessarily be dwarfs but represent immature forms. The great number of such immature individuals associated with adults in the Maxner and Miller limestones is significant in this connexion. The adults themselves in these limestones do not show striking signs of dwarfing when compared with members from an identically or closely allied species from the Avonian of the British Isles. Thus *Composita windsorensis* is perhaps identical with a species that occurs in S_1 near Settle, Yorkshire, and the adults from these two widely separated areas are quite comparable in size. Moreover *Productus lyelli* and its allies do not depart appreciably in size from mutations of the *P. corrugato-hemisphericus* group that occur in the Bristol Avonian at horizon S_2 or that are abundantly present in the lower Visean of Yorkshire and Westmoreland counties, England. The gasteropods are dominantly small species that have their nearest affinities in the Carboniferous Limestone series of Scotland, where they are likewise small. It is stated, however, by Donald[2] that many of the Scottish gasteropods are of much smaller size than their representatives in England and Belgium, and that "this discrepancy may be owing to the different physical conditions that prevailed in the two areas." The Scottish specimens are frequently abnormally well preserved, with the protoconchs still intact, which is suggestive of very slight current action and of a youthful demise rather than of distinct dwarfing. The Windsor lamellibranchs are quite comparable in size with those in the Bernician fauna of Northumberland. In short, the evidence for dwarfing, when adult forms are compared with their nearest affinities that lived at approximately the same time in other waters, is far from conclusive.

---

[1] Shimer, H. W.: Am. Nat., vol. 42, pp. 484–486 (1908).
[2] Donald, J.: Quart. Jour. Geol. Soc., London, vol. 64, p. 47 (1898).

COMPOSITION AND SOURCE OF THE FAUNA

As indicated in the accompanying faunal list the writer has identified and described from the Windsor fauna 127 species (56 new), belonging to 81 genera. In addition, a number of calcareous algæ still await study. The composition of this fauna in general is as follows:

Calcareous algæ, several genera and species
Foraminifera, 1 genus, 1 species
Corals, 5 genera, 5 species
Vermes, 3 genera, 6 species
Bryozoa, 6 genera, 7 species
    Trepostomata, 2 genera, 3 species
    Cryptostomata, 4 genera, 4 species
Crinoidea, stem fragments
Brachiopoda, 26 genera, 49 species
    Neotremata, 2 genera, 3 species
    Protremata, 11 genera, 16 species
    Telotremata, 13 genera, 30 species
Mollusca, 34 genera, 55 species
    Pelecypods, 13 genera, 27 species
    Gasteropods, 16 genera, 21 species
    Cephalopods, 5 genera, 7 species
Crustacea, 4 genera, 4 species
    Trilobita, 1 genus, 1 species
    Ostracoda, 2 genera, 2 species
    Xiphosura, 1 genus, 1 species
Vertebrata, 2 genera, 2 species

The fauna as determined by the facies is, therefore, essentially a molluscan-brachiopod one. In detail, after allowances are made for this control of facies, there are such close relationships with the upper Avonian faunas of northwestern Europe that it was clearly derived from the same source, the North Atlantic. It shows a great contrast to the Mississippian faunas of the interior of North America in the absence of a crinoid and blastoid development, of many characteristic brachiopods, and of such specialized bryozoans as the *Lyropora* and *Archimedes* type, as well as of fish remains. Affinities with the upper Mississippian of the American seas are most clearly shown by the few trepostomata bryozoans such as *Batostomella* that occur in the fauna, but certain species of *Composita* and *Diaphragmus* likewise indicate distant migratory connexions.

The accompanying table indicates the stratigraphical horizons of the species. The sequence of these horizons is the writer's interpretation of the restoration of the very broken Windsor sections and may be subject to some revision.

Table of Zonal Distribution of Fauna

—	A	B	C	D	E	Remarks
Foraminifera						cc abundant
Nodosinella priscilla (Dawson)			cc			c common
Anthozoa						r rare
Zaphrentis minas Dawson					r	rr very rare
Caninia dawsoni (Lambe)					cc	
Lophophyllum avonensis n. sp.			r		r	
Dibunophyllum lambii n. sp.			r			
Lonsdaleia pictoense (Billings)						Upper Windsor, subzone doubtful
Vermes						
Serpula annulata (Dawson)		r				
Serpula hartti n. sp.		r				
Spirorbis caperatus M'Coy		c				
Conularia planicostata Dawson		c		rr		
Conularia cf. *tenuis* Slater	c					
Conularia sorrocula Beede		rr				
Bryozoa						
Fenestella lyelli Dawson		cc				
Fenestella lyelli mut.					r	
Septopora primitiva n. sp.		r				
Batostomella exilis (Dawson)		cc				
B. abrupta		c				
Polypora schucherti n. sp.		c				
Streblotrypa biformata n. sp.		c				
Tabulipora acadica n. sp.					cc	
Brachiopoda						
Crania cincta n. sp.					rr	
Crania brookfieldensis n. sp.		rr				
Orbiculoidea sp.		rr				
Schuchertella pictoense n. sp.					r	
Schellwienella kennetcookensis n. sp.					r	
Streptorhynchus cf. *minutum* (Cummings)					rr	
Chonetes politus M'Coy					cc	
Productella baddeckensis n. sp.		r				
Protoniella beedii n. sp.					r	
Productus lyelli Verneuil		cc	c	c	r	
Productus lyelli var. *a*		cc				
Productus lyelli var. *b*		r			r	
Productus semicubiculus n. sp.				cc	r	
Productus dawsoni Beede		rr				
Productus subfasciculatus n. sp.			c			
Productus cf. *latissimus* Sowerby				rr		
Productus (*Avonia*) *spinocardinata* n. sp.					cc	
Pustula exigua n. sp.		rr			r	
Buxtonia cogmagunensis n. sp.					c	
Diaphragmus tenuicostiformis (Beede)		cc	c	r	rr	
Productus avonensis n. sp.					cc	
Camarotoechia acadiensis (Davidson)		rr				
Camarotoechia atlantica n. sp.					r	
Pugnoides ? sp.					rr	
Pugnax dawsonianus (Davidson)		cc				
Pugnax magdalena Beede		r				
Pugnax ? sp.						Horizon doubtful
Allorhynchus ramosum n. sp.		cc				
Allorhynchus hartti n. sp.			r			
Allorhynchus cf. *macra* (Hall)		c				
Romingerina anna (Hartt)		c				
Composita dawsoni (Hall and Clarke)		cc				
Composita windsorensis n. sp.		cc	r	r	r	
Composita strigata n. sp.		r	r	r	r	
Composita obligata n. sp.			c	c	c	
Composita offirmata n. sp.		rr				
Spirifer nox n. sp.					c	
Spirifer adonis n. sp.			r			
Spiriferina verneuili n. sp.		cc		r		
Spiriferina sp.				c	rr	
Ambocoelia acadica n. sp.					cc	
Martinia galataea n. sp.			r	cc	cc	

Table of Zonal Distribution of Fauna—Continued

—	A	B	C	D	E	Remarks
Brachiopoda						
Martinia thetis n. sp.					r	
Dielasma davidsoni (Hall and Clarke)		cc	cc	r	r	cc abundant
Dielasma latum n. sp.		cc				c common
Dielasma milviformis n. sp.		c				r rare
Dielasma mesaplanum n. sp.		c				rr very rare
Cranaena tumida n. sp.		c				
Harttella parva n. sp.		c				
Harttella gibbosa n. sp.			c		c	
Harttella dielasmoidea n. sp.		c				
Pelecypoda						
Sanguinolites parvus n. sp.		cc				
Sanguinolites striatogranulatus Hind		r				
Sanguinolites niobe n. sp.			rr			
Sanguinolites ? sp.					rr	
Edmondia rudis M'Coy		cc				
Edmondia hartti Dawson			r	r		
Parallelidon hardingi (Dawson)		cc				
Parallelidon dawsoni Beede		cc				
Leptodesma borealis Beede		cc				
Leptodesma dawsoni (Beede)		cc				
Leptodesma acadica (Beede)		cc				
Leptodesma ? shubenacadiensis (Dawson)		rr				
Leptodesma sp.		rr				
Pteronites gayensis Dawson		c				
Schizodus fundiensis n. sp.		r				
Schizodus cheveriensis n. sp.	c					
Aviculopecten lyelli Dawson		cc				
Aviculopecten lyelliformis n. sp.		rr				
Aviculopecten subquadratus n. sp.		cc				
Pterinopecten sp.						Horizon doubtful
Pseudamusium simplex (Dawson)		cc				
Pseudamusium debertianum (Dawson)		c	c	c	rr	
Modiola hartti n. sp.			c	c		
Modiola dawsoni n. sp.		c				
Lithophagus poolii (Dawson)		c				
Cypricardella acadica n. sp.					c	
Spathella insecta (Dawson)				r		
Scaldia fletcheri n. sp.		r				
Gastropoda						
Bellerophon sp.				r		
Euphemus cf. *urei* Fleming					c	
Bucanopsis beedii n. sp.					c	
Mourlonia ? sp.		rr				
Murchisonia gypsea Dawson		c				
Murchisonia (Stegocoelia) abrupta n. sp.		cc				
Murchisonia (Stegocoelia) compactoidea n. sp.		cc				
Straparollus minutus de Koninck		c				
Platyschisma ? dubium Dawson		c				
Euomphalus exortivus ? Dawson		r				
Euomphalus similis (Meek and Worthen)		r				
Cyclonema ? subangulatum Hall		c				
Holopea cf. *proutana* Hall		c				
Flemingia dispersa (Dawson)			r			
Flemingia minuta n. sp.						Horizon doubtful
Naticopsis howi Dawson		cc				
Naticopsis hartti n. sp.		c				
Bulimorpha maxneri n. sp.		c				
Zygopleura cara (Dawson)		c				
Aclisina acutula (Dawson)		c				
Diaphorostoma cf. *carleyana* (Hall)					r	
Cephalopoda						
Orthoceras vindobonense Dawson		c				
Orthoceras perstrictum Dawson		c				
Orthoceras sp.					rr	
Kionoceras laqueatum (Dawson)		rr				
Stroboceras hartti (Dawson)		c				

Table of Zonal Distribution of Fauna—Continued

—	A	B	C	D	E	Remarks
Crustacea						
Diodoceras avonensis (Dawson)		c				cc abundant
Poterioceras sp.					r	c common
Cypridina acadica n. sp.		rr				r rare
Paraparchites gibbus n. sp.		c	c			rr very rare
Phillipsia eichwaldi Fischer					c	
Cyclus subcircularis n. sp.		rr				
Vertebrata						
Oracanthus sp.					rr	

SUMMARY OF THE AVONIAN SEQUENCE

The term "Avonian" in English stratigraphy has replaced the older usage "Mountain Limestone." It has reference to the splendid section of Lower Carboniferous limestone displayed on Avon river near the Clifton bridge, Bristol. Vaughan,[1] using this section as a type, subdivided the Avonian into two primary divisions of major rank, and into secondary zones and subzones, on the basis of the coral and brachiopod succession. Later work, chiefly by Vaughan, Sibly, Matley, Wilmore, Douglas, Dixon, and Garwood, not only established these zones over the whole southwestern province of England and Wales, but confirmed them with minor modifications for the Midlands, Dublin district, Ireland, and the northwestern province of Westmoreland and Cumberland.

The Avon section approximates about 2,100 feet in thickness, and consists of basal calcareous shales lying disconformably on Upper Old Red sandstone, followed by massive limestones and oolites and capped by upper calcareous shales which underlie the "Millstone Grit." The zones established by Vaughan and others in Bristol district are as follows:

Upper Avonian or Kidwellian
(=Visean approx.)

Dibunophyllum zone
- D_3 Brandon Hill grit[2]
- D_2 *Lonsdaleia floriformis*
- D_1 *Dibunophyllum*

Upper *Caninia* zone — Subzone δ
- S_2 *Productus cora* mut. S_2
- S_1 *Productus semireticulatus* mut.
- C_2 *Cyathophyllum ø*

Disconformity or erosional unconformity[3]

Lower Avonian or Clevedonian (=Tournaisien approx.)

Lower *Caninia* zone
- C_1 *Syringothyris* aff. *laminosa*
- Subzone γ *Caninia patula*

Zaphrentis zone
- Z_2 *Schizophoria resupinata* or *Zaphrentis konincki*
- Z_1 *Spirifer* aff. *clathratus*
- Subzone β *Zaphrentis delanovei*

Cleistopora zone
- K_2 *Spiriferina octoplicata*
- K_1 *Productus bassus*

Disconformity
Old Red sandstone

---

[1] Vaughan, A.: Quart. Jour. Geol. Soc., London, vol. 61, p. 264 (1905).
[2] Reynolds, S. H.: Rept. Brit. Ass. Adv. Sci., 1926, p. 79.
[3] Dixon, E. E. L.: Quart. Jour. Geol. Soc., London, vol. 67, p. 484 (1911).

Reference may be made to Vaughan and the other British authors for the summary of the evidence bearing on the placement of the division line between the two periods. Vaughan's later views tended to place this line within the subzone δ, but his published facts point rather to the base of δ as the natural dividing line. A study of the faunal lists of the English authors reveals that although there are a number of "holdovers" from the Tournaisien fauna in subzone δ there is a more significant arrival of Visean precursors coupled with a distinct disconformity at the base of δ. Vaughan[1] places the "maximum shallowing" in the southwestern province at the base of δ and at the top of the *Caninia* oolite of C_1; Dixon[2] recognizes a distinct erosional unconformity at that horizon and considers it as the Visean base, so that there is satisfactory evidence for a distinct break.

In the northwestern province of England (Westmoreland and Northumberland), sections of the Visean beds are even better and more complete than those in the Bristol area. Garwood, who worked out the faunal successions in the north, presented conclusions in striking conformity with those of Vaughan so far as concerns the general faunal sequence. The agreement is particularly close for the upper Visean, i.e., for the beds above S_2. *Lithostrotion* enters abundantly at the base of the next lower zone (the *Productus corrugato-hemisphericus* zone) and this zone in other respects likewise corresponds closely with Vaughan's S_2. Garwood correlates his next underlying zone (the *Michelinia* zone) in general with C_2 (i.e., approximately δ) of the southwest province, and it is of interest to note that the *Composita gregaria* subzone occurring at the base of this *Michelinia* zone is marked likewise by distinct diastems. One of these breaks, either that recorded by the Brownber pebble bed or that denoted by the *Ortontella* algal band below, would seem to form the logical division line between the Tournaisien and the Visean, and the major diastem would appear to rise to the full rank of a disconformity, and this is supported by the fact that early Lithostrotions of the type *L. martini* occur somewhat abundantly in the *Michelinia* beds at Tarn Sike near Ravenstonedale, Northumberland, where they are reported by Garwood,[3] and where they have been collected by the writer. Moreover, they are associated there with such characteristic Visean heralds as *Clisiophyllum multiseptatum, Productus corrugato-hemisphericus,* and *Martinia* cf. *ovalis* Phillips. Furthermore, in the district of the Westmoreland Pennines there is a distinct overlap of the *Seminula (Composita) gregaria* subzone onto older rocks[4], indicating that there was in this area a distinct sea transgression not far below the horizon of the *Michelinia* zone, which sea brought with it precursors of the Visean fauna, although there still remained in suitable facies holdovers from the Tournaisien, e.g., *Syringothyris cuspidata.*

---

[1] Vaughan, A.: Quart. Jour. Geol. Soc., London, vol. 71, pp. 1-52.

[2] Dixon, E. E. L.: Quart. Jour. Geol. Soc., London, vol. 67, p. 542 (1911); ibid, vol. 71, p. 50.

[3] Garwood, E. J.: Quart. Jour. Geol. Soc., London, vol. 68, p. 501 (1912).

[4] Garwood, E. J.: Op. cit., p. 535.

BELGIAN SEQUENCE

As the terminology Tournaisien and Visean was established by the palæontological and stratigraphical work of Belgian geologists, it would be well to note briefly the sequence as developed in Belgium. The fossiliferous zones may be tabulated after Délépine[1] as follows:

Visean

Zone with *Productus giganteus*	(3) Black limestones and shales with *Productus longispinus* Sowerby (2) Limestone with *P. giganteus* Martin (1) Brecciated limestones with *P.* cf. *undiferus* de Koninck
Zone with *Productus cora*	(3) Cherty limestones (2) Blue to black limestones with *P. cora* d'Orbigny and *Lithostrotion martini* Edwards and Haime (1) Oolites with *Seminula (Composita) ficoides* Vaughan
Brecciated limestone and dolomite with *Productus* ⊖Vaughan	
Zone with *Productus sublaevis*	(2) Oolites with *Productus sublaevis* de Koninck (1) Encrinoidal limestone with *Chonetes papilionacea* de Koninck

Tournaisien

Zone with *Spirifer cinctus*	(2) Black limestones with *Caninia cylindrica* Scouler and *C. patula* Michelin (1) Encrinoidal limestone with *Spirifer cinctus* de Koninck
Black limestone with *Zaphrentis konincki* Edwards and Haime, *Caninia cornucopiae* Michelin. Entrance of *C. cylindrica* Scouler	
Zone with *Spirifer tornacensis*	(3) Calcareous shale with *Spirifer tornacensis* de Kon. and shales with *Caninia cornucopiae* Michelin. (2) Crinoidal limestone with entrance of *Caninia cornucopiae* Michelin (1) Shales with *Zaphrentis vaughani* Douglas

In general, there is a marked parallelism in the faunal succession to that of the Avonian in England, and the detailed correlations of the various subdivisions are discussed by Vaughan[2] and by Délépine.[3] It will suffice here to consider the division line between the Tournaisien and the Visean. This is placed by Vaughan and Délépine at the base of the *sublaevis* limestones as in the above table. At the same time, Vaughan places the "maximum shallowing" in Belgium at the top of the *sublaevis* limestones, and E. Dixon on this diastrophic evidence would consider the top and not the bottom of the *sublaevis* beds as the upper limit of the Tournaisien. The extensive "Waulsortien" facies developed in the Visean of Belgium, like the similar "knoll-reef" limestones in the Visean of the northern Midlands of England, presents a fauna that is more difficult of comparison with those from the more normal limestones or from the shaly facies, and for this reason the Belgian fauna will not be further considered here.

---

[1] Délépine, G.: Recherches sur le Calcaire Carbonifère de la Belgique, Paris and Lille, 1911, p. 337.

[2] Vaughan, A.: Quart. Jour. Geol. Soc., London, vol. 71, pp. 1–52 (1915).

[3] Délépine, G.: Recherches sur le Calcaire Carbonifère de la Belgique, Paris and Lille, 1911: pp. 349-387.

CORRELATION OF THE WINDSOR SERIES WITH THE VISEAN

The Windsor faunal succession may be tabulated as follows:

Upper Windsor=Upper Visean
- *Martinia* zone
  - Characterized by *Martinia galataea, M. thetis, Composita obligata, Lophophyllum avonensis, Phillipsia eichwaldi*
    - (c) *Caninia dawsoni, Zaphrentis minas*
      Chonetes politus, Tabulipora acadica, Spirifer nox
    - (b) *Productus semicubiculus, Composita obligata*
    - (a) *Nodosinella priscilla, Lophophyllum avonensis, Dibunophyllum lambii, Spirifer adonis*

Lower Windsor=Middle Visean
- *Composita* zone
  - Characterized by *Composita dawsoni, Diodoceras avonensis, Batostomella abrupta, B. exilis, Septopora parva, Diaphragmus tenuicostiformis,* and abundant *Productus* of the type *corrugato-hemisphericus*

The presence in the lower zone of abundant *Composita* associated with *Productus* of the type *corrugato-hemisphericus* Vaughan is in striking conformity with the faunal assemblage in the middle Visean (S_2) of the Avonian sequence.

The *Martinia* zone is characterized by the entrance of *Dibunophyllum* which is represented by an early form of the type of *Dibunophyllum* aff. ψ Vaughan, from Gower, South Wales,[1] as well as by the abundant occurrence of *Martinia* of the *M. glabra* form type. The following species are additional links on which a correlation with the *Dibunophyllum* zone of the Avonian is based:

Zaphrentis minas Dawson. This *Zaphrentis* is distinctly of the type of *Z. enniskilleni* Edwards and Haime, a characteristic Visean species as determined by transverse sections of the corallite. In England the *Z. enniskilleni* group ranges from C_2 to the upper *Dibunophyllum* zone.

Lophophyllum avonensis n.sp. In Europe *Lophophyllum* attains its maximum development in strata of upper Visean age, or in beds immediately succeeding, although it is found sparingly in the upper part of the Tournaisien.[2]

Caninia dawsoni (Lambe). *Caninia* in the type Avonian section attains one maximum in the upper Tournaisien and another in the lower Visean. The former includes both the *cornucopiae* and the *cylindrica* groups, whereas the later expression is a cyathophylloid modification of the *cylindrica* group (*C. patula*). The Windsor *Caninia* departs rather widely from the *C. cylindrica* group, as its septa continue to the outer wall, and the radial symmetry of a cyathophylloid is assumed at an early age. In this respect it agrees with the lower Visean *C. patula* group. Yet it differs from the latter species by converging towards a *Campophyllum,* in this respect agreeing with *Caninia gelaueri* Stuckenberg and *Caninia juddi* (Thompson). It might readily be classed as a *Campophyllum* from an

[1] Dixon, E. E. L.: Quart. Jour. Geol. Soc., London, vol. 67, Pl. XL, fig. 7 left (1911).
[2] Carruthers, R. G.: Trans. Roy. Soc. Edinburgh, vol. 47, pt. 1, p. 148 (1909).

ephebic cross-section, but neanic sections indicate quite clearly a *cornucopiae* arrangement of septa. *Caninia* cf. *subibicina* Wilmore is another upper Visean species that approaches closely the Windsor species.[1]

Tabulipora acadica n.sp. is a trepostomatous bryozoan that is very abundant near the base of the Kennetcook limestone. It is characterized by the thinness of the zooecial walls which nevertheless show a distinct moniliform structure. This tenuity of the peripheral end of the walls is a character common to *T. tenuimuralis* Lee from D_2 Lowick (Eelwell limestone) and to *T. maendria* Lee from the upper limestones of Tyrone island at a similar horizon.

Buxtonia cogmagunensis n.sp. This species is very close to *B. scabriculus* (Martin) which is characteristic of the upper Visean.

Pustula exigua n.sp. differs from *P. biseriatus* (Hall) in its smaller size and sharply differentiated auriculations. It is seemingly close to *P. elegans* (McCoy), which is rather a long-ranging type, but is rare before the upper Visean.

Productus (Avonia) spinocardinata sp. may be equivalent to *Productus sulcatus* Sowerby, but is smaller in size and bears many resemblances to *P. longispinus* Sowerby. Both the English species are upper Visean forms.

Chonetes politus M'Coy, the only *Chonetes* yet gathered from the Windsor beds, is identical in all respects with M'Coy's species, which comes from the base of the Lower Limestone series of Scotland and close to the horizon of the Scabricula limestone (D_2?).

Spirifer nox n.sp. is almost indistinguishable from *S. bisulcata* var. *oystermouthensis* Vaughan from D_2-D_3 Gower. The *bisculatus* form of *Spirifer* occurs rarely in the Middle Avonian, but has its maximum in the upper Visean.

Martinia galataea n.sp. This species lacks dental plates and has the shell structure of a true *Martinia*. *Spirifer glabra* has been shown by Buckman to be a polygenetic genus. In Davidson's "Monograph of Carboniferous Brachiopoda," figure 2 of Plate XI is given as a typical *M. glabra*, and this is a much larger as well as a more transverse form than the Nova Scotian one, and its fold is indented by a mesial sulcus.

Phillipsia eichwaldi Fischer. This species, formerly called *P. howi* Billings, has been correlated by Vogdes with *P. meramecensis* Shumard on the evidence of pygidia only. Several cranidia found in close association by the writer, one of which is still attached in a crushed rolled specimen, do not show any important differences from *P. eichwaldi* Fischer, which occurs in the Lower and Upper limestones of Scotland and at Bolland, Yorkshire.

Sanguinolites hartti (Dawson) is perhaps synonymous with *S. plicatus* Portlock from the Redesdale limestone, Northumberland (D_1).

Sanguinolites striatogranulatus is another Redesdale species that occurs at Windsor.

---

[1] Quart. Jour. Geol. Soc., London, vol. 66, Pl. XXXIX, fig. 3 (1910).

CORRELATION WITH THE AMERICAN TENNESSEEAN

The dissimilarity of the Windsor faunas to the faunas of like age in the Mississippian basin of America was early noted by Dawson, and subsequently confirmed by Schuchert and Beede. Dawson, moreover, clearly perceived the European affinity of the species and attributed their isolation from the western faunas to the existence of an Appalachian mountain barrier.

The difficulties of correlating a fauna which is dominantly a molluscan one are well exemplified by the fact that Beede, who described faunas of this age from Magdalen islands, was impressed with the Devonian or early Mississippian aspect of some of the pelecypods, whereas earlier palæontologists emphasized the Permian appearance of the fauna. There are, as indicated above, many species closely allied to, or even identical with, Visean species of western Europe, a fact that did not escape de Koninck. In the present correlation, reliance is placed rather on the occurrence of several brachiopods and bryozoans that either hold a limited range in, or make a definite entry into, Mississippi Valley basin.

As the lower zone comprising the Maxner and Miller limestones presents the greater difficulty, the upper zone is considered first. Here several species belonging to *Martinia, Composita,* and *Productus* present evidence of an age synchronous with some part of the Chester group.

Martinia galataea n.sp. is a form closely allied to *M. contracta* (Meek and Worthen), which is unknown below the Chester group in the Mississippi region. *Composita obligata* n.sp. is so close to *C. subquadrata* (Hall), a characteristic Chester species, that it may well be specifically identical. *Productus (Avonia) spinocardinata* n. sp. belongs to the species group of *P. parvus* (Meek and Worthen) from the Ste. Genevieve and Chester groups. There is consequently direct evidence of Chester affinities. Indirectly, the same conclusion is reached, as the fauna of the upper zone at Windsor correlates with that of *Dibunophyllum* age in the European time-scale. There is no doubt that the *Dibunophyllum* zone represents the Chester group in large part, but many difficulties prevent exact delimitations.

The lower fauna at Windsor, while it likewise indicates Chesterian affinities, is seemingly an earlier expression and may be in part equivalent to the Ste. Genevieve. The connexions with the Mississippian seas, to judge from the brachiopods, would seem to be even more remote. The Compositas, which are extraordinarily abundant in individual representation, belong mainly to two species of North Atlantic stock, and although the productids of the *cora* and *semireticulatus* types are too plastic for correlation purposes, they likewise are practically identical with European species. The occurrence in the fauna of a true *Diaphragmus* is suggestive, as this genus makes its first appearance in the Mississippi basin in the Ste. Genevieve. *D. elegans* (Norwood and Pratten) of Chester time in its coarse costation, which sometimes tends towards fasciculation, and in its proportionately wider diaphragm, is seemingly in a more advanced stage of evolution than the finely costate *D. tenuicostiformis* (Beede). *D. montesanae* Ulrich, however, from the Ste. Genevieve, is very close to the Windsor species. Although it is possible that *Diaphragmus* characters may have been assumed through different lines of descent, it represents a structural form that is apparently of considerable time value, as *Diaphragmus* is immediately followed in the Pennsylvanian and Permian by *Marginifera*.

The bryozoans, which are sparingly represented in the lower fauna, afford some additional evidence, and certain species show a remarkably close affinity with Chesterian forms. Thus, *Batostomella exilis* (Dawson) and *B. abrupta* Ulrich are two species, associated in abundance in the Miller limestone, that are almost indistinguishable in their external and internal characters from *B. spinulosa* Ulrich and *B. abrupta* Ulrich, respectively. Moreover, the fenestellid of most common occurrence, *Fenestella lyelli* Dawson, reveals close analogies with *F. elevatipora* Ulrich, whereas *Septopora primitiva* n.sp. is an acanthocladid that has the small delicate zoarium of *S. delicatula* Ulrich, associated with a like arrangement of accessory pores on the reverse surface. The remaining forms are less certain in their affinities, but *Polypora schucherti* n.sp. indicates relations with *F. limitaris* Ulrich, or even more closely with *Polypora biseriata* Ulrich. The direct evidence, therefore, offers some difficulty, but it is concluded that the Chesterian affinities are too strong to assign this fauna to as low a position as the St. Louis, although it may be partly equivalent tc the Ste. Genevieve. The retention in the fauna of gasteropods of St. Louis aspect, e.g., *Diaphorostoma* cf. *carleyana* Hall, and of *Euomphalus exortivus?* Dawson, *Holopea* cf. *proutana* Hall, etc., likewise suggests a low Chesterian age. Indirectly, the correlation with the European upper *Seminula (Composita)* zone would assign it to such a position.

CLIMATIC CORRELATION

Barrell[1] in a paper on the "Origin and Significance of the Mauch Chunk Shale," presented evidence to show that these shales were continental deposits laid down under conditions of semiaridity. At the top of the series there is a transition to Pottsville conditions coincident with an increase of rainfall and probably with a cooler climate. Supplementary evidence of aridity at approximately this time is seen in the gypsum and anhydrite deposits of the Michigan series in Michigan. The Waverlyan, on the other hand, except possibly during Burlington time, indicates less extreme climatic conditions, so that in a general way the semiaridity that characterized the Acadian region in Tennessean time is correlated with similar dry climates elsewhere in a geographic belt not departing widely from it in latitude.

[1] Barrell, J.: Bull. Geol. Soc. Am., vol. 18, pp. 449–476 (1907).

CHAPTER V

HISTORICAL GEOLOGY

PRECAMBRIAN ERA

The tremendous thickness of late Precambrian clastic rocks is an indicator of a nearby mountainous topography. The geosynclinal nature of the area of deposition makes it quite clear that the major tectonic axes and geosynclinal troughs of this part of the Appalachian province were established at least as early as late Precambrian time. The border of the Atlantic was then far to the east of its present position, and an extensive land-mass of ancient rock occupied the present position of the continental shelf. Rocks most nearly akin to those that were laid down in Nova Scotia at this time are found in southeastern Newfoundland. They are there, according to Buddington,[1] underlain by a thick series of volcanics and are mainly the stratified debris of those more ancient rocks. Moreover, there was extensive igneous activity with batholithic injections in Newfoundland in early late Precambrian time, and Precambrian intrusions of about the same age occur in Maryland and Virginia.[2] Thus the external evidence, as well as the internal evidence of the 28,000 feet of sediments, suggests a mountain-making period prior to the deposition of the Meguma series, and a topography of mature relief bordering the basin of sedimentation. The evidence is not altogether conclusive of a sea advance along the geosyncline in Nova Scotia, as it is quite possible that the Meguma series is in whole or in part of continental origin. Assuming a marine origin, there is no organic evidence to indicate any particular climatic control. Assuming a terrestrial origin, the high carbon content, feldspathic nature of the quartzites, and striking uniformity of the sediments would seem to favour equable humid conditions.

EARLY PALÆOZOIC TIME

Following the deposition of the thick Meguma series there was uplift, followed long afterwards in Cambrian time by differential warping which introduced or redefined the geosynclinal conditions. This basin of subsidence and deposition was established farther to the northwestward than the older trough with the Meguma series. From henceforth the geosynclinal trough that was now definitely outlined and which may appropriately be called the Cobequid geosyncline was the primal seat of deposition in the Acadian area. How nearly its former southern margin coincided with the present northern margin of the Precambrian belt of rocks is

[1] Buddington, A. F.: Jour. Geol., vol. 27, pp. 456–466 (1919).
[2] Keith, A.: Am. Geol., vol. 10, pp. 362–368 (1892).

unknown, but it was probably some distance to the south, as this Precambrian old land has been compressed and shoved towards the Laurentian continent, with a consequent narrowing of the Cobequid trough. Moreover, there has been extensive erosion, as the Silurian and Devonian strata, where they are exposed along the border region, are steeply inclined and truncated by the Carboniferous sediments.

So far as Windsor district is concerned, there is no direct evidence of marine deposition in early Palæozoic time. At the same time, a part at least of the Cobequid trough was subject to several marine invasions. The record is much broken and is not everywhere unravelled, but Middle and Upper Cambrian time are represented in St. John area, New Brunswick, and in Cape Breton island; Canadian (Lower Ordovician) time is represented likewise in St. John area, and strata of similar age are present in the Arisaig-Antigonish area and elsewhere. The contained faunas of most of these strata are directly related to the North Atlantic province, with nearest affinities in England and Wales. In early Palæozoic time, therefore, there were long, narrow seaways occupying part of Fundy region in direct connexion with the North Atlantic ocean.

In Arisaig district there was orogenic and igneous activity in the Ordovician, perhaps to be correlated directly with the Taconic disturbance of late Ordovician time, but to what extent this affected the attitude or the metamorphism of the Meguma series is not known. As the Ordovician strata of Arisaig district are much more highly deformed than Silurian strata of the same district it seems unlikely that the older Meguma series escaped the forces of metamorphism.

SILURIAN PERIOD

The representation in Windsor district of the Silurian, though meagre, is yet sufficient, by reason of the presence of *Dictyonema websteri* Hall, to indicate transgression by a shallow, muddy sea. The neighbouring New Canaan deposits supplement this evidence by furnishing several Niagaran corals that suggest connexions with the Appalachian trough of the United States. Similarly, the Silurian section at Arisaig indicates a shallow, muddy sea in communication with the North Atlantic.

THE ACADIAN OR SHICKSHOCKIAN MID-DEVONIAN DISTURBANCE

In Helderbergian and Oriskanian times there was another invasian of the Cobequid trough from the ocean. No rocks of this age are exposed in Windsor district, but some miles to the westward in Annapolis county, fossiliferous slates and quartzites occur whose faunas are allied to those of the Appalachian trough. No later Devonian strata are known here, though such are present in Gaspe area far to the north. Following their deposition came the greatest Palæozoic orogenic disturbance of this region. The rocks locally were strongly folded, the shales were metamorphosed to slates, and a regional flow cleavage was developed in Windsor district along planes dipping at a high angle to the south. Accompanying these movements as a late phase, or posterior to their completion, there were batholithic intrusions of granite. At least two distinct stages have been recognized, a primary intrusion of a coarse, commonly porphyritic, biotite granodiorite, succeeded by a more local intrusion of finer grained muscovite granite. It would seem necessary to postulate a moderately thick sedimentary cover at the time of intrusion. The presence of a regional flow cleavage in the country rock that was developed in all probability not long prior to the intrusion itself, since it affects Oriskany strata, a clear truncation of the folds of the country rock, the coarse texture of the biotite granite, the lack of evidence for marginal faulting in conformity with the outlines of the intrusive body, all favour a thick rock cover. On the other hand, the rapid base-levelling that followed suggests that this cover may not have exceeded several thousand feet. The intrusion of the granites may have begun as early as Middle Devonian time or even previously as the deposition of the Gaspe sandstone and conglomerates far to the north began as early as the Hamilton if not earlier. The denudation that followed may, therefore, have commenced locally in Middle Devonian time, and continued actively throughout the later Devonian, resulting in the exposure of large areas of granite prior to the deposition of Horton sediments. At any rate, the character of the Horton contact and of basal Horton sediments indicates a mature surface of only moderate relief in early Mississippian time.

The great pile of waste resulting from pronounced denudation of the Devonian folded ranges in late Devonian times is now nowhere visible in Windsor area, though about Gaspe there are 7,000 feet of late Devonian sandstones. Great deltas were probably built up at the mouths of the rivers, and one of these deltas formed far to the north.

MISSISSIPPIAN TIME

In early Mississippian time, new differential movements affected the old Acadian land or massif and once more initiated sedimentation in the Cobequid geosyncline, but now it is of a continental nature and the product seemingly of a moist and cool climate.

Minas basin became part of a wide flood-plain of a river system that flowed northeasterly along the foot of the denuded Devonian highlands. At first the climate was seemingly cool and pluvial, and this flood-plain was recurrently clothed with small *Lepidodendra* and fern-like trees. In Cheverie time (= middle Mississippian) there was a change to warmer conditions, accompanied by a seasonal concentration of the rainfall which brought about a state of semiaridity. This climatic evolution was likewise accompanied or preceded by accentuated or accelerated positive movements of the uplands and the Cobequid upwarp within the geosynclinal basin was probably initiated. For a time, erosion of the positive areas and deposition in the adjacent and intervening negative ones exceeded the differential subsidence of the latter. The end result, however, was a decline in the ability of the alluvium to keep pace with the relative downsinking of the

Cobequid trough, and there resulted, in later Mississippian time (=Chesterian), an invasion of the North Atlantic sea in the form of a long arm or gulf that in its maximum extension covered a great part of the present gulf of St. Lawrence south of Anticosti and of the Maritime Provinces east of St. John. The close affinity of the Windsor faunas with those of northern England and Scotland indicate sea connexions by way of the North Atlantic. This sea transgression was accompanied by conditions of still greater aridity, and the sedimentary evidence is here as striking as it is in eastern Pennsylvania or in Michigan. There is no reason to believe that this arm of the sea was ever wholly isolated as an inland basin, nevertheless communication at times was so restricted as to bring about periodic increases of salinity of an intensity intolerable to animal life and favourable to the deposition of extensive deposits of calcium sulphate. Such a condition had most probably been brought about by balanced equilibrium between evaporation, and differential subsidence under the control of rhythmic climatic oscillation. The detailed sequence of the Windsor deposits over many parts of the province is still so obscure that the present evidence is insufficient to determine the location of the strait connecting the Windsor seas with the North Atlantic ocean. The sea either had an extension across central Newfoundland with an inlet farther to the northeast, or the connexion with the Atlantic lay between Cape Breton and a landmass in eastern Newfoundland. Structural trends as well as faunal evidence appear to favour the former. Towards the close of Windsor time there was seemingly either freer communication between the outside ocean and Windsor district or climatic control was less severe as the upper Windsor limestones have a more normally marine facies. North of the Cobequid axis, however, there was a withdrawal of the sea in upper Windsor sea and sedimentation in the Cumberland trough between the Cobequid axis of Nova Scotia and the Caledonian axis of New Brunswick was mainly continental.

Following the deposition of the Windsor series there was regional uplift accomplished seemingly by differential warping and without appreciable folding, and resulting in the complete withdrawal of the sea from the Cobequid sub-troughs. The sea so far as we know at present did not again enter the Maritime Provinces until post-glacial time when a downward tilting submerged the outlying portions of Acadia and permitted the Atlantic waters to flood the lower valley lands.

PENNSYLVANIAN AND PERMIAN TIMES

In early Pennsylvanian time (early Pottsville) the Cobequid positive area was again the locus of an accelerated upward movement as well as subsequently in two stages of Upper Pottsville time.

In Windsor district, however, all traces of sediments of Pennsylvanian age have been lost, with the possible exception of a few feet of soft, flat-lying sandstones in Kennetcook valley at Centre Burlington. As the Minas basin elsewhere received thick continental deposits of Westphalian age, including formations of both the Riversdale and Cumberland series of Pottsville age, their almost total absence at Windsor may be ascribed to later denudation.

In late Pennsylvanian or early Permian times the whole region was broadly uplifted and gently folded with the cessation of sedimentation in subsiding basins and the initiation of regional subaerial denudation. This movement was an extension of that which affected the whole of the Appalachian region of America, but orogenic forces were here very subordinate, and only gentle, open folding resulted. The dominant effect was epeirogenic in nature. From this raised mass there would soon be established, by normal erosional processes, a topography of moderate relief, our last glimpse of the Palæozoic land.

MESOZOIC ERA

By Middle Triassic time the land was once more subdued almost to a peneplain, at least on the softer rocks of the Carboniferous. Gentle warping movements at this time again rejuvenated a part of the old Cobequid geosyncline, and the consequent upraising of the bordering positive masses of crystalline rock subjected them to active erosion. These movements had been followed by a climatic return to semiaridity, with a resulting rapid deposition of terrestrial detritus on the river plains of Minas basin. At this time, also, there was great volcanic activity, giving rise to a succession of basic lava flows of the fissure type over the flat plain. Possibly some block tilting and faulting took place at the close of the Triassic as in New England, and the geosyncline became once more a region of erosion.

The remainder of Mesozoic history is undecipherable in this region. No post-Triassic deposits having been found, it is possible that the whole region stood for long epochs above sea-level. There is no reason, however, to think that the area may not have been submerged once or several times beneath Mesozoic or Tertiary seas and that the absence of sediments may not be the result of later stripping. From events in the Appalachian region to the south during this long era, it is known that there was erosion or subsidence of the older Appalachian land east of the Appalachian trough, with the subsequent establishment of a continental shelf upon which Cretaceous and Tertiary sediments were deposited. Whether the Atlantic shelf-sea of the Cretaceous ever submerged the Acadian province as it did the eastern Appalachian belt is, therefore, possible, although as yet unproved.

TERTIARY AND QUATERNARY ERAS

Tertiary history as read in the eastern coastal region of the United States consists in oscillatory movements of the Atlantic strand-line, with the formation of coastal piedmont terraces. Nova Scotia probably underwent a similar experience, but its history is yet to be gathered. The end result was the establishment of the major elements of the present topography, over which advanced a lobe of the great continental ice-sheet that scraped off the residual soils and in its retreat left the residue as a heterogeneous cover of drift. The drainage system was disorganized, but major pre-Glacial river systems, e.g., that occupying Minas channel, persisted. In a late stage of the Glacial epoch, a submergence of 200 feet or more flooded the lowlands, and pronounced submergence of the whole of the coastal belt took place in post-Glacial times according to D. W. Johnston, which gave rise to the present estuaries and ria coast.

CHAPTER VI

SALINE DEPOSITION

INTRODUCTION

Windsor district for more than a century has been the centre of the gypsum industry in Nova Scotia. In 1926 the gypsum production of the whole province was 607,116 tons, of which the four operating companies in Windsor district alone provided 527,780 tons or 87 per cent. Descriptions of the quarries, accompanied by remarks on the technology and other features of the gypsum industry, have already been dealt with in reports by W. F. Jennison[1] and L. H. Cole[2]. The present chapter will deal briefly with some geological aspects of the gypsum occurrences with particular reference to the origin of the sulphate deposits. To the gypsum industry this phase of the subject may seem to have only academic interest, but the subject is of critical importance to the prospector in search for salt within the Windsor series. Since the discovery of rock salt at Malagash in 1917 there has been much speculation as to the occurrence of salt elsewhere and as to the probabilities of potash deposits somewhere within the same series of beds. By reason of the extreme solubility of these alkaline salines prospecting must be done by drilling and in the choice of drill locations as full a knowledge as possible of the depositional history of all sediments of the Windsor series, particularly of the sulphates and known rock salt, is of paramount importance.

FACTS AND HYPOTHESES OF CALCIUM SULPHATE DEPOSITION

From the standpoint of known methods of origin, existing deposits of calcium sulphate (either gypsum or anhydrite) may be classified as follows:

Class (A) Due to the evaporation of sea water.

Subclass (*a*) In marginal salt pans—shallow depressions along a sea margin into which the sea water finds intermittent entry by overwash at high tide, during storms, or during seasonal inshore winds.

Subclass (*b*) In marine salinas. A salina is a marginal depression, at or near a seashore, superficially cut off from the sea by a bar or other barrier that is nevertheless pervious in whole or in part to the seawater.

---

[1] Jennison, W. F.: Mines Branch, Dept. of Mines, Canada, "Report on the Gypsum Deposits of the Maritime Provinces," Pub. 84 (1911).

[2] Cole, L. H.: Mines Branch, Dept. of Mines, Canada, "Gypsum in Canada, Its Occurrence, Exploitation, and Technology," Pub. 245 (1915).

Subclass (*c*) In sea lagoons. Lagoons differ from salt pans in greater depth, and connexion with the open sea is not rapidly intermittent, but is continuous over or through a bar or barrier for long intervals of time.

Subclass (*d*) In relict seas—inland depressions with sea water completely severed from the parent body (Partake of qualities of both (A) and (B).

Subclass (*e*) Accumulation of cyclic salts, i.e. of salts carried inland from the sea by winds. (Partake of qualities of both (A) and (B)).

Class (B) Continental concentrations of disseminated gypsum.
Subclass (*a*) In inland lakes.
Subclass (*b*) In river valleys.
Subclass (*c*) As surface efflorescences.
Subclass (*d*) In spring deposits.
Subclass (*e*) As dunes or wind blown deposits.

Class (C) Vein deposits.

Class (D) Products of alteration or replacement.

We shall consider the sulphate deposits of Nova Scotia in relation to each of the above classes in the reverse order in an endeavour to ascertain the most probable mode or modes of origin.

It has long been known that solutions, relatively rare in nature, that carry free sulphuric acid, react upon limestone or upon lime carbonate in other rocks to form gypsum. Natural waters, for instance, carrying sulphuretted hydrogen, derived from the oxidation of pyrites or otherwise, under oxidizing conditions attack lime carbonate with the resulting formation of gypsum. Crystals of selenite up to several inches in length are forming today at cape Linzee near Port Hood, Cape Breton island, as a result of the action of droppings of sea birds upon a ledge capped by soft, pyritous, dark shale. The selenite lies on the surface of the shale or immediately beneath the surface in the form of elongate tabular prisms that are scattered or arranged rudely in rosettes about initial centres of crystallization. Gypsum may be similarly formed under oxidizing conditions by reaction between ferrous sulphate solutions and limestone. Both Sir Charles Lyell[1] and later Sir William Dawson[2] held that the major proportion of the gypsum of Nova Scotia was an alteration product of lime carbonate deposits on the sea bottom produced by the action of acid sulphurous waters poured into the Windsor sea by springs or streams that had their source in nearby volcanoes. There are several features of the sulphate deposits that make this alteration hypothesis untenable, e.g.: (1) the widespread occurrence both laterally and vertically of thick gypsum and anhydrite beds; (2) the general absence or rarity of contemporaneous vulcanism in most of the gypsum districts; (3) the absence or rarity of transition deposits of limestone and calcium sulphate with undoubted replacement phenomena; (4) the evidence in favour of original widespread anhydrite rather than gypsum deposition. As regards (1) the very amount of alteration necessary renders the hypothesis incredible. No reasonable source for such sulphuretted or sulphurous waters at all adequate for the purpose can be invoked. Thus the evidence of volcanic activity in Windsor times as stated in (2) is in

[1] "Travels in North America," vol. 2, p. 180 (1845).
[2] Dawson, J. W.: Acad. Geol., 3rd edition, pp. 262, 394.

most districts negligible and rests at the present time almost wholly on evidence derived from the occurrence of small amounts of volcanic ash or its altered product bentonite associated with sulphate or salt beds, as well as from continental deposits supposedly of Upper Windsor age that lie north of the Cobequid massif where the relative proportion of volcanic material is likewise slight. It is true, however, that argillite of Upper Windsor age has been detected at one locality in the Cobequid massif and that marble, possibly of Windsor age, occurs in the same district. The metamorphism of the argillite is inferred to be the result of associated acidic and basic volcanics, which may be of Upper Windsor age or younger. In the latter district there are no sulphate deposits in the neighbourhood of the altered Windsor sediments. As regards (3) certain intimate admixtures of limestone and gypsum are not uncommon in Nova Scotia. There are three or four major types. In one the limestone occurs in thin, recognizable beds or laminæ. Such bands are commonly oolitic and fossiliferous and the fossils generally form restricted assemblages of immature individuals or of small species including ostracoda, foraminifera, gasteropods, pelecypods, small Productids, etc. Such fossiliferous bands lend no support to the hypothesis of replacement. A second type of lime deposit, common in some gypsum masses, comprises irregular lenticular patches or stringers, commonly oolitic, occasionally fossiliferous, but more frequently not so. These more strongly simulate residual masses of unaltered limestone, but they are explained more plausibly by original deposition in lenticular beds some of which have been brecciated, deformed, and misplaced by pressure exerted by the more plastic gypsum during folding or by hydration of anhydrite. Still a third type of admixture has been noted where a limestone bed in contact above gypsum has been impregnated and intruded by gypsum, or carries a large amount of vein selenite and fibrous gypsum. It is quite possible that in certain admixtures of this type there has been some replacement of limestone by secondary gypsum, as in certain instances little remains of the original limestone but that composing the shells of fossils. Lastly there are certain dolomitic layers in close association with gypsum members that are highly pitted by what seem to be solution cavities and it does not seem improbable that the original filling matter was a soluble salt, e.g. sodium chloride. Although the form and extent of the sulphate members themselves have not been individually recognized a comparison of sections of Windsor strata at various districts leads only to the conclusion that the sulphate beds are lenticular masses in a well-defined marine series. Irregular masses of sulphate projecting unevenly into limestone beds and marked by oblique or vertical limestone contacts suggesting replacement are wholly absent.

The remaining factor (4) that mitigates against the alteration hypothesis is the widespread distribution of anyhydrite at depth, so that the gypsum quarries are floored in most instances by "hard plaster." This occurrence strongly suggests that the gypsum in large part is an hydrated product of anhydrite and there is little reason to believe that this anhydrite may not have been originally deposited as such.

In summation, therefore, the limestone alteration hypothesis for the origin of the great bulk of Nova Scotian gypsum and anhydrite must be discarded as inadequate and contrary to the facts.

Vein deposits of gypsum are quite common in the Windsor series in Nova Scotia, but they are of very minor importance and as they are quite obviously in most instances secondary deposits related to solutions that derived their gypsum from the main bodies they need not be considered further. Selenite and fibrous gypsum are the dominant forms assumed by the gypsum in the veins, some of which run parallel to bedding planes, others cutting across red shale members to form an open network.

In considering now segregations of disseminated gypsum under continental conditions as a possible genetic factor in sulphate deposition in the Windsor series we have only to scan the sections in which the anhydrite or gypsum occurs as interbedded deposits to realize the difficulty of providing a favourable environment for such action. Every such section has a frequent recurrence of marine, and for the most part fossiliferous, limestone bands. The red shale members, however, are practically unfossiliferous and whether they are all marine or in part of continental origin cannot always be stated. Moreover, some gypsum members have red shale bounding them on one, if not on both, walls. There is no physiographic difficulty in postulating intermittent continental basins within what was generally a well-defined marine basin, as a study of the Windsor sea from a physiographic viewpoint reveals that it was shallow, was oscillatory, and that conditions of crustal instability prevailed. If any subsidiary basins of a continental character did form, gypsum might accumulate in their water-filled depressions as a result of concentration of wind-borne material or of solutions carried therein by streams working over gypsiferous sediments of the former sea bottom. If the rainfall were sufficient to establish an organized drainage system, sediment would be actively contributed initially to the lake basin during the period that the lake water was becoming saturated with gypsum. The lake water may originally have been a remnant cut off from the sea, in which instance the lake would properly fall in the category of relict seas. This indeed would seem to be normally the case, as otherwise the hypothesis would involve conditions following retreat of the sea that would permit of a drainage system organized with respect to an entirely new depression rather than to the sea strand line. The hypothesis of the formation of such marginal basins cut off from the sea into which disseminated gypsum found access seems to be readily applicable to certain of the Nova Scotian sulphate deposits that rest upon red shale. It will be assumed, however, that they were of the type of relict seas rather than purely continental lacustrine bodies. It is evident that the history of formation such as outlined above for a relict sea on an emerged part of the Windsor sea bottom provides for muds highly gypsiferous in their character if evaporation deposits had previously begun to form in the parent sea, and that the subsequent concentration of the calcium sulphate parallels conditions existing for an inland lake belonging to type (B).

When we consider the other types of continental sulphate deposits it is difficult to provide satisfactory hypotheses. The only method of concentration sufficiently widespread would be by wind action and there is no evidence yet to hand of appreciable wind-borne material in the Windsor strata. The sandy beds lack highly polished and highly rounded sand grains. On the contrary angular and subangular material is not lacking, and translatory rippling of ordinary subaqueous character is common. Large accumulations of cyclic salts by wind action or otherwise are exceptional at the present time and probably have always been so. Moreover, arguments that apply against the presence of wind-blown saline dust are applicable also against wind accumulations of cyclic salt.

There remains in explanation of the Windsor sulphate and saline deposits a source that is the most obvious one and at the same time fully adequate, viz.: the sea water of the Windsor sea. Prior to the initial transgression of the sea the climate was already semi-arid, as attested by Upper Horton sediments. Continental deposits, believed to be of Windsor age, occurring in Cumberland county north of the Cobequid massif and in southern New Brunswick, likewise attest conditions of semi-aridity. The argillaceous sediments of the Windsor are practically, without exception, red in colour. The recurrent presence of oolites, algal limestones, and of rippled limestone surfaces all testify to shallow waters at corresponding stages of the sea. The environment, therefore, is decidedly favourable for saline deposits resulting from the evaporation of sea water and unfavourable for the presence of other types of deposit, with the single exception of those forming in abandoned depressions on an emerged platform during stages of sea withdrawal. One of the chief requirements for saline deposits resulting from evaporation of sea water is the nearby presence in the same region of contemporaneous marine, non-saline sediments. This requirement is fulfilled. Another requirement frequently advocated is the presence of fossils directly below the sulphate beds. Fossiliferous limestone occurs commonly in this position in the Windsor sections. A third necessity advanced is the presence of calcium carbonate within the sulphate beds in amounts (0·5 per cent +) sufficient to fulfil the requirements of equilibrium. How the Windsor deposits meet this test cannot be stated owing to the absence of sufficient complete analyses. Otherwise sufficient calcium carbonate is present at the base of many sulphate deposits to meet the general requirement of prior carbonate deposition. This latter is of general and not of particular application as it is known that calcium carbonate deposition may be segregated in favoured localities, e.g. at the mouth of streams or at exposed parts of the coast. It is scarcely necessary, therefore, to rule against a direct evaporation from sea water hypothesis for sulphate deposits that rest upon red shale or to build up for them a special environment of relict seas where continental conditions modify the inherited composition of the sea water.

But in spite of the obvious assignment of the Windsor saline deposits to Class (A) when we attempt to assign them to any one of the respective subclasses, viz.: marginal salt pans, marine salinas, sea lagoons, relict seas, difficulties immediately are encountered and until further field data have accumulated it is expedient to consider that each deposit must be evaluated on its own merits as it is probable that more than one type of saline basin existed. The facts, however, all point to the Windsor sea waters as the original source, and any hypotheses must be tied to this one generalization.

The difficulty in an unqualified application of the hypothesis of Ochsenius—viz.: of influxes of sea water over a bar or barrier in sufficient measure to compensate for evaporation in the marginal basin behind the bar—lies in the limiting depths of such basins required to accommodate the sodium chloride in solution. According to Usiglio's experiments 84 per cent of the total amount of gypsum present in sea water is thrown down upon evaporation as a deposit uncontaminated with sodium chloride. As the specific gravity of gypsum is 2·32 and as the Mediterranean water used by Usiglio contained 1·76 grams of gypsum per litre of solution, a layer approximately 0·6 foot thick of gypsum would result from the evaporation of 1,000 feet of water, assuming the precipitate deposited evenly over the bottom. The basin, of course, needs no such depth according to Ochsenius's hypothesis which provides for continuous accessions of sea water. But the depth of a basin in which the equivalent of a 1,000-foot column of sea water is partly evaporated at the stage where the last pure gypsum is deposited, must be 112 feet in order to retain the sodium chloride in solution, the volume of the solution at this stage of evaporation being 11·2 per cent of the original volume. If, therefore, a 0·6-foot bed of gypsum calls for a limiting depth of 112 feet to retain the sodium chloride in solution a 50-foot bed would require a depth of 5,600 feet and to postulate such a depth is absurd. Branson's hypothesis of marginal pans overflowing into inner depressions may serve as one possible explanation for certain rock salt occurrences free of gypsum or anhydrite, but does not materially aid in explanation of the salt-free, thick sulphate deposits of Nova Scotia, as an amount of rainfall sufficient to flush out the salt solutions from the marginal gypsum-depositing depressions would scarcely permit of gypsum deposition uncontaminated with large quantities of mud and sediment. A reasonable hypothesis must provide for the disposal of the sodium chloride in shallow basins and at the same time provide for the accumulation in them over tens of square miles at least of calcium sulphate members from 50 feet upwards in thickness. To do this more field facts must be sought. An unknown factor, for instance, at the present time, is the extent to which the present form of the deposits is a modification of the original form. The Windsor series has been subjected to much folding at successive epochs and the seeming thickness of the sulphate beds may be due in some measure to folding and doming. Secondary hydration of anhydrite may be responsible for much disturbance of the gypsum beds and of the sediments adjacent, which renders the interpretation of the structural evidence complex. Again, information regarding the possibility of segregation of sulphate deposition on the floor of depressions in which precipitation is effected is practically nil. In this connexion saline deposits of lake Assal in French Somaliland, described by M. Dégoutin,[1] are of interest. Lake Assal is a marine salina fed by salt springs that percolate from the Red sea through a barrier of basalts and volcanic tuffs. Winter temperatures of 25 degrees to 35 degrees C. prevail and summer temperatures reach 45 degrees C. or more. The spring waters, with density about that of sea water (2 degrees to 3·5 degrees Baumé),

[1] Annales des Mines, Mémoires T. 2, 12th ser., Paris, pp. 5-54 (1922).

enter at water-level and their total flow is measurable approximately by the evaporation from the lake surface. The latter is rectangular, about 10 km. by 12 km. The lake is surrounded by a ring of gypsum 5 to 12 metres in height and 50 to 500 metres wide. The lake-level is 150 metres to 160 metres below sea-level. The eastern half of the lake is open water, with greatest depth of 40 metres, the western half is a sodium chloride deposit with surface at level of lake. The density of the water in the eastern half is 1·22 or 25 degrees Baumé, which is approximately that reached by Usiglio's solutions when precipitation of sodium chloride begins. Dégoutin describes the gypsum deposit as follows: "La masse blanche dépossée autour des bords du lac est composée de couches alternates de gypse pur en cristaux aplatis (forme de fer de lance) serrés les uns contre les autres, de gypses pulvérulent mêlé d'un peu de calcaire, et de lits minces de calcaire dur, le tout très blanc ou à peine teinté de jaune." There occur also raised mounds or vaults of gypsum commonly partly sunken or with voids beneath, which are interpreted as a result of hydration of anhydrite and formation of more soluble amorphous gypsum. The temperature of the water at lake Assal was found to be 20 degrees C., and at shallow depths probably above 25 degrees C., particularly when wind is low and evaporation less. At the bottom of the lake, at least around its borders, are crystals of gypsum, some small and transparent, others very large and reddened with iron oxide. Reasoning on lines of limiting depth necessary to hold water saturated with respect to sodium chloride, and assuming a basin with vertical sides, a depth of 40 metres would result from a column of sea water, $\frac{40}{0\cdot112} = 357$ metres thick, which would be capable of supplying a layer of gypsum 357 by $0\cdot0006 = 0\cdot2$ metre thick. As, however, three-fourths of the original water is evaporated before the beginning of gypsum precipitation, and assuming a basin with gentle littoral slopes, a restricted inner basin might catch all the gypsum and be assumed to have only one-fourth the volume of the original basin. In that instance a uniform layer of gypsum 4 by 0·2 or 0·8 metre thick might be assumed for a restricted basin such as that of the present lake Assal. This is still wholly inadequate unless the gypsum is segregated about the margins. If segregation took place over a marginal area equal to one-fifth the area of the lake the depth of the gypsum might be increased to 4 metres, which is more in conformity with its actual thickness. Dégoutin, however, assigns another possible source of the gypsum in lake Assal to chemical reaction between calcium chloride and magnesium sulphate, the chlorine being furnished by volcanic waters and gases. A possible reaction of this nature is suggested by the Lake Assal water which is rich in chloride of magnesium, but weak in magnesium sulphate. Whether or not gypsum formation has been segregated in lake Assal the formation of salt is now proceeding only in the western half of the lake. Another interesting feature of lake Assal is the fact that the entering spring waters mix very quickly with the concentrated waters, there being no superposition of liquids of different densities.

Although lake Assal furnishes pertinent information on the behaviour of natural concentrated saline solutions it is a type of marine salina that is exceptional in the fact that it is severed from the sea by a large mass of porous volcanic rock and for that reason liable to be more enduring than a salina separated only by a pervious bar of gravel. It is probable that salinas were rare along the margin of the Lower Windsor sea on account of the rarity of sandstone within that portion of the Windsor series. In the Upper Windsor the sea was progressively retreating from New Brunswick and northern Nova Scotia and much terrestrial sediment was brought down into it, so that the environment may have been more favourable in that region for marine salinas or small relict seas. Elsewhere throughout the Windsor the existence of marginal salt pans and of sea lagoons would probably be favoured. A factor that has generally favoured a lagoonal origin for thick sulphate deposits is the freedom accorded to ingress of sea water from the parent body; but the limitations of depth enforced by considerations of the sodium chloride content would need to be postulated unless one assumes there was a balance of conditions whereby incoming sea waters in the channel of communication were underlain by outgoing denser concentrated solutions. Such currents do actually exist in the Mediterranean and on the whole the hypothesis of lagoonal circulation of this type is perhaps the most satisfactory that can be advanced at present in explanation of some of the thick Nova Scotian sulphate deposits. Under the conditions of circulation involved bottom conditions favourable for sulphate deposition would doubtless be restricted to local areas. The requisite separation of solutions of variable density is seemingly a function of areal expanse and of depth among other things and is little understood at the present time. A density separation would seemingly be accompanied by temperature differentiation as Kaleczinsky[1] has cited the fact that in the Medve salt lake of Hungary temperatures up to 63 degrees C. are attainable at some depth from the surface and has pointed out that such heat concentration is possible only when a zone of comparatively fresh water is resting on more concentrated solutions. The lack of density separation in lake Assal has already been noted.

ROCK SALT DEPOSITS

In view of the abundant testimony for the origin of the bedded sulphate deposits of Nova Scotia in the evaporation of water of the Windsor sea at various stages of the latter, the question arises as to the probable extent of beds of rock salt and as to the possibility of the presence of potash deposits. Rock salt, in thick beds alternating with interbanded salt and anhydrite, has already been discovered in the Windsor series at Malagash and a bed (probably only a few inches thick when the drill record is corrected for dip) was reported in a driller's log from Windsor district. A thick deposit pierced by drills in Moncton district of New Brunswick is of uncertain stratigraphic position and cannot at present be definitely assigned to the Windsor series. A favourable indication for the presence of rock salt over large areas north of the Cobequid massif in Nova Scotia,

[1] Kaleczinsky, A. V.: Foldtoni Kozlony, 3, p. 418 (1901).

and possibly also in parts of Cape Breton, is afforded by the widespread occurrence, in areas underlain by Windsor strata, of many natural brine springs. The precise horizon within the Windsor series of the Malagash salt deposit is unknown and there is a possibility that the salt has been intruded into younger sediments to some extent, although no proof of this has yet been advanced. The internal evidence of the salt deposit in the form of interlaminated anhydrite and salt is favourable to deposition from sea water and the small amount of potash present, largely concentrated at one particular horizon, is likewise in conformity with results obtained from the evaporation of sea water. There is, however, a deficiency of magnesia and H. V. Ellsworth after a chemical examination of samples from the potash horizon came to the conclusion that terrestrial waters had probably contributed to the deposit. Such a possibility is not at all detrimental to the source of the deposits as an evaporation product of a cut-off portion of the Windsor sea, i.e., a relict sea type as already outlined. The restriction of potash to layers that carry an appreciable percentage of insoluble matter, including silicates, carbonates, and crystals of quartz,[1] suggests, if the potash is primary, a source in terrestrial waters as already inferred by Ellsworth. Such terrestrial waters are largely restricted by the environmental factors of the Windsor sea to springs or streams draining what was previously part of the sea bottom, and hence previously deposited salt deposits might be worked over and potassium concentrated by differential solution. As thick potash beds are probably the resultant of such segregating action rather than original precipitation from mother liquors of sea water the possibility of more favourable basins for potash accumulation in the region of Windsor sedimentation must not be overlooked. In fact the physiographic conditions inferred for Upper Windsor time in the country north of the Cobequids are not opposed to inland basins in which salt and potash minerals derived from the leaching of leaner pre-existent Lower Windsor sulphate beds may have been concentrated. The Malagash deposit illustrates the need of considering each deposit on its individual merits, for although all may be tied up ultimately to the Windsor sea varying degrees of connexion with that sea during the formation of the deposit would produce variable results.

