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A FAUNAL AND STRATIGRAPHIC STUDY OF UPPER PALEOZOIC ROCKS OF VANCOUVER ISLAND, BRITISH COLUMBIA

ABSTRACT

Paleozoic rocks of Vancouver Island are exposed in three major belts: the China Creek-Saltspring, the Horne Lake-Cameron River, and the Buttle Lake-Big Interior belts.

Stratigraphic sequences in these three belts are grossly similar, though differing in detail. The Paleozoic rocks of each belt are correlated with the Sicker Group, originally defined in the southern part of the China Creek-Saltspring belt. Within the Sicker Group, two major lithological units are recognized, and are referred to as the Lower and Upper Divisions of the group.

The base of the Sicker Group has not been seen. The upper contact of the group appears to be a paraconformity, above which Upper Triassic volcanic and sedimentary rocks of the Vancouver Group occur.

The Lower Division consists mainly of volcanic rocks and non-calcareous clastic rocks. In the Upper Division, limestones and thin-bedded cherty sediments predominate. The major unit within the Upper Division of the Buttle Lake-Big Interior belt is a limestone formation (named herein) of 1000 to 1100 feet maximum thickness. Thin-bedded, fine-grained non-calcareous rocks of unknown age, tentatively included within the Sicker Group Upper Division, conformably overlie the limestone at certain localities.

A rich fauna of brachiopods, bryozoans, molluscs, corals and foraminifers has been found in the Upper Division. A meagre flora of algae and fragments of vascular plants is present in a locally-developed basal sandstone of the Upper Division.

At least 42 genera, represented by 52 species, have been recognized in the Upper Division fauna; many fossils remain to be identified. Four of the brachiopod species are regarded as new.

Faunas similar to that of the Upper Division of the Sicker Group have been listed or described from other northern Cordilleran regions. Correlation is thus suggested with the Permian Coyote Butte Formation of central Oregon, the Black Mountain Formation of

northwestern Washington, part of the Cache Creek Group of mainland British Columbia, and parts of the Permo-Carboniferous successions of Alaska and Yukon Territory. Permian faunas of the Arctic Archipelago, Greenland, Spitsbergen and northwestern Russia contain many genera and some species in common with the fauna of the Sicker Group. Species of Horridonia, Spiriferella and Kochiproductus are particularly significant in this regard, linking the Sicker Group fauna with the "Arctic Permian" and "Russian" boreal faunas. Despite the strong boreal affinities of the Vancouver Island fauna, however, relationships also with western Pacific equatorial faunas are suggested by certain brachiopods and many of the bryozoans.

The faunal relationships thus established, and the presence of certain diagnostic brachiopods and tentatively identified fusulinids, indicate the age of the Upper Division of the Sicker Group to be Early Permian (Wolfcampian-Leonardian).

The evident mixing in the Permian fauna of Vancouver Island of elements of boreal and equatorial faunas prohibits conclusive biogeographic analysis at the present stage of investigation. The present evidence of faunal distributions is also inconclusive with respect to the assessment of theories of continental drift and polar wandering.

Lower Division rocks represent deposits of a moderately deep gulf or basin on the continental borderland, formed during a period marked by tectonic and volcanic activity. Diminishing crustal unrest culminated in the shoaling waters and carbonate deposits characteristic of the Upper Division.

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A THESIS SUBMITTED IN PARTIAL
FULFILMENT OF THE REQUIREMENTS FOR
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DOCTOR OF PHILOSOPHY
in the Department
of
GEOLOGY

We accept this thesis as conforming to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

January, 1965.

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INTRODUCTION

STATEMENT OF PROBLEM

Previous work on Vancouver Island yielded information which suggested that the Paleozoic rocks exposed in widely separated areas belonged to the same stratigraphic unit. Evidence based on fossils from the upper part of the sequence resulted in conflicting opinions as to its age. The majority of determinations indicated Permian age, but fossils from several localities suggested that the beds were Pennsylvanian.

The present study was initiated to gather additional information with which to assess this apparent discrepancy in age determinations and to test the validity of the suggested correlation.

Rugged topography, widely separated areas of exposure, limited access in certain places, and complex structures in others, have all had some bearing on the comparative dearth of detailed information on the upper Paleozoic rocks of Vancouver Island. Probably more important, however, are the relatively complex stratigraphy of this eugeosyclinal succession, the lack of continuous marker beds, and the paucity of well-preserved fossils.

This investigation is regarded as a preliminary step in the study of a much broader aspect of Cordilleran geology - the so-called "Cache Creek problem". Although the occurrence of upper Paleozoic rocks in many areas of British Columbia has been known for about a century, regional synthesis has been limited by the small number of detailed studies of relatively well-exposed and fossiliferous sections. The Vancouver Island study, combined with others recently completed,

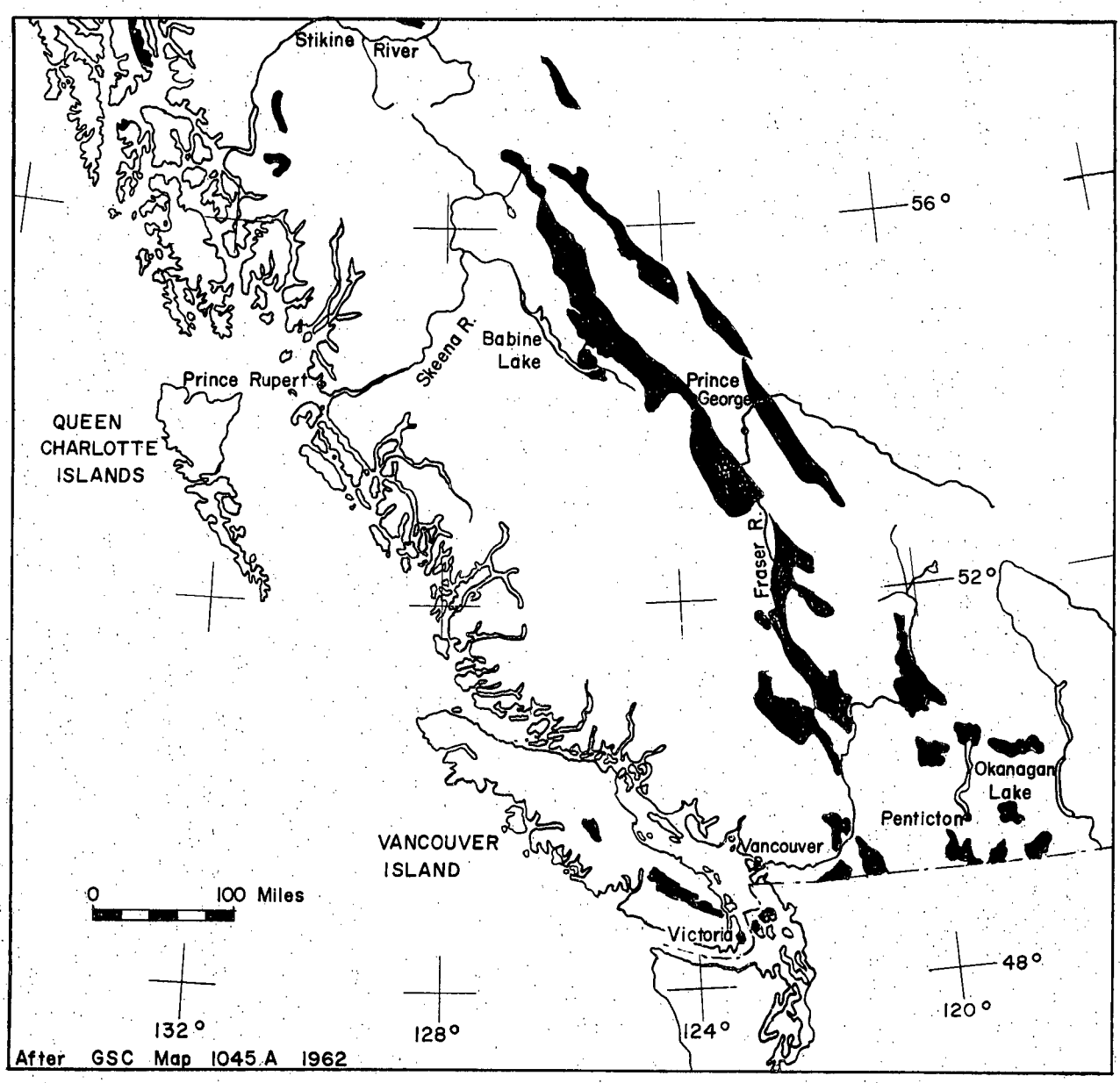

FIG. 1 Index map, western British Columbia and adjacent areas. Distribution of upper Paleozoic rocks. (Sicker Group, Cache Creek Group, and probable equivalents) shown by shaded areas.

now in progress or projected for the future, will provide data bearing on the larger problem of the history of the Cordilleran eugeosyncline in late Paleozoic (Cache Creek) time.

LOCATION AND ACCESS

The distribution of upper Paleozoic rocks in western British Columbia and adjacent regions is shown in Figure 1. Areas in which these rocks are exposed on Vancouver Island are indicated on a larger scale in Figure 2.

Paleozoic rocks occur in several parts of the Vancouver Island Ranges, which trend along the longitudinal axis of the island. These exposures may be grouped conveniently into three belts: the northern Buttle Lake-Big Interior belt; the central Horne Lake-Cameron River belt; and the southern China Creek-Saltspring belt (Figure 2). The last two belts may be continuous, but mapping is not as yet at the stage at which this continuity can be proved. The China Creek-Saltspring belt bifurcates at the east end of Cowichan Lake because of the presence of younger rocks along the Cowichan valley to the east.

The present investigation is based on field work in the northern part of the Buttle Lake-Big Interior belt, in the Horne Lake-Cameron River belt, and along the southwestern border of the China Creek-Saltspring belt.

Most exposures of the two southern belts are readily accessible from logging roads, many of which are negotiable by automobile. There are no roads traversing the northern belt, however; upper Paleozoic exposures of the northern part of the belt are accessible by boat around

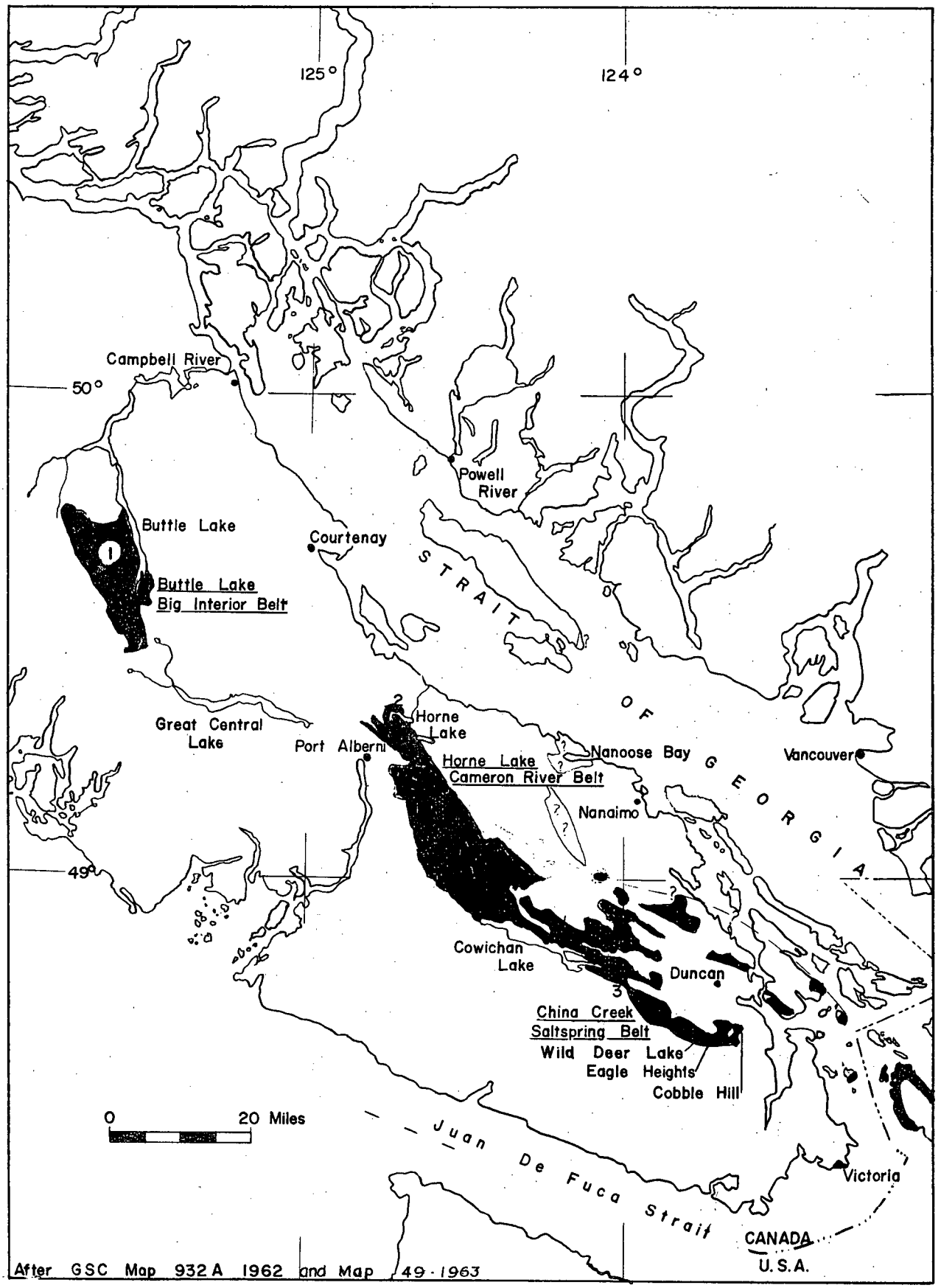

FIG. 2 Paleozoic belts of Vancouver Island. Numbers 1,2,3 indicate locations of Azure Lake, Mt. Mark, and Fairservice Mountain sections.

Buttle Lake, and by foot elsewhere. Foot-trails and mine roads provide access to a small portion of the southern part of this belt.

The Vancouver Island upper Paleozoic belts vary in relief from moderately to extremely rugged. Maximum relief in the Buttle Lake area of the northern belt is about 6500 feet; at Horne Lake it is about 2800 feet, and at Cowichan Lake in the southern belt about 4000 feet. Dense forest cover is common at lower elevations, but parts of the southern belts have been completely or partially cleared by logging operations.

Within the belts, outcrops below timber line usually occur in precipitous cliffs and steep stream valleys. Above elevations of about 4000 feet, exposures are more numerous, and in the higher ridges of the Buttle Lake-Big Interior belt, they are virtually continuous.

PREVIOUS WORK

Summary

Geological investigations on Vancouver Island began at least as early as 1858, when H. Bauerman made preliminary studies for the Boundary Commission. A.R.C. Selwyn, of the Geological Survey of Canada, was apparently the first to report the presence of Paleozoic rocks on the island (1872). The earliest record of identifications of Paleozoic fossils from Vancouver Island formations, by E. Billings, is contained in James Richardson's report of 1873.

Later workers also recognized rocks of probable Paleozoic age on southern Vancouver Island (Dawson, 1878; Clapp, 1909 to 1914). However, despite the earlier report by Richardson of upper Paleozoic fossils from the limestones of Horne Lake, all of the major limestone bodies of southern

Vancouver Island were regarded by Clapp as Mesozoic in age.

It was not until 1931 that additional fossil evidence confirmed the presence of undoubted upper Paleozoic rocks on Vancouver Island. In the year Gunning's publication dealing with the Buttle Lake area of central Vancouver Island listed a bryozoan faunule from limestones on the west side of Buttle Lake. Since then several discoveries of upper Paleozoic fossils from various localities south of Buttle Lake have been made.

The bryozoans of the Buttle Lake fauna, described by Fritz (1932), were correlated with a Permian fauna of Timor. A Permian age also has been assigned to most of the other upper Paleozoic fossil collections from Vancouver Island; descriptions of the fossils have, however, not been published.

Danner (1957), recorded the presence of faunas of Late Mississippian or Early Pennsylvanian, Early Pennsylvanian, and "Medial" and Late Permian ages in northwestern Washington. In 1960, he extended his Early Pennsylvanian determinations to some limestones of southern Vancouver Island, on the basis of lithological similarity and preliminary faunal analysis. Most of Danner's age determinations were from fusulinid evidence. The only published reference to the occurrence of fusulinids on southern Vancouver Island is that of Fyles (1955), who reported the identification of two Early Permian fusulinids from the Cowichan Lake area.

Previous stratigraphic work on the upper Paleozoic rocks of Vancouver Island and adjacent areas has been relatively limited in scope. The only detailed section measurements and descriptions available for the region are those recorded by Danner (1957), and by Smith (1961); both of these deal primarily with the upper Paleozoic sections of northwestern

Washington, including the San Juan Islands. A preliminary account (Yole, 1963) of the present writer's investigations in the Buttle Lake area dealt with the fauna, stratigraphy, and correlation of the Upper Paleozoic sequence of that area. A diagrammatic columnar section of the upper division of the sequence was presented.

History of Paleozoic Studies

The history of Paleozoic studies on Vancouver Island is extensive and complex. To the writer's knowledge a chronological summary, such as the following, is not available elsewhere. It is presented here as a background for the ensuing stratigraphic discussions, and as a reference for future workers in the field.

1872

Selwyn's preliminary exploration of the rocks of British Columbia included part of Vancouver Island. In his table of formations (1872, p. 54), he placed unit VII, "Cascade Mountains and Vancouver Island Crystalline Series" below the Lower Cache Creek Group. The latter he regarded as being of post-Silurian, pre-Triassic age, on the basis of fossils identified by Billings (Selwyn, 1872, p. 62). Similar poorly preserved, silicified, fragmentary fossils were collected from both the Cascade Mountains and Vancouver Island parts of unit VII (p. 63).

In his report on the coalfields of Vancouver Island, Richardson (1872) referred briefly to "crystalline rocks", older than the Mesozoic coal measures. Several bodies of limestone in the vicinity of Victoria were described (p. 90-92), and some "forms which appear to be silicified

fragments of Encrinal columns" mentioned. These are probably the same fossils mentioned by Selwyn, as he was assisted by Richardson in his examination of the Victoria area.

1873

Richardson's (1873) report on the Vancouver Island coalfields included a description of "crystalline rocks" encountered on a traverse across country from the mouth of the Qualicum River, westward towards Alberni, by way of Horne Lake. Corals, bryozoans, brachiopods and "large crinoidal columns" were collected from limestones at Horne Lake. These were determined by Billings (in Richardson, 1873, p. 54) to be "Permian or Carboniferous, most probably the latter".

1874

Richardson reported two additional fossil localities in the "crystalline rocks" of Vancouver Island. Poorly preserved, apparently unidentifiable forms were found near Schooner Bay, on the coast east of Nanoose Bay. A "tolerably good collection" from the Ballenas Islands was referred to as Carboniferous or Permian, "most probably the former", by Billings. This fauna included corals, brachiopods, "Encrinites" and a nautiloid cephalopod (Richardson, 1874, p. 98).

1878

G. M. Dawson (1878, p. 101) named the Victoria Series, consisting of volcanic and sedimentary rocks, including some limestones, occurring north of the Leech River "auriferous belt" of southern Vancouver Island.

The age of the Victoria series was considered to be probably Carboniferous.

1887

Dawson (1887, p. 9B) recognized that the lower portion of the "volcanic series" of the northern part of Vancouver Island was possibly older than Triassic. He included the whole sequence in the Vancouver Series, and stated (p. 10B):

> "This name may also be understood to include the similar beds of the Queen Charlotte Islands, as well as those of the southern part of Vancouver Island to which it was originally applied by Dr. Selwyn in 1871. If this great mass of rocks should eventually prove separable into Triassic and Carboniferous portions, I would suggest the retention of the name Vancouver Series for the former".

1896

Sutton (1896, p. 649) in describing the results of reconnaissance work in the vicinity of Alberni Inlet, noted that the Vancouver Series "amounts to many thousands of feet in thickness, and will most likely be found to cover not only Triassic and Carboniferous rocks, but even lower in the geological scale". Sutton also discovered limestone deposits near the head of "Hiwatches River" (now known as Franklin River) on the east side of the inlet. These rocks yielded no fossils other than crinoid stems, but according to Sutton, (p. 654) they resemble the limestone at Horne Lake and in other Vancouver Island areas (p. 654).

1909

Clapp utilized Dawson's terminology of 1873 and 1887 in describing the geology in the southern part of Vancouver Island. In Clapp's words, (1909, p. 54,55):

> "it seems best to restrict the term Vancouver Series to Triassic rocks of the northern part of the island, and to introduce a new term for the older rocks. Hence, I suggest the name Victoria Series, as a general name embracing the older metamorphics of the southern part of the island belonging to the Paleozoic era".

The Victoria Series was placed by Clapp (p. 54) in the Devonian system, on the basis of a fauna collected on the south shore of Cowichan Lake. To the north of the Victoria Series, and separated from it by a "profound unconformity", Clapp described a sedimentary and volcanic sequence named the Mt. Sicker Series, regarded as being of Mesozoic age (p. 54).

1910

The interpretation of the age of the Cowichan Lake fauna was revised (Clapp, 1910, p. 87). The fossiliferous limestone was removed from the Paleozoic sequence, and placed in a revised Vancouver "group", along with the Vancouver Volcanics and Mt. Sicker "Formation". The revised Victoria "group", including the Nitinat, Highland and Leech River Formations, and possibly the Malahat Formation, was questionably referred to the upper Paleozoic.

1911

In a preliminary account of the Victoria and Saanich areas, Clapp (1911) included in the Vancouver Group a belt of limestone lenses extend-

ing from Saanich inlet to Cowichan Lake. Limestones and associated volcanic rocks near Victoria, though possibly older than the Vancouver Group, were tentatively included within it. The Vancouver Group was said to be Lower Jurassic and probably Triassic, "and may include Upper Paleozoic" (p. 104).

1912

In Clapp's (1912) summary of his work on southern Vancouver Island, the Leech River Formation was questionably assigned to the Carboniferous (p. 36). This formation was correlated with the lower part of the Cache Creek Group and with the Peshastin Formation of Washington (p. 44). The Nitinat Formation, previously included within the Paleozoic Victoria Group, was at this time transferred to the Vancouver Group (p. 36, 49, 50).

The fossiliferous limestone of Cowichan Lake, now called the Sutton Formation, "Lower Jurassic", was extended to include "provisionally . . . all of the intercalated limestones in the Vancouver volcanics of southern Vancouver Island" (p. 61). This definition encompassed the Horne Lake area, where, according to Clapp, "Richardson records similar fossiliferous limestones" (p. 61, 70).

The Mt. Sicker Series was abbreviated to Sicker Series, and was described in detail as part of the Vancouver Group, of Triassic and Jurassic age (p. 71-83).

1913

In Clapp's memoir (1913) on the Victoria and Saanich areas the table of formations differed very little from those previously published.

The Sicker Series, however, was subdivided into two members: the Sicker Schists and Sicker Volcanics (p. 27).

1914

In a preliminary report on the Sooke and Duncan areas, Clapp (1914, p. 42, 45) stated that the Leech River Formation and Malahat Volcanics were the oldest formations of the region, provisionally assigning them to the Carboniferous. In a later report, the term "Sicker schists" was replaced by "Sicker sediments" Clapp, (1914c, p. 92).

1917

The memoir by Clapp and Cooke (1917) on the Sooke and Duncan areas contained Cooke's comment that "no definite statement can be made either as to the age of the Sicker series relative to that of the other members of the Vancouver group or as to its conformability with them" (p. 152). In the same publication, however, Clapp provisionally considered the Sicker Series to be conformable with and younger than the Vancouver Volcanics (p. 53).

1927

In describing the geology of the San Juan Islands, McLellan (1927, p. 91) correlated the Paleozoic San Juan Series with the Sicker Series of Clapp. The upper part of the San Juan Series was referred to as the Leech River Group; on the basis of fusulinids found in limestone members, it was regarded as . . . "to a large extent of Pennslyvanian age" (p. 111). This group was correlated with the upper part

of the Cache Creek Series (named by Selwyn, 1892) of central British Columbia, the upper part of the Hozomeen Series (Smith and Calkins, 1904), of the northern Cascades, and with the Chilliwack Series (Daly, 1912) of southwestern British Columbia.

The lower part of the San Juan Series, the Orcas Group, contained fossils determined as Carboniferous and Devonian, and was correlated with the lower part of the Cache Creek Series, the Bridge River Series (McCann, 1922) of southwestern British Columbia, and part of the Hozomeen Series.

1928

Map 196A of the Geological Survey of Canada, Vancouver sheet, a compilation of geological information on the southwestern part of British Columbia, showed one belt of Paleozoic rocks on southern Vancouver Island. This belt comprised Clapp's Leech River and Malahat Formations, which were shown as being of Carboniferous and? Permian age.

1931

Gunning's report (1931) on a large area in the central part of Vancouver Island disclosed the presence of fossiliferous Paleozoic rocks in the Buttle Lake area. "Fossils of Permian age were collected from certain of the limestone layers and for the first time afforded definite proof of the occurrence of rocks of Paleozoic age on Vancouver Island". (p. 59).

The bryozoans of this fauna were identified by Fritz and said to be of Permian age. Other parts of the fauna were identified by Girty, who (in Gunning, 1931, p. 59) considered that some of the spiriferid brachiopods "may belong to an horizon up in the Pennsylvanian, this being more probable than that the horizon is Permian". Gunning chose the Permian designation, but noted that the thick sequence of volcanics and other sediments beneath the limestones could be Pennsylvanian or older.

1932

Gunning's bryozoan material from Buttle Lake was described and illustrated by Fritz (1932). The "striking resemblance" between this fauna and the Permian bryozoan fauna of Timor led her to correlate them. The two areas were said to have only four bryozoan species in common, but among the other species present some of the Vancouver Island forms were closely related to the Timor species (p. 93).

1941

Several isolated limestone bodies in the Bedwell River area of central Vancouver Island were described by Sargent. Corals from these were regarded by Wilson (in Sargent, 1941, p. 19) as being of late Paleozoic age. Brachiopods from the same area were said to be Permian.

Sargent presented several lines of evidence to support a hypothesis that all of the limestone deposits of the area belonged to one horizon (p. 17). A "complex" of sedimentary, volcanic and intrusive rocks occurring below the limestones in the Bedwell River area was also assigned to the Paleozoic, on the basis of the limestone age determination and stratigraphic position (p. 16).

1945

A brachiopod collected by Stevenson from one of several limestone bodies in the China Creek area of central Vancouver Island was identified by Wilson, who (in Stevenson, 1945, p. 6) concluded that the fossil was new, "but its development suggests Upper Carboniferous or Permian".

