CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

MEMOIR 264

# CARBONIFEROUS STRATIGRAPHY AND PALÆONTOLOGY IN THE MOUNT GREENOCK AREA, ALBERTA

BY

R. A. C. Brown



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

No. 2503

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View of Mount Greenock, looking northwesterly across Athabasca River from the north end of Cinquefoil Mountain. The prominent gully extending to the summit is Spirifer Gully, with Windy Point to the left of the gully at the base of the mountain.

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## PREFACE

Studies of the stratigraphy and fossil content of the great geological systems, from Cambrian time on, are fundamental to geological mapping, to interpretations of geological structures, and to success in the search for petroleum and natural gas, for coal, and for a variety of industrial minerals. In western Canada, the recent, greatly expanded production of oil and gas, much of it from deeply buried, late Palæozoic formations, has led to detailed studies of these formations not only as represented by well cuttings and drill cores but as exposed in the Foothills and eastern Rocky Mountains.

In the present report, which deals with formations of the Carboniferous system, the author describes these formations as exposed in a relatively small area of the Rocky Mountains in Athabasca River Valley near Jasper, Alberta. Advantage was taken of the excellent exposures to make detailed sections in four adjoining thrust blocks, and representative fossils were collected at many horizons in the successive formations. The local Carboniferous section has both its upper and lower contacts present, and its study in detail should assist correlation in nearby regions as well as subsurface studies in more distant, productive or potential oil and gas fields.

The report deals fully with the structural features of the Mount Greenock area, with the detailed lithology of the several measured sections, and with the various species of Mississippian brachiopods collected in the area. Four faunules, which may serve in future as more widespread faunal subdivisions of the Carboniferous strata of the Canadian Rockies, are recognized. All four are believed to be of Mississippian age. Five plates, two of them illustrative of brachiopod species, and sixteen figures serve to assist the reader in following the descriptive text.

GEORGE HANSON,

*Chief Geologist, Geological Survey of Canada*

OTTAWA, June 15, 1951

# Carboniferous Stratigraphy and Palæontology in the Mount Greenock Area, Alberta

## CHAPTER I

## INTRODUCTION

### PURPOSE AND SCOPE OF WORK

The present report deals with the Carboniferous strata of a small area lying within the Rocky Mountains in Athabasca Valley, Alberta. It is an attempt to define in detail the Carboniferous strata within the examined area, and to use this information to clarify the succession of these strata in Athabasca Valley. The Carboniferous brachiopods collected from the area are described in detail in order to facilitate the building of a local faunal succession for the Carboniferous system.

Similar studies in the front or easternmost range of the Rocky Mountains, and in the ranges to the west of the Mount Greenock area, together with intensified collecting, would complete the Carboniferous studies in Athabasca Valley. It is hoped that the present preliminary results will in themselves be of practical use to the field geologist, and that they will help to stimulate comparative studies in neighbouring regions.

The choice of the Mount Greenock area was made because the structure within it is more suitable for stratigraphic study than in the surrounding parts of Athabasca Valley, and because the local Mississippian section there is complete.

### ECONOMIC SIGNIFICANCE OF CARBONIFEROUS STRATA IN WESTERN CANADA

The Carboniferous strata of western Canada are assuming an ever increasing economic importance, largely because of expanding petroleum and natural gas possibilities. Productive zones within them in the Foothills of the Rocky Mountains are responsible for the oil and gas production of Turner Valley, and for the enormous known natural gas reserves[1] of the Foothills region.

Porous limestones at similar horizons are widespread in the strata exposed throughout the Rocky Mountains, and petroleum geologists are anxious to obtain complete information on the number, lateral extent, and distance from an overlying datum plane, of such limestones in any given area. The chief difficulty encountered by these geologists in determining this information is that in many of the best known areas for study, particularly to the south of Banff, neither the thickness of the various formations

[1] A recent account of these reserves is contained in a special report of the Geological Survey of Canada on the "Natural Gas Reserves of the Prairie Provinces" by G. S. Hume and A. Ignatieff.

nor their time ranges within the Carboniferous system are reliably known. This is due to the variation in thickness and character of the formations, to the apparent existence of many unfossiliferous beds, and to the ever-present possibility of obscure, low-angle thrust faults.

The Carboniferous strata pinch out northeastward of the Alberta Foothills, apparently somewhat eastward of the Edmonton area. This northeasterly margin of the Carboniferous may be of significance in the search for stratigraphic traps for oil. This possibility, and the persistence of porous Carboniferous beds from near the International Boundary to well north of Athabasca Valley, add to the factors that favour oil accumulation in the Foothills and Plains of Alberta, British Columbia, and Yukon. The presence of Carboniferous strata in southern Saskatchewan and Manitoba and the new oil wells in Manitoba, North Dakota, and Montana have also stimulated greatly the interest in Carboniferous strata in western Canada. Further incentive for study of Carboniferous strata in the Rocky Mountains concerns the Upper Palæozoic succession farther west, in central British Columbia. Throughout many parts of this province there are occurrences of poorly fossiliferous, usually disturbed and intruded Permian and Carboniferous strata, some of them in mining areas, where detailed mapping is required. Comparatively little faunal information has been obtained from the Carboniferous strata of British Columbia, and in most places the relations between Carboniferous and Permian strata are not known. The writer believes that the best means of completely solving the Carboniferous stratigraphy of that province is through a thorough comparison of it with the relatively undisturbed strata of the Rocky Mountains of Alberta.

## PREVIOUS STUDIES IN ATHABASCA VALLEY

The earliest geological reconnaissance in Athabasca Valley was made by James McEvoy (21)[1], during his exploration of the Yellowhead Pass route through the mountains. In his investigation, McEvoy examined both Devonian and Carboniferous strata in parts of the mountains close to the area of the present report. He described a Devonian stratigraphic section from Miette Range, and a Carboniferous section from Folding Mountain. Small, diagnostic fossil collections were recorded.

The first regional biostratigraphic investigation in Jasper Park was made by E. M. Kindle, of the Geological Survey, who spent parts of several summers in the park. Dr. Kindle's reconnaissance led him from the most easterly ranges of the mountains to the Palisade Range, and to Maligne Lake. The first published result of this work (14) was the description of three new species of brachiopods from Devonian strata in the park. Then followed a paper (15) describing the stratigraphic and faunal succession in the park. In this paper, generalized stratigraphic sections of the Palæozoic rocks in the Miette Range, the Palisade Range, and at Maligne and Medicine Lakes, and also a Mesozoic section, were recorded and briefly discussed. Seven faunas were listed, under the separate headings of Cambrian, Devonian, Mississippian, Pennsylvanian, Triassic, Jurassic, and Cretaceous. Twenty-seven fossil localities were briefly described. In the

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[1] Numbers in parentheses refer to references in Bibliography at the end of Chapter I.

Devonian and Carboniferous cartographic succession Kindle recognized the equivalents of formations recorded in the Bow Valley region. One new Devonian formation was described.

The next stage in the stratigraphic study of Jasper Park was set by a session of the Harvard summer school, under the direction of Dr. P. E. Raymond, in association with Dr. Leon Collet and Dr. Ed. Parejas. The territory examined during this study includes the mountains bordering Athabasca River, on both sides of it, from the front range westward beyond the Palisade Range.

The stratigraphic information obtained on this project is contained in a paper (24) by Raymond, who proposed in it eight new formational names for the Devonian and Carboniferous formations in Jasper Park. Sections were recorded from Roche Miette, Mount Cinquefoil, Mount Greenock, and at Cold Sulphur Spring. Notes were made on the lithological character of the cartographic units. Fossils were allocated by reference to the formations from which they were obtained. Remarks on correlation were made, and Raymond concluded that the Devonian and Carboniferous succession in Jasper Park differs greatly from that of the Bow Valley area. It is to Dr. Raymond that we are indebted for almost all the local terminology that has been used to date for the Devonian and Carboniferous of Athabasca Valley in Jasper Park.

A palæontological contribution from the Harvard summer school survey was also made by C. H. Burgess (6), who described eight species from one of the Devonian formations named by Raymond.

Information on structural geology obtained during the Harvard investigation was published in a paper (7) by Collet and Parejas. In this paper, the structures of the main mountains were discussed separately, and generalizations on the structural conditions in Jasper Park were made. An important part of this paper is the structure section made on the northwest side of Athabasca River from the mountain front southwestward to Pyramid Mountain. The stratigraphic column for this section, although simplified, is a reflection of Raymond's conception of stratigraphy in Jasper Park.

Following the investigation by the Harvard summer school, Professors Allan, Warren, and Rutherford, of the University of Alberta, published the results (1) of a reconnaissance trip made through the same area in Jasper Park. These authors stressed the fact that theirs was a reconnaissance examination in which no detailed sections were attempted and no effort was made to collect fossils systematically through the various formations. However, their previous knowledge of the stratigraphy in the Rocky Mountains enabled them to make accurate observations on the succession in Jasper Park. Their report gives an account of the general geology, structure, stratigraphy, and palæontology.

Allan *et al.* differ from Raymond regarding the Devonian and Carboniferous stratigraphy. In fact, their work demonstrates that the general lithological and faunal succession in these systems as developed in Athabasca Valley is similar to that in the region lying between the Bow and Crowsnest Valleys to the southeast.

As a result of all work to date, the main lithological units in the Devonian and Carboniferous of Jasper Park have been delineated, and the abundantly fossiliferous horizons have been found.

The field work for this report was completed in 1944; since then, further work at many points along the strike of the Carboniferous strata between Banff and Jasper has been carried out by the geological staff of various oil companies and by officers of the Geological Survey of Canada. F. W. Beales has recently completed a restudy of the type sections in the Banff and Mount Head areas (3), and subsequent reports may be expected to deal with the palæontology and stratigraphy of the greater part of the Carboniferous system in the Rocky Mountains of Alberta. A. H. Lang's work, Memoir 244, on Brûlé and Entrance map-areas, includes sections of the Carboniferous strata of the Boule Range (17, pp. 17-20).

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# CHAPTER II

# THE MOUNT GREENOCK AREA AND ITS ENVIRONS

## ACCESSIBILITY

(*See* Figure 1)

Three travel routes traverse the Mount Greenock area. On the southeast side of the Athabasca the provincial Highway 16 follows the abandoned Grand Trunk Pacific railway grade. In its route along the valley toward Jasper, the highway traverses the sand bars between the Fish Lakes and Jasper Lake, and thence continues close to the valley wall, intersecting in a small rock-cut the extreme northwest end of Friendly Peak (*See* Plate III B) and, in a long, intermittent rock-cut, the northwest ends of Cold Sulphur Ridge and Morro Peak. The highway crosses the river at the west end of this last rock-cut, and then bends sharply southward, switching from the old Grand Trunk grade to the adjacent, former Canadian Northern grade, keeping to the west side of the river toward Jasper.

The main line of the Canadian National Railways follows the northwest side of Jasper Lake, just above water level, intersecting in a rock-cut the southeast end of Mount Greenock (Windy Point). Snaring station lies 1 mile to the southwest just to the north of the mouth of Vine Creek. The railway continues close to the Athabasca, crossing the highway near the highway bridge over the river, thence switching from the Canadian Northern to the Grand Trunk grade southward to Jasper. A forestry motor road follows around the southeast spur of Mount Greenock, traversing almost vertical bedrock, close to the railroad, at Windy and Snaring Points (*See* Figure 6). Thence it meanders southwesterly through the wooded alluvial fans of Vine, Spring, and Corral Creeks to Moberly Flat, and thence through another dense stretch of forest, on the alluvial fan of Cobblestone Creek. Farther south it swings to the southeast to emerge on a low muskeg flat, and joins the provincial highway 10 miles north of Jasper.

## GENERAL GEOGRAPHY

The Mount Greenock area is a small, roughly square region in the Rocky Mountains of Jasper Park, 12 miles north of Jasper (*See* Figure 2). It is almost entirely confined to tp. 47, rge. 1, W. 6th mer. The area is bisected by the northeast trending valley of Athabasca River, and includes the valleyward slopes of adjacent mountain ranges. The latter are underlain by a succession of parallel ridges trending northwest and the boundaries of the area trend northwesterly and northeasterly.

Northeast of the Mount Greenock area, a long, well-defined trough parallels the ranges for several miles on either side of Athabasca River, which continues its northeasterly direction to the mountain front. The trough is occupied by Snake Indian River, which joins the Athabasca from the northwest, and by Rocky River, which joins the Athabasca from the southeast.

Northeast of this trough (*See* Figure 1) the Athabasca transects a broad, lofty ridge of Palæozoic strata, comprising the long Bosche Range to the northwest, and the equally long Miette Range to the southeast. The northwest end of the latter range ends in Roche Miette, a prominent landmark, which can easily be seen from the plains far to the east.

The Miette-Bosche massif is separated from the front range of the Rocky Mountains by the Moosehorn coal basin, which is a narrow trough containing the subsequent valley of Moosehorn Creek to the northwest, and the captured part of the subsequent valley of Fiddle River to the southeast.

Finally, Athabasca Valley transects the mountain front, dividing it into the complex Boule Range, to the northwest, and the Fiddle Range, to the southeast.

The terrain to the southwest of the Mount Greenock area is featured by an abrupt change of direction in the course of Athabasca River. In contrast with its northeasterly course through and below the Mount Greenock area, the general direction from its source to this area is about north 20 degrees west. One mile upstream from this bend, the river is joined by the eastward-flowing Snaring River, and 6 miles farther south, Maligne River joins the Athabasca from the southeast. Here Athabasca Valley swings slightly to the west of south around the end of The Palisade, toward the village of Jasper, 4 miles distant.

The Palisade rises as a prominent scarp of gently west-dipping Palæozoic limestone, and farther west, towering above it, can be seen the summit of Pyramid Mountain, one of the well known scenic attractions in the Park.

North of Snaring Valley lies a group of high peaks encircling Chetamon Lake. The most easterly of these, Cobblestone Peak, marks the western extremity of the Mount Greenock area.

The eight mountains within the Mount Greenock area are arranged in two rows of four, one row on either side of Athabasca River. The four parallel, ridge-like mountains on the northwest side are, in order from southwest to northeast, Cobblestone Peak, Esplanade Mountain, Grassy Ridge, and Mount Greenock (*See* Plate III B). The northwest margin of the area passes through all the summits but that of Grassy Ridge. Each mountain is separated from the adjacent ones by small, subsequent streams, which flow southeasterly into the Athabasca. Thus, between Cobblestone Peak and Esplanade Mountain lies Cobblestone Creek; between Esplanade Mountain and Grassy Ridge is the valley of Corral Creek; and between Grassy Ridge and Mount Greenock lies Vine Creek.

Southeast of Athabasca River the Jacques and Colin Ranges include all of the mountains that lie within the Mount Greenock area.

Of these, Cinquefoil Mountain forms the northwest end of the Jacques Range. The other mountains, Morro Peak, Cold Sulphur Ridge, and Friendly Peak, form the northwest end of the Colin Range and are separated from its more lofty peaks by the valley of Morro Creek. Southeastward of Morro Creek, the Colin Range rises to Mount Hawk, the lower northwest slopes of which fall within the southeast margin of the Mount Greenock area. Between Jacques and Colin Ranges lies the subsequent valley of Jacques Creek. Friendly Peak and Cold Sulphur Ridge are separated by

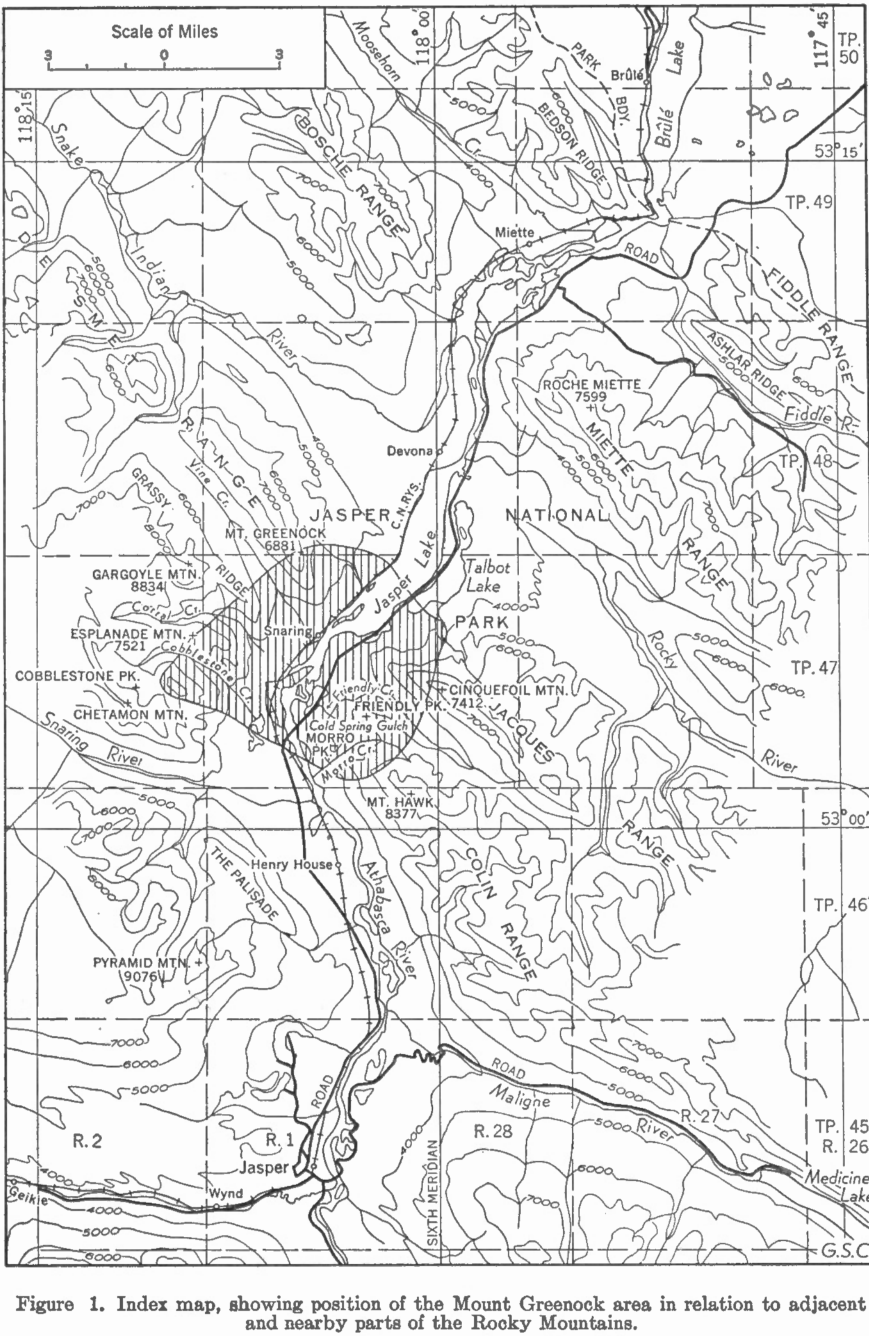


Figure 1. Index map, showing position of the Mount Greenock area in relation to adjacent and nearby parts of the Rocky Mountains.

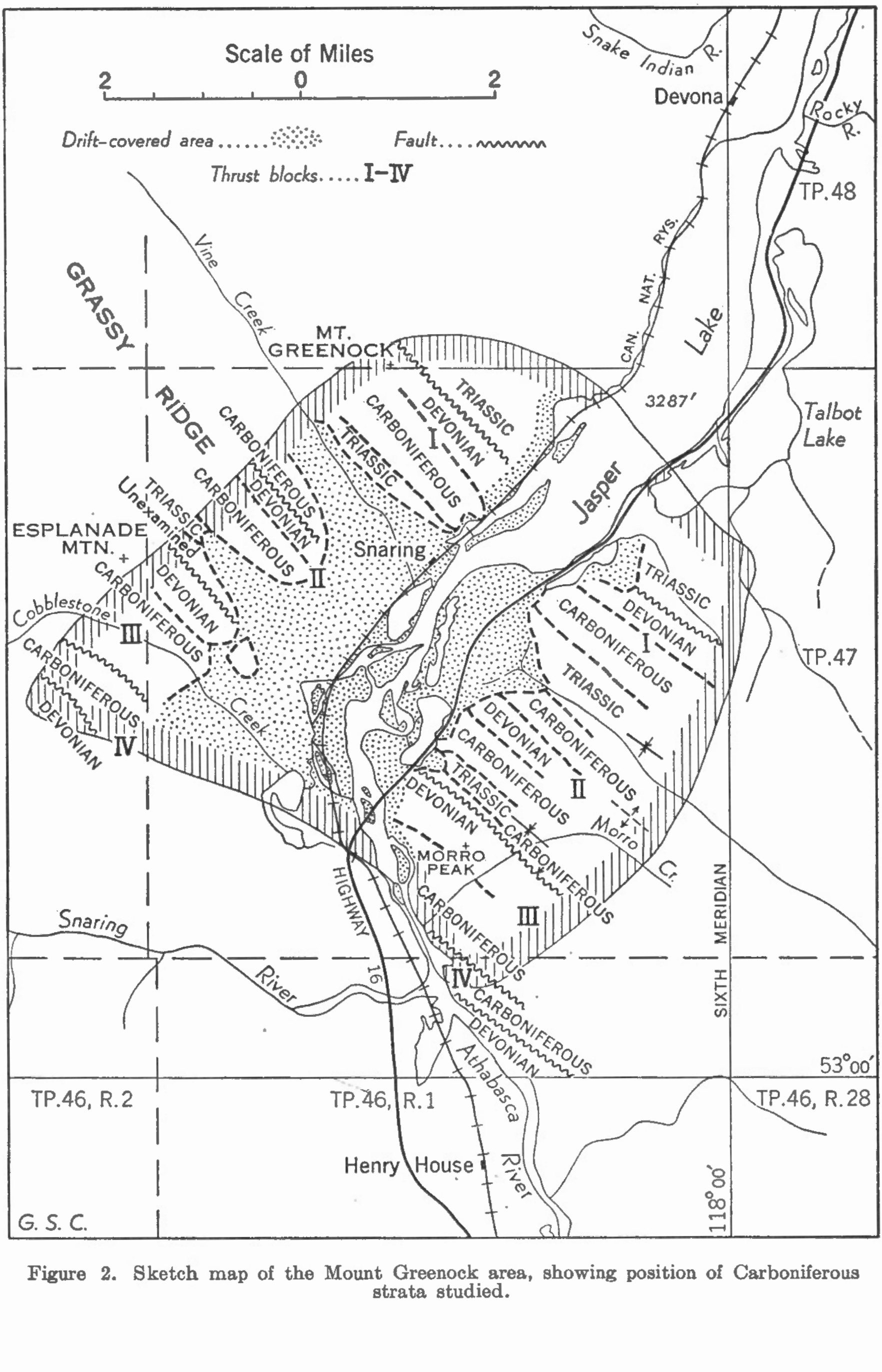


**Figure 2.** Sketch map of the Mount Greenock area, showing position of Carboniferous strata studied.

Friendly Creek, a small subsequent stream. Cold Sulphur Ridge and Morro Peak are joined by a saddle, with gullies on either side (*See* Plate II B).

The highest peak within the Mount Greenock area is that of Esplanade Mountain, the elevation of which is 7,521 feet. Beyond the boundaries, of the area, however, each of the ranges rises to above 8,000 feet.

Throughout its course in the mountains, Athabasca Valley has a cleaned-out appearance. In the Mount Greenock area in particular, each of the long limestone ridges extends down to the valley floor, which varies in width from 1 mile to 2 miles, and terraced fluvioglacial deposits are restricted to the entrances of the subsequent tributary valleys. However, some of these terraces, such as those at the mouths of Vine and Corral Creeks, are conspicuous.

The width of the valley floor and the resistant strata of the successively transected ranges combine to give Athabasca Valley some of the features of a base level in and around the Mount Greenock area. At the northeast boundary of the area, the river widens into Jasper Lake, which is 5 miles long and 1 mile wide, and through which a slow current is maintained. Along the southeast shore of the Lake, a long, narrow, wind-blown sand bar cuts off Talbot Lake, and a similar, but smaller, bar to the southwest cuts off Edna Lake. These are the Fish Lakes referred to by McEvoy (21, p. 11D). The remainder of the river's 4-mile stretch through the area follows a low-lying, rather heavily forested region with bordering lakes. The northwest side of the valley contains a broad meadow known as Moberly Flat, which merges with the broad alluvial fans of the subsequent valleys of Cobblestone and Corral Creeks.

## STRUCTURAL PATTERN

The mountains within the Mount Greenock area are the surface expression of three major thrust blocks, and one subsidiary thrust block, of Palæozoic strata.

These thrust blocks dip steeply and are represented by four mountains on each side of Athabasca River. The steep dip, and the constant character of the units of the thick stratigraphic succession, provide a close relationship between the stratigraphy and the topography. As a result, each mountain is more or less ridge-like and elongate in a northwest direction, with moderately steep sides, and long slopes running normal to Athabasca Valley. Also, each of the valley slopes is separated into long, parallel ridges and gullies, due to differential erosion of the various stratal units. Therefore, in the ensuing description of the mountains, whenever reference is made to a gully or a ridge on the long valley slopes of each of the mountains within the Mount Greenock area, that ridge or gully can be pictured as being formed of steeply or moderately west-dipping Palæozoic strata. For each prominent ridge and gully on a slope that extends toward Athabasca Valley on one side of the river, there is a corresponding ridge and gully on the corresponding slope of the opposite side. Many of these corresponding ridges are identical in shape and size, and in two instances the entire valley slopes of mountains of the same thrust block are almost identical.

The most northeasterly of the three major thrust blocks in the Mount Greenock area has been designated thrust block I. To the southwest of it lie thrust blocks II and III respectively, and a subsidiary thrust block at the southwest margin of the area will be referred to as thrust block IV. Similarly, the measured sections in thrust block I are designated IA, IB, IC, etc.; those in thrust block II, IIA, etc.; those in thrust block, III, IIIA, etc.; and those in thrust block IV, IVA, etc.

## THE MOUNTAINS OF THRUST BLOCK I

Thrust block I is represented on the northwest side of Athabasca River by Mount Greenock, of the DeSmet Range, and on the southeast side by Cinquefoil Mountain, of the Jacques Range. The two main ridges of these ranges are long, lofty, and narrow, and would form a single continuous ridge were they not cut transversely by the Athabasca.

The crests of both the DeSmet Range, and of the main row of mountains in the Jacques Range (*See* Plate II A), are composed alternately of the upper member of the Banff formation and the uppermost beds of the underlying Devonian. The Rundle and Greenock formations make dip slopes on the southwest flanks of the ranges, and the Devonian formations form the cliff faces on the northeast flanks.

Mount Greenock lies at the southeast end of the DeSmet Range, and is separated from the rest of the range by a narrow, shallow saddle. The main mass of the mountain consists of a long, rocky, southeast slope terminating at Athabasca River, 2½ miles from the summit (*See* Plate I). The flanks of the mountain are moderately steep. The east flank is almost entirely a uniform cliff face formed by the basal stratal units of the thrust block, and merging to the northeast with the long, dissected southwest valley slope of Snake Indian River. The southwest flank is less uniform, and consists of alternating, almost vertical dip slopes and massive shoulders, formed by successive resistant stratal units of the thrust block.

The Upper member of the Banff formation forms a prominent ridge on Mount Greenock; its thin-bedded limestones occupy the narrow summit, and are continuously exposed down the slope towards the base of the mountain where this member forms the prominent Windy Ridge, terminating in Windy Point at Athabasca River. Two early Lower Carboniferous faunal assemblages were obtained on Windy Ridge from this member, one with *Spirifer greenockensis* n.sp. in the lower beds, and the other with *Spirifer albertensis* Warren in the upper beds.

The Rundle formation is slightly less prominent than the upper Banff. Its upturned lower beds form a bare shoulder immediately southwest of the summit of the mountain, and below this, the upper beds occupy a heavily wooded hollow. Southeastward, the Rundle becomes a part of the broadening crest of the southeast slope; the lower beds yielded a Lower Carboniferous fauna with *Composita athabaskensis esplanadensis* n.var.

The resistant beds of the Greenock formation form a succession of wooded shoulders low on the southwest flank of Mount Greenock. Traced southeastward, these beds are seen to form the southwest margin of the crest of the southeast slope of the mountain. At the end of the slope these beds form Snaring Ridge, which is almost as prominent as Windy Ridge.

Between these two ridges the Rundle formation is exposed in a broad hollow. The uppermost beds of the Greenock formation form the bare northwest flank of Snaring Ridge, which passes abruptly into the broad, low, grassy and wooded valley slopes of Vine Creek. The lower beds of the Greenock formation on Snaring Ridge yielded a late Lower Carboniferous fauna with *Spirifer* n.sp. A.

The northeast half of the southeast slope of Mount Greenock is underlain by the Devonian strata of the thrust block. The contact with the superjacent Carboniferous is marked by a gully (Spirifer Gully), which is carved out of the lower member of the Banff formation, and which runs the entire length of the slope from the base to the summit (*See* Plate I).

Parallel with Spirifer Gully on its northeast side, the upturned, heavy-bedded Devonian limestones form a broad, rocky ridge (Spirifer Ridge). Unlike Windy Ridge and Snaring Ridge this ridge does not reach the river but its width and bare and rocky nature, together with the dominantly light colour of its rocks, give it a prominence almost equal to that of the others. Tracing these beds towards the top of the mountain, they are found to occupy the main part of the cliff face on the northeast flank of Mount Greenock. The contact with the soft, basal, Carboniferous beds is well exposed just below the summit of the mountain.

Cinquefoil Mountain (*See* Plate III A) lies directly across Athabasca River from Mount Greenock, and forms the northwest end of Jacques Range. It is almost the exact counterpart of Mount Greenock. Each of the main stratigraphic units of the thrust block produces corresponding topographic features on each mountain. Thus the summit of Cinquefoil Mountain comprises the Upper member of the Banff formation. The main mass of the mountain, as with Mount Greenock, consists of a long, valleyward slope exposing the entire succession of west-dipping strata. Furthermore, the Greenock, upper Banff, and Devonian formations form ridges corresponding in relative position with similar ridges on Mount Greenock. The Lower member of the Banff formation is, on this slope, also ill resistant to erosion, and forms Edna Gully, which corresponds in position to Spirifer Gully.

## THE MOUNTAINS OF THRUST BLOCK II

Thrust Block II is bounded on the northeast side by the Vine-Jacques trough, and on the southwest side by the Corral-Friendly Creeks trough. It is represented on the northwest side of Athabasca River by Grassy Ridge, and on the southeast side by a row of mountains that form the northeast margin of the complex Colin Range. Of this row of mountains, the part that lies within the Mount Greenock area contains only Friendly Peak.

Grassy Ridge parallels DeSmet Range, and is separated from it by Vine Creek. Like the range, its mass consists of a single block of steeply west-dipping Devonian and Carboniferous strata. Grassy Ridge is not as prominent as the DeSmet Range, as it is more dissected by small gullies, is partly bounded on the west by higher mountains, and has a rounded crest, in contrast with the sharp ridge of DeSmet Range. These features are a reflection of the geological structure of the ridge; less strata are involved in the stratigraphic succession than on Mount Greenock, and the result is a narrower topographic feature.

Grassy Ridge comprises three main spurs, of which the southernmost spur is the largest. This spur is a blunt, rocky, partly wooded slope, and its crest is composed of the basal member of the Greenock formation. Superficial deposits form the low, west slope of the spur and the rather steeply west-dipping Rundle formation forms the east part. From the Lower member of the Greenock formation on the south spur, a fragmentary faunule with *Spirifer* cf. n.sp. A was obtained.

The middle spur is known as Spring Hill, as Spring Creek emerges from its south end. It contains the Upper member of the Banff formation; farther northwest these beds occur higher in the northeast face of Grassy Ridge.

A small faunule including *Spirifer* cf. *cascadensis* Warren was collected from beds that are low in the Upper member of the Banff formation on Spring Hill. A little higher stratigraphically, a faunal assemblage with *Spirifer* cf. *cascadensis* and *Spirifer greenockensis* n.sp. was collected, and in still higher beds, near the south end of Spring Hill, the faunal associates of *Spirifer albertensis* Warren were collected.

On the southeast side of Athabasca River, immediately opposite Grassy Ridge, the thrust block is continued in the mountains forming the northeast margin of the Colin Range. Friendly Peak is a round-topped, low mountain forming the northwest extremity of this range (*See* Plate II B). The northern slope of Friendly Peak consists of a succession of steep cliff faces, which pass into the wooded slopes of Jacques Valley. The southwest slope is moderately steep, partly wooded, and bounded by Friendly Creek, which rises in a deep saddle between Friendly Peak and Cold Sulphur Ridge. The southeast slope is relatively slight and joins a saddle that, together with the headwaters of Morro Creek, separates Friendly Peak from the southeastward trending line of peaks that form the northeast margin of Colin Range.

The prominent northwest slope of Friendly Peak comprises three principal spurs sloping towards Athabasca Valley. The most westerly spur consists mainly of the basal member of the Greenock formation, from which the mid-Lower Carboniferous species *Tetracamera subcuneata* Hall was obtained.

The wooded slopes northeast of the west spur are composed of Rundle limestone, and from beds near the base of this formation an early Lower Carboniferous faunule with *Composita athabaskensis esplanadensis* n.var. was obtained.

The middle spur is slightly more prominent than its counterpart on Grassy Ridge, but is similar in its relative position and in consisting of the fossiliferous Upper member of the Banff formation.

Friendly Peak is readily accessible, and Highway 16 makes a rock cut across the end of the most westerly spur.

## THE MOUNTAINS OF THRUST BLOCK III

Thrust block III involves the thickest Palæozoic section of the Mount Greenock area. On the northwest side of Athabasca River it includes all of Esplanade Mountain; on the southeast side it includes Cold Sulphur Ridge, Morro Peak, and the broad shoulder that flanks Morro Peak on its southwest side. The thrust block is bounded on the northeast by the

Corral-Friendly Creeks trough, but its southwest margin is less well defined. Its contact with thrust block IV is not well defined, and is only marked on the west slope of Mount Hawk by a hollow between adjacent rock ridges.

The mountains of this thrust block do not exhibit the symmetry displayed by the first two. Thus, Morro Peak is entirely composed of Devonian linestones, whereas, on Esplanade Mountain, Devonian strata form the northeast slopes. The overlying Banff formation forms the summit of Esplanade Mountain but only the low west shoulder of Morro Peak.

Esplanade Mountain represents the greater part of the third thrust block northwest of Athabasca River. Its outline is broadly crescentic, and is shaped largely by the gorges of Cobblestone and Corral Creeks. The main part of the mountain is a long, stout, southeast arm consisting of three prominent parallel rocky spurs that end in the broad alluvial fans of Corral and Cobblestone Creeks, adjoining Moberly Flat. These spurs are here referred to as the west, middle, and east spurs.

The lofty peak of Gargoyle Mountain lies directly north of the summit of Esplanade Mountain, and the northeast end of the latter parallels Grassy Ridge from which it is separated by the lower, subsequent part of Corral Creek.

On the low slopes of the west spur of Esplanade Mountain, the westward dip of the strata is much shallower than on the corresponding spurs of Mount Greenock and Cinquefoil Mountain in thrust block I. This gives the crest of the spur a westward swing and creates a series of wooded scarps of upper Banff and basal Rundle beds on its east margin. The east spur is slightly more prominent than the corresponding spurs on Mount Greenock and Cinquefoil Mountain, due to the apparent thickening of the Devonian strata in thrust block III. From the west spur, a small fauna was collected, which included *Spirifer* cf. *cascadensis* Warren, *Spirifer albertensis* Warren, and *Composita athabaskensis* var. *esplanadensis* n.var.

Thrust block III is continued on the southeast side of the river as Morro Peak and Cold Sulphur Ridge, separated from Mount Hawk by the deep gorge of Morro Creek. The prominent southerly shoulder of Morro Peak is composed of the Banff formation, but the main mass of the peak together with Cold Sulphur Ridge consists of Devonian formations. At Athabasca Point, the basal Rundle beds occur at the water's edge, but farther south, approaching Morro Creek, the whole of the Banff and most of the Rundle formations are exposed. From the Upper member of the Banff formation on Athabasca Point, a prolific Lower Carboniferous faunule, including *Spirifer albertensis* Warren, was collected.

The northeast end of Morro Creek is shaped by the steeply dipping Upper Devonian limestones. The overlying strata lower down the creek yielded three Lower Carboniferous faunules: the lowest one, with *Spirifer* cf. *cascadensis*, was collected from the Upper member of the Banff formation; a faunule with *Spirifer albertensis* was obtained high in the Upper member of the Banff formation; and still higher beds in the lower part of the Rundle formation yielded a faunule with *Composita athabaskensis esplanadensis* n.var.

## THE MOUNTAINS OF THRUST BLOCK IV

On the east side of Athabasca River, to the southeast of Morro Creek, the top beds of thrust block III are succeeded by steeply dipping beds of the Banff, Rundle, and Greenock formations. A similar repetition of Carboniferous beds occurs along the same strike, on the northwest side of Athabasca River. This fourth thrust block does not involve such a great thickness of strata as the main thrust blocks and may be regarded as subsidiary to thrust block III.

From the Greenock formation of thrust block IV, on the low northwest slopes of Mount Hawk, *Brachythyris* n.sp. and fenestellid bryozoan fragments were obtained, whereas from beds believed to be high in the Greenock formation on the other side of the river, *Perditocardinia dubia* (Hall), together with poorly preserved blastoids and corals, were found.

# CHAPTER III

# DESCRIPTION OF CARBONIFEROUS FORMATIONS[1]

## BANFF FORMATION

*Author.* R. G. McConnell, 1887; emend. Kindle, 1924; Shimer, 1926.

*Type Locality.* Banff area, Alberta.

*Description.* Calcareous, dark grey shale, weathering light grey to dark grey, and thin-bedded, fossiliferous, dark grey limestone, varying from argillaceous and microcrystalline to crinoidal and coarsely crystalline. A twofold division of the Banff has been recognized by Allan, Rutherford, and Warren (1) in Jasper Park.

*Lower Member.* The Lower member consists largely of moderately hard, black or dark grey shales, weathering to soft, flat, grey pieces, alternating with rare limestone bands. In the places where the actual contact with the underlying Devonian was studied, a thin band consisting of about half an inch of yellow, fine-grained sandstone was seen. A 60-foot layer of hard, thin-bedded, alternating fine-grained argillaceous limestone and calcareous shale, 30 feet above the base, appears to be characteristic of the member on the north side of Athabasca River. No fossils were found in the Lower member. The moderately soft, dark shale of the lower 30 feet suggests the Exshaw shale of the Banff area, but as the typical fauna of the Exshaw shale was not found in the area covered by this report, the name is not used.

*Upper Member.* The basal beds of this member are relatively unfossiliferous, fine-grained, argillaceous limestone, with bedding ill-marked to platy, depending on the argillaceous content. The upper part consists of alternating crystalline limestone and argillaceous limestone, with lesser amounts of calcareous shale, in thin bands and lenses. These beds are very fossiliferous. In sections IA and IIIA, the uppermost beds include hard, finely banded siltstones that serve as marker beds.

*Local Topographic Expression.* The Lower member of the Banff, lying between the two most persistent ridge-forming units, gives rise to the long narrow gullies previously described, of which Spirifer Gully is the best example, and to narrow saddles near the tops of peaks, as on Mount Greenock and Esplanade Mountain. The Upper member forms three of the highest peaks in the area (Cinquefoil Mountain, Mount Greenock, and Esplanade Mountain) and occurs characteristically in long, sharply crested or rounded ridges.