[1] Free crystals of quartz containing anhydrite have been reported in a salt deposit from the Salt Range of India. *See* records Geol. Surv., Ind., 94, p. 258 (1914) and 24, p. 231 (1891). The quartz crystals were evidently deposited from solution.

CHAPTER VII

DESCRIPTION OF WINDSOR SPECIES

Phylum, PROTOZOA

Nodosinella priscilla (Dawson)

Plate I, figure 3

Dentalina priscilla Dawson, Acad. Geol., 2nd ed., 1868, p. 285, fig. 82.

Nodosinella priscilla Brady, Pal. Soc. 1876, p. 105, Pl. VII, figs. 8, 9.

Brady's Description. " Test slender, moniliform, formed of several more or less elongated cells separated by only slight constrictions. Length (?). Diameter $\frac{1}{40}$ inch (0·64 mm.)."

Remarks. Although certain thin bands of limestone consist mainly of the tubular remains of this organism, little success was had in adding to the knowledge concerning it. Individual fragments seldom exceed 7 mm. in length. The length of a node or distance between constrictions varies from 0·5 mm. to 1·5 mm. on different specimens. The average diameter of the tubes is about 0·5 mm. and of the walls 0·06 mm. Polished longitudinal sections commonly show fracture lines at the constrictions, but no clear evidence either of septation or branching was revealed. The walls are imperforate.

Horizon and Localities. Upper Windsor; localities,[1] 7502, 7530, 7532, 7547.

Types. Plesiotypes, 7668; National Museum of Canada, Ottawa.

Phylum, COELENTERATA

Zaphrentis minas Dawson

Plate I, figures 1, 2, 2a, 2b, 2c, 2d; Plate II, figures 1, 1a, 2

Zaphrentis Minas Dawson, Acad. Geol., 2nd ed., 1868, p. 286, fig. 84a.

Zaphrentis minas Lambe, Ottawa Naturalist, vol. XII, p. 254, 1899.

Zaphrentis minas Lambe, Geol. Surv., Canada, Cont. to Can. Pal., vol. IV, pt. II, p. 128, Pl. VII, figs. 7, 7a, 7b (1899).

Original Description

'Corallum conical, slightly curved. Calice, circular, thin edged, rather shallow; septal fossula, narrow, extending from the centre to the concave side. Principal septa about thirty-two. Tabulæ irregular. Epitheca thin, marked externally with longitudinal striæ and coarse, scaly ridges, especially near the upper part. My longest specimen is 2 inches in length, and has probably lost an inch of the lower part. It is 1 inch in diameter. The same species occurs at Cogmagun river and Stewiacke; and small specimens, possibly of the same species, at West River, Pictou. In old specimens the sides become very rugose, and the coral becomes narrowed at the top."

[1] *See* "Index to Locality Numbers" at end of Chapter.

Remarks. The septal plan is similar in general arrangement to that of *Zaphrentis delanouei* Milne-Edwards and Haime, as the following characters indicate:

(*a*) The major septa are strong, with fused inner ends (in *Z. minas* there is a more apparent bilateral symmetry), and they curve markedly convex to the fossula (seen more especially in neanic sections).
(*b*) The minor septa are only rudimentary (though better developed in *Z. minas* than in *Z. delanouei*). The minor septa flanking the counter septum are frequently more elongated than the rest.
(*c*) The cardinal fossula is conspicuous, situated on the concave side of the corallum, and extended to, or even beyond, the centre of the corallum. It is clearly defined by the walls formed by adjacent major septa. These walls are subparallel, but contracted slightly about mid-length of the fossula, or they may be subparallel distally and form a more or less prominent bulbous expansion at the inner end of the fossula. (No evidence was observed in the ontogenetic development, from such an inwardly expanded fossula to one of the *Z. constricta* type.)
(*d*) The cardinal septum extends the length of the fossula only in early neanic stages. It rapidly and progressively diminishes in length during further growth.
(*e*) The tabulæ are arched, but strongly depressed in the fossula.

Z. minas differs from *Z. delanouei* in the following characters:

(1) Much larger size—ratio of about 4:1.
(2) Rudimentary minor septa present in early as well as in late growth stages.
(3) Absence of prominent thickenings of the inner ends of the septa.
(4) Differentiation of the counter septum by its shorter length.

In many of these characters *Z. minas* approaches *Z. enniskilleni* Milne-Edwards and Haime, an affinity that did not escape notice by Lambe. In general, those characters in the septal arrangement of *Z. minas* that depart from *Z. enniskilleni* are held in common with *Z. delanouei* Milne-Edwards and Haime. It is significant in this connexion that Carruthers has noted one or two forms from a lower Visean level in the north of England, that are intermediate in type between *Z. delanouei* and *Z. enniskilleni* (Geol. Mag., Dec. 5, 1908, p. 67). The lack of serial sections illustrating the developmental stage of *Z. enniskilleni* prohibits at this time the assumption of its close homology with *Z. minas*. We may merely note that whereas *Z. minas* in the neanic stages is closely similar to *Z. delanouei* its subsequent development is not in line with that of *Z. constricta,* but to a stage converging upon *Z. enniskilleni.* The Windsor species is readily separable from many Mississippian Zaphrentids by its strongly ribbed epitheca and position of the fossula on the concave side of the corallum.

Horizon and Localities. Upper Windsor; localities, 7519, 7549, 7507, 7505.

Types. Proterotypes, Peter Redpath Museum, McGill University, Montreal. Plesiotypes, 7666, 7666a, 7667, 7667a; National Museum of Canada, Ottawa.

Genus, *Caninia* Michelin (emend. Carruthers)

Caninia dawsoni (Lambe)

Plate II, figures 3, 3a, 3b, 3c; Plate III, figures 1, 2, 3, 4, 5, 5a, 6, 6a

Zaphrentis minas pars. Dawson, Acad. Geol., 2nd ed., 1868, p. 286.

Cyathophyllum dawsoni Lambe, Ottawa Naturalist, vol. 12, p. 239 (1899).

Cyathophyllum dawsoni Lambe, Geol. Surv., Canada, Cont. Can. Pal., vol. IV, pt. 2, p. 147, Pl. 12, figs. 4-4b (1901).

Original Description

"Corallum simple, elongate, slightly curved, in the type specimen, broadest at the midlength, contracted near the top, annulated somewhat irregularly by well-marked ridges and constrictions, and by minor ridges of growth, the whole outer surface, when sufficiently well preserved, showing fine, close-set, transverse raised lines, about 12 in the space of 1 mm., as well as longitudinal septal striations. Type specimen 6 cm. long, as measured on the convex curve, imperfect below where the basal part, possibly about 3 or 4 cm. in length, has been broken off. Calyx shallowly concave, smooth at the bottom, with the septa prominent on the margin and sides. Tabulæ broad, flat, usually bent down at the edge, close set, forming a definite central area a little over 1 cm. in breadth. Septa rather crooked, of two lengths, the longer reaching the tabulæ and often encroaching on them, the shorter not quite half the length of the larger ones, irregular, rather poorly defined, numbering in all about 60. Vesicular zone, outside the tabulæ, averaging about 5 mm. in breadth, made up of unequal, arched dissepiments directed upward and outward between the septa."

Remarks. External Characters. Corallum dominantly simple, of rather large size, and irregular in growth. Commencing conical, the corallum may rapidly expand and present a rather deep calice, or become largely cylindrical, in which latter instance the calyx is usually shallow and the top of the coral commonly restricted in diameter. There may be frequent interruptions and torsions in the course of growth, giving rise locally to elliptical cross-sections. Rarely, two individuals are found connected for a part of their growth as a result of lateral gemmation.

The epitheca is moderately thick, though frequently partly excoriated, and possesses fine, sinuous, longitudinal striations and many transverse swellings and pronounced rings of growth. Stronger interruptions may mark intervals of stagnant or accidental arrest of growth, followed by constrictions and periods of rejuvenescence. The typical calice does not exceed 1 cm. in depth. Minor septa project above the external peripheral zone along the calicinal rim, but do not descend onto the floor of the calice. This floor is conspicuous and flat, and, as the fossula is not perceptibly differentiated in the calice, the latter is distinctly campophylloid in appearance. There are about 40 major septa, or specifically, 43 were present in a calice of 3·5 cm. diameter.

Internal Characters. Transverse Sections. (a) Neanic. In early neanic stages the septa are notably thickened by stereoplasm and taper to, or near, the centre of the section. Individually, they may be tortuous or curved, and at the centre fuse with, or be twisted around, one another. The fossette is clearly distinguishable by the greater distance between the pair of septa adjacent to the cardinal septum, and by the fact that the septa have a slight concavity in this direction, and that the stereoplasmic thickening is much more pronounced in this neighbourhood. The cardinal septum is long and extends to the centre. In addition to the individual stereoplasmic septal thickenings, there is a ring of stereoplasm closely appressed to the epithecal wall.

(*b*) In later neanic stages three characteristic zones are distinguishable:

(1) A central tabulate area free from septa; the withdrawal of the septa from the central area is amplexoid in nature and may perhaps be correlated with the assumption of the cylindrical habit (Carruthers, A.: Rev. of Carb. Corals, Geol. Mag., vol. 5, p. 162 (Dec. 5, 1905).
(2) A medial septate area in which the stereoplasmic development is emphasized in the cardinal quadrants. The stereoplasmic ring has now removed from the epitheca and sharply delimits this medial area from the third, or
(3) External vesicular zone, in which are developed interseptal vesicles in one or two rows. Rudimentary minor septa appear at this stage. The growth of vesicles is seemingly first affected in the counter quadrants. The cardinal septum at this stage is short and thick.

(*c*) In the development of the ephebic section, the following changes take place:

(1) The increase in the width of the external vesicular zone by the addition of new vesicles, which do not, however, except locally, interrupt the continuity of the major septa.
(2) The gradual reduction of stereoplasmic matter until the stereoplasmic inner wall is scarcely perceptible, or altogether absent in the counter quadrants, and to the stage where the septa in the cardinal quadrants are scarcely differentiated from those in the counter quadrants.
(3) The decreasing importance of the fossula and the assumption of a superficial radial, in contra-distinction to a distinctly bilateral symmetry.

The cardinal fossula is usually situated on the side of greater curvature, but somewhat laterally. The minor septa are very irregular in their development and even in adult sections may remain mere rudiments. In other specimens they traverse the external vesicular zone in greater or less part from the epitheca inwards, and may rarely succeed in reaching the inner wall in the cardinal quadrants, where their development exceeds that in the opposed quadrants.

Vertical Sections. The tabulæ are fine and closely spaced, and individually continuous across the central and medial areas. The central area is free from vesicles, but a few large vesicles, irregularly spaced, lie adjacent to the inner boundary of the external vesicular zone. In form, the tabulæ are flatly arched, with a peripheral moat, and commonly with a pronounced fossular depression that runs to the centre. Some of the tabulæ bear short vertical bars on their upper faces, which do not reach the next tabula above and which represent traces of the amplexoid septa. The vesicles of the external area are smaller and crowded along the proximal wall. They are disposed obliquely, or highly inclined outward with upper walls convex to the interior of the corallum.

Comparisons. This species bears close similarities to *Caninia cylindrica* (Scouler), but differs markedly from that species in the absence of an external peripheral subzone of large vesicles. Only rarely in the present species do isolated individual or local groups of vesicles in the peripheral regions interrupt the continuity of the major septa. In this character *C. dawsoni* resembles more closely *Caninia cylindrica* var. ***herculina*** (de Konick) which has only a meagre peripheral differentiation. Externally, the calice of that species is described as being very deep; it is of larger size and possesses a much greater number of septa. The Windsor species *C. dawsoni*, like the Russian species *C. gelaueri* Stuckenberg, shows convergence to a *Campophyllum* as it retains an amplexoid character to the septa. It still retains, however, the simple, non-vesiculate, tabulate condition of the primitive *Caninia* of the type *C. cornucopiae*.

Horizon and Locality. Upper Windsor; locality, 7519.

Types. Plesiotypes, 7650, 7650a, 7650b, 7650c, 7650d, 7650e, 7650f; National Museum of Canada, Ottawa.

Genus, *Lophophyllum* Milne-Edwards and Haime (emend. Carruthers)

Lophophyllum avonensis n.sp.

Plate IV, figures 4, 5, 6

External Characters. Corallum simple, conical and curved, or cylindrical and twisted throughout the greater part of the length. The proximal end commonly bifurcated into narrow, root-like processes. The epitheca is thin, with numerous lines and constrictions of growth, and longitudinal ribbing. Calyx, only partly known, deep, with nearly vertical wall, which is marked by strong major and weak minor septa. The columella is a small but prominent triangular plate at the inner end of the counter septum.

Internal Characters. Transverse Sections. (*a*) Neanic. Major septa run to the centre or fuse at the inner ends in the central region. They are thickened with stereoplasm and taper inwardly from a stereoplasmic ring which is closely appressed to the epithecal wall. The septa in the cardinal quadrants are differentiated more or less by their greater secondary thickening. The septa are concave to the fossette. The counter septum is long, and has a thickened inner or columellar portion. The cardinal septum runs the length of the fossette which is well defined in late neanic stages and Zaphrentoid in type. There are no minor septa, nor is there an external vesicular zone.

(*b*) Ephebic. The following changes take place in the development from youthful to adult stages. The peripheral stereoplasmic ring separates from the epithecal wall to form an inner wall, which is at first well defined, but which in later stages becomes much reduced and finally restricted practically to the cardinal quadrants. The septa also lose much of their stereoplasmic thickening and assume a radial symmetry. The fossette becomes more marked by the shortening of the cardinal and the pair of adjacent septa. The major septa recede from the centre and become amplexoid in habit while minor septa develop. Thus, in the adult section, three well-defined zones may be distinguished:

(1) A central tabulate zone free from septa which extend from tabula to tabula.

(2) A medial zone with thickened major septa and tabular dissepiments, limited externally by an inner wall of crowded vesicles or arcs of stereoplasmic thickening.

(3) An external vesicular zone with interseptal dissepiments arranged in more or less regular rings, and with major and minor septa that are unthickened. The minor septa penetrate the vesicular zone from the epitheca inwards, but seldom do they all reach the inner wall.

There are 33 major septa in a section of 1·5 cm. diameter.

Vertical Sections. The tabulæ are not closely spaced (from ½ to 1 mm. apart) and are broadly arched in the centre. Their continuity is interrupted more or less towards the inner wall by a few large vesicles. The external zone consists of strongly inclined oviform vesicles of variable size.

Horizon and Localities. Upper Windsor; localities, 7507, 7511.

Types. Holotype, 7651; paratypes, 7651b, 7652a; National Museum of Canada, Ottawa.

Dibunophyllum lambii n.sp.

Plate IV, figures 1, 1a, 1b, 1c, 1d, 1e, 1f, 1g, 2, 3

External Characters. Corallum simple, cylindrical, with thin epitheca and bearing marked constrictions and annulations of growth in addition to faint longitudinal ribbing. Calyx shallow, with prominent major and short minor septa. Floor of calice unknown.

Internal Characters. Transverse Sections. (*a*) Neanic. The differentiation into zonal areas, characteristic of the Clisiophyllids, is complete at a very early stage. The central area has a prominent, plate-like columella which thins outwardly in continuation of the cardinal and counter septa. The central area is not yet sharply marked from the succeeding medial area.

The medial area has thickened major septa that taper inwardly, and interseptal dissepiments, but the inner wall is clearly marked by dissepiments of which the walls have stereoplasmic thickening.

The external vesicular zone is narrow, and is traversed by both major and minor septa, the latter reaching from the epitheca to the inner wall.

The major septa are thickest in the middle and taper towards both ends, but are nowhere prominently thickened, nor are those in the cardinal quadrants appreciably thicker than those in the counter quadrants.

The fossula is of the open type (i.e. is not enclosed by septal walls) and is marked chiefly by the shortening of the pair of septa adjacent the cardinal septum.

(*b*) Ephebic Sections. In ephebic sections the three areas noted above are further developed. The central area has early acquired the characteristic 'spider web' structure. The plate-like columella usually falls just a little short of the circumference on the antifossular side, but is continued into the fossula as a thin projection. It is not prominently thickened medially. The vertical lamellæ are few and irregular in their development and seldom reach the columella itself. The outline of the area is cuspidate.

The medial area is now equalled or overshadowed in extent by the external vesicular area. Its inner wall is defined by a ring of more closely spaced vesicles in which there is some irregular stereoplasmic thickening, but the definition is not always emphatic.

The external area is closely vesicular and rarely shows a differentiated peripheral zone of more crowded vesicles. The major septa traverse the zone to the epitheca, but the minor septa rarely reach from the epitheca to the inner wall.

Vertical Sections. The central area is comparatively narrow. It is well delimited from the medial area by the prominent arching, greater abundance, and smaller size of the vesicles. The walls of the vesicles are largely concave in their midlength, and reach the columella at an acute angle. The medial area has large vesicles whose upper walls are convex upward and a little outward. Its peripheral boundary (inner wall of the corallum) is well defined by the small, vertically elongated vesicles of the external area. The vesicles of the latter are frequently semi-globular and their upper walls are convex upward and inward. There are traces of a peripheral differentiated zone of smaller vesicles.

Comparisons. Dibunophyllum lambii bears such close structural resemblances to *D. matlockense* Sibly and to *D* ψ Vaughan (particularly to an early expression as figured in fig. 7, Pl. xl, Quart. Jour. Geol. Soc. Lond., vol. 67, 1911) as to suggest close affinities. Its affinity seems closer to the latter, as expressed in its well-defined inner wall, its cuspidate central area, in the peripheral position of the vertical lamellæ of the central area, in the closely set vesicles of the external area, and in the absence of important local thickening of the major septa. There is little hesitation, therefore, in assigning *D. lambii* to the *Dibunophyllum* ψ 'gens or species-group' (as used by Vaughan, Quart. Jour. Geol. Soc., vol. 61, p. 183 (1905)).

Horizon and Locality. Upper Windsor; locality, 7511.

Types. Holotype in Peabody Museum, Yale University, New Haven, Conn. Paratypes, 7665c, 7665d; National Museum of Canada, Ottawa.

Lonsdaleia pictoense Billings

Plate V, figures 4, 4a

Lithostrotion pictoense Billings in Dawson, Acad. Geol., 2nd ed., 1868, p. 285, fig. 83.

Lonsdaleia pictoense Lambe, Ottawa Naturalist, vol. XII, p. 248 (1899).

Lonsdaleia pictoense Lambe, Cont. to Can. Pal., vol. iv, pt. 2, p. 173, Pl. XIV, figs. 9, 9a (1901).

Lambe's Description. Corallum compound, fasciculate, composed of long, upright, flexuous, cylindrical corallites that increase freely by lateral calcinal gemmation and are separated from each other by spaces of variable width, though frequently in contact. Corallites attaining a breadth of about 10 mm., the young ones beginning with a diameter of 2 and 3 mm. Epitheca complete. Internal structure consisting of a circumferential vesicular zone, in breadth equal to about one-fifth the diameter of the corallite, defined within by a stout inner wall that encloses a tabulate area, at the centre of which is a comparatively large columella about 1 mm. in thickness. From the inner wall converge short, strong, well-defined septa that are occasionally extended outward into the vesicular zone and more rarely reach the outer wall. The septa, about 20 in number, extend only about halfway across the space between the inner wall and the columella; alternating with them are observed occasionally rudimentary septa which are also indicated in the outer wall in those exceptional instances when the primary septa traverse the peripheral vesicular area. Tabulæ moderately regular, about 12 in a space of 5 mm. inclined upward at their junction with the inner wall and rising suddenly and inosculating with each other near the centre so as to form the columella. Vesicles of the outer area long and narrow, formed by curved plates rather unequal in size, that are directed obliquely upward and outward, and fill the space between the two walls.

" Represented in the collection by a small fragment, roughly 4 cm. broad and over 2 cm. high, embedded in compact limestone that hides the exact characters of the surface of the corallites."

Horizon and Localities. Upper Windsor; locality, East River of Pictou.

Types. Holotype, 4334; National Museum of Canada, Ottawa.

Phylum, VERMES

Serpula annulata (Dawson)

Plate V, figures 1, 1a

Serpulites annulatus (Dawson), Acad. Geol., 2nd ed., 1868, p. 312, fig. 131.

Original Description. " Cylindrical, about a line in diameter, coarsely marked with rings of growth and coiled in a loose, irregular spiral."

Emended Description. Shell is a solitary, free, tortuous, gradually expanding, calcareous tube. The loose spiral contortion is dextral in direction. Shell thick, porcellaneous, without longitudinal ridge-like thickenings, but greater local thickening of the shell may occur, especially on the inside curves. Surface marked by transverse striæ and irregular wrinkles of growth, the latter simulating annulations. The superficial shell layer appears to be faintly and microscopically crenulated by discontinuous longitudinal striæ.

Remarks. Cornulites? annulatus Beede is undoubtedly quite distinct from Dawson's species. Beede's figure suggests that it is an adherent form. Otherwise it has a rapidly tapering, trumpet-like form with regular annulations quite different from the spirally contorted habit of *S. annulatus.*

Horizon and Localities. Lower Windsor; localities, 7497, 3512, 3418, 3022, 3424, 7500.

Type. Plesiotype, 7744; National Museum of Canada, Ottawa.

Serpula hartti n.sp.

Plate V, figure 2

Description. Shell calcareous, small, attached by first spiral turn of whorl, free and uncoiling above, with aperture pointing upwards. Surface marked by fine, transverse growth striæ and rather coarse, unequal angulations irregularly spaced.

Dimensions. Diameter of mouth of tube about 1·5 mm.; total height about 3·5 mm.

Horizon and Locality. Lower Windsor; locality, 7498. Type: Holotype, 7748; National Museum of Canada, Ottawa.

Spirorbis caperatus M'Coy

Plate VI, figures 1, 2

Spirorbis caperatus M'Coy, Synop. Carb. Lime, Foss., Ireland, 1844, p. 169, t. 23, f. 26.

Description. Calcareous shell, spirally closed in one plane for two revolutions, followed by a free extension which curves obliquely upwards from the initial plane. Surface marked by prominent sharp wrinkles or annulations of growth.

Dimensions. Maximum breadth of spiral, 3 mm.; diameter of mouth of tube, 1·2 mm.

Remarks. The individuals are isolated but abundant on the outer surface of a *Spongiostoma*? There is no evidence that they were attached to any calcareous surface, although they may have been adherent to algal filaments. The Nova Scotia specimens agree perfectly with those described by E. Etheridge (Geol. Mag., vol. VII, 1880, pp. 261-262) in the uncoiling of the shell.

Horizon and Locality. Lower Windsor; locality, 7539.

Types. Plesiotypes, 7641, 7641a; National Museum of Canada, Ottawa.

Conularia planicostata Dawson

Plate XXXII, figures 1, 2

Conularia planicostata Dawson, Acad. Geol., 2nd ed., 1868, pp. 307, 308, fig. 117.

Original Description

"Form very elongate, pyramidal. Cross-section square, but by pressure becoming rhombic; surface marked by thin raised ribs, in perfect specimens with very delicate oblique striæ on their edges. The ribs vary much in their distance in different parts of the same specimen, and in different specimens (from 5 in a line to 10 in a line). They form an angle of about 120 degrees in the middle line of each face —breadth of full-grown specimens about ½ inch; length, 2 inches or more. There is no indication whatever that this shell had any internal partitions, though it occurs both flattened, as at Big Plaister Rock, and retaining its original form, as at Irish Cove and Windsor. It is curious to observe in the flattened specimens that the shell always gives way at the edges, without breaking, as if there was a suture or weak line there. The shell was exceedingly thin, especially at the smaller extremity, where it seems to terminate in an obtuse, rounded form. The aperture in the best specimens rises at the sides in angles corresponding to those of the plications."

Remarks. The number of transverse ribs is about eight or nine where the breadth of a face is 7 mm., increasing towards the apex. The angle made by them at the median line varies from 125 degrees to 140 degrees. This median line is characterized by the presence of a longitudinal ridge or rod (furrow on external moulds), at which the transverse ribs are either in apposition or in alternation. The ribs are bent towards the aperture in the marginal furrows where they alternate; their summits are smooth or more often finely tuberculate. It is doubtful whether actual tubercles are present, as the best preserved shell fragments reveal an oblique striation on those sides of the ribs directed towards the apex and this striation is seemingly correlated with faint growth lines visible at places in the intervening smooth furrows. These growth striæ run approximately at right angles to the sides of the shell and produce an oblique crenulation of the ribs. All specimens but one are preserved either as internal moulds, or internal moulds covered with an extremely thin, continuous chitinoid sheet of shell. The single exception (specimen 7672a) is of great interest, for no continuous, thin shell coat is visible, but a thicker shell is preserved revealing an entirely different structure. The shell is here made up of a series of plates overlapping shingle-wise towards the aperture. Internally the plates are slightly curved sigmoidally in a fore and aft direction in such manner that grooves are formed at their internal contacts. Externally, the edges of the shingle-like plates are thickened and form ridges opposite the internal grooves. In other words the apical or external edge of an individual plate on each face forms an external ridge approximately opposite the groove formed internally by the same plate and the apertural edge of the next smaller plate adjoining it. The positions of these external ridges or internal grooves correspond precisely to the transverse ribs on ordinary specimens. As there is no trace of a continuous chitinous film present on either face of this unique specimen it is not known whether such a film present in other specimens was laid down as a sheet over the exterior or internal faces of the plates. In either event the structure of the *Conularia* shell in this species was seemingly twofold, a series of overlapping, narrow, transverse plates underlain (?) by a thin, continuous, chitinous film. There is no evidence of an overlapping by means of shearing. The lateral continuity of the plates is not clearly revealed, but there would seem to be breaks at the marginal furrows and a structural channel at the middle line of each face. Under this interpretation a cross-section of Conularia would include four distinct plates. The individuality of the plates making up the shell of Conularia is sufficient cause for their rare preservation.

The apical angle of *Conularia planicostata* is 5 degrees to 10 degrees. This is the chief character that separates it from *Conularia quadrisculcata* Sowerby.

Horizon and Localities. Lower Windsor; localities, 7498, 7499, 3418, 3022, 3512, 3266. Upper Windsor; locality, 7521.

Types. Plesiotypes, 7672, 7672a; National Museum of Canada, Ottawa.

Conularia cf. *tenuis* Slater

Plate XXXII, figures 4, 5

Description. Shell, extremely thin. Original cross-section, square. Marginal furrows, narrow, shallow. Centre of each face marked by a pronounced, thin, longitudinal carina (the so-called "septum") or on imprints by a narrow, longitudinal groove. Transverse ridges pronounced, numbering 9 or 10 per 5 mm. where breadth of a face is 7 mm.; 6 or 7 where breadth is 11 mm.; commonly they are slightly curved sigmoidally on flattened specimens; they meet the median line in apposition or alternation at an average angle of about 132 degrees. Apical angle of shell, 13 to 15 degrees.

Remarks. The specimens are all incomplete and are flattened onto one plane. The largest does not exceed 35 mm. length. On one rock slab of the bituminous, dark, calcareous shale in which the specimens occur, three individuals are grouped radially about a common centre, suggestive of the association noted by Slater (Palæontographical Society of London, 1907, Pl. 2, fig. 1).

The species differs from *C. planicostata* in its larger apical angle and greater tenuity.

Horizon and Localities. Basal Windsor; localities, 7522, 7516.

Types. Holotype, 7715; paratypes, 7715a; National Museum of Canada, Ottawa.

Conularia sorrocula Beede

Plate XXXII, figures 3, 3a

Conularia sorrocula Beede, N.Y. State Mus. Bull. 149, p. 184, fig. t.f. (1911).

Original Description

"Shell of small size, pyramidal enlarging at an angle of 20 degrees. Edges of shell round inward, producing an impressed angle; surfaces nearly flat; mesial furrow scarcely impressed; anterior ends of sides arched forward in the centre, leaving rather deep angles at their union. Transverse striæ arched forwards on sides, frequently meeting. Sometimes interrupted at the mesial furrow; 10 in 5 mm., on the upper part of the shell, more than twice as many near the base, strongly crenulated by the crossing of longitudinal wrinkles which appear coarser and farther apart near the angles; crenulations keel-like, 10 to 13 in 2 mm.

Dimensions. Length 28 mm.; width of valve at aperture, 10 mm.; incomplete at base."

Remarks. A single apical fragment of this species is present in the collection. It differs from *C. planicostata* in the higher apical angle and in the longitudinal rather than oblique character of the crenulations on the transverse ribs.

Horizon and Locality. Lower Windsor; locality, 3418.

Types. Plesiotype, 7759; National Museum of Canada, Ottawa.

Phylum, MOLLUSCOIDEA

Fenestella lyelli Dawson

Plate VI, figures 3, 4, 5; Plate VII, figure 3; Plate VIII, figure 2

Fenestella lyelli Dawson, Acad. Geol., 2nd ed., 1868, p. 288, fig. 86 a-c.

Original Description

"This beautiful species is very characteristic of one of the limestones of the Windsor series, and is, I think, certainly new and undescribed. The non-poriferous side has thick, parallel, bifurcating ribs, with rounded surfaces finely striated longitudinally, connected by much thinner and rounded cross-bars, enclosing oval fenestrules. The poriferous side has the bars angular above, and with a central carina, bearing a row of small tubercles, which in the best specimens are seen to bear delicate spines. The pores are in two rows at the sides of the ribs. Its nearest allies are *F. retiformis* Schloto, and *F. carinata* M'Coy, but it differs materially from both, more especially in its characteristic spines."

Emended Description. Zoarium, a foliar undulating expansion somewhat infundibuliform. Branches, averaging 0·24 mm. in breadth (from 0·18 to 0·30 mm.), 22 to 25 per cm. Fenestrules, oval to quadrate, averaging 0·25 mm. by 0·44 mm., and about 19 per cm. Dissepiments, averaging 0·10 mm., slightly below level of branches. Reverse non-poriferous surfaces of branches, longitudinally striated with 4 to 6 striæ per branch; commonly the striæ are concealed by an outer, non-striated layer. Zooecia, 0·08 mm. diameter, averaging 21 per 5 mm. and 0·22 mm. apart; zooecial peristomes moderately elevated where preserved; inferior hemisepta present. Zooecial surface of branches with a low keel bearing elevated spines about 0·25 mm. apart.

Remarks. Fenestella elevatipora Ulrich has relatively more crowded branches and a larger number of fenestrules and zooecia per centimetre and lacks a spinose carina. *F. tenax* Ulrich is a more closely branched species, its spine-bearing carina is more elevated, and its reverse surface is granulated and only obscurely striated. *F. serratula* Ulrich is a closely allied species with relatively more numerous branches and zooecia, granulo-striate reverse, and nodose rather than spinose keel.

Horizon and Localities. Lower Windsor; localities, 7497, 7498, 3022, 3512, 3418, 3266, 3424.

Types. Plesiotypes, 7725, 7727a, 7729b, 7729d, 7729g; National Museum of Canada, Ottawa.

Fenestella lyelli mut.

Plate VII, figures 4, 5

Description. Zoarium a reticulated foliar expansion with 22 to 26 branches per cm. Zooecia, apertural diameters 1·02 mm., 0·19 mm. apart, or about 26 per 5 mm., with prominent raised peristomes. Diameter of individual branches averages about 0·22 mm. Fenestrules with short diameter of 0·2 mm. and long diameter 0·3 to 0·4 mm. Dissepiments depressed well below zooecial surface, short diameter 0·13 mm. A well-marked carina present, bearing spines when well preserved. Reverse surface of branches longitudinally striated with 4 or 5 striæ per branch.

Remarks. This form is very closely allied to *F. lyelli,* differing only in the closer spacing of the zooecia.

Horizon and Localities. Upper Windsor; localities, 7507, 7519.

Types. Holotype, 7753; paratype, 7730c; National Museum of Canada, Ottawa.

Septopora primitiva n.sp.

Plate VI, figure 6; Plate VII, figures 1, 2; Plate VIII, figure 1; Plate IX, figures 1, 2, 3, 4

Description. Zoarium a fenestrated, foliar, undulating, or infundibuliform expansion. Branches average 0·3 to 0·5 mm. in breadth, branch freely by dichotomy, anastomose rarely, united at irregular intervals in a fenestrated framework by short, transverse, or more rarely, oblique dissepiments. Dissepiments, diameter 0·1 to 0·2 mm., for most part non-celluliferous, rarely bearing one or two zooecia, surface non-carinated. Zooecia, 16 to 18 per 5 mm., or 0·3 mm. apart on the average, are borne in two rows, one on either side of a carina that consists of broad based spines. Zooecial apertures, circular, diameter 0·10 to 0·15 mm., surrounded by raised peristomes. Reverse surface of branches strongly striated longitudinally, furnished sparingly with scattered pores. The latter are variable in position and number and are present commonly on the bases of the dissepiments as well as on the branches. Diameter of pores about 0·76 mm.

Remarks. This species differs from typical members of the genus in the common presence of non-celluliferous dissepiments, approaching thus to *Fenestella.* As a zooecium is occasionally present on a base of a "dissepiment" the latter approaches more nearly the transverse branch characteristic of *Septopora,* so there would appear to be insufficient grounds on which to found a new genus. *S. primitiva* resembles in habit *S. delicatula* Ulrich, but is more compact and characterized by profuse dichotomy of the branches. The obverse of *S. delicatula* being undescribed forbids comparison.

Horizon and Localities. Lower Windsor; localities, 7497, 7498, 3022, 3418.

Types. Holotype, 7735a; paratypes, 7734, 7734a, 7734b, 7734c, 7735, 7735a, 7735b, 7735c; National Museum of Canada, Ottawa.

Batostomella exilis (Dawson)

Plate XI, figures 1, 2, 3; Plate XII, figures 3, 4

Stenopora exilis Dawson, Acad. Geol., 2nd ed., 1868, p. 287, fig. 85a.

Original Description

"It presents slender, cylindrical branches, ramifying irregularly and sometimes anastomosing, from half a line to a line in diameter, and covered with minute contiguous hexagonal cells with small spines or papillæ on their separating walls. In a longitudinal section the cells are seen to rise vertically, and then suddenly curve to the surface, increasing at the same time in diameter, and having near the aperture a few thin transverse plates."

Emended Description. Zoarium ramose, slender, rarely exceeding 2 mm. diameter; zooecia averaging about 8 in 2 mm., polygonal to ovate, with maximum diameter of aperture averaging 0·2 mm. Walls, at surface moderately thick, less than 0·1 mm., ornamented with acanthopore spines commonly 6 or 8 in number around a single aperture. Mesopores not abundant. Thin sections show that the walls in the axial region are thin and that the curvature to the thick-walled mature or peripheral region is rather abrupt, the zooecia meeting the surface nearly at right angles. Diaphragms absent in the axial region; two or three present near mouth of aperture. Ratio of axial region to diameter, about 60 per cent.

Remarks. This species seems to be closely allied to *B. spinulosa* Ulrich, differing, however, in the slightly larger apertures, lesser thickness of the mature walls, and in the smaller number of acanthopores. It is distinguished from *B. exilis* in the spinous surface ornamentation, less thickened walls, and fewer number of mesopores, broader mature region, somewhat less robust form.

Horizon and Localities. Lower Windsor; localities, 7497, 7498, 7553, 3022.

Types. Cotypes, 7738a, 7740; paratypes, 7737, 7738g, 7738k; National Museum of Canada, Ottawa.

Batostomella abrupta Ulrich

Plate XII, figures 1, 2; Plate XIII, figures 7, 8

Chaetetes tumidus Dawson, Acad. Geol., 2nd ed., 1868, p. 288, fig. 85b.

B. abrupta Ulrich, Geol. Surv., Ill., vol. VIII, p. 435, Pl. lxxxv, 2-2e (1890).

Remarks. Stems occasionally reach a diameter of 4 mm., although the average size is about 3 mm. Except the fact that this maximum is slightly greater than the Chester species, this form agrees with *B. abrupta* in every respect. It is separable from *B. exilis* by its more robust form, its extremely narrow cortical region, and thick cortical interspaces in which mesopores are more abundant. Moreover, when well preserved the apertures are bordered by a sloping surface as in the Chester examples.

Horizon and Localities. Lower Windsor; localities, 7497, 7498, 7536.

Types. Plesiotypes, 7686a, 7687, 7687a, 7687b; National Museum of Canada, Ottawa.

Polypora schucherti n.sp.

Plate XIII, figures 1, 2, 2a, 3, 4

Description. Zoarium a reticulated foliar expansion, averaging 20 branches per cm. and with 14 to 17 fenestrules per cm. Zooecia 20 to 22 per 5 mm.; apertures, circular, surrounded by prominent raised peristomes in well-preserved specimens, diameter variable, averaging 0·102 mm. For the most part the zooecia occur in 2 rows, one on either side of a low median slightly flexuous and obscurely nodose carina. At irregular and distant intervals and at most bifurcations the branches expand in width and bear 3 or 4 rows of zooecia without any carinæ. A single branch may vary in width from 0·25 mm. to 0·48 mm. The fenestrules are variable in size, averaging 0·26 mm. wide by 0·93 mm. long. The dissepiments, about 0·16 mm. shortest diameter, are depressed well below the level of the zooecial surface; commonly they are striated longitudinally. The reverse, non-poriferous face of the zoarium is likewise striated.

Remarks. In specimen 4338a one branch, swollen below a bifurcation, carries 3 rows of zooecia for 0·76 mm. and, higher up, 4 rows for 1·27 mm. directly below the bifurcation. Beneath other bifurcations there are only one or two accessory zooecia. One branch on the same specimen has a local enlargement for 1·78 mm. not related to a bifurcation and bears there 3 rows of zooecia. On specimen 7731 one branch is prominently swollen for 4 mm. below a bifurcation and carries in that length 3 rows of zooecia without any trace of a carina, whereas a second branch is only enlarged and triseriate for 0·5 mm. below a bifurcation.

It is evident that the species is intermediate in character between *Fenestella* and *Polypora.* Its affinities, by reason of the presence of a median carina and the rather aberrant insertion of additional zooecia, are closer to *Fenestella* than are those of *P. biseriata* Hall, a closely allied species.

Horizon and Localities. Lower Windsor; localities, 3424, 7498, 3022, 7497.

Types. Holotype, 7731; paratypes, 4338a, 7732; National Museum of Canada, Ottawa.

Streblotrypa biformata n.sp.

Plate XIII, figures 5, 6; Plate XIV, figures 1, 1a

Description. Zoarium, encrusting parasitic, or a free cylindrical stem about 1 mm. diameter, the former probably a metanepiastic stage. Zooecia, spirally arranged sub-conical tubes with subfusiform outline at the surface; apertures, situated anteriorly, about 18 or 20 in 5 mm., variable in size, commonly semiovate with truncated bases, long diameters attaining a length of about 0·4 mm. and width about 0·2 mm. Anteriorly and laterally the aperture is bordered by a raised peristome and the zooecium is outlined posteriorly by a raised line in continuity with this apertural wall. Area behind the aperture, depressed, perforated by pores (commonly 6 or 8 in number) that are variable in size up to 0·05 mm. and that are arranged irregularly in 2 or 3 transverse rows.

Remarks. Disregarding the dimorphic character of the species the characters agree perfectly with *Streblotrypa* and show little resemblance to *Cyclopora,* the ordinary parasitic unilaminar genus of the family. The species differs from *S. major* Ulrich in the spiral and more crowded arrangement of the apertures. *S. distincta* Ulrich has smaller apertures, fewer small pores, and lacks the bordering ridges of the zooecia.

Horizon and Localities. Lower Windsor; localities, 7498, 7497.

Types. Cotypes, 7741, 7741b; paratype, 7741c; National Museum of Canada, Ottawa.

Tabulipora acadica n.sp.

Plate X, figures 1, 2, 3, 3a, 4, 5

Description. Zoarium ramose, irregularly branching, rarely anastomosing. Branches up to 12 mm. diameter. Metanepiastic stage in form of encrusting plates, commonly on brachiopods or corals. Zooecial apertures, 0·3 to 0·4 mm. diameter, polygonal, about 30 per cm. A small cell commonly present between the larger ones, and also less many maculæ. Acanthopores visible under lens when preservation permits.

Microscopic sections reveal a ratio of axial region to diameter of 0·4 to 1. The mature cells lie practically at right angles to the surface. Walls in mature or cortical region moniliform, but the thickenings are less than 0·1 mm. Diaphragms, perforated centrally, about 5 per mm. in the peripheral region, rare in the axial zone. Transverse sections show small acanthopores at junction angles and a median dividing line associated with a linear succession of minute granules.

Remarks. The internal characters agree closely with *T. tenuimurialis* Lee, but the Nova Scotian species has larger zooecia and a relatively narrower axial region. The zoarium is much smaller than *T. americana* (Ulrich) to which its individual zooecia are comparable in size. *Tabulipora acadica* also differs in the absence of monticules and less distinct acanthopores.

Horizon and Localities. Upper Windsor; localities, 7507, 7512, 7537, 7519.

Types. Holotype, 7739; paratypes, 7739a, 7739b, 7739c, 7746; National Museum of Canada, Ottawa.

Crania cincta n.sp.

Plate XIV, figure 2

Description. Pedicle valve, cemented, not observed. Brachial valve, small, subcircular, with greatly thickened margins, irregular in its growth, with apex excentric and slightly pointed posteriorly. The surface from the apex to the front margin is gently convex, steeper to the posterior margin. For one-half its height the valve is marked with strong, concentric ribs, with finer ribbing between. The surface under a lens appears minutely punctate.

Dimensions. Greatest diameter, 7 mm.; height, 3 mm.; beak situated 3 mm. from the posterior border.

Remarks. No other described Mississippian species seems to bear close resemblance to this Windsor form. *Crania chesterensis* Miller and Gurley approximates it in size and form but possesses a thin shell with a peripheral thickened ring.

Horizon and Locality. Very rare in Upper Windsor; locality, 7512.

Types. Holotype, 7441; National Museum of Canada, Ottawa.

Crania brookfieldensis n.sp.

Plate XIV, figure 3

Description. Shell, calcareous, thick. Pedicle valve unknown. Brachial valve, depressed conical, suboval. Beak markedly eccentric pointed posteriorly. Slope from beak to anterior margin flatly convex, from beak to posterior margin narrowly concave. Surface marked by irregular, macroscopic, concentric rings of growth and by fine, microscopic, crowded concentric ribs.

Dimensions. Length, 5·25 mm.; width, 3·9 mm.; beak, 0·8 mm. from posterior margin.

Horizon and Locality. Lower Windsor; locality, 3418.

Types. Holotype, 7438; National Museum of Canada, Ottawa.

Orbiculoidea sp.

Plate XIV, figure 4

An imperfect pedicle valve that does not show the characters of the pedicle area. Flatly convex, with pronounced posterior depression. Surface marked by concentric rings of growth, and faint, radiating striæ visible under a hand lens. Diameter, 13·3 mm.

Horizon and Locality. Lower Windsor; locality, 7497.

Type. Holotype, Peabody Museum, Yale University, collection 2836.

Schuchertella pictoense n.sp.

Plate XIV, figures 5, 6, 7

Streptorhynchus crenistria Dawson, Acad. Geol., p. 296, fig. 96.

Description. Shell of medium size, biconvex, generally broader than long, greatest width near midlength; hinge-line, straight, a little shorter than the greatest width; cardinal extremities, obtusely angular.

Pedicle valve, gently convex, greatest convexity posterior to middle, slightly depressed towards the cardinal extremities; medial sinus absent; beak, slightly protuberant beyond cardinal margin, straight or possibly very slightly twisted; cardinal area, moderately low, inclined about 125 degrees to plane of valve, posterior margin sloping from beak to the cardinal extremities in a straight or slightly concave line; inner area narrow; delthyrium, narrowly triangular, closed by a convex deltidium. Internally, dental plates absent, but margin of delthyrium marked by callous thickening.

Brachial valve, about equally convex with the pedicle, greatest convexity a little anterior to the middle, depressed toward the cardinal extremities and in umbonal region; mesial sinus present as a shallow, triangular depression, expanding anteriorly; beak, small, not protuberant above cardinal line; cardinal process, low, stoutly supported at base.

Surface of both valves marked by subangular radiating costæ, increasing by intercalation with the greater number of intercalated costæ arising posteriorly to the midlength; the initial smaller size of the intercalated costæ gives rise to an appearance of alternating fine and coarse costæ; furrows and costæ crossed by fine, concentric lines of growth, a few becoming stronger towards the margins in old shells.

Dimensions. Brachial valve, length, 19 mm.; greatest width, 29·4 mm.; convexity, 3 mm.; length, cardinal line, 22·5 mm.

Remarks. Although the beak in the pedicle valve of one specimen is very slightly twisted and thus simulates *Streptorhyncus* other specimens are more regular and the long hinge-line, low cardinal area, low cardinal process, and general form of shell all denote *Schuchertella.* As the type specimens described come from East river there is no doubt as to the identity of this species with the form figured by Dawson as *Streptorhyncus crenistria. Schuchertella rubra* Weller from the Kinderhookian is closely similar in outward appearance, except for the inclination of the area which lies almost at right angles to the plane of the valve.

Horizon and Localities. Upper Windsor; localities, East River of Pictou and 7535.

Types. Cotypes, 7655, 7655a; parataypes, 7655b, 7463; National Museum of Canada, Ottawa.

Schellwienella kennetcookensis n.sp.

Plate XV, figures 5, 6

Description. Pedicle valve, subrectangular to semiovate in form, with hinge equal to the greatest width or nearly so, nearly straight lateral margins, smoothly rounded anterior margin. Valve pronouncedly resupinnate, with prominently raised umbonal region sloping steeply from the small beak anteriorly, more gently to the flattened cardinal extremities; remaining surface concave to the border, which is flattened or narrowly convex in the frontal part of the shell. The cardinal area is inclined at an angle of about 110 degress to the general plane of the valve. The costæ are narrowly rounded, about 2 per millimetre in front, increasing by interpolation, and crossed by fine, concentric ribs which crenulate them. The crenulations are more conspicuous in the wider intervening furrows where about 6 or 7 occur in the space of 1 mm. The frontal inflected border of the valve is marked by strong growth lamellæ.

Brachial valve (of a second individual assumed to belong to the species), depressed convex, with greater convexity anterior to the middle, and with the anterior slopes steeper than the gentle posterior slopes. Surface marked by subangular costæ and fine, concentric lines as in the opposite valve.

Dimensions. Pedicle valve (specimen 7654), length, 41 mm.; width along hinge, 48 mm.; height, 5 mm.; brachial valve (specimen 7942), length, 26·7 mm.; width along hinge, 32·8 mm.; height, 3 mm.

Remarks. In size, costation, and outline the species resembles *Schellwienella planumbona* Weller. Differences appear in the convexity and prominence of the umbonal region of the pedicle valve, in the pronounced frontal lines of growth, in possibly the much lower convexity of the brachial valve. From *S. burlingtonensis* Weller it is distinguishable by the absence of auriculate cardinal extremities, smaller size, nearly straight cardinal margins, lower convexity. Internal characters unknown, and reference to *Schellwienella* is based on the strong, resupinate character.

Horizon and Localities. Upper Windsor; localities, 7519, 7505.

Types. Holotype (pedicle valve), 7654; paratype (brachial valve), 7942; National Museum of Canada, Ottawa.

Streptorhynchus cf. *minutum* (Cummings)

Plate XV, figures 4, 4a

Description. (Based on a single somewhat crushed specimen). Shell minute, wider than long, subelliptical to subquadrate in outline, hinge-line a little shorter than greatest width. Pedicle valve, gently convex in the umbonal region, becoming flat or slightly concave anteriorly and laterally. Beak, slightly recurved, obtusely pointed.

Brachial valve flattened or concave probably due to compression; beak inconspicuous.

Surface of both valves marked by subangular, strong, radiating costæ which increase by bifurcation and intercalation. Three or four occupy the space of 1 mm. Fine concentric ribs produce a microscopic crenulation.

Dimensions. Length, pedicle valve, 4·8 mm.; width, 6 mm.; width along hinge-line, 5 mm.; height of cardinal area, 1 mm.

Remarks. The extreme flatness of the shell, in which it deviates from *S. minutum,* is probably due to deformation.

Horizon and Locality. Upper Windsor; locality, 7512.

Types. Holotype, 7462; National Museum of Canada, Ottawa.

Chonetes politus M'Coy

Plate XV, figures 1, 1a, 2, 3

Description. Shell small, outline semi-elliptical, strongly concavo-convex, wider than long; length of hinge-line equal to, or greater than, the greatest width. Cardinal angles variable, from rectangular to slightly obtuse or acute.

Pedicle valve, most convex posteriorly to the middle; slope to anterior margin gently convex, to beak narrowly so; postero-lateral slopes gently concave to the somewhat depressed cardinal extremities; ill-defined auriculations sometimes present. Mesial sinus, or mesial flattening, obsolete. Cardinal areas, narrow, flat, or slightly concave, and nearly in the plane of the valve; delthyrium closed apically by a convex deltidium. Cardinal margin marked with 4 or 5 oblique, strong spine bases on each side of the beak. Beak, minute, scarcely extended beyond the cardinal margin. Surface marked by oblique pores which may be the bases of surface spines. Commonly these pores are not apparent and rarely there are traces of discontinuous crowded radial costæ. Fine, concentric microscopic growth lines, and commonly several well-pronounced lamellæ or bands of growth are present.

Brachial valve, decidedly concave, following the surface contours of the opposite valve; cardinal area much narrower than that of the pedicle valve, and meeting it nearly in the same plane, notched and arched in front of the tripartite cardinal process, which is visible externally. Surface marked by concentric lines as in pedicle valve.

Remarks. In size and external features this species is somewhat like *Chonetes geniculatus* White. The main difference lies in the absence, or but faint representation, of costæ, and the presence of scattered pores (spine bases?) on the pedicle valve. Moreover, the brachial valve is more pronouncedly concave in its median portion, following the outlines of the convex valve, whereas the hinge-line is as long or longer than the mid-width. There are 4 or, more rarely, 5 spines situated on either side of the cardinal margin of the pedicle valve, directed obliquely outward.

When the outer layer of the shell of the pedicle valve is stripped off, there are revealed coarse, oblique pores, spaced one-half a millimetre or more apart, and arranged in quincunx. Internally, there are two slightly diverging prominent ridges flanked on either side by discontinuous radiating ridges or elongate pustules. Situated between the posterior ends of the central ridges is a short, inconspicuous median septum or ridge separating the adductors. The cardinal process is tripartite, with the larger central division bifurcate.

Dimensions. Length, 5·8 mm., width along hinge-line, 7·4 mm., convexity, 2·9 mm.

Horizon and Localities. Upper Windsor; localities, 7512, 7535, 7507, 7519.

Types. Pleisotypes, 7467, 7467a, 7467b; National Museum of Canada, Ottawa.

Productella baddeckensis n. sp.

Plate XV, figures 7, 8, 8a, 8b, 8c, 9

Description. Shell small, subovate, concavo-convex, hinge-line shorter than the greatest width. Pedicle valve, with greatest tumidity somewhat posterior to the middle; convexity of curvature along the median line progressively increases from this point to the beak and to the front; cardinal slopes steeper than the anterior or lateral slopes; non-auriculate; umbone projecting but little beyond the hinge-line; cardinal area extremely narrow; scattered spines occur over the surface, and the valve is imperfectly costate, the costæ irregular and interrupted; surface also ornamented by fine, concentric ribs and microscopic, concentric growth lines.

Brachial valve, flattened concave, with greatest depression directly in front of the minute, knob-like beak; surface marked by fine, concentric ribs and scattered, pit-like depressions.

Dimensions. Length, 9·2 mm.; width, 10·2 mm.; width along hinge-line, 7·2 mm.; convexity of pedicle valve, 4 mm.

Remarks. This species differs from *Productella concentrica* (Hall) in its shorter hinge-line, absence of auriculations, and in the finer and less conspicuous concentric ribbing, which does not take on the aspect of wrinkling. Moreover, the costation is not as coarse.

Horizon and Locality. Lower Windsor; locality, 3518.

Types. Holotype, 7962a; paratypes, 7962, 7962b; National Museum of Canada, Ottawa.

Genus, *Protoniella* n. gen.

Etymology. Diminutive of *Protonia* Link, a synonym of *Productus.*

Genoholotype. Protoniella beedii n. sp.

Diagnosis. Shell productoid, with internal characters approaching *Marginifera.* The umbone of the pedicle valve is characterized by a small, apical cicatrix of attachment. Surface of shell spinose in early stages becoming costate in later life as in the genus *Avonia* Thomas. Cardinal areas and teeth obsolescent or nearly so.

Remarks. Although the genus was probably derived from a spinose ancestor with similar habit of attachment early in life, it is not known whether this precursor possessed additional characters in common with *Strophalosia.* The genus is differentiated from *Strophalosia* in the adult shell by the absence of well-defined cardinal areas and teeth, and by the presence of a well-defined productid costation. It differs from *Avonia* in the presence of a cicatrix of attachment on the umbone of the pedicle valve. It would seem to be a survivor of a type intermediate between *Strophalosia* and *Avonia* and convergent to *Marginifera.*

Protoniella beedii n.sp.

Plates XV, figures 10, 10a, 10b, 11, 12, 13, 14

Description. Shell thin, below medium size, concavo-convex. Hinge-line as long as, or somewhat shorter than, the greatest width. Young shell attached by the umbone of the pedicle valve, later free.

Pedicle valve, gibbous, with shallow sinus variable in strength. Cardinal slopes precipitous, lateral flanks only slightly less so. Auriculations, well marked, thin, flattened, or slightly recurved. Beak, stout, strongly incurved, and the umbone projects well beyond the hinge-line. Spine bases scattered over the valve, but are somewhat more abundant on the ears where as many as 16 are arranged in one or two more or less well-defined rows, one row at foot of slope to the ears and a second less regular bordering the cardinal line. These spines increase in size outwards towards the lateral margins. The point of the umbone is marked by a small scar of attachment. Cardinal area extremely narrow or obsolescent.

Radial costæ commence in the anterior umbonal region as elongated spines, rapidly becoming well defined and continuous. They number 7 to 11 in 5 mm. and increase by bifurcation, more rarely by intercalation.

The costation becomes fainter on the cardinal slopes and is absent altogether on the ears. Fine, concentric growth lines ornament the entire surface when well preserved. They are particularly noticeable on the ears and youthful umbonal region. Several stronger wrinkles of growth may mark the cardinal flanks, but are not conspicuous over the visceral portion of the surface.

Brachial valve, subrectangular, deeply concave, but flattened in the visceral region, abruptly deflected or geniculated anteriorly and laterally ears flat, defined from rest of shells. Concentric sublamellose ribbing quite prominent bordering this deflexion. The auriculations are reflected downwards. Ornamentation as in opposite valve, but the valve is non-spinous.

Internally, the cardinal process is large, bilobate anteriorly, seemingly trilobate viewed posteriorly. The upper surfaces of the two lateral prongs are marked rugose. The median septum commencing at a pronounced callosity at the base of the cardinal septum continues as a simple septum well beyond the muscular scars to near the border of the costated portion of the visceral region. There is some indication that the median callosity posterior to the adductor scars may be made up of the two callous halves of a split septum, as there is a marked pit in the callosity at the base of the cardinal process. The visceral region has a marginal raised callous border which rises on either side as a more or less distinct ridge to the cardinal process shutting off the ears.

Dimensions. Length, hinge-line to front, 11·5 mm.; length, umbone to front, 15 mm.; width along hinge-line, 18 mm.; convexity of pedicle valve 8 mm.

Remarks. The incipient *Marginifera* character of the brachial valve is probably subject to considerable variation. *Strophalosia nebraskensiformis* Beede differs in the adult pustulose ornamentation of the brachial valve. *Productus parvus* (Meek and Worthen), with sinus obsolete, is otherwise strikingly similar in form, size, and ornamentation, but it is not stated to have a scar of attachment on the umbone of the pedicle valve. The shell is strikingly similar in form and appearance to *Marginifera longispina* var. *orientalis* Choa. Internally the *Marginifera* ridge is closer to the cardinal line, the adductor impressions are less elevated, and the median septum extends nearly to the front of the visceral area.

Horizon and Locality. Upper Windsor; localities, 7512 (common), 7507, 7519 (rare).

Types. Genoholotype, 7954d; paratypes, 7954, 7954a, 7954b, 7954c; National Museum of Canada, Ottawa.

Productus (Linoproductus) lyelli Verneuil, *nomen nudum*

Plate XVI, figures 1, 2, 2a, 3, 4, 4a, 5, 7, 8; Plate XIV, figure 1

Productus lyelli Lyell, Travels in North America, vol. 2, p. 221 (1845).

Productus lyelli Dawson, Acad. Geol., 1st edition, 1855, p. 219, fig. 9.

Productus cora Davidson, Quart. Jour. Geol. Soc. London, vol. 19, pp. 174-175, Pl. 9, figs. 22-23 (1863).

Productus cora Davidson in Dawson, Acad. Geol., 2nd. edition, 1868, pp. 297-298, figs. 98 a-b.

Lyell's Description. "Shell with fine striæ, and with long and slender tubes, the most characteristic fossil of the Lower Carboniferous formation."

Emended Description. Shell markedly concavo-convex with narrow visceral cavity and extended trail; hinge-line somewhat shorter than the greatest width. Shell substance thin.

Pedicle valve with greatest tumidity posterior to the middle, whence the slope to the front and antero-lateral margins is gently convex and without geniculation into the trail; slope to the beak progressively more narrowly convex; postero-lateral slopes precipitous to conspicuous, cardinal, depressed, auricular terraces. Bordering the hinge-line these terraces or ears are slightly rolled or convex. Outline of visceral portion of valve is sub-rectangular, uniformly convex in front, with nearly straight lateral margins. Growth varices indicate that the hinge-line in young stages was considerably shorter than the greatest width of the valve, but that on further growth the hinge-line became more extended and the lateral margins straighter and sometimes sinuous at the foot of the postero-lateral slope. Beak pointed and incurved, extending very slightly beyond the hinge-line. The surface is ornamented by fine, rounded, thread-like costæ, locally flexuous, about 13 to 18 in a space of 5 mm., increasing by intercalation in such manner that the spacing remains about constant. Rare spine bases occur on the costæ, except on the cardinal terraces where along the cardinal margin the costæ have broken up into a cluster of long, fine, tubular spines from 25 to 50 in number on either side.

Fine, regular, microscopic, concentric lines crenulate the costæ, and conspicuous concentric wrinkles mark the postero-lateral flanks and extremities, some of which may pass faintly over the mesial part of the valve.

Brachial valve, concave, the concavity approximating the convexity of the opposite valve but more depressed in the visceral region, giving rise to a subgeniculation on passage into the trail. Visceral portion subhemispherical, but the cardinal extremities appear as flat, triangular auriculations. Surface ornamented as in opposite valve except that the costæ increase by bifurcation, the spine bases are lacking, and the concentric wrinkles extend prominently over the mesial region of the valve.

The cardinal process is small, rarely exceeding 0·5 mm. in length beyond the hinge-line and 1·75 mm. in breadth. A median septum extends forward from the base of the process for one-fifth to two-fifths length of the valve. Muscular and brachial impressions not preserved.

Dimensions. Neotype, 7952: length, hinge-line to front, 26 mm.; length, umbone to front, 31·5 mm.; midwidth, 28 mm.; width along hinge-line, 23+ mm.; convexity of pedicle valve, 19 mm. Plesiotype, 7952a:

length, hinge-line to front, 19·5 mm.; length, umbone to front, 21·5 mm.; midwidth, 23 mm.; width along hinge-line, 22+ mm.; convexity of pedicle valve, 11 mm.

Remarks. Although *Productus lyelli* agrees in size and general characters with *Productus cora* d'Orbigny the costæ are finer, the presence of spine bases on the flanks or venter is extremely rare, and the auriculations are wrinkled, slightly rolled, more extended, and marked by a cluster of spines which, several spines in depth, borders the cardinal area. The costæ over these flattened extremities curve towards the cardinal margin and distally are continued as spines. D'Orbigny's figure on the other hand represents costated, unwrinkled auriculations. These differences from *P. cora* characterizing the Windsor species, distinguish it also from *P. ovatus* Hall, although the Chester forms of this latter species resemble very closely some variants of the Windsor form. *P. cora* Davidson is typically a much larger form. *P. dawsoni* Beede is more depressed and lacks postero-lateral wrinkling. *Productus auriculispinus* Beede is perhaps synonymous, representing young forms of *P. lyelli,* but the distribution of spines on the auricular areas is somewhat different. *Linoproductus tenuistriatus* (Verneuil) as described by Chao is quite closely allied to *Linoproductus lyelli.* The auriculations, however, are smaller and the number of spines bordering the cardinal line fewer.

Horizon and Localities. Lower Windsor: localities, 7497, 7498, 7502, 7513, 7533, 7551, 3266, 3424, 3518. Upper Windsor: localities, 7505, 7511, 7532, 7519, 7501, 7554, 7510.

Types. Neotype, 7952; plesiotypes, 7952a, 7952b, 7952d, 7952f, 7952g, 7952h; National Museum of Canada, Ottawa.

Productus lyelli var. *a*

Plate XVI, figures 9, 10, 11

Remarks. A form smaller in size, more regularly transverse, and with a relatively shorter hinge-line occurs at Summerville, Hants county, and at Maccan river, Cumberland county, seemingly in slightly lower horizons than *P. lyelli.* Several of the Summerville specimens of this form display abundant slender spines, 10 millimetres or more in length along the cardinal border of the pedicle valve. Similar spines lie sparsely scattered over the anterior flanks of the same valve. These specimens are much flattened or depressed by pressure and occur in dark, bituminous, calcareous shale. Specimen 7964, from Maccan river, is preserved without distortion, and is chosen as the holotype representing the mean of the forms of this nature. Its dimensions are: length hinge-line to front, 16 mm., length umbone to front, 19 mm., midwidth, 20 mm., width along hinge-line, 15 mm., convexity of pedicle valve, 9 mm.

Horizon and Localities. Lower Windsor: localities, 7545, 7522.

Types. Holotype, 7964; paratypes, 7964a, 7949; National Museum of Canada, Ottawa.

Productus lyelli var. *b*

Plate XVI, figure 6

Remarks. The costæ are broader and more prominent than in *P. lyelli,* numbering about 11 in 5 mm. upon the main flanks of the pedicle valve.

Horizon and Locality. Lower Windsor, locality 5475.

Types. Holotype, 7684; National Museum of Canada, Ottawa.

Productus (Linoproductus) dawsoni Beede

Plate XVII, figure 1

Productus dawsoni Beede, N.Y. State Mus. Bull. 149, p. 162, figure (1911).

Original Description

"Specimen nearly subquadrate in outline, widest somewhat in front of the middle. The hinge is slightly shorter than the greatest width of the shell, the lateral margins are concave posteriorly and very gently rounded into the evenly curved anterior margin. The shell is quite depressed for a *Productus* and the beak barely projects beyond the hinge, not recurving round it. The ears are nearly flat, triangular, carrying many fine spines. The remaining characters are common to the rest of the surface. The surface of the pedicle valve is ornamented with very fine striæ which are sharply rounded and narrower than the valleys separating them, somewhat inclined to be wavy, increasing by implantation. The spines of this form seem to be confined to the ears, or nearly so. Posteriorly there are very slight concentric wrinkles."

Dimensions. Length and width of shell 20 mm., length of hinge 15 mm. The specimen figured has a convexity of 4 mm., though it may be very slightly flattened. Fifteen or more striæ in 5 mm."

Remarks. This species is very similar to specimens labelled *Productus cora* var. *dawsoni* Hartt from the Carbonic limestone of Nova Scotia. It is also very closely related to the form figured by De Koninck from the limestone of Vise, Belgium, under the term *P. striatus.*"

Remarks. The single pedicle valve assigned to this species agrees in all essentials with Beede's type. It is probably but a variant of *P. lyelli,* although it is much more depressed than typical members of that species and the angle at which the umbone converges to the beak is more acute. It has no close connexion with *Productus (Striatifera) striatus* (Fisher).