The sediments associated with the limestones, according to Stevenson (p. 7), are "schistose and ... very similar to some of the Sicker schists found ... on Mount Sicker, near Duncan".

1947

A study of calcareous deposits of the Georgia Strait area by Mathews (1947) included comments on Paleozoic limestones of both mainland and Vancouver Island regions of British Columbia, of the San Juan Islands and mainland Washington. Several deposits, previously assigned to the Mesozoic Vancouver group were at this time shown to be of Paleozoic age. One of these is the limestone body within the Sicker "Series" at Mt. Brenton, southern Vancouver Island (p. 56).

To the writer's knowledge, Figures 4 and 20 of Mathews' report are the earliest published maps on which Paleozoic age was assigned to the Sicker rocks. Mathews further suggested (p. 41) that the larger Paleozoic limestone deposits of the whole region belonged to the same horizon.

The Leech River Formation of southern Vancouver Island was indicated in this report as "age uncertain" (Figs. 4, 20).

1948

On a geological compilation map of British Columbia (Geol. Surv. Canada Map 932A, 1948), most of the Vancouver Island rocks now regarded as being of Paleozoic age were grouped under one map unit, described as "Upper Triassic" but "including some fossiliferous Permian beds". The Leech River Formation on this map was designated "Carboniferous and later".

1955

Clapp's Sicker Series was formally revised and removed from the Mesozoic Vancouver Group in a report and map of the Cowichan Lake area by Fyles (1955). Clapp's Sicker Series was changed to "Sicker Group", of Permian and older age (p. 11, 19). Limestone on the peninsula at the southeast end of Cowichan Lake, previously included in the Triassic Sutton Formation of the Vancouver Group, yielded fossils which were reported to be of Early Permian age (p. 19). The limestone was considered to be "the uppermost formation of the Sicker group" (p. 16), and "the top of the limestone is considered to be the base of the Vancouver group" (p. 19).

Geological Survey of Canada compilation map 1054A (1955) showed three belts of "Carboniferous and Permian" rocks on Vancouver Island. These were in the Buttle Lake area, Horne Lake-Cowichan Lake area, and the Leech River belt of southern Vancouver Island.

1957

Mathews and McCammon's (1957) revision of Mathews' 1947 work on calcareous deposits of the Georgia Strait area of British Columbia gave

additional information on several Paleozoic areas. Figure 3 of this report showed the regional distribution, as presently understood, of Paleozoic limestones and other rocks in southwestern British Columbia.

Lockie (1957) described the petrography of some Paleozoic limestones of Vancouver Island and mainland British Columbia. Certain criteria were presented which suggested that Paleozoic limestones could be distinguished in hand-specimen and thin sections from those of younger age.

Danner (1957) tentatively correlated the Early Permian Black Mountain Formation of northwestern Washington (p. 298) with the Sicker Group of Vancouver Island. The Black Mountain beds were dated on evidence from fusulinids, bryozoans and corals (p. 152, 153). Lower Pennslyvanian, and "Middle" and Upper Permian strata were also recognized by Danner in the Upper Paleozoic sequence of the region.

1959

Geological Survey of Canada Map 1069A, Victoria-Vancouver, compiled by Rice, (1959) shows several belts of rocks on southern Vancouver Island as "Permian and/or earlier". The formations included in these belts are Clapp's Leech River Formation and Malahat Volcanics, and Fyles' Sicker Group.

1960

In a stratigraphic summary of the southwestern British Columbia and northwestern Washington region, Danner (1960) proposed the inclusion of "some limestones of Horne Lake and Cowichan Valley" within a sequence

of Early and "Medial" Pennsylvanian age, correlated in part with the Red Mountain Formation of Washington (Fig. 1, p. 3). An accompanying map (Plate 1), compiled by Danner and others, indicated the Sicker Group of southern Vancouver Island as Pennsylvanian, and the belt occupied by Clapp's Leech River Formation and Malahat Volcanics as of unknown age.

Kirkham (1960), in a study of mine workings near the Koksilah River on southern Vancouver Island described a small section of Sicker Group rocks. Poorly preserved corals and crinoid remains were found in limestones of the upper part of the sequence (p. 10-14).

1961

A detailed stratigraphic and lithological study of the Early Pennsylvanian? Red Mountain Formation of Washington, correlated in part with the Sicker Group of Vancouver Island by Danner (1960) was the subject of a thesis by Smith (1961). The Red Mountain fauna of foraminifera, brachiopods, corals, pelecypods, gastropods and radiolaria was listed but not described.

1962

Geological Survey of Canada Map 932A, second edition (1962, compiled by Little) indicated two areas of Paleozoic rocks on Vancouver Island. These are the Buttle Lake-Big Interior area, and a continuous belt extending from Horne Lake to Saltspring Island. The Paleozoic formations are listed as sedimentary and volcanic rocks, "mainly or entirely Permian". The Leech River and Malahat Formations of southern Vancouver Island, shown on earlier Geological Survey maps as Paleozoic,

were placed in the Mesozoic (Triassic and/or Jurassic).

1963

A preliminary account (Yole, 1963) of part of the present investigation described the stratigraphy, and listed and illustrated the fauna of upper Paleozoic rocks of the Buttle Lake Area. Informal nomenclature for the sequence was used. Correlations with Permian faunas of Cordilleran and Arctic Regions were proposed.

PRESENT WORK

Scope

The present study is essentially an attempt to provide more precise correlation and dating of the upper Paleozoic rocks of Vancouver Island. It is based on a regional reconnaissance of the main upper Paleozoic outcrop areas, measurements of sections in each of three widely separated parts of the region, and fossil collections from each of these areas. Geologic mapping performed concurrently with these studies is also presented.

Fossils were collected and identified by the writer. The descriptions appear in a later section of this report. Comparisons of the faunas of the three Paleozoic belts are presented, in support of the suggested lithologic and stratigraphic correlations. Longer-range correlation and dating of the Vancouver Island upper Paleozoic rocks have also been accomplished by use of the fossils. These topics are discussed, under appropriate headings, in later sections of this report.

In each of the three areas studied by the writer, stratigraphic sections of the upper part of the upper Paleozoic rock succession (Upper Division, Sicker Group) were measured. Although geological maps by earlier workers were available for at least parts of each of the areas investigated by the writer, new data were mapped in each. Stratigraphic sections (Figure 6) and maps (Figures 3, 4, 5) are presented for each of the areas studied.

Field Work

Studies on which the present report is based commenced in April, 1960. At that time, the writer, prompted by a suggestion from W. R. Danner, visited the limestone deposits at Horne Lake. A small collection of brachiopods, bryozoans and corals was obtained from this locality. The same area was again visited in October of that year to augment fossil collections and to examine the stratigraphy of the Upper Paleozoic section.

This preliminary examination having indicated a relatively rich fauna in the Horne Lake limestones, a broader study was undertaken with the following objectives: (a) to ascertain if fossil evidence, would yield significant information as to the age of the limestones; (b) to determine whether the widely separated Upper Paleozoic limestone bodies of Vancouver Island were of similar or widely differing ages; (c) to measure sections where feasible, and attempt correlations of these. These phases of the project were undertaken in the summer and early autumn of 1961, and parts of the summers of 1962 and 1963. A total of 20 weeks field work was accomplished.

Limestone deposits and associated rocks of the Upper Paleozoic sequence at Cobble Hill, Wild Deer Lake, Cowichan Lake, Nanoose Bay, Cameron River, Horne Lake and Buttle Lake were examined (See Figure 2). Measured sections were obtained in the Cowichan, Horne Lake, and Buttle Lake areas, in which areas the majority of field work was done.

In places where geological maps were available, these were utilized to select suitable places for section measurements and for collecting fossils. Reconnaissance mapping on aerial photographs and one inch to one mile topographic maps was done in the early stages of the work. In later stages, parts of the three areas which afforded more or less complete stratigraphic sections of the limestone unit of the Upper Paleozoic were mapped at a scale of one inch to one-half mile with the aid of aerial photographs. The mapped data are shown on Figure 3 (Cowichan area), Figure 4 (Horne Lake area), and Figure 5 (Buttle Lake area).

In the early stages of the work, traverses were arranged to outline the extent of the limestone-bearing unit, (Sicker Group, Upper Division) to examine its contacts, and to traverse across the strike of the formations in as many places as time and terrain permitted. In Cowichan, Horne Lake, and Buttle Lake areas additional traverses were made across the rocks below the limestone (Sicker Group, Lower Division). In each of these three areas, the limestone unit was measured in more than one place. The most complete sections obtained are presented in Figure 6.

The section measurements were made by use of a 5' staff ("pogo stick"). In the Cowichan area a section was also measured by the tape and compass method.

Fossils were collected in the field where this was practicable; otherwise, provisional identifications were made in situ.

Rock samples for lithological studies and microfaunal analysis were obtained from all sections examined. In the later stages of the work, more or less systematic sampling of the measured sections was undertaken. Specimens were spaced about five feet apart in the more thinly-bedded units, and about ten to twenty feet in the massive limestone units. Where preferred orientation of fossils or graded textures were apparent, oriented specimens were obtained.

Laboratory Work

Small batches of limestone from Horne Lake were treated with various acids (hydrochloric, acetic, formic) to provide material for study of insoluble residues. Hydrochloric acid was found to be most effective on the material, of which twenty specimens were completely digested. Fragmentary bryozoans, brachiopods and gastropods, and a few foraminifers were removed from the rock matrix in this manner. The bryozoan material thus obtained was generally adequate for generic, and in a few cases, specific identification. A few foraminifers and brachiopods were identifiable, but the majority of material other than the bryozoans was in too fragmentary a state, or too poorly preserved for precise determination.

The small size and poor preservation of the foraminifers prevented their recognition or identification in hand specimen. These fossils are so sparsely distributed in these rocks that is was decided to make "thin" sections of as many rock specimens as possible. A total of 205 sections were made providing not only faunal data, but also petrographic information on the limestones. For this type of work, rock slices of thicknesses somewhat greater than the standard 0.03 mm.

were found to be preferable. There is no single thickness which will always provide the best definition of both rock textures and fossil details. In the slides made by the writer, optimum thickness for each individual slide was determined by visual inspections during the final stages of grinding.

The thin sections yielded a small number of recognizable fusulinids, some well-preserved bryozoans, and fragmentary remains of other fossils for microscopic study.

The preservation of a few fusulinids in friable sandstone of the basal unit of the limestone formation at Buttle Lake permitted the removal of the fossils from the matrix by mechanical means, thus permitting oriented sections of the shells to be made. Unfortunately, silicification prevents determination of the wall structure of these specimens.

Serial sections were made for two of the brachiopod species, to ascertain critical internal features. The few corals available in the collection were not intensively studied.

Plant-bearing beds at the base of the Azure Lake section of the Buttle Lake area were sampled for plant microfossils. Several samples of these rocks were treated with a standard maceration technique. The presence of a few plant microfossils was thus disclosed, but no identifiable spores, or other microfossils were found. Time did not permit further rock work in this direction.

REGIONAL GEOLOGY

GENERAL STATEMENT

The known Paleozoic rocks of Vancouver Island are found in three separate parts of the region, each of which, for convenience, may be referred to as a "belt" (Figure 2). The northern belt, herein called the Buttle Lake-Big Interior Belt, trends approximately north-south from Wolf River, on the west side of Buttle Lake, to Big Interior Mountain, northwest of Great Central Lake. Its southern boundary has not been delimited. The southern, or China Creek-Saltspring belt, extends in a northwest-southeast direction from China Creek, seven miles southeast of Port Alberni, to the southern portion of Saltspring Island, east of Duncan. A much smaller area of Paleozoic rocks, the Horne Lake-Cameron River belt may continue southward to join the China Creek-Saltspring belt, but mapping has not yet covered the intervening area.

The Buttle Lake-Big Interior belt is approximately twenty-five miles long; its width varies from three to ten miles. The length of the China Creek-Saltspring belt is approximately sixty miles. In the southern portion the width is from ten to fifteen miles. Outliers of Mesozoic rocks are numerous and extensive in the wider part of the belt. The northeastern boundary of the belt has been determined over only a small portion of its extent. The known length of the Horne Lake-Cameron River belt is about twelve miles; the width is four miles at Horne Lake, and is possibly greater to the south.

A small area underlain by rocks of possible Paleozoic age is present on the coast near Nanoose Bay, between Nanaimo and Parksville on the east coast of Vancouver Island (Figure 2). No fossils from the rocks of this area have been identified. From the Ballenas Islands, about three miles offshore to the north, fossils of Carboniferous or Permian age were collected by Richardson (1874, p. 98).

The main bodies of the granitic rocks of the Coast Intrusions intrude Paleozoic and Triassic sequences of the Sicker and Vancouver Groups. Minor igneous bodies, perhaps related to the same general magmatic period, are known to intrude Upper Cretaceous Nanaimo Group rocks in certain parts of Vancouver Island.

TABLE OF FORMATIONS

The following (Table 1) is a tabular summary of the major formations encountered in and near the Paleozoic belts of Vancouver Island.

TABLE OF FORMATIONS

Series *	Group and Formation			Lithology
Upper Cretaceous	Nanaimo Group			Shale, sandstone, conglomerate
*	U N C O N F O R M I T Y			
Upper Triassic and? Jurassic	Vancouver Group	Bonanza Fm.		Andesitic to basaltic flows, breccias, tuffs; Argillaceous and tuffaceous sedimentary rocks
Upper Triassic		Sutton Fm. / Quatsino Fm.		Crystalline limestone, minor volcanic rocks.
Upper Triassic and? earlier		Franklin Creek Volcanics / Karmutsen Fm.		Basaltic flows, diabase; minor sedimentary rocks / Basaltic and andesitic flows, pyroclastic rocks; minor limestone
? x?	P A R A C O N F O R M I T Y			
Lower Permian	Sicker Group	Upper Division	Unnamed unit	Thin bedded clastic rocks
			Buttle Lake Formation	Limestone and chert; thin bedded cherty rocks, minor sandstone, tuffaceous? rocks.
Lower Permian and? earlier		Lower Division		Thin bedded clastic rocks tuffs, breccias, conglomerates, minor limestone?
				Tuffs, breccias; minor thin bedded tuffaceous and/or cherty rocks.

TABLE 1

Table of formations, Vancouver Island Paleozoic belts. In part after Fyles (1955), Gunning (1932), and Hoadley (1953).

* * Approximate span of time (Jurassic to Early Tertiary) during which several periods of granitic intrusion occurred (Coast Intrusions).

x x Approximate time span (post-Early Permian, pre-Late Triassic) of basic intrusions associated with Franklin Creek Basalt and equivalent rocks (Cassiar orogeny?).

STRATIGRAPHY

In each of the three belts the exposed Paleozoic (Sicker Group) sequence from base to top is: (1) a thick section of fine to coarse grained, bedded to non-bedded rocks of mainly volcanic origin; (2) a unit consisting largely of limestone and chert, with a thickness in the order of 500' to 1000'. Overlying the Paleozoic sequence, apparently comformably, is a thick succession of mainly basaltic igneous rocks of the Triassic Vancouver Group, the lower portion of which commonly contains pillow lavas.

In the Cowichan Lake area, the Paleozoic succession has been called the Sicker Group (Clapp, 1909; Fyles, 1955). The visible similarities of the Paleozoic rocks of all three belts have led to suggestions that they are correlatable (Mathews, 1947, p. 41; Fyles, 1955, p. 19, 27) with the Sicker Group. The two lithologically distinctive parts of the group are referred to as the Lower and Upper Division in the present report.

LIMESTONES OF THE SICKER GROUP

Diagnostic fossils have been found in the upper limestone unit (Upper Division, Sicker Group of this report) of all three belts. The age of the limestone, based on the fossil evidence, is Permian at Buttle Lake (Gunning, 1931, p. 59A), Big Interior Mountain (Sargent, 1941, p. 19), and Cowichan Lake (Fyles, 1955, p. 19). At Lizard Lake, in the China Creek area, a brachiopod suggesting Late Carboniferous or Permian age was found (Stevenson, 1945, p. 6). Fossils collected at Horne Lake were determined as being "either Permian or Carboniferous,

most probably the latter" (Richardson, 1873, p. 54).

Distinctive brachiopods and fusulinids from Fyles' Cowichan Lake locality permitted a more refined age determination than was possible for the other localities. Both fossil groups indicated an Early Permian age; the fusulinids suggested Wolfcampian (M. L. Thompson in Fyles, 1955, p. 19). Fossils collected and identified by the present writer provide evidence in support of Early Permian age for the main limestone bearing beds of each of the three Paleozoic belts. These data are discussed in more detail in other sections of this account.

Lithologically, the Permian limestone units of the three belts have certain characteristics in common. Much of the limestone is crinoidal, and is associated with light-to dark-coloured, fine-grained chert, in irregular nodules and thin intercalated sheets. Certain lithological differences do occur, and certain rock types found in one area are not found in others (Figure 6). However, limestones of almost identical lithology occur in all three belts in the upper part of the Paleozoic sequence. The proportion of pure limestone within the Upper Division of the Sicker Group is lower in the Cowichan Lake area than in the other areas examined. Thin bedded, cherty sediments form more than half of the unit in parts of the area.

The distribution of relatively pure limestone beds and lenses within the upper part of the sequence is not uniform. In the Buttle Lake area (the northern part of the Buttle Lake-Big Interior belt) limestone forms a relatively thick and persistent formation, comprising almost the whole of the upper unit of the Paleozoic sequence (see Figure 5, 6). Gunning (1931, p. 60A) stated that "at least two other

beds of limestone lower in the Paleozoic section", were exposed in the area. In the area covered by the present study the presence of only one other limestone lens besides the upper calcareous formation is suggested.

Between Buttle Lake and the southern end of this belt, limestones are not as persistent as in the Buttle Lake area (Sargent, 1941, p. 21; Fig. 1). Isolated masses of limestone are also characteristic of the China Creek area (Stevenson, 1945, p. 6; map), in the northern part of the China Creek-Saltspring belt, where limestones may occur well below the top of the Paleozoic sequence, as well as in the upper part.

In the Horne Lake and Cowichan Lake areas of the two southern belts, limestone is generally restricted to the Upper Division of the Sicker Group. The limestone lenses on Mt. Landalt, north of Cowichan Lake, possibly represent a calcareous horizon lower in the section than the main limestone unit of the sequence. These lenses were correlated with the main limestones of the upper part of the Sicker Group by Fyles (1955, p. 17) on the basis of apparent stratigraphic position, lithology, and poorly preserved fossils.

BASIC INTRUSIVE ROCKS

Basic igneous rocks, referred to in the literature as basalts, diabases or gabbros intrude the volcanic and sedimentary rocks of the Sicker Group in all three belts. In form, they vary from sill-like bodies to dikes and irregular masses (see Figures 5, 23, 42). In the Cowichan Lake area, these rocks have been called the Franklin Creek

volcanics (Stevenson, 1945, Fyles, 1955, p. 20) and assigned to the Triassic Vancouver Group. In the Buttle Lake area, Gunning (1931, p. 60A) considered similar rocks to be either late Paleozoic or early Mesozoic.

COAST INTRUSIONS

The Buttle Lake-Big Interior belt and the China Creek-Saltspring belts are intruded by small to large-sized bodies of the Coast Intrusions, of diorite, granodiorite or quartz-diorite composition. These igneous rocks are usually correlated with the batholithic rocks of the mainland. In the Cowichan Lake area and Buttle Lake area the granodiorite plutons have been dated on structural and stratigraphic evidence as being of pre-Upper Cretaceous, post-Triassic age (Fyles, 1955, p. 28, Gunning, 1931, p. 62A). Younger plutonic rocks, of similar appearance, also may be present in the region (Gunning, 1931, p. 64A).

STRUCTURE

The structural pattern within the Upper Paleozoic belts is complex. The larger scale features are gently plunging folds (see Fig. 51) with axial traces tending to be parallel to the trends of the belts themselves, and faults of longitudinal type. The major structure in the Buttle Lake-Big Interior belt and Horne Lake-Cameron River belt appears to be anticlinal (Gunning, 1931, p. 61A, Mathews and McCammon, 1957, p. 51) and may well be in the China Creek-Saltspring belt also. Innumerable minor folds and transverse and oblique

faults are also present. The Paleozoic rocks are thus broken into myriads of small fault blocks (see Figures 5, 42), making local correlations in areas of incomplete outcrop difficult.

The intensity of deformation is apparently least in the north, in the Buttle Lake-Big Interior belt, where the folds are open and dips relatively shallow except in the vicinity of faults and large intrusive bodies of the Coast Intrusions. In contrast, folds in the China Creek-Saltspring belt are tighter, and commonly assymmetrical to overturned. In this belt, dips are moderate to steep. Knowledge of the structure of the Horne Lake-Cameron River belt is incomplete. On the flanks of the belt, dips are moderate to steep. The northern border of the belt is complexly faulted, but the overall attitudes suggest that the Paleozoic rocks dip at a moderate angle (25° to 35°) below the overlying Vancouver Group to the north.

In the Cowichan Lake area of the southern belt, which is mapped in more detail than any other large area of upper Paleozoic rocks of the Island, structural evidence indicates that at least two, and probably three, periods of deformation have affected the Paleozoic rocks (Fyles, 1955, p. 25).

The two identified deformation periods are: (1) pre-Coast Intrusions (Saanich Granodiorite, which is of post-Triassic, pre-Upper Cretaceous age) and (2) post-Upper Cretaceous.

The major unconformity beneath the Upper-Cretaceous sediments bevelled the complex structure of Paleozoic and Triassic rocks, and exposed the granitic rocks in places. This indicates at least a large scale uplift and it is possible that folding and faulting also occurred

during the interval represented by the unconformity (Jurassic-Lower Cretaceous, i.e. Coast Range Orogeny (White, 1959)).

SUMMARY

The boundaries of the Paleozoic belts are not completely mapped. From the present evidence, however, it is clear that at least two distinct outcrop belts are present, separated by areas underlain by younger volcanic, plutonic or sedimentary rocks.

The age of the lowest exposed unit (Lower Division, Sicker Group) of mainly volcanic rocks is presumed to be of Permian or older age.

The upper part of the Paleozoic sequence, (Upper Division, Sicker Group) consists of sedimentary rocks, of which limestone is a prominent constituent. Fossils indicate that the age of the limestone is Permian.

The Paleozoic sequence of all three belts is overlain by mainly volcanic rocks of the Triassic Vancouver Group. The whole assemblage, from the base of the exposed Paleozoic rocks to the Vancouver Group appears to be a conformable succession.

Stratigraphic, lithologic, and faunal evidence indicates that the Paleozoic sequences of each of the three belts are correlative, and belong to the Sicker Group.

The Paleozoic belts probably are the cores of major anticlinal folds. Each is affected by important steeply dipping longitudinal, oblique, and transverse faults. Numerous minor faults have reduced the major structural elements to an assemblage of relatively small

fault blocks. These structures are the result of at least two, and probably three or more, periods of tectonic activity.

Intrusive rocks of at least two and probably more distinct periods of igneous activity are known within the belts. The earlier period of Triassic and? Late Permian age (Cassiar orogeny, White 1959) resulted in extensive bodies of diabasic rocks probably related to basaltic extrusive rocks of Triassic age. The later period produced the major granitic bodies of the region, probably of Jurassic and Early Cretaceous age (Coast Range orogeny, White 1959).

CHINA CREEK-SALTSPRING BELT

GENERAL STATEMENT

Paleozoic rocks are exposed in a belt of variable width extending from China Creek southward and southeastward to Cowichan Lake, then east-southeastward to Saltspring Island, off the east coast of Vancouver Island (Figures 2, 7). Large parts of this belt were mapped by Clapp (1912 G.S.C. Map 17A) and Clapp and Cooke (1917, G.S.C. Map 42A). More recent mapping by Fyles (1955, Fig. 2) in the Cowichan Lake area clarified the interpretation of the stratigraphic sequence, and provided substantial evidence for the age of Clapp's Sicker "series" (changed by Fyles, p. 19, to Sicker "Group"). According to Fyles, (p. 13, 19) the whole of the exposed Paleozoic succession should be included in the Sicker Group, "of Permian and older age".

Within the China Creek-Saltspring belt, considerable areas are underlain by rocks younger than the Sicker Group. These younger rocks consist of Coast Intrusions and outliers and salients of volcanic and sedimentary rocks of the Triassic Vancouver Group and Upper Cretaceous Nanaimo Group. Southeastward from the east end of Cowichan Lake, the increasing area occupied by rocks younger than the Sicker restricts the Paleozoic exposures to narrow discontinuous bands on the edges of the belt (see Figure 8).

The present investigation was restricted to an examination of the Upper Division of the Sicker Group and small sections of the underlying rocks along the southwestern border of the China Creek-Saltspring belt. The Upper Division rocks were examined on the

Figure 7. Southeastern end of China Creek-Saltspring belt. View east from Cobble Hill (Sicker Group) across low-lying belt of Mesozoic granitic intrusions and Upper Cretaceous sedimentary rocks toward southern end of Saltspring Island (left background) composed of rocks of Sicker and Vancouver Groups.

Figure 8. Cowichan Valley, east of Lake Cowichan. View east-northeast from Fairservice Mountain toward Mt. Prevost (distant peak). Permian limestones in right foreground. Upper Cretaceous sedimentary rocks of the valley, mantled by Pleistocene and recent sediments, probably in fault contact with complex of Sicker Group rocks and Mesozoic granitic intrusions of northern valley-wall.

peninsula at the east end of Cowichan Lake *(Bald Mountain peninsula), on the north face of the ridge southeast of Lake Cowichan townsite *(Fairservice Mountain), and in the area between Fairservice Mountain and Tadjiss Lake to the southeast. Reconnaissance work disclosed the presence of limestones of the same unit farther southeast, at Wild Deer Lake. The limestone deposits of Eagle Heights and the Cobble Hill area were briefly examined.

Relatively complete sections of the limestone unit in the China Creek-Saltspring belt were obtained only in the Fairservice Mountain exposures. Partial sections, or sections where structural complexity prohibited significant measurements, were examined on Bald Mountain peninsula, along *Chanlog Creek, and on the west fork of *Bear Creek.

STRATIGRAPHY

Sequence and Nomenclature

The history of the stratigraphic terminology of the rocks of the China Creek-Saltspring belt now assigned to the Paleozoic is given briefly in the earlier section on previous work, and in Fyles' discussion (1955, p. 18-19) of the Sicker Group. The present writer follows Fyles in assigning the entire exposed section of Paleozoic rocks in the China Creek-Saltspring belt to the Sicker Group.

Two major lithologic units within the Sicker Group were recognized by Fyles (1955, Fig. 2): a lower major unit, "volcanics", which

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* These names are in local use, but do not appear on published maps.

could be subdivided into "mainly amygdaloidal flows" and "mainly breccias"; an upper unit of "sediments", which was divided into subunits "cherty tuff, crystal tuff, and thin bedded sediments" and "mainly limestone".