*Field Relations.* The contact of the Banff with the overlying Rundle formation is transitional. It was determined in sections IB, IIIA, and IIID, and, doubtfully, in section IIA. Relying on the definitions of these formations in the type area, the contact is placed below the basal unit of massive or uniformly heavy-bedded limestone that occurs in the area. The thin bands of silty limestone recorded just below the contact in sections IB and IIIA, may also have stratigraphic significance.

[1] It should be emphasized here that the ensuing general descriptions of the formations are the results of the completed study, including both field and laboratory work, and that the field descriptions in Chapter IV are based only on field observations, and although containing the necessary detail do not differentiate between dolomite and limestone.

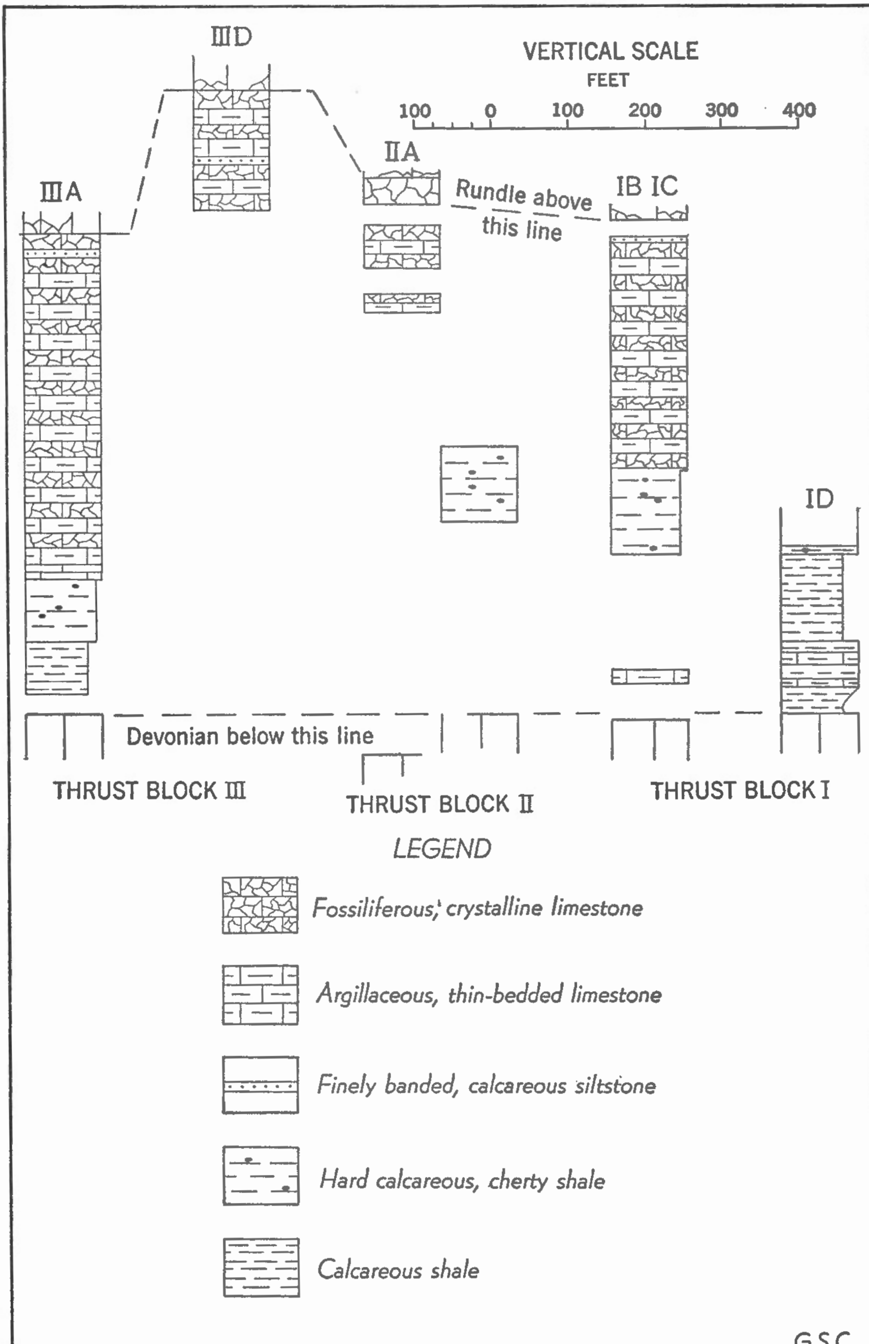


Figure 3. Generalized stratigraphic sections of the Banff formation.

*Summary of Stratigraphic Sections.* Figure 3 provides a general summary of the various sections of the Banff formation. These sections do not indicate the complete variation of the Banff formation and its members within the Mount Greenock area, but it is known that between section ID on Mount Greenock and section IIIA, Morro Creek, the total thickness is approximately the same.

Section ID shows that the lower member of the Banff is 207 feet thick at the top of Mount Greenock. Section IIIA, although it belongs, structurally, westward of section ID, actually is almost 5 miles south and $\frac{1}{4}$ mile east of it. The Lower member of the Banff formation thins from 207 feet in the former section to 96 feet in the latter. This member was not measured on Cinquefoil Mountain or Friendly Peak, but was observed briefly at these localities and found to be very thin. Plate III A shows that soft shaly beds are comparatively thin immediately above the Devonian limestone, passing quickly into moderately bedded fossiliferous limestones. On Friendly Peak also, the lower member is noticeably thinner. In contrast, on the northwest side of Athabasca River the section thickens from 207 feet on the top of Mount Greenock to an estimated 250 to 300 feet on the top of the more westerly Esplanade Mountain. The covered thickness in section IIA is, judging from the thickness of cherty shales of the basal Upper member, not much more than the true thickness of the Lower member. The Lower member thus appears to thicken decidedly to the west and apparently some to the north, within the area.

The Upper member thickens from 407 feet in section IB to 524 feet in section IIIA to the south. A comparative thickness for the northwest side of Athabasca River in fault block III was not available. The trend in the variation of the total thickness of the Banff formation is not discernible from the available data. However, present results indicate that there is no apparent variation from the Mount Greenock section southward to Morro Creek.

The information on the east-west trend, however, is not satisfactory. It is possible that the concealed parts of sections IIA and IIID contain minor thrusts that repeat the strata. If not, the Banff formation thickens westward within the Mount Greenock area, according to the measurements. Section IIA contains an unsatisfactory exposure of the Banff formation, and the contact with the overlying Rundle beds may be even higher than indicated in Figure 3. The beds above the indicated contact are transitional.

## RUNDLE FORMATION

*Author.* E. M. Kindle, 1924.

*Type Locality.* Mount Rundle, Banff, Alberta.

*Description.* In the Mount Greenock area the basal beds of the Rundle formation are in general massive to moderately bedded and coarsely crystalline, and pass abruptly upward into a thin argillaceous zone.

Above this argillite, the formation consists predominantly of dense, dark grey, moderately dolomitic to poorly dolomitic limestone, weathering dark brown to light grey. It is mostly finely crystalline, occasionally coarsely crystalline. Chert is common, occurring finely disseminated and commonly concentrated in dark patches. A common associated type of lithology is a hard, dark grey, cherty, microcrystalline limestone, commonly in 1- to 2-foot beds, but also massive and containing characteristic, small, isolated patches of crystalline calcite throughout. The calcite in the matrix is commonly white. This limestone has frequently been called speckled limestone in field descriptions.

*Local Topographic Expression.* The Rundle formation, although resistant to erosion, does not make the highest ridges in the Mount Greenock area. Where the strata dip steeply, the Rundle forms a flattened area between the slightly more resistant upper Banff formation and the Greenock formation, as, for example, between Snaring Point and Windy Point, and between the southeast and southwest spurs of Grassy Ridge, or else it forms the flat tops of low, broad mountains such as Friendly Peak and Grassy Ridge. Where the dip is moderate and the Rundle is thick, the formation may comprise the greater part of a prominent, massive, vertical cliff, as on the west side of Cobblestone Creek. The bedded lower part of the formation tends to make even slopes, but the unbedded upper part, due to lens-like variation in chert content, tends to form undulating surfaces along the strike of the formation.

*Field Relations.* The Rundle formation overlies the Banff, and its contact with the succeeding Greenock formation is transitional, the contact being placed where massive, crystalline dolomite gives way upward to sharply bedded, pale weathering, predominantly aphanitic, grey, argillaceous and silty limestone, with rusty weathering chert bands and nodules.

*Summary of Stratigraphic Sections.* The Rundle formation is best exposed on the south flank of Mount Greenock, although the contact with the underlying Banff formation is best exposed in the sections examined in the Morro Creek (No. III) thrust block.

The formation is about 782 feet thick in section IB (Mount Greenock), and 908 feet in section IIA (Grassy Ridge). This westward increase is more strongly indicated in thrust block III, as the thickness measured in the Morro Peak fault block is 1,154 feet in section IIIA (Morro Creek), and 1,135 feet in section IIID (Cobblestone Creek). The upper 800 feet of the Rundle formation, as defined in thrust block III, has no palæontological control. Thus the increase in thickness in the third of three so closely spaced thrust blocks would suggest the possibility of a repeat by a thrust fault within the formation in thrust block III. However, there is no definite change of dip and strike to support this idea, and a few facts combine to suggest that it is not true. First, the two measurements of the Rundle in the Morro Peak thrust block, made 3 miles apart, are closely comparable in thickness, and each section has a changing lithological succession. Secondly, the *Composita esplanadensis* faunule occurs in the same position as in thrust blocks I and II, and was not found higher. However, this can possibly be checked by a complete detailed section of thrust block IV as exposed to the south of Morro Creek.

In Figure 4, the sections of the Rundle formation are compared. The lithological characters can be seen to vary considerably laterally, but some features seem to persist, namely, the relatively coarsely crystalline, nonporous, and massive to heavy-bedded character of the basal 50 feet, and the presence of speckled and porous beds in the middle part.

Section IB shows that in thrust block I the Rundle formation contains massive, coarsely crystalline beds at the base, and moderately bedded, porous and speckled beds in the main part, with thick lenses of finely

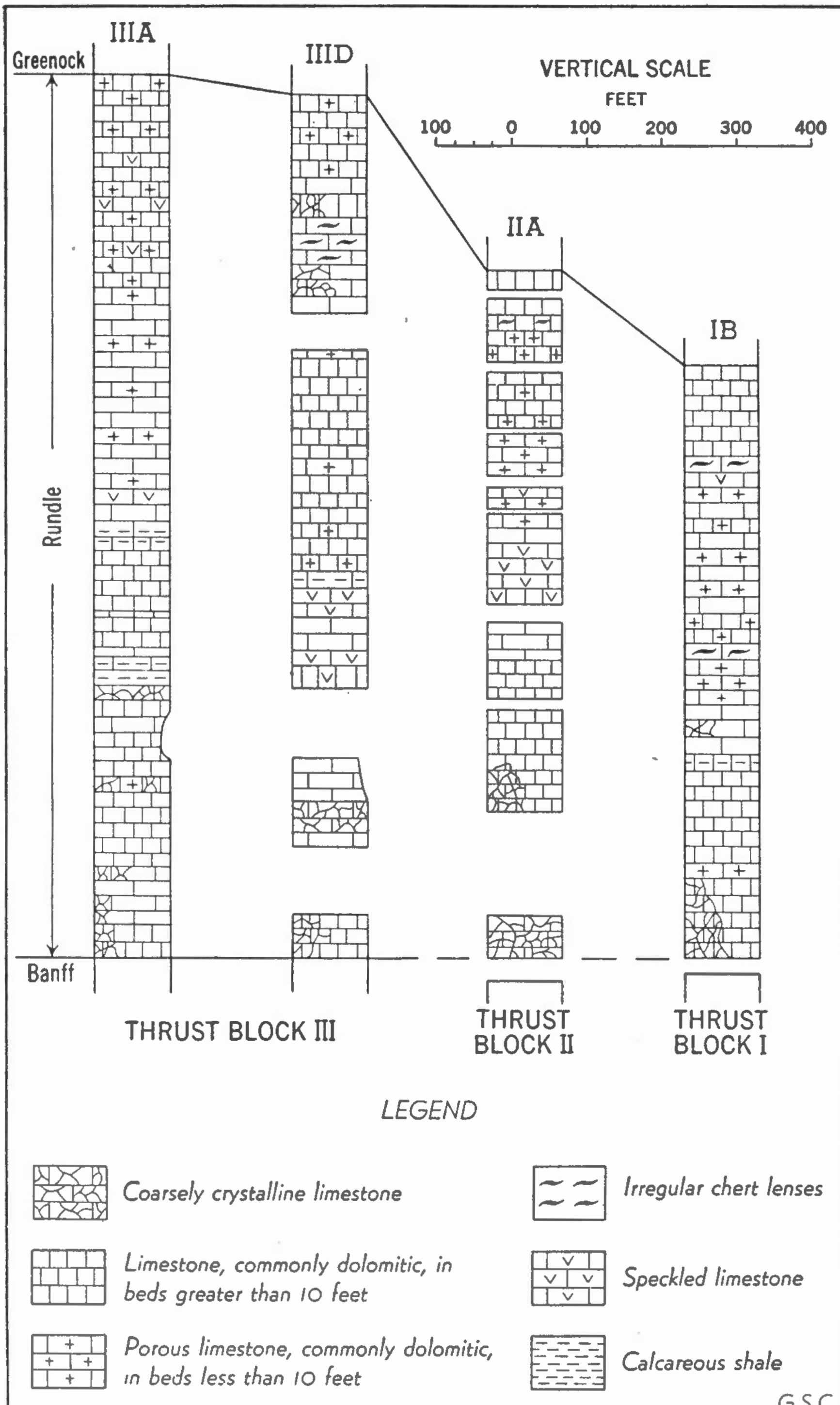


Figure 4. Generalized stratigraphic sections of the Rundle formation.

crystalline limestone appearing at the top. The *Composita esplanadensis* faunule is apparently confined beneath the shaly horizon marked in section IB.

In thrust block II, the contact with the underlying Banff limestone was not determined with certainty, due to the poor exposure of part of section IIA. According to the present interpretation of the contact, the basal 60 feet of Rundle beds in thrust block II are coarsely crystalline and moderately bedded. It is here presumed that this basal unit passes into massive limestone in the concealed section above. If this is so, then the non-porous, crystalline unit occurring at the base of section IB, is slightly thicker in section IIA. The middle, speckled and porous unit is slightly thinner than in section IB, and the top, finely crystalline, massive unit is slightly thicker, and slightly porous. The *Composita esplanadensis* faunule was not located in section IIA, probably due to poor exposure.

In thrust block III, the basal, coarsely crystalline unit becomes argillaceous between 200 and 300 feet above the base, and contains the *Composita esplanadensis* faunule. The middle and upper units are here not separable, and the bedding and porosity are variable. The strata are, however, predominantly dense, and massive beds are prominent.

The present sections, therefore, indicate that the Rundle formation thickens to the westward, above the beds that contain the *Composita esplanadensis* faunule, and that massive limestones become more prominent westward. Below the top of the *Composita esplanadensis* faunule, coarsely crystalline beds are common, and bedding appears to increase westward.

## GREENOCK FORMATION

*Type Locality.* Southwest spur of Mount Greenock, immediately north of Snaring Point (sections IA, IB). Mount Greenock area, Jasper Park, Alberta.

*Discussion.* Between the massive to moderately bedded, dark, in places speckled, dolomitic beds of the Rundle formation, and the finely banded Triassic siltstones, there exist in the Mount Greenock area light-coloured strata consisting mainly of bedded cherty dolomitic siltstone, massive chert, and quartzitic sandstone.

In the nearly complete sections that were studied, namely, sections IA, IB, and IIB, this sequence is divisible into a lower cherty dolomite member, a middle, massive chert member, and an upper, quartzitic sandstone member (*See* Figure 5). It is here proposed to name this sequence the Greenock formation, from the sections on the southeast end of Mount Greenock.

The Lower member of the Greenock formation is transitional into the underlying massive or speckled Rundle limestone, and the contact would be undoubtedly difficult to trace through several successive mountain ranges without a series of measured sections. This can be illustrated by a brief reference to the Carboniferous section on Folding Mountain, which lies east of the front range in Athabasca Valley. In this section the writer has noted only about 20 feet of cherty, bedded, light-coloured limestone lying above massive Rundle beds, and below finely banded siltstones referable to the Triassic, Spray River formation. Whether this represents strata referable to all of the Greenock formation as defined above, or only its basal beds, or even a local facies in the Rundle formation is not at present discernible. Further work will determine whether facies change or regressive overlap is the predominating condition in the upper part of the Carboniferous section in Athabasca Valley.

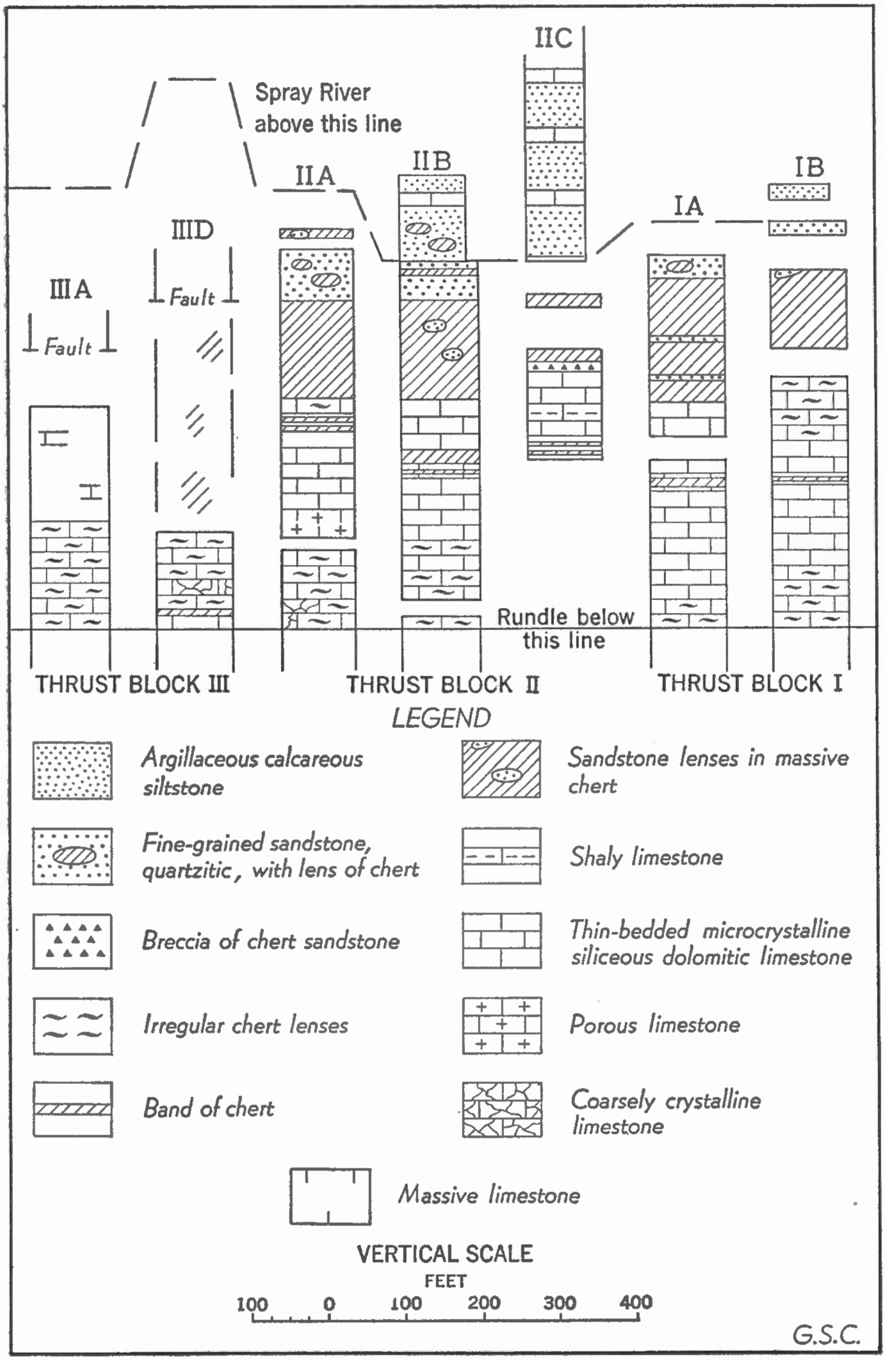


Figure 5. Generalized stratigraphic sections of the Greenock formation.

Notwithstanding its variable lithology the Greenock is here regarded as a single formation because of the interlensing of its lithological types. Lenses and thin bands of sandstone identical with that of the Upper member are present in the Middle member (*See* Figure 5, sections IA and IB). Also, though not shown in the figure, cherty limestones in the Lower member of sections IIA and IIC were apparently replaced a short distance along their strike by massive chert. The change in the thickness of the massive chert in passing from section IA to section IB on Mount Greenock, and from section IIB to section IIC on Friendly Peak, further testify to the irregular boundary between the two lower members.

The strata in the type section of the Greenock formation were measured by Raymond, and referred by him to the Rocky Mountain formation of the Bow Valley region. Raymond (24, p. 299) assigned a thickness of 580 feet to these beds compared with 525 in the present report. Allan, Warren, and Rutherford (1, pp. 240-241) also referred these strata to the Rocky Mountain formation. This was a logical procedure, as both formations occupy the same stratigraphic positions and are characterized by similar lithological types. However, two points illustrate the advisability of a new name for the Mount Greenock beds. First, as mentioned above, the reliable sections in the area show that the Greenock formation contains three distinctive members. Such a division has not been recognized in the type area of the Rocky Mountain formation. Secondly, the age of the Rocky Mountain formation, although still in doubt, is thought to be Pennsylvanian or Permian by those who have studied it, but the only fossils obtained from the Greenock formation indicate that at least its lower member is of Mississippian age. Because of these two facts, the name Greenock has been proposed for the beds in the Mount Greenock area hitherto referred to the Rocky Mountain formation.

*Lower Member*. The Lower member is variable, consisting predominantly of white weathering dark blue-grey, hard, lithographic siliceous dolomites, usually in well-marked beds 1 foot to 5 feet thick, in some places bearing conspicuous nodules and bands of rusty weathering dark grey chert, which are usually 1 inch or more thick. The nodules are for the most part irregular, and may anastomose. They are commonly pseudomorphs or internal moulds of brachiopods.

A less common type of lithology of the lower member is moderately crystalline, occasionally coarsely crystalline, crinoidal limestone, apparently well dolomitized.

*Middle Member*. The middle member is light grey, massive, finely recrystallized chert, weathering pink, white, and occasionally dark grey. Lenses of sandstone are common even in the lower part of this member, as in the type section, IA. The thickness of the middle member is 138 feet in the type section, and 125 feet in the Grassy Ridge section, IIA. Uncertainty as to structure prevents an estimate of the thickness in the Cobblestone Creek section, IIID.

*Upper Member*. The uppermost member of the Greenock formation contains light grey, fine-grained, poorly bedded, quartzitic sandstone, commonly containing lenses of pink weathering, light grey chert. This member attains a thickness of 65 feet in section IIA (Grassy Ridge), 47 feet in section IIB (Friendly Peak), and 42 feet in section IA on Mount Greenock.

*Field Relations.* The Greenock underlies the Triassic[1], Spray River formation; the contact is marked locally by an abrupt upward change from quartzitic sandstone to dark grey, finely banded, argillaceous, calcareous siltstone.

The contact between the Greenock and underlying Rundle formation is transitional, and no key bed appears to be available for reference. The position of the contact is defined as the point at which massive or speckled dolomitic limestones become subordinate upward to pale weathering, bedded, silty dolomite, with conspicuous, irregular chert nodules.

On slopes not exposed to maximum weathering, the chert masses do not stand out in such prominent relief, and in such places the contact is not as well defined.

*Local Topographic Expression.* The Greenock formation forms cliffs, its lowest member making up such prominences as Snaring Ridge (the long, low ridge extending northward from Snaring Point), part of Friendly Peak and its northwest spur, and the southwest spur of Grassy Ridge as well as the ridge itself. It is 526 feet thick on Mount Greenock, at least 510 feet thick on Grassy Ridge, and 468 feet on Friendly Peak. It thus appears to thin southward in the area. The contact with the overlying Triassic, Spray River formation is not exposed in No. III (Morro Creek) thrust block, and so the westward trend in thickness of the formation is uncertain.

*Summary of Stratigraphic Sections.* The Greenock formation was studied in detail in thrust blocks I and II. In blocks III and IV, several sections were studied, but in none of these is it certain that the succession is either complete or unfaulted.

Thrust blocks I and II exhibit a concentration of limestone at the base, chert in the middle, and sandstone at the top of the formation (*See* Figure 5). From the available data it is impossible to state whether or not this condition holds in No. III thrust block, and whether the thickness increases or decreases. Thus the members recorded in the detailed sections (Chapter IV) may be of very local significance. A comparison of the sections shows the variable thickness of each member, and the arrangement of the members in the sections suggests that the chert member is thicker to the northwest of Athabasca River than to the southeast.

The datum plane used for the sections is the contact with the underlying Rundle formation; that is, the horizon below which the beds are predominantly massive, crystalline, non-argillaceous, dolomitic limestone, with minor amounts of chert, usually finely disseminated.

In the first two thrust blocks, each section shows at one particular horizon a well-marked interbanding of chert and limestone, through thicknesses of from 10 to 20 feet. The stratigraphic proximity of these bands in the different sections, as shown in Figure 5, suggests that they may represent one marker band. For reasons already stated, it is impossible to be certain how the sections of thrust block III fit into those of the other two. However, the variation in thickness of massive chert and the variation in its distance above the base of the formation, make it appear that the deposition of the chert was lens-like in character. This is further suggested by the actual tracing, as already mentioned, of limestone beds laterally along the strike to lenses of massive chert.

[1] The possibility that the local Spray River beds contain Palæozoic strata is not overlooked, but is not evident from the present study.

# CHAPTER IV

## DETAILS OF MEASURED SECTIONS

### GENERAL STATEMENT

The following tabulations represent the detailed field descriptions of the strata studied in different parts of the Mount Greenock area. They are presented as a record, mainly of field observations, in which little attempt was made to distinguish between limestone and dolomite in the sections.

The measured stratigraphic sections form the framework to which all the stratigraphic information obtained in the area has been related. In nearly all cases important fossil localities occur in each of the formations included in these sections. Wherever possible the measurements were continued into the Triassic Spray River formation overlying the Carboniferous and into the Devonian limestones below, in order to fix the upper and lower limits of the Carboniferous system.

The sections were measured mainly on the long spurs that terminate the mountains, where most of the fossil localities lie, and where detailed locality maps could be made. The positions of some of the sections are shown on these maps and the position of those not actually shown is given in the text. The stratigraphic sections are numbered I, II, and III to denote the particular thrust block in which each occurs. Letters are affixed to these numbers to differentiate between the sections in each thrust block.

The stratigraphic information on thrust block I is obtained in sections IA to IC on the southeast end of Mount Greenock (*See* Figure 6). Section IA extends from beds near the top of the Greenock formation to beds in the upper part of the Rundle formation, on Snaring Ridge.

Section IB begins in the basal Triassic beds on Snaring Ridge, a short distance southeast of section IA. It passes through the Greenock and Rundle formations, and through part of the Banff formation. The basal bed of this section was traced to Section IC, so that the latter section and section IB overlap.

Section IC was begun in the uppermost-exposed beds of the Upper member of the Banff formation, south of the forestry road on Windy Point. It passes over Windy Ridge, to the southeast end of 'Spirifer' Ridge, where it extends stratigraphically downwards into the Devonian system.

Section IIA was made at the southeast end of Grassy Ridge, and its position is shown in Figure 7. It extends from beds high in the Upper member of the Greenock formation, downward to beds within the upper part of the underlying Devonian system.

Section IIB includes basal Triassic beds and the Greenock and upper Rundle formations, on top of Friendly Peak.

Section IIC was made at the end of the long northwest spur of Friendly Peak, at a road cut on highway 16, and involves most of the Greenock formation and the basal Triassic beds.

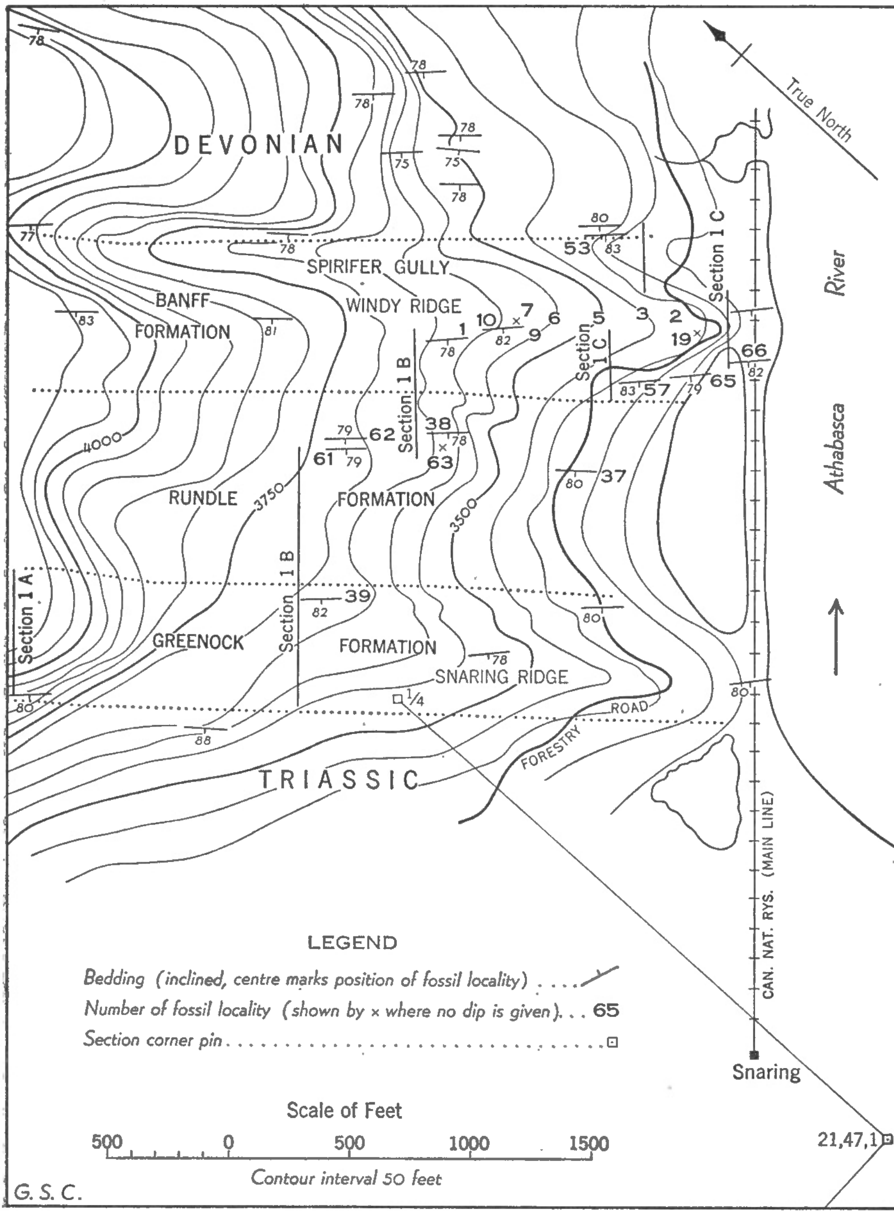


Figure 6. South end of Mount Greenock, showing geology, position of stratigraphic sections IA, IB, and IC, and fossil localities.

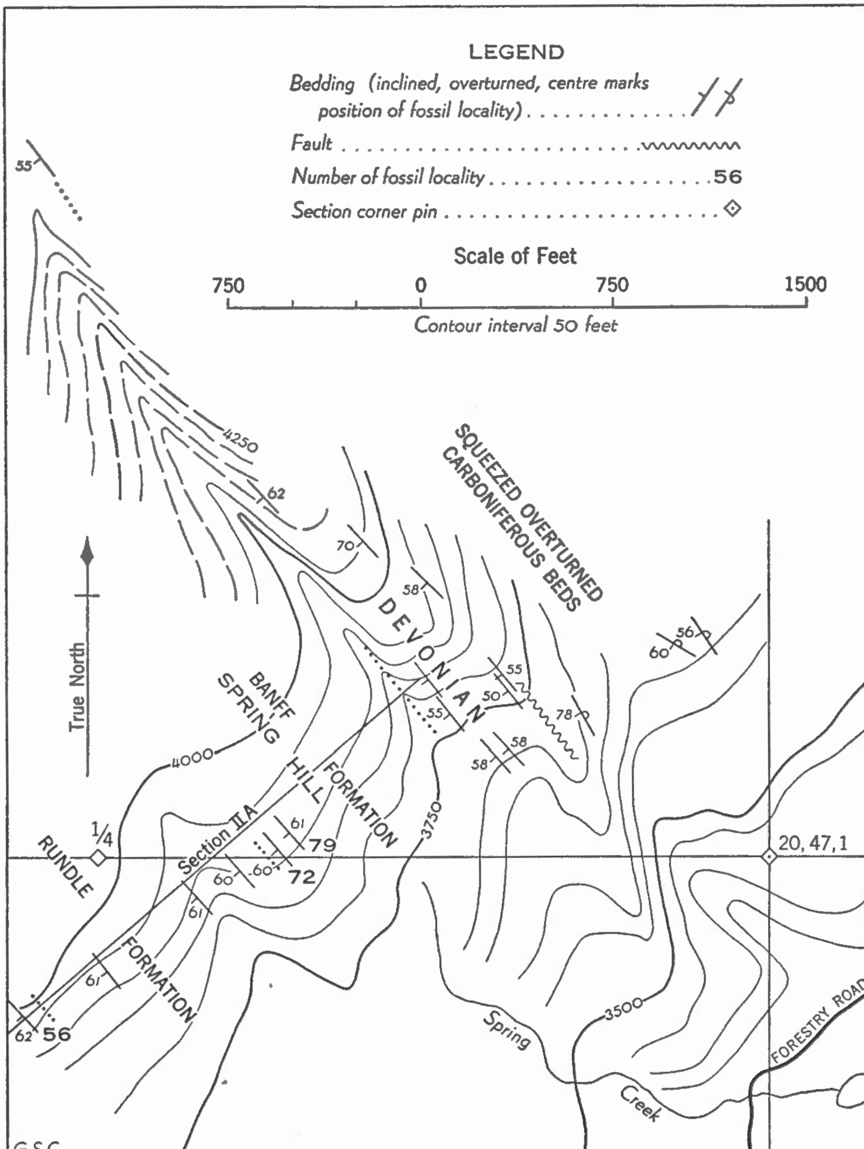


Figure 7. Southeast end of Grassy Ridge, showing geology, position of stratigraphic section IIA, and fossil localities.

Section IIIA (*See* Figure 5) was made on Morro Creek, on the west slopes of Morro Peak, and consists of the basal beds of the Greenock formation, all of the Rundle and Banff formations, and the topmost Devonian beds.

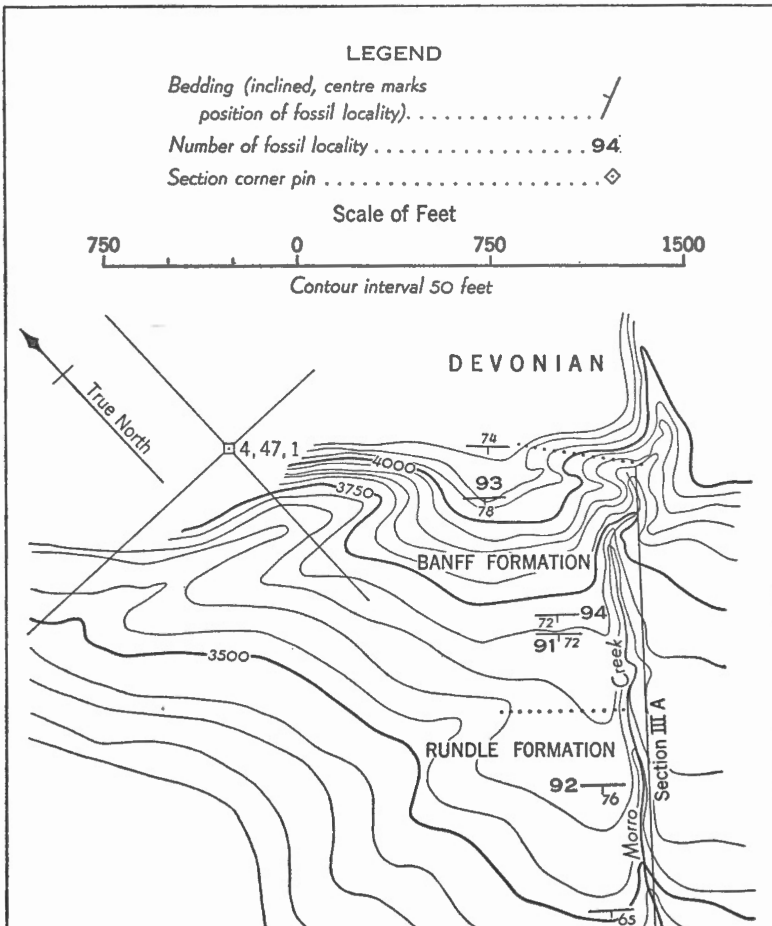


Figure 8. Morro Creek and vicinity, showing geology, position of stratigraphic section IIIA, and fossil localities.

Section IIID was measured on Cobblestone Creek. It includes most of the Greenock, all of the Rundle, and the upper part of the Banff formation (*See* Figure 9).

The guide used in describing the crystal size of limestones is as follows: coarsely crystalline—1 mm. or more in diameter; medium crystalline—0·1 to 1 mm.; finely crystalline—up to 0·1 mm; and microcrystalline—microscopic.

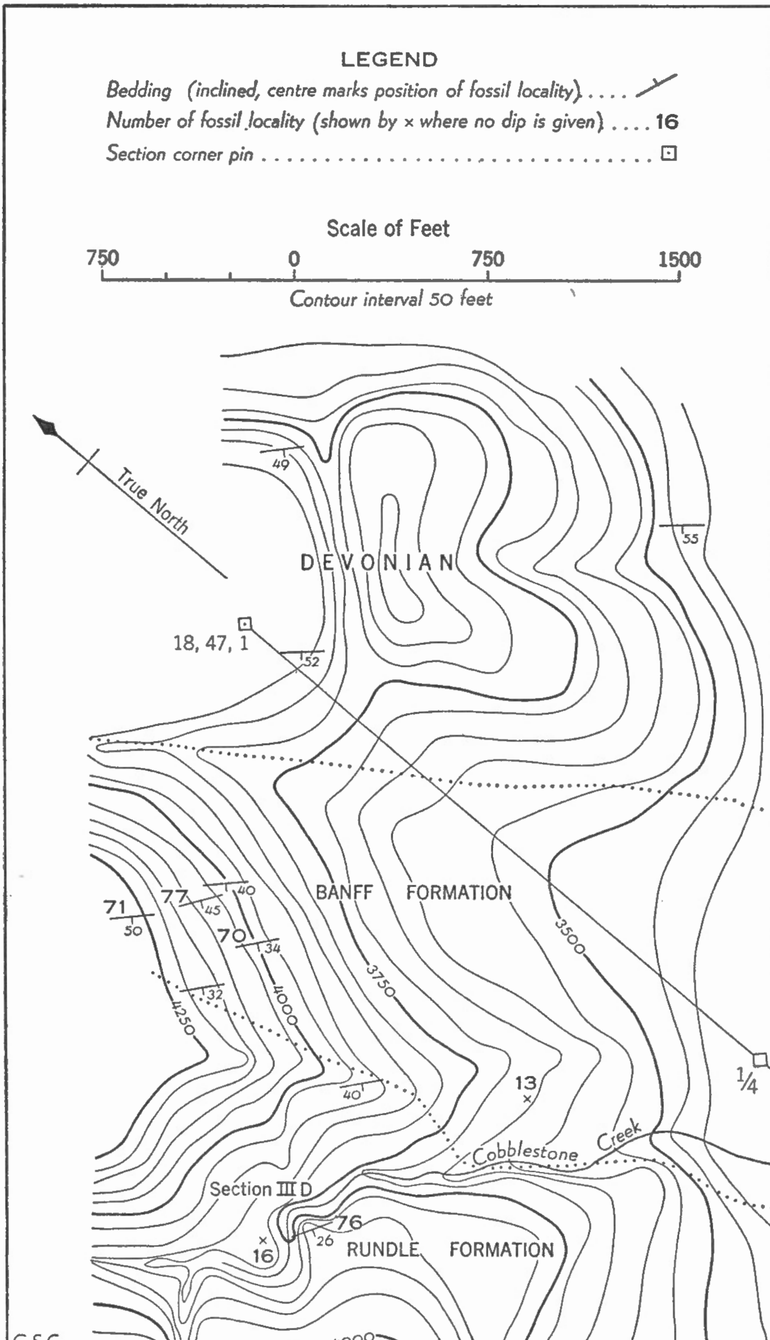


Figure 9. Southeast end of Esplanade Mountain, showing geology, position of stratigraphic section IIID, and fossil localities.