The dimensions of the Windsor form are: length 15·5 mm.; greatest width 17·8 mm.; length of hinge, 15·5 mm.; convexity, 4 mm. There are 15 striæ per 5 mm.

Horizon and Locality. Lower Windsor: locality, 3424.

Types. Plesiotype, 7963; National Museum of Canada, Ottawa.

Productus (Linoproductus) semicubiculus n. sp.

Plate XVII, figures 4, 5, 6, 6a

Description. Small, strongly convex, sub-semicubical, auriculate; hinge-line nearly equal to the greatest width.

Pedicle valve, convex, subgeniculate posteriorly, with well-marked, triangular, flattened, or slightly rolled auriculations. The postero-lateral slopes to these auriculations are abrupt, concave at the base. The ears bear about 15 rather stout, unequal spine bases. Occasional spine bases are situated on the costæ of the main flanks. Surface marked by radial costæ which are flatly rounded and which increase regularly by intercalation; those over the mesial portion of the shell originate for the most part at, or posterior to, the geniculate inflexion; interpolation on the lateral flanks occurs at more frequent intervals. From 12 to 17 costæ occupy a space of 5 mm. Fine, concentric growth lines crenulate the costæ, and strong wrinkles mark the ears and postero-lateral flanks, several of which may traverse the venter, but much more faintly. Brachial valve follows rather closely the contour of the pedicle valve. Concentric ribbing passes more strongly over the median portion, particularly in the neighbourhood of the geniculation. The costæ increase by bifurcation, and spine bases are absent; fine, concentric growth lines are present as in the opposite valve.

Dimensions. Length, umbone to front, 14·2 mm.; midwidth, 13·2 mm.; width along hinge-line, 12 mm.+; convexity of pedicle valve, 7 mm.

Remarks. This species was first thought to represent young or dwarf individuals of *P. lyelli* with which it is closely related. However, few, or no, certain gradational forms occur, and the species is further characterized by its relatively broader costæ, and by the subgeniculate inflexion of the pedicle valve not far in front of the cardinal margin.

It is distinguished from *P. auriculispinus* Beede by its subgeniculate form, relatively longer hinge-line, and by the presence of strong, concentric wrinkles on the ears of the pedicle valve; from *P. scitulus* Meek and Worthen by its depressed unbonal region, by the cluster of spine bases on each auriculation, and by the regular increase of the costæ of the pedicle valve by intercalation with no differentiation into groups.

Horizon and Localities. Upper Windsor: localities, 7521, 7501, 7550, 7509, 7508, 7509, 7542, 7522, 7507, 7535, 7526, 7527, 7541.

Types. Holotype, 7951; paratypes, 7947, 7961; National Museum of Canada, Ottawa.

Productus subfasciculatus n. sp.

Plate XVII, figures 7, 8, 9, 10, 10a, 11, 11a, 11b

Description. Pedicle valve, approximating in general form to the specimen figured by Davidson (1858-63, Mon. Brit. Foss. Brach., vol. 2, Pal. Soc.) in figures 2a and 2b, under the name of *Productus semireticulatus*. In comparison the valve is more elongate and is subgeniculated, the umbonal portion is more depressed, and the lateral flanks are more precipitous.

The sinus is obsolete or represented by a faint, shallow depression. The beak is compressed, and narrowly recurved around the hinge-line. The costæ, which are equal in size over the pronouncedly reticulated posterior portion of the shell, where they increase by bifurcation, tend anteriorly with age to differentiate into groups raised above the general surface. Five or six lie within the space of 5 mm. Several stout spine bases are situated on, or border, the auriculations, and smaller ones are sparingly scattered over the rest of the valve.

The shell is thick, with the inner layers pronouncedly punctate or pustulose. The surface is finely crenulated by concentric growth striæ.

Brachial valve, geniculate, with sharply delimited rectangular visceral portion, which is flattened or truncated marginally and gently concave centrally with a slight suggestion of a median fold. Strong concentric ribbing or wrinkling marks this visceral portion of the valve, and this wrinkling is particularly pronounced laterally. Seven to nine costæ occupy a space of 5 millimetres in the visceral portion, which in conjunction with the heavy ribs results in a pronounced *Leptaena*-like rugosity. The flattened border in front is inclined upward, is non-costated, but sparingly nodose.

Dimensions. Length, hinge-line to front, 30 mm.; length, umbone to front, 35 mm.; midwidth, 32·5 mm.; width along hinge-line, 32 mm.; convexity of pedicle valve, 21 mm.

Remarks. Its smaller size, square-cut sides, and semi-cubical form, distinguish this species from *Productus semireticulatus*. In these characters it resembles more closely *P. martini* Sowerby, from which, however, it is distinguished by the character of its costation.

In the tendency of the anterior costæ towards a fascicular arrangement, as well as in the distribution of spine bases, the species resembles *P. fernglenensis* Weller; but has a longer hinge-line than that species and an inferior, and more regular, curvature of the pedicle valve.

The costation is finer than in *P. costatus* Sowerby, from which it differs also in the smaller auriculations, the absence of auricular ridges, and the less abruptly arched pedicle valve.

Horizon and Localities. Upper Windsor; localities, 7511, 7505, 7524.

Types. Holotype, Peabody Museum, Yale University. Paratypes, 7955, 7958, 7959; National Museum of Canada, Ottawa.

Productus (Striatifera) cf. *latissimus* Sowerby

Plate XVIII, figure 12

1822. *Productus latissimus* Sowerby, Min. Conch; Pl. 330.

Description. (Based on a single, imperfect, distorted pedicle valve.) Shell smaller than *P. latissimus* Sowerby, but otherwise much like it in general form, which departs widely from other Producti. Mesial sinus obsolete. The costæ increase by intercalation, numbering 5 per 5 mm. posteriorly, increasing to about 8 per 5 mm. anteriorly. Beak small, projecting slightly, recurved behind the hinge-line. Spine bases not preserved. A shallow concave area, scarcely exceeding 1 mm. in width, borders the cardinal line in the cast of the pedicle valve.

Dimensions. (Imperfect on account of distortion.) Length, hinge-line to frontal margin, 25 mm., length umbone to front, 38 mm., half the width along hinge-line, 22·5 mm., convexity of pedicle valve, 23·5 mm.

Horizon and Locality. Upper Windsor; locality, 7527.

Types. Holotype, 7435; National Museum of Canada, Ottawa.

Productus (Avonia) spinocardinata n. sp.

Plate XVII, figures 2, 2a, 2b, 3, 3a, 3b

Description. Shell small, concavo-convex, subquadrate, auriculate; hinge-line about equal the greatest width.

Pedicle valve with greatest tumidity posterior to the middle, whence the slope to the cardinal margin is abruptly convex and to the frontal margin somewhat less so. Venter, broad and flattened; lateral flanks, precipitous. Beak, blunt, incurved; umbone, projecting well beyond the hinge-line. Auriculations, small but stout, convexly rolled. Surface marked over the youthful umbonal region by scattered spine bases; over the rest of the valve by pronounced costæ, which become of unequal strength and breadth over the frontal half of the valve, where 4 or 5 occupy the space of 5 mm. The costæ increase by bifurcation. Pronounced concentric wrinkles extend from the cardinal line over the visceral portion of the surface, sharply differentiating this region from the frontal extension. Scattered spines are borne on the costæ, with the junction of the concentric visceral ribbing and costæ either nodose or spinose. Where the concentric ribs emerge on the hinge-line there is a linear cardinal row of spines that recurve sharply around the cardinal margin. Twelve or more commonly lie on either side the beak, increasing in size towards the cardinal extremities. Fine concentric growth lines cover the surface of well-preserved specimens.

Brachial valve deeply concave, otherwise characters unknown.

Dimensions. Length, hinge-line to front, 11·5 mm.; length, umbone to front, 15 mm.; midwidth, 17·5 mm.; width along hinge-line, 14·5 mm.; convexity of pedicle valve, 8 mm.

Remarks. The species differs externally both from *Protoniella beedii* and *Productus avonensis* in the coarseness and inequality of its costæ, in the more marked concentric visceral ribbing of the pedicle valve, and in the row of spine bases set close upon the hinge-margin. It agrees so closely with *Productus muricatus* Phillips that it may be identical with it. It is, however, specifically distinct from American forms designated *P. muricatus.* As compared with Phillips' species it is somewhat more transverse, and is characterized by the strong concentric ribbing of the visceral portion of the pedicle valve. From *P. muricatus* Norwood and Pratten the following differentia may be noted: (1) the auriculations are not thin and flattened, but small, stout, and convex; (2) the beak is stout and projects somewhat beyond the cardinal border; (3) the shell is more strongly convex and of larger size. It is smaller than *P. costatus* Sowerby, has narrower costæ, and much less pronounced auriculations.

Horizon and Localities. Upper Windsor; localities, 7505, 7507, 7512, 7519, 7535.

Types. Holotype, 7950; paratype, 7948; National Museum of Canada, Ottawa.

Pustula exigua n.sp.

Plate XVIII, figures 19, 20, 20a, 20b

Description. Pedicle valve with general form like *Productus biseriatus* Hall, but smaller, and with conspicuous curved auriculations. The umbone is narrow, projects prominently above the hinge-line, and has a closely incurved beak. The hinge-line is shorter than the greatest width, the shell spreading laterally with cardinal angles about 130 degrees. The ornamentation is similar to that of *P. biseriatus* Hall or *Pustula elegans* (M'Coy).

Remarks. The Windsor species is distinguished from *Pustula biseriatus* (Hall) by its smaller size, and rather sharply differentiated auriculations. As compared with *Pustula elegans* (M'Coy) the main differences are: (*a*) The minor spine bases of the posterior row are situated frequently in alternation, one between a pair of the major ones. (*b*) The auriculations are well delimited and curved. It has characteristic differentia from *Pustula venusta* Thomas, as: (1) the ears are more sharply delimited; (2) the concentric bands are narrower; (3) the anterior or weaker spine bases occur in not more than two rows; (4) the brachial valve is less concave; (5) the concentric bands are sharply differentiated without gradation from one to another.

Weller has proposed the name *Echinoconchus* for the pustulose Producti almost contemporaneously with the separation by Thomas of the same group under the name *Pustula.* Thomas' classification, however, seems to have had priority in print. Weller's genus *Echinoconchus* is included in Thomas' genus *Pustula* as the latter embraces not only those forms typified by *Productus punctatus* and *Productus pustulosus* which possess more or less sharply defined concentric bands or ribs, but, as well, forms such as *Productus spinulosus* in which the concentric ornamentation is not clearly defined.

Horizon and Locality. Upper Windsor; localities, 7511, 7503.

Types. Holotype, 7436; paratype, 7967; National Museum of Canada, Ottawa.

Buxtonia cogmagunensis n.sp.

Plate XVIII, figures 13, 14, 15, 16, 17, 18, 18a

Description. (Based on a crushed specimen). The form of the pedicle valve approximates the associated species *Productus avonensis,* but is characterized by an abundance of closely appressed spine bases on the surface of both valves, giving the costæ the appearance of overlapping recumbent spines. The sinus is shallow and broad. The lateral and anterior margins are smoothly rounded, with cardinal extremities subrounded and making an angle of 90 degrees or more with the former. Concentric ribbing is conspicuous only on the cardinal and lateral flanks. The beak is closely incurved. Brachial valve, semiovate to semicircular, flattened in the visceral portion, with greater concavity immediately in front of the conspicuous knob-like beak, geniculated laterally and anteriorly. Concentric ribbing passes over the visceral portion of the valve.

As a result of this concentric marking and the frequent bifurcation and discontinuity of the costæ, the surface has the appearance of being marked with anastomosing costæ furnished with abundant spines.

Internally, the median septum is divided posteriorly as in *P. scabriculus* Martin. Anteriorly, the single septum is relatively longer than in that species.

The shell substance is apparently thin, as the specimens are usually crushed and distorted.

Remarks. This species is readily distinguished from its associates by the spinous ornamentation of both valves. It is closely related to, and may be identical with, *Productus scabriculus* Martin, as the internal as well as the external characters are similar.

Horizon and Locality. Upper Windsor; localities, 7507, 7512, 7519, 7505, 7535.

Types. Holotype, 7442d; paratypes, 7442, 7442a, 7442b, 7442c, 7465; National Museum of Canada, Ottawa.

Diaphragmus tenuicostiformis (Beede)

Plate XVIII, figures 1, 1a, 1b, 2, 2a, 2b, 3, 4, 5, 6, 7, 7a, 8, 8a, 9, 10, 11

Productus tenuicostiformis Beede, N.Y. State Mus. Bull. 149, p. 164, figs. (1911).

Original Description

"Shell subquadrate, gibbous; hinge as long or longer than the transverse diameter of the shell; lateral margins nearly straight from the hinge nearly to the front of the shell where they gently curve nearly to the straight anterior border; beak but slightly produced beyond the hinge, not recurved very slightly and very broadly inflated. Pedicle valve very strongly arcuate longitudinally, and a terrace is frequently traceable around the shell at the edge of the visceral chamber; surface sculptured with moderately fine radiating striæ about equal in width to the intervening depression, increasing largely by interpolation in the older part of the shell and by splitting in the anterior portion. Ten or twelve spines are scattered over the surface of the shell and several crowded on the ears. Posterior part of the valve marked with concentric wrinkles becoming stronger near the ears. The interior of the valve has the muscular attachments well developed and sharply defined as is revealed in a cast; anterior adductors attached to low, indistinct ridges; diductors attached to 4 or 5 low bilobate or looped ridges on either side of the adductors. Brachial valve more clearly subquadrate than the pedicle valve, the hinge being about equal to the anterior width of the shell. Valve nearly flat over the visceral region, somewhat depressed in the central region and elevated around it, geniculated at the margin (unless surrounded by a wall). Beginning at the ears, a very narrow platform extends outward, enlarging as it passes around the sides to the anterior of the valve where it has a width of a millimetre or more. Mesial septum reaching well toward anterior part of valve. Adductor attachments nearly round, but showing a tendency to digitigrade lobation. Cardinal process bilobate at least below, as shown in the cast."

Dimensions. Length of shell, 14 mm; width, 18 mm; length of hinge, 19 mm; 9 or 10 striæ in 5 mm."

Remarks. As supplementary to Beede's description the following characters may be noted. The ears are well-marked, flattened, or semicylindrical. Spines are most numerous on the cardinal and lateral flanks where as many as 35 on either side may be present; they are more freely scattered over the visceral portion of the venter of the pedicle valve than in front of the shell. The umbonal portion has only faint, or discontinuous, costæ, but is marked by close, concentric ribs (particularly noticeable on very young individuals), fine concentric striæ, and scattered spine bases. The development of costation, therefore, is similar to that of Thomas' genus *Avonia* and suggests that that character arose independently in parallel stocks. The average number of costæ in the frontal portion of the shell is about 9 in a space of 5 mm., the number varying from 6 to 12.

The internal platform that characterizes Girty's genotype, *Productus cestriensis* Worthen, is well marked in the present species as a thin, distinct diaphragm connecting the 2 valves at the margin of the visceral portion or at the geniculation. It may be horizontal in position, but is more commonly inclined slightly upwards when the brachial valve is held in a dorsal position. It is faintly marked with costæ seemingly in line with those of the brachial valve and in this character differs from *D. cestriensis* of which the diaphragm is finely striated. This platform is so constantly seen whenever the preservation is suitable that its genetic importance seems warranted.

Externally, *D. tenuicostiformis* differs from *P. tenuicostus* Hall in its smaller size, in the rather abrupt initial geniculation of the pedicle valve a little in front of the hinge-line, in the depression of the region of the valve posterior to this geniculation, and in the beak that scarcely projects beyond the hingle-line.

This species is only separable from *D. montesanae* Ulrich by its relatively broader hinge-line and visceral region, and by the more abrupt slope from the summit of geniculation to the cardinal margin, the umbonal region not protruding so conspicuously beyond the hinge-line. It departs from that species too in the coarseness of the costation, and in the ratio of breadth to length. Otherwise the internal diaphragm is situated in average specimens from 9 to 10 mm. in front of the hinge-line and is about 2 mm. in breadth, which is in close agreement with the Monte Sana species.

Dimensions. Length, hinge-line to front, 15 mm.; length, umbone to front, 17 mm.; midwidth, and hinge-line, 19·3 mm.; gibbosity, pedicle valve, 10 mm.

Horizon and Localities. Lower Windsor (abundant); localities, 7498, 7497, 7522, 7539, 7513; Upper Windsor (rare); localities, 7526, 7502, 7515, 7503, 7504, 7509, 7511, 7525, 7540, 7505, 7501, 7527, 7522.

Types. Plesiotypes, 7460, 7943, 7943a, 7943b, 7943d, 7943k, 7944, 7944a, 7945, 7946, 7960b; National Museum of Canada, Ottawa.

Productus avonensis n.sp.

Plate XIX, figures 15, 16, 17, 18, 19, 19a, 20, 21, 22, 22a, 23

Productus semireticulatus Davidson, Quart. Jour. Geol. Soc. Lond., vol. 19, p. 174, Pl. 9, figs. 20-21 (1863).

Productus semireticulatus Dawson, Acad. Geol., 2nd ed., 1868, pp. 296-297, figs. 97A.

Description. Shell, medium size, subgeniculate, concavo-convex, hinge-line shorter than the greatest width. Pedicle valve with greatest convexity posterior to the middle, from which the slope to the cardinal margin over the visceral portion of the shell is precipitous. Posterior lateral slopes to the flattened auriculations are nearly perpendicular anterior and antero-lateral slopes more gently convex. A mesial rounded sulcus begins as a shallow depression posteriorly and becomes most pronounced in general at the geniculation, flattening anteriorly. Surface ornamented with from 5 to 9 rounded costæ per 5 mm., which increase by bifurcation, more rarely by interpolation. The visceral portion of the valve is crenulated by concentric wrinkles, which are especially pronounced over the cardinal slopes. Fine concentric growth lines when preserved produce a microscopic crenulation of the costæ. Scattered spine bases, rather delicate, are borne on the costæ, but are somewhat more numerous in the vicinity of the auriculations. Brachial valve, nearly flat over the visceral region, subgeniculate laterally and anteriorly. Beak, minute, inconspicuous, fronted by a small, subcircular, markedly concave area representing a strongly concave youthful stage. Commencing anterior to this depression there is a triangular, slightly raised but not sharply defined, fold corresponding to the sulcus of the opposite valve. The costæ increase by intercalation and are pronouncedly crenulated in the visceral portion of the valve by concentric ribbing. Spine bases seemingly absent. Internally, the median septum is long and slender, extending four-fifths length of the flattened visceral area. It is bifid posteriorly, arising at the base of a stout bifid cardinal process. The cardinal margin is bordered by a thickened ridge on either side of the cardinal process. Elongated anterior adductor callosities about 3 mm. in length border the median septum posteriorly. Surrounding the visceral costated portion of the valve, at the geniculation, is a narrow, slightly rugose border or terrace about 1 mm. in breadth, representing an extremely narrow diaphragm.

Dimensions. Length, hinge-line to front, 19 mm.; length, umbone to front, 22·5 mm.; midwidth, 25 mm.; width along hinge-line, 25 mm.

Remarks. Internally the characters are somewhat similar to *D. tenuicostiformis* with the exception that the adductor scars are more elongate and the border or diaphragm of the visceral portion is relatively much narrower.

Certain individuals of *D. tenuicostiformis* that show more or less of a sulcation in the pedicle valve closely resemble small individuals of the present species. Spines are more freely scattered over the surface of *P. avonensis* and are not noticeably clustered along the borders of the ears as in *tenuicostiformis*. Dawson's fig. b. Acad. Geol., p. 297, is in all probability *D. tenuicostiformis*. Of the *P. semireticulatus* group figured by Davidson (Mon. Brit. Foss. Brach., vol. 2, 1858-63, Pl. 43) figs. 9, 10 of *P. concinnus*, and figs. 6, 7, 8, of *P. martini* resemble this species closely in external form. The typical *P. semireticulatus* of figure 1 is a much larger and more strongly semireticulate form.

P. avonensis is seemingly closely allied to *P. inflatus* McChesney. The auriculations, however, are somewhat more depressed; there is a more pronounced tendency for the costæ to bifurcate and coarsen towards the anterior margin and the presence of scattered spine bases on the costæ of the body of the pedicle valve is more pronounced. In some of these characters, as well as in the shallowness of the mesial sinus, the Windsor species agrees with *P. burlingtonensis* Hall, but is less convex than that species; its umbone is less inflated; the auriculations are more pronounced and they are marked by a number of well-defined spine bases; the costæ remain pronounced to the anterior margin and carry a greater number of spines; the brachial valve, too, is more strongly plicated and wrinkled. Although the costæ commonly broaden and flatten anteriorly in *P. avonensis* there is absent a distinct tendency to fasciculation that marks the costæ of *P. fernglenensis* Weller.

Horizon and Localities. Upper Windsor: localities, 7519, 7505, 7507, 7512, 7510, 1302.

Types. Holotype, 7953; paratypes, 7953a, 7953b, 7953c, 7956a, 7957, 7965, 7966a, 7670; National Museum of Canada, Ottawa.

Camarotoechia acadiensis (Davidson)

Plate XIX, figures 3, 3a, 3b

Rhynchonella acadiensis Davidson in Dawson, Acad. Geol., 2nd ed., 1868, pp. 294, 295, fig. 94.

Original Description

"Shell small, obscurely rhomboidal, about as wide as long; dorsal valve rather more convex than the ventral, and presenting, when viewed in profile, a regular curve. The mesial fold commences towards the middle of the valve, while the surface is ornamented with 12 or 13 small radiating ribs, of which 4 or 5 occupy the surface of the fold. The sinus in the ventral valve is of moderate depth, and the surface is ornamented as in the dorsal valve. The beak is gently incurved, and exhibits a small, circular foramen under its angular extremity. Length 5 lines, width 5 lines, depth 3 lines."

Remarks. Specimen 4348a has a maximum width of 10·3 mm., length 8·7 mm., thickness 5·5 mm. It is, therefore, more ovate than the specimen figured by Davidson and has much the same form as *Camarotoechia atlantica.* The costæ in *C. acadiensis* are less prominently raised than in *C. atlantica* and are more numerous; the beak in the pedicle valve is more tumid and rises more prominently beyond the other valve.

Horizon and Locality. Lower Windsor; locality, Windsor, N.S.

Types. Plesiotype, 4348a; National Museum of Canada, Ottawa.

Camarotoechia atlantica n.sp.

Plate XIX, figures 1, 1a, 1b, 2, 2a, 2b, 2c

Description. Pedicle valve, broader than long, depressed convex, with rather broad sinus commencing in the midregion, and with a frontal truncated lingual extension. Greatest convexity is in the umbonal region, whence the slope, abrupt to the cardinal margins, is gently convex to the antero-lateral margins, or even slightly concave contiguous to the margins. Beak acutely pointed, prominent, incurved over the umbone of the brachial valve. Two or three subangular costæ lie in the sinus, with 3 to 5 on either side. Surface marked in addition by concentric ribbing and finer growth lines. Internally, the dental lamellæ are prominent, nearly straight, and relatively long, being longer than the median septum of the brachial valve. They diverge slightly anteriorly, and are unsupported by accessory plates.

Brachial valve, gibbous, with greatest convexity near the front, gently convex medially, but descending more rapidly to the margins. The fold is differentiated in the forward half of the valve, and carries 3 or 4 plications. Otherwise ornamented as the pedicle valve. Internally, a median septum reaches forward from the beak to about one-third the length of the valve. In the posterior rostral portion this septum is divided so as to form a crural chamber, which is roofed over for a short distance by the hinge-plate, and which is subdivided by two short plates running from the neighbourhood of the beak to each lateral septum. Anteriorly the hinge-plate is divided.

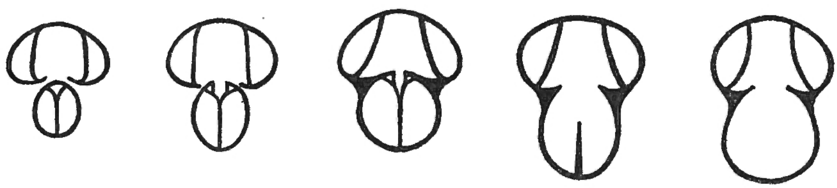


Figure 4. Serial sections of rostral end of shell of *Camarotoechia atlantica* (x 4), showing median septum, crural cavity, and divided hinge-plate of brachial valve, and dental lamellæ, of pedicle valve.

Remarks. *Camarotoechia elegantula* Rowley is a smaller American species which resembles this one in its transverse form, but which seems to lack the concentric ribbing, and which bears a greater number of plications in the sinus.

Dimensions. Length of pedicle valve, 10·7 mm.; length of brachial valve, 9·2 mm.; midwidth, 12 mm.; thickness, 6·5 mm.; width of sinus in front, 7·5 mm.

Horizon and Localities. Upper Windsor; localities, 7519, 7535, 7507.

Types. Holotype, 7473; paratypes, 7475, 4348a; National Museum of Canada, Ottawa.

Pugnoides ? sp.

Plate XIX, figures 5, 6

Remarks. Associated with *Camarotoechia atlantica* is a rhynchonellid of much the same form, but with fewer plications, which are restricted to the middle and frontal portions of the shell. The fold of the brachial valve bears 3 subangular plications, and 2 or 3 oblique ones occur on either side.

Assuming that the internal characters are camarotoechoid the obsolescence of costæ in the posterior region of the shell would place this species under the genus *Pugnoides* Weller.

Dimensions. Length, brachial valve, 11 mm.; width, restored, 10 mm.±

Horizon and Localities. Upper Windsor; localities, 7535, 7519.

Types. Holotype, 7469; paratype, 7469a; National Museum of Canada, Ottawa.

Pugnax dawsonianus (Davidson)

Plate XIX, figures 7, 7a, 8, 8a, 9, 10, 11, 12, 12a, 13, 14

Rhynchonella dawsoniana Davidson, Quart. Jour. Geol. Soc. Lond., vol. 19, p. 172, Pl. 9, figs. 13-14 (1863).

Camarophoria? globulina? Davidson (non Phillips), Quart. Jour. Geol. Soc. Lond., vol. 19, p. 171, Pl. 9, fig. 11 a, b, c (1863).

Rhynchonella dawsoniana Davidson in Dawson, Acad. Geol., 2nd. ed., 1868, p. 294, fig. 93.

Camarophoria? globulina? Davidson in Dawson, Acad. Geol., 2nd ed., 1868, p. 293, fig. 92b.

Rhynchonella evangelina Hartt in Dawson, Acad. Geol., 1868, p. 299.

Pugnax? dawsonianus Hall and Clarke, Pal. N.Y., vol. 8, pt. 2, Pl. 62, figs. 30-33 (1894).

Original Description

"Shell very small, almost circular, a little wider than long; dorsal valve moderately and uniformly convex to about half its length from the umbone, at which point a very slightly elevated and flattened mesial fold begins to rise, and extends to the front; the surface of the shell is also either almost entirely smooth or ornamented with from 8 to 12 slightly marked ribs. The ventral valve is gently convex, with a wide sinus; beak small and incurved. Length, 3½ lines, width, 4 lines, depth, 2½ lines."

Remarks. This species is extremely variable in gibbosity, strength of fold and sinus, and the number of plications. Individuals, perfectly smooth, occur in association with those having from 1 to 5 plications in the sinus of the pedicle valve. Except in young individuals, which commonly have a smooth frontal margin, a fold and sinus are usually present in the anterior part of the shell. But this sinus may vary from the merest shallow, rounded impression to a pronounced sinus with anterior linguiform extension. The costæ may be gently rounded to subangular; they may be entirely absent, or be several in number, on the antero-lateral flanks of the shell. Increase of costæ on the fold or sinus commonly takes place by bifurcation.

The beak of the pedicle valve is typically produced well beyond the hinge-line, and is only slightly incurved. The pedicle valve has a well-marked inflexion of the cardinal flanks so as to produce a pseudo-area. The delthyrium is rather large and is partly closed by marginal deltidial plates.

The general outline is subtriangular to subovate, with an apical angle of 90 degrees to 110 degrees.

The shell has a pearly or iridescent lustre, and the surface of both valves is marked by fine, concentric lines of growth, with occasionally stronger ones towards the front margins.

Internally, there are short, well-developed, slightly diverging, simple dental plates. The cruræ are abruptly bent downward into the pedicle valve. Although a slight ridge separates the adductors in the brachial valve, a true septum is absent, and there is no trace of a septum in the pedicle valve.

Figure 5. Serial sections of rostral end of shell of ***Pugnax dawsonianus*** (x 4), showing dental lamellæ of pedicle valve and absence of lamellæ in brachial valve.

Dimensions. Length, pedicle valve, 8·9 mm. (specimen 7483), 8·8 mm. (7481b), 9·4 mm. (7489), 8·2 mm. (7481a); length, brachial valve, 8 mm. (7483), 7·5 mm. (7481b), 7·2 mm. (7489), 7·3 mm. (7481a); greatest width, 9·2 mm. (7483), 7·5 mm. (7481b), 9 mm. (7489), 9·8 mm. (7481a); thickness, 5·3 mm. (7483), 4·2 mm. (7481b), 4·8 mm. (7489), 6 mm. (7481a).

Remarks. This plastic and prolific Windsor species is more transverse than *Pugnax wortheni* (Hall) and the dental plates are more divergent than in that species.

Horizon and Localities. Lower Windsor; localities, 7497, 7498, 3418, 3266, 3518, 7546.

Types. Plesiotypes, 7481a, 7481b, 7481d, 7482, 7483, 7484, 7484a, 7489; National Museum of Canada, Ottawa.

Pugnax magdalena Beede

Plate XX, figures 1, 1a, 1b, 2, 2a, 3, 3a

Camarophoria? globulina? Davidson (non Phillips), Quart. Jour. Geol. Soc. Lond., vol. 19, pp. 171-172, Pl. 9, fig. 12-12b (1863).

Camarophoria? globulina? Davidson in Dawson, Acad. Geol., 1868, p. 293, fig. 92a.

Pugnax magdalena Beede, N.Y. State Mus. Bull. 149, 1911, p. 156, fig.

Original Description

"Specimens of moderate size, flattened upon fossilization, apparently rather gibbous and orbicular in outline in uncompressed specimens. Posterior third of shell smooth, anterior two-thirds with fold, sinus, and costæ; fold, decidedly elevated and divided by a median sulcus into two strong, angular costæ. There are 2 or 3 costæ on the sides of the brachial valve. Pedicle valve, gently convex posteriorly, deeply and broadly sinuate in front with single broad, low fold in the centre and 2 or 3 on the sides of the valve. The cast, though excellently preserved, shows no indication of a mesial septum in the brachial valve.

Dimensions. Length, 8·5 mm.; width, 9·5 mm.; somewhat modified by flattening."

Remarks. Pugnax magdalena might properly be considered as a varietal form of *P. dawsoni*, as gradations occur between its typical form to both smooth and plicated individuals of *dawsoni*. But certainly it is more serviceable to assign a specific rank to the central *magdalena* form than to employ the more cumbersome trinomial nomenclature. The typical *magdalena* individual differs from the mean *dawsoni* in its sharply elevated fold that is marked by but two angular costæ, and also in its more rhomboid to subtriangular outline.

Dimensions. Length, pedicle valve, 6·5 mm.; width, 6·3 mm.; thickness, 4·2 mm.

Horizon and Localities. Lower Windsor; localities, 3022, 3424, 3518. 7497, 7498.

Types. Plesiotypes, 7479, 7480, 7480a; National Museum of Canada, Ottawa.

Pugnax? sp.

Plate XIX, figures 4, 4a, 4b

Description. Below medium size, globose, subovate, markedly ineqivalve. Greatest width lies at midlength. Internal characters unknown.

Pedicle valve, depressed convex, greatest elevation in the umbonal region. The cardinal and lateral slopes are low and flattened, the former being the steeper. Beak, blunt, incurved, not rising conspicuously above the hinge-line and little, if at all, above that of the opposite valve. The sinus commences a little posterior to the middle, is well defined by a pair of bordering costæ, broadens rapidly anteriorly, but remaining shallow and with flattened bottom. Two simple median costæ arise at the origin of the sinus and strengthen to the front. Two short additional costæ are present in the sinus close to the anterior margin. Two or three rounded costæ mark the anterior lateral flanks. The sinus has a pronounced truncated lingual extension. The surface is marked with fine, concentric growth lines, a few of which are pronounced as wrinkles. Brachial valve, tumid, and much more convex than the pedicle valve. Greatest convexity near the middle. Umbonal region is inflated, and terminates in a small beak that extends a little beyond the cardinal line and is probably hidden by the opposite valve in perfect specimens. Cardinal flanks, precipitous; lateral flanks, steeply sloping. Along the venter the slope to the beak progressively steepens; the anterior slope is comparatively gentle. The fold is only moderately well-defined, arising a little posterior to the middle. It is marked by 3, well-rounded plications, of which the median is simple and of least width. Near the anterior margin the 2 lateral costæ of the fold bifurcate, the intervening sulci thus formed corresponding to the short frontal costæ in the sinus of the opposite valve. Three or more flattened plications mark the anterior half of the valve on either lateral flank and these also tend to be sulcated near the anterior margin.

Dimensions. Length of the brachial valve, 11·5 mm.; greatest width, 13·5 mm., width of sinus in front, 9·3 mm.; thickness, 8·5 mm.

Remarks. From *Pugnax dawsoni* (Davidson) the present species differs conspicuously in the tumid character of the umbonal regions, in the inconspicuous false cardinal area of the pedicle valve, and in the presence of a sharply delimited pedicle sinus.

Horizon and Locality. Lower (?) Windsor; locality, 3512.

Types. Holotype, 7490; National Museum of Canada, Ottawa.

Allorhynchus ramosum n. sp.

Plate XX, figures 6, 6a, 6b, 7, 7a, 7b, 8, 9, 10

Description. Shell small, subrhomboidal to subovate, wider than long, with greatest width anterior to the middle. Pedicle valve, convex on the umbone, with surface sloping abruptly to the cardinal margins, where on either side of the beak there is a narrow inflexion producing a pseudo-area. Towards the lateral margins, the surface is nearly plane; from the beak to the front the surface is more strongly convex. A sinus originates at, or a little back of, the middle of the valve, deepens gently and broadens rapidly anteriorly where it terminates in a broad, rounded extension. The beak rises a short distance beyond the other valve, and is slightly incurved. The delthyrium, about 1 mm. wide at the base, is bordered by narrow deltidial plates. Neanic portion of shell smooth. Subangular costæ arise in the posterior third of the valve, and divide once or twice by dichotomy or, more rarely, increase by interpolation. They number about 25 in the marginal region, of which 7 or 8 lie in the sinus.

Internally, the hinge-teeth are delicate, crescent-shaped, and supported by short, dental lamellæ.

Brachial valve, much more convex than the pedicle, with greatest convexity in the umbonal region whence the surface slopes abruptly to the cardinal margins and more gently and regularly to the antero-lateral and frontal margins. The mesial fold is scarcely differentiated from the mid-length forward as a gentle, inconspicuous arch. The costation is pronouncedly branched by bifurcation as on the opposite valve. The shell-layers are imperforate.

Internally, the hinge-plate is wholly divided, but the valve lacks supporting and medial septa.

Figure 6. Two sections of rostral end of shell of *Allorhynchus ramosum* (x 4), showing dental plates of pedicle valve and absence of lamellæ in brachial valve.

Remarks. The marked increase of the costæ by bifurcation distinguishes this species from other Mississippian rhynchonellid shells.

Dimensions. Length of pedicle valve, 9 mm.; length of brachial valve, 8·5 mm.; greatest width, 11·5 mm.; thickness, 6·5 mm.

Horizon and Localities. Lower Windsor: localities, 3418, 3266.

Types. Holotypes, 7477; paratypes, 7478, 7478b, 7478c, 7478d; National Museum of Canada, Ottawa.

Allorhynchus hartii n. sp.

Plate XX, figures 11, 11a, 11b

Description. Pedicle valve, wider than long, depressed convex, with greatest convexity in the umbonal region; posterior flanks are abruptly convex; the surface from the umbone to the antero-lateral margin is gently convex or slightly concave contiguous to the margins. A sinus begins in the middle or more posteriorly, is very shallow and ill-defined, broadens rapidly anteriorly. The beak is acuminate, strongly incurved over the umbone of the opposite valve. The costæ are rounded, and number 5 on the pedicle sinus, and about 5 are well defined on either lateral flank, with 2 or 3 shorter ones on the postero-lateral border.

Internally, dental lamellæ are present.

Brachial valve, gibbous, and more convex than the opposite valve. The greatest convexity lies in the umbonal region, from whence the descent is about equally steep to the posterior as to the anterior margins. The transverse profile is about semicircular. The fold is ill-defined from the general surface in the frontal half of the valve. The beak is hidden, and incurved beneath the opposite valve.

Figure 7. Serial sections of rostral end of shell of *Allorhynchus hartti* (x 4), showing dental plates of pedicle valve and absence of lamellæ in brachial valve.

Dimensions. Length, pedicle valve, 10 mm.; length, brachial valve, 9 mm.; greatest width, 14 mm.; thickness, 7 mm.

Remarks. Outwardly the species bears strong resemblance to *Camarotoechia atlantica,* but is distinguishable by the greater number of costæ on the fold and sinus as well as by the closely infolded beak of the pedicle valve.

Horizon and Localities. Upper Windsor: localities, 7526, 7511, 7522.

Types. Holotype, 7468; National Museum of Canada, Ottawa.

Allorhynchus cf. *macra* (Hall)

Plate XX, figures 4, 4a, 5, 5a

Rhynchonella sp. Davidson, Quart. Jour. Geol. Soc. London, vol. 19, Pl. 9, figure 15 (1863).

Remarks. Shell small, sub-ovate to subtriangular in outline, with 9 to 11 rounded costæ on each valve.

Pedicle valve, depressed convex, with greatest convexity in the umbonal region. The sinus is shallow, ill-defined, commencing about the middle of the valve and rapidly broadening to the front. The beak is pointed, scarcely incurved, and projects conspicuously beyond the opposite valve. Cardinal slopes inflected in a narrowly concave pseudo-area. Delthyrium triangular, partly closed by deltidial plates. Foramen apical.

Brachial valve, slightly more convex than the pedicle valve, with greatest convexity a little in front of the middle. The anterior and lateral slopes are steeper than the flattened posterior slopes. The fold is ill-defined.

Internal characters are unknown.

Dimensions. Length of pedicle valve, 6 mm.; length of brachial valve, 5·3 mm.; midwidth, 6·4 mm.; thickness, 2·5 mm.

Remarks. Only a lack of knowledge of the internal characters of this little shell forbids its certain identification with *A. macra* (Hall). There seems to be less doubt of its specific identity with the form figured by Davidson.

Horizon and Localities. Lower Windsor: locality, 7513.

Types. Holotype, 7466a; paratype, 7466; National Museum of Canada, Ottawa.

Romingerina anna (Hartt)

Plate XX, figures 12, 12a, 13, 14, 15, 15a, 15b

Centronella anna Hartt in Dawson, Acad. Geol., 2nd ed., 1868, p. 300, figs. 99 a-b.

non *Harttina anna* Hall and Clarke

Original Description

"Shell orbicular, lenticular, equilateral, inequivalve, the dorsal (ventral, Hall) valve being considerably more arched than the ventral (dorsal, Hall). Dorso-ventral diameter about half that of the width of shell—length about a quarter of an inch.

Ventral valve with lamellæ which take their origin near together. These lamellæ separate slightly from one another until they are inclined to one another at an angle from 30 degrees to 45 degrees, when they curve towards the mesial line, and meeting at a very acute angle, are prolonged backwards in a pointed arch to three-quarters to four-fifths the length of the shell, the width of the arch being approximately one-half its length. The planes of the lamellæ are at first parallel, but their dorsal edges soon become moderately inclined outward. The lateral bands are not only bent toward the mesial line, but they are strongly curved, with the convexity towards the ventral valve, the curve being slightly greater than that of the valve. This loop supports on the dorsal side a thin plate, whose plane coincides with the dorso-ventral and anterior-posterior diameter of shell, and a thin plate extends from the apex of the arch forward (backward *auct*), for about two-thirds its length. This plate seems to be of uniform thickness throughout. At the point of the arch the supporting lamellæ are exceedingly slender. Tracing them anteriorly, they are seen running along the central border of the mesial plate, on each side, like a raised line. Increasing in width, they separate themselves more and more along the dorsal margin from the mesial plate, to whose ventral border they are attached for its whole length. The plate has an outline similar to that of a transverse section of a biconvex lens whose diameter is twice its thickness, but in both the loops under examination there is on the dorsal edge a notch that appears to be organic, and to correspond to that of the loop of *Centronella julia* Billings.

The mode of attachment of the mesial plate with the lateral bands is very well shown in my specimens. Professor Hall has called attention to the strong resemblance between the loops of *Centronella* and *Rensselaria*, but there is a much greater resemblance between the loops of my Carboniferous species and that of *Rensselaria.*

This species is not uncommon in the Windsor limestones at Windsor, where it is usually so preserved as to show the interior with loop. The shell appears to be very fragile, and specimens showing the external characters are rare; at least I do not possess an example. There is a species of *Centronella* occurring in the Stewiacke limestones at Windsor and Stewiacke which may be identical with this, but I have no good specimens for comparison."

Emended Description. Shell small, subquadrate to ovate. Pedicle valve, with greatest tumidity posterior to the middle; surface with convexity increasing from frontal margin to the beak, concave and inflected along the cardinal margin. The beak is broad and depressed, well in front of the opposite valve, and pointing at a right angle to the plane of the valves, perforated by a subcircular foramen, which opens anteriorly into the delthyrium. Deltidial plates either exposed or more or less covered by the umbone of the brachial valve. Internally, dental plates, if present, must be widely divergent and closely appressed to the floor of the valve.

Brachial valve, less tumid than the pedicle; greatest convexity in the umbonal region, with almost plane slopes to the lateral and postero-lateral margins, or even slightly concave near the cardinal margins. Surface from the umbone to the frontal margin gently convex. An inconspicuous, extremely narrow, shallow sulcus may be present in the anterior half of the valve. Several rather marked growth ribs in some cases border the frontal margins of the shell, and finer lines are present over the rest of the surface. Internally, the hinge-plate is divided, and the brachidium exhibits a modified centronelloid structure. From slightly diverging vertical positions, the loop lamellæ become horizontal, and, rapidly converging downwards along the median axis of the shell, they unite so as to form a high, median vertical plate, which projects well into the pedicle cavity. Anteriorly this structure gradually diminishes in size, and posteriorly there is a prominent extension, although in the specimen sectioned this was not preserved. The plan of structure is identical with *R. julia* (Winchell). Inner layers of shell finely punctuate.

Dimensions. Length pedicle valve, 9·2 mm. (specimen 7472), 7·5 mm. (7472a); length brachial valve, 8·3 mm. (7472), 6·8 mm. (7472a); greatest width, 9·7 mm. (7472), 7 mm. (7472a); thickness, 4·9 mm. (7472), 3·3 mm. (7472a).

Remarks. The species is variable in form and some individuals are nearly identical with *R. julia* (Winchell), but the mean form is slightly broader. The affinity, however, with the Mississippian species must be very close. Hall was clearly in error in identifying his genotype of *Harttina* with *Centronella anna* Hartt. (Pal. N.Y. vol. 8. pt. 2, pp. 291-292, Pl. 79, figs. 37-39 (1894).) Not only has Dawson's description of the brachidium of *C. anna* been confirmed, but the external characters of *C. anna* have been differentiated and have been found to be wholly unlike *Harttina anna* Hall. In fact *Harttina anna* Hall is a larger size shell that is practically homomorphous with *Dielasma latum*. Hall's genotype of *Harttina* is, therefore, renamed *Harttina halli* to avoid confusion.

Horizon and Localities. Lower Windsor; localities, 7497, 7498, 3022, 3424, 3418, 3512.

Types. Neotype, 7472a; plesiotypes, 7472, 7472b, 7471; National Museum of Canada, Ottawa.

Harttina halli n.sp.

Harttina anna Hall and Clarke, Intr. to study of Brach., pt. 2, Pl. 52, figs. 29-31 (1894).

Harttina anna Hall and Clarke, Pal. N.Y., vol. 8, pt. 2, pp. 291-292, Pl. 79, figs. 37-39, text figs. 211, 212 (1895).

Hall's Description

"The external form of the shell is unusual, being plano-convex or naviculoid, as in the typical species of the genus *Centronella;* the brachial valve is depressed-convex or nearly flat and the pedicle-valve medially ridged with abrupt slopes at the sides. The dental lamellæ of the pedicle-valve are well developed as in *Centronella.* In the brachial valve there is a short, tripartite hinge-plate, supported by a median septum of considerable height in the umbonal region and extending for fully one-half the length of the valve, becoming low anteriorly.

The crura are very short and are continued almost immediately into the long, convergent crural apophyses. The descending branches of the brachidium extend for nearly the entire length of the shell, following the curvature of the valve and approaching each other anteriorly, their extremities being again directed outward. The ascending branches extend backward to points not far in front of the crural apophyses, where they are united by a transverse band. The outer margins of the descending lamellæ are fringed with rather long, irregularly set spinules directed toward the commissure of the valves. There are no spinules elsewhere on the brachidium. Although we are not inclined to place a high value upon the presence of these spinules, they seem to be, in many cases, a natural accompaniment of the brachidium in late Palæozoic species (*See* observations on Athyris); but the entire combination of the centronellid contour of the shell, highly developed median septum, with the fimbriated descending branches of the brachidium, warrants the separation of this type of structure from other known genera from which it may be distinguished by the term *Harttina.*"

(Pal. N.Y., vol. 8, pt. 2, pp. 291-292).

Remarks. The holotype of *H. halli* is preserved with an infilling of clear, crystalline calcite that has artificially been cut out or corroded until the dark outline of the brachidium is conspicuous. A specimen, either a holotype or cotype, kindly loaned by the University of Chicago, agrees in all respects as regards the form of the brachidium, brachial septum, dental lamellæ, with the description of Hall. The shell substance is conspicuously punctate and in form and size is almost indistinguishable from *Dielasma latum.* Although careful search among the writer's material has so far failed to reveal any forms showing an internal *Harttina* structure, it is not improbable such may occur, as the accurate diagnosis of these terebratuloid shells necessitates the grinding or sectioning of many individuals.

Hall was clearly in error in identifying his shell with *Centronella (Romingerina) anna* Hartt in Dawson, because forms agreeing both in size and internal characters with *R. anna* have been identified. *R. anna* is a much smaller shell, and the pedicle valve is depressed and more abruptly upcurved anteriorly.

Holotype, No. 12470, University of Chicago collection.

Composita dawsoni (Hall and Clarke)

Plate XX, figures 16, 16a, 17, 18, 19, 20, 21, 22, 22a, 22b, 23, 23a, 23b

Athyris subtilita (non Hall) Davidson, Quart. Jour. Geol. Soc. London, vol. 19, p. 170, Pl. 9, figs. 4, 5 (1863).

Seminula dawsoni Hall and Clarke, Pal. N.Y., vol. 8, pt. 2, pp. 95-96, 364, Pl. XLVII, figs. 32, 34 (1894); 13th Ann. Rept. N.Y. State Geol., 1894, p. 652; 14th Ann. Rept. N.Y. State Geol. 1895, p. 359, Pl. 9, figs. 14, 16.

Composita dawsoni Beede, N.Y. State Mus. Bull. 149, p. 180 (1911).

Description. Shell, subovate to subquadrangular or rarely subtriangular; width usually less than, but may be equal to, or greater than, the length; greatest width anterior to midlength. Fold and sinus obsolete or but faintly represented anteriorly. Pedicle valve most convex posterior to the middle, with abrupt curvature from the umbonal region to the cardinal margins; sinus obsolete except for a shallow emargination of the anterior border; beak pronounced, strongly incurved, and perforated by a subcircular foramen; delthyrium in open connexion with the foramen, but nearly or entirely, filled by the beak of the opposite valve. Brachial valve, subovate, commonly faintly trilobate, with greatest gibbosity posterior to the middle; mesial fold usually faintly developed in the anterior half of the shell; beak, hidden beneath opposite valve.

Surface of both valves, smooth, but with crowded concentric lines of growth.

Dimensions. Length of pedicle valve, 16·1 mm. (specimen 7501a), 15·4 mm. (specimen 7501), 14 mm. (7501b); length of brachial valve, 14 mm. (7501a), 13·3 mm. (7501), 12·2 mm. (7501b); greatest width, 17·8 mm. (7501a), 15·3 mm. (7501), 13 mm. (7501b); gibbosity, 11·2 mm. (7501a), 11·1 mm. (7501), 9 mm. (7501b).

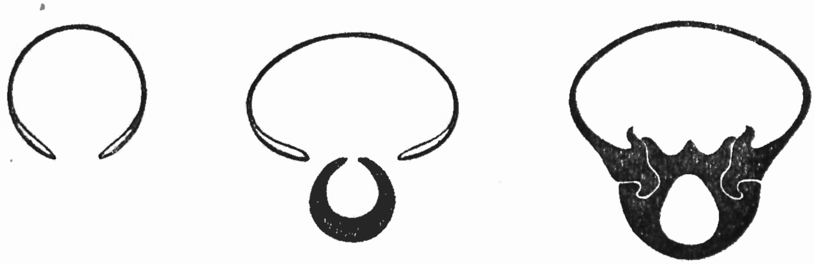


Figure 8. Serial sections of rostral end of shell of ***Composita dawsoni*** (x 4), showing character of hinge and dental lamellæ of pedicle valve.

Remarks. In outward form some individuals of this very variable species resemble *C. subquadrata* (Hall and Clark) and *C. trinuclea* (Hall) from the Mississippian region. The majority of the Windsor forms, however, differ from the above related species in the absence of a ventral sinus. Hall has indicated certain differential characters of this species as follows:

"In *Athyris subquadrata* Hall the lateral branches of the loops are long and projected forward at a sharp angle. In *A. trinuclea* Hall the origin of the loop is more anterior; the branches erect and high, the surface of the bilobed saddle lying close under the opposite side of the coils. *A. dawsoni* is a very interesting form occurring with the most beautiful and exceptional preservation, the brachidium being retained with the slightest incrustation of calcareous matter upon it; all the rest of the shell and the filling of its interior cavity being removed. In this species the loop is almost without a saddle; at the union of the lateral branches there is a slight protuberance on each side, the stem arising therefrom almost without angulation; the accessory lamellæ lie upon the inner edges of the primary lamellæ, and not between the primary and secondary lamellæ as usual; furthermore, these accessory lamellæ are very narrow."

It is this latter character of the accessory lamellæ that particularly characterizes *C. dawsoni* and *C. windsorensis*. It is possible that in one of these species the saddle is less well developed than in the other, or it may be a variable specific character. The edges of both the jugal and spiral lamellæ are fimbriated, although this character is usually obscured by secondary calcite coatings.

Horizon and Localities. Lower Windsor; localities, 7497, 7498, 3022, 3266, 3418, 3424, 3512, 3514.

Types. Cotypes, 12374; University of Chicago, Illinois. Plesiotypes, 7501, 7501a, 7501b, 7501c, 7501d, 7501e, 7501f; National Museum of Canada, Ottawa.

Composita windsorensis n.sp.

Plate XXI, figures 7, 8, 9, 10, 11, 11a, 11b, 12, 13, 14, 14a, 15, 15a, 16, 16a, 17, 17a, 18, 18a

Description. Shell small, typically subcircular but variable to subovate, with greatest width about midlength but commonly more posteriorly. Valves subequally convex. Pedicle valve, with greatest convexity posterior to the middle; cardinal flanks, precipitous, inflected near the beak; lateral flanks and forward slope of venter more gently and regularly convex. A shallow sinus typically present, which commences near the centre or more rarely on the umbone of the valve, and either broadens anteriorly into a shallow depression, or runs to the front with little increase of breadth. Beak, prominent, incurved, but hardly touching the umbone of the opposite valve. Foramen, large and connected with the delthryium, which is largely or entirely closed by the beak of the opposite valve. Surface marked with concentric ribs and bands of growth. Internally has all the characters of *Composita.*

Brachial valve, with greatest convexity posterior to the middle; cardinal slopes, steep, remaining slopes more gently convex; surface rather depressed postero-laterally, and occasionally, somewhat compressed anterolaterally; umbone, small, but rather conspicuous, with beak hidden beneath the opposite valve; median fold, obsolete, or broad and ill-defined anteriorly. Occasionally a short, shallow frontal sinus is present, or in other specimens a narrow, shallow sulcus marks the median line from the umbone forwards. Surface marked as the pedicle valve.

Remarks. The species varies widely in the ratio of length to width, in gibbosity, and in the extent of development of the sinus in either valve.

All gradations are found to a group of individuals, variety *incisa,* possessing a distinct sinus in the frontal portion of the brachial valve with corresponding frontal emargination. Elongate forms of this latter assemblage are treated elsewhere as a distinct species, *C. strigata.*

Differences. From its associates this species is differentiated by its subcircular form and pedicle sinus. The ventral beak is more delicate and less elevated than that of *C. dawsoni.* The shell is larger, more transverse, and broader posteriorly than *Composita lewisensis* Weller. The umbone and beak of the pedicle valve are more delicate than in *Athyris leveillei* de Koninck. Internally the brachial spires are more abruptly conical than in *C. dawsoni,* possessing marked concave outlines anteriorly, and the jugal saddle is possibly more strongly developed than in that species. The adductor scars in the brachial valve are shorter than in *D. dawsoni* and the dental plates in the pedicle valves are likewise shorter.

There is a slight tendency for the growth bands to become lamellose and in this character the species approaches *Athyris.*

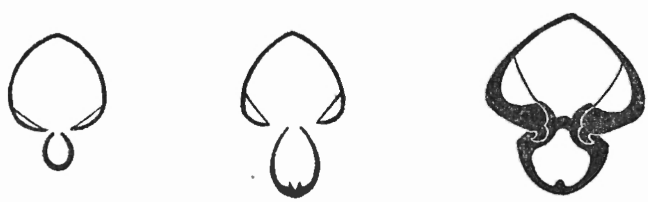


Figure 9. Serial sections of rostral end of shell of *Composita windsorensis* (x 4), showing character of hinge and dental lamellæ of pedicle valve.

Dimensions. Length of pedicle valve, 15·2 mm. (H.T. 7516), 12 mm. (7514), 14·8 mm. (7514a); length of brachial valve, 13·9 (H.T. 7516), 11 mm. (7514), 13 mm. (7514a); greatest width, 14 mm. (H.T. 7516), 10 mm. (7514), 15·9 mm. (7514a); thickness, 9·6 mm. (H.T. 7516), 7·5 mm. (7514), 9 mm. (7514a).

Horizon and Localities. Lower Windsor (abundant); localities, 7497, 7498, 7513, 3022, 3266, 3424, 3418, 3515, 3518. Upper Windsor; localities 7507, 7501, 7512, 7509, 7511, 7505, 7524, 7521.

Types. Holotype, 7516; paratypes, 7515a, 7515b, 7515, 7514, 7514a, 7516a, 7516b var. *incisa;* holotype, 7518; paratypes, 7512, 7516c, 7517; National Museum of Canada, Ottawa.

Composita strigata n.sp.

Plate XXI, figures 3, 4, 5, 5a, 6, 6a

Description. Shell small, subovate, with variable ratios of length to width, the length being typically greater than the width. The 2 valves are subequally convex.

Pedicle valve, greatest convexity posterior to the middle. Cardinal flanks, closely incurved, inflected in the neighbourhood of the beak. Lateral flanks, regularly convex. A narrow sinus originates in anterior umbonal region and becomes more prominent towards the front, but remains shallow. Frontal margin, narrowly emarginate, or truncated. Umbone, narrow, prolonged little beyond opposite valve. Beak, truncated by large, circular foramen. Delthyrium open, but partly or wholly concealed by opposite valve.

Brachial valve, commonly a little less gibbous than the pedicle, somewhat depressed antero-laterally. A narrow umbone projects a little beyond the cardinal line. Beak hidden under opposite valve. A median sinus begins a little posterior to the middle of the valve and runs as a shallow furrow to the front, where, in conjunction with the opposite sinus, it forms a slight emargination.

Surface of both valves marked with narrow, concentric bands which are closer together and more prominent near the frontal margins.

Dimensions. Holotype, length, pedicle valve, 8·2 mm.; length, brachial valve, 7·5 mm.; greatest width, 7·0 mm.; thickness, 4·8 mm.

Remarks. This species is closely connected through gradational forms with *Composita windsorensis.* The distinctive characters displayed by typical specimens are the elongated form and the presence of a sinus in the brachial valve in addition to that in the pedicle.

Horizon and Localities. Lower Windsor; localities, 3418, 7498, 7497, 3266, 3022, 3424. Upper Windsor; localities 7512, 7507, 7511, 7521, 7527.

Types. Holotype, 7510b; paratypes, 7510, 7511, 7510a; National Museum of Canada, Ottawa.

Composita obligata n.sp.

Plate XX, figure 26; Plate XXI, figures 1, 1a, 1b, 2, 2a

Description. Shell of medium size, gibbous; width, equal to, or greater than, the length; subovate to subquadrate in outline. Greatest width at, or anterior to, the middle. Shell substance impunctate.

Pedicle valve, convex, with greatest convexity in the umbonal region. Cardinal flanks precipitous. Lateral flanks and venter moderately convex. A sinus originates in the umbone as a narrow, shallow groove, and broadens and deepens in the anterior half of the shell, producing a strong emargination of the anterior border. Beak rather large, closely incurved, with large, open foramen. Surface marked by concentric ribs, and lamelliform bands, but seemingly the webbed lamellæ characteristic of *Athyris* are not present. Internally, dental plates are well developed, widely divergent. Hinge-teeth strong, with recurved ends.

Brachial valve, convexity equalling, or a little less than, that of the pedicle valve. Greatest height usually back of the middle in the umbonal region. Cardinal flanks steep. Lateral flanks more gently convex, and venter still more so. A fold arises at, or in front of, the middle of the valve, gently rounded or flattened on top, sometimes with a median depression.

Occasionally, a shallow, or more or less pronounced, sinus borders the base of the fold on either side, giving a trinucleate appearance. Beak incurved beneath the opposite valve. Surface marked like the pedicle valve. Internally, there is a prominent, undivided crural plate, which has a minute perforation in the region of the beak. Posteriorly, two short, lateral prolongations of the inner walls of the dental sockets seemingly bear the cruralium.

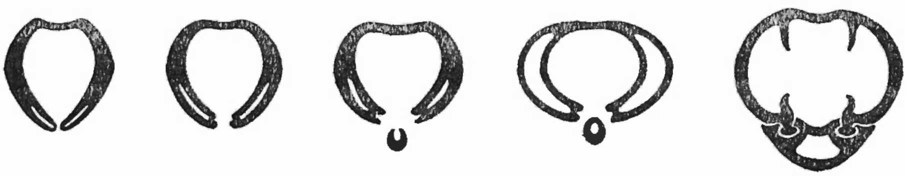


Figure 10. Serial sections of rostral end of shell of *Composita obligata* (x 2), showing hinge, and dental plates of pedicle valve.

Dimensions. Length of pedicle valve, 19 mm. (H.T. 7526b). 16 mm. (7526); length of brachial valve, 16 mm. (H.T.), 13·2 mm. (7526); greatest width, 20 mm. (H.T.), 16·9 mm. (7526); thickness, 12·9 mm. (H.T.), 9·5 mm. (7526).

Remarks. This species is very variable in form. Individuals may be chosen that resemble strongly *C. subquadrata* (Hall), whereas others are very like *C. trinuclea* (Hall). The Windsor species is undoubtedly closely allied to the Mississippian *C. subquadrata,* and may even be identical.

Horizon and Localities. Upper Windsor; localities, 7511, 7512, 7505, 7527, 7510, 7567, 7519, 7534.

Types. Holotype, 7526b; paratypes, 7526, 7526a; National Museum of Canada, Ottawa.

Composita offirmata n.sp.

Plate XX, figures 24, 24a, 24b, 24c, 24d

Description. Shell, transversely subovate, smooth. Pedicle valve, sloping gently from the umbone forward; narrowly convex from the umbone to the incurved beak; cardinal slopes precipitous; foramen in connexion with open delthyrium, but the latter concealed by beak of brachial valve. A shallow, narrow sulcus extends from the umbonal region forwards, but only slightly, or not at all, emarginates the frontal margin. Surface marked by concentric ribs of growth, irregularly pronounced.

Brachial valve, tumid in umbonal region, whence the surface slopes rather evenly laterally and anteriorly, and precipitously to the cardinal margins. Beak extends beyond the cardinal margin and closes the delthyrium of the opposite valve. A faint indication of a sinus may mark the anterior half of the valve. Concentric marking as in pedicle valve.

Dimensions. Length of pedicle valve, 10·8 mm.; length of brachial valve, 10·0 mm.; greatest width, 13·0 mm.; thickness, 8·0 mm.

Remarks. The transversely ovate form sufficiently distinguishes this species from its neighbours. Its beak does not extend beyond the hinge-line as far as that of *Composita obligata.*

Horizon and Locality. Lower Windsor; locality, 3266.

Types. Holotype, 7507; National Museum of Canada, Ottawa.

Spirifer nox n.sp.

Plate XXII, figures 10, 10a, 10b

Description. Shell, medium-sized, wider than long, with greatest width along the hinge-line in adult forms. Cardinal extremities rectangular or bluntly obtuse when young, becoming acute with age.

Pedicle valve, gibbous, with greatest tumidity near the middle. The umbonal region is tumid, narrowly convex transversely, and extended well beyond the hinge-line. The cardinal slopes are precipitous and concave, flattened at the postero-lateral angles. Antero-lateral slopes regularly convex. The convexity along the median line of the sinus increases markedly from the anterior border to the beak, which is narrowly incurved. The sinus begins near the beak and continues over the umbone as a narrow groove, flattened at the bottom; anteriorly it broadens and deepens, but the bottom remains gently rounded or flat, and the sides are not clearly differentiated from the lateral surfaces. In the sinus a median costa appears in the umbonal region, and proceeds undivided to the front; one or two costæ are disposed on either side, which are derived from successive bifurcations of the costa that borders the sinus. There are 9 or 10 costæ on each lateral flank, which are simple, or rarely 1 or 2 may bifurcate. In addition there are several faint costæ on the nearly smooth, postero-lateral extremities. The costæ are flattened or depressed -rounded. The surface is further marked by fine, sharp, undulating growth lines and by a few coarse, concentric ribs resulting in an imbricating ornamentation. The cardinal area is moderately high, runs the length of the hinge-line, and makes an angle of about 45 degrees to the plane separating the valves; it is flatly triangular, with the lateral margins near the beak gently concave and the distal margins subparallel to the cardinal line; it is marked transversely by close, rounded, irregular plications, and in some cases longitudinally by one or more ribs parallel to the hinge-line. The width of the delthyrium at the base exceeds its height.

Brachial valve, imperfectly known, but the fold is seemingly low and marked medially by a shallow, inconspicuous sinus.

Remarks. The pedicle valve closely approximates *Spirifer bisulcatus* Sowerby in form. It has, however, fewer costæ and these are more depressed, and only rarely increase by bifurcation and never by intercalation on the lateral flanks. The shell is also probably less gibbous. In the broad, scarped ribs, concentric ornamentation, transverse form, and almost smooth cardinal region, the Windsor species is much closer to *Spirifer bisulcatus* var. *oystermouthensis* Vaughan.

As compared with *Spirifer increbescens* Hall, the plications are depressed, faint in the umbonal region, and nearly or wholly obsolete in the postero-lateral regions; moreover, the hinge-line is less mucronate, and the umbonal region is narrow and tumid. The division of the ventral costæ is alike in the two species.

Spirifer loydensis Weller is also somewhat similar in form. Its cardinal area, however, is more incurved and its costæ greater in number both on the sinus and on the lateral flanks.

Dimensions. Length of pedicle valve, 27 mm.; width of pedicle valve, 32 mm.; Convexity of pedicle valve, 12 mm.; height of cardinal area, 4·3 mm.