The present writer's work confirms the suggestion that the Sicker Group of the China Creek-Saltspring belt may thus be subdivided into two parts. The lower part is a complex unit, of variable lithology and marked facies changes; various lithologic sub-units, or "facies" can be recognized locally. Details of the distribution of the subordinate lithologic units of the lower division have not been studied by the present writer. The upper part contains Fyles' limestone subunit, which was "thought to belong to the uppermost formation of the Sicker Group" (Fyles, 1955, p. 16). Referring to the occurrences of this stratigraphic unit in the Rift Creek, Bald Mountain peninsula, and Fairservice areas, Fyles stated (p. 17): "Although the localities are many miles apart, there is no doubt that the sediments belong to the same formation". In this the writer concurs, and can add that the characteristic features of this "formation" are recognizable in the southwestern border of the China Creek belt from Mt. Spencer in the China Creek area to at least as far southeast as Bear Creek, southeast of the Cowichan Lake area.

It is herein proposed that the lower, volcanic and sedimentary unit of the Sicker be provisionally designated as the "Lower Division" and the upper, sedimentary unit the "Upper Division" (see Table 2). Each of these divisions may eventually warrant formational name or names rather than the proposed terms. However, the stage achieved in

stratigraphic studies of the upper Paleozoic sequence of the China Creek-Saltspring belt seems in the writer's opinion to warrant at present only provisional nomenclature. The units appear to be correlatable over long distances, but at the present time, detailed correlations are not possible. As has been suggested earlier in this account, and discussed further in a following section, the Upper Division of the southern belts probably correlates with the Buttle Lake Formation and a superjacent unit of the Buttle Lake-Big Interior belt. However, rather than extending the term Buttle Lake Formation to southern areas, it is considered advisable for the present to use the more generalized nomenclatural system proposed above. When certain stratigraphic problems of the Buttle Lake area are resolved and more precise correlations established, formational nomenclature may be extended over the entire region.

Table of Formations

Table 2 indicates the terminology and relationships of the units recognized in the Paleozoic and Triassic successions in this belt.

System	Series	Group	Formation	Lithology
Triassic	Upper Triassic	Vancouver Group	Unnamed unit	Pyroclastics and non-calcareous sediments
			Sutton Limestone	Fine-grained limestone and non-calcareous sediments
			Franklin Creek Volcanics	Basalt flows and intrusions of diabase; minor limestone and other sediments
?	?			
Paraconformity				
?	?			
Permian	Lower Permian	Sicker	Upper Division	Fine-to coarse-grained limestone; chert, siliceous limestone, minor argillite
?				
Permian and/or Older	?	Group	Lower Division	Breccias, massive tuffs, fine-grained non-calcareous sediments, basaltic flows, minor limestone.

TABLE 2

Table of formations, with proposed nomenclature for subdivisions of Sicker Group, China Creek-Saltspring belt.

Sicker Group

Stratigraphic boundaries

The lower boundary of the Sicker Group has not been seen on Vancouver Island. Equivalents of the Sicker Group probably are present in adjacent regions, where a sequence of rocks, believed to lie below, and older than, the Sicker Group, is known (Danner, 1960, p. 1-3; 1962, p. 8-12; 2 maps). However, stratigraphic relationships between the upper Paleozoic sequence and the earlier rocks are not clear.

The upper contact of the Sicker Group is probably an unconformity. Its nature has been discussed by Fyles (1955, p. 25, 27). The present investigation of the China Creek-Saltspring belt has yielded no visible evidence of a break between the Sicker Group and the overlying Vancouver Group, other than the striking change in lithology from the limestone or cherty rocks of the Sicker to massive or pillowed basalts of the succeeding unit. The contact is in many places a fault; in others, the contact surface is not exposed. The bedded rocks of the Sicker Group below the contact appear to be parallel to the contact where it is not faulted. The Sicker rocks at the contact are not always the same lithology; this is not necessarily proof of bevelling of the upper surface of the Sicker Group, for facies changes within the Sicker are common. The best evidence in support of unconformable relationships at the contact between the Sicker and Vancouver Groups lies in the apparent disparity in ages of these two units. The age of the lower part of the Vancouver Group

of the Cowichan Lake area is "Triassic and (or) Permian" according to Fyles (p. 11). The stratigraphic relationships between the basal unit of the Vancouver Group (Franklin Creek volcanics) and the overlying Sutton Limestone, as described by Fyles (p. 24-25), are strong evidence for interpreting this as a conformable succession, and the age of the two formations as being not widely different. The age of the Sutton is Late Triassic. The age of the Upper Division of the Sicker Group has been determined as Early Permian. If the interpretation given above is valid, then the contact between the Franklin Creek volcanics and the Sicker Group is a paraconformity (Dunbar and Rogers, 1958, p. 119). The lacuna (Wheeler, 1958) represented may thus include the time interval from mid-Permian to mid-Triassic. This interval is considered to have been a time of uplift and erosion in other parts of British Columbia (Armstrong, 1949, p. 42-43; White, 1959, p. 72).

Lower Division

Rocks of the Lower Division have been described by Fyles (1955, p. 13-15). Amygdaloidal rocks, breccias and massive tuffaceous sediments, and thin-bedded non-calcareous sediments (cherty and feldspathic tuffs, tuffaceous greywackes and breccias) are among the prominent lithologies present. According to Fyles (p. 13), "this general assemblage may be recognized widely on southern Vancouver Island".

The present investigation did not include detailed studies of this part of the sequence. Each of the main rock types mentioned

by Fyles was examined by the writer, and the rapid facies changes noted by Fyles (p. 13) were apparent in even this limited survey. Rocks varying from massive green tuffaceous? sediments to breccias and greywacke-argillite sequences are exposed immediately beneath the calcareous and cherty sequence of the Upper Division.

Marker horizons are rare to absent in this heterogeneous unit. A 600 foot sequence of thin-bedded cherty tuffs in the middle of the exposed section (of about 7500 to 9000 feet) of the Lower Division rocks on the north side of Cowichan Lake appears to be recognizable over at least 20 miles (Fyles, p. 18).

In general, it would appear from descriptions and cross sections by Fyles (1955, Fig. 2) that volcanic rocks are dominant below the marker and sedimentary rocks above.

Upper Division

Bald Mountain Peninsula Section

On Bald Mountain, on the north face at its east end (see Figure 3), an incomplete section of the Upper Division was estimated to be 700 feet in thickness. Of this thickness, less than 300 feet consists of limestone; the remainder of the interval is thin-bedded, fine grained chert and siliceous limestone, or covered. The base of the sequence is occupied by massive limestone estimated to be 100 feet in thickness. The middle portion of the section (about 300 feet) is composed of thin-bedded, dark grey chert. The limestone exposures in the upper part of the section are interspersed with those of the cherty rocks, or with covered intervals, with the thickest limestone

at the top, estimated at 50 feet. The lower contact of the Upper Division was not seen in this area. Fine to coarse volcanic breccias, presumably underlying the Upper Division rocks, are exposed on a low knoll north of Marble Bay. According to Fyles (1955, p. 17) breccias and clastic sediments of the north and east sides of the peninsula "are overlain and grade laterally into limestone and chert".

The upper contact, where seen by the writer, was in a covered interval between the uppermost limestone member of the Upper Division, Sicker Group, and brown weathering volcanic rocks above. Fyles (p. 17) mentions a band of varicoloured chert, up to 40 feet thick near the contact.

Fairservice Mountain Section

Several section measurements were attempted on the north face of Fairservice Mountain. The sections examined on the south side of Fairservice Creek, and in a gully south of *Skidders Flat were not satisfactory for measurements because of inadequate exposure and complex structure. A section along the west fork of Chanlog Creek (see Figure 9) at the east end of Fairservice Mountain, provided relatively good exposure of the Upper Division. However, faulting, with accompanying shearing and brecciation, and the presence of several intrusive bodies in the lower part of this section detract from its stratigraphic value. Despite these deficiencies the section was measured, and provides a useful comparison with a more satisfactory section to

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*Local name; see Figure 3

Figure 9. Chanlog Creek section, upper part. View southwest. Creek exposures of rocks of Upper Division, Sicker Group, overlain by volcanic rocks of Vancouver Group (upper left, below horizontal band of timber).

Figure 10. Chanlog Creek exposures of limestones and siliceous limestone-chert beds of Upper Division, Sicker Group.

the north. The latter was measured in a large gully and several smaller near-by exposures, which lie midway between Chanlog Creek and Skidders Flat, one and one-half miles south-west of the Chanlog railpoint. This section, although not offering as complete exposure as that on Chanlog Creek is less complicated by faulting, and includes almost the whole interval occupied by the limestone formation. This section is referred to as the Fairservice Mountain section, and is shown diagrammatically in Figure 6.

The measured thickness of the Upper Division in the Fairservice Mountain section is 2580 feet. The basal contact with the underlying massive green volcanic rocks is not exposed, but must lie within a few tens of feet of the base of the measured section. The upper contact of the Sicker Group lies within a few feet of the top of the measured section, which is separated by a covered interval from the overlying Franklin Creek volcanics.

The majority of the exposed section, as is shown in Figure 6, is composed of thinly bedded (1 inch to 6 inches) to medium-bedded (6 inches to 2 feet) dark grey to black chert and fine-grained medium grey limestone (see Figure 10). Small lenses of light grey, coarse-grained crinoidal limestone, with thicknesses from 1 foot to 6 feet, are sparsely scattered through the section (Figure 11). Above the middle of the section, exposure is poor, except for two thick limestones, one of 182 feet and the other 112 feet in thickness. These limestones are medium to coarse-grained, crinoidal and thick-bedded to massive. The upper limestone is extremely cherty in the top 20 feet, and contains a few poorly preserved brachiopods.

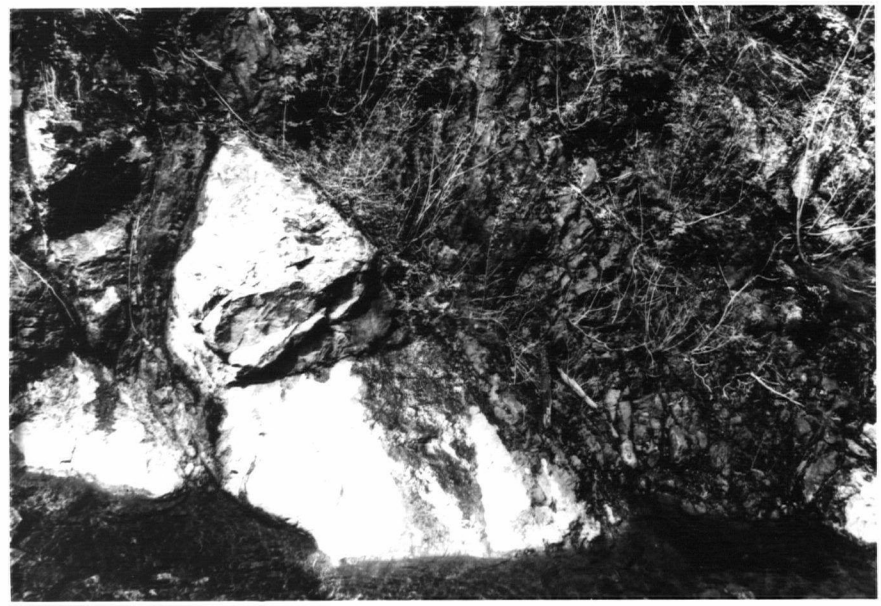

Figure 11. Limestone lens within thin-bedded siliceous sequence of Upper Division, Sicker Group, on Chanlog Creek.

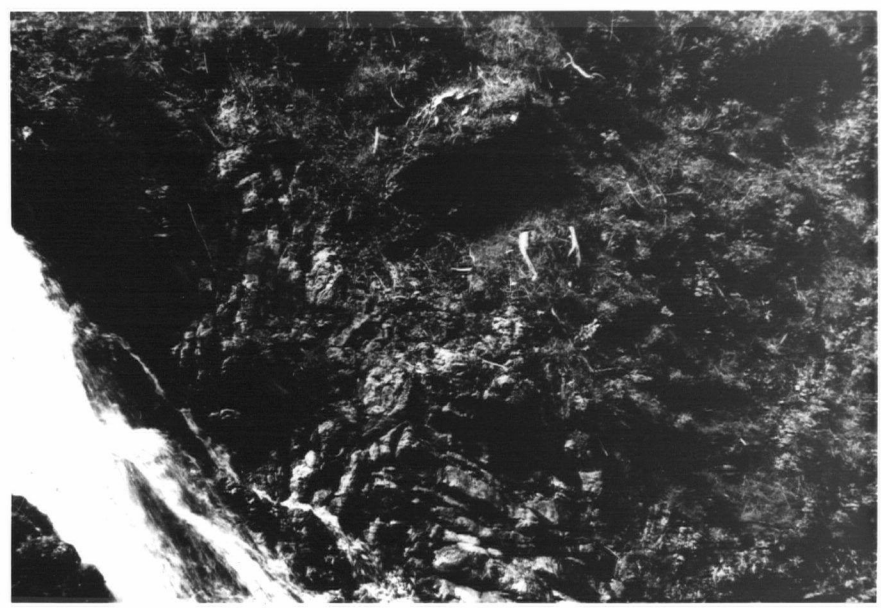

Figure 12. Contorted thin-bedded siliceous rocks of Upper Division, Sicker Group, on Chanlog Creek.

The interval from the top of the uppermost thick limestone to the top of the section is covered, except for the upper five feet. In traverses across the hillside to the south, this interval has been found to consist of thin-bedded chert with minor limestone lenses. In the small exposure at the top, thin-bedded chert and limestone, with lenses of coarse-grained, fossiliferous limestone, all highly contorted, are present. Within a few feet above this, fine-grained greenstone of the base of the Vancouver Group is exposed.

A comparison of the Fairservice Mountain section with that obtained on Chanlog Creek shows that the two are comparable on a gross scale. Detailed correlation between the two, a little over half a mile apart, is, however, impossible; one of the two thick limestones of the Fairservice Mountain section, for instance, does not appear to outcrop in the Chanlog Creek section. Similar disparities in detailed lithologic succession are apparent when the Fairservice Mountain section is compared to the roughly estimated section one-half mile to the north, in the gully south of Skidders Flat. In the latter, the only prominent thick limestone is near the base, and is perhaps comparable to the 90 foot limestone in a similar position in the Fairservice Mountain section.

There is no doubt that some of the difficulties involved in attempting to match these closely spaced sections are the result of structural complexities and incomplete exposure. However, the lensing habit of the limestones themselves probably is the major factor contributing to the difficulty in such short range correlations.

The thin-bedded cherty rocks of this section appear to be

Figure 13. Limestone exposures, Upper Division, Sicker Group, southeast from west fork of Chanlog Creek.

Figure 14. Sink hole exposures of limestones of Upper Division, Sicker Group, on Fairservice Mountain, south of headwaters of Chanlog Creek. Franklin Creek volcanics in hillside, left background. View north.

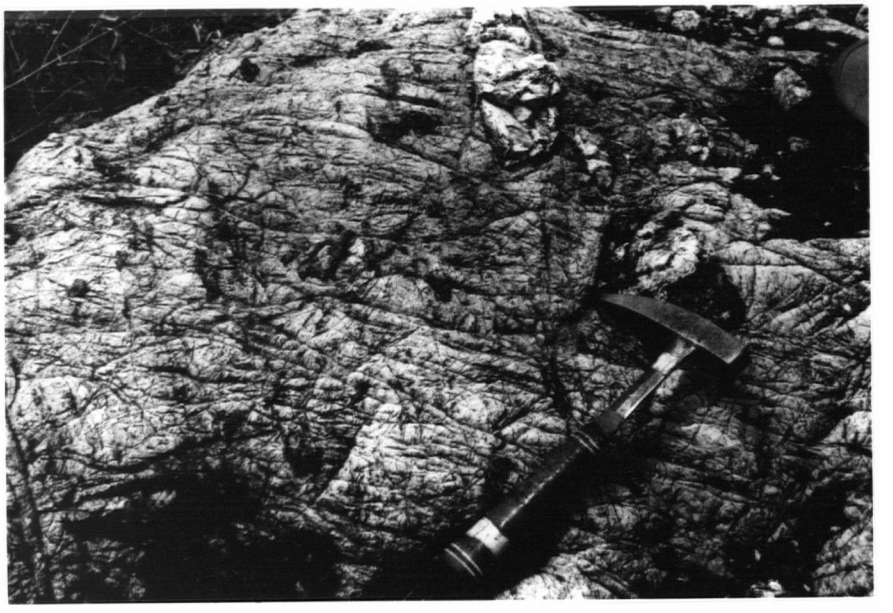

Figure 15. Fractured, partly silicified and dolomitized limestone, with chert nodules; Upper Division Sicker Group, near headwaters west fork, Chanlog Creek.

Figure 16. Thin-bedded siliceous limestone-chert sequence, Upper Division, Sicker Group, in road-cut, east side of Fairservice Creek.

identical to those from the same stratigraphic interval described by Fyles (1955, p. 16, pl. VIII). In most of the large exposures, they are highly contorted; in single exposures, 10 to 50 percent of the section may be involved in tight, small amplitude folds (Figure 12). The effect of such deformation of the original total thickness of the formation cannot be estimated with the data available.

Bear Creek Section

Along the west fork of Bear Creek, approximately the same thickness of Upper Division Sicker Group rocks are exposed as on the northeast face of Fairservice Mountain and at the east end of Bald Mountain. A unit of fine to medium-grained, greenish greywacke (see Figures 18, 19) occurs here, however, in a medial band of exposures separating two sections of the Upper Division calcareous and cherty rocks. One attitude in the greywackes, for which top determinations were obtained from graded bedding, small-scale channeling and cross-laminations, indicates tops to the east in a near-vertical sequence. In the northeastern section of Upper Division rocks, three-quarters of a mile north of Bear Creek, graded bedding in outcrops of steeply-dipping chert and siliceous limestone also indicates tops to the east (see Figures 3, 20).

These data suggest that the exposures represent a folded section, with the greywackes exposed in the core of an anticline. The greywackes do not reappear on the northeast boundary of the Upper Division; here a narrow zone of greenish tuffs and fine breccias lies between the most northeasterly limestone outcrop and the massive,

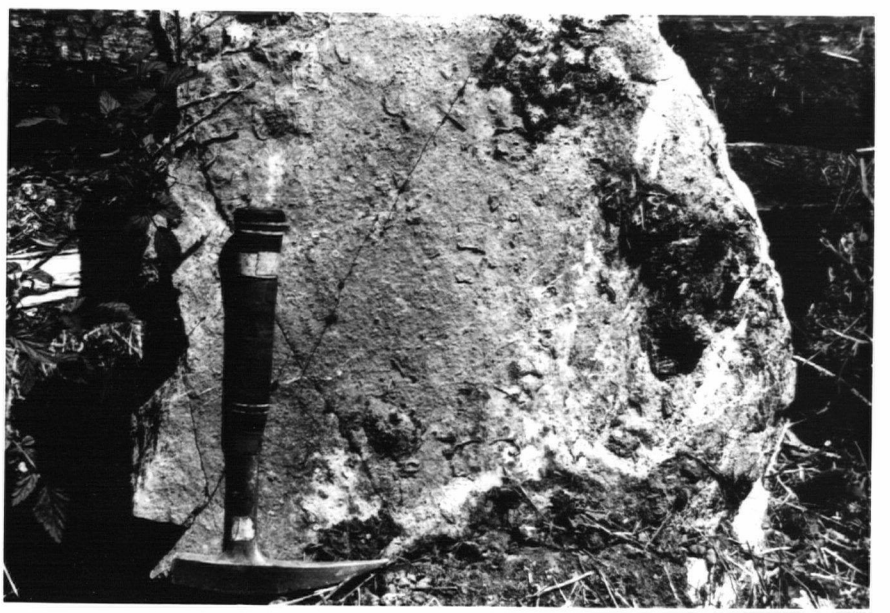

Figure 17. Limestone containing partly silicified fossils (brachiopods, bryozoans); Upper Division, Sicker Group, on Bear Creek.

Figure 18 (above). Greywacke and argillite, Lower Division, Sicker Group; south bank of west fork, Bear Creek. Exposure 30 to 40 feet high.

Figure 19 (left). Greywacke and argillite, north bank of west fork, Bear Creek. Near-vertical beds strike northwest-southeast, and face northeast.

fine-grained greenstones of the Lower Division to the north. Whether the greywackes are missing because of faulting, or have been replaced in a facies change by the pyroclastic rocks is still open to question. That these rocks underlie the limestone is shown by the attitudes northwest of the northeasterly greywacke contact, by the interfingering of limestone and greywacke at the contact, and by the absence of such rocks above the limestone elsewhere (e.g., along the northwest face of Fairservice Mountain) where the beds face southwest and are overlain by Franklin Creek volcanics. The greywackes probably are the same type of rocks described by Fyles (1955, p. 17; Fig. 2) as "clastic sediments" on the north side of Bald Mountain peninsula. He suggests that here also the clastic sediments interfinger with the limestone.

Stratigraphic sequence and thickness

The interpretation of the stratigraphic succession within the Upper Division of the Sicker Group hinges on the sections obtained on Fairservice Mountain and in adjacent areas. These sections are involved in structures of large and small magnitudes. Marker beds, with which to decipher the detailed structural pattern, are not known. It was hoped that fossil horizons might be of some use in this analysis. Unfortunately, fossils are scarce, and where they are present, are usually so poorly preserved that precise identifications are difficult, if not impossible. With such a poor fauna, it is unwise to place much credence in detailed local correlations based on the fossils. In the absence of other criteria for recognizing stratigraphic horizons within the limestone unit, however,

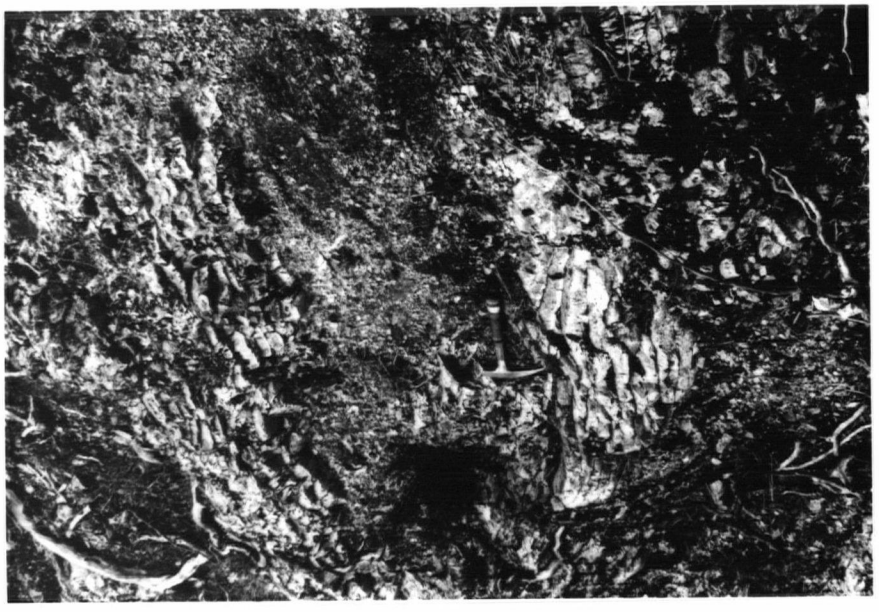

Figure 20. Thin-bedded siliceous limestone and chert of Upper Division, Sicker Group; Fairservice Mountain, east of Bear Creek. Beds strike north to northwest, and face east. View north.

the following extremely tentative conclusions are given as a basis for the writer's interpretations.

The evidence from complete or partial stratigraphic sections in the area between Cowichan Lake and Tadjiss Lake (see Figures 3, 6) indicates that limestone lenses of the Upper Division are sporadic in their vertical and horizontal distribution with the unit. Fossils of similar general character, and in some cases the same genera, appear throughout the length of this segment of the China Creek-Saltspring belt. The two known occurrences of the fusulinid genus Schwagerina? (Bald Mountain peninsula, Fairservice Mountain) are in the Upper one-third of the Upper Division of the Sicker Group. Distinctive brachiopods occur in the upper one-third of exposed section of the limestone formation on Bald Mountain peninsula. Similar brachiopods occur near the middle of the Bear Creek section, stratigraphically above rocks of the Lower Division.

Fyles (1955, p. 17; fig. 2, cross sections A-B, C-D), interpreted the structure on Bald Mountain and Fairservice Mountain as a pair of folds, anticlinal on the west, synclinal on the east. Information from the present study of these two sections gives no conclusive evidence pertaining to this hypothesis. The three prominent limestone members of the Fairservice Mountain section could possibly represent repetitions of the same horizon; but they differ in exposed thickness, detailed lithology and observed fossil content. However, in the area between Chanlog Creek and Bear Creek, the distribution of rock types and structural data obtained tend to corroborate Fyles' interpretation (see page 43).

Structural repetition of the sequence of limestone, chert and siliceous limestone of the Upper Division thus seems probable in sections from Bald Mountain peninsula to Bear Creek. The absence of marker beds within the unit prevents an accurate measurement of the true thickness of beds involved in the folding. Depending on the style of folding, figures of one-quarter to one-third of the exposed thickness may be postulated as reasonable estimates of the true thickness. If the above analysis of the Bear Creek section is valid, the thickness of the western upper limb of the anticline is calculable from the western part of the Bear Creek exposures. A thickness of about 1,000 feet of the Upper Division appears to be present on this limb. An estimate, made on the assumption of similar structure, of 700 to 900 feet is calculated for the measured Fairservice Mountain section.

Fyles (1955, p. 16, 17) estimated the thickness of the limestone "formation" to be about 1,000 feet northwest of the west end of Cowichan Lake and 500 to 1,000 feet at Fairservice Mountain, based on his structural interpretation. In the China Creek area, Stevenson (1945, map; cross-section C-D) shows a minimum of 1,000 feet of limestone on the east face of Mt. Spencer.

The structural hypothesis given above appears adequate to explain the field relationships and the variations in stratigraphic sections. It must still be regarded however as an hypothesis, for conclusive evidence in the form of marker horizons folded in the configuration proposed (an anticline-syncline pair) has not been found. Either faulting or facies changes, or a combination of

faulting and facies change within the upper Sicker Group, could also account for the observed data. Additional structural and stratigraphic information is needed to satisfactorily resolve the problem.

Fauna

The fossils found in limestones of the Upper Division of the Sicker Group in the sections mentioned above consist of a few silicified brachiopods, several foraminifera, one coral, and abundant fragmentary remains of ramose and fenestrate bryozoans. Those in the present writer's collections are not specifically identifiable, but some at least are similar to fossils present in other collections from the area.

