CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

BULLETIN 21

AMMONITE FAUNAS OF THE UPPER CRETACEOUS ROCKS OF VANCOUVER ISLAND, BRITISH COLUMBIA

BY

J. L. Usher

EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1952

Price, $1

CONTENTS

Illustrations

PREFACE

The Upper Cretaceous rocks of southeastern Vancouver Island contain important coal deposits, which have been known for more than a century and have long provided British Columbia with a major industry. Gradual depletion of the more accessible reserves has resulted in efforts both by company officials and, from time to time, by Government geologists, to acquire additional structural and stratigraphic information that might serve to prolong the life of these deposits.

The present report by Dr. Usher, based on field studies in 1945 and 1948, is related to the stratigraphy of the coal-bearing area. More specifically, it deals with the invertebrate fossil content of the Nanaimo group of formations as exposed in the Nanaimo and Comox sedimentary, coal-bearing basins. Correlation of the thick series of strata in each basin is based largely on the diagnostic ammonite faunas of the several formations, but also takes into account the depositional and structural history of these basins. The palæontological studies are the most complete yet attempted, and much of the report is devoted to an account of the ammonite faunas and to detailed descriptions of the many ammonite species collected. It is hoped that this information may serve to facilitate further exploratory work for coal, not only on Vancouver Island but elsewhere in western Canada where extensive Upper Cretaceous coal-bearing measures are known to occur.

The report is provided with a sketch-map of the Nanaimo-Comox area, showing the locations from which fossil collections were obtained, and contains many plates illustrative of the ammonite species described.

GEORGE HANSON,
Chief Geologist, Geological Survey of Canada

OTTAWA, June 25, 1951

AMMONITE FAUNAS OF THE UPPER CRETACEOUS ROCKS OF VANCOUVER ISLAND, BRITISH COLUMBIA

INTRODUCTION

LOCATION AND AREA

The ammonites dealt with in this report were collected from a succession of Upper Cretaceous rocks, the Nanaimo group, outcropping along the east coast of Vancouver Island and on adjacent islands in the Strait of Georgia. Vancouver Island is almost entirely mountainous, and is separated from the Coast Mountains of the mainland of British Columbia by part of the Coastal Trough (Bostock, 1948, pp. 88-90)[1], and from the Olympic Mountains of Washington by a narrow trough occupied by Juan de Fuca Strait. The area underlain by the Nanaimo group is a lowland lying along the eastern foot of the mountains of Vancouver Island and is a partly emerged western part of the Georgia Depression, which in turn is part of the Coastal Trough. It forms a discontinuous strip, 2 to 16 miles wide, from Campbell River, Vancouver Island, to Orcas Island, in the state of Washington, a distance of 150 miles. Lesser, separate patches of Upper Cretaceous rocks occur to the west of the main belt, the two largest being in the Alberni area west of Beaufort Range and in the Cowichan Bay-Cowichan Lake Lowland. The strip extends diagonally from the northwest to the southeast corners of a rectangle lying between longitudes 122°30′ and 125°45′ and between latitudes 48°35′ and 50°05′. This area of about 1,500 square miles includes the important Nanaimo and Comox coal basins.

FIELD WORK

Detailed palæontological investigation was begun by the author in the field season of 1945, under the guidance of A. F. Buckham of the Geological Survey, who was at that time studying the geology of the Upper Cretaceous Series in the Comox area. Collections from the rocks in this area were made along the major rivers and on Denman and Hornby Islands. Late in the same season, attention shifted to the Nanaimo district where an incomplete survey of known fossil zones was made. In 1948, work in the Nanaimo district was resumed, and the investigation was extended to the upper formations of the Nanaimo group exposed on the southern islands of the Strait of Georgia. Prior to this, in 1876, extensive collections had been made by Richardson in the Nanaimo coalfield, but exhaustive palæontological examination had not been extended to these islands.

Fossil collecting has been delayed in the Alberni and Cowichan areas pending the completion of more extensive stratigraphic and structural investigations, but with these exceptions, all known fossil localities have, where possible, been visited by the writer, and many new localities established.

[1] Names and/or dates in parentheses are those of references listed in Bibliography at the end of this report.

ACKNOWLEDGMENTS

Thanks are due to Mr. S. J. Nelson for his field assistance during the 1948 season. To Mr. A. F. Buckham a debt of gratitude is owing for his invaluable guidance, collaboration, and technical advice in both field and office. Special thanks are given to Dr. F. H. McLearn and other palæontologists of the Geological Survey of Canada, and to Professor T. H. Clark of McGill University, for their helpful discussion on the problems involved.

Grateful acknowledgment is made to Dr. John B. Reeside, Jr., of the United States National Museum, who aided by supplying plaster casts of some of the type specimens, and to Mr. G. Clifford Carl of the British Columbia Provincial Museum, who loaned some of Whiteaves' original specimens.

Finally, to those inhabitants of the field area, and particularly to Mr. Michael Bond of Hornby Island, goes the author's express gratitude for courteous and generous help.

PREVIOUS WORK

The study of the Upper Cretaceous rocks of the southeast coast of Vancouver Island began nearly a century ago, and a lively interest in them has continued to the present. Probably the most significant single factor on which this interest is based is the association of the extensive coal deposits with these sedimentary formations. Coal has been known on Vancouver Island since 1835, at which time samples were brought from Suquash at the northern end of the island, where some mining was done in 1849 and 1850. Reports of coal at Nanaimo were made in 1849, and in May of the following year J. W. McKay of the Hudson's Bay Company at Victoria prospected the area around Nanaimo and located the coal seam that came to be known as the Douglas seam. Prospecting in the Nanaimo area was accelerated during 1851, and the next year saw the first serious attempt at coal mining there, a mine being opened in August 1852.

It was not, however, until 1857 that the Cretaceous age of these coal-bearing rocks was made known. This discovery, the first evidence of Cretaceous rocks on the western coast of North America, was made by Dr. J. S. Newberry, geologist of Lieutenant Williamson's northern California and Oregon exploratory expedition (Newberry, 1857). Newberry based his conclusion on fossils collected from the rocks at Nanaimo, which were studied and described by F. B. Meek, and although Newberry's report was issued in 1857, it was not until 1864 that Meek's descriptions of the new species from Nanaimo were published (Meek, 1858-1864).

In 1859, B. F. Shumard recorded three additional invertebrate fossils from Nanaimo River. In the same year, D. Lesquereux described five new species of plants from Nanaimo, but ascribed a Miocene age to the rocks in which they were found.

H. Bauermann reported several species of Cretaceous invertebrates from Nanaimo and "Cormuck's or Comoux Island" (Bauermann, 1860, p. 201), stating that the beds from which they were taken underlay the coal-bearing grits. However, he gave the latter a Tertiary dating because they contained no fossils and because they had already been identified as Miocene by Lesquereux.

In 1861, Hector, geologist and physician with Captain J. Palliser's exploratory expedition between Lake Superior and the Pacific Ocean, described the rock outcrops at Nanaimo, and gave a sketch map of the Nanaimo district. In his report he included several small lists of fossils collected at Nanaimo and Comox. Unfortunately, the fossils from the two localities were mixed, but, according to Hector, all of them were unquestionably Cretaceous.

Additional palæontological evidence was accumulated from 1861 to 1864 by Meek, who described new fossils from Vancouver and Sucia Islands (Meek, 1861); by Newberry, who described two new species of plants from Nanaimo (Newberry, 1863); and by Gabb, who added two more new species of invertebrates from Nanaimo in his first volume of the Palæontology of California (Gabb, 1864).

During the years 1863 to 1866, Dr. Robert Brown investigated the geology of parts of Vancouver Island for the local government. His work is embodied in a report "On the Physical Characteristics and Geographic Distribution of the Coal-Fields of Northwest America", published in 1869. In the same year the second volume of the Palæontology of California (Whitney and Gabb) appeared, and in it the Cretaceous coal-bearing rocks of Vancouver Island were for the first time correlated with the Chico group of California.

The first extensive investigation of the Vancouver Island coalfields for the Geological Survey of Canada was conducted by James Richardson during the years 1871 to 1876. Richardson's work formed the basis of later, more detailed, studies of the stratigraphy, structure, and palæontology of the Cretaceous rocks, for he established the basic concept of three separate areas of deposition, the Comox, Nanaimo, and Cowichan basins, and within the first two basins he separated many of the stratigraphic units that later came to be known as formations. His findings are published in the Reports of Progress of the Geological Survey of Canada for the years 1871-72, 1872-73, and 1876-77. The last report is a summary of the stratigraphy and structure of the three basins, and is illustrated with a map and cross-sections on a scale of 1 inch to 4 miles.

In 1875, A. R. C. Selwyn corrected Lesquereux' reiteration that the coal of Nanaimo was of Lower Eocene age (Lesquereux, 1873). He pointed out that at Nanaimo the coal beds were overlain by nearly 4,000 feet of Cretaceous sandstones, shales, and conglomerates. Selwyn was in turn reminded by Gabb (1875) that Gabb and Whitney had drawn attention to this fact 8 years previously.

Between the years 1875 and 1890, G. M. Dawson did much exploratory geological work in British Columbia, including important investigations on Vancouver Island. He published accounts of the mineral wealth of the province (1878 and 1889), and his description of the coalfields of the island in these particular reports includes a fair amount of new data. He spent some time studying the Cretaceous deposits at Suquash and Quatsino Sound on northern Vancouver Island, and a description of these areas was published in 1886.

During this time, while Dawson was carrying on his British Columbia investigations, J. F. Whiteaves, palæontologist to the Canadian Geological Survey, was engaged in important research on the invertebrate fauna of the coal-bearing beds. His publication, Mesozoic Fossils, Part II (Whiteaves, 1879), was the first comprehensive work on the fossil invertebrates of the Vancouver Island Upper Cretaceous beds.

Up to the time that Dawson had begun work on Vancouver Island, and for some time after, no name had been given to the Upper Cretaceous sedimentary succession there. It had been discussed merely as an extension of the California Chico group. However, in 1889, C. A. White applied the name "Vancouver group" (White, 1889, p. 33) to the section. This unhappy choice was quickly rectified by Dawson, who pointed out that the name was preoccupied and suggested in its place the use of the present name, the "Nanaimo group" (Dawson, G. M., 1890, p. 181). Yet even in this article by Dawson there is uncertainty as to whether the unfossiliferous uppermost sandy members of the group were Cretaceous or Eocene.

From 1893 to 1903, Whiteaves published several more palæontological reports dealing with additional collections from the island. Part of this material consisted of new collections made by residents of the island, Rev. G. W. Taylor, Walter Harvey, Dr. C. F. Newcombe, *et al.;* part came from the British Columbia Provincial Museum, and the remainder from the original collections made by Hector. A description of this new material, together with a revision of some of his earlier work, was embodied in 1903 in Part V of Mesozoic Fossils, which was Whiteaves' final report on the fossils from Vancouver Island. Therein Whiteaves mentioned briefly the correlations of the Nanaimo group with the Chico group of California and the Montana formation of the Western Interior, and, in a general way, with the Upper Chalk of England and the European Senonian. The striking resemblance of the fauna to that from the Upper Cretaceous of southern India and from the Japanese island of Saghalien was made apparent by Whiteaves' identifications, and he showed further that the Vancouver Island fauna was almost exclusively marine.

In 1908, C. H. Clapp began an extensive study of the rocks of the east coast of Vancouver Island, a study that included not only the stratigraphy and structure of the coal-bearing strata but also of the pre- and post-Cretaceous rocks. His ultimate goal was to achieve a complete geological picture of the southern and eastern part of the island. The results of his work appeared in part as previews and summaries of field work, which are included in the Summary Reports of the Geological Survey of Canada from 1908 to 1913, and later as full and comprehensive treatises of the areas studied, published as memoirs of the Geological Survey from 1912 to 1917. In addition to this work for the Canadian Government, he made, for a private company on the island, a brief survey of the Nanaimo area as well as a report on the possibilities of coal on some of the southern gulf islands (Clapp, 1913c). In his investigations, he found, as Richardson had before him, that the Cretaceous beds lay in three separate areas, the Cowichan, Nanaimo, and Comox basins. When he first began he was of the opinion that in the Cowichan basin there were "at least two unconformable formations, which cannot be distinguished lithologically, or at present structurally, and are, therefore, grouped together provisionally under the general name of Cowichan group. The larger part of the group doubtless belongs to the Nanaimo formation or series as defined by Richardson, Whiteaves, and Dawson" (Clapp, 1912a, p. 124; *See also* Clapp, 1909, p. 89). The name Cowichan group was, however, later discarded when subsequent studies proved that the sediments in both basins were entirely of the Nanaimo group (Clapp, 1913, p. 94; 1917, p. 219).

A similar change of view occurred in Clapp's early conception that the uppermost members of the Nanaimo group might have been Tertiary, and he stated in his summary report on the Nanaimo map-area that: "As the upper unfossiliferous member (Gabriola sandstones) is very unlike the Eocene sandstones near the city of Vancouver, being much more indurated, it is very doubtful if it is of Eocene age as Dawson suggests it might be. It seems best, therefore, to enlarge the scope of the name Nanaimo so as to embrace the entire conformable series of sedimentary rocks" (Clapp, 1912b, p. 96). The formational names of the Nanaimo group in the Nanaimo map-area are also credited to Clapp; they are recorded first in his summary report of 1911 and again, with more complete descriptions, in his memoir on the Nanaimo map-area (Clapp, 1914). The formations, as set down by Clapp, are equivalent to the subdivisions originally described by Richardson (1873-74) and reproduced by Dawson (1889-90), except that they did not subdivide the lower productive measures into formations, but grouped them into one formation, the Productive Coal Measures or Formation A. Clapp split this formation into six lithologically separable formations. Later, he applied, wherever he could, the formational names at Nanaimo to the corresponding stratigraphic units in the southern part of the Nanaimo basin and, still farther south, in the Cowichan basin. This, of course, was done at the time when he recognized the fact that his Cowichan group was synonymous with the Nanaimo group. He did not, however, extend the formational names north into the Comox basin, but did give names to the two lowest formations in that basin: that which had been called the Productive Coal Measures he named the "Comox formation", and for the succeeding formation, the Lower Shales, he proposed the name "Trent River Shales" (Clapp, 1911, p. 105).

During the 1921 and 1922 field seasons, J. D. MacKenzie, one-time assistant to Clapp on Vancouver Island, assumed the task of studying the stratigraphy of the Comox coal basin and of continuing the work begun by Clapp in the coal areas farther south. Working under a serious physical handicap, having been wounded in World War I, MacKenzie accomplished an amazing amount of work during his short sojourn on the island. He did a detailed survey of the Comox coal basin and completed the mapping of all the southern and eastern part of the Vancouver Island Cretaceous, including the Alberni area. In addition to field work, he published papers on the coal deposits of the Comox and Alberni areas respectively (MacKenzie, 1922a, 1922b) and made a re-estimation of the coal reserves of the southern and eastern parts of the island, including the Alberni area (MacKenzie, 1923). Part of the work on the Comox basin was incorporated in a Ph.D. thesis by T. B. Williams at the University of Wisconsin, in 1924. Dr. Williams had assisted MacKenzie in the Comox area and continued the work there following MacKenzie's untimely death in 1923.

The period 1924 to 1939 witnessed no concentrated geological investigation of the Vancouver Island coalfields, but short reports on coal production and on the general prospects of these fields have been issued in summary reports of the Geological Survey of Canada and the British Columbia Department of Mines.

A detailed study of the problems of the Vancouver Island coalfields was begun in 1939 by A. F. Buckham, under the direction of the Geological Survey of Canada. With the exception of the years 1940-1942 inclusive, Mr. Buckham worked until 1948 on these problems. He has published two brief accounts (1947a, 1947b) of the progress of this work.

STRATIGRAPHY

The Upper Cretaceous rocks of Vancouver Island constitute a thick series of clastic sediments consisting of conglomerates, sandstones, shales, and some coal, of mixed continental and marine origin, that were rapidly accumulated and deposited. Variation in the lithology is marked both vertically and laterally, and few individual beds have a wide lateral extent. The series rests unconformably upon an eroded surface of late Palæozoic to early Mesozoic metamorphosed volcanic and sedimentary rocks and late Jurassic and (or) early Cretaceous acidic intrusions. Some of the formations, particularly the shales, are undoubtedly of marine origin, as shown by the fossil content; other formations suggest that deposition occurred near shore or in the littoral zone; and still others may be of continental origin, as evidenced by abundant mud-cracked surfaces, mud flakes, and the presence of land plants and thick accumulations of coal. Buckham (1947a) has described the physiographic conditions under which the Nanaimo group was deposited: a range of mountains formed the axis of the island, a depression existed where the Strait of Georgia now is, and between the two was a low, rolling plain. It was on this coastal plain that the Upper Cretaceous sediments were laid down. A prominent ridge of pre-Cretaceous rocks divided the coastal belt at Nanoose Bay into what were, apparently, two major areas of deposition, and the unity of these was in turn broken by additional hills and spurs of older rocks. The two major areas are referred to in this report as the Nanaimo basin, encompassing that area of Upper Cretaceous rocks south of Nanoose Bay, and the Comox basin, between Nanoose Bay and Campbell River. A separate set of names has been applied to each of the successions of Upper Cretaceous rocks in the two basins, but it is not to be inferred from this expedient division that the two basins and the two groups of formations are completely exclusive; the similarities in the faunal and lithological successions are close, and the two basins, during times of maximum marine flooding, must have been co-extensive. However, they do present contrasts, and the two sections have been given distinctive nomenclatures because of: (1) lack in the Comox basin of formations equivalent to some of the lowest in the Nanaimo basin; (2) differences in the coal horizons in the two areas; (3) distinctions between the respective faunas; and (4) difficulties encountered in trying to apply formational names over a considerable distance to stratigraphic units that show pronounced later variation in lithology. Earlier geologists were the first to realize that two distinct but related groups of formations existed, and the perpetuation of their ideas has not been improvident. The following table lists and correlates the formations in the two basins:

TABLE OF UPPER CRETACEOUS FORMATIONS OF NANAIMO GROUP

Age	Nanaimo basin			Comox basin		
	Formation	Thickness in feet	Lithology	Formation	Thickness in feet	Lithology
Maestrichtian	Gabriola	2,000–3,000	Sandstone	Hornby	600–800	Sandstone, conglomerate
	Northumberland	2,000–2,700	Shale	Spray	800–830	Shale, sandstone
			Sandstone	Geoffrey	1,100–1,300	Conglomerate
			Shale	Lambert	800	Shale
Campanian	De Courcy	800–1,000	Sandstone	Denman	900–1,000	Sandstone, conglomerate
	Cedar District	700–1,000	Shale	Trent River	1,000	Shale
	Protection	650	Sandstone	Comox	600	Sandstone, coal deposits
	Newcastle	215–400	Sandstone, shale; Newcastle and Douglas coal seams	Qualicum	(?) 1,800	Shale, sandstone
	Cranberry	200–600	Sandstone, conglomerate	—?—?—?	—?—?—?	—?—?—?—?—
Lower Campanian or (?) Santonian	Extension	600–800	Conglomerate, sandstone			
	East Wellington member	35	Sandstone; Wellington coal seam			
	Haslam	600–1,500	Shale			
	Benson	100	Conglomerate			

In the southeastern part of the Nanaimo basin the Nanaimo group has a thickness of more than 10,000 feet. Farther north in the same basin it measures about 7,500 feet. Throughout this distance, all of the formations are represented, and it might be drawn from this that the basin was deepest in the southeast. In the Comox basin the rocks have a thickness of between 5,000 and 6,000 feet, but here some of the lower units are lacking. Buckham (1947a) has pointed out, for instance, that from Qualicum River north to Campbell River, rocks equivalent to the six lowest formations in the Nanaimo basin, representing a total thickness of 2,000 feet, are missing, and that from Qualicum River south to Nanoose Bay, rocks equivalent to the four lowest formations in the Nanaimo basin are missing. The progressive decrease, from south to north, in the thickness of the series, and the non-deposition of the earliest strata in the north suggest a progressive overlap of the Upper Cretaceous sea in such a way that as deposition continued the north shore of the sea migrated from south to north along the Georgia Depression.

THE NANAIMO BASIN

The Nanaimo basin occupies the southeast corner of Vancouver Island and extends southeast from Nanoose Bay to the International Boundary and south into United States waters for another 10 miles to include the islands of Sucia, Patos, Maria, Waldron, Spiedon, Stuart, and John. It is limited on the east by the Strait of Georgia and on the west by crystalline rocks of the eastern slopes of the Vancouver Island Ranges and by the southwest side of Cowichan Lake and Cowichan River Valley, which together comprise the Cowichan Lowland. The basin has a maximum length of 75 miles and a maximum width of 30 miles. Its area includes all of the Upper Cretaceous rocks on Vancouver Island south of Nanoose Bay, as well as a large salient of pre-Cretaceous rocks separating the Cowichan Lowland from the remainder of the basin.

Systematic collecting of fossils has never been done in the Cowichan Lowland; consequently, this report discusses the Nanaimo group and its fauna to the exclusion of that area.

The Nanaimo group in the Nanaimo basin is an alternating succession of conglomerates, sandstones, shales, and coal seams, with a total thickness varying between 7,500 feet in the north part of the basin and 10,000 feet in the south. The group is divided into eleven formations, more or less well defined lithologically, of which the lower formations are confined mostly to Vancouver Island whereas the upper ones are found chiefly on the islands bordering the coast from Gabriola Island south to Sucia Island. Outcrops of the two youngest formations are restricted entirely to the island chains.

Whereas each formation is generally well defined lithologically, most of them consist of several kinds of rock types. Commonly the lithology changes rapidly, and the group, as a whole, is a thick pile of interfingering and overlapping lenses. Accumulation and deposition of these sediments was obviously rapid; fluctuations in the relative supply of sediment and capacity of the shallow basin resulted in alternate neritic, littoral, and paralic conditions. In general, the Nanaimo group is arenaceous, even the thick shale formations containing much sandy and silty material. Marine invertebrate fossils are restricted mostly to the shales, but occur as well in some of the fine-grained sandstones. Fossil plants and other indications of plant life are most plentiful in those beds associated with the coal seams, but have been reported from nearly every formation in the group.

Folding and faulting along northwest-southeast lines has given the sedimentary strata a prevailing northeast dip. Broad open folds and small minor folds are typical of the northern part of the basin, whereas farther south folding has been more intense and the strata commonly stand on edge or are overturned to the southwest. Along the entire length of the basin, faults have cut the measures into innumerable slices and have made it difficult, and in places impossible, to determine stratigraphic horizons.

The fauna, which is found principally in three formations of marine shales, the Haslam, Cedar District, and Northumberland formations, is characteristic of Upper Cretaceous time and, more specifically, indicates that the rocks are of Campanian and Maestrichtian age.

Benson Formation

The Benson conglomerate is the lowest stratigraphic unit of the Nanaimo group. Its distribution is apparently limited, and exposures of the formation occur in only a few places such as Haslam Creek canyon, Nanaimo River upstream from the mouth of Elkhorn Creek, and west of the headwaters of Brannan Creek. Generally, where the contact with the pre-Cretaceous crystalline rocks can be seen, the Haslam shales, which succeed the Benson, rest directly on the pre-Cretaceous rocks. The best exposure of the Benson is in Haslam Creek canyon, where its thickness "varies from nothing to about 400 feet, and averages about 100 feet" (Clapp, 1914a, p. 53). The lithology is fairly uniform, beds being composed of subangular to rounded pebbles, cobbles, and boulders of the pre-Cretaceous volcanic rocks thoroughly cemented in a greenish matrix of volcanic detritus. The contact with the underlying crystalline rocks is an angular unconformity. Where it is exposed in Haslam Creek, the formation grades up into the Haslam formation. Clapp describes the contact thus: ". . . . . the conglomerate is interbedded with arkose-sandstones which grade upward into interbedded arkosic and shaly sandstones characteristic of the base of the overlying Haslam formation" (op. cit.). No fossils have been found in the Benson conglomerate.

Haslam Formation

The Haslam formation is a thick series of shales, sandy shales, and sandstones lying atop the Benson conglomerate, or, in the absence of the latter, resting directly on the underlying pre-Cretaceous rocks. The formation outcrops in an irregular belt, $\frac{1}{8}$ mile to 3 miles wide, along the southwest margin of the Nanaimo basin, extending from the northern limit of the basin to Ladysmith and thence to Crofton. Presumably it underlies the sea from Crofton to Saltspring Island, and on the latter it is faulted against pre-Cretaceous rocks along a northwest-southeast course across the centre of the island. The formation is reported to be extensive in the Cowichan Lowland, but mapping in that area is incomplete. Most of the area that the formation underlies is covered by drift; consequently, exposures of the Haslam are confined almost entirely to stream channels, and, in the southern part of the basin, to the seashore. Haslam Creek, Chemainus River, Nanaimo River, and Elkhorn Creek afford the best exposures, the first two occupying gorges 100 to 300 feet deep cut into the formation.

In the northern part of the basin, the Haslam formation is composed largely of shales and averages about 600 feet thick. Farther south, the thickness is greater; on Chemainus River, over 1,500 feet of Haslam sediments have been measured, more than 600 feet of which are sandstones. The numerous faults and folds that have disturbed the formation will not permit more than an approximation of its true thickness.

The formation for the most part is composed of thin-bedded, commonly banded, light to dark grey or bluish grey, arenaceous shale and greyish black carbonaceous shale. These beds grade laterally and vertically into fine-grained argillaceous and siliceous sandstones. Calcareous cement is common throughout most of the formation. Most of the beds weather a brownish grey, but, occasionally, carbonaceous beds bearing finely disseminated pyrite weather rusty yellow. It is typical of the argillaceous beds to weather spheroidally. Lenticular concretions up to 6 feet long and 18 inches thick, and irregularly shaped concretions up to 6 inches in diameter occur throughout the formation but most typically in the argillaceous parts. They are fine-grained, arenaceous, and bluish grey, with calcareous cement, and weather a buffish colour; many of the small ones contain fossils.

In the lower and lower middle parts of the Haslam formation, thin beds of fine-grained, commonly calcareous, siliceous sandstones are interbedded with typical sandy shales. Toward the base of the formation, the sandstones become thicker bedded and more coarsely grained, grading into arkosic sandstones with interbedded shales. "The arkoses either show rather abrupt transition into the Benson basal conglomerate or lie directly upon the underlying crystalline rocks" (Clapp, 1914a, p. 54). Occasionally these coarser beds contain coal fragments and, rarely, thin beds of pebble-conglomerate.

Near the top of the Haslam, sandstone beds are more numerous, thicker, and usually darker and more flaggy than in other parts of the formation. In the area around Nanaimo, these beds grade upward into a zone of sandstone, 35 feet thick, known as the East Wellington sandstone, on top of which lies the Wellington coal seam. Clapp, in his work on the southern part of the basin, was not able to separate the East Wellington member from the Haslam; it is probably represented by the arenaceous beds that grade upward from the top of the Haslam into the overlying Extension formation.

Near Departure Bay, the Haslam formation differs markedly in lithology from elsewhere. Here it rests directly and disconformably on the pre-Cretaceous meta-andesites, and is composed of yellowish green to greyish green, coarse-grained, commonly pebbly, calcareous sandstone, the grains of which are weathered meta-andesite. This rock contains a high percentage of shell fragments, and Clapp referred to it as a sandy calcarenite.

With the exception of the uppermost and lowermost, coarser grained, more arenaceous parts, marine invertebrates are found throughout the Haslam formation, but are most abundant in the lower two-thirds. Most of the fossils occur singly in small, rounded concretions, which are scattered irregularly through the shales, but on Brannan Creek small concretions less than 6 inches in diameter may carry as many as a dozen specimens of *Inoceramus* cf. *schmidti* Michael emend. Sokolow as well as several specimens of smaller pelecypod and gastropod genera. Ammonites are either partly or completely encased in concretions. Occasionally, as at one zone on Brannan Creek and another on Elkhorn Creek, shaly sandstone beds are filled with poorly preserved fragments of small pelecypods and gastropods, and the argillaceous beds commonly show indistinct impressions of larger pelecypods and ammonites.

Eleven species of ammonites have been found in the Haslam formation: *Bostrychoceras elongatum* (Whiteaves), *Epigoniceras epigonum* (Kossmat), *Hauericeras gardeni* (Baily), *Baculites chicoensis* Trask, *Diplomoceras? subcompressum* (Forbes), *Pachydiscus newberryanus* (Meek), *P. buckham* n.sp., *P. haradai* (Jimbo), *P.* cf. *haradai* (Jimbo), *P. elkhornensis* n.sp., and *Pseudo-*

schloenbachia brannani n.sp. Of these, the last four are unknown above the Haslam formation. Specimens of *Pachydiscus newberryanus* in the Haslam shales, such as those collected from Brannan Creek, are commonly small, whereas those in the younger Cedar District formation are large, though not as numerous. The other *Pachydiscus* species are almost entirely from Nanaimo River and its tributaries. Elsewhere in the Nanaimo group, *Bostrychoceras elongatum*, *Epigoniceras epigonum*, and *Hauericeras gardeni* are found in the succeeding Trent River formation of the Comox basin but not in the stratigraphically equivalent Cedar District shales of the Nanaimo basin. The implications of this discrepancy are considered later in the report.

An immature specimen of cf. *Baculites chicoensis* Trask was recovered from the Haslam shales on Brannan Creek, but there is no further evidence of this genus in the formation.

Inoceramus cf. *schmidti* is found abundantly on Brannan Creek and from the upper part of the formation between Nanoose Bay and Blunden Point, and *I.* ex gr. *subundatus* Meek is common in most other parts of the formation. Additional pelecypods recorded from the Haslam shales include *Anatina quadrata* Gabb, *Anomia vancouverensis* Gabb, *Cyprimeria lens* Whiteaves, *Exogyra parasitica* Gabb, *Lima suciaensis* Whiteaves, *Martesia parvula* Whiteaves, *Meleagrina antiqua* Gabb, *Nucula (Acila) truncata* Gabb, *Nemodon vancouverensis* Meek, *Thracia occidentalis* Whiteaves, *T. subquadrata* Meek, and *Trigonia evansana* Meek.

Anisomyon vancouverensis (Whiteaves), *A. tenuiscostatus* (Whiteaves), *Cylichna costata* Gabb, *Depranochilus costata* (White), and *Oligoptyche obliqua* (Gabb) have also been reported from this formation.

East Wellington Sandstone Member. In the Nanaimo district, the uppermost flaggy, arenaceous beds of the Haslam formation grade upward into a zone of sandstone called the East Wellington sandstone. This zone, which is from 25 to 50 feet thick, with an average thickness of 35 feet, forms the firm floor of the Wellington coal seam, the lowest productive coal seam in the Nanaimo area. The rock is composed almost entirely of thin-bedded, fine- to medium-grained, greenish grey sandstone, weathering yellowish to greyish brown. Sandy shale, coarse-grained sandstone, and thin lenses of pebble-conglomerate are rare. Clapp reports that the chief constituents of these arenaceous beds are "angular quartz grains, with some feldspar and light and dark mica in a brownish green matrix composed of calcite, chlorite, and serpentine, with an abundant calcareous cement" (1914a, p. 56).

In the southern part of the Nanaimo basin, where the Wellington coal seam is missing, it has not been possible to distinguish the East Wellington beds from the top of the Haslam formation, and the latter is directly overlain by the Extension conglomerate.

No fauna has been discovered in the East Wellington sandstone.

Extension Formation

The Extension conglomerate and sandstone formation outcrops along a belt extending, with interruptions by the sea, from the north end of the Nanaimo basin to Ganges on the east shore of Saltspring Island.

From Ladysmith to Chemainus, the formation is, presumably, submarine. It appears again at Chemainus to outcrop along the coast within a mile of Crofton. From there to the west side of Saltspring Island it, again presumably, is covered by the waters of Stuart Channel. In the southern half of the basin, steep dips narrow the outcrop width of the formation to 1,000 or 2,000 feet. In the north, the formation forms a band more than a mile wide, and in places, where folding and faulting have caused the beds to be repeated, as much as 2 and 3 miles wide. The thickness of the Extension formation varies between 500 and 1,000 feet, but averages between 600 and 800 feet.

The formation is typically a pebble-conglomerate, but the lithology varies extremely, both laterally and vertically, from a coarse boulder-conglomerate to a crossbedded sandy shale. Crossbedding and soft-rock deformation[1] are common structures throughout almost all of the formation. The conglomerate is normally composed of subangular to rounded pebbles of quartz, chert, slaty rocks, granite-like rocks, porphyries, and trap, embedded in a medium- to coarse-grained, greenish tinged matrix of angular quartz and feldspar fragments, and fine-grained chlorite and biotite; the whole is cemented with secondary quartz and calcite. A noteworthy difference in the composition and constitution of the formation exists between the two extremities of the basin. In the north, the conglomerate, which is there composed almost entirely of quartz, chert, and slaty fragments, with few particles of granite-like or trap rocks, is more typical of the upper half of the formation; the lower half is almost entirely sandstone, granular sandstone, and shale. Some of the shale beds are thick and have associated with them thin coal seams and coaly lenses. In the southern half of the basin, the conglomerates, which are there coarser and have a higher percentage of granitic and trap pebbles and cobbles, are more typical of the lower part of the formation, whereas the upper part includes thick beds of coarse-grained sandstone, shaly sandstone, and sandy shale.

Throughout the area where the Wellington coal seam is mined, the Extension formation forms the roof of the seam. At different heights above the base of the formation are thin coal seams, 1 foot to 3 feet thick. In the extreme northern part of the basin, the Little Wellington seam lies 30 to 75 feet above the base of the formation; farther south, discontinuous seams occur at distances up to 250 feet above the base, but their areal extent is virtually unknown.

With the exception of comminuted plant fragments associated with some of the shaly and coaly lenses and coal seams, no fossils have been reported from the Extension formation.

Cranberry Formation

In the northern half of the Nanaimo basin, the Cranberry formation is a series of thin-bedded, flaggy sandstones, interbedded sandy shales, and fine pebble-conglomerates, outcropping along a narrow belt, ½ to 1 mile wide, from Newcastle Island to Ladysmith. In this area the base of the formation is at the top of the last 25-foot bed of Extension conglomerate. Above this horizon, conglomerate beds of the Cranberry formation

[1] The expression 'soft-rock deformation' is used in this report to denote deformation that occurred prior to consolidation of the sediments.

do occur, but they are more thinly bedded, finer grained, and sandier than those of the Extension. The top of the Cranberry lies at the base of the Newcastle coal seam. In the southern half of the Nanaimo basin, where the Newcastle seam is missing, it is not possible to distinguish the Cranberry from the overlying Newcastle formation. It is in this area that Clapp referred to these combined units as ". . . . a single formation . . . . . the Ganges formation . . . . ." (1917, p. 229).

Exposures of the two formations in this southern area are confined almost entirely to the low valley that crosses Saltspring Island from Booth Bay on the west coast to Ganges Harbour on the east coast. The combined thickness here is about 750 feet, whereas in the northern end of the basin the Cranberry formation varies from 200 to 600 feet, with an average thickness of 500 feet, and the Newcastle formation from 125 to 400 feet, with an average thickness of 175 feet.

The Cranberry formation is, in the north, typically composed of dark greyish green, spheroidal weathering, thin-bedded, fine- to coarse-grained, flaggy and shaly sandstones, which have in places scatterings of fine pebbles or very coarse sand grains. Trap, chert, and slate grains are the chief constituents and lend the greenish hue to the beds. Sandy shale beds occur throughout, and many of the more argillaceous beds are also carbonaceous, with fragments of plant remains. Fine pebble-conglomerate beds up to 20 feet thick occur in the lower parts of the formation, and most of these and the coarse sandstone strata are crossbedded.

On Saltspring Island, the strata of the Cranberry-Newcastle formations are alternating fine-grained, green to greyish green, brown weathering, carbonaceous and calcareous sandstones and very fine-grained, bluish grey, calcareous shale. All gradations from shale through siltstone to fine sandstones are represented. The sandstone beds are thin, and commonly banded, and many of them show soft-rock deformation features. Rarely, they may be as much as 7 feet thick. Thick zones of laminated shales, uninterrupted by beds of sandstone, may carry numerous, rounded, calcareous concretions and concretionary lenses similar to those in the Haslam formation. They do not, however, contain invertebrate fossils; nor have coal seams or plant fossils been found in these beds. In the north, plant remains are not uncommon in the Cranberry formation, but invertebrate fossils are unknown.

Newcastle Formation

The Newcastle formation, which contains the Douglas and Newcastle coal seams, lies between the Cranberry and Protection formations. As previously noted, it is distinctly separable from the underlying Cranberry formation in only the northern half of the Nanaimo basin, whereas in the southern half the two have been referred to in this report as the Cranberry-Newcastle, the equivalent of Clapp's Ganges formation.

The Newcastle can be traced along a strip ½ mile wide, from Newcastle Island to Ladysmith. Its upper contact with the Protection formation is well marked, and its lower contact is the base of the Newcastle coal seam. On Newcastle Island the formation measures only 125 feet thick, but farther south it may reach a maximum thickness of 400 feet; for the most part it averages about 175 feet thick.

The lithology varies extremely, both vertically and laterally. The most typical and abundant rock is an "olive green, brownish weathering, and in a few places, cross-bedded, grit" (Clapp, 1914a, p. 61), the fragments of which are granules of volcanic rocks, chert, and slate embedded in a greenish, sandy matrix of angular quartz, feldspar, and volcanic debris. Thin beds of fine pebble-conglomerate and medium- to fine-grained sandstones occur in the 'grit'. On Newcastle Island and south along Nanaimo River, the 'gritty' beds give way to fine- and medium-grained, spheroidal weathering, dark greyish green, shaly and silty sandstone and arenaceous shales showing crossbedding and wave ripple-mark structures. Coarse granule layers and lenses occur within the shalier parts. Many of the arenaceous beds contain small, angular, shale fragments; carbonaceous layers, coaly partings, and numerous plant remains occur in the argillaceous beds. The Newcastle coal seam, which varies in thickness from 20 inches to 8 feet, is succeeded, above a barren interval of about 60 feet, by the Douglas seam, which in turn varies in thickness from nil to 30 feet.

From the roof of the Douglas seam in Number One mine at Nanaimo, marine pelecypods and gastropods have been extracted. Whiteaves was able to identify the following forms from this horizon: *Asaphis multicostata* Gabb, *Crassatella tuscana* Whiteaves, *Glycymeris veatchi* Gabb, *Lithophaga nitidus* (Whiteaves), *Nucula hornbyensis* Whiteaves, *N. (Acila) truncata*, *Pholadomya subelongata* Meek, *Yoldia diminutiva* Whiteaves, *Cerethium harveyi* Whiteaves, *Cylichna costata*, *Lunatia shumardiana* Gabb, *Potamides tenuis* Gabb, and *Trochacteon semicostatus* Whiteaves. Other than these, no invertebrate fossils have been reported from the Newcastle formation, although rocks equivalent in age in the Comox basin carry a small fauna of ammonites and pelecypods.

Protection Formation

Lying conformably above the Newcastle formation is a uniform thickness of generally massive sandstones, the Protection formation. It outcrops along a belt ¼ mile to 1½ miles wide from Newcastle Island to Ladysmith, thence southeastward, presumably beneath the waters of Stuart Channel, to be exposed on several small islands bordering the coast between Chemainus and Crofton. Farther south, it forms a narrow strip less than ¼ mile wide across Saltspring Island, where it borders the north shore of Booth Bay and Ganges Harbour. For the most part the sandstones are well exposed. The lower contact is well defined where the thick-bedded white sandstones of the Protection overlie the dark, sandy shales and shaly sandstones of the Newcastle formation. The upper contact is not generally so distinct, and where exposed represents a transition upward into the sandy and silty shales of the overlying Cedar District formation. On the whole, the Protection formation is an easily recognizable unit and is considered by Clapp to be ". . . . . the best horizon marker in the Nanaimo series" (1914a, p. 62). In addition, it is the most uniform in thickness of any of the formations in the Nanaimo group, ranging between 600 and 750 feet, and averaging 650 feet.

The sandstones are white to greyish white, fine- to medium-grained, generally thick-bedded rocks that on a fresh surface look exceedingly like a fine- to medium-grained granite. This appearance becomes explicable in view of the composition of the sandstone, which consists of subangular to angular quartz, white feldspar, and black and white mica flakes; minute grains of argillaceous and, rarely, carbonaceous material were observed as well. The cement is secondary quartz, but the rock is not firmly indurated, and following exposure becomes soft and friable, with thin shaly partings. The sandstone weathers buff to brownish, or in places greyish yellow. Shaly beds, and thin, flaggy, shaly sandstone layers are common in parts of the formation, particularly at the lower and toward the upper contacts. In the lower part of the formation, plant remains are commonly well preserved in these beds and have provided an excellent fossil flora. Plant impressions, coal lenses, and carbonaceous layers occur as well in the more purely arenaceous beds, and coal seams up to 9 inches thick are known in the lower part of the formation. These occur in the same zone as the productive measures of the Comox basin, but do not occupy stratigraphic positions corresponding to the seams of the Comox formation.

About midway of the Protection formation, many of the thick sandstone beds are coarse grained, and contain lenses of granules, pebbles, and even fine- to medium-grained cobble-conglomerate. Crossbedding, ripple-marks, and shale breccias in coarse sandstone matrices occur in many parts of the formation, but are more common in the lower and middle parts.

On Protection Island, flaggy, calcareous sandstone carries external moulds and casts of *Inoceramus* sp., but other than plant remains the formation is almost entirely barren of fossils.

Cedar District Formation

Lying conformably above the Protection sandstones is a series of thin-bedded, sandy shales that comprise the Cedar District formation. It underlies, but is poorly exposed in, a wide, valley-like depression stretching from the mouth of Nanaimo River to Ladysmith Harbour, and is exposed farther east on the flanks of an anticline that brings the formation to the surface immediately south of Dodd Narrows. Here the formation outcrops both on the shore of Vancouver Island and the west shore of Mudge Island bordering the Narrows. South from Ladysmith, exposures are found on several small islands between Chemainus and Crofton, and on Saltspring Island the formation underlies a low, narrow valley northeast of, and adjacent to, the ridge of Protection sandstone that extends across the middle of that island. The uppermost beds of the formation outcrop on the southwest sides of Mayne and Saturna Islands below massive cliffs of De Courcy sandstone and conglomerate. Cedar District shales occur again on the limbs of folds exposed along the east shore, the deeply indented bay on the southeast shore, and the southwest corner of North Pender Island, and on the north and east shores of South Pender Island. Farther south, across the International Boundary, fossil-bearing beds of about the same zone as those on the southwest side of Saturna Island, outcrop on the south side of Sucia Island.

Because of the greater proportion of arenaceous beds towards the top and bottom of the Cedar District formation, neither its upper or lower limits are well defined, but are transitional into the underlying Protection and the overlying De Courcy sandstone formations.

Like the Protection formation, the Cedar District is fairly regular in thickness, ranging between 700 and 1,000 feet in the north and being nearly 800 feet thick in the south part of the basin. The latter figure approximates the average thickness of the formation.

The formation consists almost entirely of thin beds of bluish grey to dark grey, spheroidal weathering, carbonaceous and ferruginous, and in places calcareous, sandy shales alternating with brownish grey, fine-grained sandstone. The sediments are well bedded; the shales are commonly laminated, and the sandstones flaggy. Ripple-marks, cross-bedding, soft-rock deformation features, and shale breccias in sandstone matrices are normally seen throughout most of the formation, but sandstone dykes are almost entirely restricted to the upper, more arenaceous part. Small, irregular or rounded, limy concretions are commonly abundant in the most argillaceous parts of the formation and, on occasion, they enclose invertebrate fossils.

Near the contact with the overlying De Courcy sandstone, the Cedar District sandstone beds are thicker and more coarse grained, with scatterings of pebbles and cobbles; on Saturna Island, they carry numerous fossil shells. The beds on Saturna Island commonly pass laterally into coarse, pebble- and cobble-conglomerate made noteworthy by virtue of the large quantity of milky white, angular, quartz fragments embedded in a black and green matrix of trap debris. The same beds outcrop on Sucia Island, where they are underlain by blue, friable, argillaceous, strongly cross-bedded, medium- to coarse-grained sandstones.

The fauna of the Cedar District formation consists, like that of the Haslam, Trent River, and Lambert formations, almost entirely of molluscs, but differs from that of the other principal fossil-bearing units in that it is much sparser. The greatest percentage of specimens from the formation have been recovered from outcrops in the southern part of the Nanaimo basin on Sucia, Saturna, and Pender Islands. Ammonites appear to be mostly confined to the middle, thin-bedded, and dominantly argillaceous parts of the formation, whereas the upper, sandier beds enclose mostly pelecypods and gastropods. In particular, the outcrops on Sucia Island are the most prolific of any in the Nanaimo group, and have contributed many fine specimens to the collection.

Nine species of ammonites have been found in the Cedar District formation: *Hoplitoplacenticeras vancouverense* (Meek), *Pachydiscus* cf. *jacquoti* Seunes, *Diplomoceras?* sp., *Pachydiscus neevesi* Whiteaves, *P. newberryanus* (Meek), *Phylloceras* sp., *Schluteria selwyniana* (Whiteaves), *Baculites chicoensis* Trask, and *B. occidentalis* Meek. Of these, the first three species listed above are restricted to the Cedar District formation and to a single outcrop of that formation, namely, that on Sucia Island. *Pachydiscus neevesi*, which has also been recovered from rocks of the Nanaimo group on James Island, is, with the exception of the latter locality, restricted as well to Sucia Island. These four specimens, unknown elsewhere in Upper Cretaceous rocks of Vancouver Island, suggest that the formation in which they are found might well be of Maestrichtian rather than Upper Campanian age. On the other hand, however, the presence of *Pachydiscus newberryanus*, which first appears in the Haslam formation and does not go beyond Cedar District time, and *Baculites chicoensis*, which is found in the Haslam and Trent River formations, and rarely in the Lambert formation, suggests that the Cedar District formation is related in time to the Haslam and Trent River formations (of Campanian age) more closely than it is to the Maestrichtian Lambert and Northumberland formations. This view is supported with additional faunal evidence by the co-tenancy of *Schluteria selwyniana* and *Phylloceras* sp. in both the Trent River and Cedar District formations. The study of the lithology and the sedimentary succession also bears out this conclusion.

Pelecypods are numerous in parts of the Cedar District shales, among them *Inoceramus* ex gr. *subundatus, Cuspidaria suciensis* Whiteaves, *Eriphyla umbonata* Gabb, *Laevicardium* sp., *Lucina nasuta* Gabb, *L. subcircularis* Gabb, *Nucula traskana* Meek, *Pinna calamitoides* Shumard, and *Thracia subtruncata* Meek.

Other molluscs include *Anchura callosa* Whiteaves, *A. axillis* Gabb, *Capulus corrugatus* Whiteaves, *Cypraea* sp., *Epitonium mathewsoni* (Gabb), *Fusus kingsi* Gabb, *Sycodes glaber* (Shumard), *Vanikoropsis suciensis* White, *Entalis cooperi* (Gabb), and *Nautilus campbelli* Meek.

De Courcy Formation

The De Courcy is a thick sandstone formation. It outcrops on the east flank of an anticline to form part of Mudge Island and the De Courcy Islands, and on the west flank of the anticline from the point of land between Dodd Narrows and the mouth of Nanaimo River south to Ladysmith Harbour. Farther south it is well exposed in shore outcrops on the islands of Thetis, Reid, Mayne, Saturna, North and South Pender, and Prevost, and on the north end of Saltspring Island. It underlies, but is only partly exposed on, the east side of Kuper Island. In addition, numerous tiny islands and reefs bordering the larger islands are underlain by De Courcy sandstone. The formation forms cuestas on the De Courcy Islands and Mayne Island, as well as on some of the highest mountains on Saturna and North and South Pender Islands.

The formation is predominantly sandstone, but both the upper and lower parts are thin bedded and shaly. These beds are transitional into the underlying Cedar District shales and the overlying lower shaly member of the Northumberland formation; the transition zone may be as much as 100 or 200 feet thick. As a consequence, it is commonly difficult to determine the upper and lower limits of the formation. Clapp reports a maximum thickness of 1,400 feet in the Woodley Range (1914a, p. 64), but the formation is generally between 800 and 1,000 feet thick, averaging about 900 feet.

The most abundant and typical rock of the De Courcy formation is a fine- to coarse-grained, in places pebbly, sandstone, composed of angular quartz, feldspar, shale, and trap fragments, with shreds of black and white mica and a greenish matrix. It weathers yellowish brown to greenish brown. The cement is siliceous, and in some beds ferruginous. Beds are generally massive, but may weather into flaggy layers; massive cross-bedding, particularly in coarse-grained zones, is common. Large, spheroidal, calcareous concretions are abundant in many of the thick layers and may occur in coarse-grained phases of a normally fine- or medium-grained bed.

As in most of the arenaceous formations of the Nanaimo group, the De Courcy sandstone shows continual and rapid variation in texture and grain size both along and across the strike of the beds. The range of variability extends from sandy shales through sandstones to granule- and pebble-conglomerates, and in a few places to cobble-conglomerates.

Shaly sandstone beds occur throughout the formation, but are most typical of the upper and lower 200 feet. They vary rapidly in texture and composition, and in some places are carbonaceous, with layers of coaly fragments and thin, short, coaly lenses.

No fossils other than indeterminable plant fragments have been recovered from the De Courcy formation.

Northumberland Formation

The shaly sandstones of the upper part of the De Courcy formation pass gradually into the lowest, shaly member of the succeeding Northumberland formation. The latter is a thick, heterogeneous unit, which can generally be divided into a middle arenaceous member and upper and lower argillaceous members. It does not outcrop on Vancouver Island, although it is assumed to underlie a small area on the east side of Ladysmith Harbour. It is found on all of the large and most of the small islands in the Nanaimo basin from Gabriola to Saturna. It outcrops in a syncline on both the north and south sides of Gabriola Island; as a narrow strip along the southwest side of Valdes Island; on the south end of Galiano Island; across the middle of Mayne Island; along the north side of Saturna Island; on Thetis, Kuper, and the Secretary Islands east of Kuper in Trincomali Channel; on the northwest and northeast sides of Saltspring Island; on the southwest side of Prevost Island; in a syncline on North Pender Island; and on the south end of South Pender Island.

Although the upper and lower Northumberland contacts are gradational, the top of a 25-foot bed of sandstone at the base of the lower shale member and the base of a 75-foot bed of sandstone at the top of the upper shale member mark, respectively, the limits of the formation. Between these limits the thickness varies from about 2,000 feet in the north to about 2,700 feet on Mayne Island, but averages about 2,400 feet. Of this, the middle member occupies about one-half, and of the upper and lower members, here one, there the other, is the thicker. On the south end of Mayne Island, the middle sandstone accounts for less than one-quarter of the formation, and the rest of the formation is made up of shale.

The shales of the Northumberland formation, which are generally arenaceous and in most instances interbedded with fine-grained or silty sandstone beds, are thin bedded and laminated, blue-grey, highly fractured, and brown or buff weathering. They resemble the Cedar District shales, but are not as carbonaceous. At irregular intervals are thick, coarse-grained sandstone beds, and sandstone dykes traverse the shales in large numbers. Flattened, irregular, reddish weathering, calcareous concretions several inches long, and irregular concretionary lenses occur along bedding planes in both the upper and lower shale members; rarely do they contain invertebrate remains. Both shale members become progressively sandier as they approach the limits of the middle sandstone member.

The middle sandstone member is a thick accumulation of fine- to coarse-grained sandstone, much resembling the De Courcy and Gabriola sandstones, and passes laterally and vertically into fine-, medium-, and coarse-grained conglomerates. The sandstone is massive and flaggy, greyish to yellowish brown, dark brown or greenish weathering, and is composed of angular quartz fragments with feldspar, a high percentage of black mica flakes, and greenish trap debris. Large, spheroidal concretions similar to those of the De Courcy formation are abundant. The conglomeratic beds are extremely heterogeneous in composition, and the textures are as diverse as the composition. Quartz, chert, schistose rocks, granodiorite, diorite, porphyries, meta-volcanic rocks, limestone, sandstone, shale, conglomerate, and concretionary fragments are the chief constituents, and the textures range from coarse sandstone, with scatterings of granules, through wide variations in subangular to rounded pebble, cobble, and boulder types. They occur as thin, lens-like interbeds in, and coarse-grained phases of, sandstone beds, or as persistent, massive beds interstratified with, and commonly grading into, sandstone. Bedding planes are irregular, and crossbedding, channelling, and soft-rock deformation are features normally associated with this middle member of the Northumberland formation. The conglomerates attain their greatest thickness, of more than 1,000 feet, and their most massive character on Mount Sutil at the south end of Galiano Island, but are responsible as well for high topographic elevations on Mayne Island.

Few fossils have heretofore been reported from the Northumberland formation, but recent collections from both the lower and upper shale members have established the marine origin of these parts of the formation, and the respective stratigraphic equivalency to the Lambert and Spray formations of the Comox basin. Ammonites and pelecypods have been collected from some of the concretions in the shales. What may be fossil burrows or the trails of crawling animals were observed on the surface of many of the thin sandstone layers in the shales. Thin layers of calcite prisms are common along bedding planes, and the belief that these may be crystallized shells of crushed pelecypods and ammonites of enormous size is based on the association of faint impressions of *Inoceramus*-like and ammonite-like ornament with the calcite layers. Some of these may be as much as 36 inches in length. This belief is further strengthened by the discovery of large fragments of what were originally enormous pachydiscids and inocerami in both the upper and lower members.

Collections from the formation have been made on Gabriola, Valdes, Galiano, Mayne, and Thetis Islands, but unfortunately the remains of the invertebrates are fragmentary, and identification of species is not always possible. Only three species of ammonites have been identified: *Pachydiscus suciaensis* (Meek), *P. ootacodensis* (Stoliczka), and *Pseudophyllites indra* (Forbes). All of these have been recovered from the lower shale member of the formation, whereas only *P. suciaensis* has been definitely recognized in the upper member. In addition, the pelecypods *Anatina tryoniana* Gabb, *Idonearca truncata* (Gabb), *Inoceramus* spp., *Linearia meekana* (Whiteaves), *Nucula (Acila) truncata*, *Pholadomya subelongata* Meek, and *Tellina occidentalis* Whiteaves, and the gastropod *Oligoptyche obliqua* are reported from the formation. None of these forms is abundant, and, as in the Haslam formation, they occur at random throughout the shales with no apparent limitation to individual beds, layers, or zones.