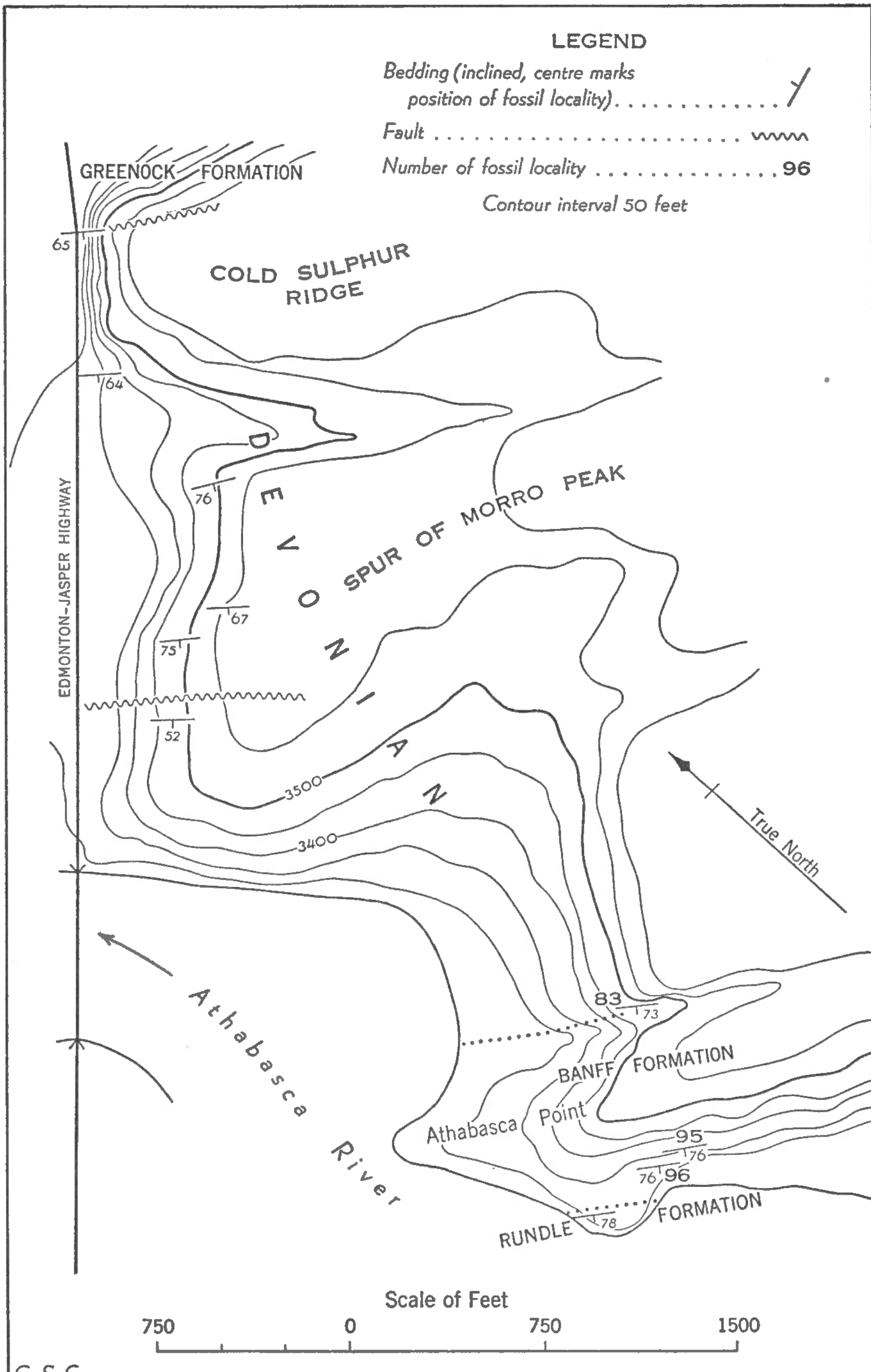


Figure 10. Morro Peak and vicinity, showing geology and fossil localities.

## SECTION IA, MOUNT GREENOCK

(*See* Figures 4, 5, 6)

### GREENOCK FORMATION

Top of section

| | Thickness Feet |
|---|---|
| ***Upper Member*** | |
| [1] *Sandstone, light grey, fine-grained, highly quartzitic, in rather poorly marked 0·1-foot beds weathering reddish brown to pale yellow. Lenses and streaks of chert permeate the sandstone irregularly. The grains appear well rounded | 42·0 |
| Total | 42·0 |
| ***Middle Member*** | |
| *Chert, grey, cryptocrystalline, massive, weathering light grey, stained rusty brown and spalling off in hard brittle pieces 0·1 foot in diameter | 58·0 |
| Sandstone, dark grey, fine-grained, massive, weathering grey to reddish brown | 9·0 |
| *Chert, very light grey, weathering white | 51·0 |
| Sandstone, dark grey, fine-grained, weathering grey to reddish brown. The grains are mostly quartz, but dark chert is also common | 10·5 |
| Chert | 4·0 |
| Covered | 5·5 |
| Total | 138·0 |
| ***Lower Member*** [2] | |
| *Limestone, argillaceous, light grey, microcrystalline, very hard, breaking into small, irregular, brittle fragments. Occasional 0·2-foot lenses of chert occur throughout | 39·5 |
| Covered | 35·0 |
| Limestone, silty, weathering dull grey in places | 24·0 |
| *Limestone, argillaceous, but with 0·1-foot bands of rusty weathering dark grey chert alternating with the limestone | 12·0 |
| *Limestone, grey, finely crystalline, finely porous, in 3-foot beds, weathering light grey to buff. Towards the base, the limestone becomes more coarsely crystalline | 57·0 |
| *Limestone, medium to coarsely crystalline, with more massive limestone | 20·5 |
| Limestone, crinoidal, finely porous | 5·0 |
| *Limestone, blue-grey, finely crystalline, hard, weathering light brown | 13·5 |
| *Limestone, microcrystalline, very hard, in 0·5- to 1-foot beds, weathering white | 32·5 |
| Limestone, as above but in heavier beds, basal 15 feet varying from hard to moderately hard | 35·0 |
| Limestone, as above but containing chert nodules, 0·05 to 0·5 foot in diameter | 31·5 |
| Total | 305·5 |

[1] Descriptive items designated by an asterisk relate to rocks identified petrographically from samples obtained in the field.

[2] Laboratory examination of specimens revealed up to 8 per cent insoluble matter in the light grey, white weather-limestone; also, that the coarsely crystalline limestone contains up to 30 per cent magnesium carbonate.

RUNDLE FORMATION[1]

| | Thickness Feet |
|---|---|
| *Limestone, dolomitic, blue-grey, finely crystalline, in 1-foot beds weathering pale brown. Scattered clusters 0·01 foot in diameter, of calcite crystals weather out on the smooth surface and give the limestone a speckled appearance | 137·0 |
| Limestone, grey, finely crystalline, crinoidal, weathering white | 2·0 |
| Limestone as above, but less crinoidal | 5·5 |
| Limestone, finely crystalline, speckled; rare chert | 29·5 |
| Limestone, crystalline, hard, in 4-foot or thicker beds, weathering light brown to light grey. Large lenses and bands of chert occur in top 10 feet | 69·5 |
| Covered | 10·0 |
| Limestone, weathered, light brown, coarsely crystalline, crinoidal, porous throughout, with cavities 0·1 to 0·3 foot in diameter; rare lenses of black chert | 8·5 |
| Limestone, dark grey, finely crystalline, massive, weathering light grey. | 8·5 |
| Limestone, weathered, light brown, finely crystalline, crinoidal, moderately hard, finely porous throughout and containing fragmentary corals | 17·0 |
| Total | 287·5 |

Base of section

## SECTION IB, MOUNT GREENOCK

(*See* Figures 3, 4, 5, 6)

SPRAY RIVER FORMATION

| Top of section | Thickness Feet |
|---|---|
| *Siltstone, calcareous, argillaceous, dark grey, occurring in 0·003- to 0·01-foot dark and light grey interbands, and having a paper-thin to 0·02-foot shaly parting, weathering pink to brown, on 0·01-foot laminæ, crossbedded in places | 25·0 |
| Covered | 25·0 |
| Total | 50·0 |

GREENOCK FORMATION

*Upper Member*

| | |
|---|---|
| *Sandstone, calcareous, dark grey, very fine grained, in well-marked beds approximately 0·1 to 0·2 foot thick, weathering pink, grey, and pale brown | 26·5 |
| Covered | 37·0 |
| Total | 63·5 |

*Middle Member*

| | |
|---|---|
| Chert, light grey, massive, weathering light grey to rusty brown, to pink, in rounded masses, making a long, rounded ridge. Interlenses of dark grey, fine-grained, reddish brown weathering sandstone, and chert at the top | 98·0 |
| Covered | 41·0 |
| Total | 139·0 |

[1] Acid tests suggest that much of the limestone in this formation is dolomitic.

| *Lower Member*[1] | Thickness Feet |
|---|---|
| Limestone, dolomitic, cherty, argillaceous, blue-grey, lithographic, hard, brittle, in beds 0·5 foot to 3 feet thick, weathering white. Chert occurs as small irregularly round nodules 0·2 foot in diameter, and more rarely as dark grey lenses 0·5 foot to 2 feet thick, weathering brown | 93·5 |
| Limestone as above, but chert weathers out prominently in rusty 0·05-foot bands, 0·05 to 0·5 foot apart. The silty feel and hardness of the limestone suggest that silt is present | 23·0 |
| Limestone, hard, dark grey, microcrystalline to very finely crystalline, in beds 0·5 foot to 2 feet thick, weathering pale brown | 108·5 |
| Covered | 17·0 |
| Limestone, grey, lithographic, hard, in beds approximately 1 foot thick, weathering white, containing many nodules of chert, 0·05 to 0·5 foot in diameter. The chert is grey and weathers rusty brown. Many of the chert nodules are replacements of brachiopods. *Fossil localities* 39 and 35 | 15·0 |
| Limestone, as above, but the chert nodules are unfossiliferous. Nodules are rare in the middle 30 feet of this unit, but especially common at the base | 66·5 |
| Total | 323·5 |

RUNDLE FORMATION[2]

| | |
|---|---|
| Covered | 26·0 |
| Limestone, grey, microcrystalline to finely crystalline, hard, massive to poorly bedded, with vertical fractures common, weathering light grey, with silty feel, exposures intermittent | 57·0 |
| Limestone as above, but weathering lighter grey and having irregular, reticulate, brown weathering chert nodules, which become more common toward the base | 22·0 |
| Covered | 6·0 |
| Siltstone?, calcareous, in 2- to 6-foot beds, weathering light grey, with rusty brown weathering chert nodules weathered out. The chert forms irregular bands and networks | 15·0 |
| Limestone, grey, finely crystalline; basal 10 feet weathering light brown, with white specks 0·01 foot in diameter covering the weathered surface. Some of these specks are found to be parts of crinoid columnals. Coral fragments occur in the basal 2 feet | 20·5 |
| Limestone, grey, medium crystalline, hard, heavy bedded, porous, and weathering dark to light grey in a massive cliff. The pores are 0·005 foot in diameter, and are sparse | 70·0 |
| Limestone, crystalline, crinoidal, massive to bedded, and pale brown. Pores are common and larger than in the overlying beds | 98·0 |
| Limestone, as above, but massive, except for sparse poor bedding in the basal 20 feet. Caverns are as much as 0·3 foot in greatest diameter; pores are usually concentrated in 0·5-foot bands, and are commonly 0·01 foot in diameter | 43·0 |
| Limestone, grey, lithographic, fracturing in small brittle pieces, usually less than 0·5 foot in diameter, weathering white. Dull dark patches in the limestone appear to be cherty | 16·0 |
| Limestone, crystalline, porous, moderately hard, ill-bedded, weathering light grey | 18·0 |
| Limestone, lithographic, hard, much fractured, with silty feel, in poorly marked 1-foot beds, weathering light grey | 15·0 |

[1] Laboratory examination revealed the presence of much insoluble matter in the light grey white weathering limestone.

[2] Acid tests suggest the occurrence of dolomitic limestone in much of this formation, particularly the upper part, but not to the extent of the dolomitic linestone in the Greenock formation.

| | Thickness Feet |
|---|---|
| Limestone, crystalline, hard, porous, in 1-foot beds, weathering light grey | 4·0 |
| Limestone, finely crystalline, glistening, hard, brittle, fractured, weathering very light grey | 4·0 |
| *Limestone, finely crystalline, pale brown, moderately hard, porous, in 1- to 2-foot beds, weathering light grey | 18·0 |
| Limestone, crystalline, soft, porous, bedded, weathered, poorly and intermittently exposed | 38·0 |
| *Limestone, blue-grey, lithographic, hard, porous, in 0·05- to 2-foot beds weathered light grey. White calcite crystals and particles 0·1 foot in diameter are scattered throughout; many of these appear to be fillings of pores by calcite. Close fractures normal to bedding are common | 25·5 |
| *Limestone, blue-grey to dark grey, finely crystalline, glistening, hard, silty feeling, cherty, fractured perpendicular to beds 0·1 foot to 2 feet thick, weathering light brown, with shaly partings; *fossil locality* 61 at base | 32·5 |
| Limestone, as above, but more uniformly bedded from 0·5 to 1 foot and with chert seemingly more finely disseminated. The basal 15 feet are only intermittently exposed | 27·0 |
| Limestone, grey, coarsely crystalline, crinoidal, moderately hard, in 0·5-foot beds, weathering light grey, with black chert particles 0·01 to 0·2 foot in diameter; *fossil locality* 62 at top | 3·5 |
| Siltstone, grey, calcareous, with 0·2-foot shaly parting, weathering brown | 2·5 |
| Siltstone, grey, calcareous, hard, massive, weathering light grey with rough exterior | 1·0 |
| Siltstone, grey, calcareous, with 0·2-foot shaly parting, weathering brown | 1·5 |
| Covered | 3·0 |
| Limestone, dark grey, glistening, finely crystalline, with silty feel, massive, with fractures 0·005 to 0·5 foot apart at right angles to the bedding. Horn and colonial coral fragments observed | 9·5 |
| Limestone, dark grey, massive, weathering light brown, in flat slabs 0·02 foot thick; *fossil locality* 63 at base | 17·0 |
| Limestone, dark grey, in ill-defined beds, weathering light grey; small chert particles 0·005 foot in diameter; horn corals and colonial corals observed | 21·5 |
| Limestone, as above, but more fractured, and weathering brown | 7·0 |
| Covered | 23·5 |
| Limestone, grey, crystalline, crinoidal, blocky, poorly bedded, weathering grey, horn corals observed | 4·0 |
| Covered | 12·0 |
| Limestone, coarsely crystalline, crinoidal, slightly porous, in 1-foot beds weathered to rounded blocks; *fossil locality* 38 | 6·5 |
| Limestone, well exposed throughout, similar to above, but more massive. Occasional masses, approximately 4 feet thick and 20 feet in horizontal diameter, of darker, finer grained, more cherty limestone occur in this unit, but these, too, are usually crinoidal. The beds are not noticeably porous | 114·5 |
| Total | 782·5 |

BANFF FORMATION

*Upper Member*

| | |
|---|---|
| Covered | 23·0 |
| Siltstone (?), calcareous, dark grey, fossiliferous with 0·02-foot shaly partings, and weathering pale brown | 2·0 |
| Covered | 23·0 |
| Limestone, dark grey, fine-grained, in 0·1- to 0·5-foot beds, weathering dull grey | 10·5 |

| *Upper Member*—Concluded | Thickness Feet |
|---|---|
| Limestone, very fossiliferous | 0·5 |
| Limestone, dark grey, hard, shaly, interlensing with soft, crystalline limestone | 1·0 |
| Covered | 40·0 |
| Limestone, dark grey, medium to finely crystalline in 0·1- to 0·5-foot beds, mostly with rare 0·02-foot bedding planes weathered out; *fossil locality* 1 at top | 16·0 |
| Limestone, crinoidal, weathering light grey | 1·5 |
| Covered | 7·5 |
| Limestone, moderately hard, fossiliferous, in poorly marked 0·05-foot beds, weathering light grey | 1·5 |
| Covered | 14·5 |
| Limestone, grey, coarsely crystalline, crinoidal | 22·0 |
| Covered | 32·0 |
| Limestone, grey, coarsely crystalline, fossiliferous in one bed with a tendency to finer banding | 2·0 |
| Covered | 15·0 |
| Limestone, medium to finely crystalline, fossiliferous, in 0·2- to 0·5-foot beds, alternating in 0·5-foot interbeds with 0·05-foot beds of shaly limestone; *fossil locality* 10 at base | 42·0 |
| Limestone, similar to above; brown weathering, flat, cherty masses occur throughout; *fossil localities* 6 and 7 at top | 14·5 |
| Total | 268·5 |

Base of section

## SECTION IC, MOUNT GREENOCK

(*See* Figures 3, 6)

### BANFF FORMATION

Top of section

| *Upper Member* | Thickness Feet |
|---|---|
| Limestone, grey, finely crystalline, in 0·2-foot beds weathering dark grey, underlain by dark grey limestone with shaly 0·02- to 0·05-foot partings, weathering grey to buff; *fossil locality* 57 at base | 20·0 |
| Limestone, dark grey (almost black); lithographic in poorly marked 0·1- to 0·5-foot beds, weathering grey. Crinoid remains are sparse | 22·0 |
| *Limestone, dark grey, finely crystalline, silty in 0·02- to 0·01-foot undulating shaly bands, weathering buff | 3·0 |
| Covered | 9·0 |
| Limestone, fossiliferous, almost a coquina in some bands in 0·2- to 0·7-foot beds, weathering buff to rusty brown, to grey, and in intermittent paper-thin laminæ; *fossil locailty* 64 at top | 18·5 |
| Limestone, finely crystalline, concretionary and shaly; *fossil locality* 65 at top | 0·5 |
| Shale, grey, in paper-thin laminæ | 7·0 |
| Limestone, dark grey, with a few coarse calcite crystals and tiny chert fragments | 1·0 |
| Limestone, dark grey, slightly fossiliferous, veined with secondary calcite, and weathering buff to light grey. An 0·3-foot bed of shale lies 0·5 foot from base | 2·0 |
| Covered | 2·5 |
| Limestone, grey, finely crystalline, fossiliferous, in 0·1- to 0·5-foot beds, alternating with grey, 0·02-foot bedded shale and fossiliferous crystalline limestone; *fossil locality* 66 at base | 34·5 |
| *Limestone, dark grey, argillaceous, silty, crystalline, fossiliferous, in 2- to 4-foot beds weathering pale grey to buff, alternating with finely crystalline, dark grey, impure, massive, splintery limestone | 36·5 |

| *Upper Member*—Concluded | Thickness Feet |
|---|---|
| Limestone, dark grey, crystalline, fossiliferous, in 2- to 4-foot beds weathering pale grey to buff; a 2-foot coarsely crystalline bed is at the base | 10·5 |
| Limestone, as above, in 2- to 3-foot bands, alternating with dark, splintery 0·02-foot, poorly bedded shale | 15·0 |
| Limestone, dark grey, impure, coarsely crystalline in top 2 feet, moderately crystalline in the remainder, in 2- to 4-foot beds, weathering pale grey to buff | 10·5 |
| Limestone, dark grey, impure, finely crystalline, weathering buff, alternating in 0·4- to 2-foot beds with crystalline, more fossiliferous limestone weathering light grey. Rare 0·2- to 0·5-foot beds of black silty shale have 0·02-foot light and dark grey bands. *Fossil locality* 6 bed at base | 40·0 |
| Limestone, as above, but dark chert nodules, weathering rusty brown, are scattered throughout and weather to irregular flat masses, commonly 0·5 foot in lateral diameter and 0·05 foot thick | 47·5 |
| *Shale, calcareous, dark blue-black, in 0·2-foot dark grey bands alternating with 0·05-foot buff (silty) bands. In weathered cliffs this unit shows as grey (0·1 to 0·5-foot) beds of buff weathering shale breaking into 0·05-foot laminæ. Chert nodules are present in the upper half, becoming rarer downwards. Irregular fractures are common. Rectangular pieces break from the fresh surface. | 67·0 |
| Shale as above, but more strongly fractured, more uniformly shaly | 38·0 |
| Total | 385·0 |

| *Lower Member* | |
|---|---|
| Covered | 141·0 |
| Limestone, dark grey, massive, weathering grey, alternating in 0·1- to 0·5-foot beds with dark grey, hard, strongly fissile shale weathering buff | 21·0 |
| Covered[1] | 56·5 |
| Total | 218·5 |

## SECTION ID, MOUNT GREENOCK

(*See* Figure 3)

### BANFF FORMATION

Top of section (base of Upper Member)

| *Lower Member* | Thickness Feet |
|---|---|
| Shale, dark grey, calcareous, cherty, brittle, rectangular-breaking, weathering blue-grey | 9·5 |
| Limestone, grey, hard, in 0·2- to 2-foot beds, weathering light grey | 9·0 |
| Shale, dark grey, calcareous, cherty, rectangular-breaking, weathering blue-grey | 10·0 |
| Limestone, brittle, splitting in 0·02- to 0·01-foot fissile laminæ, weathering buff, with silty appearance; makes cliff | 2·0 |
| Covered | 24·0 |
| Limestone as above | 1·5 |
| Shale, soft-weathering, dark grey, breaking in 0·5 x 0·5 x 0·005 foot flat pieces, alternating over 0·5 to 1 foot with dark blue-grey, fine-grained, hard, brittle limestone in 0·1-foot beds weathering pale buff | 21·0 |

[1] Fauna with *Cyrtospirifer* spp. collected 15 feet below the top of Devonian limestone.

| *Lower Member*—Concluded | Thickness Feet |
|---|---|
| Limestone, brittle, splitting in 0·02- to 0·01-foot fissile laminæ, weathering buff, with silty appearance; makes cliff | 3·0 |
| Shale, dark grey, breaking in 0·005-foot pieces in 0·5- to 1-foot beds weathering lighter grey, soft, alternating with dark blue-grey, fine-grained, hard, brittle limestone, in 0·1-foot bands, weathering pale buff | 26·5 |
| Limestone, blue-grey, very finely crystalline, hard, weathering grey, alternating in 0·4-foot bands and lenses with dark grey shale, weathering buff in semi-fissile pieces. This forms the prominence immediately east of the peak of Mount Greenock. This same unit forms the lowermost exposed beds of the Banff formation in section IC | 65·5 |
| *Shale, dark grey, calcareous in 0·05- to 0·01-foot beds, fissile, weathering grey, alternating with rare 0·2-foot dark grey siltstone bands, weathering light grey. The siltstone bands are both massive and finely interbanded | 29·5 |
| *Shale, dark grey, semi-fissile, weathering to small, soft, grey pieces | 2·5 |
| Covered | 3·0 |
| *Shale, as above, alternating with much weathered, fine-grained, fragmental (?) sandstone, weathering orange to brown | 0·5 |
| Total | 207·5 |

Unmeasured Devonian limestone at base

## SECTION IIA, GRASSY RIDGE

(*See* Figures 3, 4, 5, 7)

### GREENOCK FORMATION

Top of section (covered above)

| *Upper Member* | Thickness Feet |
|---|---|
| Chert, light grey, massive, fracturing in rectangular 0·1-foot pieces, weathering pink to pale grey, lensing in equal amounts in 1-foot beds, with light brown, fine-grained sandstone in 0·5- to 1-foot beds, weathering buff to light brown | 7·0 |
| Covered | 17·0 |
| Sandstone, quartzitic, grey, fine-grained, massive, weathering pink | 18·0 |
| *Sandstone as above, with many lenses of chert as described below | 18·5 |
| *Sandstone, quartzitic, grey, fine-grained, massive, weathering pink, containing lenses of chert 1 foot to 25 feet in diameter | 33·0 |
| Total | 93·5 |
| *Middle Member* | |
| Chert, as described above, but in a solid, massive cliff | 125·5 |
| Total | 125·5 |
| *Lower Member*[1] | |
| *Limestone, cherty, light grey, lithographic, hard, commonly 3-foot beds weathering white. Occasional 6-foot wide, 1-foot thick lenses of chert weathering a cream colour | 24·0 |
| Limestone, light grey, lithographic, seemingly varying laterally to light grey, finely fractured, massive chert | 3·0 |
| Covered | 5·5 |

[1] Laboratory examination revealed the presence of much insoluble matter in the light grey, white weathering limestone; also that the coarsely crystalline limestone is dolomitic.

| *Lower Member*—Concluded | Thickness Feet |
|---|---|
| *Chert, light grey, massive, weathering pink, interbanded every 0·1 to 0·3 foot with calcareous silstone weathering light grey | 9·0 |
| Limestone, grey, finely crystalline, glistening, massive, weathering light grey | 22·0 |
| *Limestone, light grey, coarsely crystalline, in poorly defined 2- to 6-foot beds weathering dark grey. Small black spots, presumably chert, are scattered throughout, and the calcite crystals occur in darker and lighter patches, 0·05 foot in diameter | 82·0 |
| Covered | 14·0 |
| Limestone, grey, glistening, finely crystalline, finely porous, weathering grey | 14·0 |
| *Limestone, light grey, lithographic, becoming finely crystalline and finely porous toward top, in 0·5- to 2-foot beds weathering grey to buff | 10·0 |
| Covered | 12·0 |
| *Limestone, light grey, lithographic to finely crystalline, in poor, 1- to 3-foot beds, and breaking in 0·1-foot square fragments, weathering light grey. Chert lenses 0·07 to 0·3 foot in diameter weathering grey to rusty brown are very common. In the top 15 feet the chert occurs largely in 0·02- to 0·2-foot bands and lenses, usually 0·1 foot apart. This character varies laterally, the bands being somewhat sparse in places; *fossil locality* 56 at base | 19·5 |
| Covered | 3·5 |
| Limestone, light grey, lithographic, in 1- to 3-foot beds, weathering light grey. Small 0·02- to 0·1-foot round, rusty weathering, dark grey chert nodules make up about one-tenth of volume and are scattered irregularly throughout | 4·5 |
| Limestone, grey, medium-crystalline, crinoidal, porous, blocky, in poorly marked 2-foot beds, weathering light grey | 7·0 |
| *Limestone, dark grey, microcrystalline, hard, massive, weathering light grey. Some lenses (0·3 to 0·5 foot) are darker (cherty?) and weather slightly rusty. Occasional coarser crystals of calcite are present both isolated and in small lenses | 19·0 |
| Limestone, as above, with at least one-third of the volume composed of rusty weathering grey chert in reticulating and anastomosing lenses | 2·0 |
| Limestone, as above, but no chert lenses | 2·0 |
| *Limestone, light grey, coarsely crystalline, in poor 2- to 6-foot beds, weathering dark grey. Black spots, approximately 2 mm. in diameter (chert?) are scattered throughout | 16·0 |
| Limestone, dark grey to blue-grey, finely crystalline, in 1- to 3-foot beds (the latter well marked), weathering light brown. The limestone is veined with 0·1-foot white bands of calcite on weathered surface. One 0·1-foot chert band is immediately above the base, another at the base | 10·0 |
| Covered | 3·0 |
| Limestone as above. Poorly preserved, silicified, horn coral fragments occur in the chert | 1·5 |
| Covered | 6·0 |
| Total | 289·5 |

RUNDLE FORMATION[1]

| | |
|---|---|
| Limestone, dark grey, very finely crystalline, massive, weathering dark grey. Occasional fine (0·01-foot) orange spots pattern the limestone. These probably represent limonitic stains of once present concretionary particles | 14·5 |
| Covered | 9·0 |

[1] Acid tests suggest that much of the limestone in this formation is dolomitic.

| | Thickness Feet |
|---|---|
| Limestone, dark grey, finely crystalline, crinoidal, hard, massive, weathering dark grey | 2·0 |
| Limestone, crinoidal, medium crystalline, massive | 2·0 |
| Limestone, dark grey, finely crystalline, hard with orange spots as above, massive, weathering light grey | 15·0 |
| Limestone, crinoidal, coarsely crystalline, massive and softer than rest of cliff, weathering light grey | 6·0 |
| Limestone, dark grey, finely crystalline, porous, containing flat reticulating chert nodules about 0·5 foot thick | 10·0 |
| Limestone, light grey, crinoidal, coarsely crystalline, weathered only moderately hard in places | 8·0 |
| Limestone, lithographic in top 2 feet, becoming finely crystalline toward basal 2 feet, thence moderately so to base, *Syringopora* sp. fragments | 8·5 |
| Limestone, grey, medium crystalline, finely porous, massive, weathering light grey | 19·5 |
| Limestone, medium crystalline, varying occasionally to finely or coarsely crystalline | 17·0 |
| Limestone, dark grey, mostly finely crystalline (top 2 feet almost lithographic), in poorly marked 1-foot beds weathering light grey | 10·5 |
| Covered | 10·0 |
| Limestone, grey, finely crystalline, finely porous, hard, in 2-foot beds weathering light brown | 29·0 |
| Limestone as above, but in one massive bed | 18·5 |
| Covered | 3·5 |
| Limestone, dark grey, finely crystalline, hard, in 0·5- to 2-foot, fairly well marked beds weathering grey | 15·5 |
| Covered | 5·0 |
| Limestone, as above | 4·0 |
| Limestone, dark grey, very finely crystalline, finely porous to non-porous, hard, in 2- to 8-foot moderately marked beds, weathering light grey | 38·5 |
| Limestone, as above, bedding intermittently marked, but sharp | 20·5 |
| Covered | 20·5 |
| *Limestone, dark grey, finely crystalline to lithographic, speckled. This speckled appearance is due to the presence of scattered clusters, 0·01 foot in diameter, of calcite crystals | 23·5 |
| Covered | 5·5 |
| Limestone, as above, speckled throughout, porous at top, in 2- to 8-foot beds, sharply marked toward base | 29·0 |
| Limestone, grey, glistening, fine-grained, in 1- to 2-foot beds, weathering light grey | 5·5 |
| Limestone, as above, varying laterally to speckled limestone | 10·0 |
| Limestone, dark grey, lithographic, speckled, in beds 1 foot to 5 feet thick | 72·0 |
| Limestone, grey, glistening, fine-grained, unspeckled, in 1- to 2-foot beds weathering light grey | 5·0 |
| Covered | 20·0 |
| *Limestone, dark grey, finely crystalline, splintery, silty feeling, hard, in poorly marked thin beds; 0·2-foot fractures approximating bedding are common. The limestone weathers patchy brown to light grey, corresponding to more or less cherty lenses. Small (0·02-foot) dark chert fragments show on the weathered surface. Horn corals, poorly preserved, are common | 53·0 |
| Limestone, very dark grey, very hard, massive, with no sign of bedding excepting in basal 10 feet. It is veined with micro-fragments of chert | 38·0 |
| Covered | 10·0 |
| Limestone, as above | 1·0 |
| Covered | 13·0 |
| Limestone, very dark grey, finely crystalline, splintery, veined with secondary calcite, in fairly well marked 2- to 4-foot beds, weathering pale brown to grey | 12·0 |

| | Thickness Feet |
|---|---|
| *Limestone, oolitic, dark grey, finely crystalline, finely mottled, due to closely packed 0·005-foot cherty, fossiliferous oolites | 8·5 |
| Limestone, dark grey, finely crystalline, seemingly non-porous, weathering dark to light grey; chert lenses, approximately 3 feet by 1 foot, weather rusty brown to dark grey | 11·5 |
| Limestone, dark grey, finely crystalline, upper part massive, in 2-foot beds in basal 10 feet, weathering light grey | 21·0 |
| Limestone, grey, finely to coarsely crystalline, with bedding not distinctly marked, weathering light to dark grey. Chert occurs in angular pieces 0·005 foot in diameter | 80·0 |
| Covered | 143·0 |
| Limestone, grey, crinoidal, coarsely crystalline (some very coarse with columnals abundant), 0·5- to 3-foot beds weathering light grey | 60·0 |
| Total | 908·0 |

BANFF FORMATION

*Upper Member*

| | |
|---|---|
| Covered | 25·0 |
| Limestone, grey, crinoidal, weathering light grey, interbanded and interlensed every 0·2 to 1 foot with dark grey, finely crystalline limestone weathering blue-grey, and with finely crystalline, shaly limestone with 0·02-foot fractures approximating bedding. Chert, appearing in 0·05-foot, irregularly rounded, rusty brown weathering lenses, is common in the fossiliferous limestone, and some of the fossils seem silicified. In the 9 feet below the upper 17 feet of this unit, the limestone is uniformly coarsely crystalline in 0·7-foot beds; *fossil locality* 72 at 25 feet below top | 53·5 |
| Covered | 36·0 |
| Limestone, dark grey (argillaceous?), predominantly concretionary in 0·5- to 1-foot beds, and strongly fractured both normal to and parallel with bedding (mostly normal in 0·01-foot fractures), and commonly weathering light grey to buff; *fossil locality* 79 at top | 26·0 |
| Covered | 142·0 |
| Dark, hard, irregularly breaking, calcareous shale, *fossil locality* 55 at top | 176·0 |
| Total | 458·5 |

*Lower Member*

| | |
|---|---|
| Covered[1] (approximately) | 252·0 |
| Total | 252·0 |

## SECTION IIB, FRIENDLY PEAK

(*See* Figure 5)

SPRAY RIVER FORMATION

| Top of section | Thickness Feet |
|---|---|
| Siltstone to sandstone, calcareous, argillaceous, very fine-grained, alternately dark and light grey in 0·003- to 0·01-foot interbands, bedded in 0·005- to 0·05-foot undulating laminæ, weathering rusty brown, red, and light grey | 112·0 |
| Total | 112·0 |

[1] Fauna with *Cyrtospirifer whitneyi* (Hall) collected at exposed top of Devonian beds.