Brachiopods collected by Fyles (1955, p. 19) from limestone of the Sicker Group on Bald Mountain peninsula include a species of Spiriferella. The same locality yielded fossils of a genus identified as Horridonia? (Dutro, pers. comm. to Danner, 1962). These two genera have been tentatively identified by the writer in limestones of the upper part of the Sicker Group on Bear Creek, where they are associated with other brachiopods, bryozoans and corals.

M. L. Thompson (in Fyles, 1955, p. 19) identified the genus Schwagerina in specimens from the upper part of the limestone formation on Bald Mountain peninsula. This genus has been tentatively identified also in specimens of limestone collected by the present writer from the upper, thick limestone of the Fairservice Mountain section, about 730 feet from the top of the section. Other small foraminifera, including Tetrataxis and a small fusulinid species

occur in the same section, and also in limestone exposures near Bear Creek. W. R. Danner (1962, pers. comm.) collected foraminifera from limestones of the upper Sicker Group on the west side of Bear Creek, south of Skutz Falls. The stratigraphic position from which the specimens were obtained is not known. The most interesting and significant of the fossils is a fusulinid species which has been stated by J. W. Skinner (pers. comm. to W. R. Danner, 1962) to belong to one of three genera: Fusulinella, Waeringella, or Pseudofusulinella. The small fusulinid mentioned above, which has been found in the Fairservice Mountain and Bear Creek sections, is similar to the specimens discussed by Skinner.

Large thick shelled brachiopods, silicified and unidentifiable even at the generic level, have been found in the limestone exposed in the Wild Deer Lake area. Some of the forms vaguely resemble brachiopods from the Bald Mountain peninsula (e.g., "Horridonia?"). From the large limestone body on the southeast flank of Eagle Heights, poorly preserved, and thus far unidentified, brachiopods, bryozoans and solitary corals were collected. In general aspect the fauna looks similar to that of the limestones to the northwest along the China Creek-Saltspring belt. In both the Wild Deer Lake and Eagle Heights areas, mapping has not yet been done, and the stratigraphic sequence remains to be worked out.

Examinations of the limestones at Cobble Hill (see Figure 2) were mainly directed towards a search for identifiable fossils. No fossils were found in the deposits being developed by the British Columbia Cement Company, (referred to as the "Raymond" deposit by

Mathews and McCammon, 1957, p. 45), one and three-quarter miles west-southwest of Cobble Hill station. The small limestone exposure on the southeast side of Cobble Hill, one-half mile southwest of Cobble Hill station, contains poorly preserved, silicified brachiopods, solitary corals and coarse crinoidal debris. The fauna, though not precisely identifiable, looks similar in general character to that of the other fossiliferous limestones of the China Creek-Saltspring belt.

The age of the fauna discussed above and listed below is treated in detail in a later section of this report (p. 109).

Faunal lists

The following is a compilation of fossil identifications from the Upper Paleozoic rocks of the China Creek-Saltspring belt.

Lizard Lake

From limestone one-half mile southeast of Lizard Lake (Stevenson, 1945, map; p. 6):

Spiriferella
Crinoid disks and stems

Bald Mountain peninsula

From limestone one and one-half miles northwest of Marble Bay, at elevation of about 1,000 feet; from beds "between 200 and 400 feet below the base of the Franklin Creek basalt" (Fyles, 1955, p. 19):

Productus cf. P. *uralicus* Tschern.
Productus cf. P. *weyprechti* Toula
Spiriferella saranae var. *arctica* Haughton

Schwagerina?

From limestone "one-quarter mile by trail from the end of a forestry lookout road" and "20 to 25 feet east of the trail". "The horizon appears to be stratigraphically near the top of the limestone bed". (W. R. Danner, personal communication, 1962):

Muirwoodia?
"Dictyoclostus"
Horridonia?
Spiriferella

Localities 61-7-10, 18, 20 - Forestry trail south of limestone cliffs:

Fusulinids.

Fairservice Mountain
Locality unknown: (Fyles, 1955, p. 19)

Quasifusulina

Locality 62-48-2F - Top of Fairservice Mountain section (1.4 miles southwest of Chanlog railpoint), Upper Division, Sicker Group (Unit 32):

Tetrataxis sp
Cladochonus sp.
Rhabdomeson sp
Streblascopora pulchra?

Locality 62-43A-3 - Fairservice Mountain section, limestone between 1773 feet and 1851 feet from base of section (Unit 30):

Schwagerina? sp. (72' from top of limestone)
Goniocladia sp. (82' from top of limestone)
Streblascopora pulchra? (62' from top)

Locality 62-43-12 - Fairservice Mountain section, limestone 1013 feet from base of section (Unit 22):

Fistuliporid bryozoan

Locality 62-43-11 - Fairservice Mountain section, limestone 957' from base of section (Unit 20):

Fusulinid

Locality 62-45-3F - Fairservice Mountain section, limestone between 150' and 240' from base of section (Unit 2):

Tetrataxis

West Fork Bear Creek

Locality 62-52-3 - 1 3/4 miles west of confluence with east fork:

Spiriferella? sp.
Horridonia? sp.
Hustedia? sp
Schizophoria sp.
Michelinia sp. A
Sulcoretepora
solitary rugose corals.

East fork Bear Creek, and adjacent area on each side.

Various localities

Tetrataxis
Fusulinids
Streblascopora pulchra?
Rhabdomeson sp.
Goniocladia sp
Fistuliporid bryozoan

"From the south side of the Cowichan Valley about 2 or 3 miles south of Skutz Falls" (W. R. Danner, personal communication, 1962).

Fusulinella? (possibly Waeringella or Pseudofusulinella)
Millerella or Paramillerella

STRUCTURE

Structure within the China Creek-Saltspring belt is complex. Fyles' (1955) report on the Cowichan Lake area provides the source for most of the detailed structural information. Along the west side of the belt in the Cowichan Lake area, the gross structure is homoclinal, with steep westerly and southwesterly dips predominating. Within the belt, large-scale folds are evident (Fyles, p. 26; fig. 2). Axial planes dip southwest in the western portion, where over-turned folds are common. The northeastern part of the Cowichan Lake area is characterised by less steep dips and folds with northeast-dipping axial planes. Longitudinal faults of considerable length have been mapped; these appear to subdivide the belt into longitudinal segments,

differing from one another in either structural pattern or dominant rock types, or both (Fyles, fig. 2). Transverse and oblique faults are common wherever mapping within the belt has been done to scales other than regional (e.g., Fyles, fig. 2; Stevenson, 1945, map; Figure 3 of this report).

The almost complete lack of marker beds within the Sicker Group makes interpretation of local structure exceedingly difficult. The upper part of the Sicker Group in the western border of the belt, contains a unit (the Upper Division) in which limestone is a prominent constituent. Within the remainder of the Paleozoic sequence, limestones are rare or absent, and only one lithologic unit with value as a horizon marker has so far been found. The latter is a 600 foot sequence of thin bedded cherty tuffs, occurring at least 3,500 feet below the top of the Sicker Group, recognizable over a distance of at least twenty miles on the north side of Cowichan Lake (Fyles, 1955, p. 18). The thin-bedded pyroclastic and sedimentary rocks which form a large proportion of the Sicker Group are usually poorly exposed, and where they do crop out, are commonly found to be highly contorted. Within them, in certain localities, overturned and isoclinal folds can be observed.

The discussion on pages 43 and 44 of this account illustrates the problems of local structural interpretation in this belt.

HORNE LAKE-CAMERON RIVER BELT

GENERAL STATEMENT

Of the area underlain by rocks of Paleozoic or possible Paleozoic age in the Horne Lake-Cameron River belt, only small portions have been mapped. The majority of available map information is that contained in Fig. 6 of Mathews (1947), and Fig. 5 of Mathews and McCammon (1957), both dealing with the limestone deposits around Horne Lake. Earlier maps by Richardson (1873), MacKenzie (1922, fig. 5), and Clapp (1912, Map 17A) cover parts of the belt, but provide only data of a reconnaissance type. Field work by the present writer, has added information mainly in the Horne Lake area (Figure 4).

As shown in Figure 4, Paleozoic rocks are known to occur in an area extending from the south face of Mt. Mark, on the north side of Horne Lake, to a point on the east side of Cameron River 2.2 miles east-southeast of Summit Lake.

The eastern boundary of the belt extends southward from the outlet of Horne Lake, Qualicum River, through the west end of Cameron Lake to the west face of the ridge on the east side of Cameron River, just south of Cameron Lake.

The western boundary of the belt has been mapped in the Horne Lake area. South of the west end of Horne Lake, this boundary is not well-known; Mathews (1947, fig. 20) indicates that Paleozoic rocks are present in a prominent salient west of Horne Lake, between the lake and the Esquimalt and Nanaimo Railway.

The northwest-southeast stretch of railway line between Cameron River and Bainbridge forms an approximate southwest limit of this portion of the belt, with Upper Cretaceous sedimentary rocks of the Nanaimo Group forming the bulk of exposures to the southwest (see Figure 21). South of the Alberni Highway, and west of Cameron River, MacKenzie (1922, fig. 5) mapped rocks (which he referred to the Vancouver Group) similar to those north of the highway and railway, and assigned by Mathews (1947) to the Paleozoic. This area of pre-Cretaceous rocks, whose western margin trends north-northwest near the northeast end of Bainbridge Lake, appears to extend southward toward the northern mapped boundary of Sicker Group rocks of the China Creek area. It has been shown as "mainly or entirely Permian" on the latest compilation map covering the area (Geological Survey of Canada, Map 932A, 2nd Edition, 1962, by H. W. Little). If this interpretation is valid, the Horne Lake-Cameron River belt of Paleozoic rocks is contiguous with the China Creek-Saltspring belt to the south. Field work by the present writer has not covered the area in question; rocks correlatable with the Paleozoic rocks of Horne Lake have been traced only as far south as the point on the east side of the Cameron River mentioned above, and as far west as a point 0.7 miles east of the junction of the Alberni and Port Alberni highways.

Limestones of the Paleozoic sequence are known to occur on the north and west sides of Horne Lake, in Cameron Draw between Mt. Horne and Mt. Wesley, and in the west face of the steep-sided ridge paralleling Cameron River, south of the west end of Cameron Lake.

Figure 21. Unconformity between Nanaimo Group conglomerates (upper left) and schistose volcanic rocks of Sicker Group (lower right), Alberni Highway, 0.3 miles southeast of Stokes Creek. Contact is irregular surface dipping west (to left).

Richardson (1873, p. 55-56) reported large limestone deposits at "View Mountain", between the west end of Horne Lake and Alberni. These deposits have apparently not been examined by later workers (e.g., Mathews 1947; Mathews and McCammon, 1957). The exact location of "View Mountain" cannot be determined from Richardson's map; it could be one of the several hills in the area, none of which bears that name on recent maps.

STRATIGRAPHY

Sequence and Nomenclature

The lower portion of the observed section comprises coarse tuffs and breccias. Between these rocks and the base of an upper portion of limestones are interbedded massive green tuffs and thin-bedded tuffs or tuffaceous sedimentary rocks. Locally, the base of the coarse crinoidal limestones of the upper part of the sequence grade laterally into green and maroon tuffaceous rocks and breccias. In other places, the fine-grained varicoloured clastic rocks grade upwards into crinoidal limestone over 1 to 15 foot intervals.

The limestone is best exposed on Mt. Mark (see Figures 22, 23), where it is divisible into thick-bedded upper and lower coarse crinoidal units, separated by a unit of more thinly bedded crinoidal and impure, tuffaceous? limestones. Locally, sandy to conglomerate members are present in the middle unit (Figures 6, 27, 28).

The upper contact of the limestone and overlying pillow lavas of the Triassic Vancouver Group has been actually seen in only one place, where its character is not well displayed. On the northeast face of Mt. Mark, overall attitudes of the limestone appear to strike

in the same direction as the upper contact.

According to Mathews and McCammon (1957), there is a westward thinning of the limestone unit on Mt. Mark, and also eastward toward the exposures of Qualicum River. In the West Horne Lake exposures (Figure 24), the Cameron Draw exposures (Figure 25), and the Cameron River exposures, thicknesses of only a few hundreds of feet of limestone are present compared to the 1500' of section measured on Mt. Mark. The West Horne Lake exposures, are obviously faulted at the upper contact; the other sections are not known to be bounded by faults.

That the limestone units of the succession are lensing in habit is indicated by lateral gradations from limestones to non-calcareous rocks on the west side of Horne Lake, and by the discontinuous exposures of limestone on the east side of Cameron Draw and east side of Cameron River.

Mathews and McCammon (1957, p. 50) suggested that the apparent variations in thickness of the limestones, and the absence of the upper part of the limestone section in certain places indicated an "unconformable contact between the limestone and overlying lava". With the information on hand, no angular unconformity can be proved to be present, and no evidence of an erosional break is visible at the contact. The apparent thinning of the limestone unit may be attributable to its lensing habit, facies changes, or both. As discussed in an earlier section of this account, the most cogent evidence in support of placing an unconformity in this position is given by the age disparity of the rocks below and above the contact. In this regard,

petrologic character and stratigraphic position of the volcanic rocks overlying the limestone indicate that they are equivalent to the Franklin Creek Volcanics of the China Creek-Saltspring belt.

The similarities of the Paleozoic sequence of rocks in the Horne Lake-Cameron River belt to those of the other Paleozoic belts of Vancouver Island have been pointed out earlier. Faunal criteria for correlating the sequences in all three belts are given in detail in a later section. In the writer's opinion, there is no doubt that the Horne Lake-Cameron River belt contains rocks which are the stratigraphic equivalent of the Sicker Group of the China Creek-Saltspring belt. The evidence available also indicates that the major divisions of the Sicker Group recognized in the southern belt are also present in the Horne Lake-Cameron River belt. It is therefore proposed that the same terminology be applied in both belts.

In the Horne Lake-Cameron River belt, however, the Lower Division of the Sicker Group, comprising the non-calcareous part of the sequence, may be further subdivided into a lower part consisting mainly of breccias, and an upper part characterised by thin-bedded tuffs or tuffaceous sedimentary rocks. Both of these lithologies also occur in the Cowichan Lake area of the southern belt. In the latter area, however, "cherty tuffs" and other thin-bedded clastic rocks probably occur in more than one stratigraphic position in the sequence (see Fyles, 1955, p. 18; fig. 2, section K-L). Such a stratigraphic sequence may eventually be found also in the Horne Lake-Cameron River belt, when the total thickness of exposed pre-limestone rocks has been investigated in detail. At the present time, it can only be stated

that the Horne Lake sections of the Lower Division of the Sicker Group are similar to the upper part of the same unit of the Sicker in the Cowichan Lake area.

For the reasons given in the earlier discussion of the nomenclature in the China Creek-Saltspring belt, formational names are not proposed at this time. The proposed "divisions" of the Sicker Group may with further work be shown to have true formational status.

Table of Formations

The following diagram (Table 3) illustrates the writer's proposals for nomenclature in the Horne Lake-Cameron River belt.

System	Series	Group	Formation	Lithology
Triassic	Upper Triassic	Vancouver Group	Franklin Creek volcanics	Basaltic pillow lavas; intrusive diabase
?	?			
?	?	Paraconformity		
Permian	Lower Permian	Sicker Group	Upper Division	Fine to coarse-grained limestone; chert and siliceous limestone; thinly interbedded, fine-grained non-calcareous sediments; minor conglomerate
Permian and/or older	?		Lower Division	Interbedded massive and thin-bedded tuffs or tuffaceous sediments; minor breccias
				Mainly coarse tuffs and breccias.

TABLE 3

Table of formations, with proposed nomenclature for sub-divisions of the Sicker Group, Horne Lake-Cameron River belt.

Sicker Group

Lower Division

Greenish fine-grained clastic rocks and breccias, presumed to be of mainly volcanic origin, are exposed below limestones on the hillsides above the west arm of Horne Lake, along the southern shore-line and in the west slopes of the peninsula between the west arm and the main body of the lake. A thickness of over 5,000 feet is estimated for the exposed rocks of the Lower Division of the Sicker Group. The total thickness of this unit is not known, for the base has not been seen.

The lower half of the observed section is coarse-grained on the whole, with fine to coarse breccias and coarse tuffs forming the predominant constituents. Angular and rounded fragments of massive, green, fine-grained rocks, greenish cherty rocks and maroon and green porphyritic volcanic rocks up to one foot in maximum dimension comprise the clasts in the breccias. No stratification has been observed in these rocks.

The upper half is mainly fine-to coarse-grained thin to medium bedded tuffs or tuffaceous sedimentary rocks, with minor fine breccias. In the uppermost portion, pale green and white, thinly banded units occur.

On the west side of Cameron Draw, a section of 1,500 feet of banded tuffs or tuffaceous sedimentary rocks of the upper part of the Lower Division of the Sicker Group was examined. The rocks are pale green to bright green, fine-to very fine-grained, with a pale green to white weathered surface. Thin to medium bedded units are interstratified with thick massive units. Some of the thin bands display

weakly graded textures (see Figure 26), and more rarely, faint cross laminations; both of these features suggest tops to the east in the east- or northeasterly-dipping sequence.

Along the Alberni highway, west of Cameron River, scattered exposure of massive green, fine-grained rocks, presumably of the Lower Division, are interspersed with outcrops of flat-lying to gently dipping conglomerates and sandstones of the unconformably overlying Upper Cretaceous Nanaimo Group (Figure 21). The older rocks are strongly fractured and schistose in places.

Upper Division

Mt. Mark Section

The most complete exposures of the limestones of the upper part of the Paleozoic sequence are on the south and southeast sides of Mt. Mark. Transverse or oblique faults were encountered in each of several attempts to measure an undisturbed section here. The section given in Figure 6 is composite; one or more faults may occur in the upper 500', where attitudes are variable and exposure less than complete. It was measured in exposures extending from an elevation of about 800' to 2,300' immediately south of the 2,037' peak.

The base of the sequence is covered at this locality. The lowest observed exposures are of aphanitic to fine-grained, green clastic rock, with thin laminae of sand-sized angular feldspar grains. It contains scattered radiolarian fossils. A covered interval separates these probably tuffaceous sedimentary rocks from the base of the main

Figure 22. Mt. Mark section, Upper Division, Sicker Group (measured right of centre). Volcanic rocks of Vancouver Group in dark-weathering cliffs above limestone (upper left). Dark-weathering diabase separates two portions of limestone section (upper right). View northeast from southwest corner of Horne Lake.

Figure 23. Mt. Mark section, aerial view to north.

limestone cliff exposures. Maroon and green fine-grained fossiliferous clastic rocks grade upwards, through a 15 foot interval into the coarse, crinoidal limestones of the lower cliff section.

Coarse-grained crinoidal limestone is the dominant lithology in the lower 500 feet of the section. Thin, varicoloured, impure limestone beds are common in this interval. Grey chert and silicified limestone in the form of nodules and thin discontinuous beds are abundant from 75 to 260 feet from the base.

From 550 feet above the base of the limestone to the base of a thick sill-like, diabase intrusion, dark-weathering thin-bedded impure limestone and calcareous, fine-grained clastic rocks predominate. This unit is gradational into the one below, as the amount of light coloured crinoidal limestones gradually decreases upwards.

The basic intrusive splitting the limestone section (see Figure 23) occurs between elevations of about 1,700 to 1,900 feet; it is estimated to be about 150 to 200 feet in thickness. The lower contact was not seen, as it occurs in an inaccessible portion of the cliff. The upper contact of the diabase and limestone unit is covered, with about 10 feet separating the two rock types. The diabase is a dark green to black, medium to coarse-grained, massive rock. The petrology of the intrusive has been investigated by Farquharson (1963), who concluded (p. 25-26) that:

> "Its mineralogical character is consistent with the mineralogy of other well known diabases ... The bulk composition of the sill parallels the composition of the late differentiates of some large diabasic intrusives where the pyroxene has passed from the two pyroxene field into the one pyroxene field. It is evident that the Horne Lake Sill is differentiated".

The field relations of the "sill" and limestone have not been firmly established. The diabase is cut off by a steeply dipping fault on the west. Its eastern extent has not been determined, but Farquharson (p. 4) has traced it 1,500' in this direction. The obscured contact between the diabase and limestone appears to follow the strike of the limestone above. No other sill-like bodies are present in the measured section. Mathews and McCammon (1957, p. 50), however, state that "several gabbro sills are visible" in the upper part of the section.

Above the diabase, cherty, impure, fine-to medium-grained limestone occurs. Next, above a 30 foot covered interval, is a 55 foot section of medium to coarse grained, slightly arenaceous limestone. This unit contains angular to rounded clear quartz grains scattered throughout the calcareous matrix. In the upper 10 feet of the arenaceous unit, several lenses of conglomerate 1" to 4" thick appear (Figure 27). The clasts are rounded pebbles, 1/4" to 2" in maximum dimension, of green and maroon non-calcareous clastic rocks and dark, fine-grained porphyritic volcanic rocks. Associated with the coarse clasts of the pebbly lenses are large productid brachiopod shells, up to 2 inches in maximum dimension (Figure 28). Partings in the enclosing impure limestones display small-scale cross laminations in units up to 6 inches thick.

The remainder of the section, above the conglomeratic beds, is partially covered. Thin-bedded, impure, cherty limestone grades upwards into medium to thick bedded crinoidal limestone with numerous thin lenses and nodules of chert (Figure 29). Between the top of the

limestone section and the base of the fine-grained, dark green pillow lavas of the Vancouver Group, a 30' covered interval intervenes.

The limestone-volcanic contact trends northeastward along the base of a steep scarp to Hunts Creek (see Figure 4), where the limestone terminates against a fault, with pillow lavas on the north side of the fault. On the south side of the creek, an almost flat-lying limestone-volcanic contact is exposed. The contact is sheared and altered and affords little evidence of the type of surface it represents. The basal part of the Vancouver Group is a pale green, fine-grained to aphanitic rock, grading upwards into fine to medium-grained basaltic pillow lavas.

The base of the Upper Division has been taken here as being the base of the 15 foot transition zone below the main body of limestone. Elsewhere along the base of the cliff, this transition zone from fine-grained green or maroon non-calcareous clastic rocks to limestones occupies 1 foot to 10 feet of section. Using this concept of the base, the Upper Division on Mt. Mark measures 1,525 feet in thickness.

Such a thickness of limestone is not attained in any other known exposure of the unit in the Horne Lake-Cameron River belt.

West Horne Lake Section

Along a logging road south of the Qualicum River, west of the west arm of Horne Lake, limestones and other rocks of the upper part of the Paleozoic sequence are exposed. The limestones are in fault contact on the west with pillow lavas of the lower part of the Vancouver Group; the fault trends north-south, and appears to be vertical.

Figure 24. West Horne Lake section. View southwest from Mt. Mark. Upper Division limestones occur in logged area (centre) between Vancouver Group (partly cleared scarp) and volcanic and sedimentary rocks of Lower Division (sparsely timbered knolls).

Figure 25. North end of Cameron Draw (right centre), viewed southeast from Mt. Mark. Limestone of Upper Division at about timber's edge in draw, with Vancouver Group above and left, Lower Division right.

The limestone is exposed in two small areas, separated by outcrops of massive green clastic rocks and thin bedded grey chert. In the southern patch of limestone, one mile southwest of the mouth of Qualicum River, lateral gradations between the calcareous rocks and varicoloured tuffs and breccia are evident at the base of the limestone. The maximum thickness of limestone exposed is estimated to be 500 to 1,000 feet.

According to Mathews and McCammon (1957, p. 50), the limestone deposits of the west side of the lake terminate against a fault two miles south of Qualicum River, "although other deposits, undoubtedly parts of the same main body, occur within a mile" southwards. To the north, the limestones, though broken by transverse faults, extend across the Qualicum River, toward the western end of the Mt. Mark limestone exposures. Mathews and McCammon consider that the limestone section above the northwest corner of the lake is thinner than in the main cliff exposures of Mt. Mark. They state (p. 50): "the section thins to less than 400 feet" here.

Cameron Draw Section

Along an old logging road in Cameron Draw, exposures of massive fine-grained green rocks and banded greenish tuffs or tuffaceous sedimentary rocks are poorly exposed (see Figure 4). Overlying these rocks, along the east side of the draw, with the contact not exposed, limestones occur. One lens-like limestone body is one mile south of the southeast corner of Horne Lake; another was found one-half mile south of the first.

Figure 26. Thin-bedded tuffs, Lower Division, Sicker Group. East side Cameron Draw. Vertical beds strike northwest-southeast, and face northeast (graded bedding).

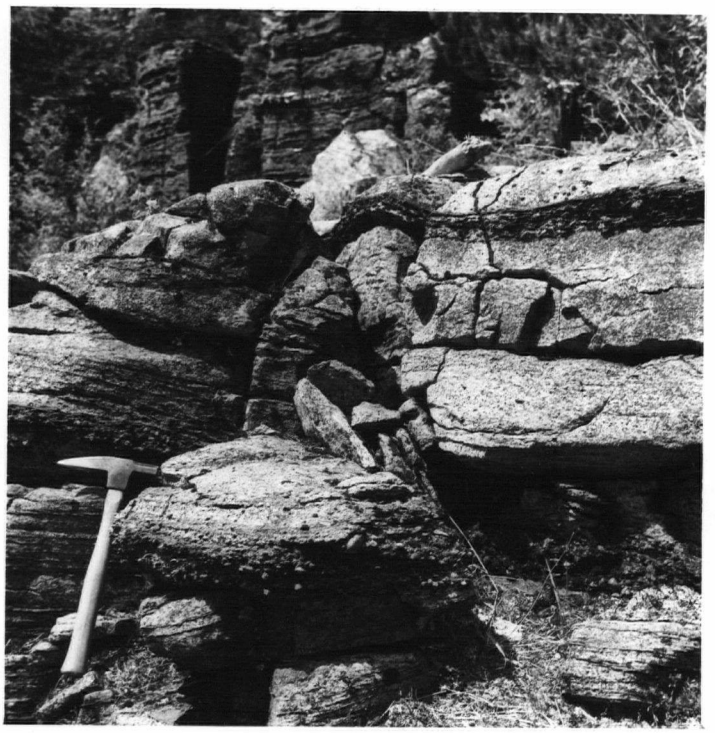

Figure 27. Conglomeratic limestone (Unit 23) of Mt. Mark section, Upper Division, Sicker Group.

The northerly limestone consists of a coarse crinoidal rock, contorted and broken by faults and fractures, lying between elevations of about 1,400 and 1,600 feet. Not more than 50 feet of vertical exposure is visible at any one place. The north-south extent of the body is several hundreds of feet. A covered interval to the south separates this limestone from a body of apparently similar size to the south. Massive blue-green volcanic rocks lie above the limestone. Contact relationships are not decipherable here because of incomplete exposure and complex minor structures. Brown weathering massive volcanic rocks of the Vancouver group extend above toward the top of Mt. Wesley and to the north east.

No limestone was seen at the head of Cameron Draw, and none occurs on the north side of Cameron Lake (Mathews, 1947, p. 59).