Gabriola Formation

The youngest formation of the Nanaimo group in the Nanaimo basin, the Gabriola formation, is restricted to the outer chain of islands bordering the southeast coast of Vancouver Island. Besides numerous tiny islands and rocks and reefs nearby, the formation outcrops on Gabriola, Valdes, Galiano, and Mayne Islands. On Gabriola, the formation occupies a syncline extending the length of the island; on the other islands mentioned, the formation is exposed in cuestas, with southwest-facing escarpments up to 500 feet high, and gentle back slopes dipping northeast at 10 to 20 degrees.

The contact of the Gabriola with the underlying thin-bedded sandy shales of the Northumberland formation is marked by the base of a massive sandstone zone, 75 feet or more thick. The formation is thickest on the south end of Galiano Island, where nearly 3,000 feet have been measured; farther north, 2,000 to 2,500 feet of sandstones and shaly sandstones remain, and on Gabriola Island only 1,400 feet of the formation is observable.

The predominant rock of the formation is thin- to thick-bedded, yellowish grey, fine- to coarse-grained, greyish brown weathering quartzose sandstone composed of angular grains of quartz and feldspar, with lesser amounts of black mica, trap, and shale fragments in a greenish matrix of trap debris. Much of the sandstone has a silty appearance resulting from the decomposition of the feldspar on weathered surfaces. Bedding is generally massive, but thin interbeds of shaly sandstone occur throughout. The argillaceous content is greater toward the upper and lower limits of the formation, and shaly beds at the base are transitional into the underlying Northumberland formation. These beds are usually laminated and commonly carbonaceous, with narrow, short coal seams in some places. Upon weathering they become soft, friable, and brightly coloured, and show small-scale crossbedded structures more readily than on a fresh surface. Disk-like calcareous concretions lie parallel with the stratification in these shaly beds, but do not bear fossils.

In the most massive, middle part of the Gabriola formation, the typically fine- to medium-grained sandstones pass vertically and laterally into coarse-grained or granular sandstones or lens-like accumulations of pebbles. The lack of extensive, coarse cobble-conglomerates is one feature that is useful in distinguishing these sandstones from those of the Northumberland formation.

Structures such as crossbedding (in many places on a massive scale), soft-rock deformation structures, shale breccias in sandstone matrices, and large spheroidal concretions similar to those found in lower arenaceous formations are common. The processes that resulted in the deposition of the Gabriola formation were, apparently, not unlike those that produced the De Courcy and the mid-Northumberland sandstones.

Prior to the present report, no specific record of a fauna in the Gabriola formation has been made. Invertebrate fossils have since been found in one outcrop of the formation; they consist of cameræ fillings of large ammonites, probably of *Pachydiscus sucianesis*, and were found in blue-grey, argillaceous shales 175 to 200 feet above the base of the formation on Mayne Island. Plant fragments are associated with some of the carbonaceous shaly zones, but they are too poorly preserved to be identified.

THE COMOX BASIN

The Comox basin encompasses a narrow belt along the east coast of Vancouver Island from Campbell River in the north to Nanoose Bay in the south, a distance of about 75 miles. Its eastern boundary is the Strait of Georgia and its western boundary is the eastern flanks of the Beaufort Mountains. In the vicinity of Nanoose Bay it is separated from the Nanaimo basin by a ridge of metamorphic and igneous rocks. The maximum width of the basin is 20 miles, but its average width is less than 8 miles. The continuity of the basin is almost broken at two points, at Wolf Lake by a granite intrusion, and at Deep Bay by a ridge of pre-Cretaceous volcanic rocks that reaches almost to the sea. Within this area, and dipping gently northeast, lies the northern development of the Nanaimo group.

The sedimentary strata of the Comox basin are an alternating succession of shales, sandstones, and conglomerates with a total thickness of more than 5,000 feet. The group is divided into eight formations, the lowest of which, the Qualicum, is restricted to the area between Deep Bay and Nanoose Bay and is presumed to be the stratigraphic equivalent of the Cranberry-Newcastle formations of the Nanaimo basin. Throughout the remainder of the Comox basin, the lowest formation is the Comox sandstone, resting directly and unconformably on the Vancouver volcanic rocks. Within this formation are the productive coal seams mined extensively in the Cumberland area. No coal of economic value is found above the Comox sandstone.

All of the formations of the Comox basin had been named prior to the present report, but because the names of two of the upper formations were preoccupied, appropriate substitutions for these have been made. The following table illustrates the changes in the stratigraphic nomenclature.

Richardson's divisions 1872-73, p. 35	Williams' formations, 1924, p. 35	Buckham and Usher's formations
G. Upper conglomerate	St. John formation	Hornby formation
F. Upper shales	Tribune formation	Spray formation
E. Middle conglomerate	Hornby formation	Geoffrey formation
D. Middle shales	Lambert formation	Lambert formation
C. Lower conglomerate	Denman formation	Denman formation
B. Lower shales	Trent River formation[1]	Trent River formation
A. Productive coal measures	Comox formation[1]	Comox formation
		Qualicum formation

[1] Clapp, 1912c, p. 105.

The names 'St. John' and 'Tribune' are preoccupied (Wilmarth, 1938, pp. 1877, 2182) and have been replaced with 'Hornby' and 'Spray' (after Spray Point) respectively. In place of 'Hornby' for the middle conglomerate, the name 'Geoffrey' is now used (after Mount Geoffrey), in view of the fact that the middle conglomerate underlies that mountain. The five uppermost formations are to be found only on Denman and Hornby Islands, which stand above sea-level by virtue of the massive conglomerates of the Denman, Geoffrey, and Hornby formations.

The fauna of the Comox basin is confined almost exclusively to two formations, the Trent River shales and the Lambert shales, both of which are of marine origin. Rare occurrences of invertebrates in the other formations are recorded. The fauna is uppermost Cretaceous, ranging in age from Campanian to Maestrictian (*See* Table of Formations, p. 7).

Qualicum Formation

The lowest stratigraphic unit of the Upper Cretaceous Series in the Comox basin is a little known formation, the Qualicum, confined to the southern part of the basin along a strip of coast, 2 to 6 miles wide, between the pre-Cretaceous ridges at Deep Bay on the north and at Nanoose Bay on the south, a distance of about 30 miles. This area is comparatively low and flat, and is thickly drift-covered. Little field work has been done on the formation, and most of the data concerning it have been obtained from bore-hole logs. Unfortunately, reliable information for most of these is lacking.

At the northern end of its area, the Qualicum is overlain by the Comox formation. The contact between the two formations is not exposed, but they appear to be structurally conformable, and the contact is probably gradational. Generally the lower contact of the Qualicum is covered, but it has been observed in several places in river bottoms. On Little Qualicum River, dense blue-grey shales rest directly on an irregular erosion surface of weathered quartz diorite, whereas on Englishmans River an irregular erosion surface cut into hard volcanic rocks is overlain unconformably by weathered, crossbedded conglomerate, which in turn grades upward through sandstone into the typical massive shales of the Qualicum formation.

Data on the thickness of the Qualicum formation are meagre, but, presumably, the formation consists of well over 1,000 feet of shale and sandy shale. In the vicinity of Northwest Bay, the uppermost 125 to 150 feet of the formation are predominantly sandstone, with minor conglomerate and sandy shale, apparently transition beds into the overlying Comox sandstone. About 35 feet of these upper arenaceous beds are exposed at the head of a small bay southwest of Arbutus Point and on the point of land in the southwest corner of Northwest Bay. These beds are greenish grey weathering, fine- to medium-grained, shaly and impure sandstone that weathers into shaly laminæ. Pebble-conglomerate lenses and hard, calcareous, dark brown weathering, concretionary lenses and beds and many small rounded calcareous concretions were observed. Crossbedding is common. These upper beds of the Qualicum formation are presumably the stratigraphic equivalent of the Newcastle formation at Nanaimo.

Fossil invertebrates were found in the upper beds of the Qualicum formation at Northwest Bay, but their distribution is not restricted to any particular bed and they are found randomly placed throughout exposures. Some of the small, rounded concretions enclose specimens of *Inoceramus* cf. *schmidti* as well as fragments of carbonized wood, some of which are filled with *Teredo* borings. The ammonite species *Pachydiscus multisulcatus* Whiteaves and *Gaudryceras denmanense* Whiteaves are represented, the former being restricted to this formation. The pelecypods *Trigonia tryoniana* Gabb, *T. evansana*, and *Inoceramus* cf. *schmidti* are plentiful. *Crassatella tuscana, Idonearca truncata, Martesia clausa* Gabb, *Glycymeris veatchi*, and *Drepanochilus gabbi* (White) have also been reported from these beds.

Comox Formation

The Comox formation is a white to brownish grey sandstone, with interbeds of shales, fine gritty sandstones, conglomerate lenses, and coal seams. It is the productive coal formation of the Comox basin. Underlying a strip of the coast 1½ to 2 miles wide, it extends from the northern limits of the basin in a southeasterly direction to the mouth of Qualicum River. The northeast boundary of the formation is fairly regular, and is marked by the conformable southeast trending contact with the overlying Trent River formation. The southeast boundary of the Comox formation, where it is in contact with the underlying volcanic rocks, is highly irregular, except in that southern part of the basin where the Qualicum formation underlies it. This irregular boundary is due in part to the pre-Cretaceous erosion surface, upon which the sandstone was deposited, and in part to post-Cretaceous erosion. Deep embayments cut back into the older rocks during earlier Mesozoic times and subsequently filled with Cretaceous sediments are now exposed as outliers of Comox sandstone resting on, and surrounded by, these older rocks. The pronounced unconformity marking the contact between the Upper Cretaceous and older rocks represents the pre-Cretaceous topography developed on the earlier Mesozoic volcanic rocks. This topography has a relief of some 440 feet (MacKenzie, 1922, p. 675), and accounts for the variability in the thickness of the Comox sandstone, which averages about 600 feet but may vary from a few hundred to more than 1,000 feet. The formation has, with local variations, a fairly regular dip of about 5 degrees northeast.

The predominant rock in the Comox formation is a homogeneous, chalky white to brownish grey or greyish green, fine- to medium-grained, occasionally calcareous sandstone, composed mainly of angular quartz fragments, feldspar grains, mica flakes, and argillaceous fragments. Beds are generally 2 to 4 feet thick, but some massive, homogeneous, inconspicuously crossbedded strata are as much as 40 feet thick. Lenses of pebble-conglomerate, one of them interfingering with the basal sands of the formation, and thick, irregular bands of cobble- and boulder-conglomerate are found at random intervals through the formation. They are notable facies in the otherwise fine-grained sandstone, but are nonetheless of restricted distribution and of no value as horizon markers.

Shale interbeds in the Comox formation are mostly thin-bedded, fine-grained, brownish grey, and arenaceous, or grey and black, argillaceous and carbonaceous types. Associated with the latter are the coal seams, five of which are of economic importance. The coal seams vary in thickness from a few inches to many feet, but almost all of the thick seams contain much clay shale, black carbonaceous shale, or highly carbonaceous shale known as bone. These five seams, although variable in thickness and in stratigraphic position, are widely distributed through the basin and are the best horizon markers in the formation.

Invertebrate fossils are rare in the formation, but plant fossils, some of them excellently preserved, have been collected from the roofs of the coal seams in the mines operating in the area. The few marine invertebrates that are reported have been found in nests or pockets in the sandstone. Those found in the roof of a coal seam mined at Cumberland are mostly comminuted, thick-shelled, littoral pelecypods (MacKenzie, 1922, p. 679; Williams, 1924, p. 55). Williams mentions, as well, an ammonite from the same locality and "crinoid roots" and "fossil bulbs" (ibid.) from concretions in a sandstone outcropping on Cowie Creek.

Trent River Formation

Conformably overlying the Comox sandstone is a thick series of shales comprising the Trent River formation. The shales outcrop over a strip of country about 35 miles long and, on the average, 4 miles wide, stretching along the east coast of Vancouver Island from beyond Wolf Creek in the northwest to Qualicum in the southeast. The formation reaches its maximum outcrop width of 5½ miles along Trent River. On the southwest, the formation is in contact with the underlying Comox formation, but its northeast boundary is exposed only on the west side of Denman Island. Here, the upper boundary is marked by the generally conformable contact with the overlying Denman formation; a massive, in places conglomeratic, bed of sandstone lies atop the uppermost shaly sandstone beds of the Trent River formation and marks the base of the Denman formation.

Although there are numerous local undulations in the northeast monoclinal dip of the measures, and although, locally, in the vicinity of faults, there may be high angles of inclination, the formation maintains a fairly persistent dip of 5 to 10 degrees northeast. Its thickness is given as 1,000 feet by Richardson (1878, p. 162), but Williams (1924, pp. 87-88) records a bore-hole, drilled on the southern end of Denman Island, that penetrated 1,300 feet of shales without reaching the thick sands of the Comox formation.

The lithology of the Trent River formation contrasts strongly with that of the Comox in being predominantly, and in places in the middle part of the section, entirely, shale. For the most part, the shale is very fine grained, thin bedded, grey to brown weathering, blue-grey, argillaceous and calcareous, and commonly finely laminated. Towards the upper and lower contacts, the shales become increasingly arenaceous, and range in composition from argillaceous shales, with thin interbeds of sandstone, to thick-bedded, homogeneous, fine- and medium-grained sandstones. Hard, calcareous, buff weathering, blue-grey, concretionary lenses and bands, as well as small, spheroidal and ellipsoidal, fossil-bearing concretions of the same material, occur throughout the formation. Black carbonaceous shale and thin coal lenses are not uncommon. A purely local feature is the occurrence of thick, lens-like intercalations of coarse sandstone and pebble- and cobble-conglomerate. Some of the sandstone beds contain angular fragments of shale.

An outstanding feature of the Trent River formation is the abundance, particularly in the upper and lower, sandier parts of the formation, of sandstone dykes. They range from 1 inch to 3 or 4 feet in width, and may be continuous for several hundred feet. They form a complicated network, intersecting the shales in all directions but usually at high angles to the stratification.

Marine invertebrate fossils are found preserved throughout the entire thickness of the Trent River shales, but they are not prolific and are never concentrated in a single bed. Preservation is best in the small calcareous concretions, but fragile impressions are commonly seen in the highly fractured, thin-bedded, argillaceous shales. Ammonites and pelecypods are the most abundant fossils, but gastropods, crustaceans, brachiopods, and fish vertebræ were also noted. Plant remains are scarce and poorly preserved.

Several species of ammonites, such as *Pachydiscus binodatus* Whiteaves, *P. perplicatus* Whiteaves, and *Ptychoceras vancouverense* (Gabb), are peculiar to this formation. Others such as *Diplomoceras? subcompressum* (Forbes), *Bostrychoceras elongatum*, *Epigoniceras epigonum*, *Hauericeras gardeni*, *Pachydiscus buckhami*, and *Phylloceras* sp. indet. occur as well in the Nanaimo basin but in the lower stratigraphic zone of the Haslam formation. *Baculites chicoensis*, *Phylloceras* sp., and *Schluteria selwyniana* occur in the Trent River formation and in the presumably stratigraphically equivalent Cedar District formation of the Nanaimo basin. *Inoceramus* cf. *schmidti* and *I.* ex gr. *subundatus* are common forms in the Trent River shales, and are most common as external moulds in argillaceous strata.

Anomia vancouverensis, *Mytilus pauperculus* Gabb, *Nucula (Acila) truncata*, *N. richardsoni* Whiteaves, and *Yoldia striatula* Forbes, as well as the gastropods *Anisomyon meeki* Whiteaves, *Cylichna costata*, *Drepanochilus gabbi*, *Littorina compacta* Gabb, *Oligoptyche obliqua*, and *Tessarolax distorta* Gabb have also been reported from this formation.

Denman Formation

From the northwest to the southeast tips of Denman Island a thick accumulation of sandstones, conglomerates, and minor amounts of shale, the Denman formation, forms the backbone of the island. Richardson referred to this unit as the 'Lower Conglomerate' in view of the massive conglomerate beds in it, but the bulk of the formation consists of sandstone.

The massive sandstone bed that forms the prominent southwest-facing escarpment along the west shore of the island marks the base of the formation. The upper contact is more difficult to locate because of overburden, but where the rocks are exposed it is found that the coarse-grained Denman clastic rocks pass gradually upward into the predominantly shaly beds of the overlying Lambert formation. The plane of contact is arbitrarily placed at that horizon below which the rocks are predominantly sandstones and conglomerates of the Denman formation and above which the rocks are sandstones and arenaceous shales of the Lambert formation. The formation is 900 to 1,000 feet thick.

In general, the lower half of the Denman formation is characterized by sandstones and shales and the upper half by sandstones and conglomerates. The arenaceous beds at base are massive, olive-green to greenish grey, medium- to fine-grained, quartz sandstones containing large spheroidal concretions, lenses of pebble-conglomerate, and very fine-grained, calcareous layers. Above these basal beds, thin-bedded, arenaceous shales, argillaceous shales, and fine-grained sandstones make up the remainder of the lower part of the formation. In places they contain thin lenses of pebble-conglomerate. Shaly coal lenses and plant fragments occur in, and sandstone dykes traverse, the more argillaceous beds.

The upper half of the Denman formation is predominantly conglomeratic, with thick beds of greenish to yellowish grey, fine- to coarse-grained sandstone. There is a constant lateral variation in the texture of these upper beds ranging from fine sandstone to massive conglomerate, with subangular cobbles of argillite, volcanic rocks, chert, quartz, and porphyries. Commonly the finer grades of conglomerate and the coarse-grained, in many places pebbly, sandstones contain small angular shale fragments. The sandstone interbeds are strongly crossbedded and interdigitate with the conglomerate beds. Toward the top of the formation the conglomerates become progressively finer grained, more thinly bedded, and more widely separated by thick beds of fine-grained, greenish grey, quartz sandstone. The top of the formation is marked by one of these sandstone beds, above which the thin-bedded shales and fine arenaceous beds of the Lambert formation begin.

Fossils are generally lacking in the coarse-grained clastic rocks of the Comox basin, but Richardson (1873, p. 47) reported an ammonite and a pelecypod in the Denman conglomerate at the south end of the island. Williams (1924, p. 98) records that a few ammonites have been found in calcareous bands in the upper measures of the formation, but it is more probable that the beds to which he refers are part of the Lambert formation. Norris Rock, a small island off the southern end of Hornby Island, is underlain by the upper beds of the Denman formation, and the fine pebble-conglomerates and coarse sandstones exposed there contain broken fragments of thick-shelled pelecypods. *Gaudryceras denmanense* Whiteaves was collected from these beds by Richardson (Whiteaves, 1873, p. 112; 1903, p. 329). Plant fragments in argillaceous beds of the lower half of the formation are too poorly preserved to be of value in fixing the age of the formation. Its stratigraphic position and similar lithology suggest an equivalency with the De Courcy formation of the Nanaimo basin.

Lambert Formation

Succeeding the Denman formation on the northeast side of Denman Island, is a series of arenaceous shales with minor beds of sandstone, forming the lower measures of the Lambert formation. The upper part of the formation is exposed eastward on Hornby Island whereas the thick middle part is covered by the waters of Lambert Channel. Based on the assumption that across Lambert Channel the beds maintain a monoclinal dip of about 8 degrees northeast and that the structure is not complicated by faulting, the maximum thickness of the formation is estimated to be about 800 feet. Hornby Island is the southwest limb of a broad open syncline, the axis of which plunges gently southeast. Near the trough of this fold, on the north shore of the island, several normal faults of small displacement cut the Lambert shales.

The upper contact of the Lambert formation is abruptly defined by the succeeding Geoffrey conglomerate; the lower contact, as previously noted, is gradational.

On Denman Island the lowest measures of the Lambert formation are fine-grained, thinly laminated, crossbedded, brown, quartz sandstone interbedded with layers of fine-grained, laminated, grey, rusty brown to dark brown weathering, sandy and silty shale. Higher in the section the sandstone beds become thinner and the argillaceous beds relatively more abundant. Many of these beds contain calcareous material and weather blue-grey. Pockets of poorly preserved invertebrate fossils are found along with pebbles of shale in some of the calcareous, sandstone layers. Fine-grained, hard, buff weathering, calcareous, concretionary lenses and spheroidal and ellipsoidal concretions also occur in these beds, and some of the concretions contain fragments of ammonites and pelecypods. A few sandstone dykes traverse this lower part of the formation.

On Hornby Island, the upper part of the Lambert formation is a succession of thin-bedded, dark blue-grey, highly fractured, brownish grey weathering, clay shales, with thin beds of fine-grained argillaceous sandstone. Concretionary lenses and rounded concretions similar to those near the base of the formation on Denman Island occur with these beds; the concretions contain the well-preserved and abundant fauna that has made Hornby Island a well known fossil collecting ground.

Toward the upper contact of the Lambert formation, the arenaceous content of the beds steadily increases, the uppermost beds being predominantly light brown to yellowish grey weathering, fine-grained, thinly laminated, crossbedded sandstones, with thin interbeds of black or brownish grey, arenaceous shale. Plant fragments occur in some of the shale. The sandstones are composed chiefly of quartz, feldspar, mica, and chert grains. Lenses of shale breccia and structures of soft-rock deformation are numerous.

A well-preserved molluscan fauna of Maestrichtian age is contained in the argillaceous beds of the upper Lambert fauna. Such well known Indo-Pacific ammonite species as *Pseudophyllites indra* (Forbes), *Phyllopachyceras forbesianum* (d'Orbigny), and *Pachydiscus ootacodensis* Stoliczka are represented, as well as *Neophylloceras ramosum* (Meek), *N. lambertense* n.sp., *Pachydiscus suciaensis* (Meek), and *Baculites occidentalis* Meek. Specimens of *B. chicoensis* Trask were also observed, but are subordinate in numbers to those of *B. occidentalis* and are more typical of the Cedar District formation of the Nanaimo basin. The irregularly coiled *Anisoceras cooperi* (Gabb), *Diplomoceras notabile* Whiteaves, and *Nostoceras hornbyense* Whiteaves are abundant, but only one specimen of "*Hamites*" *obstrictus* Jimbo is recorded from these upper beds. *Gaudryceras denmanense* is found only in the lower part of the formation, but a fragment of a large ammonite from Hornby Island is doubtfully referred to that genus.

In addition to the well-preserved ammonite fauna, many other molluscs are reported from the Lambert formation. Among the more abundant are *Inoceramus* spp., *Nucula hornbyensis*, *Corbula traski* Gabb, *C. minima* d'Orbigny, *Meretrix arata* Gabb, *Yoldia striatula*, *Tellina quadrata* Gabb, *Cylichna costata*, *Drepanochilus gabbi*, *Margarites ornatissima* (Gabb), "*Perissolax*" *brevirostris* Gabb, *Serrifusus vancouverensis* Whiteaves, and *Tessarolax distorta*. *Entalis cooperi* and *Nautilus campbelli* are also reported from the upper beds of the formation, the former being particularly abundant in the shales at Boulder point on Hornby Island.

Geoffrey Formation

The outstanding topographic feature of Hornby Island is Mount Geoffrey, a mountain 980 feet high, with precipitous west and southwest facing escarpments of conglomerate and interbedded sandstone. It is of interest to compare the appearance of, and the rocks underlying, Mount Geoffrey with those of Mount Sutil on Gabriola Island. Both owe their topographic relief to conglomerates that are of equivalent stratigraphic age.

The Geoffrey formation outcrops in a boomerang-shaped strip across the centre of Hornby Island, the point of maximum curvature coinciding with the west-southwest salient of Mount Geoffrey. The contact with the underlying Lambert formation is abrupt and disconformable; massive, coarse conglomerates rest directly on the thin-bedded sandstones and shaly sandstones of the Lambert. The contact with the overlying thin-bedded shales and shaly sandstones of the Spray formation is gradational on the north shore of the island but abrupt on the south shore. In the area intervening between the north and south shore of the island outcrops are rare, and this upper contact is only approximately located. It is in this central part of the island that the formation reaches its greatest thickness of at least 1,100 and possibly 1,300 feet. Northwards and southwards it thins to about 700 feet. The formation is finer grained and less conglomeratic in the northern outcrops than it is to the south.

The Geoffrey conglomerate occurs in massive beds up to 300 feet thick separated by beds and lenses of sandstone. In general, it is unsorted, and contains pebbles and cobbles, and boulders up to 2 feet in diameter. The texture is finer grained towards the top of the formation. The components of the conglomerate are mostly well rounded, and comprise fragments of trap, quartz, quartz diorite, diorite porphyries, granite-like rocks, gneisses, schists, chert, argillite, sandstone, and rare, calcareous concretions. The matrix is fine- to coarse-grained, brownish grey to reddish brown weathering sand.

Sandstone beds and lenses, of irregular thickness and wide lateral extent, separate the thick conglomerate beds. They are fine- to medium-grained, brown sandstones consisting of angular grains of quartz with subordinate amounts of feldspar, mica, and argillite fragments, with a calcareous, argillaceous cement. Layers, lenses, patches, and pockets of coarser material, from coarse sand grains to cobbles occur randomly throughout the sandstone beds. Crossbedding, coarse shale breccias, and evidences of soft-rock deformation are abundant.

Persistent beds of shaly sandstone and sandy shale make their appearance near the top of the Geoffrey formation. They are thin bedded, greyish brown weathering, bluish to brownish grey, and very fine grained. Thin layers of pure argillaceous shale are uncommon and may contain small, flattened, calcareous concretions.

Fossil invertebrates have been found in the conglomerates of Mount Geoffrey, but they are extremely rare. In each instance they have been enclosed in a shaly or concretionary cobble of the conglomerate and probably represent fragments eroded from an older formation.

Spray Formation

The Spray formation is a series of thin-bedded shales and sandstones outcropping on Hornby Island over a strip of country 1 mile to $1\frac{1}{4}$ miles wide, and stretching through an arc of 135 degrees from the southeast to the north of the island. The rocks underlie a lowland of which Tribune Bay, between Dunlop Point and St. John Point, is a drowned part. Northward, the formation is more massive, the land is higher, and the shore less shelving.

On the south shore of Hornby Island, the contact of the Spray with the underlying Geoffrey formation is well marked by the sudden change in lithology from massive conglomerate to thin-bedded shaly sandstone; on the north shore, the contact is gradational, and is marked by the uppermost bed of Geoffrey conglomerate. The contact with the overlying Hornby formation is placed at the top of the section covered by the waters of Tribune Bay. The thickness of the formation is about 800 feet.

On the north shore of Hornby Island the Spray formation consists of brown weathering, fine- to medium-grained, light grey to medium grey, thick-bedded, quartz sandstone composed predominantly of angular quartz, feldspar, and black mica flakes. Most of the sandstone has a high argillaceous and calcareous content in the form of fine cement and medium-grained particles of calcareous shale. In addition, lenses of shale breccia in a coarse-grained, arenaceous matrix, and pebble- and cobble-conglomerates occur with no apparent regularity throughout the sandstone. Here and there, thin beds of laminated, brown to yellow weathering, fine-grained, sandy shale separate some of the massive sandstone beds. Crossbedding is well displayed in all of these strata. Large, hemispherical, dark brown weathering concretions of dark grey, calcareous, quartz sandstone weather out on the surface of massive sandstone beds where the latter form flat reaches on the shore.

On the south shore of Hornby Island, the Spray strata are generally finer grained, more shaly, and more thinly bedded. They range from fine-grained sandstones to laminated, blue-grey, pure argillaceous shales. Toward the top of the formation in this area, the beds become more arenaceous, and here and there, thick, quartz sandstone strata are interbedded in the more shaly members. Associated with some of these beds are shale breccias, structures of soft-rock deformation, intricate crossbedding, coarse sand and granule layers, and thin coaly lenses.

The Spray formation is virtually unfossiliferous. Fragments of carbonized wood are found in concretions and as localized accumulations in sandstone and shale strata. A few pieces of broken invertebrate shells were seen in the matrix of a conglomerate lens on the north shore of the island, among them fragments of a *Dentalium* species and a gastropod. Probably they are indigenous to the formation, but it is possible that they were eroded from some older formation and redeposited in the Spray.

Hornby Formation

Above the thin-bedded, argillaceous measures of the Spray formation is a succession of massive sandstones and conglomerates, comprising the Hornby formation. This is the youngest formation of the Nanaimo group in the Comox basin, and is exposed on Hornby Island where it underlies and forms the precipitous cliffs of St. John Point and Flora Island. The beds strike northwest and dip 8 to 10 degrees northeast. The thickness of the formation is between 600 and 800 feet.

The Hornby formation may be divided roughly into three, about equal parts; a lower massive sandstone, a middle massive conglomerate, and an upper sandstone and conglomerate. The basal, sandstone member is most completely exposed in the cliffs of St. John Point where it overlies the shaly, thin-bedded strata of the Spray formation along the northeast side of Tribune Bay. It is a fine- to medium-grained, buff to pale yellow-brown, thick-bedded unit composed of angular, white to greenish white, quartz grains, with dark grey chert, biotite, and feldspar fragments cemented in very fine-grained calcareo-argillaceous material. Bedding is irregular, commonly lens-like, and usually crossbedded on a large scale. Large, brown weathering, calcareous, sandstone concretions protrude from the cliffs. Layers, lenses, and irregular patches of granules, pebbles, and cobbles are common in the sandstones, and increase in number and thickness upward to where they finally surpass the sandstones in quantity.

The middle member consists of subrounded to rounded, pebble-, cobble-, and even boulder-conglomerates. Fragments of quartz, chert, trap, porphyries, granite, sandstone, shale, conglomerate, and, rarely, calcareous concretions, in a matrix of fine- to medium-grained, impure, greenish grey, quartz sand form the constituents of these beds. Cross-bedded layers and lenses of sandstone are interbedded with, and become more plentiful toward the top of, this member to where it passes upward into the overlying interbedded sandstone and conglomerate zone. The strata in the youngest member, and particularly the conglomerate beds, are finer grained than those immediately below, although the sandstones much resemble those toward the base of the formation.

Fossil belemnoids have been reported by Richardson and Whiteaves from the lowest sandstone member of the formation. These specimens have not been found in the collections of the Geological Survey nor have additional ones been found in the field. In the absence of any other fossils, the Hornby formation is correlated by means of its stratigraphic position with the Gabriola formation in the Nanaimo basin.

PALÆONTOLOGY

INTRODUCTORY STATEMENT

The fauna of the Upper Cretaceous rocks of Vancouver Island is restricted almost entirely to marine shale formations. These include the Haslam, Cedar District, lower and upper Northumberland, and lower Gabriola formations in the Nanaimo basin, and the Qualicum, Trent River, and Lambert formations of the Comox basin. Less than a score of cephalopod specimens were discovered in pure arenaceous beds, which in every case were intercalations of sandstone in a marine shale formation.

Most of the fauna is well preserved; those specimens found in shales usually retain their shells and appear to have suffered little or no change since burial. Ammonites and large pelecypods are commonly embedded in hard, spheroidal, calcareous concretions, and it is probably to this strong protective covering that most of the specimens owe their fine state of preservation. Commonly large specimens are not completely covered by the concretion, and those parts of the shell not so protected are generally crushed, and have lost all but the grosser features. Many pelecypods and gastropods are interred in the rocks without a concretionary shield, and upon exposure the shells disintegrate leaving behind only internal moulds. These forms are particularly difficult to collect. Impressions of cephalopods in the shales are not uncommon and they, too, because of the highly fractured, friable nature of the rock, almost defy collecting.

For the most part, arenaceous strata yield meagre faunas of poorly preserved gastropods and pelecypods. Two notable exceptions are the sandy beds of the Haslam formation at Nanoose Bay and the upper part of the Cedar District formation in Saturna and Sucia Islands where these classes of molluscs are well preserved and easy to collect.

It was found during the present investigation that the best collecting could be done in the summer and early autumn, along stream channels where bedrock was exposed and where fresh talus slopes provided large accessible blocks of shale. The latter, in a partly weathered condition, yielded the most perfect specimens. In the Comox basin, the greater part of the Trent River fauna was collected along Browns, Trent, and Tsable Rivers; in the Nanaimo basin, Nanaimo River, Elkhorn Creek, Haslam Creek, and Brannan Creek Valleys provided most of the Haslam fauna. In addition to the streams of Vancouver Island, the shores of adjacent small islands offered good exposures of some of the upper fossiliferous shale formations. Since Richardson's days of exploring, the Lambert shales on Hornby Island have achieved wide recognition for the prolific and excellently preserved ammonite fauna; the Cedar District shales of Sucia Island are no less productive.

One of the most pertinent features of the Upper Cretaceous fauna is the apparent lack of restriction of fossils to particular beds or to narrow zones within formations. Occasional beds a few inches thick, or at most 2 or 3 feet thick, are packed with fossils; the best of such rare occurrences are in the Haslam formation along the shore east of Nanoose Bay, at Departure Bay, and in the Cedar District formation on Saturna and North Pender Islands. In each of these places the fossil-bearing bed is arenaceous and the shells comminuted. The general appearence is that of a shore or shallow water, coquina-like deposit. Elsewhere, the fossils are scattered at random throughout the shales either singly or in groups of a few, and are separated from other specimens by distances of a few score or a few hundred feet.

The want of narrow fossil zones within formations has prevented detailed zoning of the fauna, and such attempts had to be applied on the much larger scale of single formations. In some cases it has been possible to show that a species is found in only the upper or lower part of a formation, but because continuous outcrops across the strike are exceptional and because faults may confuse the stratigraphic succession, it is impossible to state the limits of a species in terms of feet above or below a known stratigraphic horizon.

The ensuing analysis of the ammonite fauna and description of species is based: (1) on numerous specimens collected during the 1945 and 1948 field seasons; (2) on the large earlier collections in the possession of the Geological Survey of Canada; and (3) on additional specimens and plastotypes from other Canadian and American scientific institutions. Almost all of the hitherto described ammonite species from the Nanaimo and Comox basins are herein redescribed; many of them are reillustrated and their types designated. Four new species are proposed.

COMMENTS ON THE ENVIRONMENT OF THE AMMONITES

The ammonites of the Nanaimo and Comox basins are found almost exclusively in thin-bedded, fine-grained, argillaceous, commonly calcareous shales and interbedded, very fine-grained, arenaceous shales. Their absence from the coarser sandstones and conglomerates, such as the Denman, Hornby, De Courcy, Northumberland, and Gabriola formations, suggests that these animals definitely avoided waters where this type of sediment was being deposited. Presumably, the arenaceous clastic rocks were laid down in water too shallow, or too brackish, or where temperatures changed too rapidly for the well-being of the ammonites. They have not been found in shaly beds that show any evidence of having been deposited in shallow water. Their general absence from beds containing numerous, thick-shelled, littoral pelecypods and gastropods again points to their avoidance of the shallow, shoreward zones. But confined as they are to the deeper water, shaly facies within the series, there appears to have been little or no palæoecological segregation of the Vancouver Island ammonite genera in that facies.

In his discussion of the palæoecology of the Texas Upper Cretaceous ammonites, Scott (1940) subdivided the neritic and bathyal zones into several subzones lying between specified bathymetric limits. He found that ammonites occurring in the deposits of each subzone possessed morphological traits distinctive from those ammonites occurring in shallower or deeper water facies, and that associated with each group were other classes of marine invertebrates also characteristic of that particular depth. For instance, the smooth, obese representatives of the phylloceratids and lytoceratids apparently lived in the deeper waters of the bathyal zone, below 100 fathoms, hence beyond the depth to which light from the surface penetrates. Sediments deposited in this zone would contain these ammonites in considerable numbers and to the almost complete exclusion of other molluscs. Highly sculptured, robust, quadrate, evolute, thick-shelled ammonites, the straight, hooked, bent, and spirally coiled types, presumably lived in waters 20 to 80 fathoms deep; this habitat they shared with numerous other invertebrates. The tenuous, flattened, smooth or striate, and commonly keeled types preferred still, shallower water, living between 5 and 20 fathoms.

The application of this fine classification of neritic and bathyal sediments has not been possible in the Nanaimo group. The most that can be said is that the sediments are either littoral, shallow water neritic, or deep water neritic. The littoral sediments contain thick-shelled pelecypods and gastropods and commonly large quantities of broken shells; the shallow water, neritic sediments contain more fragile types of pelecypods and gastropods, with occasional ammonites; the deep water facies contain ammonites of numerous shapes and ornaments, a few large pelecypods, and in several instances many tiny gastropods and pelecypods. In these latter sediments, which probably accumulated under 25 to 75 fathoms of water, representatives of each of Scott's morphological groups are found; smooth, obese phylloceratids and lytoceratids; thick-shelled, coarsely ribbed pachydiscids; and smooth flattened and keeled genera such as *Hauericeras* and *Pseudoschloenbachia*. It is possible, of course, that the proposed bathyal types may have been empty shells that drifted into unfamiliar waters, but their considerable number and lack of transportational wear and tear oppose the view that drift was an important factor in their distribution.

Supporting the typical Upper Cretaceous ammonites that it did, there seems to be little doubt that the sea occupying the ancestral Strait of Georgia had open connections with the parent Pacific Ocean. Uniform temperatures and composition of the water would thereby be maintained, and free movement in and out of the basin would be allowed the fauna. The wide distribution of many of the genera of the Indo-Pacific fauna makes it reasonable to assume that either all of the Upper Cretaceous ammonoidea were stenothermal, or that climatic zones were less defined and extreme and temperatures universally more uniform. The evidence offered by the fossil plants in the Nanaimo group points to an equable Upper Cretaceous climate.

ANALYSIS OF THE AMMONITE FAUNA

Nine families, eighteen genera, and thirty-four species of ammonites are recorded from the Upper Cretaceous series of Vancouver Island (*See* Table I, p. 34). Of these, twelve species are common to both the Nanaimo and Comox basins; the remainder belong to various horizons within either one or the other basin, thirteen species being confined to the Comox basin and nine to the Nanaimo basin. Compared with Upper Cretaceous rocks in other areas, the Vancouver Island groups contain fewer genera and fewer specimens, but this paucity is partly compensated for by the diverse morphology and splendid preservation of the forms present.

Ammonites occur in four principal faunizones, three of which, the Haslam, Qualicum, and Cedar District-Trent River, belong to the Campanian Stage; the fourth, the Northumberland-Lambert faunizone, contains an almost totally different fauna, of Maestrichtian age. The equivalency in time of the Northumberland and Lambert formations is beyond doubt, despite the disparity of fossils in the Northumberland. The contemporaneity of the two formations and their unmistakable Maestrichtian age is in contradistinction to that of the lower faunizones, which, as in the case of the Cedar District and Trent River formations, are difficult to reconcile in time on the limited grounds of faunal content, and which, as

Table I

Stratigraphic Occurrence of Ammonite Species in the Nanaimo Group of Vancouver Island

	Nanaimo group					
	Nanaimo basin			Comox basin		
	Haslam	Cedar District	Lower Northumberland	Qualicum	Trent River	Lambert
Pachydiscus elkhornensis n.sp.	×					
P. haradai Jimbo	×					
P. cf. *haradai*	×					
Pseudoschloenbachia brannani n.sp.	×					
Pachydiscus multisulcatus Whiteaves				×		
Bostrychoceras elongatum (Whiteaves)	×				×	
Epigoniceras epigonum (Kossmat)	×				×	
Hauericeras gardeni (Baily)	×				×	
Pachydiscus buckhami n.sp.	×				×	
Diplomoceras? subcompressum (Forbes)	×				×	
Baculites chicoensis Trask	×	×			×	×
Pachydiscus (Canadoceras) newberryanus (Meek)	×	×				
Diplomoceras? sp.		×				
Hoplitoplacenticeras vancouverense (Meek)		×				
Pachydiscus neevesi Whiteaves		×				
P. cf. *jacquoti* Seunes		×				
Phylloceras sp.		×			×	
Schluteria selwyniana (Whiteaves)		×			×	
Pachydiscus binodatus Whiteaves					×	
P. perplicatus Whiteaves					×	
Ptychoceras vancouverense Whiteaves					×	
Baculites occidentalis Meek		×				×
Pachydiscus ootacodensis (Stoliczka)			×			×
P. suciaensis (Meek)			×			×
Pseudophyllites indra (Forbes)			×			×
Gaudryceras denmanense Whiteaves				×		×
G. sp.						×
Anisoceras cooperi Gabb						×
Diplomoceras notabile Whiteaves						×
"Hamites" obstrictus Jimbo						×
Neophylloceras lambertense n.sp.						×
N. ramosum (Meek)						×
Nostoceras hornbyense (Whiteaves)						×
Phyllopachyceras forbesianum (d'Orbigny)						×

in the case of the Haslam formation, contain faunal elements known elsewhere in Santonian as well as Campanian rocks. Thus, the correlation and chronological dating of formations in the two basins below the Northumberland-Lambert zone are subject to more than one interpretation. Earlier investigators of the Nanaimo group have not attempted to correlate the formations in the Nanaimo basin with those in the Comox basin on the basis of faunal content and faunal succession, but, instead, founded their correlation entirely on the lithology of the rocks and the sedimentary sequences. These were not only reasonable data to use, as the succession of sedimentary rocks in the Comox basin, from the Comox sandstone upwards, is almost identical with that part of the succession in the Nanaimo basin, above and including the Protection sandstone, but also because the faunal succession was unknown. The present palæontological study of the Nanaimo group throws some doubt on the validity of the accepted and purely lithological correlation. As it is presently understood (*See* Table of Formations) the group in the Comox basin lacks several of the lowermost units found in the Nanaimo basin, in particular the Benson conglomerate, the Haslam formation and East Wellington sandstone member, and the Extension formation. It should, however, be noted that the total thickness of the Qualicum formation, the lowest unit in the Comox basin, is unknown. Future investigation may reveal that whereas the upper part of the Qualicum is now correlated with the Cranberry and Newcastle formations, a lower, unknown thickness of the Qualicum may be equivalent to all or part of the Extension and Haslam formations. This possibility is, however, of little value over the northern two-thirds of the Comox basin where the Comox sandstone rests directly on the pre-Cretaceous basement rocks. Because of their outstanding similarity in lithology and thickness, the Comox and Protection sandstone have provided an opportune datum for correlation. That this datum is not unwarranted or improvident is shown by the almost identical lithological successions in the two basins that follow upon these two formations. On the assumption that this correlation is essentially correct, the lack of units still older than the Comox sandstone in the north has been explained to be the result of non-deposition, and that the Upper Cretaceous sea entered the Georgia Depression from the south, gradually spreading northward until, by 'Comox' time, the sea had flooded all of the eastern coastal plain of Vancouver Island at least as far north as Campbell River. There is no structural evidence to suggest that accumulation and deposition was not continuous once begun. On the contrary, all the structural and lithologic criteria point to persistent sedimentation in the basins, marred only by local diastems.

Considerations of the faunal succession apart from lithology suggest a somewhat different point of view. On the assumption that similar ammonite faunas are synchronous, it has already been noted that there is no doubt as to the contemporaneity of the Northumberland and Lambert formations. Below this zone, the Trent River fauna of the Comox basin contains elements more numerously in favour of correlation with the Haslam fauna than with that of the Cedar District formation. In fact, the Trent River has five species of ammonites in common with the Haslam formation whereas it has only three species in common with the fauna of the Cedar District formation. On the basis of the above assumption, there would seem to be little doubt that the Trent River formation is equivalent to the Haslam formation. This would mean that a fauna synchronous with that of the Cedar District is lacking in the Comox basin and that either a considerable erosional interval is represented at the Denman-Trent River contact in the north, or that the Denman sandstone and conglomerate, of about 1,000 feet thickness, is the lithologic and chronologic equivalent of the Protection sandstone, the Cedar District shale, and the De Courcy sandstone, with a combined thickness exceeding 2,500 feet. Both of these possibilities demand an unequal rate of sediment accumulation in the two basins; the southern, Nanaimo basin, closer to the parent Pacific, receiving sediments at a fairly uniform rate while the northern, Comox basin filled spasmodically. There is neither structural nor lithologic evidence to support the contention that while 1,500 feet of Haslam sediments collected in the south, 3,400 feet of Qualicum, Comox, and Trent River sediments were laid down in the north. Should this have been the case, however, the events that must necessarily have followed are even more unfounded, for they would have consisted of a sudden reversal of conditions in which sedimentation in the north either ceased abruptly or slowed to half that in the south. The incompatibility of the sedimentational and faunal correlations below the Northumberland-Lambert zone are thus not reasonably resolved by supposing a complex tectonic history of the deposition basins.

Because of: (1) the marked resemblance of the simple stratigraphic successions in the two basins; (2) the lack of any profound structural or stratigraphic unconformity in the Nanaimo group below the Northumberland-Lambert zone; (3) the unequivocal Maestrichtian Age of the Northumberland-Lambert fauna; and (4) the occurrence of predominantly Campanian forms and the lack of categorical Santonian species in the lower faunizones, it is believed that the Nanaimo group was deposited during the Campanian and Maestrichtian Stages of the Upper Cretaceous Epoch; that the Upper Cretaceous sea spread from south to north along the Georgia Depression; that the rate of sedimentation was, on the average, uniform throughout the locus of deposition, though beginning earlier in the south; that the Haslam formation has no counterpart, unless it be the lowermost Qualicum formation, in the Comox basin; and that elements from the Haslam fauna migrated northward with the sea to become interred in Trent River sediments at approximately the same time as the Cedar District formation and its enclosed fauna were accumulating farther south. The disparity in age between the Haslam and Cedar District-Trent River faunizones would be, in this case, insufficient to attribute with certainty subdivisions of the chronology finer than that of Campanian. The interpretation so evolved would mean that within some part of the Campanian Stage and within a limited area along the southeast coast of Vancouver Island, part of a fauna migrated through space and time to become preserved in two stratigraphically and chronologically different horizons.

The Haslam Faunizone

Ammonites from the Haslam formation have been collected from Nanaimo River, Haslam Creek, Elkhorn Creek, Brannan Creek, Maple Bay and Saltspring Island. The most numerous and typical forms are *Bostrychoceras elongatum, Hauericeras gardeni, Epigoniceras epigonum, Diplomoceras? subcompressum, Pachydiscus haradai*, and *P. buckhami. P. elkhornensis, P. newberryanus, P.* cf. *haradai*, and *Pseudoschloenbachia brannani* are represented by very few specimens, or, in the case of the last two species, by a single specimen.

The ascription of the Haslam fauna to the Campanian Stage cannot be made without question. *Hauericeras gardeni* is found in the Aryalur and Valudayur beds of India, but in Japan ranges through Coniacian, Santonian, and Campanian rocks. Among other places in its wide areal distribution, it occurs in 'Upper Senonian'[1] rocks of Pondoland, Zululand, Natal, and Madagascar. *Epigoniceras epigonum* is less widely distributed, and is not commonly found in rocks younger than Santonian. However, the presence of two other forms, *Bostrychoceras elongatum* and *Pseudoschloenbachia brannani*, which are close to *B. polyplocum* Roemer and *P. umbulazi* (Baily), respectively, favour a Campanian rather than a Santonian dating. This conclusion is strengthened further by the persistence of *B. elongatum, Hauericeras gardeni, Epigoniceras epigonum, Diplomoceras? subcompressum, Pachydiscus buckhami, P. newberryanus,* and *Baculites chicoensis* into the Cedar District-Trent River faunizone, which in turn is succeeded by the Maestrichtian faunizone of the group. The first five of the seven above listed species, although ranging through to the Cedar District-Trent River faunizone, are found only in the Trent River formation and are unknown in the stratigraphically equivalent Cedar District formation. This observation may possibly be a result of the dearth of fossils in the exposed outcrops of Cedar District formation, but in view of the lithologic and structural relations already considered it seems more likely that the five species common to the Haslam and Trent River formations are a migratory element that accompanied the northward advancing waters of the Upper Cretaceous sea. *P. newberryanus* is confined to the Nanaimo basin, and its range extends from the Haslam into the Cedar District formation. Elsewhere it is recorded from the Yolo stage of the Panoche group in California, but in the light of the present study of this species it is possible that the Nanaimo and California forms are not synonyms. *Baculites chicoensis* is another form common to both Cedar District and Haslam formations, and it is found as well in the Comox basin in the Trent River and Lambert faunizones. It is, however, found rarely in the Haslam and Lambert zones, and is more typical of, and abundant in, the Cedar District-Trent River zone; in California, *B. chicoensis* is a Campanian species. *Pachydiscus haradai* is a Japanese species ranging from mid-Santonian to Maestrichtian, but in the Nanaimo group it is confined to the Haslam formation.

That the Haslam formation is conclusively of Campanian age cannot be decided on the evidence presented by the ammonites, nor do the other molluscs provide a more definite determination. *Inoceramus* cf. *schmidti*, probably the most diagnostic of the pelecypods in the Haslam faunizone, is a Santonian-Campanian form in Japan. It accompanies the several ammonite species into the higher Cedar District-Trent River faunizone. The community of these several species in the Haslam and succeeding Cedar District-Trent River faunizones indicates that there was no major faunal change until the end of Cedar District-Trent River time. Because there is little doubt that the Northumberland-Lambert fauna is Maestrichtian and because no major break in sedimentation is apparent in the group, it seems reasonable to assume that the Haslam faunizone as well as that of the Cedar District-Trent River, can be related to the Campanian

[1] 'Upper Senonian' is a common but often ambiguous time term applied generally to rocks of Campanian and Maestrichtian age. It is currently deprecated because of its several interpretations and is quoted herein only where a more precise dating has been impossible.

Stage. It is, however, referred to that stage with reservations, for there still remains the not unfounded possibility that the Haslam formation represents instead a part or parts of the Santonian Stage.

The Qualicum Faunizone

Situated between the Haslam and the Cedar District-Trent River faunizones is a narrow zone at the top of the Qualicum formation that contains two species of ammonites. The first, *Pachydiscus multisulcatus*, is represented by numerous specimens and is closely related, on the one hand, to *P. newberryanus* in the Nanaimo basin and, on the other, to *P. perplicatus* in the Comox basin. The second, *Gaudryceras denmanense*, is represented by a unique specimen in this formation, and records the first appearance of that species in the Nanaimo group of the Comox basin. With these ammonites is the pelecypod *Inoceramus* cf. *schmidti*. On the basis of its stratigraphic position, the Qualicum faunizone is considered to represent part of the Campanian Stage, and this fossiliferous upper part of the Qualicum formation is probably the stratigraphic equivalent of the Newcastle formation of the Nanaimo basin.

The Cedar District-Trent River Faunizone

Combining the faunas of the Cedar District and Trent River formations into a single faunizone, when, in fact, the Trent River formation contains more ammonite species in common with the Haslam formation, does not appear to be justified from a strictly palæontological point of view. But when a comparison of the stratigraphic sequences in the two basins is made, this more comprehensive view would seem to weigh the balance in favour of correlating the Trent River formation with the Cedar District formation.

A consideration of the Table of Formations shows that the lithology of the formations, as they are there correlated, follows almost precisely the same sequence in the Nanaimo and Comox basins. In particular, the close similarity between the Comox and Protection sandstones and the similarity of the several conglomeratic units in the two basins are important evidence of the uniformity in the conditions of sedimentation that prevailed in the Upper Cretaceous sea along the western shores of the Georgia Depression. This contended correlation is further strengthened by palæontological evidence in the case of the Northumberland and Lambert formations, which contain elements of the same fauna, and also in the case of the Trent River and Cedar District formations, which, too, possess certain species, *Schluteria selwyniana*, *Phylloceras* sp., and *Baculites chicoensis*, in common with one another. Against this weight of evidence is the presence in the Trent River formation of five Haslam species. It should be noted that two Haslam species, *Pachydiscus newberryanus* and *Baculites chicoensis*, also persist into the Cedar District formation. The four species *Hoplitoplacenticeras vancouverense*, *Pachydiscus neevesi*, *P.* cf. *jacquoti*, and *Diplomoceras?* sp., which are peculiar to only the Cedar District formation, have all been recovered from a single outcrop on Sucia Island. Each of these latter forms has near relatives in Maestrichtian rocks elsewhere in the world, *H. vancouverense* being close to *H. plasticus-laevis* Paulcke of the Patagonian deposits, and the two *Pachydiscus* species predicting the less robust and more subtly ornamented pachydiscids of the Northumberland-Lambert faunizone and other Maestrichtian rocks. Of the three species the Cedar District has in common with the Trent River formation, *Schluteria selwyniana* is close to *S. diphylloides* Forbes of India and Japan, where it is typically found in Campanian rocks; it is probably synonymous with *S. crassa* van Hoepen from the South African 'Upper Senonian'. *Baculites chicoensis* occurs in Santonian rocks of the Californian Upper Cretaceous, and *Phylloceras* sp. indet. occurs widely in the two formations over most of both basins. *Baculites occidentalis* also appears in the Cedar District formation, but does not reach its maximum development until Maestrichtian time, when it flourished during the deposition of the Lambert shales farther north.

Other than those species common to the Cedar District and Haslam formations, the Trent River formation contains *Pachydiscus binodatus* and *P. perplicatus;* the abundant specimens of the latter form are probably allied to *P. newberryanus*, through the stratigraphically intermediate form *P. multisulcatus.* Both of these Trent River species are typical of the robust, coarsely ribbed pachydiscids of the Campanian Stage. *Ptychoceras vancouverense,* found only in the lower part of the Trent River shales, is close to *P. pseudo-galtinum* Yokoyama from 'Upper Senonian' rocks of Japan.

The Cedar District-Trent River fauna has considerable in common with that of the Haslam faunizone, and for this reason the two faunizones are considered to be younger and older parts of the same stage. It has already been pointed out how certain elements in the Haslam faunizone suggest that it might be Santonian rather than Campanian, but in view of the share that several species exercise in both faunizones, and the presence in the higher Cedar District-Trent River zone of such forms as *Hoplitoplacenticeras vancouverense, Ptychoceras vancouverense, Schluteria selwyniana,* and *Pachydiscus* cf. *jacquoti,* it is probable that the Cedar District-Trent River faunizone is part (and possibly the upper part) of the Campanian Stage. This probability is strengthened by the contiguity of the overlying Maestrichtian fauna in the Northumberland and Lambert formations.