GREENOCK FORMATION

| | Thickness Feet |
|---|---|
| *Upper Member* | |
| Sandstone, fine-grained, light grey with pinkish tinge, glistening, quartzitic, in poorly marked beds (0·1- to 0·4-foot) weathering light grey. Top 0·1 foot contains 0·05-foot lenses of lighter weathering sandstone | 8·0 |
| Sandstone as above, interlensing in equal volume with white weathering chert | 2·0 |
| Chert, non-bedded, irregular and much fractured, weathering white. Fine-grained sand is apparently finely distributed throughout, tending to be more abundant in certain poorly defined lenses | 5·5 |
| Sandstone and chert as described above, the latter occurring as lenses from 0·1 to 0·3 foot in diameter, and 0·1 to 0·3 foot apart, in the former. The bedding (0·4 foot) is poor. Weathering is pink and with a cavernous (0·005- to 0·1-foot) surface | 16·0 |
| As above, but chert lenses less common | 8·5 |
| *Sandstone, fine-grained, quartzitic with conspicuous black mineral (chert) composing approximately one-twentieth of volume | 7·0 |
| Total | 47·0 |
| *Middle Member* | |
| *Chert, non-bedded, finely fractured, brittle, weathering white and glistening; with sparsely distributed lenses, usually 0·3 foot thick and 2 to 5 feet long, of quartzitic, fine-grained, grey sandstone weathering brown | 39·0 |
| Chert, as above (apparently without sandstone lenses) | 77·0 |
| Chert, dark grey, glistening to non-glistening, weathering blue-grey, with white patches | 7·9 |
| Total | 123·9 |
| *Lower Member* | |
| Limestone, very finely crystalline, light grey, with large lenses of chert as described above | 4·0 |
| Limestone as above, with irregular bands and lenses of chert, 0·02 to 0·05 foot thick and commonly 0·5 to 1 foot apart. Bedding not well marked | 16·0 |
| Limestone, finely crystalline, with 0·005-foot dark grey, rusty weathering bands undulating parallel with bedding, which is 0·2 to 0·5 foot, with occasional 0·05-foot shaly partings; no chert bands | 7·5 |
| Limestone, very finely crystalline, almost lithographic, light grey, hard, massive, alternating in 4-foot thicknesses with 0·02- to 0·05-foot beds and in lesser thicknesses with 0·5- to 1-foot beds. The heavier bedded limestone appears to contain more chert, which weathers out to a mottled network, the adjoining pieces being 0·01 foot thick. Occasional 0·05- to 0·2-foot lenses of dark grey chert weathering rusty brown are scattered sparsely throughout, as are occasional lenses of much-fractured quartzite. An 0·3-foot lens-like band of quartzite occurs 6 feet above the base of this unit | 31·0 |
| Limestone, almost lithographic, light grey, weathering white, and dark grey weathering chert in alternating bands 0·01 to 0·3 foot thick. The chert is very cavernous on weathered surface. The limestone occurs in 0·2- to 0·8-foot moderately well marked beds | 7·5 |
| Limestone, finely crystalline, glistening, light grey, very hard, in beds commonly 2 feet thick, and weathering white. It contains irregular 0·02- to 0·2-foot masses of chert, uniting to form larger reticulate masses. These chert masses occupy from 10 to 50 per cent of volume, and stand out well in relief | 20·5 |

| *Lower Member*—Concluded | Thickness Feet |
|---|---|
| Limestone, as above, but bedding ill-marked and chert occurs in small, closely packed particles 0·003 foot or less in diameter scattered throughout matrix | 11·0 |
| Limestone as in above 20·5-foot unit, but bedding not well marked | 22·0 |
| Covered | 12·0 |
| Limestone, finely crystalline, light grey, weathering white, only intermittently exposed; seemingly no chert lenses. Some medium-sized crystals of calcite | 9·0 |
| Covered | 5·0 |
| Limestone as above | 3·0 |
| Limestone, almost lithographic, light grey, weathering white. Occasional 0·2-foot chert lenses stand out in relief | 12·5 |
| Limestone, finely crystalline, light grey, in poorly marked beds weathering white | 19·0 |
| Covered | 15·0 |
| Limestone, very finely crystalline, light grey, weathering white, with lenses of chert in bands 0·05- to 0·2-foot thick and the same distance stratigraphically apart | 5·5 |
| Limestone, very finely crystalline, light grey, mostly in 2- to 4-foot beds, weathering white. Chert nodules 0·02 to 0·2 foot in diameter are scattered throughout | 33·0 |
| Covered | 4·5 |
| Limestone, finely crystalline, slightly porous, non-bedded, weathering very light grey, in rounded masses with irregular fractures; fragmentary horn corals, colonial corals, and crinoid columnals; dark, obscure patches on weathered surface are scattered throughout and are cherty | 13·0 |
| Limestone, very finely crystalline, light grey, with 0·02- and 0·05-foot shaly partings, weathering very light grey | 1·0 |
| Limestone, very finely crystalline, light grey, much fractured, weathering light grey, containing sparsely scattered, dark grey chert patches 0·01 to 0·2 foot in diameter | 8·5 |
| Covered | 15·5 |
| Limestone, very finely crystalline, crinoidal, in beds 1 foot to 3 feet thick, weathering very light grey to light brown. Irregular chert nodules 0·02 to 0·1 foot long and 0·1 foot thick occur throughout | 14·0 |
| Covered | 2·5 |
| Limestone, almost lithographic, grey, with 0·02- to 0·1-foot fractures, approximately parallel with bedding planes | 4·5 |
| Total | 297·0 |

RUNDLE FORMATION

| | |
|---|---|
| Limestone, finely crystalline, crinoidal, sparsely porous, dark grey, glistening, in poorly marked 1- to 2-foot beds, with crinoidal material weathering out as small white specks on the light brown to light grey weathered surface | 15·5 |
| Limestone, mostly finely crystalline, dark grey, glistening, porous and non-porous, massive to poorly bedded, weathering light grey to light brown | 321·0 |
| Limestone, very finely crystalline, well marked 1-foot beds, weathering light blue-grey, filled with white weathering 0·02- to 0·005-foot patches of crystalline calcite (speckled limestone) | 46·0 |
| Total | 382·5 |

Base of section

## SECTION IIC, FRIENDLY PEAK

(*See* Figure 5)

### SPRAY RIVER FORMATION

| | Thickness Feet |
|---|---|
| Shale, silty, dark grey, brittle, fissile, with intervening bands (up to 1 foot) of hard, dark grey, impure limestone, in 0·5-foot beds weathering buff. Fine interbands (0·005 foot and less) of darker and lighter grey shale are believed due to relative amounts of fine, dark chert particles.......... | 97·5 |
| Shale, as above, but with limestone appearing only as occasional 0·5-foot lenses and bands.......... | 12·1 |
| Shale, silty, calcareous, dark grey, brittle, fissile, weathering light brown, here and there alternating laterally to 0·2-foot lenses of dark grey, hard, impure, buff weathering limestone.......... | 146·2 |
| Covered.......... | 137·5 |
| Shale, as above, appearing in places more like a very fine-grained argillaceous sandstone.......... | 69·4 |
| Total.......... | 462·7 |

### GREENOCK FORMATION

| | |
|---|---|
| *Upper Member* | |
| Covered.......... | 40·3 |
| Total.......... | 40·3 |
| *Middle Member* | |
| Chert, dark grey, massive to poorly bedded (1 foot to 2 feet), weathering dark grey, fractured in pieces 0·01 foot in diameter and veined with secondary calcite, intermittently exposed.......... | 22·7 |
| Covered.......... | 48·5 |
| *Chert, dark grey, massive, in poorly marked 1- to 2-foot beds, fracturing to pieces 0·01 foot in diameter, weathering dark grey.......... | 13·9 |
| *Shale, cherty, organic, crumbly, weathering brown with orange patches | 1·3 |
| Chert, dark grey, with 0·1-foot band of dark brown shale as above.... | 2·3 |
| Silt, rusty weathering, lensing laterally with pale blue clay (bentonite?) | 0·3 |
| *Sandstone, with very fine-grained silty matrix, in 0·5-foot beds weathering buff, with rusty patches and containing angular fragments, commonly 0·01 foot in diameter, of limestone and dark chert.......... | 0·5 |
| Clay, rusty to pale blue (bentonite?).......... | 0·3 |
| Total.......... | 89·8 |
| *Lower Member* | |
| Sandstone, quartz, fine-grained, with calcareous cement, light grey, lithographic, weathering light brown to grey to rusty to dark grey. Angular chert and limestone fragments (0·02- to 0·05-foot) make up one-tenth of volume; 0·001-foot dark chert fragments permeate the limestone throughout. In top foot, 0·05-foot lenses of dark chert are common.......... | 3·9 |
| Limestone, grey, lithographic, irregularly fractured.......... | 1·7 |
| Limestone, grey, lithographic, in alternating dark and light grey, 0·01 foot bands, weathering grey to buff, with a 0·2 foot chert band, 0·6 foot above the base.......... | 3·0 |
| Limestone, lithographic, with 0·02-foot shaly partings.......... | 0·1 |
| Limestone, light grey, lithographic, weathering light grey, with pale orange stains.......... | 3·6 |

| *Lower Member*—Concluded | Thickness Feet |
|---|---|
| Limestone, white, crystalline, with one bedding plane 1·5 feet below top, and weathering light grey to yellow. Small stylolites are common and tiny needle-like dark grey chert (?) fragments permeate the mass. Brachiopod fragments common; *fossil locality* 80 at base | 8·0 |
| Limestone, grey, lithographic, in two main beds, weathering yellow-grey. A few, darker, cherty patches | 2·5 |
| Limestone, light grey, lithographic, in two beds, finely fractured at an angle to the bedding, weathering buff to light grey | 2·8 |
| Limestone, light grey, lithographic, in two irregular but well-marked beds, weathering buff. Occasional lenses of black chert, 0·1 foot to 6·0 feet in diameter; secondary calcite veins are common | 4·3 |
| Silt, grey, in 0·005-foot bands, weathering light grey | 0·5 |
| *Limestone, light grey, lithographic, hard, cherty, in 0·2- to 1-foot beds, weathering light grey. Many lenses of black chert 0·1 foot to 6·0 feet thick, along bedding planes | 8·0 |
| Shale, silty, grey, in alternating 0·005-foot dark and light bands, weathering pale brownish grey. Occasional lenses of cherty limestone (0·1 to 0·2 foot) occur in basal 0·3 foot and top 0·3 foot | 0·8 |
| *Limestone, argillaceous, light grey, very fine-grained, hard, massive, with one bedding plane 1 foot below top, weathering white to pale yellow with pink patches. Fine mottling is apparently due to chert content | 3·1 |
| Limestone, light grey, alternating in 0·1-foot bands and lenses with moderately soft, light grey, poorly bedded shale | 0·5 |
| Limestone, light grey, massive, weathering white | 1·6 |
| Shale, weathered, pale grey, in moderately hard, 0·01- to 0·5-foot poorly marked beds, giving way to irregular fractures in top half | 1·4 |
| *Limestone, light grey, silty, finely crystalline, in 0·1-foot bands weathering pale grey | 1·0 |
| Limestone, light grey, lithographic, fracturing irregularly, weathering light grey | 0·8 |
| Limestone, light grey, finely crystalline, hard, massive, weathering pale yellow. Sparse chert patches, commonly 1 by 1 foot, and finely disseminated chert | 19·5 |
| *Limestone, light grey to blue-grey, very finely crystalline to lithographic, hard, weathering pale yellow with grey patches. Black specks 0·003 foot in diameter are common. Chert occurs in 0·02- to 0·1-foot bands and lenses, usually 0·05 to 0·5 foot apart | 31·7 |
| Limestone, as above, but chert more common, making up one-quarter of the volume, in dark grey, irregular, anastomosing lenses approximately 0·5 foot in diameter | 15·0 |
| *Limestone, light grey to blue-grey, very finely crystalline to lithographic, massive, irregularly fracturing, weathering white. Irregular patches of dark grey chert (commonly 0·2 foot in diameter) are common, often anastomosing | 6·2 |
| Total | 120·0 |

Base of section

## SECTION IIIA, MORRO CREEK

(*See* Figures 3, 8)

### GREENOCK FORMATION

| | |
|---|---|
| Not examined in detail (obscured by talus) | 400 |
| Total | 400 |

94741—4½

RUNDLE FORMATION

| | Thickness Feet |
|---|---|
| Limestone, intermittently exposed, grey, finely to very finely crystalline, porous, hard, massive, occasionally speckled in 10- to 20-foot beds weathering light grey to brown | 208·4 |
| Limestone, as above, basal 50 feet with 6-foot beds | 116·8 |
| Limestone, grey, finely to very finely crystalline, porous, hard, massive, occasionally speckled in 10- to 20-foot beds, weathering light grey to light brown | 62·0 |
| Limestone, light grey, very finely crystalline, non-porous, compact, blocky, in 0·5- to 2-foot beds weathering very light grey | 5·0 |
| Covered | 3·0 |
| Limestone as above, but in one bed | 3·0 |
| Limestone, light grey, very finely to finely crystalline, porous, massive, with very few bedding planes throughout the entire unit, weathering brown to dark grey with occasional buff patches | 107·0 |
| Limestone, light grey, very finely crystalline, in 0·1-foot beds weathering very light grey | 1·0 |
| Limestone as above, but in 0·2- to 1-foot beds | 6·0 |
| Limestone, very porous, in 0·2- to 0·5-foot beds, mostly weathering light brown | 5·0 |
| Limestone, light grey, very finely crystalline, massive, weathering white | 2·0 |
| Limestone, very porous, in 0·2- to 0·5-foot beds, mostly weathering light brown | 12·6 |
| *Limestone, cherty, dark grey, lithographic to finely crystalline, speckled, in 0·5- to 2-foot beds | 18·5 |
| Covered | 2·5 |
| Limestone, grey, finely crystalline, massive, weathering brown to light grey. Chert forms a network | 15·0 |
| Limestone, grey, very finely crystalline, finely porous, massive, much fractured, weathering light brown | 4·0 |
| Limestone, cherty, dark grey, medium crystalline, fossiliferous, massive, with faint bedding every 10 feet, weathering light grey. In the top 5 feet lenses of almost lithographic limestone alternate laterally with the coarser limestone | 28·0 |
| Limestone as above, uniformly medium crystalline, except for two 0·2-foot shaly beds in the lower 3 feet | 32·0 |
| Limestone, argillaceous, very dark grey, very fine-grained, in 0·6-foot or less beds, weathering buff | 6·5 |
| Covered | 2·5 |
| Limestone, cherty, fossiliferous, crinoidal (bedding infrequent), massive, weathering light grey to brown | 58·0 |
| Limestone as above, with two bedding planes | 6·0 |
| Limestone, cherty, dark grey, fossiliferous, crinoidal, massive, in 10-foot beds, faintly marked, weathering dark grey to light grey to brown | 44·5 |
| Covered | 6·0 |
| Limestone, dark grey, finely crystalline, hard, in intermittently marked beds, commonly 1-foot weathering brown. Chert particles, 0·005 foot or less in diameter, appear to make up 5 per cent or more of the rock. The chert is concentrated in streaks approximately parallel with bedding. Fossil fragments are abundant | 19·5 |
| Covered | 6·5 |
| Limestone, cherty, dark grey, very finely crystalline, very porous, weathering light grey to buff; fossiliferous in moderately crystalline patches | 9·0 |
| Limestone, cherty, dark grey, porous, non-bedded, much fractured | 1·0 |
| Limestone, dark grey, fossiliferous, finely porous, in poorly defined beds weathering brown, irregularly fractured to flat slabs 0·05 foot thick | 5·0 |
| Limestone, moderately to finely crystalline, very porous, fossiliferous, in 0·1- to 0·3-foot slabby, ill-defined beds, with almost lithographic buff weathering patches scattered throughout | 5·5 |

| | Thickness Feet |
|---|---|
| Limestone, dark grey, medium crystalline, massive, weathering light grey to brown; fossiliferous in basal foot. Chert weathers out in 0·01-foot black pieces, lending a mottled appearance | 10·0 |
| Limestone, dark grey, finely crystalline, very porous, with 0·02- to 0·05-foot cavities; fossiliferous; in 1- to 2-foot beds weathering brown to light grey | 3·0 |
| Limestone, as above, but finely porous | 13·0 |
| Limestone, argillaceous (silty?), grey, lithographic, massive, weathering buff | 1·0 |
| Limestone, dark grey, medium crystalline, in one bed, weathering brown. Fossils are closely packed and broken | 3·5 |
| *Limestone, grey, argillaceous, lithographic, in 0·05- to 0·1-foot beds, weathering buff with smooth surface | 0·5 |
| Limestone, dark grey, finely crystalline, porous, fossiliferous, breaking into flat 0·05- to 0·2-foot slabs | 1·0 |
| Limestone, dark grey, finely crystalline, crinoidal, with coarse calcite crystals scattered throughout and in lenses; weathers predominantly light buff | 2·5 |
| Limestone, dark grey, finely crystalline, fossiliferous, massive, weathering brownish grey. Chert weathers out in 0·001-foot closely spaced black particles. The rock is highly weathered and very porous | 18·0 |
| Limestone, dark grey, medium crystalline, fossiliferous, massive, irregularly fractured, weathering light brown; small chert fragments 0·005 foot in diameter | 5·0 |
| Limestone, dark grey, medium to coarsely crystalline, crinoidal, in a well-marked bed, weathering light grey, small chert particles, 0·005 foot in diameter, weather black on surface | 1·0 |
| Limestone, cherty, grey, glistening, finely crystalline, massive, much fractured, weathered | 5·0 |
| Limestone, dark grey, glistening, finely to medium crystalline, in massive cliff, weathering light grey; chert noticeable in fine dark streaks on weathered surface (0·003 to 0·05 foot). This banding is the only evidence of bedding other than two prominent planes in the middle part of the unit. *Fossil locality* 92 at top | 58·0 |
| Limestone, weathered, light brown to light grey, finely crystalline, with lesser amounts of coarsely crystalline limestone, finely porous. The limestone is heavily veined with secondary calcite | 16·0 |
| Limestone, dark grey, glistening, finely to medium crystalline, massive, much fractured (in large blocks), weathering light grey | 49·0 |
| Limestone, dark grey, glistening, finely crystalline, non-bedded, irregularly fractured, weathering light brown to grey | 13·0 |
| Limestone, grey, glistening, finely crystalline, in poorly marked 1- to 2-foot beds, weathering brown | 5·5 |
| Limestone, dark grey, very finely crystalline, fracturing normal to and also about parallel with the bedding (0·2 to 0·4 foot) | 10·0 |
| Limestone, light grey, coarsely crystalline, crinoidal, massive, weathering light grey | 5·0 |
| Limestone, light grey, very finely crystalline, irregularly fractured, weathering buff | 10·5 |
| Limestone, cherty, dark grey, finely crystalline, in 2-foot beds, with 0·05- to 0·5-foot dark lenses; chert sparsely distributed; limestone weathering grey to brown | 13·0 |
| Limestone, cherty, dark grey, very finely crystalline, bedding obscure, irregularly fractured, weathering brown to grey | 5·0 |
| *Limestone as above, but bedding faintly but sharply marked (0·2 to 0·8 foot) | 10·0 |
| Limestone, cherty, dark grey, finely crystalline, hard, irregularly fracturing, weathering in lens-like streaks of brown and grey, due presumably to alternation in chert content | 18·0 |
| *Limestone, as above, but without patchy weathering | 2·5 |
| Limestone, cherty, grey, coarsely crystalline, crinoidal, finely porous, massive | 6·0 |

| | Thickness Feet |
|---|---|
| Limestone, dark grey, glistening, finely crystalline, hard, fracturing irregularly, weathering brown. Chert weathers out on the surface in 0·01- to 0·02-foot black, irregular, shiny, elevated masses commonly joining to form larger, continuous masses................ | 1·5 |
| Limestone, grey, coarsely crystalline, crinoidal, finely porous, massive, with 20-foot beds. Dark lenses of cherty limestone grade into the less cherty limestone mass, and are commonly 0·05 to 0·3 foot thick, and 1 foot or more wide.................................. | 66·0 |
| Total........................................... | 1,154·0 |

BANFF FORMATION

*Upper Member*

| | |
|---|---|
| *Limestone, dull grey, very finely crystalline, irregularly fractured, non-bedded, but finely interbanded and cross-banded, weathering dark grey to yellow. The interbands are 0·003 foot thick and are black and light grey due to variation in chert content............ | 6·0 |
| *Limestone as above, but chert bands are fainter.................... | 11·5 |
| Limestone, grey, very finely crystalline, massive, weathering in 0·005-foot light and dark grey bands and lenses, due to presence of more and less chert.............................................. | 13·0 |
| Shale, dark grey, semi-fissile, in 0·02- to 0·05-foot beds, fractured, weathering light grey........................................ | 1·5 |
| Limestone, dark grey, medium crystalline, fossiliferous (crinoidal), in poorly marked 0·5- to 2-foot beds, weathering light grey to brown. Blastoids are common and poorly preserved in the top bed........ | 20·0 |
| Limestone, grey, finely to medium crystalline, fossiliferous, in 0·05- to 0·1-foot slabby beds, weathering light brown.................. | 3·0 |
| Limestone, grey, finely to medium crystalline, fossiliferous, in 2-foot beds, weathering light brown.................................... | 8·5 |
| Covered.................................................. | 3·5 |
| Limestone, dark grey, finely crystalline to rarely coarsely crystalline, in well-marked 2-foot beds, weathering dark to light grey.......... | 39·5 |
| *Limestone, argillaceous, cherty, in 0·01- to 0·02-foot beds, and irregularly fractured in pieces approximately 0·05 foot in diameter..... | 6·5 |
| Limestone, grey, medium to coarsely crystalline, fossiliferous, in 0·05- to 1-foot irregularly and poorly marked beds, weathering brown. Chert is common throughout in 0·02- to 0·05-foot irregularly shaped fragments, and in still finer particles. *Fossil locality* 91 at top.... | 12·5 |
| Covered.................................................. | 3·8 |
| Limestone, dark grey, medium to coarsely crystalline, very fossiliferous, in well-marked 1-foot beds, weathering brown to light grey. Occasional shaly bands are 0·1 foot thick, but these vary laterally into limestone. Chert is common throughout in particles 0·02 to 0·05 foot or less in diameter; *Spirifer rutherfordi*, *Cliothyridina* spp., etc., are common............................................ | 35·0 |
| Shale, dark grey, calcareous, weathering blue-grey to buff, interlensing with crystalline to aphanitic limestone every 0·1 to 0·2 foot...... | 31·0 |
| Limestone, cherty, fossiliferous (crinoidal), 0·4- to 1·5-foot beds, alternating with rare 0·1- to 0·3-foot beds of dark grey calcareous shale.................................................. | 20·0 |
| Shale, calcareous, silty, dark grey, breaking into 0·02-foot pieces weathering buff, alternating in 0·4- to 0·8-foot bands with crystalline, fossiliferous, thin-bedded limestone weathering light grey to blue-grey............................................. | 14·5 |
| Limestone, dark grey, finely crystalline, with subordinate, coarsely crystalline, crinoidal patches and weathering light grey to blue-grey, alternating in 0·1- to 0·4-foot lenses with calcareous dark grey shale weathering buff. Chert is sparsely scattered throughout in dark grey 0·02-foot irregular patches, commonly joining to form larger patches................................................ | 58·5 |

| *Upper Member*—Concluded | Thickness Feet |
|---|---|
| Limestone, coarsely to very finely crystalline, crinoidal, in 4-foot beds weathering buff to light grey, alternating with subordinate 0·05-foot bands of dark grey calcareous shale. Dark grey weathering cherty patches form a fine meshwork over the surface. Basal 10 feet transitional to limestone beneath | 38·5 |
| *Shale, calcareous, silty, weathering dark grey; chert appears as particles ranging from microscopic size to 0·02 foot in diameter. A 0·1-foot band of black weathering chert occurs at the top | 15·0 |
| Limestone, argillaceous, grey, in 0·02-foot beds, alternating in 0·1- to 0·4-foot bands and lenses with grey, finely crystalline, hard, more massive limestones; in the latter, fine lenses, 0·005 to 0·02 foot thick and the same distance apart, weather brown and have a silty feel. They are characteristic of the more massive limestone but can be seen in the more shaly beds | 29·5 |
| Limestone, alternating crinoidal and argillaceous, in sharp 0·1- to 0·5-foot beds, weathering light grey to buff to dark grey | 12·5 |
| Limestone, grey, medium to coarsely crystalline, crinoidal, in beds 0·1 to 0·8 foot thick, nearly always separated by black, semi-fissile shale in 0·02-foot beds weathering light grey to buff. Argillaceous lenses are also irregularly distributed throughout the limestone, which weathers light grey to buff to dark grey; chert present as seen from silicified fossils; *fossil locality* 93 at top | 59·5 |
| Shale, black, hard, weathering to slabs 0·02 to 0·1 foot thick, alternating in 0·2- to 0·8-foot bands with 0·2- to 0·4-foot beds of dark grey, finely crystalline, argillaceous (?) limestone, weathering buff, top 10 feet with limestone bands becoming more prominent. Some of them are crinoidal and coarsely crystalline in places | 68·0 |
| Shale, calcareous, black, hard, weathering light grey to buff in slabs 0·02 to 0·1 foot thick. Fine alternation of more and less silty layers is suggested by alternate buff and blue-grey weathered surface. One or two 0·2-foot bands are more like argillaceous limestone | 13·0 |
| Total | 527·0 |
| *Lower Member* | |
| *Shale, as above, but softer, though brittle, and weathering to semi-fissile pieces, 0·01 foot in diameter | 52·5 |
| *Shale, bituminous, calcareous, weathered, grey to greenish grey, soft, semi-fissile, breaking up into irregular pieces approximately 0·01 to 0·05 foot in diameter. Bands of dull grey, argillaceous (?) limestone, weathering buff, are 0·1 foot thick and 0·4 to 0·6 foot apart | 18·0 |
| Covered with heavy talus and gravel | 26·0 |
| Total | 96·5 |

Devonian beds

## SECTION IIID, COBBLESTONE CREEK

(*See* Figures 3, 4, 5, 6)

### GREENOCK FORMATION

Top of section

| *Upper Member* | |
|---|---|
| Sandstone, grey, very fine-grained, quartzitic, in 1- to 2-foot beds weathering light grey | 16·4 |
| Covered | 17·2 |
| Total | 33·6 |

| | Thickness Feet |
|---|---|
| *Middle Member* | |
| *Chert and limestone, light to dark grey, weathering pink | 298·5 |
| *Lower Member* | |
| *Limestone, argillaceous, light grey, microcrystalline in faintly marked, even, 1-foot beds weathering white; bands 0·2 foot thick of dark grey chert | 8·9 |
| Limestone, light grey, very finely crystalline, massive, with round, finely fracturing, 0·5-foot bands of irregularly distributed chert | 16·1 |
| Limestone, light grey, very finely crystalline, with occasional 1-foot bedding planes. Chert occurs in irregular bands and lenses 0·1 foot thick | 7·0 |
| *Limestone, light cream-grey, very fine-grained, in blocky beds (0·2 to 1 foot) with 0·01-foot bands weathering light cream | 4·8 |
| Covered | 3·2 |
| Limestone, light grey, very finely crystalline, much fractured, in poor 1-foot beds, weathering white. Chert common and irregularly distributed in 0·3-foot patches | 18·0 |
| Limestone, coarsely crystalline, with dark, cherty, porous patches up to 2 feet thick, and commonly 10 feet wide | 12·5 |
| *Limestone, light grey, very finely crystalline, in poor 1-foot beds, weathering white. Chert is common in irregular 0·3-foot patches | 21·4 |
| Limestone, light brown to cream, very fine-grained, glistening to lithographic, in 1- to 2-foot beds, weathering light grey. Three 0·5-foot shaly, calcareous, light grey bands occur, 2, 11, and 13 feet above the base. Chert bands and lenses are prominent just above the top shaly band, through a thickness of 3 feet | 34·4 |
| Total | 126·2 |

RUNDLE FORMATION

| | |
|---|---|
| Limestone, grey, coarsely crystalline, hard, porous, massive, irregularly fractured, stained dark grey; top 15 feet and lower 9 feet dominantly coarsely crystalline, hard and porous; remaining central part light grey, fine-grained to lithographic, weathering grey to buff | 68·2 |
| Limestone, grey, finely crystalline, hard, porous, massive, weathering grey to buff | 20·7 |
| Limestone, light grey, coarsely crystalline, porous, hard, mostly massive, with rare 2-foot beds, weathering pale grey | 24·9 |
| Limestone, light grey, finely crystalline, massive; middle part moderately crystalline and finely porous | 10·0 |
| Limestone, light grey, coarsely crystalline, massive; bryozoa | 32·9 |
| Limestone, dull grey, lithographic, in 2- to 10-foot beds; chert nodules 0·2 to 0·4 foot in diameter usually 1 foot apart; horn corals | 60·2 |
| Limestone, finely crystalline, massive, weathering pale grey | 7·0 |
| *Limestone, light grey, finely to coarsely crystalline, crinoidal, porous, weathering light grey; porous microcrystalline limestone at base | 54·3 |
| Covered | 5·2 |
| Limestone, light brown to light grey, lithographic, weathered white | 5·4 |
| Covered | 38·0 |
| Limestone, coarsely crystalline and porous, massive, stained pale buff[1] | 10·0 |
| Limestone, light brown, finely crystalline, massive, stained pale buff[1] | 15·0 |
| Limestone, coarsely crystalline, massive, stained pale buff[1] | 22·3 |
| *Limestone, brown, finely crystalline, cherty, sparsely porous, weathering light grey | 36·0 |
| *Limestone, brown, finely crystalline, glistening, massive, blocky, fracturing irregularly | 10·0 |
| Limestone, finely to coarsely crystalline, porous, cherty, massive, weathering light grey; basal 15 feet softer and more porous than remainder | 48·7 |
| Limestone, buff-grey, finely crystalline, hard, porous, in 2- to 4-foot beds, weathering buff | 23·9 |

[1] It seems probable that these buff weathering limestones in this or other sections are dolomitic.—Ed.

| | Thickness Feet |
|---|---|
| Limestone, grey, finely crystalline, porous, in 2- to 4-foot beds, weathering light grey, with some darker cherty patches | 18·5 |
| Covered | 36·1 |
| Limestone, dark grey, hard, porous, massive, weathering grey; becomes more porous and finely crystalline toward the base | 28·9 |
| Limestone, as above, containing caverns 0·2 to 0·4 foot in diameter, spaced about 1 foot to 3 feet apart | 34·5 |
| *Limestone, light brown to dark grey, finely crystalline, massive, hard, porous, fracturing irregularly, commonly in 0·4-foot pieces | 12·7 |
| Limestone, dark grey, finely crystalline, glistening, porous | 7·1 |
| Shaly parting in limestone | 1·0 |
| Limestone, finely crystalline, in 2-foot beds, stained dark grey. A speckled appearance is caused by scattered coarse calcite crystals | 23.2 |
| *Limestone, dark brown, microcrystalline, 'speckled', in 2- to 10-foot beds, weathering dark to light grey | 30·3 |
| Limestone, dark grey, microcrystalline, in 2-foot well-marked beds, weathering grey | 29·1 |
| *Limestone, as above, in well-marked 3-foot beds and with a 6-inch dark grey fossiliferous band 12·5 feet below the top | 24·6 |
| Limestone, micro- to finely crystalline, 'speckled' in well-marked 1- to 10-foot beds | 41·5 |
| Covered | 94·1 |
| Limestone, dark grey, finely crystalline, impure, massive, weathering light to dark grey | 2·7 |
| Covered | 0·5 |
| Limestone, dark grey, finely crystalline, in one bed, weathering light grey | 1·0 |
| Shale, dark grey, soft, semi-fissile, in 0·01-foot beds | 2·0 |
| Limestone, dark grey, finely crystalline, impure, massive | 3·7 |
| Limestone, dark grey, impure, fossiliferous, microcrystalline, in lenses alternating with 0·01- to 0·05-foot bands of semi-fissile, shaly limestone; weathers light grey | 3·8 |
| Limestone, dark grey, microcrystalline to finely crystalline, impure, in 0·05- to 0·2-foot beds; shaly partings in basal 5 feet | 11·0 |
| Limestone, dark grey, shaly, fossiliferous, in 0·2- to 0·5-foot beds | 1·8 |
| Limestone, dark grey, very finely crystalline, in 0·1-foot poorly marked beds; *fossil locality* 16 | 2·6 |
| Limestone, dark grey, finely crystalline, fossiliferous, in 0·05- to 0·2-foot beds with also 0·01-foot poorly marked bedding planes; top foot shaly limestone | 5·8 |
| Limestone, as above, alternating in 0·02- to 0·05-foot beds with dark shale in 0·01-foot beds; *fossil locality* 76 | 3·0 |
| Limestone, as above, without the shale | 5·0 |
| Limestone, dark grey, finely crystalline, in poorly marked 1- to 6-foot beds, weathering light grey to buff | 10·7 |
| Limestone, as above, but finely fractured in irregular 0·05-foot pieces; massive to poorly bedded | 7·0 |
| Limestone, dark grey, coarsely crystalline, crinoidal, in 1- to 6-foot beds | 47·1 |
| Covered | 97·5 |
| *Limestone, coarsely crystalline, moderately hard, very poorly bedded, weathering light grey to buff in irregular, rounded masses | 55·7 |
| Total | 1,135·2 |

BANFF FORMATION

*Upper Member*

| | |
|---|---|
| Limestone, grey, finely to coarsely crystalline, crinoidal, in 2-foot beds, weathering light grey | 28·1 |
| Limestone, light brown, finely crystalline, hard, glistening, in 1- to 3-foot beds, weathering light grey | 16·4 |
| Limestone, dark grey, very finely crystalline, massive, breaking irregularly | 1·5 |

| *Upper Member*—Concluded | Thickness Feet |
|---|---|
| Limestone, light grey, finely crystalline, hard, porous, fossiliferous..... | 3·9 |
| Limestone, grey, coarsely crystalline, crinoidal, massive to bedded (2 feet), alternating with finely crystalline massive limestone..... | 15·2 |
| Limestone, grey, finely crystalline, in 0·05- to 2-foot beds, weathering light grey.......... | 13·8 |
| Covered.......... | 1·4 |
| Limestone, grey, coarsely crystalline, crinoidal, weathering light grey. Poorly preserved horn corals are common.......... | 16·4 |
| Limestone, grey, finely crystalline, poorly bedded, weathering buff to light grey.......... | 3·0 |
| Covered.......... | 4·1 |
| Limestone, dark grey, blocky, in 1-foot beds weathering light grey..... | 4·1 |
| Covered.......... | 0·5 |
| Limestone, dark grey, medium to coarsely crystalline, fossiliferous, in 0·05- to 0·4-foot, poorly marked beds, in 2-foot, well-marked beds, weathering light grey to buff.......... | 4·3 |
| Covered.......... | 4·5 |
| Limestone, dark grey, finely crystalline, impure, crinoidal, with occasional 0·02-foot, shaly partings, and with apparent crossbeds.... | 4·0 |
| Limestone, dark grey, impure, finely crystalline, in 0·02- to 1-foot beds, alternating with 0·1-foot beds of dark grey to paper-thin to 0·05-foot thick, slightly organic, moderately hard, crumbly shale....... | 3·6 |
| Covered.......... | 2·5 |
| Limestone, dark grey, impure, medium to finely crystalline, poorly bedded, crinoidal, fracturing irregularly into 0·4- to 2-foot blocks, weathering light grey.......... | 7·8 |
| Covered.......... | 2·0 |
| Limestone, fossiliferous (upper bed at *fossil locality* 13).......... | 2·6 |
| Limestone, dark grey, impure, finely crystalline, in 0·5- to 2-foot beds, with intermittent 0·5-foot shaly partings.......... | 5·8 |
| Limestone and shale in alternating 0·3-foot beds.......... | 1·2 |
| Limestone, dark grey, fossiliferous, crinoidal, rather dense, in 0·5-foot beds, weathering light grey.......... | 0·6 |
| Limestone, as above, in 0·05-foot beds.......... | 0·5 |
| Limestone, as above, in 0·5-foot beds.......... | 1·2 |
| Limestone, dark grey, shaly, semi-fissile, rather fossiliferous, weathering light brownish grey.......... | 0·5 |
| Limestone, dark grey, impure, very fossiliferous, weathering light grey; *fossil locality* 13.......... | 1·0 |
| Total.......... | 150·5 |

Base of section

# CHAPTER V

# STRATIGRAPHIC PALÆONTOLOGY

## GENERAL STATEMENT

There is at present no local subdivision of the Carboniferous system in the Canadian Rocky Mountains based on faunal evidence. Shimer (27) and Warren (31, 32, 33) have recognized several faunas and referred them to the formations of the standard Mississippi Valley section.

Allan, Rutherford, and Warren have remarked on the predominantly Kinderhook aspect of the Banff formation from the vicinity of Banff northward to Jasper (1, pp. 224-227, 239-240), as a result of their studies in those regions. Warren has also traced faunas in the Rundle formation from the vicinity of Banff southward to the Crowsnest area, and has named the *Spirifer rundlensis* zone after one of them (32, p. 155).

In the Mount Greenock area, the most fossiliferous part of the Carboniferous succession is the upper member of the Banff formation. The basal part of the Rundle is also quite fossiliferous, but the remainder of the succession is only sparsely so. For this reason, the information that will be of use in erecting a local biostratigraphic succession is largely confined to the lower part of the Rundle and to the upper part of the Banff formations.

## RANGE OF CARBONIFEROUS BRACHIOPODS IN THE MOUNT GREENOCK AREA

The range charts shown in Figures 11, 12, and 13 illustrate graphically the occurrence of Carboniferous brachiopod species obtained by the writer from each of the three main fault blocks. They differ in general from the most common kind of range chart in three main particulars: (1) each chart shows the actual stratigraphic position of the identified species as obtained in the field; (2) the three charts are largely duplicates of the same stratigraphic section, so that visual comparison of the results of each can be made; and (3) formations are shown to scale beside the species obtained from them, and this affords visual comparison of the independently measured stratigraphic and faunal successions.

The details of the present charts would doubtless be considerably modified as a result of more prolonged collecting, and, consequently, the charts are intended as a framework for future work. They may be used as such because of the accurately known and accessible geographic position both of the fossil localities and of the stratigraphic sections, and because of the close proximity of the former to the latter.

In Figure 11, the localities are all allocated to stratigraphic sections IB and IC, which are connected to each other by a "walked out" bed. The contact with Devonian strata is the sharpest and most reliable to which to refer the faunal succession. The uppermost exposed Devonian beds in section IC are within 20 feet of the actual contact.

Figure 12 is not as satisfactory as Figure 11. Exposures of the fossiliferous beds are comparatively poor (cf. section IIA), and the position of the uppermost Devonian exposure is not so certain. Further, only six localities were collected from, and these are only moderately fossiliferous. Four of these localities are directly along the path of section IIA, on Grassy Ridge. The other localities, Nos. 80 and 97, lie across Athabasca River, on the northwest slopes of Friendly Peak. The stratigraphic position of locality 97 was calculated from plane-table measurement down to the exposed top of the Devonian limestone. This horizon is, therefore, approximate, particularly as there appears to be a difference in the thicknessof Carboniferous strata on opposite sides of the Athabasca. That its general

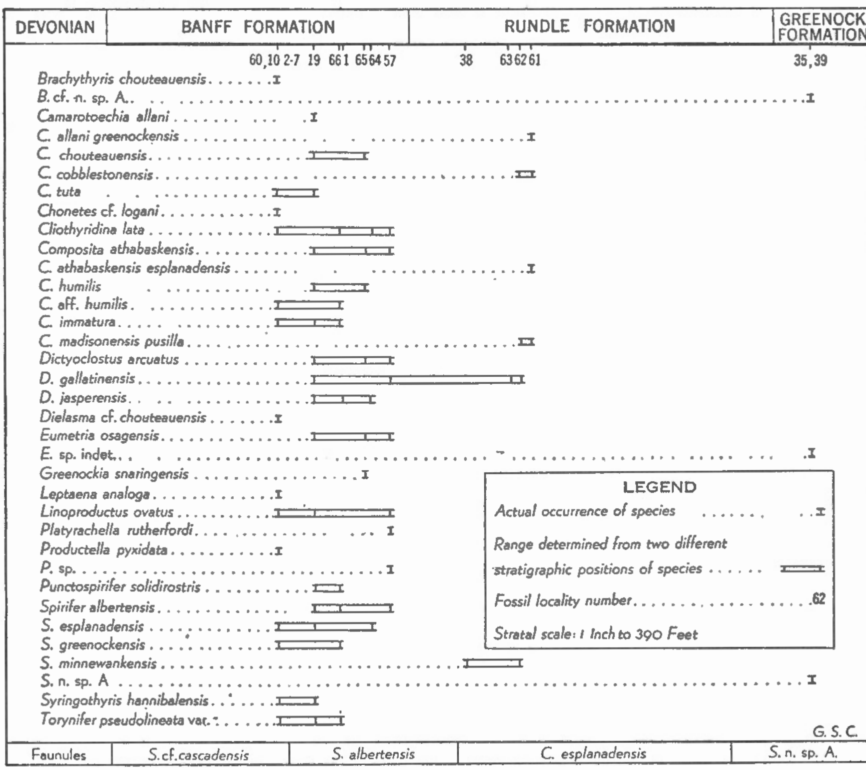


**Figure 11. Range chart for Carboniferous brachiopods in thrust block I.**

stratigraphic position relative to the localities of section IIA is correct, can, however, be readily demonstrated. A complete Carboniferous section for Friendly Peak was not measured, but the various lithological units were briefly examined. Their counterparts occur on Grassy Ridge. Locality 80 lies in section IIC, at the northwest end of Friendly Peak. A complete, detailed faunal and lithological examination of the Carboniferous section on Friendly Peak would add much to the knowledge of the succession in thrust block II.