Cameron River Area

Several limestone outcrops occur along the west slope of the ridge on the east side of Cameron River, south of the west end of Cameron Lake. One of these is crossed by a trail from Cameron River to Mt. Arrowsmith. The limestone is 1.4 miles east-southeast of the right angle bend in the Alberni Highway east of Summit Lake. It occurs at an elevation of about 2,600 feet, on the north side of a small, west-flowing tributary of Cameron River. The rock is a light-coloured, coarse crinoidal limestone, with minor cherty lenses and nodules. It extends about 200 feet in a north-south direction, and 100 feet up the slope. Contacts are not exposed. Bedding attitudes were not obtainable. Massive green and maroon, fine-grained clastic

Figure 28. Upper surface of conglomeratic bed of Unit 23, Mt. Mark section. Partly silicified productid shells centre and upper left.

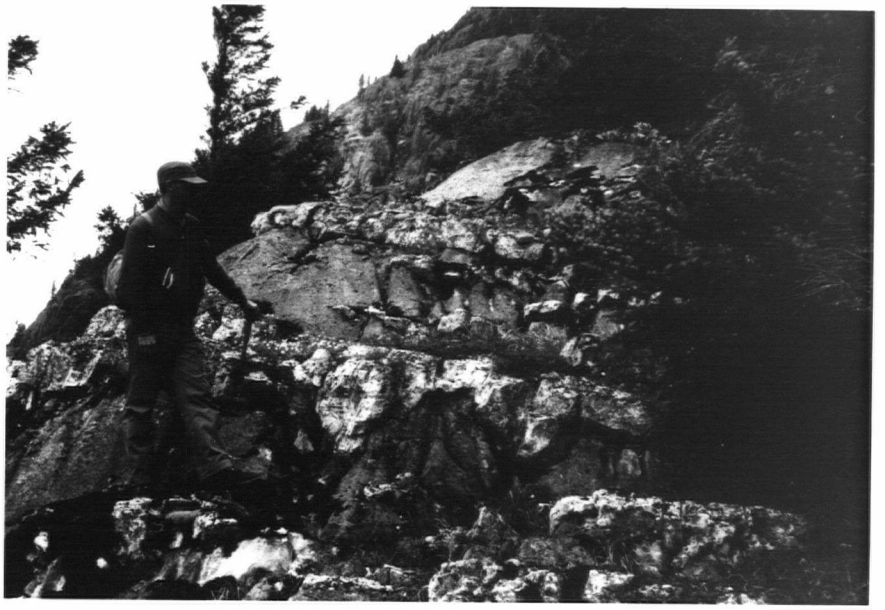

Figure 29. Chert layers (white-weathering) in limestone, upper part of Mt. Mark section, Upper Division, Sicker Group.

rocks are poorly exposed 400 to 500 feet below the limestone. In the steep cliffs above the limestone, fine to medium-grained, green volcanic rocks, with the characteristic brown weathered surface of the Vancouver Group, are the only rocks visible. Similar rocks appear to form the peaks of Mt. Arrowsmith to the south.

Fauna

Richardson's collections of brachiopods, corals, bryozoans and crinoid stems from Horne Lake were determined by E. Billings as being "either Permian or Carboniferous, most probably the latter" (Richardson, 1873, p. 54). The limestones of "View Mountain", southwest of Horne Lake contained crinoidal debris, according to Richardson (p. 55), suggesting rocks similar to those of Horne Lake. Crinoidal remains are the only fossils found to date in the limestones of Cameron Draw and on the east side of Cameron River.

The present writer's collections of fossils from the limestones of the Upper Division of the Sicker Group on the north and west sides of Horne Lake include numerous bryozoans, brachiopods, and a few corals and molluscs, and very few foraminifers.

The upper part of the section yielded specimens of a fusulinid tentatively identified as Schwagerina? sp., and thick shelled brachiopods. The latter are probably conspecific with Horridonia sp. A. identified in talus blocks from the same area. These fossils, together with several other genera and species bearing close similarities to Permian forms identified in sections in the Buttle Lake-Big Interior belt, indicate a similar age for the Horne Lake beds. The correlation

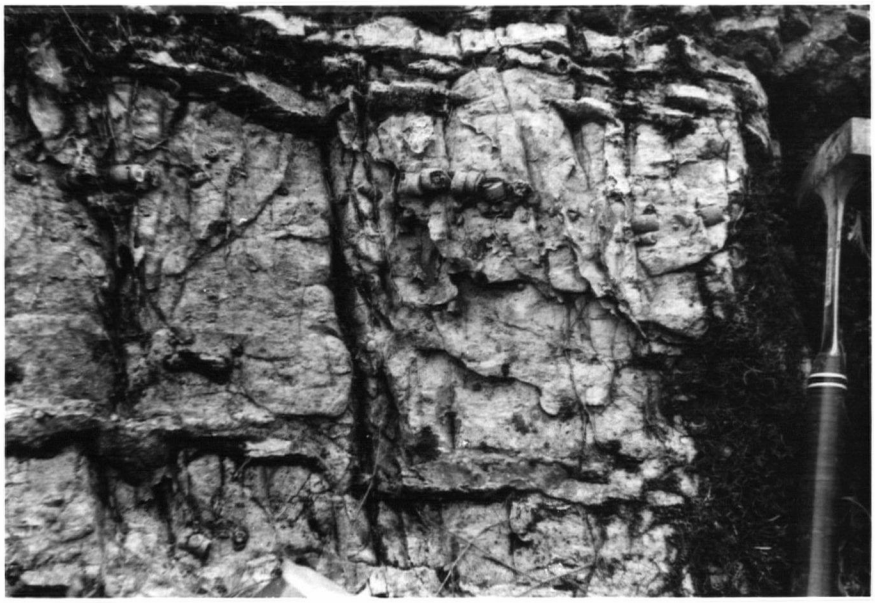

Figure 30. Silicified crinoid stem fragments, parallel to bedding planes, in limestone of Upper Division, Sicker Group; lake-shore exposure, Horne Lake, west side of outlet (Qualicum River).

and age of this fauna are discussed in more detail in a following section of this account (p. 109).

Faunal lists

Mt. Mark

Locality 62-56-1F - Base of limestone cliff, east side of large gully on south face of Mt. Mark, one-quarter mile northeast of power-line crossing logging road near west end of Horne Lake:

Tetrataxis
Michelinia? sp. A.
Brachiopods
Solitary rugose corals

Locality 62-56-2A - Base of Mt. Mark limestone section, about 500 feet east of Locality 56-1F, elevation approximately 850 feet (Unit 1):

Brachiopods
Chaetetes sp.
Solitary rugose corals
Fenestrate bryozoans

Locality 62-56-2 - Mt. Mark section, above diabase:

Fusulinid 400' above diabase (Unit 25)
Schwagerina? 350' above diabase (Unit 25)
Streblascopora pulchra)
Sulcoretepora sp.) 55' to 110'
Fusulinid) above diabase
Brachiopods) (Unit 23)

Locality H-2 - Base of limestone cliff, north of power-line crossing road, west end of Horne Lake:

Schizophoria sp.
Hustedia?

Michelinia sp. B.
Penniretepora grandis
Sulcoretepora sp
Goniocladia cf. G. intermedia

Talus - Chaetetes sp.

Locality 61-24TF - Talus slope on north side of Horne Lake, 0.8 miles southeast of 3,165' peak of Mt. Mark (east of Locality 61-56-2); elevation about 800':

Squamularia? sp.
Horridonia sp. A.
Corals
Bryozoans

Locality 62-55-4F - On south side of logging road, on east spur of Mt. Mark, 0.35 miles southeast of 3,037' peak; elevation about 2,060':

Brachiopods

Locality 62-55-9F - On logging road, 0.5 miles east - southeast of 3,037' peak of Mt. Mark; elevation about 1,700':

Brachiopods
Bryozoans

West side Horne Lake

Locality 62-58-1F - On west side logging road, one-quarter mile southwest of upper bridge over Qualicum River, elevation 620':

Cladochonus sp
Bryozoans

STRUCTURE

Published structural information from the Horne Lake-Cameron River belt of Paleozoic rocks is limited to that given in Mathews' (1947) and Mathews and McCammon's (1957) maps for the Horne Lake area, and a few attitudes shown on Richardson's (1873) and MacKenzie's (1922) earlier maps. The present writer's mapping has added some information in the Horne Lake area, along the Alberni Highway, and on the east side of Cameron River.

According to Mathews and McCammon (1957, p. 51), at Horne Lake "the rocks are folded into a broad northerly plunging anticline complicated by subordinate folds and numerous faults". Pillow lavas of the Vancouver Group are in fault contact with Paleozoic limestones of the west limb of this fold, west of the Horne Lake (see Figure 24). Southwest of Horne Lake, Richardson reported a limestone-bearing sequence in which the rocks are either vertical or east dipping (1873, p. 55) suggesting that another anticlinal fold, west of the Horne Lake anticline, brings Paleozoic rocks to the surface.

The gross structural pattern of the belt thus appears to be that of an anticlinorium, with north-northwesterly plunge. Subordinate folds and longitudinal and transverse faults control the local distribution of rock types (see Figure 4).

Structural information is lacking for the pillow lava sequence of the Vancouver Group which overlies the Paleozoic rocks. Stratification is not prominent in these rocks; the few doubtful attitudes obtained suggest only that these rocks have also been subjected to deformation.

BUTTLE LAKE-BIG INTERIOR BELT

GENERAL STATEMENT

The only published maps showing the distribution of rock types within this belt are those of Sargent (1941, fig. 1), and Mathews (1947, fig. 20), and Mathews and McCammon (1957, fig. 3). The former is on a scale of one inch to one mile; the latter two are sixteen miles to the inch maps. Figure 2 of this report shows the overall distribution of Paleozoic rocks of this belt. In Figure 7, results of the writer's mapping in the Buttle Lake area are indicated.

Exposures of Paleozoic rocks extend from Mt. Con Reid, west of Buttle Lake, to the valley of Drinkwater Creek, northwest of the west end of Great Central Lake. The eastern boundary of the belt trends along the east side of the south half of Buttle Lake, south along the east side of Price Creek and along the east side of the Drinkwater valley. Volcanic rocks of the Vancouver Group lie to the east of the boundary.

The northern boundary of the belt occurs along the north side of Marblerock Creek, then trends northwesterly across the southern flank of Mt. McBride, across Wolf River to Mt. Con Reid. The west boundary is along the east flanks of El Piveto Mountain and Mt. De Voe, then trends southeasterly to the northern spur of the Golden Hinde. Exposures on the east face of Golden Hinde are terminated to the south against the contact with a large body of Coast Intrusions, which forms the western boundary of the Paleozoic belt from here to the southern-most known exposures of the Buttle Lake-Big Interior belt, near Big

Figure 31. Big Interior Mountain, southern end of Buttle Lake Big-Interior belt. View northwest from air. Complex of Upper Division, Sicker Group, and granitic intrusives in cirque (right centre). Lower Division complex in foreground.

Figure 32. West fork of Wolf River, view southwest. Limestones of Buttle Lake Formation form lower, light-weathering cliffs right of centre. Upper cliffs are volcanic rocks of Vancouver Group.

Interior Mountain (see Figure 31).

The majority of the area included in the belt is underlain by non-calcareous rocks, mainly tuffs, breccias, and thin-bedded sediments. Along the borders of the belt, limestones are prominent, occurring either as persistent units parallel to the boundary or as relatively small isolated blocks.

STRATIGRAPHY

Sequence and Nomenclature

For the Buttle Lake area, Gunning (1931, p. 59A) concluded that the Paleozoic rocks:

> "consist of a thick series of volcanic rocks including andesitic to basaltic flows, tuffs, and coarse volcanic breccias with at least two and probably three interbedded horizons of white, grey, or pink, crystalline limestone and minor amounts of argillite and quartzite. The uppermost horizon of limestone is the only one that is well exposed for any distance".

Sargent (1941, p. 13, 16, 17) divided the rocks of the Bedwell River portion of the belt into two units. The lower rocks were grouped into a "Paleozoic and Mesozoic Complex", described as follows: "Complex stratigraphically below the Permian limestones; volcanics, tuffaceous and argillaceous sediments, of Paleozoic age; basic intrusives, related to Lower Mesozoic volcanics; and granitic intrusives (Coast Range)" (p. 13). The upper unit he referred to as "Permian Limestone".

The upper unit in the Bedwell River area includes not only the bulk of the calcareous rocks of the area, but also an overlying unit of

"thin-bedded, siliceous and probably tuffaceous, argillites ... usually separated from the limestone by from 10 to 200 feet of black basalt which is intrusive into the limestone" (Sargent, p. 18). The thickness and upper contact of these sediments were not described.

The writer's work in the Buttle Lake area has yielded more detailed information on the stratigraphic succession in the Buttle Lake portion of the belt. Breccias are dominant in the lowermost part of the sequence. The middle portion is characterised by fine to coarse tuffs and thin-bedded tuffaceous sediments. The uppermost units are limestone of variable thickness and overlying thin-bedded non-calcareous sediments of unknown thickness.

In the southern part of the belt, basaltic pillow lavas of the lower part of the Vancouver Group have been found directly overlying the Permian limestone (Sargent, p. 21). In the Buttle Lake area, the upper stratigraphic contact of the limestone has not been seen. In some places, a fault separates the limestone from younger rocks of the Vancouver Group. In others, a covered interval is present in the same position. In at least one locality, a thick basaltic intrusive separates the uppermost limestone from overlying, apparently conformable, fine-grained, non-calcareous sedimentary or tuffaceous rocks. Thus the nature of the upper limestone contact is not well-known. A thick sequence of pillow lavas is known to occur within a few hundreds of feet above the limestone and non-calcareous sediments, but the base of the lavas has not been observed.

Thus, in the Buttle Lake area, the known Paleozoic sequence consists of two major divisions; the lower unit comprises non-calcareous

rocks, which may be subdivided into a lower section of massive tuffs and breccias, and an upper part of largely thin bedded clastic rocks. The upper division is made up of light to dark limestones, with variable amounts of light to dark chert in nodules and thin lenses. A thin basal sandstone of the upper division has been seen at one locality.

The base of the lower, non-calcareous division has not been seen. The thickness of the division is probably in the order of several thousands of feet; a thickness of about 4,000' of these rocks is exposed between Phillips Creek and Marblerock Creek, assuming uniform attitudes. In the same place, the upper, thinly-bedded part of this division has been calculated to be about 1,000 feet in thickness.

The upper, limestone division of the Paleozoic sequence measures 1,050 feet in thickness in the Azure Lake section. It is about 800 to 900 feet thick on Marblerock Creek, and 800 feet on the west side of Wolf River; according to Sargent, it is 700-800 feet in maximum thickness in the Bedwell River area. Incomplete exposures of the limestone division elsewhere in the area suggest thicknesses less than these figures. Gunning (1931, p. 61A) considered that the limestones varied in thickness from 100 to 500 feet.

A relatively thin section of thin-bedded fine-grained clastic rocks is known to overlie the limestone of the Upper Division in certain parts of the belt. Where this unit has been seen (west of Wolf River, Azure Lake section, and Bedwell River area), it appears to be conformable with the underlying limestones and may belong to the upper division of the Paleozoic sequence. Its relationships with

overlying basalts of the Vancouver Group are not clear, however, on the basis of present information.

Although no fossils have as yet been found in this upper, non-calcareous unit, it seems probable that it is Paleozoic, as implied by Sargent (1941, p. 18). Its relationships with basaltic rocks similar to those of the Vancouver Group appear to be gradational on Wolf River and other areas seen only from aircraft. The black basalts intercalated with the clastic rocks are massive, whereas the overlying lavas are pillowed. The base of the pillow-lava sequence has not been seen by the writer except from a distance. If, as suggested by Sargent (1941, p. 21-22), pillow-lavas of the basal part of the Vancouver Group in some localities of the belt directly overlie the limestones of the Paleozoic sequence, whereas in other parts of the Bedwell River area and the Buttle Lake area thin-bedded sediments separate the limestone from the pillow-lavas, the absence of the clastic rocks may be the record of an erosional interval.

The contact between the pillow lavas and the underlying rocks thus may represent an unconformity at the Paleozoic-Mesozoic boundary. As was mentioned in the discussion of the same horizon in the other belts of Paleozoic rocks, age determinations based on fossils favour the placing of a major stratigraphic break of the "paraconformity" type here. Structural information on the overlying pillow basalts of the Triassic Vancouver Group is sparse, and cannot be considered adequate at the present time for postulating a structural discordance at this stratigraphic level.

The two major units of the known and probable Paleozoic rocks are regarded as "Divisions" as in the other belts. Subunits of these

divisions are recognizable. The only stratigraphic unit about which sufficient is known of its lateral persistence and contacts to warrant formal nomenclature is the limestone unit, for which the name "Buttle Lake Formation" is here proposed (see p. 82).

Table of Formations

Table 4 presents the writer's proposal for nomenclature of the stratigraphic units in the Paleozoic succession and immediately overlying rocks of the belt.

System	Series	Group	Formation	Lithology
Triassic	Upper Triassic and? earlier	Vancouver Group	Karmutsen Formation	Basaltic pillow lavas; minor pyroclastic and sedimentary rocks.
?	?			
Paraconformity				
?	?			
Permian or Triassic	?	?—?	Unnamed unit	Thin-bedded, non-calcareous clastic rocks
Permian	Lower Permian	Sicker Group	Buttle Lake Formation	Light-coloured crinoidal limestone; dark dolomitic limestone; light to dark chert. Thin basal sandstone in places
Permian and/or older	?		Lower Division	Mainly thin-bedded non-calcareous clastic rocks; minor tuffs and breccias ———?———? ———?——— Mainly massive tuffs and breccias; minor thin-bedded non-calcareous clastic rocks

TABLE 4

Table of formations, Buttle Lake-Big Interior belt, with proposed nomenclature for Paleozoic sequence.

Sicker Group

Gunning (1931, p. 59A) suggested the name "Buttle Lake group or formation" for all or part of the Paleozoic rocks in the Buttle Lake area. The lithology, stratigraphic sequence and faunal content of the Paleozoic sequence of the Buttle Lake-Big Interior belt are so closely similar to those of the Paleozoic rocks in the other belts that the present writer considers that they should be referred to by the same name. The sequence has been named "Sicker Group" (Clapp, 1909, p. 56; Fyles, 1955, p. 19) in the China Creek-Saltspring belt.

Gunning's suggested name may therefore most conveniently be applied to a formation within the Sicker Group of the Buttle Lake-Big Interior belt (see p. 82).

Lower Division

Some of the best exposures of rocks of this division crop out in a gully on the southeast face of El Piveto Mountain, 2.5 miles southwest of the junction of the main and west forks of Wolf River (Figure 32).

The exposed section of pre-limestone rocks is composed of sandstones, conglomerates and argillite, in a thin to medium-bedded sequence. The sandstone is of greywacke type, fine to medium-grained, grey to greenish in colour. Faint cross-laminations occur in some beds, and poorly developed graded textures in others. The argillite is dark grey, black or green. It occurs in the upper parts of graded sandstone beds, and as thicker units with minor sandy and silty laminae in the upper portion of the measured section. The conglomerates are found as pebbly lenses in the coarser sandstone beds, or as single beds up to

6 feet thick. In one thick bed maximum pebble size reaches 2 inches, and argillite slivers up to one foot long are present at its top. Scattered outcrops of similar conglomerates, in which the clasts are composed of well-rounded to subangular fragments, up to 6 inches maximum dimension of light to dark grey, fine-grained massive or thinly laminated clastic rocks, are found to the northeast.

The exposed thickness of these sediments is 365 feet. The base was not seen and the interval above is also covered. Between the uppermost exposures of the clastic sediments and the lowest limestone exposure above, is an interval presumed to be underlain largely by clastic noncalcareous rocks, the calculated thickness of which is 350 feet.

In addition to the limited section of pre-limestone rocks described above, two traverses over considerably greater thicknesses of these rocks were made. One of these covered the lower reaches of Phillips Creek (Figure 33), and the southeast flank of the mountain of which Marble Peak is the summit. The other traverse crossed these rocks on the east flank of the same mountain, east of Marble Peak (Figure 34).

The Phillips Creek-Marble Peak traverse encountered massive greenish tuffs and fine breccias mainly. In the upper portion of the section, zones of thin-bedded, pale green, buff, and maroon-weathering clastic rocks up to 10 feet in thickness are intercalated in the massive sequence. The section terminates at the top against a mass of medium-grained basaltic intrusive rock, below the limestone exposures of the flat ridge top (between 4,500 and 5,000 feet elevation) south of Marble Peak. The contact is probably faulted, with the upper part of the Lower Division succession missing on the south side of the easterly trending fault.

Figure 33. Phillips Creek valley, viewed south from Marble Peak. Valley incised in rocks of Lower Division, Sicker Group.

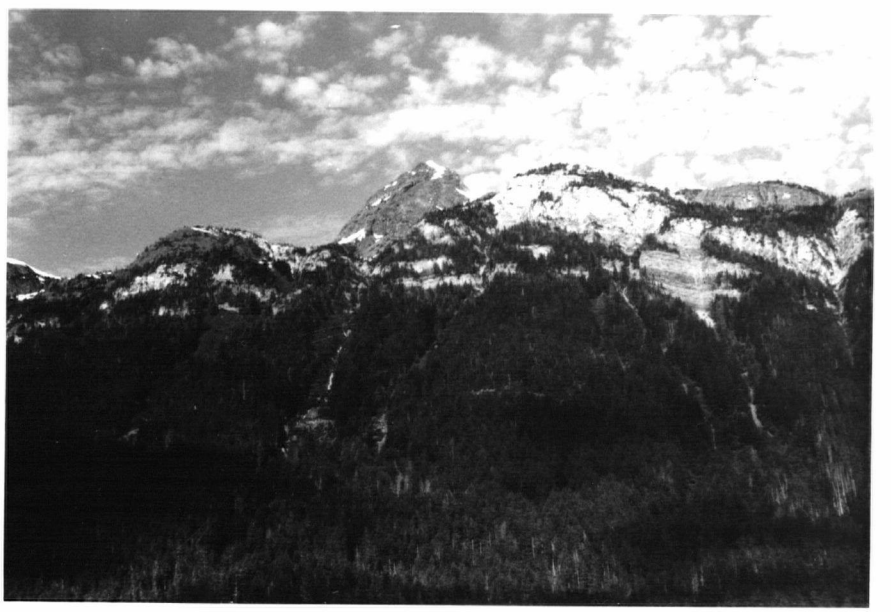

Figure 34. Light-weathering limestones of Buttle Lake Formation on west side Buttle Lake, below Marble Peak. View west from lake.

The section on the east face of the mountain rising to Marble Peak contains scattered exposures of the upper part of the Lower Division. At lake level, coarse to fine tuffs and banded to laminated clastic sedimentary rocks are visible. Between lake level and the base of a medium to coarse dioritic intrusive body, at elevation 2,190 feet, massive green tuffs and fine breccias are dominant (see Figure 35). Above the top of the intrusive, which occurs at about 2,630 feet, thinly bedded rocks form the majority of the scattered exposures. The lower part of this bedded sequence appears to be greenish tuffaceous rocks, but from 2,950 upwards, sandy textured rocks of the greywacke type, thinly interbedded with black argillaceous rocks are seen. The latter, if they extend up to the base of the overlying limestones, have a thickness of about 1,000 feet. The contact between the sequence of thin-bedded clastic rocks and the limestones is covered at this locality, and has not been seen elsewhere in the area.

Gunning suggested the presence of limestone below the prominent, upper calcareous unit. He stated (1931, p. 60A): "At least two other beds of limestone, lower in the Paleozoic section, are exposed on the west side of Buttle Lake, one on the bay just north of the mouth of Phillips Creek, and the second on the first point south of "Marble Creek" (Marblerock Creek).

The first mentioned limestone, on the north side of Phillips Creek, has been examined by the writer. The second one mentioned by Gunning has not been found. The rise of lake level since the construction of the dam to the north on Campbell River has probably covered Gunning's exposure.

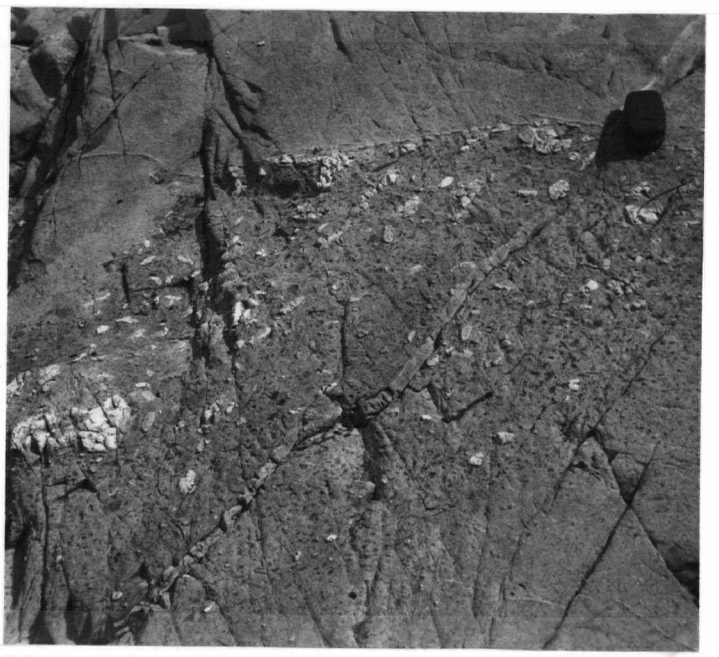

Figure 35. Tuffs and breccias of Lower Division, Sicker Group; lake-level exposure, west side Buttle Lake, 2 miles north of Phillips Creek.

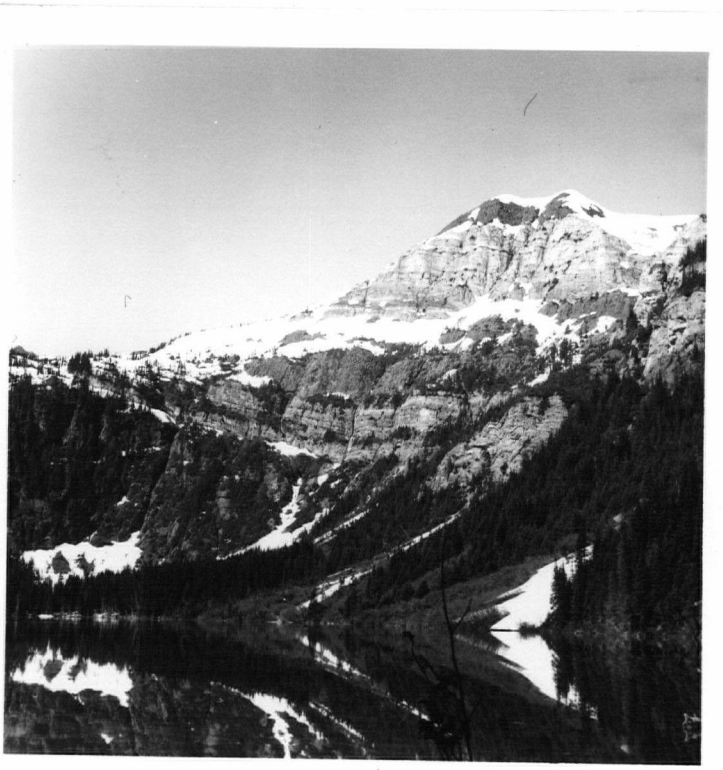

Figure 36. View southwest across Azure Lake. Light-weathering Buttle Lake Formation split and overlain by dark basic intrusions.