The Northumberland-Lambert Faunizone

An entirely new group of ammonite species appears in this zone. *Baculites chicoensis, B. occidentalis,* and *Gaudryceras denmanense* are the only forms that survived from the lower beds, the *Baculites* species apparently with difficulty, for it is greatly reduced in numbers, and *Gaudryceras denmanense* with a sudden flourish.

The pachydiscids in this zone are, in general, more delicately sculptured than those in the Cedar District and Trent River formations, although *P.* cf. *jacquoti* displays shell characteristics that show it is closely related to *P. suciaensis.* The latter and *P. ootacodensis,* found in both the Lambert and Northumberland formations, are, respectively, representatives of the *P. egertoni-neubergicus* and *P. colligatus* groups from the Maestrichtian of Europe and India. *P. suciaensis* also resembles *P. arkansanus* Stephenson from the Nacatoch sand of Texas. The general tendency of these pachydiscids to lose their costation in advanced stages of maturity is typical in the Maestrichtian and is best exemplified by the *P. egertoni-neubergicus* group.

The smooth, commonly deeply involute phylloceratids and lytoceratids are abundant in the Lambert formation, but only *Pseudophyllites indra* has been found in the Northumberland. The latter formation has a sparse fauna, but fortunately it contains in addition to *Pseudophyllites* both species of *Pachydiscus*. *Neophylloceras*, *Phyllopachyceras*, and *Gaudryceras* are important members of the faunizone. *Gaudryceras* is restricted to the lower part of the Lambert formation; the only other representative of this genus in the Upper Cretaceous is a unique specimen from the top of the Qualicum formation. There is no record of it in the Cedar District or Trent River formations.

Many straight, hooked, and spirally coiled forms also occur in the Lambert formation. *Nostoceras hornbyense* is analogous to two of the Texas Maestrichtian forms, *N. hyatti* Stephenson and *N. helicinum* (Shumard). The latter species is also recorded from Angola by Haas. *Anisoceras cooperi* and *Diplomoceras notabile* are conspicuous elements in the fauna, and a single specimen of '*Hamites*' *obstrictus* has been recovered from Hornby Island. In view of this indicative fauna there is little reason to doubt the Maestrichtian age of the Northumberland-Lambert faunizone.

Résumé of Faunizones

A retrospective consideration of the several faunizones reveals: (1) the absence of such well-known Upper Cretaceous genera as *Scaphites*, *Placenticeras*, *Sphenodiscus*, *Pusozia*, and belemnoids. The numerous specimens of *Pachydiscus* recall the Upper Ammonite beds in the Japanese Upper Cretaceous; the two series have several species in common. In general the Vancouver Island ammonites are more closely related to those from Indo-Pacific countries nearest Vancouver Island than to those more distant. This would seem to indicate that the general position of the circum-Pacific coast line was much the same in Upper Cretaceous time as it is today; (2) the introduction of a large proportion of new species and the corresponding disappearance of part of the old fauna with each succeeding marine horizon, the greatest change occurring between the Cedar District-Trent River and Northumberland-Lambert faunizones (*See* Table I). The Haslam formation contains eleven species, and the Cedar District-Trent River formations contain seventeen species, ten of which are unknown in the Haslam. The Northumberland-Lambert formations contain fourteen ammonite species, of which only three appear in the Nanaimo and Comox basins prior to that stage; (3) that those species persisting from a lower to a higher faunizone have, in general, not only moved stratigraphically upwards, but also geographically northwards. This probably resulted from the northward overlap of the Upper Cretaceous sea, and is best exemplified by migrations of five Haslam species into the Comox basin when the sea flooded that area during Trent River time. To some extent the migratory process was repeated by the movement northward of *Baculites* in Northumberland-Lambert time; (4) that, in reality, stratigraphically equivalent formations have few species in common. For instance, of the seventeen species found in the Cedar District-Trent River fauna, only three, *Phylloceras* sp., *Schluteria selwyniana*, and *Baculites chicoensis*, are found in both basins. There is, however, a close similarity between some of the *Pachydiscus* species; (5) that *Pachydiscus*, which is the most abundant ammonite genus in the

European Scale Stage	Vancouver Island: Nanaimo Basin	Vancouver Island: Comox Basin	Southern Interior Plains of Canada (Russell, 1950, p.36): S.E. Alberta	Southern Interior Plains of Canada (Russell, 1950, p.36): S.W. Saskatchewan	Great Plains of U.S.A. (Stephenson, Reeside, 1938, p.1631)	Central Montana	East-Central Texas (Stephenson, 1941, p.9)	California (Anderson, 1943, p. 185)		Japan (Matumoto, 1943, p. 229)		India (Kossmat, 1895, p. 102)
Danian	Nanaimo group of this report		St. Mary River	Frenchman Battle Whitemud Eastend	Lance	Lance	Midway group	Moreno group	Garzas	Hetonian	Neohetonian	Aryalur group and Valudayur beds
Maestrichtian	Gabriola Northumberland	Hornby Spray Geoffrey		Bearpaw	Fox Hills sandstone; Pierre shale	Lennep sandstone; Bearpaw shale	Navarro group		Quinto Moreno		Paleohetonian	
Campanian	De Courcy Cedar District Protection Cranberry Newcastle Extension Haslam Benson	Lambert Denman Trent River Comox Qualicum	Blood Reserve Bearpaw; Oldman Foremost	Oldman Foremost		Judith River; Claggett shale; Eagle sandstone	Taylor marl	Panoche group	Los Gatos Stage; Joaquin Stage	Urakawan	Infrahetonian	Trichinopoly group
Santonian	?		Pakowki Milk River	Lea Park equivalents		Telegraph Creek	Austin chalk		Butte Stage		Neourakawan	
Coniacian			Alberta group	Alberta group	Niobrara	Colorado shale			Yolo Stage		Paleourakawan	
Turonian					Benton shale		Eagle Ford shale	Pioneer group	Bellavista Stage	Gyliakian	Neogyliakian	Utatur group
Cenomanian			?	?	Dakota sandstone ?	?	Wood Bine sandstone		Gaines Stage		Paleogyliakian	

The chart is not to scale with respect to either time or thickness of formations. It shows only the inferred position of the Vancouver Island formations relative to the divisions of the European time scale and to the formations or groups of other Upper Cretaceous rocks in North America and parts of Asia. For example, those formations below the De Courcy and Denman are believed to be Campanian in age, but they do not necessarily represent all of the Campanian Stage; they are approximately equivalent in time to the Taylor marl of east-central Texas. Sediments younger than the De Courcy and Denman formations represent part or all of the Maestrichtian Stage and are equivalent in time to rocks of the Navarro group of east-central Texas.

Shaded areas on the chart represent absence of strata as a result of either non-deposition or erosion. In the Comox basin of Vancouver Island an alternative interpretation, discussed in the text of this report and based solely on faunal evidence, would indicate that the Trent River formation may be correlative with the Haslam formation of the Nanaimo basin.

The sections chosen for comparison have been excerpted, without alteration, from the publications signified at the top of each column; the author has made no attempt to show changes that have been made in some of these stratigraphic sections since their publication. For instance, in the section of the Great Plains of the United States, it is doubtful if such a gap exists between the Pierre shale and the Niobrara formation.

Geological Survey of Canada

Figure 2. Tentative correlation of formations of the Nanaimo group, Vancouver Island, with other Upper Cretaceous rocks in North America, and elsewhere.

series, evolved rapidly during the time the series was accumulated and deposited, and that there was a tendency within the genus for the ornament to lose some of its coarseness; (6) that about 50 per cent of the ammonite species are indigenous to the area, but about one-half of these have close analogues in other Indo-Pacific faunas.

FAUNAL RELATIONSHIPS OF THE AMMONITES OF THE NANAIMO GROUP IN WESTERN NORTH AMERICA

(*See* Figure 2)

California

The Upper Chico has long been correlated with the Nanaimo group and both were considered to have a time range that coincided approximately with that of the Colorado of the western interior of the continent, but which did not include latest Cretaceous time. In recent years the California beds have been subdivided into three groups, the Pioneer, Panoche, and Moreno, and these groups into stages. The time interval covered by the Chico series extends from the Cenomanian to the close of the Cretaceous. The complete revision and correlation of the numerous separate areas and faunas of Upper Cretaceous rocks in California have not been completed, but a brief report by Anderson (1943) indicates the major faunizones and zone fossils.

Pachydiscus newberryanus is reported from the Yolo (Coniacian) stage, where it is associated with *Inoceramus* aff. *undulatoplicatus* Roemer and *I.* aff. *digitatus* (Sowerby). This dating is considerably earlier than that of *P. newberryanus* and *I.* cf. *schmidti* of the Haslam and Cedar District-Trent River faunas, but in view of the present revision of the former species it does not appear feasible to attach too much significance to the differences in range. *Baculites chicoensis* is similarly found at a stage lower in California, the Butte (Santonian) stage, but in the Upper Cretaceous Series of Vancouver Island it ranges through the Campanian into the Maestrichtian Stage of the Northumberland-Lambert formations. In the Los Gatos (upper Campanian) stage, with which the Cedar District-Trent River faunizone is equivalent, there are few species in common but several analogous forms; *Pachydiscus catarinae* is not unlike *P. perplicatus*, and *Bostrychoceras* is known in both zones. *'Hamites' vancouverensis* Gabb and *Ptychoceras vancouverensis* Whiteaves are not congeneric. *Nemodon vancouverensis* Meek is common to both areas, but on Vancouver Island it ranges down to the upper part of the Haslam faunizone and may even extend upward into the Northumberland-Lambert. A *Nostoceras* sp. is reported from the Los Gatos, but this genus, in the Nanaimo group of the Comox basin, is restricted to the uppermost faunizone.

The Moreno group of California, which corresponds to the Northumberland-Lambert faunizone farther north, contains *Baculites occidentalis*, *Pachydiscus ootacodensis*, and *Diplomoceras* sp., the first two of which are found in the Lambert formation; *Diplomoceras* spp. are associated with these forms in the same formation. *Bostrychoceras* and *Solenoceras* are not known at this late stage in the Canadian section.

The Nanaimo group lacks such genera as *Placenticeras*, *Mortoniceras*, and *Submortoniceras* and, on the other hand, *Epigoniceras*, *Pseudophyllites*, *Phyllopachyceras*, and *Hauericeras* do not appear to be represented in the California beds. With the publication of additional descriptions and illustrations of the California fauna it is probable that species of *Desmoceras*, *Schluteria*, *Bostrychoceras*, *Nostoceras*, '*Hamites*', *Anisoceras*, and *Diplomoceras* in the two series may show much closer affiliation than heretofore known. On the basis of the current data it is concluded that the Vancouver Island Upper Cretaceous Series is equivalent to that part of the Chico series including the upper half of the Panoche and Moreno groups.

Western Interior and Gulf Region

There appears to have been no connection during Upper Cretaceous time between the epicontinental seas that covered the western interior and southern gulf regions of North America and the small, narrow basins that lay immediately inside the western border of the continent. With the exception of representative species of *Baculites*, *Pachydiscus*, *Bostrychoceras*, *Nostoceras*, and *Ptychoceras*, profound differences in the constitution of the Upper Cretaceous ammonite faunas exist east and west of the North American Cordillera. Even the distinctions between the faunas of the western interior and the Atlantic and Gulf coastal plain are considerable, although Stephenson and Reeside believe the "paleontologic data available indicate communication between the Gulf and inland seas during most of Upper Cretaceous time . . . . . ." (1938, p. 1630).

Despite the lack of species in common, the Texas and Vancouver Island measures contain ammonite genera that reflect the stratigraphic equivalency of the Vancouver Island Upper Cretaceous Series to the Taylor marl and Navarro group of east-central Texas. The lower of the two Texan groups contains analogues of several Haslam and Trent River forms, among them *Bostrychoceras* aff. *polyplocum*, *Pseudoschloenbachia chispaensis*, *Baculites ovatus* Say, and *Pachydiscus* aff. *wittekindi* Schlüter. *Ptychoceras* and *Hoplitoplacenticeras* are also represented in the Taylor marl. The Haslam pelecypod *Exogyra parasitica* is probably of the group *E. ponderosa* Roemer, which is characteristic of the lower Texan zone. The correlation of the Navarro group with the Northumberland-Lambert and younger formations is illustrated by such close species as *Nostoceras helicinum* and *N. hornbyense*, *Pachydiscus arkansanus* and *P. suciaensis*, and *Baculites undatus* Stephenson and *B. occidentalis*. The smooth or delicately striate phylloceratids and lytoceratids of the Vancouver Island fauna are not present in Texas, whereas *Placenticeras*, *Parapuzosia*, *Prionocyclus*, *Sphenodiscus*, and *Mortoniceras* are prominent elements in the Texas section and unknown on Vancouver Island.

The problem of correlation with the Upper Cretaceous rocks of the western interior of North America, and particularly with the western interior of Canada, on the basis of the ammonite fauna is hazardous, for there are no species and extremely few genera in common between this vast area and Vancouver Island. *Pseudophyllites*, *Epigoniceras*, *Phyllopachyceras*, *Gaudryceras*, and *Hauericeras* apparently did not live in the epicontinental seas of North America, and the typical plains genera, *Scaphites*, *Acanthoscaphites*, *Discoscaphites*, *Sphenodiscus*, and *Placenti-*

ceras, had no representatives on the Canadian west coast. *Baculites* is the only ammonite that occurs abundantly in the two separate regions, but *Pachydiscus*, *Bostrychoceras*, *Nostoceras*, and forms with hamitoid coiling, which are a conspicuous part of the Nanaimo and Comox fauna, are relatively rare in the interior continent. Future study of other molluscs, in particular *Inoceramus*, may contribute more explicit basis for correlation. For example, Williams and Dyer (1930) record *I. vancouverensis* Shumard from the higher beds of the Bearpaw formation on the north slope of Cypress Hills; Whiteaves found this species to be restricted below the Northumberland-Lambert faunizone. Thus become apparent the numerous difficulties in applying, through the medium of the ammonite faunas, a direct correlation between the Upper Cretaceous Series of the western interior of Canada and Vancouver Island. In lieu of a common fauna, the stratigraphical correlation of the two regions is best made via the Texas Upper Cretaceous.

Stephenson and Reeside (1938) have demonstrated that the Taylor marl and Navarro group of east-central Texas are equivalent to post-Colorado and pre-Lance rocks of the United States Interior Plains, which have, in turn, stratigraphic equivalents in west-central Canada. In the latter region, the problem of establishing a generalized Upper Cretaceous section is made difficult by the plurality of localized formations and the continuous lateral and vertical variation of the lithology. In addition, the marked paucity of short-ranging fossil species discourages attempts to distinguish stages in these Upper Cretaceous rocks equivalent to those of the European scale. It is generally agreed, however, that in the southern Interior Plains of Canada, that part of the section equivalent to post-Colorado rocks of the United States embraces strata above the Alberta group. By means of such circuitous methods of correlation it becomes evident that the Upper Cretaceous Series on Vancouver Island is stratigraphically equal to formations that in southern Alberta range from the Milk River into the St. Mary River and in southern Saskatchewan from the Lea Park into the Eastend. The Milk River formation has been traced into the Eagle sandstone of Montana and is probably lower Campanian in age. Russell and Landes (1940) showed that the Bearpaw formation, because it contains *Acanthoscaphites nodosus* (Owen), as well as numerous varieties of that species, is related in age to the upper part of the European Campanian; Furnival (1946) is of the same opinion. Stephenson and Reeside (1938) consider the Bearpaw in Montana to be in part Maestrichtian, and it would appear that Russell (1950) is in agreement with the latter as he classifies the Eastend formation overlying the Bearpaw in southeastern Saskatchewan as equivalent to the Fox Hills sandstone (Upper Maestrichtian) of the United States. From this conflicting evidence it is deduced that the pre-Northumberland-Lambert rocks of the Nanaimo group can be tentatively correlated with those rocks of the southern Interior Plains of Canada that occupy a stratigraphic position between the top of the Alberta group and somewhere near the base of the St. Mary River formation. The Northumberland-Lambert and younger formations of the Nanaimo group would then relate to the greater part of the St. Mary River formation in southeastern Alberta, and to the upper part of the Bearpaw (including the Oxarart, Belanger, and Thelma members), the Eastend, and possibly the Whitemud, Battle, and Frenchman formations of southwestern Saskatchewan.

FAUNAL RELATIONSHIPS OF THE AMMONITES OF THE NANAIMO AND COMOX GROUPS IN REGIONS OTHER THAN NORTH AMERICA

(*See* Figure 2)

The West Indies

Upper Cretaceous molluscs from Jamaica, Haiti, and other West Indian Islands show, in general, a closer relationship to the Gulf Coast and Texas formations than to the Indo-Pacific fauna. Ages ranging from Cenomanian to Maestrichtian have been credited to the West Indian strata. On the basis of *Pachydiscus* cf. *gollevillensis* (d'Orbigny), *Epigoniceras* sp., and *Baculites* sp., reported from Jamaica by Spath, and *Pachydiscus woodringi* and *P. gardneri*, reported from Haiti by Reeside, it seems certain that at least Santonian and probably younger rocks are represented on these islands. Reeside's species are very close to *P. buckhami* n.sp. and *P. elkhornensis* n.sp. from the Haslam shales of the Nanaimo group.

South America

Upper Cretaceous rocks are reported from several parts of South America, but a close dating of them is not always possible. The Rio de Oro formation of Venezuela and Colombia is considered to be uppermost Cretaceous but may possibly include lowermost Tertiary rocks. Maestrichtian rocks are described from northern Brazil where *Pachydiscus* and *Sphenodiscus* species show affinity to the European Upper Cretaceous. Beds of the same age and older are also reported from Argentina. There is little if anything in common between these faunas and that of Vancouver Island. More similar South American faunas are to be found on the west coast and southern end of that continent where the Chilean and Patagonian Upper Cretaceous forms belong to the Indo-Pacific faunal province.

The Circum-Pacific Area

The Vancouver Island fauna is a part of the life that existed around the borders of the Pacific and Indian Oceans in Upper Cretaceous times. South along the eastern border of the Pacific, the Quiriquina beds off the Chilean coast, the Patagonian beds, and the Upper Cretaceous sedimentary rocks of Snow Hill and Seymour Island in Antarctica contain species, some of which are identical, and others analogous, with those of the Nanaimo group. *Neophylloceras, Guadryceras, Pachydiscus, Epigoniceras, Baculites, Hoplitoplacenticeras,* and *Anisoceras* are typically common genera, although each locale has a more or less distinctive fauna and not all of these forms are represented in each area. The occurrence of a large number of *Hoplitoplacenticeras* specimens in the Patagonian sequence is a distinguishing feature that led Paulcke to compare the series with that of northern Europe and to suggest that Patagonia may have had an Atlantic connection that did not affect other parts of the Pacific area. The Seymour Island and Snow Hill fauna have several species in common with that of Vancouver Island, among them *Anisoceras cooperi*, but lack *Baculites* and *Ptychoceras*, which is surprising considering the generally universal distribution of these genera. The Chilean beds are classed as Upper Senonian by Steinmann and Wilckens, but Stephenson considers them equal to the Texan Navarro group. Kilian and Reboul date the Antarctica fauna from Cenomanian to 'Upper Senonian', but Wilckens, on the basis of pelecypods, believes they are entirely 'Upper Senonian' (i.e., Campanian and Maestrichtian). This extremely southern fauna is most closely related to that of New Zealand; the two have in common such genera as *Maorites, Madrasites,* and *Gunnarites,* which are unknown in North America.

The ammonites of the Japanese Upper Cretaceous are more closely related to those of Vancouver Island than are any others of the Indo-Pacific faunal province. They form a connecting link with the Aryalur and Valudayur fauna of India, and it is probably via Japan and India that the faunas of the southwestern Pacific and east African areas are related to those of the Nanaimo group. In addition to the common species *Epigoniceras epigonum, Hauericeras gardeni, Pachydiscus haradai,* and *'Hamites' obstrictus,* the Japanese deposits contain close analogues of Canadian forms, that is: *Neophylloceras subramosum* (Shimizu), *Gaudryceras tenuiliratum* Yabe, *Schluteria diphylloides, Pachydiscus subtililobatus* Jimbo, *P. naumanni* Yokoyama, *P. yokoyamai* Jimbo, *P.* aff. *egertoni* (Forbes), and *Bostrychoceras japonicum* Yabe. It is of interest that *Pseudophyllites indra* and *Phyllopachyceras forbesianum,* so common in other deposits of the same age, are not represented in the Japanese Cretaceous. Matumoto considers the Infrahetonaian and Paleohetonaian rocks to be respectively of Campanian and Maestrichtian age; these groups approximate the time range represented by the Vancouver Island series. Of the same age are the Aryalur and Valudayur beds of India, which contain *Phyllopachyceras forbesianum, Epigoniceras epigonum, Pseudophyllites indra, Diplomoceras? subcompressum, Pachydiscus ootacodensis,* and *Hauericeras gardeni* as well as numerous analogues of Canadian species. *Holcodiscus, Scaphites, Sphenodiscus,* and *Placenticeras* are an integral part of the Indian fauna that is unknown to Vancouver Island.

South Africa

The South African faunas in Natal, Pondoland, and Angola have been described by Woods, van Hoepen, Spath, and Haas. Spath determines the age of these African deposits to be principally Campanian-Maestrichtian. Two species, *Pseudophyllites indra* and *Hauericeras gardeni,* are in common with the Vancouver Island beds as well as analogous species of *Baculites, Pachydiscus, Pseudoschloenbachia, Nostoceras, Gaudryceras, Schluteria,* and *Neophylloceras.*

Europe

The European Upper Cretaceous fauna differs considerably from that of the Indo-Pacific area, and it is considered that, with the exception of restricted connections, the Upper Cretaceous basins in Europe were separate from those of the Indo-Pacific. Except for *Hauericeras gardeni,* no European species is found in the Vancouver Island series, but *Pachydiscus suciaensis* is clearly of the *P. egertoni-neubergicus* group that constitutes an important part of the European Maestrichtian. The large, commonly maturely smooth *P. colligatus* Binkhorst and *P. wittekindi* are represented by similar species in the Northumberland and Gabriola formations, and *Bostrychoceras polyplocum* has a close analogue in *B. elongatum. Belemnitella mucronata* (Schlotheim) is unknown on Vancouver Island.

INDEX TO LOCALITY NUMBERS

10. North bank of Browns River, 27 chains above junction with Puntledge River. Coll. A. F. Buckham, 1939.
12. Browns River, 3 chains above diversion dam. Coll. A. F. Buckham, 1939.
14. Trent River, 85½ chains at 230 degrees from junction with Bradley Creek. Coll. A. F. Buckham, 1939.
17. Puntledge River, 16 chains above CC(D) powerhouse. Coll. A. F. Buckham, 1939.
18. South bank of Puntledge River, 25 chains above powerhouse. Coll. A. F. Buckham, 1939.
19. South bank of Puntledge River, 26 chains at 27 degrees from powerhouse. Coll. A. F. Buckham, 1939.
20. Puntledge River, 43 chains at 193 degrees from junction of Puntledge and Browns Rivers. Coll. A. F. Buckham, 1939.
21. South bank of Puntledge River, 0 to 19 chains below powerhouse. Coll. A. F. Buckham, 1939.
23. Probably Trent River. Coll. A. F. Buckham, 1939.
104. Denman Island; middle of east side about 75 feet stratigraphically below the highest outcrop of Lambert shales. Coll. J. L. Usher, 1945, 1948.
107. Denman Island; 500 feet from lighthouse between lighthouse and government wharf on west side of island. Coll. J. L. Usher, 1945.
109. Hornby Island between Shingle Spit and Savoie's wharf. Coll. J. L. Usher, 1945, 1948.
110. Boulder Point, Hornby Island. Coll. J. L. Usher, 1945.
111. Phipps Point, Hornby Island. Coll. J. L. Usher, 1945.
112. Between Phipps Point and Manning Point, Hornby Island. Coll. J. L. Usher, 1945.
113. Manning Point, Hornby Island. Coll. J. L. Usher, 1945.
114. Between Manning Point and small stream 1,100 feet to the east, Hornby Island. Coll. J. L. Usher, 1945.
115. Between small stream of locality 114 and Boulder Point, Hornby Island. Coll. J. L. Usher, 1945.
118. Puntledge River; shale bank on south shore immediately below CC(D) powerhouse. Coll. J. L. Usher, 1945.
120. Puntledge River; directly across river from locality 118. Coll. J. L. Usher, 1945.
121. Puntledge River; south bank of river opposite lower end of small island downstream from mouth of Browns River. Coll. J. L. Usher, 1945.
122. Puntledge River; south bank opposite mouth of Browns River. Coll. J. L. Usher, 1945.
123. Puntledge River; north bank, 500 feet above hairpin curve upstream from CC(D) powerhouse. Coll. J. L. Usher, 1945.
124. Puntledge River; north bank, 600 feet above locality 123. Coll. J. L. Usher, 1945.
125. Puntledge River; between localities 121 and 122 on north bank of river. Coll. J. L. Usher, 1945.
127. Browns River; south bank at mouth. Coll. J. L. Usher, 1945.
128. Browns River; 300 feet upstream from mouth. Coll. J. L. Usher, 1945.
129. Browns River; 725 feet upstream from mouth. Coll. J. L. Usher, 1945.
134. Browns River; at small tributary entering Browns River from the south about 2,000 feet upstream from mouth of river. Coll. J. L. Usher, 1945.
135. Browns River; lip of 10-foot waterfall, 300 feet upstream from locality 134. Coll. J. L. Usher, 1945.
139. Browns River; first outcrop on north bank upstream from bridge crossing Browns River. Coll. J. L. Usher, 1945.
140. Browns River; 700 feet upstream from locality 139, on south bank. Coll. J. L. Usher, 1945.
141. Browns River; south bank, 420 feet below overflow outlet of diversion dam. Coll. J. L. Usher, 1945.
142. Browns River; north bank, opposite locality 141. Coll. J. L. Usher, 1945.
143. Browns River; road cut along river between overflow outlet and diversion dam. Coll. J. L. Usher, 1945.
144. Browns River; outcrop at diversion dam. Coll. J. L. Usher, 1945.
150. Trent River; 100 feet downstream from mouth of Bradley Creek. Coll. J. L. Usher, 1945.
151. Trent River, at foot of lower falls. Coll. J. L. Usher, 1945.
152. Trent River; immediately upstream from where former railroad spur crossed the river. Coll. J. L. Usher, 1945.

153. Trent River; immediately upstream from locality 152. Coll. J. L. Usher, 1945.
154. Trent River; 500 feet upstream from locality 153. Coll. J. L. Usher, 1945.
155. Trent River; outcrop at top of lower falls. Coll. J. L. Usher, 1945.
156. Trent River; south bank of river, at first bend above lower falls. Coll. J. L. Usher, 1945.
157. Trent River; second bend above lower falls. Coll. J. L. Usher, 1945.
158. Trent River; third bend above lower falls. Coll. J. L. Usher, 1945.
159. Trent River; fourth bend above lower falls. Coll. J. L. Usher, 1945.
160. Trent River; 800 feet upstream from locality 159. Coll. J. L. Usher, 1945.
161. Trent River; 130 feet upstream from locality 160. Coll. J. L. Usher, 1945.
162. Trent River; at point where former railroad spur crossed the river. Coll. J. L. Usher, 1945.
163. Tsable River; near mouth. Coll. J. L. Usher, 1945.
164. Tsable River; 1,000 feet upstream from bore-hole in river bank. Coll. J. L. Usher, 1945.
165. Tsable River; immediately upstream from locality 164. Coll. J. L. Usher, 1945.
166. Tsable River; hairpin bend downstream from contact of Trent River and Comox formations. Coll. J. L. Usher, 1945.
167. Tsable River; lowest 10 feet of Trent River formation. Coll. J. L. Usher, 1945.
168. Pearl Rock; small point just north of Arbutus Point, Northwest Bay. Coll. J. L. Usher, 1948.
170. Northwest Bay. Coll. J. L. Usher, 1948.
200. Nanoose Bay area; in cliff south of the end of a road leading to the shore between lots 53 and 66, north of Lanceville. Coll. J. L. Usher, 1945.
201. Nanoose Bay; on shore below locality 200. Coll. J. L. Usher, 1945.
204. Brannan Creek; where trail crosses stream a short distance upstream from division of distributaries. Coll. J. L. Usher, 1945.
205. Brannan Creek; 400 feet upstream from locality 204. Coll. J. L. Usher, 1945.
206. Brannan Creek; north bank, 100 feet upstream from locality 205. Coll. J. L. Usher, 1945.
208. Brannan Creek; first outcrop immediately below locality 209. Coll. J. L. Usher, 1945.
209. Brannan Creek; at foot of 8-foot cascade upstream from locality 205. Coll. J. L. Usher, 1945.
210. Brannan Creek; 300 feet upstream from locality 309. Coll. J. L. Usher, 1945.
213. Brannan Creek; downstream from locality 215, beyond hairpin bend of stream. Coll. J. L. Usher, 1945.
215. Brannan Creek; at foot of 50-foot waterfall downstream from where logging bridge crosses stream. Coll. J. L. Usher, 1945.
216. Brannan Creek; between logging bridge and crest of waterfall. Coll. J. L. Usher, 1945.
222. Nanaimo River; south bank at first bend downstream from Lake Trail bridge. Coll. J. L. Usher, 1945.
224. Nanaimo River; south bank between localities 222 and 225. Coll. J. L. Usher, 1945.
225. Nanaimo River; south bank opposite lower end of rocky island. Coll. J. L. Usher, 1945.
226. Nanaimo River; 300 feet upstream from former suspension cable. Coll. J. L. Usher, 1945.
227. Elkhorn Creek; where logging road to No. 8 mine crosses creek. Coll. J. L. Usher, 1945.
228. Elkhorn Creek; 150 feet upstream from locality 227. Coll. J. L. Usher, 1945.
229. Elkhorn Creek; 80 feet upstream from locality 228. Coll. J. L. Usher, 1945.
233. Elkhorn Creek; first outcrop below locality 227. Coll. J. L. Usher, 1945.
234. Elkhorn Creek; west bank, immediately below locality 233. Coll. J. L. Usher, 1945.
236. Elkhorn Creek; at sharp bend immediately above waterfall downstream from locality 234. Coll. J. L. Usher, 1945.
237. Elkhorn Creek; brink of second waterfall below locality 236. Coll. J. L. Usher, 1945.
238. Elkhorn Creek; immediately below locality 237. Coll. J. L. Usher, 1945.
239. Elkhorn Creek; 200 feet downstream from locality 238. Coll. J. L. Usher, 1945.
240. Elkhorn Creek; east bank immediately downstream from locality 239. Coll. J. L. Usher, 1945.
242. Haslam Creek; north fork, at the top of a 2-step waterfall immediately upstream from the mouth. Coll. J. L. Usher, 1948.
244. Haslam Creek; north fork, third waterfall above mouth. Coll. J. L. Usher, 1948.
245. Haslam Creek; north bank immediately downstream from mouth of north fork. Coll. J. L. Usher, 1948.

246. Haslam Creek; upstream from mouth of north fork and logging bridge at point where small tributary cascades into main stream. Coll. J. L. Usher, 1948.
251. Haslam Creek; south fork, upstream from high logging bridge and 200 feet upstream from where the second tributary enters the south fork. Coll. J. L. Usher, 1948.
252. Haslam Creek; south fork, 1,000 feet upstream from where second tributary enters south fork. Coll. J. L. Usher, 1948.
254. Haslam Creek; south fork, 500 feet upstream from locality 252. Coll. J. L. Usher, 1948.
259. Gabriola Island, about middle of south shore opposite Mudge Island near top of lower shale member of Northumberland formation. Coll. J. L. Usher, 1948.
260. Gabriola Island; opposite the southeast end of Mudge Island and about 1 mile east of locality 259. Coll. J. L. Usher, 1948.
264. Mayne Island; east shore, opposite the north end of Curlew Island. Coll. J. L. Usher, 1948.
266. Mayne Island; head of Campbell Bay. Coll. J. L. Usher, 1948.
268. Saturna Island; south shore at sea-level about 2,000 feet west of Murder Point. Coll. J. L. Usher, 1948.
271. Saturna Island; south shore, immediately east of Murder Point. Coll. J. L. Usher, 1948.
273. North Pender Island; 50 feet below the top of the Cedar District shales, north of Hope Bay. Coll. J. L. Usher, 1948.
274. North Pender Island; about ½ mile north of Hope Bay; stratigraphically below locality 273. Coll. J. L. Usher, 1948.
275. North Pender Island; southwest corner on a small neck of land ½ mile southeast of Moatt Point. Coll. J. L. Usher, 1948.
276. North Pender Island; about 1,500 feet southeast of locality 275. Coll. J. L. Usher, 1948.
277. North Pender Island; about 800 feet southeast of locality 276. Coll. J. L. Usher, 1948.
281. North Pender Island; inside the entrance to Bedwell Harbour in a small bay due west of Hay Point. Coll. J. L. Usher, 1948.
283. Saltspring Island; west side, 500 feet north of small stream that enters sea north of Erskine Point. Coll. J. L. Usher, 1948.
284-A. Saltspring Island; Fernwood Point. Coll. J. L. Usher, 1948.
284. Saltspring Island; northeast shore opposite Atkins Reef, 1½ miles south of Walker Hook. Coll. J. L. Usher, 1948.
285. Saltspring Island; outer Ganges Harbour about ½ mile west of Yeo Point. Coll. J. L. Usher, 1948.
290. Sucia Island; Washington, U.S.A. Coll. J. L. Usher, 1948.
500. Hornby Island; northwest side. Coll. W. Harvey, 1893.
501. Hornby Island; northwest side. Coll. J. Richardson, 1872.
502. Hornby Island; north side. Coll. W. Harvey, 1895.
503. Hornby Island; northwest side. Coll. E. W. Robbins, 1895.
504. Comox River (Puntledge River). Coll. J. B. Bennett, 1896.
505. Comox River (Puntledge River). Coll. F. Newcombe, 1892.
506. Comox River (Puntledge River). Coll. W. Harvey, 1891
507. Comox River (Puntledge River). Coll. W. Harvey, 1895.
508. Comox River (Puntledge River). Coll. W. Harvey, 1893.
509. Puntledge River. Coll. W. Devereux, 1890.
510. Browns River. Coll. J. Richardson, 1872.
511. Trent River. Coll. J. Richardson, 1872.
512. Trent River, above "The Falls". Coll. J. Richardson, 1872.
513. Trent River, below "The Falls". Coll. J. Richardson, 1872.
514. Bradley Creek. Coll. J. Richardson, 1872.
515. Denman Island; ½ mile south of Village Point. Coll. W. Harvey, 1896.
516. Denman Island; middle of east side. Coll. W. Harvey, 1893.
517. Norris Rock, near Hornby Island. Coll. J. Richardson, 1871.
518. Brannan Creek. Coll. Miss Jones, 1928.
519. Brannan Creek. Coll. Rev. G. W. Taylor.
520. Northwest Bay. Coll. J. Richardson, 1873.
521. Northwest Bay. Coll. W. Harvey, 1891.
522. Nanaimo River; 10 to 12 miles upstream. Coll. W. Harvey, 1891.
523. Nanaimo River; 10 miles from mouth. Coll. A. Raper, 1893.
524. Maple Bay. Coll. J. Richardson, 1875.
525. James Island; north of Victoria. Coll. F. Neaves, 1888.
526. Sucia Island. Coll. J. Richardson, 1874.
527. Komooks (Comox), Vancouver's Island. Coll. G. Gibbs, prior to 1861.

DESCRIPTION OF SPECIES

Family, PHYLLOCERATIDAE

Genus, *Neophylloceras* Shimizu, 1935, emend. Spath, 1939

Genotype, *Phylloceras subramosum* Shimizu, 1935

1935. Shimizu, S.: Jour. Shanghai Inst., sec. II, vol. 1, p. 193.
1939. Spath, L. F.: Geol. Mag., vol. LXXVI, p. 453.
1942. Matumoto, T.: Proc. Imp. Acad. Tokyo, vol. XVIII, No. 133, p. 674.

In this phylloceratid genus of Senonian age, the suture is more complicated and more finely and deeply cut than that of *Phylloceras* s.s.; the phylloidal endings of saddles are almost lost in ephebic stages; and ontogenetic development is similar to *Phylloceras* s.s.

In his reorganization of the genus *Neophylloceras*, Spath concludes that Shimizu intended the species *Phylloceras subramosum* Shimizu to be the genotype. The lack of a proper definition made invalid Shimizu's original designation of the species, but this default was in part relieved by Spath, and later by Matumoto. The latter author, for what appears to be an obvious but unelaborated reason, replaced the genotype *Neophylloceras subramosum* with Meek's species *N. ramosum*. In the light of present knowledge, it is concluded that Spath's definition has priority, and *N. subramosum* Shimizu emend Spath, 1939, is herein accepted as the genotype of *Neophylloceras*.

In addition to having a more finely incised suture line and in lacking strongly phylloidal endings of the saddles, *Neophylloceras* s.s. differs from *Phylloceras* s.s. in being more compressed; the whorl width of the former is about 30 per cent of the shell diameter, whereas in the latter this ratio is 34 to 37 per cent. Compared stratigraphically, *Neophylloceras* is typically a Coniacian or later form, whereas *Phylloceras* seldom extends beyond the Turonian. Possibly the Senonian neophylloceratids are descendants of the Albian *P. velledae* group and the Neocomian *P. thetys* (d'Orbigny). The relationships of the Senonian forms to one another are not presently clarified but may be morphologically serial species, as Matumoto suggests for *N. compressum* and *N. subramosum*. The Canadian species indicate a close connection with the Indo-Pacific and South African *N. subramosum* (Shimizu), *N. compressum* Matumoto, *N. hetonaiense* Matumoto, *N. nera* (Forbes), *N. woodsi* (van Hoepen), and *N. umzambiense* (van Hoepen).

Neophylloceras ramosum Meek, 1857

Plate I, figures 4, 5

1857. *Ammonites (Scaphites?) ramosus* Meek, Trans. Albany Inst., vol. IV, p. 45.
1876. *Phylloceras ramosum* Meek, Bull. U.S. Geol. Geog. Surv. Terr., vol. III, No. 4, p. 371, Pl. V, figs. 1, 1a, 1b.
1879. *Ammonites velledae* Michelin. Whiteaves, Mesozoic Fossils, vol. I, pt. II, p. 103.
1895. *Phylloceras ramosum* Meek. Whiteaves, Trans. Roy. Soc., Canada, 2nd ser., vol. I, sec. IV, p. 128.
1903. *Phylloceras ramosum* Meek. Whiteaves, Mesozoic Fossils, vol. I, pt. V, p. 327.
1920. *Phylloceras ramosum* Meek. Gignoux, Contr. Etude Céph. Paléocrét. S.E. Mém. Expl. Cartegéol., France, p. 93 (table).
1921. *Phylloceras ramosum* Meek. Spath, Ann. Durban Mus., vol. III, pt. 2, p. 40.

1927. *Phylloceras* cf. *ramosum* Meek. Yabe, Tohuku Imp. Univ., Sci. Rpts., 2nd ser., vol. XI, p. 31(5), Pl. IX (VII), figs. 30, 36.
1928. *Phylloceras* ex aff. *ramosum* Meek. Collignon, Ann. Paléont., vol. XVII, p. 7 (1943), Pl. I, figs. 2-4.
1942. *Neophylloceras ramosum* (Meek). Matumoto, Proc. Imp. Acad. Tokyo, vol. XVIII, No. 133, p. 674.

Dimensions. Specimen No. 5811: 47; 58; 30; 6.

A plaster cast of the holotype shows clearly the numerous, crowded, narrow ribs, which in the earlier stages are reduced to the size of striæ. The ribs are much more flexuous than described and figured by Meek. They rise out of the umbilicus with a slight forward inclination, and extend thus along about one-third of the flank. Here they bend forward even more, and on the middle third of the flank they trace a well-marked sigmoidal curve, bending first forward, then backward, and again slightly forward. Thence to and across the venter they are inclined, almost imperceptibly, forward. On a specimen 60 mm. in diameter, 2 ribs coalesce into a wider-than-average, but flat, rib; 5 such fusions occur on this shell.

The centres of the flanks are strongly flattened, the lower mid-flanks being even somewhat depressed so that the umbilical border appears to be slightly raised. The umbilicus is narrow and deep, with short steep walls and a flaring umbilical shoulder.

The suture line is more deeply cut than shown by Meek; the main axes of the lobes are extremely narrow and vein-like.

Neophylloceras ramosum differs from *N. lambertense* n.sp. in having more sinuous ribs, a deeper umbilicus, and more flattened flanks. *N. subramosum* may be synonymous with the Canadian species, but it is at present impossible to make a definite comparison; the ribs on the Japanese species appear to be more inclined, particularly at the umbilical border. Kossmat's *N. nera* is close to *N. ramosum*, but is less compressed, the ribbing is less sinuous, and 5 to 7 sulci radiate from the umbilicus. Spath thinks the two forms may belong to the same species, but *N. ramosum* lacks the sulci and is more compressed in mid-flank. *N. umzambiense* has the strong sigmoidal ribs of *N. ramosum*, but the whorls of van Hoepen's species are much more rounded.

Occurrence. Upper Lambert formation, localities 109, 112, 113, 502.

Types. Holotype, U.S.N.M. Cat. No. 12451, "Komooks, Vancouver's Island" (probably Lambert formation, Hornby Island, British Columbia); plesiotype, G.S.C. No. 5811, locality 502, upper Lambert formation, Hornby Island, British Columbia; plastotype, G.S.C. No. 10068, of the above holotype.

Neophylloceras lambertense n.sp.

Plate I, figures 1-3

1895. *Phylloceras ramosum* Meek. Steinmann, Neues Jahrb. f. Min., Beil.-Bd. X, p. 80, Pl. V, figs. 4a, 4b.
1903. *(pro parte) Phylloceras ramosum* Meek. Whiteaves, Mesozoic Fossils, vol. I, pt. V, p. 327.
1904. *Phylloceras ramosum* Meek. Wilckens, Neues Jahrb. f. Min., Beil.-Bd. XVIII, p. 187.
1908. *Phylloceras (Schluteria?) ramosum* Meek. Kilian and Reboul, Schwed. Südpolar-Exped., Geol. u. Pal., vol. III, pt. 6, p. 9, Pl. I, figs. 3a, 3b.

Dimensions. Specimen No. 5811a: 74; 60; 30; 5.

Shell discoidal, narrowly umbilicated; whorls strongly involute, high and narrow, greatest thickness at lower mid-flank; venter strongly convex, narrowly rounded; flanks nearly flat, converging gradually and smoothly towards venter and sloping gradually into umbilicus; umbilicus covered, characteristics unknown.

Ornament consisting of numerous, fine, narrow ribs or subcostæ on outer half of whorls, becoming much finer and striæ-like towards umbilicus. On inner half of whorl, ribs trace a shallow sigmoidal curve, being directed posteriorly on the umbilical shoulder, thence swinging slightly forward on the lower flank; ribs straighten at mid-flanks, passing directly to and across venter. Sinuosity of ribbing is so faint as to be undetected at first glance. Faint, shallow, radial depressions begin at umbilical shoulder, paralleling the ribbing on lower flanks, and disappear before reaching mid-flanks. Six such depressions occur on outer whorl of holotype; on the outer flanks, the continuation of the depressions is marked by 6, wider-than-average inter-rib spaces.

Suture line deeply cut, distinctly phylloid in early whorls, this aspect beginning to disappear in outermost whorl. EL[1] very short; L_1 large, unequally trifid, the outer branch very large, so that S_1 appears to overhang L_1; L_2 indistinctly trifid; auxiliary lobes bifid; main stems of lobes narrow and branch-like. Saddles bifid, with slightly expanded endings; S_1 the largest, S_2 and s_1 progressively smaller; remaining auxiliary saddles decreasing rapidly in size to umbilicus; 13 saddles present on a radius of 40 mm.

Specimens completely septate; no living chamber preserved.

Whiteaves identified all of the Vancouver Island phylloceratids as *Phylloceras ramosum* Meek, which is distinguished from the present species by its more sinuous ribbing, peculiar depression-like flattening of the flanks, and lack of radiating sulci-like depressions on the inner flanks.

The South American and Antarctic *P. ramosum* are conspecific with *Neophylloceras lambertense.* It is to be noted in Steinmann's figure of the suture line (1895, p. 80, fig. 6) that a line touching the posterior ends of the auxiliary lobes is concave forward. This is reproduced exactly in the Hornby Island specimens, and is a significant difference from van Hoepen's *N. woodsi.* The resemblance to the latter form is, however, otherwise striking, there being slight differences in the trend of the ribs at the umbilicus. *N. woodsi* may have a deeper umbilicus and has a steeper umbilical shoulder and more conspicuous radiating sulci. The two species may be synonymous.

N. subramosum is close to the present species, the outstanding dissimilarity being that the Japanese species has much more sinuous ribs, less compressed whorls, and lacks radiating sulci.

The Indian *N. nera* is less compressed, has more sinuous ribs, and well defined, longer, radiating sulci.

Occurrence. Upper Lambert formation, locality 502.

Types. Holotype, G.S.C. No. 5811a, locality 502, upper Lambert formation, Hornby Island, British Columbia; paratype, G.S.C. No. 10011, locality 502, upper Lambert formation, Hornby Island, British Columbia.

[1] Abbreviations for sutural elements used in this report are: EL=external lobe; L_1=first or superior lateral lobe; L_2=second or inferior lateral lobe; l_1, l_2, l_3, etc.=first, second, and third, etc., auxiliary lobes; S_1=first lateral saddle; S_2=second lateral saddle; s_1, s_2, s_3, etc.=first, second, and third auxiliary saddles.

Phylloceras sp. indet.

Several fragments and impressions of *Phylloceras*-like ammonites have been recovered from the shale formations, other than the Lambert formation of the Nanaimo and Comox basins. Specific determination of these forms is rendered impossible by their poor preservation, but one fragment from the Trent River shales outcropping on Browns River typifies the uniform ornament and the generally large size of the specimens. The suture line on this specimen (G.S.C. No. 10012) is not visible; the ribs rise from a narrow, open umbilicus and sweep backwards to the venter in a broad, convex arc; they cross the venter at right angles to the siphonal line. The flanks are flattened and meet the umbilical shoulder in a smooth but well-rounded contour. The specimen must have measured 5 inches in diameter when complete, and the whorl thickness is estimated to have been at least one-third of the diameter.

Occurrence. Haslam formation, locality 226; Cedar District formation, localities 271, 274; Trent River formation, localities 10, 127, 164.

Type. Plesiotype, G.S.C. No. 10012, locality 10, Trent River formation, Browns River, Vancouver Island, British Columbia.

Genus, *Phyllopachyceras* Spath, 1925

Genotype, *Ammonites infundibulum* d'Orbigny, 1840

1840. d'Orbigny, A.: Pal. franç., Terr. crét., vol. I, p. 131.
1850. d'Orbigny, A.: Prodr. de Paléont., vol. II, p. 213.
1895. Kossmat, A.: Beitr. z. Pal. u. Geol. Österr.-Ung., vol. IX, p. 110.
1920. Gignoux, M.: Mém. Expl. Cartegéol. France, pp. 97-100.
1925. Spath, L. F.: Mus. d'Hist. Nat. Marseilles, Ann., vol. XX, p. 101.

In this genus, the whorls are rounded, deeply or completely involute; the shell is smooth, with fine striæ and growth lines, or it has obtuse ribs passing over the venter; striæ and ribs curve forward. The suture consists of numerous lobes and saddles passing in a straight line from venter to umbilicus; EL is the deepest, L_1 and L_2 trifid, and the auxiliary lobes are irregular, the saddles are bifid, phylloid, decreasing rapidly in size to the umbilicus.

This description of *Phyllopachyceras* is more inclusive than was originally designated by Spath who created the genus because of the distinctive ornament of *Phylloceras infundibulum* (d'Orbigny). The close relationship of this species with *P. rouyanum* (d'Orbigny), *P. ezoense* Yokoyama, and *P. forbesianum* (d'Orbigny) insists on the inclusion of all of them in *Phyllopachyceras*.

Phyllopachyceras forbesianum (d'Orbigny), 1850

Plate II, figures 1-5; Plate XXXI, figures 11, 12

1845. *Ammonites rouyanus* d'Orbigny. Forbes, Trans. Geol. Soc. London, 2nd ser., vol. VII, p. 108, Pl. VIII, fig. 6.
1850. *Ammonites forbesianum* d'Orbigny, Prodr. de Paléont., vol. II, p. 213.
1865. *Ammonites rouyanus* d'Orbigny. Stoliczka, Cret. Rocks S. India, Pal. Indica, vol. I, p. 117, Pl. LIX, figs. 5, 5a, 6, 7.
1895. *Phylloceras forbesianum* (d'Orbigny). Kossmat, Beitr. z. Pal. u. Geol. Österr.-Ung., vol. IX, p. 109, Pl. XV (I), figs. 1a-1d.
1898. *Phylloceras forbesianum* (d'Orbigny). Kossmat, op. cit., vol. XI, p. 124.

1903. *Phylloceras forbesianum* (d'Orbigny). Whiteaves, Mesozoic Fossils, vol. I, pt. V, p. 328.
1907. *Phylloceras forbesianum* (d'Orbigny). Pervinquière, Etudes de Pal. Tunis., I, Céphs. des Terr. second., p. 57, Pl. III, figs. 12a, 12b.
1920. *Phylloceras forbesianum* (d'Orbigny). Gignoux, Contrib. Etude Céph. Paléocrét. S.E. France, Mém. Expl. Carteg ol. France, pp. 97-100.
1926. *Phylloceras forbesianum* (d'Orbigny). Marshall, Trans. N. Zealand Inst., vol. 56, p. 136, Pl. 19, fig. 6; Pl. 27, figs. 3, 4.
1938. *Phyllopachyceras forbesianum* (d'Orbigny). Roman, Ammon. Jur. et Crét., pp. 17 and 26.
1942. *Phyllopachyceras forbesianum* (d'Orbigny). Matumoto, Proc. Imp. Acad. Tokyo, vol. XVIII, No. 133, p. 674.

Dimensions. Specimen No. 10014: 17; 60; 50; 3; No. 5812: 53; 60; 50; 3; No. 10013: 73; 58; 50; 4.

Shell inflated, deeply involute, outer whorl embracing almost all of inner whorls; umbilicus very narrow, no more than 4 per cent of shell diameter. Whorls smoothly rounded, no nodes, ribs, or angulations; youthful stage, circular in cross-section, smoothly rounded from venter to umbilicus, greatest width one-third to one-half the way up the inner flanks; mature stage, oval in cross-section, slightly higher than wide, greatest width one-third of the way up the inner flank. Inner third of the flanks concave, flattened, sloping from line of maximum whorl width into umbilicus.

Ornament of extremely fine, crowded, radiating, curved striæ arising radially from umbilicus, swinging forward in a broad arc to the line of maximum whorl width, where they straighten slightly and then pass over the outer two-thirds of the flanks and across the venter in a faint forward arc. Youthful specimens carry 12 to 15 striæ per mm. and at regular intervals of about 1 mm., faint, impressed lines trace the same pattern direction as the striæ. On adult specimens, striæ are 0·8 mm., and impressed lines 4 to 5 mm. apart on the venter; in addition, very low, faint, rib-like undulations, 4 to 5 mm. apart, cross the outer flanks and venter. Spiral striæ, 0·5 to 1 mm. apart, cover the mature outer whorl; aided by the radial striæ, they describe a finely reticulate pattern on the shell. Where the shell is missing the cast is entirely smooth.

Suture line deeply cut; saddles with distinct, inflated, phylloid endings; lobe endings sharp and serrated. EL deep, with a single, median siphonal saddle; L_1 as deep as EL, trifid, with a broad stem; L_2 shorter, broad, asymmetrically trifid; 5 auxiliary lobes simpler, decreasing regularly in size to umbilicus. S, large, bifid, with lobate endings; S_2 nearly as large as S_1, bifid; 5 auxiliary saddles, the outermost two larger than the others and bifid. Even at a diameter of 7 to 8 mm. as many as 5 auxiliary lobes and 5 auxiliary saddles are found.

The suture line is very close to that of *P. rouyanum* as shown by d'Orbigny (1840, Pl. 110, fig. 5) and to that of *P. forbesianum* as shown by Marshall (1926, Pl. 19, fig. 6) except that both species have more auxiliary elements than the Canadian specimens. The closest comparison in sutural aspects is with that shown by Kossmat (1895, Pl. 15, figs. 1c, 1d).

The species *Ammonites forbesianum* was created by d'Orbigny for the Indian ammonite that Forbes had classified as *A. rouyanus*. d'Orbigny first described *A. rouyanus* and *A. infundibulum* as separate species, but later concluded that *A. rouyanus* was a younger stage of *A. infundibulum*, and that the Indian species was distinct. Kossmat agreed with his view, but upon seeing specimens from Vancouver Island, concluded that the Indian forms belonged to two species, *Phylloceras whiteavesi*, from the Cenomanian, and *P. forbesianum*, from the 'Upper Senonian'. Meanwhile the Japanese species *P. ezoense* Yokoyama, 1890, was described as having smooth inner whorls, at which stage it resembled *P. forbesianum*, and ribbed outer whorls as in *P. infundibulum*. Pervinquière (1907) and Matumoto (1942) have since shown that the Japanese species is similar to, but distinct from, the Indian and Canadian species.

Gignoux (1920, p. 98), noting that Kilian, Haug, Sayn, and Pervinquière treated *P. rouyanum* and *P. infundibulum* as distinct species, divided this group of Lower Cretaceous phylloceratids into two series; one, to which *P. infundibulum* belongs, represented by narrow shells with radiating ribs, and the other, to which *P. rouyanum* belongs, represented by more inflated shells with circular or oval cross-section and having a smooth, striated shell; the latter series gave rise to the Upper Cretaceous *P. forbesianum*.