Figure 13 illustrates the Carboniferous fossil localities of thrust block III, and is composed of two separate charts. The first of these, as in Figure 11, has its localities clustered mainly around one section. Thus, all but two of the fossil localities in the upper chart occur along the length

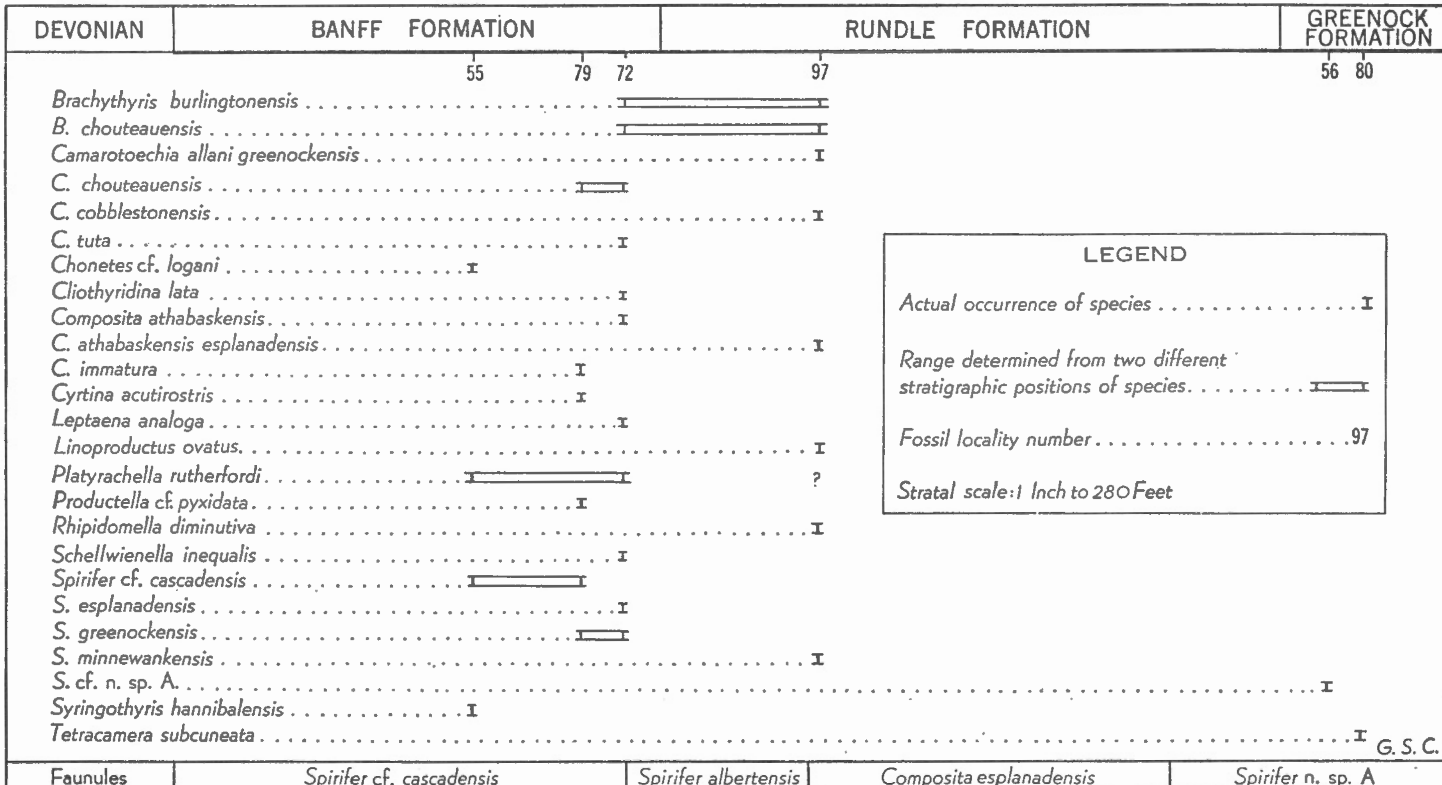


Figure 12. Range chart for Carboniferous brachiopods in thrust block II.

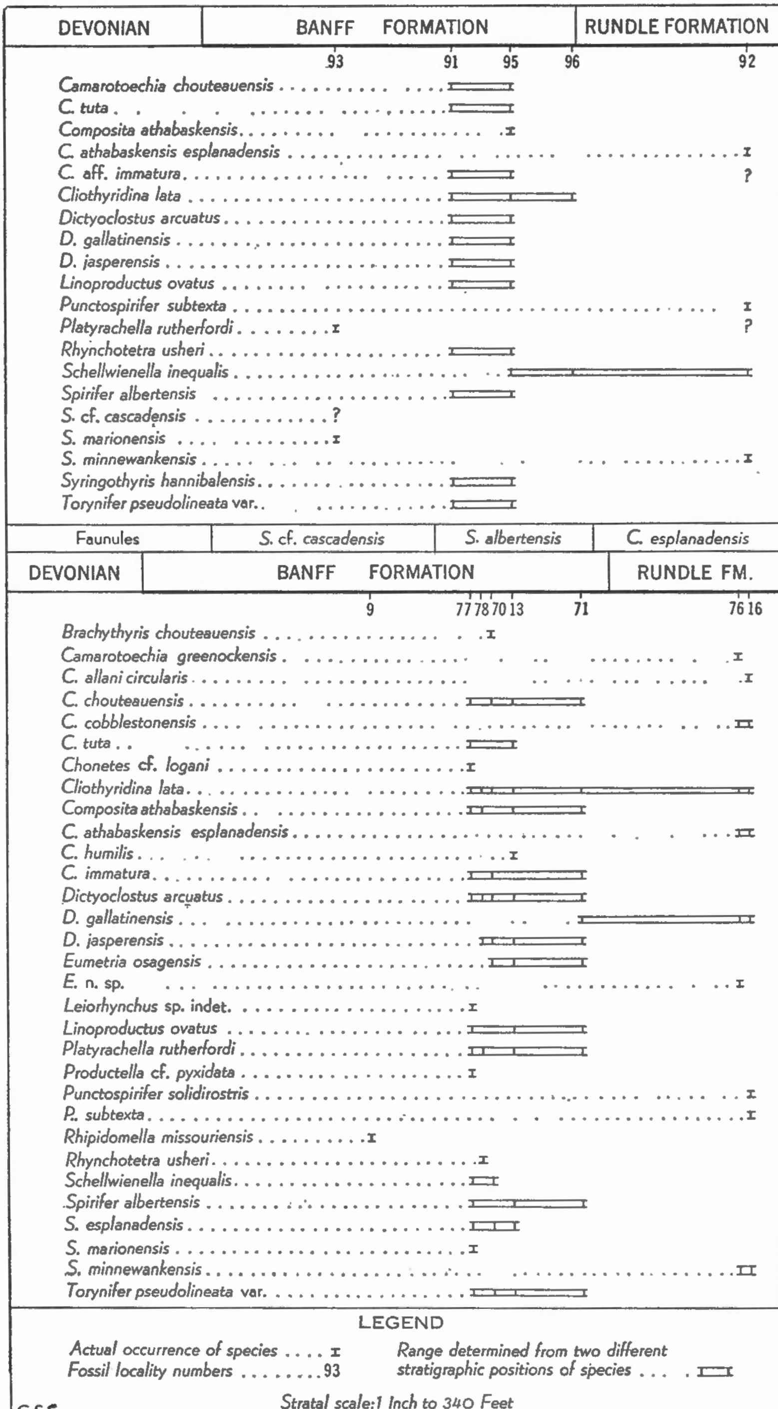


Figure 13. Range chart for Carboniferous brachiopods in thrust block III.

of section IIIA, and are tied by tape measurement to each other and to the exposed top of the Devonian limestone. The other two localities, Nos. 95 and 96, occur less than a mile northward, at Athabasca Point, and their stratigraphic position in the section relative to the top of the Devonian limestone was obtained by calculation from plane-table measurement. Tape measurement was also made from locality 96 upward to the local contact with the Rundle limestone. Here, as in thrust block I, the Devonian contact appears to make a satisfactory datum plane.

Figure 13 also shows those fossil localities of thrust block III that occur on the northwest side of Athabasca River. Localities 13, 16, and 76 were tied directly to section IIID. A bed in the section, lying somewhat above locality 13, was traced northward toward locality 71, and the latter was connected to the other localities by tape measurement. Due to concealment of the lower part of the Carboniferous section, and of the adjacent Devonian beds, the localities of Figure 13 are not readily referable to the top of the Devonian limestone. However, an approximation of this horizon is shown.

## TOURNAISIAN AND VISEAN ASSEMBLAGES

Figures 11 and 12 indicate that in thrust blocks I and II there is one major faunal gap in the Carboniferous succession. Below this gap fossils are abundant, but above it, comparatively rare. Fossils were not found in the less prolific, higher horizons, in thrust block III, and so no break is shown in Figure 13. However, these higher horizons are represented by scattered occurrences in thrust block IV.

The abundantly fossiliferous Carboniferous beds contain a lower Mississippian faunal assemblage that falls within the limits of the Tournaisian stage of the European Carboniferous system. It is, therefore, called a Tournaisian faunal assemblage, and appears to contain three faunules.

The horizons of the higher, less fossiliferous part of the local Carboniferous succession, according to present world-wide correlation, fall well within the Visean stage[1], and comprise one faunule.

### TOURNAISIAN ASSEMBLAGE

As can be judged from the report of Allan *et al.* (1) the Tournaisian assemblage in the Mount Greenock area has a decided Kinderhook affinity. This can be seen by the following list of species from the fauna, which are also diagnostic of Kinderhook formations of Mississippi Valley:

*Brachythyris burlingtonensis* Weller
*B. chouteauensis* Weller
*Camarotoechia chouteauensis* Weller
*C. tuta* (Miller)
*Cyrtina acutirostris* (Shumard)
*Dictyoclostus arcuatus* (Hall)
*Eumetria osagensis* (Swallow)
*Leptaena analoga* (Phillips)
*Punctospirifer solidirostris* (White)
*Rhipidomella missouriensis* (Swallow)
*Schellwienella inequalis* (Hall)
*Spirifer marionensis* Shumard
*Syringothyris hannibalensis* (Swallow)

[1]The local faunal assemblages are dated Tournaisian and Visean respectively by their correlation with Mississippi Valley faunas, which are at present thought to lie well within the limits of the Tournaisian and Visean stages.

Further evidence of the Kinderhook age of this fauna is found in the occurrence of *Composita immatura* (Girty), *C. humilis* (Girty), and *Dictyoclostus gallatinensis* (Girty). These species are all abundant in the lower part of the Madison group of Wyoming. In a preliminary study of these beds, Girty noted the predominant Kinderhook aspect of his faunal assemblage.

*Cliothyridina lata* Shimer occurs in the Lower Mississippian of the Lake Minnewanka area, and in the Middle member of the Banff formation of the Banff area. *Rhipidomella diminutiva* Rowley occurs in high Kinderhook and low Burlington beds in Mississippi Valley. The remaining species are either new or described locally.

Figures 11, 12, and 13 show that the following identified species extend upward to the top of the local Tournaisian faunal assemblage, and downward to the lowermost abundantly fossiliferous Carboniferous horizons of either thrust block I or III.

*Brachythyris chouteauensis* Weller
*Cliothyridina lata* Shimer
*Dictyoclostus gallatinensis* (Girty)
*Schellwienella inequalis* (Hall)

Another species, *Platyrachella rutherfordi* (Warren), has been doubtfully recorded in the top horizon of the assemblage, in thrust block II, and occurs in the basal beds of this thrust block.

*Brachythyris burlingtonensis* Weller was observed only in thrust block II, but it there bridges the major gap in the Tournaisian assemblage. *Punctospirifer solidirostris* White was found at a markedly different horizon in thrust block I than it was in thrust block III.

*Schellwienella inequalis, Brachythyris burlingtonensis, B. chouteauensis,* and *Punctospirifer solidirostris* are all characteristic fossils of the Kinderhook group of Mississippi Valley, and thus indicate a close relationship between all parts of the Tournaisian assemblage of the Mount Greenock area.

Figures 11, 12, and 13 demonstrate the continued occurrence of a major gap in the Tournaisian faunal assemblage, bridged only by a few species, as has been observed. The species found in association above this gap are here grouped into the *Composita esplanadensis* faunule, which is well differentiated and is named from one of its most characteristic forms.

A more prolific faunal association occurs below the gap in the Tournaisian assemblage, and within it, two faunules have been recognized—a lower, or *Spirifer* cf. *cascadensis* faunule, and an upper, or *Spirifer albertensis* faunule. The boundary between these two faunules is rather indefinite at the present stage of study, and they are to a slight extent composite, as can be seen by comparing Figures 11, 12, and 13.

Future collecting will be needed to ensure that these two faunules are true and not apparent, though the present results are considerably affected by the relative completeness of the stratigraphic sections. Section IIA was not as well exposed as any other entire sections of the Banff formation. Also, the few fossil localities exposed in it were much less prolific than the main localities examined in thrust blocks I and III.

### *Spirifer* cf. *cascadensis* and *S. albertensis* Faunules

The boundary between the *Spirifer* cf. *cascadensis* and *Spirifer albertensis* faunules is drawn tentatively between fossil localities 91 and 93 on the south side of Athabasca River in thrust block III.

The species that are thought to characterize the *Spirifer* cf. *cascadensis* faunule are:

*Chonetes* cf. *logani* Norwood and Pratten
*Cyrtina acutirostris* (Shumard)
*Productella* cf. *pyxidata* Hall
*Leptaena analoga* (Phillips)
*Rhipidomella missouriensis* (Swallow)
*Spirifer* cf. *cascadensis* Warren
*S. greenockensis* n.sp.
*S. marionensis* Shumard

The species that are here thought to characterize the *Spirifer albertensis* faunule are:

*Composita athabaskensis* Warren
*C. humilis* (Girty)
*Dictyoclostus jasperensis* (Warren)
*Eumetria osagensis* (Swallow)
*Greenockia snaringensis* n.sp.
*Spirifer albertensis* Warren
*S. esplanadensis* n.sp.

This faunule was not strongly represented in thrust block II, whereas the *S.* cf. *cascadensis* faunule is better developed there than in the other two main thrust blocks. This suggests that these two faunules, as listed above, may be somewhat influenced by facies changes. However, a more complete examination of thrust block II might disprove this.

Apart from the actual distribution of the species, several other points indicate that the two faunules are of biostratigraphic significance, and they are listed below:

1. Representatives of true Productinae (i.e., species of *Dictyoclostus* and *Linoproductus*) are commonly associated with the *Spirifer albertensis* faunule, and with higher faunules, but are rarely associated with the *Spirifer* cf. *cascadensis* faunule. This is analogous to the condition in Mississippi Valley, where these genera seem to make their appearance in higher Kinderhook strata, not having been recorded in the Louisiana formation or its equivalents.
2. The genus *Composita* is represented only by a few specimens in the *Spirifer* cf. *cascadensis* faunule, and these are simple, dwarfed forms, related to *Composita immatura* and *C. humilis*. In contrast to this, the *Spirifer albertensis* faunule contains an abundant and varied representation of the genus (*See* Figure 15). In Mississippi Valley, the basal Kinderhook formations do not appear to contain any species of *Composita*, but the higher ones do.

3. The following species of the *S.* cf. *cascadensis* faunule are present in one or more of the Louisiana, Saverton, and Sylamore formations, which are near the base of the Kinderhook group in Mississippi Valley:[1]

   *Rhipidomella missouriensis* (Swallow)
   *Cyrtina acutirostris* (Shumard)
   *Spirifer marionensis* Shumard

   Of these species, *R. missouriensis* and *S. marionensis* have been questionably reported as well from the Hannibal shale. *R. missouriensis* has also been reported from the Chouteau formation, but Williams (36, p. 44) believes that it occurs in a part of the Chouteau formation that is equivalent in age to the Louisiana formation. These species, therefore, appear to be restricted to the basal part of the Kinderhook group. The only species that occurs in the *S.* cf. *cascadensis* faunule and is also apparently restricted to the upper part of the Kinderhook group is *Leptaena analoga* (Phillips). (*Chonetes* cf. *logani* Norwood and Pratten and *Productella* cf. *pyxidata* Hall are not definitely identifiable with those Mississippi Valley forms).

4. *Eumetria osagensis* (Swallow), of the *Spirifer albertensis* faunule, occurs in the upper part of the Kinderhook group in Mississippi Valley. *Spirifer albertensis* itself seems to be very closely related to *Spirifer missouriensis* Swallow, which is also confined to the upper part of the Kinderhook.

5. Two species that characterize both the *Spirifer* cf. *cascadensis* and *S. albertensis* faunules may have similar ranges in Mississippi Valley to their ranges in the Mount Greenock area. Of these species, *Camarotoechia tuta* is common in the upper part of the Chouteau limestone, and ranges upward into the Burlington group. It has also been doubtfully recorded by Williams from the Louisiana formation (36, p. 82). *Syringothyris hannibalensis* occurs in the Louisiana, Saverton, and Sylamore formations (36, p. 87). It appears to be almost, if not, identical with species described from stratigraphically higher formations.

   The specimens from the Mount Greenock area are not uniformly well enough preserved or abundant enough for the determination of slight variations, but it is here thought possible that the vertical range of this species is similar there to its range in Mississippi Valley.

6. The persistence, in their same general order, in the Boule Range, of the species that in the Mount Greenock area characterize the *S.* cf. *cascadensis* and *S. albertensis* faunules, is indicated by collections that the writer obtained from the Carboniferous strata there[2].

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[1]The Kinderhook formations of Mississippi Valley are many and varied, and their relations not altogether certain, due to intermittent exposure and lateral variation. Of the more widely known formations, the Louisiana, Sylamore, and Saverton occur near the base of the Kinderhook group, the Hannibal shale occurs in the middle part, and the Chouteau limestone occurs near the top. The Chouteau formation varies markedly in its vertical extent from place to place, and in some areas its downward extent reaches beds that are correlated with the Louisiana formation.

[2]Part of unpublished section examined by G. S. Hume in 1946, *See* p. 00.

Less than 10 feet above the contact with the uppermost *C. whitneyi*-bearing beds of the underlying Devonian strata, the following species were collected:

*Rhipidomella* aff. *missouriensis* (Swallow)
*Schizophoria* sp.
*Schellwienella?* sp.
*Dictyoclostus arcuatus* Hall
*Punctospirifer* sp. indet.
*Spirifer greenockensis* n.sp.
*Syringothyris hannibalensis* (Swallow)
*Composita immatura* Girty
*Dielasma* cf. *chouteauensis* Weller

At an estimated 100 feet above this faunule, in the same section, the following species were collected:

*Rhynchopora* cf. *pustulosa* (White)
*Reticularia* cf. *cooperensis* (Swallow)
*Cliothyridina* sp.
*Cliothyridina lata* Shimer
*Composita athabaskensis* Warren
*C. humilis* (Girty)
*Eumetria osagensis* (Swallow)

The long-ranging Tournaisian species of the Mount Greenock area do not give such definite evidence concerning the two faunules, because the specimens are sparsely scattered in their occurrences, and poorly preserved. Of these species, *Punctospirifer solidirostris* ranges downward to the base of the *Spirifer albertensis* faunule. *Linoproductus ovatus* and *Schellwienella inequalis* are scattered through the *S. albertensis* faunule, and occur with species of the *S.* cf. *cascadensis* faunule, but are not present at the type fossil localities (55 and 79) of this faunule. *Brachythyris burlingtonensis* and *B. chouteauensis* occur at locality 72, associated there with both *S.* cf. *cascadensis* and *S. albertensis* elements. In Mississippi Valley these forms are confined to the upper part of the Kinderhook group, at least in those areas where the Louisiana limestone occurs.

The little information obtained from these species would, therefore, suggest either that the relation between the *Spirifer* cf. *cascadensis* and *S. albertensis* faunules is closer than that between the faunas of the Louisiana and restricted Chouteau formations, or else that some of the species lagged in a migration from the Rocky Mountain area to Mississippi Valley.

It is hoped that the separation of the *Spirifer* cf. *cascadensis* and *S. albertensis* faunules will help to stimulate the faunal study of the basal part of the Carboniferous section in the Rocky Mountains. A more exact knowledge of the horizons at which brachiopod genera such as *Dictyoclostus*, *Linoproductus*, *Eumetria*, *Torynifer*, and *Composita* enter the Carboniferous succession in the Canadian Rockies would be of assistance in local stratigraphic problems, and would also aid inter-regional correlation and stratigraphic boundary problems.

## *Composita esplanadensis* Faunule

Occurring above the major gap in the Tournaisian faunal assemblage, the *Composita esplanadensis* faunule stands out distinctly, in sharp contrast with the other two faunules. It has seven species in common with the *Spirifer albertensis* faunule. Nine species or varieties are restricted to the

*Composita esplanadensis* faunule. Seven of them are present in thrust block III, and four of these are common to all thrust blocks. In each block the faunule appeared to be limited to a narrow band. The complete faunule is listed below:

*Brachythyris burlingtonensis* Weller
*B. chouteauensis* Weller
*Camarotoechia allani* var. *circularis* n.var.
*C. allani* var. *greenockensis* n.var.
*C. cobblestonensis* n.sp.
*Cliothyridina lata* Shimer
*Composita athabaskensis* var. *esplanadensis* n.var.
*Composita* aff. *madisonensis* var. *pusilla* (Girty)
*Dictyoclostus gallatinensis* (Girty)
*Eumetria* n.sp.
*Linoproductus ovatus* (Hall)
*Platyrachella rutherfordi* (Warren)
*Punctospirifer solidirostris* (White)
*Punctospirifer subtexta* (White)
*Schellwienella inequalis* (Hall)
*Spirifer minnewankensis* Shimer
*Rhipidomella diminutiva* Rowley

*Linoproductus ovatus* is a long-ranging form, occurring in Mississippi Valley from the Kinderhook group upward at least to the Meramec group. *Brachythyris chouteauensis*, *B. burlingtonensis*, *Punctospirifer solidirostris*, *P. subtexta*, and *Schellwienella inequalis* are all Kinderhook species and are characteristic of the Chouteau formation. *Rhipidomella diminutiva* occurs in the Kinderhook and Burlington groups in Mississippi Valley. *Dictyoclostus gallatinensis* and *Composita pusilla* were described from the Madison formation of Wyoming by Girty (11), who correlated the fossiliferous beds with the Kinderhook. *Cliothyridina lata* and *Spirifer minnewankensis* were described from Mississippian beds at Banff. The rest of the species of the *Spirifer minnewankensis* faunule were described from Athabasca Valley.

The fossil content suggests that this faunule is also referable to the Kinderhook group. It is, therefore, possible that the three faunules just described are expressions of the lower, middle, and upper Kinderhook faunal assemblages of Mississippi Valley.

The writer believes that a detailed study of the Carboniferous faunal succession from the front range to beyond the Mount Greenock area will show the relation between the faunal and lithological succession, and may establish the existence of the *Composita esplanadensis*, *Spirifer albertensis*, and *S.* cf. *cascadensis* faunules in Athabasca Valley.

### VISEAN ASSEMBLAGE

In each of the four thrust blocks of the Mount Greenock area, the upper part of the Rundle formation was found to contain poorly preserved coral fragments, in each case some distance above the occurrence of the *Spirifer minnewankensis* faunule. Some unsuccessful attempts were made to find good specimens at these horizons, but they were not followed far along the strike. It is, therefore, quite possible that a coral faunule exists between the *Spirifer minnewankensis* faunule below and the succeeding faunal assemblage, which is found everywhere in the Greenock formation within the area. The latter assemblage has been named the *Spirifer* n.sp. A faunule, after a species occurring in thrust block I, and is tentatively referred to the Visean stage.

### *Spirifer* n.sp. A Faunule

A small faunule occurs stratigraphically far above the Tournaisian local faunal assemblage, and in typical beds of the lower member of the Greenock formation. The following species occur at fossil locality 39:

*Brachythyris* cf. n.sp. A
*Spirifer* n.sp. A
*Eumetria* sp. indet.
*Cliothyridina* sp.
Productids, indet.

A fragmentary specimen, which may be *Spirifer* n.sp. A, also occurs at a similar horizon in thrust block II, at fossil locality 56, also a fragment doubtfully comparable to *S. pellaensis* Weller.

In beds within thrust block IV, at fossil locality 84, the following species is represented:

*Brachythyris* n.sp. A

At fossil locality 80, in beds that lie in a similar stratigraphic position with respect to the top of the Carboniferous succession as those of fossil localities 39 and 56, but with different lithology, *Tetracamera subcuneata* (Hall) was collected.

Although all of the above collections may not be from the same horizon, their stratigraphic positions are not far removed from each other. *Brachythyris* and *Eumetria* are characteristic Mississippian genera, although they do occur in the recurrent Morrow fauna of Arkansas, which may be of Pennsylvanian age. *Tetracamera subcuneata* is a characteristic Salem species. Another bit of evidence has a bearing on this point. A small collection, from near the top of Cobblestone Peak, is from beds whose exact structure and horizon are uncertain. The lithology is that of the Greenock formation, and the stratigraphic relations of the beds indicate that at least some part of the Greenock formation is involved. The collection includes *Perditocardinia dubia* (Hall), which is characteristic of Upper Mississippian strata of North America. This further suggests the Mississippian age of at least the lower member of the Greenock formation. The writer believes that its affinities are with the Meramec group of Mississippi Valley[1].

## CHARACTER OF THE BRACHIOPOD FAUNA

The Carboniferous brachiopod fauna will now be considered biologically, to find the most prolific families and genera and the best means of studying them, and to discover the stratigraphic significance of the various species. The genus *Spirifer* is the most prolific from the standpoint of number of species and specimens, and also makes the best genus for the zonation of species.

Of the eight local species of *Spirifer*, seven were described from the Rocky Mountains, and all but *Spirifer* n.sp. A are readily definable by their costæ. Only the poor preservation of the rostral area prevents the

[1]Recently Laudon (18) recorded what he stated to be a Meramec fauna from Mississippian strata in Tetsa River Valley at mile 381·5, Alaska Highway. The fauna includes *Productina* sp., *Productella* sp., *P. moorefieldana*, *Avonia oklahomaensis*, *Dictyoclostus inflatus* var. *coloradoensis*, *D.* sp., *Linoproductus pileiformis*, *L. altonensis*, *Marginifera adairensis*, *Buxtonia* sp., *Leiorhynchus carboniferum*, *Spirifer arkansanus*, *Brachythyris gurleyi*, *Ambocoelia* sp., and *Deltopecten batesvillensis*. According to Laudon, most of these species occur in the Calico Bluff formation (Mertie, 22) of Meramec age. No Kinderhook is present in this particular area according to Laudon, although it has been found well represented elsewhere in that general region, Hume (13), Hage (12, p. 4).

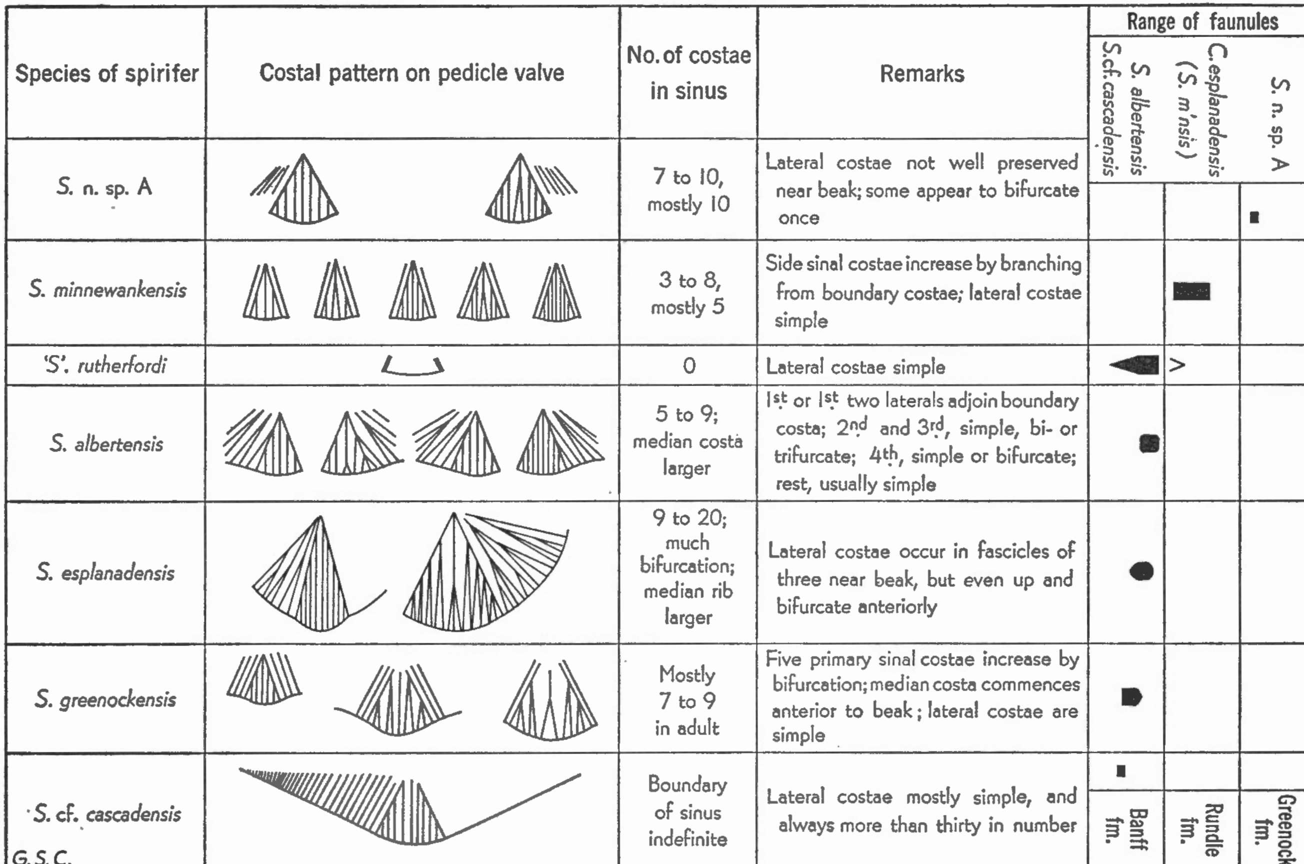


Figure 14. Costæ as key to Carboniferous spirifers of the Mount Greenock area.

specimens of that species from also being readily determined by costæ. The combination of a large number of sinal costæ and of branching lateral costæ would, if present, as it so appears, be diagnostic.

Thus, adequate material is available for the study of variation in *Spirifer.* The accompanying chart (Figure 14) shows the observed variation in the type of costæ on the flanks, and in the type and number in the sinus, on the pedicle valves of the different species. The remarks explain features other than the number of sinal costæ. The accompanying range chart shows the relative stratigraphic range of the species. The writer invites comparison of the stratigraphic succession of these species with those of the same species in other parts of the Canadian Rocky Mountains.

The longest-ranging species, *'Spirifer' rutherfordi*, occurs in all three faunules of the local Tournaisian faunal development. All the others appear to be comparatively short-ranged forms. The chart shows that *Spirifer albertensis* and *S. minnewankensis* appear to have, in the Mount Greenock area at least, non-overlapping stratigraphic ranges. The former species always has bifurcating lateral ribs next to the ribs that border the sinus. The latter species always has simple lateral ribs.

*S. greenockensis*, which might otherwise be confused with the others, has its primary sinal ribs bifurcating, and its median sinal rib forms late. *Spirifer esplanadensis*, the only other species having all its primary ribs bifurcating, has lateral ribs that are fasciculate near the beak. The latter species is the one referred to by Raymond (24, p. 299) as a small variety of *Spirifer grimesi* Hall.

There is little speciation in the remainder of the local Spiriferacea. *Torynifer cooperensis* var. *jasperensis* has constant characters throughout its range. Allan, Rutherford, and Warren's faunal list (1, p. 239) includes *T. cooperensis* and *T. pseudolineata.* No specimens collected by the author are referable to these species, but the local variety has affinities with both of them. The genera *Punctospirifer* and *Brachythyris* are represented by species denoting the Lower or Upper Mississippian character of the faunas.

In the Rostrospiracea, *Composita* is the outstanding genus, and shows next to *Spirifer* the most abundant development of any genus in the local Carboniferous strata. The local representatives exhibit much variation in outline, convexity, size of beaks, and development of sinus. These characters intergrade so as to make it difficult to separate species and varieties. For instance, forms identical with such species as *Composita humilis* (Girty), *C. madisonensis pusilla* (Girty), and *C. athabaskensis* Warren, appear to grade into each other in a single bed. There are also differences in the vertical distribution of characters. These features are shown on a chart (Figure 15) in which the trends in vertical and lateral variation and in evolution are inferred by arrows. In Figure 14, *Composita* cf. *humilis* at fossil localities 10 and 79, *C.* cf. *immatura* at locality 92, and *C.* cf. *madisonensis pusilla* at localities 61 and 62 are each represented by single specimens at those localities. The rest of the forms occur abundantly at one or more localities.

Specimens of *Composita* are rare and of small size in the *Spirifer* cf. *cascadensis* faunule, and two types are present, one elongate-subcircular, with moderately prominent beaks and no sinus (*C.* cf. *humilis*), and the other elongate-subpentagonal with small beaks and a faint broad sinus. The latter appear to be dwarfed examples of *C. immatura* Girty.

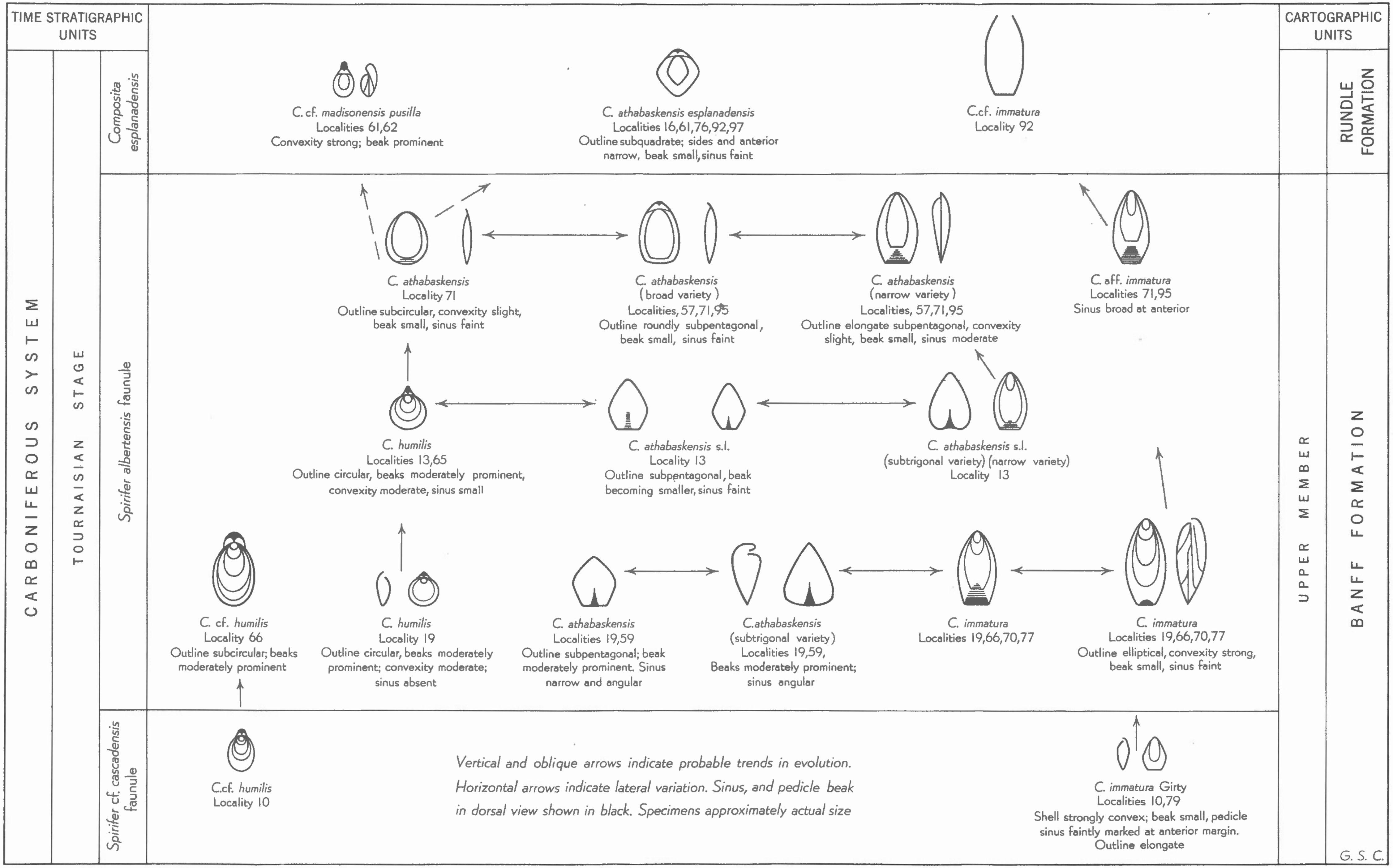


**Figure 15.** Form chart, showing trends in variation in the genus *Composita* in the Tournaissian strata of the Mount Greenock area.

In the basal beds of the *Spirifer albertensis* faunule, the most common form is a subtrigonal variety of *C. athabaskensis*, with convexity strong near the umbonal area, and a prominent sinus at the anterior margin, disappearing in the posterior third of the shell. This variety grades imperceptibly into the roundly subpentagonal form of *C. athabaskensis*. These forms still retain a moderately prominent sinus and beak. Associated with this variety is *C. humilis*, with its circular outline, an elongate form resembling *C. humilis*, and moderately large specimens of *C. immatura* (Girty). Some variation in this species leads to rare flattened forms approaching *C. athabaskensis* s.s. All of these forms except *C.* cf. *humilis* are present in the middle beds of the strata of the *S. albertensis* faunule. The upper beds contain *C. immatura*, with a more deeply sinuate anterior than in the lower beds. These forms gradually pass laterally into the narrow variety of *C. athabaskensis*, and thence to the broad, flat *C. athabaskensis* s.s.

The *Composita esplanadensis* faunule contains *C. athabaskensis* var. *esplanadensis*, with subquadrate outline, shallow convexity, and rather small beaks. Another form occurring rarely is a small, gibbous specimen with large beaks and faint sinus at the anterior margin. This form is close to *C. madisonensis pusilla* (Girty), and could most easily be derived from *C. humilis* var., of the *S.* cf. *cascadensis* faunule. One specimen doubtfully referable to *C. immatura* (Girty) was also found.

From the standpoint of characters alone, it is apparent from Figure 14 that a subtrigonal outline and a sharp sinus are characteristic of the lower part of the *S. albertensis* faunule, that is, in the lower beds of the upper member of the Banff formation. A subquadrate outline is confined, in adult specimens, to the *Composita esplanadensis* faunule, as are the rarely found protuberant beaks. A circular outline is only rarely present, but seems more characteristic of the lower beds of the *S. albertensis* faunule. In higher beds *C. athabaskensis* tends to become flatter, with less prominent beaks. *C. immatura* has a broader, deeper sinus in the upper beds.

The above facts suggest that a few simple forms of the genus *Composita* entered the Mount Greenock area early in Tournaisian time, and that the genus soon flourished in number and variety, and remained until, at least, some time before the beginning of Visean time.

The genus *Composita* might prove to be of significance in the identification of horizons within the Carboniferous succession of the Canadian Rockies. It is well represented in the upper part of the Rundle limestone, southward of the Banff area, and the species that occur there differ externally in having a more mature appearance than those of the Mount Greenock area.

If the Mount Greenock species and varieties can be shown to have a wide geographic range, and a vertical distribution similar in other regions to that within the Mount Greenock area, *Composita* will be useful in correlation. However, specimens from the successions of several distinct regions should be compared before any conclusions are reached, as the external form of *Composita* is known to be extremely variable, and cannot be used reliably to identify species from remote regions.

Specimens of the genus *Cliothyridina* occur abundantly throughout the Mississippian strata of the Mount Greenock area. All the identifiable specimens are placed by the writer in the species *C. lata* Shimer. *C. glenparkensis* Weller?, *C. hirsuta* (Hall), and *C. obmaxima* McChesney are in Allan, Rutherford, and Warren's faunal list (1, p. 239). All specimens resembling these species are regarded as variations in the species *C. lata* or as stages in its development. There do not appear to be any vertical trends in the variation. The writer regards this genus as an unsatisfactory zone fossil, and believes that reference of solitary specimens of it to species of remote localities on the basis of form is of little value in correlation.

Of the Strophomenacea, the productids are common, but few in species. *Dictyoclostus jasperensis* is the most prolific species. It is characteristic of the *Spirifer albertensis* faunule. No evolutionary development of the productids was noticeable.