The Phillips Creek exposures are of coarse crinoidal limestone, light grey to maroon in colour. They grade downwards into red and purplish fine-grained non-calcareous clastic rocks and conglomerates. In addition to crinoidal debris, the limestones contain tabulate and rugose corals, and ramose and fenestrate bryozoans. These lake shore exposures are faulted, and attitudes are variable. The structural pattern and stratigraphic succession have not been resolved. The limestones appear to be overlain to the north by tuffs, fine-grained sedimentary rocks and breccias.

It is thus possible that these exposures represent a limestone low in the Paleozoic succession. Because of faulting, it also appears possible that they could represent part of the Upper Division. Outcrops of the latter unit occur 1.5 miles southeast, on the east shore of the lake.

On the basis of the present information the problem cannot be resolved. If the Phillips Creek limestone exposures are lower in the section than the main limestone exposures of the area (Buttle Lake Formation), they are bodies of lensing habit not evident elsewhere in the area.

Upper Division

As explained previously, the Upper Division rocks consist principally of limestone. An incompletely-known unit overlies the limestones, and consists of an unknown thickness of fine-grained non-calcareous clastic rocks.

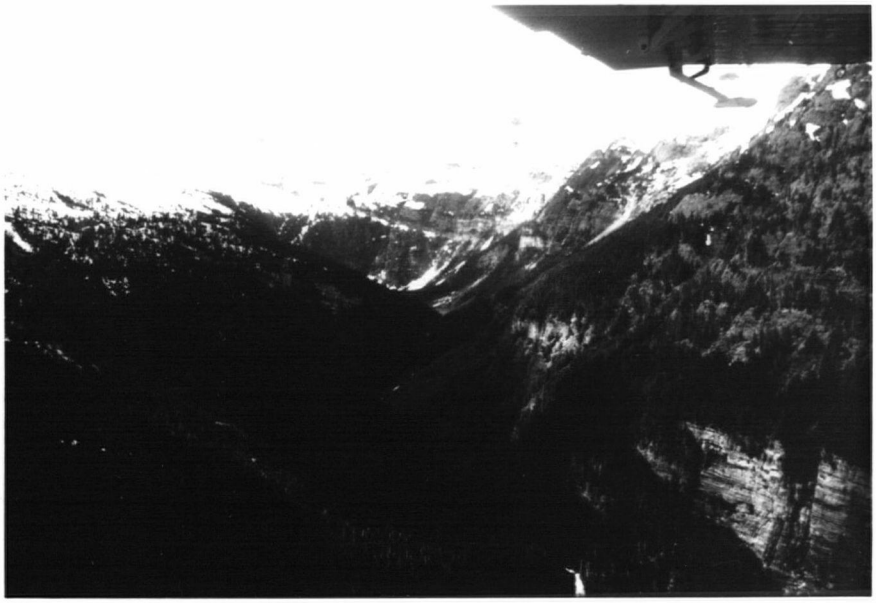

Figure 37. View southwest up Marblerock Creek toward Azure Lake. Section of Buttle Lake Formation measured up base of cliffs at lower right. Dark weathering rocks above are volcanic flows of Vancouver Group.

Figure 38. Mt. Golden Hinde. View southwest. Limestones of Buttle Lake Formation above right centre; Vancouver Group above, Lower Division rocks below.

Buttle Lake Formation

As the limestone formation near the upper part of the Sicker Group is the most clearly definable unit, and the most useful at present for mapping purposes, the name Buttle Lake Formation is herein proposed for it. The name comes from the name of the large lake near which the most spectacular exposures of the formation are found, and the type section is designated as the "Azure Lake" section (Figures 6, 36), mentioned below, and described in detail in the Appendix.

The formation consists mainly of medium-to coarse-grained, light grey limestone. Nodules and irregular thin bands of light and dark grey chert and silicified limestone occur in zones between thick-bedded and massive limestones. At the type section, a thin basal sandstone occurs; it has not been seen elsewhere. In the same section, a thick bed of dark grey to black, richly fossiliferous, dolomitic limestone is present in the upper part of the formation (see Figure 6).

The lower contact of the formation has been seen only at the type section, where it is a sharply defined, gently undulating surface. The basal sandstone is immediately underlain by coarse tuffs and breccias of the Lower Division of the Sicker Group.

At the type section a thick, basic, sill-like intrusion separates the uppermost limestone of the Buttle Lake Formation from overlying thin-bedded, fine-grained non-calcareous clastic rocks. Elsewhere, similar rocks lie directly over the Buttle Lake Formation, with conformable attitudes.

At the type section, the formation measures 1,050 feet in thickness. Other measurements in the Buttle Lake area give thicknesses of

800 to 900 feet. Visual estimates for smaller exposures in the Buttle Lake and Bedwell River area by other authors (Gunning, 1931; Sargent, 1941) suggest thinner sections, some as thin as 100 feet being cited (Gunning, 1931, p. 61A).

Sill-like intrusions of dark green to black basic crystalline rocks are common in sections of the Buttle Lake Formation in the vicinity of Marblerock Creek, Azure Lake and Marble Peak. In this part of the area, one intrusive body occurs in the middle of the limestone section, splitting the formation into two parts.

The known distribution of the formation is shown on Figure 5. The Buttle Lake Formation is well exposed in the areas around Marble Peak (Figure 34), along the northwest side of Marblerock Creek (Figure 37), surrounding "Azure Lake" (Figure 36), and on the ridge extending south from Mt. McBride. Other exposures occur from Mt. Con Reid to Golden Hinde (Figure 38), in the ridges flanking the west (Figure 32), and main forks of Wolf River. Gunning (1931, p. 60A) considers that limestones exposed on the east side of Buttle Lake and along the east side of Price Creek to the south probably belong to the same formation as the exposures mentioned above. On the east side of the lake the writer has examined only the lake-level exposures, from which no diagnostic fossils were obtained and no stratigraphic relationships could be determined.

Azure Lake section

A complete section of the Upper Division is exposed in the area

Figure 39. Buttle Lake Formation southwest of Azure Lake. View northeast across measured Azure Lake section. Dark rocks capping hill are basic intrusive.

Figure 40. View northeast from Azure Lake section to limestone capped ridge on east side of Azure Lake.

southwest of a small lake* at the headwaters of the west branch of Marblerock Creek. The base of the section measured (the "Azure Lake" section, Figure 6) is in a low saddle between two knolls on an east-west trending ridge, 0.7 miles south of the west end of "Azure Lake". The basal sandstone and lower limestone of the Division are exposed on the eastern side of the western knoll, the top of which is composed of dark green, medium-grained crystalline rock in intrusive contact with the limestone. Exposures of the intrusive extend westward to the base of a north-south trending ridge, on the western slopes of which the upper part of the limestone was measured. The top of the limestone occurs near the crest of this western ridge, 1.2 miles southwest of "Azure Lake". The limestone is overlain here by a sill-like, basic intrusive several hundreds of feet in thickness (Figure 39). Above the intrusive a few tens of feet of varicoloured, thin-bedded fine-grained clastic rocks (tuffs or tuffaceous siltstones) are exposed at the crest of the ridge.

The rocks below the basal sandstone of the section are medium to coarse-grained, green and maroon colour-mottled tuffs and breccias, which locally grade into thinly bedded, pale to dark green tuffaceous rocks. These are underlain by coarse breccias of dark green, medium to coarse-grained, porphyritic rock, bounded on the east by a fault contact with a limestone-igneous complex.

The basal 10 feet of the Azure Lake section consists of fine to medium-grained greywacke, which is highly calcareous in the upper

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*Unnamed, but herein referred to as "Azure Lake".

Figure 41. Basal sandstone (Unit 1) of Buttle Lake Formation, Azure Lake section. Contact with coarse tuffs and breccias of Lower Division, Sicker Group, is beneath hammer. View to north toward Azure Lake. This is Locality 61-34-3F, from which abundant brachiopods, molluscs, bryozoans, and some fusulinids and plant fragments were collected.

few feet (Figure 41). The sandstone is thin-to medium-bedded, with vague indications of gently inclined cross-stratification. The lower contact is sharp and gently undulating. Thin pebbly lenses, a few inches in maximum thickness, and several feet in maximum length, occur in the lower part of the unit. Pebbles are well-rounded to sharply angular, varying in size from 3 mm. to 10 mm., with the average being about 5 mm. They are composed of fine-grained porphyritic and amygdaloidal volcanic rocks, light-coloured, fine-grained clastic rocks and grey and white cherty fragments.

Above the basal sandstone, a covered interval is overlain by grey, fine-grained, impure limestone. A 50 foot covered interval separates these beds from the main limestone section above. The lower portion of the main limestone section is light-grey, coarsely crinoidal and thick-bedded. Above this to the top of the section, with the exception of one 60 foot interval, coarse-grained, crinoidal limestone forms the dominant lithology, interbedded with finer grained, cherty limestone. The interval from 660 feet to 720 feet above the base is occupied by a dark-grey to black cherty, dolomitic limestone.

Two basic intrusions cut the limestones of the Azure Lake section. The lowest, about 20 feet thick, is 420 feet above the base of the section; the other occurs 40 feet above this, and is calculated to occupy a distance of 750 feet perpendicular to the bedding in the limestone. The thinner of the two intrusive bodies, traced laterally, was found to pinch out to the north, and coalesce with the upper, thicker body within a few hundreds of feet to the south. The lower intrusive contact thus is interfingered with the limestone in this

Figure 42. Panoramic view (at 245 degrees to 340 degrees from southeast side of lake) of exposures of Buttle Lake Formation on northwest side of Azure Lake. Dark-weathering rocks between light-coloured limestone units, and immediately above upper limestone cliffs, are basic intrusives. Rugged cliffs at top are volcanic rocks of Vancouver Group, rising to peak of Mt. McBride. Several transverse faults disrupt the section in the central area shown, and the northeastern end of the section (extreme right) terminates against such a fault.

locality. The intrusive is dark green, fine to medium-grained crystalline rock, similar to diabase intrusions of the Horne Lake-Cameron River belt.

Between the uppermost limestone of the section and the top of the ridge, a sill-like body of basic intrusive with poorly developed, but conspicuous, columnar jointing is present (see Figure 43). It is overlain, on the crest of the ridge, by a small section of thin-bedded fine grained to aphanitic, clastic non-calcareous rocks varying in colour from green to red and purple. The upper limit of this unit has not been examined in the Buttle Lake area.

The measured thickness (excluding the intrusives) from the basal sandstone to the top of the uppermost limestone, is 1,050 feet. The line of section crosses several transverse faults of unknown displacement. In addition, the section measured extends over a horizontal distance of 0.9 miles, over which the stratigraphic position of the contacts of the sill-like intrusion in the middle of the limestone section may have changed. Field observations and inspection of aerial photographs indicate that no major fault displacements have occurred in the immediate area of the line of section. The effect of possible shifts in stratigraphic position of the intrusive contacts cannot be fully evaluated with the available data; it is the writer's opinion that the stratigraphic measurements are not seriously effected by such changes.

Marblerock Creek section

From a northwesterly trending fault (Figure 45), which crosses Marblerock Creek about 1.2 miles southwest of its mouth, to "Azure Lake",

Figure 43. Basic intrusive body splitting Buttle Lake Formation on east slope of Marble Peak. View north. Lower limestone in foreground. Note vague columnar jointing in intrusive.

Figure 44. Contact between basic intrusive (above) and lower limestone of Buttle Lake Formation, southeast of Marble Peak. Note stepping upwards of contact to north (right).

limestone of the upper part of the Paleozoic is exposed on the northwest side of the creek. As at the "Azure Lake" section, the limestone section is split into an upper and lower part by a sill-like basic intrusive (Figures 46, 47).

A measurement of the exposed portion of the limestone unit was obtained between a point on the northwest side of the creek, 1.6 miles from its mouth, and the lower of two small lakes, 2.2 miles from the mouth of the creek. The base of the unit is not exposed. The majority of the measured section consists of medium to coarse-grained crinoidal limestone with irregularly spaced zones of chert bands and nodules (Figures 48, 49). A covered interval of several hundreds of feet separates the uppermost limestone from steep cliffs of brown-weathering volcanic rocks of the Vancouver Group (see Figure 50) above the small lake at the upper end of the section.

The thickness of limestone measured here is 858 feet. At least one fault occurs in the section measured. The occurrence on the southwest side of the fault of dark, cherty, fossiliferous limestones which were not observed in the lower part of the block to the northeast suggests that the limestone formation is relatively lower on the southwest side than on the northeast. Field observations and inspection of aerial photographs indicate, however, that the displacement is not large. Field observations show that the basic intrusive of the section cuts stratigraphically upwards to the north-east at a small angle to the bedding. Because of these two factors, (faulting and possible minor repetition caused by stratigraphic shift in the intrusive contacts) and the lack of exposure of the base of the limestone formation, an

Figure 45. View west up Marblerock Creek from Buttle Lake. Light-coloured limestones of Buttle Lake Formation, split by sill-like basic intrusion, on north bank to left, upper cliffs of volcanic rocks of Vancouver Group. In right half of picture, exposures visible are all of Vancouver Group, in block separated from that at left by a north-trending fault.

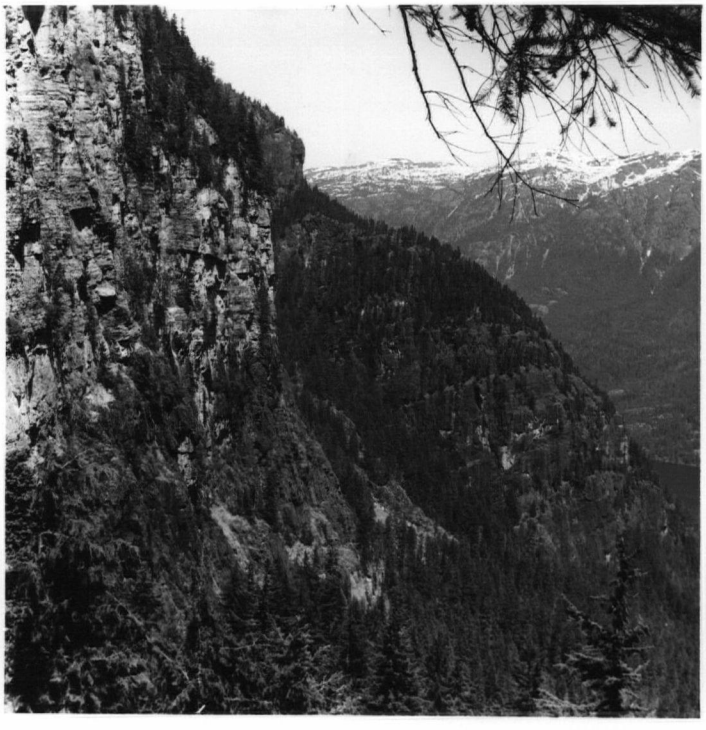

Figure 46. View northeast, from point about two miles southwest of mouth of Marblerock Creek, across fault shown in Fig. 45. Buttle Lake Formation and basic intrusive to left, Vancouver Group to right.

Figure 47. Upper contact of basic intrusion and limestone of upper part of Buttle Lake Formation; north side Marblerock Creek, 2 miles southwest of mouth. Note limestone inclusion in intrusive.

Figure 48. Cherty limestone of Buttle Lake Formation, just above contact shown in Fig. 47. View northeast toward Buttle Lake.

Figure 49. Siliceous nodules in limestone of Buttle Lake Formation, below medial intrusive, north bank of Marblerock Creek, below locality of Figures 47, 48.

Figure 50. Talus block of pillow basalt from Vancouver Group; north side of Marblerock Creek.

accurate calculation of the true thickness of the formation is not possible from the Marblerock Creek measurements. An estimate in the order of about 800 to 900 feet seems reasonable to the writer.

West Fork Wolf River section

Limestone of the Upper Division of the Sicker Group is exposed on the northwest side of the west fork of Wolf River from Mt. Con Reid to the confluence of two smaller tributaries south-southeast of El Piveto Mountain (Figure 32). Partial sections of the limestone and adjacent rocks were obtained from exposures in a gully on the southeast face of El Piveto, 2.5 miles southwest of the junction of the main and west forks of Wolf River, and along the northern tributary of the west fork, 1.5 miles south-southeast of El Piveto peak.

On the southeast face of El Piveto, at an elevation of 2,425 feet, a small limestone exposure in the northeast side of a gully is taken as the base of the limestone formation. At 2,500 feet, the main cliff exposures of the limestone, of which 600 feet was measured, commence. The measured interval is overlain by more limestone, inaccessible at the time of measuring, estimated to be 100 feet in thickness.

The limestone is fine to coarse-grained, medium to light grey in colour. Thin black chert nodules and lenses are prominent in closely spaced zones in the lower part, but become less common toward the top of the measured section.

Above the limestone cliffs, a recessive unit, covered with talus and vegetation is visible, with an estimated 1,000 feet of brown-weathering volcanic rocks above. Talus from these rocks consists of

basaltic pillow lavas typical of the Vancouver Group.

The limestone unit of the section described above rakes down the hillside to the south, crossing the west fork of Wolf River at the confluence of two tributaries. On the tributary flowing from the north, thin-bedded, fine-grained, sandy-textured rocks and black argillite overlie the limestone in apparently conformable succession. About 90 feet of the non-calcareous rocks are visible in the west bank of the stream. To the north, they are overlain by massive fine-grained basaltic rocks, with intercalated zones up to 5 feet thick of thin-bedded, light-weathering clastic rocks. This succession was not examined in detail. The uppermost exposures seen, at an elevation of about 2,330 feet, were of massive basaltic rock. In the stream bed, talus blocks of pillow-lavas indicate that such rocks occur above the massive basalts. It is thus apparent that this section is very similar to that overlying the limestone section measured in the gully to the northeast. The covered recessive interval above the limestones of the gully section is probably occupied by the thin-bedded sedimentary rocks seen on the northern tributary.

The exposed, upper part of the Paleozoic succession in this area thus comprises about 700 feet of fine-grained non-calcareous clastic rocks and conglomerate at the base, overlain by approximately 800 feet of limestone. The age of the overlying section of thin-bedded non-calcareous clastic rocks is not known.

Fauna

Bryozoans from the upper, limestone formation of the Paleozoic sequence, collected by Gunning, were identified by Fritz who states

(in Gunning, 1931, p. 59A): "I propose to correlate this fauna with the one recorded by Dr. Bassler from the Island of Timor in the East Indies which is considered to be of Permian age".

Brachiopods from Gunning's collections were submitted to Girty, who "stated, as his best guess on the material available, that the spirifers may belong in an horizon high up in the Pennsylvanian, this being at least more probable than that the horizon is Permian" (Gunning, ibid.).

When Fritz (1932) later described the bryozoans, she concluded that the resemblance of the Vancouver Island fauna to that from Timor "leaves little doubt as to the similarity in age of the deposits on Vancouver Island" (p. 93).

Fossils collected by the present writer are described and discussed in later sections of this account. Of particular interest for the present discussion are the brachiopods from the Buttle Lake area, found in the limestones of the Buttle Lake Formation of the Upper Division, Sicker Group. They indicate a relatively close faunal affinity to the brachiopods of Permian deposits of several other North American areas, and of more distant regions such as Russia. As is shown in the later sections of this report, the newly described faunas of the Buttle Lake area support Fritz' earlier conclusion of a Permian age for the limestones, and suggest Early, rather than Late Permian.

Faunal lists

Bedwell River area - various localities, from limestone (Sargent, 1941, p. 19, fig. 1):

Zaphrentis sp.
Cyathophyllum sp.
Syringopora sp.
Michelinia sp.

Productus sp. - P. vishnu-type
Orthotetes sp.
Reticularia sp.
Spirifer sp. - S. musakheylensis-type
Spirifer sp. - about S. rajah Salter
Dielasma sp. - about D. problematicum Waagen

Buttle Lake area

Locality "around the headwaters of Marble Creek" (Gunning, 1939, p. 59A). "from a thick upper layer of crystalline limestone lying in a series of lenticular, carbonaceous beds. These beds are located between the headwaters of the north fork of Phillips Creek and Marble Creek ..." (Fritz, 1932, p. 93):

Stenopora prolifica
Nicklesopora? porifera
Streblascopora pulchra
Clausotrypa spinosa
Fenestella basleonsis
Fenestella parviuscula
Fenestella cf. pulchradorsalis
Polypora consanguinea
Polypora vancouverensis
Polypora elongata
Polypora megastoma
Polypora sykesi
?Thamniscus unilateralis
Protoretepora cf. haimeana
Acanthocladia
Penniretepora grandis
Gonocladia intermedia

(N.B. - Some of the generic designations of Fritz' list have been changed to agree with Bassler's (1953) concepts)

Locality 61-20F - Dark grey to black, cherty limestone, above northeast end of small lake, 2 miles upstream from mouth of Marblerock Creek; elevation about 3,000 feet:

Ramose and fenestrate bryozoans
In talus - Orthotetid brachiopod
Spiriferid brachiopod

Locality 61-33-10F - Limestone on ridge 0.45 miles east of southwest end of "Azure Lake"; elevation about 3,875 feet:

Spirifer spp.
?Brachythyrina cf. B. ufensis
Pterospirifer? sp.
Productid brachiopods

Locality 61-34-3F - Basal sandstone, Buttle Lake Formation, "Azure Lake" section (Unit 1):

Krotovia? sp. B
Neospirifer sp.
Pterospirifer? sp.
Ingelarella? sp. A.
Ingelarella? sp. B.
Ingelarella sp. C
Squamularia? sp.
Spiriferina? sp.
Rhynchopora n. sp.
Orthotichia? sp.
Derbyia? sp.
Nuculana sp.
Chaenomya? sp.
Schizodus sp.
Aviculopecten? sp.
Gastropods
Stenopora prolifica
Rhabdomeson sp.
Clausotrypa spinosa
Fusulinid
Rugose, solitary corals

In addition to the animal fossils listed above, carbonized plant fragments and undetermined calcareous algae are present at this locality.

Locality 61-34-5 - "Azure Lake" section, Buttle Lake Formation, limestone, 80 feet above base of formation (Unit 5):

Tetrataxis sp.

Locality 61-34-7 - "Azure Lake" section, Buttle Lake Formation, limestone, 135 feet above base of formation (Unit 6):

Fusulinid

Locality 61-35-5F - "Azure Lake" section, Buttle Lake Formation, dark grey to black, dolomitic limestone, 690 to 720 feet above base of formation (Unit 11):

Horridonia sp. B.
Antiquitonia sulcata
Echinoconchus inexpectatus
Kochiproductus n. sp.
Krotovia? sp. A.
Muirwoodia? sp.
Neospirifer? n. sp.
Brachythyrina cf. B. ufensis
Hustedia meekana

Cleiothyridina sp.
Laevicamera n. sp.
Cladochonus sp.
Stenopora prolifica
Streblascopora pulchra
Nicklespora? porifera
Fenestella cf. F. parviuscula
Fenestella sp.
Polypora cf. P. consanguinea
Polypora cf. P. sykesi
Protoretepora cf. P. haimeana
Acanthocladia multipora
Pennireteporo grandis
Goniocladia cf. G. intermedia

Locality 61-35-13F - "Azure Lake" section, Buttle Lake Formation, limestone, upper 75 feet of formation, 975 to 1,050 feet above base (Unit 21):

Spiriferella saranae
Productid brachiopods

Locality 61-61A-7F-8F - Limestone exposures on flat ridge top, 0.5 miles south of Marble Peak; upper part of Buttle Lake Formation.

Spiriferella saranae
"Spirifer" sp.
Horridonia sp. A.
Productid brachiopods

Locality 63-65-1F - Limestone, 0.25 miles north of Phillips Creek, at lake level.

Michelinia sp. A. ?
Solitary rugose corals
Ramose and fenestrate bryozoans

Locality 63-68A-108CF - Limestone, on east side of Wolf River, south of Mt. McBride, about 1.2 miles west of southwest end of "Azure Lake"; upper part of Buttle Lake Formation, elevation about 5,100 feet.

Spiriferid with short hinge line.

STRUCTURE

Reliable attitudes are rarely obtainable in the non-calcareous, lower part of the Paleozoic sequence. The distribution and attitudes

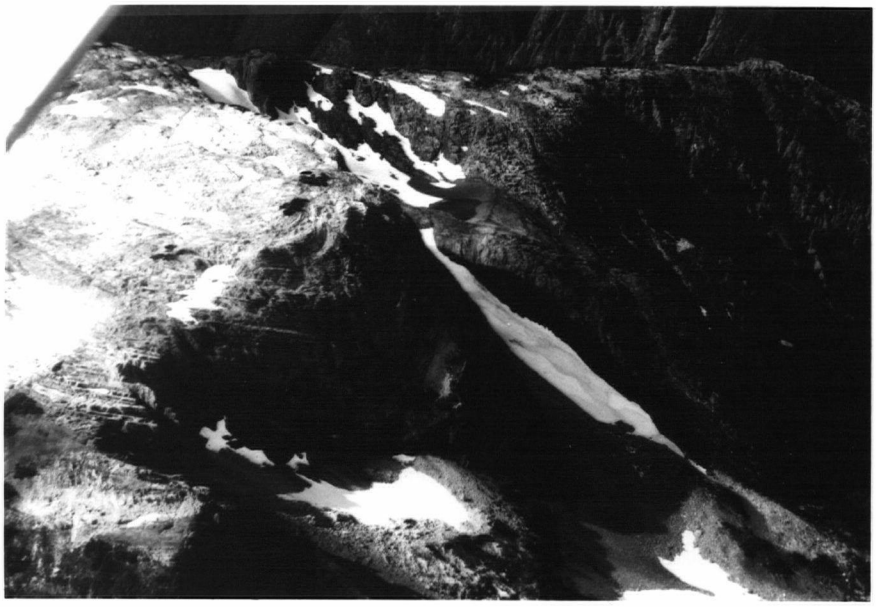

Figure 51. Syncline in Buttle Lake Formation, 3 miles south-southwest of Mt. McBride. Dark-weathering rocks of Lower Division in right half of picture, separated from limestone by north-trending fault. View southwest from air.