Spath created the new genus *Phyllopachyceras* for *P. infundibulum*, "because of its very distinctive ornamentation this species may be chosen as the type of a new genus *Phyllopachyceras*, gen. nov. (genotype: *Amm. infundibulum*, d'Orbigny . . . . . .)" (1925, free translation p. 101). Roman accepted the new genus and added to its description: "Forms with rounded section and narrow and deep umbilicus, ornamented with obtuse ribs passing across the outer region and stretching toward the umbilicus, between the major ribs; other ribs alternate with these and occupy only the outer quarter of the whorl" (Roman, 1938, free translation p. 17). Although this author makes no mention of smooth shells, he suggests that *P. forbesianum* d'Orbigny be added to the group of *P. infundibulum*, and notes that it is one of the last true phylloceratids. In view of the close connection of *P. rouyanum* with both *P. infundibulum* and *P. forbesianum*, the genus *Phyllopachyceras* is, herein, considered to include such smooth forms as *P. rouyanum* and *P. forbesianum* as well as *P. ezoense*.

Occurrence. Upper Lambert formation, localities 112, 113, 502.

Types. Plesiotypes, G.S.C. Nos. 5812, locality 502; 10013, 10014, locality 112; upper Lambert formation, Hornby Island, British Columbia.

Family, LYTOCERATIDAE

Genus, *Epigoniceras* Spath, 1925

Genotype, *Lytoceras (Tetragonites) epigonum* Kossmat, 1895

1895. Kossmat, A.: Beitr. z. Pal. u. Geol. Österr.-Ung., vol. IX, p. 135.
1925. Spath, L. F.: Geol. Mag., vol. LXII, p. 29.
1942. Matumoto, T.: Proc. Imp. Acad. Tokyo, vol. XVIII, No. 132, p. 671.

Epigoniceras is mainly a Senonian lytoceratid, with a rounded whorl, a smooth shell, and a suture line in which the auxiliary elements decrease rapidly in an oblique direction into the umbilicus; the internal suture has two large saddles.

Epigoniceras epigonum (Kossmat), 1895

Plate II, figures 6, 7; Plate III, figure 1; Plate XXXI, figure 13

1865. *(pro parte) Ammonites timotheanus* Pictet and Roux. Stoliczka, Cret. Rocks S. India, Pal. Indica, vol. I, p. 146, Pl. LXXIII, fig. 5.
1895. *Lytoceras (Tetragonites) epigonum* Kossmat, Beitr. z. Pal. u. Geol. Österr.-Ung., vol. IX, p. 135, Pl. XVII (III), figs. 4a, 4b, 4c, 5a, 5b, 10.
1903. *Tetragonites timotheanus?* Pictet and Roux. Whiteaves, Mesozoic Fossils, vol. I, pt. V, p. 329.
1903. *Tetragonites* cf. *epigonus* Kossmat. Yabe, Jour. Coll. Sci., Imp. Univ. Tokyo, vol. XVIII, p. 49, Pl. VII, fig. 3.
1907. *Lytoceras (Tetragonites) epigonum* Kossmat. Pervinquière, Etudes de Pal. Tunis., I, Céphs. des Terr. second., p. 76, Pl. III, figs. 27, 28; text figs. 15, 16.
1907. *Lytoceras (Tetragonites) epigonum* Kossmat. Paulcke, Ber. Naturforsch. Ges. Freiburg, vol. XV, p. 174.
1908. *Lytoceras Tetragonides epigonum* Kossmat (sic.). Kilian and Reboul, Schwed. Südpolar-Exped., vol. III, pt. 6, p. 14.
1925. *Epigoniceras epigonum* (Kossmat). Spath, Geol. Mag., vol. LXII, p. 29, Pl. I, figs. 2a, 2b.
1926. *Epigoniceras epigonum* (Kossmat). Marshall, Trans. N. Zealand Inst., vol. 56, p. 149, Pl. 29, figs. 6, 7.
1942. *Epigoniceras epigonum* (Kossmat). Matumoto, Proc. Imp. Acad. Tokyo, vol. XVIII, No. 132, p. 671.
1943. *Epigoniceras epigonum* (Kossmat). Matumoto, Mem. Fac. Sci., Kyusyu Imp. Univ., vol. II, No. 1, chart, p. 127.

Dimensions. Specimen No. 10016: 50; 50; 47; 24; No. 10017: 58; 43; 46; 25; No. 10015: 70; 50; 49; 21.

Shell discoidal, whorls increasing rapidly in size; involution one-half to two-thirds; umbilicus small, deep, step-shaped. Whorl section nearly square, varying between that in which whorl height is slightly greater than whorl width and that in which this relationship is reversed; whorl widest at or just exterior to umbilical shoulder. Umbilical wall vertical, meeting the flattened flank in a sharply rounded umbilical shoulder. Flanks meet the broad flattened venter in a smoothly but abruptly rounded ventro-lateral angle of 90 degrees.

Shell surface appears smooth and polished, but close examination reveals numerous fine lines or striæ passing radially up the umbilical wall. At the umbilical shoulder they bend sharply forward, and pass across the flanks in a straight line inclined forward at an angle of about 45 degrees to a radial line. Striæ cross ventro-lateral angle and the venter with a smooth slightly forward convexity. Rarely, shallow, narrow constrictions are seen on the cast crossing the flanks; they appear abruptly on the umbilical wall, and parallel the striæ, crossing the flanks in a straight line inclined obliquely forward; they are not as pronounced on the venter as on the flanks. Some shells have no visible constrictions, and on those specimens that have them a maximum of 3 per whorl is recorded.

External suture close to that figured by Kossmat. EL wide, deep, with a prominent, narrow, blunt siphonal saddle (this siphonal saddle in *T. timotheanus* is lanceolate); L_1 broad, bifid, not as deep as EL, with a prominent, median secondary saddle; L_2 a smaller reproduction of L_1; 4 or 5 auxiliary lobes decreasing rapidly in size and passing obliquely backwards into the umbilicus. S_1 broad, unequally bifid, outer branch most developed, with 3 main terminations; inner branch with 2 principal terminations; S_2 trifid, but with a quinquipartite appearance that results from the outer and inner branches being bifid, with the single median branch of the saddle separating them; auxiliary saddles bifid; s_2 on umbilical shoulder.

Spath (1925c) differentiates *Tetragonites* and *Epigoniceras* on the basis of their suture lines (*See* Pl. XXXI, figs. 13, 14); that of *Tetragonites* passes in a straight line from the siphonal to the antisiphonal lobe with 4 small internal saddles; that of *Epigoniceras* passes obliquely backward from the siphonal lobe to the umbilical suture, then sweeps obliquely forward again to the antisiphonal lobe, with 2 large internal saddles. According to Kilian and Reboul, *E. epigonum* is a mutation of *T. timotheanus;* Spath expresses their similarity by calling them "heterochronous homoeomorphs" (1925c, p. 29). Whiteaves classified the Vancouver Island forms as *T. timotheanus*, but the oblique direction of the external suture line is more indicative of *Epigoniceras.* None of the specimens shows an internal suture line, and until it can be observed the identity of these forms will remain doubtful. In addition to sutural differences and chronological inequalities (*T. timotheanus* has been recorded from the Albian to the Coniacian; *E. epigonum*, from the Turonian to the Santonian) the two forms also show differences in whorl section and ornament. *T. timotheanus* is much more squarish, with a very broad venter, and the cast has numerous sinuous constrictions passing obliquely forward across the flanks. *E. epigonum* has a more rounded appearance, though still possessing ventro-lateral and umbilical-lateral angles. Constrictions are few and straight, passing obliquely forward from umbilicus to venter. The Vancouver Island specimens, in general, have the more rounded whorl shape and the few straight constrictions of *E. epigonum*, but there is a variation from this type of shell to one shaped more like *T. timotheanus* that has no constrictions. This lack of constrictions is a characteristic of *T. timotheanus* var. *nautiloide* (Pictet), but the latter species has whorls much broader than high, and, consequently, a cross-section very different from that of *E. epigonum.*

Whiteaves' specimens of *Tetragonites* from the Queen Charlotte Islands are not conspecific with those from Vancouver Island. The Japanese species *E. popetense* (Yabe) is close to *E. epigonum* but has a wider umbilicus, a more rounded venter, and many constrictions. *E. glabrum* (Jimbo) is comparable with *E. epigonum* in the lack of many constrictions but differs in having much more rounded whorls.

Occurrence. Haslam formation, localities 201, 213, 226, 229, 246, 518, 519, 522; Trent River formation, localities 152, 154, 155, 156, 605.

Types. Plesiotypes, G.S.C. Nos. 10015, locality 518; 10016, locality 519; 10017, locality 213; Haslam formation, Brannan Creek, Vancouver Island, British Columbia.

Genus, *Pseudophyllites* Kossmat, 1895

Genotype, *Ammonites indra* Forbes, 1845

1895. Kossmat, A.: Beitr. z. Pal. u. Geol. Österr.-Ung., vol. IX, p. 137.

Pseudophyllites is a very involute form, with a small, deep umbilicus; the whorls are rounded in youth, becoming more elliptic at maturity, with a large, convex venter and somewhat flattened flanks. Ornament consists of very fine striæ inflected forward and passing radially across venter; faint spiral bands appear at maturity. The suture consists of bifid lobes and saddles; L_1 deeper than EL; S_1 with large external branch where internal branch of S_2 is the larger.

Pseudophyllites indra (Forbes), 1845

Plate III, figures 2-13; Plate XXXI, figures 15-17

1845. *Ammonites indra* Forbes, Trans. Geol. Soc. London, 2nd ser., vol. VII, p. 105, Pl. XI, fig. 7.
1865. *Ammonites indra* Forbes. Stoliczka, Cret. Rocks S. India, Pal. Indica, vol. I, p. 112, Pl. VIII, figs. 2a, 2b.
1879. *Ammonites indra* Forbes. Whiteaves, Mesozoic Fossils, vol. I, pt. II, p. 105, Pl. 13, figs. 2, 2a.
1895. *Pseudophyllites indra* (Forbes). Kossmat, Beitr. z. Pal. u. Geol. Österr.-Ung., vol. IX, p. 137, Pl. XVI (II), figs. 6-9; Pl. XVII (III), figs. 6, 7; Pl. XVIII (IV), fig. 3.
1895. *Phylloceras indra* (var.) (Forbes). Whiteaves, Trans. Roy. Soc., Canada, 2nd ser., vol. I, sec. IV, p. 129.
1903. *Pseudophyllites indra* (Forbes). Whiteaves, Mesozoic Fossils, vol. I, pt. V, p. 331.
1906. *Pseudophyllites indra* (Forbes). Woods, Ann. S. African Mus., vol. IV, p. 334, Pl. XLI, figs. 6a, 6b.
1908. *Pseudophyllites indra* (Forbes). Kilian and Reboul, Schwed. Südpolar-Exped., Geol. u. Pal., vol. III, pt. 6, p. 14.
1922. *Pseudophyllites indra* (Forbes). Spath, Trans. Roy. Soc., S. Africa, vol. X/2, pt. 3, p. 119.
1926. *Pseudophyllites indra* (Forbes). Marshall, Trans. N. Zealand Inst., vol. 56, p. 152, Pl. 20, fig. 1; Pl. 29, figs. 3-5.

Dimensions. Specimen No. 10018: 5·8; 45; 53; 34; No. 10019: 8; 45; 50; 30; No. 10020: 14; 46; 50; 32; No. 10021: 24; 50; 59; 25; No. 10022: 86; 52; 46.5; 20; No. 10023: 95; 53; 42; 21.

Few specimens of *Pseudophyllites indra* are in the present collection of the Geological Survey of Canada. They range in size from tiny larvæ, less than 5 mm. in diameter, to large adults, 177 mm. in diameter. Natural changes in the relationships of shell dimensions from youth to maturity have been observed in these specimens; in proportion to the diameter of the shell the height of the whorl increases where the width of the whorl and the width of the umbilicus decrease. The Vancouver Island specimens are remarkably close to those described by Kossmat, but several instances of variation will be considered later.

Shell discoidal, whorls increasing rapidly in size, with an involution of about two-thirds in the early stages, increasing to about three-quarters at maturity. Except in the larval stage, where the whorls are nearly round and slightly wider than high, the whorls are higher than wide, the greatest width being at the umbilical shoulder. Kossmat's young specimens (Pl. XVI, figs. 6, 8) differ in this respect; in the Indian species, the greatest width of the outer whorl in youth is at the middle or upper flank, and in all of his figured specimens (excepting Pl. XVI, fig. 9) the whorls have a squarish cross-section.

Umbilicus deep, narrow, step-like, showing one-quarter to one-third of all of the inner whorls; umbilical wall high, steep, meeting the somewhat flattened flank with a smooth, abruptly rounded curve.

Shell surface mostly smooth; but rarely, where entire shell is intact, narrow, indistinct, rib-like thickenings arise at the umbilical shoulder and disappear half-way up the flanks. Remaining ornament consists of numerous, crowded, very fine striæ that originate at the umbilical suture, pass straight up the umbilical wall, swing strongly forward on the umbilical shoulder, and sweep across the lower three-quarters of the flank in a broad, forward arcuity. They cross the venter in a straight, radial line or are flexed almost imperceptibly forward. Faint spiral bands 2 to 5 mm. wide may be observed where the outer shell layers are preserved. There are no grooves or sulci.

Mature suture line deeply cut; S_1 unsymmetrically bifid, the outer branch the longer; S_2 also bifid, but here the inner branch is the longer; auxiliary saddles bifid, inclined rapidly into the umbilicus. EL as deep as L_1; L_1 very wide, with a long, median, secondary saddle; L_2 and auxiliary lobes lack the long secondary saddle.

This suture pattern is essentially the same through all the known stages of the Canadian specimens of *P. indra:* the unsymmetrical bifid saddles are developed even in specimens less than 5 mm. in diameter. Herein lies the significant difference from the young specimens described and figured by Kossmat (pp. 138, 139; Pl. XVII, figs. 7a, 7b). That author maintains that *P. indra* in its youth has symmetrically trifid saddles, the endings of which are phylloid. Presumably, with growth, the saddles become asymmetrical and bifid, and lose the phylloid character. He does not state at which stage the change ensues, but, apparently, sometime after the shell has reached a diameter of 18 mm. There is no suggestion of a trifid character in the saddles of the Canadian specimens, and the young forms do not have the squarish cross-section of the Indian specimens.

There are, however, three tiny specimens (pleisotypes, G.S.C. Nos. 10024, 10025, 10026), all of them less than 15 mm. in diameter, that show the same characteristics as those attributed by Kossmat to the young of *P. indra.* The whorls have a rectangular cross-section, with the maximum whorl width exterior to the umbilical shoulder. The umbilicus varies somewhat from that of a typical *P. indra* in that it is not step-like, the inner whorls being narrower and more rounded at the umbilical shoulder, lending the umbilicus a smooth, funnel-shaped appearance. The simple suture has broad lobes and symmetrical, trifid saddles, with phylloid endings. EL is deeper than L_1 and has a long, sharp, median siphonal saddle. Because no specimen larger than 15 mm. has been found, and because they do not compare with the young of any other species known to the author, it is presently impossible to state the species to which they belong. It is undoubtedly certain that neither they nor the immature Indian specimens with the same type of suture and whorl shape are young stages of *P. indra.*

Besides occurring in the Valudayur and *Trigonarca*-beds of India, *Pseudophyllites indra* is reported from the Upper Cretaceous rocks of New Zealand and Pondoland. Kossmat suggests a close similarity to *P. postremus* (Redtenbacher) from the Gosau beds, but the whorl shape of this form is totally unlike that of the Canadian and Indian species.

Occurrence. Upper Lambert formation, localities 109, 111, 112, 113, 114, 501, 502; Northumberland formation, locality 264.

Types. Plesiotypes, G.S.C. Nos. 5851, locality 501; 10018, 10019, 10020, 10021, and 10022, locality 113; 10023, locality 502; upper Lambert formation, Hornby Island, British Columbia.

Genus, *Gaudryceras* de Grossouvre, 1893, emend. Kossmat, 1895

Genotype, *Ammonites mitis* von Hauer, 1866

1893. de Grossouvre, A.: Amm. de la Craie sup., pt. II, p. 226.
1895. Kossmat, A.: Beitr. z. Pal. u. Geol. Österr.-Ung., vol. IX, p. 113.
1903. Yabe, H.: Jour. Coll. Sci., Imp. Univ., Tokyo, vol. XVIII, p. 8.
1923. Spath, L. F.: Amm. of the Gault, p. 22.
1938. Roman, F.: Amm. Jur. et Crét., p. 44.
1942. Matumoto, T.: Proc. Imp. Acad. Tokyo, vol. XVIII, No. 131, p. 666.

The genus *Gaudryceras* includes evolute, discoidal ammonites with rounded whorls increasing in size with progressive rapidity; the shells are smooth or striate and commonly constricted; the suture has numerous elements, all bifid.

De Grossouvre separated *Gaudryceras* from *Lytoceras* on the basis of the fine, flexuous striæ and numerous auxiliary sutural elements of the former. In youth, the whorls increase slowly in size but the rate accelerates with age and at maturity the whorls are more involute.

Kossmat, in emending the genus, noted the sutural differences between the bifid saddles of *Gaudryceras* and the trifid saddles of *Tetragonites*, as well as their dissimilar internal sutures. Yabe separated the genus into six sub-groups, based on differences of ornament, whorl shape, and suture line.

The remarkable similarity among immature specimens of the numerous *Gaudryceras* species strongly suggests that many of the species are subspecific variations.

Gaudryceras denmanense Whiteaves, 1879

Plate IV, figures 1, 2

1879. *Ammonites jukesii?* Sharpe. Whiteaves, Mesozoic Fossils, vol. I, pt. II, p. 111, Pl. XIII, figs. 3, 3a, 3b.
1895. *Lytoceras jukesii* (Sharpe). Whiteaves, Trans. Roy. Soc., Canada, 2nd ser., vol. I, sec. IV, p. 129, Pl. II, figs. 1, 2.
1901. *Lytoceras (Gaudryceras) denmanense* Whiteaves, Ottawa Naturalist, vol. XV, p. 31.
1903. *Gaudryceras denmanense* Whiteaves, Mesozoic Fossils, vol. I, pt. V, p. 329.
1903. *Gaudryceras denmanense* Whiteaves. Yabe, Jour. Coll. Sci., Imp. Univ., Tokyo, vol. XVIII, p. 17.

Dimensions. Specimen No. 5800: 38; 32; 27; 47; No. 10027: 82; 41; 36; 35; No. 5854: 103; 40; 33; 35.

Shell discoidal, flattened, with wide shallow umbilicus, the inward slope of which is modified by the rounded contours of the inner whorls. Involution about one-third; less than that in early stages. Umbilical walls steep, increasing rapidly in height at maturity; umbilical shoulder broadly rounded in youth, more sharply rounded at maturity. Whorl section nearly circular in early stages, becoming more elliptical as whorl height increases. Flattened flanks meet narrow, rounded venter with a smooth, rounded contour.

Ornament coarsens with growth. Inner whorls covered with fine, radiating, flexuous striæ originating at umbilical suture and bending strongly forward on umbilical wall. At a line immediately above the umbilical shoulder striæ bifurcate or trifurcate, straighten radially, then bend gracefully backwards, tracing a pronounced forward convexity on the lower third of the flank. On the outer two-thirds of the flank, striæ straighten somewhat and cross venter in a faint, posteriorly directly, arc. On outer whorl, striæ coarsen to narrow, sharp, high ribs, reaching the acme of this development on the venter and adjacent flanks. Course of ribs follows trace of earlier striæ. At this stage, bifurcation ceases and smallest ribs are intercalated at the umbilical shoulder. On syntype No. 5854a, all ribs on outer whorl are equal, arising gradually from the umbilical suture with neither bifurcations nor intercalations.

Periodic constrictions, averaging 4 per whorl, occur on all inner whorls and are manifested by high, narrow, sharply rounded ribs, comparable in size, but not in acumination, to the ribs of the outer volution. Constrictions bordered in front by wide, shallow, smooth grooves; behind, by a much narrower, smooth slope. No constrictions on last half of outer whorl.

Suture line imperfectly known. Lobes and saddles bifid and deeply indented, the auxiliary elements passings obliquely backward into the umbilicus.

G. denmanense is most closely related to the Indian species *G. kayei* (Forbes) and the Japanese *G. tenuiliratum* Yabe. From the former it differs by having much coarser ornament on the outer whorl, and from the latter by the lack of periodic constrictions on the outer whorl. The young stages of *G. denmanense* and *G. tenuiliratum* are exceedingly similar, and it may be that the Canadian species is a younger, mutant variation of the Japanese form.

Occurrence. Qualicum formation, locality 168; Denman formation, locality 517; lower Lambert formation, localities 104, 516.

Types. Lectotype, G.S.C. No. 5854, locality 516, lower Lambert formation, Denman Island, British Columbia; paratypes, G.S.C. Nos. 5854a, 5854b, and 10027, locality 516, lower Lambert formation, Denman Island, British Columbia; G.S.C. No. 5800, Denman formation, Norris Rock, British Columbia.

Gaudryceras sp.

A single fragment of the body chamber of a large *Gaudryceras* shows, on one side only, a series of very fine and narrow, sharp, densely crowded, flexuous, sub-costæ. They originate on the umbilical wall in a radial direction, bend gracefully forward on the umbilical shoulder and the lower third of the flanks, then straighten to cross the mid-flank radially; on the outer third of the flank they are directed backward in a gentle arcuity. The venter is missing. Bifurcations and intercalations of sub-costæ occur at the umbilical shoulder; as many as 25 equidistant sub-costæ occur on a space of 1 inch on the flanks.

The ornament closely resembles that of *Gaudryceras mitis* (von Hauer) de Grossouvre (1893, p. 227, Pl. 39, figs. 1a, 1b) but the sub-costæ are more closely spaced than on the latter species.

Occurrence and Type. Plesiotype, G.S.C. No. 10028, locality 109, upper Lambert shale, Hornby Island, British Columbia.

Family, DESMOCERATIDAE

Genus, *Hauericeras* de Grossouvre, 1893

Genotype, *Ammonites pseudo-gardeni* Schlüter, 1872

1893. de Grossouvre, A.: Amm. de la Craie sup., p. 219.
1898. Kossmat, A.: Beitr. z. Pal. u. Geol. Österr.-Ung., vol. XI, p. 122.
1904. Yabe, H.: Jour. Coll. Sci., Imp. Univ., Tokyo, vol. XX, p. 29.
1907. Pervinquière, L.: Etudes de Pal. Tunis., I, Céphs. des Terr. second., p. 165.

The shell is flattened, narrow, and discoidal, with a large shallow umbilicus; the whorls are narrow, flat or slightly convex, with a sharp ventral keel; the shell smooth or with few periodic constrictions. The suture is analogous to *Desmoceras*, *Puzosia*, and *Pachydiscus*; EL is as deep as L_1.

Kossmat attached *Hauericeras* to *Puzosia*, seeing a relationship between the constrictions and suture lines of the two genera. *Hauericeras* is distinguished by its sharp keel and detailed sutural differences; that is, in *Puzosia* EL is considerably shorter than L_1, a stage not reached until maturity in *Hauericeras* and, in the latter, the siphonal saddle dividing EL is straight and trifid instead of being oblique and bifid. Pervinquière recognized that *Hauericeras* had lateral lobes of a particular form; that is, L_1 is asymmetrical, the external branch more developed than the internal branch (the opposite is true in *Puzosia*); L_2 is twisted toward the umbilicus with the auxiliary lobes directed toward the venter.

Hauericeras gardeni (Baily), 1855

Plate V, figures 1, 2; Plate XXXI, figure 10

1855. *Ammonites gardeni* Baily, Quart. Jour. Geol. Soc., London, Proc., vol. XI, p. 456, Pl. XI, figs. 3a, 3b, 3c.
1865. *Ammonites gardeni* Baily. Stoliczka, Cret. Rocks S. India, Pal. Indica, vol. I, p. 61, Pl. XXXV, figs. 4a, 4b.
1879. *Ammonites gardeni* Baily. Whiteaves, Mesozoic Fossils, vol. I, pt. II, p. 102.
1890. *Desmoceras gardeni* (Baily). Yokoyama, Verst. japan. Kreide, Paleontographica, vol. 36, p. 184, Pl. XX, figs. 10a, 10b.
1893. *Hauericeras gardeni* (Baily). de Grossouvre, Amm. de la Craie sup., p. 219.
1895. *Desmoceras gardeni* (Baily). Whiteaves, Trans. Roy. Soc., Canada, 2nd ser., vol. I, sec. IV, p. 131.
1898. *Hauericeras gardeni* (Baily). Kossmat, Beitr. z. Pal. u. Geol. Österr.-Ung., vol. XI, p. 122, Pl. XVIII (XXIV), figs. 7, 8, 10.
1903. *Hauericeras gardeni* (Baily). Whiteaves, Mesozoic Fossils, vol. I, pt. V, p. 352.
1904. *Hauericeras gardeni* (Baily). Yabe, Jour. Coll. Sci., Imp. Univ. Tokyo, vol. XX, p. 32.
1906. *Hauericeras gardeni* (Baily). Woods, Ann. S. African Mus., vol. IV, p. 332.
1907. *Hauericeras gardeni* (Baily). Pervinquière, Etudes de Pal. Tunis., I, Céphs. des Terr. second., p. 165.
1921. *Hauericeras gardeni* (Baily). van Hoepen, Ann. Transvaal Mus., vol. VIII, pt. 1, p. 27, text fig. 15.
1921. *Hauericeras gardeni* (Baily). Spath, Ann. S. African Mus., vol. XII, p. 238, text fig. A.
1922. *Hauericeras gardeni* (Baily). Spath, Trans. Roy. Soc., S. Africa, vol. X/2, pt. 3, p. 129.
1942. *Hauericeras gardeni* (Baily). Matumoto, Proc. Imp. Acad. Tokyo, vol. XVIII, No. 6, p. 28, fig. 2.

Dimensions. Specimen No. 10029: 120; 32·5; 17·5; 41.

Shell discoidal, much compressed; whorls high, narrow. Involution about one-third; umbilicus wide, shallow; umbilical wall short, vertical or very steep, meeting flattened flank in sharply rounded angle. Flanks flat to slightly convex. Venter narrow, sharp, with keel; where shell is missing, cast has sharply rounded venter with no keel. Shell nearly smooth; ornament consisting of extremely fine, radial lines bent in a broad, forward arcuity on flanks. Narrow, deep to shallow constrictions cross flanks paralleling radial lines and bent somewhat more strongly forward on venter. As many as 4 constrictions per whorl.

EL broad, deep, with 2 branches on each side of venter; siphonal saddle short, broad; L_1 broad, trifid, deeper than EL, asymmetric, external branch most developed, median branch inclined towards venter giving L_1 an unbalanced appearance; L_2 shorter than EL, irregularly trifid; 3 or 4 small auxiliary lobes diminishing rapidly and obliquely to umbilical suture. S_1 broad, irregularly bifid, inner branch more developed than outer; S_2 projects farther forward than S_1; S_2 irregularly bifid; outer branch much larger than inner; 2 auxiliary saddles much reduced in size.

Hauericeras gardeni is readily distinguishable by its extreme compression, wide umbilicus, keeled venter, and paucity of ornament. The Vancouver Island specimens are, in every respect—form, ornament, suture, and time range—in harmony with the species as it is known in India, Africa, and Japan. The keel was, apparently, a hollow structure and does not show on casts of specimens. It is closely related to the European Senonian *H. pseudo-gardeni* (Schlüter), 1872, but is distinguished from the latter by its much wider umbilicus and slightly thicker whorl. According to Spath (1922a, p. 129), Crick found the Pondoland specimens to have mean whorl proportions of: —; 35; 19; 39. The Canadian specimens have closely corresponding dimensions, varying within 2·5 per cent of Crick's mean.

Occurrence. Haslam formation, localities 216, 229, 233, 238, 239, 245, 251, 252; Trent River formation, localities 10, 12, 19, 20, 118, 120, 121, 127, 128, 143, 144, 151, 155, 156, 157, 161, 163, 165, 167, 505, 512, 514.

Type. Plesiotype, G.S.C. No. 10029, Haslam formation, Elkhorn Creek, Vancouver Island, British Columbia.

Genus, *Schluteria* de Grossouvre, 1893, emend. Spath, 1921

Genotype, *Desmoceras larteti* Seunes, 1891

1893. de Grossouvre, A.: Amm. de la Craie sup., p. 216.
1921. Spath, L. F.: Ann. Durban Mus., vol. III, pt. 2, p. 45.
1942. Matumoto, T.: Proc. Imp. Acad. Tokyo, vol. XVIII, No. 6, p. 24.

Schluteria is a smooth, constricted, deeply involute desmoceratid with well-rounded whorls and a deep umbilicus; the suture line is similar to *Desmoceras*. There is no agreement among students as to the systematic position of *Schluteria*, nor about its holo-genotype; even its validity as a genus is questionable. de Grossouvre created the genus for those Upper Cretaceous forms that had a shape and ornament similar to *Phylloceras* but whose suture line approached that of *Puzosia* and *Pachydiscus*. The genus is not related to *Phylloceras*, and for that reason several of de Grossouvre's contemporaries, among them Kossmat, Steinmann, and Pervinquière, did not accept it. Had they done so, *Schluteria* would have been synonymous with *Latidorsella* (genotype: *Ammonites latidorsatus* Michelin), a genus that those scientists upheld as valid. *A. latidorsatus* is, however, the genotype of *Desmoceras* s.s. As it is presently understood, *Schluteria* is used "for the Senonian Desmoceratids that, erroneously, have been included in 'Latidorsella' " (Spath, 1921, p. 46).

Schluteria selwyniana (Whiteaves), 1879

Plate V, figures 3, 4; Plate VI, figures 1-3; Plate XXXI, figure 20

1879. *Ammonites selwynianus* Whiteaves, Mesozoic Fossils, vol. I, pt. II, p. 104, Pl. 13, figs. 1, 1a.
1898. *Desmoceras selwynianum* (Whiteaves). Kossmat, Beitr. z. Pal. u. Geol. Österr.-Ung., vol. XI, p. 109.
1903. *Desmoceras selwynianum* (Whiteaves), Mesozoic Fossils, vol. I, pt. V, p. 351.
1921. *Desmoceras selwynianus* (Whiteaves). van Hoepen, Ann. Transvaal Mus., vol. VIII, pt. 1, p. 20.
1921. *Schulteria crassa* (van Hoepen), op. cit., p. 20, Pl. IV, figs. 3, 4, text fig. 11.

Dimensions. Specimen No. 5809b: 34; 53; 41; 7; No. 5803: 35; 57; 48; 8; No. 5809: 50; 54; 40; 6; No. 5803d: 53; 54; 45; 9; No. 5803b: 55; 54; 42; 9.

Shell discoidal, highly involute, moderately narrow. Whorls higher than wide; greatest width at mid-flank. Flanks flattened or very slightly convex, somewhat depressed between mid-flank and umbilicus. Venter broad, convex, smooth, meeting flanks with gentle contour. Umbilicus very narrow, deep, with vertical walls; umbilical shoulder narrowly rounded.

Ornament of very fine, sinuous, closely packed striæ that are preserved on the shell but not on the internal cast. Striæ trace sigmoidal curve, beginning radially on umbilical wall, then sweeping obliquely forward to mid-flank. On the outer flank they bend slightly backward and then forward again in a deep, narrow, tongue-shaped lappet on the venter. Five to seven deep constrictions parallel the striæ on the outer whorl at periodic intervals. Cross-sections of the constrictions show them to be asymmetric, with the steepest part of the groove on the leading edge.

Suture line complex, almost identical with *S. diphylloides* Kossmat sp. EL broad, as deep as L_1, with a short, median, siphonal saddle and long, well-developed, secondary lateral saddles cutting each branch, on either side of the siphon, into two equal parts (a feature that distinguishes it from *Desmoceras latidorsatus*); L_1 and L_2 symmetrically trifid; 5 auxiliary lobes decreasing regularly in size to the umbilical shoulder. S_1 broad, bifid, both branches projectiong an equal distance forward; S_2 narrower, bifid; 6 auxiliary saddles.

S. selwyniana is a rare fossil restricted to the Cedar district and Trent River formations. The specimens found in the Trent River shales are more compressed and have a smaller umbilicus than those in the Cedar District shales in Sucia Island, but agree in all other morphological characters. The apparent differences might be attributed to crushing and poor preservation of the more northern specimens.

S. diphylloides Kossmat sp. is close to *S. selwyniana*, the latter being distinguished by narrower ventral lappets and a much smaller umbilicus. *S. larteti*, from the European Maestrichtian, is much more compressed than the Canadian species.

The African species *S. simplex* (van Hoepen) and *S. crassa* (van Hoepen) have been separated from *S. selwyniana* on the basis of tenuous dissimilarities in the whorl shape and the curvature of the constrictions; the suture lines of the three species are the same. *S. simplex* approaches the more flattened specimens of *S. selwyniana*, whereas, on the other hand, *S. crassa* is synonymous with the Sucia Island specimens, the two species being the same in all respects except an apparent lack of constrictions on the African species.

Occurrence. Cedar District formation, localities 268, 526; Trent River formation, localities 118, 127, 515.

Types. Lectotype, G.S.C. No. 5803b, locality 526, Cedar District formation, Sucia Island, Washington, U.S.A.; plesiotypes, G.S.C. Nos. 5809 and 5809b, locality 515, upper Trent River formation, Denman Island, British Columbia.

Genus, *Pachydiscus* Zittel, 1884

Genotype, *Ammonites neubergicus* von Hauer, 1858

1893. de Grossouvre, A.: Amm. de la Craie sup., p. 176.
1898. Kossmat, A.: Beitr. z. Pal. u. Geol. Österr.-Ung., vol. XI, p. 89.
1900. Hyatt, A.: Textbook of Paleont., Zittel-Eastman, p. 570.
1907. Pervinquière, L.: Etudes de Pal. Tunis., I, Céphs. des Terr. second., p. 171.
1908. Kilian, W., and Reboul, P.: Schwed. Südpolar-Exped., Geol. u. Pal., vol. III, pt. 6, p. 41.
1913. Nowak, J.: Bull. Internat. Acad. Sci., Cracovie, No. 6B, pp. 335-368.
1922. Spath, L. F.: Trans. Roy. Soc., S. Africa, vol. X/2, pt. 3, pp. 120-126.
1926. Spath, L. F.: Jour. Roy. Soc., W. Australia, vol. XII, No. 5, p. 55.
1939. Spath, L. F.: Geol. Mag., vol. LXXVI, pp. 293-296.
1947. Reeside, J. A., Jr.: U.S. Geol. Surv., Prof. Paper 214-A, p. 3.

". . . . . Compressed to moderately stout shell, with relatively small umbilicus, gently rounded umbilical shoulder, rounded external margin; surface costate, no ventral nodes; costæ generally flexuous, including both umbilical and intercalated costæ; late stages mostly smooth. Suture much dissected, crowded, with long slender elements; first lateral lobe the longest, tops of saddles in nearly straight line." (Reeside, 1947, p. 3.)

Spath's clarification (1939) of the genus *Pachydiscus* has reduced *Parapachydiscus* Hyatt, 1900, to a state of synonomy. Prior to this, Spath's subdivision of the genus into a number of sub-genera (1922a) involved some of the Vancouver Island *Pachydiscus* species, in particular *P. newberryanus* (Meek), *P. multisulcatus* Whiteaves, *P. binodatus* Whiteaves, and *P. perplicatus* Whiteaves. There is a tendency, as Spath noted, for the latter three forms to acquire the oblique costation of *Kossmaticeras*, but it is not one of the outstanding features of the species. Some specimens of *P. multisulcatus* show deep constrictions inclined forward more obliquely than adjacent ribs, which thus tend to be intersected by the constrictions toward the periphery. Spath's observation of the similarity between the inner whorls of *P. multisulcatus*, *P. binodatus*, *P. perplicatus*, and *P. newberryanus* has little significance in view of the present investigations of these species. *P. multisulcatus* is closely related to *P. newberryanus* and is probably a predecessor of such forms as *P. perplicatus* and *P. binodatus*. There is no difficulty, however, in distinguishing the young whorls of three of the species, but unfortunately only one specimen of *P. binodatus* has ever been found and it does not permit investigation of the younger stages. It may be necessary to assign the latter species to a new sub-genus in view of its ventro-lateral nodes, but the other coarse-ribbed species from the Nanaimo group will be retained in *Pachydiscus* until it can be demonstrated that their differences warrant the establishment of a new genus.

P. suciaensis must certainly be retained in this genus as it is the Canadian representative of *P. egertoni-neubergicus*.

Pachydiscus (Canadoceras) newberryanus (Meek), 1857

Plate VI, figures 4-7; Plate VII, figure 1; Plate VIII, figures 1, 2; Plate XXXI, figure 4

1857. *Ammonites newberryanus* Meek, Trans. Albany Inst., vol. IV, p. 47.
1864. *(non) Ammonites newberryanus* Meek. Gabb, Paleont. Calif., vol. I, p. 61, Pl. XXVII.
1876. *Ammonites newberryanus* Meek, Bull. U.S. Geol. Geog. Surv., Terr., vol. II, No. 4, p. 367, Pl. IV, figs. 3, 3a, 3b.
1879. *(pro parte) Ammonites newberryanus* Meek. Whiteaves, Mesozoic Fossils, vol. I, pt. II, p. 109; *(non)* Pl. 14, figs. 1, 1a.
1892. *Desmoceras newberryanum* (Meek). Whiteaves, Trans. Roy. Soc., Canada, 1st ser., vol. X, sec. IV, p. 114.
1895. *Pachydiscus newberryanus* (Meek). Stanton, Bull. U.S. Geol. Surv., No. 113, p. 16.
1898. *Pachydiscus newberryanus* (Meek). Kossmat, Beitr. z. Pal. u. Geol. Österr.-Ung., vol. XI, p. 100.
1903. *Pachydiscus newberryanus* (Meek). Whiteaves, Mesozoic Fossils, vol. I, pt. V, p. 348.
1905. *Pachydiscus newberryanus* (Meek). Anderson, Proc. Calif. Acad. Sci., 3rd ser., vol. II, p. 102.
1921. *Parapachydiscus newberryanus* (Meek). Spath, Ann. S. African Mus., vol. XII, No. 16, p. 228.
1921. *Parapachydiscus newberryanus* (Meek). Spath, Ann. Durban Mus., vol. III, pt. 2, p. 49.
1922. *Canadoceras newberryanum* (Meek). Spath, Trans. Roy. Soc., S. Africa, vol. X/2, pt. 3, p. 125, Pl. VII, fig. 5; Pl. VIII, fig. 4.

Dimensions. Specimen No. 10033: 60; 41·6; 39; 28·3; No. 10030: 113; 42; 37; 26·5; No. 10031: 150; 44; 35; 25·3; No. 10032: 205; 46·4; 30; 24·3.

At 60 Millimetres Diameter. Shell discoidal, narrow, umbilicated; whorls flattened to convex, higher than wide, greatest width at umbilical shoulder; venter oval to narrowly rounded, sloping abruptly into the flanks; umbilicus wide, not deep; involution more than one-half, whorls increasing gradually in size; umbilical shoulder broadly rounded, walls smooth, steep; inner whorls with major ribs beginning in bullæ on umbilical shoulder; constrictions on apertural border of major ribs.

Ornament consists of 42 to 44 ribs, 8 of which are longer and larger than the others and arise at the umbilical border in pronounced tubercle-like bullæ. Five of the primary ribs are bordered on their apertural side by deep, concave constrictions each of which is, in turn, bordered on the forward edge by a long secondary rib emerging part way down the umbilical wall. Three to seven secondary ribs are intercalated between each pair of primaries, beginning gradually, without bullæ, near the umbilical shoulder. Some of the shortest secondaries begin farther up the flanks, and these are usually on the apertural side of each group of secondaries; occasionally they arise as a bifurcation of a primary or from a large secondary rib. All ribs begin on lower flanks in a radial direction and arch strongly forwards towards and across the venter. On venter, all ribs are of equal strength, with a pronounced forward arcuity.

EL broad, not as deep as L_1; L_1 trifid; L_2 much narrower than, but as deep as, L_1; 4 or 5 auxiliary lobes decrease gradually in size in a straight line to the umbilical suture. S_1 largest, broad, bifid; S_2 and s_1 each smaller than the preceding; 4 auxiliary saddles.

At 120 Millimetres Diameter. Shell essentially an enlarged duplicate of 60 mm. specimen; whorl higher and more compressed; umbilicus slightly smaller, deep, with smooth, steep walls; umbilical shoulder with bullæ, each bordered in front by a narrow, deep constriction. Four to eight (average, 5 or 6) secondary ribs arise gradually on the lower flank between each pair of primaries and attain same strength on venter as primaries; the latter are distinguished on the venter by accompanying constrictions. All ribs bend forward on flanks and venter.

EL broad, 2 branches on each side of siphon; L_1 deeper than EL; lateral lobes trifid. S_1 largest, external branch most developed; S_2 much smaller than S_1; auxiliary saddles decreasing gradually in size; all saddles bifid.

At 150 Millimetres Diameter. Slight increase in height and decrease in width of whorls. Maximum whorl width external to umbilical shoulder. Primary ribs beginning to lose sharp bullæ, being distinguished from secondary ribs at the umbilical shoulder by greater length, height, and width and by having a pinched appearance. Constrictions occur as before. On venter, all ribs equal, constrictions indicating position of primaries.

At 200 Millimetres Diameter. Ribs have become broader and farther apart, particularly on venter where they arch deeply forward. On lower flanks ribs have lost their sharpness; bullæ of primary ribs obsolete on living chamber. Here all ribs rise above umbilical shoulder, which is smooth and uninterrupted; primary ribs distinguished by constrictions or deep grooves bordering them on their apertural side. Maximum whorl width at mid-flank.

EL very broad, with 3 main branches on each side of the siphon; L_1 straight, with a broad stem, equally trifid, deeper than EL; L_2 about same depth as L_1; trifid, with a broad stem; l_1 narrow, trifid, inclined; l_2 vaguely trifid; l_3 oblique. S_1 large, with broad stem, unequally bifid, largest branch on siphonal side; S_2 smaller than S_1 but nearly as high; s_1 much smaller than S_2, unequally bifid, inclined towards umbilicus; s_2 about one-half the size of s_1, bifid, inclined; s_3 on umbilical shoulder, broad stem in proportion to height; s_4 oblique.

Most of the specimens of *Pachydiscus newberryanus* have been recovered from the Haslam shales, whereas those collected from the stratigraphically higher Cedar District shales are few in number and may be imperfectly preserved. The Cedar District specimens vary somewhat from the typical forms of the Haslam shales in that the whorls are much more compressed, the whorl widths being only 25 to 30 per cent of the diameter. The whorl height is also less, that is, 30 to 40 per cent, so that on these specimens the umbilicus is much wider and shallower and the umbilical wall is short and steep. Ribs are strong and rounded, the primaries beginning in bullæ at the umbilical shoulder and having deep constrictions bordering their apertural edge. There are 6 to 10 secondary ribs between each pair of primaries, and they obtain a size equal to the primaries on the venter. All of the ribs bend obliquely forward on the flanks and are convex forward on the venter.

Among the *Pachydiscus* species in the Nanaimo group, *P. newberryanus* might be confused by superficial resemblances to two other forms, *P. haradai* Jimbo and *P. suciaensis* (Meek). The three species are contrasted in the following table.

Elsewhere, the young stages of *P. yokoyamai* Jimbo are very similar in ornament to *P. newberryanus*, but the Japanese species is much more inflated and has a broadly rounded venter. *P. vaju* Stoliczka has a similarly shaped cross-section, but it lacks constrictions and has more numerous primary ribs and fewer, shorter, secondary ribs. *P. jimboi* Kossmat has ornament comparable to *P. newberryanus* but its whorl shape is closer to that of *P. haradai*.

TABLE II

Comparison of Pachydiscus Species from Vancouver Island

—	*P. newberryanus* (Meek)	*P. haradai* Jimbo	*P. suciaensis* (Meek)
Youth	Ornament. Whorl height> [1] whorl width	Ornament not known. Whorl height = whorl width	Smooth. Whorl height < whorl width
Early maturity	Whorl height> whorl width	Whorl height = whorl width	Whorl height> whorl width
Maturity			
Dimensions	150; 46; 30; 24	153; 43; 46; 25	145; 48; 36·5; 24
Whorls	Compressed	Squarish	Flattened
Venter	Oval	Broadly rounded	Oval
Ribbing	Arched forward	Arched forward	Straight
Major ribs	7 per whorl; usually followed by constriction; sharp tubercles in youth on umbilical shoulder; becoming bullæ during maturity	11 per whorl; no constrictions; elongated tubercles (bullæ) strong throughout life	14 per whorl; no constrictions; elongated tubercles (bullæ) becoming low and blunt with age
Secondary ribs	5-6 between each pair of primaries	3 between each pair of primaries, decreasing to 1 or 2 in old age	1-3 between each pair of primaries decreasing to 1 or 2 in old age
	Commonly bifurcated; reach almost to umbilicus	Not bifurcated; reach 4/5 of way to umbilicus; 1/2 way in old age	Not bifurcated; reach 4/5 of way to umbilicus; 1/2 way in old age
Umbilicus	Moderately deep, steep walls	Deep; nearly vertical walls	Moderately deep; steep walls
Umbilical shoulder	Rounded	Squarely rounded	Broadly rounded
Suture	EL: 2 lobules, one deeply bifurcated	EL: 2 lobules, one distinctly bifurcated	EL: 2 lobules, both bifurcated
	L_1: slightly deeper than EL	L_1: deeper than EL	L_1: same length as EL
	l_1: slightly inclined; remaining auxiliary lobes and saddles oblique	l_1: inclined; remaining auxiliary lobes and saddles slightly oblique	l_2: first inclined; remaining auxiliary lobes and saddles very oblique
Stratigraphic position	Haslam shales; Cedar District shales	Haslam shale	Lambert shale

[1] > = greater than; < = less than.

Occurrence. Haslam formation, localities 206, 216, 246, 522; Cedar District formation, localities 275, 276, 277, 281, 290, 526.

Types. Holotype, U.S.N.M. Cat. No. 12394, "Komooks, Vancouver Island" (probably Nanaimo district); plesiotypes, G.S.C. No. 10031, Haslam formation, Nanaimo district, Vancouver Island, British Columbia; G.S.C. Nos. 10030, locality 277; 10032, locality 281; Cedar District formation, North Pender Island, British Columbia; plastotype, G.S.C. No. 10033, of the holotype.

Pachydiscus suciaensis (Meek), 1861

Plate IX, figures 1-11; Plate X, figures 1-3; Plate XXXI, figures 2, 3

1861. *Ammonites complexus* var. *suciaensis* Meek, Proc. Acad. Nat. Sci., Philadelphia, vol. XIII, p. 317.
1869. (?) *Ammonites suciaensis* Meek. Gabb, Paleont. Calif., vol. II, p. 133, Pl. XXI, figs. 11, 11a, 11b.
1876. *Ammonites complexus ?* var. *suciaensis* Meek, Bull. U.S. Geol. Geog. Surv. Terr., vol. II, No. 4, p. 369, Pl. V, figs. 2, 2a, 2b, 2c.
1879. *Ammonites complexus* var. *suciaensis* Meek. Whiteaves, Mesozoic Fossils, vol. I, pt. II, p. 106.
1898. *Pachydiscus suciaensis* (Meek). Kossmat, Beitr. z. Pal. u. Geol. Österr.-Ung., vol. XI, p. 96.
1903. *Pachydiscus suciaensis* (Meek). Whiteaves, Mesozoic Fossils, vol. I, pt. V, p. 344.
1921. *Canadoceras suciaensis* (Meek). Spath, Trans. Roy. Soc., S. Africa, vol. X/2, pt. 3, p. 125.

Dimensions. Specimen No. 10034: 7·7; 44; 49; 26; No. 10035: 23·3; 46·3; 47·2; 22·7; No. 10036: 39; 46·9; 41; 24·6; No. 10037: 90; 43·3; 39; 25; No. 5840: 98; 44; 41; 27; No. 10038: 108; 48; 38; 25; No. 10039: 145; 48; 36·5; 25.

At 4 Millimetres Diameter. EL broad-stemmed, bifid branch on each side of siphon; L_1 same depth or somewhat deeper than EL, not deeply trifid; L_2 bifid, located on umbilical shoulder, much shorter than L_1; l_1 bifid; much shorter than L_2. S_1 the largest saddle, as broad as lobes, bifid, outer branch bifid and larger than inner branch; S_2 shorter than S_1, not deeply bifid; s_1 indistinctly bifid, shorter than S_2.

At 8 Millimetres Diameter. Shell round, inflated; venter broadly rounded; whorl widest three-quarters of the way down the flank; umbilicus deep, with broadly rounded, gently sloping walls; umbilical shoulder broad; involution three-quarters to four-fifths.

Shell smooth; numerous very fine lines visible on thin, transparent shell, appearing and directed slightly backward at umbilical suture, straightening on umbilical shoulder to pass abruptly across flanks and over venter.

Suture deeply cut; lobes and saddles with broad stems; lobes indistinctly trifid, saddles indistinctly bifid.

At 17 Millimetres Diameter. Flanks begin to flatten; whorls not as broadly rounded as in earlier stage; venter elliptically ovate, smooth. Whorl widest about two-thirds of the way down the flanks. Umbilical shoulder more sharply rounded than in earlier stage; umbilical walls smooth and much steeper. Ratio of whorl height to whorl width reduced from 44 : 49 at 8-mm. stage to 44·5 : 47·4 at 17-mm stage. Shell smooth except for fine, numerous lines as before.

Suture more deeply cut; L_1 same depth as EL, trifid, each lobule trifid; L_2 narrower and shorter than L_1; S_2 much shorter and narrower than S_1; s_1 narrower than S_2 but of same height.

At 19 Millimetres Diameter. First ornament appears as very faint, broad undulations of the shell on the umbilical shoulder at 18 mm. diameter. At 19 mm. diameter, low, narrow bullæ arise just over the edge of the umbilical shoulder and stretch radially, without curvature, one-third of the way up the flanks where they merge into the smooth, flattened to slightly rounded surface of the flanks. Bullæ highest and most pinched on umbilical shoulder, and spaced, at first appearance, at intervals of 45 degrees around umbilicus. First inter-bullæ area flat or very broadly concave; second inter-bullæ area distinctly concave, smooth. Involution, two-thirds to three-quarters.

At 45 Millimetres Diameter. Ratio of whorl height to whorl width altered to the extent that whorls are now higher than wide. Umbilical diameter enlarged; flanks flattened, only very slightly convex; venter elliptically ovate, meeting flanks with rounded contour; umbilical shoulder smoothly and abruptly rounded, steepening rapidly into nearly vertical umbilical wall. Involution, three-quarters to four-fifths.

Bullæ on umbilical shoulder have elongated into primary ribs, which lengthen with shell growth, each one reaching progressively farther than the last towards the venter. The fifth or sixth primary rib is the first to cross the venter. Primaries originate, just over the edge of the umbilicus, in moderately sharp, raised or pinched, radially elongated bullæ. They decrease in height and width about one-third of the way up the flank, crossing the upper flanks and the venter as radial, straight, low, narrow ribs. With increase in whorl size, the ribs become progressively closer together and begin higher up on the umbilical shoulder. At 45 mm. diameter there are 7 primary ribs on the younger half of the outermost whorl. Here, a secondary rib appears between each pair of primaries, abruptly but smoothly intercalated at about mid-whorl. They shortly equal the primaries in size, and cross the flanks and venter in a straight, radial direction. On the venter, primary and secondary ribs are indistinguishable. Additional ornament consists of fine, densely packed, radiating lines covering all of the outer shell layer.

Suture line more ramified and more deeply cut than, but reflecting, the earlier pattern. L_1 somewhat deeper than EL, the latter with 2 principal bifid branches on each side of the siphon. These 4 lobules may be the 4 branches to which Whiteaves referred in distinguishing the suture of *P. suciaensis* from that of *P. newberryanus.* S_2 nearly as high as S_1.

At 90 Millimetres Diameter. Whorl distinctly compressed; venter smoothly but narrowly rounded; umbilical shoulder more sharply rounded than in earlier stages; umbilical wall steep to vertical.

Ornament as in previous stage; 11 long, narrow, bullate major ribs arise on the edge of the umbilicus. At this point they are inclined faintly backwards, but straighten quickly to pass directly across the flanks and venter. Between each pair of major ribs and reaching various distances (rarely beyond three-quarters of the way) down the flanks, is 1, and towards the aperture, 2, minor ribs. The minor ribs shortly attain the same strength as the majors, and parallel them across the flanks and venter. Dense, fine lines are still observable. On the lower flanks the minor ribs tend to originate close to major ribs, vaguely suggesting bifurcation.

Suture pattern as before; L_1 deeper than EL, main stem wider than that of EL; L_2 unequally trifid, same depth as EL; l_1 unequally bifid; S_1 narrower than EL, deeply cut, nearly equally bifid; S_2 smaller than S_1, unequally bifid, stem very narrow; s_1 shorter and smaller than S_2, unequally bifid. Remaining auxiliary lobes and saddles oblique.

At 145 Millimetres Diameter. Concomitant with the increase in size from the last to the present stage are four noteworthy trends in the dimensions and ornament of the shell:

(1) The comparative height of the whorl increases.

(2) The comparative thickness of the whorl decreases.

(3) The minor costæ become fewer but stronger, particularly toward the umbilicus, so that there is less disparity between the relative size of the major and minor costæ. On specimens of approximately 150 mm. diameter there are, on the average, 15, more or less equal, straight, bullate costæ on the outer whorl, arising immediately over the edge of the umbilical shoulder and passing directly across the flanks and over the venter.

(4) The costæ are the most strongly developed on the inner flanks and venter and toward the aperture; the ribs become low and ill-defined in mid-flank. This tendency becomes more manifest as the shell increases in size and in large specimens (200 mm. diameter) the costæ, in addition to being almost obsolete across the middle flanks, are poorly defined across the venter.

Among the specimens of *P. suciaensis* from Hornby Island are two specimens varying somewhat from the typical ornament of the species. The first specimen (G.S.C. No. 10038) presents a modification in which the bullæ on the umbilical shoulder tend to bifurcate, at a point immediately beyond the umbilicus, into 2 major costæ, which pass straight across flanks and venter. The bifurcation is not always clearly distinguishable and not all of the primary ribs show it. On the last half of the second inner whorl, the bullæ as well are indistinct, and they become increasingly broader and more subtle towards the aperture. The outer whorl shows 11 major costæ, with 1 to 3 (usually 2) minor costæ intercalated between each pair of major costæ.