Horizon and Localities. Upper Windsor; localities, 7534, 7501, 7524.

Types. Holotype, 7532; National Museum of Canada, Ottawa.

Spirifer adonis n. sp.

Plate XXII, figures 11, 11a, 11b, 11c, 11d

Description. Shell, medium-sized, wider than long, the hinge-line smaller than the greatest width, the cardinal extremities obtusely subangular.

Pedicle valve, gibbous, with the greatest tumidity near the middle, closely incurved umbone, precipitous cardinal and umbonal flanks, inflated cheeks, and steep lateral and anterior flanks. A narrow sinus commences near the beak, where it is subangular in cross-section, and runs to the anterior umbonal region, whence it rapidly broadens to the frontal border and is there produced as a moderately high, rounded, lingual extension. In the anterior half of the valve the sinus is broad and gently rounded, with flattened bottom. The cardinal area is low, triangular, and narrowly concave. The beak is incurved, but does not project beyond the plane separating the valves. The costæ are much depressed or flattened. In the middle region about 7 occupy the broad, shallow, ill-defined sinus; 12 or more occur on either side of the valve and in addition several fainter, smaller ones lie on the cardino-lateral flanks. Towards the front their number is increased by bifurcation, and as such division may occur almost simultaneously at one stage of growth, the posterior region with a few broad costæ may contrast strongly with the anterior region with its many narrower costæ. Strong growth lines occur at irregular intervals, particularly in the forward part of the valve.

Brachial valve, less gibbous than the pedicle valve, subcarinate along the mid-antero-posterior line. The greatest height of the valve at, or near, the anterior border. The surface, flatly convex along the anterior half of the venter, becomes more narrowly curved towards the beak. The lateral flanks are most gibbous in the umbonal region, but are almost plane, sloping at an angle of about 30 degrees to the horizontal, depressed postero-laterally, slightly compressed antero-laterally. The fold becomes differentiated in the umbonal region, and broadens regularly anteriorly, so that its lateral margins make an apical angle of about 30 degrees. The lateral flanks of the fold curve gradually into the lateral flanks of the valve; on top the fold is narrowly rounded. Surface has flat costæ over both fold and lateral flanks.

Dimensions. Length of pedicle valve, 35 mm.; length of brachial valve, 25·8 mm.; width along hinge-line, 34 mm.; thickness, 24·2 mm.; height of cardinal area, 3 mm.

Remarks. *S. humerosus* Phillips has somewhat greater relative thickness, but is otherwise very similar in form. *Spirifer carinatus* Rowley has a greater proportional width, differs in its costation, and has a more convex brachial valve. The distinguishing characteristics of *S. adonis* are its depressed costæ, its inflated lateral flanks, and the closely incurved umbone of the pedicle valve.

Horizon and Localities. Upper Windsor; localities, 7511, 7524.

Types. Holotype, Peabody Museum, Yale University, Collection 3194.

Spiriferina verneuili n. sp.

Plate XXII, figures 6, 6a, 6b, 6c, 7, 8, 9, 9a

Spirifer cristatus de Verneuil (non Schlotheim) in Lyell, Travels in North America, vol. 2, p. 221 (1845).

Spirifer minimus de Verneuil (non Sowerby), Ibid, p. 221 (1845).

Spirifer octoplicatus de Verneuil (non Sowerby), Ibid, p. 221 (1845).

Spirifera cristata Davidson (non Schlotheim), Quart. Jour. Geol. Soc. Lond., vol. 19, pp. 170-171, Pl. 9, fig. 6 (1863).

Spirifera acuticostata Davidson (non de Koninck), Ibid, p. 171, Pl. 9, figs. 7-8 (1863).

Spirifera cristata Davidson (non Schlotheim) in Dawson, Acad. Geol., 2nd ed., 1868, pp. 291-292, fig. 90.

Spirifera acuticostata Davidson (non de Koninck) in Dawson, Ibid, 1868, pp. 292-293, fig. 91.

Description. Shell, small, wider than long, with hinge-line equal to, or a little less than, the greatest width.

Pedicle valve, convex, with elevated umbone whence the surface is narrowly convex to the beak, moderately convex to the front, but with steep, flattened, lateral slopes. The sinus is sharply delimited, begins at the beak, moderately deep, with flattened bottom. From 4 to 8 subangular to rounded costæ lie on either side of the sinus, of which the first is the most prominent and of which the remainder weaken progressively to the lateral margins. Commonly a faint, more rarely well-defined, costa arises near the middle of the sinus and strengthens towards the anterior border. There is a slight, angular or truncated lingual extension of the pedicle valve. The cardinal area is moderate in size, gently concave, with increasing curvature to the beak; the anterior angle between the area and the plane of the valve slightly exceeds a right angle. The delthyrium varies from less wide, to wider, than high; marginal deltidial plates present. The surface is marked by fine, undulating lamellose growth ribs (commonly two or three per millimetre); the shell substance is markedly punctate. Internally, a prominent, high, median septum runs some two-fifths the length of the valve. The dental plates diverge slightly, and are only about one-half as long as the median septum.

Brachial valve, much less convex than the pedicle, highest near the middle, with posterior slopes steeper than the anterior, postero-laterally depressed at the cardinal extremities. Cardinal areas, small, linear, approximately in the plane of the valve. Beak, small, incurved slightly beyond the cardinal line. The fold is prominent, elevated but little above the general surface, truncated on top, and frequently with a narrow, median sulcus, which originates posteriorly to the middle. The surface ornamented as in the pedicle valve.

Remarks. The various synonyms that have previously been applied to this species are an indication of its prolific variation. The two main directions of variation are in the number of lateral costæ, and in the extent of development of a secondary median fold and sinus.

The species is seemingly closely allied to *Spiriferina spinosa* (Norwood and Pratten), but it is a less transverse form, has a flattened fold with commonly a median groove, and internally the median septum and dental plates are relatively longer. A few specimens from Windsor suggest a possible spinose ornamentation, but secondary mineralization renders the interpretation difficult as slightly exfoliated specimens frequently show a papillose surface due to the mineral fillings of the shell pores. The general form approximates closely to that of *Spiriferina cristata* Schlotheim, except in the narrower and more highly inclined cardinal area, in the truncated brachial fold, in the common presence of secondary fold and sinus, in the shallower ventral sinus and less elevated costæ. It is a less transverse form than *Spiriferina octoplicata* Sowerby. Distinctions from *Spiriferina solidirostris* White are found in its rounded cardinal extremities, relatively shorter hinge-line, narrower umbone, fewer lateral plications, variability in the development of a secondary fold and sinus, and in the longer and thinner dental plates. Also, from *Spiriferina subtexta* White, it differs in a lesser proportionate width, lesser gibbosity, fewer plications, and frequent presence of a secondary fold and sinus.

Spiriferina kentuckiensis Shumard is markedly like *Spiriferina verneuili* in appearance, but is somewhat smaller in size, relatively wider, and commonly more gibbous.

Dimensions. Length of pedicle valve, 8·3 mm. (7521), 8·8 mm. (7521a); length of brachial valve, 6·3 mm. (7521), 7·3 mm (7521a); greatest width, 8·8 mm. (7521), 10·5 mm. (7521a); thickness, 6 mm. (7521), 5·9 mm. (7521a); height of cardinal area, 1·5 mm. (7521), 1·7 mm. (7521a); width of mesial sinus in front, 3 mm. (7521), 3·3 mm. (7521a).

Horizon and Localities. Lower Windsor; localities, 7497, 7498, 3418, 3266, 3512, 3022, 3424, 7536. Upper Windsor; localities, 7521, 7501, 7515, 7526.

Types. Cotypes, 7521, 7521a; paratypes, 7520, 7522; National Museum of Canada, Ottawa.

Spiriferina cf. *octoplicata* Sowerby

Plate XXII, figures 1, 2

Remarks. Shell three or four times as large as the typical *Spiriferina verneuili,* or about the size of *Spiriferina octoplicata* Sowerby, with which it is closely comparable; variable in the ratio of length to width. Five or six narrowly rounded plications, relatively more widely spaced than in *S. verneuili,* occur on either side of the sinus in the pedicle valve. The fold of the brachial valve is narrow, flattened on top, and marked typically by a pronounced median sinus which deepens towards the front. A corresponding fold may arise in the sinus of the pedicle valve. The surface in front is ornamented by sub-lamellose, undulating growth ribs. The shell is rather coarsely punctate.

Dimensions. Length of pedicle valve, 14 mm.; width of pedicle valve, 17 mm.

Horizon and *Localities.* Upper Windsor; localities, 7515, 7501, 7521, 7507, 7526, 7509.

Types. Cotypes, 7519, 7513; National Museum of Canada, Ottawa.

Ambocoelia acadica n. sp.

Plate XXII, figures 3, 3a, 3b, 4, 4a, 4b

Description. Shell, small, plano-convex, subovate, broader than long, greatest width near the midlength, hinge-line shorter than greatest width, cardinal extremities rounded.

Pedicle valve, convex, with greatest tumidity in the prominent umbonal region; cardinal slopes abrupt and concave, lateral and anterior slopes even and more gentle; beak, strongly incurved. Cardinal area, almost at a right angle to plane of valve at hinge-line, concave towards the beak; delthyrium open, as wide as high. Sinus, altogether obsolete, or rarely represented by a very shallow, narrow sulcus that originates in the umbonal region.

Brachial valve, depressed convex, with greatest convexity posterior to the middle, sloping rather uniformly anteriorly and laterally, more steeply posteriorly with slight concavity. Beak, small, scarcely projecting beyond the cardinal margin; cardinal area, very narrow and with open delthyrium. Sinus obsolete.

Surface marked by fine, concentric growth lines, and one specimen has preserved the bases of minute spinules.

Dimensions. Length, pedicle valve, 5 mm.; length, brachial valve, 4 mm.; greatest width, 5·8 mm.; width along hinge-line, 3·8 mm.; thickness, 3·4 mm.

Remarks. This species is very close in form to *Ambocoelia levicula* Rowley. It differs from Weller's figure and description of that species (Illinois, St. Geol. Surv. Mon. 1, p. 426, Pl. 67, figs. 26-31 (1914)), in the obsolescence of a medium sinus in the brachial valve, as well as its rare presence in the pedicle valve, and in the concentric ornamentation that is commonly well defined in the frontal part of the shell; the surface, moreover, was probably minutely spinulose. The Pennsylvanian species *A. planoconvexa* Shumard has a similar form, but is of larger size, and has a more protuberant umbone.

No close approximation to this species could be found in the illustrations of European species. *A. urii* (Fleming) as figured by Davidson (Brit. Foss. Brach., 1857-62, Pl. 12, figs. 13-14d) has a more pronounced sinus with frontal indenture and somewhat more protuberant umbone. It is similar in the presence of surface spinules.

A form figured by de Koninck (Faune du Calcaire Carbonifère de la Belgique, 1887, Pl. 36, figs. 19-23) differs in the narrowness and prominence of the median septum of the brachial valve.

Horizon and Localities. Upper Windsor; localities, 7512, 7507.

Types. Holotype, 7525; paratype, 7525a; National Museum of Canada, Ottawa.

Martinia galataea n.sp.

Plate XXII, figures 5, 5a, 5b; Plate XXIII, figures 1, 1a, 2, 2a, 2b, 2c, 3

Spirifer glaber Verneuil in Lyell, Travels in North America, vol. 2, p. 221 (1845).

Spirifer glaber Dawson, Acad. Geol., 1st ed., 1855, p. 376.

Spirifera glabra Davidson, Quart. Jour. Geol. Soc. London, vol. 19, p. 170, Pl. 9, figs. 9-10 (1863).

Spirifera glabra Davidson in Dawson, Acad. Geol., 2nd ed., 1868, pp. 291-292, fig. 89.

Description. Pedicle valve, gibbous, as wide or wider than long, imperfectly subquadrate. Greatest tumidity posterior to the middle, whence the surface curves abruptly with a concave slope to the cardinal margins, and more moderately to the lateral and anterior margins. Umbonal region extends posteriorly well beyond the hinge-line. Beak, incurved, not reaching as high as the plane separating the valves. Area small, rather ill-defined from the concave, reflected cardinal flanks of the valve, but its surface marked with transverse lines. Delthyrium large, with narrow, deltidial plates. A sinus begins in front of the umbonal region, is broad and shallow anteriorly, and produced in a moderate, rounded, lingual extension. Surface marked by scarcely visible fine costæ which occur over the sinus as well as on the lateral flanks, numbering about 3 or 4 per millimetre, and there may be a faint indication of a broader costation. Concentric growth lines irregularly pronounced, commonly coarse on anterior half of shell.

Internally, sharp, rather discontinuous, plicæ occur on the internal mould. Dental plates absent, but a pair of flange-like laminæ project from the delthyrial border.

Brachial valve, much less tumid than the pedicle valve, with greatest convexity posterior to the middle. Somewhat compressed postero-laterally and antero-laterally. The fold commences in the umbonal region, but is ill defined from the rest of the surface. The beak is inconspicuous, extending a little beyond the cardinal margin, cardinal area narrow. Surface faintly striated, and internally on the mould costæ occur as in opposite valve.

Remarks. The tumid, non-transverse form of this species would seem to make it a derivative of some costate *Brachythyris.* The absence of true dental or septal plates also favours such a derivation. Davidson's *Spirifer glabra* has been shown by Buckman to be a polygenetic species. Of this group figured by Davidson (Mon. Brit. Foss. Brach., 1858-63, vol. 2, Pls. 11, 12) figure 2, Plate 11, is a typical *Martinia glabra* Martin, and is a much larger, as well as a more transverse, form than the Nova Scotian species. Moreover, its fold is typically indented by a mesial sulcus. Figure 9, Plate 12, more closely approximates the Windsor species, although it is also a larger form. Figures 5, 6, 7, Plate 12 (=*Brachythyris rhomboidalis* (M'Coy)) are also alike in form, but have coarser costæ.

Martinia contracta (Meek and Worthen) from the Chester group differs mainly in its relatively greater length, finer and more pronounced striation, and in the mesial depression of the brachial fold. *Martinia sulcata* Weller has a lower ventral umbone, more prominent sinus anteriorly, and has faint or obsolete concentric ribbing.

Dimensions. Length of pedicle valve, 15 mm. (cotype 7524), 23·5 mm. (7523); length of brachial valve, 11·5 mm. (7524), 18·8 mm. (7523); greatest width, 16 mm. (7524), 23 mm. (7523); width along hinge-line, 9 mm. (7524); thickness, 8·5 mm. (7524), 16·5 mm. (7523).

Horizon and Localities. Upper Windsor; localities 7543, 7530, 7521, 7527, 7505, 7533, 7501, 7519, 7511, 7512, 7534.

Types. Cotypes, 7524, 4343; paratypes, 7523, 7524a; National Museum of Canada, Ottawa.

Martinia thetis n.sp.

Plate XXIII, figures 4, 4a, 4b, 4c

Description. Pedicle valve, wider than long, with greatest width posteriorly, convex, with greatest height on the umbone whence the surface drops rapidly with a slightly concave curve to the cardinal margins; slope from the umbone is gently convex to the lateral and frontal margin; more rapidly convex to the beak, which is only slightly incurved. Cardinal area well defined, a little shorter than the greatest width of the valve, making an angle of about 70 degrees with the plane separating the valves, delimited more or less sharply from the cardinal flanks. The delthyrium is large and open in the fossil state. The sinus commences in the anterior umbonal region, and is shallow and ill defined. Surface marked by fine, concentric ribs and bands of growth.

Brachial valve, somewhat less convex than the pedicle valve, greatest convexity in the umbonal region. The cardinal extremities are flattened and lateral slopes depressed. Fold scarcely differentiated save near the frontal margin.

Remarks. This species differs from *Martinia galataea* in its greater relative width, longer hinge-line, and conspicuous cardinal area.

Dimensions. Length of pedicle valve, 13·5 mm.; length of brachial valve, 12 mm.; greatest width, 16·4 mm.; width along hinge-line, 12·5 mm.; thickness, 8·6 mm.

Horizon and Localities. Upper Windsor; localities, 7519, 7512.

Types. Holotype, 7533; National Museum of Canada, Ottawa.

Dielasma davidsoni (Hall and Clarke)

Plate XXIII, figures 8, 9, 9a, 9b, 10, 15, 16, 17, 18

Terebratula elongata (non Schlotheim), and

Terebratula sufflata (non Schlotheim), Verneuil, in Lyell, Travels in North America, 2, p. 220, 1845 (1855).

Terebratula elongata (non Schlotheim) Dawson, Acad. Geol., 1st ed., 1855, p. 219, fig. 27e.

Terebratula sacculus (non Martin) Davidson, Jour. Geol. Soc. Lond., vol. 19, p. 169, Pl. 9, figs. 1, 2, 3 (1863).

Terebratula sacculus (non Martin) Davidson, in Dawson, Acad. Geol., 2nd ed., 1868, pp. 289-290, fig. 87.

Beecheria davidsoni Hall, 14th Rept. N.Y. State Geol., 1894, p. 372, Pl. 14, figs. 8, 9; Hall, Intr. Study of Brach., 1894, pt. 2, Pl. 53, figs. 1-3; Hall, Pal. N.Y., 8, pt. 2, p. 300, fig. 224, Pl. 79, fig. 35 (1895).

Dielasma sacculus (non Martin) Beede, N.Y. State Mus. Bull. 149, 1911, p. 167, fig.

Description. Shell very variable in form, typically elongate-ovate. In mean forms the greatest width is near or anterior to the middle and the anterior margin is rounded. Ratio of length to width 1·3 to 1·5. Pedicle valve smoothly arched along the median line, with convexity increasing posteriorly, surface abruptly inflected to the cardinal extremities. Mesial sinus, obsolete. Beak, prominent, incurved, with large, subovate foramen that encroaches upon the umbonal region of the valve. Deltidial plates may or may not be concealed depending on the variable height and incurvature of the beak. Brachial valve rather evenly convex; no fold or sinus present; beak, acute and hidden by opposite valve.

Surface of both valves smooth, but marked by concentric lines of growth, some of which may be strongly developed. Shell structure finely punctate.

In the pedicle valve dental lamellæ are well developed, diverging slightly anteriorly and extending from one-sixth to one-fifth length of valve. In the brachial valves the socket plates are separated from the crural plates. The latter originate on the inner surface of the valve and between them there is a concave plate with obsolete or rudimentary septum to which muscles were attached. Medially and posteriorly this plate is closely appressed to the valve, but it rises slightly anteriorly, as well as laterally to its union with the crural lamellæ. The brachidium is short, and confined to the posterior half of the valve.

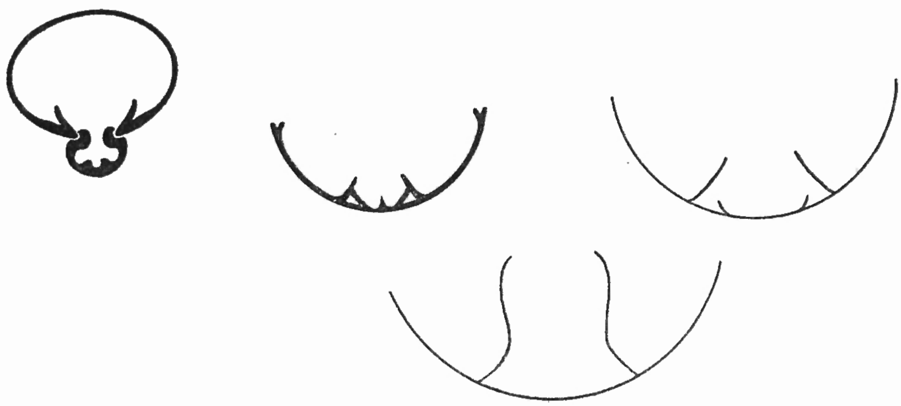


Figure 11. Serial sections of rostral end of shell of *Dielasma davidsoni* (x 4), showing crural lamellæ of brachial valve developed independently on the floor of the valve, adpressed muscular plate between the lamellæ, and remnant of dental plates in the pedicle valve.

Remarks. Hall's description of *Beecheria davidsoni* is as follows:

"Shells small, terebratuliform, broadest medially, attenuate at the beak, valves biconvex, surface smooth. On the anterior the pedicle valve is without dental plates, and the loop, which is short, is supported by a divided hinge plate."

On the grounds of the supposed absence or rudimentary condition of the dental plates Hall created a new genus *Beecheria* for its inception. But among hundreds of individuals collected by the writer, no species was found possessing the internal characters of *Dielasma* and at the same time lacking dental plates. Permission was kindly granted by Dr. Weller of Chicago University to examine the type material of *Beecheria*. Of the four specimens marked as cotypes, one (reproduced as fig. 9, Pl. 14, 14th Ann. Rept. N.Y. State Geol. (1894), and fig. 35, Pl. 79, Pal. N.Y., vol. 8 (1895)) possesses well-marked dental plates and is hereby selected as the lectotype of *Dielasma davidsoni* (Hall and Clarke); a second is a brachial interior of the same species with the cruralium attached to the floor of the valve and this was doubtless the model for fig. 8, Pl. 14, 14th Ann. Report, and fig. 224, page 300, Pal. N.Y.; the remaining two cotypes (reproduced in figs.

7, 10, 11, Pl. 14, 14th Ann. Report, and as figs. 33, 34, 36, Pal. N.Y.) are specimens of *Cranaena tumida* Bell. The diagnosis of ***Beecheria,*** can, therefore, be based no longer on any known Windsor material and its validity as a genus must rest on the characters of ***Hemiptychina sublaevis*** Waagen. There would indeed seem to be insufficient grounds to separate it from *Hemiptychina,* since *H. sublaevis* is stated by Waagen to be connected through gradational slightly plicated forms with *H. himalayensis.*

Dielasma davidsoni is not sharply divided from *Dielasma latum, Dielasma milviformis,* or *Dielasma mesaplanum.* There are perplexing gradational forms. Hence the three latter species have the valve only of " form species " and would doubtless be classed by many authors as varieties.

Dielasma formosum Hall is externally very like the Windsor species. Internally, the dental plates of the Mississippian species are somewhat longer and the muscle plate of the brachial valve is not so closely appressed to the floor of the valve.

Dimensions. Length of pedicle valve, 15·6 mm. (lectotype); 21 mm. (specimen 7486); length brachial valve, 13·2 mm. (lectotype); 19 mm. (7486); greatest width, 9·5 mm. (lectotype); 14·7 (7486); thickness, 7·9 mm. (lectotype); 10·1 mm. (7486).

Horizon and Localities. Lower Windsor; localities 7497 (very abundant), 7498 (abundant), 3266, 3022, 3512, 3514, 7545, 7546, 3424, 7548, 7499, 7540, 4340, 3418. Upper Windsor; localities, 7527, 7512, 7507, 7519, 7526, 7528, 7510.

Types. Lectotype, 12223—475, University of Chicago, Chicago, Illinois. Plesiotypes, 7486, 7485a, 7754, 7485, 7674, 7487; National Museum of Canada, Ottawa.

Dielasma latum n.sp.

Plate XXIII, figures 5, 5a, 5b, 13, 14; Plate XXIV, figures 1, 1a, 2, 3, 4, 4a, 4b, 4c

Description. Outline subrhomboidal to subovate; greatest width typically near the midlength or posterior to the middle; ratio of length to width, 1·1 to 1·2; pedicle valve, rather naviculoid, with rounded medial crest, compressed lateral slopes, steep and narrowly reflected cardinal slopes. Beak well defined, moderately incurved; foramen, subcircular to subelliptical, apical, or encroaching upon umbone; deltidial plates concealed or partly exposed. Angle made at beak by postero-lateral sides averages about 90 degrees. Dental plates well developed.

Brachial valve, less gibbous than the pedicle valve, greatest tumidity medially, with lateral slopes depressed, cardinal slopes steep. Internally like *D. davidsoni.*

Shell substance, punctate. Surface, smooth or marked only by fine concentric growth lines.

Dimensions. Length, pedicle valve, 19 mm. (7500), 14·8 mm. (7493); length, brachial valve, 17·5 mm. (7500), 13·2 mm. (7493); greatest width, 16·7 mm. (7500), 12 mm. (7493); thickness, 11·8 mm. (7500), 5·7 mm. (7493).

Remarks. Although there are gradations that connect this form with *D. davidsoni,* there are abundant individuals that one may group about the mean form of the holotype of *D. latum*, which are readily separable from *D. davidsoni.* The gibbosity varies greatly, as is evident from a comparison of the measurements of specimen 7500 with specimen 7493, and whereas many individuals have their greatest width posterior to the middle, other specimens are widest at midlength or even anteriorly.

Horizon and Localities. Lower Windsor; localities, 7498, 7497, 3022, 3418, 7499.

Types. Cotypes, 7491, 7673; paratypes, 7491a, 7493, 7488, 4340; var. *gibbosum:* holotype, 7492; paratype, 7500; National Museum of Canada, Ottawa.

Dielasma milviformis n. sp.

Plate XXIV, figures 5, 5a, 6, 7, 8, 9, 10

Description. Outline subrhomboidal, with greatest width typically posterior to the middle. Pedicle valve, rather naviculoid, with tumid, rounded medial crest and depressed lateral slopes; cardinal slopes, precipitous and narrowly inflected. Deltidial plates, partly exposed or almost concealed by incurvature of beak. Beak, stout, incurved; foramen, large, subcircular. Angle made by postero-lateral sides at beak 80 degrees to 85 degrees. Dental plates well developed.

Brachial valve, less tumid than the pedicle, obscurely naviculoid, with greatest tumidity medially and with somewhat depressed lateral slopes; cardinal slopes, moderately steep; beak, inflated, pointed. Internal characters seemingly like *D. davidsoni.*

Surface of both valves smooth save for concentric ribbing which may be coarsely developed. Shell, punctate.

Remarks. This is a second "form species" connected by gradational forms with *D. davidsoni.* It is even more closely related in form to *D. latum* and to *D. mesaplanum,* differing from the former in the greater ratio of length to width (1·3 to 1·4 as compared with 1·1 to 1·2), from the latter in the absence of mesial flattening. Compared with *D. davidsoni* the naviculoid form and subrhomboidal outline are distinctive and the shell is less gibbous.

Dimensions. Holotype, length pedicle valve, 18 mm.; length, brachial valve, 17 mm.; greatest width, 13·5 mm.; thickness, 8 mm.

Horizon and Locality. Lower Windsor; locality, 7497.

Types. Holotype, 7494c; paratypes, 7493, 7494, 7494b, 7497, 7755; National Museum of Canada, Ottawa.

Dielasma mesaplanum

Plate XXIII, figures 6, 6a, 7, 11, 11a, 11b, 12

Description. Outline subrhomboidal to elongate ovate, greatest width about midlength; ratio of length to width about 1:3. Pedicle valve somewhat variably naviculoid with greatest tumidity medially; lateral slopes, depressed, cardinal slopes precipitous and narrowly inflected. A mesial flattening or truncation rarely present, and the naviculoid profile more common. Beak, stout, moderately incurved; foramen, large, semielliptical, and encroaching on the umbone; angle made by postero-lateral sides 75 degrees to 80 degrees. Dental plates conspicuous.

Brachial valve with greatest tumidity posterior to the middle; lateral slopes less depressed than in pedicle valve; cardinal slopes, steep; beak, tumid. A mesial flattening or truncation marks the forward three-fifths of the valve or may even commence faintly on the umbone. Internally, seemingly like *Dielasma davidsoni.* Shell punctate.

Dimensions. Holotype; Length, pedicle valve, 19·2 mm.; length, brachial valve, 17·8 mm.; greatest width, 14 mm.; thickness, 9 mm.

Remarks. The form of the shell is intermediate between *D. davidsoni* and *D. milviformis.* It differs from both in the mesial truncation of the brachial valve, is slightly naviculoid, and otherwise distinguishable from *D. davidsoni* in its lesser gibbosity and less infolded beak.

Horizon and Localities. Lower Windsor; localities, 7497, 3022.

Types. Holotype, 7495; paratypes, 7495a, 7496, 7751; National Museum of Canada, Ottawa.

Cranaena tumida n. sp.

Plate XXIV, figures 11, 11a, 12, 13, 14, 14a, 15, 16

Description. Shell, terebratuliform, longer than wide, with greatest width about mid-length, valves subequally convex, finely punctate.

Pedicle valve, with greatest depth of valve near the middle, with curve of convexity progressively becoming narrower to the beak, but gently convex to the anterior margin. Lateral regions tumid. Postero-laterally the surface is narrowly inflected. Beak relatively large, incurved, protuberant over the hinge-line, but scarcely touching the brachial umbone. Delthyrium closed. Foramen oviform encroaching forward over the umbone. Surface marked by concentric growth lines and bands. Internally, the dental plates are short and wide apart, so as to follow closely the umbonal walls. The foramen is bordered and partly closed by testaceous matter of secondary growth.

Brachial valve, tumid, with greatest height of valve near the middle. Longitudinal profile a circular arc; transverse profile semi-elliptical. Cardinal slopes steeper than the lateral and frontal slopes. Beak, pointed, hidden beneath the pedicle valve. Internally, the socket plates are connected by a concave hinge-plate which is undivided, except possibly at the extreme apex. Situated as projections on the hinge-plate, and a little in from the socket walls, are the diverging crural ridges which anterially are produced into the crural lamellæ. The socket connexions of these ridges persist beyond the termination of the median concave part of the plate. The brachidium is short and Dielasma-like, but the descending lamellæ are relatively farther apart due to their greater divergence anteriorly from the point of origin.

Remarks. The external configuration of this species is so similar to *Cranaena globosa* Weller that in the absence of actual specimens of the latter species no essential distinctions may be made, excepting perhaps its lesser gibbosity.

The interior, however, offers some important modifications. The hinge-plate of *C. tumida* is more concave than that in *Cranaena globosa,* in this respect approaching *Hamburgia,* and the socket connexions persist beyond the median, concave part of the plate. Posteriorly, also, a perforation is either absent or much restricted. In addition the dental plates in the Windsor species are short and reach only to the lateral umbonal walls.

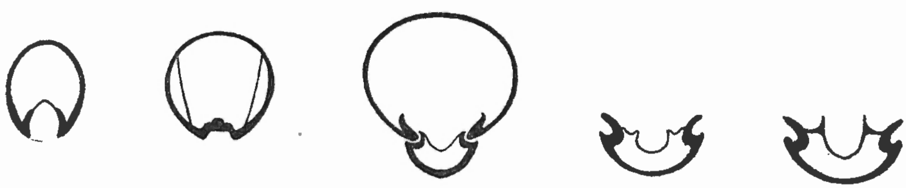


Figure 12. Serial sections of rostral end of shell of *Cranaena tumida* (x 4), showing concave hinge-plate of brachial valve and dental plates of pedicle valve.

Dimensions. Length, pedicle valve, 14 mm. (H.T. 7504), 12·2 mm. (7503); length, brachial valve, 12·5 mm. (H.T.), 11·6 mm. (7503); greatest width, 9·8 mm. (H.T.), 11 mm. (7503); thickness, 9 mm. (H.T.), 7 mm. (7503).

Horizon and Localities. Lower Windsor; localities, 3022, 3424, 3518, 7497, 7498, 3418, 3516.

Types. Holotype, 7504; paratypes, 7503, 7756, 7502, 7503a; National Museum of Canada, Ottawa. Paratype, University of Chicago, Cat. No. 12223.

Harttella n.g.

Etymology. From C. F. Hartt, an early student of the Windsor faunas.

Genoholotype. Harttella parva n.sp.

Diagnosis. Shell, smooth, dielasmoid, punctate; foramen, apical, large, subcircular. Dental plates wanting. Brachial socket plates supported by a pair of oblique, lateral septa that converge to a vertical rather short, median septum and that continue beyond the articulation of the valves as a support to the cruralium. Brachidium a short dielasmoid loop.

Remarks. The internal characters are much like *Girtyella* Weller except that there is an absence of dental plates in the pedicle valve. *Hemiptychina* Waagen likewise lacks dental plates, but has the septal plates of the brachial valve independent of the socket plates and attached directly to the floor of the valve as in *Dielasma.*

Harttella parva n.sp.

Plate XXIV, figures 17, 17a, 17b, 18

Description. Shell, small, smooth, subovate, dielasmoid. Pedicle valve with gentle anterior slopes, abruptly inflected cardinal slopes; foramen subcircular, apical. Beak bent obliquely or nearly at right angles to valve. Brachial valve, rather more tumid than the pedicle valve, with greatest tumidity in the umbonal region. Both valves marked with concentric ribs of growth.

Internally, the pedicle valve lacks dental plates. The dental sockets of the brachial valve are supported by oblique septal plates which converge medially at an angle a little greater than a right angle, and unite in a short, median septum. In other words there is a concave hinge plate supported by a median septum. The septal plates continue anteriorly beyond the articulation and support the cruralium. The brachidium is a short, dielasmoid loop.

Dimensions. Holotype, length, pedicle valve, 7 mm.; length, brachial valve, 6·5 mm.; greatest width, 6·2 mm.; thickness, 3·7 mm.

Figure 13. Serial sections of rostral end of *Hartella parva* (x 8), showing brachial median septum and septal plates that anteriorly support cruralium. Ventral valve nonseptate.

Remarks. This species is scarcely distinguishable in form from some young individuals of the species of *Dielasma.* By etching slightly with acid the presence of a median brachial septum and the absence of dental plates are readily determinable.

Horizon and Localities. Lower Windsor; localities, 7497, 3266, 3512, 7522, 7546.

Types. Holotype, 7498; paratype, 7498a; National Museum of Canada, Ottawa.

Hartella gibbosa n.sp.

Plate XXIV, figures 22, 22a, 23, 23a, 24, 24a, 24b, 25, 25a, 25b

Description. Shell, small, smooth, gibbous, dielasmoid, punctate, marked with strong, irregular, concentric ribbing of growth. Pedicle valve, gibbous in the umbonal region, cardinal slopes concave; umbone narrowly bent upward and beak recurved; foramen large, subcircular. Near the anterior margin there is commonly a shallow sinus. Brachial valve, subcircular; greatest gibbosity medially; anterior margin slightly notched in the holotype opposite the depression in the other valve.

Pedicle valve lacks dental plates. In brachial valve a pair of plates support the dental sockets and obliquely converge medially to form a short, median septum which is confined to the posterior half of the valve. The septal plates continue in front of the articulation and bear the cruralium. Loop dielasmoid.

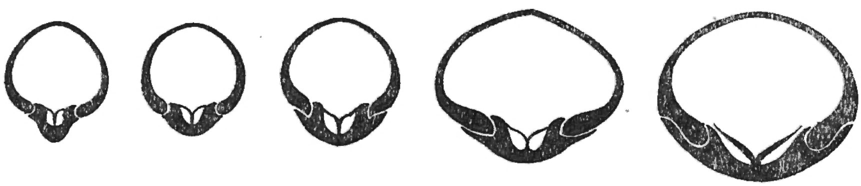


Figure 14. Serial sections of rostral end of shell of *Harttella gibbosa* (x 4), showing median septum and divided hinge-plate (or septal plates) in brachial valve. Anteriorly the latter support the cruræ.

Dimensions. Holotype, length, pedicle valve, 8·3 mm.; length, brachial valve, 7 mm.; greatest width, 6·8 mm.; thickness, 5·6 mm.

Remarks. This species is more gibbous than *Harttella parva* and has a more recurved beak. Internally the septal plates of the brachial valve converge at a wider angle (about 107 degrees).

Horizon and Localities. Upper Windsor; localities, 7511, 7518, 7502, 7513.

Types. Holotype, 7505; paratypes, 7506, 7509, 7508; National Museum of Canada, Ottawa.

Harttella dielasmoidea n. sp.

Plate XXIV, figures 19, 19a, 19b, 20, 20a, 20b, 21, 21a

Description. Shell, small, elongate, ovate, smooth, terebratuloid, punctate. Pedicle valve, with convexity along the median line gradually increasing from the frontal margin to the beak. Cardinal slopes narrowly incurved. Beak bent towards a right angle to the plane of the valves and reaching a little beyond that plane, extending well beyond the hinge-line. Foramen, subcircular or ovate, encroaching forwards on the umbone. Delthyrium covered. Surface marked by concentric growth lines irregularly accentuated. Internally, lacks dental plates. Brachial valve, somewhat inflated; beak hidden by opposite valve; surface as in pedicle valve. Internally a short, median septum supports a hinge plate as in *Harttella parva.*

Dimensions. Length, pedicle valve, 9·1 mm.; length, brachial valve, 8·2 mm.; greatest width, 6·5 mm.; thickness, 4·8 mm.

Remarks. In *Harttella dielasmoidea* the angle of the beak is less than a right angle; in *H. parva* it is greater. *H. dielasmoidea* is further distinguished by its elongate, ovate outline.

Horizon and Localities. Lower Windsor; localities, 4352, 7497.

Types. Holotype, 7499b; paratypes, 7499a, 7499; National Museum of Canada, Ottawa.

Phylum, MOLLUSCA

Sanguinolites parvus n.sp.

Plate XXV, figures 5, 6, 6a, 7, 8, 9, 10, 10a

Description. Shell, small, inequilateral, subtrapezoidal, diagonally gibbous, greatest height posteriorly. The anterior end is very short, compressed, with rounded border and well-marked lunule in front of the beaks. The inferior border is almost straight, diverging from the hinge-line until it meets the posterior border at a slightly obtuse angle. The posterior margin is almost vertical in the lower half, but somewhat obliquely truncated above so as to meet the hinge-line at an obtuse angle of about 135 degrees. The hinge-line is arched in front, straight behind, with rolled edges. The umbones are small, incurved, little elevated, placed well forward. There is a distinct but rounded branchial crest from the umbone to the postero-inferior angle that delimits the dorsal slope. The dorsal slope, though compressed, is convex and defined from the escutcheon by an erect ridge. The anterior slope or pedal area is compressed, but there is no distinct sinus.

The anterior adductor scar is relatively large, pyriform, occupying the greater part of the anterior portion of the valve. It is limited behind by a well-marked ridge extending from in front of the beak slightly backwards to half the distance to the inferior margin. A small, oval accessory scar lies above the main adductor scar and in front of the umbone. Hinge-line edentulous. Internal moulds, smooth, or marked by irregular undulations of growth. Externally the surface was ornamented by concentric, uneven ribs giving a rugose appearance.

Dimensions. Length, 10·3 mm. (holotype 7550a), 11·9 mm. (7536c); height at beak, 4·1 mm. (7550a), 4·5 mm. (7536c); height, medial, 4·5 mm. (7550a), 6 mm. (7536c); thickness, 4 mm. (7550a), 4·5 mm. (7536c).

Remarks. This little species has somewhat the form of *S. ovalis* Hind, but is more obliquely gibbous, more expanded posteriorly, and the well-marked adductor ridge is directed obliquely backwards and not forwards.

Horizon and Localities. Lower Windsor; localities, 7497, 7498, 3266, 3418, 7546.

Types. Holotype, 7550a; paratypes, 7550c, 7550b, 7550, 7606, 7606b; National Museum of Canada, Ottawa.

Sanguinolites striatogranulatus Hind

Plate XXIV, figures 26, 27, 28, 29, 30; Plate XXV, figures 1, 2, 2a, 3, 4

?*Sanguinolites brookfieldianus* Dawson, Rept. Peter Redpath Mus., McGill University, *See* No. 2m., p. 11.

Description. Shell, transversely elongate, subelliptical to subrectangular; anterior end narrowly rounded; inferior margin, flatly convex, subparallel to dorsal margin; postero-inferior angle not far removed from a right angle, but the posterior margin about midway in its course curves forwards to meet the hinge-line in an obtuse angle of about 140 degrees; dorsal margin slightly arched anteriorly, nearly straight posteriorly. Umbones, small, contiguous, little raised above hinge-line, their apices directed forwards. Greatest tumidity of a valve along a narrowly rounded elevation running obliquely from the umbone to the postero-inferior border; the surface in front of this elevation is depressed, but sinus is obsolete; the dorsal slope is likewise compressed; it is marked by 2 low carinæ (rarely 3) running from the umbone to the posterior margin, and is limited above by the prominent border of a large escutcheon.

Internal moulds, which alone comprise the material examined, are marked by rather coarse, concentric ribbing. In their course over the dorsal slope their growth ribs are deflected forwards at their crossing with the radial carinæ. The largest specimen shows traces of a radial striation in its posterior part. The anterior adductor scar is sharply defined by a groove running almost vertically downwards from the lunule. This scar occupies a large part of the anterior end.

Dimensions. Large specimen (7538) measures 47·7 mm. length and 21 mm. height; thickness, left valve, 8·5 mm. Specimen 7537 has a length of 28 mm.; height, 11·5 mm.

Remarks. The identification is based on Hind's figures and description.[1] Until Dawson's type of *S. brookfieldianus* is examined doubt is expressed as to its synonomy. It is mentioned as having a subtruncate posterior end and as being nearly allied to *S. plicatus* M'Coy. *Sphenotus aeolus* Hall is readily distinguished from the present species by its hatchet-shaped prominent anterior end, marked branchial sinus, and obliquely truncated posterior border.

Horizon and Localities. Lower Windsor; localities, 7497, 7498, 7540, 7546, 3022, 3266.

Types. Plesiotypes, 7538, 7536, 7536a, 7537, 7537a, 7537b, 7551, 7604, 7605; National Museum of Canada, Ottawa.

Sanguinolites niobe n.sp.

Plate XXV, figures 11, 12, 12a, 12b

Description. Shell of medium size, elongate, rather gibbous. Anterior end, very short, narrowly curved, protuberant antero-ventrally due to the excavation of its upper part by a prominent deep lunule. As a result the

[1] Hind, W. H.: Pal. Soc. Mon. Brit. Carbon. Lamell., vol. 1, pp. 393-394, Pl. 42, figs. 16-22 (1900).

anterior margin appears to be continuous with that of the umbone. The inferior margin is very slightly convex and ascends slightly to the postero-lateral angle which is a rounded right angle. The posterior end is abruptly truncate, and the posterior margin meets the hinge-line in an obtuse angle. Hinge-line, straight, bordered behind the beaks by an elongate, rather deep escutcheon. Externally, the escutcheon is bordered by a nearly straight angular ridge that separates it from the concave dorsal slope. The latter is bounded below by a rounded crest or ridge and a faint, angular ridge runs from the umbone over its medial surface. The remainder of the surface, excluding the lunule, is convex as a whole, but it is crossed commonly by a shallow depression that, commencing in the lower umbonal region, broadens to the inferior border.

Surface of internal mould marked by prominent concentric ribs, which bend abruptly in crossing the crest that limits the dorsal area, and which continue more faintly over that latter area.

Adductor scars and pallial line are not preserved. Hinge apparently edentulous.

Dimensions. Length, 24 mm.; height at umbone, 13·2 mm.; posterior height, 10·6 mm.; thickness, 10·6 mm.

Remarks. This species resembles somewhat closely the European *Sanguinolites angustatus* (Phillips), but is more tumid and less transverse. These differences are held in common with *S. argutus* (Phillips). The anterior end of the latter is, however, more conspicuous and semi-ovate and the postero-inferior angle is acute.

Horizon and Localities. Upper Windsor; localities, 7511, 7524.

Types. Holotype, 7535; paratype, 7607; National Museum of Canada, Ottawa.

Sanguinolites ? sp.

Plate XXV, figure 13

A transversely elongated species with external concentric rugose ornamentation; not very gibbous; the anterior third of the shell is somewhat compressed, and there is a tumid, broad swelling running obliquely backwards from the umbone towards the postero-inferior margin; the postero-superior surface is markedly depressed. The umbone lies about one-third the length from the anterior margin. Length, about 40 mm.; height, about 22·5 mm.

Remarks. The concentric striæ are irregular, and in places compound by being bunched together in ridges. This is a character common to some species of both *Sanguinolites* and *Edmondia.*

Horizon and Localities. Upper Windsor; locality, 7519.

Type. Holotoype, 7608; National Museum of Canada, Ottawa.

Edmondia rudis M'Coy

Plate XXV, figures 14, 15, 16, 16a, 17, 18, 18a, 18b

Cardiomorpha vindobonensis Hartt in Dawson, Acad. Geol., 2nd ed., 1868, p. 304, fig. 109.

Description. Shell, equivalve; outline of valves sub-oval to sub-quadrate; inequilateral; anterior margin nearly straight medially, obliquely curved towards umbone, broadly curved to the lower margin; lower margin, gentle convex, broadly curved to posterior margin; posterior margin nearly straight medially and subparallel to anterior margin, obliquely curved to join upper margin; umbones, conspicuous, with their apices rising well above the hinge-line, pointed, and slightly twisted so as to point forwards. Hinge edentulous.

In the internal mould of each valve a long, narrow, oblique groove, deeply incised, runs backwards from beneath the umbone, sub-parallel to the hinge margin. Bordering this groove and separated from the margin by a broad, shallow groove is a low ridge, striated posteriorly.

Dimensions. A large, right valve measures: length, 31 mm.; height, 24 mm.; gibbosity, 8·5 mm. A small complete specimen measures: length, 24 mm.; height, 19·5 mm.; gibbosity, 18·5 mm.

Horizon and Localities. Lower Windsor; localities, 7497, 7498, 7540, 3418, 3424, 3266, 3022.

Remarks. The identification is based on Hind's description and figures of the species.[1] The external ornamentation, rarely preserved, shows the characteristic rugose appearance of the growth lines. Internal moulds commonly possess a marked concentric ornamentation, but are in some cases smooth except for a few concentric ribs or swellings.

Types. Plesiotypes, 4360, 7610, 7543, 7543a, 7609; National Museum of Canada, Ottawa.

Edmondia hartti Dawson

Plate XXVI, figures 21, 22, 23

Edmondia hartti Dawson, Acad. Geol., 1868, p. 303, fig. 104.

Original Description

"Transversely oblong, flattened, regularly rounded posteriorly, marked with very coarse concentric lines of growth. Resembles *E. sulcata* Phillips of the English Carboniferous limestone, but is more elongated and rounded posteriorly. Length, $1\frac{6}{10}$ inches, breadth $\frac{8}{10}$ inch."

Remarks. Only internal moulds that do not reveal the hinge characters are known. The ornamentation of these moulds is similar to that of *E. sulcata* Phillips or *E. expansa* Hind, with the shell contour approach-

[1] Palæontographical Soc. Mon. of the Brit. Carbon. Lamell., vol. 1, pt. 4, pp. 302-304, Pl. 27, figs. 15, 15a, Pl. 28, figs. 8-14 (1899).

ing more closely that or *E. expansa,* as the posterior margin is straighter, and the anterior deeper, than that of *E. sulcata.* The present species, however, seemingly never obtained the size of *E. expansa.*

Dimensions. Length, 36 mm.; height, 19·5 mm.

Horizon and Localities. Upper Windsor; localities, 7511, 7515.

Types. Plesiotypes, 7548, 7548a, 7611; National Museum of Canada, Ottawa.

Parallelidon hardingi (Dawson)

Plate XXVI, figures 13, 14, 15, 16, 16a, 17, 17a, 18, 19

Macrodon hardingi Dawson, Acad. Geol., 1868, p. 302, fig. 102 (*a*), non fig. b. c.

Macrodon curtus Dawson, Acad. Geol., 1868, p. 302.

Original Description

"Hinge-line nearly straight, with the short cardinal teeth and long, narrow posterior teeth characteristic of the genus. Length about twice the depth, but variable; beak one-fourth of the length from the front, which is pointed, and descends with a regular curve to the straightish or slightly incurved ventral margin. Posterior extremity truncated, almost vertically, angular above, slightly rounded below. In old specimens very tumid at the beaks, so that the thickness sometimes exceeds the breadth. The shell, which seems to have been thick, is usually represented by casts of the interior, which are smooth, sometimes with deep marks of the muscular impressions and a trace of a rib proceeding from the front of the beak; but when the outer surface is preserved, it is seen to be covered with regular squamous concentric folds, fringed at the edges with delicate radiating lines."

Emended Description. Shell tumid, but markedly compressed dorsoventrally in its posterior half. Anterior margin meets the hinge-line in a right or obtuse angle, and curves regularly downwards and backwards into the ventral margin. The ventral margin in the posterior half of the shell is semi-truncate, in some cases slightly sinuate as a result of a faint umbonal sinus. The postero-ventral angle is a narrowly rounded right angle. The posterior margin is nearly straight, truncated, meeting the hinge-line at a slightly obtuse angle. The umbones are markedly gibbous, particularly so in gerontic individuals, merging gently into the swollen anterior half of the shell, but abruptly limited postero-dorsally by the depressed, slightly concave, dorsal slope. The short anterior end in internal moulds is frequently "keeled" due to a slight gaping of the thick tests. The beaks, which are strongly incurved and well above the hinge-line, are separated by a broad, ligamental area which is markedly striate.

The only ornamentation consists of numerous, pronounced, irregular, sublamellose bands of growth, with little or no trace of radial plication.

There are at least 4 oblique teeth in front, smaller crenulations of the hinge behind, and 2 (?) posterior lateral teeth extend backward to near the end of the hinge-line.

The anterior adductor scars are well marked on the antero-dorsal slope. Posterior adductor not defined. Pallial line, entire, and situated some 4 mm. from the edge of the valve.

Remarks. As Beede has pointed out Dawson included two distinct species under *Macrodon hardingi.* Beede selected figure (*a*) as the type of *P. hardingi.* Figure (*a*), however, is an exceedingly poor representation of *P. hardingi,* as it fails to show the compressed and narrowing posterior end characteristic of the species. There is considerable variation in the extent of this narrowing, but the writer has not seen amongst hundreds of specimens as broad a posterior end as suggested by Dawson's figure or by Beede's figure of *P. hardingi?*. It is probable that the latter belongs to *P. dawsoni,* as it has not only the form but the ornamentation characteristic of that species.

The rugose sub-lamellar ornamentation, the greater gibbosity, the form, and the breadth of the ligamental area, all distinguish this species from *P. dawsoni* Beede.

P. hardingi is unlike any of the European or American species described.

Horizon and Localities. Lower Windsor; localities, 7497, 7498, 3418, 3512, 3514, 3022, 3266.

Types. Plesiotypes, 7565a, 7565b, 7565c, 7565d, 7566, 7571, 7572; National Museum of Canada, Ottawa.

Parallelidon dawsoni Beede

Plate XXVI, figures 9, 10, 11, 12

Parallelidon dawsoni Beede, New York State Mus. Bull. 149, p. 168 (1911).

Parallelidon hardingi? Beede, Ibid, p. 168.

Original Description

"Shell small, subquadrangular, beaks very convex and arched over the cardinal area. Anterior end short, abruptly rounding downward and backward into the gently sinuate ventral margin. Posterior lateral edge evenly and abruptly rounded into the truncated posterior margin which reaches the hinge at a slightly obtuse angle, the anterior and posterior borders being nearly parallel. The length of the hinge is equal to the length of the shell, and its direction nearly parallel to the ventral margin. The cast shows fine, concentric lines and larger growth varices.

Dimensions. Length, 13·5 mm.; height, 7 mm.; beak, 4·5 mm. from front."

Remarks. The test of this species is thick, but is rarely preserved. Where present, the ornamentation consists of regular growth varices whose lower borders are marked by microscopic radial crenulations. The lamellæ are more widely spaced over the hollowed dorsal slopes. The lamellar spacing is much more uniform than in the case of *P. hardingi.* The presence of such an ornamentation is the only character by which the writer can distinguish the Nova Scotia species from *P. theciformis* de Koninck and it should be noted that Hind mentions a radial granulation as present in British species of *P. theciformis.* Dawson's figures *b* and *c* figure 102, indicate the above ornamentation. The species is somewhat variable in form as the posterior height may be equal to, or be greater or less than, the anterior height. Thus Beede's figure of *P. hardingi?* indicates a quadrate form, whereas some of the larger specimens conform closely to de Koninck's type of *P. theciformis*.

There are at least 5 oblique anterior teeth in the right valve, a crenulated hinge, and 2 or 3 subparallel posterior teeth. The pallial line is simple and submarginal.

Horizon and Localities. Lower Windsor; localities, 3418, 3512, 3266, 7497, 7498.

Types. Plesiotypes, 4354, 7567, 7576, 7575; National Museum of Canada, Ottawa.

Genus, *Leptodesma* Hall

Hall's diagnosis of *Leiopteria* was as follows:

"Shell aviculoid, oblique, sub-rhomboidal. Anterior extremity auriculate; wing large, extremity produced. Test without proper rays. Ligament external. Ligamental area marked by fine, parallel, longitudinal striæ. Hinge with 1 or 2 oblique, slender, lateral teeth. The cavity of the beak is partly separated from the anterior end by a short partition or diaphragm. Examples, Pl. XX, fig. 17; Pl. LXXXVIII, figs. 5, 27."

(Pal. N.Y. vol. V, pt. I, p. XIII (1884).)

Following this description the genus *Leptodesma* was defined as:

"In its prevailing forms it is similar to *Leiopteria*, except that the anterior end is always nasute and acute instead of auriculate and rounded. Hinge narrow, furnished with a slender lateral tooth just posterior to the beak and nearly parallel to the hinge-line. Ligament external. Ligamental area narrow, extending the entire length of the hinge, marked by fine, sharp longitudinal striæ. Test with concentric striæ. Examples, Pl. XXI, fig. 14; Pl. XXII, fig. 21; Pl. XC, fig. 28; Pl. XCI, figs. 9, 16."

A critical analysis of the figures of the 15 species of *Leiopteria* illustrated by Hall will convince one of the frail foundation upon which the diagnosis of *Leptodesma* rests. If *Leiopteria laevis* be accepted as the genotype of *Leiopteria* and *Leptodesma longispinum* as the genotype of *Leptodesma*, a pronouncedly auriculate anterior end with downwardly sloping upper margin is contrasted with an anterior end less differentiated from the remainder of the shell, making a right or acute angle with the hinge-line, and with upper margin in line with the hinge-line. The downward sloping or oblique, anterior ear of *Leiopteria laevis* is likewise exemplified in *Leiopteria greeni, L. bigsbyi, L. mitchelli, L. troosti, L. oweni,* and *L. linguiformis*. But amongst such species as *L. conradi, L. rafinesquii, L. sayi, L. dekayi, L. leai, L. gabbi, L. chemungensis,* and *L. toneyi,* the marginal outlines of the anterior ends correspond very closely to some of those present amongst the species assigned to *Leptodesma*. Moreover, the characters of concentric ornamentation, and the known characters of the hinge are precisely comparable in both genera. It is difficult to evaluate the significance of the so-called diaphragm mentioned in the diagnosis of *Leiopteria*, as the only figure illustrating any such structure is figure 9, Plate 87, a specimen of *Leiopteria dekayi*, as its presence has not been demonstrated in *Leiopteria laevis* and in other species it is not a character that can be utilized to differentiate *Leptodesma*.

Although the unsatisfactory diagnosis of *Leptodesma* is conceded, the term is retained here for those species allied to *Leiopteria,* which lack a well-differentiated anterior ear oblique to the hinge-line, and in which the anterior angle is a narrowly rounded right or acute angle. This usage would include the British species of *Leiopteria* described by Hind.[1]

Leptodesma borealis Beede

Plate XXVI, figure 20

Leptodesma borealis Beede, N.Y. State Mus. Bull. 149, 1911, p. 169, fig.

Beede's Description

"Cast of right valve small, aviculiform, with long projection in front of the beak. Hinge about as long as the shell; posterior margin sinuate above, but soon becoming gently convex and gradually rounding into the ventral margin. Ventral margin quite sinuate beneath the beak on account of the strong depression in the shell beyond which the border is convex to the tip of the hinge. The umbonal ridge nearly dies out posteriorly. Surface marked with varices of growth and smaller striæ.

Dimensions. Length of hinge, 8 mm.; length of umbonal ridge, 6mm.; beak, 2 mm. from front of hinge; height of shell at posterior end of hinge, 4·75 mm.; angle of umbonal ridge to hinge, about 30 degrees."

Remarks. In the right valve a long, slender, posterior tooth or ridge diverges very slightly from the cardinal line close behind the beak, and runs nearly parallel to the cardinal line for three-fourths the distance to the posterior end. Above this, and parallel to it, there is a more slender and shorter, ridge-like tooth. Anterior to the beak one or more (?) short, ridge-like teeth run slightly divergent to the cardinal line for three-fourths the distance to the anterior end.

Anterior adductor is round and situated dorso-medially on the oval area of the valve. Between it and the beak there is seemingly a small, accessory, byssal muscular scar. Posterior scar not preserved.

Horizon and Localities. Lower Windsor; localities, 7497, 7498, 7499, 3418, 3515.

Types. Plesiotype, 7578; National Museum of Canada, Ottawa.

Leptodesma dawsoni (Beede)

Plate XXVI, figures 1, 2

Liopteria dawsoni Beede, N.Y. State Mus. Bull. 149, 1911, pp. 169-170, figs. p. 170.

Bakewellia antiqua (non Munst.) Dawson in Beede, N.Y. State Mus. Bull. 149, 1911, p. 170, fig.

Beede's Description

"Cast of left valve small, moderately convex, hinge shorter than the length of the umbonal ridge. Posterior margin sinuate, rather evenly rounded at the termination of the umbonal ridge; ventral margin somewhat sinuate anteriorly, but convex

[1] Hind, W. H.: Mon. of the Brit. Carbon. Lamell., vol. II, pp. 9-22, Pls. II-III (1901).

around the lobe projecting in front of the beak. The lobe is small and nearly triangular. The weak teeth parallel to the posterior end of the hinge are shown. Varices of growth more widely spaced along the umbonal ridge than elsewhere; the finer lines being about evenly spaced except near the beak.

Dimensions. Length of hinge (from beak to posterior end in this case), 7·5 mm.; length of umbonal ridge, 8 mm.; height at extremity of hinge, 6 mm.; angle of umbonal ridge to hinge, 35 degrees."

Remarks. The Windsor examples of this species agree in all essential respects with those figured from Magdalen islands and with *Bakewellia antiqua* Dawson. Beede's figure of the latter more truly represents the contour of the anterior margin, as the hinge actually projects for a short distance in front of the beak and is not directed downwardly. The anterior border like that of *L. acadica* is narrow and depressed and its margin meets the hinge-line at a right or very slightly obtuse angle.

There is a short, ridge-like anterior tooth anterior to the beak, and one or more posterior long, ridge-like teeth sub-parallel to the cardinal line. There is seemingly also a small, cardinal tooth slightly anterior to the beak. The anterior adductor scar is round, impressed, situated centrally in the oral area and in addition there is a small muscular scar (byssal muscle) situated between the anterior adductor and the beak.

The posterior margin of *L. dawsoni* is more oblique than that of *L. borealis,* less so than that of *L. acadica.* Typically the angle made by the general course of posterior margin with the hinge-line in *L. acadica,* is greater than 125 degrees, in *L. dawsoni* is less than 125 degrees, in *L. borealis* is nearly a right angle. The concentric striation is less crowded and more regular than in *L. acadica.*

Pteronites spergenensis Whitfield closely resembles *L. dawsoni* and it is possible that that species is a Leiopterid closely allied to the Windsor species.

Dimensions. Length of hinge, 12 mm. (7577), 10 mm. (7577a); length along umbonal crest from beak, 13·7 mm. (7577), 11·8 mm. (7577a); distance beak to anterior end, 3·1 mm. (7577), 3 mm. (7577a); height at posterior end of hinge, 9 mm. (7577), 7 mm. (7577a); angle of umbonal ridge to hinge-line, 30 degrees (7577), 28 degrees (7577a).

Horizon and Localities. Lower Windsor; localities, 3418, 3266, 7498, 7497, 3515, 3022, 3424, 7499, 7530, 7546.

Types. Plesiotypes, 7577, 7577a; National Museum of Canada, Ottawa.

Leptodesma acadica (Beede)

Plate XXVI, figures 3, 4, 5

Liopteria acadica Beede, N.Y. State Mus. Bull. 149, 1911, p. 170, fig.

Beede's Description

"Cast of left valve small, aviculiform, well inflated for this genus, hinge shorter than the shell. Beak well elevated; umbonal ridge elevated and very oblique; posterior margin obliquely sinuate, rounding regularly and rapidly into the convex, posterior, ventral margin; ventral border sinuate beneath the beak; anterior end of shell lobate, the front sloping downward. Cast shows the usual varices and finer striæ of growth common to these shells from this locality.

Dimensions. Length of hinge, 7 mm.; length of umbonal ridge, 11 mm.; greatest length of shell, 12 mm.; angle of umbonal ridge to hinge, 25 degrees."

Remarks. The only apparent difference between the Windsor specimens and that figured by Beede is in the contour of the anterior end. Beede represents this as sloping downward from the hinge-line. This is seemingly true in those Windsor specimens that are not perfectly preserved, but where the anterior border is in good state of preservation it is seen to meet the hinge-line at a straight or slightly obtuse angle. The byssal groove which delimits the anterior end of the shell makes a posterior angle of about 80 degrees with the hinge-line. The greater part of the anterior end in front of this sinus is inflated, but it is bordered anteriorly by a narrow, depressed margin. Where this margin is hidden beneath the matrix, or broken off, the contour of the anterior end is precisely like that figured by Beede.

There is a long, posterior tooth subparallel, and close, to the cardinal line, a slender, anterior, ridge-like tooth, and longitudinally striated ligamental cardinal region. The adductor scar is round, slightly impressed, situated dorso-centrally on the anterior or oral area.

The regular, elevated, fine, concentric growth lines when well preserved are seen to be much farther apart over the region of the umbonal crest.

The shell is distinguished from *L. borealis* and *L. dawsoni* by the greater obliquity of its posterior margin.

Dimensions. Length of hinge-line, 8 mm.; length of umbonal ridge, 10 mm.; greatest oblique length, 11·5 mm.; height of posterior end of hinge, 7·5 mm. Angle of umbonal ridge to hinge-line, about 25 degrees.

Horizon and Localities. Lower Windsor; localities, 7497, 7498, 3266, 7546, 7499, 3022.

Types. Plesiotypes, 7582, 7581, 7683; National Museum of Canada, Ottawa.

Leptodesma? shubenacadiensis (Dawson)

Plate XXVI, figures 7, 8

Macrodon? shubenacadiensis Dawson, Acad. Geol., 2nd ed., 1868, pp. 302-303, fig. 103.

Original Description

"Short and ovate, hinge-line straight, umbo one-third of the distance from front. Posterior extremity broadly and regularly rounded. Anterior end gibbous and narrow. Very common at Shubenacadie and Windsor, also in Cape Breton. Its genus is uncertain."

Emended Description. Shell, obliquely ovate-triangular. Anterior end relatively large for a *Leptodesma;* posterior end, depressed, with no differentiated wing. Anterior margin bluntly rounded; ventral margin, slightly sinuate, nearly straight anteriorly, convex posteriorly into the rounded, posterior margin; posterior margin obliquely subtruncated above to meet the hinge-line in an obtuse angle of about 130 degrees. Umbone, blunt, with umbonal gibbosity rapidly diminishing and spreading posteriorly. The sulcus on the antero-ventral slope is very shallow.

Hinge characters not well exposed. Posteriorly a pronounced, ridge-like, lateral tooth slightly oblique to the cardinal line runs from the umbone nearly to the posterior margin. A second frailer and shorter tooth lies above this. Anterior to the beak there is seemingly one or more short, ridge-like teeth subparallel to the margin.

The internal mould is faintly marked with growth ribs.

Dimensions. Length, 11·3 mm.; length of hinge-line, 8·5 mm; height at posterior end of hinge, 7·8 mm.; height at beak, 6 mm.; distance from beak to postero-ventral border, 10·2 mm.; beak situated 3 mm. from anterior end.

Remarks. This species differs from *Leptodesma dawsoni* in the larger and more bluntly rounded anterior end and less aviculoid shape. In these characters it approaches the genus *Parallelidon,* but the hinge characters are seemingly those of *Leptodesma.*

Horizon and Localities. Lower Windsor; localities, 3022, 3512, 7497, 7546.

Types. Plesiotypes, 7585; National Museum of Canada, Ottawa. Plesiotype; Peabody Museum, Yale University.