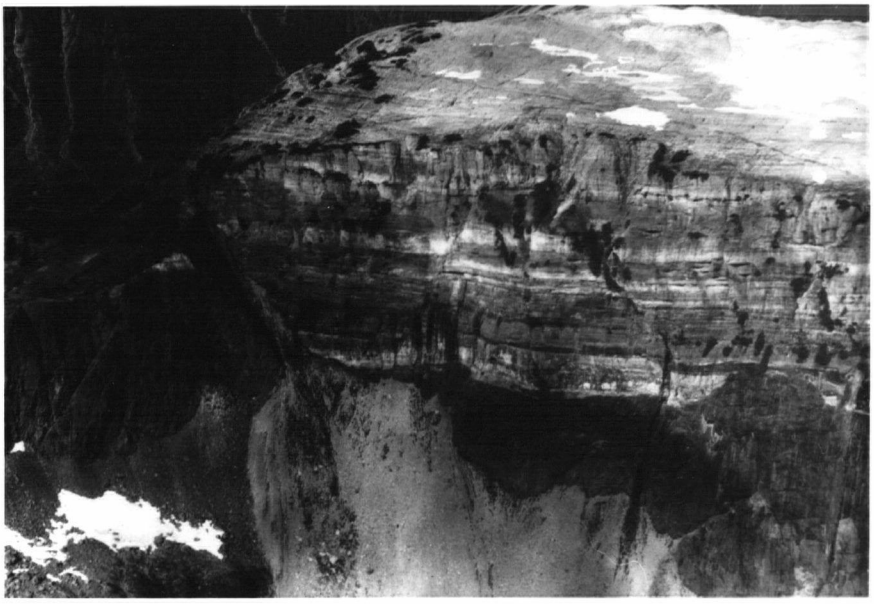

Figure 52. Transverse fault (about east-west), south end of syncline shown in Fig. 51. Note small remnant of limestone on footwall (left centre) and apophysis of intrusion in limestone (lower right). View west from air.

of the persistent limestone unit of the upper part of the sections in the Buttle Lake area, however, provide evidence of the major structural pattern of the belt. In this part of the belt, Gunning (1931, p. 61A) states:

> "The rocks are folded into a broad anticline pitching to the north. Within this major structure there are at least two minor synclinal folds. One of these is beautifully exposed on the divide between Phillips and the south fork of Wolf Creek; the second is less definite and lies farther east. The axis of the major structure trends almost due north. All the folds are open, the westerly limb of the anticline dipping from 20 degrees to 30 degrees west and the easterly limb, on Price Creek, at lower angles to the east. The minor synclinal folds are gentle flexures and the flat dips imparted to the limestone account for the extensive exposures of that rock which cover the summits between Phillips and Marble creeks".

Strikes and dips in the southern portion of the belt suggested to Sargent (1941) the possibility of a major fold plunging to the south; the only minor fold mapped has a northwesterly trending axial trace.

Faults are ubiquitous in the Buttle Lake and Bedwell River areas. The majority of the observed faults are transverse or oblique to the strike of the rocks. As Gunning (1931, p. 61A), mentions, they are variable in both strike and magnitude of their effect on the adjacent rocks. Gunning found several major, north-westerly striking shear zones in the southern part of the Buttle Lake area. In the northern part of the area, several faults of the same strike cut off the Paleozoic rocks, with younger volcanic rocks on the northeast sides of the breaks (Figure 45). Numerous minor faults disrupt the limestone unit of the upper part of the sequence, indicating that the whole region has been broken into innumerable small fault blocks (Figures 5, 42, 52, 53). A similar

Figure 53. View north-northwest of Marble Peak. Basic intrusive in foreground, overlain by upper limestone of Buttle Lake Formation in mid-distance. Volcanic rocks of Vancouver Group in steep cliffs above. Limestone in fault contact with Vancouver Group in southwest spur of Marble Peak (above left centre). Mt. McBride in left background.

structural pattern is found in the southern part of the belt, as indicated by Sargent's map and discussion (1941, fig. 1; p. 25-28). The major faults of Sargent's area appear to be of northwest-southeast trend.

CORRELATION

REGIONAL CORRELATIONS, VANCOUVER ISLAND

Rocks of the three Paleozoic belts, as discussed in previous sections of this account, are generally similar in stratigraphic sequence, gross lithology, and faunal content. These similarities lead to the conclusion that these rocks should be included within the same stratigraphic unit, namely the Sicker Group, originally defined in the southern belt (Clapp, 1909, Fyles, 1955). Divisions within the Sicker Group are recognizable in all three belts. The lithologic and stratigraphic aspects of this correlation have been discussed in the preceding sections, and are shown diagrammatically in Figure 54. Faunal correlations between the three Paleozoic belts are shown in Table 5, and are discussed below.

As the faunas of the two southern belts are less well-known than that of the Buttle Lake-Big Interior belt, mainly because of poor preservation, a statistical comparison of the total faunas is not possible. Compared with 52 species of 42 genera recognized in the Buttle Lake-Big Interior belt, only 18 genera in the China Creek-Saltspring belt and 12 genera in the Horne Lake-Cameron River belt have so far been identified, with only a few of these being classifiable to specific level. Of the many presently unidentified fossils found in the southern two belts, some will probably be found to be comparable to forms in the northern belt.

From Table 5, it can be concluded that the China Creek-Saltspring belt has among the identified fossils 2 species and 8 genera in common with the fauna of the Horne Lake-Cameron River belt and the same numbers

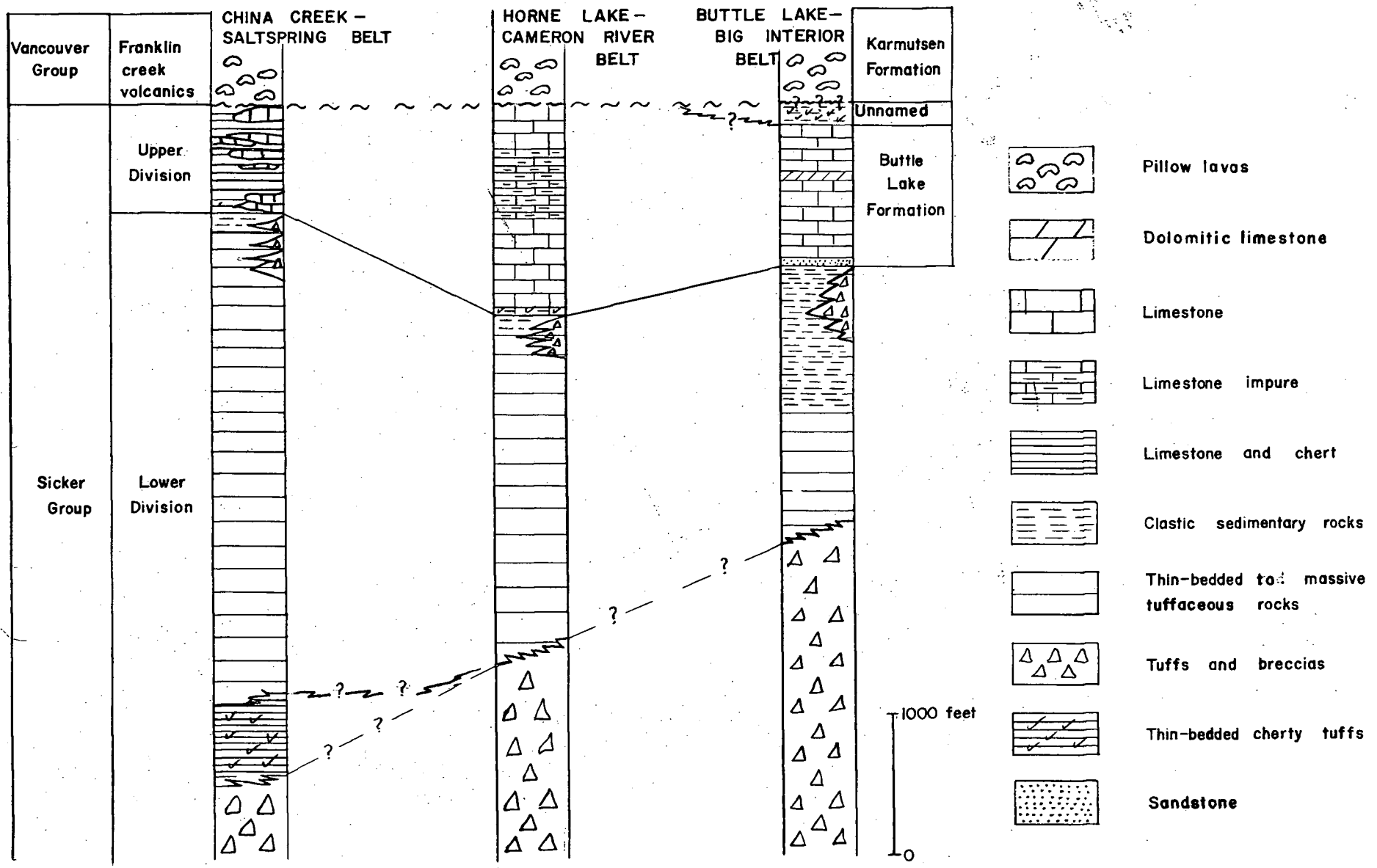

Figure 54 Correlation diagram, Sicker Group, Vancouver Island, highly generalized.

	China Creek-Saltspring belt	Horne Lake-Cameron River belt	Buttle Lake-Big Interior belt
Specific comparisons			
Cladochonus sp.	X	X	X
Michelinia sp. A	X	X	
Streblascopora pulchra	X?	X	X
Goniocladia intermedia	Genus	X	X
Penniretepora grandis		X	X
Horridonia sp. A.	Genus	X	X
Squamularia sp.		X	X
Spiriferella saranae	X		X
Generic comparisons			
Tetrataxis	X	X	X
Schwagerina?	X	X	
Pseudofusulinella?	X	X?	X?
Rhabdomeson	X		X
Sulcoretepora	X	X	
Muirwoodia?	X		X
Hustedia	X?	X?	X
Schizophoria	X?	X	
Antiquitonia	X?		X

TABLE 5

Faunal correlations between the three Paleozoic belts of Vancouver Island. Only fossils represented in two or more belts are shown.

of species and genera in common with the Buttle Lake-Big Interior belt. The Horne Lake-Cameron River belt has 6 species and 7 genera in common with the Buttle Lake-Big Interior belt. The two southern belts may be contiguous, as explained in an earlier section. If, therefore, they are treated as a single faunal unit, they may be said to have 7 species and 11 genera in common with the northern, Buttle Lake-Big Interior belt. By using some of the questionable identifications, these figures could be raised slightly.

Thus, faunal similarity of the two southern belts to the northern belt may be expressed by saying that of the 13 specific identifications from the former, 7 are also present in the northern belt. Simpson (1947, p. 672) states that "the best simple measure of taxonomic resemblance" is given by using the formula $\frac{C}{N} \times 100$ where N is the number of taxonomic units in the smaller of two faunas, and C is the number of units common to the two faunas. If the figures for the comparison given above are utilized in the formula, an index of faunal similarity of 54 is the result. Calculations made in the same way for Permian brachiopod faunas of Greenland and Spitzbergen as compared to that of Grinnell Peninsula, from lists given in Harker and Thorsteinsson (1960, p. 16-17) yield indices of 57 and 42, respectively. Harker and Thorsteinsson indicate that these areas show "close faunal relationships".

The stratigraphic correlations indicated on Figure 54 show that the Upper Division of the Sicker Group consists of the Buttle Lake Formation and a locally developed, relatively thin overlying unit of fine-grained, non-calcareous clastic rocks in the Buttle Lake-Big Interior belt. The upper, clastic unit of the northern belt may possibly belong to the overlying Triassic Vancouver Group. However, if the correlation

suggested in Figure 54 is valid, the Upper Division of the Sicker Group in the two southern belts is probably a facies equivalent of the Buttle Lake Formation. The name "Buttle Lake Formation" is not extended to the southern belts at the present time for the following reasons. The limestones of the Upper Division of the Sicker Group are probably of lens-like form, thus making detailed lithological correlations hazardous. Fossil zonation has not been developed to the point at which firm faunal correlations on a detailed scale can be attempted. Finally, the upper boundary of the Upper Division is probably an unconformity, the angular relationship of which to stratigraphic horizons within the underlying rocks has not been determined. It is thus considered advisable for the present to restrict the name Buttle Lake Formation to rocks of the type area.

INTER-REGIONAL CORRELATIONS

Correlation with central Oregon

Carboniferous and Permian formations near the centre of Oregon, 15 Miles southeast of Paulina, have been described by Merriam and Berthiaume (1943). The Permian Coyote Butte Formation of this area contains a large fauna of fusulinids, corals and brachiopods.

Two species of Pseudofusulinella, two species of Schwagerina and five species of Parafusulina were identified by Henbest (in Dunbar, et al., 1960, p. 1780-1781) in collections from the Coyote Butte Formation. Schwagerina and Pseudofusulinella have been tentatively identified in the fauna of the Upper Division of the Sicker Group.

Three of the 60 species of 39 genera of Coyote Butte brachiopods described by Cooper (1957) occur also in the Vancouver Island faunas, in

which 25 brachiopod species of 22 genera have been identified. The species common to the faunas are:

Antiquitonia sulcata
Echinoconchus inexpectatus
Kochiproductus cf. K. porrectus (= Kochiproductus n.sp.)

Four additional species of the Vancouver Island brachiopods are comparable, and three are possibly related, to central Oregon species. These are:

*Cleiothyridina sp	?	C. gerardi
Horridonia sp. A	?	Pleurohorridonia? elongata
Krotovia? sp. A	?	K. aff. K. barenzi
Squamularia sp	?	S. rostrata
Rhynchopora n. sp.	??	R. magna
Spiriferella saranae s.l.	??	S. draschei
Muirwoodia? sp.	??	M. transversa

Considering the geographic separation (400 miles), facies differences, and the incomplete knowledge of the Vancouver Island faunas, the faunal relationships thus indicated between the two regions are relatively close. If the ten similar and possibly comparable species are used to derive Simpson's index of faunal similarity, an index of 40 is obtained for the brachiopods.

Correlation with the Cache Creek Group

Large areas of mainland British Columbia, from Dease Lake in the north to the Chilliwack area in the south are underlain by sedimentary and volcanic rocks of the Cache Creek Group or probable stratigraphic equivalents (Armstrong, 1949, p. 50; G.S.C. Map 932A, 2nd Ed., 1962). The faunas of this upper Paleozoic sequence of rocks are largely undescribed. Faunal lists from many localities are available, but in most

*In this and succeeding lists of compared species the Vancouver Island fossils are listed on the left.

cases only tentative identifications have been attempted. From such incomplete information, it has been concluded that the Cache Creek faunas include seven species of brachiopods and one bryozoan species comparable to species found in the fauna of the Upper Division of the Sicker Group of Vancouver Island. These pairs of comparable species are listed below:

Spiriferella saranae s.l.		S. saranae, Jones, 1959 pp. 43, 47
Spirifer rajah?		Spiriferella rajah, Jones 1959, pp. 43-47
Neospirifer n. sp.	?	Spirifer cameratus, Kerr 1926, p. 81
Schizophoria sp.	?	S. aff. jurasenesis, Kerr, 1948, P. 84
Rhynchopora n.sp.	?	R. cf. R. nikitini, Kerr, 1948, p. 84
	?	R. cf. R. nikitini, Jones, 1959, pp. 43-47
Squamularia sp.	?	S. aff. S. rostrata, Kerr, 1948, p. 84
Antiquitonia sulcata	?	Productus cf. uralicus, Aitken, 1959, p. 31
Fenestella basleoensis	?	F. cf. F. basleoensis, Jones, 1959, p. 43-47

The citations after the listed Cache Creek species refer to the authors of the publications; the fossil identifications are by Harker and Kindle.

The Vancouver Island faunas contain tentatively identified fusulinids of the genera Schwagerina and Pseudofusulinella, both of which also occur in the Cache Creek Group (Pitcher, 1960 among others).

Thus, evidence from both brachiopods and fusulinids indicates that the Upper Division of the Sicker Group is correlatable with at least part of the Cache Creek Group.

Correlation with Alaska

Upper Paleozoic rocks occur in several parts of Alaska, including the Alexander Archipelago. Faunal lists from several Permian areas

(Buddington and Chapin, 1929; Moffitt, 1938, 1954; Wright and Wright, 1908; Mertie, 1930) indicate a large fauna, for which few descriptions are available. From these faunal lists, it appears that at least 14 species of brachiopods are directly comparable or similar to species from the Upper Division of the Sicker Group of Vancouver Island. These comparable pairs are listed below.

Laevicamera n. sp.	?	Camarophoria aff. C. pentameroides, 2*.
Kochiproductus n. sp.		Productus porrectus, 1,2,4,5.
Horridonia sp. A	?	Productus aff. or cf. P. timanicus, 1,2,4,5.
Horridonia sp. B	?	P. aff. or cf. horridus, 1,3,4)
Echinoconchus inexpectatus		Productus aff. or cf. P. fasciatus, 1,2,3,4,5.
Antiquitonia sulcata	?	Productus inflatus, 2.
Muirwoodia? sp.	?	Productus aff. or cf. P. mammatus, 1,2,3,4.
Spiriferella saranae s.l.		S. aff. S. saranae, 1,2,3,4,5.
Neospirifer n. sp.	?	Spirifer cameratus, 1,2,3,4. cf. or aff.
Pterospirifer? sp.	?	Spirifer aff. S. alatus, 1,2,5.
Brachythyrina cf. B. ufensis		Spirifer aff. or cf. S. ufensis, 1,2,4.
Cleiothyridina sp.	?	C. cf. C. pectinifera, 4.
Rhynchopora n. sp.		R. aff. or cf. R. nikitini, 1,2,3,4,5.
Hustedia meekana		H. cf. or aff. H. meekana, 2,3.

A relatively high faunal similarity between the two regions (index of 56) is suggested. Until such time as the Alaskan faunas are more adequately known, this relationship cannot be firmly established, but the general similarity of the two faunas is, in the opinion of the writer, unquestionable, and the sequences are correlatable on their faunal content. The majority of species listed above is present in the Permian of the Alexander Archipelago, where lithologies of the fossiliferous sequence

---

*The numbers indicate the source of the listed species: 1 = Wright and Wright, 1908; 2 = Buddington and Chapin, 1929; 3 = Mertie, 1930; 4 = Moffitt, 1938; 5 = Moffitt, 1954.

are similar to those of Vancouver Island, 700 miles to the south.

Correlation with the Yukon

The Permo-Carboniferous succession of eastern Alaska is correlated with a sequence of similar age in the northern Yukon (Nelson, 1961a, b; 1962b, c). At least 7 of the species from the Alaska Permian listed above are present in the Tahkandit Formation of the Eagle District, near the Alaska-Yukon border. The Yukon Permo-Carboniferous succession is composed of the Mississippian Calico Bluff Formation, the Pennsylvanian? Lower Limestone unit, Middle Recessive unit (Wolcampian?) and the Tahkandit Formation of Leonardian age. The faunas of these rocks have not been fully described or listed. From the published information, the following specific comparisons may be made between the Yukon faunas and the faunas of the Upper Division of the Sicker Group of Vancouver Island.

Spiriferella saranae s.l.		S. saranae, Nelson, 1961a, b.
Brachthyrina cf. b. ufensis		"Spirifer" cf. S. ufensis, Nelson, 1961b.
Neospirifer n. sp.	?	N. sp., Nelson, 1961a, b.
Horridonia sp. A	?	Pleurohorridonia scoresbyensis Nelson, 1961b.
Horridonia sp. B	?	Horridonia from Lower Limestone, Nelson, 1962b.
Muirwoodia? sp.	?	M. transversa, Nelson, 1961b.
Michelinia sp. B	?	M. harkeri, Nelson, 1962c.

In the Yukon, Spiriferella saranae is found only in the Tahkandit Formation; the other listed fossils are from the Lower Limestone unit, with the exception of Neospirifer which occurs in both formations.

The tentative identification in the Upper Division of the Sicker, of the genus Schwagerina, found also in the Yukon Tahkandit, together with the occurrence of Spiriferella saranae in both the Tahkandit and Vancouver Island beds, suggest a correlation between these two units. The evi-

dence from these two Permian index fossils is supported by the presence of seven species of brachiopods from the Alaskan Tahkandit which are comparable to Vancouver Island fossils (see preceding list; Mertie 1930). The apparently greater number of species similar to Sicker Group fossils in the Lower Limestone unit must be regarded for the present as a result of the incomplete knowledge of the Yukon faunas. Only 17 species are at present known from the Yukon beds, and only a few of these (tabulate corals) have been fully described. In addition, the faunas of the two fossiliferous Yukon formations are "genetically related" (Nelson, 1961a, p. 4), and have been treated as single assemblage (the "Russian fauna", Warren and Stelck, in Nelson, 1961a, p. 4; 1961b, p. 31).

If the combined known faunas of the Lower Limestone and Tahkandit are compared with that of the Upper Division of the Sicker, a Simpson index of 41 may be derived from the comparable species. For two units separated by 1,000 miles this appears to be a relatively close similarity. It is thus concluded that the Vancouver Island faunas are generally similar to the Permo-Carboniferous faunas of the Yukon, but that the most reliable index fossils suggest a closer affinity to the Tahkandit formation than to the Lower Limestone.

Correlation with Grinnell Peninsula

Two highly fossiliferous Permian formations are present on the Grinnell Peninsula of Devon Island in the Canadian Arctic Archipelago. The older, Belcher Channel Formation, mainly limestone, contains a fauna of fusulinids, corals and brachiopods. The younger Assistance Formation of glauconitic sandstones contains abundant brachiopods and a few ammonoids (Harker and Thorsteinsson, 1960).

In the fauna of the Belcher Channel Formation described by Harker and Thorsteinsson, two brachiopods are comparable to species found in the Upper Division of the Sicker Group of Vancouver Island. Spiriferella saranae is present in both faunas. Derbyia? sp. from Vancouver Island is similar to Derbyia sp. of the Belcher Channel. Three species of the fusulinid genus Schwagerina and one of Pseudofusulinella have also been described from the Belcher Channel. These two genera are tentatively identified in the Sicker Group fauna, but specific comparisons are not yet possible.

Harker and Thorsteinsson have described 24 species of brachiopods from the Assistance Formation. Seven of these represent species identical or similar to species found in the Upper Division of the Sicker Group. These are listed below on the right, opposite the comparable Vancouver Island species.

Spiriferella saranae		S. saranae
Antiquitonia sulcata	?	Dictyoclostus cf. D. neoinflatus
Muirwoodia? sp.	?	Muirwoodia mammatus
Rhynchopora n. sp.	?	R. cf. R. nikitini
Pterospirifer? sp.	?	Pterospirifer cf. P. alatus
Neospirifer n. sp.	?	Spirifer striato-paradoxus
Kochiproductus n. sp.	?	K. freboldi

The faunas thus suggest some degree of correlation between the Upper Paleozoic formations of Grinnell Peninsula and Vancouver Island, which are about 2,000 miles apart; a Simpson index of 20 is obtained using the combined faunas of Belcher Channel and Assistance Formations; for the Belcher Channel alone, and Assistance alone, the figures are 11 and 26 respectively, reflecting the dominance of brachiopods in the Assistance Formation. The evidence from foraminifera, (see above) however, suggests that the closest affinities are between the Belcher Channel and Upper Division of the Sicker.

Correlations with other Arctic regions

Faunal similarities between the Permian of Grinnell Peninsula and Greenland are listed by Harker and Thorsteinsson (1960, p. 16). In addition to five species of this list which are probably common to both the Grinnell Peninsula and Vancouver Island, the following species of the Upper Division of the Sicker Group are represented in the Permian beds of Greenland by directly comparable or similar forms.

Antiquitonia sulcata	?	Dictyclostus neoinflatus, Dunbar, 1962
Horridonia sp. A	?	Sowerbina granulifera, Dunbar, 1962
	?	Pleurohorridonia scoresbyensis, Dunbar, 1955
Hustedia meekana	?	H. sp., Dunbar, 1955
Cleiothyridina sp.	?	C. pectinifera, Dunbar, 1955
Spiriferella saranae	?	S? sp. undet., Dunbar, 1955
Spiriferina? sp.	?	S. multiplicata, Dunbar, 1955
Nuculana sp.	?	N. speluncaria, Newell, 1955
Chaenomya? sp.	?	Allorisma elegans, Newell, 1955
Schizodus sp.	?	S. obscurus, Newell, 1955

It is thus apparent that at least 14 of the Vancouver Island species are represented by similar species in the Greenland Permian faunas.

Similarly, Harker and Thorsteinsson's comparison of the Grinnell Peninsula faunas with those of Novaya Zemlya includes several species comparable to Vancouver Island fossils. To this list may be added Productus fasciatus, Neospirifer cameratus, Krotovia barenzi, Brachythyrina ufensis and Rhyncopora geinitziana, which occur in the Novaya Zemlya Permian faunas described by Miloradovich (1935), and are similar to species in the Vancouver Island Permian faunas.

The faunas of Spitzbergen Permian formations have been compared by Dunbar (1955, p. 57) to those of Greenland, and by Harker and Thorsteinsson (1960, p. 16) to those of the Grinnell Peninsula, with the result that relatively large numbers of species are suggested as being com-

mon to the three areas. Stepanov (1937) illustrates Neospirifer condor, Cleiothyridina royssiana, Muirwoodia mammatus and Rhyncopora nikitini from Spitzbergen, all of which are similar to species from Vancouver Island.

Correlations with Russia

As can be seen in the names given to many of the fossils of the Permian localities mentioned above, and discussed in more detail in the section on systematic paleontology, many of the brachiopod species have been identified or compared with Russian Permo-Carboniferous species, and especially with those described in Tschernychew's monograph (1902) on the Urals and Timan. At least 13 of the 213 species listed by Tschernyschew (p. 352-360) are represented by almost identical or similar species in the brachiopod fauna of Vancouver Island. Tschernyschew's species Rhynchopora nikitini, Camerophoria pentameroides, Hustedia indica, Spiriferella saranae, Spirifer ufensis, Productus fasciatus, Productus porrectus and Productus timanicus are among the most closely comparable forms. Of these, H.indica, S.saranae, and P.porrectus are restricted to Permian beds.

The bryozoan fauna of Vancouver Island is also linked to Upper Paleozoic faunas of Russia by common or similar species. Among these are Fenestella basleoensis and F. parviuscula (Elias and Condra, 1957, p. 78, p. 108).

Correlation with Australia

Three species of pelecypods, one tabulate coral, and four species of bryozoa present in the Upper Division of the Sicker Group are repre-

sented in the Permian faunas of Western Australia by almost identical or similar species. The closest comparisons link Streblascopora pulchra and Fenestella parviuscula of Vancouver Island with S. marmionensis and F. horologia respectively of the western Australian faunas (Crockford, 1944a; 1957).