Specimen No. 5840 is only slightly more rotund than the typical *P. suciaensis.* Eleven major costæ pass straight across the flanks and venter, 10 of them originating from the bifurcation of 5 bullæ at the umbilical shoulder. The bifurcations are well marked, and the costæ are equal in size on the venter, although, at the point of bifurcation, the posterior costa of each pair is the coarser. Between each pair of major costæ are inserted 1 to 3 minor costæ, which appear about mid-flank and on the venter equal the major costæ in size. On the younger half of the outer whorl the bullæ are narrower and sharper than on the older half, but the costæ tend to become obscure in mid-flank and towards the venter on the younger part of the whorl.

Specimen No. 5840 stands half-way in morphological characteristics between specimen No. 10038 and *P.* cf. *jacquoti* (specimen No. 5839) in which strong bifurcations and a rotund whorl are the outstanding features. *P.* cf. *jacquoti* is remarkably close to *P. jacquoti* Seunes, which de Grossouvre referred to *P. neubergicus* (van Hauer). This similarity suggests a close relationship of *P. suciaensis* to the *P. egertoni-neubergicus* group of the European Upper Cretaceous. Table III compares and contrasts the three species.

TABLE III

Comparison of Pachydiscus egertoni, P. neubergicus, and P. suciaensis

—	*P. egertoni* (Forbes)	*P. neubergicus* (van Hauer)	*P. suciaensis* (Meek)
Dimensional indices	Forbes 105; 45; 33; 27 Stoliczka 105; 44; 33; 28	de Grossouvre 94; 44; 27; 28 van Hauer 250; 48; 37; 17	90; 43; 39; 25; 108; 48; 38; 25
Shell shape........	Subcompressed......	Moderately inflated; compressed mid-maturity; $\frac{1}{2}$ to $\frac{2}{3}$ involute	Subcompressed
Shell whorl........	Elliptically cordate x-section; whorls rounded; venter narrowly rounded	Oval x-section; whorls rounded	Oval x-section; whorls rounded
Ornament.........	Major costæ—10 on outer whorl; low; prominent on umbilical border; obsolete on mid-flank; reappear on venter; not present on venter in old age Minor costæ—inserted between majors on venter	Youth-smooth. Mid-stage—node-like ribs at umbilicus (13-15 nodes or bullæ); costæ on venter Maturity—60 ribs on venter; obsolete on lower flanks	Youth—smooth; with bullæ at umbilicus Mid-stage — straight; low, narrow, bullate costæ crossing flanks and venter; 1-3 minor costæ per pair of majors on ventral whorl Maturity—costæ indistinct on mid-flanks; becoming faint on venter; tendency to bifurcate at bullæ; total number major costæ 11-15; becoming smooth in old age, particularly ventral part of whorl
Suture...........	EL—bifid, shorter than L_1; L_1—largest lobe, trifid; S_1—broadest saddle; S_2—longer than S_1;—all saddles bifid	EL—shorter than L_1; L_1—trifid	EL—shorter than L_1; L_1—trifid; S_1—largest, bifid; external branch largest

The similarities among these three forms are more obvious than their differences; each of them passes through comparable ontogenetic stages, that is: (1) a smooth early youth; (2) appearance of umbilical bullæ;

(3) elongation of the bullæ into major costæ crossing the flanks and venter and separated on the ventral half of the whorl by 1 to 3 minor costæ; and (4) reduction and disappearance of the costation, on two of the forms, on the venter and mid-flanks, and, in the third form, on the lower flanks. *P. suciaensis* has more numerous major costæ, and these are narrower and sharper during youth and early maturity than are those of the European species. Neither Meek nor Whiteaves record bifurcation of the major costæ, and this tendency has been found on only a very small proportion of the total number of specimens. The unequivocal affinity of the Canadian species with the *P. egertoni-neubergicus* group of Europe and Asia warrants the retention of this species in the genus *Pachydiscus*.

Comparison of *P. suciaensis* with *P. newberryanus* and *P. haradai* has been previously outlined. *P. suciaensis* is found in the upper Lambert formation of Hornby Island, and in the Northumberland and Gabriola formations of the Nanaimo basin. It is related through morphologically intermediate forms to *P.* cf. *jacquoti*, which is recorded from the Cedar District formation on Sucia Island.

Occurrence. Upper Lambert formation, localities 109, 111, 112, 113, 114, 502; Northumberland formation, localities 260, 264, 284; Gabriola formation, locality 266.

Types. Cotype, U.S.N.M. Cat. No. 12396, "Komooks, Vancouver Island" (probably Hornby Island); plesiotypes, G.S.C. Nos. 10034, 10035, and 10039, locality 109; 10036, locality 113; 10037, 10038, and 5840, locality 502; upper Lambert formation, Hornby Island, British Columbia.

Pachydiscus sp. cf. *P. jacquoti* Seunes, 1890

Plate XI, figures 1-3; Plate XXXI, figure 1

1890. *Pachydiscus jacquoti* Seunes, Mém. Soc. Geol., France, Paléont. No. 2, vol. I, pt. 1, p. 5, Pl. II, figs. 1-3.
1890. *Pachydiscus jacquoti* Seunes, Recherches terr. second. rég. souspyrénéene, vol. XVIII, p. 237, Pl. IX, figs. 1-4.
1891. *Pachydiscus jacquoti* Seunes, Mém. Soc. Geol., France, Paléont., No. 2, vol. II, pt. 3, p. 9, Pl. III, figs. 4a, 4b.
1893. *Pachydiscus egertoni* (Forbes). de Grossouvre, Amm. de la Craie sup., p. 207.

Dimensions. Specimen No. 5839: 108; 42; 39; 22.

Shell discoidal, moderately inflated, more than 4 whorls visible; whorls higher than wide, rounded, with somewhat flattened flanks; venter well rounded; whorl shape oval, deeply emarginate; involution about two-thirds; umbilicus moderately deep, with steep walls; umbilical shoulder smoothly rounded; two inner whorls show elongated tubercles on the margin of the umbilicus jutting slightly over the edge of the shoulder and disappearing where the umbilical wall begins to steepen.

Ornament of outer whorl consists of 12 primary costæ beginning on umbilical shoulder in broad (2 to 4 mm.), raised or pinched, radial bullæ, which quickly merge into the contour of the umbilical wall. Each primary costa bifurcates, one-quarter to one-third up the lower flank, into two equal, narrow costæ, which may undulate slightly on the upper flanks but which usually cross the venter in a straight line. The point of bifurcation may be somewhat obscured by a reduction in the size of the costæ at that point, and there is, in addition, a reduction in the strength of the costæ along the siphonal line. The oldest quarter of the outer whorl shows strong, well-defined costæ, but on the youngest three-quarters of the same whorl, the costæ become lower and broader, losing their sharpness. Here the bifurcation is most obscure and the costæ become obsolete in mid-flank.

One to three (usually two) minor ribs are intercalated between each pair of primary ribs. On the oldest quarter of the outer whorl the minor costæ originate from near the umbilicus to about two-thirds of the way up the flank, arising progressively farther and farther from the umbilicus on the youngest three-quarters of the whorl. On the venter they are generally indistinguishable from the major costæ. All costæ, with the exception of one or two that are slightly curved, cross the flanks and venter in a straight line.

Suture line deeply cut and extremely ramified, very close to that of *P. suciaensis;* EL broad, with 2 bifurcated terminal branches equal in length to L_1; L_1 as deep as EL, unequally trifid, central lobule trifid, 2 lateral lobules unequally bifid, stem as broad as that of S_1; L_2 unequally trifid, somewhat shorter than L_1; l_1 narrow, situate on umbilical shoulder, shorter than L_2; l_2 inclined; l_3 very short, very oblique. S_1 straight, unequally bifid, outer branch the larger, each branch again bifid, main stem narrower than that of EL; S_2 narrower, with crooked main stem, nearly equally bifid, inner branch the larger, same height as S_1; s_1 narrow, unequally bifid, shorter than S_2; s_2 much shorter than s_1, bifid; s_3 very short, oblique, not bifid.

Shell shape and ornamentation of the single Sucia Island specimen are incredibly like that of Seunes' figured specimen. Sutural line differences are manifest in the earlier reduction in size of the auxiliary elements of the American form. It seems likely that *P. jacquoti* is a variation of the *P. egertoni-neubergicus* group and that *P.* cf. *jacquoti* and *P. suciaensis* are North American representatives of that same group. The U.S.N.M. cotype No. 1276 is probably another specimen of *P.* cf. *jacquoti.*

Occurrence and Type. Plesiotype, G.S.C. No. 5839, locality 526, Cedar District formation, Sucia Island, Washington, U.S.A.

Pachydiscus (*=Eupachydiscus?*) *haradai* Jimbo, 1894

Plate XII, figures 2-4; Plate XIII, figures 1-3; Plate XXXI, figure 6

1894. *Pachydiscus haradai* Jimbo, Paleont. Abh. Neue Folge, vol. II, pt. 3, p. 29, Pl. II (XVIII), figs. 2, 2a, 2b.
1895. *Pachydiscus haradai* Jimbo. Whiteaves, Trans. Roy. Soc., Canada, 2nd ser., vol. I, sec. IV, p. 132, Pl. III, fig. 6.
1903. *Pachydiscus haradai* Jimbo. Whiteaves, Mesozoic Fossils, vol. I, pt. V, p. 345.
1921. *Parapachydiscus haradai* (Jimbo). Spath, Ann. S. African Mus., vol. XII, No. 16, p. 230.
1922. *Eupachydiscus haradai* (Jimbo). Spath, Trans. Roy. Soc., S. Africa, vol. X/2, pt. 3, p. 124.
1926. *Mesopachydiscus haradai* (Jimbo). Yabe and Shimizu, Proc. Imp. Acad. Japan, vol. II, No. 4, art. 60, p. 172.
1927. *Parapachydiscus (Mesopachydiscus) haradai* (Jimbo). Yabe, Tohoku Imp. Univ., Sci. Rpts., 2nd ser., vol. XI, pp. 27 (1), 100 (74), Pl. VII, figs. 10a, 10b.
1935. *Eupachydiscus haradai* (Jimbo). Shimizu, Jour. Shanghai Inst., sec. II, vol. 1, p. 159.

Pachydiscus haradai is found in the Upper Cretaceous rocks of Japan and Vancouver Island and, in the latter beds, it is one of the most abundant of several *Pachydiscus* species. Typically, *P. haradai* shows considerable variation in size, shape, and ornament, but there is no published account of this diversity. The perplexities resulting from the lack of replete observations have been augmented by descriptions and illustrations that do not concur. For example, Jimbo's figured specimen is recorded having dimensions of 160; —; 43·1; 34·4; whereas his illustration measures 156; 45; 44; 25. Yabe subsequently showed the umbilical index to be between 24 and 25 per cent, and the present investigation has confirmed this observation. Yabe and Shimizu's generic subdivision of the Japanese parapachydiscids (that is, pachydiscids) was based, to a large extent, on whorl shape, yet the cross-section they show for *P. haradai* has a height index of as much as 9 per cent *less* than that described as the typical whorl height of the species.

It is evident that a complete restudy of the type material is needed to establish the median characteristics and limits of variation of the species, as well as a full account of comparisons with other *Pachydiscus* species.

The present collection contains fifteen specimens of *P. haradai*. The one described and figured by Whiteaves is the best specimen for its size, and has been used as a basis for comparison. Half of the specimens range from 50 to 100 mm. in diameter; the other half between 100 and 200 millimetres. Variation is most marked in the smaller specimens, and because there is no published account of the young stages of *P. haradai* and no large specimen in the present collection that shows the inner whorls well enough for study, a detailed description of the ontogenetic development of the Canadian specimens is not possible.

Dimensions. Specimen No. 10043: 47·7; 42; 46; 23; No. 10042: 84·5; 45; 45; 22·5; No. 10044: 109; 44; 42; 23; No. 5848: 154; 42·8; 40; 25; No. 10045: 182; 40; 38; 24.

At Diameter of 150 Millimetres. Shell discoidal, composed of large, somewhat flattened whorls; ventro-lateral angle broadly rounded; venter broadly rounded, somewhat squarish near aperture, ovate on oldest part of outer whorl; flanks pass smoothly into abruptly rounded dorso-lateral angle of umbilical shoulder; umbilicus deep, equal to one-quarter of shell diameter; umbilical walls steep, smooth; involution two-thirds; whorls higher than wide, greatest width on lower flank; aperture squarely ovate, about two-thirds emarginate by preceding whorl.

Eleven major costæ arise at umbilical shoulder in slightly raised bullæ, and arch broadly forward across flanks to venter across which they display a strong forward arcuity. Bullæ disappear abruptly down umbilical wall. Inter-costal areas between major costæ shallow, concave to flat, interrupted by 1 to 4 minor costæ that parallel the major costæ across flanks and venter and that reach almost to the umbilical shoulder, where they taper to a point and disappear into the rounded slope of the shoulder. Minor costæ unequal in size and length, the largest being somewhat smaller than major costæ and extending nearly to the umbilicus. At beginning of outer whorl, 3 to 4 minor costæ occur between each pair of major costæ and extend three-quarters to seven-eighths of the distance down the flanks. On younger parts of the outer whorl, minor costæ number 1 or 2 per intermajor costal areas and reach one-half to three-quarters of the distance down the flanks. On the venter, minor costæ nearly equal major costæ in size. Entire shell covered with densely packed, fine lines beginning at umbilical suture and paralleling the costæ across the flanks and venter; lines best preserved in inter-rib areas.

Suture indistinct; L_1 deeper than EL; L_2 about same depth as L_1. Saddles broad. Lobes and saddles decrease gradually and regularly in size towards umbilicus; 3 auxiliary lobes and 3 auxiliary saddles visible; l_2 on umbilical shoulder; s_2 somewhat inclined, remainder of auxiliary saddles oblique.

At Diameter of less than 150 Millimetres. Young specimens of *P. haradai* (diameters, less than 75 mm.) have whorls slightly wider than high, but with increase in size this relationship changes to where, at about 75 mm. diameter, the height and width of the outer whorl are equal; beyond this stage the whorls become, and remain, higher than wide. Costation of young specimens is strong and well defined. Nine or ten major costæ begin abruptly on the umbilical shoulder in a sharp, pointed tubercle. Between each pair of major costæ 2 to 4, unequal, minor costæ are intercalated and reach to within a few millimetres of the umbilical shoulder where they quickly pinch out and merge into the smoothly but abruptly rounded dorso-lateral angle of the umbilical shoulder. The weakest minor costæ extend only three-quarters of the distance down the flanks. All costæ are high and sharply rounded, with equally deep, concave grooves between them; all bend forward across the flanks in a gentle arcuity and describe a distinct forward convexity on the venter where, except for the weakest of minor costæ, all are of equal size.

The umbilicus is deep, with steep, smooth walls. The high, and commonly sharp, tubercles on the umbilical shoulder are an outstanding feature of all of the small, young specimens. Later tubercles are less conspicuous, so that, on shells 100 mm. in diameter, they are still prominent but not sharp or high. At 150 mm. diameter, the tubercles have been replaced by transversely elongated bullæ. The sharply rounded, ridge-like costæ of youth also become supplanted on later whorls by broader, flatter costæ and the minor costæ are shorter.

The sutural pattern established early in youth is maintained throughout maturity; the lobes are broad, and L_1 is the deepest; L_2 is slightly shorter than EL; s_2 is at first located on the umbilical shoulder but is replaced by l_2 and moves onto the upper umbilical wall; lateral lobes are trifid but auxiliary lobes and all saddles are bifid.

At Diameter of More Than 150 Millimetres. With increase in size beyond 150 millimetres, the major costæ retain strong bullæ that are coarser and broader than those found on smaller whorls. The costæ also broaden and flatten, in some cases becoming indistinct on centre flanks. Intercostal spaces are wide and flat, and are interrupted at mid-flank by 1 or 2 gradually rising, low, broad, subdued minor costæ. The umbilicus deepens perceptibly, with high, vertical outer walls. Sutures of the largest Canadian specimens of *P. haradai* are unknown.

Résumé of Ontogeny

The most notable ontogenetic change in *P. haradai* takes place in the whorl shape; specimens less than 70 mm. in diameter have whorls wider than high; specimens 70 to 85 mm. in diameter have whorls as wide as high; specimens greater than 100 mm. in diameter have whorls higher than wide. In other words, the ratio of the whorl height to the whorl width is a constantly increasing quantity, at first less than unity, but with growth becoming greater than unity as the height exceeds the width. This holds true with very few exceptions. In proportion to the increasing diameter of the shell, the height of the whorl remains fairly uniform, whereas the whorl width decreases somewhat; the width of the umbilicus in proportion to the diameter of the shell tends to decrease slightly from the early stages up to shell diameter of 100 mm. and to increase again very slightly as the shell grows beyond 100 millimetres.

The ontogenetic change in ornamentation is towards larger, broader, less acute costation, with a decrease in the number and length of minor costæ and a replacement of early umbilical tubercles by transversly elongated bullæ of the more mature stages. Sutural changes are manifested by more intricate ramifications of the early established pattern.

The Canadian *P. haradai* is reasonably close to the Japanese specimens. Mature forms from Nanaimo River are more compressed and the venter seems to be more narrowly ovate. As a result, the whorl section has a high appearance. Yabe and Shimizu's cross-section of *Mesopachydiscus* (=*P. haradai*) is more rectangular and considerably wider than high, a condition incongruous with pre-defined determinations. The suture line of *Mesopachydiscus* is dissimilar to the typical *P. haradai* suture in that it has an L_1 nearly equal in length to, and not longer than, EL.

Whiteaves suggested that *P. haradai* was not very different from the Indian *P. egertoni* Forbes. The two species are similarly costate, but *P. egertoni* is much more compressed and its costæ become obscure in mid-flank, a tendency barely beginning in very late stages of *P. haradai*. Compared with *P. suciaensis*, *P. haradai* is less compressed, with fewer major costæ, sharper tubercles, and more strongly ornamented youthful stages.

Yabe and Shimizu suggested that *P. yokoyamai* Jimbo is a juvenile specimen of *P. haradai* and Jimbo's figures of the former much resemble those of equal sized *P. haradai* from the Haslam shale. The high, sharp tubercles on the major costæ, the strong, sharp ribbing, and the wider-than-high whorls are closely similar in the two species. *P. yokoyamai* has, however, much wider whorls and umbilicus than *P. haradai*. The ornament of *P. teshionensis* is close to that of *P. haradai*, differing in the greater number of costæ on a larger, more rounded, and wider outer whorl.

Additional species from India resemble *P. haradai*, among them *P. jimboi* Kossmat (1898, Pl. 14, figs. 1a, b), the whorl shape of the two species being alike; *P. haradai* lacks periodic constrictions. The *Ammonites denisonianus* Stoliczka referred to *P. jimboi* by Kossmat has much finer and more numerous costæ than *P. haradai*. *P. vaju* has sharp umbilical tubercles, but the costæ undulate across the flanks and the minor costæ reach only half-way down the flanks.

P. carezi de Grossouvre possesses the sharp tubercles and distinct costæ of *P. haradai*, but its costæ become progressively coarser and have frequent bifurcations. Its shape and dimensional indices are unknown.

In Japan, *P. haradai* ranges from mid-Santonian to middle Upper Maestrichtian; on Vancouver Island, it is restricted to the Haslam formation.

Occurrence. Haslam formation, localities 215, 225, 226, 233, 242, 244, 245, 522, 523.

Types. Plesiotypes, G.S.C. Nos. 10042, locality 244; 10043, locality 245, north fork of Haslam Creek; 10044, locality 226; 10045, locality 225; 5848, locality 523, Nanaimo River; Halsam formation, Vancouver Island, British Columbia.

Pachydiscus sp. cf. *P. haradai* Jimbo

1903. *(pro parte) Pachydiscus newberryanus* (Meek). Whiteaves, Mesozoic Fossils, vol. I, pt. V, p. 349.

Whiteaves (1903, p. 349) referred to a unique specimen (G.S.C. No. 5949) from "Shopland, near Maple Bay, Cowitchan district, about thirty miles south of Nanaimo, V.I." as an abnormal form of *P. newberryanus* ". . . . . in which there are no periodic constrictions on the cast of the interior of the shell". This specimen is better referred to *P. haradai* on the basis that it has: (1) dimensions of 76; 43; 43; 25; (2) a more broadly rounded venter than *P. newberryanus;* (3) flattened flanks; (4) 11 major costæ sharply bullate at the umbilical shoulder; (5) 2 to 4 minor costæ between each pair of major costæ at the beginning of the outer whorl and 1 or 2 minor costæ between each pair of major costæ on the younger half of the same whorl; and (6) lack of constrictions. The costæ are narrower, higher, and have more highly pinched bullae than other specimens of *P. haradai.* At a diameter of 100 mm. its dimensions are 100; 48; 42; 22; the height of the whorl at this stage is greater than that of the average *P. haradai*, but this may, in part, be due to distortion of the specimen. There is no visible suture. The preservation is unusual in that the fossil is almost jet-black; a preserved fragment of the thin outer shell layer is black, crystalline calcite.

Occurrence and Type. Plesiotype, G.S.C. No. 5949, locality 524-A, ? Haslam formation, Shopland, near Maple Bay, Cowitchan district, about 30 miles south of Nanaimo, Vancouver Island, British Columbia.

Pachydiscus perplicatus Whiteaves, 1903

Plate XII, figure 1; Plate XIII, figures 4-6; Plate XIV, figures 1-3; Plate XV, figures 1, 2; Plate XXXI, figure 5

1903. *Pachydiscus perplicatus* Whiteaves, Mesozoic Fossils, vol. I, pt. V, p. 346, Pl. 48, fig. 1.

1903. *(pro parte) Pachydiscus newberryanus* (Meek). Whiteaves, op. cit., p. 348 (specimens from Browns and Trent Rivers).

Dimensions.	Specimen No. 10046:	13	54	54	—
		28	46	48	21
		55·5	45	50	23
		104	45	50	23
	No. 10047:	45	46·6	53·3	22·2
		101	44	50	23
		177	41·8	50	28
	No. 10048:	194	41·2	51·5	27·3

At Diameter of 45 Millimetres. Shell discoidal, rotund, costate, about two-thirds involute; whorls broadly rounded, considerably wider than high; venter broad, evenly rounded; umbilicus moderately deep, occupying one-fifth to one-quarter of the shell; umbilical shoulder wide, smoothly rounded.

Ornament of 30 to 32 simple, broad, low costæ separated by concave grooves equal to, or slightly wider than, the costæ. Costæ appear at umbilical shoulder, passing across flanks in a graceful forward curve and crossing venter with a shallow, but well-defined, forward arcuity. Costæ of two kinds alternating with one another in the ratio of 1:1; the stronger ribs originate closer to the umbilicus, are slightly bullate at this point, and extend across the flanks and venter with undiminished vigour; the lesser costæ are non-bullate, with their point of appearance at first near the umbilicus and later, on younger parts of the whorl, somewhat farther up the flank from the umbilicus. Occasionally, on the outer flanks and venter, the lesser costæ become as strongly developed as the major costæ, whereas others become more obscure or may disappear on the ventro-lateral shoulder. With continued growth, new costæ are coarser and more widely spaced.

EL very broad, with 2 main lobules on each side of the siphon, the two adjacent to the siphon being trifid; siphonal saddle short, square; L_1 broad, equally trifid, same depth as EL; remaining lobes unknown. S_1 unequally bifid, the outer branch the larger; remaining saddles unknown. At a diameter of 80 mm. L_1 is deeper than EL; the extremity of L_2 is inclined towards the venter; 4 auxiliary lobes, of which the first is trifid. Five auxiliary saddles, s_3 the first to be inclined towards umbilicus. Auxiliary elements strongly dependent beyond l_2.

At Diameter of 100 Millimetres. Whorl shape much as in younger stages; appears somewhat broader as a result of decrease in the whorl height; umbilicus proportionally larger, and deep, with inclined, smooth walls; venter and umbilical shoulders broadly rounded.

Ornament of irregularly alternating, coarse, major and minor costæ curving gracefully forward on the flanks and over the venter. Outer whorl with 7 or 8 bullate, major costæ arising on the umbilical shoulder. Most major costæ immediately followed by a deep, concave constriction extending from the umbilical shoulder to and over the venter. Between each pair of major costae, 2 to 4 (usually 3) non-bullate, minor costæ appear on the lower flanks at various distances ventral to the umbilical shoulder. Minor costæ weaker than major on lower flanks, but increase gradually in size to where, on outer flanks and venter, they are indistinguishable from the major costæ. In those instances where 4 minor costæ occur between 2 major costæ, 1 or 2 of them may be shorter and weaker than the others throughout their length; occasionally these lesser minor costæ show an indistinct tendency to originate as a bifurcation of a larger minor costa. Intercostal spaces are moderately deep and concave.

The suture at and beyond this stage becomes deeply ramified, the lobes and saddles broad and uniform; from l_1, which is situate on the umbilical shoulder, the auxiliary elements descend obliquely and with a rapid decrease in size into the umbilicus. L_1 is almost equally trifid and somewhat deeper than EL; saddles are equally bifid.

Between Diameters of 100 and 200 Millimetres. The whorls maintain much of the earlier shape except to be slightly wider and more broadly rounded as a result of the decrease in the height index. The umbilicus becomes broader and deeper, with smooth, abruptly rounded shoulders and vertical walls.

The coarseness of the costation varies considerably at this mature stage. The major costæ, numbering about 14, are directed radially on the lower flanks, then swing forward in a wide arcuity across the outer flanks and venter; no constrictions occur at this stage. They are large and coarse on the inner flanks, and although the bullæ are obsolete, the costæ at the umbilical shoulder are high, narrow, and sharply rounded. They broaden and flatten as they sweep towards the venter, but remain large and obtuse on the inner flanks. Here, the intercostal spaces may be broadly concave or deep and narrowly concave, and, in the latter case, the costæ near the umbilicus appear extremely coarse. On the outer flanks and towards the venter, the more subdued major costæ are separated by wide, flat spaces, and on the venter the costæ are reduced to wide, rounded, undulatory-like folds or low, fold-like ribs. At about mid-flank, where the major costæ become more subdued and begin to bend forward, an obscure, fold-like minor costa arises between each pair of major costæ, and, paralleling the latter, crosses the outer flanks and venter; in some specimens these minor costæ are lacking, and none of them is ever equal in size to the major costæ. Generally they occur halfway between major ribs on the venter, but in some specimens they lie closer to the major costa on their apertural side.

At Diameter of 200 Millimetres. The suture is extremely digitated, the lobes being deep and very sharply pointed: EL almost as deep as L_1, with two main branches on each side of the siphon and each branch bifid, with the branchlets next to the siphon paralleling the plane of symmetry; L_1 deep, with very sharp, attenuated terminations; unequally trifid, with a large outer secondary saddle and a needle-like, trifid, centre lobule; L_2 not as deep as EL, but sharp and more symmetrically trifid; l_1 equally trifid, situated on umbilical shoulder; 4 remaining auxiliary lobes dependent and oblique, decreasing rapidly in size to the umbilical suture. S_1 very large, with narrow stem, unequally bifid, the outer (siphonal side) branch the larger; S_2 nearly as large as S_1, unequally bifid, the inner branch, in this case, being the larger; s_1 equally bifid, much smaller than S_2; 5 remaining auxiliary saddles; the first 2 bifid and gradually decreasing in size, the inner 3 being very small.

Throughout the ontogeny of *P. perplicatus* there is a constant, slow decrease in the height and width of the whorl proportionate to the diameter of the shell, but the ratio of height to diameter decreases more rapidly than that of height to width, so that the whorls become wide and broadly rounded. The umbilicus increases in diameter, becoming deep and infundibuliform. The costation coarsens particularly on the inner flanks surrounding the umbilicus, whereas on the outer flanks and venter the costæ are large but low and less protruding. Bullæ, which are best developed in late youth and early maturity, are lost at full maturity, although the major costæ are high and narrow at their origin. Minor costæ decrease in number from 3 to 1 between each pair of majors, and in large specimens are greatly reduced in size proportionate to the major ribs. In a few specimens, the major costæ are most strongly developed on the outer whorl, giving the shell a rugged, coarsely corrugated appearance. The constrictions of early stages are almost always obsolete at maturity.

In the latest stages, the suture line achieves its maximum complexity, L_1 being at first equal to, and then exceeding, EL in depth and becoming very sharply digitated; L_1 also changes from nearly equally trifid to asymmetrically trifid, with a lanceolate central lobule. The saddles, at first equally bifid, become unequally bifid, the outer branch of the first lateral saddle and the inner branch of the second lateral saddle being the larger in each case.

P. perplicatus bears a superficial resemblance to *P. newberryanus* and *P. haradai*, particularly in the ornamentation of specimens of about 100 mm. diameter; they can, however, be distinguished by differences in whorl shape and dimensional indices (i.e., *P. haradai*, 100; 44·5; 41; 22; *P. newberryanus*, 113; 42; 37; 26·5; *P. perplicatus*, 101; 44; 50; 23). In specimens of this size, *P. perplicatus* has broad, rounded, nearly circular whorls that are much wider than high. Except for ventro-lateral nodes, the sculpture of *P. binodatus* is almost identical with that of *P. perplicatus*. *P. peninsularis* Anderson and Hanna from the 'Upper Chico' of California has much the same whorl shape as the Canadian species, but its ribbing is much more reduced.

The ornament of *P. isculensis* Redtenbacher is very close to that of *P. perplicatus* except that the latter appears to have more numerous minor costæ in the early mature stages of development; Redtenbacher's species has a much different whorl shape, especially in large specimens where the height is greater than the width. De Grossouvre's specimens of *P. isculensis* are much closer to the Vancouver Island species, particularly in late youth and early maturity; the suture lines of the two forms show close similarity, especially in the deep, lanceolate, central lobule of L_1; L_1 of *P. perplicatus* is, however, less equally trifid. The suture also can be compared favourably with that of *P. naumanni* Yokoyama, which differs from the Canadian form in having more numerous, but finer, costæ, and an even wider and more robust whorl.

P. perplicatus, which includes those specimens from the Trent River shales on Browns, Puntledge, and Trent Rivers identified as *P. newberryanus* by Whiteaves, is restricted to that formation, and almost entirely to its lower beds.

Occurrence. Trent River formation, localities 21, 120, 128, 129, 153, 154, 155, 158, 166, 167, 504, 508, 512, 513.

Types. Holotype, G.S.C. No. 5852, locality 504, Trent River formation, Comox River (i.e., Puntledge River), Vancouver Island, British Columbia; plesiotypes, G.S.C. Nos. 10046, locality 21, Puntledge River; 10047, locality 128, Browns River; 10048, locality 153; 10049, locality 513, Trent River; Trent River formation, Vancouver Island, British Columbia.

Pachydiscus multisulcatus Whiteaves, 1903

Plate XVI, figures 1–4; Plate XXXI, figure 8

1879. *(pro parte) Ammonites newberryanus* Meek. Whiteaves, Mesozoic Fossils, vol. I, pt. II, p. 110, Pl. 14, figs. 1, 1a.
1903. *Pachydiscus multisulcatus* Whiteaves, Mesozoic Fossils, vol. I, pt. V, p. 349, Pl. 50.

Dimensions.

Specimen No. 10050:	6·5;	39 ;	61·5;	39 ;
	12 ;	37·5;	54 ;	37 ;
	24 ;	37·5;	46 ;	35·4;
	47 ;	40 ;	42·6;	35 ;
	92 ;	43 ;	42·4;	30·4;
No. 5842:	130 ;	43·5;	40 ;	27 ;
No. 5856:	190 ;	44·2;	41 ;	28 ;
No. 5842b:	223 ;	45·7;	49 ;	24·4;

At Diameter of 6 Millimetres. This stage is represented by the second volution. Whorls much broader than high, greatest width about one-third of the way from the umbilicus to the venter; venter broadly rounded; flanks short, sloping broadly into the short, inclined wall of the umbilicus. Ornament at first lacking; on last half of volution 2 or 3 bullæ appear, beginning just above the umbilical suture, and passing diagonally across the lower flanks; immediately posterior to each of these is a comparatively deep, narrow constriction arising very close to the umbilical suture. Ventral ornament unknown, probably lacking. Visible suture consists of 3 lobes, 2 saddles; EL broad, bifid, with a short, flattened siphonal saddle; L_1 broad, irregularly trifid, equal in depth to EL; L_2 short, broad, irregular in pattern; S_1 high, broad, bifid, outer branch the larger; S_2 small, bifid, inner branch the larger.

At Diameter of 12 Millimetres (Whorl No. 3). By the beginning of the third whorl, the bullate major costæ are well defined; between them are intercalated 1 or 2 minor costæ, beginning higher up from the umbilicus on the lower flank. Whorl height progressively increases, whereas whorl width progressively decreases. Bullæ of major costæ begin higher up on the umbilical shoulder to where, at the end of this whorl, the umbilical wall, which is short but steeper than on the earlier whorl, is smooth. There are 8 high, narrow, and sharply rounded bullæ on this whorl, but only 2 or 3 of them are bordered posteriorly by constrictions. Major costæ pass more radially across the flanks and are exceptionally coarse for a shell of this size.

At Diameter of 24 Millimetres (Whorl No. 4). Costation consists of 10 major, bullate ribs, each followed by 1 to 3 minor costæ. Bullæ at first highly pinched, but toward last half of the whorl, diminish in sharpness and narrowness and become coarse and dull; major costæ large and rounded. Minor costæ have not increased in size proportionately to major costæ, and appear smaller than in preceding whorl; only 1 or 2 of them begin low enough to be seen in the umbilicus. Umbilicus reduced in size, deeper than before, with short, smooth, nearly vertical walls and a rapidly rounded shoulder. Whorl section more ovate as a result of continued increase in its height and decrease in its width.

At Diameter of 48 Millimetres (Whorl No. 5). Bullate major costæ persist as on preceding volution, 2 or 3 of them bordered posteriorly by constrictions, each of which, in turn, is bordered by a few minor costæ.

The narrow and transversely elongated bullæ project about one-third of the distance down the much higher umbilical wall. Non-bullate minor costæ increase in number and size on this volution, there being at first 1 to 3 of them intercalated after each major costa, and later, on the outer part of the fifth whorl, 4 to 6 of them between each 2 major costæ. They begin at, and various distances above, the umbilical shoulder. By mid-flank they are all equal in size and only somewhat smaller than the major costæ. At irregular intervals, a larger-than-average minor costa bifurcates on the lower flanks. All costæ are flexuous and bend forward slightly on the flanks. On the venter they describe a definite but not profound forward convexity. On the youngest part of this volution the minor costæ are much stronger, and on the venter they are practically indistinguishable from the major costæ.

At Diameter of 96 Millimetres (Whorl No. 6). The trend towards uniform-sized costation, which appeared in the last whorl, is accelerated on this whorl by the gradual disappearance of the bullæ and a lengthening of some of the minor costæ toward the umbilicus. On this whorl there are 24 costæ, half of which are larger and extend nearer to the umbilicus than the other 12. The shorter ones begin on the lower flanks, but on the last eighth of this whorl almost all of the costæ are equal in length. Three lobes and 4 saddles can be distinguished. The lobes are trifid, EL and L_1 equal in length. S_1 is large, bifid, its outer branch the larger.

During the growth from the second to the sixth whorl a progressive change in the dimensions and shape of the shell takes place; the whorl height increases from 39 to 43 per cent of the diameter; the whorl width decreases rapidly from 60 to 42 per cent; and the umbilicus narrows from 39 to 30 per cent. The outermost whorls become much more ovate, with a more narrowly rounded, subcircular venter, flattened flanks, and abruptly rounded umbilical shoulders. These trends continue in stages beyond that of the sixth whorl, and are coincident with a wide variation in the coarseness of the costation. Whiteaves figured a specimen (1879, Pl. 14, figs. 1, 1a) on which the costæ are very numerous (about 35 on half of the outer whorl) and are almost all of equal size and originate near the umbilicus. Unfortunately, the illustration is not a good representation of the specimen, particularly with respect to the inner whorls and to the curvature of the ribs, which are, in reality, radial and straight on the flanks. This specimen is, however, unique in its numerous, comparatively fine costæ.

On other specimens of *P. multisulcatus* of between 100 and 200 mm. diameter, the ornament coarsens. At 150 mm., about 40 costæ cross the venter in a gentle forward arcuity. Of these about 18 emerge suddenly about midway from the contour of the umbilical shoulder and describe a straight or slightly flexed course across the flanks. Between these, 1 to 4 shorter but equally strong costæ are inserted, beginning at various distances up the flank but commonly on the lower third; occasionally one of these shorter costæ may bifurcate on the lower flank. The costæ are strong and rather narrow but well rounded, with smooth, deeply concave grooves separating them.

The tendency for gross costation persists in specimens beyond 200 mm. in diameter and is coincident with a decrease in the number of shorter minor costæ. At 250 mm. diameter, the major costæ emerge slowly from the general contour of the umbilical shoulder. On the flanks and venter they are much wider, lower, and more obtuse than at any earlier stage, and are separated from one another by wide, concave grooves. One or two smaller costæ may arise on the lower mid-flanks. If constrictions are present they are indistinguishable from the coarse intercostal grooves.

From 150 to 250 mm. diameter, the whorls become proportionally broader, whereas the relationships of the whorl height and umbilical width to the diameter of the shell remain constant.

At a diameter of 225 mm., the suture is intensely ramified and deeply cut; EL very narrow, with two principal, bifid, lanceolate lobules on each side of the short, squat, siphonal saddle; L_1 with a straight narrow stem, as deep as EL, nearly equally trifid, with needle-like terminations; the more ventral secondary saddlet of trifid L_1 is the larger; L_2 shorter than, but similar to, L_1; l_1 on the border of the umbilical shoulder, very irregularly bifid, the inner lobule the larger; the two remaining auxiliary lobes are inclined obliquely, with their terminations toward the venter. S_1 very large, with an extremely narrow stem, unequally bifid, the outer branch much the larger; S_2 about half as broad as S_1 but nearly as long; inner branch the larger; s_1 much smaller, more equally bifid; two additional auxiliary saddles; the first on the umbilical shoulder, and the second considerably smaller, are inclined with their bases toward the venter.

The ontogeny of *P. multisulcatus* has several concomitant trends; these may be briefly reviewed:

(1) A change from whorls broadly rounded to more narrowly ovate to ovate; this can best be observed in comparing the change in dimensional indices:

Diameter of shell	7 mm.	50 mm.	90 mm.	130 mm.	150 mm.	225 mm.
	%	%	%	%	%	%
Whorl height...........	39	40	43	43	45	45
Whorl width...........	60	42	42	40	41	49
Umbilicus width........	39	35	30	27	24	24

(2) Major costæ high and narrow, commonly with narrow sharp bullæ projecting over the edge of the umbilicus; becoming duller and wider in late stages. Bullæ become obsolete on large, mature whorls.

(3) Major costæ begin, at first, close to umbilical suture and migrate up the umbilical wall to where, on large mature specimens, they originate at the outer edge of the umbilical shoulder, leaving the wall on the umbilicus smooth and uninterrupted.

(4) Minor costæ at first shorter and smaller than major costæ, becoming stronger in later stages and increasing in number up to early or middle stages, beyond which they decrease in number; in fully mature shells they are equally as coarse but not as long as major costæ.

(5) Periodic constrictions in early shell stages occur at irregular intervals posterior to major costæ; in late stages they tend to become obsolete.

(6) Umbilicus at first wide and shallow, with sloping walls; becoming narrow and deep with vertical walls and abruptly rounded shoulders.

In contrast with the uniform changes in the shape of the shell is the mutability of the costation. Among the specimens in the present collection the following costal variations have been observed. The costæ: (1) can continue the youthful pattern into maturity; (2) can lose such youthful characters as bullæ, constrictions, and straightness; (3) may persist as two distinct kinds, major and minor costæ, of which the major costæ are larger and longer than the minor costæ; or (4) the major and minor costæ may be equally large but different in length; or (5) both kinds may coarsen with growth; or (6) the minor costæ may increase or decrease in numbers; or (7) they may diminish in size so that they remain on the outer whorls as indistinct undulations or small, close, faint ribbing; or (8) they may vary in degree of straightness from those that are straight from the umbilicus to the ventro-lateral shoulder, or bent at various degrees forward across the flanks.

Judging from some of the earlier collections, it appears that Whiteaves experienced considerable difficulty in distinguishing *P. multisulcatus* from *P. newberryanus*. It is not difficult to understand this when the variability of the former species and its close approach, in many specimens, to the latter are considered. *P. newberryanus* is a much more compressed shell, with more uniform ribbing. In addition, the costæ are not as numerous, are more obtuse, and possess large, transversely elongated, commonly node-like bullæ. The stratigraphic differences are similarly noteworthy: *P. newberryanus* is found in the Haslam and Cedar District formations and *P. multisulcatus* is restricted to the Qualicum formation and, so far, has been collected at only one locality, Northwest Bay.

Pachydiscus grossouvrei Kossmat has costation and ridge-like bullæ similar to those of *P. multisulcatus*, but retains the bullæ to a much later stage than does the Canadian species, its costæ are fewer and coarser at maturity, and its umbilicus is much narrower than that of *P. multisulcatus*. *P. levyi* de Grossouvre is much more compressed, has more numerous major costæ beginning farther down in the umbilicus, the its mature ornament is unlike that of *P. multisulcatus*.

After seeing Whiteaves' holotype, Kossmat observed that ". . . . . the constrictions are more strongly bent forward than the ribs behind them, so that they have a tendency to cut off one of the ribs" (Whiteaves, 1903, p. 351). This tendency is apparent on the holotype and one or two other specimens.

Occurrence. Upper Qualicum formation, Northwest Bay, Vancouver Island, British Columbia, localities 168, 170, 520, 521.

Types. Holotype, G.S.C. No. 5856, locality 520; upper Qualicum formation, Northwest Bay, Vancouver Island, British Columbia; plesiotypes, G.S.C. Nos. 5842, 5842b, locality 520; 10050, locality 521; Qualicum formation, Northwest Bay, Vancouver Island, British Columbia.

Pachydiscus ootacodensis Stoliczka, 1865

Plate XVII, figures 1-5; Plate XVIII, figure 1; Plate XIX, figure 1; Plate XX, figures 1, 2

1865. *Ammonites ootacodensis* Stoliczka, Cret. Rocks S. India, Pal. Indica, vol. I, p. 109, Pl. LIV, figs. 3, 4; Pl. LVI.
1894. *Pachydiscus otacodensis* (Stoliczka). Kossmat, Jahrb. K.K. Geol. Reich., Wien, vol. XLIV, p. 472.
1895. *Pachydiscus otacodensis* (Stoliczka). Whiteaves, Trans. Roy. Soc., Canada, 2nd ser., vol. I, sec. IV, p. 131.
1898. *Pachydiscus otacodensis* (Stoliczka). Kossmat, Beitr. z. Pal. u. Geol. Österr.-Ung., vol. XI, p. 98, Pl. XVI (XXII), figs. 1a, 1b; Pl. XVII (XXIII), fig. 1.
1903. *Pachydiscus otacodensis* (Stoliczka). Whiteaves, Mesozoic Fossils, vol. I, pt. V, p. 340, Pl. 46, fig. 1; text fig. 20.
1922. *Parapachydiscus* aff. *ootacodensis* (Stoliczka). Spath, Trans. Roy. Soc., S. Africa, vol. X/2, pt. 3, p. 132, Pl. VII, fig. 6.
1935. *Parapachydiscus ootacodensis* (Stoliczka). Anderson and Hanna, Proc. Calif. Acad. Sci., 4th. ser., vol. XXIII, No. 1, p. 20, Pl. VI, figs. 1, 2.

Dimensions. Specimen No. 10051: 91; 45; 46; 26; No. 5850: 126; 51; 50; 23.

Stoliczka's original definition of *Pachydiscus ootacodensis* was broad, and included specimens whose shells were compressed or inflated, smooth or ornamented in youth, or provided, at maturity, with ribs of different length, strength, and number. That author identified his species with *P. colligatus* Binkhorst, but there are well-defined distinctions between the two species. *P. colligatus* has a great number of alternating large and small costæ, the larger of which begin at the umbilicus in light tubercles. Young specimens of *P. ootacodensis* are nearly smooth, with only distant ribs on the venter; young examples of *P. colligatus* have sharp costæ, with tubercles at the umbilical border.

Kossmat enlarged the data on *P. ootacodensis*, explaining the change, with growth, of the ratio of the whorl height to the whorl width. At the same time he narrowed the species somewhat by separating from it *P. grossouvrei* Kossmat and by confining to *P. ootacodensis* those forms that are mostly smooth in youth, but that in early middle age begin to show distant narrow costæ on the venter. With the advance of later stages, the costæ extend down the flanks along with numerous striæ, both costæ and striæ describing sinuosities on the flanks and a broad anterior arcuity on the venter. The umbilical region and the inner half of the flanks remain unsculptured. The costæ are narrow and moderately close together, with flat interspaces. At 60 to 80 mm. diameter, the costæ of the Indian forms become more widely spaced—about 2 centimetres apart—and with further growth of the shell the younger ribs weaken and finally become obsolete. Kossmat does not mention any alternation of major and minor costæ. In his lengthy discussion of the species he noted that the Vancouver Island and Indian forms were, with minor differences, identical, and that the species in many respects much resembled the South American *P. quiriquina* Steinmann.

The specimen of *P. ootacodensis* figured by Whiteaves (1903, Pl. 46) was identified and thoroughly described by Kossmat. Its outstanding features are: (1) the deep, step-like umbilicus, shaped like a miniature spiral staircase; (2) the smooth and rather sharply rounded umbilical shoulder; the flank immediately ventral to the shoulder is flattened and the umbilical wall is overhanging (*See* Whiteaves' Text Fig. 20); (3) the absence of umbilical tubercles; and (4) the broad striæ paralleling the costæ in a wide forward curve across the flanks and venter.

Additional specimens of *P. ootacodensis* are essentially the same as that described by Whiteaves. At a diameter of 100 mm., the outer whorl is rotund and inflated, with a broadly rounded venter, increasing rapidly in size. The flanks are gently rounded or very slightly compressed, the greatest width about mid-flank. There are 28 narrow, sharply rounded, cordiform costæ beginning at various distances up the flank. The intercostal spaces are wide and flat. The costæ bend forward across the flanks and, with increased strength, across the venter in a broad forward arcuity. In later stages, this ventral convexity of the costæ is even more pronounced. Coarse and fine striæ cross the flanks and venter. Tubercles and bullæ are lacking, and the umbilical shoulder is smooth and uninterrupted; the umbilicus is deep, with steep walls. The outer shell layer is covered with fine pustules 0·25 mm. in diameter and, on the average, 1·0 mm. apart.

At a diameter of about 200 mm., the outer whorl is large, rounded, and almost entirely smooth, with slightly flattened flanks and a broadly rounded venter, and the umbilical shoulder rounds sharply into an overhanging wall. A dozen, more or less obscure, low, broad, flexuous costæ begin on the lower flanks and disappear before reaching the smooth venter.

The suture line of the Canadian specimens is complex and deeply cut. EL is broad-stemmed, with 2 principal lobules on each side of the siphon and a small, broad siphonal saddle with lobate anterior corners; L_1 broad, trifid, somewhat deeper than EL; L_2 much shorter than L_1; l_1 on umbilical shoulder; remaining lobes decreasing rapidly in size to the umbilical suture. S_1 is broad and almost twice as large as S_2; remaining saddles decrease gradually in size towards the umbilicus.

P. ootacodensis is found in the Aryalur group of India and the Panoche group of California. In the Nanaimo group it is restricted to the upper Lambert and Northumberland formations. It bears resemblance to *P. elkhornensis* of the Haslam formation.

Occurrence. Upper Lambert formation, localities 109, 110, 111, 115, 503; Northumberland formation, locality 259.

Types. Plesiotypes, G.S.C. Nos. 5850, locality 503; 10051, locality 115; 10052, locality 110; upper Lambert formation, Hornby Island, British Columbia.

Pachydiscus binodatus Whiteaves, 1903

Plate XXI, figures 1, 2; Plate XXXI, figure 9

1903. *Pachydiscus binodatus* Whiteaves, Mesozoic Fossils, vol. I, pt. V, p. 347, Pl. 49, figs. 1, 1a; text fig. 23.

Dimensions. Specimen No. 5838: 103; 41; 52; 26.

"Shell strongly ribbed and moderately inflated, but depressed in the middle on both sides, the umbilicus occupying a little more than one-third of the entire diameter, though its margin is rounded and indistinctly defined. Volutions rather closely involute, more than one-half of the inner ones being covered by those which succeed them, increasing rapidly in size, the outer one rounded between the ribs and near the aperture, but subpentagonal upon the ribs, where the siphonal region is broadly flattened, and the sides slightly and somewhat obliquely compressed. Between the ribs, and near the aperture, the outline of a transverse section of the outer volution is not far from circular, but wider than high, and concavely and rather deeply emarginate by the encroachment of the preceding volution; but if taken at the ribs the section is more nearly pentagonal.

"Surface of the outer volution marked by rather distant, usually simple, but sometimes bifurcating longer ribs which are prominent and concavely curved on the sides, but feebly developed, almost obsolete and nearly straight in the flattened siphonal region, at least near to the aperture. All of these longer ribs extend to, or commence at, the umbilical margin, and alternate with one or two shorter ones. On the outer portion of the last volution each rib bears two large obtusely conical nodes, one on each side of the periphery or venter, at the ventrolateral angle." (Whiteaves, 1903, p. 347.)

The unique specimen that Whiteaves described has not been duplicated in any of the more recent collections, and for that reason it has not been possible to describe the morphology of the younger stages of the species. Additional study of the specimen shows the suture line to be deeply cut. EL is broad, bifid, lanceolate; L_1 deeper than EL, asymmetrically trifid, with a broad stem; the two outer lobules of L_1 are more deeply cut and larger than the inner lobules; L_2 shorter than L_1, equally trifid; l_1 trifid, situated on the umbilical shoulder; remaining 3 auxiliary lobes decreasing rapidly in size to the umbilical suture. S_1 narrow, asymmetrically bifid, outer branch the larger; S_2 much smaller than S_1, but nearly as high, bifid, inner branch the larger; s_1 much shorter, broad; additional 3 or 4 auxiliary saddles.

P. binodatus is extremely close to *P. perplicatus* and, indeed, may be a variety of the latter species. The distinguishing features of *P. binodatus* are its dimensions (*P. perplicatus* 104; 45; 50; 23), its ventro-lateral nodes, and its earlier coarsening and wider spacing of the costæ.

Occurrence. Trent River formation, locality 508, Puntledge River, Vancouver Island, British Columbia.

Type. Holotype, G.S.C. No. 5838, locality 508, Trent River formation, Puntledge River, Vancouver Island, British Columbia.

Pachydiscus neevesi Whiteaves, 1903

Plate XXII, figures 1, 2; Plate XXXI, figure 7

1903. *Pachydiscus neevesii* Whiteaves, Mesozoic Fossils, vol. I, pt. V, p. 342, Pl. 47, fig. 1; text fig. 21.
1935. *Parapachydiscus neevesii* (Whiteaves). Anderson and Hanna, Proc. Calif. Acad. Sci., 4th ser., vol. XXIII, No. 1, pp. 19, 20.

Dimensions. Specimen No. 5853: 196; 45·4; 36·7; 20.

"Shell compressed convex and rather narrowly umbilicated, volutions somewhat closely convolute, a little more than half of the inner ones being covered by those that succeed them; umbilicus occupying one-fourth of the entire diameter, its margin rounded and its inner wall rather steep. Aperture higher than wide, broadly subelliptical but rather deeply emarginate by the encroachment of the preceding volution.

"Surface of the outer volution marked with numerous, very slightly elevated, gently flexuous, transverse ribs, which are everywhere much narrower than the very shallowly concave or nearly flat spaces between them. On the periphery and near the aperture of the specimen figured the ribs average from two to three millimetres in breadth, and from seven to ten (but exceptionally sixteen) mm. apart at their summits. Most of these ribs are simple and continuous, from the umbilical margin on one side to that on the other, but they occasionally almost bifurcate or trifurcate at or near the umbilical margin, and a few shorter ribs are here and there intercalated between the longer ones, where one or more faint and obscure minute riblets can also be detected. On each side of this volution and especially near the aperture, some of the longer ribs are strongly flattened downward at their summits, and widened, sometimes for quite a long distance, longitudinally. On the inner wall of the umbilicus all the ribs are obsolete, and its surface consequently is quite smooth." (Whiteaves, 1903, pp. 342-343.)

The younger whorls of *P. neevesi* are much the same as those more mature whorls described by Whiteaves. The volutions are high and comparatively narrow, with strongly compressed flanks and an ovate venter. The costation is not nearly so well defined as on older whorls, and consists of numerous, irregularly spaced, unequal, narrow ribs that rise gradually from near the umbilical shoulders and describe flexuous courses across the flanks.

The suture is deeply cut. EL large, deep, with lanceolate terminations and a small, squared siphonal saddle; L_1 as deep as EL, asymmetrically trifid, the external lobule the largest; L_2 shorter than L_1 but on the same plan, its main stem proportionately broader than that of L_1; l_1 much shorter, broad, indistinctly trifid. S_1 very large and deeply cut, equally or nearly equally bifid; S_2 smaller than S_1 but as high; s_1 and s_2 progressively shorter, equally bifid. The main stems of the saddles are very narrow.

P. neevesi is distinguished from the *P. ootacodensis* group, which probably includes the new species *P. buckhami* and *P. elkhornensis*, by its high, ovate whorls, narrow venter and compressed flanks, and the subdued, numerous, narrow costæ, which show no regular disposition to being divisible into alternating major and minor groups.

Only two specimens of *P. neevesi* remain in the present collections, namely, the lectotype figured by Whiteaves and the specimen he records from Sucia Island. The former was obtained at an unknown horizon in the "Nanaimo Group undivided" on James Island; the latter, in all likelihood, came from the Cedar District shale of Sucia Island. Of the two other specimens mentioned by Whiteaves, one, its horizon unknown, was found at Nanaimo; the other, from Hornby Island, probably came from the upper Lambert formation.

Occurrence. Nanaimo group, locality 525, Cedar District formation, locality 526.