Leptodesma sp.

Plate XXVI, figure 6

Description. Left valve, aviculiform, obliquely gibbous. Umbonal crest, broadly expanding and flattening posteriorly, with rather inflated ventral slope and concave dorsal slope. Anterior end produced, sub-acute, narrowly rounded. Byssal sulcus, shallow and ill-defined. Ventral margin nearly straight for the greater part of its length, broadly rounded posteriorly. Posterior margin meeting the hinge-line nearly at right angles, gently sinuate above. Hinge-line straight and about as long as the valve. Dorsal or intestinal area, gently concave, separated from the unbonal crest by a narrow, obscure, shallow furrow. Surface ornamented with fine, concentric lines and stronger varices of growth. Shell along posterior margin is thick and somewhat laminose. Right valve unknown.

Dimensions. Length of hinge-line, 16·5 mm.; height near posterior end of hinge, 12 mm.; beak situated 4 mm. from anterior end.; angle between umbonal crest and hinge-line about 30 degrees.

Remarks. In contour this species is similar to *L. borealis,* but is much larger and there are seemingly no gradational forms.

Horizon and Locality. Lower Windsor; locality, 7498.

Types. Holotype, 7584; National Museum of Canada, Ottawa.

Pteronites gayensis Dawson

Plate XXVII, figures 1, 2, 3, 4

Pteronites gayensis Dawson, Acad. Geol., 2nd ed., 1868, p. 301, fig. 101.

Pteronites gayensis var. *ornatus* Dawson, Can. Nat., 2nd ser., vol. X, p. 415 (1883).

Original Description

"Similar in general form to *P. latus* M'Coy. Beaks prominent, pointed, hinge-line straight, reflected, anterior extremity very short, posterior part flattening and widening with a regular curve to the broad rounded posterior extremity. Surface with rounded concentric wrinkles."

To this may be coupled Dawson's description of ornatus:

" General form of shell similar to that of *Pteronites gayensis,* but differs in its somewhat larger size and in the ornamentation of the whole shell with delicate, raised, concentric lines instead of obscure, rounded wrinkles. The left beak is considerably more prominent than the right, the hinge-line slightly curved inward, and the ridge along it well marked. Length of shell one centimetre. Port-au-Port, Newfoundland."

Remarks. The Windsor material does not permit of any varietal separation. Internal moulds commonly show only concentric undulations of growth, but well-preserved exteriors reveal an *ornatus* type of sculpture.

Of several incomplete specimens observed, one shows very well the sharp, simple concentric ribs. They are almost hair-like and over the dorsal, flattened area of the shell are ½ to 1 mm. apart; they are much more crowded anteriorly. These lines meet the dorsal margin at an angle little less than a right angle and are very slightly sinuate over the dorsal surface where they cross a faint, shallow furrow.

Pteronites americanus (Meek) is a species with comparable ornamentation, but with a greater relative height. *Pteronites angustatus* M'Coy as figured by Hind agrees likewise in ornamentation, but the concentric lines meet the hinge at a well-defined, acute angle. *P. latus* M'Coy has a nearly straight or sinuous anterior border unlike the convex border of *gayensis.*

Dimensions. Imperfect left valve: length of hinge-line, 19·5 mm.; maximum height, 10·7 mm.

Horizon and Localities. Lower Windsor; localities, 7499, 5475.

Types. Plesiotypes, 7682, 7752, 7752a, 7752c; National Museum of Canada, Ottawa.

Schizodus fundiensis n.sp.

Plate XXVII, figures 5, 5a, 5b, 5c, 6

Description. Shell of medium size; anterior margin, gently convex, rounding insensibly into the superior margin, more abruptly into the inferior margin; posterior margin, oblique, nearly straight, making a rounded angle of about 90 degrees with the inferior margin and about 130 degrees with the hinge-line. Three-fourths of the shell tumid, the greatest tumidity lying below the umbones; the remaining fourth comprising the postero-superior corner is depressed and concave. This depression takes place suddenly, but without distinct angulation. Umbonal angle about 90 degrees. Beaks acute, inclining slightly forwards, and rising slightly above hinge-line. Surface of internal mould, smooth, with slight, concentric undulations of growth. Hinge characters incompletely known, but there is a rather prominent cardinal tooth in each valve, that of the right valve anterior to that of the left, pointing forward, and lying in connexion with an anterior lateral sessile tooth or thickening of the test.

Dimensions. Length, 22·5 mm.; height, 18·3 mm.; gibbosity, 10·7 mm.

Remarks. This species bears some resemblance to *S. antiquus* Hind, but lacks the anterior compression of that species and the anterior border is less regularly rounded. It is a larger and more quadrate form than *S. denysi* Beede and lacks the pronounced angulation of that species.

Horizon and Localities. Lower Windsor; localities, 7497, 3524, 3261, 3418, 3424.

Types. Holotype, 7546; paratypes, 7613; National Museum of Canada, Ottawa.

Schizodus cheveriensis n.sp.

Plate XXVII, figures 7, 8

Description. Shell, subrhomboidal, narrowing behind; posterior margin, obliquely truncated, and postventral extremity a narrowly rounded right angle. Ventral margin, gently convex, curving more rapidly into the anterior margin which approaches an arc of a circle. Hinge-line, straight. Shell in front of a line drawn from the beak to the postventral extremity is swollen; above this line is depressed concave, but there is no sharp umbonal angulation.

Dimensions. Length, 24 mm.; height (umbonal), 14 mm.; length of hinge, 15 mm.; posterior margin makes an angle of about 135 degrees with hinge-line.

Remarks. Internal moulds of connected valves, which are spread flatly open, abound on the upper surface of the basal Windsor quartzite at Cheverie. The species is distinguished from *S. fundiensis* by its transverse form.

Horizon and Locality. Basal Windsor; locality, 7556.

Types. Holotype, 7547a; paratype, 7547; National Museum of Canada, Ottawa.

Aviculopecten lyelli Dawson

Plate XXVII, figures 9, 10, 11, 12, 13, 14, 15; Plate XXVIII, figures 1, 2, 3

Aviculopecten lyelli Dawson, Acad. Geol., 2nd ed., 1868, p. 305, fig. 11.

Aviculopecten reticulatus Dawson, Acad. Geol., 2nd ed., 1868, p. 306, fig. 112.

Aviculopecten lyelli Beede, N.Y. State Mus. Bull. 149, 1911, pp. 171, 172, figs.

Original Description

"Shell orbicular, as wide as long, narrowed behind, hinge-line equal to three-fourths the longitudinal diameter. Left valve slightly convex, greatest convexity just behind the middle, sloping thence gradually to the border, where it is almost plane; umbo well marked, and quite strongly incurved. Ears flattened, the posterior not separated from the umbo, but sloping gently therefrom. Anterior separated from the umbo by a narrow, steep, smooth slope. Anterior ear rounded, and with a wide, shallow notch under it; posterior pointed, and with its lateral margin concave. Surface of valve ornamented with about 60 rounded, well-marked, radiating plaits, separated by deep furrows as wide as the plaits. The plaits increase both in height and breadth in going from the umbo to the margin. They increase near the front and sides by implantation. Those on the side of the valve are slightly curved; on the umbo they can scarcely be distinguished. The plaits are ornamented by numerous sharp, squamous processes, which appear to be arranged in concentric rows. These rows are separated by a space equal to that between the plaits. The plaits in the internal cast appear nodose. The ribs are visible in the casts of the interior, but less distinctly. In some specimens that have the surface well preserved, the tubercles in the ribs become elegant scaly processes, and in others the spaces between the ribs have regular microscopic concentric lines between the ribs. In others there are occasional coarse, concentric ridges. Though at first disposed to regard some of these varieties as distinct, the comparison of a great number of specimens induces me to regard them as varieties of the same species. It is allied to *A. fallax* M'Coy, and *A. occidentalis* Shumard."

Remarks. *A. fallax* as figured by Hind does not closely resemble the Windsor species. Its posterior ear is much more pointed, sharply differentiated from the rest of the valve, and whereas in *A. lyelli* the angle in the right valve comprised between the ears approximates a right angle, in *A. fallax* it is very obtuse. *A. plicatus* Sowerby in its contour as well as in its ornamentation agrees much more closely with *A. lyelli.* In *A. lyelli,* however, the posterior ear in the left valve appears as a depressed portion of the general surface and is not sharply defined by a fold. The umbone of the left valve of *A. lyelli* is pointed and rises above the hinge-line; that of the right valve is nearly obsolete. The costæ of the right valve are flatter and less marked than those of the left, and they increase by bifurcation. Moreover, the concentric ribbing does not appear to be subimbricating as in the left valve. The notch below the anterior ear in the right valve is deeper and narrower than that of the opposite valve. There seems little doubt that *A. reticulatus* Dawson was founded on young individuals of *A. lyelli.* Two specimens collected by Dawson and labelled *A. reticulatus* show no characters that would separate them from *A. lyelli.*

Dimensions. Average individual: length, 17 mm.; width, 18·5 mm.; length, hinge-line, 16 mm.; thickness, left valve, 3·5 mm.

Horizon and Localities. Lower Windsor; localities, 3022, 3266, 3512, 3516, 3518, 3424, 4361, 4362, 7497, 7498.

Types. Plesiotypes, 4361, 4361a, 4361b, 4361c, 7553, 7553a, 7553b, 7554, 7590, 7587; National Museum of Canada, Ottawa.

Aviculopecten lyelliformis n.sp.

Plate XXIX, figures 1, 2

Description. Agrees in all essentials with *A. lyelli* except that the shell is larger, the costæ fewer and with broader spaces between. The concentric ornamentation forms a cancellated pattern, somewhat squamose over the costæ, as in *A. lyelli.* A left valve having a length of about 30 mm. is marked by about 30 plications on the body of the shell, increasing by interpolation. Each ear has about 6 plications, which are wider apart in the medial areas as in *A. plicatus.* The angle of the beak is about 90 degrees. Right valve unknown.

Remarks. This species is clearly closely allied to *A. lyelli,* of which it might perhaps be considered a varietal form.

Horizon and Localities. Lower Windsor; localities, 3022, 3418, 7498.

Types. Holotype, 7559; partype, 7560; National Museum of Canada, Ottawa.

Aviculopecten subquadratus n.sp.

Plate XXVIII, figures 4, 5, 6, 7, 7a, 8, 9, 10, 10a, 11

Description. Left valve with greatest tumidity about one-quarter of the dorso-ventral length of the shell from the hinge-line. Umbone prominent, with pointed beak projected beyond the hinge-line. Anterior ear, somewhat rolled, sharply delimited by an oblique sulcus inclined 45 degrees to 50 degrees to the hinge-line. Posterior wing occupying an abrupt depression of the postero-dorsal part of the shell, extended as an acute prolongation of the hinge somewhat beyond the posterior margin of the shell. Posterior margin in a general direction nearly perpendicular to the hinge, convex below, concave above. Surface of body of valve marked by about 15 to 20 angular plications (rounded on internal moulds), separated by broad interspaces. Three to five finer and less marked plications lie on each ear, but the ears of the internal moulds are frequently smooth. When surface is well preserved crowded concentric ribs form a cancellated pattern and at intervals imbricate over the plications and are prolonged as flat-lying, spinous processes.

Right valve is much flatter than the left; plications flatter and broader, occasionally bifurcated; umbone obscure, not rising above hinge; anterior ear separated by a prominent sulcus.

Dimensions. Height, 22·2 mm.; length, 22·2 mm.; beak projecting 1·2 mm. above hinge-line; gibbosity, about 6 mm.

Remarks. Differs from *A. stellaris* Phillips chiefly in the less extension of the hinge-line posteriorly and in the elevated umbonal beak of the left valve, as well as in the spinose ornamentation. Readily distinguishable from *A. lyelli* by the subquadrate shape, oblique sulcus below the slightly rolled, anterior ear, greater gibbosity, coarser plication.

Horizon and Localities. Lower Windsor; localities, 7498, 3418, 3512, 3518, 3516, 3022, 3424, 3266.

Types. Cotypes, 7555, 7593; paratypes, 7592, 7593b, 7594, 7555a, 7593a; National Museum of Canada, Ottawa. Paratype, Peabody Museum, Yale University.

Pterinopecten sp.

Plate XXVIII, figure 12

Description. A single right valve known. It is broadly convex, with the hinge-line much shorter than the total length of the shell. The umbone is broadly tumid and pointed, and rises very slightly above the hinge-line. The anterior ear is straight, obtuse, marked off by a deep byssal sulcus; the limiting umbonal border below the ear is inclined about 35 degrees to the hinge-line. Anterior margin projects well beyond the ear. Posterior margin more broadly convex than the anterior one, and is deflected somewhat at the postero-superior angle so as to meet the hinge-line in an acute angle.

Surface of internal mould marked with 8 or 9 costæ per 5 mm., which increase by intercalation and bifurcation, and by a few concentric undulations and obscure fine lines of growth. The concentric ribbing is especially prominent on the anterior ear, which is also marked by a prominent radial costa situated in a broad groove or excavation close to the hinge-line.

Remarks. The configuration and ornament of the anterior ear distinguish this shell from *P. meleanginoides* M'Coy which it most closely resembles in form.

Dimensions. Length, 23 mm.; height, 20 mm.; length of hinge-line, 17 mm.; gibbosity, 3·5 mm.

Horizon and Locality. Lower Windsor; locality, 3516.

Types. Holotype, 7556; National Museum of Canada, Ottawa.

Pseudamusium simplex (Dawson)

Plate XXVIII, figures 13, 13a, 13b, 14, 15, 16, 17, 18

Aviculopecten simplex Dawson, Acad. Geol., 2nd ed., 1868, p. 306, fig. 113a, b.

Original Description

"Shell semi-orbicular, equivalve, very convex, the thickness being equal to half the transverse diameter, greatest just behind the middle, sloping thence with a gradual curve to the front, hinge-line less than longitudinal diameter. Ears well marked, anterior ones abruptly flattened, that of the right valve being flatter than the other, and separated from the umbo by an oblique groove. Anterior ear of the left valve with a shallow, rounded notch; that of the right valve much deeper. The groove separating the ear from the umbo is concave, narrow and shallow at first, but becomes wider and deeper until it runs into the notch. The right valve has a narrow, concave, triangular area. Umbones approximate, much inflated. That of the left valve touches and passes slightly beyond the hinge-line. That of the right valve is elevated above the hinge-line by the hinge-area. Surface of valves generally smooth, ornamented by a few more or less prominent, concentric lines of growth."

Remarks. The shells are really inequivalve as the left valve is more convex than the right. There is a narrow, concave, cardinal area in both valves. Both beaks are elevated above the hinge-line, the left one slightly more than the right. The umbone of the left valve is more inflated than the opposite one. Although the surface in general is smooth, more or less regular concentric ribbing is present and commonly the internal moulds are marked by fine radial costæ of irregular strength just visible to the naked eye, spaced about 15 in 5 mm. Specimen No. 7598, a young individual, has some of the external surface still preserved over the umbone and this youthful surface is marked by fine, microscopic costæ (*See* Plate XXVIII, figure 14). Several internal moulds of right valves show 3 or 4 obscure costæ on the ears.

This species is relatively higher dorso-ventrally than *P. gibbosum* M'Coy, to which it bears a strong resemblance.

Dimensions. Length of hinge-line, 12 mm.; length of shell, 16·5 mm.; height, 16·2 mm.; gibbosity of right valve, 5·6 mm.; gibbosity of left valve, 4·4 mm.

Horizon and Localities. Lower Windsor; localities, 7497, 7498, 3302, 3022, 3512, 3424.

Types. Plesiotypes, 4364, 4364f, 7557, 7557a, 7597, 7598; National Museum of Canada, Ottawa.

Pseudamusium debertianum (Dawson)

Plate XXIX, figures 3, 4, 5

Aviculopecten debertianus Dawson, Acad. Geol., 2nd ed., 1868, p. 307, fig. 116.

Original Description.

"Shell rather flat, broader than long, small; breadth less than half an inch. Anterior ear narrow, convex, separated by a deep notch from the margin. Posterior ear very small. Surface in perfect specimens marked with concentric furrows and obscure radiating lines."

Remarks. The short hinge-line and small posterior ears characterize this species. The posterior margin meets the hinge-line at a very obtuse angle. Regular concentric ribbing is well marked and more defined than in *P. simplex.* The faint costæ that mark the internal moulds are of irregular breadth, but the costation is much coarser (about 8 costæ per 5 mm.) than that of *P. simplex.* Were it not for its smaller size there would be little justification for considering this Windsor species separate from *P. ellipticum* Phillips.

Dimensions. Length, 13 mm.; height, 13 mm.

Horizon and Localities. Lower Windsor; localities, 3424, 3022, 3512, 7545, 7551, 7522. Upper Windsor; localities, 7535, 7548, 7550.

Types. Plesiotypes, 7595, 7596, 7596a; National Museum of Canada, Ottawa.

Modiola hartti n. sp.

Plate XXIX, figures 10, 11

Description. Shell, small, obliquely tumid, subtriangular to subovate. Hinge-line, straight and equalling two-thirds to one-half total length of the shell. Umbones, nearly terminal. Anterior half of the shell compressed against a prominent, narrowly rounded crest that runs from the umbone towards the postero-ventral border. This prominence subsides rapidly in the latter half of the shell, which is expanded and flattened. Anterior margin very short, narrowly rounded; ventral margin nearly straight, making an angle of 15 degrees to 20 degrees with the hinge-line; postero-ventral margin bluntly rounded; postero-dorsal margin straighter and running obliquely forward to the hinge-line. A faint posterior ovate adductor scar has been noted on the backward slope of the siphonal area a little above the crest. Surface smooth except for fine, concentric growth lines.

Dimensions. Total length, 8·2 mm.; length hinge-line, 4 mm.; posterior maximum height, 4·8 mm.; thickness of right valve, about 2 mm.

Remarks. The species occurs in great numbers at certain horizons, suggesting a gregarious habit. Its form closely resembles *M. macadamii* Portlock as described by Hind, but is smaller and the oblique swelling or branchial crest in the Windsor forms is seemingly more angular.

Lithophagus poolii (Dawson) is a larger form, less oblique, has a longer hinge-line and a longer and wider anterior end.

Horizon and Localities. Upper Windsor; localities, 7520, 7509, 7543, 7501.

Types. Holotype, 7564; paratypes, 7564a; National Museum of Canada, Ottawa.

Modiola dawsoni n. sp.

Plate XXIX, figures 6, 7, 8, 9

Description. Shell, small, ovately triangular. Anterior margin minute, narrowly rounded; ventral margin, nearly straight, inclined about 35 degrees to the hinge-line; posterior margin, nearly at right angles to the ventral margin, smoothly curved below, obliquely subtruncate above so as to meet the hinge-line in an obtusely rounded angle. Hinge-line about three-fifths to three-quarters the length of the shell. Beaks, small, pointed forwards, almost contiguous and subterminal. Anterior half of the shell narrow and tumid; posterior half, compressed and expanded. A prominent gibbosity extends from the umbones to the postero-ventral corner, broadening and flattening posteriorly. The surface of the shell below this swelling is precipitous to the ventral margin, unmarked by any definite sinus; surface above the swelling gradually expanded and depressed postero-dorsally.

Anterior adductor scar, small, ill defined; posterior adductor not defined. Surface of internal moulds marked by crowded growth ribs, some of which are more strongly accentuated than others.

Dimensions. Length, 14·1 mm.; height at posterior end of hinge, 8·8 mm.; length of hinge-line, 8·5 mm.; thickness, 6·2 mm.

M. dawsoni is larger and relatively less elongate than *M. hartti.* It is likewise less elongate than *Lithophagus poolii* (Dawson).

Horizon and Localities. Lower Windsor; localities, 3022, 3424, 7498, 7546.

Types. Holotype, 7561; paratypes, 7601, 7562, 7600; National Museum of Canada, Ottawa.

Lithophagus poolii (Dawson)

Plate XXIX, figures 12, 13, 13a, 14, 15, 16, 17, 17a, 18

Modiola poolii Dawson, Acad. Geol., 2nd ed., 1868, p. 301.

Modiola poolii Beede, N.Y. State Mus. Bull. 149, 1911, p. 173, fig.

Description. Shell elongate, subcylindrical, slightly expanded posteriorly. Hinge-line about two-thirds of the total length of the shell. Beaks small, almost anterior, incurved, non-contiguous. Umbones scarcely defined from the rest of the shell. Greatest gibbosity of shell along the antero-dorsal postero-ventral axis. Anterior margin narrowly rounded. Ventral margin gently convex; posterior margin rather narrowly rounded below to its junction with the ventral margin, obliquely truncated above to its junction with the hinge-line at a wide, obtuse angle. Sinus obsolete. Surface marked with crowded, minute growth lines and a few more pronounced growth undulations. The latter alone affect the internal moulds. These growth ribs are markedly oblique to the ventral margin.

Adductor scars not preserved. Fine marginal striæ border the hinge-line in the impressed zone of ligamental attachment.

Dimensions. Specimen 7602 measures: length, 23·5 mm.; posterior height, 11·8 mm.; gibbosity, 10·7 mm. A young specimen (7603) measures, respectively, 14 mm., 5·7 mm., 3·9 mm.

Remarks. In form the Windsor species most nearly resembles *L. carbonarius* Hind, but is more expanded posteriorly.

Horizon and Localities. Lower Windsor; localities, 7497, 7498, 3022, 3516.

Types. Neotype, 7602; Plesiotypes, 7552, 7552a, 7552b, 7552c, 7602a, 7603; National Museum of Canada, Ottawa.

Cypricardella acadica n.sp.

Plate XXX, figures 5, 5a, 5b

Description. Shell oblong, subquadrangular. Anterior end, narrow; posterior, broad, and truncate. Cardinal margin, nearly straight behind beak, obliquely inclined downwards in front of beak at an angle of about 120 degrees with posterior portion; anterior margin, narrowly rounded into ventral margin which is nearly straight midway and about parallel to the posterior part of hinge; posterior margin almost perpendicular, slightly convex. Beaks tumid, shell compressed behind the gentle umbonal swellings. Lunule and linear escutcheon conspicuous. Surface marked by regular, elevated, angular growth ribs.

Dimensions. Length, 7·5 mm.; height, 5·5 mm.; thickness, 3·7 mm.

Remarks. This species is very close in form to *Cypricardella oblonga* Hall. The ratio of height to length, however, is greater and the posterior umbonal swelling is more broadly rounded.

Horizon and Localities. Upper Windsor; localities, 7535, 7534.

Types. Holotype, 7615; National Museum of Canada, Ottawa.

Spathella insecta (Dawson)

Plate XXX, figures 1, 2, 3

Cypricardia insecta Dawson, Acad. Geol., 2nd ed., 1868, p. 303, fig. 106.

Original Description

"Transversely oblong. Thrice as wide as long, anterior end very short, posterior somewhat keeled. Hinge-line rather more than half as long as the shell, posterior margin rounded. Surface covered with strong, concentric folds. Length, $1\frac{9}{10}$ inches."

Emended Description. Shell transversely ovate, inequilateral, broadest behind, obliquely tumid, compressed dorso-posteriorly. A shallow sulcus causes a slight sinuosity of the ventral margin. Postero-dorsal slopes slightly concave. Anterior end, short, narrowly truncated; ventral margin, slightly convex, subparallel to the dorsal margin; posterior end bluntly rounded. Hinge-line, straight or slightly arcuate about three-fourths of the greatest length. Umbones tumid, raised, incurved, contiguous. Lunule absent. Escutcheon narrow, elongate.

Surface of internal moulds marked by prominent growth ribs, the innermost of which run obliquely to the ventral margin; these ribs broaden noticeably posteriorly. Hinge, unknown.

Dimensions. Length, 33·5 mm.; height, 15·7 mm.; gibbosity, 10·3 mm.

Remarks. In form characters this species is intermediate between *S. cylindrica* (M'Coy) and *S. tumida* Hind. A sulcus is present as in the former species, whereas the ornamentation and posterior contour are similar to that of *S. tumida.* But *Cypricardia insecta* Dawson, as figured, has the posterior contour of *S. cylindrica.* Although Dawson's species is based on a larger form than that described here it comes from the same horizon, and there is little doubt of the specific identity of all the forms.

Horizon and Localities. Upper Windsor; localities, 7510, 7501, 7504, 7527.

Types. Plesiotypes, 7534, 7539, 7540; National Museum of Canada, Ottawa.

Scaldia fletcheri n.sp.

Plate XXX, figures 4, 4a

Description. Shell, small, subcircular, gibbous. Anterior and ventral margins, subcircularly rounded, beginning beneath the umbones. Postero-dorsal margin somewhat truncated. Umbones, subcentral; beaks, small, acute, incurved, rising slightly above the hinge-line and directed forwards.

Internal mould, smooth, showing a short, shallow anterior depression inclined to the hinge-line, in front of the beak, and a shallow depression parallel the hinge posterior to the beak. A single cardinal tooth seemingly present beneath the umbone in each valve. A single imperfect specimen known.

Dimensions. Length, 14·8 mm.; height, 15 mm.; gibbosity, 9·5 mm.

Horizon and Locality. Lower Windsor; locality, 7498.

Types. Holotype, 7563; National Museum of Canada, Ottawa.

Bellerophon sp.

Plate XXX, figures 6, 6a, 7

Specimens imperfect. Medium size, as wide as, or wider (across the laterally extended aperture) than, the shell is long. Sinual band marked by a narrow furrow on the inner portion of the last volution, but surface smooth or only slightly ridged towards the aperture. Lenth about 25·5 mm.

Horizon and Locality. Upper Windsor; locality, 7527.

Type. Holotype in Yale Collection, Peabody Museum, New Haven. Paratype, 7639; National Museum of Canada, Ottawa.

Euphemus cf. *urei* Fleming

Plate XXX, figure 8

Only two specimens have been seen, one showing the surface features much distorted. They agree with *E. urei* Fleming as defined and figured by de Koninck,[1] in the shallow umbilical fossula, the smooth outer half of the surface of the body whorl, and the presence, farther in, of about 10 well-defined, revolving carinæ with wider intervening furrows on either half of the shell; the carinæ are about equally spaced, 3 in the space of 1 millimetre. Diameter, 10·5 mm. +, thickness, 6·7 mm +.

Remarks. The *Euphemus* described and figured by Beede and identified by him with *Euphemus?* sp. Weller, may be identical with the above species. The smaller number of carinæ present in the Magdalen Island specimen may be accounted for by the smaller diameter of the shell. Unfortunately, the outer part of the last whorl is missing, so that it is not possible to say whether the carinæ disappeared in the apertural region as in the present species.

Horizon and Locality. Upper Windsor; locality, 7534.

Types. Holotype, 7678; National Museum of Canada, Ottawa.

Bucanopsis beedii n.sp.

Plate XXX, figure 9

Description. Body whorl widely expanded laterally, so that the breadth probably exceeds the height. Apertural lips expanded laterally. Umbilicus small, and junction of external and umbilical margins abrupt. Sinual band, narrow, about 1 mm. in width near the aperture, raised and flattened medially. Entire surface, including band, marked with fine, closely spaced, thread-like striæ of unequal strength, crenulated microscopically by growth lines, and crossed by a few broader sulci of growth which bend sharply backwards at the sinual band. About 8 striæ in the space of 1 millimetre.

[1] Faune du Calcaire Carbonifère de la Belgique, 4, p. 157, Pl. 42 bis, figs. 41-43.

Remarks. The ornamentation recalls that of *B. striata* Fleming, but the present species is a larger shell and is more expanded laterally. It is quite distinct from *B. textilis* (Hall).

Horizon and Localities. Upper Windsor; localities, 7519, 7507.

Types. Holotype, 7638; National Museum of Canada, Ottawa.

Mourlonia?

Plate XXX, figures 10, 10a

Description. (Based on a single imperfect individual). The sutures are deep, and the whorls are flattened beneath them. Sinual band, convex, raised, narrow, situated above the centre on the body whorl. Surface of the body whorl below the band marked by 3 or more rounded spiral ribs, and seemingly there are 2 or more similar ribs above the band. The whorls rapidly increase in size from the apex downwards.

Horizon and Locality. Lower Windsor; locality, 7497.

Type. Holotype, 7628; National Museum of Canada, Ottawa.

Murchisonia gypsea Dawson

Plate XXX, figures 11, 12

Murchisonia gypsea Dawson, Acad. Geol., 2nd ed., 1868, p. 310, fig. 123.

Original Description. "Like *M. nana* de Koninck, but larger, and with only two revolving ridges on the whorls."

Emended Description. Shell small, conical, composed of 10 or more whorls that are convex and somewhat depressed at the sutures, contiguous or overlapping slightly, umbilicate. The surface features are indistinctly exposed on the smooth, internal moulds of the shell, but 4 revolving ribs are indicated, the 2 most prominent enclosing a median band.

Dimensions. Length, 7·5 mm.; width of body whorl, 2·6 mm.; apical angle about 18 to 20 degrees.

Remarks. It is not improbable that this species is identical with *M. nana* de Koninck. Until better specimens, however, reveal more clearly the ornamentation it is considered best to retain Dawson's species.

Horizon and Localities. Lower Windsor; localities, 3022, 7497.

Types. Plesiotypes, 7636, 4368; National Museum of Canada, Ottawa.

Murchisonia (Stegocoelia) abrupta n.sp.

Plate XXX, figures 16, 17

Description. Shell, small, abruptly conical, composed of about 5 whorls. The whorls are convex, somewhat depressed, the body whorl where 4 whorls are preserved, occupying a little more than half the total length of the shell. Ornamentation consists of 5 or more angular revolving carinæ of which the most pronounced lies slightly above the median line of a whorl. A faint additional carina lies close above the main keel, and between this and the overlying suture there are 3 carinæ, the middle one fainter than the other 2 and spaced close to the lowermost of the 3. Below the main keel there are two carinæ preserved on most whorls, but on the body whorl the number may increase to five or possibly more.

Dimensions. Length of a small individual, 4·6 mm.; width of body whorl, 2·8 mm.; apical angle about 62 degrees.

Remarks. This species is the most common murchisonid in the Lower Windsor beds. It is characterized by its wide, apical angle, which distinguishes it from *M. compactoidea* and *M. gypsea.* On account of this depressed form it departs widely from typical *Murchisonia* and approaches *Pleurotomaria,* but there is no slit band and the sinuosity of the growth lines above the angle of the whorl is like that of *M. compacta* Donald.

Horizon and Locality. Lower Windsor; locality, 7497.

Types. Holotype, 7624; paratype, 7624a; National Museum of Canada, Ottawa.

Murchisonia (Stegocoelia) compactoidea n. sp.

Plate XXX, figures 13, 14, 15, 15a

Description. Shell, small, conical, composed of from 6 to 9 whorls. Sutures pronounced. There are 3 or 4 prominent, angular, revolving carinæ on each whorl, approximately equidistant, but the space between the first and second that lie below the suture a little wider. The strongest of the 4 keels lies slightly above the centre line of the whorl; below it lies 1, and above it lie 2, all about equally pronounced. In addition a fifth, much less prominent carina lies about medially and close to the third keel below the suture line. Growth lines, indistinct, but a narrow, sinual curve is indicated between the main keel and the next prominent one above.

Dimensions. Length, 5·5 mm.; width of body whorl, 2·7 mm.; apical angle about 30 degrees.

Remarks. This species may prove to be identical with *M. tricingulata* Dawson. It is closely allied to, and may be a varietal form of, *M. compacta* Donald. The latter has a faint carina accompanying the uppermost keel and lacks that one which in the present species accompanies the third keel below the suture line.

Horizon and Localities. Lower Windsor; localities, 7497, 7498, 7546.

Types. Holotype, 7633a; paratypes, 7640, 7633; National Museum of Canada, Ottawa.

Straparollus minutus de Koninck

Plate XXX, figures 18, 18a, 19, 20, 21

Description. Shell, very flatly turbinate, almost discoidal. Whorls round, loosely coiled in about 5 volutions. Umbilicus, very broad. Surface of whorls smooth except for fine, crowded transverse growth striæ which commonly become so pronounced on the body as to form sharp folds or rugæ.

Dimensions. Total height, 7·2 mm.; height of body whorl, 5 mm.; diameter of base of shell, 16 mm. Respective measurements of a second specimen are 5·5 mm., 4 mm., 11·5 mm.

Remarks. *S. spergenensis* Hall is more depressed and more tightly coiled than this species.

Horizon and Locality. Lower Windsor; locality, 7497.

Types. Plesiotypes, 7623, 7623a, 7675; National Museum of Canada, Ottawa.

Platyschisma? dubium Dawson

Plate XXXI, figures 1, 1a, 1b, 2

Platyschisma dubia Dawson, Acad. Geol., 2nd ed., 1868, p. 309, fig. 121.

Description. Shell, depressed, conical, with 5 or 6 whorls. About one-half the height of the early whorls is enveloped by subsequent ones. Sutures, very shallow. Umbilicus, marked, but narrow. Growth lines, gently convex, without a sinus.

Dimensions. Height, 11·6 mm.; greatest diameter of body whorl, 8·7 mm.; apical angle about 100 degrees.

Remarks. The absence of a broad, apertural sinus renders the assignment of this species to *Platyschisma* doubtful. Externally it agrees fairly closely with *P. glabratum* de Koninck, but the latter is larger and possesses a greater apical angle.

Horizon and Localities. Lower Windsor; localities, 7497, 7498, 3022.

Types. Plesiotypes, 7619, 7619a; National Museum of Canada, Ottawa.

Euomphalus exortivus ? Dawson

E. exortivus Dawson, Acad. Geol., 2nd ed., 1868, p. 308, fig. 118.

A small fragment of a whorl showing a prominent, rounded rib situated almost medially as viewed from above. The growth lines bend backward; forming a sinus on passing over the rib, below which they curve smoothly forward and then obliquely backwards. In these characters it is closely akin to *E. spergenensis* var. *planorbiformis,* but the raised rib is more central than in that species.

Horizon and Locality. Lower Windsor; locality, 7497.

Euomphalus similis (Meek and Worthen)

Description. Shell, small, terraced, conical, composed of 4 whorls. Umbilicus broad and open. The whorls are flattened above, producing a pronounced carination with the remainder of the surface, the carinæ lying almost peripheral when viewed from above. One specimen with the shell removed shows a second carina on the body whorl, situated at the periphery of the lower surface, and giving rise to a slightly hollowed space between it and the main carination. A second specimen with shell well preserved does not carry this accessory ridge. The growth lines are strong, close, and irregular, and pass over the upper carina almost in a straight line running obliquely backwards over the umbilical region. Test thick, so much so that it is doubtful whether the dorsal carination is marked on internal moulds.

Dimensions. Diameter, 9·3 mm.; height, 5·5 mm.+; height of last whorl, 3 mm.; diameter of umbilicus, 4 mm. A second specimen has a height of 5·5 mm. to a diameter of 5·5 mm.

Remarks. The Windsor forms apparently agree with the Ohio specimens in the irregularity of the occurrence of a carina on the medial line of the whorls.

Young individuals of *E. crotalostomus* M'Coy are very similar to this species, agreeing also in the thick test and strong growth lines. *E. elegans* de Koninck is likewise an analagous form.

Horizon and Localities. Lower Windsor; localities, 7546, 3022.

Types. Plesiotypes, 7757, 7758; National Museum of Canada, Ottawa.

Cyclonema? subangulatum Hall

Plate XXXI, figures 3, 3a, 4, 4a, 5, 6

Description. Whorls, 5 or 6 in number, depressed below the deep sutures. Ornamentation consists of a number of revolving carinæ of which 3 stand out most prominently; of these 3, the lower 2 lie on the periphery, and the uppermost at the angle formed by the flattened, dorsal slope of the whorl. A fourth well-marked carina lies about the middle of the dorsal surface, and a fifth, less marked, borders the suture. Six or more closely spaced, but less well-defined, carinæ lie on the lower surface of the body whorl.

Dimensions. Height, 6 mm.+; diameter of base, 5 mm.; apical angle, about 70 degrees.

Remarks. There does not appear to be sufficient evidence to separate this species specifically from the Spergen Hill form. If the apertural characters were known the species would probably be removed from *Cyclonema.* In the revolution of the whorls there is a short prolongation into the columellar cavity, but whether the inner lip formed a callosity over the columellar area is not known. The growth lines are not preserved, but there is no evidence of a sinus of the *Pleurotomaria* type. It is possible, however, that the species would fall under de Koninck's genus *Mourlonia*.

Horizon and Locality. Lower Windsor; locality, 7497.

Types. Plesiotypes at Peabody Museum, Yale University, collection No. 3194. Plesiotypes, 7620, 7620a; National Museum of Canada, Ottawa.

Holopea cf. *proutana* Hall

Plate XXXI, figures 7, 7a, 8

Description. Shell consisting of 5 whorls, of which the body whorl occupies seven-tenths of the total height. Body whorl moderately ventricose, remaining whorls somewhat compressed. Sutures well defined. Aperture, obliquely subovate with acute upper angle.

Surface ornamented with striæ of growth, and the young whorls at least seemingly marked with transverse ribs parallel to the growth lines.

Dimensions. Height, 8 mm.; width across body whorl, 5·5 mm.; apical angle about 52 degrees.

Remarks. In size and contour this species agrees well with *Holopea proutana*. The specimens are not well enough preserved to indicate the significance of the transverse ribs on the whorls of the young. Seemingly it would suggest affinities with *Callonema*.

Horizon and Localities. Lower Windsor; localities, 3022, 7497, 7546.

Types. Holotype, 7625; paratype, 7626; National Museum of Canada, Ottawa.

Flemingia dispersa (Dawson)

Plate XXXI, figures 9, 10

Pleurotomaria dispersa Dawson, Acad. Geol., 2nd ed., 1868, p. 310.

Original Description

"There are several small species of this genus. One which is very abundant in bed (*b*), Hartt, at Windsor, is that above named. It has 4 flat whorls, giving it an almost regular conical form, with delicate striæ across the whorls."

Emended Description. Shell, small, conical, imperforate, consisting of 5 whorls; apical angle 35 degrees. Median vertical section a triangle on account of the flat surfaces of whorls. Sutures between whorls, narrow. Body whorl, nearly half as high as shell, obliquely extended, abruptly rounded into the depressed basal surface, so that its oblique prolongation is separated off from the upper part of the whorl by a rounded but scarcely carinate elevation. Surface marked by oblique, pronounced ribs of growth.

Dimensions. Height, 6·6 mm.; height of body whorl, 3·1 mm.; breadth across base, 4 mm.

Horizon and Localities. Upper Windsor; locality, 7514; Upper? Windsor; locality, 7552.

Types. Plesiotypes, 4370, 4370b; National Museum of Canada, Ottawa.

Flemingia minuta n. sp.

Plate XXXI, figures 11, 11a

Description. Shell, small conical, imperforate, 5 whorled. Median vertical section triangular. Surface of whorls flattened. Apical angle 40 degrees. Body whorl, obliquely extended, more than half the total height, abruptly curved into the depressed base, with angle of curvature subcarinate. Carinate curvature of penultimate whorl likewise visible above suture. Surface marked by oblique pronounced ribs of growth.

Dimensions. Height, 4 mm.; height of body whorl, 2·9 mm.; breadth of base, 2·7 mm.

Remarks. Differentiated from *F. dispersa* by greater apical angle and more marked carination of basal part of whorls.

Horizon and Locality. Upper? Windsor; locality, 7552.

Types. Holotype, 7681; National Museum of Canada, Ottawa.

Naticopsis howi Dawson

Plate XXXI, figures 12, 13, 13a, 14?, 15

Naticopsis howi Hartt *nomen nudum.* Can. Nat., new ser., vol. 3 (1867).

Naticopsis howi Dawson, Acad. Geol., 2nd. ed., 1868, p. 309, fig. 119.

Naticopsis dispassa Dawson, ibid, p. 309, fig. 120.

Original Description. "Allied to *N. plicistria* Phillips, but different in markings, having merely delicate growth lines on the whorls, and always of small size". Of *Naticopsis dispassa* Dawson writes "A small species of the type of *N. ampliata* Phillips and marked in the same way with delicate, transverse lines of growth, but flatter in general form, and less depressed in the spire".

Remarks. Hartt stated *Naticopsis howi* is one of the commonest fossils of the Avon beds. As the many individuals collected by the writer from these beds are only referable to one species, and as Dawson's figure 119 obviously represents a specimen with incomplete body whorl, there is little doubt of the specific identity of all forms, including *N. dispassa.*
The closest European ally is seemingly *N. planispira,* Phillips, which has an apical angle of 135 degrees as compared with 115 degrees of the present species. Both forms agree in having the upper part of the body whorl depressed, or even slightly concave, near the suture, in having a thin, channelled columella, and in the possession of fine growth lines. *N. elegans* de Koninck with similiar proportions differs in its ornamentation of fine, regular folds.

Dimensions. A large specimen has a height of 11·3 mm.; width of body whorl at periphery, 8·1 mm. An average-sized specimen measures: height, 7·3 mm.; diameter of body whorl, 5·7 mm.

Horizon and Localities. Lower Windsor; localities, 7,497, 3266, 3418, 3022, 7498, 7546.

Types. Plesiotypes, 7630, 7631, 7632; National Museum of Canada, Ottawa. Plesiotype?; Peabody Museum, Yale University, Collection No. 2836.

Naticopsis hartti n. sp.

Plate XXXI, figures 16, 17, 17a, 18

Description. Shell small, with 4 or 5 whorls rapidly increasing in size. The body whorl occupies seven-eighths of the total height. The sutures are linear, and considerably more than half of the surface of the inner whorls are enveloped. The surface is marked by fine lines of growth.

Dimensions. Height, 7·2 mm.; greatest diameter of body whorl at periphery, 6·1 mm.; spiral angle, about 100 degrees.

Remarks. Externally this species closely resembles *N. mammillaris* de Koninck. It is smaller in size, and the apertural characters are not known.

Horizon and Localities. Lower Windsor; localities, 7498, 7497.

Types. Holotype, 7634; paratypes, 7634a, 7635; National Museum of Canada, Ottawa.

Bulimorpha maxneri n. sp.

Plate XXXI, figures 23, 24, 25

Description. Shell, minute, consisting of about 5 whorls, of which the body whorl makes up seven-tenths of the total height. The whorls are compressed with the sutures slightly channelled. The aperture is ovately acuminate, caniculate, outer margin sinuously curved. Growth lines, convex below, bending backward in a broad sinus below the suture.

Dimensions. Height, 6 mm.; greatest breadth, 3 mm.; height of body whorl, 4·3 mm.; apical angle about 55 degrees.

Remarks. This species is evidently quite close to *Bulimorpha caniculata* Hall. The body whorl and spire are a little more slender than in the Spergen Hill species.

Horizon and Locality. Lower Windsor; locality, 7497.

Type. Holotype, 7621; paratypes, 7622, 7629; National Museum of Canada, Ottawa.

Zygopleura cara (Dawson)

Plate XXXI, figures 19, 20, 21

Loxonema cara Dawson, Can. Nat., 2nd. ser., vol. X, p. 412 (1883).

Original Description

"Shell small, elongate, surface polished and shining, volutions about 8, regularly curved and marked by about 30 thin, vertical ridges crossing the whole of each volution. Aperture, apparently, regularly oval. Length 7 mm., breadth at second turn 2 mm. It somewhat resembles a species figured, but not named, in Worthen's Illinois Reports, vol. V, Pl. XXIX, fig. 3."

Dawson gave no figure.

Remarks. The protoconch is unknown. The whorls are deeply adpressed. The transverse ribs are closely spaced, and but slightly bent backward in a smooth curve.

An incomplete specimen measured 3·5 mm. in length, 1·5 mm. breadth, across lowest whorl, apical angle about 16 degrees. Another specimen measured 5·5 mm. length, 2 mm. in breadth across the base, apical angle about 18 degrees.

A fragment of the basal portion with whorls 2·5 mm. across, shows fine growth lines that are slightly sigmoidal, but less so than in the genus *Aclisina,* from which it differs also in the absence of spiral lines. Still less have the growth lines the curvature characteristic of *Loxonema.* On the other hand the straighter growth lines, transverse ribbing, and adpressed upper surface agree closely with the genus *Zygopleura* Koken.

Tmetonema includes similar ribbed forms, but they possess a spiral groove and are in general less turatellate.

Horizon and Localities. Lower Windsor; localities, 7497, 7498.

Types. Holotype, 6353; University of Chicago. Plesiotypes, 7627, 7627a; National Museum of Canada, Ottawa.

Aclisina acutula (Dawson)

Loxonema acutula Dawson, Acad. Geol., 2nd ed., 1868, p. 309, fig. 122.

Original Description

"An extremely slender species, scarcely 2 lines long, and with 15 or more whorls, marked with traces of 4 or 5 revolving lines. It corresponds to *L. polygyra* M'Coy and *L. acicula* Phillips, but is more slender and delicate than either."

Remarks. The apical angle scarcely exceeds 5 degrees. The lines of growth are indistinct. The lower two-thirds of a whorl is marked by 4 or 5 raised threads of which the first and the third are the strongest. A specimen nearly complete apically has 10 whorls in a length of 5·5 mm.; the width of the lowermost whorl is about 1 mm. Another specimen less complete has 5 whorls in 4 mm., with a width at base about 1·3 mm. and at top about 1 mm. Dawson's figure represents a specimen still more slender with 15 whorls in 4 mm., and a width at base of only 0·6 mm. The nearest European form to this species appears to be *A. aciculata* Donald.

Horizon and Locality. Lower Windsor; locality, 7497.

Types. Plesiotype, 7637; National Museum of Canada, Ottawa.

Diaphorostoma cf. *carleyana* (Hall)

Plate XXXI, figure 22

This species is rare and too poorly preserved for satisfactory identification. Body whorl large, rapidly expanding; aperture obliquely subovate; growth lines, gently curved forwards, strong, irregular. Height, about 20 mm.; breadth, 25 mm.; greatest diameter of aperture, 22 mm.

Horizon and Localities. Upper Windsor; localities, 7535, 7505.

Types. Holotype, 7676; National Museum of Canada, Ottawa.

Orthoceras vindobonense Dawson

Plate XXXI, figures 26, 26a, 27

Orthoceras vindobonense Dawson, Acad. Geol., 2nd ed., 1868, p. 311, fig. 127.

?*Orthoceras* sp. Beede, N.Y. State Mus. Bull. 149, 1911, p. 185 (1st. sp.).

Original Description

"Section nearly round. Siphuncle about one-third the diameter from the side. Septa distant from each other rather less than one-half the diameter. Resembles *O. laterale,* but is smaller, more cylindrical, and with septa more distant in proportion."

Remarks. The angle of convergence of the sides towards the apex is from 7 to 9 degrees. One specimen where diameter is 8 mm. has the septa 1·8 mm. apart and the same individual where diameter is 4·7 mm. has the siphuncle of 1·2 mm. diameter situated about 2 mm. from the margin. The suture lines are undulating, running nearly straight or with a low, broad fold on the side nearest the siphuncle, and latterly running obliquely with low, broad saddles. The undulation of the sutures on the side opposite the siphuncle was not established, but they are seemingly nearly straight. Beede's species from Magdalen islands probably belongs here, although its septa are more crowded than is typically the case.

Horizon and Localities. Lower Windsor; localities, 7497, 7498, 3512, 3424, 3022.

Types. Plesiotypes, 4372c, 7542; National Museum of Canada, Ottawa.

Orthoceras perstrictum Dawson

O. perstrictum Dawson, Acad. Geol., 2nd ed., 1868, p. 312, fig. 129.

The identification is based on the presence of straight, transverse ribs and by the spacing of the septa, as the material is too poor and fragmentary for further study. A small fragment in an early youthful stage is subcircular, has a diameter of 3·8 mm., a siphuncle about 0·5 mm. and about 1·5 mm. from the margin, with septa distant 2 mm., and with transverse ribs about 6 per millimetre. Seemingly closely allied to *O. conquestrum* de Koninck.

Horizon and Locality. Lower Windsor; locality, 7497.

Orthoceras sp.

Plate XXXIII, figure 1

A single fragment with rounded annulations about 2 mm. apart. Apical angle about 6 degrees; siphuncle subcentral; septa opposite the annulations.

Horizon and Locality. Upper Windsor; locality, 7519.

Types. Holotype, 7544; National Museum of Canada, Ottawa.

Kionoceras laqueatum (Dawson)

Plate XXXIII, figure 2

Orthoceras laqueatum Dawson, Acad. Geol., 2nd ed., 1868, p. 312, fig. 128.

Original Description

"Round with submarginal siphuncle, and about 26 regular smooth flutings. Resembles *A. gesneri* De Koninck, but differs in being round, destitute of sculpture on the flutings, and with septa more distant from each other about one-third of the diameter of the shell."

Remarks. The shell tapers at an angle of 3 or 4 degrees. Where the diameter is 4·4 mm. on one specimen there are 23 longitudinal costæ. With a diameter of 3·7 mm. the siphuncle is situated about 1·5 mm. from the margin, so that it is nearer the centre than it is to the margin. Figure 128 in Dawson does not show the siphuncle to be submarginal and agrees with the specimens gathered by the writer.

Horizon and Localities. Lower Windsor; localities, 3424, 3512, 3022.

Types. Plesiotype, 7529; National Museum of Canada, Ottawa.

Stroboceras hartti (Dawson)

Plate XXXIII, figures 3, 3a, 3b; Plate XXXIV, figures 1, 2

Gyroceras hartti Dawson, Acad. Geol., 2nd ed., 1868, p. 311, fig. 125.

Discites hartti Dawson, Report on the Peter Redpath Museum, McGill University, No. 2, 1883, p. 10.

Stroboceras hartti Hyatt, Genera of Fossil Cephalopoda, Proc. Boston Soc. Nat. Hist., vol. XXII, p. 291 (1883).

Description. None of the specimens gathered was complete. The young shell is markedly cyrtoceran and the umbilicus is very large. Through a gyroceran substage the nautiloid form is attained. The section of the whorl at an early stage is subtrigonal to fluted trapezoidal. The abdomen is flat, is bordered on either side by a concave ventral-lateral zone of 2 or 3 unequal facets due to the presence of 1 or 2 longitudinal carinæ close to the lateral angle. The latter is sharply defined. The lateral face consists of 3 main facets, of which the lower is the broadest and most markedly concave. These facets are separated by angles or carinæ and an additional fainter carina is sometimes observed on the uppermost facet. In the ephebic stage the dorso-lateral facets become gibbous and the profile rounds off to the dorsum.

The sutures on the abdomen are 2 mm. apart where the dorso-ventral diameter is 7 mm. They run almost straight across the abdomen, have narrow saddles at the two prominent angles that border the ventral-lateral zone, and have broad lobes on the ventro-lateral, lateral, and dorsal faces.

The siphuncle lies about 0·6 mm. from the ventral border where the dorso-ventral diameter is 3·4 mm. and 1·5 mm. where diameter is 7·5 mm. Very fine and regular growth lines indicate a broad hyponomic sinus and a pair of lateral sinuses in the aperture. The latter lie in line with the middle lateral facet. ....

Remarks. The species approaches nearer to the European species *Stroboceras belgicum* Hyatt than to Waverlyan species such as *S. triculcatus* (Meek and Worthen) or *S. trigonus* (Winchell).

Horizon and Localities. Lower Windsor; localities, 7497, 7498.

Types. Plesiotypes, 7549, 4374a, 4374b; National Museum of Canada, Ottawa.

Diodoceras avonensis (Dawson)

Plate XXXIII, figures 4, 5, 6, 7

Nautilus avonensis Dawson, Acad. Geol., 2nd ed., 1868, p. 311, fig. 124a-b.

Endolobus avonensis Hyatt, Proc. Bost. Soc. Nat. Hist., vol. XXII, p. 288 (1883); Proc. Am. Phil. Soc., vol. 32, pp. 536-537, Pl. VIII, figs. 36-39 (1893).

Original Description

"A large species, the outer chamber sometimes 2 inches or more in diameter. Whorls much flattened dorso-ventrally, slightly angulated at inner edge. Siphuncle dorsal (= ventral), septa convex (towards apex), about one-eighth of an inch apart."

Emended Description. In all stages later than early nepionic the transverse section of an individual chamber is transversely elliptical to diagonal. The umbilicus is wide, revealing all the coils as the involution scarcely overlaps all the abdominal surface. The impressed zone begins early in the neanic stage as a contact furrow, which broadens and shallows with age, but which leaves an umbilical zone. The living chamber of an immature individual, consisting of little more than two volutions, is about one-half of a volution in length; its aperture has a deep funnel-shaped, hyponomic sinus and broad abdominal crests. The living chamber of a gerontic individual has the aperture free, a distance of 12 mm. separating the dorsum at the aperture from the venter of the next inner whorl; its hyponomic sinus is broad and deep, lateral abdominal crests broad, and there is a narrow sinus opposite each lateral angle; the area of the apertural margin affected by these sinuses is somewhat constricted.

In early nepionic substages the suture lines are nearly straight and lack dorsal lobes; shallow dorsal lobes appear in paranepionic septa as well as faint lateral saddles. The septa across the venter in neanic and ephebic stages run nearly straight, or there is a broad, shallow, ventral lobe over the abdomen.

In the nepionic stage the shell is marked by conspicuous revolving costæ. They are revealed only on external moulds of the umbilical surfaces where 8 costæ occur in 3 mm. This longitudinal ribbing dies out in early neanic life.

The siphuncle occupies a position from near subventron in nepionic stage to centroventron or even higher in later stages.

Dimensions. The largest specimen seen is a gerontic or mature individual in the collection of Yale Museum, having three volutions. The apertural transverse diameter is 70 mm., dorso-ventral diameter about 40 mm.; depth of hyponomic sinus about 13 mm.; some 40 mm. back of the apertural margin the breadth of the umbilical zone on either side from the impressed zone to the umbilical shoulder is about 20 mm. A second specimen, No. 4373a, Geological Survey, Canada, with two volutions, measures 23 mm. across the aperture and has an hyponomic sinus 8 mm. in depth.

Remarks. Hyatt's description of the species makes reference to ventral saddles and faint, lateral lobes; but broad, nearly flat, ventral lobes and faint, lateral saddles were characteristic of the specimens observed by the writer. With the exception of the dorsal lobes, however, the undulation of the sutures is very slight. The absence of the tetragonal sections characteristic of *Temnocheilus* and absence of tubercles on the lateral angle are of sufficient importance to remove the Windsor species to a distinct genus. Hyatt in 1900 proposed the name *Diodoceras.*[1] The species bears resemblances to *Temnocheilus conchiferons* Hyatt and *T. depressus* Hyatt. *Temnocheilus coxanus* Meek and Worthen has revolving costæ that persist into the ephebic stage.

Discitoceras leveillianum Koninck has nepionic longitudinal ribbing crossed by fine growth lines and has also a free aperture in the ephebic stage, but its profile is quite distinct.

Horizon and Localities. Lower Windsor; localities, 7497 (abundant), 7498 (rather rare), 7538 (abundant), 7546, 7539.

Types. Plesiotypes, 7527, 4373, 4373a; National Museum of Canada, Ottawa. Plesiotype; Peabody Museum, Yale University, New Haven, Conn.

Poterioceras sp.

Plate XXXIV, figures 3, 4

The specimens are too imperfect for a good diagnosis. The shell is seemingly straight even in the apical region or very slightly curved with an apical angle of about 12 degrees. Nearly all the specimens are compressed, but the shell in the young stage was circular or nearly so, whereas it was seemingly somewhat transversely elliptical when mature. The body chamber shows a distinct contraction towards the aperture, but the latter is simple and open.

In one specimen the septa nearest the body chamber are 4 mm. apart where the diameter of the shell is 32·7 mm.; in another specimen near the apex the septa are 1·5 mm. apart where the diameter is 5 mm. The largest fragment has a maximum diameter of 6·4 cm., but this is excessive on account of compression.

The siphuncle is subcentral in position. It is 0·5 mm. in diameter in the apical region.

Remarks. In general form, and position of siphuncle, the species is comparable with the Visean species *P. fusiforme* (de Koninck)[2] which according to Foord is distinct from *P. fusiforme* (Sowerby).

[1] Textbook of Palæontology, Zittel, 2nd ed., vol. 1, p. 607 (1900).
[2] *Gomphoceras fusiforme* de Koninck. Ann. du Mus. Roy. d'Hist. Nat. de Belg., tome 5, p. 42, Pl. 37, fig. 4.

Horizon and Localities. Upper Windsor; localities, 7505, 7519, 7507, 7503, 7534.

Types. Holotype, 7541; paratype, 7545; National Museum of Canada, Ottawa.

Phylum, ARTHROPODA

Cypridina acadia n. sp.

Plate XXXIV, figures 5, 5a

Description. Shell, departing from a subquadrate outline as a result of greater height of shell posteriorly. Dorsal margin very slightly convex; posterior margin truncated nearly at right angles to dorsal line; postero-ventral margin convex, anterior margin convex and with a shallow notch above the middle line. Shell moderately gibbous, rather compressed in postero-dorsal corner. Muscle scar well defined, 2 mm. diameter, subcentral.

Length, 7·1 mm.; oblique antero-postero length, 7·4 mm.; height, 5·9 mm.; gibbosity of left valve, 3·9 mm.

Remarks. The form of the shell resembles quite closely that of *Cypridina thompsoniana* Jones and Kirkby, but *C. acadica* is somewhat more produced postero-ventrally.

Horizon and Localities. Lower Windsor; localities, 7497, 3418.

Types. Holotype, 7742; National Museum of Canada, Ottawa.

Paraparchites gibbus n. sp.

Plate XXXIV, figures 6, 6a, 6b

Description. Carapace subovate, except for straight, dorsal line, smooth, greatest gibbosity about midlength but slightly more tumid anteriorly than posteriorly. Right valve slightly overlapping the left, except dorsally where reverse takes place and where the left valve is higher and receives the right valve. Both valves slightly channelled along line of junction. Length, 2·1 mm.; height, 1·6 mm.; thickness, 1·2 mm.; length of dorsal line, 1·3 mm.

Remarks. The species resembles closely *P. humerosus* Ulrich and Bassler, except that the dorsal line is straighter. In the description of *P. humerosus* it seems as if the word "left" was substituted for "right" and vice versa throughout, and this error occurs also in the explanatory matter to the figures.

Horizon and Localities. Lower Windsor; localities, 7497, 7498, 7530, 7547.

Types. Holotype; Peabody Museum, Yale University.

Phillipsia eichwaldi Fischer

Plate XXXV, figures 3, 4, 5, 6

Phillipsia howi Billings, Can. Nat., vol. VIII, p. 209, fig. (1863).

P. howi Dawson, Acad. Geol., 2nd ed., 1868, p. 313, fig. 133.

P. vindobonensis Hartt in Dawson, Acad. Geol., 2nd ed., 1868, p. 313.

P. howi Herrick, Bull. Sci. Lab. Denison Univ., vol. II, p. 63 (1887).

P. vindobonesis Herrick, Bull. Sci. Lab. Denison Univ., vol. II, p. 63 (1887).

P. howi Vogdes, Ann. N.Y. Acad. Sci., vol. 4, p. 91 (1887).

P. vindobonensis Vogdes, Ann. N.Y. Acad. Sci., vol. 4, p. 89 (1887).

P. meramecensis Vogdes (non Shumard), Ann. N.Y. Acad. Sci., vol. 4, in synonomy pp. 86, 92 (1887).

Billings Description

"Pygidium semi-elliptical, strongly convex, width at the interior margin a little less than the length, 17 or 18 articulations in the axis, side lobes with 10 or 12 ribs and a smooth border. The axis is very prominent, about one-third the width, gradually and uniformly tapering and terminating abruptly at five-sixths of the whole length in an obtusely rounded apex. The ribs on the axis are depressed convex becoming smaller and more crowded towards the apex, each with 8 or 9 small tubercles, which are confined to the middle third of the width of the axis, and are situated near the posterior margin of the ribs. The side lobes have 10 or 12 depressed convex ribs, the last three indistinct, the first 3 or 4 with a very obscure, fine groove near the posterior edge, in the outer third of the length. The smooth border is about one-fourth the width of the side lobes at the anterior angles, but a little wider behind; all the space behind the apex of the axis is smooth. Each rib has 9 or 10 small tubercles near its posterior margin. On the posterior third of the pygidium there is an obscure, shallow groove along the inner edge of the smooth border.

Length of the specimen six lines; width at the anterior margin, nearly the same, about one-sixth of a line less."

Remarks. Several cranidia were found in close association in the same beds that carry pygidia, and one specimen, much crushed, shows a cranidium on one side and a pygidium on the other in the position assumed by a rolled individual. The characters of the cephala revealed by these specimens indicate clearly the identification of this species as *P. eichwaldi* Fischer as figured by Woodward (Brit. Carbon. Tril. 1883-1884, Pl. IV). There are no differences of importance, the agreement extending to the presence of a median tubercle more prominent than the rest on the aurical segment, and also to the presence of a pore at either side of the glabella in front of the eye. A single fragment of a free cheek reveals the presence of a relatively large eye (at least 2·5 mm. by 1 mm.) situated about 1 mm. from the inner margin of a broad (1·5 mm.) raised border.

Billings' description of the pygidium requires little emendation; pleural grooves are commonly preserved on the first 5 or 6 segments, the grooves lying near the posterior margins of the pleura and beginning about one-third the length of the pleura from the axis, deepening outward. Although only one row of tubercles is commonly preserved on the pleura of the lateral lobes of the pygidia a second row of smaller tubercles is indicated parallel to the first, but lying posteriorly to the pleural groove. The number of pleura on a lateral lobe is 10 or 11.

Horizon and Localities. Upper Windsor; localities, 7519, 7534, 7507, 3514.

Types. Plesiotypes, 4375a, 7677, 7677a, 7677b; National Museum of Canada, Ottawa.

Cyclus subcircularis n. sp.

Plate XXXV, figure 7

Description. Carapace, subcircular, bluntly acuminate posteriorly. The posterior two-thirds has a median spinous ridge which fork-like, branches anteriorly. This fork is closed anteriorly by a triangular circuit formed of 5 subequal tubercles, two lateral pairs and one single situated anteriorly and medially at the apex of the triangle. Inside the rhombic area so enclosed are 2 tubercles or "centrals," both in the middle line, the anterior of which lies centrally between the two lateral pairs of the enclosing circuit; the posterior is enclosed within the fork and is isolated in a triangle formed of faintly raised carinæ. There are two additional pairs of external or "peripheral" tubercles; a large, posterior pair almost in line with the basal pair of the anterior circuit and somewhat like a revival of the swellings of the fork ridges; and an anterior pair in front of them lying close to the anterior margin. Further ornamentation consists in a broadly U-shaped posterior fork consisting on either side of a delicate spinous carina terminating in a very small node or "clapper" that is inserted between the basal pair of the anterior circuit and the posterior "peripherals." The surface is markedly punctate, so that the internal moulds are pustulate. A well-marked basal terrace or flat border about 0·75 mm. wide is present laterally and posteriorly; it is not known whether this terrace continues around the anterior end. This flat border is coarsely punctate and shows indications of rude radial plications. Length about 6 mm. Diameter 5·8 mm.

Remarks. The plan of ornamentation of this species is comparable in many respects to that of *C. jonesianus* Woodward. The latter species is more highly elevated and no mention is made of peripheral tubercles or swellings.

Horizon and Localities. Lower Windsor; localities, 7497, 7498.

Types. Holotype, 7642; National Museum of Canada, Ottawa.

Phylum, VERTEBRATA

Oracanthus sp.