## FOSSIL LOCALITIES

| Locality | Formation | Geographic position | Illustration | Species collected |
|---|---|---|---|---|
| 2 | Banff | Windy Point | Figure 6 | *Brachythyris chouteauensis* Weller |
| 3 | Banff | Windy Point | Figure 6 | *Spirifer greenockensis* n.sp. |
| 5 | Banff | Windy Point | Figure 6 | *S. greenockensis* n.sp. |
| 7 | Banff | Windy Point | Figure 6 | *Chonetes* cf. *logani* Norwood and Pratten |
| | | | | *Cliothyridina lata* Shimer |
| | | | | *Leptaena analoga* (Phillips) |
| | | | | *Productella* cf. *pyxidata* Hall |
| | | | | *Spirifer esplanadensis* n.sp. |
| | | | | *S. greenockensis* n.sp. |
| 9 | Banff | Summit of Esplanade Mountain | Figure 6 | *Rhipidomella missouriensis* (Swallow) |
| 10 | Banff | Windy Ridge | Figure 6 | *Chonetes* cf. *logani* N. and P. |
| | | | | *Composita* cf. *humilis* (Girty) |
| | | | | *Composita immatura* (Girty) |
| | | | | *Dielasma* cf. *chouteauensis* Weller |
| | | | | *Linoproductus ovatus* (Hall) |
| | | | | *Spirifer greenockensis* n.sp. |
| | | | | *S. esplanadensis* n.sp. |
| 13 | Banff | Cobblestone Creek | Figure 9 | *Camarotoechia chouteauensis* Weller |
| | | | | *C. tuta* (Miller) |
| | | | | *Cliothyridina lata* Shimer |
| | | | | *Composita athabaskensis* (Girty) |
| | | | | *C. humilis* (Girty) |
| | | | | *Dictyoclostus arcuatus* (Hall) |
| | | | | *D. jasperensis* (Warren) |
| | | | | *Eumetria osagensis* (Swallow) |
| | | | | *Linoproductus ovatus* (Hall) |
| | | | | *Platyrachella rutherfordi* (Warren) |
| | | | | *Spirifer albertensis* Warren |
| | | | | *S. esplanadensis* n.sp. |
| | | | | *Torynifer pseudolineata* var. *jasperensis* n.var. |

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|---|---|---|---|---|
| 16 | Rundle | Cobblestone Creek | Figure 9 | *Camarotoechia allani* var. *circularis* n.var. |
| | | | | *C. cobblestonensis* n.sp. |
| | | | | *Cliothyridina lata* Shimer |
| | | | | *Composita athabaskensis* var. *esplanadensis* n.var. |
| | | | | *Dictyoclostus gallatinensis* (Girty) |
| | | | | *Punctospirifer solidirostris* (Hall) |
| | | | | *P. subtexta* (Hall) |
| | | | | *Spirifer minnewankensis* Shimer |
| 19 | Banff | Windy Point | Figure 6 | *Camarotoechia allani* Warren |
| | | | | *C. chouteauensis* Weller |
| | | | | *C. tuta* (Miller) |
| | | | | *Composita athabaskensis* Warren |
| | | | | *C. humilis* (Girty) |
| | | | | *C. immatura* (Girty) |
| | | | | *Dictyoclostus arcuatus* (Hall) |
| | | | | *D. gallatinensis* (Girty) |
| | | | | *D. jasperensis* (Warren) |
| | | | | *Eumetria osagensis* (Swallow) |
| | | | | *Linoproductus ovatus* (Hall) |
| | | | | *Punctospirifer solidirostris* (Hall) |
| | | | | *Spirifer albertensis* Warren |
| | | | | *S. esplanadensis* n.sp. |
| | | | | *Syringothyris hannibalensis* (Swallow) |
| | | | | *Torynifer pseudolineata* var. *jasperensis* n.var. |
| 33 | Rundle | Grassy Ridge | | Colonial corals, unidentified |
| 35 | Greenock | Snaring Ridge | | *Spirifer* n.sp. A |
| | | | | *Brachythyris* n.sp. A |
| | | | | *Eumetria* sp. indet. |
| 38 | Rundle | South end Mount Greenock | Figure 6 | *Spirifer minnewankensis* Shimer |
| 39 | Greenock | Snaring Point | Figure 6 | *Spirifer* n.sp. A |
| | | | | *Brachythyris* cf. n.sp. A |
| | | | | *Eumetria* sp. |
| 55 | Banff | Grassy Ridge | | *Chonetes* cf. *logani* N. and P. |
| | | | | *Platyrachella rutherfordi* (Warren) |
| | | | | *Spirifer* cf. *cascadensis* Warren |
| | | | | *Syringothyris hannibalensis* (Swallow) |
| 56 | Greenock | Grassy Ridge | Figure 7 | *Spirifer* cf. *pellaensis* |
| | | | | *S.* cf. n.sp. A |

FOSSIL LOCALITIES

| Locality | Formation | Geographic position | Illustration | Species collected |
|---|---|---|---|---|
| 57 | Banff | Windy Point | Figure 6 | *Cliothyridina lata* Shimer<br>*Composita athabaskensis* (Warren)<br>*Dictyoclostus arcuatus* (Hall)<br>*D. gallatinensis* (Girty)?<br>*Eumetria osagensis* (Swallow)<br>*Linoproductus ovatus* (Hall)<br>*Platyrachella rutherfordi* (Warren)<br>*Productella* sp.<br>*Spirifer albertensis* Warren |
| 60 | Banff | Windy Ridge | Figure 6 | *Camarotoechia tuta* (Miller)<br>*Linoproductus ovatus* (Hall)<br>*Spirifer greenockensis* n.sp.<br>*Syringothyris hannibalensis* (Swallow)<br>*Torynifer pseudolineata* var. *jasperensis* n.var. |
| 61 | Rundle | Southeast end of Mount Greenock west of Windy Point | Figure 6 | *Camarotoechia allani* var. *greenockensis* n.var.<br>*C. cobblestonensis* n.sp.<br>*Composita athabaskensis* var. *esplanadensis* n.var.<br>*Composita* cf. *madisonensis* var. *pusilla* (Girty) |
| 62 | Rundle | Between Windy and Snaring Ridges | Figure 6 | *Camarotoechia cobblestonensis* n.sp.<br>*Composita* cf. *madisonensis* var. *pusilla* (Girty)<br>*Dictyoclostus gallatinensis* (Girty)<br>*Spirifer minnewankensis* Shimer |
| 63 | Rundle | | Figure 6 | *Dictyoclostus gallatinensis* (Girty) |
| 64 | Banff | Windy Point | Figure 6 | *Cliothyridina lata* Shimer<br>*Dictyoclostus jasperensis* (Warren)<br>*Greenockia snaringensis* n. gen. and sp.<br>*Spirifer esplanadensis* n.sp. |
| 65 | Banff | Windy Point | Figure 6 | *Camarotoechia chouteauensis* Weller<br>*Composita athabaskensis* (Girty)<br>*C. humilis* (Girty)<br>*Dictyoclostus arcuatus* (Hall)<br>*Eumetria osagensis* Weller |

| | | | | |
|---|---|---|---|---|
| 66 | Banff | Windy Point | Figure 6 | *Cliothyridina lata* Shimer<br>*Composita* cf. *humilis* (Girty)<br>*C. immatura* (Girty)<br>*Dictyoclostus jasperensis* (Warren)<br>*Punctospirifer solidirostris* White<br>*Spirifer albertensis* Warren<br>*S. greenockensis* n.sp.<br>*Torynifer pseudolineata* var. *jasperensis* n.var. |
| 70 | Banff | Southeast end of Esplanade Mountain | Figure 9 | *Brachythyris chouteauensis* Weller<br>*Camarotoechia chouteauensis* Weller<br>*Cliothyridina lata* Shimer<br>*Composita immatura* (Girty)<br>*Dictyoclostus arcuatus* (Hall)<br>*D. jasperensis* (Warren)<br>*Eumetria osagensis* (Swallow)<br>*Schellwienella inequalis* (Hall)<br>*Torynifer pseudolineata* var. *jasperensis* n.var. |
| 71 | Banff | Southeast end of Esplanade Mountain | Figure 5 | *Camarotoechia chouteauensis* Weller<br>*Cliothyridina lata* Shimer<br>*Composita athabaskensis* (Girty)<br>*C. immatura* (Girty)<br>*Dictyoclostus arcuatus* (Hall)<br>*D. gallatinensis* (Girty)<br>*D. jasperensis* (Warren)<br>*Eumetria osagensis* (Swallow)<br>*Linoproductus ovatus* (Hall)<br>*Platyrachella rutherfordi* (Warren)<br>*Spirifer albertensis* Warren<br>*Torynifer pseudolineata* var. *jasperensis* n.var. |
| 72 | Banff | Grassy Ridge | Figure 7 | *Brachythyris burlingtonensis* Weller<br>*B. chouteauensis* Weller<br>*Camarotoechia tuta* (Miller)<br>*Camarotoechia chouteauensis* Weller<br>*Cliothyridina lata* Shimer<br>*Composita athabaskensis* (Girty)<br>*Leptaena analoga* (Phillips)<br>*Platyrachella rutherfordi* (Warren)<br>*Schellwienella inequalis* (Hall)<br>*Spirifer greenockensis* n.sp.<br>*S. esplanadensis* n.sp. |

FOSSIL LOCALITIES

| Locality | Formation | Geographic position | Illustration | Species collected |
|---|---|---|---|---|
| 73 | Greenock | East flank Cobblestone Peak | | *Cliothyridina* sp. |
| | | | | *Perditocardinia dubia* (Hall) |
| | | | | *Spirifer* sp. |
| 74 | Greenock | Same as 73 | | cf. *Clisiophyllum banffensis* Warren |
| | | | | Blastoid fragments |
| 76 | Rundle | Cobblestone Creek near 11 | Figure 9 | *Camarotoechia allani* var. *greenockensis* n.var. |
| | | | | *C. cobblestonensis* n.sp. |
| | | | | *Cliothyridina lata* Shimer |
| | | | | *Composita athabaskensis* var. *esplanadensis* n.var. |
| | | | | *Dictyoclostus gallatinensis* (Girty) |
| | | | | *Eumetria* n.sp. |
| | | | | *Spirifer minnewankensis* Shimer |
| 77 | Banff | Southeast end Esplanade Mountain | Figure 9 | *Camarotoechia chouteauensis* Weller |
| | | | | *C. tuta* (Miller) |
| | | | | *Chonetes* cf. *logani* Norwood and Pratten |
| | | | | *Cliothyridina lata* Shimer |
| | | | | *Composita athabaskensis* (Girty) |
| | | | | *C. immatura* (Girty) |
| | | | | *Dictyoclostus arcuatus* (Hall) |
| | | | | *Leiorhynchus* sp. indet. |
| | | | | *Linoproductus ovatus* (Hall) |
| | | | | *Platyrachella rutherfordi* (Warren) |
| | | | | *Productella* cf. *pyxidata* Hall |
| | | | | *Schellwienella inequalis* (Hall) |
| | | | | *Schizophoria* sp. indet. |
| | | | | *Spirifer albertensis* Warren |
| | | | | *S. esplanadensis* n.sp. |
| | | | | *S. marionensis* Shumard |
| | | | | *Torynifer pseudolineata* var. *jasperensis* n.var. |

| | | | | |
|---|---|---|---|---|
| 78 | Banff | Same as 77 | | *Cliothyridina lata* Shimer |
| | | | | *Composita athabaskensis* (Girty) |
| | | | | *Dictyoclostus arcuatus* (Hall) |
| | | | | *D. jasperensis* (Warren) |
| | | | | *Platyrachella rutherfordi* (Warren) |
| | | | | *Rhynchotetra elongata* var. *usheri* n.var. |
| 79 | Banff | Grassy Ridge | Figure 7 | *Camarotoechia chouteauensis* Weller |
| | | | | *Composita immatura* (Girty) |
| | | | | *Cyrtina acutirostris* Shumard |
| | | | | *Productella* cf. *pyxidata* Hall |
| | | | | *Spirifer greenockensis* n.sp. |
| | | | | *Spirifer* cf. *cascadensis* Warren |
| 80 | Greenock | Friendly Peak | Plate II B | *Tetracamera subcuneata* (Hall) |
| 84 | Greenock | South of Morro Creek | | *Brachythyris* n.sp. A |
| 91 | Banff | Morro Creek | Figure 8 | *Camarotoechia chouteauensis* Weller |
| | | | | *C. tuta* (Miller) |
| | | | | *Cliothyridina lata* Shimer |
| | | | | *Composita* aff. *immatura* (Girty) |
| | | | | *Dictyoclostus arcuatus* (Hall) |
| | | | | *D. gallatinensis* (Girty) |
| | | | | *D. jasperensis* (Warren) |
| | | | | *Linoproductus ovatus* Hall |
| | | | | *Rhynchotetra elongata* var. *usheri* n.var. |
| | | | | *Martinia* cf. *rostrata* Girty |
| | | | | *Spirifer albertensis* Warren |
| | | | | *Syringothyris hannibalensis* (Swallow) |
| | | | | *Torynifer pseudolineata* var. *jasperensis* n. var. |
| 92 | Rundle | Morro Creek | Figure 8 | *Composita athabaskensis* var. *esplanadensis* n.var. |
| | | | | *Composita immatura* (Girty) |
| | | | | cf. *Platyrachella rutherfordi* (Warren)? |
| | | | | *Punctospirifer subtexta* (White) |
| | | | | *Schellwienella inequalis* (Hall) |
| | | | | *Spirifer minnewankensis* Shimer |
| 93 | Banff | Morro Creek | Figure 8 | *Platyrachella rutherfordi* (Warren) |
| | | | | *Spirifer* cf. *cascadensis* Warren |
| | | | | *S. greenockensis* n.sp. |
| | | | | *S. marionensis* Shumard |

FOSSIL LOCALITIES

| Locality | Formation | Geographic position | Illustration | Species collected |
|---|---|---|---|---|
| 95 | Banff | Athabasca Point | Figure 10 | *Camarotoechia chouteauensis* Weller |
| | | | | *C. tuta* (Miller) |
| | | | | *Cliothyridina lata* Shimer |
| | | | | *Composita athabaskensis* (Girty) |
| | | | | *Composita immatura* (Girty) |
| | | | | *Dictyoclostus arcuatus* (Hall) |
| | | | | *D. gallatinensis* (Girty) |
| | | | | *D. jasperensis* (Warren) |
| | | | | *Linoproductus ovatus* (Hall) |
| | | | | *Rhynchotetra elongata* var. *usheri* n.var. |
| | | | | *Schellwienella inequalis* (Hall) |
| | | | | *Spirifer albertensis* (Warren) |
| | | | | *Syringothyris hannibalensis* (Swallow) |
| | | | | *Torynifer pseudolineata* var. *jasperenesis* n.var. |
| 96 | Banff | Athabasca Point | Figure 10 | *Cliothyridina lata* Shimer |
| | | | | *Schellwienella inequalis* (Hall) |
| 97 | Rundle | Friendly Peak | Plate II B | *Brachythyris burlingtonensis* Weller |
| | | | | *B. chouteauensis* Weller |
| | | | | *Camarotoechia allani* var. *greenockensis* n.var. |
| | | | | *C. cobblestonensis* n.sp. |
| | | | | *Composita athabaskensis* var. *esplanadensis* n.var. |
| | | | | *Linoproductus ovatus* (Hall) |
| | | | | *Platyrachella rutherfordi* (Warren) |
| | | | | *Rhipidomella* cf. *diminutiva* Rowley |
| | | | | *Spirifer minnewankensis* Shimer |

# CHAPTER VI

## COMPARISON OF THE MOUNT GREENOCK FAUNAL SUCCESSION WITH OTHER AREAS IN ALBERTA, MONTANA, AND WYOMING

### COMPARISON WITH OTHER SECTIONS IN ALBERTA

The Banff region contains the type sections of the Carboniferous formations that have been applied to the Canadian Rocky Mountains. The present formational nomenclature is shown in Figure 16.

The strata are all recorded in McConnell's reconnaissance (20). Kindle's summary (16, p. 115) shows the evolution of terminology for Carboniferous strata, beginning with McConnell's application of the term Banff to Devonian, Carboniferous, and Triassic strata and ending with Kindle's own column showing Banff, Rundle, and Rocky Mountain quartzite. Recently Warren (34) subdivided the Rocky Mountain formation into upper (Mount Norquay) and lower (Tunnel Mountain) members.

Kindle designated the north slope of Mount Rundle the type section for the Rundle formation. Beales (3, p. 2) states that the type section of the Banff formation is on the north end of Mount Rundle, and (p. 4) that of the Rocky Mountain formation is on the south face of Tunnel Mountain.

The relations of the Mount Greenock Carboniferous succession to the one in the Banff and Crowsnest regions is shown by comparison of the brachiopod faunas. It is to be noted that a Kinderhook fauna is represented in the Banff formation in the area between Banff and Jasper, but the thick section in the Crowsnest area has so far proved to contain no fossiliferous Banff equivalent. This has been demonstrated by Warren and others (31, p. 24; 1, p. 239; 33, p. 116).

A comparison of the data accumulated by Warren, Shimer, and Beach (2) in their respective areas with that of the Mount Greenock area leads to the following generalizations:

1. Although some species are common to the Banff formation of these two areas, a large number, judging from the known faunal lists, appear to differ.
2. The typical elements of the *Spirifer rundlensis* fauna are missing in the Mount Greenock area.
3. The *Composita esplanadensis* faunule in the lower Rundle formation of the Mount Greenock area seems to be represented in the basal Rundle formation of the Lake Minnewanka area, but not in the Banff area. It is more comparable with the fauna of the upper Banff beds in that area though not definitely related to it.

The writer concludes that in the Banff and lower Rundle formations of the Canadian Rockies the successive faunules may be scattered, and that the complete succession can only be worked out after a detailed study of many sections.

Recently Laudon (19, p. 295) stated that the Mississippian beds at Banff contain no recognizable Osage (Burlington or Keokuk), and that the massive limestone beds of the lower part of the Rundle carry typical late Kinderhook faunas and correlate with the restricted Mission Canyon

| MOUNT GREENOCK AREA (PRESENT STUDY) | | OUTER ATHABASCA VALLEY | BOW VALLEY: BANFF (Warren, 1927) | | BOW VALLEY: LAKE MINNEWANKA (Shimer, 1926) | | BOW VALLEY: MOOSE MOUNTAIN (Beach, 1943) | | CROWSNEST VALLEY (Warren, 1927, 1933) | | MONTANA (Scott, 1935; Sloss, Hamblin, 1942; Perry, Sloss, 1943; Laird, 1947) | N.W. WYOMING (Branson, 1937) | SCALE OF REFERENCE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Rocky Mountain formation | Indefinite faunule | Rocky Mountain formation | | | | | Quadrant | Quadrant | Permian? |
| | Moosehorn | | | | | | | | | Rocky Mountain formation | Amsden formation | Amsden formation | Penn? |
| *S. n. sp. A.* faunule | Greenock formation | Greenock formation | | | | | | | | | | | Chester |
| | | | *S.* cf. *pellaensis* faunule | Rundle formation | *S.* cf. *pellaensis* faunule | | *S.* cf. *pellaensis* faunule | Rundle formation | *S.* cf. *pellaensis* faunule | Rundle formation | Big Snowy group | Sacajawea formation | Meramec |
| | Rundle formation | Rundle formation | *S. rundlensis* zone | | | Rundle formation | *S. rundlensis* zone | | *S. rundlensis* zone | | Madison Mission Canyon formation | | Osage |
| *S. minnewankensis* faunule | | | Burlington-like faunule | Banff Upper | *S. minnewankensis* faunule | | Burlington-like faunule | Banff Upper | | | | Madison group | |
| *S. albertensis* faunule<br>*S. cascadensis* faunule | Banff formation group | Banff formation | Kinderhook fauna | Middle<br>Lower formation | Kinderhook fauna | Banff formation | Kinderhook fauna | Middle<br>Lower formation | | Banff formation | Lodgepole formation group | | Kinderhook |

G.S.C.

Figure 16. Table showing tentative correlation of Carboniferous strata in the northern Rocky Mountains, based on faunal studies.

section in Montana. Laudon also states that there is a marked unconformity between the Meramec part of the Rundle and the late Kinderhook limestones of the Banff area.

Fossils have not yet been collected from the Banff formation in the Crowsnest area, the lowest Carboniferous fauna yet reported being from the base of the Rundle formation in the *Spirifer rundlensis* zone, dated Burlington-Keokuk by Warren.

Typical elements of this fauna, and of the succeeding brachiopod faunas in the Rundle formation of the Banff-Crowsnest areas, have yet to be found in the Mount Greenock area.

In the Banff-Crowsnest region, no definite local zones have been recognized above that of *Spirifer rundlensis*. However, Warren has recognized in the Rundle limestone a coral fauna with several lithostrotionid species that he correlates with a similar one in the St. Louis limestone of Mississippi Valley occurring below a prolific fauna in which brachiopods are predominant. Warren believes also that this latter faunal development is most probably of late Mississippian (Chester) age. Shimer (27, facing p. 6) had previously recognized a fauna closely similar to Warren's coral fauna in the upper part of the Rundle formation in the Lake Minnewanka area. He dated it as lower Pennsylvanian, but Warren (31, p. 33) contested this view.

If the brachiopod fauna near the top of the Rundle limestone is of Chester age, then it would seem that the basal member, at least, of the Greenock formation of the Mount Greenock area is to be correlated with beds somewhat lower down in the Rundle formation of the Banff area. The coral horizon in the Rundle of the Mount Greenock area is correlated tentatively with the reef horizon described by Warren.

There is no faunal evidence to indicate possible relationship between any part of the Greenock formation and the formation that occupies a similar stratigraphic position in the Bow Valley area, namely, the Rocky Mountain formation. The Rocky Mountain quartzite has been described in some detail from the Cascade-Rundle Ranges at Banff (Warren, 31, pp. 34-38; Beales, 3, pp. 39-45), and also from the Lake Minnewanka area (Shimer, 27, pp. 4, 11-13, 14). It has not been recorded in the front range of the Moose Mountain area by Beach, the basal Triassic (Spray River) beds there resting directly on cherty limestone mapped as Rundle. Shimer's study of the Rocky Mountain formation showed, in the sections examined, three faunal zones, and he regarded the formation as Permian in age.

In the Rocky Mountain formation of the Banff area, Warren listed a fauna almost identical with the one recorded by Shimer. He pointed out the apparent restriction of *Bakewellia parva*, *Plagioglypta canna*, and *Euphemites arenaria* to the uppermost beds of the formation, the occurrence of these species in both Pennsylvanian and Permian strata of North America, and the apparent Pennsylvanian affinity of the remainder of the fauna.

Both Shimer and Warren have recorded '*Spirifer rockymontanus*' from the Rundle and Rocky Mountain formations. A closely similar form was collected by Beach from the Rundle formation of the Moose Mountain area and identified as *Spirifer pellaensis* Weller.

It seems possible that the basal part of the beds in the Banff and Lake Minnewanka sections of the Rocky Mountain formation may be of Mississippian age, that is, if the fauna at the top of the Rundle is Mississippian as it seems to be. The fossils from the Rocky Mountain formation are few and poorly preserved, and it is at present impossible to be certain of the age of the formation in its type area. A detailed study of the vertical variation in specimens of '*Spirifer rockymontanus*' may help in the solution of this problem. There appears to be the possibility that one or all of the Mississippian, Pennsylvanian, and Permian systems may be represented in the type area of the Rocky Mountain formation. Most of the faunal information on the formation has been obtained from sections in the type area, but the uncertainty of these data in itself adds doubt to the age of the unfossiliferous upper part of the Greenock formation.

## COMPARISON WITH SECTIONS IN MONTANA AND WYOMING

The Mount Greenock faunal succession has a slight bearing on that of Montana and Wyoming, and the following brief summary of work on the Carboniferous of these states may serve to illustrate these relationships.

Sloss and Hamblin (29) have shown that the basal unit of the Carboniferous in Montana, the Madison group, can be broken up into two well-defined formations, the Lodgepole, corresponding lithologically and stratigraphically to the Banff formation of Alberta, and the Mission Canyon, corresponding lithologically and stratigraphically to the Rundle formation. They have also demonstrated the wide distribution of these units throughout Montana.

H. W. Scott (25) has summarized the stratigraphy of formations occurring above the Madison group in Montana and Wyoming. He shows that in central Montana the Madison is overlain by another marine succession for which he (p. 1023) proposed the name Big Snowy group. Scott listed bryozoa, brachiopods, pelecypods, and gastropods from the Otter and Heath formations of this group and correlated the group with the Chester of Mississippi Valley, stating that the age is not older than Warsaw or younger than upper Chester. Subsequently, Scott (26) described an ostracod fauna from the Otter formation and dated it Chester, finding the affinities closer to the upper Chester. Easton (10, p. 522) described a coral fauna from the Otter and stated that it appeared to be of Chester age. The next higher Carboniferous formation in this region is the Amsden. It was originally described in northwestern Wyoming by Darton, 1904, and dated Pennsylvanian, but later found to be partly of Mississippian age by Branson and Greger (5).

Branson (4) has given the name Sacajawea to the Mississippian strata previously included in the Amsden, and from it has described a Mississippian fauna of Meramec age. He correlated the Sacajawea tentatively with the unfossiliferous Kibbey formation of the Big Snowy group. Scott (26, p. 152), on the other hand, believed that there may be some Chester beds at the top of the Sacajawea, as indicated by the affinity of the ostracod assemblage to that in the Big Snowy group.

A point of particular interest here is the occurrence in the Sacajawea fauna of *Tetracamera subcuneata* (Hall), one of the few species present in the *Spirifer* n.sp. A faunule of the Mount Greenock area. This species is diagnostic of the Meramec series of Mississippi Valley.

Perry and Sloss (23) discussed the Amsden formation, and noted the fact that the Pennsylvanian strata included in this formation are now referred to the Tensleep formation. They state that there are beds in northwestern Wyoming and southern Montana that are older than Pennsylvanian and younger than the Sacajawea, and they proposed the restriction of the Amsden to these beds. A coral faunule was obtained from the restricted Amsden and dated Chester by Sloss (28, p. 309).

Perry and Sloss further show a series of block diagrams (23, p. 1289) illustrating the palæogeography of the Carboniferous formations of Montana. They show that the restricted Amsden occupies a strip along the south boundary of Montana, bordering the Big Snowy group to the north. They also state that there is an unconformity between these two formations, and that the Amsden overlaps the Big Snowy group from the south. They further show an isopach map of the Big Snowy group illustrating its distribution throughout central and eastern Montana, western North Dakota, northwestern South Dakota, and its presumed extension into western Wyoming, southern Alberta, and southwestern Saskatchewan.

Near the British Columbia border in northwestern Montana, the Yakinikak formation contains a late Mississippian fauna, and is correlated by Sloss (28, p. 309) with parts of the Rundle and Hannan limestone of the Rocky Mountain front.

The foregoing information is included to show that strata having faunal relations with the Meramec and Chester series of Mississippi Valley appear to exist throughout most of Montana and extend into Wyoming, and that they overlie Madison beds that resemble lithologically, and in stratigraphic position, the Rundle formation of Alberta.

J. S. Williams (36) further discusses the question of the Mississippian and Pennsylvanian formations in Montana.

The most comprehensive faunal study to date on strata of this general region is that by Girty (11) on the Palæontology in Yellowstone Park. No recent detailed work has supplemented this early study, and the writer feels that the bearing of the Mount Greenock succession upon it is of interest.

The Carboniferous formations from which the fossils were described are the Madison limestone and the Quadrant quartzite. The Madison limestone proved to be the most fossiliferous, and Girty's study deals almost entirely with it.

Girty included in his monograph a range chart in which the occurrences of species from nine successive horizons were recorded. Information on the succession was partly assembled by Girty from isolated stratigraphic sections, and it is possible that some of his faunal sequences may be open to question. However, this range chart shows faint suggestions of relationship to the Mount Greenock Carboniferous succession. As many species from Bow and Athabasca Valleys have been recorded in common with those of Girty's monograph, it is here thought advisable to analyse Girty's succession so far as the local study will permit. As the Carboniferous palæontology of the Mount Greenock area has been limited here to a study of the brachiopods, the latter alone can be considered. Several species of Carboniferous brachiopods are common to the Mount Greenock area and to the Madison limestone of Yellowstone Park. The writer has been able to compare plaster casts of the types of five of these species with the material from the Mount Greenock area.[1] These species are: *Composita immatura, C. humilis, C. madisonensis, C. madisonensis* var. *pusilla*, and *Dictyoclostus gallatinensis*. Other species common to the two areas were compared by photographs, or by specimens other than the types.

Table I, following, shows brachiopod species occurring in Girty's range table, their range, and the occurrence of these species in the Mount Greenock area in the *Spirifer cascadensis, S. albertensis,* and *Composita esplanadensis* faunules respectively.

Although the grouping of the Madison horizons is, as Girty has stated, partly conjectural, and the ranges of the species are, for the most part, long, a few species do appear to have restricted ranges, such as *Spirifer striatus* var. *madisonensis* and *Composita immatura,* which were found only in the basal bed.

*Composita madisonensis* was found only in the top horizon of those given in Girty's table; *C. madisonensis* var. *pusilla* and *Spirifer centronatus* var. *semifurcatus* were found only in the third to fifth horizons. The latter is close to, if not identical with, *S. minnewankensis* Shimer. It is thus possible that future work will show that both *S. greenockensis* and *S. minnewankensis* must be suppressed as synonyms.

*Composita madisonensis* is very close to the Upper Mississippian C. *trinuclea* and *C. subquadrata,* and identical forms are found high in the Rundle limestone in the Banff and Crowsnest areas. The only other species comparable with the Mount Greenock species, and ranging upward to the top horizon is *Martinia rostrata* Girty. *Composita humilis* ranges from the basal to the sixth horizon, and in the Mount Greenock area occurs throughout the *S. albertensis* zone.

The above information suggests a tentative correlation of the basal two horizons of Girty's Madison limestone section with the *S. cascadensis-albertensis* faunules. It suggests also that horizons 3 to 5 may possibly correspond with the *C. esplanadensis* faunule, as both of the short-ranged species in these beds are found in the latter faunule. The highest horizon, at least, may possibly correspond with those beds high in the Rundle formation of southern Alberta that carry abundant *Composita trinuclea* and *subquadrata.* These species occur in the faunas listed by Scott from the Big Snowy group and the Amsden formation (25, pp. 1022, 1028, 1029). *C. madisonensis* differs from all *Composita* in the *C. esplanadensis* and lower faunules of the Mount Greenock area.

The writer realizes that the above correlation is based on little material, and is dependent on a composite section of the Madison group. Large collections of brachiopods, as well as other organisms, will have to be examined from the Carboniferous deposits of many localities in Wyoming, Montana, and Alberta, before confidence can be felt regarding the detailed correlation of the Banff and Rundle formations of Alberta with corresponding strata in the western United States. However, it is hoped that the preceding observations will serve as a stimulus toward the making of such correlation.

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[1] These specimens were sent to the National Museum of Canada as exchange material through the kindness of Dr. G. A. Cooper, of the United States National Museum.

TABLE I

*Comparison of Brachiopod Species Described by Dr. Girty from Yellowstone Park, Wyoming, with Species Occurring in the Mount Greenock Area, Alberta*

| Occurrence in Mount Greenock area | | | Species from Madison limestone | Occurrence in the Madison limestone in Wyoming | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *S. cascadensis* faunule | *S. albertensis* faunule | *C. esplanadensis* faunule | | Basal horizon | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Top horizon |
| | x | x | *Productus laevicostata* = *P. ovatus* | x | x | x | x | x | x | | x | x |
| | x | x | *Productus gallatinensis* | x | x | x | x | | | x | | |
| | | x | *Spirifer centronatus* var. *semifurcatus* | | | x | x | x | | | | |
| x | x | | *Spirifer greenockensis* n.sp.? | x | | | | | | | | |
| | x | | *Martinia rostrata* | x | x | x | x | | | x | x | x |
| | ? | | *Reticularia cooperensis* var. | | x | | | x | | | | |
| x | x | | *Brachythyris peculiaris* (figure looks like *B. chouteauensis*) | x | | x | | | | | | |
| | ? | | *Eumetria verneuiliana* | x | x | x | x | x | | | | |
| | | | *Composita madisonensis* Girty | | | | | | | | | x |
| | | ? | *Composita madisonensis* var. *pusilla* | | | x | | x | | | | |
| ? | x | x | *Composita humilis* | x | | x | x | x | | | | |
| x | x | ? | *Composita immatura* | x | | | | | | | | |

NOTE: These species only represent part of the brachiopod fauna that Girty described from the Madison limestone of Yellowstone Park (11, pp. 484-486).

# CHAPTER VII

## DESCRIPTION OF CARBONIFEROUS BRACHIOPODS

### CLASSIFICATION TABLE

Order, **PROTREMATA** Beecher, 1891
- Superfamily, ORTHACEA Walcott and Schuchert, 1908
  - Family, RHIPIDOMELLIDAE Schuchert, 1913
    - Genus, *Perditocardinia* Schuchert and Cooper, 1931
      - *Perditocardinia dubia* (Hall)
    - Genus, *Rhipidomella* Oehlert, 1890
      - *Rhipidomella* cf. *diminutiva* Rowley
      - *Rhipidomella missouriensis* (Swallow)
  - Family, SCHIZOPHORIIDAE Schuchert, 1929
    - Subfamily, SCHIZOPHORIINAE
      - Genus, *Schizophoria* King
        - *Schizophoria* sp. indet.
- Superfamily, STROPHOMENACEA Schuchert, 1896
  - Family, STROPHOMENIDAE King, 1846
    - Subfamily, RAFINESQUINAE Schuchert, 1893
      - Genus, *Leptaena* Dalman, 1828
        - *Leptaena analoga* (Phillips)
    - Subfamily, ORTHOTETINAE Waagen, 1884
      - Genus, *Schellwienella* Thomas, 1910
        - *Schellwienella inequalis* (Hall)
  - Family, CHONETIDAE Hall and Clarke, 1895
    - Genus, *Chonetes* Fischer, 1837
      - *Chonetes* cf. *logani* Norwood and Pratten
  - Family, PRODUCTIDAE Gray, 1840
    - Subfamily, PRODUCTELLINAE Schuchert, 1929
      - Genus, *Productella* Hall, 1867
        - *Productella* cf. *pyxidata* Hall
        - *Productella* sp.
    - Subfamily, PRODUCTINAE Waagen, 1884
      - Genus, *Dictyoclostus* Muir-Wood, 1930
        - *Dictyoclostus arcuatus* (Hall)
        - *Dictyoclostus gallatinensis* (Girty)
        - *Dictyoclostus jasperensis* (Warren)
      - Genus, *Linoproductus* Chao, 1927
        - *Linoproductus ovatus* Hall

Order, **TELOTREMATA** Beecher, 1891

Superfamily, RHYNCHONELLACEA Schuchert, 1896

Family, CAMAROTOECHIIDAE Schuchert, 1929

Subfamily, CAMAROTOECHIINAE Schuchert, 1929

Genus, *Camarotoechia* Hall and Clarke, 1893
*Camarotoechia allani* Warren
*Camarotoechia allani* var. *circularis* n.var.
*Camarotoechia allani* var. *greenockensis* n.var.
*Camarotoechia chouteauensis* Weller
*Camarotoechia cobblestonensis* n.sp.
*Camarotoechia tuta* (Miller)

Genus, *Greenockia* n.gen.
*Greenockia snaringensis* n.sp.

Genus, *Leiorhynchus* Hall, 1860
*Leiorhynchus* sp. indet.

Genus, *Rhynchotetra* Weller, 1910
*Rhynchotetra elongata* var. *usheri* n.var.

Genus, *Tetracamera* Weller, 1910
*Tetracamera subcuneata* (Hall)

Superfamily, TEREBRATULACEA Waagen, 1883

Family, DIELASMATIDAE Schuchert, 1913

Genus, *Dielasma* King, 1859
*Dielasma* cf. *chouteauensis* Weller

Superfamily, SPIRIFERACEA Waagen, 1883

Family SPIRIFERIDAE King 1846

Subfamily, SPIRIFERINAE Schuchert, 1913

Genus, *Platyrachella* Fenton and Fenton, 1924
*Platyrachella* rutherfordi (Warren)
cf. *Platyrachella rutherfordi* (Warren)

Genus, *Spirifer* Sowerby, 1818
*Spirifer albertensis* Warren
*Spirifer* cf. *cascadensis* Warren
*Spirifer esplanadensis* n.sp.
*Spirifer greenockensis* n.sp.
*Spirifer marionensis* Shumard
*Spirifer minnewankensis* Shimer
*Spirifer* n.sp. A

Genus, *Brachythyris* McCoy, 1844
*Brachythyris burlingtonensis* Weller
*Brachythyris chouteauensis* Weller
*Brachythyris* n.sp. A

Subfamily, SYRINGOTHYRINAE Schuchert, 1929

Genus, *Syringothyris* Winchell, 1863
*Syringothyris hannibalensis* (Swallow)

Subfamily, RETICULARIINAE Waagen, 1883
Genus, *Torynifer* Hall and Clarke, 1895
*Torynifer pseudolineata* var. *jasperensis* n.var.

Subfamily, MARTINIINAE Waagen, 1883
Genus, *Martinia* McCoy, 1884
*Martinia* cf. *rostrata* Girty

Family, SPIRIFERINIDAE Davidson, 1884
Subfamily, CYRTININAE Schuchert, 1929
Genus, *Cyrtina* Davidson, 1858
*Cyrtina acutirostris* (Shumard)

Subfamily, SPIRIFERININAE Schuchert and LeVene, 1929
Genus, *Punctospirifer* North, 1920
*Punctospirifer solidirostris* (White)
*Punctospirifer subtexta* (White)

Superfamily, ROSTROSPIRACEA Schuchert and LeVene, 1929
Family, ATHYRIDAE Phillips, 1841
Subfamily ATHYRINAE Waagen, 1883
Genus, *Cliothyridina* Buckman, 1906
*Cliothyridina lata* Shimer

Genus, *Composita* Brown, 1849
*Composita athabaskensis* Warren
*Composita athabaskensis* var. *esplanadensis* n.var.
*Composita humilis* (Girty)
*Composita* cf. *humilis* (Girty)
*Composita immatura* (Girty)
*Composita* cf. *madisonensis pusilla* (Girty)

Family, THECASPIRIDAE
Genus, *Eumetria* Hall, 1895
*Eumetria osagensis* (Swallow)
*Eumetria* n.sp.
*Eumetria* sp. indet.

## DESCRIPTION OF SPECIES

### Genus, *Perditocardinia* Schuchert and Cooper, 1932

#### *Perditocardinia dubia* (Hall)

*Orthis dubia* Hall, Trans. Albany Inst., vol. 4, p. 12, 1856.

*Orthis cooperensis* Swallow, Trans. St. Louis Acad. Sci., vol. 2, p. 82, 1863.

*Orthis dubia* Whitfield, Bull. Am. Mus. Nat. Hist., vol. 1, p. 45, Pl. 6, figs. 1-5, 1882. Hall, 12th Ann. Rept. Geol. Surv. Ind., p. 324, Pl. 29, figs. 1-5, 1883. Hall and Clarke, Pal. N.Y., vol. 8, pt. 1, Pl. 12, figs. 10-13, 1892. Keyes, Mo. Geol. Surv., vol. 5, p. 64, 1894.

*Rhipidomella dubia* Beede, 30th Ann. Rept. Geol. Surv. Ind., p. 1303, Pl. 22, figs. 1-4, 1906. Weller, Mon. Ill. State Geol. Surv., vol. 1, p. 160, Pl. 20, figs. 22-26, Pl. 83, figs. 9-10, 1914.

*Perditocardinia dubia* Schuchert and Cooper, Amer. Jour. Sci., ser. 5, vol. 22, p. 246, 1931; Mem. Peabody Mus. Nat. Hist., vol. iv, pt. 1, p. 135, Pl. 19, figs. 12, 14-17, 20-22, 1932.

*Perditocardinia dubia* Cooper in Shimer and Schrock, Index Fossils of North America, p. 355, Pl. 139, figs. 30-34, 1944.