Types. Lectotype, G.S.C. No. 5853, locality 525, Nanaimo group (probably Cedar District formation), James Island, British Columbia; syntype, G.S.C. No. 10053, locality 526, Cedar District formation, Sucia Island, Washington, U.S.A.

Pachydiscus buckhami n.sp.

Plate XXIII, figures 1–5

1903. *(pro parte) Pachydiscus otacodensis* (Stoliczka). Whiteaves, Mesozoic Fossils, vol. 1, pt. V, p. 341.

Dimensions. Specimen No. 10054: 32; 42; 50;—; 74; 47; 50; 20; 160; 47; 50; 22; No. 10055: 44; 44; 52; 27; No. 5947: 90; 43; 51; 24.

Whorls in young stages broadly rounded; whorl section nearly circular, lower flanks somewhat flattened; whorls wider than high, greatest width at lower mid-flank; venter very broad, rounded; umbilicus moderately wide, deep, with sharply rounded shoulders and vertical walls; involution about two-thirds. Whorls ornamented with numerous (about 30) costæ, which cross the flanks in a straight, radial direction and swing forward on the ventro-lateral shoulder to form a broad, shallow arcuity across the venter. Of these bullæ, approximately 12 are longer and larger than the others and extend over the edge of the umbilical shoulder where they are pinched into a high tubercle. Each of these large costæ is high and narrow, sharply rounded and cordiform. Between each pair of them, the flat or shallowly concave spaces are interrupted by 1 or 2 smaller, lower, but narrow and sharply rounded, minor costæ, which extend various lengths down the flanks but none to the same length as the major costæ. At the beginning of the outer whorl on a specimen 30 mm. in diameter, all of the costæ are equally strong on the venter, but on the outer half of the same whorl only a few of the minor costæ maintain the same strength on the venter as the major costæ. The suture at this stage is unknown.

At later stages, the whorls become more rotund and much wider. The venter is extremely wide and broadly rounded. The umbilicus is deep, with well-rounded shoulders and vertical to overhanging walls. The ornament is essentially the same as on younger whorls, with high, narrow, sharply rounded major costæ ending on the umbilical border. Slightly smaller, but still high and narrow, minor costæ emerge from the flat spaces between the larger costæ on the lower flanks. All of the ribs are straight and radial on the lower flanks, then bend gracefully forward at mid-flank to trace a deep, forward arcuity on the outer flanks and venter. Suture unknown.

Pachydiscus buckhami is close to *P. elkhornensis* n.sp., the costation of both species differing only in number and pattern. On *P. buckhami*, the costæ are more numerous (costæ are spaced 15 mm. apart on a specimen 160 mm. in diameter), and they trace a deep, almost squarish convexity on the venter. In addition, the young whorls of *P. buckhami* are more ornamented than those of *P. elkhornensis*. The whorls of *P. buckhami* are much wider and more circular in section than those of the other species and become higher than wide as the shell enlarges.

Pachydiscus buckhami bears some small resemblance to *P. colligatus* Binkhorst, but the dimensions of the latter are different, the height being greater than the width. The costæ of the latter species are more regular and are neither as high nor as narrow as those on the Canadian form. *P. cayeuxi* de Grossouvre has similar ribbing but a different whorl shape. Reeside's species *P. woodringi* and *P. gardneri* resemble *P. elkhornensis* and lack the numerous, fine, sharp ribs of *P. buckhami*.

Three specimens from Puntledge River were formerly classified as *P. ootacodensis* and recorded from "The Comox River, near Comox, V.I." (Whiteaves, 1903, p. 341). 'Comox' is a former name for Puntledge River.

Occurrence. Haslam formation, localities 229, 233, 238; Trent River formation, locality 508.

Types. Holotype, G.S.C. No. 5947, locality 508, Trent River formation, Puntledge River, Vancouver Island, British Columbia; paratypes, G.S.C. Nos. 10054, locality 238; 10055, locality 233; Haslam formation, Elkhorn Creek, Vancouver Island, British Columbia.

Pachydiscus elkhornensis n.sp.

Plate XXIV, figures 1, 2

Dimensions. Specimen No. 10056: 30; 51; 51; 20; 89; 48; 47; 23; No. 10057: 42; 49; 50; 21; 124; 45; 42; 25.

At Diameter of 30 Millimetres. Whorls compressed, with flattened flanks meeting a narrow, squarely ovate venter in a smooth but not broadly rounded contour; umbilicus small, deep, with smooth, rapidly rounded shoulder; umbilical wall vertical; involution about three-quarters, whorl widest near umbilical margin; shell at first smooth, then with obscure, rib-like folds arching forward across flanks and crossing the venter with a strong, squarish, forward arcuity.

With increase in size, narrow, sharply rounded ribs become well marked on the venter and maintain the earlier arcuity. At a diameter of 40 mm. the costæ are clearly outlined on the venter and outer flank, at about the middle of which they begin and across which they bend strongly forward towards the venter. They are spaced 5 to 6 mm. apart. About 12 radiating striæ occupy each intercostal space, arising near the umbilicus, and paralleling the ribs across the shell. In addition, 1, and rarely 2, obscure, almost invisible, minor costæ can be seen intercalated between each pair of larger costæ on the ventral part of the whorl. By the time the 50 mm. diameter is reached, the major costæ extend to the umbilical shoulder and are high, narrow, and cordiform. At this stage, the height and width of the whorl have decreased and the venter is broader but still flattened.

At a Diameter of 90 Millimetres. Whorls retain their earlier shape, with the exception that the flattened flanks show some convexity. The venter has become more broadly rounded, meeting the flanks in a broad, open contour. The whorl is widest at the umbilical shoulder, which rounds smoothly and abruptly into the deep, vertical-walled umbilicus.

Ornament consists of very sharply rounded, narrow (1 mm.), high, cordiform ribs spaced 10 mm. apart. They begin on the umbilical shoulder and flex across the flanks (at first radially, then slightly backward, then strongly forward from mid-flank to the venter). On the venter they describe a wide anterior arcuity, which at the siphon is straightened, giving them a squarish contour. On the last half of the outer whorl are 11 major costæ. Each flat interspace between these costæ is interrupted by one, and sometimes an obscure second, minor rib, which emerges gradually from the lower flank. These latter ribs are narrower and weaker than the major costæ, which they parallel. Fine and medium-fine striæ occur as well. The interspaces between the major costæ are about 5 mm. wide at the umbilical shoulder and about 20 mm. wide on the venter. The smaller, secondary costæ are placed about half-way between the major costæ. Occasionally 2 major costæ are very close together and appear to have originated from a common point on the umbilical shoulder, remaining close (4 to 5 mm. apart) and parallel from the umbilicus to the venter.

In later stages the major costæ increase in number, and at 125 mm. diameter they are still only 20 mm. apart on the venter. They retain their cordiform shape and are undiminished in size from the umbilicus to the venter. The minor costæ persist on the ventral flanks of the shell but remain weaker than the major costæ.

Suture line imperfectly known, but closely resembling that of *P. woodringi* Reeside. EL very deep and narrow, siphonal saddle squarish; L_1 asymmetrically trifid, the two outer lobules better developed than the inner one and separated from each other by a large, oblique, secondary saddle; median lobule of L_1 lanceolate and slightly deeper than EL; L_2 even more asymmetrically trifid, the medium lobule shorter than EL and inclined obliquely toward the venter; auxiliary lobes bifid, with very oblique axes. S_1 large, bifid, deeply ramified, external branch much the larger; S_2 shorter and narrower than S_1 and equally bifid; remaining saddles decreasing rapidly in size and obliquity, axes greatly inclined.

P. elkhornensis can be separated from *P. ootacodensis* by its extremely narrow, high costæ and its more squarely ovate whorl; *P. buckhami* has more numerous costæ, a more inflated, rotund shell, and highly ornamented young whorls. Outside of the Nanaimo group, the closest species are *P. woodringi* and *P. gardneri*. Although the ornamentation of the early whorls is very much alike in both species, *P. gardneri* differs from *P. elkhornensis* in having weaker costæ and a smaller umbilicus. *P. woodringi* can be separated by its more rounded whorl, its narrow umbilicus, and its somewhat obscure costation in late stages, although the costæ are more closely spaced and the shorter ones are more strongly developed than in the Canadian species. Nevertheless, *P. woodringi* and *P. elkhornensis* are exceptionally close and may be conspecific.

Occurrence. Haslam formation, localities 228, 239.

Types. Holotype, G.S.C. No. 10056, locality 228, Haslam formation, Elkhorn Creek, Vancouver Island, British Columbia; paratype, G.S.C. No. 10057, locality 239, Haslam formation, Elkhorn Creek, Vancouver Island, British Columbia.

Family, PRIONOTROPIDAE

[Genus, *Pseudoschloenbachia* Spath, 1921

Genotype, *Ammonites umbulazi* Baily, 1855

1921. Spath, L. F.: Ann. S. African Mus., vol. XII, No. 16, p. 236.
1921. Spath, L. F.: Ann. Durban Mus., vol. III, pt. 2, p. 43.
1922. Spath, L. F.: Trans. Roy. Soc., S. Africa, vol. X/2, pt. 3, p. 139.

This genus includes strongly involute *Schloenbachia*-like forms that have high narrow whorls, a strong convex venter in youth that becomes keeled in maturity, umbilical and commonly ventral tubercles, as well as growth lines and flexuous ribbing; constrictions may be present. The suture line consists of large, broad, outer lobes and saddles, and numerous small auxiliary elements.

Pseudoschloenbachia brannani n.sp.

Plate XXIV, figures 3, 4; Plate XXXI, figure 25

Dimensions. Specimen No. 10058: 75; 50; 25; 13.

Shell discoidal, compressed, umbilicated; whorls deeply involute, high and narrow, greatest thickness at mid-flank; flanks nearly flat, very slightly convex, converging gradually to the high, narrow, keeled venter, which is flanked on either side by low, angular shoulders marking the ventro-lateral edges; umbilicus narrow, deep, with sharply rounded umbilical shoulders and nearly vertical walls; within umbilicus inner whorls are seen as flat, step-like platforms, umbilicus bordered at shoulder by 12 low, obscure, flattened nodes, which are somewhat elongated in an obliquely radial direction.

Flanks covered with closely spaced, obscure, rib-like growth lines, which arise at the umbilical shoulder and pass forward toward the venter at the same angle as the elongated, umbilical nodes. This oblique, straight direction is interrupted at mid-flank where the lines bend sharply backward. Half-way between mid-flank and the venter they curve strongly forward; this anterior inclination is increased at the ventro-lateral shoulder and on the keel, where the lines are angulated sharply forward. At the ventro-lateral shoulder is a second series of low, broad, oblique nodes, which are so indistinct as to be seen with difficulty.

Suture line consists of a very broad, shallow EL divided by a broad, short, flattened siphonal saddle; EL has two bifid branches on each side of the venter; L_1 very broad, almost twice as deep as EL, irregularly trifid, the central lobule the largest and deepest and irregularly tripartite; L_2 much smaller, shorter than EL, irregularly trifid; auxiliary lobes decrease regularly in size toward umbilicus. S_1 bifid with two nearly equal branches, stem narrow; S_2 smaller than S_1, bifid; s_1 smaller still, bifid, not as digitate as S_1; remaining auxiliary saddles decrease regularly in size.

Pseudoschloenbachia brannani is a unique specimen in the Upper Cretaceous fauna of Vancouver Island. It is close to *P. umbulazi* (Baily) and *P. griesbachi* (van Hoepen), differing from the former in having more obscure ornament and from the latter by less pronounced ribbing and the presence of ventro-lateral nodes. The suture of *P. brannani* differs from those of the South African species in having a much deeper L_1 and a shorter L_2.

The South African species are found in the "Upper Senonian" (Campanian and Maestrichtian) beds of Pondoland, Zululand, and Natal.

Occurrence and Type. Holotype, G.S.C. No. 10058, locality 205, Haslam formation, Brannan Creek, Vancouver Island, British Columbia.

Family, ENGONOCERATIDAE

Genus, *Hoplitoplacenticeras* Paulcke, 1907

Genotype, *Hoplites plasticus-hauthali* Paulcke, 1907

1907. Paulcke, W.: Ber. Naturforsch Ges. z. Freiburg, vol. XV, p. 12(178).
1938. Roman, F.: Amm. Jur. et Crét., p. 505.

"Shell more or less thick, umbilicus relatively narrow. Whorl section oval, higher than wide in youth, becoming sub-hexagonal in maturity. Flanks ornamented by strong radial ribs swelling towards the internal quarter with a strong tubercle, from which the ribs bifurcate. In young individuals a second row of tubercles occurs towards the external border; this row weakens in old age. The ribs end at elongated tubercles leaving a small space on the venter. Some secondary ribs are intercalated between the primaries.

"Suture line with L_1 very enlarged at the base and deeply cut; auxiliary lobe equal in form and size to the *branch partielle* of L_1." (Free translation from Roman, 1938, p. 505.)

The name *Hoplitoplacenticeras* was applied by Paulcke to those Upper Senonian forms of southern Patagonia that possessed morphological traits reminiscent of both *Hoplites* and *Placenticeras.*

Hoplitoplacenticeras vancouverense (Meek), 1861

Plate XXV, figures 1, 2; Plate XXXI, figures 21, 22

1861. *Ammonites vancouverensis* Meek, Proc. Acad. Nat. Sci., Philadelphia, vol. XIII, p. 317.
1876. *Placenticeras ? vancouverense* Meek, Bull. U.S. Geol. Geog. Surv. Terr., vol. II, No. 4, p. 370, Pl. VI, figs. 1, 1a, 1b, 1c.
1879. *Ammonites vancouverensis* Meek. Whiteaves, Mesozoic Fossils, vol. I, pt. II, p. 103.
1892. *Hoplites vancouverensis* (Meek). Whiteaves, Trans. Roy. Soc., Canada, 1st ser., vol. X, sec. IV, p. 118.
1903. *Hoplites vancouverensis* (Meek). Whiteaves, Mesozoic Fossils, vol. I, pt. V, p. 339.

Dimensions. Specimen No. 5846a: 82; 51; 38; 19; No. 10059: 110; 51; 35; 16·5.

Shell discoidal, deeply involute; umbilicus narrow, deep, with almost vertical walls; umbilical shoulder sharply rounded and interrupted by nodes; whorls flattened, with slightly convex flanks and a narrow, flat, tuberculated venter; venter and flanks meet at obtuse angle; whorls increase gradually in size in early stages, but more rapidly in later stages; whorl height greater than width; greatest width on lower flank. Bordering the narrow venter along the ventro-lateral angle is a row of high, narrow, pinched tubercles oriented with their long axes parallel with the plane of bilateral symmetry. The tubercles, 9 or 10 per half whorl, and the low interspaces between them are equal in length. A row of sharp nodes borders the umbilicus on the umbilical shoulder, arising part way down the umbilical wall. They mark the beginning of obscure, nearly straight, anteriorly inclined, transverse costæ, each of which extends from an umbilical node toward the venter, but becomes obsolete on the middle and upper flanks. Each costa is alined with a peripheral tubercle, but is inclined forward to such an extent that the alinement is not with the radially opposite tubercle but with the second tubercle in front of the radially opposed one. Between each two major costæ are intercalated one or two obscure minor ribs and numerous striations; one of the minor ribs may reach the venter. At a diameter of about 140 mm., the peripheral tubercles and umbilical nodes are unchanged in appearance and disposition, but the costation is obsolete and the flanks are almost smooth and still very slightly convex; only obscure striations and irregularities on the shell surface can be seen.

The suture lines of the specimens at hand are indistinct but appear to conform with that illustrated by Meek. They show considerable enlargement of the lateral elements over those of the Hoplitidae, that is, *Dimorphilites* Spath and *Anahoplites* Hyatt, and the slender terminations are drawn out, giving the suture a bent form similar to that of *Placenticeras.* On the other hand, the shape and ornament of the shell, with some reservations, are very close to those of such species as *P. intercalare* Meek, *P. placenta* DeKay, *P. tamulicum* Kossmat, and *P. subkaffrarium* Spath. The Sucia Island species is most closely allied to, and indeed may be synonymous with, *Hopitoplacenticeras plasticus-laevis* Paulcke; the sutural elements are not identical but are very close and the ornament differs only in the relatively greater number of umbilical nodes, peripheral tubercles, and obscure costæ of *H. vancouverense.*

As in many of Meek's species from Vancouver Island, the holotype of *Hoplitoplacenticeras vancouverense* is reported to have come from "Komooks, Vancouver Island" (Meek, 1876, p. 371), a synonym for the present day Comox. Unfortunately, Comox is situated on post-Cretaceous sedimentary rocks, and it is believed that although many of the early described Cretaceous fossils came from the general district around Comox, a few of them must have come from other parts of the Georgia basin. It is probable that the species in question is peculiar to only the Cedar District formation, which is confined to the southern part of the basin. This conviction is based on the fact that of the few specimens collected, all of them, with the exception of the holotype, are recorded from the Cedar District formation outcropping on Sucia Island. It is probable that the holotype as well was collected from this locality.

Occurrence. Cedar District formation, localities 290, 526.

Types. Holotype, U.S.N.M. Cat. No. 1342, "Komooks, Vancouver Island"; probably Cedar District formation, Sucia Island, Washington, U.S.A.; plesiotypes, G.S.C. Nos. 5846a, locality 526; 10059, locality 290; Cedar District formation, Sucia Island, Washington, U.S.A.; plastotype, G.S.C. No. 10060, of the holotype.

Family, BACULITIDAE

Genus, *Baculites* Lamarck, 1801

Genotype, *Baculites anceps* Lamarck, 1801

1801. Lamarck, A.: Système des animaux sans vertebres, p. 103.
1820. Say, T. G.: Amer. Jour. Sci., 1st ser., vol. II, p. 40.
1828. Sowerby, J.: Min. Conch., vol. VI, p. 186.
1864. Gabb, W. M.: Paleont. Calif., vol. I, p. 80.
1865. Stoliczka, F.: Cret. Rocks S. India, Pal. Indica, vol. I, pp. 165, 196.
1876. Meek, F. B.: Geol. Surv. Terr., vol. IX, p. 391.
1891. Brown, A. P.: Proc. Acad. Nat. Sci., Philadelphia, vol. XLIII, p. 159.
1892. Brown, A. P.: ibid., vol. XLIV, p. 136.
1901. Smith, J. P.: Amer. Nat., vol. XXXV, p. 39.

The shell of *Baculites* is at first enrolled spirally (a little more or less than 2 whorls), then straightens into a long, straight, tubular baguet that increases slowly in diameter. The transverse section of the whorl is oval, rounded, or rounded polygonal. The flanks are smooth with flexuous growth lines and/or with short curved ribs or nodes; both the ribs and the growth lines follow the trace of former apertures. The suture is composed generally of 5 lobes and 5 saddles, all of which are bifid except the antisiphonal lobe.

A restricted number of *Baculites* species occur in the Upper Cretaceous rocks of the Pacific coast of North America, *B. chicoensis* Trask, 1856, from the Chico group of California being the first to be described. Unfortunately, Trask illustrated a half-inch fragment of a young specimen from which the outer shell material had been lost and on which the suture line must still have been in an immature stage of development. Meek (1861) recognized two additional species, *B. inornatus* and *B. occidentalis* from the Vancouver Island Upper Cretaceous deposits, but subsequently admitted the synonymy of *B. inornatus* with Trask's species. He also suggested that *B. occidentalis* might well be a variation of *B. chicoensis.* The latter was acceptable to White (1889) and Whiteaves (1903), both of whom concluded that *B. chicoensis* was the only species of *Baculites* in the Pacific Coast Upper Cretaceous rocks.

This conclusion did not find complete favour, and *B. occidentalis* continued to be reported from the California beds. Anderson and Hanna (1935) recognized, in addition, *B. inornatus,* principally on the grounds that the suture line of that species was distinctive and that it was more oval in section than *B. occidentalis.* It is concluded from the present study that *B. chicoensis* and *B. occidentalis* are closely related but clearly distinguishable by differences in ornament, whorl section, and suture line, and that *B. inornatus* is synonymous with *B. chicoensis.*

It is of interest to note that the two neosyntypes of *B. chicoensis* (Taff, Hanna, and Cross, 1940) differ considerably from the species that first Trask, and later Gabb and Meek, described and figured. The whorl section and the keel-like ridge of the neosyntypes are unique among specimens hitherto described from the California Upper Cretaceous, although one of Gabb's figures suggests such a venter. Although these features bear a resemblance to the section and narrow venter of *B. occidentalis*, they appear to oppose specifically two of the diagnostic characters of *B. chicoensis.* It seems improbable that Trask would have figured an atypical specimen, or that if any of his specimens had obovate or subtrigonal cross-sections resembling those of the neosyntypes, he would have failed to describe them.

Baculites chicoensis Trask, 1856

Plate XXVI, figures 1-4; Plate XXXI, figure 18; Text Figure 3

1856. *Baculites chicoensis* Trask, Proc. San Francisco Acad. Nat. Sci., vol. I, p. 85, Pl. II, fig. 2.
1857. *Baculites ovatus?* (Say). Meek, Trans. Albany Inst., vol. IV, p. 48.
1861. *Baculites inornatus* Meek, Proc. Acad. Nat. Sci., Philadelphia, vol. XIII, p. 316.
1864. *Baculites chicoensis* Trask. Gabb, Paleont. Calif., vol. I, p. 80, Pl. XIV, figs. 27, 29a; Pl. XVII, figs. 27, 27a.
1876. *Baculites chicoensis* Trask? Meek, Bull. U.S. Geol. Geog. Surv. Terr., vol. II, No. 4, p. 364, Pl. IV, figs. 2, 2a, 2b, 2c.
1879. *Baculites chicoensis* Trask. Whiteaves, Mesozoic Fossils, vol. I, pt. II, p. 114.
1889. *Baculites chicoensis* Trask. White, C. A., Bull. U.S. Geol. Surv., No. 51, p. 47.
1895. *Baculites chicoensis* Trask. Whiteaves, Trans. Roy. Soc., Canada, 2nd ser., vol. I, sec. IV, p. 116.
1903. *Baculites chicoensis* Trask. Whiteaves, Mesozoic Fossils, vol. I, pt. V, p. 339.
1935. *Baculites inornatus* Meek. Anderson and Hanna, Proc. Calif. Acad. Sci., 4th ser., vol. XXIII, No. 1, p. 24, Pl. VIII, figs. 1, 2.
1940. *Baculites chicoensis* Trask. Taff, Hanna, and Cross, Bull. Geol. Soc. Am., vol. 51, No. 9, p. 1321, Pl. I, figs. 3, 4.

Shell small to medium size, ranging up to 45 mm. in maximum diameter; average specimen 25 mm. in diameter. Shell very gradually tapering, long and straight. Section shaped like the outline of an egg, changing only slightly with growth (*See* Figure 3). Dorsum well rounded, becoming broader in late stages (but not flattened as in *B. occidentalis*); dorso-lateral angles smoothly rounded; flanks slightly convex, tapering gradually to a somewhat narrow, elliptically rounded venter (the latter not as sharply rounded as that of *B. occidentalis*). As shell increases in size it tends to become somewhat narrower and to flatten laterally, the point of maximum lateral width shifting from the dorso-lateral area of the flank to mid-flank. Surface ornamented with closely spaced growth lines that become more apparent in later stages; from a smooth, semicircular convexity on the dorsum, the growth lines bend backward in a similar convexity on the dorso-lateral flanks, then straighten in mid-flank to proceed obliquely forward in a straight line across the ventro-lateral flanks and to describe a rounded contour on the venter.

Suture line not as deeply cut as Meek's illustration; EL very broad, bifid, with a broad, short, siphonal saddle; L_1 same depth as EL, not as perfectly bi-symmetrical as L_1 of *B. occidentalis*; L_2 broader than L_1, almost as deep but with a much shorter, narrower, dividing secondary saddle; antisiphonal lobe short but deeper than that of *B. occidentalis.* S_1 broad, bifid, shorter than that of *B. occidentalis*; S_2 broader and higher than S_1; antisiphonal saddle much as in *B. occidentalis,* but not as deeply cut and with thicker branches.

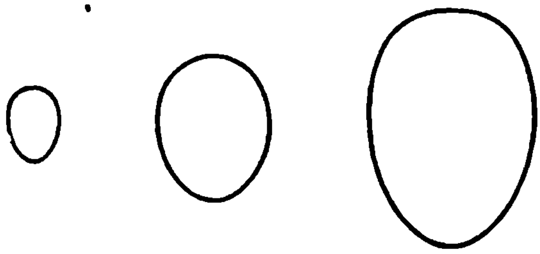


Figure 3, Transverse sections of *Baculites chicoensis* at successive stages of growth.

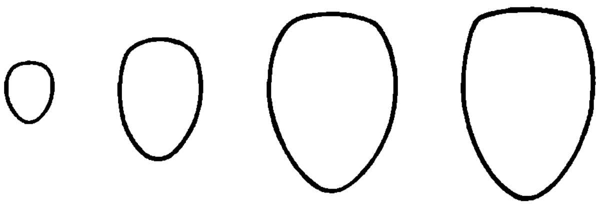


Figure 4, Transverse sections of *Baculites occidentalis* at successive stages of growth.

The species is very close to *Baculites ovatus* Say but the cross-section of *B. chicoensis* is less perfectly ovate and costæ are lacking. The change in the whorl shape of *B. compressus* Say is the distinguishing feature of that species. *B. inornatus* Meek is a synonym of *B. chicoensis.* Paulcke's specimen *B.* cf. *anceps* Lamarck from the Upper Cretaceous rocks of southern Patagonia is very close to *B. chicoensis* in all features and is almost certainly of that species. The New Zealand species *B. rectus* Marshall resembles *B. chicoensis* in shape and ornament, but has a suture line more deeply cut, with a more prominent siphonal saddle.

Occurrence. Haslam formation, localities 204, 205, 210; Cedar District formation, localities 273, 290, 526; Trent River formation, localities 120, 134, 142, 154; Lambert formation, locality 113.

Type. Plesiotype, G.S.C. No. 5796a, locality 526; Cedar District formation, Sucia Island, Washington, U.S.A.

Baculites occidentalis Meek, 1861

Plate XXVIII, figure 1; Plate XXXI, figure 19; Text Figure 4

1861. *Baculites occidentalis* Meek, Proc. Acad. Nat. Sci., Philadelphia, vol. XIII, p. 316.
1876. *Baculites occidentalis* Meek, Bull. U.S. Geol. Geog. Surv. Terr., vol. II, No. 4, p. 366, Pl. IV, figs. 1, 1a, 1b.
1879. *Baculites occidentalis* Meek. Whiteaves, Mesozoic Fossils, vol. I, pt. II, p. 115.
1895. *Baculites occidentalis* Meek. Whiteaves, Trans. Roy. Soc., Canada, 2nd ser., vol. I, sec. IV, p. 117.
1935. *Baculites occidentalis* Meek. Anderson and Hanna, Proc. Calif. Acad. Sci., 4th ser., vol. XXIII, No. 1, p. 24, Pl. VIII, figs. 3, 4.

Shell medium size, ranging up to 50 mm. in maximum diameter, very gradually tapering, long and straight. Section changes rapidly from ovate in early stages to subtrigonal in middle and later stages (*See* Figure 4). At a diameter of 7 mm., dorsal side broadly rounded to slightly flattened, dorso-lateral angle well rounded, flanks slightly convex, converging to obtusely rounded venter. With increase in size, dorsum becomes broad, flattened, with quickly and sometimes suddenly rounded dorso-lateral angles; flanks slightly convex but now converge much more abruptly to sharply rounded, highly obtuse, narrow venter; section, in some specimens becomes almost triangular. Surface ornamented with flexuous, parallel growth lines and costæ. Growth lines across dorsum with a smooth, semi-circular, forward convexity, then pass backwards on the dorso-lateral flanks tracing there a deep forward concavity. At mid-flank they bend forward again and sweep, in an oblique straight line, towards the venter and cross the latter in a sharply rounded angle. Costæ, varying from smooth, narrow ribs to broad, deep, fold-like corrugations, are confined mostly to the dorso-lateral flanks where they parallel the growth lines and where they are strongest on the forward concavity described above. Spacing of the costæ varies with specimens and with change in size; at a diameter of 7 mm. costæ are 5 to 7 mm. apart; at 14 mm. diameter they are 7 to 10 mm. apart; at 25 mm. diameter they are 13 mm. apart; at 38 mm. diameter they are 13 to 16 mm. apart. Three specimens in the collection show a modified variation in the costation in that, at a shell diameter of 13 mm., the costæ are not as strong or as fold-like as in the more typical specimens; they are prolonged farther toward the siphonal side and are spaced about 3·5 mm. apart. Other characters of these three specimens are typical of the species. Costæ become weak or obsolete in mid-flank and are generally lacking on the ventro-lateral flanks or on the venter; only growth lines are apparent on these parts of the shell. Growth lines persist unchanged throughout the ontogeny, whereas costæ show a marked variation. The smallest specimen in the collection has a diameter, at its smaller end, of about 5 mm., and at this diameter fold-like costæ are well developed. Their strength is maintained or slightly increased up to an average diameter of 25 to 30 mm., but varying from 20 to 35 mm., and from this stage on, the costæ are not enlarged or strengthened whereas their spacing remains proportional to the growth of the shell. As a result, the costæ appear to weaken or become almost obsolete in late stages, but the stage at which this takes place is not precisely determinable. There is, in addition, no marked change in the gradual decline of the costation in passing from the septate to the non-septate part of the shell, the ornamental modifications appearing to be associated with the shell-size and growth-stages rather than with any particular part of the shell.

The suture line is much as shown by Meek with the saddle endings not as deeply cut as his illustrations show. EL broad, bifid, with a broad, squarish siphonal saddle; L_1 symmetrically bifid, deeper than EL, with a broad stem; L_2 much broader than L_1, bifid, with a wide, short, median, secondary saddle; antisiphonal lobe very short, dividing the large, bifid, antisiphonal saddle. S_1 and S_2 broad, of equal size, bifid, each branch with three short terminations.

Baculites occidentalis has previously been included in *B. chicoensis*, but differs markedly from the latter in its trigonal cross-section, broad flattened dorsum, narrow sharply rounded venter, and fold-like costæ that appear at an early stage and persist into the latest stages of maturity. Suture lines of the two species also differ; that of *B. occidentalis* having longer saddles and deeper lobes, whereas the sutural elements of *B. chicoensis* are less digitate and less deeply cut.

Whiteaves (1895, p. 117) remarked that *B. occidentalis* was similar to the Indian *B. vagina* Forbes, but the latter has a node-like ornament, a pentagonal cross-section, and a narrow, squared, keel-like venter. These same differences in whorl section are to be seen in Steinmann's specimen of *B. vagina* from the Quiriquina beds of Chile. The ornament of the latter species is similar to that of *B. occidentalis*, but the suture and keel-like venter of the South American form are distinctive. *B. occidentalis* has ornament somewhat like *B. ovatus*, but the whorl sections are entirely different. *B. compressus* is much closer in whorl shape to Meek's species, but the changes in section of *B. compressus* differ in that the trigonal section does not appear until a very late stage and at a size that *B. occidentalis* has not been known to reach. The suture lines of the two species are very close but the ornament of *B. compressus* is neither as strong nor as early developed as that of *B. occidentalis*.

Occurrence. Cedar District formation, locality 526; Lambert formation, localities 501, 502, 109, 110, 111, 112, 113.

Types. Plesiotypes, G.S.C. Nos. 5952, 5952a, and 5952b, locality 502, upper Lambert formation, Hornby Island, British Columbia.

Family, HAMITIDAE

Genus, *Hamites* Parkinson, 1811

Genotype, *Hamites attenuatus* Sowerby, 1817

1811. Parkinson, J.: Organic Remains of a Former World, vol. III, p. 145, Pl. X, figs. 1-5.
1840. d'Orbigny, A.: Pal. franç., Terr. crét., vol. I, p. 526.
1864. Pictet, F. J., and Campiche, G.: Terr crét. de Ste. Croix, pt. II (1861-64), p. 77.
1865. Stoliczka, F.: Cret. Rocks S. India, Pal. Indica, vol. I, p. 190.
1895. Kossmat, A.: Beitr. z. Pal. u. Geol. Österr.-Ung., vol. IX, p. 144.
1922. Spath, L. F.: Trans. Roy. Soc., Edinburgh, vol. LIII, pt. 1, No. VI, p. 147.
1938. Roman, F.: Amm. Jur. et Crét., p. 45.
1943. Matumoto, T.: Mem. Fac. Sci., Kyusyu Imp. Univ., vol. II, No. 1, p. 133 (table).

The uncoiled ammonites within this genus consist of 2 or 3 straight or slightly curved, nearly parallel arms connected to one another by elbows or bends of 180 degrees. The surface of the shell is usually ornamented with numerous, simple costæ that are continuous all around; tubercles are for the most part absent. The suture consists of nearly equal, bifid lobes, a small antisiphonal lobe and 5 strongly bifid saddles. The genus has been divided, in many instances on the basis of geological age, into numerous sub-genera. Spath restricts it to the Aptian and Albian and refers the hamitoid Upper Cretaceous forms to such genera as *Diplomoceras*, *Metaptychoceras*, and *Solenoceras*. Japanese authors put the Senonian Hamitidae in *Polyptychoceras*. The single specimen from the Nanaimo group (Comox basin) is herein classified as '*Hamites*'.

'*Hamites*' *obstrictus* Jimbo, 1894

Plate XXVI, figure 7

1894. *Hamites obstrictus* Jimbo, Paleont. Abh. Neue Folge, vol. II, pt. 3, p. 38, Pl. VII (XXIII), figs. 2, 2a, 2b.
1895. *Hamites obstrictus* Jimbo. Whiteaves, Trans. Roy. Soc., Canada, 2nd ser., vol. I, sec. IV, p. 130.
1903. *Hamites obstrictus* Jimbo. Whiteaves, Mesozoic Fossils, vol. I, pt. V, p. 334, Pl. 44, fig. 3.
1908. *Anisoceras obstrictum* (Jimbo). Kilian and Reboul, Schwed. Südpolar-Exped., Geol. u. Pal., vol. III, pt. 6, p. 17, Pl. IV.
1921. *Diplomoceras obstrictus* (Jimbo). Spath, Ann. S. African Mus., vol. XII, No. 16, p. 256.
1927. *Hamites (Polyptychoceras) obstrictum* Jimbo. Yabe, Tohoku Imp. Univ., Sci. Repts., 2nd ser., vol. XI, p. 44(18).
1943. *Polyptychoceras obstrictum* (Jimbo). Matumoto, Mem. Fac. Sci., Kyusyu Imp. Univ., vol. II, No. 1, pt. 2, p. 113, fig. 24.

The single specimen of '*Hamites*' *obstrictus* from the Nanaimo group has no visible suture. The specimen from Sucia Island that Whiteaves first described as *H. cylindraceus?* Defrance and later referred to *H. obstrictus* does not belong to the latter species, but is more probably a *Diplomoceras*. Its larger size, finer costation, and more deeply cut diplomoceratid suture readily distinguish it from '*H.*' *obstrictus*.

The present species is very close to *Diplomoceras? indicum* (Forbes) as identified by Spath from the Upper Senonian of Zululand, but the costæ of '*H*'. *obstrictus* Whiteaves sp. are more numerous, less sharp, and more oblique to the axis of the limb than those of *D.? indicum*. In addition, on Spath's specimen ". . . . the hooked portion forms the smaller end, not the larger, as in Kossmat's figured example" (Spath, 1921a, p. 256). Kossmat's specimen of *H. indicus* is even more finely and transversely ribbed than the Hornby Island form.

Kilian and Reboul report an *Anisoceras* species from Antarctica that is similar to *'H.' obstrictus* but is easily separated by its very large size and fine ribbing. Paulcke's *Hamites* sp. is smaller than *'H.' obstrictus.*

Occurrence and Type. Plesiotype, G.S.C. No. 5958, locality 500, upper Lambert formation, Hornby Island, British Columbia.

Genus, *Ptychoceras* d'Orbigny, 1840

Genotype, *Ptychoceras emercianus* d'Orbigny, 1840

1840. d'Orbigny, A.: Pal. franç. Terr. crét., vol. I, p. 554.
1853. Pictet, F. J., and Roux, W.: Moll. foss. grès. verts. Genève, 1847-1853, p. 394.
1876. Meek, F. B.: U.S. Geol. Surv. Terr., vol. IX, p. 410.
1900. Hyatt, A.: Textbook of Paleont., Zittel-Eastman, vol. I, p. 571.
1922. Spath, L. F.: Trans. Roy. Soc., Edinburgh, vol. LIII, pt. 1, No. VI, p. 147.
1927. Yabe, H.: Tohoku Imp. Univ., Sci. Repts., 2nd ser., vol. XI, p. 44(18).

The shell of *Ptychoceras* is a slender, elongate, cylindrical, U-shaped tube in which the two limbs grow parallel and contiguous or with the smaller limb somewhat embraced by the larger. One or both of the limbs may be smooth or ornamented with fine, transverse striæ and simple, transverse or oblique costæ. The aperture is oval or subcircular. The siphon is on the outer, ventral side; the dorsal side where the limbs are embracing or contiguous is generally smooth. The suture consists of 2 or 3 nearly equal, bifid lobes and saddles; EL is slightly longer than L_1. Although it resembles *Hamites* in its mode of growth, *Ptychoceras* is distinguished from that genus by its suture line and by the much closer proximity of its limbs. *Diptychoceras* features a double U-shaped curve with three limbs, and *Solenoceras* is so constructed that the smaller limb is deeply embraced by the larger.

Hyatt classified *Ptychoceras* as a member of the Macroscaphitidae, and Roman also considers it to belong to the lytoceratids. Spath regards those Upper and Lower Cretaceous forms having ptychoceratid type of coiling as homeomorphs, and suggests that Neocomian and Senonian forms be classified under a new genus or else kept in *Hamites.* Yabe applied, but did not define, the name *Polyptychoceras* to the Japanese Upper Cretaceous specimens and included *'Hamites' obstrictus* in this genus as well.

Ptychoceras vancouverense Whiteaves, 1879

Plate XXVI, figures 5, 6

1879. *Ptychoceras vancouverense* Whiteaves, Mesozoic Fossils, vol. I, pt. II, p. 113, Pl. 14, figs. 3, 3a.
1927. *Hamites (Polyptychoceras)* cfr. *vancouverensis* (Whiteaves). Yabe, Tohoku Imp. Univ., Sci. Repts., 2nd ser., vol. XI, p. 44(18).

"These [specimens] for the most part consist of nearly the whole of the last limb and part of the last but one, with the elbow or shoulder which connects them. Immediately at the bend the limbs are scarcely two lines apart at their inner margins, and at a distance of rather more than an inch from it they touch each other. The outline of a transverse section of either limb is ovately-orbicular in most specimens, the antisiphonal side being wider than the siphonal, but in some it is oval or ovate. . . . . . .

"The sculpture varies somewhat in different individuals and in different parts of the same shell. Both limbs are more or less strongly ribbed on the periphery and sides, but their inner surface is quite smooth. In the middle of the penultimate limb the ribs are transverse, but at and near the shoulder or bend they are oblique; whereas on the last limb all the ribs are transverse. They are always most strongly marked at the point farthest from the aperture, and almost disappear just before reaching it. Thus, in the centre of the penultimate limb the surface markings appear as flattened, band-like, transverse constrictions and re-elevations, at close and regular intervals, and near the bend these gradually pass into oblique, raised and rounded rib-like folds, which are much narrower than the shallowly concave spaces between them. On the last limb the rib-like folds become fainter and more distant, until at last they fade away into a few irregularly disposed transverse raised striæ near the mouth, at a short distance from which there is a single, deeply concave, transverse groove or constriction. In some individuals the surface of the shell and cast of both limbs is also longitudinally and closely striated." (Whiteaves, 1879, pp. 113–114.)

To this description may be added that the suture line consists of 5 lobes and 5 saddles; EL narrow, deep, bifid; L_1 almost as deep as EL with a somewhat wider stem, bifid, with branches more diverging than EL; L_2 same depth as L_1, smaller; S_1 bifid, not deeply cut, stem wider than lobe stems; S_2 larger than S_1 but on the same plan; antisiphonal saddle short, bifid, with deep median secondary lobule.

The species demonstrates a certain amount of ornamental mutability, which is expressed by variations in the coarseness of the costation. The penultimate limb is always the more coarsely ornamented, with regular, transverse (and sometimes slightly oblique), wide or narrow, rounded, flattened or sharp ribs, whereas the larger limb is generally smoother, with fewer and finer costæ. The whorl is circular or subcircular in small specimens but may become ovate in late stages; the diameter varies from 5 to 15 millimetres.

Ptychoceras pseudo-gaultinum Yokoyama from the Santonian, Campanian, and Maestrichtian horizons, Japan, approaches most closely to the Canadian species, but is more finely costated, with the same type of ornament on both limbs. The Japanese species is smaller, and the whorl increases in diameter much more rapidly than that of *P. vancouverense*.

Occurrence. Trent River formation, localities 14, 139, 152, 162, 511.

Types. Lectotype, G.S.C. No. 5798, locality 511, Trent River formation, Trent River, Vancouver Island, British Columbia; paratypes, G.S.C. Nos. 5798a, 5798b, 5798c, 5798d, 5798e, 5798f, 5798g, and 5798h, locality 511, Trent River formation, Trent River, Vancouver Island, British Columbia.

Family, TURRILITIDAE

Genus, *Nostoceras* Hyatt, 1894

Genotype, *Nostoceras stantoni* Hyatt, 1894, emend. Stephenson, 1941

1893. Hyatt, A.: Proc. Am. Philos. Soc., vol. XXXII, p. 569.
1921. Spath, L. F.: Ann. S. African Mus., vol. XII, p. 248.
1941. Stephenson, L. W.: Univ. Texas Pub., No. 4101, p. 407.
1942. Haas, O.: Bull. Amer. Mus. Nat. Hist., vol. LXXXI, p. 199.
1943. Haas, O.: Am. Mus. Novitates, No. 1222, p. 1.

"The so-called ephebic stage of the shell includes a closely coiled spiral of 3 to 6 volutions, which may be either dextral or sinistral; typically this is followed by a free, down-drooping, U-shaped retroversal old age volution, which brings the aperture back to a position just beneath the base of the last volution of the spire. The shell is ornamented with costæ, most of which are single, but some of which may bifurcate. Two rows of ventral tubercles are more or less prominently developed. A contact furrow is present only where the whorls are in contact." (Stephenson, 1941, p. 407.)

Nostoceras hornbyense (Whiteaves), 1895

Plate XXVII, figures 1, 2; Plate XXVIII, figure 2; Plate XXXI, figure 23

1895. *Heteroceras hornbyense* Whiteaves, Can. Rec. Sci., vol. VI, No. 6, p. 316.
1895. *Heteroceras perversum* Whiteaves, op. cit.
1903. *Heteroceras hornbyense* Whiteaves, Mesozoic Fossils, vol. I, pt. V, p. 332, Pl. 42, figs. 1-4.
1915. *Turrilites (Hyphantoceras) hornbyence* [sic] (Whiteaves). Yabe, Tohoku Imp. Univ., Sci. Repts., 2nd ser. vol. IV, p. 18.
1921. *Didymoceras hornbyense* (Whiteaves). Spath, Ann. S. African Mus., vol. XII, No. 16, p. 251.
1921. *Didymoceras hornbyense* (Whiteaves). Spath, Ann. Durban Mus., vol. III, pt. 2, p. 56.
1924. *Didymoceras hornbyense* (Whiteaves). Haughton, Commun. Serv. Geol., Portugal, vol. XV, p. 95, Pl. IV, fig. 2.
1943. *Nostoceras hornbyense* (Whiteaves). Haas, Am. Mus. Novitates, No. 1222, p. 5.

Shell moderately large, dextral or sinistral coils, 4 to 6 volutions wound into a low spiral, with an apical angle of 70 to 90 degrees. Volutions in contact in earliest stages, becoming separated in mature stage and passing into a large, uncoiled, downward twisted or retroversal volution. Umbilicus wide and deep. Volutions at first ovate in cross-section, increasing rapidly in size and becoming circular or subcircular in free volutions.

Shell ornamented with numerous, high, rather coarse, sharp-crested, evenly spaced, simple or, in a few specimens, occasionally bifurcating costæ that increase in size and coarseness on the latest volutions. In young stages, the costæ are straight and vertical on the outer, ventral part of the volution but are flexed forward in a shallow arcuity and are not as strong on the inner, antisiphonal side. At irregular intervals in the early stages, small tubercles occur in a line below the mid-point of the outer whorl. In later whorls, the costæ become narrow and sharp or, in a few instances, with flattened or worn crests. They are separated by deep, smooth, concave intercostal grooves, and are inclined rather obliquely forward from the top to the bottom of the whorl and are flexed sharply forward at the impressed zone to form a deep, forward convexity on the inner part of the whorl. At sparse intervals in the mature stages, deep constrictions, bordered on each side by a high, thick rib, are well marked. Two rows of high, sharp, commonly elongated tubercles appear at early maturity, the upper row located about mid-whorl and the lower row a short distance below on the lower, outer part of the volution. Between the two rows is the siphuncle. As the whorls become larger, the tubercles migrate lower on the shell to where the upper row springs from the shell directly over the siphuncle and then passes below it. At a whorl diameter of 1 inch, both rows are on the lower, outer part of the volution. At their first appearance, the nodes occur on every other third or fourth rib, and at later stages on every other second or third rib. Where costæ bifurcate they do so at the nodes. Rarely, fibulation of the ribs between the two rows of nodes may be observed.

Suture line imperfectly known; close to that of *Didymoceras nebrascense* Meek and Hayden. EL deep, narrow, and divided by a short, broad, rectangular median saddle into two branches that parallel the siphon and each of which is in turn split into two sharp terminations; L_1 very large, more than twice as deep as EL, asymmetrically bifid, divided by an elaborate secondary saddle, which does not reach as high as the median siphonal saddle; each branch of L_1 is irregularly bifid and deeply cut, the inner branch being the larger. S_1 high and relatively narrow, divided by a strongly digitate secondary lobule that reaches to the level of the median siphonal saddle; outer branch of S_1 the higher, and both branches in turn divided by small, digitate lobules; S_2 smaller and narrower than S_1, divided by a deep lobule. Remainder of suture unknown.

Nostoceras hornbyense is close to *N. hyatti* Stephenson, but can be distinguished by its finer ribbing and lower spire. Even closer are *N. hornbyense* and *N. helicinum* (Shumard), the chief difference appearing to be in the larger size of the Canadian specimens. As Haas (1943, p. 5) has pointed out, Stephenson's neotype "might even suggest conspecificity" and there is little doubt that they are congeneric.

Didymoceras nebrascense bears many resemblances to the Hornby Island species, but the young stages of Meek and Hayden's species are unknown and the loss and regain of tubercles in the parephebic stage and the loss of all ornament in the paragerontic stage are unknown in *N. hornbyense*. *Didymoceras tortum* Meek is too imperfectly known for an exacting comparison, although the whorl shape and ornament are similar to those of the present species. The L_1 of *D. tortum* is not as deep and the secondary saddle of L_1 is not as well developed as in *N. hornbyense.*

Turrilites (Hyphantoceras) oshimi Yabe resembles *N. hornbyense,* but the spire of the Canadian species is lower and its suture line precludes *Turrilites.*

Occurrence. Upper Lambert formation, localities 111, 112, 113, 500, 502.

Types. Lectotype, G.S.C. No. 5805, locality 500, upper Lambert formation, Hornby Island, British Columbia; paratypes, G.S.C. Nos. 5805a, 5805b, 5805c, and 5827, locality 502, upper Lambert formation, Hornby Island, British Columbia; plesiotypes, G.S.C. Nos. 10061, locality 500; 10069, locality 113; upper Lambert formation, Hornby Island, British Columbia.

Genus, *Bostrychoceras* Hyatt, 1900

Genotype, *Turrilites polyplocum* Roemer, 1840

1840. Roemer, F.: Verst. Norddeutsch. Kreidegeb., p. 92.
1872. Schlüter, C.: Paleontographica, vol. 21, p. 112.
1900. Hyatt, A.: Textbook of Paleont., Zittel-Eastman, vol. I, p. 588.
1907. Pervinquière, L.: Etudes de Pal. Tunis, I, Céphs. des Terr. second., p. 102.

The shell of *Bostrychoceras* is enrolled in a turrilitid spiral, usually sinistrally. The whorls are rounded and increase slowly in diameter. The ornament consists of numerous, simple, slightly undulating costæ that may bifurcate only rarely; tubercles may or may not be present. The siphon is located midway on the outer part of the whorl. The last whorl is generally free and may be retroversal. Comprising the suture is an EL with 2 bifid branches; a well-developed L_1 that is longer than EL and deeply cut into 2 unequal branches; and an L_2 similar to L_1 but greatly reduced in size. S_1 is bifid with a very narrow base; S_2 is shorter than S_1 with a deep, dividing lobule.

Bostrychoceras elongatum (Whiteaves), 1903

Plate XXVIII, figures 3, 4; Plate XXXI, figure 24

1879. *Heteroceras conradi* (Morton). Whiteaves, Mesozoic Fossils, vol. I, pt. II, p. 100, Pl. 12, figs. 1, 1a, 2, 2a, 3.
1903. *Heteroceras elongatum* Whiteaves, Mesozoic Fossils, vol. I, pt. V, p. 331, Pl. 44, fig. 2.
1910. *Helicoceras (Bostrychoceras) elongatum* (Whiteaves). Grabau and Shimer, N.A. Index Fossils, vol. II, p. 205, fig. 1473.
1915. *Turrilites elongatum* (Whiteaves). Yabe, Tohoku Imp. Univ., Sci. Repts., 2nd ser., vol. IV, p. 18.

Shell large, composed of 4 to 9 spiral volutions; specimens rarely complete, apical parts generally missing. Shell wound dextrally or sinistrally, whorls in contact; in a few specimens the last (gerontic) whorl is free and bent downwards or retroversally. Apical angle 30 to 40 degrees, spire long and moderately narrow, whorls increasing gradually in size. Umbilicus very small, less than one-sixth of the diameter of the last whorl. Whorl section somewhat elliptical in early stages, compressed laterally, becoming subcircular to circular in mid-growth and remaining circular as far as the last, free whorl, which tends to show a more compressed, elliptical section.

Whorls ornamented with large, smooth, simple costæ that cross the whorls obliquely. On a complete whorl of about 25 mm. diameter, there are from 25 to 28 costæ. These are broad at their bases and rise into high, sharply rounded crests on the external part of the whorl; on the inner, umbilical side they are finer and lower, and are crowded more closely together. The change from the coarse external costation to the fine inner costation occurs on the upper whorl surface at the line of contact with the preceding whorl. There the ribs that cross the outer half of the whorl bend suddenly forward through an angle of almost 90 degrees, and pass obliquely down across the inner part of the whorl; it is at the 90-degree bend that they become crowded and change to finer costæ. At the edge of the umbilicus they bend obliquely and gracefully backward onto the external whorl surface and increase rapidly in strength. Intercostal spaces are wide, deep, and smoothly concave. Rarely, deep constrictions occur and can be distinguished from ordinary intercostal spaces by their greater depth and narrowness and by their steep apertural edge, which is bordered by a larger-than-average rib. Nodes, tubercles, and bifurcated costæ are missing. The simplicity of the ornament, with its uniform, strong, coarse costation is the most definitive character of the species.

Suture consists of a broad external lobe, 2 lateral lobes, 2 lateral saddles, and the antisiphonal or dorsal saddle. EL broad, short, and bifid, with a short, moderately narrow, digitated, median siphonal saddle; each branch of EL in turn bifid, the outer branch parallel with the siphon, and the inner branch directed at about 45 degrees away from the siphon. L_1 very large and deeply bifid, with a large, expanding secondary saddle; almost twice as deep as EL; outer branch of L_1 the larger, almost at right angles to the siphon and deeply cut by a short tertiary saddle into two, sharply digitated lobules, the outer of which reaches almost to the siphon and the inner of which (also the deeper) parallels the siphon. L_2 is wide and short, almost equally bifid, divided by a short, trapezoidal, secondary saddle. S_1 is high, unequally bifid, the inner branch the larger; the base and stem of S_1 are very narrow and inclined away from the siphon at an angle of about 30 degrees; each branch is unequally divided by a short tertiary lobule. S_2 is somewhat shorter but very much wider than S_1, and is divided by an extremely deep, broad, digitated secondary lobe; each branch is again cut by tertiary lobules. The antisiphonal saddle is as wide as L_2 and about one-half as high as S_2, and is deeply cut by a trifid lobule that occupies at least one-third of the width of the entire saddle; each branch of the antisiphonal saddle is equally bifid.

Whiteaves pointed out the parallelism, in general shape and mode of coiling, between his species and *Bostrychoceras polyplocum* Schlüter sp. The two species are undoubtedly very nearly alike, but can be differentiated by the simple, strong, and unadorned costæ of *B. elongatum* as contrasted with the much more numerous, finer, commonly tuberculated and bifurcated costæ of *B. polyplocum*. The same contrast exists between *B. elongatum* and *B. indicus* Stoliczka, and in the latter the whorls are smaller than those of the Canadian form. *B. japonicum* Yabe is almost certainly conspecific with *B. elongatum*.

Bostrychoceras elongatum is found in two formations of the Nanaimo group, the Haslam, and the lower part of the Trent River, and is much more abundant in the former than in the latter. Specimen No. 5806 (Whiteaves, 1903, Pl. 44, fig. 2) is reported to be from the Lambert formation on Hornby Island. It is questionable whether this is so, because no other specimens of the species have ever been recorded from the prolific fauna of Hornby Island, and the mode of preservation of specimen No. 5806 is entirely unlike that of the other ammonites found there.

Occurrence. Haslam formation, localities 224, 225, 227, 228, 229, 233, 234, 237, 238, 240, 245, 252, 283, 285, 524; Trent River formation, localities 21, 22, 107, 120, 125, 136, 155, 159, 164, 165.

Types. Lectotype, G.S.C. No. 5806, locality recorded from Hornby Island, more probably Trent River formation in the Comox basin, Vancouver Island, British Columbia; paratypes, G.S.C. Nos. 5837, 5837a, 5837b, and 5837c, locality 524, Haslam formation, Maple Bay, Vancouver Island, British Columbia; plesiotypes, G.S.C. Nos. 10062, locality 234; 10067, locality 237; Haslam shale, Elkhorn Creek, Vancouver Island, British Columbia.