Plate XXXV, figures 2, 2a, 2b, 2c

Remarks. The specimen comprises incomplete fragments of a single spine. One fragment 38 mm. in length has a base 18 mm. by 10·5 mm. and its sides converging to an apical angle of about 25 degrees. The central cavity of the spine is visible at the base in the form of an oval calcite filling 13 mm. by 7·5 mm., but the upper end of the spine was solid bone for at least 2·5 cm. The ornamentation of the spine, asymmetrical, agrees in general with that of *Oracanthus milleri* Agassiz, but the spine has a more acuminate apex like that of *O. vetustus* Leidy. As compared with the latter species the following distinctions are noted: (1) The coalescence of the tubercles and their orderly transverse alignment has proceeded to such a degree that undulating, cuspidate ridges obscure a primitive longitudinal arrangement. A fragment nearer the base of the spine, however, has the tubercles dominantly isolated as subcircular, unsymmetrical, striated cones and thus more nearly resembling *O. vetustus*. (2) On the left lateral face the summits of the arches of the upwardly convex rows of tubercles instead of being near the middle of the face lie about two-thirds of the distance from the anterior to the posterior border. Between the summits and the rear margin the continuity of the individual crests is interrupted and there is greater irregularity. (3) The coalescence of the tubercles into cuspate ridges is still more definite on the right lateral face. Of 5 rows that occur in a length of 12 mm. the bottom row is continuous and each of the other four is continuous in its course to about 2 mm. from the postero-lateral angle where there is a break and an offset. (4) The tubercles on the posterior face are isolated, or confluent in pairs, and are subcircular cones where single, but are not compressed laterally.

The anterior face is worn smooth and precludes comparison. *Oracanthus rectus* St. John and Worthen seems to display some of the above characters, but unfortunately its representative is too fragmentary for satisfactory comparison.

Oracanthus milleri has a much wider apical angle, but possesses very similar ornamentation in the apical region, particularly *O. milleri* Davis from Armagh, Ireland. The summit of curvature of the tubercular rows in the latter species is near the posterior side as in the Nova Scotia species.

Horizon and Locality. Upper Windsor; locality, 7505.

Type. Holotype, 7745; National Museum of Canada, Ottawa.

INDEX TO LOCALITY NUMBERS

1302 Arisaig, near Lismore, N.S.
3022 Windsor, Hants county, near Dominion Atlantic Railway bridge. Collector, H. M. Ami, 1908.
3261 McLellan Brook post office, 3½ miles east of Stellarton, Pictou county.
3266 Brookfield, Colchester county. Collector, H. M. Ami, 1899.
3302 Riverside, Cumberland county. Collector, H. M. Ami, 1899.
3418 Brookfield, Colchester county.
3424 Brookfield, Colchester county, from McDonald's quarry near Graham's siding. Collector, L. Russell.
3433 Windsor, Hants county, Miller's quarry. Collector, H. M. Ami, 1898.
3512 Windsor, Hants county, at Avon river. Collector, H. S. Poole, 1896.
3514 Kennetcook, Hants county.
3515 Windsor, Hants county. Collector, H. S. Poole and H. Fletcher.
3516 Stellarton, Pictou county. Collector, H. S. Poole.
4352 Windsor, Hants county. Collector, J. W. Dawson, 1877.
4361 Windsor, Hants county. Collector, J. W. Dawson, 1877.
4362 Gay river, Shubenacadie. Collector, J. W. Dawson, 1877.
5475 Markhamville, New Brunswick, from manganese pits.
7497 Windsor, Hants county, Maxner point.
7498 Windsor, Hants county, Miller's quarry.
7499 Boisdale hill, Cape Breton.
7500 Maccan river, near mouth, talus.
7501 Windsor, Hants county, Avon river, beds (*e*), section 9.
7502 Dimock, Hants county, from Canadian Pacific Railway cut, near wharf.
7503 Cogmagun river, Hants county, near second road bridge above Lower Burlington.
7504 Windsor, Hants county, north of Wentworth gypsum quarry.
7505 Windsor, Hants county, on St. Croix river about ½ mile east-northeast of Windsor.
7506 Boularderie island, Cape Breton, north shore.
7507 Cogmagun river, Hants county, above Lower Burlington.
7508 Windsor, Hants county, one mile east of Windsor and south of road to Dimock.
7509 Wilkins siding, Windsor, Hants county.
7510 Sydney, Cape Breton, Louisburg quarry, Point Edward.
7511 Windsor, Hants county, Avon river, beds (*g*), section 5.
7512 Hebert river, Hants county, at Murphy Road bridge.
7513 Brookfield, Colchester county.
7514 Windsor, Hants county, Avon river.
7515 Windsor, Hants county, beds (*g*), section 9.
7516 South Maitland, Hants county.
7519 Kennetcook river, Hants county, at mouth.
7520 Windsor, Hants county, Avon river, beds (*h*), section 9.
7521 Windsor, Hants county, Avon river, beds (*f*), section 9.
7522 Avon river, Hants county, east bank at first creek south of Summerville.

7523 Avon river, Hants county, east bank at second creek north of Avondale wharf.
7524 Windsor, Hants county, on Avon river about 800 feet northeast of fertilizer plant.
7525 Windsor, Hants county, on Avon river, beds (*d*), section 9.
7526 Windsor, Hants county, Avon river, north of wharves.
7527 Windsor, Hants county, on Avon river about 400 feet north of fertilizer plant.
7528 Shawfield point, Boularderie island, Cape Breton.
7529 Newport Landing, Hants county, north of wharf, on Avon river.
7530 Branch of St. Croix river, above Avondale Road bridge.
7531 Windsor, Hants county, Avon river, talus from section 9.
7532 St. Croix river at gypsum wharf, Dimock.
7533 Windsor, Hants county, section 2.
7534 Avon river, east bank, at first creek south of Kennetcook river.
7535 On Murphy road, 2 miles south of Scotch village, Hants county.
7536 Stewiacke river.
7538 Cape Maringouin, Shepody bay, New Brunswick.
7539 Minudie, Cumberland county, base of Joggins section.
7540 Newport Landing, Hants county, section north of Avondale wharf on Avon river.
7541 Near Cape Dauphin, Bras d'Or lake, Cape Breton.
7542 Hebert creek, Hants county.
7543 Windsor, Hants county, Avon river, beds (*b*), section 5.
7544 Anticline east of Wilkins siding, Windsor.
7545 Maccan river, Cumberland county, near mouth.
7546 Maccan river, Cumberland county, upper beds at mouth.
7547 About ¾ mile west of Wentworth Creek post office, Hants county.
7548 In gypsum belt west of Wentworth Creek post office.
7549 Kennetcook river, north of Brooklyn, Hants county.
7550 About ½ mile south of Wentworth Creek post office, Hants county.
7551 Ravine near Nappan, Cumberland county.
7552 Johnson brook, Springhill, Cumberland county.
7553 Newport Landing, Hants county, at second creek south of wharf.
7554 Sydney harbour, northwest arm, Point Edward section
7556 Cheverie, Hants county, on Avon river.

PLATE I

Zaphrentis minas (Dawson). (Page 90.)

Figure 1. Exterior lateral view. Nat Mus. of Canada, Cat. No. 7666a, plesiotype, natural size.

Figures 2, 2a, 2b, 2c. Series of transverse sections of corallum. Nat. Mus. of Canada, Cat. No. 7667, plesiotype, X 2.

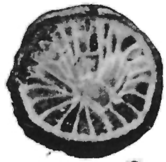
Figure 2d. View of calyx. Nat. Mus. of Canada, Cat. No. 7667, plesiotype, X 2.

Nodosinella priscilla (Dawson). (Page 90.)

Figure 3. Nat. Mus. of Canada, Cat. No. 7668, plesiotypes, X 4.

Plate I

1

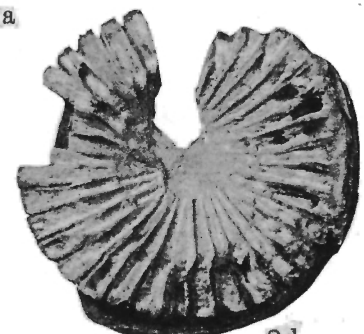


2

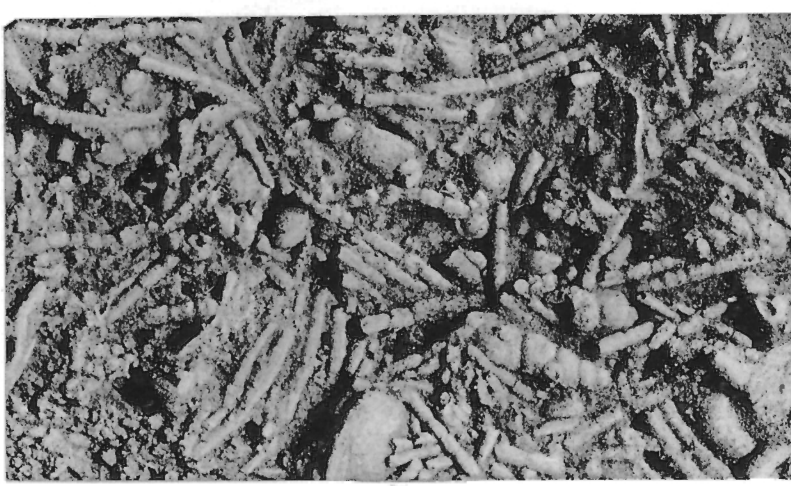
2 b

2 a

2 c



2d



3

Plate II

Zaphrentis minas (Dawson). (Page 90.)

Figure 1. Exterior view of side that bears counter septum. Nat. Mus. of Canada, Cat. No. 7666, plesiotype, X 2.

Figure 1a. Same specimen. Exterior view of calyx and side that bears cardinal septum, X 2.

Figure 2. Longitudinal section. Nat. Mus. of Canada, Cat. No. 7667a, plesiotype, X 2.

Caninia dawsoni (Lambe). (Page 91.)

Figures 3, 3a, 3b, 3c. Series of transverse sections. Nat. Mus. of Canada, Cat. No. 7650d, plesiotype, X 2.

Plate II

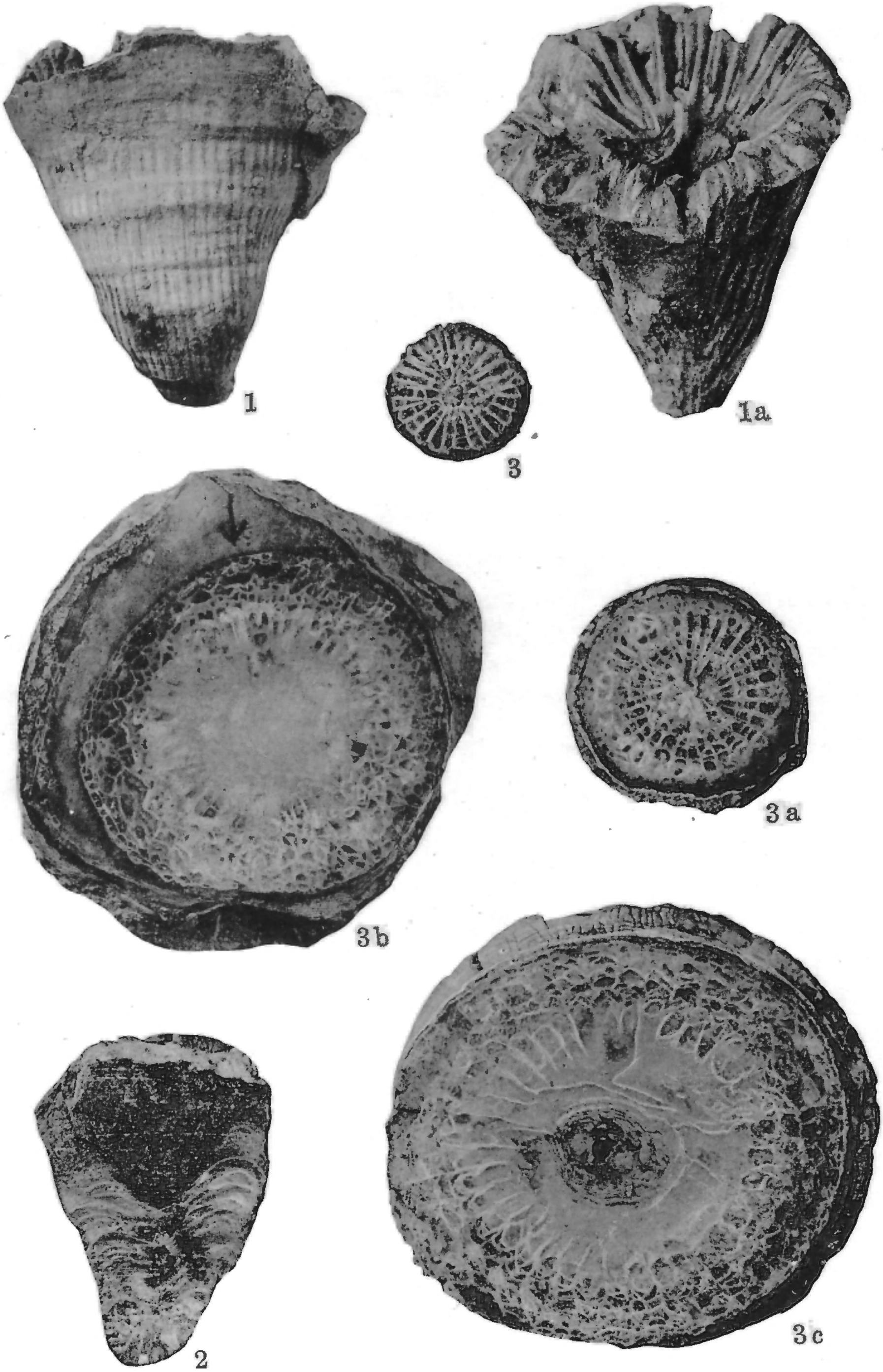


Plate III

Caninia dawsoni (Lambe). (Page 91.)

Figure 1. View of exterior. Nat. Mus. of Canada, Cat. No. 7650f, plesiotype, natural size.

Figure 2. Longitudinal section. Nat. Mus. of Canada, Cat. No. 7650, plesiotype, natural size.

Figure 3. View of exterior. Nat. Mus. of Canada, Cat. No. 7650e, plesiotype, natural size.

Figure 4. Longitudinal section. Nat. Mus. of Canada, Cat. No. 7650a, plesiotype, natural size.

Figures 5, and 5a. Lateral and calicinal views. Nat. Mus. of Canada, Cat. No. 7650c, plesiotype, natural size.

Figures 6 and 6a. Transverse sections at two levels. Nat. Mus. of Canada, Cat. No. 7650b, plesiotype, X 2.

Plate III

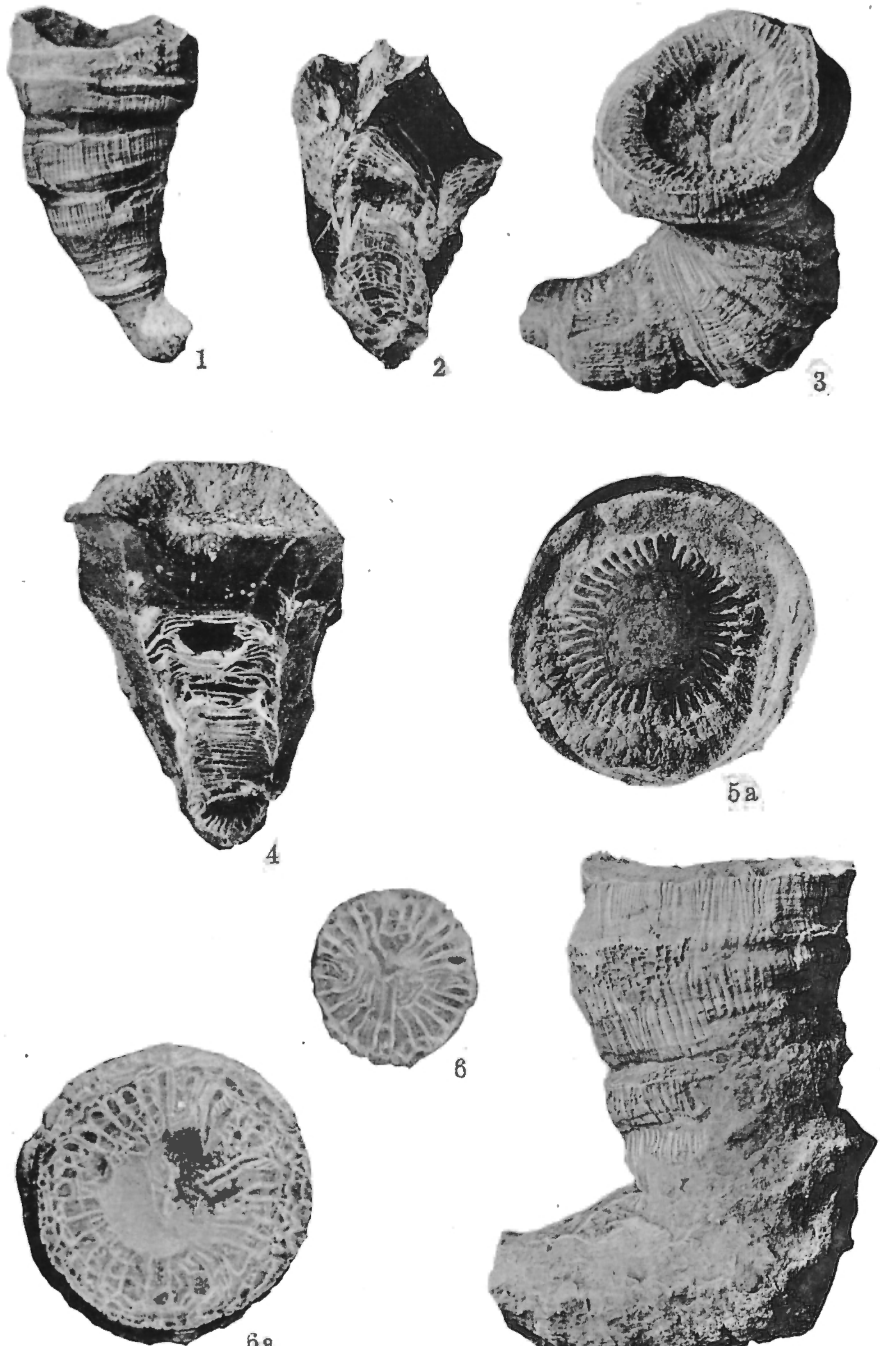


Plate IV

Dibunophyllum lambii Bell. (Page 95.)

Figures 1, 1a, 1b, 1c, 1e, and 1f. Series of transverse sections. Peabody Museum, Yale University, holotype, X 2.

Figure 1d. Longitudinal section between levels c and e of same specimen, X 2.

Figure 1g. Calicinal view of same specimen, X 2.

Figure 2. Exterior lateral view. Nat. Mus. of Canada, Cat. No. 7665d, paratype, natural size.

Figure 3. Exterior view. Nat. Mus. of Canada, Cat. No. 7665c, paratype, natural size.

Lophophyllum avonensis Bell. (Page 94.)

Figure 4. Exterior. Nat. Mus. of Canada, Cat. No. 7651, holotype, X 2.

Figure 5. Transverse section. Nat. Mus. of Canada, Cat. No. 7652a, paratype, natural size.

Figure 6. Longitudinal section. Nat. Mus. of Canada, Cat. No. 7651b, paratype, natural size.

Plate IV

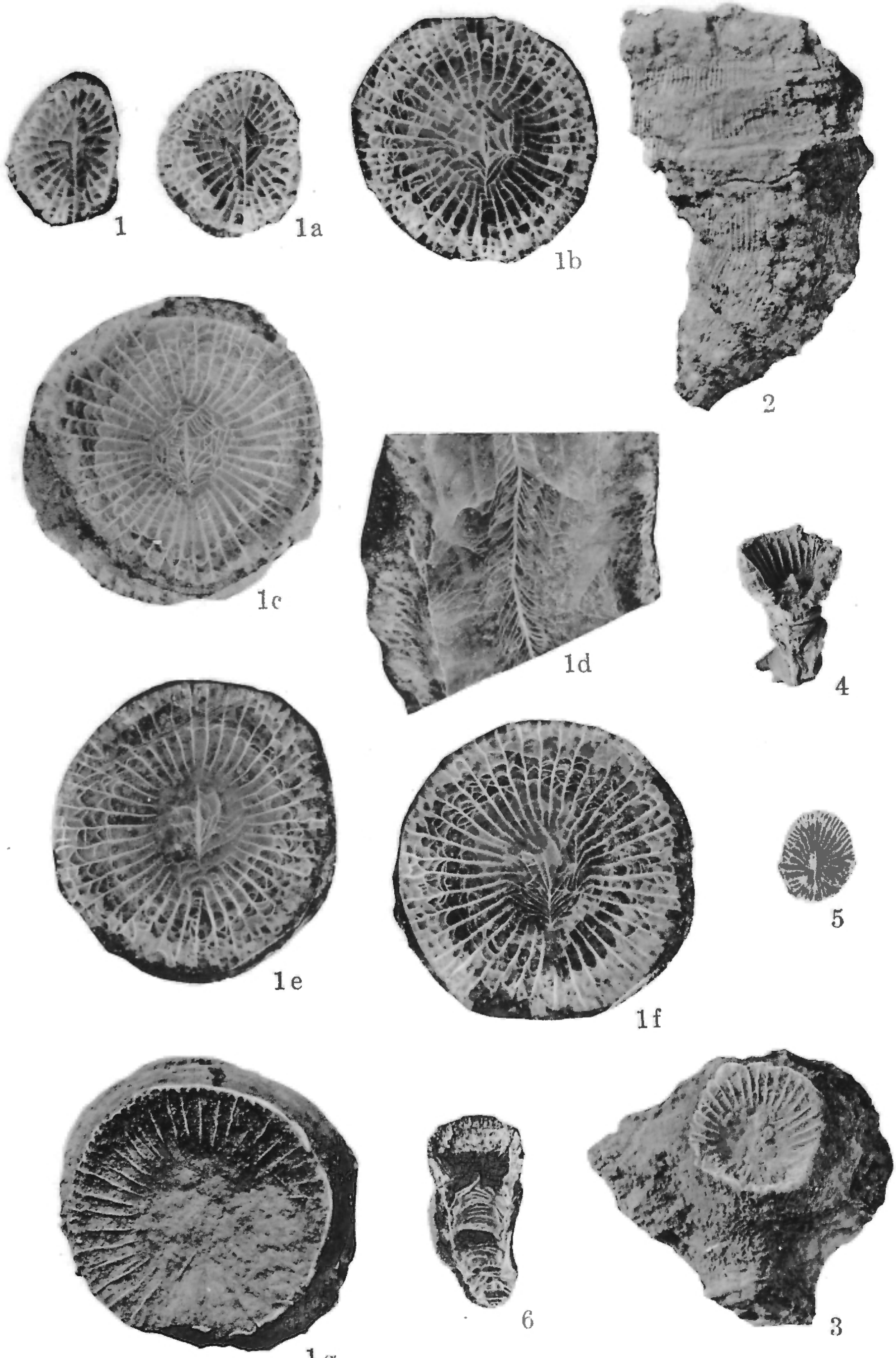


PLATE V

Serpula annulata (Dawson). (Page 97.)

Figure 1. Nat. Mus. of Canada, Cat. No. 7744, plesiotype, natural size.
Figure 1a. Same specimen, X 4.

Serpula hartti Bell. (Page 98.)

Figure 2. Nat. Mus. of Canada, Cat. No. 7748, holotype, X 4.

Fenestella lyelli Dawson. (Page 101.)

Figure 3. Nat. Mus. of Canada, Cat. No. 7725, plesiotype, X 12.

Lonsdaleia pictoense (Billings) Lambe. (Page 96.)

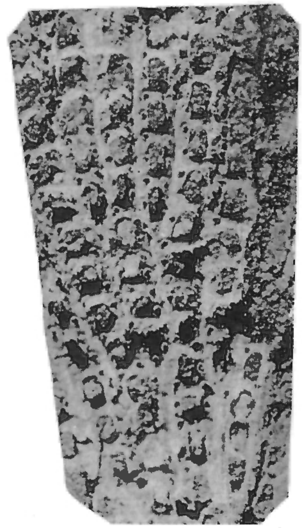
Figure 4. Transverse sections of corallites of a fasciculate corallum. Nat. Mus. of Canada, Cat. No. 4334, holotype, X 4.
Figure 4a. Longitudinal section of a corallite of same corallum, X 4.

Plate V

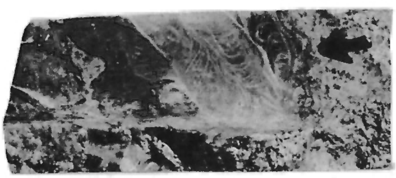
1

1a

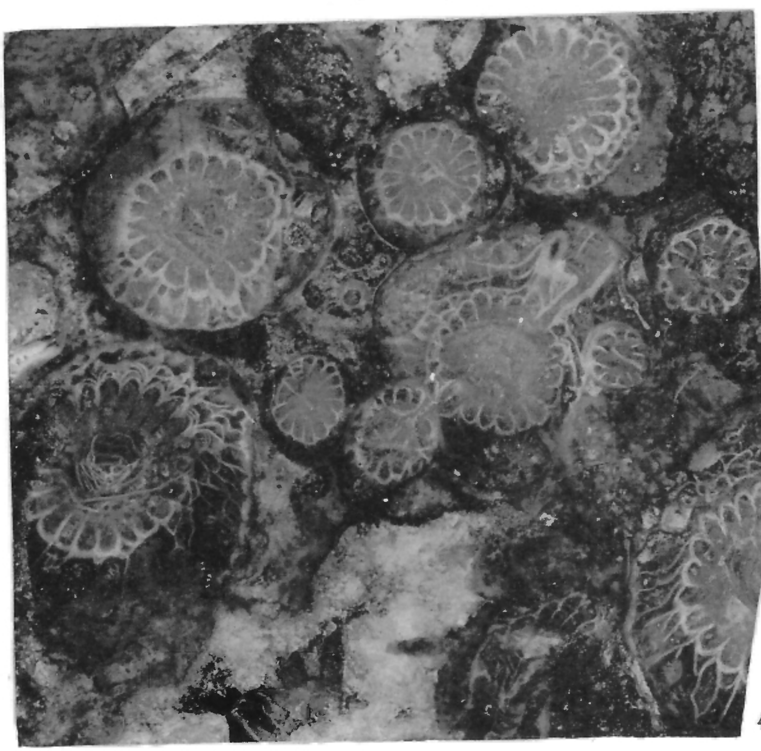
2



3



4a



4

Plate VI

Spirorbis caperatus M'Coy. (Page 98.)

Figure 1. Nat. Mus. of Canada, Cat. No. 7641, plesiotype, X 4.

Figure 2. One of many specimens encrusting an algal nodule. Nat. Mus. of Canada, Cat. No. 7641a, X 4.

Fenestella lyelli Dawson. (Page 101.)

Figure 3. Zooecial surface. Nat. Mus. of Canada, Cat. No. 7729b, plesiotype, X 12.

Figure 4. A specimen broken to show interiors of zooecia. Nat. Mus. of Canada, Cat. No. 7727a, plesiotype, X 12.

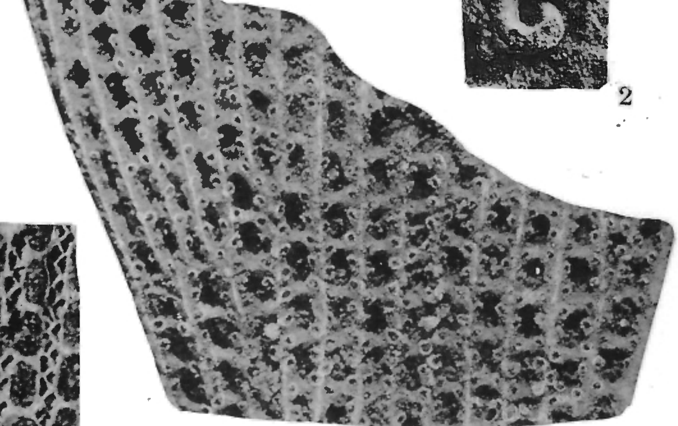
Figure 5. Non-poriferous surface of a zoarium. Nat. Mus. of Canada, Cat. No. 7725, plesiotype, X 2.

Septopora primitiva Bell. (Page 102.)

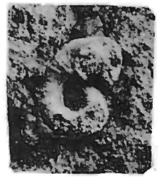
Figure 6. Zooecial surface. Nat. Mus. of Canada, Cat. No. 7734c, paratype, X 12.

Plate VI

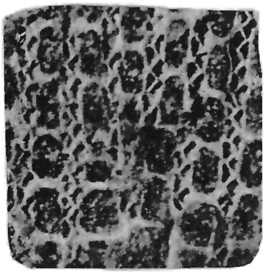
1



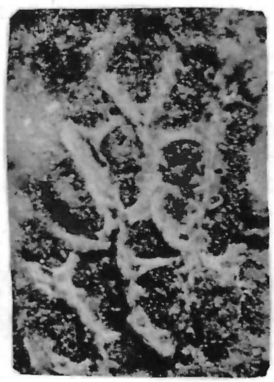
3



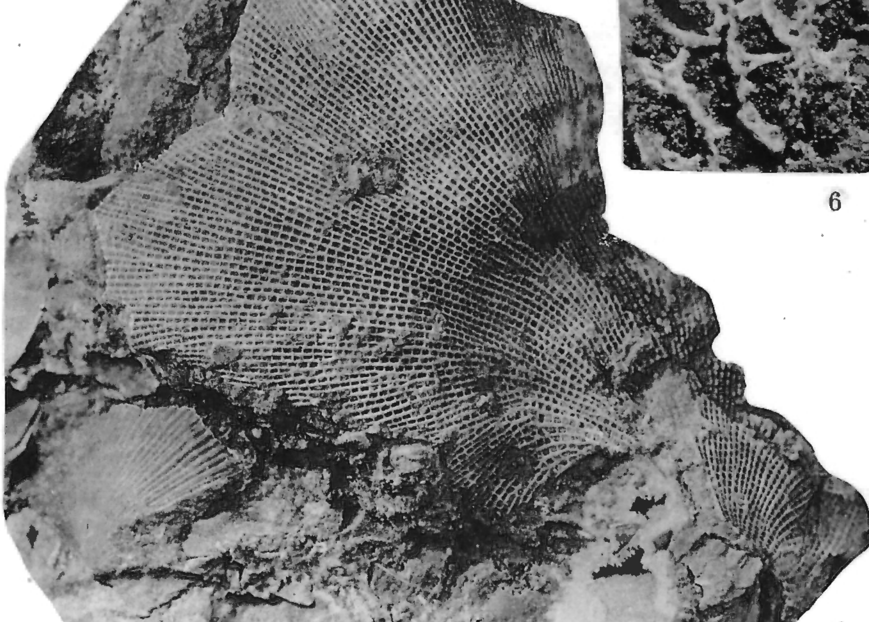
2



4



6



5

PLATE VII

Septopora primitiva Bell. (Page 102.)

Figure 1. Zooecial surface. Nat. Mus. of Canada, Cat. No. 7734a, paratype, X 12.

Figure 2. Part of zoarium broken to show interiors of zooecia. Nat. Mus. of Canada, Cat. No. 7735c, paratype, X 12.

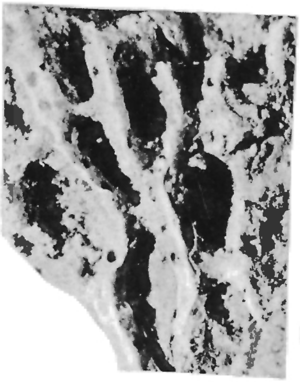
Fenestella lyelli Dawson. (Page 101.)

Figure 3. Reverse non-poriferous surface of zoarium. Nat. Mus. of Canada, Cat. No. 7729g, plesiotype, X 12.

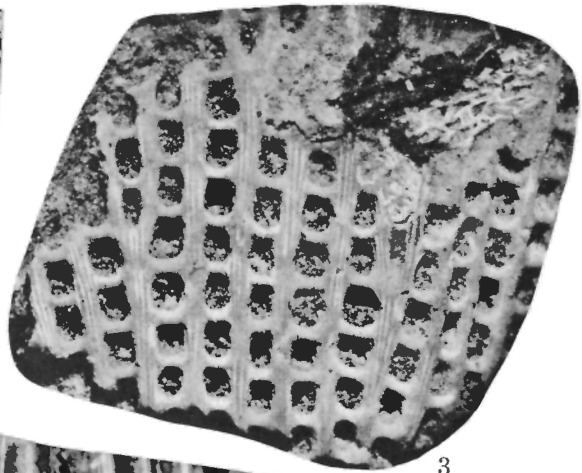
Fenestella lyelli mut. (Page 101.)

Figure 4. Reverse non-poriferous surface. Nat. Mus. of Canada, Cat. No. 7753, holotype, X 12.

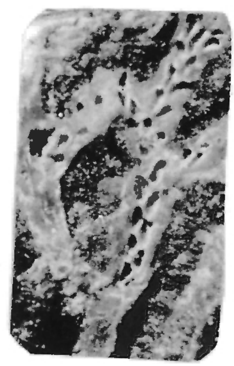
Figure 5. Reverse surface of zoarium. Nat. Mus. of Canada, Cat. No. 7730c, paratype, X 12.



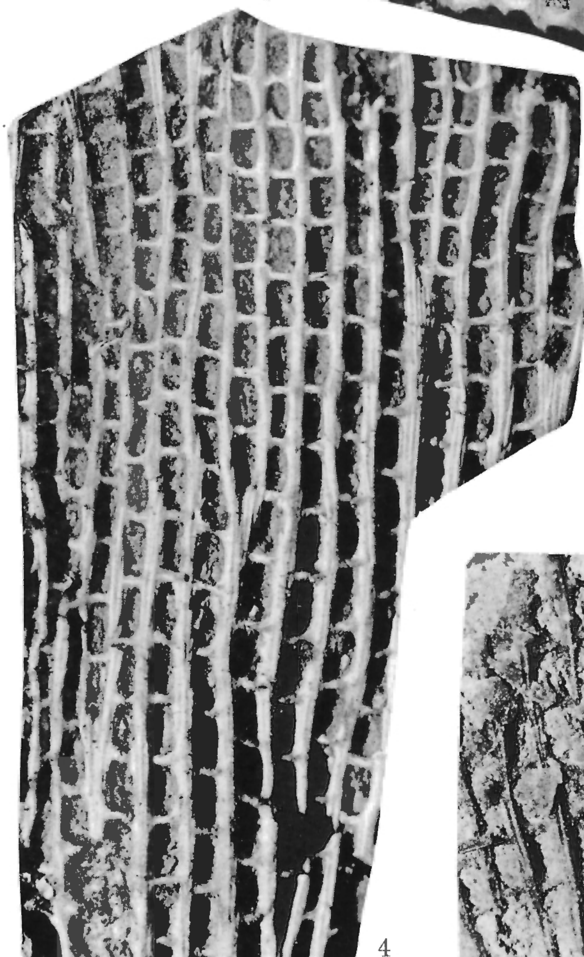
1



3



2



4

5

PLATE VIII

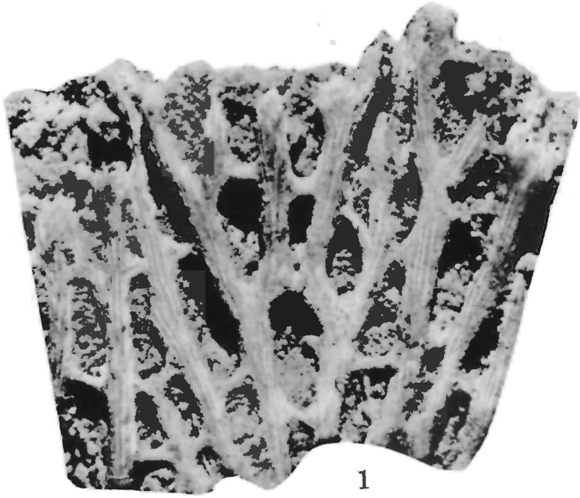
Septopora primitiva Bell. (Page 102.)

Figure 1. Reverse surface of zoarium. Nat. Mus. of Canada, Cat. No. 7734b, paratype, X 12.

Fenestella lyelli Dawson. (Page 101.)

Figure 2. Zooecial surface. There is a median row of spine bases on each branch, but they fail to show in the photograph. Nat. Mus. of Canada, Cat. No. 7729d, plesiotype, X 12.

Plate VIII


1

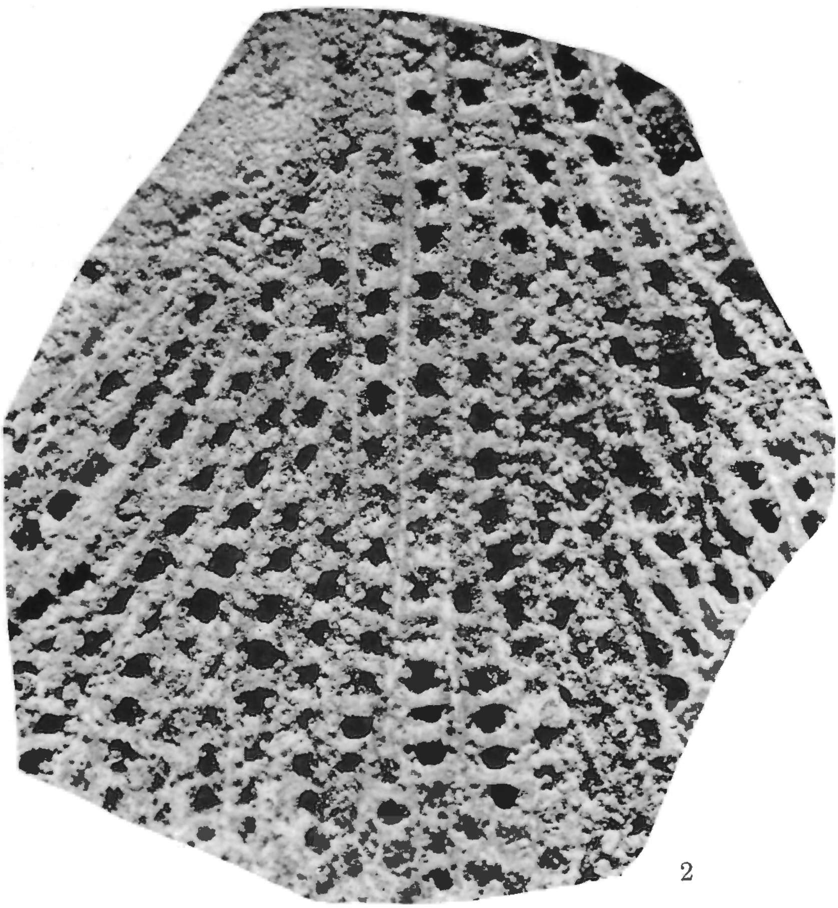

2

Plate IX

Septopora primitiva Bell. (Page 102.)

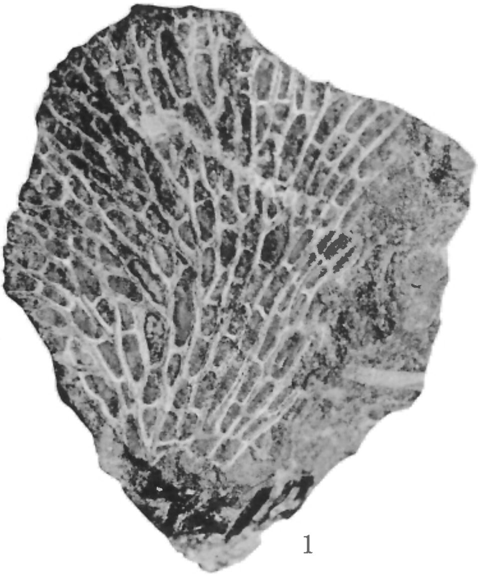
Figure 1. View of reverse side of zoarium that is partly fractured to show zooecia. Nat. Mus. of Canada, Cat. No. 7735a, holotype, X 3.

Figure 2. Zooecial surface of zoarium. Nat. Mus. of Canada, Cat. No. 7734, paratype, X 12.

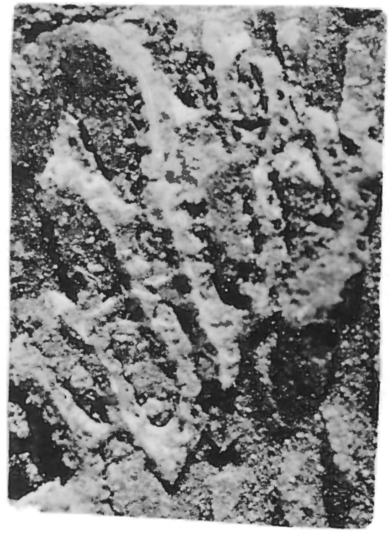
Figure 3. View of reverse side of zoarium that is partly fractured to show zooecia. Nat. Mus. of Canada, Cat. No. 7735b, paratype, X 12.

Figure 4. Reverse surface of zoarium showing distribution of pores. Nat. Mus. of Canada, Cat. No. 7735, paratype, X 12.

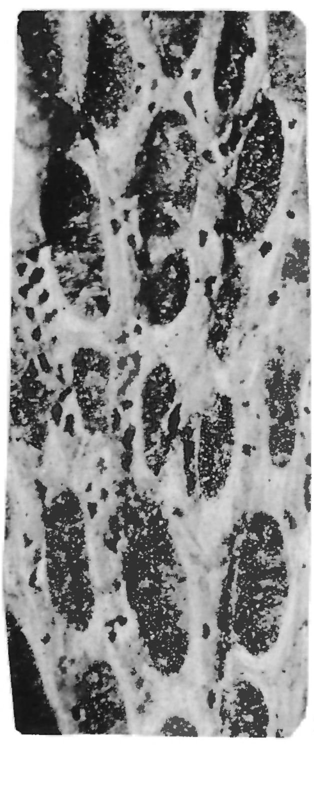
Plate IX



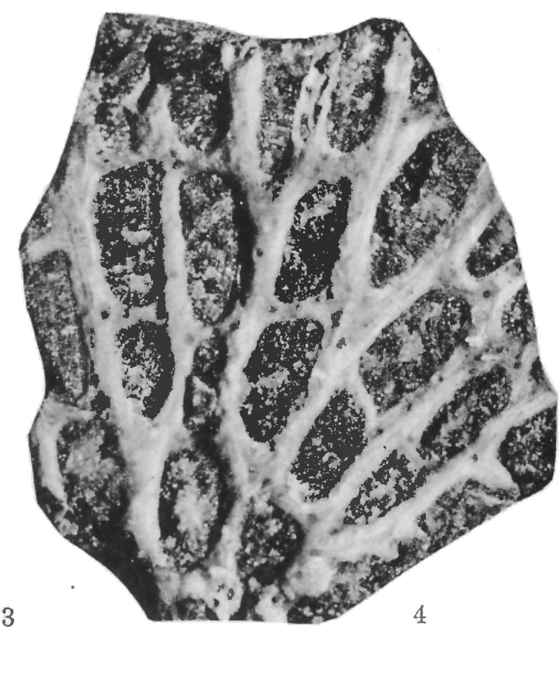
1



2



3



4

PLATE X

Tabulipora acadica Bell. (Page 105.)

Figure 1. Longitudinal section, showing perforated diaphragms in the zooecial tubes. Nat. Mus. of Canada, Cat. No. 7739b, paratype, X 7½.

Figure 2. Transverse section. Nat. Mus. of Canada, Cat. No. 7739a, paratype, X 7½.

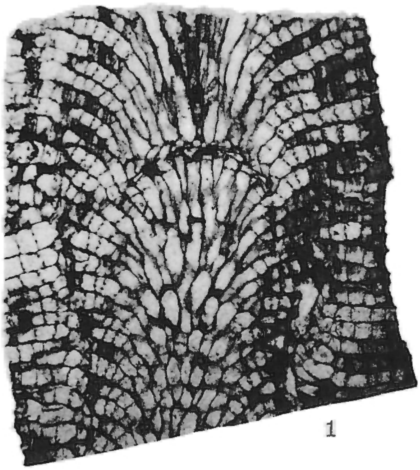
Figure 3. Surface of a large zoarium. Nat. Mus. of Canada, Cat. No. 7739, holotype, natural size.

Figure 3a. Part of surface below arrow of same specimen, magnified six times to show differentiation of cells.

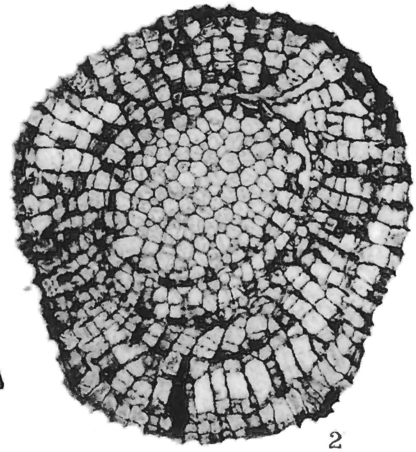
Figure 4. Tangential section, showing dividing lines between cells. Nat. Mus. of Canada, Cat. No. 7739c, paratype, X 7½.

Figure 5. Surface of small specimen. Nat. Mus. of Canada, Cat. No. 7746, paratype, X 6.

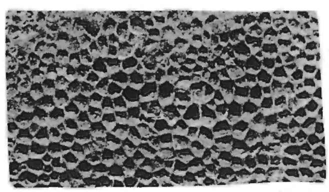
Plate X



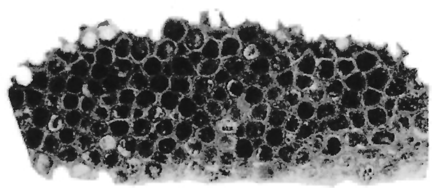
1



2

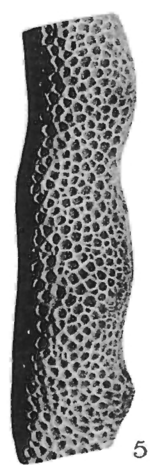


3a



4

3



5

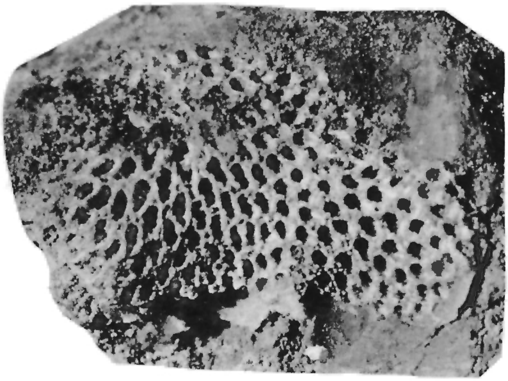
PLATE XI

Batostomella exilis (Dawson). (Page 102.)

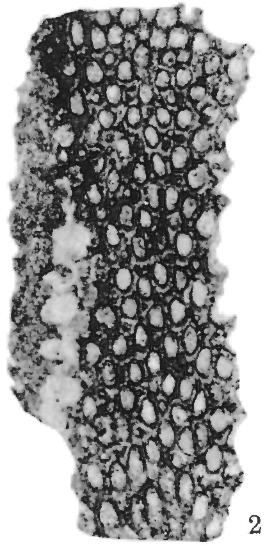
Figure 1. Zoarium in metanepiastic stage, encrusting *Pugnax magdalena*. Nat. Mus. of Canada, Cat. No. 7740, cotype, X 12.

Figure 2. Tangential section of mature zoarium, showing acanthopores. Nat. Mus. of Canada, Cat. No. 7738k, paratype, X 15.

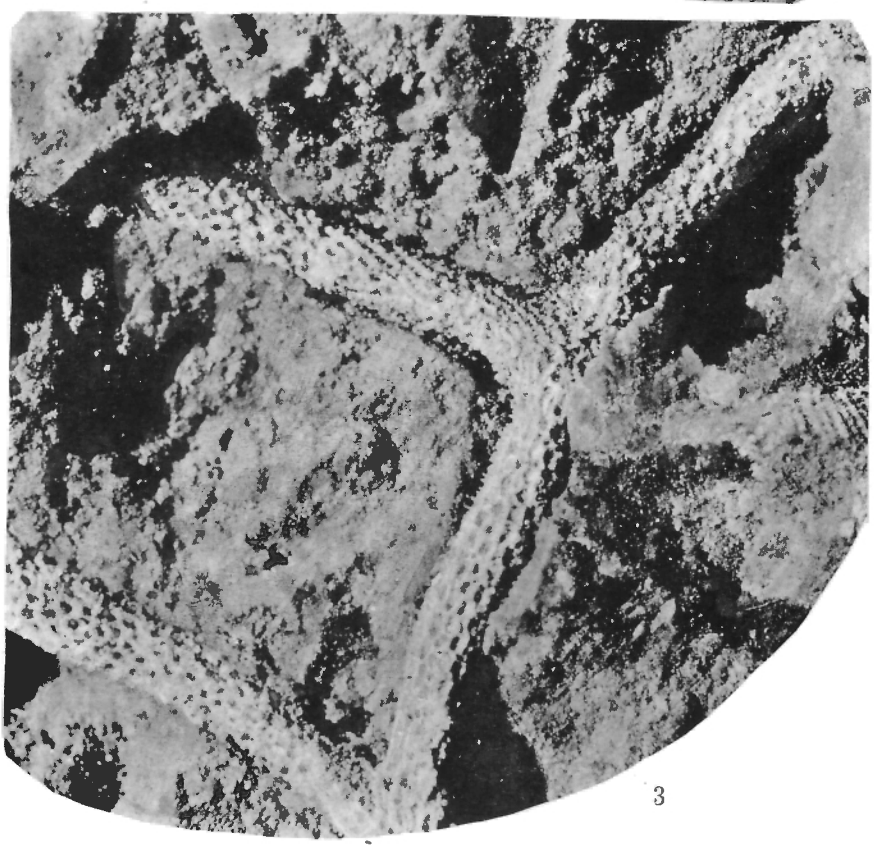
Figure 3. Mature branching zoarium. Nat. Mus. of Canada, Cat. No. 7738a, cotype, X 12.



1



2



3

Plate XII

Batostomella abrupta Ulrich. (Page 103.)

Figure 1. Tangential section showing distribution of mesopores and acanthopores. Nat. Mus. of Canada, Cat. No. 7687b, plesiotype, X 15.

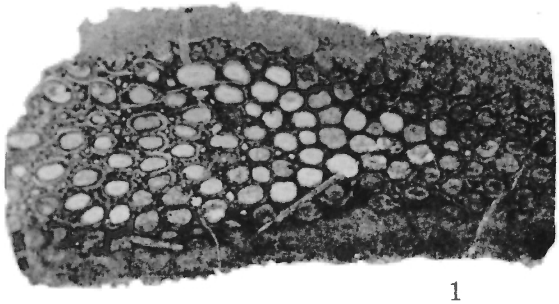
Figure 2. Exterior view. Nat. Mus. of Canada, Cat. No. 7686a, plesiotype, X 12.

Batostomella exilis (Dawson). (Page 102.)

Figure 3. Longitudinal section showing presence of a few diaphragms in the thick-walled peripheral region. Nat. Mus. of Canada, Cat. No. 7738g, plesiotype, X 15.

Figure 4. Exterior view. Nat. Mus. of Canada, Cat. No. 7737, plesiotype, X 12.

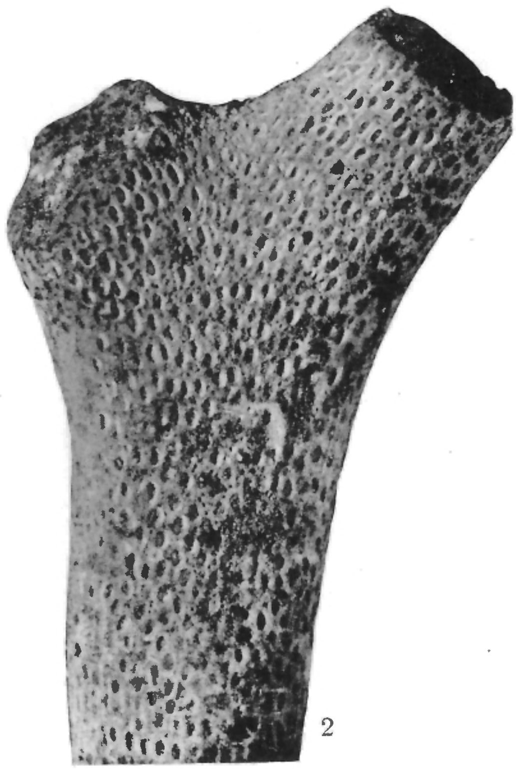
Plate XII



1

3

4



2

Plate XIII

Polypora schucherti Bell. (Page 103.)

Figure 1. Zooecial surface showing a branch much swollen before bifurcation. Nat. Mus. of Canada, Cat. No. 7731, holotype, X 12.

Figures 2 and 2a. Zooecial surface. Nat. Mus. of Canada, Cat. No. 4338a, paratype, X 12.

Figure 3. Zooecial surface. Nat. Mus. of Canada.

Figure 4. Reverse surface. Nat. Mus. of Canada, Cat. No. 7732, paratype, X 12.

Streblotrypa biformata Bell. (Page 104.)

Figure 5. A free zoarium. Nat. Mus. of Canada, Cat. No. 7741, cotype, X 12.

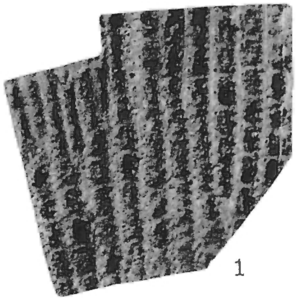
Figure 6. An encrusting zoarium. Nat. Mus. of Canada, Cat. No. 7741b, cotype, X 12.

Batostomella abrupta Ulrich. (Page 103.)

Figure 7. Longitudinal section showing occasional diaphragms and abrupt turn to peripheral region. Nat. Mus. of Canada, Cat. No. 7687, plesiotype, X 15.

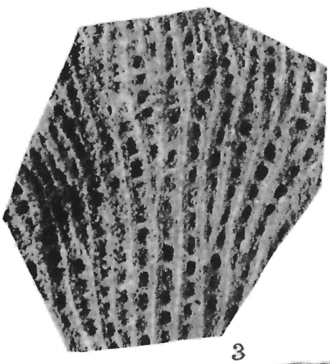
Figure 8. Transverse section. Nat. Mus. of Canada, Cat. No. 7687a, plesiotype, X 15.

Plate XIII



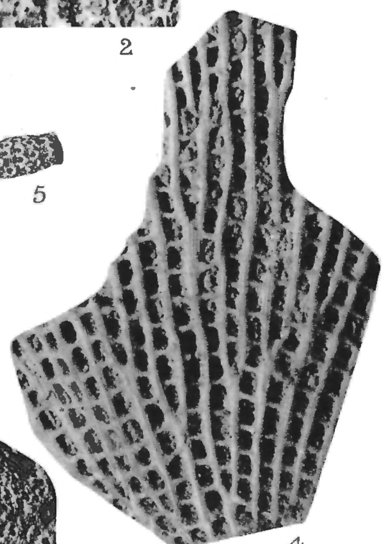
1

2



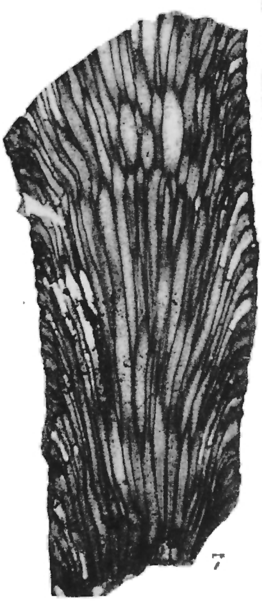
3

5

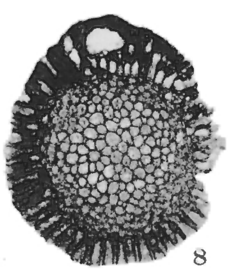


4

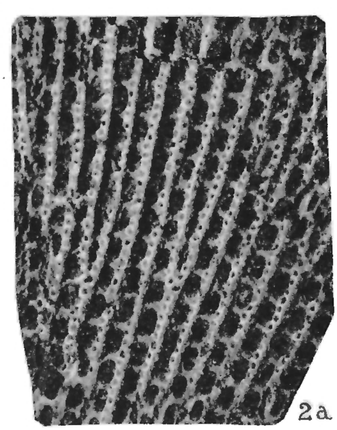
6



7



8



2a

PLATE XIV

Streblotrypa biformata Bell. (Page 104.)

Figure 1. Zoaria encrusting *Productus lyelli*. Nat. Mus. of Canada, Cat. No. 7741c, paratype, X 3.

Figure 1a. Portion of zoarium of 7741c, X 12.

Crania cincta Bell. (Page 105.)

Figure 2. Brachial valve. Nat. Mus. of Canada, Cat. No. 7441, holotype, natural size.

Crania brookfieldensis Bell. (Page 106.)

Figure 3. Brachial valve. Nat. Mus. of Canada, Cat. No. 7438, holotype, X 4.

Orbiculoidea sp. Bell. (Page 106.)

Figure 4. Pedicle valve. Peabody Museum, Yale University, collection 2836.

Schuchertella pictoense Bell. (Page 106.)

Figure 5. Part of cardinal area of pedicle valve. Nat. Mus. of Canada, Cat. No. 7463, paratype, natural size.

Figure 6. Brachial valve. Nat. Mus. of Canada, Cat. No. 7655b, paratype, natural size.

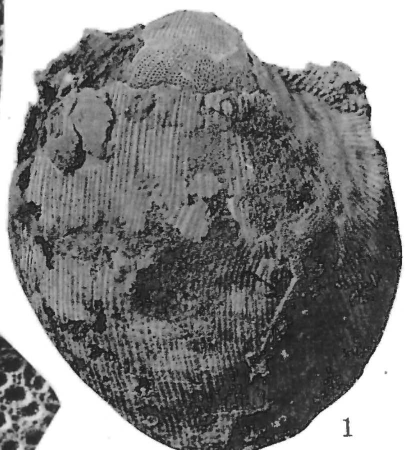
Figure 7. Pedicle and brachial valves. Nat. Mus. of Canada, Cat. No. 7655, 7655a, cotypes, natural size.

Plate XIV

1 a

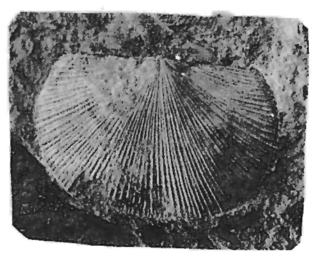
2

3



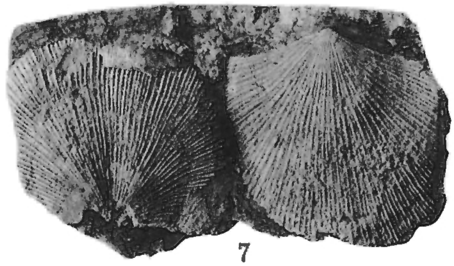
1

5



6

4



7

Plate XV

Chonetes politus M'Coy. (Page 108.)

Figure 1. Pedicle valve. Nat. Mus. of Canada, Cat. No. 7467b, plesiotype, X 4.

Figure 1a. Brachial view of same specimen showing cardinal areas, X 4.

Figure 2. Brachial view of a specimen with well-preserved spine bases. Nat. Mus. of Canada, Cat. No. 7467a, plesiotype, X 2.

Figure 3. Pedicle view of another specimen showing acute cardinal angles. Nat. Mus. of Canada, Cat. No. 7467, plesiotype, X 2.

Streptorhyncus cf. *minutum* (Cummings). (Page 108.)

Figures 4 and 4a. Pedicle and brachial views. Nat. Mus. of Canada, Cat. No. 7462, holotype, X 2.

Schellwienella kennetcookensis Bell. (Page 107.)

Figure 5. Pedicle valve. Nat. Mus. of Canada, Cat. No. 7654, holotype, natural size.

Figure 6. A brachial valve. Nat. Mus. of Canada, Cat. No. 7942, paratype, natural size.

Productella baddeckensis Bell. (Page 109.)

Figure 7. Imprint of brachial valve. Nat. Mus. of Canada, Cat. No. 7962b, paratype, X 2.

Figures 8, 8a, 8b, 8c. Pedicle, brachial, posterior, and lateral views of a complete specimen. Nat. Mus. of Canada, Cat. No. 7962a, holotype, natural size.

Figure 9. Pedicle valve. Nat. Mus. of Canada, Cat. No. 7962, paratype, natural size.

Protoniella beedii Bell. (Page 110.)

Figures 10, 10a, 10b. Pedicle, brachial, and lateral views. Nat. Mus. of Canada, Cat. No. 7954d, genoholotype, natural size.

Figure 11. Pedicle valve. Nat. Mus. of Canada, Cat. No. 7954c, paratype, natural size.

Figure 12. Interior of brachial valve. Nat. Mus. of Canada, Cat. No. 7954a, paratype, natural size.

Figure 13. Brachial view of a somewhat crushed specimen. Nat. Mus. of Canada, Cat. No. 7954, paratype, natural size.

Figure 14. Posterior view. Nat. Mus. of Canada, Cat. No. 7954b, paratype, natural size.

Plate XV

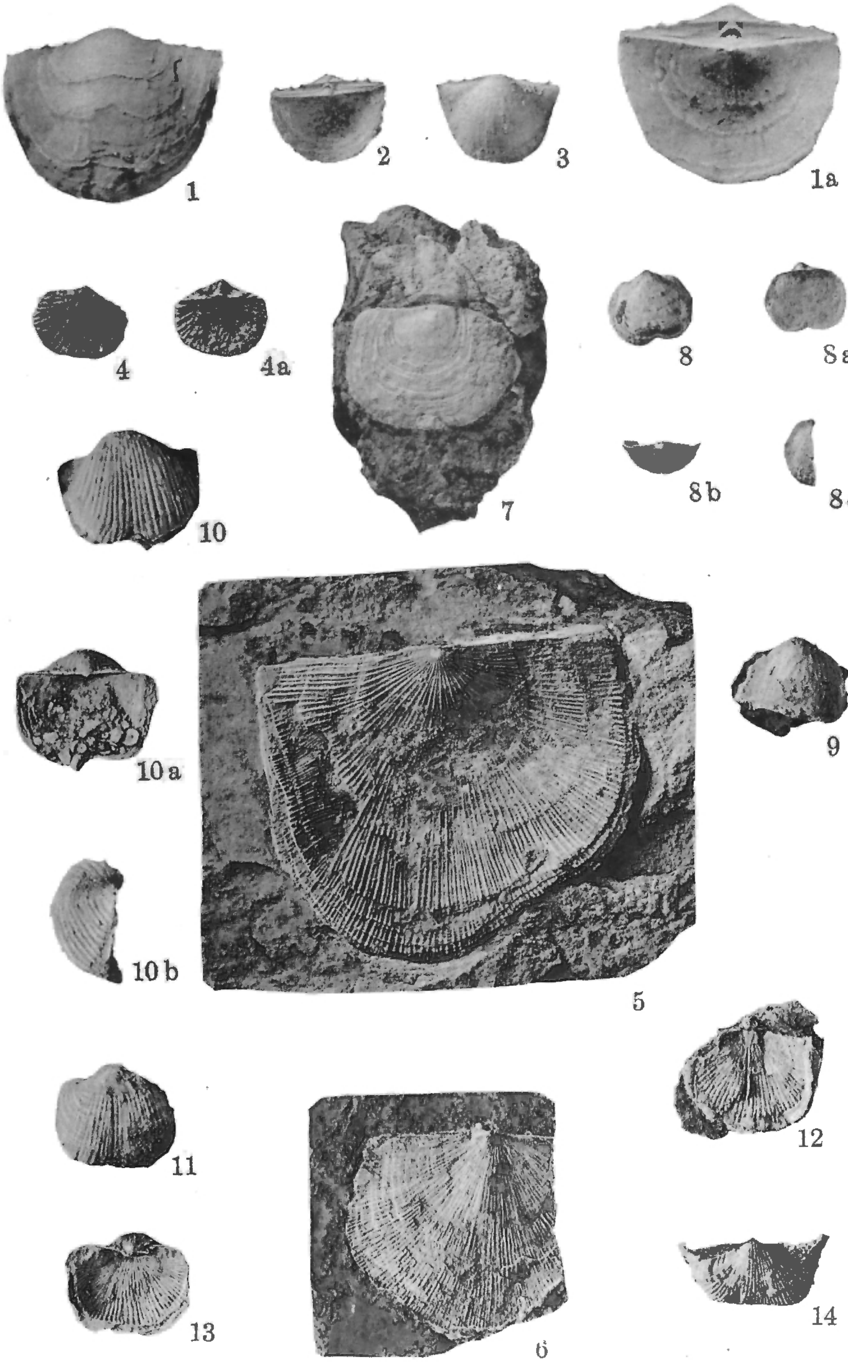


Plate XVI

Productus (Linoproductus) lyelli Verneuil. (Page 112.)