*Remarks.* Two silicified pedicle valves and one brachial valve are externally identical with Hall's species but were not examined internally. There are 4 striæ to 1 mm. at the anterior of the largest specimen. The outline of this shell is similar to that of *Rhipidomella cascadensis* Warren, but the latter is much larger.

*Occurrence.* Greenock formation; locality 73.

### Genus, *Rhipidomella* Oehlert, 1890

#### *Rhipidomella* cf. *diminutiva* Rowley

*Rhipidomella diminutiva* Rowley, Am. Geol., vol. 25, p. 261, Pl. 5, figs. 41-43, 1900. Weller, Mon. Ill. State Geol. Surv., vol. 1, p. 153, Pl. 20, figs. 9-18, 30-35, 1914.

*Remarks.* A single almost complete specimen, with shell partly removed; agrees with typical specimens of this species in all respects but size. It is 10·2 mm. long and 10 mm. wide, and has 13 striæ in a space of 3 mm. at the anterior margin.

*Occurrence.* Rundle formation, basal beds; locality 97.

#### *Rhipidomella missouriensis* (Swallow)

*Orthis missouriensis* Swallow, Trans. St. Louis Acad. Sci., vol. 1, p. 639, 1860. Hall and Clarke, Pal. N.Y., vol. 8, pt. 1, Pl. 6A, figs. 16-17.

*Rhipidomella missouriensis* Rowley, Mo. Bureau Geol. and Mines, vol. 8, 2nd ser., p. 78, Pl. 17, figs. 43-47. Weller, Mon. Ill. State Geol. Surv., vol. 1, p. 148, Pl. 20, figs. 1-8, 1914. Williams, Prof. Paper U.S. Geol. Surv., No. 203, p. 72.

*Remarks.* Three pedicle interiors show the characteristic ornamentation, small beak, and pedicle muscle impressions of this species. The best preserved specimen has 16 striæ in 5 mm.

*Occurrence.* Banff formation, Upper member; locality 9.

### Genus, *Schizophoria* King, 1850

#### *Schizophoria* sp. indet.

*Remarks.* A single partly preserved pedicle exterior is specifically indeterminate. It is about 20 mm. long and 24 mm. wide, and contains about 10 striæ in a width of 5 mm. at the anterior margin.

*Occurrence.* Banff formation, Upper member; locality 77.

### Genus, *Leptaena* Dalman, 1828

#### *Leptaena analoga* (Phillips)

*Producta analoga* Phillips, Geol. Yorkshire, vol. 2, p. 215, Pl. 7, fig. 10, 1836.

*Strophomena rhomboidalis* var. *analoga* Davidson, Brit. Foss. Brach., vol. 2, p. 119, Pl. 28, figs. 1-2, 1859.

*Strophomena rhomboidalis* White, Prelim. Rept. Inv. Foss., p. 17, 1874. U.S. Geog. Survs. W. 100 Mer., vol. 4, p. 85, Pl. 5, fig. 5, 1877. Hall and Whitfield, U.S. Geol. Expl. 40th Par., vol. 4, p. 253, Pl. 4, fig. 4, 1877. Herrick, Bull. Sci. Lab. Denison Univ., vol. 4, Pl. 9, fig. 6, 1889.

*Leptaena rhomboidalis* Hall and Clarke, Int. to Study of Brach., pt. 1, Pl. 13, fig. 9, 1892.

*Plectambonites rhomboidalis* Keyes, Mo. Geol. Surv., vol. 5, p. 70, Pl. 39, fig. 6, 1894.

*Strophomena rhomboidalis* Herrick, Geol. Surv. Ohio, vol. 7, Pl. 20, fig. 6, 1895.

*Leptaena rhomboidalis* Girty, Mon. U.S. Geol. Surv., vol. 32, p. 525, 1899. Prof. Paper U.S. Geol. Surv. No. 21, p. 48, Pl. 10, fig. 3, 1904. Weller, Bull. Geol. Soc. Amer., vol. 20, p. 292, Pl. 12, figs. 2-3, 1909.

*Leptaena analoga* Weller, Mon. Ill. State Geol. Surv., vol. 1, p. 49, Pl. 2, figs. 1-10, 1914. Shimer, Bull. Geol. Surv., Canada, No. 42, p. 32. Branson, Univ. Mo. Studies, vol. 13, No. 3, p. 24, Pl. 5, fig. 31. Cooper, in Shimer and Shrock, Index Fossils of N.A., p. 343, Pl. 132, figs. 28, 29.

*Remarks.* Several more or less incomplete specimens of separate pedicle and brachial exteriors occur in argillaceous limestones. An almost complete pedicle valve measures 19 mm. in length and 29 mm. in width, and has 10 concentric wrinkles posterior to the geniculation.

*Occurrence.* Banff formation, Upper member; localities 7, 72.

### Genus, *Schellwienella* Thomas, 1910

#### *Schellwienella inequalis* (Hall)

*Orthis inequalis* Hall, Geol. Iowa, vol. 1, pt. 2, p. 490, Pl. 2, figs. 6a-c, 1858.

*Streptorhynchus inequalis* Winchell, Proc. Am. Phil. Soc., vol. 11, p. 251, 1865.

*Streptorhynchus equivalvis* Hall and Whitfield, U.S. Geol. Expl. 40th Par., vol. 4, p. 252, Pl. 4, figs. 1, 2, 1877.

*Orthothetes inequalis* Hall and Clarke, Pal. N.Y., vol. 8, pt. 1, Pl. 9a, figs. 20-23, 1892. Girty, Mon. U.S. Geol. Surv., vol. 32, p. 522, Pl. 68, fig. 3a, 1899. Weller, Trans. St. Louis Acad. Sci., vol. 11, pp. 159 and 195, Pl. 14, figs. 16-18, and Pl. 19, fig. 9, 1901. Girty, Prof. Paper U.S. Geol. Surv. No. 16, p. 276, 1903.

*Schellwienella inequalis* Weller, Mon. Ill. State Geol. Surv., vol. 1, p. 67, Pl. 3, figs. 14-16, 1914. Shimer, Geol. Surv., Canada, Bull. No. 42, p. 35, 1926.

*Occurrence.* Banff formation, Upper member; Rundle limestone, lower part; localities 70, 72, 77, 92, 95, 96.

### Genus, *Chonetes* Fischer, 1837

#### *Chonetes* cf. *logani* Norwood and Pratten

*Chonetes logani* Norwood and Pratten, Jour. Acad. Nat. Sci. Phil. (2), vol. 3, p. 30, Pl. 2, figs. 12 a-c, 1855. Winchell, Proc. Acad. Nat. Sci. Phil., p. 116, 1865. Hall, Pal. N.Y., vol. 3, Pl. 22, figs. 23, 26-27, 1867. Herrick, Bull. Sci. Lab. Denison Univ., vol. 3, p. 35, Pl. 7, fig. 22, Pl. 3, fig. 12, 1888. Hall and Clarke, Pal. N.Y., vol. 8, pt. 1, Pl. 16, fig. 25, 1892. Keyes, Mo. Geol. Surv., vol. 5, p. 53. Weller, Trans. St. Louis Acad. Sci., vol. 11, p. 182, Pl. 16, figs. 10-11, 1901. Weller, Bull. Geol. Soc. Am., vol. 20, p. 299, Pl. 12, figs. 12-13.

*Remarks.* The local specimens are slightly less convex than *C. logani*, and have 4 costæ in 1 mm., close to the anterior. They resemble *C. ornatus* Shumard in all but the fine costation.

*Occurrence.* Banff formation, Upper member, localities 7, 10, 55, 77.

## Genus, *Productella* Hall, 1867

### *Productella* cf. *pyxidata Hall*

*Productus pyxidatus* Hall, Iowa Geol. Surv., vol. 1, pt. 2, p. 498, Pl. 3, figs. 8a-e, 1858.
*Productus shumardianus* Hall (part) idem, vol. 1, pt. 2, p. 499, Pl. 3, fig. 9 (*not* Pl. 7, fig. 2), 1858.
? *Productella pyxidata* Hall, N.Y. State Geologist Rept. for 1882, Pl. (18) 48, fig. 34, 1883.
*Productus pyxidata* Walcott, U.S. Geol. Surv. Mon. 8, p. 130, 1884.
*Productella pyxidata* Hall and Clarke, New York State Geologist Eleventh Ann. Rept., Pl. 21, figs. 20, 23, 1892. Hall and Clarke, Palæontology of New York, vol. 8, pt. 1, Pl. 17A, fig. 14. Keyes, Missouri Geol. Surv., vol. 5, p. 52, Pl. 38, figs. 4a-d, 1894. Weller, U.S. Geol. Surv. Bull. 153, p. 481. Rowley, Missouri Bur. Geol. and Mines, 2d ser., vol. 8, p. 77, Pl. 17, figs. 5, 30-36, 1908. Weller, Mon. Ill. Geol. Surv., vol. 1, p. 100, Pl. 19, figs. 1-21, 1914.
*Productella pyxidata?* Girty, U.S. Geol. Surv. Bull. 598, p. 34, 1915.
*Productella pyxidata* Shimer, Geol. Surv., Canada, Bull. No. 42, p. 37, 1926. Cooper, Oklahoma Geol. Surv., Circ. 9, p. 21, 1926. Moore, Missouri Bur. Geol. and Mines, 2d. ser., vol. 21, p. 265, 1928.

*Remarks.* Three local imperfectly preserved specimens are similar to *P. pyxidata*, but are larger and more convex than typical representatives of that species.

*Occurrence.* Banff formation, Upper member; localities 7, 77, 79.

### *Productella ?* sp.

*Remarks.* Several small poorly preserved specimens are specifically unidentifiable.

*Occurrence.* Banff formation, Upper member; localities 13, 57, 72.

## Genus, *Dictyoclostus* Muir-Wood, 1930

The following three productoid species possess the diagnostic characters of *Dictyoclostus*, including the semireticulate pedicle exterior and the absence of a diaphragm in the pedicle valve.

### *Dictyoclostus gallatinensis* (Girty)

*Productus gallatinensis* Girty, Mon. U.S. Geol. Surv., vol. 32, pt. 2, Pl. 68, figs. 7a, b, c, and 11a, b, c, d.

*Occurrence.* Banff formation, Upper member; localities 19, 57, 71, 91, 95; Rundle formation, lower part; localities 16, 62, 63, 76.

### *Dictyoclostus jasperensis* (Warren)

*Productus jasperensis* Warren, Trans. Roy. Soc., Canada, sec. IV, 3rd ser., vol. XXVI, pp. 245-247, Pl. II, figs. 16-21, 1932.

*Occurrence.* Banff formation, Upper member; localities 13, 19, 64, 66, 71, 78, 91, 95.

### *Dictyoclostus arcuatus* (Hall)

*Productus arcuatus* Hall, Geol. Iowa No. 1, pt. 2, p. 518, Pl. 7, figs. 4a-b, 1858. Proc. Amer. Phil. Soc., vol. 2, p. 250, 1870. Rept. N.Y. State Geol. for 1882, Pl. (17) 48, figs. 31, 32, 1883. Herrick, Bull. Sci. Lab. Denison Univ., vol. 3, p. 31, Pl. 3, fig. 18, 1888. Hall and Clarke, Pal. N.Y., vol. 8, pt. 1, Pl. 17, figs. 31, 32, 1892. Keyes, Mo. Geol. Surv., vol. 5, p. 40, 1894. Weller, Trans. St. Louis Acad. Sci., vol. 2, p. 160, Pl. 14, fig. 23, p. 185, Pl. 16, fig. 15, 1901. Weller, Mon. Ill. State Geol. Surv., p. 107, Pl. 13, figs. 1-8, 9-12, 1914.

*Occurrence.* Banff formation, Upper member; localities 13, 19, 57, 65, 70, 71, 77, 78, 91, 95.

## Genus, *Linoproductus* Chao, 1927

### *Linoproductus ovatus* Hall

*Productus ovatus* Hall, Geol. Iowa, vol. 1, pt. 2, p. 674, Pl. 24, fig. 1, 1858.
*Productus pileiformis* McChesney, Desc. New Pal. Foss., p. 40, 1859.
*Productus laevicostus* White, Jour. Boston Soc. Nat. Hist., vol. 7, p. 230, 1860.
*Productus cordeformis* Swallow, Trans. St. Louis Acad. Sci., vol. 2, p. 94, 1863.
*Productus prattenianus* (-? *P. laevicostus*) White, Prelim. Rept. Inv. Foss., p. 17, 1874 (pars.). White, U.S. Geog. Surveys W. 100th Mer., vol. 4, p. 113, 1877.
*Productus laevicostus* ? Hall and Whitfield, U.S. Geol. Expl. 40th Par., vol. 4, p. 266, Pl. 5, figs. 7, 9, 1877.
*Productus ovatus* Hall, Rept. N.Y. State Geol. for 1882, Pl. (18) 49, fig. 19, 1883.
*Productus pileiformis* Whitfield, Ann. N.Y. Acad. Sci., vol. 5, p. 582, Pl. 13, figs. 13-14, 1891.
*Productus ovatus* Hall and Clarke, Pal. N.Y., vol. 8, pt. 1, Pl. 18, fig. 19, 1892.
*Productus laevicostus* Keyes, Mo. Geol. Surv., vol. 5, p. 41, Pl. 38, fig. 1, also p. 44, 1894.
*Productus pileiformis* Whitfield, Geol. Surv. Ohio, vol. 7, p. 470, Pl. 9, figs. 13-14, 1895.
*Productus laevicosta* Girty, Mon. U.S. Geol. Surv., vol. 32, p. 534, Pl. 69, figs. 9a-c, 1899. Weller, Trans. St. Louis Acad. Sci., vol. 10, p. 71, Pl. 1, figs. 1, 2, 1900. Girty, Prof. Paper, U.S. Geol. Surv., No. 16, p. 284, 1903.
*Productus pileiformis* Girty, Bull. U.S. Geol. Surv. No. 377, p. 26, Pl. 2, fig. 7, 1909. U.S. Geol. Surv. No. 439, p. 44, Pl. 4, figs. 1-2, 1911. Morse, Proc. Ohio State Acad. Sci., vol. 5, p. 370, figs. 8a-c, 1911.
*Productus ovatus* Weller, Mon. Ill. State Geol. Surv., vol. 1, p. 132, Pl. 16, figs. 1-15, 1914. Cooper, in Shimer and Schrock, p. 351, Pl. 137, figs. 32-34, 1944.

*Occurrence.* Banff formation, Upper member; localities 10, 13, 19, 57, 71, 77, 91, 95; Rundle formation, lower part; locality 97.

## Genus, *Camarotoechia* Hall and Clarke, 1893

### *Camarotoechia allani* Warren

*Camarotoechia allani* Warren, Trans. Roy. Soc., Canada, sec. IV, 3rd ser., vol. XXVI, 1932, p. 244, Pl. II, figs. 12-15, 1932.

*Remarks.* It has been difficult to find specimens that in any one bed show range in variation of rib number indicated by Warren in his description of this species. Specimens from locality 19C, however, have from 5 to 8 in the sinus and about 9 to 12 on each flank. These specimens differ from Warren's cotypes only in being slightly smaller. However, they grade in rib number imperceptibly into specimens of similar shape that are referable to *C. chouteauensis*.

*Occurrence.* Banff formation, Upper member; locality 19.

### *Camarotoechia allani* var. *circularis* n.var.

Plate IV, figure 4

*Description.* Outline circular; fold and sinus poorly marked, and only in anterior fourth of shell; costæ 22 to 27, roundly angular, with roundly angular interspaces of the same size.

Pedicle valve shallow, beak small, slightly incurved, umbonal area moderately full to silght, postero-lateral slopes slightly convex to slightly concave.

Brachial valve moderately and evenly convex; fold containing 5 costæ.

*Types and Dimensions*

| Type | G.S.C. Cat. No. | Length | Width | Height | Rib total |
|---|---|---|---|---|---|
| | | mm. | mm. | mm. | |
| Holotype............ | 9175 | 15 | 15 | 9 | 27 |
| Paratype............ | 9176 | 15 | 16 (Est.) | 8 | 22 |

*Remarks.* This variety differs from typical *C. allani* in tending to be subcircular rather than subtrigonal, and in having a poorly differentiated sinus.

*Occurrence.* Rundle formation; locality 16.

*Camaratoechia allani* var. *greenockensis* n.var.

Plate IV, figures 1 a-c

*Description.* Outline subtrigonal to subpentagonal, total rib number varying from 18 to 27. Pedicle valve slightly convex, with sinus well marked in anterior half to third of shell, containing 4 to 7 roundly angular costæ with more angular interspaces; lingual extension slightly to moderately prominent; beak sharply pointed, gently curved to almost erect; umbonal area scarcely differentiated from rest of valve.

Pedicle muscle field usually long and narrow, generally extending to middle of valve, with subparallel sides and gently convex anterior margin; sides more rarely diverging gently anteriorly.

Brachial valve convex, with obscure bend in convexity just anterior to middle of shell.

*Types and Dimensions*

| Type | No. | Length | Width | Height | Pedicle muscle area | |
|---|---|---|---|---|---|---|
| | | | | | Length | Width |
| | | mm. | mm. | mm. | mm. | mm. |
| Holotype......... | 9177 | 11·9 | 11·5 | | | |
| Paratype......... | A 9178 | 11·0 | 13·0 | 7 | | |
| Paratype......... | B 9179 | 13·6 | 13·9 | 6·0 | 5·7 | 3·6 |

*Remarks.* Differs from *C. allani* in being much less obese, in having a slightly more acuminate beak, and in having from 5 to 8 ribs on the fold and 7 to 11 on the flanks.

*Occurrence.* Rundle formation, lower part; localities 61, 97, 76; type locality 61.

### *Camarotoechia cobblestonensis* n.sp.

Plate IV, figures 3 a-d

*Description.* Shell roundly subpentagonal, wider than long, rather strongly convex. Pedicle valve moderately convex, with well-marked sinus having prominent anterior lingual extension and having its greatest width equal to slightly less than half greatest width of shell; beak not well preserved in largest specimens, but seemingly moderately curved, prominent, and erect, in adolescent stages. In an immature topotype from locality 97 the deltidial plates are visible, are higher than wide; the broadly triangular cardinal area is separated by a sharp angle from the adjacent narrow pseudo-cardinal areas.

Dental lamellæ prominent, not strongly thickened laterally. Brachial valve strongly and evenly convex along median line; greatest convexity on flanks is half-way between beak and anterior margin.

Brachial muscle field ovate, posterior adductors slender, in shallow depression, bordering postero-lateral side of triangular anterior adductors, and curving around posterior ends of the latter.

*Remarks.* *Camarotoechia cobblestonensis* differs from *C. allani* in having 5, rarely 4, costæ on the fold, and in having 6 to 9 on the flanks. The outline is always roundly subpentagonal, whereas that described by Warren is subtrigonal. *C. chouteauensis* is a smaller shell, with from 6 to 8 costæ on the flanks.

*Types and Dimensions*

| Type | No. | Length | Width | Height | Costæ | | Pedicle muscle area | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Sinus | Flank | Length | Width |
| | | mm. | mm. | mm. | | | mm. | mm. |
| Holotype.... | 9181 | 14·9 | 15·9 | 10 | 4 | 0 | | |
| Paratype.... | 9180 | 16·5 | 18·0 | 11·4 | 4 | 6 | 6·3 | 5·8 |

*Occurrence.* Rundle formation, lower part; localities 16, 61, 62, 76, 97; type locality 61.

### *Camarotoechia chouteauensis* Weller

*Camarotoechia chouteauensis* Weller, Bull. Geol. Soc. Amer. 21, p. 510, fig. 10, 1910; Mon. Ill. State Geol. Surv., vol. 1, 1914.

*Remarks.* Specimens from the Mount Greenock area are slightly smaller, the largest having a width of 11·5 mm., but have the characteristic shape of this species. They have from 3 to 4 ribs in the sinus, and from 5 to 8 on each flank.

*Occurrence.* Banff formation, Upper member; localities 13, 19, 65, 70, 71, 72, 77, 79, 91, 95.

### *Camarotoechia tuta* (Miller)

*Rhynchonella tuta* Miller, Jour. Cinn. Soc. Nat. Hist., vol. 4, p. 315, Pl. 7, figs. 11-11b.
*Camarotoechia tuta* Weller, Mon. Ill. State Geol. Surv., vol. 1, p. 179, Pl. XXIV, figs. 9-28, 1914.

*Occurrence.* Banff formation, Upper member; localities 13, 19, 60, 72, 77, 91, 95.

### Genus, *Greenockia* gen. nov.

Medium-sized, costate, non-punctate rhynchonelloid shells with costæ preserved on all parts of shell, including the bordering walls of sinus and fold. Genus characterized internally by covering over crural cavity, making socket plate entire throughout; also by broad, ovate brachial muscle scar, with posterior adductors lying against oblique postero-lateral margins of pear-shaped anterior adductor scar.

*Remarks.* This genus differs externally from *Rhynchopora* King in having a non-punctate shell structure, and slightly finer costæ. It differs from *Moorefieldella* Girty in having an entire hinge, and in having well-marked costæ posteriorly and laterally. *Wellerella* Dunbar and Condra (9, p. 286) differs in having plications that are obsolete posteriorly.

Genotype, *Greenockia snaringensis* n.sp.

### *Greenockia snaringensis* n.sp.

Plate IV, figures 2 a-f

*Description.* Shell subtrigonal, subquadrate or rounded subpentagonal, strongly bi-convex to subangular; anterior commissure with gentle to broad sinus ventrad.

Pedicle valve moderately convex, with broad, flat sinus; beak strongly incurved over brachial valve, obscuring deltidial plates from view in largest specimens; cardinal area two narrow linear extensions from beak; pseudo-cardinal areas narrowly triangular, making broad angles with cardinal areas and passing imperceptibly into incurved postero-lateral slopes; umbonal area only rarely attenuate, usually passing imperceptibly to broadly convex middle part of valve, postero-lateral shoulder broadly rounded; sinus present only in anterior half of adult shell, prolonged anteriorly to broad lingual extension; bordering walls of sinus usually containing one to three costæ, here included with sinal costæ, which number from 6 to 10; flanks containing from 14 to 23 costæ, most commonly 16 to 17; shell substance impunctate.

Pedicle muscle impression flabellate, in depressed area, and having flanks sharply excavated posteriorly; diductor scars sub-trigonal, with concave inner margins uniting anteriorly to enclose elliptical adductor track; adductors slightly depressed, posteriorly; pedicle adjustors slender, forming posterior third of sharply excavated outer edge of muscle area; dental lamellæ usually joined for almost entire length to thickened shell wall; only their bases project anterior to teeth, forming part or all of outer margin of pedicle adjustor scars; vascular markings projected anteriorly from two main trunks that begin at end of sinus in anterior third of shell and curve gently toward postero-lateral extremities of shell. About ten branches extend perpendicularly from trunks toward anterior.

Brachial valve convex, evenly so along median line, slightly greater anteriorly along flanks. Fold well marked on anterior half alone.

Brachial muscle area ovate; anterior adductor track pear-shaped, each adductor separated by slender low ridge; posterior adductors rhomb-shaped, depressed posteriorly and separated posteriorly by well-developed median septum, and antero-laterally by oblique margins of posterior half of anterior adductors; socket plate entire, containing crural cavity united basally to median septum; vascular markings as in pedicle valve, but main trunks usually confined to posterior half of shell.

*Type and Dimensions*

| Type | Type No. | Length | Width | Height | Costæ in sinus | Costæ, total | Pedicle diductor scar, length | Pedicle diductor scar, width | Brachial adductor scar, length | Brachial adductor scar, width | Height of beak above brachial valve | Distance between teeth (approx.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | mm. | mm. | mm. | | | mm. | mm. | mm. | mm. | mm. | mm. |
| Holotype........ | 9183 | 19·6 | 18·7 | 13·0 | 8 | 38 | ...... | 5·5 | ...... | 4·5 | 1 | |
| Paratype A...... | 9187 | ...... | 22·5 | ...... | ...... | ...... | ...... | 7·5 | 5·0 | ...... | ...... | 3·1 |
| " B...... | 9188 | 17·5 | 16·0 | 11·0 | 9 | 37 | 4·5 | 4·0 | 6·4 | 3·7 | ...... | 3·8 |
| " D..... | 9190 | 17·7 | 17·0 | ...... | ...... | ...... | 5·2 | 4·8 | ...... | ...... | ...... | ...... |

*Type Locality.* 65.

*Occurrence.* Banff formation, Upper member; locality 65.

## Genus, *Leiorhynchus* Hall, 1860

### *Leiorhynchus ?* sp. indet.

*Remarks.* One specimen has the shape, size, and ornament characteristic of this genus.

*Occurrence.* Banff formation, Upper member; locality 77.

## Genus, *Rhynchotetra* Weller, 1910

### *Rhynchotetra elongata* var. *usheri* n.var.

Plate V, figures 5 a-c

*Description.* Outline subtrigonal; length greater than width; greatest width in anterior third of shell; sides long, gently convex; anterior margin broadly convex, broadly nasute; rostral part acutely subcuneate.

Pedicle valve depressed convex, greatest convexity posterior to middle; pedicle view shows four angular plications persisting to beak, with deeply concave interspaces; sinus obsolete; posterior lateral margins abruptly deflected towards opposite valve, forming half of a gently concave elliptical area, containing one to two faint indications of branch costæ, which come off the outer main costæ at right angles; beak small, gently incurved; valve covered with finely reticulate pattern due to radial and concentric raised lines; pedicle interior with long dental lamellæ, united basally by low median septum.

Brachial valve flatter than pedicle, containing five simple roundly angular plications, with deeply concave interspaces; ornamentation similar to that on pedicle valve.

Brachial interior with strong median septum supporting crural cavity having margins extending ventrad of hinge plate.

*Type and Dimensions*

| Type | G.S.C. Cat. No. | Length | Width | Height | Number of plications | |
|---|---|---|---|---|---|---|
| | | | | | Ped. valve | Brach. valve |
| | | mm. | mm. | mm. | | |
| Holotype............ | 9194 | 31·8 | 20·0 | 10·3 | 4 | 5 |

*Remarks.* The holotype of *R. elongatum* Weller[1] differs from the local variety in having at least nine plications visible in a pedicle view.

*Occurrence.* Banff formation, Upper member; localities 78, 91, 95.

## Genus, *Tetracamera* Weller, 1910

### *Tetracamera subcuneata* (Hall)

*Rhynchonella subcuneata* Hall, Trans. Albany Inst., vol. 4, p. 11, 1856.
*Rynchonella subcuneata* Hall, Geol. Journ., vol. 1, pt. 2, p. 658, Pl. 23, figs. 3a-c, 1858.
*Rhynchonella perrostellata* Swallow, Trans. St. Louis Acad. Sci., vol. 2, p. 85, 1863.
*Rhynchonella subcuneata* Whitfield, Bull. Amer. Mus. Nat. Hist., vol. 1, p. 51, Pl. 6, figs. 47-49, 1882.
*Rhynchonella subcuneata* Hall, 12th Rept. Geol. Surv. Ind., p. 333, Pl. 29, figs. 47-49, 1883.
*Camarophoria subcuneata* Hall and Clarke, Intro. to Study of Brach., pt. 2, Pl. 45, figs. 3, 4, 1894.
*Rhynchonella subcuneata* Keyes, Mo. Geol. Surv., vol. 5, p. 102, 1894.
*Camarophoria subcuneata* Hall and Clarke, Pal. N.Y., vol. 8, pt. 2, Pl. 62, figs. 34-37, 1895.
*Camarophoria subcuneata* Beede, 30th Ann. Rept. Geol. Surv. Ind., p. 1304, Pl. 22, figs. 47-49, 1906.
*Tetracamera subcuneata* Weller, Bull. Geol. Soc. Amer., vol. 21, p. 503, fig. 4, 1910.
*Tetracamera subcuneata* Weller, Mon. Ill. Geol. Surv., vol. 1, p. 214, Pl. XXVIII, figs. 13-24, 1914.

*Remarks.* Silicified specimens show separate pedicle and brachial valves. A partly etched pedicle valve shows spondylium and buttress plate.

*Occurrence.* Greenock formation, lower member; locality 80.

[1] Weller, S. A.: The Mississippian Brachiopoda of the Mississippi Valley Basin; Ill. Geol. Surv., Mon. 1, 1914.

## Genus, *Dielasma* King, 1859

### *Dielasma* cf. *chouteauensis* Weller

*Dielasma formosa* Hall and Clarke, Pal. N.Y., vol. 8, pt. 2, Pl. 81, fig. 24 (not figs. 12-23, 25-26), 1895.

*Dielasma chouteauensis* Weller, Mon. Ill. State Geol. Surv., vol. 1, p. 257, Pl. 32, figs. 1-17, 1914.

*Remarks.* A slightly distorted specimen is more elongated than is usual for this species; it is 28·4 mm. long and 17·2 mm. wide. A small brachial valve is also present.

*Occurrence.* Banff formation, Upper member; locality 10.

## Genus, *Platyrachella* Fenton and Fenton, 1924

### *Platyrachella rutherfordi* (Warren)

Plate V, figures 6 a-e

*Spirifer rutherfordi* Warren, Trans. Roy. Soc., Canada, 3rd ser., vol. XXVI, sec. IV, p. 247, Pl. II, figs. 1–4, 1932.

*Description.* Outline semi-elliptical, length from $\frac{3}{7}$ to $\frac{2}{3}$ width, cardinal extremities strongly mucronate to subrectangular; hinge line equal to, or, more commonly, greater than width of shell; sides conforming with semi-elliptical outline, or straight in middle part, strongly diverging.

*Types and Dimensions*

| (Pedicle) | Number | Length | Width | Sinus width | Delthyrium | | Number of ribs on one flank |
|---|---|---|---|---|---|---|---|
| | | | | | Height | Width | |
| | | mm. | mm. | mm. | mm. | mm. | |
| Topotype.......... | 9196 | 28 | 41 | 9·7 | 6 | 9 | 16-17 |
| Topotype.......... (brachial) | 9197 | 21 | 45 | 8·5 | | | 24 |

Pedicle valve moderately convex in most specimens, gently convex in a few mucronate examples; convexity always noticeably greater in posterior half, becoming almost flat anteriorly in elongate forms; point of greatest convexity always posterior to middle, close to hinge line in forms with large cardinal areas; beak small, incurved, never quite intersecting plane of commissure; cardinal area broadly triangular, of moderate height, gently curved toward beak; umbonal region low; postero-lateral slope concave near beak, becoming flat midway between beak and cardinal extremities; antero-lateral slope gently and evenly convex; sinus almost always shallow, flat-bottomed, to faintly arched, beginning as narrow groove at beak, widening gradually to $\frac{1}{5}$ or $\frac{1}{4}$ width of shell; sinus marked by complete absence of costæ; height of delthyrium $\frac{2}{3}$ its width; flanks each containing usually 20 broadly rounded costæ of low relief and with narrow interspaces ranging in number from 16 in elongate forms to 25 in mucronate forms; costæ broadly rounded, of low relief, and with narrower interspaces; fine, well-marked, radially arranged tubercles cover entire surface (9 to 15 in 1 mm.), still finer concentric lines commonly preserved; one or two interruptions in growth present; dental lamellæ united close to beak in delthyrial cavity leaving narrow space beneath on floor of valve. Toward hinge line this thickening disappears and thin lamellæ extend anterior to hinge line.

*Remarks.* *P. mesastrialis* Hall, from the Chemung of New York, has a more rounded sinus in the pedicle valve. *Spirifer desiderata* Walcott, from the lower part of the Mississippian section of the Eureka district, Nevada, is a somewhat similar species externally, but is known only from the brachial valve (Walcott, 30, p. 219, Pl. 8, fig. 8).

*Occurrence.* Banff formation, Upper member; localities 13, 55, 57, 71, 72, 77, 78, 93.

### cf. *Platyrachella rutherfordi* (Warren)

*Remarks.* Several small specimens with a faint narrow hollow on the brachial fold are otherwise externally identical with *P. rutherfordi* (Warren).

*Occurrence.* Rundle formation, localities 92, 97.

## Genus, *Spirifer* Sowerby, 1815

### *Spirifer albertensis* Warren

*Spirifer albertensis* Warren, 1932, Trans. Roy. Soc., Canada, sec. IV, vol. XXVI, p. 244, Pl. I, figs. 7-14.

Outline, sub-semicircular; length approximately $\frac{3}{5}$ width; greatest width at hinge line; cardinal extremities mucronate to nearly rectangular; sides sinuate, diverging moderately in middle part; anterior margin gently rounded to slightly nasute; anterior commissure strongly arched medially, flattening laterally.

Pedicle valve convex, particularly in posterior third; beak small, strongly incurved; cardinal area typically narrow, broadly triangular, making an angle of 110 to 140 degrees with plane of commissure at hinge line, and bending or gradually curving dorsad half-way toward apex; delthyrium approximately $\frac{1}{5}$ as wide as hinge line and about $\frac{4}{5}$ as high as wide; postero-lateral slope concave, adjoining moderately prominent umbonal region; median sinus well-marked throughout, narrow and shallow at beak, widening and deepening steadily anteriorly with a longitudinally sub-elliptical cross-section at the anterior margin; lateral costæ from 16 to approximately 21 in number, broadly rounded to roundly angular, of moderate relief, with similar interspaces; sinal costæ number from 5 to 9. Surface covered with fine radial lines approximately 10 to 1 mm.; the middle costæ where not bifurcated, noticeably broader than others; with the striæ, equally fine concentric lines make a reticulate pattern.

Brachial valve about half as convex as pedicle valve; convexity greater in posterior half; beak ill-defined, but umbonal area differentiated from gently concave postero-lateral slope; antero-lateral slope straight; median fold scarcely recognizable at beak, gradually increasing to great prominence at anterior margin; fold roundly angular, with elevation at anterior margin varying from slight to strong; fold containing from 6 to 10 costæ, similar to those on flank; median costa, when unbranched, is wider and more flat-topped than others.

*Types and Dimensions*

| Type | G.S.C. Cat.No. | Length | Width | Height | Delthyrium | | No. of ribs on one flank | No. of ribs in sinus |
|---|---|---|---|---|---|---|---|---|
| | | | | | Height | Width | | |
| | | mm. | mm. | mm. | mm. | mm. | | |
| Plesiotype..... | 9192 | 22 | 36 | 21·5 | | | 20 | 5 |
| Plesiotype..... | 9193 | 28·5 | 39 | 15 | | | 18 | 9 |
| Plesiotype..... | 9195 | 23 | 33 | | 4·0 | 4·5 | 18 | 6 |

*Remarks.* *Spirifer missouriensis*, from the Chouteau limestone of Missouri, is a closely similar form. Its chief difference, as already shown by Warren, is its tendency to have more of its lateral ribs bifurcate. Illustrations by Weller indicate that it has a more sharply marked umbonal area than *S. albertensis*, and that it has straighter sides. *Spirifer centronatus* Winchell, a widespread Kinderhook species originally described from the Waverly group of Ohio, has simple ribs on the flanks, and less variety of branching of costæ in the sinus. *Spirifer marionensis* Shumard, from the Louisiana limestone of Missouri, has stronger concentric ornamentation and simpler lateral ribs, a smaller umbonal region, and narrower cardinal area.

*Occurrence.* Banff formation, Upper member; localities 13, 19, 57, 66, 71, 77, 91, 95.

### *Spirifer* cf. *cascadensis* Warren

*Spirifer cascadensis* Warren, 1927, Geol. Surv., Canada, Mem. 153, p. 58, Pl. VII, figs. 1, 2.

*Remarks.* Ten more or less incomplete specimens from the Jasper area are comparable with this species. In these specimens the length varies from a little less than one-half to more than two-thirds width, which attains 65 mm. In the brachial valve, the fold may be almost flat to moderately raised above the surface of the valve. The umbonal region of this valve may be almost flat, or moderately raised above the low, flat, posterior lateral slope. This latter condition may also be seen in one of the co-types of the species.

In the Jasper specimens, bifurcation of lateral costæ rarely occurs at a distance of more than 10 mm. from the beak, and is often sporadic, affecting only certain costæ. As in the co-types, the costæ are broadly rounded, of low relief, and with narrow interspaces; concentric lamellose lines are not as many as in the co-types.

*Occurrence.* Banff formation, upper member; localities 55 and 79; a fragmentary specimen probably of this species was collected at locality 93.

### *Spirifer esplanadensis* n.sp.

Plate V, figures 1 a-e

Outline sub-elliptical; length equal to width; hinge line shorter than greatest width; cardinal extremities obtusely angular; sides moderately and evenly convex; anterior commissure sharply sinuate ventrally; lateral commissure inclines ventrally in an anterior direction, curving dorsally close to anterior.

Pedicle valve strongly convex, greatest convexity slightly posterior to middle; umbonal region prominent posteriorly, fanning out anteriorly, passing gradually into postero-lateral slope, the latter steep but gently concave near the cardinal extremities; beak broadly acute, strongly incurved, overhanging plane of commissure; cardinal area of moderate height, broadly triangular, flat in basal half, becoming strongly concave toward beak; antero-lateral slopes steep, gently convex; median sinus narrow and shallow posteriorly, broadening and becoming still shallower toward the anterior, where it contains a broad, faint, mesial elevation; costæ all derived from 5 to 8 major ribs on each side of beak, and one central costa originating near tip of beak; throughout a radius of approximately 10 mm. from beak, costæ are fasciculate due to trifurcation of major ribs; in this stage the two sinus bounding costæ are the most prominent, thus emphasizing sinus. Beyond fasciculate stage, costæ of more equal size, flat topped, of low relief and bounded by narrow interspaces; fine radial lines lie on costæ; fine concentric growth lines present throughout; pauses in shell growth, most common in anterior fourth of shell.

Pedicle muscle area narrowly elliptical, lying in posterior third to half of valve, bounded posteriorly by strong dental lamellæ; the latter thickened internally, usually filling delthyrial cavity; costæ well marked on anterior half only.

Brachial valve wider than long, moderately convex, with fold scarcely marked at beak, strong at anterior margin; convexity, disregarding fold, greatest slightly posterior to middle of valve; postero-lateral slopes becoming slightly concave near cardinal extremities, with low inclination there. From 5 to 8 (usually 6) lateral costæ, and one mesial costa radiate from beak; mesial and first lateral costæ generally bifurcate close to beak, and remainder trifurcate; beyond this fasciculate stage increase is by bifurcation; brachial muscle field not distinct; costæ impressed throughout.

*Types and Dimensions*

| Type | G.S.C. Cat. No. | Length | Width | Delthyrium | | Number of ribs at anterior margin |
|---|---|---|---|---|---|---|
| | | | | Height | Width | |
| | | mm. | mm. | mm. | mm. | |
| Holotype......... | 9199 | 37 | 37 | | | 120 est. |
| Paratype......... | 9200 | 345 | 34 | 4 | 6 | 76 approx. |
| | 9201 | 30 | 29 | 3 | 5 | 70 approx. |
| | 9202 | 27 | | | | |

Holotype has 70 ribs at a distance of 23 mm. from the beak and at a distance of 4 mm. from the anterior margin specimen 9200 has 90 ribs. There are 5 ribs in 5 mm. at the anterior margin of the holotype.

*Remarks.* The described characters are constant for the twenty specimens from the type locality. In the material from localities on Mount Greenock, there are tendencies to finer ribbing, flattening of valves near cardinal extremities, and slight mucronation of the latter. These tendencies occur both separately and in combination. Until abundant material is obtained, no varieties are recognized.