Family, ANISOCERATIDAE

Genus, *Anisoceras* Pictet, 1854

Genotype, *Hamites saussureanus* Pictet, 1846

1854. Pictet, F. J.: Traité de Paléont., vol. II, p. 705, Pl. LVI, figs. 12, 12a.
1864. Pictet, F. J., and Campiche, G.: Terr. crét. de Ste-Croix, pt. II (1861-1864), p. 57.
1865. Stoliczka, F.: Cret. Rocks S. India, Pal. Indica, vol. I, p. 170.
1895. Kossmat, A.: Beitr. z. Pal. u. Geol. Österr.-Ung., vol. IX, p. 144.
1900. Hyatt, A.: Textbook of Paleont., Zittel-Eastman, vol. I, p. 587.
1907. Pervinquière, L.: Etudes de Pal. Tunis., I, Céphs. des Terr. second., p. 83.
1908. Kilian, W., and Reboul, P.: Schwed. Südpolar-Exped., Geol. u. Pal., vol. III, pt. 6, p. 15.
1910. Grabau, A. W., and Shimer, H. W.: N.A. Index Fossils, vol. II, p. 208.
1938. Roman, F.: Amm. Jur. et Crét., p. 51.

Anisoceras is an irregular, loosely coiled ammonite, sinuous in youth, forming an irregular helicoid spiral with free whorls. In maturity the shell develops a long, eccentric, *Toxoceras*-like whorl and finally terminates in a retroversal, U-shaped bend as in *Ancyloceras*. During early growth stages the ornament consists of simple strong costæ with usually 2 rows of tubercles on each side of the siphonal line. In later stages the costæ vary in strength and often bifurcate at the tubercles; one or both rows of tubercles may become stronger or one row may become obsolete. The suture line is distinctive, with 5 lobes all bifid; the 2 lateral lobes are nearly equal; EL is slightly shorter than L_1, with 2 trifid branches; the auxiliary lobes are very short and unequally trifid; of the 5 bifid saddles, S_2 is the largest.

The name *Anisoceras* has been applied doubtfully to many fragments of uncoiled and irregularly coiled ammonites. For those who would assign narrow limits to the genus there are others who would make it a large, comprehensive assemblage of similar forms; still others would limit it to particular stratigraphic units. From the accumulation of opinions expressed concerning the morphology of the genus, several agreeably distinguishing features emerge: the helicoid coiling of the early shell, the bifid lobes and saddles, and the wide range of ornamentation. Unfortunately, it is only the retroversal living chamber of the animal that is generally found; consequently, diagnosis of the genus becomes based almost entirely on such unsatisfactory features as the size, shape, and ornamentation of this extremely variable part of the shell.

Anisoceras cooperi (Gabb), 1864

Plate XXIX, figure 1

1864. *Ammonites cooperi* Gabb, Paleont. Calif., vol. I, p. 69, Pl. XIV, figs. 23, 23a.
1876. *Heteroceras cooperi* (Gabb). Meek, Bull. U.S. Geol. Geog. Surv. Terr., vol. II, No. 4, p. 367, Pl. III, figs. 7, 7a.
1895. *Anisoceras vancouverensis* (Gabb). Whiteaves, Trans. Roy. Soc., Canada, 2nd ser., vol. I, sec. IV, p. 130.
1895. *Anisoceras vancouverensis* (Gabb). Whiteaves, Can. Rec. Sci., vol. VI, No. 6, p. 313, Pl. II.
1903. *Anisoceras cooperi* (Gabb). Whiteaves, Mesozoic Fossils, vol. I, pt. V, p. 336, Pl. 43, fig. 1.

Only the retroversal, roughly U-shaped parts of the shell have been found, none of which shows the suture line distinctly; the earlier stages of the Canadian specimens are unknown. The preserved tube is spirally twisted, as demonstrated by the lateral position of the two rows of tubercles bordering the siphon. The surface is strongly ribbed and many of the costæ bear a large conical tubercle on each side of the periphery.

An important characteristic that Gabb noted in his original description of the species, but upon which Whiteaves did not elaborate, was the disposition of the costæ between the two rows of nodes. In the earlier part of the whorl, two, low, coarse, rounded ribs originate at a node and pass across the venter, diverging from one another and each joining with one of two opposite nodes. "The surface is ornamented by two rows of nodes . . . . . with ribs extending across, some passing through one, some through two of the nodes, while others originate in one and end in another." (Gabb, 1864, p. 69.) The result is a 'zigzag' pattern back and forth between the two rows of nodes. This ornament is replaced more or less suddenly by, but may alternate with, an arrangement in which the two costæ leaving one tubercle diverge from one another to a maximum distance apart of 4 or 5 mm. at the siphon and then converge again to join at the opposite node. Instead of a 'zigzag' pattern, the trans-siphonal costæ form a button and loop style of fibulation, each pair beginning and ending in diametrically opposite nodes. Where the 'zigzag' pattern prevails, the opposing rows of tubercles are offset slightly from one another so that a line drawn from one node across the venter to the nearest opposite node is oblique to the siphonal line. Some of the broken nodes or tubercles are large and blunt, suggesting, as Whiteaves noted, that they may be the base of former spines.

It is noteworthy that this type of ornament is not uncommon on the gerontic whorl of *Nostoceras hornbyense*, and it may well be that the specimens of *Anisoceras cooperi*, which in the Nanaimo group are found only in the Lambert shales of Hornby Island, are the remnants of the retroversal free whorls of the former species. The present specimens are larger and more coarsely ribbed than *Nostoceras hornbyense*, but the size differences are commonly not great enough to preclude possible synonymy. The suture lines, although only fragmentary, compare more favourably with *Anisoceras* Pictet than with *Nostoceras*, but it is admitted that there are only small differences in the suture lines of the two genera.

Occurrence. Upper Lambert formation, localities 109, 112, 113, 500, 503.

Types. Plesiotypes, G.S.C. Nos. 5959, locality 500; 5960, locality 503; 10063, locality 112; upper Lambert formation, Hornby Island, British Columbia.

Genus, *Diplomoceras* Hyatt, 1900

Genotype, *Hamites cylindraceum* d'Orbigny sp., 1840

1840. d'Orbigny, A.: Paléont. franç., Terr. crét., vol. I, p. 551, Pl. CXXXVI, figs. 1-4.
1900. Hyatt, A.: Textbook of Paleont., Zittel-Eastman, vol. I, p. 371, fig. 1187.

In the absence of any formal description of Hyatt's genus, the following is translated from d'Orbigny's definition of *Hamites cylindraceum* Defrance.

"Shell very elongated, forming an elliptical spire the bends of which are blunt, and the intervals, between the elbows, nearly straight. The mould of the shell is entirely smooth and subcylindrical, but where the outer shell is present, equal, transverse ribs circle the whorl. The mouth is nearly round, only slightly compressed. The suture is divided into 5 lobes and 5 saddles; EL much narrower and shorter than L_1, ornamented on each side by 4 narrow branches the lower of which has 3 deeply divided lobules; L_1 narrow at its base, greatly enlarged at its extremity, ornamented on each side by 3 very much divided branches of which the lowest is enormous; L_2 smaller than, but similar in form to, L_1. ES much smaller than L_1, deeply divided into 2 branches, each of which is subdivided; S_1 as large as L_1, subdivided three times into bifurcated pairs. The antisiphonal saddle is slightly narrower than S_1, divided into 2 oblique branches by a narrow, short, wedge-shaped antisiphonal lobule, which in turn is divided into 5 branches one of which is terminal. It is to be noted that the suture of *Diplomoceras* is not greatly different from that of *Anisoceras* or *Hamites*."

Diplomoceras notabile Whiteaves, 1903

Plate XXIX, figure 2; Plate XXX, figure 1; Plate XXXI, figures 26, 27

1903. *Diplomoceras notabile* Whiteaves, Mesozoic Fossils, vol. I, pt. V, p. 335, Pl. 44, figs. 4, 4a, 4b.

1908. *Anisoceras notabile* (Whiteaves). Kilian and Reboul, Schwed. Südpolar-Exped., vol. III, pt. 6, p. 15, Pl. II, fig. 1; Pls. III, IV, V; Pl. VI, fig. 1.

"Shell very large when perfect, subcylindrical and transversely ribbed, ribs simple, leaving no impressions upon the cast. The only specimen known to the writer is a nearly straight piece of the prolonged portion, from Hornby Island, about ten inches and three-quarters long, and septate for by far the greater portion of its length. It is slightly compressed at the sides, broadly oval and not far from circular in transverse section. Near the smaller end it measures forty-seven millimetres in its diameter from the siphonal to the antisiphonal side, and thirty-eight mm. in its lateral diameter. Near the larger end the corresponding measurements are fifty-five mm. by forty-six.

"The ribs are numerous, closely and regularly disposed, nearly transverse, but slightly oblique, rounded, and about as wide as the shallowly concave grooves between them. On the middle of each side there are about eight and a half ribs to the inch near the smaller end, and seven at the larger. In addition to the ribs there are two widely distant, narrow, transverse constrictions, running parallel with them.

". . . . . A careful study, however, shows that the septation of this specimen is essentially similar to that of *Hamites cylindraceus*, as figured by d'Orbigny on Plate 136, figure 4, of the Atlas to the first volume of the 'Terrains Crétacés', which is the type of Hyatt's recently proposed genus *Diplomoceras*. In both there are six lobes, viz., two large laterals (the 'latéral supérieur' and the 'latéral inférieur' of d'Orbigny) on each side; one siphonal lobe and one antisiphonal. In both, also, the two lateral lobes, on each side, are very nearly equal in size. But the lobes and saddles of the Hornby Island specimen are still more numerously incised than are those of the French fossil, and this may be easily seen by comparing the siphonal saddle, the largest of the three accessory saddles between the first and second laterals, and the antisiphonal lobe, of both.

The figure of the siphonal saddle of *H. cylindraceus* in the Atlas to the Terrains Crétacés, for example, represents it as entire at the summit and only twice incised on each side, whereas in the Hornby Island specimen, the same saddle is twice incised at the summit and four times on each side." (Whiteaves, 1903, p. 335.)

On the basis that *Diplomoceras* is a synonym of *Anisoceras*, Kilian and Reboul have reclassified Whiteaves' species as *A. notabile*, and have illustrated the coiled and curved parts of the shell. A much more comprehensive study of this nomenclatural problem will have to be completed before a solution is reached.

Other than in the Nanaimo group, *Diplomoceras notabile* has been recorded only from the Senonian rocks of Grahamland. Several specimens, one showing the bend of the whorl, have been recovered from the Lambert shales of Hornby Island.

Occurrence. Upper Lambert formation, localities 109, 503.

Types. Holotype, G.S.C. No. 10064, locality 503, upper Lambert formation, Hornby Island, British Columbia; plesiotype, G.S.C. No. 10065, locality 109, upper Lambert formation, Hornby Island, British Columbia.

Diplomoceras? subcompressum (Forbes), 1845

Plate XXIX, figure 3

1845. *Hamites subcompressum* Forbes, Trans. Geol. Soc., London, 2nd ser., vol. VII, p. 116, Pl. XI, figs. 6a-c.
1895. *Hamites (Anisoceras) subcompressum* Forbes. Kossmat, Beitr. z. Pal. u. Geol. Österr.-Ung., vol. IX, p. 116, Pl. XIX (V), figs. 10a, 10b, 11a, 11b.
1903. *Anisoceras subcompressum* (Forbes). Whiteaves, Mesozoic Fossils, vol. I, pt. V, p. 338, Pl. 45, figs. 1, 1a, 1b.
1906. *Hamites (Anisoceras) subcompressum* Forbes. Woods, Ann. S. African Mus., vol. IV, p. 339, Pl. XLIII, fig. 2.
1908. [*pro parte*] *Anisoceras notabile* (Whiteaves). Kilian and Reboul, Schwed. Südpolar-Exped., vol. III, pt. 6, pp. 15-16.

The shell ". . . . . is at first coiled in an irregular, loose, open spiral, but it rapidly straightens out afterwards towards the aperture. It consists of rather more than one volution, which is not coiled upon quite the same plane, its earliest portion being curved a little to one side. In the specimen from the Trent River, however, the straighter anterior portion is a little twisted laterally. The surface of all the specimens is marked by thin, sharp and simple transverse ribs, with concave grooves between them. In most of the specimens the ribs are somewhat distant over the whole surface but in the specimen figured they are comparatively close together posteriorly. Septum unknown." (Whiteaves, 1903, p. 338.)

It is doubtful if Whiteaves' assignment of this species to *Anisoceras* is correct. The small size of the forms, the narrow, sharp, regular, simple ribs, and the complete lack of tubercles would seem to oppose its classification in that genus. The morphology is more like that of *Diplomoceras? indicum* (Forbes), differing from the latter in its elliptic whorl section and periodic constrictions. The two forms are found together in the Valudayur beds of India and the Upper Senonian beds of Pondoland.

A small form compared to *D.? subcompressum* is reported from the Diego-Suarez beds of Madagascar where *D. indicum* has also been found.

Occurrence. Haslam formation, localities 227, 228, 237, 252, 283; Trent River formation, localities 10, 17, 118, 120, 122, 124, 125, 127, 165.

Types. Plesiotypes, G.S.C. Nos. 10066, locality 17; 5962, locality 509; Trent River formation, Puntledge River, Vancouver Island, British Columbia.

Diplomoceras? sp.

1879. *Hamites cylindraceus?* Defrance. Whiteaves, Mesozoic Fossils, vol. I, pt. II, p. 113, Pl. 14, figs. 2, 2a.
1895. [*pro parte*] *Hamites obstrictus* Jimbo. Whiteaves, Trans. Roy. Soc., Canada, 2nd ser., vol. I, sec. IV, p. 130.
1903. [*pro parte*] *Hamites obstrictus* Jimbo. Whiteaves, Mesozoic Fossils, vol. I, pt. V, p. 334.
1908. [*pro parte*] *Anisoceras notabile* (Whiteaves). Kilian and Reboul, Schwed. Südpolar-Exped., vol. III, pt. 6, p. 15.

The flattened, poorly preserved fragment illustrated by Whiteaves (1879) consists of parts of two limbs joined by a U-shaped elbow. The penultimate limb is ornamented by numerous, fine, narrowly rounded, oblique ribs separated from one another by narrow, shallow, concave grooves equal in width to the ribs. Ribbing diminishes around the elbow, finally becoming obsolete at the beginning of the ultimate limb where a deep, wide, smooth, concave constriction circles the shell. Ultimate whorl ornamented with numerous very fine, transverse striæ.

Suture line as in *Diplomoceras cylindraceum* d'Orbigny sp.

Only the one specimen has been found in the Nanaimo group.

Occurrence and Type. Plesiotype, G.S.C. No. 5799, locality 526, Cedar District formation, Sucia Island, Washington, U.S.A.

BIBLIOGRAPHY

Anderson, F. M.

(1905): Cretaceous Deposits of the Pacific Coast; Proc. Calif. Acad. Sci., 3rd ser., vol. II, No. 1, pp. 1-154.

(1943): Synopsis of the Later Mesozoic in California; Bull. Calif. Dept. Nat. Res., No. 118, pp. 185-186.

Anderson, F. M., and Hanna, G. D.

(1935): Cretaceous Geology of Lower California; Proc. Calif. Acad. Sci., 4th ser., vol. XXIII, No. 1, pp. 1-34.

Baily, W. H.

(1855): Cretaceous Fossils from the South African Collection of Garden; Quart. Jour. Geol. Soc., London, Proc., vol. XI, pp. 454-465.

Basse, E.

(1927): Quelques faunes d'Ammonites du Sud-Ouest de Madagascar; Bull. Geol. Soc. France, 4th ser., vol. XXVII.

(1931): Monographie paléontologique du Crétacé de la Province de Maintirano, Madagascar; Gouv. gén. de Madagascar et dépendances.

Bauermann, H.

(1860): On the geology of the southeastern part of Vancouver Island; Quart. Jour. Geol. Soc. London, Proc., vol. XVI, pp. 198-202.

Binkhorst, van D.

(1861): Monographie des Gastéropodes et des Céphalopodes de la Craie supérieure du Limbourg. Bruxelles-Maestricht.

Bohm, J.

(1891): Die Kreidebildungen des Furbergs und Sulzbergs bei Seigsdorf in Oberbayern; Paleontographica, vol. 38, pp. 1-106.

Bostock, H. S.

(1948): Physiography of the Canadian Cordillera; Geol. Surv., Canada, Mem. 247.

Brown, A. P.

(1891): On the young of *Baculites compressus;* Proc. Acad. Nat. Sci., Philadelphia, vol. XLIII, p. 159.

(1892): The development of the shell in the coiled stage of *Baculites compressus;* Proc. Acad. Nat. Sci., Philadelphia, vol. XLIV, pp. 136-141.

Buckham, A. F.

(1947a): The Nanaimo Coal Field; Trans. Can. Inst. Min. Met., vol. L, pp. 460-472.

(1947b): Preliminary Map, Nanaimo Coalfield, British Columbia; Geol. Surv., Canada, Paper 47-22.

Clapp, C. H.

(1909): The Southeastern portion of Vancouver Island; Geol. Surv., Canada, Sum. Rept. 1908, pp. 52-60.

(1910): Southern Vancouver Island; Geol. Surv., Canada, Sum. Rept. 1909, pp. 84-97.

(1911): Geology of the Victoria and Saanich Quadrangles, Vancouver Island, B.C.; Geol. Surv., Canada, Sum. Rept. 1910, pp. 102-109.

(1912a): Southern Vancouver Island; Geol. Surv., Canada, Mem. 13.

(1912b): Geology of Nanaimo Sheet, Nanaimo Coalfield, Vancouver Island; Geol. Surv., Canada, Sum. Rept. 1911, pp. 91-105.

(1912c): Notes on the Geology of the Comox and Suquash Coalfields, Vancouver Island; Geol. Surv., Canada, Sum. Rept. 1911, pp. 105-107.

Clapp, C. H.—*Continued*

(1912d): The Geology of the Nanaimo Coal District, Vancouver Island, B.C.; Trans. Can. Min. Inst., vol. XV, pp. 334-353.

(1913): Geology of the Victoria and Saanich Map-areas, Vancouver Island, B.C.; Geol. Surv., Canada, Mem. 36.

(1914a): Geology of the Nanaimo Map-area, B.C.; Geol. Surv., Canada, Mem. 51.

(1914b): Geology of Portions of the Sooke and Duncan Map-areas, Vancouver Island, B.C.; Geol. Surv., Canada, Sum. Rept. 1912, pp. 41-54.

(1914c): Coal formation on Galiano, Mayne and Saturna Islands; B.C. Min. of Mines, Ann. Rept. for 1913, pp. 292-299.

(1917): Sooke and Duncan Map-areas, Vancouver Island; Geol. Surv., Canada, Mem. 96.

Clapp, C. H., and Cooke, H. C.

(1914): Geology of a Portion of the Duncan Map-area, Vancouver Island, B.C.; Geol. Surv., Canada, Sum. Rept. 1913, pp. 84-106.

Collignon, M.

(1928): Les Céphalopodes du Cénomanian Pyriteux de Diego-Suarez; Ann. Paléont., vol. XVII, No. 15, pp. 1-79.

(1932): Fossiles du Crétacé supérieur du Menabe; Ann. Paléont., vol. XXI.

Crick, G. C.

(1907): Cretaceous Fossils from Natal; Third Rept. Geol. Surv., Natal and Zululand, pp. 153-250.

Dawson, G. M.

(1878): General note on the mines and minerals of economic value of British Columbia; Geol. Surv., Canada, Rept. of Prog. 1876-77, pt. V, pp. 103-149.

(1887): Report on a geological examination of the northern part of Vancouver Island and adjacent coasts; Geol. Surv., Canada, Ann. Rept. 1886, vol. II, pt. B, pp. 1-107.

(1889): Mineral Wealth of British Columbia; Geol. Surv., Canada, Ann. Rept. 1887-88, vol. III, pt. R, pp. 100-101.

(1890): Notes on the Cretaceous of the British Columbia Region, The Nanaimo Group; Am. Jour. Sci., 3rd ser., vol. XXXIX, pp. 180-183.

Diener, C.

(1925): Ammonoidea neocretacea; Fossilium Catalogus, 1, Animalia, pt. 29.

Forbes, E.

(1845): Report on the Fossil Invertebrates from Southern India; Trans. Geol. Soc. London, 2nd ser., vol. VII, pp. 97-174.

Furnival, G. M.

(1950): Cypress Lake Map-area, Saskatchewan; Geol. Surv., Canada, Mem. 242.

Gabb, W. M.

(1864): Triassic and Cretaceous Fossils; Paleont. Calif., Geol. Surv. Calif., vol. I.

(1869): Cretaceous and Tertiary Fossils; Paleont. Calif., Geol. Surv. Calif., vol. II.

(1875): Note on the age of the Cretaceous of Vancouver Island and Oregon; Am. Jour. Sci., 3rd ser., vol. X, p. 308.

Gignoux, M.

(1920): Les Phyllocératidés et les Lytocératidés du Paléocretacé. (In Kilian, Contributions à l'Etude des Céphalopodes Paléocrétacés du Sud-Est de la France); Mém. p. serv. à l'explic. de la Carte géol. dét. de la France, pp. 85-131.

Grabau, A. W., and Shimer, H. W.

(1910): North American Index Fossils, vol. II, Invertebrates.

de Grossouvre

(1893): Recherches sur la Craie supérieure, pt. II, Paléontologie, Les Ammonites de la Craie supérieure; Mém. p. serv. à l'explic. de la Carte géol. dét. de la France.

Haas, O.

(1942a): The Vernay Collection of Cretaceous (Albian) Ammonites from Angola; Bull. Am. Mus. Nat. Hist., vol. LXXXI, pp. 1-224.

(1942b): Some Upper Cretaceous Ammonites from Angola; Am. Mus. Novitates, No. 1182.

(1943): Some Abnormally Coiled Ammonites from the Upper Cretaceous of Angola; Am. Mus. Novitates, No. 1222.

Hauer, F. van

(1861): Uber die Cephalopoden der Gosauschichten; Beitr. z. Pal. u. Geol. Österr.-Ung., vol. I, Wien, pp. 7-14.

Haughton, S. H.

(1924): Notes sur quelques Fossiles crétacés de l'Angola (Céphalopodes et Echinides); Commun. Serv. Geol., Portugal, vol. XV, pp. 79-106.

Hector, J.

(1861): On the Geology of the Country between Lake Superior and the Pacific Ocean; Quart. Jour. Geol. Soc., London, Proc., vol. XVII, pp. 388-445.

Hoepen, N. van

(1920): Description of some Cretaceous Ammonites from Pondoland; Ann. Transvaal Mus., vol. VII, pt. 2, pp. 142-147.

(1921): Cretaceous Cephalopoda from Pondoland; Ann. Transvaal Mus., vol. VIII, pt. 1, pp. 1-48.

Hyatt, A.

(1893): Phylogeny of an Acquired Characteristic; Am. Philos. Soc., Proc., vol. XXXII, pp. 349-616.

(1900): Cephalopoda, Textbook of Paleontology; Zittel-Eastman, 1st edit., vol. I, pp. 566-590.

Jimbo, K.

(1894): Beitrage zur Kenntniss der Fauna der Kreideformation von Hokkaido; Pal. Abhandl. v. Dames u. Kayser, N.F., vol. II, pt. 3.

Kilian, W., and Reboul, P.

(1908): Les Céphalopodes néocrétacés des îles Seymour et Snow Hill; Wissen. Ergebn. der Schwed. Südpolar-Exped., Geol. und Paleont., 1901-03, vol. III, pt. 6.

Kossmat, A.

(1894): Die Bedeutung der sudindischen Kreideformation; Jahrb. K.K. Geol. Reich., Wien, vol. XLIV, pp. 459-478.

(1895-98): Untersuchungen über die Südindische Kreideformation; Beitr. z. Pal. u. Geol. Österr.-Ung. und des Orients, vol. IX (1895), pp. 97-203; vol. XI (1898), pp. 89-152.

Lamarck, A. de

(1801): Système des animaux sans vertebres.

Lasswitz, R.

(1904): Die Kreide-Ammoniten von Texas; Geol. u. Pal. Abhandl. Koken, N.F., vol. VI (X).

Lesquereux, D. L.

(1859): On some questions concerning the coal formations of North America; Am. Jour. Sci., 2nd ser., vol. XXVIII, pp. 21-37.

(1872): Lignitic formation and fossil flora; U.S. Geol. Surv. Terr., Sixth Ann. Rept., pt. II, pp. 317-427.

MacKenzie, J. D.
(1922): The Coal Measures of Cumberland and Vicinity, Vancouver Island; Trans. Can. Inst. Min. Met., vol. XXV, pp. 382-409.
(1923a): The Alberni Area, Vancouver Island, British Columbia; Geol. Surv., Canada, Sum. Rept. 1922, pt. A, pp. 61-67.
(1923b): Coal Resources of Southern Vancouver Island; Geol. Surv., Canada, Mimeographed Rept., June 1.

McLellan, R. D.
(1927): The Geology of the San Juan Islands; Univ. Washington Pub., vol. 2.

Mantell, G. A.
(1822): The fossils of South Downs or Illustrations of the geology of Sussex. London.

Marshall, M. A.
(1926): The Upper Cretaceous Ammonites of New Zealand; Trans. New Zealand Inst., vol. 56, pp. 129-210.

Matumoto, T.
(1936): Contributions to the Cretaceous Paleontology of Japan, I, Preliminary notes on the so-called *Parapachydiscus egertoni* (Forbes) from Japan; Jap. Jour. Geol. and Geog., vol. XIII, No. 34, p. 259.
(1942-43): Fundamentals in the Cretaceous Stratigraphy of Japan, parts 1, 2, and 3; Mem. Fac. Sci., Imp. Univ. Kyusyu, ser. D, vol. I, No. 3 (pt. 1, 1942); vol. II, No. 1 (pts. 2 and 3, 1943).
(1942): Notes on the Japanese Cretaceous Ammonites belonging to the Desmoceratidae, Guadryceratidae, Tetragonitidae and Phylloceratidae; Proc. Imp. Acad. Tokyo, vol. XVIII, Nos. 6, 131, 132, 133.

Meek, F. B.
(1857): Descriptions of new organic remains from the Cretaceous rocks of Vancouver's Island; Trans. Albany Inst., vol. IV (1858-64), pp. 37-49.
(1861): Descriptions of new Cretaceous Fossils collected by the Northwestern Boundary Commission on Vancouver and Sucia Islands; Proc. Acad. Nat. Sci., Philadelphia, vol. XIII, pp. 314-374.
(1876a): Descriptions and illustrations of fossils from Vancouver and Sucia Islands and other northwestern localities; Bull. U.S. Geol. and Geog. Surv. Terr., vol, II, No. 4, pp. 351-374.
(1876b): Invertebrate Cretaceous and Tertiary Fossils; Bull. U.S. Surv. Terr., vol. IX.

Muller, S. W., and Schenck, H. G.
(1943): Standard of Cretaceous System; Bull. Am. Ass. Pet. Geol., vol. 27, No. 3, pp. 262-278.

Newberry, J. S.
(1857): Report on the geology of the route of Williamson's survey in California and Oregon; U.S. Pac. R.R. Expl., pt. 2, pp. 5-68.

Nowak, J.
(1913): Untersuchungen über die Cephalopoden der oberen Kreide in Polen, pt. III; Bull. Int. de l'Acad. des Sci. de Cracovie, No. 6B, pp. 335-415.

d'Orbigny, A.
(1840): Paléontologie française, Terr. crét., vol. I, Céphalopodes.
(1850): Prodr. de Paléont. stratig. universelle, vol. II.

Parkinson, J.
(1811): Organic remains of a former world, vol. III.

Paulcke, W.
(1907): Die Cephalopoden der oberen Kredie Südpatagoniens; Ber. Naturforsch Ges. z. Freiburg, vol. XV, pp. 167-244.

Peacock, M. A.
(1935): Fiord-land of British Columbia; Bull. Geol. Soc. Am., vol. XLVI, No. 4, pp. 633-696.

Pervinquière, L.
(1907): Etudes de Paléontologie Tunisienne, I. Céphalopodes des Terraine secondaires; Cartegéol. de la Tunis, Paris.
(1910): Sur quelques Ammonites du Crétacé algerien; Mém. Soc. Géol. France, Pal., vol. XVII, No. 42.

Pictet, F. J.
(1854): Traité de Paléontologie, vol. II.

Pictet, F. J., et Roux, W.
(1853): Description des Mollusques fossiles des grès verts des environs de Genève; Mém. Soc. Phys. et Hist. nat., Genève, vols. XI, XII, XIII (1847-1853).

Pictet, F. J., et Campiche, G.
(1864): Descriptions des fossiles du Terrain crétacé des environs de Ste. Croix; Matériaux pour la Paléontol. Suisse, 3rd sér., Genève, pt. I (1858 and 1860), pt. II (1861-64).

Reeside, John B., Jr.
(1927): The Cephalopods of the Eagle Sandstone; U.S. Geol. Surv., Prof. Paper No. 151.
(1947): Upper Cretaceous Ammonites of Haiti; U.S. Geol. Surv., Prof. Pap. 214-A.

Richardson, J.
(1872): Coal Fields of the East Coast of Vancouver Island; Geol. Surv., Canada, Rept. of Prog. 1871-72, pt. 3, pp. 73-100.
(1873): Coal Fields of Vancouver Island; Geol. Surv., Canada, Rept. of Prog. 1872-73, pt. 4, pp. 32-65.
(1878): Coal Fields of Nanaimo, Comox, Cowichan, Burrard Inlet and Sooke, B.C.; Geol. Surv., Canada, Rept. of Prog. 1876-77, pt. 7, pp. 160-192.

Roemer, F.
(1840): Die Versteinerungen des Norddeutschen Kreidegeberges.
(1852): Die Kreidebildungen von Texas und ihre organischen Einschüsse.

Roman, F.
(1938): Les Ammonites Jurassiques et Crétacés.

Russell, L. S.
(1950): Correlation of the Cretaceous-Tertiary Transition in Saskatchewan and Alberta; Bull. Geol. Soc. Am., vol. LXI, No. 1, pp. 27-42.

Russell, L. S., and Landes, R. W.
(1940): Geology of the Southern Alberta Plains; Geol. Surv., Canada, Mem. 221.

Say, T. G.
(1820): Observations on some species of zoophytes, shells, etc., principally fossil; Amer. Jour. Sci., 1st ser., vol. II, pp. 34-45.

Schlüter, C.
(1872-76): Cephalopoden der oberen deutschen Kreide; Paleontographica, vol. 21 (1872), pp. 1-120; vol. 24 (1876).

Schmidt, F.
(1873): Uber die Petrefacten der Kreideformation von der Insel Sachalin; Mém. Acad. Imp. des Sc. de Saint-Pétersbourg, 7th ser., vol. XIX, No. 3, pp. 1-33.

Scott, G.
(1940): Paleoecological factors controlling the distribution and mode of life of Cretaceous ammonoids in the Texas area; Jour. Paleont., vol. 14, No. 4, pp. 299-323.

Selwyn, A. R. C.

(1875): Age of the lignitic coal formation of Vancouver Island; Am. Jour. Sci., 3rd. ser., vol. IX, p. 318.

Seunes, J.

(1890-91): Contributions à l'étude des Céphalopodes du Crétacé supérieur de France; Mém. Soc. Géol., France, Paléont., No. 2, vol. I, pt. 1, pp. 1-7 (1890); vol. II, pt. 3, pp. 9-22.

(1890): Recherches géologiques sur les terraines secondaire et l'Eocène Inférieur de la région sous-pyrénéenne du sud-ouest de la France; Ann. Mines, 8th ser., vol. XVIII, pp. 209-458.

Sharpe, D.

(1854): Fossil remains of Mollusca found in Chalk of England, Cephalopoda; Paleont. Soc. London.

Shimizu, S.

(1935): The Upper Cretaceous Cephalopods of Japan, pt. 1; Jour. Shanghai Inst., sec. II, vol. 1, pp. 159-226.

Shumard, B. F.

(1859): Descriptions of new fossils from the Tertiary formation of Oregon and Washington Territories and the Cretaceous of Vancouver Island; Trans. Acad. Sci., St. Louis, vol. I, pp. 113-114.

Smith, J. P.

(1901): The larval stage of Baculites; Amer. Nat., vol. XXXV, pp. 39-46.

Sowerby, J.

(1812-45): The Mineral Conchology of Great Britain, 7 vols.

Spath, L. F.

(1921a): On Cretaceous Cephalopoda from Zululand; Ann. S. African Mus., vol. XII, No. 16, pp. 217-321.

(1921b): On Upper Cretaceous Ammonoidea from Pondoland; Ann. Durban Mus., vol. III, pt. 2, pp. 39-56.

(1922a): On the Senonian Ammonite Fauna of Pondoland; Trans. Roy. Soc., S. Africa, vol. X/2, pt. 3, pp. 113-147.

(1922b): On Cretaceous Ammonoidea from Angola, collected by Prof. J. W. Gregory; Trans. Roy. Soc., Edinburgh, vol. LIII, pt. 1, No. VI, pp. 91-160.

(1925a): Sur quelques Ammonites du Gault; Mus. d'Hist. Nat. Marseilles, Ann., vol. XX, pp. 97-105.

(1925b): An appendix on Upper Cretaceous Ammonites from Maputoland; Ann. Transvaal Mus., vol. XI, pt. 3, p. 179.

(1925c): On Senonian Ammonoidea from Jamaica; Geol. Mag., vol. LXII, pp. 28-32.

(1926): Note on two ammonites from the Gin Gin Chalk; Jour. Roy. Soc., W. Australia, vol. XII, No. 5, pp. 53-55.

(1923-30): A Monograph of the Ammonoidea of the Gault; Paleont. Soc., London.

(1939): Problems of Ammonite Nomenclature. No. 6, The genus *Pachydiscus* Zittel; No. 7, The genera *Paraphylloceras* and *Neophylloceras* Shimizu; Geol. Mag., vol. LXXVI, pp. 293-296 and 451-454.

Stanton, T. W.

(1893): The Faunas of the Shasta and Chico Formations; Bull. Geol. Soc. Am., vol. IV, pp. 245-256.

(1895): Contributions to the Cretaceous Paleontology of the Pacific Coast; Bull. U.S. Geol. Surv. No. 133.

Steinmann, G., *et al.*

(1895): Das Alter u. die Fauna der Quiriquina Schichten in Chile; Neues Jahrb. f. Min., Geol. und Paleont., Beil.-Bd. X, pp. 1-94.

Stephenson, L. W.

(1941): The Larger Invertebrate Fossils of the Navarro Group of Texas; Univ. Texas Publ. No. 4101.

Stephenson, L. W., and Reeside, J. B., Jr.

(1938): Comparison of Upper Cretaceous Deposits of Gulf Region and Western Interior Region; Bull. Am. Assoc. Pet. Geol., vol. XXII, No. 12, pp. 1629-1638.

Stoliczka, F., and Blandford, H. F.

(1865): The fossil Cephalopoda of the Cretaceous Rocks of Southern India; Mem. Geol. Surv. India, Pal. India, vol. I.

Taff, J. A., Hanna, G. D., and Cross, C. M.

(1940): Type locality of the Cretaceous Chico Formation; Bull. Geol. Soc. Am., vol. LI, No. 9, pp. 1311-1328.

Trask, J. B.

(1856): Description of a new species of ammonite and baculite, from the Tertiary rocks of Chico creek; Proc. San Francisco Acad. Nat. Sci., vol. I, pp. 85-86.

Twenhofel, W. H.

(1939): Principles of Sedimentation; McGraw-Hill, New York and London.

White, C. A.

(1889): On invertebrate fossils from the Pacific Coast; Bull. U. S. Geol. Surv., No. 51.

Whiteaves, J. F.

(1879): On the fossils of the Cretaceous rocks of Vancouver and adjacent islands in the Strait of Georgia; Geol. Surv., Canada, Mesozoic Fossils, vol. I, pt. 2.

(1892): Notes on the Ammonites of the Cretaceous rocks of the District of Athabasca; Trans. Roy. Soc., Canada, 1st ser., vol. X, sect. IV, pp. 111-120.

(1893): The Cretaceous System in Canada; Trans. Roy. Soc., Canada, 1st ser., vol. XI, sect. IV, pp. 3-19.

(1895a): On some Fossils from the Nanaimo group of the Vancouver Cretaceous; Trans. Roy. Soc., Canada, 2nd ser., vol. I, sect. IV, pp. 119-133.

(1895b): Notes on some fossils from the Cretaceous rocks of British Columbia; Can. Rec. Sci., vol. VI, No. 6, pp. 313-318.

(1895c): Notes on some of the Cretaceous fossils collected during Captain Palliser's explorations in British North America, 1857-60; Trans. Roy. Soc., Canada, 2nd ser., vol. I, sect. IV, pp. 101-117.

(1901): Note on a supposed new species of *Lytoceras* from the Cretaceous rocks at Denman Island, in the Strait of Georgia; Ottawa Nat., vol. XV, pp. 31-32.

(1903): On some additional fossils from the Vancouver Cretaceous, with a revised list of the species therefrom; Geol. Surv., Canada, Mesozoic Fossils, vol. I, pt. V.

Wilckens, O.

(1904): Revision der Fauna der Quiriquina Schichten; Neues Jahrb. f. Min., Geol. und Paleont., Beil.-Bd. XVIII, pp. 181-284.

Williams, M. Y., and Dyer, W. S.

(1930): Geology of Southern Alberta and Southwestern Saskatchewan; Geol. Surv., Canada, Mem. 163.

Williams, T. B.

(1924): The Comox Coal Basin; Ph.D. thesis, Univ. Wisconsin.

Woods, H.

(1906): The Cretaceous Fauna of Pondoland; Ann. S. African Mus., vol. IV, pp. 331-350.

Yabe, H.

(1903-04): Cretaceous Cephalopoda from the Hokkaido, pts. 1 and 2; Jour. Coll. Sci., Imp. Univ. Toyko, vol. XVIII, art. 2 (1903); vol. XX, art. 2 (1904).

Yabe, H.—*Continued*

(1915): Notes on Some Cretaceous Fossils from Anaga on the Island of Awaji, and Toyajo in the Province of Kii; Tohoku Imp. Univ., Sci. Repts., 2nd ser., vol. IV, pp. 13-24.

(1927): Cretaceous Stratigraphy of the Japanese Islands; Tohoku Imp. Univ., Sci. Repts., 2nd ser., vol. XI, pp. 27-100.

Yabe, H., and Shimizu, S.

(1926): A Study of *Parapachydiscus;* Proc. Imp. Acad. Japan, vol. II, No. 4, art. 60.

Yokoyama, M.

(1890): Versteinerungen aus der japonischen Kreide; Paleontographica, vol. 36, pp. 159-202.

PLATE I

(Except where otherwise stated all figures are natural size)

Figures 1, 2, 3. *Neophylloceras lambertense* n.sp. Side, ventral, and apertural views, respectively. Holotype, G.S.C. No. 5811a, from locality 502; upper Lambert formation, Hornby Island, British Columbia. (Page 50.)

Figures 4, 5. *Neophylloceras ramosum* (Meek). Side and ventral views. Plesiotype, G.S.C. No. 5811, from locality 502; upper Lambert formation, Hornby Island, British Columbia. (Page 49.)

2

1

3

4

5

PLATE II

Figures 1, 2. *Phyllopachyceras forbesianum* (d'Orbigny). Side and ventral views. Plesiotype, G.S.C. No. 10013, from locality 112; upper Lambert formation, Hornby Island, British Columbia. (Page 52.)

Figures 3, 4, 5. *Phyllopachyceras forbesianum* (d'Orbigny). Side, apertural, and ventral views, respectively. Plesiotype, G.S.C. No. 10014, from locality 112; upper Lambert formation, Hornby Island, British Columbia. (Page 52.)

Figures 6, 7. *Epigoniceras epigonum* (Kossmat). Side and ventral views. Plesiotype, G.S.C. No. 10015, from locality 518; Haslam formation, Brannan Creek, Vancouver Island, British Columbia. (Page 55.)

PLATE II

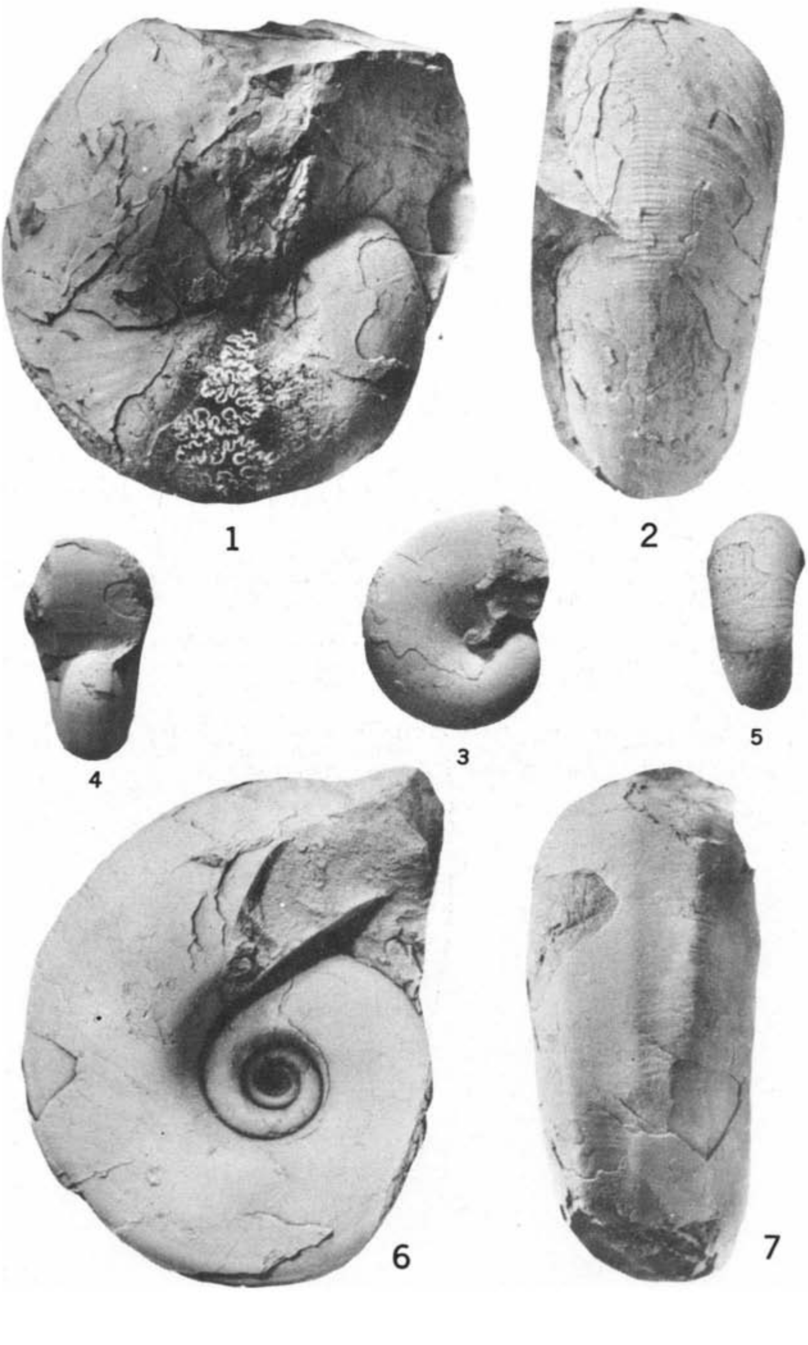


Plate III

Figure 1. *Epigoniceras epigonum* (Kossmat). Transverse-sectional view. Plesiotype, G.S.C. No. 10017, from locality 213; Haslam formation, Brannan Creek, Vancouver Island, British Columbia. (Page 55.)

Figure 2. *Pseudophyllites indra* (Forbes). Side view (x3). Plesiotype, G.S.C. No. 10018, from locality 113; upper Lambert formation, Hornby Island, British Columbia. (Page 57.)

Figures 3, 4. *Pseudophyllites indra* (Forbes). Side and ventral views (x2). Plesiotype, G.S.C. No. 10019, from locality 113; upper Lambert formation, Hornby Island, British Columbia. (Page 57.)

Figures 5, 6, 7. *Pseudophyllites indra* (Forbes). Side, ventral, and apertural views, respectively. Plesiotype, G.S.C. No. 10020, from locality 113; upper Lambert formation, Hornby Island, British Columbia. (Page 57.)

Figures 8, 9, 10. *Pseudophyllites indra* (Forbes). Side, ventral, and apertural views, respectively. Plesiotype, G.S.C. No. 10021, from locality 113; upper Lambert formation, Hornby Island, British Columbia. (Page 57.)

Figures 11, 12, 13. *Pseudophyllites indra* (Forbes). Side, ventral, and apertural views, respectively. Plesiotype, G.S.C. No. 10023, from locality 502; upper Lambert formation, Hornby Island, British Columbia. (Page 57.)

PLATE III

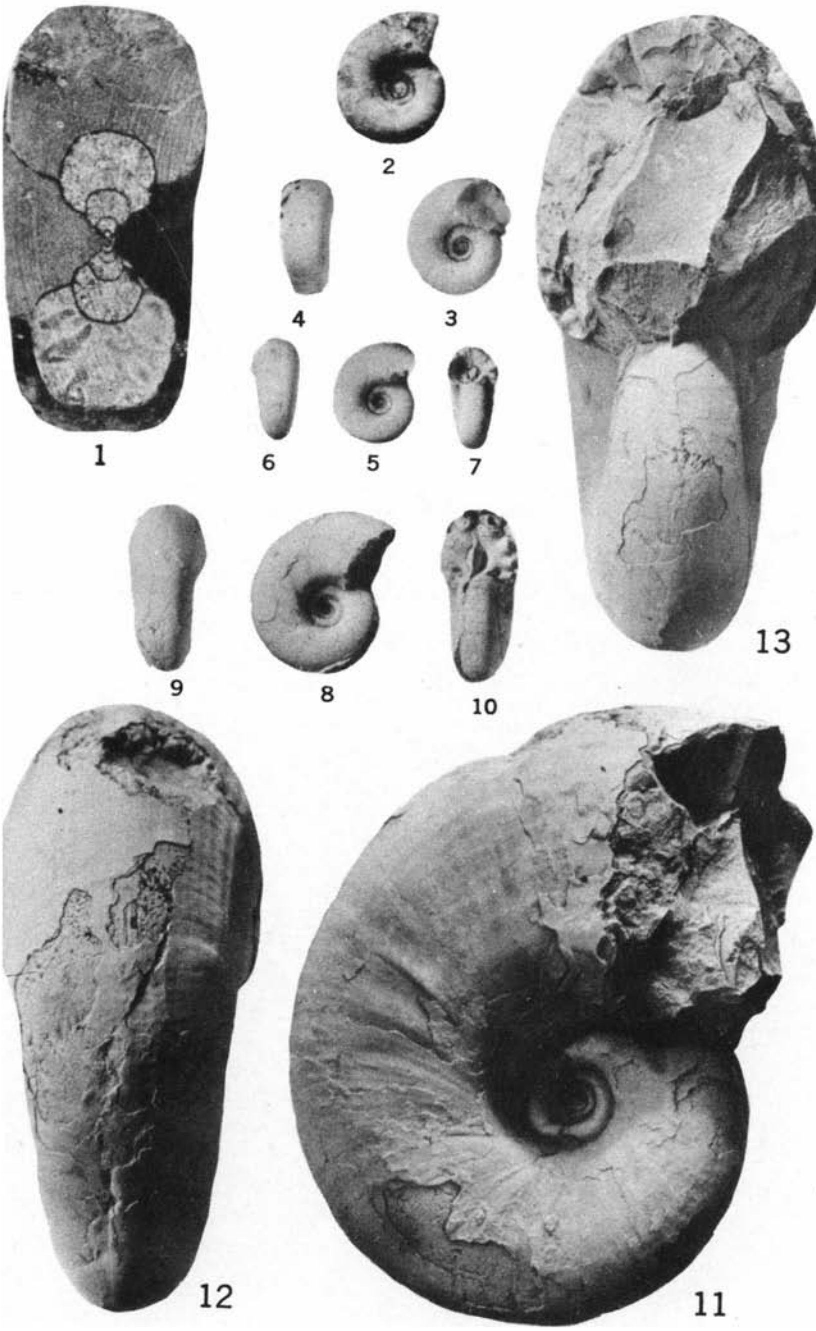


PLATE IV

Figure 1. *Guadryceras denmanense* Whiteaves. Side view. Lectotype, G.S.C. No. 5854, from locality 516; lower Lambert formation, Denman Island, British Columbia. (Page 59.)

Figure 2. *Gaudryceras denmanense* Whiteaves. Side view. Paratype, G.S.C. No. 5854a, from locality 516; lower Lambert formation, Denman Island, British Columbia. (Page 59.)

PLATE IV

1

2

PLATE V

Figures 1, 2. *Hauericeras gardeni* (Baily). Side and ventral views. Plesiotype, G.S.C. No. 10029, from locality 238; Haslam formation, Elkhorn Creek, Vancouver Island, British Columbia. (Page 61.)

Figures 3, 4. *Schluteria selwyniana* (Whiteaves). Side and ventral views. Lectotype, G.S.C. No. 5803b, from locality 526; Cedar District formation, Sucia Island, Washington, U.S.A. (Page 63.)

PLATE V

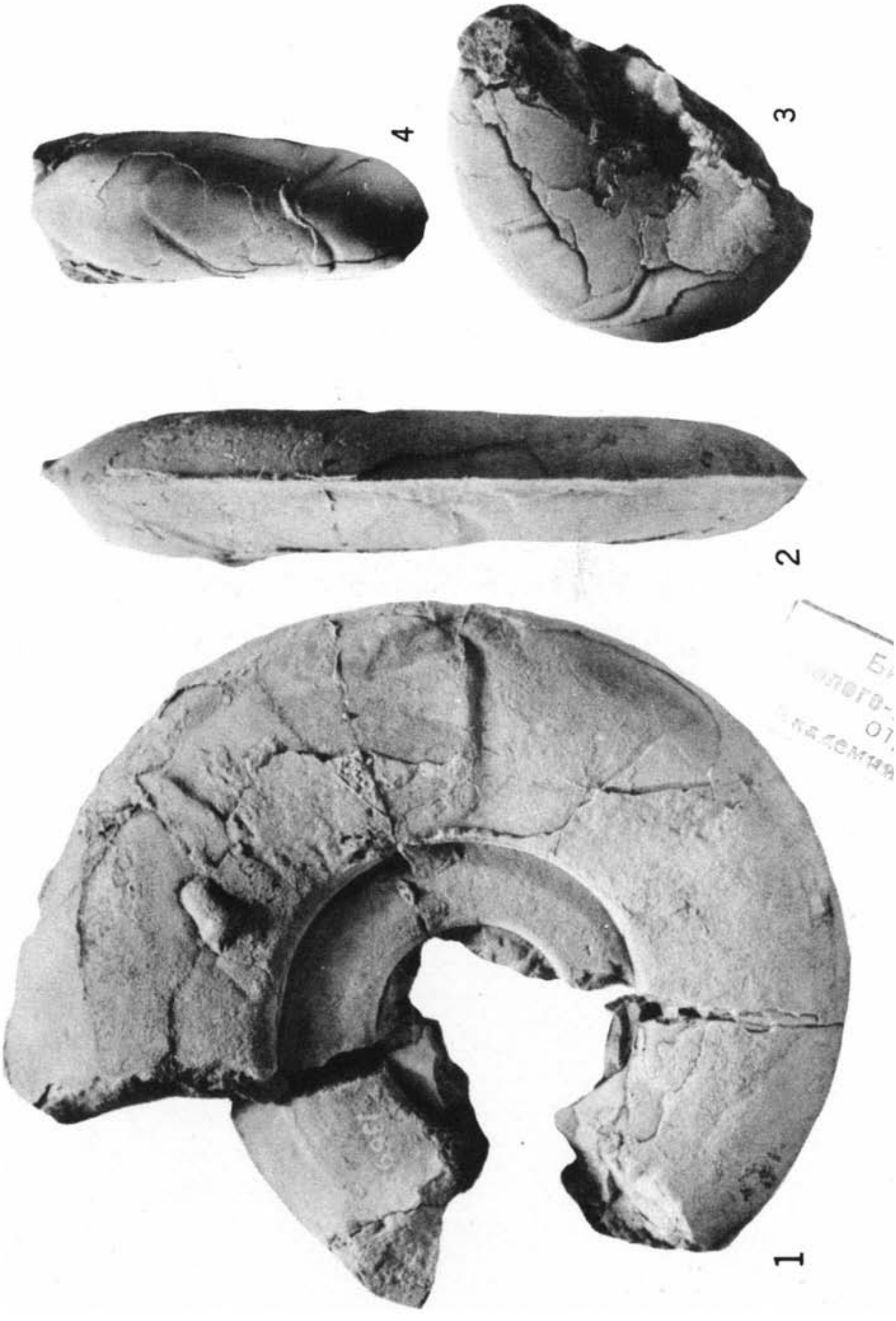


PLATE VI

Figures 1, 2, 3. *Schluteria selwyniana* (Whiteaves). Side, ventral, and apertural views, respectively. Plesiotype, G.S.C. No. 5809b, from locality 515; upper Trent River formation, Denman Island, British Columbia. (Page 63.)

Figures 4, 5, 6. *Pachydiscus (Canadoceras) newberryanus* (Meek). Side, ventral, and apertural views, respectively. Plastotype, G.S.C. No. 10033, of the holotype, U.S.N.M. Cat. No. 12394, from "Komooks, Vancouver Island". (Page 65.)

Figure 7. *Pachydiscus (Canadoceras) newberryanus* (Meek). Side view (x½). Plesioty, e, G.S.C. No. 10032, from locality 281; Cedar District formation, North Pender Island, British Columbia. (Page 65.)