Figure 1. Pedicle valve. Nat. Mus. of Canada, Cat. No. 7952, neotype, natural size.

Figures 2, 2a. Lateral and full views of an imprint of a brachial valve. Nat. Mus. of Canada, Cat. No. 7952h, natural size.

Figure 3. Posterior view of inner surface of brachial valve. Nat. Mus. of Canada, Cat. No. 7952g, plesiotype, natural size.

Figure 4. A pedicle valve with long cardinal line. Nat. Mus. of Canada, Cat. No. 7952a, plesiotype, natural size.

Figure 4a. Posterior view of same valve; the beak is broken off.

Figure 5. Lateral view of a specimen showing geniculation and relation of valves. Nat. Mus. of Canada, Cat. No. 7952f, plesiotype, natural size.

Productus (Linoproductus) lyelli var. b. Bell. (Page 114.)

Figure 6. Pedicle view. Nat. Mus. of Canada, Cat. No. 7684, holotype, natural size.

Productus (Linoproductus) lyelli Verneuil. (Page 112.)

Figure 7. A specimen showing spine bases on ears of pedicle valve, and that is so broken as to reveal inner surface of brachial valve. Nat. Mus. of Canada, Cat. No. 7952b, plesiotype, natural size.

Figure 8. Imprint of a brachial valve of a variant, more depressed laterally. Nat. Mus. of Canada, Cat. No. 7952d, plesiotype, natural size.

Productus (Linoproductus) lyelli var. a. Bell. (Page 113.)

Figure 9. Imprint of a brachial valve with remnants of pedicle valve. Nat. Mus. of Canada, Cat. No. 7964a, paratype, natural size.

Figure 10. A crushed pedicle valve. Nat. Mus. of Canada, Cat. No. 7949, paratype, natural size.

Figure 11. A pedicle valve. Nat. Mus. of Canada, Cat. No. 7964, holotype, natural size.

Plate XVI

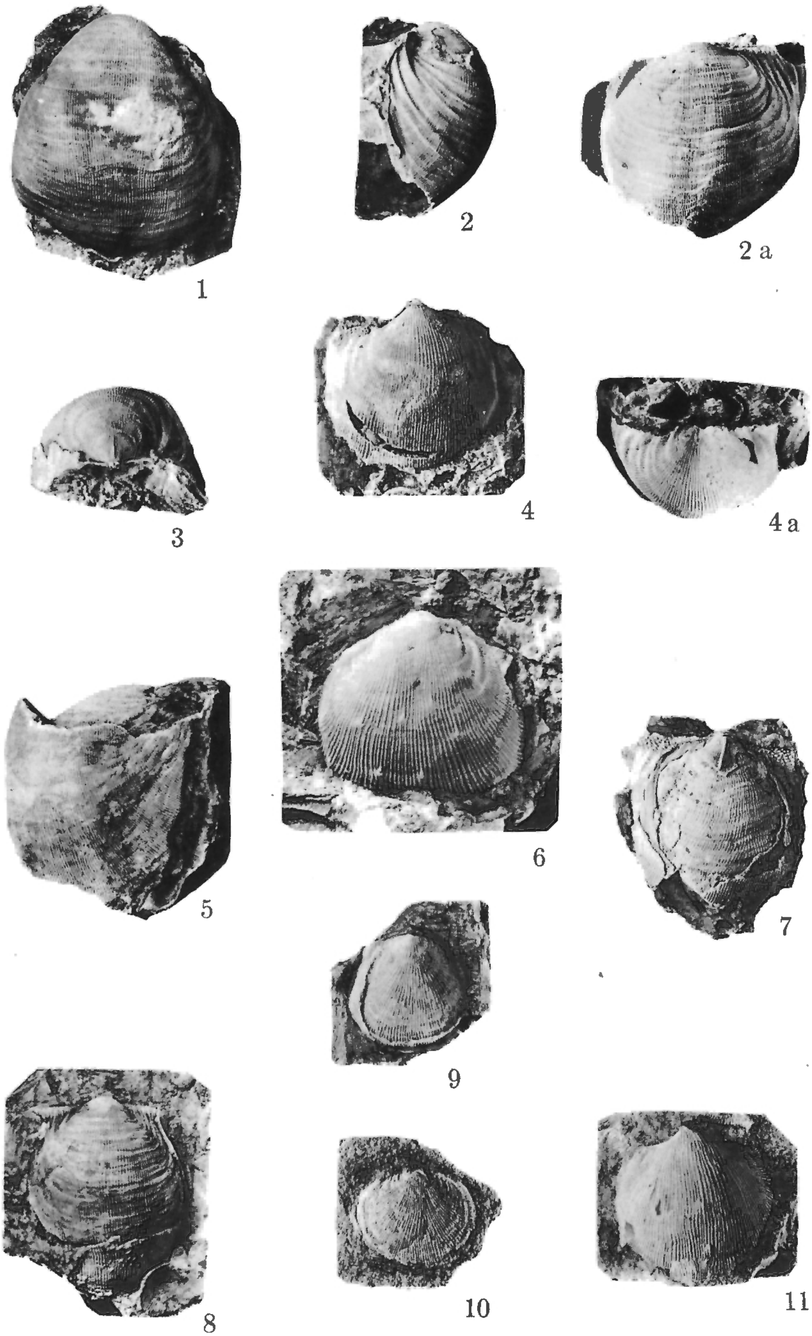


Plate XVII

Productus (Linoproductus) dawsoni Beede. (Page 114.)

Figure 1. Pedicle valve. Nat. Mus. of Canada, Cat. No. 7963, plesiotype, natural size.

Productus (Avonia) spinocardinata Bell. (Page 117.)

Figures 2, 2a, 2b. Three views of a pedicle valve. Nat. Mus. of Canada, Cat. No. 7948, paratype, natural size.

Figures 3, 3a, 3b. Three views of a pedicle valve. Nat. Mus. of Canada, Cat. No. 7950, holotype, natural size.

Productus (Linoproductus) semicubiculus Bell. (Page 114.)

Figure 4. Pedicle valve. Nat. Mus. of Canada, Cat. No. 7961, paratype, X 2.

Figure 5. A number of specimens, several of which are broken so as to show imprints of the brachial valves. Nat. Mus. of Canada, Cat. No. 7947, paratypes, natural size.

Figures 6, 6a. A pedicle valve. Nat. Mus. of Canada, Cat. No. 7951, holotype, natural size.

Productus subfasciculatus Bell. (Page 115.)

Figure 7. An inner view of visceral region of a brachial valve. Nat. Mus. of Canada, Cat. No. 7959, paratype, natural size.

Figure 8. Pedicle valve. Peabody Museum, Yale University, holotype, natural size.

Figure 9. Pedicle valve. Peabody Museum, Yale University, paratype, natural size.

Figures 10, 10a. Views of pedicle valve of a young individual. Nat. Mus. of Canada, Cat. No. 7958, paratype, natural size.

Figures 11, 11a, 11b. Views of pedicle valve. Nat. Mus. of Canada, Cat. No. 7955, paratype, natural size.

Plate XVII

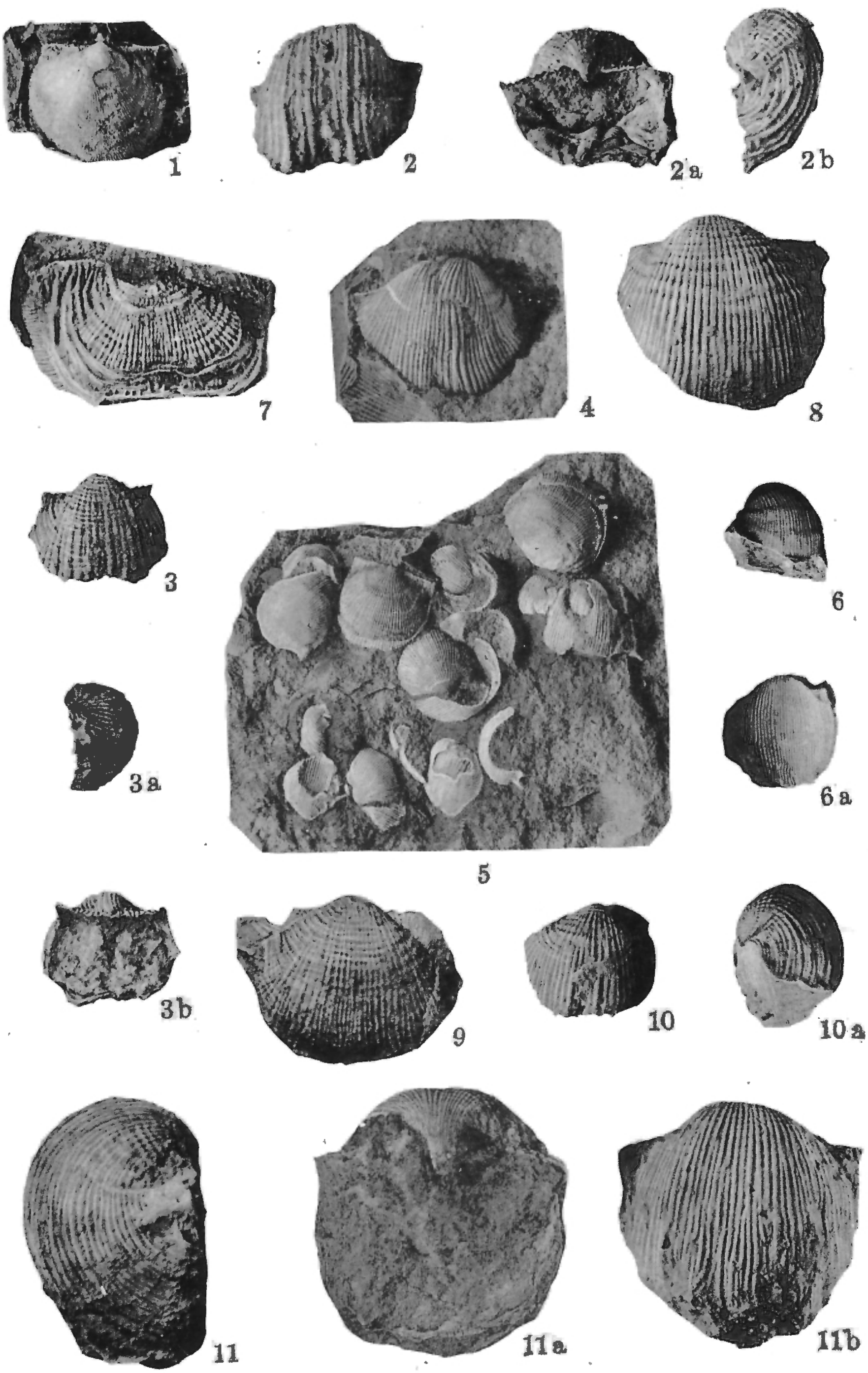


Plate XVIII

Diaphragmus tenuicostiformis (Beede). (Page 119.)

Figures 1, 1a, 1b. Pedicle, brachial, and lateral views. Nat. Mus. of Canada, Cat. No. 7943a, plesiotype, natural size.

Figures 2, 2a, 2b. Pedicle, lateral, and brachial views. Nat. Mus. of Canada, Cat. No. 7460, plesiotype, natural size.

Figure 3. Brachial view of specimen. Nat. Mus. of Canada, Cat. No. 7945, plesiotype, natural size.

Figure 4. Interior view showing diaphragm. Nat. Mus. of Canada, Cat. No. 7943, plesiotype, natural size.

Figure 5. Posterior view of interior of pedicle valve. Nat. Mus. of Canada, Cat. No. 7944a, plesiotype, natural size.

Figure 6. Interior of brachial valve. Nat. Mus. of Canada, Cat. No. 7960b, plesiotype, natural size.

Figures 7, 7a. Pedicle and lateral views of specimen. Nat. Mus. of Canada, Cat. No. 7944, plesiotype, natural size.

Figures 8, 8a. Views of pedicle valve of a variant possessing coarser costæ. Nt. Mus. of Canada, Cat. No. 7946, plesiotype, natural size.

Figure 9. Interior and imprint of brachial valve with diaphragm and frontal part of pedicle valve. Nat. Mus. of Canada, Cat. No. 7943b, plesiotype, natural size.

Figure 10. Interior of brachial valve. Nat. Mus. of Canada, Cat. No. 7943k, plesiotype, X 2.

Figure 11. Brachial view of a young individual. Nat. Mus. of Canada, Cat. No. 7943d, plesiotype, X 4.

Productus (Striatifera) cf. *latissimus* Sowerby. (Page 116.)

Figure 12. Imperfect pedicle valve. Nat. Mus. of Canada, Cat. No. 7435, holotype, natural size.

Buxtonia cogmagunensis Bell. (Page 118.)

Figure 13. Brachial view of a crushed specimen. Nat. Mus. of Canada, Cat. No. 7442, paratype, natural size.

Figure 14. Pedicle valve. Nat. Mus. of Canada, Cat. No. 7465, paratype, natural size.

Figure 15. Pedicle valve. Nat. Mus. of Canada, Cat. No. 7442a, paratype, natural size.

Figure 16. Pedicle valve. Nat. Mus. of Canada, Cat. No. 7442b, paratype, natural size.

Figure 17. Interior of brachial valve. Nat. Mus. of Canada, Cat. No. 7442c, paratype, natural size.

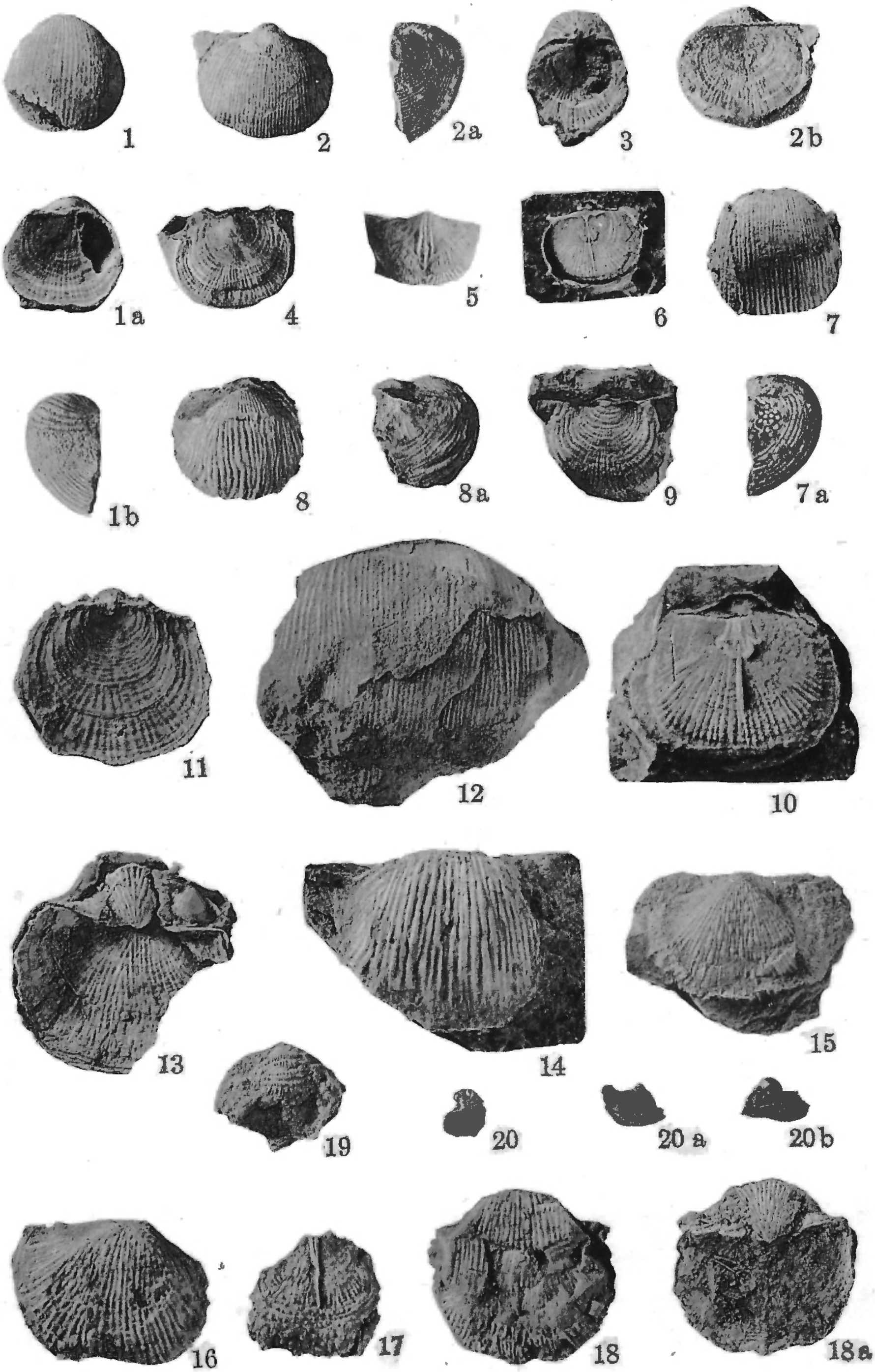
Figures 18, 18a. Two views of pedicle valve. Nat. Mus. of Canada, Cat. No. 7442d, holotype, natural size.

Pustula exigua Bell. (Page 118.)

Figure 19. Pedicle valve. Nat. Mus. of Canada, Cat. No. 7967, paratype, natural size.

Figure 20, 20a, 20b. Three views of pedicle valve. Nat. Mus. of Canada, Cat. No. 7436, holotype, natural size.

Plate XVIII



1
2
2a
3
2b
1a
4
5
6
7
1b
8
8a
9
7a
11
12
10
13
14
15
19
20
20 a
20b
16
17
18
18a

Plate XIX

Camarotoechia atlantica Bell. (Page 122.)

Figures 1, 1a, 1b. Pedicle, brachial, and posterior views of a large specimen. Nat. Mus. of Canada, Cat. No. 7475, paratype, natural size.

Figures 2, 2a, 2b, 2c. Lateral, anterior, pedicle, and brachial views of an average specimen. Nat. Mus. of Canada, Cat. No. 7473, holotype, natural size.

Camarotoechia acadiensis (Davidson)

Figures 3, 3a, 3b. Pedicle, lateral, and brachial views of a specimen with four costæ on fold. Nat. Mus. of Canada, Cat. No. 4348a, plesiotype, natural size.

Pugnax ? sp. Bell. (Page 126.)

Figures 4, 4a, 4b. Brachial, anterior, and lateral views. In figure 4a the beak of brachial valve rises above the pedicle valve as the beak of the latter is broken off. Nat. Mus. of Canada, Cat. No. 7490, holotype, natural size.

Pugnoides ? sp. Bell. (Page 123.)

Figure 5. An imperfect brachial valve. Nat. Mus. of Canada, Cat. No. 7469, holotype, natural size.

Figure 6. An imperfect pedicle valve. Nat. Mus. of Canada, Cat. No. 7469a, natural size.

Pugnax dawsonianus (Davidson). (Page 124.)

Figures 7, 7a. Brachial and anterior views of a specimen with 2 costæ on the fold. Nat. Mus. of Canada, Cat. No. 7484a, plesiotype, natural size.

Figures 8, 8a. Pedicle and brachial views of a specimen with 3 costæ on the fold. Nat. Mus. of Canada, Cat. No. 7481a, plesiotype. Figure 8, natural size; figure 8a, enlarged 2 diameters.

Figure 9. Brachial view of a specimen with costæ almost obsolete. Nat. Mus. of Canada, Cat. No. 7481d, plesiotype, natural size.

Figure 10. Brachial view of a specimen with fold consisting of a single bifurcated costa. Nat. Mus. of Canada, Cat. No. 7484, plesiotype, natural size.

Figure 11. Brachial view of a specimen with 3 costæ on fold. Nat. Mus. of Canada, Cat. No. 7482, plesiotype, natural size.

Figures 12, 12a. Lateral and brachial views of a specimen with 5 costæ on fold. Nat. Mus. of Canada, Cat. No. 7483, plesiotype, natural size.

Figure 12b. Same specimen, anterior view, X 2.

Figure 13. Lateral view of a specimen with costæ nearly obsolete. Nat. Mus. of Canada, Cat. No. 7489, plesiotype, natural size.

Figure 14. Brachial view of a specimen with abnormally high beak on pedicle valve. Nat. Mus. of Canada, Cat. No. 7481b, plesiotype, natural size.

Productus avonensis Bell. (Page 120.)

Figure 15. Interior of brachial valve. Nat. Mus. of Canada, Cat. No. 7966a, paratype, natural size.

Figure 16. Imprint of brachial valve surrounded by narrow diaphragm. Nat. Mus. of Canada, Cat. No. 7965, natural size.

Figure 17. Posterior view of pedicle valve. Nat. Mus. of Canada, Cat. No. 7953a, natural size.

Figure 18. A crushed pedicle valve. Nat. Mus. of Canada, Cat. No. 7953b, natural size.

Figures 19, 19a. Two views of a pedicle valve. Nat. Mus. of Canada, Cat. No. 7953, holotype, natural size.

Figure 20. A pedicle valve showing trail. Nat. Mus. of Canada, Cat. No. 7953c, paratype, natural size.

Figure 21. A crushed pedicle valve with spines well preserved. Nat. Mus. of Canada, Cat. No. 7957, paratype, natural size.

Figures 22, 22a. Two views of a somewhat distorted pedicle valve. Nat. Mus. of Canada, Cat. No. 7956a, natural size.

Figure 23. Brachial valve with part of diaphragm. Nat. Mus. of Canada, Cat. No. 7670, paratype, X 2.

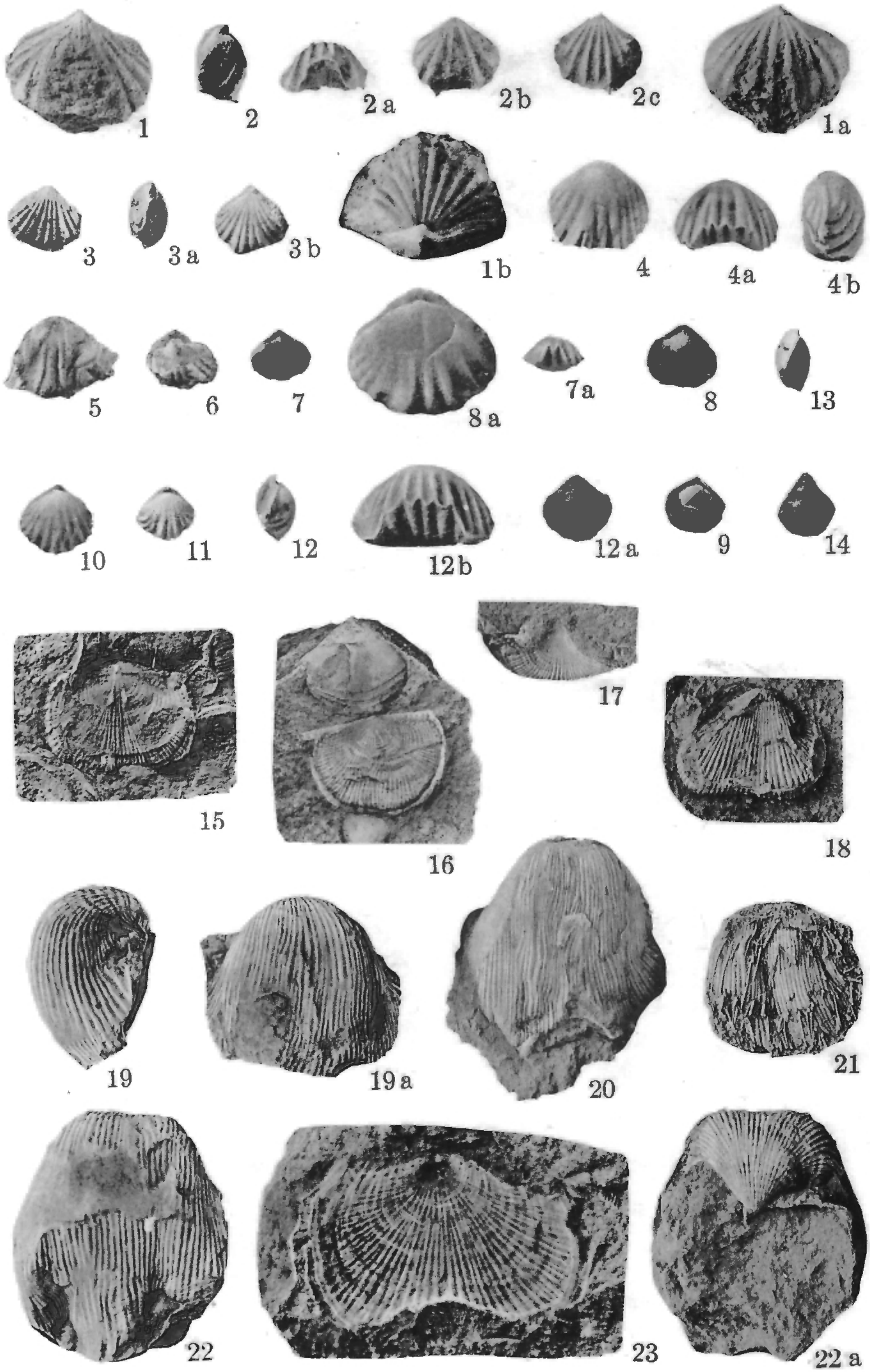

1
2
2 a
2 b
2 c
1 a
3
3 a
3 b
1 b
4
4 a
4 b
5
6
7
8 a
7 a
8
13
10
11
12
12 b
12 a
9
14
15
16
17
18
19
19 a
20
21
22
23
22 a

Plate XX

Pugnax magdalena Beede. (Page 125.)

Figures 1, 1a, 1b. Lateral, anterior, and pedicle views. Nat. Mus. of Canada, Cat. No. 7479, plesiotype, natural size.
Figures 2, 2a. Brachial and anterior views of another specimen. Nat. Mus. of Canada, Cat. No. 7480a, plesiotype, natural size.
Figures 3, 3a. Brachial and pedicle views. Nat. Mus. of Canada, Cat. No. 7480, plesiotype, natural size.

Allorhyncus cf. *macra* (Hall). (Page 128.)

Figures 4, 4a. Pedicle and brachial views. Nat. Mus. of Canada, Cat. No. 7466a, holotype, natural size.
Figures 5, 5a. Brachial and pedicle views. Nat. Mus. of Canada, Cat. No. 7466, paratype, natural size.

Allorhyncus ramosum Bell. (Page 127.)

Figures 6, 6a, 6b. Pedicle, lateral, and brachial views. Nat. Mus. of Canada, Cat. No. 7478, paratype, natural size.
Figures 7, 7a, 7b. Brachial, lateral, and pedicle views. Nat. Mus. of Canada, Cat. No. 7477, holotype, natural size.
Figure 8. Brachial view of young individual. Nat. Mus. of Canada, Cat. No. 7478b, paratype, natural size.
Figure 9. Pedicle view of young individual. Nat. Mus. of Canada, Cat. No. 7478c, paratype, natural size.
Figure 10. Brachial valve. Nat. Mus. of Canada, Cat. No. 7478d, paratype, natural size.

Allorhyncus hartti Bell. (Page 128.)

Figures 11, 11a, 11b. Brachial, lateral, and anterior views. Nat. Mus. of Canada, Cat. No. 7468, holotype, natural size.

Romingerina anna (Hartt) Bell. (Page 129.)

Figures 12, 12a. Pedicle and brachial views. Nat. Mus. of Canada, Cat. No. 7472b, plesiotype, natural size.
Figure 13. Brachial view. Nat. Mus. of Canada, Cat. No. 7472, plesiotype, natural size.
Figure 14. Interior of brachial valve. Nat. Mus. of Canada, Cat. No. 7471, plesiotype, natural size.
Figures 15, 15a, 15b. Pedicle, lateral, and brachial views. Nat. Mus. of Canada, Cat. No. 7472a, neotype, natural size.

Composita dawsoni (Hall and Clarke). (Page 132.)

Figures 16, 16a. Brachial and anterior views. Nat. Mus. of Canada, Cat. No. 7501b, plesiotype, natural size.
Figure 17. Interior of brachial valve. Nat. Mus. of Canada, Cat. No. 7501e, plesiotype, natural size.
Figure 18. Internal mould of pedicle valve. Nat. Mus. of Canada, Cat. No. 7501f, plesiotype, X 2.
Figure 19. Internal mould of brachial valve. Nat. Mus. of Canada, Cat. No. 7501c, plesiotype, natural size.
Figure 20. Pedicle view of specimen with frontal sinus and fold almost obsolete. Nat. Mus. of Canada, Cat. No. 7501d, plesiotype, natural size.
Figure 21. Brachial view of a broad variant. Nat. Mus. of Canada, Cat. No. 7501a, plesiotype, natural size.
Figures 22, 22a, 22b. Lateral, brachial, and anterior views of a broad, gibbous specimen. Nat. Mus. of Canada, No. 7501, plesiotype, natural size.
Figures 23, 23a, 23b. Brachial, lateral, and anterior views of cotype. University of Chicago, Cat. No. 12374, cotype.

Composita offirmata Bell. (Page 136.)

Figures 24, 24a, 24b, 24c, 24d. Pedicle, posterior, anterior, lateral, and brachial views of holotype. Nat. Mus. of Canada, Cat. No. 7507, natural size.

Diaphragmus tenuicostiformis (Beede). (Page 119.)

Figure 25. Pedicle valve of a young individual, showing simple concentric ornamentation in umbonal region. Nat. Mus. of Canada, Cat. No. 7943, plesiotype, X 4.

Composita obligata Bell. (Page 135.)

Figure 26. Pedicle view. Nat. Mus. of Canada, Cat. No. 7526, paratype, natural size.

Plate XX

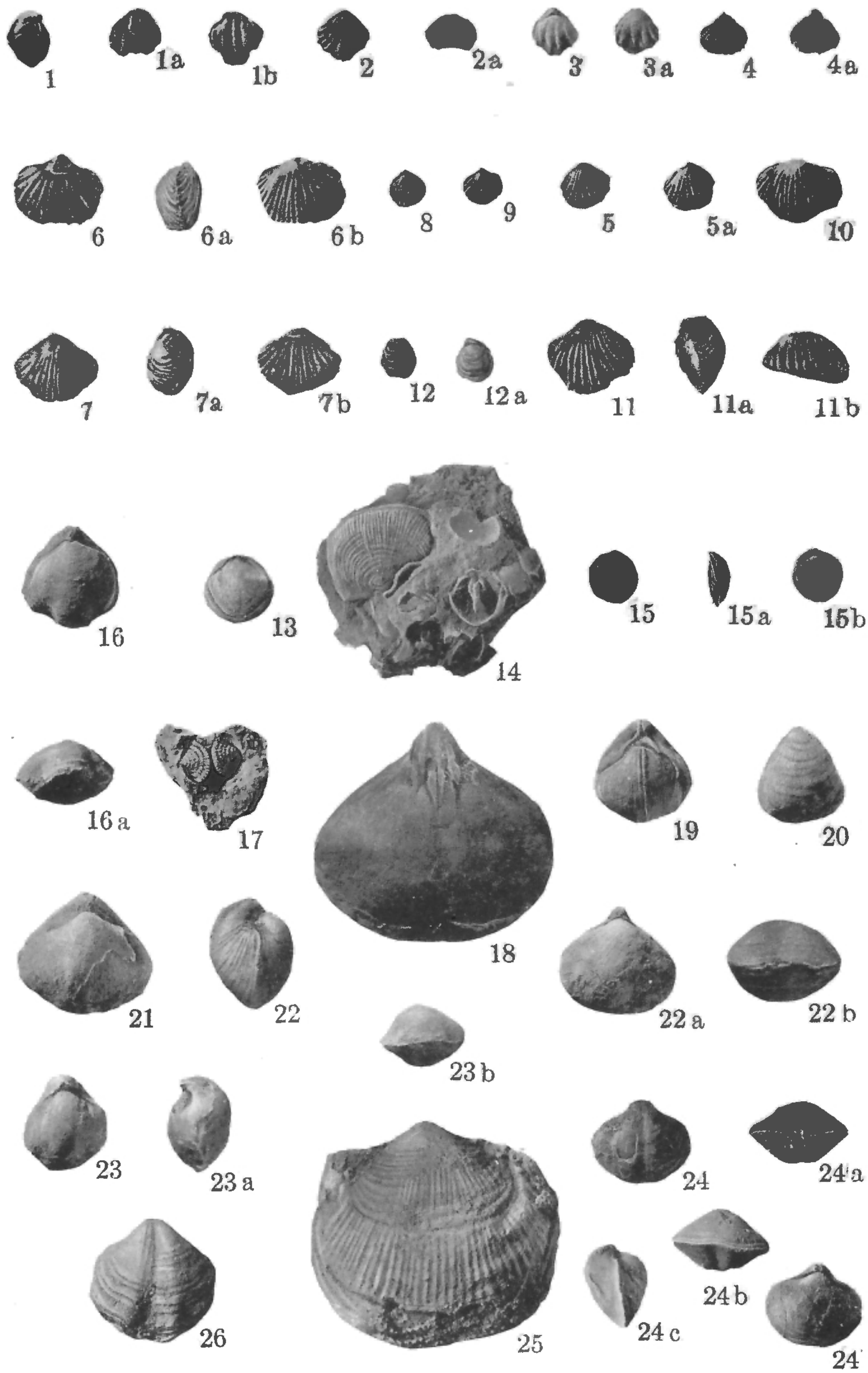

1
1a
1b
2
2a
3
3a
4
4a
6
6a
6b
8
9
5
5a
10
7
7a
7b
12
12a
11
11a
11b
16
13
14
15
15a
15b
16a
17
18
19
20
21
22
22a
22b
23b
23
23a
24
24a
25
26
24b
24c
24

Plate XXI

Composita obligata Bell. (Page 135.)

Figures 1, 1a, 1b. Pedicle, anterior, and lateral views of holotype. Nat. Mus. of Canada, Cat. No. 7526b, holotype, natural size.

Figures 2, 2a. Pedicle and lateral views. Nat. Mus. of Canada, Cat. No. 7526a, paratype, natural size.

Composita strigata Bell. (Page 134.)

Figure 3. Brachial view. Nat. Mus. of Canada, Cat. No. 7510, paratype, X 2.

Figure 4. Interior of brachial valve. Nat. Mus. of Canada, Cat. No. 7510a, paratype, X 2.

Figures 5, 5a. Brachial and anterior views. Nat. Mus. of Canada, Cat. No. 7510b, holotype, natural size.

Figures 6, 6a. Pedicle and brachial views. Nat. Mus. of Canada, Cat. No. 7511, paratype, X 2.

Composita windsorensis Bell. (Page 133.)

Figure 7. Brachial view. Nat. Mus. of Canada, Cat. No. 7516b, paratype, natural size.

Figure 8. Brachial view of a relatively long specimen. Nat. Mus. of Canada, Cat. No. 7516a, paratype, natural size.

Figure 9. Brachial view of a broad-shouldered specimen. Nat. Mus. of Canada, Cat. No. 7515a, paratype, natural size.

Figure 10. Brachial view of a subrhombic specimen. Nat. Mus. of Canada, Cat. No. 7514, paratype, X 2.

Figures 11, 11a, 11b. Pedicle, anterior, and brachial views of var. *incisa* that approaches *C. strigata*. Nat. Mus. of Canada, Cat. No. 7512, paratype, natural size.

Figure 12. Interior of brachial valve. Nat. Mus. of Canada, Cat. No. 7515, paratype, natural size.

Figure 13. Brachial view of var. *incisa*. Nat. Mus. of Canada, Cat. No. 7516c, paratype, X 2.

Figures 14, 14a. Brachial and lateral views of holotype. Nat. Mus. of Canada, Cat. No. 7516, holotype, natural size.

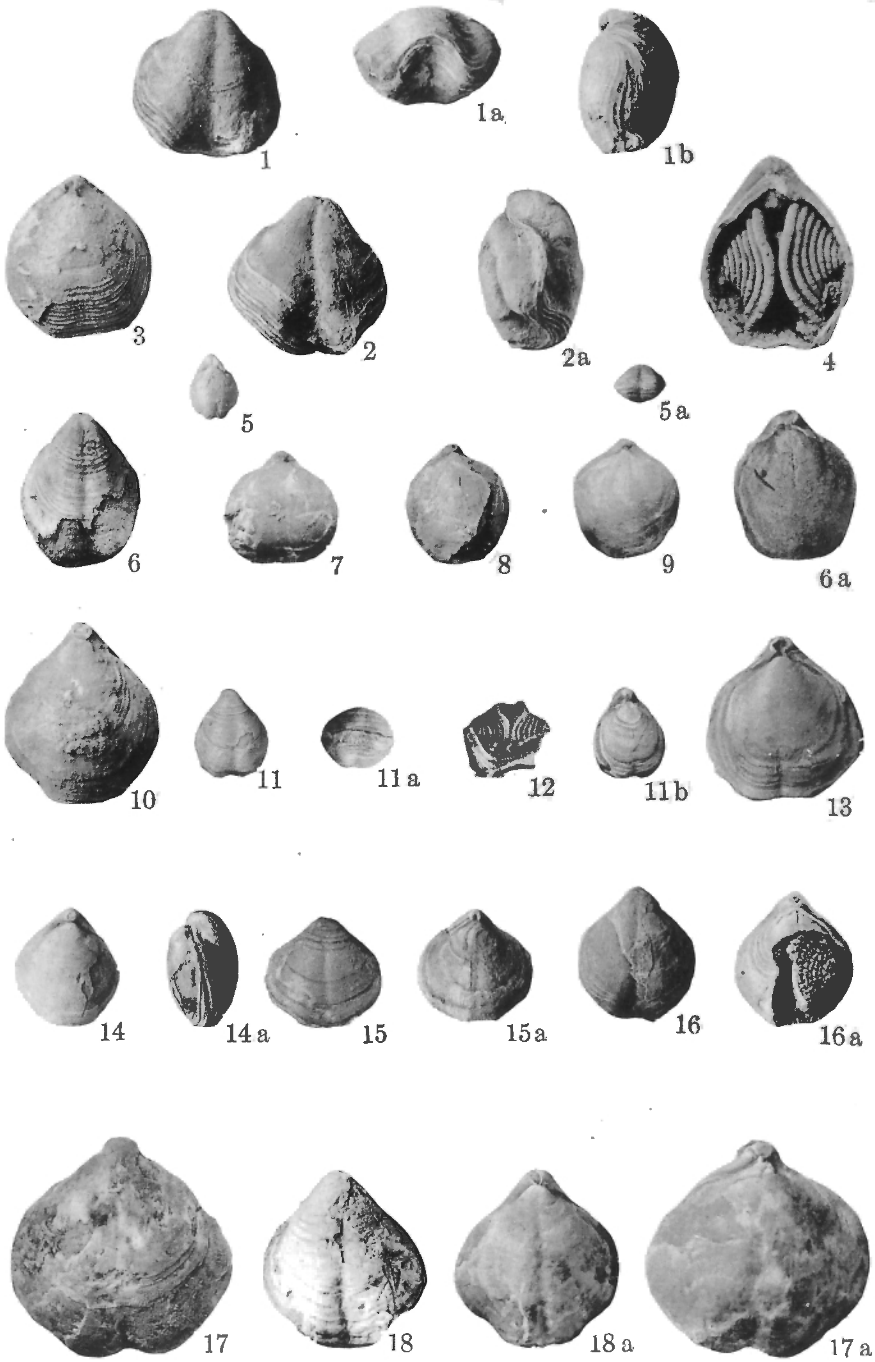
Figures 15, 15a. Pedicle and brachial views. Nat. Mus. of Canada, Cat. No. 7514a, paratype, natural size.

Figures 16, 16a. Pedicle and brachial views. Nat. Mus. of Canada, Cat. No. 7515b, paratype, natural size.

Figures 17, 17a. Pedicle and brachial views of holotype of variety *incisa*. Nat. Mus. of Canada, Cat. No. 7518, holotype, X 2.

Figures 18, 18a. Pedicle and brachial views of var. *incisa*. Nat. Mus. of Canada, Cat. No. 7517, paratype, X 2.

Plate XXI



1
1a
1b
3
2
2a
4
5
5a
6
7
8
9
6a
10
11
11a
12
11b
13
14
14a
15
15a
16
16a
17
18
18a
17a

Plate XXII

Spiriferina cf. *octoplicata* Sowerby. (Page 141.)

Figure 1. Pedicle valve. Nat. Mus. of Canada, Cat. No. 7519, cotype, natural size.

Figure 2. Brachial valve. Nat. Mus. of Canada, Cat. No. 7513, cotype, natural size.

Ambocoelia acadica Bell. (Page 141.)

Figures 3, 3a, 3b. Pedicle, lateral, and brachial views of holotype. Nat. Mus. of Canada, Cat. No. 7525, holotype, X 2.

Figures 4, 4a, 4b. Pedicle, lateral, and posterior views. Nat. Mus. of Canada, Cat. No. 7525a, paratype, X 2.

Martinia galataea Bell. (Page 142.)

Figures 5, 5a, 5b. Lateral, posterior, and pedicle views of an incomplete specimen. Nat. Mus. of Canada, Cat. No. 4343, cotype, natural size.

Spiriferina verneuili Bell. (Page 139.)

Figures 6, 6a, 6b, 6c. Anterior, lateral, pedicle, and brachial views. Nat. Mus. of Canada, Cat. No. 7521, cotype, natural size.

Figure 7. Interior of pedicle valve. Nat. Mus. of Canada, Cat. No. 7522, paratype, natural size.

Figure 8. Brachial view. Nat. Mus. of Canada, Cat. No. 7520, paratype, natural size.

Figures 9, 9a. Brachial and posterior views. Nat. Mus. of Canada, Cat. No. 7521a, cotype, natural size.

Spirifer nox Bell. (Page 137.)

Figures 10, 10a, 10b. Three views of a pedicle valve. Nat. Mus. of Canada, Cat. No. 7532, holotype, natural size.

Spirifer adonis Bell. (Page 138.)

Figures 11, 11a, 11b, 11c, 11d. Posterior, anterior, brachial, lateral, and pedicle views of holotype. Peabody Museum, natural size.

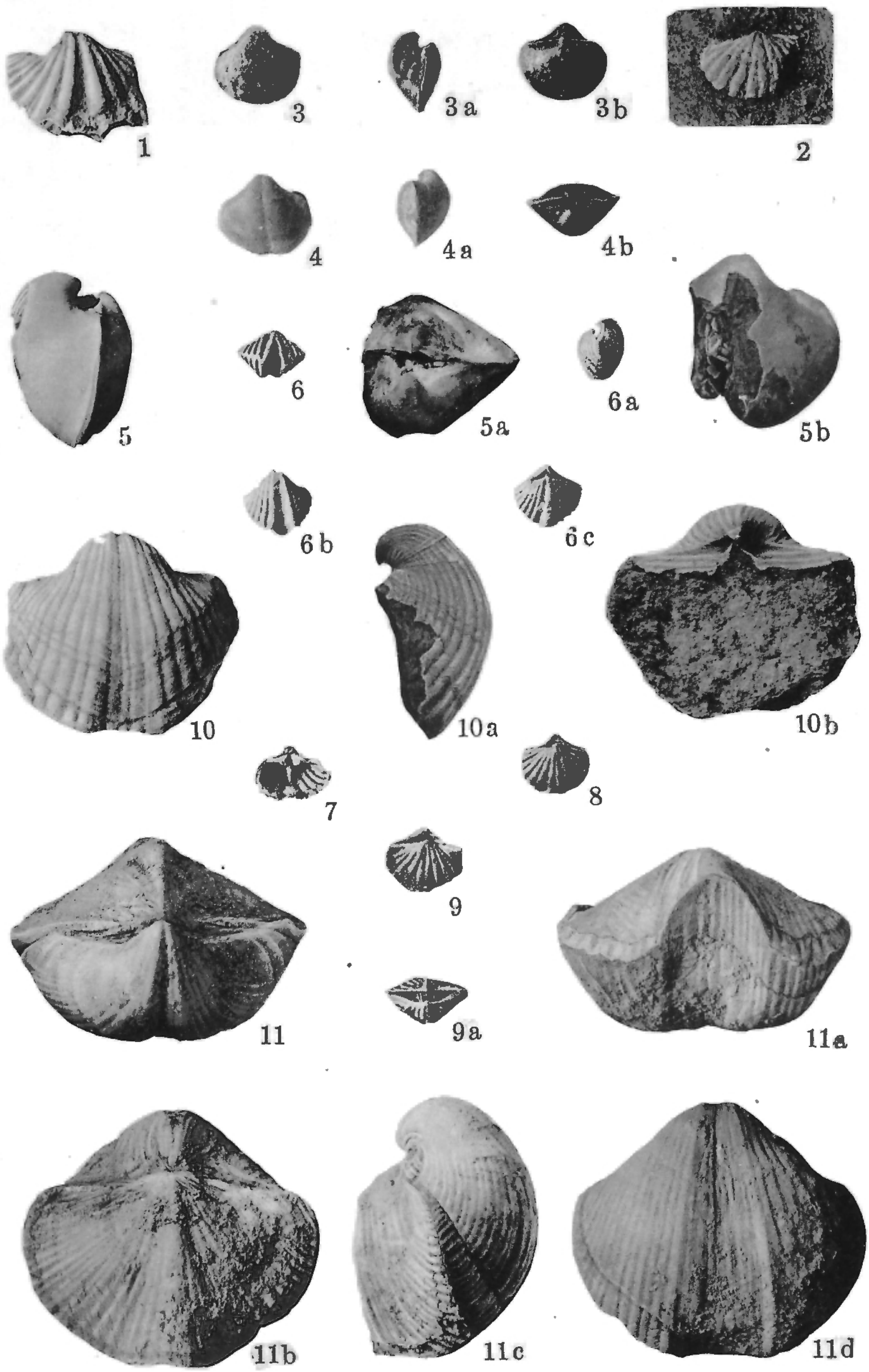

1
3
3a
3b
2
4
4a
4b
5
6
5a
6a
5b
6b
6c
10
10a
10b
7
8
9
11
9a
11a
11b
11c
11d

PLATE XXIII

Martinia galataea Bell. (Page 142.)

Figures 1, 1a. Pedicle and brachial views. Nat. Mus. of Canada, Cat. No. 7524a, paratype, natural size.

Figures 2, 2a, 2b, 2c. Pedicle, brachial, anterior, and lateral views. Nat. Mus. of Canada, Cat. No. 7524, cotype, natural size.

Figure 3. Pedicle view. Nat. Mus. of Canada, Cat. No. 7523, paratype, natural size.

Martinia thetis Bell. (Page 143.)

Figures 4, 4a, 4b, 4c. Pedicle, brachial, lateral, and posterior views. Nat. Mus. of Canada, Cat. No. 7533, holotype, natural size.

Dielasma latum Bell. (Page 146.)

Figures 5, 5a, 5b. Lateral, pedicle, and brachial views of a gibbous variant. Nat. Mus. of Canada, Cat. No. 7491a, paratype, natural size.

Dielasma mesaplanum Bell. (Page 148.)

Figures 6, 6a. Brachial and posterior views. Nat. Mus. of Canada, Cat. No. 7495, holotype, natural size.

Figure 7. Brachial view. Nat. Mus. of Canada, Cat. No. 7495a, paratype, natural size.

Dielasma davidsoni (Hall and Clarke). (Page 144.)

Figure 8. Brachial view of an excellent specimen. Nat. Mus. of Canada, Cat. No. 7486, plesiotype, natural size.

Figures 9, 9a, 9b. Lateral, brachial, and posterior views of a typical specimen. Nat. Mus. of Canada, Cat. No. 7485a, plesiotype, natural size.

Figure 10. Brachial view of lectotype. University of Chicago, Cat. No. 12223-475, lectotype, natural size.

Dielasma mesaplanum Bell. (Page 148.)

Figures 11, 11a, 11b. Brachial, anterior, and pedicle views. Nat. Mus. of Canada, Cat. No. 7496, paratype, natural size.

Figure 12. Pedicle view of incomplete large specimen that approaches *D. latum*. Nat. Mus. of Canada, Cat. No. 7751, paratype, natural size.

Dielasma latum Bell. (Page 146.)

Figure 13. Brachial view of gibbous variant. Nat. Mus. of Canada, Cat. No. 7488, paratype, natural size.

Figure 14. Brachial view of large specimen showing traces of dental plates. Nat. Mus. of Canada, Cat. No. 4340, paratype, natural size.

Dielasma davidsoni (Hall and Clarke). (Page 144.)

Figure 15. Brachial view. Nat. Mus. of Canada, Cat. No. 7485, plesiotype, natural size.

Figure 16. Brachial view of a typical specimen. Nat. Mus. of Canada, Cat. No. 7754, plesiotype, natural size.

Figure 17. Interior of shell showing socket and dental plates and independent crural plates. Nat. Mus. of Canada, Cat. No. 7487, plesiotype, X 2.

Figure 18. Interior of shell showing dental and crural plates. Nat. Mus. of Canada, Cat. No. 7674, plesiotype, natural size.

Plate XXIII

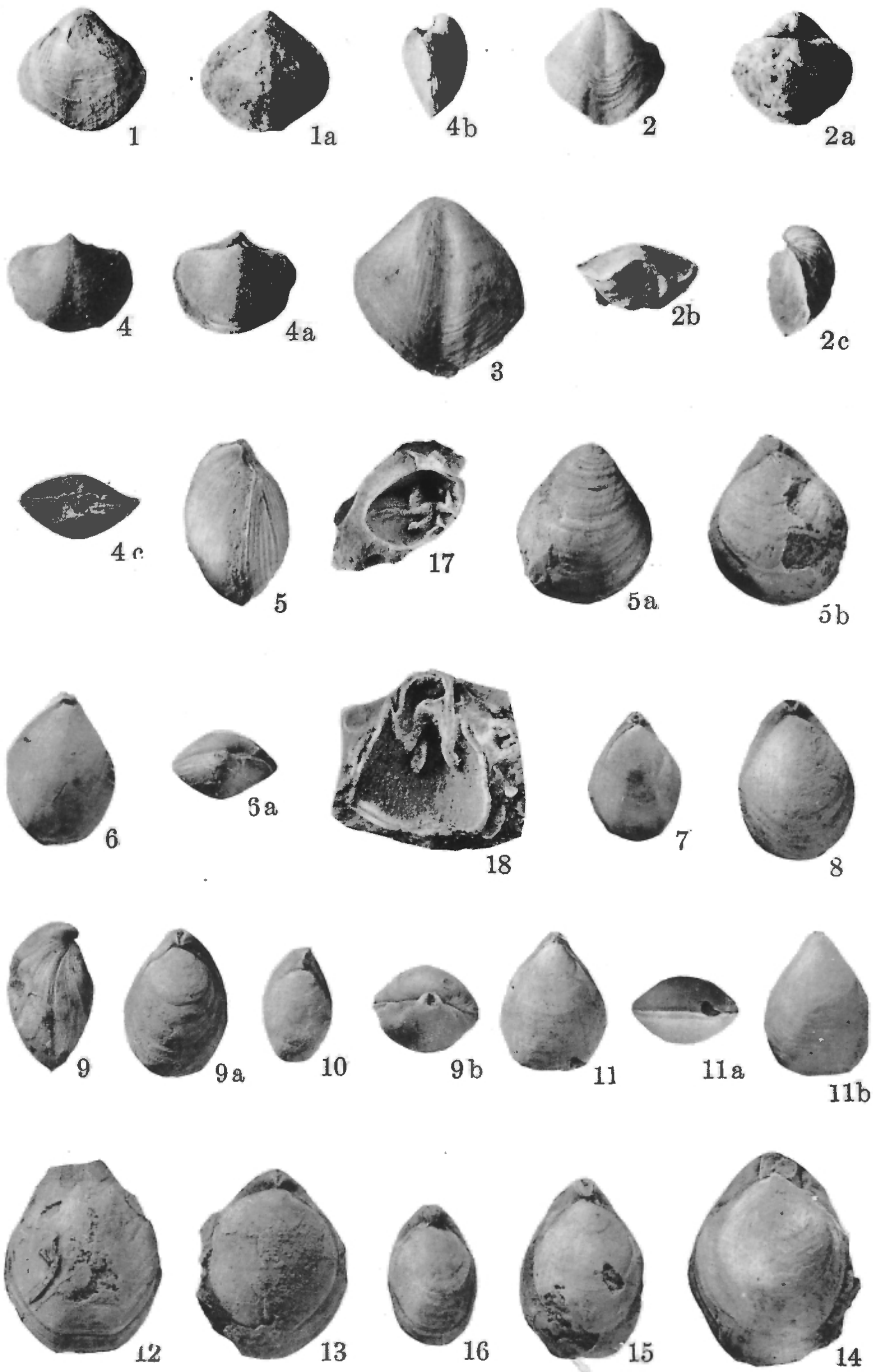

1
1a
4b
2
2a
4
4a
3
2b
2c
4c
5
17
5a
5b
6
6a
18
7
8
9
9a
10
9b
11
11a
11b
12
13
16
15
14

Plate XXIV

Dielasma latum Bell. (Page 146.)

Figures 1, 1a. Brachial and lateral views of var. ***gibbosum***. Nat. Mus. of Canada, Cat. No. 7500, paratype, natural size.
Figure 2. Brachial views of perfect specimen. Nat. Mus. of Canada, Cat. No. 7491, cotype, natural size.
Figure 3. Internal mould showing traces of dental and crural plates. Nat. Mus. of Canada, Cat. No. 7673, cotype, natural size.
Figures 4, 4a, 4b, 4c. Holotype, of variety *gibbosum*. Nat. Mus. of Canada, Cat. No. 7492, natural size.

Dielasma milviformis Bell. (Page 147.)

Figures 5, 5a. Brachial and lateral views of a broad variant. Nat. Mus. of Canada, Cat. No. 7755, paratype, natural size.
Figure 6. Nat. Mus. of Canada, Cat. No. 7494, paratype, natural size.
Figure 7. Typical specimen. Nat. Mus. of Canada, Cat. No. 7493, paratype, natural size.
Figure 8. A dwarf individual. Nat. Mus. of Canada, Cat. No. 7497, paratype, natural size.
Figure 9. Nat. Mus. of Canada, Cat. No. 7494b, paratype, natural size.
Figure 10. Nat. Mus. of Canada, Cat. No. 7494c, holotype, natural size.

Cranaena tumida Bell. (Page 148.)

Figures 11, 11a. Brachial and lateral views. Nat. Mus. of Canada, Cat. No. 7504, holotype, natural size.
Figure 12. Interior showing socket and hinge plates. Nat. Mus. of Canada, Cat. No. 7503a, natural size.
Figure 13. Interior, showing part of cruralium. Nat. Mus. of Canada, Cat. No. 7502, natural size.
Figures 14, 14a. Lateral and brachial views. Nat. Mus. of Canada, Cat. No. 7503, paratype, natural size.
Figure 15. One of the cotypes of *Beecheria-davidsoni* (Hall and Clarke). University of Chicago, Cat. No. 12223.
Figure 16. A perfect individual. Nat. Mus. of Canada, Cat. No. 7756, natural size.

Harttella parva Bell. (Page 150.)

Figures 17, 17a, 17b. Pedicle, brachial, and lateral views. Nat. Mus. of Canada, Cat. No. 7498, genoholotype, natural size.
Figure 18. Section showing crural plates. Nat. Mus. of Canada, Cat. No. 7498a, paratype, X 4.

Harttella dielasmoidea Bell. (Page 151.)

Figures 19, 19a, 19b. Pedicle, brachial, and lateral views. Nat. Mus. of Canada, Cat. No. 7499a, paratype, natural size.
Figures 20, 20a, 20b. Pedicle, lateral, and brachial views. Nat. Mus. of Canada, Cat. No. 7499b, holotype, natural size.
Figures 21, 21a. Brachial and lateral views. Nat. Mus. of Canada, Cat. No. 7499, paratype, natural size.

Harttella gibbosa Bell. (Page 150.)

Figures 22, 22a. Brachial and lateral views. Nat. Mus. of Canada, Cat. No. 7508, paratype, natural size.
Figures 23, 23a. Pedicle and anterior views. Nat. Mus. of Canada, Cat. No. 7506, paratype, natural size.
Figures 24, 24a, 24b. Pedicle, brachial, and lateral views. Nat. Mus. of Canada, Cat. No. 7505, holotype, natural size.
Figures 25, 25a, 25b. Brachial, posterior, and pedicle views. Nat. Mus. of Canada, Cat. No. 7509, paratype, natural size.

Sanguinolites striatogranulatus Hind. (Page 153.)

Figure 26. A right valve. Nat. Mus. of Canada, Cat. No. 7605, plesiotype, natural size.
Figure 27. A left valve and cardinal areas. Nat. Mus. of Canada, Cat. No. 7537a, plesiotype, natural size.
Figure 28. Left valve. Nat. Mus. of Canada, Cat. No. 7537, plesiotype, natural size.
Figure 29. View of left valve. Nat. Mus. of Canada, Cat. No. 7536a, plesiotype, natural size.
Figure 30. Imperfect right valve. Nat. Mus. of Canada, Cat. No. 7536, plesiotype, natural size.

Plate XXIV

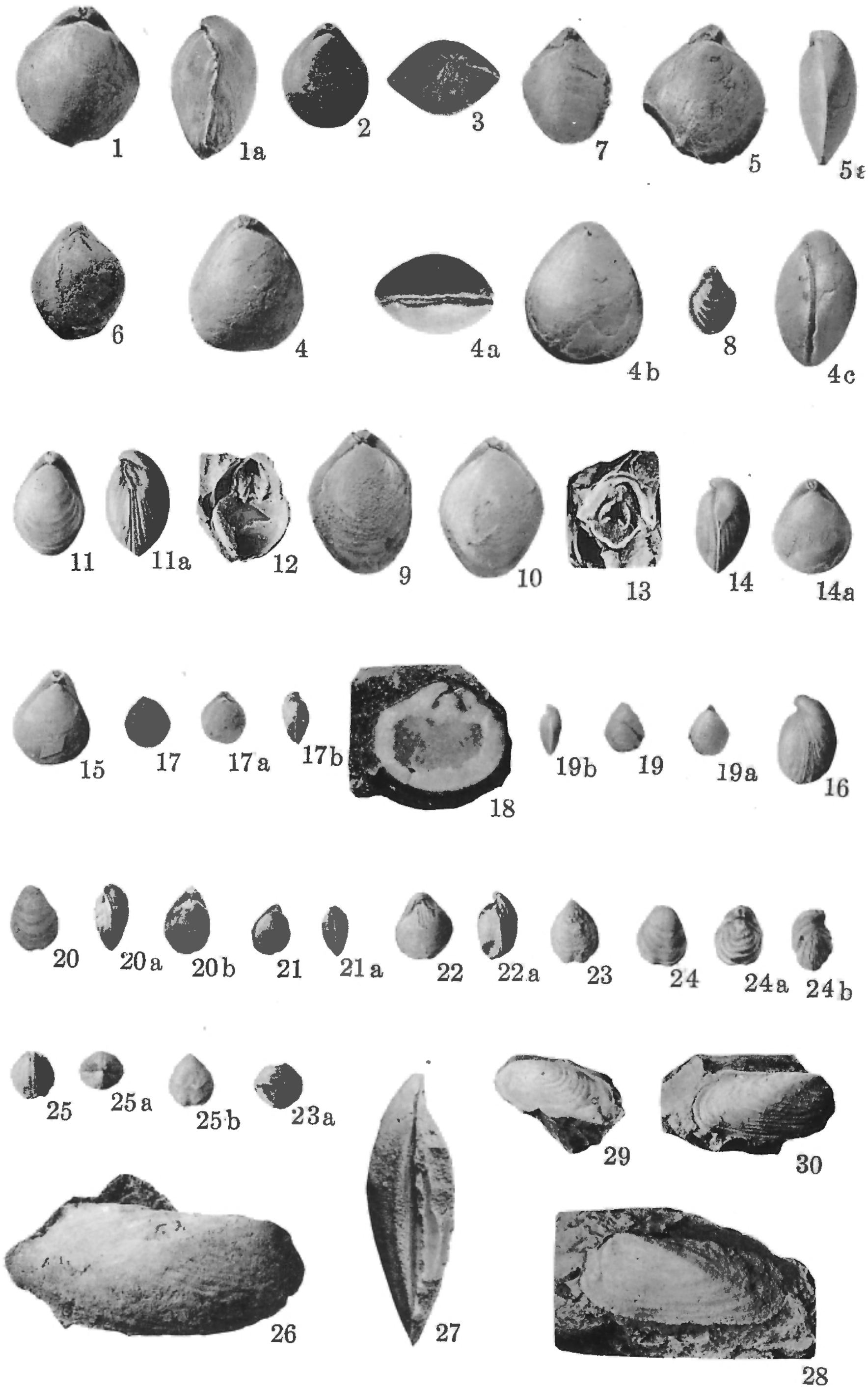

1
1a
2
3
7
5
5a
6
4
4a
4b
8
4c
11
11a
12
9
10
13
14
14a
15
17
17a
17b
18
19b
19
19a
16
20
20a
20b
21
21a
22
22a
23
24
24a
24b
25
25a
25b
23a
26
27
29
30
28

Plate XXV

Sanguinolites striatogranulatus Hind. (Page 153.)

Figure 1. Right valve of complete specimen. Nat. Mus. of Canada, Cat. No. 7537b, plesiotype, natural size.

Figures 2, 2a, Left valve and cardinal view. Nat. Mus. of Canada, Cat. No. 7604, plesiotype, natural size.

Figure 3. Left valve. Nat. Mus. of Canada, Cat. No. 7551, plesiotype, natural size.

Figure 4. Large left valve. Nat. Mus. of Canada, Cat. No. 7538, plesiotype, natural size.

Sanguinolites parvus Bell. (Page 152.)

Figure 5. Left valve. Nat. Mus. of Canada, Cat. No. 7606, paratype, X 2.

Figures 6, 6a. Right valve and cardinal view. Nat. Mus. of Canada, Cat. No. 7550c, paratype, X 2.

Figure 7. View of left valve. Nat. Mus. of Canada, Cat. No. 7550b, paratype, natural size.

Figure 8. Left valve. Nat. Mus. of Canada, Cat. No. 7550, paratype, natural size.

Figure 9. Left valve. Nat. Mus. of Canada, Cat. No. 7606b, paratype, X 2.

Figures 10, 10a. Right valve and cardinal view. Nat. Mus. of Canada, Cat. No. 7550a, holotype, natural size.

Sanguinolites niobe Bell. (Page 153.)

Figure 11. Right valve. Nat. Mus. of Canada, Cat. No. 7607, paratype, natural size.

Figures 12, 12a, 12b. Left valve, anterior and cardinal views. Nat. Mus. of Canada, Cat. No. 7535, holotype, natural size.

Sanguinolites ? sp. (Page 154.)

Figure 13. View of left valve. Nat. Mus. of Canada, Cat. No. 7608, holotype, natural size.

Edmondia rudis M'Coy. (Page 155.)

Figure 14. Right valve. Nat. Mus. of Canada, Cat. No. 7543a, plesiotype, natural size.

Figure 15. Both valves. Nat. Mus. of Canada, Cat. No. 4360, plesiotype, natural size.

Figures 16, 16a. Left valve and cardinal view. Nat. Mus. of Canada, Cat. No. 7609, natural size.

Figure 17. Right valve. Nat. Mus. of Canada, Cat. No. 7610, natural size.

Figures 18, 18a, 18b. Left valve, cardinal and anterior views. Nat. Mus. of Canada, Cat. No. 7543, natural size.