*Spirifer rostellatus* Hall from the Keokuk limestone of Warsaw, Illinois, is a smaller form with more sharply rounded sides, a shorter hinge margin, coarser costation, a less nasute anterior margin, and an apparently less-curved beak. *Spirifer gregeri* Weller, from the Chouteau limestone, Sedalia, Missouri, has valves of more equal convexity, a sub-hemispherical outline, a relatively broader fold, and a less nasute anterior margin. Its pedicle sinus is more prominent anteriorly than posteriorly. *Spirifer grimesi*, from the Burlington formation of Iowa, is a larger form with relatively shorter, more divergent dental lamellæ, and a shorter, broader pedicle muscle area. *Spirifer subrotundus* Weller, from the Kinderhook of Iowa, is known only from internal moulds. Its fold is relatively less prominent, and its sinus more prominent than in *S. esplanadensis.* The anterior commissure is much less sinuate and the postero-lateral slopes seemingly less rounded than in *S. esplanadensis.* *S. brazerianus* Girty, from the Brazer limestone, Crow Creek Quadrangle, Idaho, is closely similar, but has (according to its author) no fasciculation of ribs on any part of the shell. It is to be noted, however, that the figured specimens of this species are poor, and do not show the ornamentation of the beak.

*Occurrence.* Banff formation, upper member; localities 7, 10, 13, 19, 64, 72, 77.

*Spirifer greenockensis* n.sp.

Plate IV, figures 5 a-c

*Description.* Outline semi-circular to longitudinally semi-elliptical; width greatest at hinge line; cardinal extremities broadly acute in adult stages; more mucronate in young stages; sides subparallel in posterior half, gradually passing into a broadly convex anterior margin, with central part slightly nasute.

Pedicle valve moderately convex, greatest convexity slightly posterior to mid-length; umbonal region moderately prominent, quickly passing into general convexity of valve; lateral slopes flattened, with a gentle concavity toward the cardinal angle; beak small, incurved; cardinal area rather narrow, but triangular, gently curved from beak to hinge line; sinus narrow and shallow, broadening and almost disappearing anteriorly, smooth posteriorly; costæ relatively broad, gently rounded, with shallow narrow interspaces and numbering from 20 to 30 on the flanks; sinus-bounding costæ divide close to beak, one branch entering sinus; farther anterior, another branch from bounding costa enters sinus; median costa formed later than primary side sinal costæ; increase in number of sinal costæ is by bifurcation of five primary sinal costæ; fine longitudinal striæ present, one costa containing up to 10 of them; fine concentric markings also present.

Pedicle muscle field small, ovate, its width equal to $\frac{3}{4}$ of length, which never exceeds $\frac{1}{2}$ length of valve; pedicle callosity thick; dental lamellæ moderately stout, their anterior ends forming posterior boundary of muscle field; teeth small, slender projections at base of delthyrium.

Brachial valve slightly less convex than pedicle valve, greatest in posterior third, convexity even except for poorly defined umbonal area; posterior-lateral slopes gently concave near beak, flattening toward cardinal margin; ornamentation similar to that of pedicle valve.

*Type and Dimensions*

| Type | G.S.C. Cat. No. | Length | Width | Delthyrium | | Pedicle muscle area | |
|---|---|---|---|---|---|---|---|
| | | | | Height | Width | Length | Width |
| | | mm. | mm. | mm. | mm. | mm. | mm. |
| Holotype...... | 9204 | 31·7 | 36·1 | | | | |
| Paratype...... | 9206 | 16·5 (incomplete) | 31 | 4 | 5·6 | 8 | 8 |
| Paratype...... | 9207 | | | 4 | 5·0 | 7·5-9 (est.) | |

The holotype has an estimated number of 8 costæ in the sinus and 27 on the flank.

*Remarks.* The material shows considerable variation, particularly in the umbonal region; the latter may be only moderately developed, as in the holotype, or prominent, as in the paratypes. The cardinal area correspondingly has straight sides, or concave sides, and may have a large initial angle with the plane of commissure, or a small one. Variation in the number of sinal ribs is not uncommon. Occasionally, one of the lateral ribs close to the sinus bifurcates.

*Spirifer marionensis* Shumard is a similar shell, but has typically more diverging sides, sharper cardinal extremities, and a linear cardinal area, with a resultant smaller and sharper beak and a more gentle posterior lateral slope. It also has typically less ribs in the sinus, and the lateral ribs near the sinus bifurcate more commonly. Its muscle area is more deeply impressed.

*Spirifer centronatus* Winchell (35) has sharper ribs, with greater interspaces, and most commonly 3 to 5 ribs in the sinus. *Spirifer striatus madisonensis* Girty has a higher cardinal area, and the lateral ribs are said to bifurcate near the anterior margin. *Spirifer albapinensis* Hall and Whitfield is a proportionately wider form, with relatively prominent boundary plications.

*Occurrence.* Low in upper member of Banff formation; localities 7, 10, 60, 66, 72, 79.

### *Spirifer marionensis* Shumard

*Spirifer marionensis* Shumard (part), Missouri Geol. Surv., Ann. Rept., vol. 1-2, p. 203, Pl. G, figs. 8a, b (not fig. 8c), 1855.

*Occurrence.* Two small specimens at locality 77; one fragmentary specimen at locality 93.

## *Spirifer minnewankensis* Shimer

Plate IV, figures 6 a-d

*Spirifer centronatus* var. *minnewankensis* Shimer, Geol. Surv., Canada, Bull. No. 42, 1926.

*Description.* Outline, semi-elliptical to semi-circular; gently mucronate, young stages having long linear cardinal extensions, which disappear in adult; sides moderately to widely divergent, straight medially, commonly gently concave adjoining cardinal extremity, moderately convex anteriorly, meeting a narrow, gently convex anterior margin.

Pedicle valve slightly to moderately and evenly convex, greatest convexity slightly posterior to middle; umbonal region poorly differentiated from remainder of valve; postero-lateral slope gently concave in middle part, low toward cardinal extremities; lateral slopes of adult shells containing 16 to 28 rounded costæ, with more angular, narrower interspaces; lateral costæ seldom number less than 20; sinus shallow but well defined throughout, sinal costæ consisting of one median rib, which may or may not bifurcate, and 2 to 6 lateral ribs, which come off the two boundary costæ; beak small, slightly incurved; cardinal area long and narrow, almost linear, straight from hinge line almost to beak, thence faintly curved; delthyrium an equilateral triangle; costæ covered with fine radial lines; interruptions in growth rarely noticed.

Brachial valve gently and evenly convex, fold well marked throughout but never more than moderately prominent, containing 4 to 9 costæ, with two median costæ; lateral costæ similar to those on pedicle valve. Brachial muscle field longitudinally elliptical.

*Type and Dimensions*

| Type | G.S.C Cat. No. | Length | Width | Delthyrium | | Brachial muscle area | |
|---|---|---|---|---|---|---|---|
| | | | | Height | Width | Length | Width |
| | | mm. | mm. | mm. | mm. | mm. | mm. |
| Hypotype.......... | 10007 | 23·4 | 45 | 6·2 | 6·4 | 6·8 | 4·9 |

*Remarks.* This species is characterized by its straight, widely diverging sides and narrow anterior, its small beak, and its straight cardinal area. *S. albertensis* Warren has branching costæ on the lateral slopes, and has less diverging sides, a more prominent beak, a more curved cardinal area, and a deeper sinus and stronger fold than *S. minnewankensis*. *S. albapinensis* has a much different sinus, with thickened boundary costæ and three late-forming sinal costæ. *S. biplicoides* Weller from the Kinderhook of Mississippi Valley is smaller, more convex, with sharply mucronate cardinal extremities, less sinal costæ, and with thickened boundary costæ. *S. centronatus* Winchell from the Waverly of Ohio has less divergent sides, less costæ on the flanks, a more prominent beak, and a more curved cardinal area. *S. marionensis* Shumard has flatter costæ, late-forming median sinal costæ, and many interruptions in shell growth. *S. centronatus* var.

*semifurcatus* Girty is closely similar, and it is possible, if this is in future made a species, that *S. minnewankensis* as a species may have to be suppressed.

*Occurrence.* Rundle formation, lower part; localities 16, 38, 62, 76, 92, 97.

### *Spirifer* n.sp. A

This species is characterized by its short diverging nasute anterior, and by its broad, usually shallow sinus and straight, steep lateral slopes. The costæ branch irregularly, but fasciculation is never consistent enough for inclusion of the species in the genus *Neospirifer*. *Neospirifer cameratus* Morton, from the Lower Pennsylvanian Alleghany group of Ohio, is a thinner shell, with slightly deeper sinus, less nasute anterior margin, and a more definite tendency to fasciculation of costæ near the beak. *Spirifer pellaensis* Weller, from the Ste. Genevieve group, and *S. increbescens*, from the Chester group, are much more coarsely ribbed forms. *S. rockymontanus* Marcou, from the Magdalena limestone of New Mexico, is a small shell with simple lateral costæ and prominent umbonal region, and *S. occidentalis* Girty from Pennsylvanian strata at Muskogee, Oklahoma, is a more coarsely costate form, as also is *S. opimus* Hall from the Lower Pennsylvanian of Iowa.

*Occurrence.* Greenock formation, Lower member; localities 35, 39, 56.

## Genus, *Brachythyris* McCoy, 1844

### *Brachythyris burlingtonensis* Weller

*Brachythyris burlingtonensis* Weller, Ill. State Geol. Surv., p. 371, Pl. 53, figs. 8, 9, Pl. 83, fig. 6, 1914.

*Occurrence.* Banff formation, Upper member; locality 72; 2 specimens; Rundle formation, lower part; locality 97; one pedicle valve.

### *Brachythyris chouteauensis* Weller

*Spirifer chouteauensis* Weller, Bull. Geol. Soc. Am., vol. 20, p. 305, Pl. 13, fig. 11.
*Brachythyris chouteauensis* Weller, Mon. Ill. State Geol. Surv., vol. 1, 1914.

*Occurrence.* Banff formation, Upper member; localities 2, 70, 72; Rundle formation, lower part; locality 97.

### *Brachythyris* n.sp. A

*Description.* Shell medium-sized; outline semi-circular; hinge line equal almost to greatest width, which is at about mid-length; sides truncate at postero-lateral extremities; profile from beak to postero-lateral extremities straight to gently concave; lateral commissure straight; anterior commissure gently sinuate, ventrad in narrow middle part.

Pedicle valve moderately convex, strongly so in posterior fourth, with inflated flanks and post-umbonal area; beak not well preserved, strongly incurved; umbonal area not differentiated from convex postero-lateral slopes; pseudo-cardinal area present on broad shoulder. Median sinus distinct, but usually only flattened summit of steep flanks is present anterior to posterior third of shell; sinus containing normally 3 roundly angular costæ with similar interspaces; costæ on flanks usually similar to those in sinus, and with narrow interspaces.

Brachial valve with rather prominent, narrow umbonal region; median sinus faint at beak, moderately prominent at anterior.

*Remarks.* *Brachythyris chouteauensis* Weller has a relatively narrower hinge line, less angular cardinal extremities, a more prominent beak, less definite costation in the sinus, and flat-topped ribs on the flanks; *B. suborbicularis* (Hall) has a relatively narrower hinge line, rounded cardinal extremities, and only obscure costation on the sinus. The local species is not named or figured, due to lack of adequate material, but it is apparently new, and has a definite stratigraphic value.

*Occurrence.* Greenock formation, locality 84. Of twelve silicified specimens three are moderately well-preserved internal moulds. An incomplete specimen from locality 39 has the characteristic shape and outline of the species, but is larger, and has three extra interpolated ribs in the sinus.

### Genus, *Syringothyris* Winchell

#### *Syringothyris hannibalensis* Swallow

*Spirifer (Cyrtia ?) hannibalensis* Swallow, Trans. St. Louis Acad. Sci., vol. 1, p. 647, 1860.
*Syringothyris halli* (Winchell) (part), Proc. Acad. Nat. Sci. Philadelphia, vol. for 1863, p. 7 (not specimens from Burlington, Iowa), 1863.
*Syringothyris carteri* Schuchert (part), Ninth Ann. Rept. N.Y. State Geologist, 1890, p. 30.
*Syringothyris carteri* Keyes (part), Missouri Geol. Surv., vol. 5, p. 87 (*not* Pl. 40, fig. 10), 1894.
*Syringothyris hannibalensis* Hall and Clarke, Palæontology of New York, vol. 8, pt. 2, Pl. 25, figs. 33-35, 1895.
*Syringothyris carteri* Weller (part), Bull. U.S. Geol. Surv., Bull. No. 153, p. 619, 1898.
*Syringothyris hannibalensis* Rowley, Missouri Bur. Geol. and Mines, 2nd ser., vol. 8, p. 82, Pl. 18, figs. 6-9; p. 88; Pl. 19, figs. 4-5, 1908.
*Syringothyris hannibalensis* Weller, Mon. Ill. State Geol. Surv., vol. 1, p. 388, Pl. 68, figs. 1-7, 1914.
*Syringothyris hannibalensis* Williams, Prof. Paper, U.S. Geol. Surv., No. 203, p. 86, Pl. 8, figs. 51-56, 1943.

*Occurrence.* Banff formation, Upper member; localities 19, 55, 60, 91, 95.

### Genus, *Cyrtina* Davidson, 1858

#### *Cyrtina acutirostris* Shumard

*Cyrtina acutirostris* Shumard, Missouri Geol. Surv., First and Second Ann. Repts., p. 204, Pl. C, figs. 3a-c, 1855.
*Cyrtina acutirostris* Hall and Clarke, 13th Ann. Rept. N.Y. State Geologist, vol. 2, Pl. 29, fig. 18, 1894.
*Cyrtina acutirostris* Keyes, Missouri Geol. Surv., vol. 5, p. 89, Pl. 39, figs. 10a-b, 1894.
*Cyrtina acutirostris* Hall and Clarke, Pal. N.Y., vol. 8, pt. 2, Pl. 28, figs. 38-42, 44, 54, 1895.
*Cyrtina acutirostris* Weller, Bull. U.S. Geol. Surv., p. 208, 1898.
*Cyrtina acutirostris* Rowley, Missouri Bur. Geol. and Mines, 2nd ser., vol. 8, p. 84, Pl. 18, figs. 16-20; p. 87; Pl. 19, fig. 2; 1908.
*Cyrtina acutirostris* Weller, Mon. Ill. State Geol. Surv., vol. 1, p. 286, Pl. 35, figs. 6-21, 1914.

*Remarks.* A single partly crushed specimen.

*Occurrence.* Banff formation, Upper member; locality 79.

## Genus, *Torynifer* Hall and Clarke, 1895

### *Torynifer pseudolineata* var. *jasperensis* n.var.

*Remarks.* Shimer described *Reticularia pseudolineata* Hall from the Mississippian of Lake Minnewanka, but recognized certain differences between his specimens and the available illustrated topotypes of Hall's species. The same differences exist in the specimens from the Mount Greenock area. These consist of more sharply rounded sides, a definite pedicle sinus and brachial fold, and a smaller cardinal area. These differences are considered enough on which to make a variety.

*Occurrence.* Banff formation, Upper member; localities 13, 19, 60, 66, 70, 71, 77, 91, 95.

## Genus, *Martinia* McCoy, 1884

### *Martinia* cf. *rostrata* Girty

*Martinia rostrata* Girty, Mon. U.S. Geol. Surv., vol. 32, pt. 2, p. 553, Pl. 70, figs. 5a-g, 1915.

*Remarks.* One small almost complete specimen.

*Occurrence.* Banff formation; locality 91.

## Genus, *Punctospirifer* North

The following two species previously included in the genus *Spiriferina* are here included in the genus *Punctospirifer* following the usage of Dunbar and Condra.

### *Punctospirifer subtexta* (White)

*Spiriferina subtexta* White, Proc. Boston Soc. Nat. Hist., vol. 9, p. 25.
*Spiriferina subtexta* Weller, Trans. St. Louis Acad. Sci., vol. 11, p. 199, Pl. 20, figs. 5, 6.
*Spiriferina subtexta* Weller, Bull. Geol. Soc. Amer., vol. 20, p. 309, Pl. 13, figs. 16-19.
*Spiriferina subexta* Weller, Mon. Ill. State Geol. Surv., vol. 1, 1914, p. 29, Pl. 36, figs. 35-40.

*Remarks.* Two incomplete pedicle valves are identified with this species.

*Occurrence.* Rundle formation; localities 16, 92.

### *Punctospirifer solidirostris* (White)

*Spirifer solidirostris* White, Jour. Boston Soc. Nat. Hist., vol. 7, p. 232, 1860.
*Spiriferina solidirostris* White, Proc. Boston Soc. Nat. Hist., vol. 9, p. 24, 1862.
*Spiriferina solidirostris* Winchell, Proc. Acad. Nat. Sci. Phil., p. 120.
*Spiriferina solidirostris* Girty, Mon. U.S. Geol. Surv., vol. 32, p. 545, Pl. 7, fig. 10a, 1899.
*Spiriferina solidirostris* Weller, Trans. St. Louis Acad. Sci., vol. 11, p. 198, Pl. 20, figs. 2-4, 1901.
*Spiriferina solidirostris* Girty, Prof. Paper U.S. Geol. Surv., No. 16, p. 294, Pl. 1, figs. 3, 4.
*Spiriferina solidirostris* Weller, Mon. Ill. State Geol. Surv., vol. 1, p. 292, Pl. 36, figs. 25-34, 1914.

*Occurrence.* Banff formation, Upper member; localities 19, 66; lower part of Rundle formation; locality 16.

## Genus, *Cliothyridina* Buckman, 1906

### *Cliothyridina lata* Shimer

*Cliothyridina lata* Shimer, Geol. Surv., Canada, Bull. No. 42, p. 71, Pl. IV, figs. 1a, b, c, 1926.

*Remarks.* This species shows much variety in size, outline, and depth of pedicle sinus. Some specimens attain a much larger size than Shimer's holotype, and a few approach *Cliothyridina obmaxima* McChesney, which ranges from Upper Kinderhook to Keokuk in the Mississippi Valley section.

*Occurrence.* Banff formation, Upper member; localities 7, 13, 57, 64, 66, 70, 71, 72, 77, 78, 91, 95, 96; Rundle formation, lower part; localities 16, 76.

## Genus, *Composita* Brown, 1849

### *Composita athabaskensis* Warren

*Composita athabaskensis* Warren, Trans. Roy. Soc., Canada, 3rd ser., vol. XXVI, sec. IV, p. 248, Pl. II, figs. 5-11, 1932.

*Remarks.* Variation in this species is marked, and includes combinations of all of the following characters; curvature of sides, relative dimensions, convexity, prominence of beaks, and posterior extension, and prominence of sinus. Some of the elongate forms are close to those identified with *C. immatura* Girty, but are not as convex transversely. Others approach *C. humilis* Girty.

*Occurrence.* Banff formation, Upper member; localities 13, 19, 57, 65, 71, 72, 77, 78, 95.

### *Composita athabaskensis* var. *esplanadensis* n.var.

Plate V, figures 2 a, b

*Description.* Outline circular to subquadrate; length equal to width; anterior margin narrow, rounded, sometimes faintly nasute or faintly concave; antero-lateral and postero-lateral margins straight to slightly convex, meeting in a broadly rounded angle approaching a right angle; anterior commissure slightly sinuate ventrad, lateral commissure straight.

Pedicle valve moderately convex, flattening gradually from beak to anterior, with faint, narrow sinus present in anterior third, sometimes prolonged to faint nasute extension; beak small, strongly curved, projecting over brachial valve; umbonal area moderately prominent, passing imperceptibly into moderately steep postero-lateral slope.

Pedicle muscle field subovate, extending anteriorly beyond middle of shell; diductor marks longitudinally elliptical, set in slight depression, separated medially by a low ridge and having gently convex outer margins; adductor impressions obscure; pedicle callosity slight but long, equal to $\frac{1}{3}$ length of valve; dental lamellæ long; moderately stout; pallial trunks more obscure than in brachial valve, seemingly about 7 or 8 on each side, running subparallel antero-laterally from sides of muscle track.

Brachial valve slightly more convex than pedicle valve, with greatest convexity in posterior third, gradually flattening towards anterior.

Brachial muscle field narrowly rectangular, equal in length to about $\frac{1}{2}$ length of valve. Posterior adductors separated by median septum, which extends to beak and is equal to $\frac{1}{2}$ length of valve; main pallial trunks 4 to

5 in number; median pair of trunks diverging in a narrow angle from the anterior end of the adductor track, bifurcating half-way toward the anterior margin, the branches and their sub-branches also bifurcating close to anterior margin.

*Remarks.* *Composita athabaskensis* s.s. has greater proportional length, longer, straighter sides, and a broader anterior margin. *C. humilis* has a circular outline and a relatively more prominent beak.

*Types and Dimensions*

| Type | G.S.C. Cat. No. | Length | Width | Thickness |
|---|---|---|---|---|
| | | mm. | mm. | mm. |
| Holotype...................... | 9208 | 17·2 | 17·2 | 10·2 |

*Occurrence.* Rundle formation, lower part; localities 16, 61, 76, 92, 97; type locality 16.

### *Composita humilis* (Girty)

*Seminula humilis* Girty, U.S. Geol. Surv., Mon. 32, pt. 2, p. 565, Pl. 71, figs. 6a, b, c, 1915.

*Occurrence.* Banff formation, localities 13, 19, 65.

### *Composita* cf. *humilis* (Girty)

*Remarks.* Similar to *C. humilis*, but larger, slightly more elongate, and with a more prominent beak.

*Occurrence.* Banff formation, Upper member; localities 10, 66.

### *Composita immatura* (Girty)

Plate V, figures 4 a, b

*Seminula immatura* Girty, U.S. Geol. Surv., Mon. 32, pt. 2, p. 566, Pl. 71, figures 5a, 5b, 5c, 5d, 1915.

*Remarks.* The specimens from locality 79 are dwarfed, but have the characters of this species. The specimen from locality 92 is not complete, and the surface is not preserved. It may not be a *Composita*.

*Occurrence.* Banff formation, Upper member; localities 10, 19, 66, 70, 71, 77, 79, 91, 95; Rundle formation, locality 92.

### *Composita* cf. *madisonensis* var. *pusilla* (Girty)

*Seminula madisonensis* var. *pusilla* Girty, U.S. Geol. Surv., Mon. 32, pt. 2, p. 564, Pl. 71, figs. 3a, b, 1915.

*Remarks.* Two specimens have external form similar to this species.

*Occurrence.* Banff formation, Upper member; localities 61, 62.

## Genus, *Eumetria* Hall, 1895

### *Eumetria osagensis* (Swallow)

Plate V, figure 3

*Retzia ? osagensis* Swallow, Trans. St. Louis Acad. Sci., vol. 1, p. 653.
*Acambona ? osagensis* Hall and Clarke, Introduction to Study of Brachiopoda, pt. 2, Pl. 37, figs. 7-9.
*Eumetria osagensis* Weller, Mon. Ill. State Geol. Surv., vol. 1, p. 439, Pl. 76, fig. 12.

*Description.* Shell roundly subtrigonal, with strongly convex sides and broadly convex anterior margin; lateral commissure faintly convex ventrad; costæ flat-topped, with linear interspaces, numbering from 45 to 66, most commonly about 50.

Pedicle valve moderately convex, with faint median sinus; umbonal area attenuate; beak strongly curved over brachial valve, pierced by large elliptical pedicle foramen; postero-lateral slopes strongly convex posteriorly, passing into triangular concave pseudo-cardinal areas on either side of the beak.

Brachial valve moderately convex; beak slightly raised above contour of valve; lateral slopes steep, gently convex, meeting in narrowly rounded post-umbonal area.

Brachial muscle field long and narrow, attenuate-ovate, with greatest width always close to anterior.

*Remarks.* *E. verneuiliana* (Hall) differs in not having an attenuate beak, and in having a resulting more evenly rounded outline. *E. vera* (Hall) has fewer ribs and straighter postero-lateral margins.

*Occurrence.* Banff formation, Upper member; localities 13, 19, 57, 65, 71. An immature distorted specimen from locality 70 is doubtfully included in this species.

### *Eumetria* n.sp.

*Remarks.* A single internal mould of a brachial valve is not identifiable with any previously known species of *Eumetria.* It has about 124 costæ. It is moderately and evenly convex, with greatest convexity at beak. Its outline is subtrigonal with broadly rounded antero-lateral margin, and gently convex sides. The muscle field is long and narrow, with straight sides, 2 mm. wide at anterior end, 4 mm. between crural lamellæ, which are 4 mm. long.

*Occurrence.* Rundle formation, locality 76.

### *Eumetria* sp. indet.

*Remarks.* Several fragmentary specimens have the general outline and surface markings suggesting the genus *Eumetria,* but they are specifically unidentifiable.

*Occurrence.* Greenock formation, lower member; localities 35 and 39.

A. View of Grassy Ridge from the forestry motor road at Moberly Flat, showing the relative positions of the three major thrust blocks. The east spur of Esplanade Mountain is shown on the left, with the summit of Gargoyle Mountain behind it. The DeSmet Range is in the right background. (Page 12.)


B. View, from left to right, of Friendly Peak, Cold Sulphur Ridge, and Morro Peak, respectively, as seen from the northwest side of Athabasca River at Moberly Flat. Thrust blocks II and III are represented. Steeply dipping Carboniferous strata are visible on Friendly Peak. A ridge of the Upper member of the Banff formation is seen above point 'a'. The Rundle formation extends up along the dark wooded patch from 'a' to the summit. The white streak to the right of the wooded patch represents the Greenock formation, and its upper contact passes above point 'b'. The gully between Friendly Peak and Cold Sulphur Ridge is underlain by a syncline in Triassic (Spray River) strata, and to the right of it, at point 'c', is an anticline in Greenock and Rundle strata. The white line to the right marks the contact of Devonian beds of thrust block III faulted against the southwestern limb of this anticline. Between the two faults are the Devonian and Carboniferous beds of thrust block III. (Pages 11, 14.)

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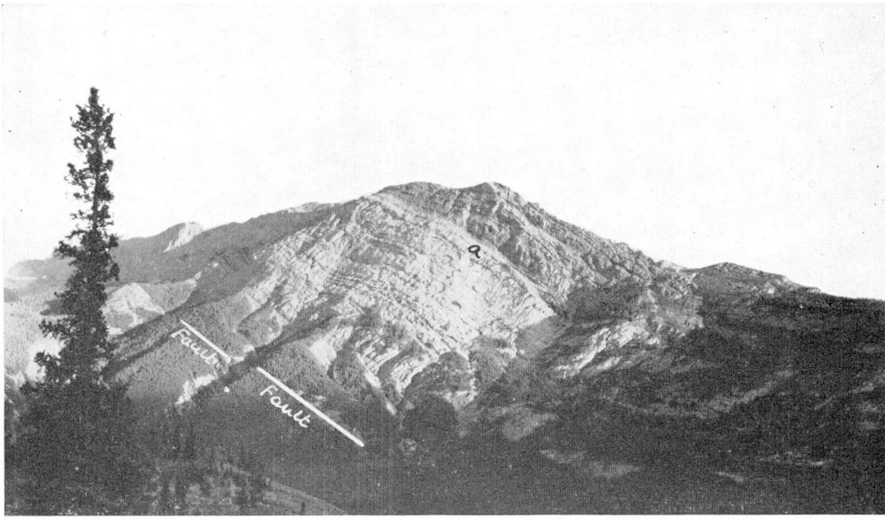



A. View of northeast face of Cinquefoil Mountain, showing the cliff face formed of steeply west-dipping Palæozoic strata of the Mount Greenock thrust block. These strata are thrust over beds of the Triassic (Spray River) formation along the fault line. The summit is composed of beds of the Banff formation, and the contact with the underlying Devonian limestone is shown at point 'a'. (Page 13.)

B. View north along highway 16 from a point about 10 miles north of Jasper, showing the DeSmet Range at the right background, Cobblestone Peak to the left of centre, and part of Chetamon Mountain at the extreme left. (Pages 7, 8.)

PLATE IV

(Except where otherwise stated all figures are natural size)

Figure 1. *Camarotoechia allani* var. *greenockensis* n.var.: 1a, pedicle view of an internal mould showing muscle field, G.S.C. No. 9179 x 2; 1b, pedicle view of holotype, G.S.C. No. 9178 x 2; 1c, pedicle view of a small specimen, G.S.C. No. 10010. (Page 89.)

Figure 2. *Greenockia snaringensis* n. gen. and sp.: 2a, pedicle view of an immature specimen, G.S.C. No. 10009 x 2; 2b, pedicle view of a young specimen, G.S.C. No. 9188; 2c, rostral view of a squeezed, internal mould of a mature specimen, showing part of a pedicle muscle field, impressions of the left pallial trunk and of the dental lamellæ, brachial muscle impressions, and the pitted interior surface of the brachial valve, G.S.C. No. 9187; 2d, pedicle view of an internal mould, showing details of muscle field, G.S.C. No. 9189; 2e, pedicle view of an internal mould, showing muscle field, G.S.C. No. 9190; 2f, brachial view of the holotype. The shell is preserved only near the beak, G.S.C. No. 9183. (Page 91.)

Figure 3. *Camarotoechai cobblestonensis* n.sp.: 3a, pedicle view of an internal mould, showing muscle field, G.S.C. No. 9181; 3b, side view of same specimen; 3c, brachial view of holotype, G.S.C. No. 9180; 3d, brachial view of small, internal mould, showing muscle field, G.S.C. No. 9182 x 2. (Page 90.)

Figure 4. *Camarotoechia allani* var. *circularis* n.var., pedicle view of holotype, G.S.C. No. 9175. (Page 88.)

Figure 5. *Spirifer greenockensis* n.sp.: 5a, interior of a pedicle valve, showing teeth, dental lamellæ, and pedicle callosity, G.S.C. No. 9206; 5b, pedicle view of holotype, G.S.C. No. 9204; 5c, pedicle interior, showing teeth and dental lamellæ, G.S.C. No. 9207. (Page 98.)

Figure 6. *Spirifer minnewankensis* Shimer: 6a, pedicle view of a specimen from locality 16, G.S.C. No. 10005; 6b, brachial view of same specimen; 6c, pedicle view of specimen from locality 76, G.S.C. No. 10006; 6d, brachial view of specimen, showing pedicle palintrope and internal mould of brachial valve, with impression of pitted surface and muscle field, G.S.C. No. 10007. (Page 100.)

PLATE IV

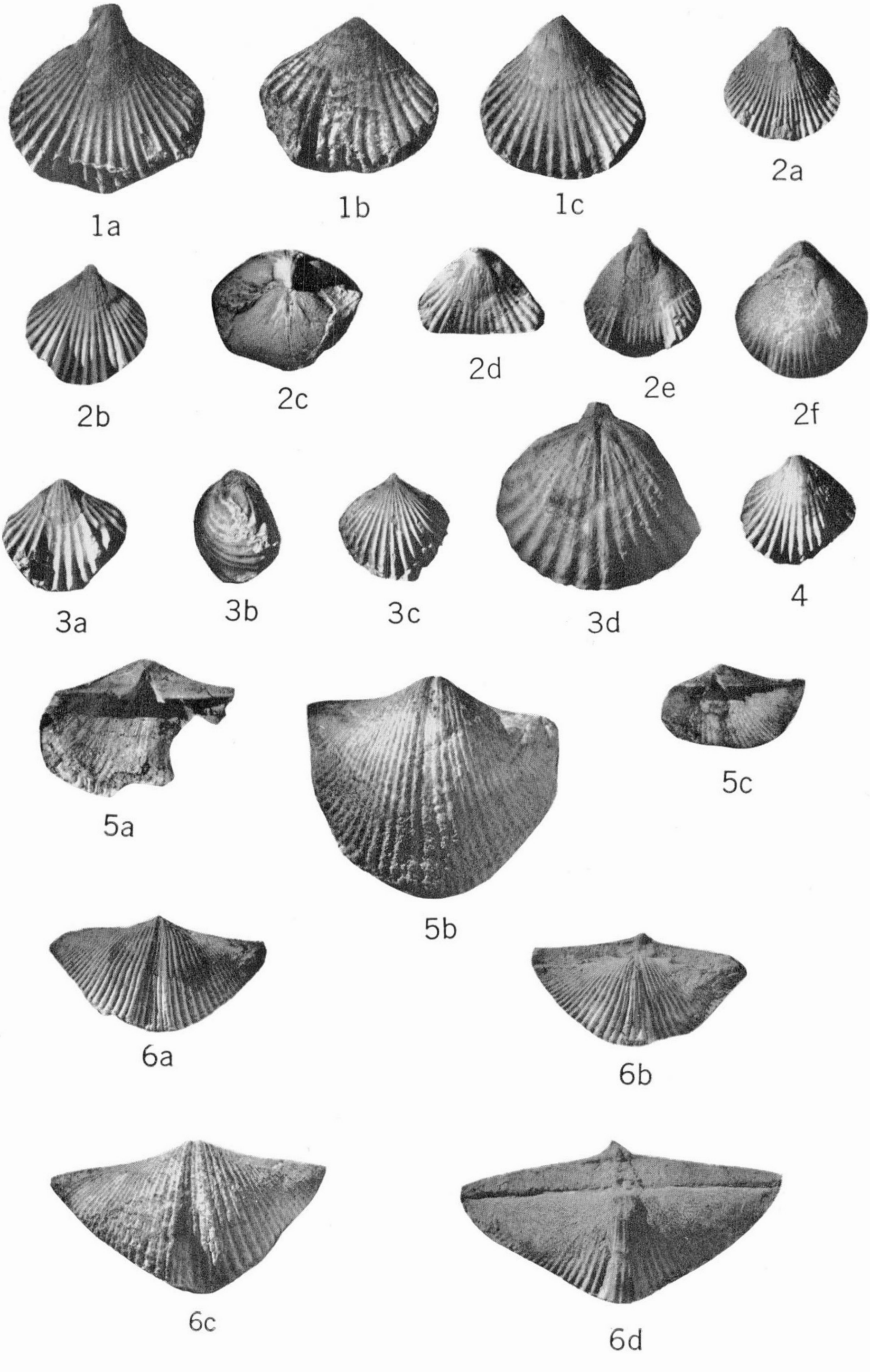


PLATE V

(Except where otherwise stated all figures are natural size)

Figure 1. *Spirifer esplanadensis* n.sp.: 1a, ventral view of holotype, G.S.C. No. 9199; 1b, view of pedicle interior, etched and with muscle field blackened, G.S.C. No. 9202; 1c, brachial view of specimen showing delthyrium and pedicle palintrope, G.S.C. No. 9201; 1d, side view of holotype, G.S.C. No. 9199; 1e, brachial view of holotype. (Page 97.)

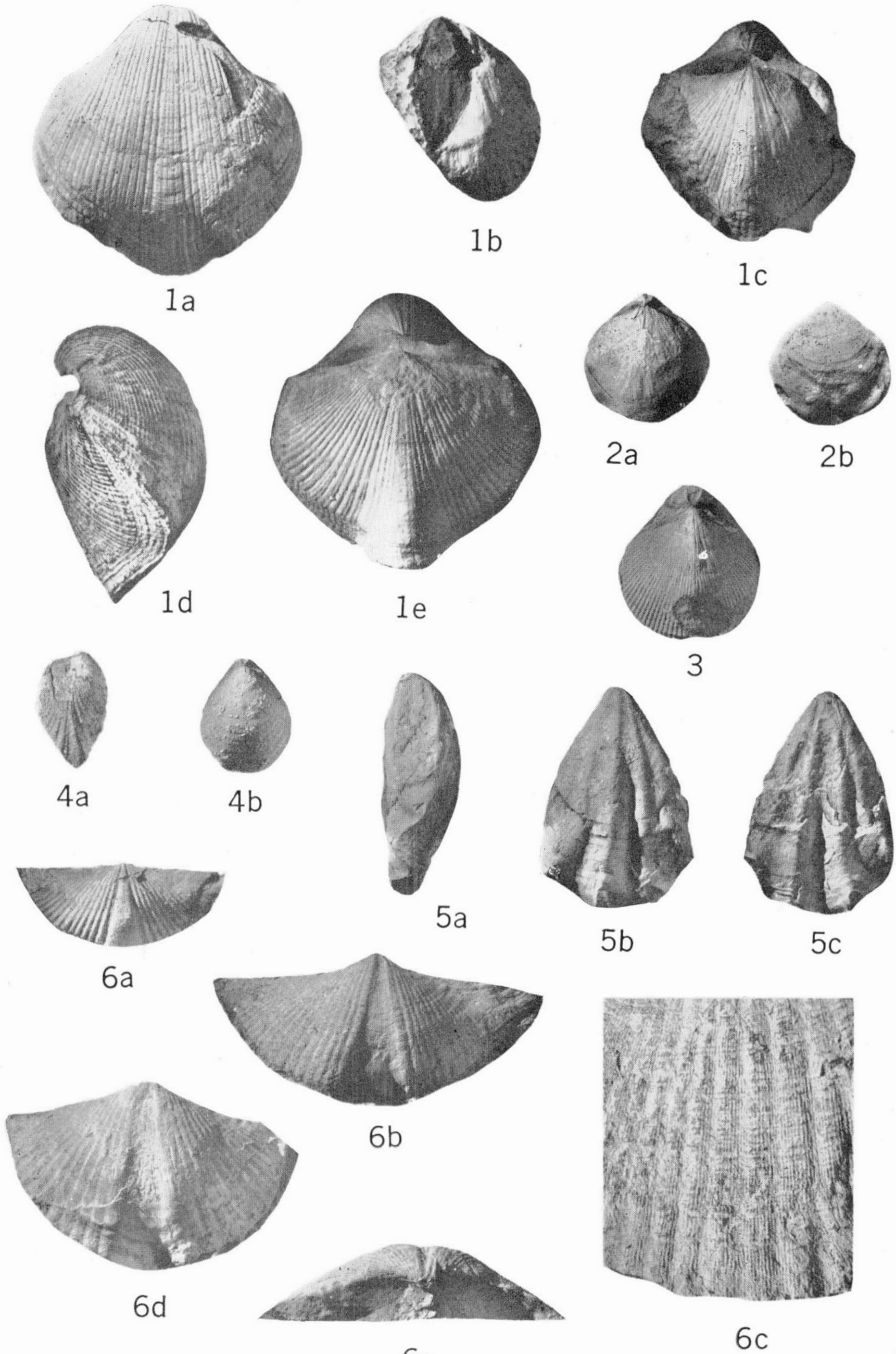
Figure 2. *Composita athabaskensis* var. *esplanadensis* n.var.: 2a, dorsal view of holotype, G.S.C. No. 9208; 2b, brachial valve of holotype. (Page 104.)

Figure 3. *Eumetria osagensis* (Swallow). Brachial view of an internal mould from locality 65, showing muscle field; G.S.C. No. 9205. (Page 106.)

Figure 4. *Composita immatura* (Girty): 4a, side view of specimen from locality 70, G.S.C. No. 10007; 4b, brachial view of same specimen. (Page 105.)

Figure 5. *Rhynchotetra elongata* var. *usheri* n.var.: 5a, side view of holotype, G.S.C. No. 9194; 5b, brachial view of same specimen; 5c, pedicle view of same specimen, showing reticulate ornament of radial striæ and growth lines. (Page 92.)

Figure 6. *Platyrachella rutherfordi* (Warren): 6a, brachial view of small specimen from locality 13; 6b, pedicle view of specimen, G.S.C. No. 9197; 6c, surface of specimen No. 9197 magnified to show fine radial striæ and growth lines superimposed on costæ; 6d, pedicle view of specimen, G.S.C. No. 9196; 6e, cardinal view of specimen No. 9196. (Page 94.)


1a
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1d
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