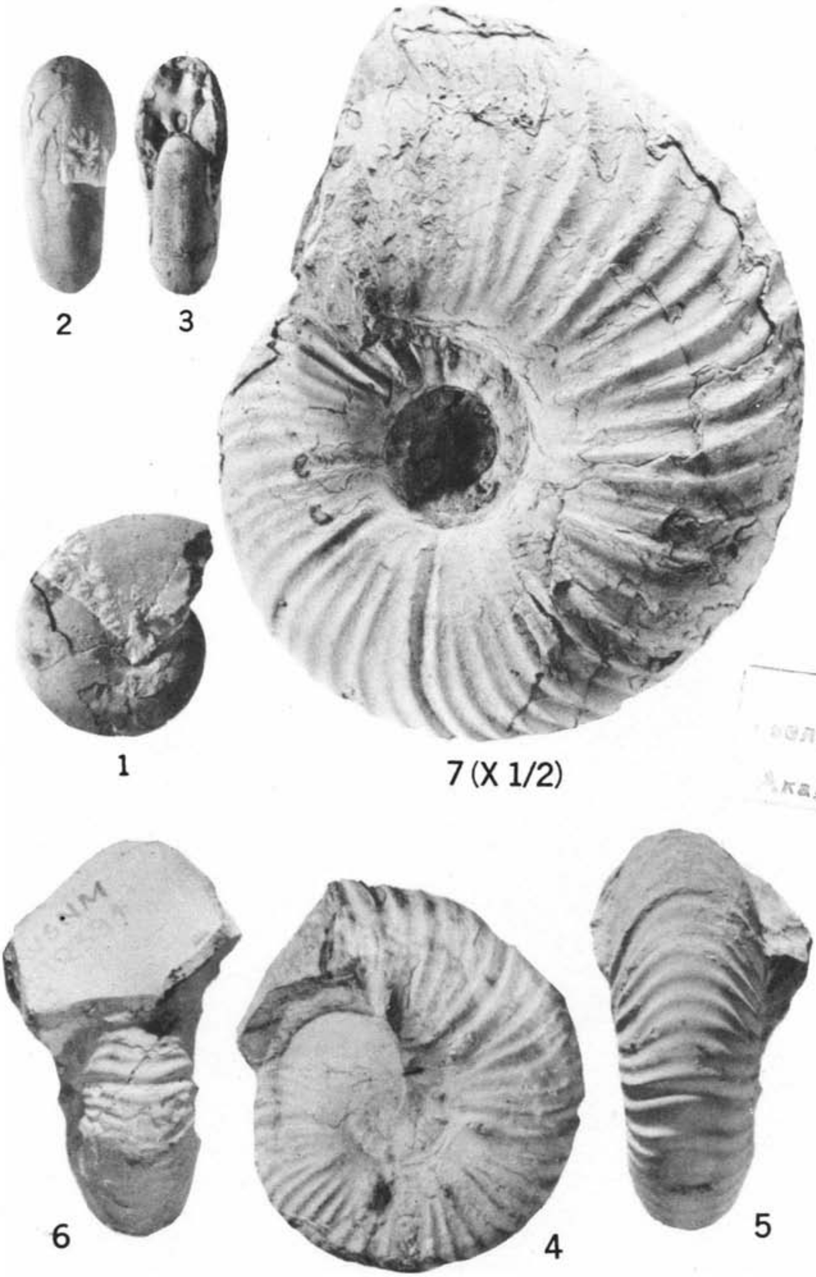

2
3
1
7 (X 1/2)
6
4
5

PLATE VII

Figure 1. *Pachydiscus (Canadoceras) newberryanus* (Meek). Side view. Plesiotype, G.S.C. No. 10031, from an unknown locality; Haslam formation, Nanaimo district, Vancouver Island, British Columbia. (Page 65.)

(NOTE: *See* Plate VIII for other views of plesiotype No. 10031.)

1

PLATE VIII

Figures 1, 2. *Pachydiscus (Canadoceras) newberryanus* (Meek). Apertural and ventral views. Plesiotype, G.S.C. No. 10031, from an unknown locality; Haslam formation, Nanaimo district, Vancouver Island, British Columbia. (Page 65.)

(NOTE: *See* Plate VII for side view of plesiotype No. 10031.)

PLATE VIII

1

2

95395—10

PLATE IX

Figures 1, 2, 3. *Pachydiscus suciaensis* (Meek). Side, ventral, and apertural views (x2), respectively. Plesiotype, G.S.C. No. 10034, from locality 109; upper Lambert formation, Hornby Island, British Columbia. (Page 68.)

Figures 4, 5, 6. *Pachydiscus suciaensis* (Meek). Side, ventral, and apertural views, respectively. Plesiotype, G.S.C. No. 10035, from locality 109; upper Lambert formation, Hornby Island, British Columbia. (Page 68.)

Figures 7, 8. *Pachydiscus suciaensis* (Meek). Side and ventral views. Plesiotype, G.S.C. No. 10036, from locality 113; upper Lambert formation, Hornby Island, British Columbia. (Page 68.)

Figures 9, 10, 11. *Pachydiscus suciaensis* (Meek). Side, ventral, and apertural views, respectively. Plesiotype, G.S.C. No. 5840, from locality 502; upper Lambert formation, Hornby Island, British Columbia. (Page 68.)

PLATE IX

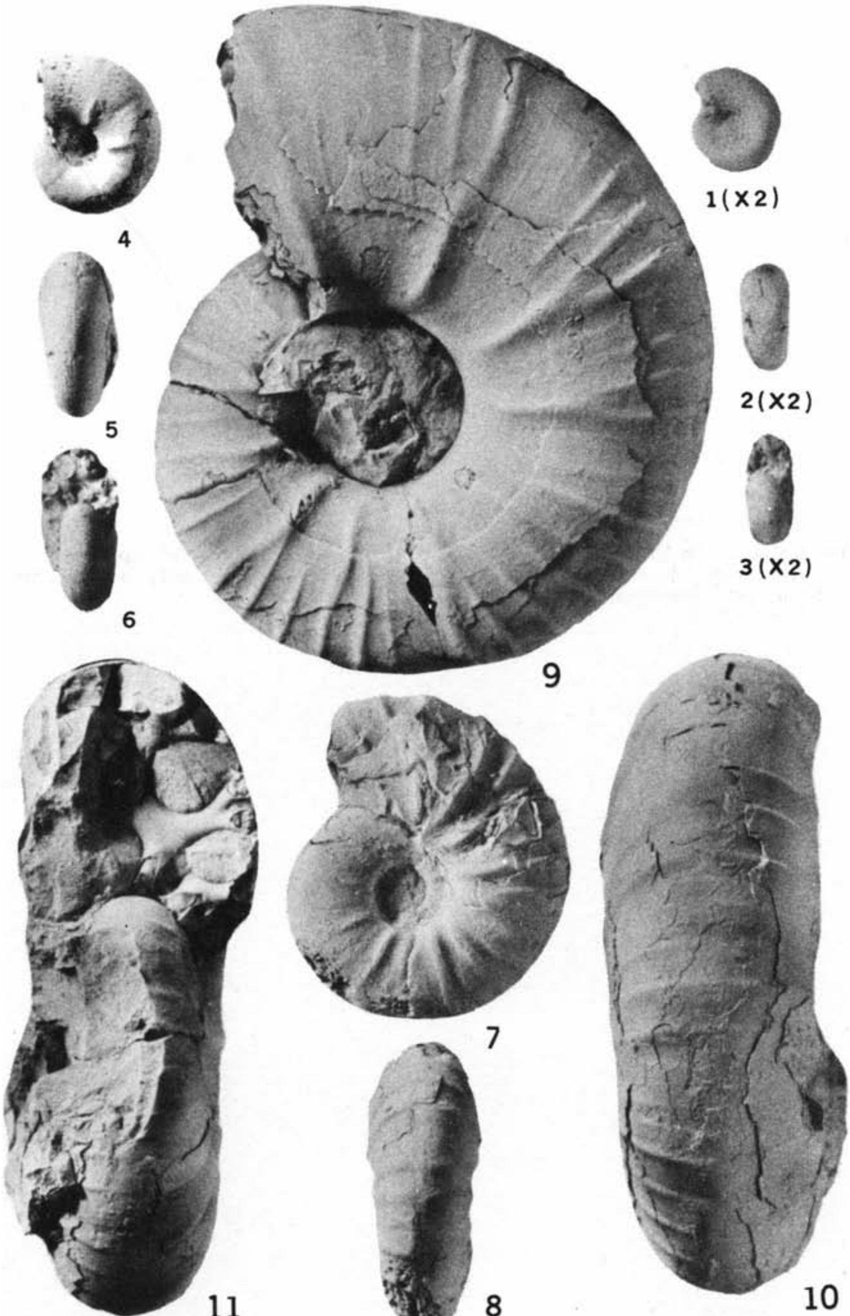


PLATE X

Figures 1, 2, 3. *Pachydiscus suciaensis* (Meek). Side, ventral, and apertural views, respectively. Plesiotype, G.S.C. No. 10037, from locality 502; upper Lambert formation, Hornby Island, British Columbia. (Page 68.)

PLATE X

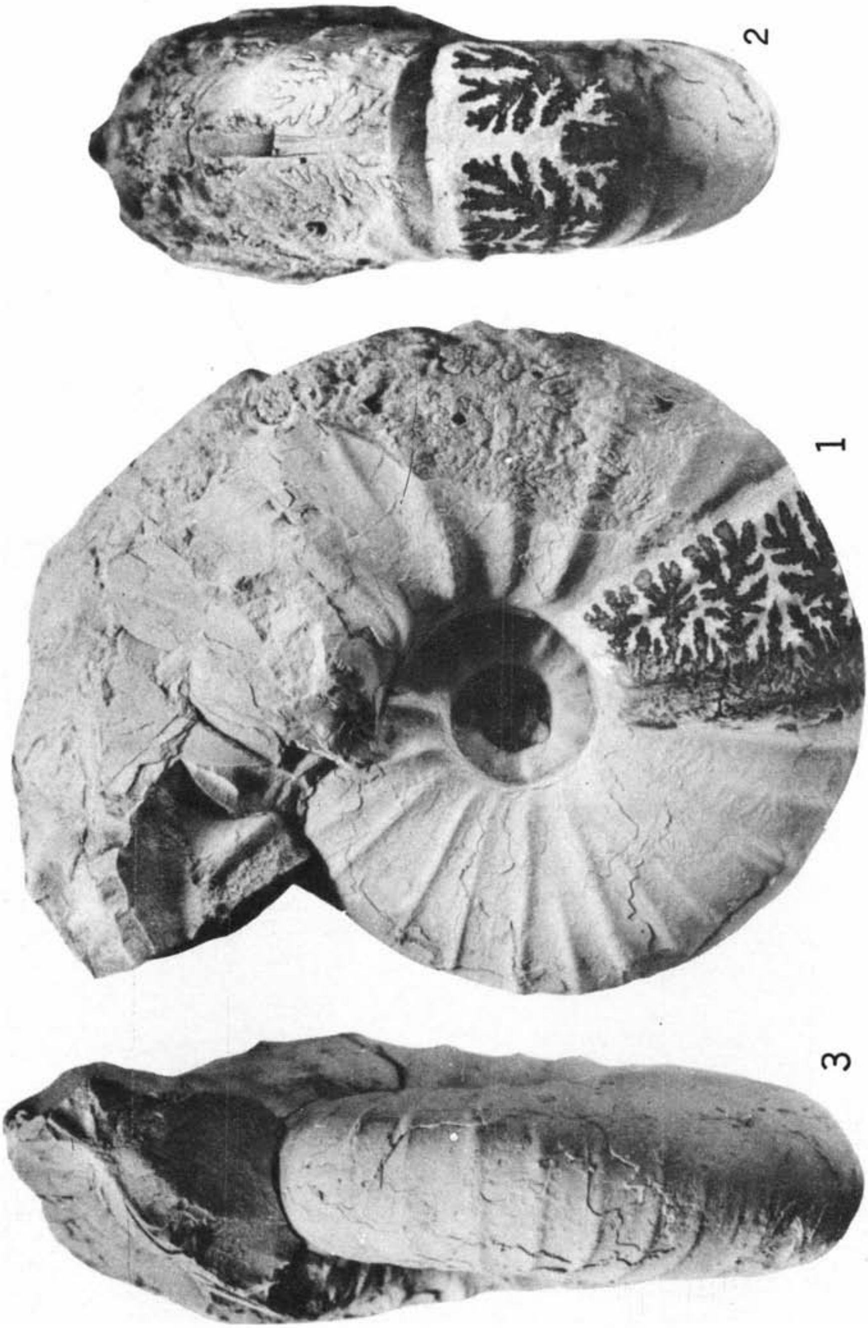


PLATE XI

Figures 1, 2, 3. *Pachydiscus* sp. cf. *P. jacquoti* Seunes. Side, ventral, and apertural views, respectively. Plesiotype, G.S.C. No. 5839, from locality 526; Cedar District formation, Sucia Island, Washington, U.S.A. (Page 72.)

PLATE XI

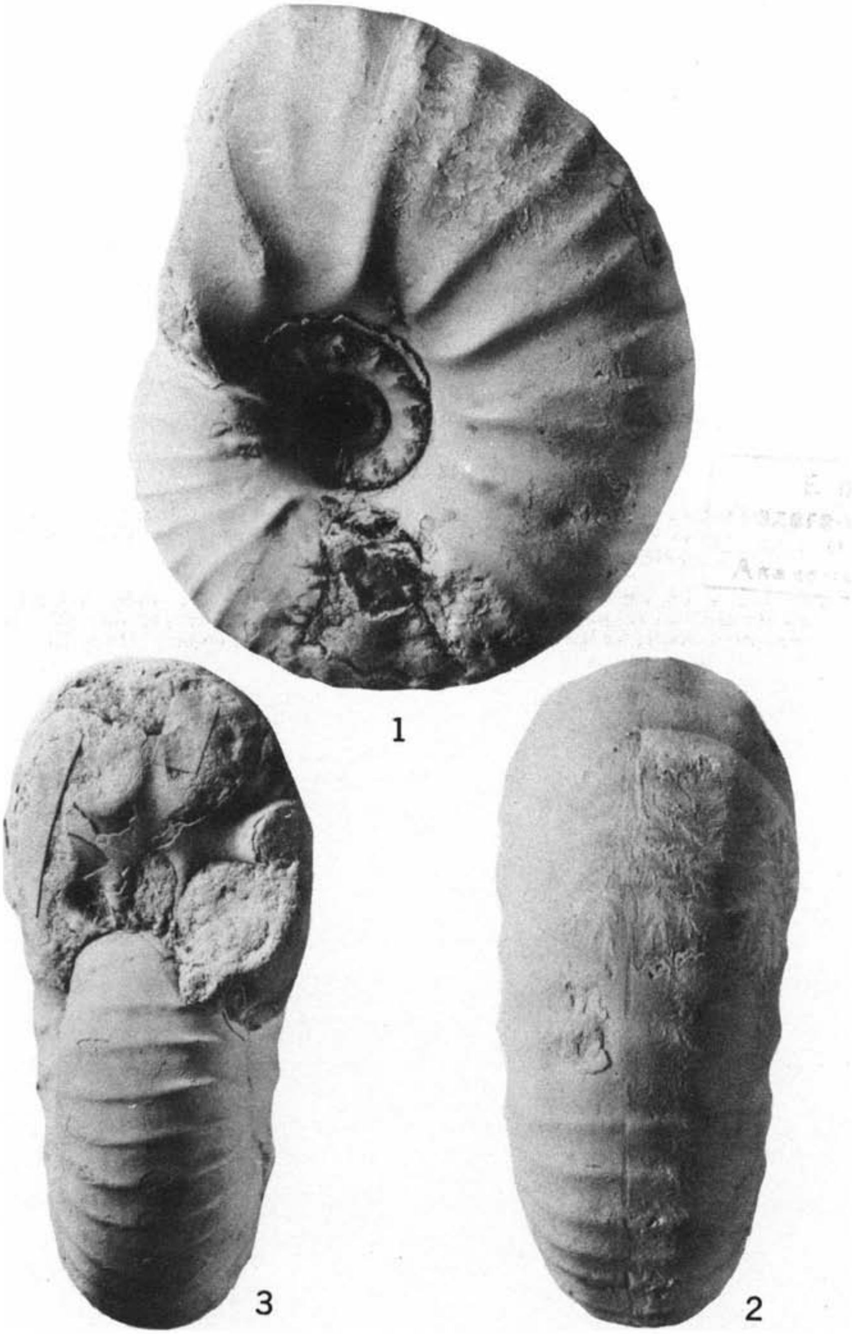


PLATE XII

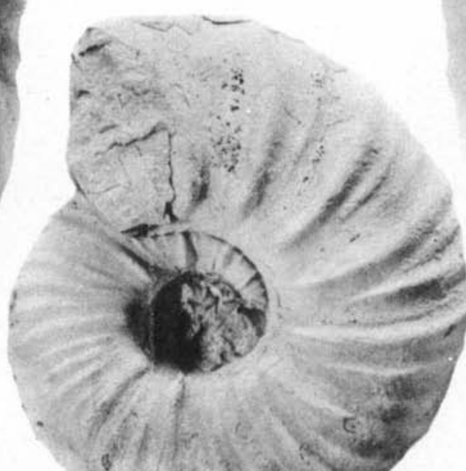
Figure 1. *Pachydiscus perplicatus* Whiteaves. Side view (x½). Holotype, G.S.C. No. 5852, from locality 504; Trent River formation, Puntledge River, Vancouver Island, British Columbia. (Page 77.)

Figures 2, 3, 4. *Pachydiscus (=Eupachydiscus?) haradai* Jimbo. Side, ventral, and apertural views, respectively. Plesiotype, G.S.C. No. 5848, from locality 523; Haslam formation, Nanaimo River, Vancouver Island, British Columbia. (Page 73.)

1 (X 1/2)

4

3



2

PLATE XIII

Figures 1, 2, 3. *Pachydiscus (=Eupachydiscus?) haradai* Jimbo. Side, ventral, and apertural views, respectively. Plesiotype, G.S.C. No. 10042, from locality 244; Haslam formation, Haslam Creek, Vancouver Island, British Columbia. (Page 73.)

Figures 4, 5, 6. *Pachydiscus perplicatus* Whiteaves. Side, ventral, and apertural views, respectively, of third last whorl. Plesiotype, G.S.C. No. 10047, from locality 128; Trent River formation, Browns River, Vancouver Island, British Columbia. (Page 77.)

(NOTE: *See* Plates XIV and XV for second last and outermost whorls of plesiotype No. 10047.)

PLATE XIII

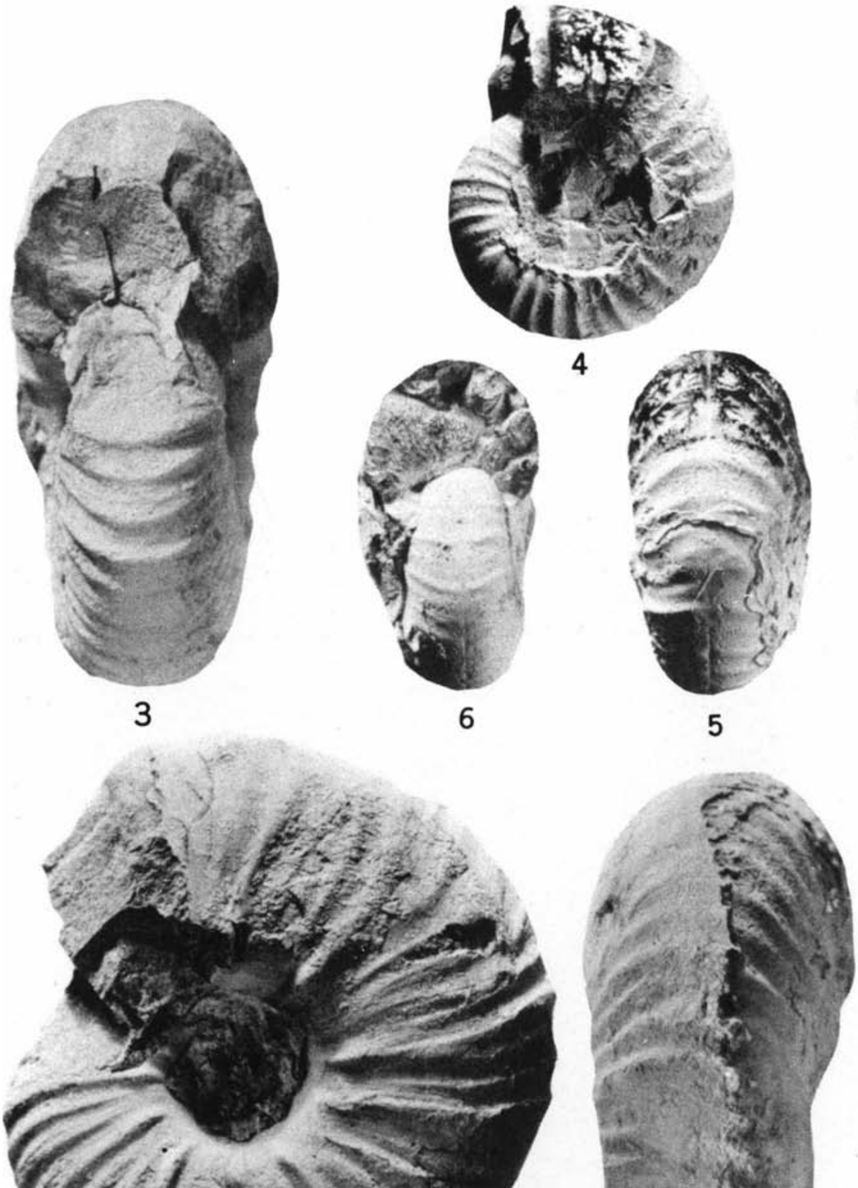


PLATE XIV

Figures 1, 2, 3. *Pachydiscus perplicatus* Whiteaves. Side, ventral, and apertural views, respectively, of second last whorl. Plesiotype, G.S.C. No. 10047, from locality 128; Trent River formation, Browns River, Vancouver Island, British Columbia. (Page 77.)

(NOTE: *See* Plates XIII and XV for third last and outermost whorls of plesiotype 10047.)

PLATE XIV

2

1

3

PLATE XV

Figures 1, 2. *Pachydiscus perplicatus* Whiteaves. Side and ventral views ($x\frac{7}{8}$) of outermost whorl. Plesiotype, G.S.C. No. 10047, from locality 128; Trent River formation, Browns River, Vancouver Island, British Columbia. (Page 77.)

(NOTE: *See* Plates XIII and XIV for third and second last whorls of plesiotype No. 10047.)

PLATE XV

2 (X 2/3)

1 (X 2/3)

PLATE XVI

Figure 1. *Pachydiscus multisulcatus* Whiteaves. Side view (x½). Holotype, G.S.C. No. 5856, from locality 520; upper Qualicum formation, Northwest Bay, Vancouver Island, British Columbia. (Page 81.)

Figures 2, 3, 4. *Pachydiscus multisulcatus* Whiteaves. Side, ventral, and transverse-sectional views, respectively. Plesiotype, G.S.C. No. 10050, from locality 521; upper Qualicum formation, Northwest Bay, Vancouver Island, British Columbia. (Page 81.)

PLATE XVI

1(X 1/2)

3

4

2

95395—11

PLATE XVII

Figures 1, 2, 3. *Pachydiscus ootacodensis* (Stoliczka). Side, apertural, and ventral views, respectively. Plesiotype, G.S.C. No. 10052, from locality 110; upper Lambert formation, Hornby Island, British Columbia. (Page 85.)

Figures 4, 5. *Pachydiscus ootacodensis* (Stoliczka). Side and ventral views of second last whorl. Plesiotype, G.S.C. No. 10051, from locality 115; upper Lambert formation, Hornby Island, British Columbia. (Page 85.)

(NOTE: *See* Plate XVIII for outermost whorl of plesiotype No. 10051.)

PLATE XVII

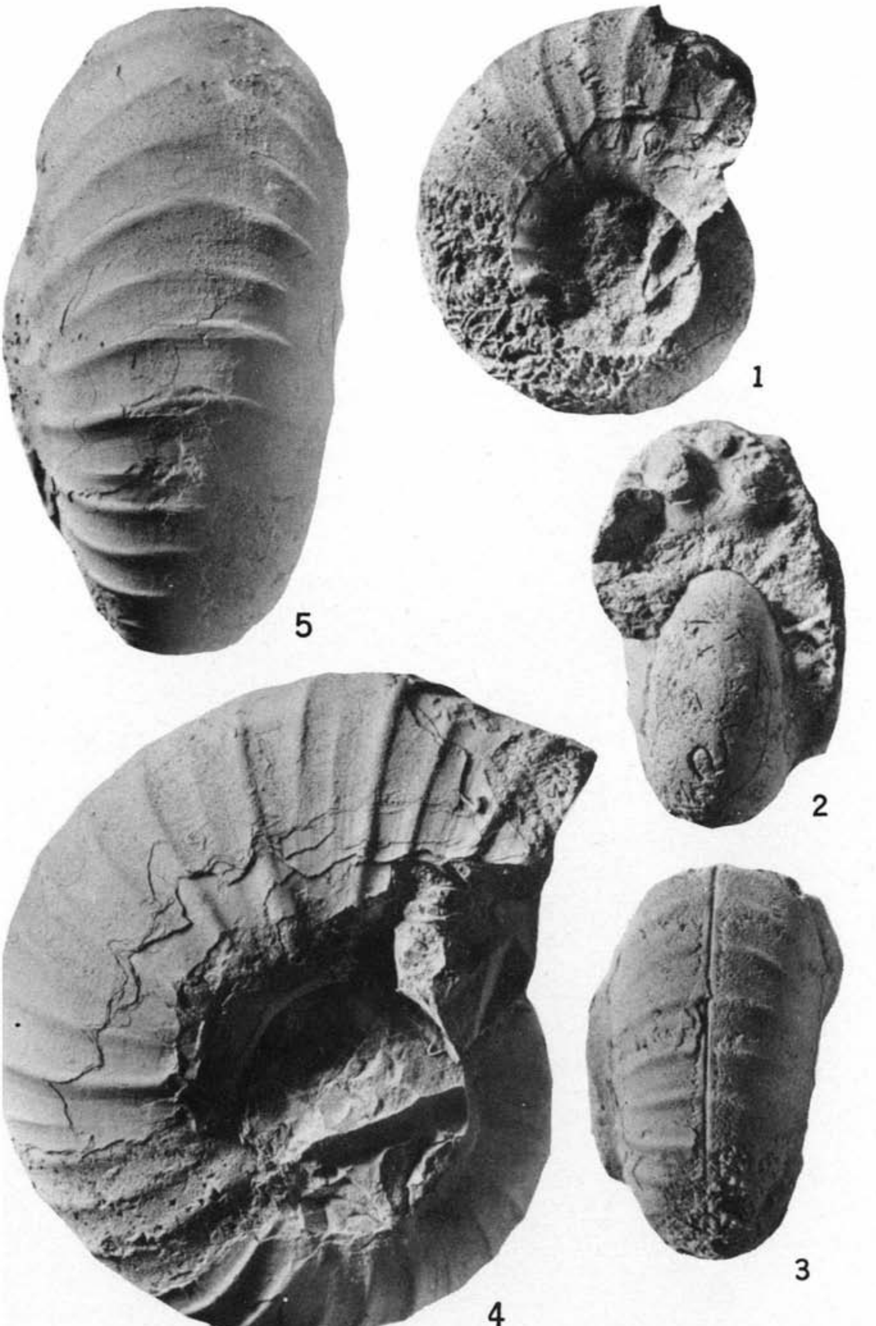


PLATE XVIII

Figure 1. *Pachydiscus ootacodensis* (Stoliczka). Side view of outermost whorl. Plesiotype, G.S.C. No. 10051, from locality 115; upper Lambert formation, Hornby Island, British Columbia. (Page 85.)

(NOTE: *See* Plate XVII for second last whorl of plesiotype No. 10051.)

PLATE XVIII

1

PLATE XIX

Figure 1. *Pachydiscus ootacodensis* (Stoliczka). Side view. Plesiotype, G.S.C. No. 5850, from locality 503; upper Lambert formation, Hornby Island, British Columbia. (Page 85.)

(NOTE: *See* Plate XX for other views of plesiotype No. 5850.)

PLATE XIX

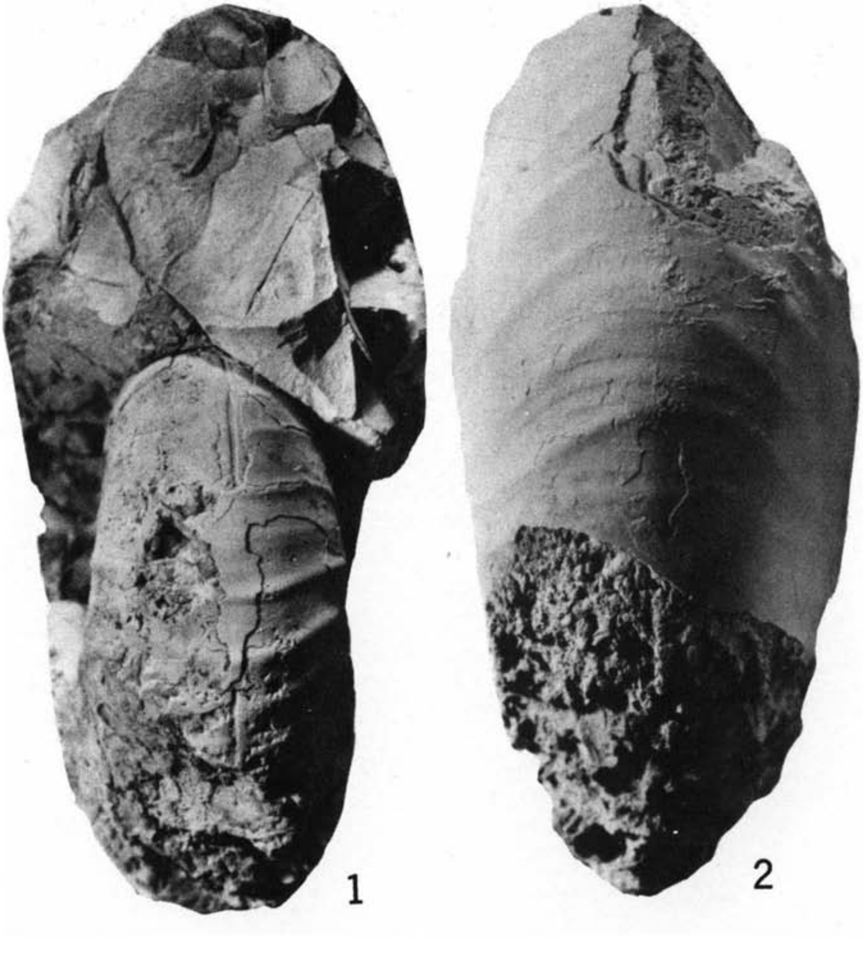
1

PLATE XX

Figures 1, 2. *Pachydiscus ootacodensis* (Stoliczka). Apertural and ventral views. Plesiotype, G.S.C. No. 5850, from locality 503; upper Lambert formation, Hornby Island, British Columbia. (Page 85.)

(NOTE: *See* Plate XIX for side view of plesiotype No. 5850.)

PLATE XX



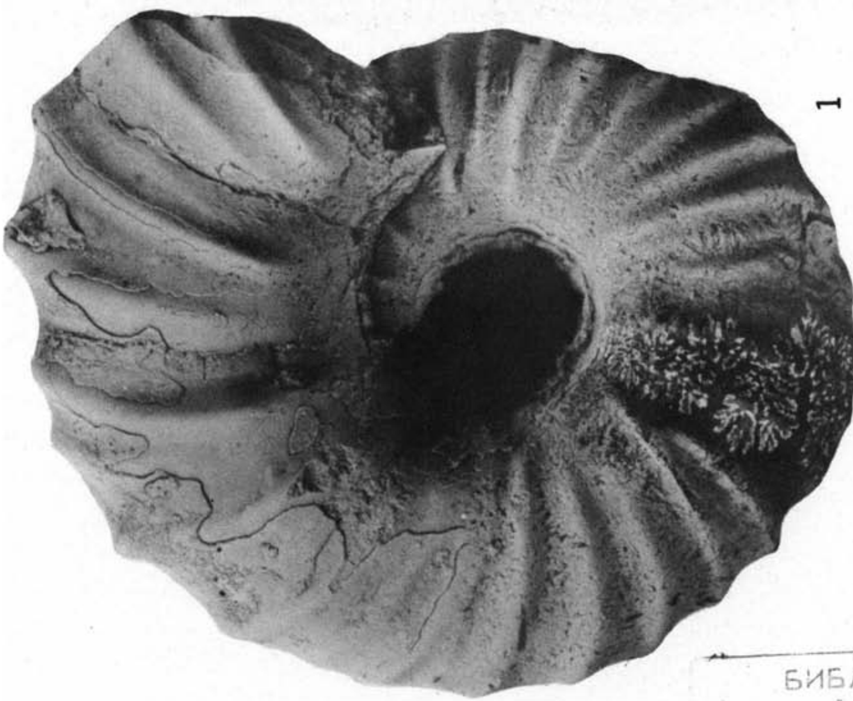
1 2

PLATE XXI

Figures 1, 2. *Pachydiscus binodatus* Whiteaves. Side and ventral views. Holotype, G.S.C. No. 5838, from locality 508; Trent River formation, Puntledge River, Vancouver Island, British Columbia. (Page 86.)

PLATE XXI

2

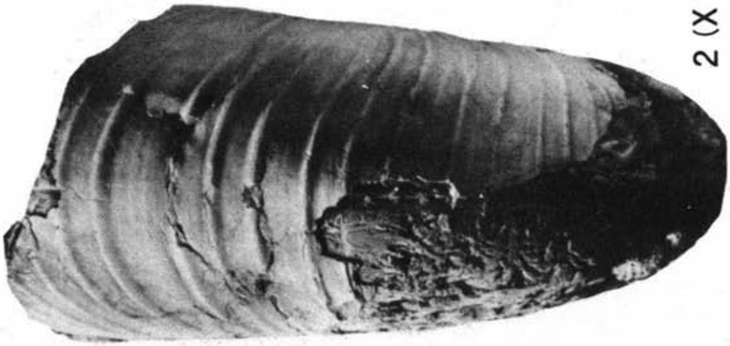


1

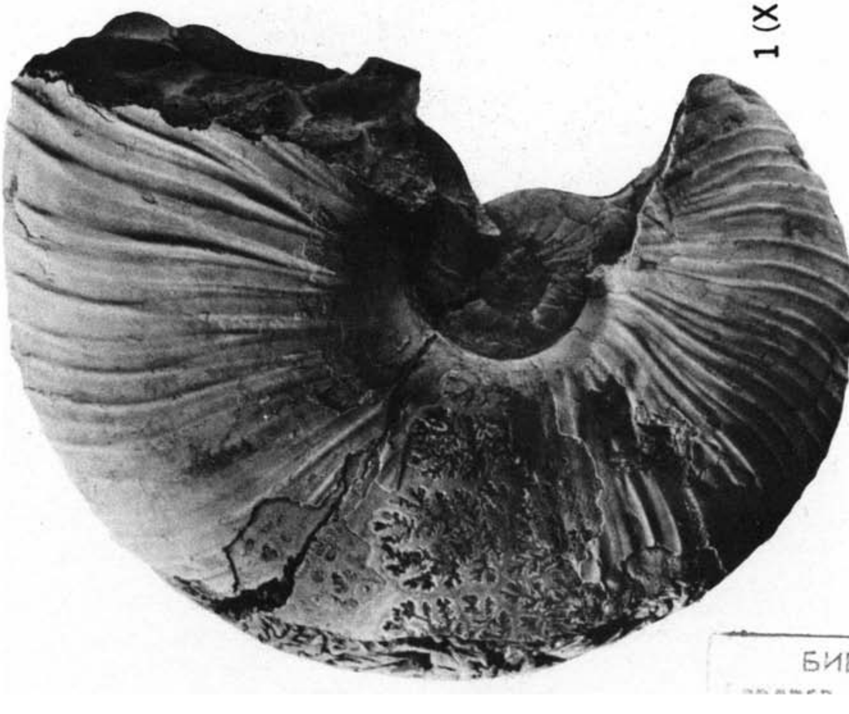
PLATE XXII

Figures 1, 2. *Pachydiscus neevesi* Whiteaves. Side and ventral views (x½). Lectotype, G.S.C. No. 5853, from locality 525; Nanaimo group, James Island, British Columbia. (Page 87.)

PLATE XXII



2 (X 1/2)



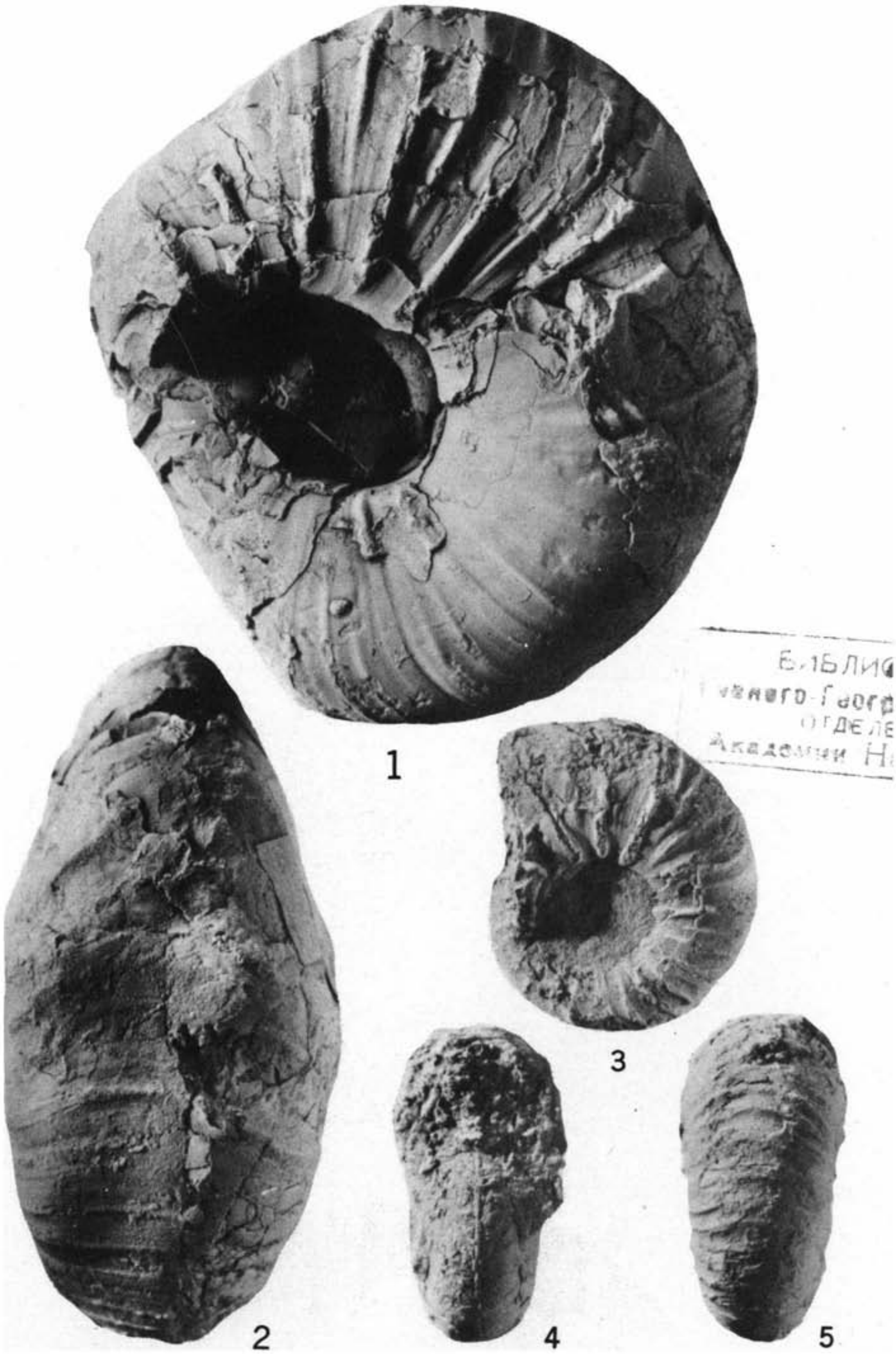
1 (X 1/2)

PLATE XXIII

Figures 1, 2. *Pachydiscus buckhami* n.sp. Side and ventral views. Holotype, G.S.C. No. 5947, from locality 508; Trent River formation, Puntledge River, Vancouver Island, British Columbia. (Page 89.)

Figures 3, 4, 5. *Pachydiscus buckhami* n.sp. Side, apertural, and ventral views, respectively, of second last whorl. Paratype, G.S.C. No. 10055, from locality 233; Haslam formation, Elkhorn Creek, Vancouver Island, British Columbia. (Page 89.)

PLATE XXIII



1 2 3 4 5

PLATE XXIV

Figures 1, 2. *Pachydiscus elkhornensis* n.sp. Side and ventral views. Holotype, G.S.C. No. 10056, from locality 228; Haslam formation, Elkhorn Creek, Vancouver Island, British Columbia. (Page 90.)

Figures 3, 4. *Pseudoschloenbachia brannani* n.sp. Side and ventral views. Holotype, G.S.C. No. 10058, from locality 205; Haslam formation, Brannan Creek, Vancouver Island, British Columbia. (Page 92.)

PLATE XXIV

3

4

1

2

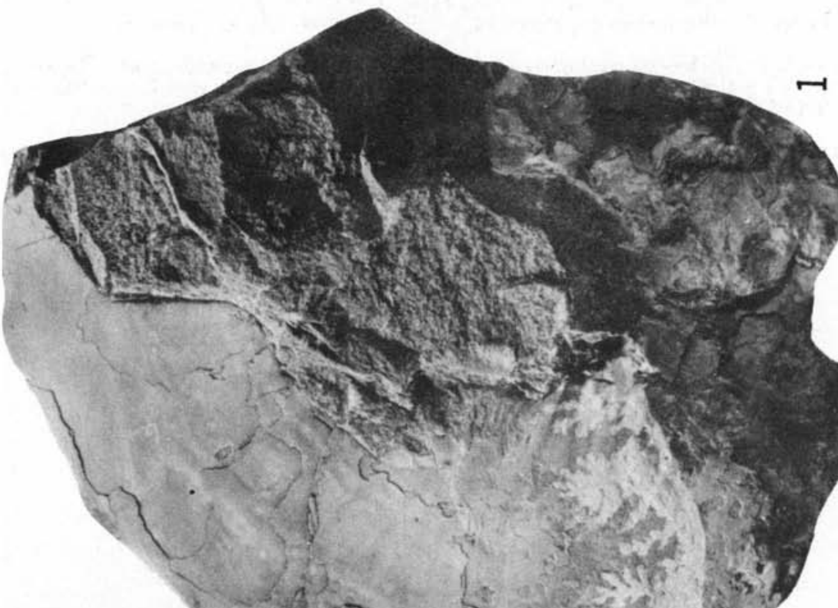
95395—12

PLATE XXV

Figures 1, 2. *Hoplitoplacenticeras vancouverense* (Meek). Side and ventral views. Plesio type, G.S.C. No. 10059, from locality 290; Cedar District formation, Sucia Island Washington, U.S.A. (Page 93.)

PLATE XXV

2



1

PLATE XXVI

Figures 1, 2, 3, 4. *Baculites chicoensis* Trask. Side, ventral, dorsal, and transverse-sectional views, respectively. Plesiotype, G.S.C. No. 5796a, from locality 526; Cedar District formation, Sucia Island, Washington, U.S.A. (Page 96.)

Figures 5, 6. *Ptychoceras vancouverense* Whiteaves. Side and ventral views. Lectotype, G.S.C. No. 5798, from locality 511; Trent River formation, Trent River, Vancouver Island, British Columbia. (Page 101.)

Figure 7. '*Hamites*' *obstrictus* Jimbo. Side view. Plesiotype, G.S.C. No. 5958, from locality 500; upper Lambert formation, Hornby Island, British Columbia. (Page 100.)

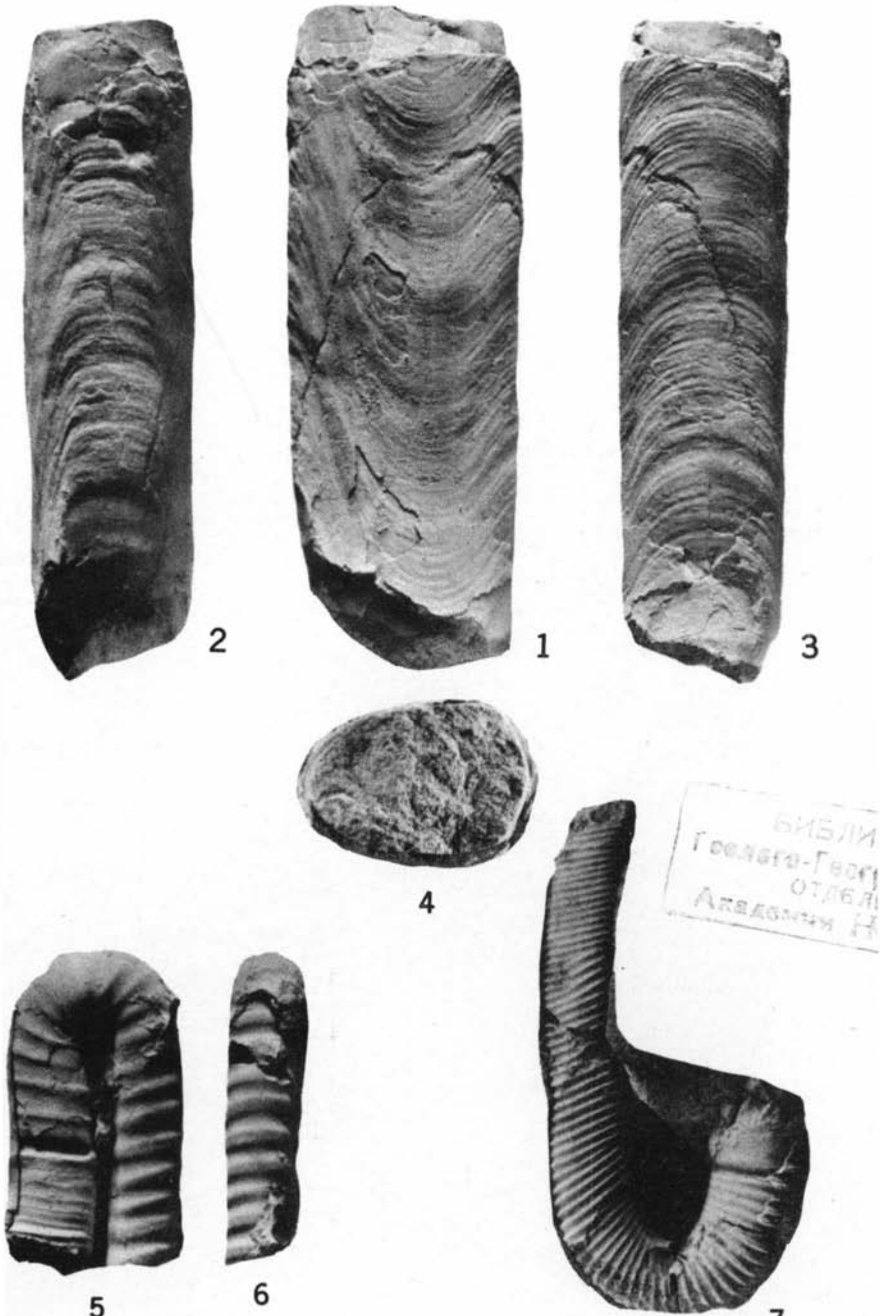

2
1
3
4
5
6
7

PLATE XXVII

Figures 1, 2. *Nostoceras hornbyense* (Whiteaves). Two views from opposite sides. Plesiotype, G.S.C. No. 10061, from locality 500; upper Lambert formation, Hornby Island, British Columbia. (Page 103.)

PLATE XXVII

PLATE XXVIII

Figure 1. *Baculites occidentalis* Meek. Side view. Plesiotype, G.S.C. No. 5952, from locality 502; upper Lambert formation, Hornby Island, British Columbia. (Page 98.)

Figure 2. *Nostoceras hornbyense* (Whiteaves). Plesiotype, G.S.C. No. 10069, from locality 113; upper Lambert formation, Hornby Island, British Columbia. (Page 103.)

Figure 3. *Bostrychoceras elongatum* (Whiteaves). Lectotype, G.S.C. No. 5806, recorded from Hornby Island, but more probably from the Trent River formation, Vancouver Island, British Columbia. (Page 105.)

Figure 4. *Bostrychoceras elongatum* (Whiteaves). (x½). Plesiotype, G.S.C. No. 10062, from locality 234; Haslam formation, Elkhorn Creek, Vancouver Island, British Columbia. (Page 105.)

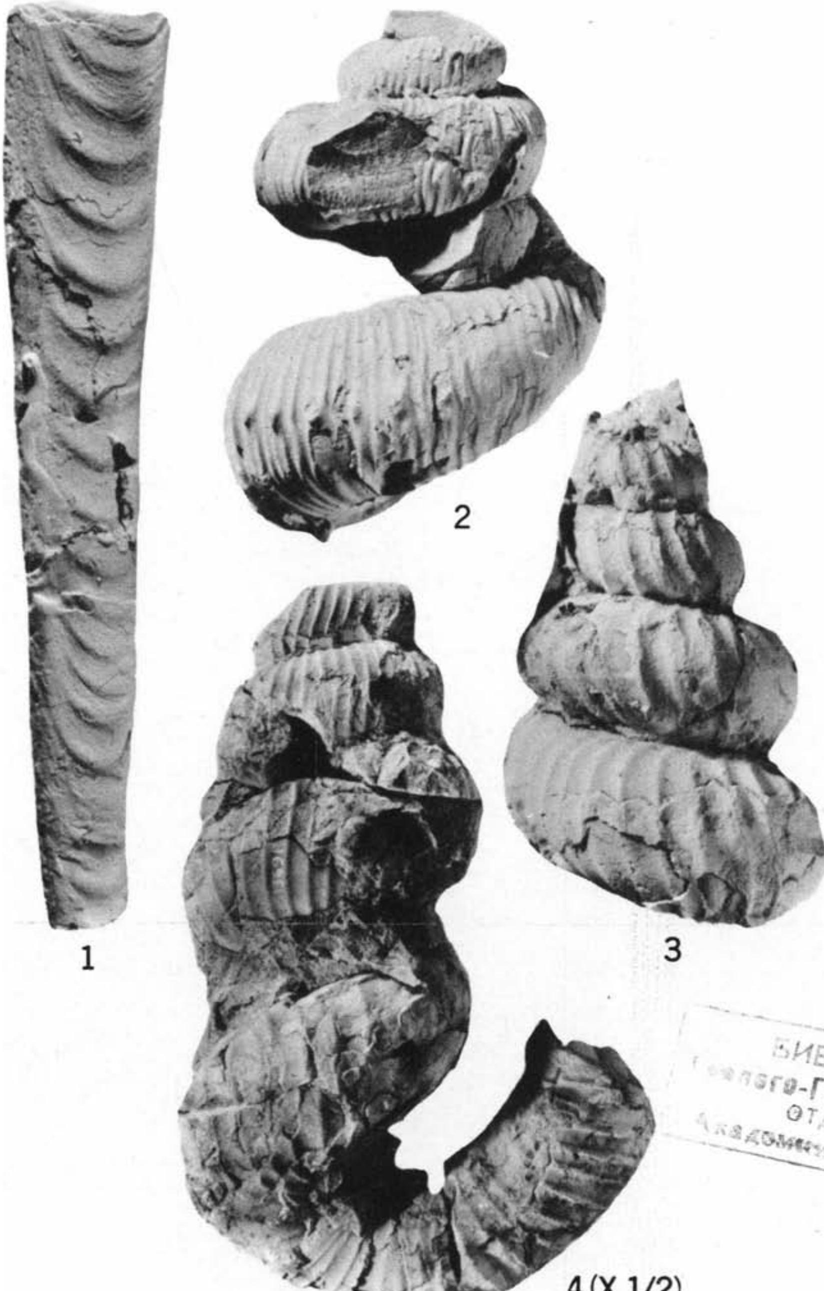

1
2
3
4 (X 1/2)

PLATE XXIX

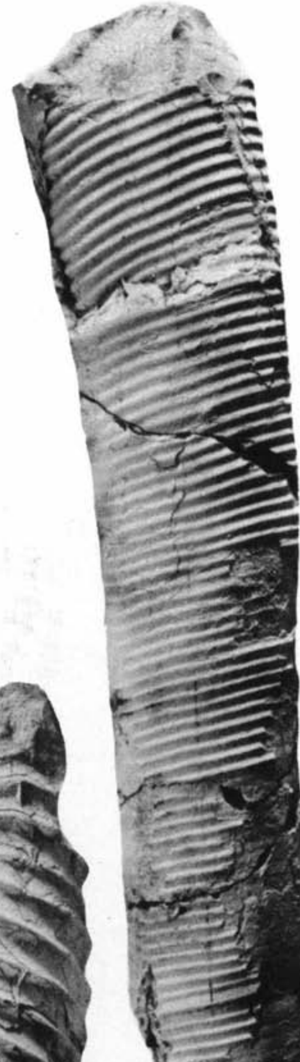
Figure 1. *Anisoceras cooperi* (Gabb). (x½). Plesiotype, G.S.C. No. 10063, from locality 112; upper Lambert formation, Hornby Island, British Columbia. (Page 107.)

Figure 2. *Diplomoceras notabile* Whiteaves. Side view (x½). Holotype, G.S.C. No. 10064, from locality 503; upper Lambert formation, Hornby Island, British Columbia. (Page 109.)

Figure 3. *Diplomoceras? subcompressum* (Forbes). Side view. Plesiotype, G.S.C. No. 10066, from locality 17; Trent River formation, Puntledge River, Vancouver Island, British Columbia. (Page 110.)

Plate XXIX

3



2 (X 1/2)

1 (X 1/2)

PLATE XXX

Figure 1. *Diplomoceras notabile* Whiteaves. Side view. Plesiotype, G.S.C. No. 10065, from locality 109; Upper Lambert formation, Hornby Island, British Columbia. (Page 109.)

PLATE XXX

1

INDEX TO FOSSILS