Plate XXV

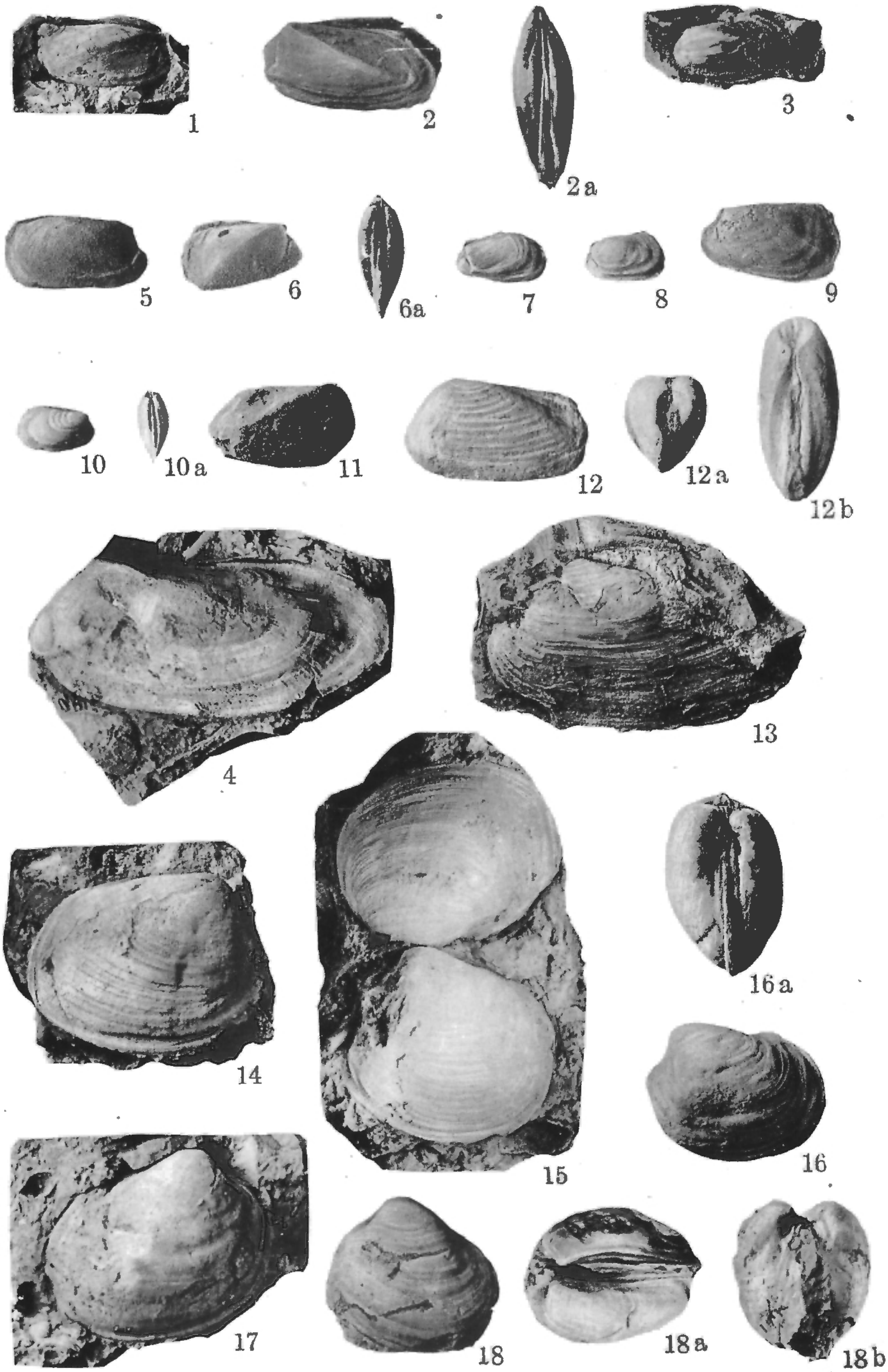


Plate XXVI

Leptodesma dawsoni (Beede). (Page 159.)

Figure 1. Left valve. Nat. Mus. of Canada, Cat. No. 7577a, plesiotype, natural size.
Figure 2. Left valve. Nat. Mus. of Canada, Cat. No. 7577, plesiotype, natural size.

Leptodesma acadica (Beede). (Page 160.)

Figure 3. Left valve. Nat. Mus. of Canada, Cat. No. 7582, plesiotype, natural size.
Figure 4. Right valve. Nat. Mus. of Canada, Cat. No. 7581, plesiotype, natural size.
Figure 5. Left valve. Nat. Mus. of Canada, Cat. No. 7683, plesiotype, X 2.

Leptodesma sp. Bell. (Page 162.)

Figure 6. Left valve. Nat. Mus. of Canada, Cat. No. 7584, holotype, natural size.

Leptodesma ? shubenacadiensis (Dawson). (Page 161.)

Figure 7. Right valve. Nat. Mus. of Canada, Cat. No. 7585, plesiotype, natural size.
Figure 8. Left valve. Peabody Museum, Yale University.

Parallelidon dawsoni Beede. (Page 157.)

Figure 9. Left valve. Nat. Mus. of Canada, Cat. No. 7567, plesiotype, natural size.
Figure 10. Left valve. Nat. Mus. of Canada, Cat. No. 4354, plesiotype, X 2.
Figure 11. Right valve. Nat. Mus. of Canada, Cat. No. 7575, plesiotype, natural size.
Figure 12. Cardinal view. Nat. Mus. of Canada, Cat. No. 7576, plesiotype, X 4.

Parallelidon hardingi (Dawson). (Page 156.)

Figure 13. Left valve. Nat. Mus. of Canada, Cat. No. 7565c, plesiotype, natural size.
Figure 14. View of right valve. Nat. Mus. of Canada, Cat. No. 7572, natural size.
Figure 15. Anterior view showing adductor scars and pallial line. Nat. Mus. of Canada, Cat. No. 7565d, plesiotype, natural size.
Figures 16, 16a. Right valve and anterior end. Nat. Mus. of Canada, Cat. No. 7565a, plesiotype, natural size.
Figures 17, 17a. Cardinal and anterior views. Nat. Mus. of Canada, Cat. No. 7571, plesiotype, natural size.
Figure 18. Right valve of a large specimen. Nat. Mus. of Canada, Cat. No. 7565b, plesiotype, natural size.
Figure 19. Cardinal view showing mould of teeth. Nat. Mus. of Canada, Cat. No. 7566, plesiotype, natural size.

Leptodesma borealis Beede. (Page 159.)

Figure 20. Right valve. Nat. Mus. of Canada, Cat. No. 7578, plesiotype, natural size.

Edmondia hartti Dawson. (Page 155.)

Figure 21. Right valve. Nat. Mus. of Canada, Cat. No. 7548a, plesiotype, natural size.
Figure 22. Right valve. Nat. Mus. of Canada, Cat. No. 7611, plesiotype, natural size.
Figure 23. View of left valve. Nat. Mus. of Canada, Cat. No. 7548, plesiotype, natural size.

Plate XXVI

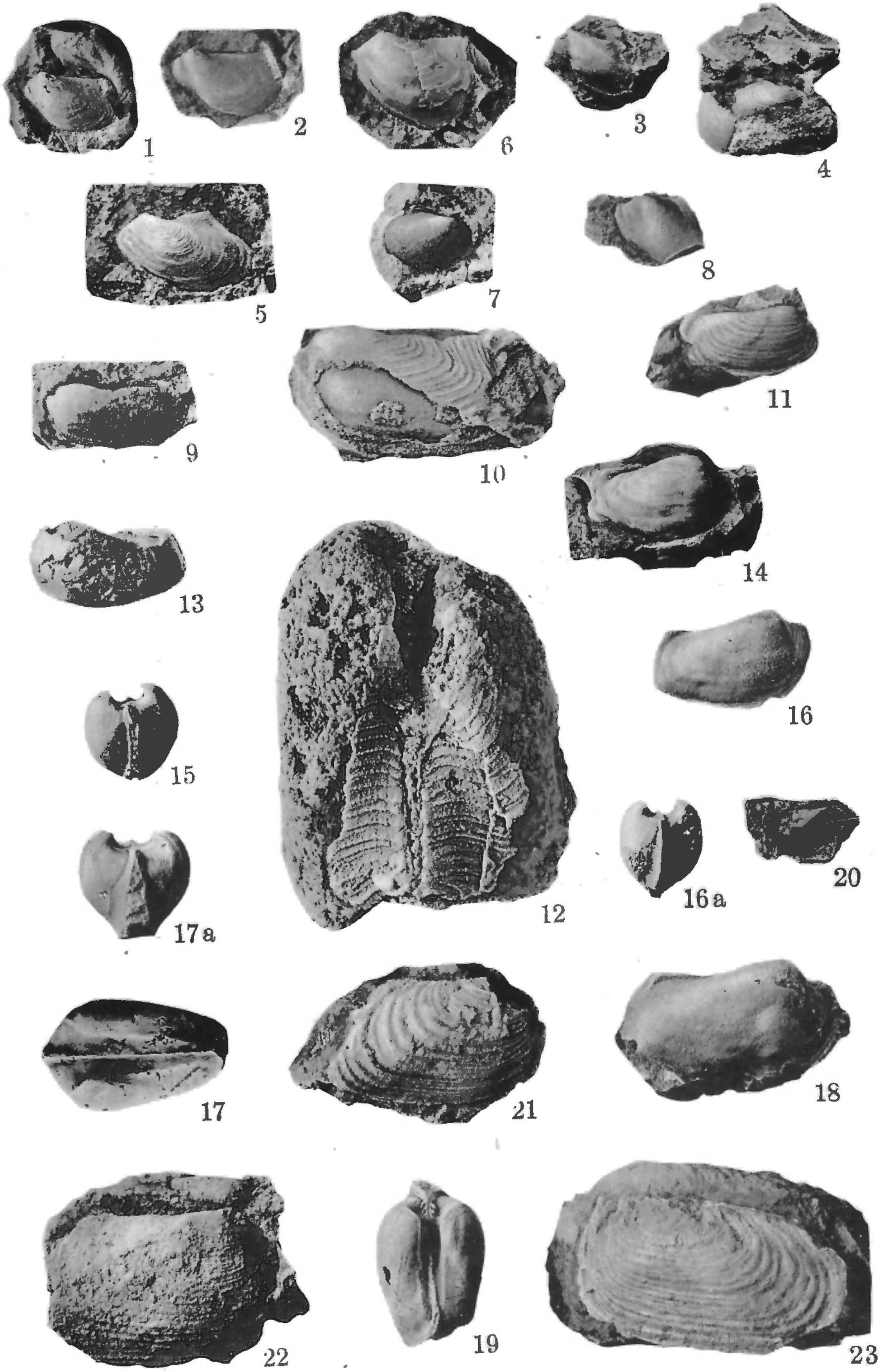


PLATE XXVII

Pteronites gayensis Dawson. (Page 162.)

Figure 1. An internal mould of left valve. Nat. Mus. of Canada, Cat. No. 7752a, plesiotype, X 2.

Figure 2. Right valve showing concentric ornamentation. Nat. Mus. of Canada, Cat. No. 7752c, plesiotype, X 2.

Figure 3. A left valve with shell partly preserved showing the *ornatus* type of ornamentation. Nat. Mus. of Canada, Cat. No. 7752, plesiotype, X 2.

Figure 4. A left valve. Nat. Mus. of Canada, Cat. No. 7682, plesiotype, X 2.

Schizodus fundiensis Bell. (Page 163.)

Figures 5, 5a, 5b, 5c. Left valve, right valve, anterior and cardinal views of a complete internal mould or cast of the interior. Nat. Mus. of Canada, Cat. No. 7546, holotype, natural size.

Figure 6. Right valve. Nat. Mus. of Canada, Cat. No. 7613, paratype, natural size.

Schizodus cheveriensis Bell. (Page 164.)

Figure 7. Internal moulds of attached valves. Nat. Mus. of Canada, Cat. No. 7547, paratype, natural size.

Figure 8. Internal moulds of attached valves. Nat. Mus. of Canada, Cat. No. 7547a, holotype, natural size.

Aviculopecten lyelli Dawson. (Page 164.)

Figure 9. Left valve. Nat. Mus. of Canada, Cat. No. 7553b, plesiotype, natural size.

Figure 10. Left valve. Nat. Mus. of Canada, Cat. No. 7553, plesiotype, natural size.

Figure 11. Right valve. Nat. Mus. of Canada, Cat. No. 7554, plesiotype, natural size.

Figure 12. Right valve. Nat. Mus. of Canada, Cat. No. 7553a, plesiotype, natural size.

Figure 13. A part of left valve magnified to show ornamentation. Nat. Mus. of Canada, Cat. No. 7587, plesiotype, X 4.

Figure 14. Right valve. Nat. Mus. of Canada, Cat. No. 7590, plesiotype, natural size.

Figure 15. Left valve. Nat. Mus. of Canada, Cat. No. 4361, plesiotype, natural size.

Plate XXVII

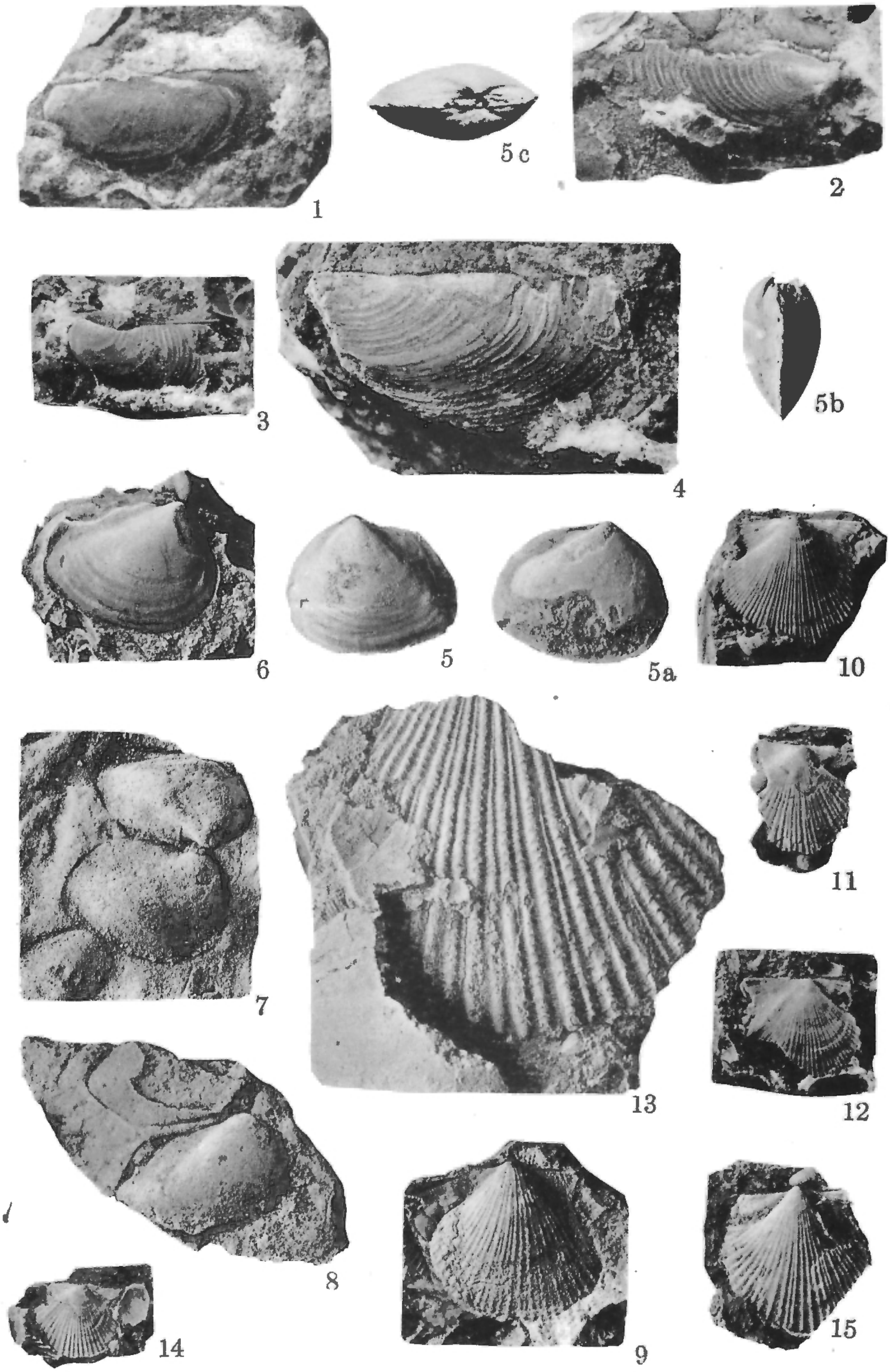


Plate XXVIII

Aviculopecten lyelli Dawson. (Page 164.)

Figure 1. Left valve. Nat. Mus. of Canada, Cat. No. 4361b, plesiotype, natural size.

Figure 2. A left valve with coarser costation. Nat. Mus. of Canada, Cat. No. 4361a, plesiotype, natural size.

Figure 3. A left valve. Nat. Mus. of Canada, Cat. No. 4361c, natural size.

Aviculopecten subquadratus Bell. (Page 166.)

Figure 4. View of right valve of cast of interior. Nat. Mus. of Canada, Cat. No. 7555a, paratype, natural size.

Figure 5. Left valve. Nat. Mus. of Canada, Cat. No. 7593b, paratype, natural size.

Figure 6. Left valve. Nat. Mus. of Canada, Cat. No. 7593a, paratype, natural size.

Figure 7. Left valve of young individual. Nat. Mus. of Canada, Cat. No. 7593, cotype, natural size.

Figure 7a. Same specimen, X 4, to show spinous ornamentation.

Figure 8. A left valve. Nat. Mus. of Canada, Cat. No. 7592, paratype, natural size.

Figure 9. View of right valve. Nat. Mus. of Canada, Cat. No. 7594, paratype, natural size.

Figures 10, 10a. Right and left valves of a small specimen. Peabody Museum, Yale University.

Figure 11. Left valves. Nat. Mus. of Canada, Cat. No. 7555, cotypes, natural size.

Pterinopecten sp. Bell. (Page 166.)

Figure 12. A right valve. Nat. Mus. of Canada, Cat. No. 7556, holotype, natural size.

Pseudamusium simplex (Dawson). (Page 167.)

Figure 13. View of right valve of internal moulds of attached shells. Nat. Mus. of Canada, Cat. No. 7557, plesiotype, natural size.

Figure 13a. Posterior view of same specimen, natural size.

Figure 13b. Left valve of same specimen, natural size.

Figure 14. A young individual magnified to show fine costation. Nat. Mus. of Canada. Cat. No. 7598, plesiotype, X 4.

Figure 15. Right valve. Nat. Mus. of Canada, Cat. No. 7597, plesiotype, natural size.

Figure 16. Posterior view of cast of interior. Nat. Mus. of Canada, Cat. No. 4364, plesiotype, natural size.

Figure 17. A right valve with ear broken off, but showing fine costation well. Nat. Mus. of Canada, Cat. No. 7557a, plesiotype, natural size.

Figure 18. Posterior view of cast of interior. Nat. Mus. of Canada, Cat. No. 4364f, plesiotype, natural size.

Plate XXVIII

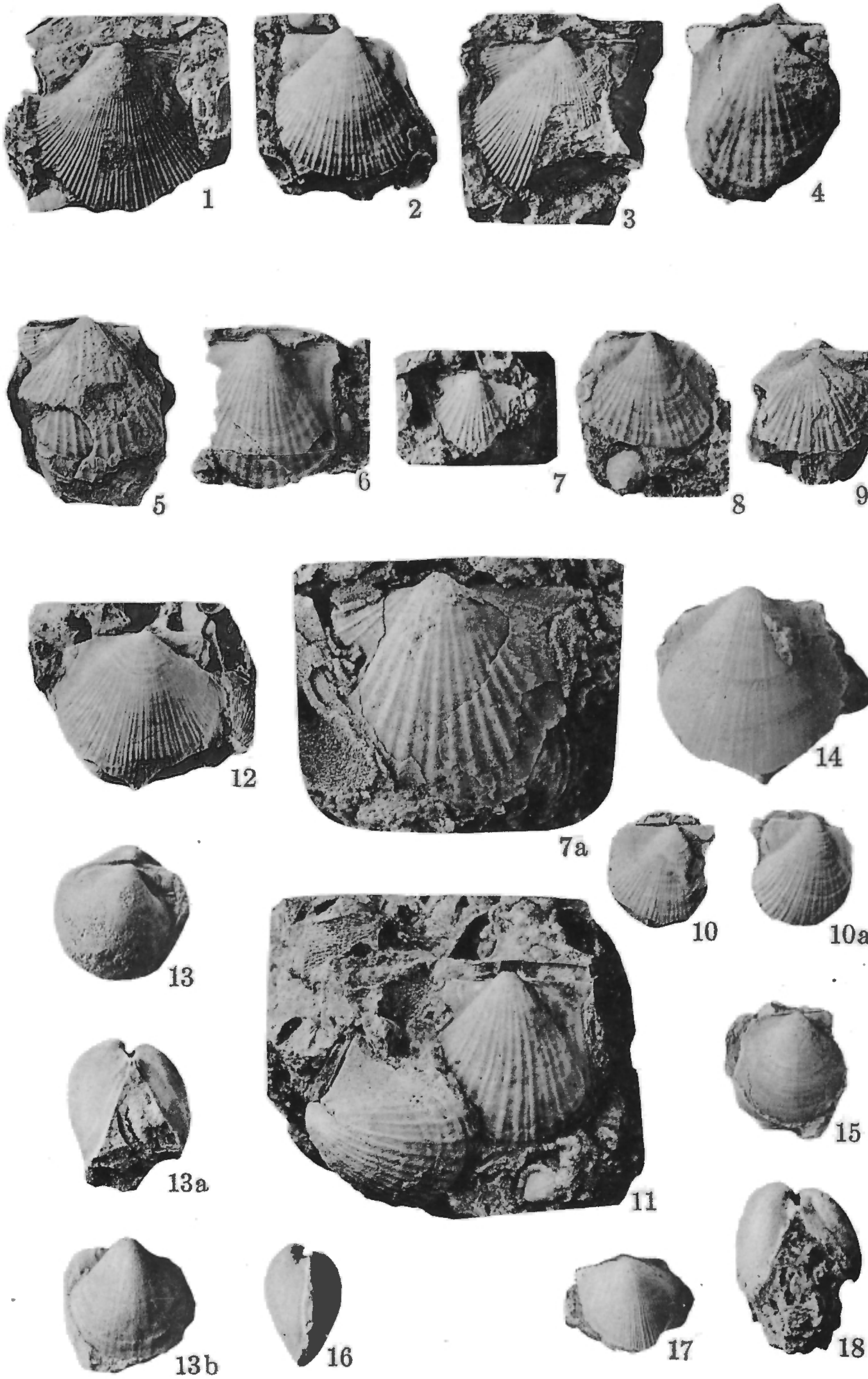


Plate XXIX

Aviculopecten lyelliformis Bell. (Page 165.)

Figure 1. Left valve. Nat. Mus. of Canada, Cat. No. 7559, holotype, natural size.

Figure 2. Left valve. Nat. Mus. of Canada, Cat. No. 7560, paratype, natural size.

Pseudamusium debertianum (Dawson). (Page 168.)

Figure 3. A left valve. Ear and postero-cardinal corner incomplete. Nat. Mus. of Canada, Cat. No. 7596, plesiotype, natural size.

Figure 4. A second imperfect left valve. Nat. Mus. of Canada, Cat. No. 7595, plesiotype, natural size.

Figure 5. Left valve with entire posterior border, but anterior ear incomplete. Nat. Mus. of Canada, Cat. No. 7596a, plesiotype, natural size.

Modiola dawsoni Bell. (Page 169.)

Figure 6. Cardinal view of cast of interior. Nat. Mus. of Canada, Cat. No. 7562, paratype, natural size.

Figure 7. Right valve. Nat. Mus. of Canada, Cat. No. 7601, paratype, natural size.

Figures 8, 8a. Incomplete left valve and cardinal view of cast of interior. Nat. Mus. of Canada, Cat. No. 7600, paratype, natural size.

Figure 9. View of left valve of cast of interior. Nat. Mus. of Canada, Cat. No. 7561, holotype, natural size.

Modiola hartti Bell. (Page 168.)

Figure 10. Illustrates gregarious habit. Nat. Mus. of Canada, Cat. No. 7564a, paratypes, natural size.

Figure 11. Right valve. Nat. Mus. of Canada, Cat. No. 7564, holotype, natural size.

Lithophagus poolii (Dawson). (Page 170.)

Figure 12. Cardinal view of cast of interior. Nat. Mus. of Canada, Cat. No. 7552, plesiotype, natural size.

Figures 13, 13a. Cardinal view and right valve of cast of interior. Nat. Mus. of Canada, Cat. No. 7602, neotype, natural size.

Figure 14. Left valve. Nat. Mus. of Canada, Cat. No. 7552b, plesiotype, natural size.

Figure 15. Right valve of a small specimen agreeing in all respects with ***Modiola poolii*** Dawson. Nat. Mus. of Canada, Cat. No. 7552c, plesiotype, natural size.

Figure 16. Right valve. Nat. Mus. of Canada, Cat. No. 7602a, plesiotype, natural size.

Figures 17, 17a. Right and left valves. Nat. Mus. of Canada, Cat. No. 7603, plesiotype, X 2.

Figure 18. Right valve. Nat. Mus. of Canada, Cat. No. 7552a, plesiotype, natural size.

Plate XXIX

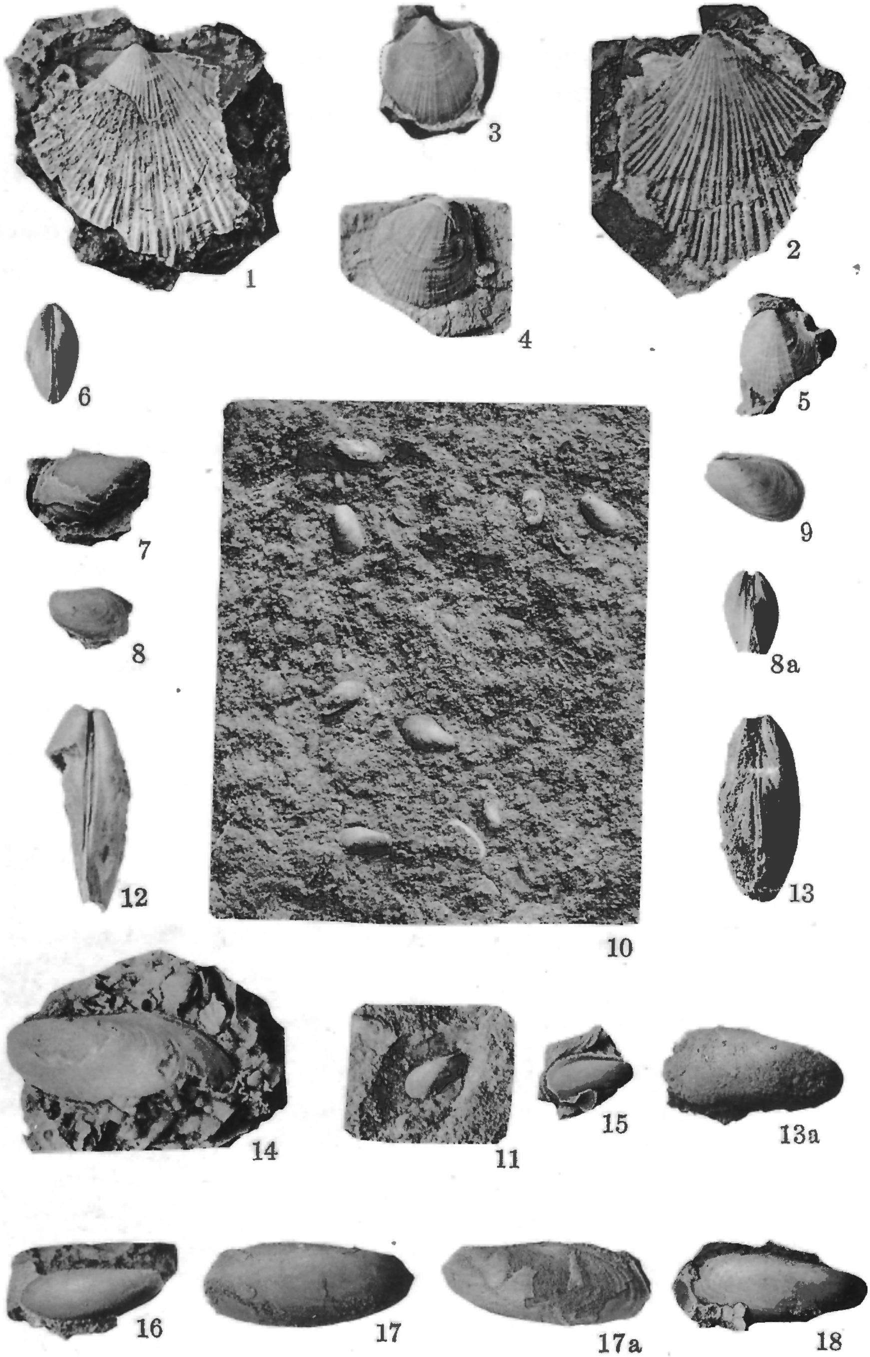


PLATE XXX

Spathella insecta (Dawson). (Page 171.)

Figure 1. Left valve. Nat. Mus. of Canada, Cat. No. 7534, plesiotype, natural size.
Figure 2. Anterior view. Nat. Mus. of Canada, Cat. No. 7540, plesiotype, natural size.
Figure 3. Left valve. Nat. Mus. of Canada, Cat. No. 7539, plesiotype, natural size.

Scaldia fletcheri Bell. (Page 171.)

Figures 4, 4a. Left valve and anterior view of cast of interior. Nat. Mus. of Canada, Cat. No. 7563, holotype, natural size.

Cypricardella acadica Bell. (Page 170.)

Figures 5, 5a, 5b. Right valves, anterior view, and left valve. Nat. Mus. of Canada, Cat. No. 7615, holotype, X 2.

Bellerophon sp. Bell. (Page 172.)

Figures 6, 6a. Umbilical and frontal views. Peabody Museum, Yale University, holotype, natural size.
Figure 7. Frontal view. Nat. Mus. of Canada, Cat. No. 7639, paratype, natural size.

Euphemus cf. *urei* Fleming. (Page 172.)

Figure 8. Umbilical view. Nat. Mus. of Canada, Cat. No. 7678, holotype, X 2.

Bucanopsis beedii Bell. (Page 172.)

Figure 9. Ventral view. Nat. Mus. of Canada, Cat. No. 7638, holotype, natural size.

Mourlonia ? sp. Bell. (Page 173.)

Figures 10, 10a. Two views of incomplete shell. Nat. Mus. of Canada, Cat. No. 7628, holotype, natural size.

Murchisonia gypsea Dawson. (Page 173.)

Figure 11. Nat. Mus. of Canada, Cat. No. 7636, plesiotype, X 4.
Figure 12. Nat. Mus. of Canada, Cat. No. 4368, plesiotype, X 2.

Murchisonia (Stegocoelia) compactoidea Bell. (Page 174.)

Figure 13. Nat. Mus. of Canada, Cat. No. 7640, paratype, X 4.
Figure 14. Nat. Mus. of Canada, Cat. No. 7633, paratype, X 4.
Figures 15, 15a. Nat. Mus. of Canada, Cat. No. 7633a, holotype, X 4.

Murchisonia (Stegocoelia) abrupta Bell. (Page 173.)

Figure 16. Nat. Mus. of Canada, Cat. No. 7624, holotype, X 2.
Figure 17. Nat. Mus. of Canada, Cat. No. 7624a, paratype, X 4.

Straparollus minutus de Koninck. (Page 175.)

Figures 18, 18a. Nat. Mus. of Canada, Cat. No. 7623, plesiotype, natural size.
Figure 19. Umbilical view. Nat. Mus. of Canada, Cat. No. 7623a, plesiotype, X 2.
Figure 20. Nat. Mus. of Canada, plesiotype, natural size.
Figure 21. Nat. Mus. of Canada, Cat. No. 7675, plesiotype, X 2.

Plate XXX

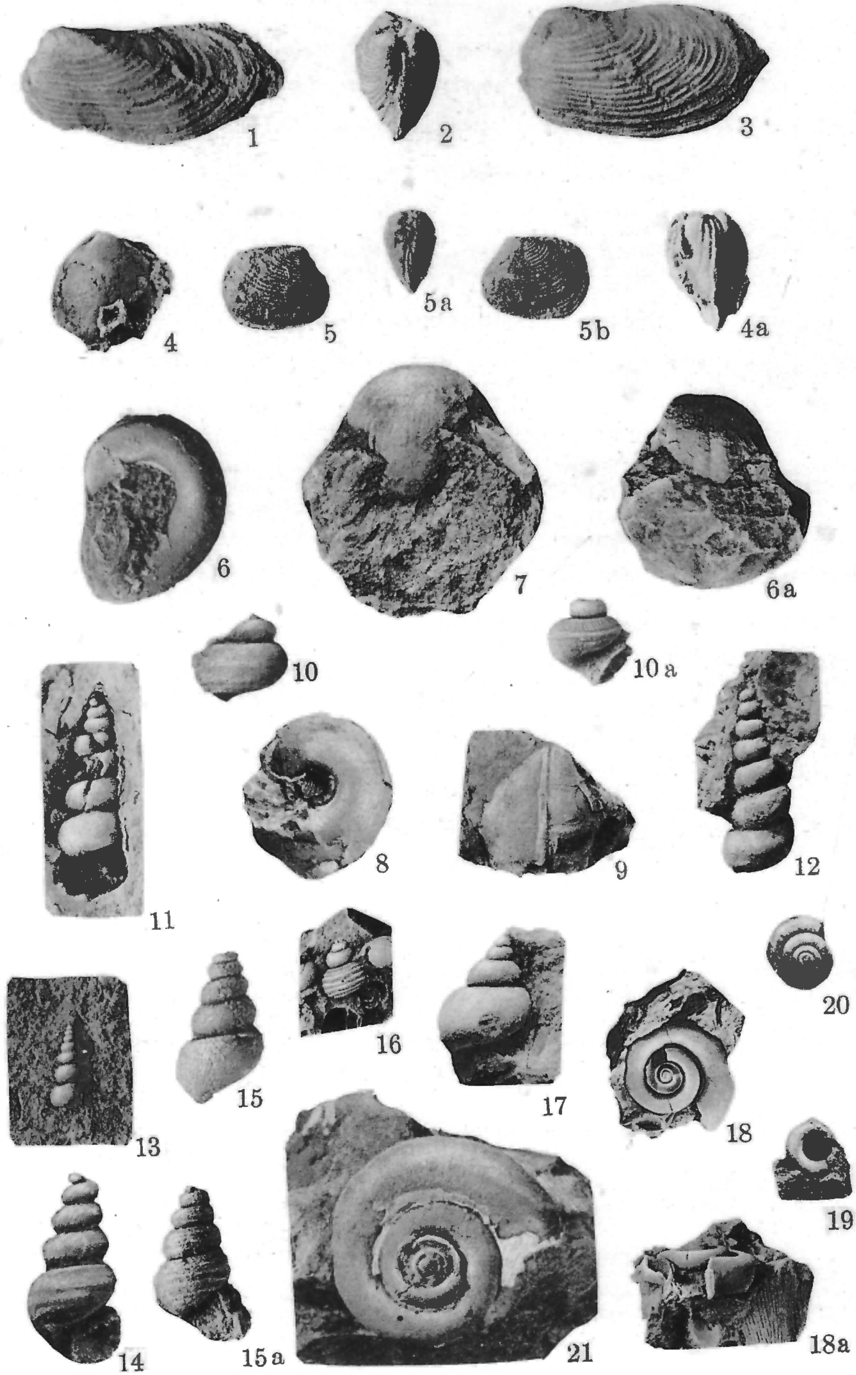

1
2
3
4
5
5a
5b
4a
6
7
6a
10
10a
11
8
9
12
13
15
16
17
18
20
19
14
15a
21
18a

Plate XXXI

Platyschisma ? dubium Dawson. (Page 175.)

Figures 1, 1a, 1b. Apical, lateral, and umbilical views. Nat. Mus. of Canada, Cat. No. 7619a, plesiotype, natural size.
Figure 2. Lateral view. Nat. Mus. of Canada, Cat. No. 7619, plesiotype, natural size.

Cyclonema ? subangulatum Hall. (Page 176.)

Figures 3, 3a. Lateral views. Nat. Mus. of Canada, Cat. No. 7620a, plesiotype, X 2.
Figures 4, 4a. Lateral views. Nat. Mus. of Canada, Cat. No. 7620, plesiotype, X 2.
Figure 5. Peabody Museum, Yale University, Collection 3194.
Figure 6. Peabody Museum, Yale University, Collection 3194.

Holopea cf. *proutana* Hall. (Page 177.)

Figures 7, 7a. Lateral views. Nat. Mus. of Canada, Cat. No. 7625, holotype, X 2.
Figure 8. Nat. Mus. of Canada, Cat. No. 7626, paratype, X 2.

Flemingia dispersa (Dawson). (Page 177.)

Figure 9. Lateral view. Nat. Mus. of Canada, Cat. No. 4370b, plesiotype, X 4.
Figure 10. Lateral view. Nat. Mus. of Canada, Cat. No. 4370, plesiotype, X 4.

Flemingia minuta Bell. (Page 178.)

Figures 11, 11a. Lateral views. Nat. Mus. of Canada, Cat. No. 7681, holotype, X 4.

Naticopsis howi Dawson. (Page 178.)

Figure 12. Nat. Mus. of Canada, Cat. No. 7632, plesiotype, X 2.
Figures 13, 13a. Nat. Mus. of Canada, Cat. No. 7630, plesiotype, natural size.
Figure 14. Large individual, perhaps a distinct species. Peabody Museum, Yale University, Collection 2836, natural size.
Figure 15. Nat. Mus. of Canada, Cat. No. 7631, plesiotype, natural size.

Naticopsis hartti Bell. (Page 179.)

Figure 16. Nat. Mus. of Canada, Cat. No. 7634, holotype, X 2.
Figures 17, 17a. Nat. Mus. of Canada, Cat. No. 7634a, paratype, X 2.
Figure 18. Nat. Mus. of Canada, Cat. No. 7635, paratype, X 2.

Zygopleura cara (Dawson). (Page 179.)

Figure 19. Nat. Mus. of Canada, Cat. No. 7627, plesiotype, X 4.
Figure 20. Nat. Mus. of Canada, Cat. No. 7627a, plesiotype, X 2.
Figure 21. University of Chicago, Cat. No. 6353, holotype, X 2.

Diaphorostoma cf. *carleyana* (Hall). (Page 180.)

Figure 22. Nat. Mus. of Canada, Cat. No. 7676, holotype, natural size.

Bulimorpha maxneri Bell. (Page 179.)

Figure 23. Nat. Mus. of Canada, Cat. No. 7621, holotype, X 2.
Figure 24. Nat. Mus. of Canada, Cat. No. 7629, paratype, X 4.
Figure 25. Nat. Mus. of Canada, Cat. No. 7622, paratype, X 2.

Orthoceras vindobonense Dawson. (Page 181.)

Figures 26, 26a. Nat. Mus. of Canada, Cat. No. 7542, plesiotype, natural size.
Figure 27. Nat. Mus. of Canada, Cat. No. 4372c, plesiotype, natural size.

Plate XXXI

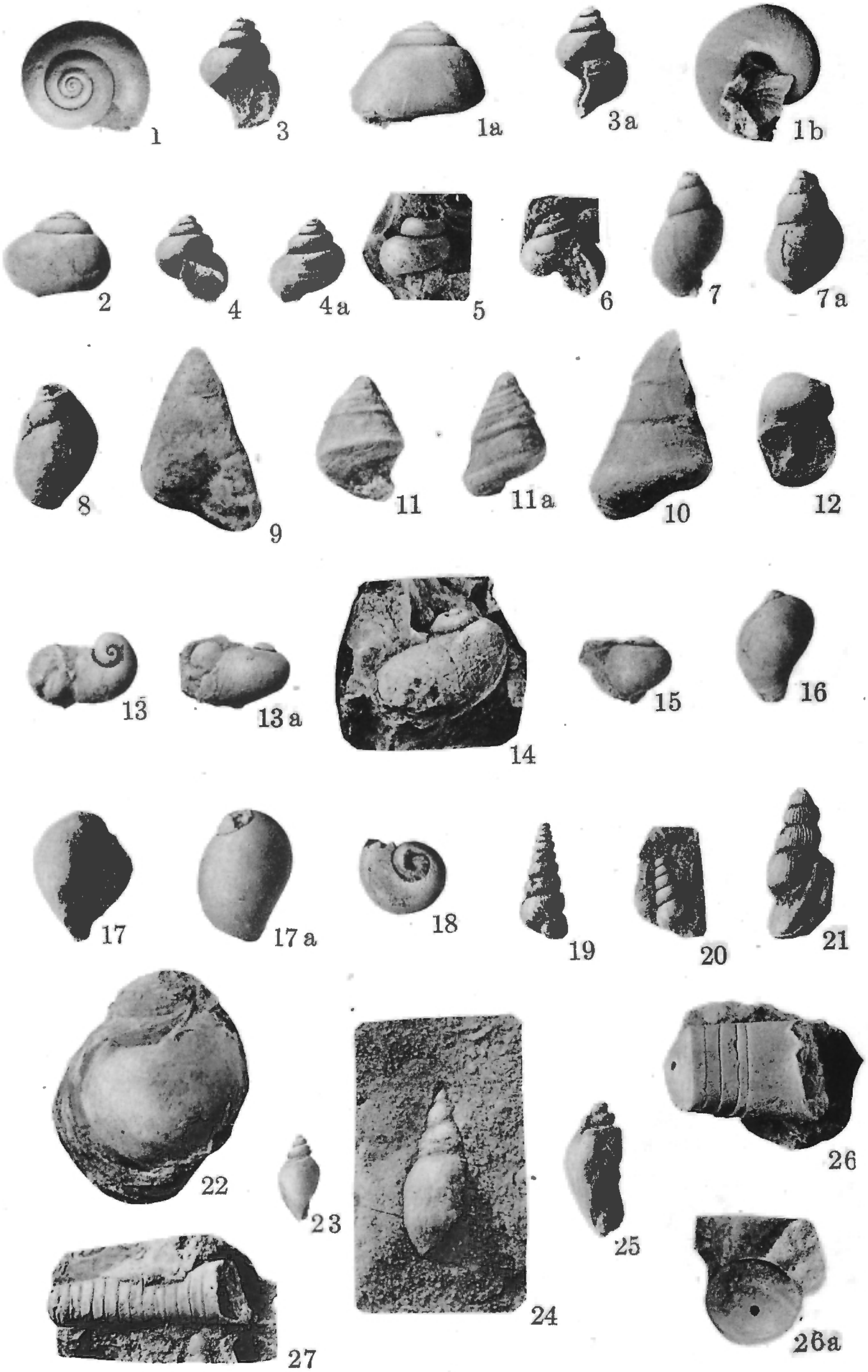

1
3
1a
3a
1b
2
4
4a
5
6
7
7a
8
9
11
11a
10
12
13
13a
14
15
16
17
17a
18
19
20
21
22
23
24
25
26
26a
27

Plate XXXII

Conularia planicostata Dawson. (Page 98.)

Figure 1. Specimen showing overlapping plates. Inner surface. Nat. Mus. of Canada, Cat. No. 7672a, plesiotype, X 4.

Figure 2. Fragment of specimen preserved in the normal manner. Nat. Mus. of Canada, Cat. No. 7672, plesiotype, X 4.

Conularia sorrocula Beede. (Page 100.)

Figure 3. Nat. Mus. of Canada, Cat. No. 7580, plesiotype, X 2.

Figure 3a. Same specimen, X 4.

Conularia cf. *tenuis* Slater. (Page 100.)

Figure 4. Flattened specimen. Nat. Mus. of Canada, Cat. No. 7715, holotype, X 2.

Figure 5. Three individuals radially grouped about a probable centre of attachment. Nat. Mus. of Canada, Cat. No. 7715a, paratype, X 2.

Plate XXXII

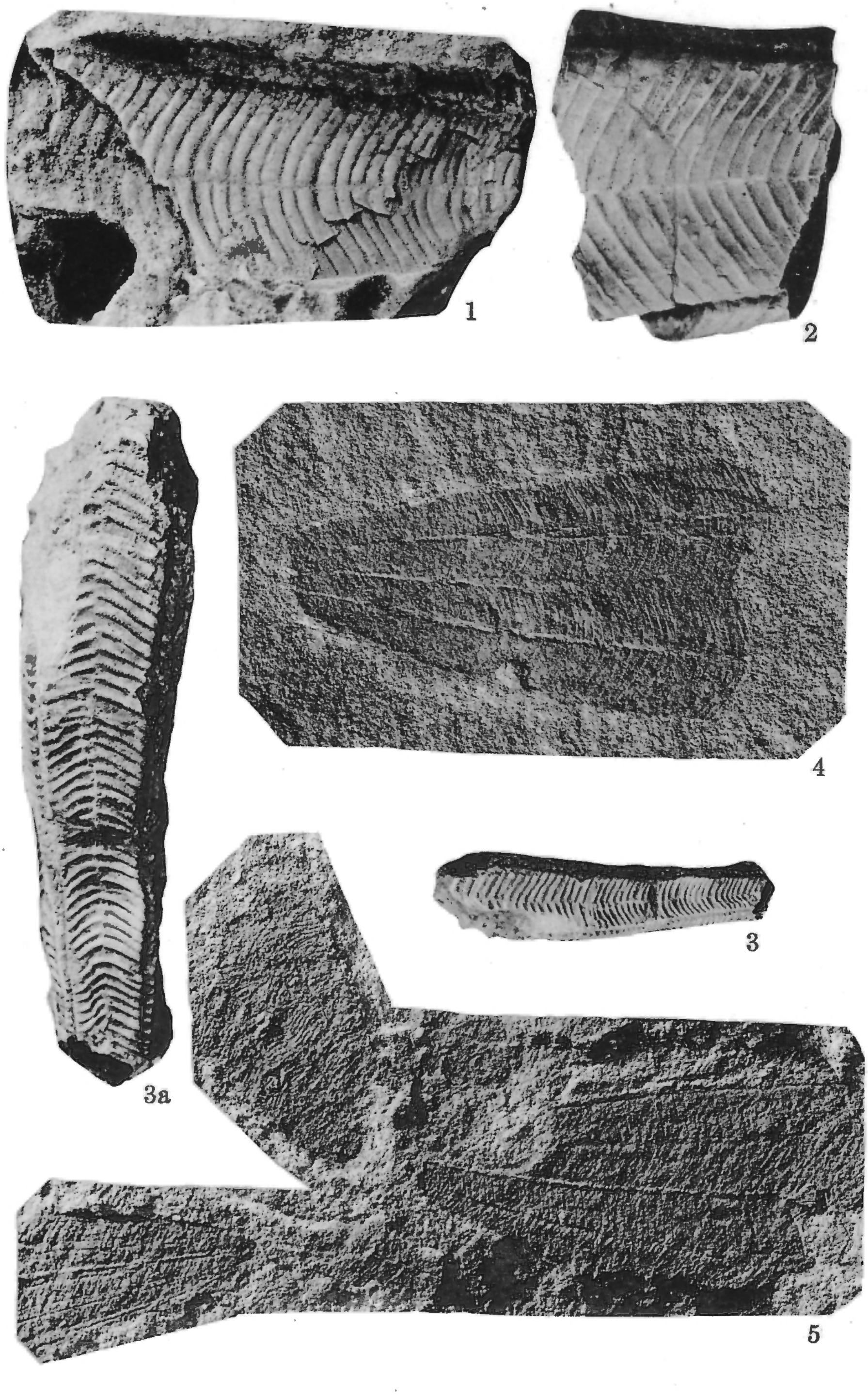


Plate XXXIII

Orthoceras sp. Bell. (Page 181.)

Figure 1. Nat. Mus. of Canada, Cat. No. 7544, holotype, natural size.

Kionoceras laqueatum (Dawson). (Page 182.)

Figure 2. Nat. Mus. of Canada, Cat. No. 7529, plesiotype, natural size.

Stroboceras hartti (Dawson). (Page 182.)

Figures 3, 3a, 3b. Nat. Mus. of Canada, Cat. No. 7549, plesiotype, X 4.

Diodoceras avonensis (Dawson). (Page 183.)

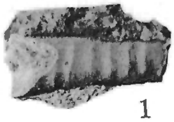
Figure 4. A well-preserved young individual. Nat. Mus. of Canada, Cat. No. 4373a, plesiotype, natural size.

Figure 5. Nat. Mus. of Canada, Cat. No. 7527, plesiotype, natural size.

Figure 6. Nat. Mus. of Canada, Cat. No. 4373, plesiotype, natural size.

Figure 7. Gerontic individual. Peabody Museum, Yale University.

Plate XXXIII



1

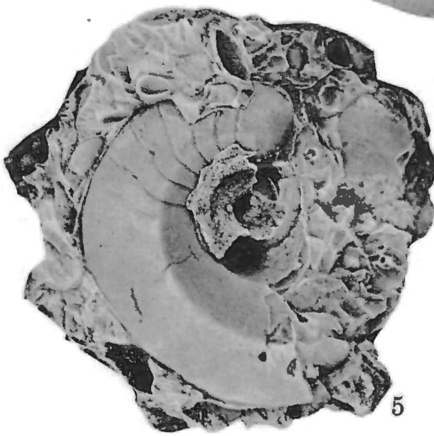
2

3

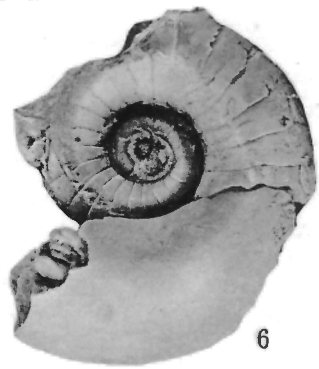
3a

4

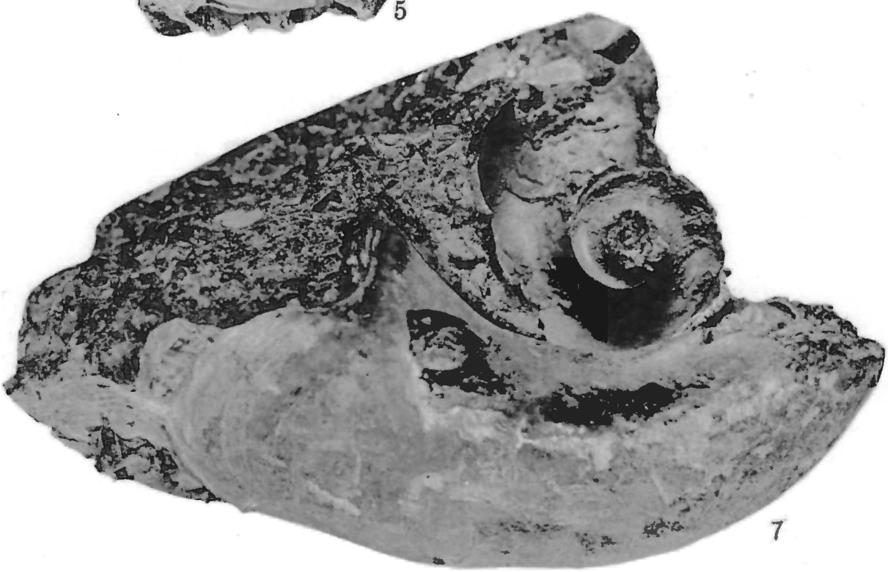
3b



5



6



7

PLATE XXXIV

Stroboceras hartti (Dawson). (Page 182.)

Figure 1. Nat. Mus. of Canada, Cat. No. 4374a, plesiotype, X 2.

Figure 2. Nat. Mus. of Canada, Cat. No. 4374b, plesiotype, X 2.

Poterioceras sp. Bell. (Page 184.)

Figure 3. Nat. Mus. of Canada, Cat. No. 7541, holotype, natural size.

Figure 4. Body chamber. Nat. Mus. of Canada, Cat. No. 7545, paratype, natural size.

Cypridina acadica Bell. (Page 185.)

Figure 5. Left valve, showing muscle spot. Nat. Mus. of Canada, Cat. No. 7742, holotype, X 4.

Figure 5a. Anterior view of same specimen, X 4.

Paraparchites gibbus Bell. (Page 185.)

Figure 6. Right valve. Peabody Museum, Yale University, holotype, X 12.

Figure 6a. Anterior end of same specimen showing overlapping of right valve towards ventral border, X 12.

Figure 6b. Cardinal view of same specimen. Left valve (on left) is higher and receives right valve, X 12.

Plate XXXIV

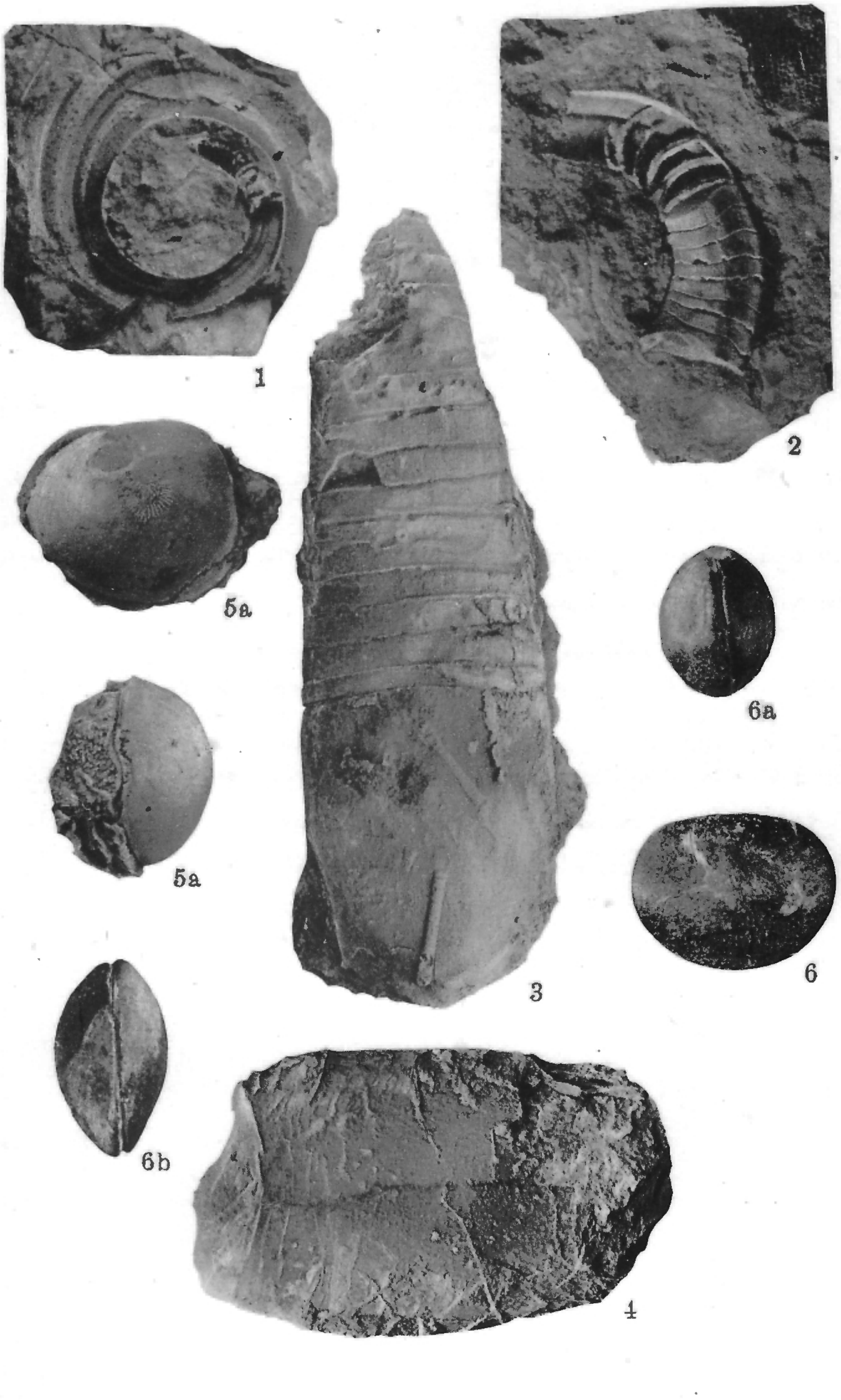


Plate XXXV

Figure 1. Shark's tooth. Nat. Mus. of Canada, Cat. No. 7743, X 2.

Oracanthus sp. Bell. (Page 187.)

Figure 2. View of left lateral face of spine. Nat. Mus. of Canada, Cat. No. 7745, holotype, natural size.

Figure 2a. Part of right lateral face; anterior face to right. Same specimen, X 2.

Figure 2b. Lower end of fragment of figure 2a, showing calcite filling at core. Anterior face at right, natural size.

Figure 2c. Posterior face of fragment of figure 2a, X 2.

Phillipsia eichwaldi Fischer. (Page 186.)

Figure 3. Glabella. Nat. Mus. of Canada, Cat. No. 7677b, plesiotype, X 4.

Figure 4. Pygidium. Nat. Mus. of Canada, Cat. No. 7677a, plesiotype, X 2.

Figure 5. Pygidium. Nat. Mus. of Canada, Cat. No. 4375a, plesiotype, X 2.

Figure 6. Glabella. Nat. Mus. of Canada, Cat. No. 7677, plesiotype, X 4.

Cyclus subcircularis Bell. (Page 187.)

Figure 7. Nat. Mus. of Canada, Cat. No. 7642, holotype, X 2.

Plate XXXV

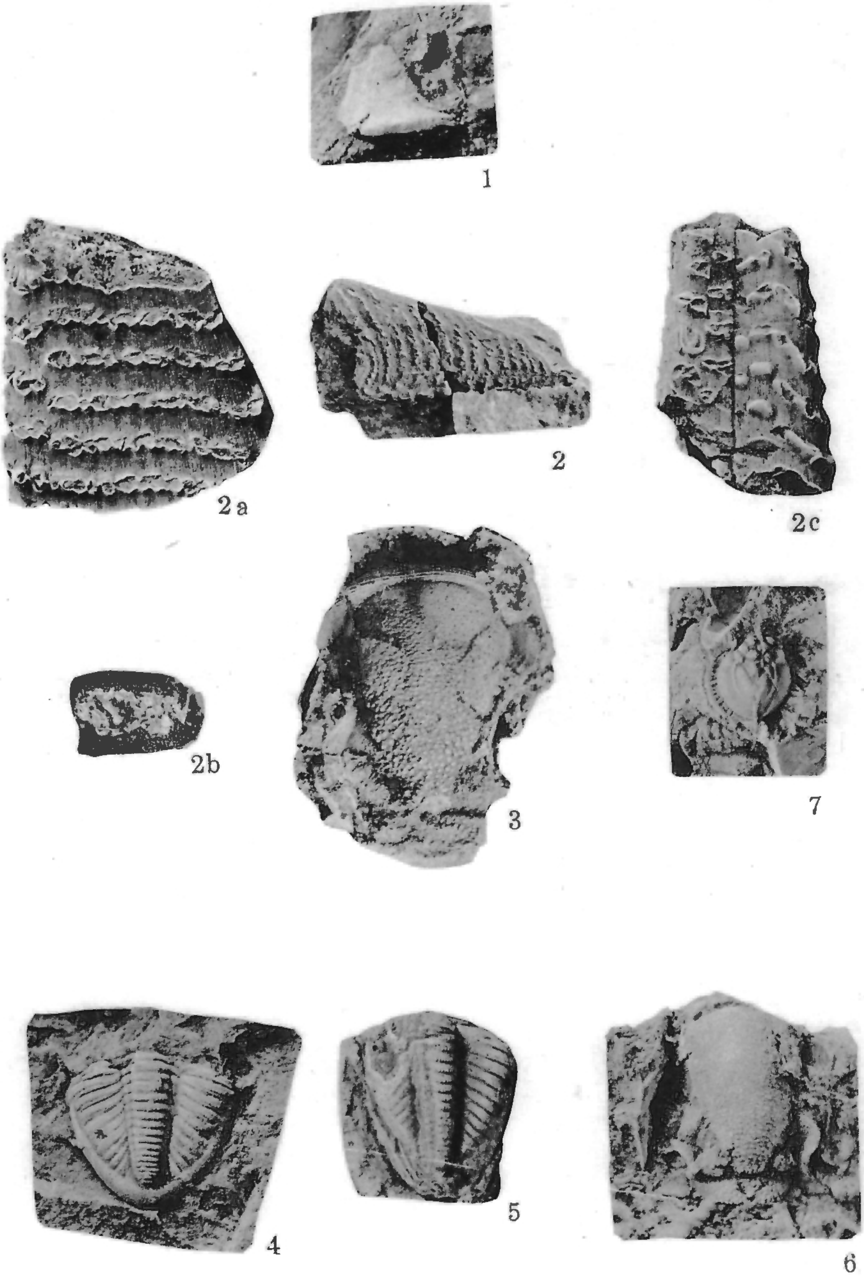
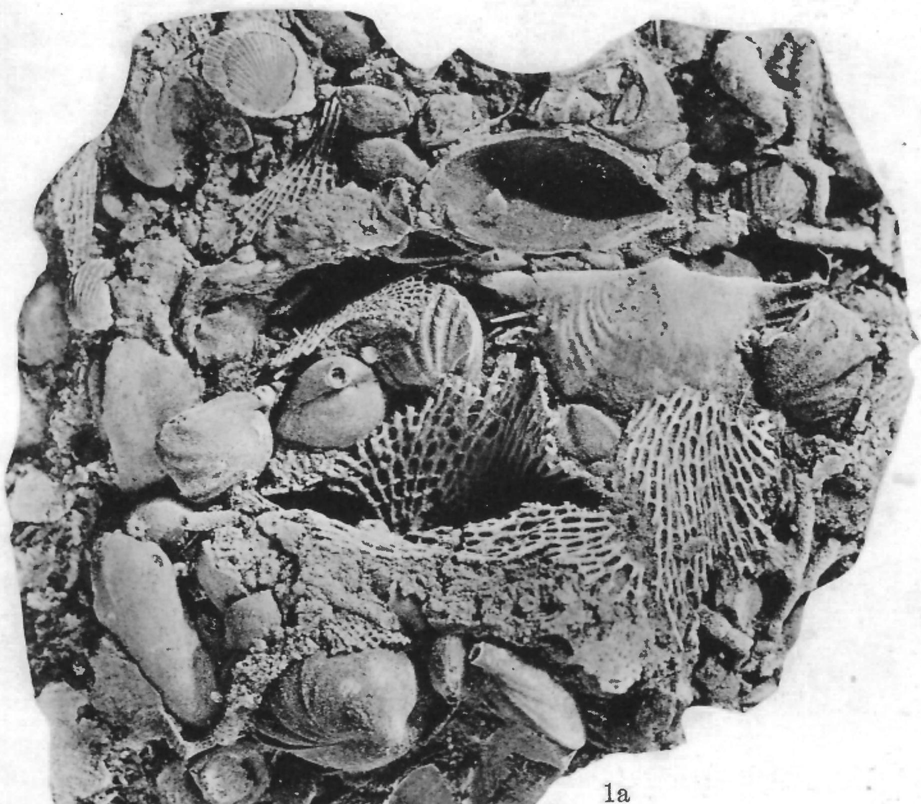


Plate XXXVI

Figure 1. Weathered face of Miller limestone showing exceptional preservation of the fossils. X 2½.

Figure 1a. Reduced diagram to indicate some of the species represented: (a) ***Productus lyelli,*** young individual; (b) ***Serpula annulata;*** (c) ***Batostomella exilis;*** (d) ***Spiriferina verneuili;*** (e) ***Diaphragmus tenuicostiformis;*** (f) ***Dielasma latum;*** (g) ***Pugnax dawsonianus;*** (h) ***Parallelidon hardingi;*** (i) ***Composita windsorensis;*** (j) ***Aviculopecten subquadratus;*** (k) ***Septopora primitiva.***

1



1a

INDEX