The three Vancouver Island species tentatively assigned to the genus Ingelarella are particularly interesting in that the genus has been found in few places other than Eastern Australia, and has not before been recognized in North America (see Campbell, 1959, p. 341).

Correlation with southwestern United States

Despite the predominance of species closely comparable or similar to Arctic or Russian fossils, the faunas of the Upper Division of the Sicker Group contain several species resembling those of the Permian of Texas and adjoining regions of southern United States. While the resemblances do not appear to be as close as those with northern faunas, at least one species, Hustedia meekana appears identical to the American species from the limited information available from the few specimens found on Vancouver Island. Other Texas species which resemble Vancouver Island fossils are "Horridonia" texana (H. sp.A), Buxtonia victorioensis (Kochiproductus, n.sp.), Productus hessensis (Antiquitonia sulcata), and Neospirifer huecoensis (N. n. sp.) among the brachiopods, and the bryozoans F. cf. F. parviuscula and Acanthocladia guadalupensis? (A. multipora).

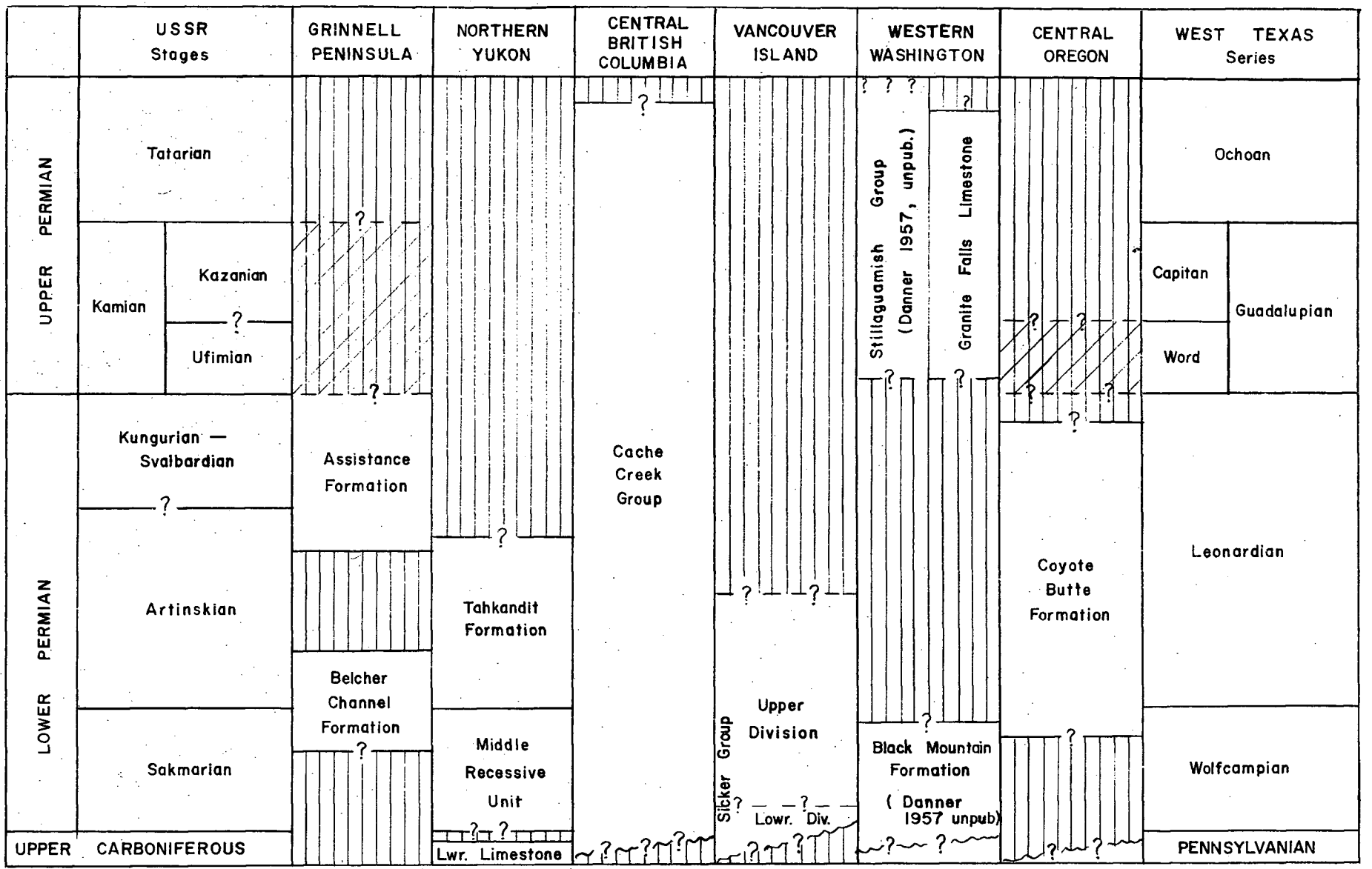

Fig. 55 Correlation of Permian formations of Cordilleran and Arctic regions. In part after Harker and Thorsteinsson (1960), Dutro (1961), Dunbar et al (1960), Danner (1957, 1962). Dutro's alternative ages of formations containing "Arctic Permian fauna" shown by diagonal shading.

AGE OF THE SICKER GROUP FAUNA

The age ranges of many of the fossils of the Upper Division of the Sicker Group and the closely comparable forms mentioned above, are not well known. Some extend from Upper Carboniferous to Permian, but several are entirely restricted to the Permian, and almost entirely to the Lower Permian (in the Russian sense, and that proposed for the American sequences by Cohee, 1960, p. 1579). Among these index fossils are the genera Kochiproductus, Muirwoodia, Ingelarella and Streblascopora, and the species Hustedia meekana, Spiriferella saranae. The association of these or closely comparable fossils in the Vancouver Island beds strongly suggests Lower Permian age. The tentative identification of the fusulinids Schwagerina and Pseudofusulinella tend to confirm this age determination, for these genera are largely confined to the Wolfcampian and Leonardian series.

The brachiopods of the Vancouver Island fauna have marked similarities to certain species from the Coyote Butte Formation of central Oregon. The Coyote Butte has been dated on the basis of fusulinids as Wolfcampian and Leonardian. The Grinnell Peninsula fauna has also several species comparable to forms from the Upper Division of the Sicker Group, and has been partially dated from fusulinid evidence. Harker and Thorsteinsson regard the older fusulinid-bearing Belcher Channel Formation as being Wolfcamp-Leonardian in age. The younger Assistance Formation is Leonard-Wordian (mainly Kungurian, or Svalbardian in the Russian terminology) on the basis of its stratigraphic position and relationship to beds with similar brachiopod faunas (the "Arctic Permian fauna", Harker and Thorsteinsson, 1958, p. 1577; 1960, p. 15). However, the age of the Arctic Permian fauna is not yet firmly established.

Dunbar (1955, p. 52) would date beds in Greenland bearing this fauna as Late Permian (Zechstein). It has been suggested by Dutro (1961, p. C-226) that the age of the Arctic Permian fauna lies between those ages suggested by Harker and Thorsteinsson and Dunbar, and is equivalent to the Kamian (Likharev, 1959), or Kazanian and Ufimian (early Late Permian). If Nelson's age determinations of the Yukon sequence are valid, certain elements of the Arctic Permian fauna are common in the Pennsylvanian Lower Limestone unit (see discussion above and Nelson, 1961a; 1961b; 1962b,c).

It may well be that the Arctic fauna is diachronic, with slightly differing ages in different places within its wide distributional realm. That it is not entirely a facies fauna is shown by the resemblance between the faunas of such predominantly limestone units as the Upper Division of the Sicker and the predominantly arenaceous Assistance Formation of Grinnell Peninsula.

The conclusion drawn from the above discussions of age and correlation are that the closest general similarities of the Vancouver Island fauna are to faunas of Early Permian (Wolfcampian-Leonardian; Sakmarian-Artinskian) age, and the same age is suggested by the most reliable index fossils in the fauna. As the study of the fauna is incomplete, and the distribution of the fossils within the stratigraphic column is not uniform or well-known, the presence of older or younger beds within the sequence must still be considered as a possibility. The distribution and relationships of certain fossils of the "Russian" and "Arctic Permian" faunas in Cordilleran, Arctic and Russian regions are shown in Table 6. The differing interpretations of the age of these faunas are indicated in Figure 55.

	VI	NWW	CO	CBC	A	"Russian" Fauna Y LLs	"Russian" Fauna Y T	"Arctic" Permian Fauna GP Bc	"Arctic" Permian Fauna GP Ass	NWR
Fenestella basleoensis	O	G		X	G					O(L)
Fenestella parviuscula	O									X(L)
Goniocladia intermedia	O				G					X
Polypora megastoma	O	G		G	G		G			O(UC)
Antiquitonia sulcata	O		O	X(L)	X				X	X(L)
Cleiothyridina gerardi	X		O		G		G			O(L)
Echinoconchus inexpectatus	O		O		X		X			X(L)
Horridonia sp. A	O		X		X?	X?	X?			X?(L)
Horridonia sp. B	O				X?	X?	X?			X?(L)
Hustedia cf. H. meekana	O				X		X			X(L)
Kochiproductus n. sp.	O		O		X		X		X	X(L)
Krotovia? sp. A.	O		X		G		G			X(L)
Laevicamera n. sp.	O				X					X(L)
Neospirifer? n. sp.	O			X	X	X?	X?		X	X(L)
Rhynchopora n.sp.	O		X?	X	X		X		X	X
Brachythyrina cf. B. ufensis	O				X	X				X(L)
Spiriferella saranae	O		X	O	X		O	O	O	O(L)
Squamularia rostrata	X		O	X	G		G		G	O(L)
Tetrataxis	G			G(U)						G?
Parafusulina alaskensis					O(L)		G	G		X(L)
Parafusulina? calx			O	X(L)			G	G		G(L)
Parafusulina gracilis			O	O(L)			G	G		G(L)
Parafusulina? turgida			O	X(L)			G	G		G(L)
Pseudofusulinella montis	G	O		X(L)				G		G?
Pseudofusulinella occidentalis	G	O		O(L)				G		G?
Schubertella kingi				O(L)				O		G
Schwagerina	G	G		G(L)			G	G		G(L)

LEGEND: O - species present; X - comparable species; X - also in upper Carboniferous; G - genus present; species not compared.

(L), (U), (UC) - Lower Permian, Upper Permian, Upper Carboniferous occurrence.

COLUMN HEADINGS: VI - Vancouver Island, Buttle Lake Formation. NWW - Northwest Washington, Black Mountain Formation (Wolfcamp?). CO - Central Oregon, Coyote Butte Formation (Wolfcamp-Leonard). CBC - Central B.C., Cache Creek Group (Pennsylvanian? and Permian). A - Alaska, Permian. Y - Yukon and Alaska border, Permo-Carboniferous; LLs - Lower Limestone (Pennsylvanian?), T - Tahkandit Formation (Leonard?). GP - Grinnell Peninsula, Permian; Bc - Belcher Channel Formation (Wolfcamp-Lower Leonard); Ass - Assistance Formation (Upper Leonard). NWR - Northwestern Russia, Permian.

SOURCES: Aitken, 1959, Armstrong, 1949. Branson 1948, Buddington and Chapin, 1929. Cooper, 1957. Danner, 1957. Dunbar, 1946. Dunbar et al., 1960. Dutro, 1961. Elias and Condra, 1957. Fritz, 1932, 1946. Harker and Thorsteinsson, 1960. Jones, 1949, Lord, 1948. Mertie, 1930, Moffitt, 1938, 1954. Nelson, 1961a, b; 1962. Pitcher, 1960. Sarycheva and Sokalskaya, 1952. Trettin, 1961. Tschernyschew, 1902. Wright and Wright, 1908.

TABLE 6

Distribution of certain key fossils in Cordilleran, Arctic and Russian regions.

BIOGEOGRAPHY

The concept of biogeographic realms in paleogeographic studies of fossil assemblages has played an important role in historical geology. Although modern investigations of facies, ecological, environmental, migration and dispersal and oceanographic factors have modified earlier biogeographic interpretations, the realm concept still is valid.

Because of their significance in relation to late Paleozoic glacial intervals and to assessment of the hypotheses of continental drift and polar wandering, biogeographic studies of the Permian system have been given considerable attention (Schuchert, 1928, 1935; Stehli, 1957; Runcorn, 1962; Bullard, 1964).

Schuchert (1935) defined seven marine faunal realms of the Permian. Four of these were regarded as "warm-water" realms, of which the Tethyan (realm I) is characteristic. The remaining three, a typical example of which is the Eastern Australian realm (VI), were described as "cold-water" realms (Schuchert, 1935, p. 4, fig. 1).

The American Cordilleran realm (III), in which cold waters from the Arctic and warm waters from the Pacific and the Mexican region "united for a time in the Middle Permian" (p. 4), was subdivided into the cold Alaskan province (IIIa, including parts of British Columbia, eastern Alaska and the Yukon) and the warm Texan province (IIIb, the southern Cordilleran region). The cold-water Sibero-Alaskan realm (VII, northern Siberia and western Alaska) was connected with the Alaskan province of the Cordilleran realm, perhaps through northwestern Alaska or the Aleutian chain. From Schuchert's paleogeographic map (1935, fig. 1), it also appears that the Alaskan province was connected through the Arctic Archipelago, Greenland, Spitsbergen (Svalbard) and Novaya Zemlya with the

Uralo-Germanic realm (V, probably also with a "cool-water fauna"). The third cold-water realm, the Eastern Australian, appears from Schuchert's map to isolated from the other two; its only connections with other realms seem to be in the Western Australian province (Ib), an outpost of the Tethyan realm, where the warm- and cold-water faunas "became more or less mixed" (p. 4).

Schuchert's work thus suggests a circumpolar distribution of northern faunas, with some extensions to the south but more or less distinct from a group of warm-water, equatorial faunas and from a southern cold-water fauna in Eastern Australia.

Later workers present evidence in support of a similar interpretation of Permian biogeography. Newell (1957, p. 407), for instance, concluded for Texas Permian fossils:

> "The marine faunas are most similar to contemporaneous faunas at low latitudes in the Eastern Hemisphere (Tethys). This is probably a result of circumequatorial conditions."

He further states (p. 426):

> "On the other hand, the Permian faunas of northern Europe and the Arctic Islands form quite a different, boreal facies. ....Lack of well-defined latitudinal zonation in the boreal faunas of high latitudes....suggests prevailing mild climates well into Arctic regions."

Harker and Thorsteinsson (1960, p. 19) have described an "Arctic Permian fauna" which they regard as representative of a widespread Early Permian faunal realm. They also postulated "a fairly free marine connection" between Arctic and western Cordilleran regions.

One of the most distinctive of the brachiopod genera of this boreal fauna, Horridonia, has been studied in detail by Gobbett (1961). The restricted boreal distribution indicated, Gobbett (1961, p. 46; fig. 1) is now modified by Yukon occurrences (Nelson, 1961b; 1962) and

Vancouver Island occurrences described in the present work.

Despite these indications of distinctive boreal and equatorial faunas, certain elements of the American Cordilleran realm, and the Alaskan province in particular, present evidence of more complex, and at present confusing, relationships. Anderson (1941), Thompson and Wheeler (1942), Thompson, Wheeler and Danner (1950) and Danner (1957, 1959) have pointed out the Tethyan affinities of the fusulinid faunas of the northwestern Cordilleran region. Connection of the Alaskan province with equatorial regions is also suggested by the bryozoan evidence (Fritz, 1932).

The present study also suggests that faunas with mixed biogeographic relationships existed in Early Permian times in Schuchert's Alaskan province. The Vancouver Island brachiopods, though as a whole similar to the "Arctic Permian fauna", include at least one genus characteristic of the Texan province, and one apparently related to an Eastern Australian fossil of the "cold-water" fauna. Certain pelecypods and bryozoans are similar to fossils of the Western Australian outpost of the Tethyan fauna (see section on systematic paleontology).

Early interpretations of fossil biogeographic realms relied heavily on physical barriers (i.e. land masses, uplifts) as an explanation of the distinctive assemblages. More recent studies tend to emphasize the importance of environmental controls (Lochman-Balk and Wilson, 1958; Ross, 1963). For instance, Ross (1963, p. 45) suggests that the Early Permian Pseudoschwagerina fusulinid assemblage characteristic of the southern Cordilleran region and the contemporaneous Pseudofusulinella-Schwagerina assemblage of the northwestern Cordilleran were "largely restricted to different environments rather than being geographically separated".

Among studies of biogeographic evidence in evaluations of the hypotheses of continental drift and polar wandering, the Permian data presented by Stehli (1957) are of significance to the present work. The distributions of several groups of intensively-studied marine invertebrates (brachiopods and fusulinids) were plotted on world maps. Two patterns of distributions were the result: one, a general, world-wide pattern; and second, distributions in a belt limited to low and middle latitudes, parallel to the equator. The north boundary of the low-middle latitudinal belt is suggested as being analagous to the modern faunal break parallel to the 15 degrees Centigrade winter isotherm. The latter may also be correlated with a prominent physico-chemical boundary.

The present data from Vancouver Island Permian faunas corroborate Newell's suggestion of lack of latitudinal zonation in the boreal regions. However, this does not signify lack of relative movements of the continents, or polar wandering. The distribution of the "Arctic Permian fauna", as presently understood, has the same latitudinal spread (about 40 degrees) on present world maps as it has on reconstructions based on paleomagnetic data for the Permian. The latter (van Hilten, 1962, fig. 8; Runcorn, 1962, fig. 25) interpret the data as being consistent with both polar wandering and continental drift since the Permian. The distribution of the "Arctic Permian fauna" does not appear to coincide closely with Stehli's (1957) interpretations, as his major faunal break occurs at about 55 degrees north latitude, in the middle of the range of "Arctic Permian fauna". A 15 degree southward extension of this boundary, perhaps effected by major ocean currents, seems to the writer to be a possibility at least.

In summary, then, it is the writer's opinion that the present information on the composition and distribution of the "Arctic Permian fauna" is inconclusive with respect to differing interpretations of Permian biogeography and to the hypotheses of polar wandering and continental drift. The relatively incomplete status of faunal studies of the northern Cordilleran region does, however, suggest a fruitful field for further study.

ENVIRONMENT OF DEPOSITION

Evidence from which to interpret environments of deposition of the Sicker Group has not as yet been fully compiled. Certain aspects of the rocks, such as their detailed petrography and their geochemical characteristics, remain to be investigated. However, observations made prior to and during the present study suggest some tentative conclusions relevant to environmental analysis.

PETROGRAPHIC AND STRATIGRAPHIC EVIDENCE

The majority of the Lower Division of the Sicker Group is of volcanic origin. Pyroclastic breccias, cherty and feldspathic tuffs and porphyritic or amygdaloidal flows of basaltic or andesitic composition are intercalated with, grade into or interfinger with sequences of massive to thin-bedded tuffaceous greywackes, greywacke-argillite and local conglomerates.

The gross characteristics of this succession suggest the dominance of volcanic flows and coarse pyroclastic rocks in the lower half and of thin-bedded fine pyroclastics and bedded to massive greywackes in the upper part (Fyles, 1955, p. 18; fig. 2. Figure 9 of this thesis). Lateral variations in the succession modify this generalized sequence. For instance, Fyles (ibid.) notes a local coarsening to the north and west of the clastic rocks of the Sicker Group in the Cowichan Lake area. The occurrence of coarse breccias immediately below the calcareous rocks of the Upper Division in the West Horne Lake section and the Azure Lake section may indicate a similar trend toward a coarsening of the clastic rocks to the west.

The rocks of the Upper Division of the Sicker Group conformably overlie those of the Lower Division in most places. The basal pebbly sandstone of the Azure Lake section of the Upper Division (Figures 6, 41) probably overlies a local disconformity.

The limestone-bearing Upper Division, though not as heterogeneous lithologically as the Lower Division, contains a variety of calcareous and siliceous rocks.

The calcareous suite includes calcilutites, calcarenites, calcirudites, dolomitic limestones and crystalline limestones. The proportions of individual rock types have not been closely determined, but preliminary examination of the sections indicates the dominance of medium to coarse grained crinoidal rocks in the Buttle Lake area and the Horne Lake area. Similar rocks form smaller lenses within the thin-bedded limestone-chert sequence of the Cowichan area.

In terms of Folk's (1959, 1962) limestone classification, the majority of the rocks fall into classes I and II (crinoidal biosparite and biosparudite, and crinoidal biomicrite and biomicrudite). Impure (tuffaceous?) bryozoan biomicrites and biomicrudites form distinctive but subordinate portions of the sections of the Upper Division.

Siliceous rocks associated with the carbonate rocks are of two distinct types, one of which is common in all three belts of the Sicker Group, in contrast to the other which is restricted to the China Creek-Saltspring belt.

The first, ubiquitous type of chert is white, grey or black, micro- to cryptocrystalline silica which occurs in nodules, lenses and irregular layers in the limestones (Figures 29, 48, 49). In

thin-sections, all stages of replacement of original limestone textures can be seen. This type of chert forms up to 50 per cent of short vertical intervals; in the total sections of the Upper Division, the cherty zones are concentrated in certain portions of the sequence, comprising in aggregate perhaps only 5 per cent of the rock. These cherts show remarkable similarity to shelf and miogeosynclinal cherts of other parts of the Cordilleran region (see Bissell, 1959, pls. II, V).

The second mode of chert occurrence, apparently confined to the China Creek-Saltspring belt, was originally described by Fyles (1955, p. 16; pl. VIII). It is found in thin-bedded, graded sequences with grey, fine-grained, commonly siliceous limestone (Figures 16, 18). Laminae composed almost entirely of siliceous sponge spicules are found in some thin-sections of this sequence. In the China Creek-Saltspring belt, chert-limestone sequences such as this are more abundant than the thicker-bedded, coarser crinoidal limestones (Figure 6).

EVIDENCE FROM SEDIMENTARY AND OTHER STRUCTURES

Sedimentary rocks of the Lower Division include sequences of thin, graded units (Figure 27). Tuffs and greywacke-argillite intervals display, in addition to graded bedding, some disrupted bedding features, minor local disconformities, and laminated units with obscure cross-stratification.

Rare pillow structures and scoriaceous basalts are evidence of the presence of volcanic flows in the Lower Division. Most of the amygdaloidal rocks of the Cowichan Lake area (similar to volcanic

rocks in other belts) are considered by Fyles (1955, p. 13) to be flows.

In Upper Division rocks, graded bedding in chert-limestone sequences has already been mentioned. Isolated instances of graded texture in individual beds of coarse calcarenite and calcirudite have also been observed. Crudely cross-stratified beds have been observed in conglomeratic rocks at Horne Lake (Figure 27).

EVIDENCE FROM FOSSILS

The only fossils found to date in the rocks of the Lower Division are radiolaria from Horne Lake. Possible radiolarian fossils have been described by Fyles (1955, p. 15; pl. VII) from cherty tuffs of the Cowichan Lake area.

The most common fossils of the Upper Division are productid and spiriferid brachiopods, ramose and fenestrate bryozoans, and crinoids represented mainly be disarticulated skeletal plates. One or more of these groups is represented in most of the limestone exposures of the Upper Division.

The crinoidal debris forms the dominant "allochem" (Folk, 1959, 1962) component of most of the clastic limestones. At one locality, Horne Lake, articulated stem segments in one bed are oriented parallel to the bedding planes (Figure 30).

Brachiopods are found as scattered fragmentary shells throughout the limestones, and more rarely, in coquinoid layers within the sequence. The most striking example of the latter type of occurrence is the spiriferid-productid coquinas locally present in a dolomitic limestone unit in the upper part of the Azure Lake section (see

Figure 6). The preservation in this bed of productids with intact brushes of long slender spines, and of articulated valves of spiriferids is another notable feature of this bed (Plate I, Figures 3, 4, 5. Plate II, Figures 1, 2, 3).

The mode of occurrence of bryozoans is in part similar to that of the brachiopods; the two groups commonly are found in the same bed, with one or the other showing local dominance. However, in the more impure carbonates, especially in the basal portion of the Upper Division, fenestrate bryozoans appear to the characteristic fossils, commonly forming coquinoid layers. In this mode of occurrence, large fragments of delicate fronds are preserved, aligned in the bedding planes; none has been found in growth position.

A few corals have been found in the Upper Division. They tend to occur most frequently in the impure carbonates near the base of the unit. The collections include both solitary horn corals and small colonies of tabulate forms.

The bulk of the gastropods and pelecypods of the writer's collections come from the basal sandstone of the Buttle Lake Formation, where they are associated with a distinctive brachiopod faunule (Rhynchopora, ingelarellids? and small spiriferids), fusulinids, ostracods, and plant remains.

Except for a few complete, silicified fusulinids in the basal sandstone of the Buttle Lake Formation, foraminifers occur mainly as fragmentary fossils in clastic limestones of the Upper Division of the Sicker Group.

DISCUSSION

The volcanic-sedimentary complex of the Lower Division of the Sicker Group is the record of an upper Paleozoic period of mainly submarine volcanicity, the intensity of which waxed and waned, with a general tendency toward less activity in the younger parts of the sequence in this region. The sedimentary portions of the rock succession are the direct (pyroclastic) or indirect, detrital or chemical, (greywacke, chert) products of volcanic action. The thin, graded units of parts of the sequence, the largely undisturbed stratification planes and scarcity of structures formed by strong current action, and the lack of fossils other than a few radiolarian remains are indicative of predominantly quiet-water deposition (i.e. below wave-base).

The environment of deposition of the Lower Division therefore may be classified as "pelagic". This is not to say that depth of water was excessive (e.g. bathyal or abyssal). Depth of water is not in itself critical for the accumulation of pelagic siliceous organisms; and "pelagic" sediments may form in enclosed arms of the sea or on continental shelves or borderlands (Riedel, 1959, p. 80, 81, 91). The term "basinal" suite for this assemblage of rocks is perhaps a more apt name.

The carbonate deposits of the Upper Division of the Sicker Group represent an environment markedly different from that discussed above. Compared to modern marine carbonate sediments, limestones of the Sicker Group appear most similar to those sediments classified by Rodgers (1957, p. 3) as "lime-sands and muds of certain of the continental shelves". They show no resemblance, in the

writer's opinion, to the other major classes of carbonate deposits - those of the deep seas and of organic reef complexes.

The light colour and general lack of organic matter in these limestones are indicative of an oxidizing environment and pH near 7.5 (Ginsburg, 1957, p. 89). The clastic nature of much of the carbonate rock, the coarseness of much of the crinoidal debris, and evidence of currents strong enough to produce cross-stratification and conglomerate lenses, are also indicative of a relatively shallow marine environment.

The fossil assemblages of the Upper Division also suggest shallow water environments. Similar assemblages, containing in some cases identical genera and species, are found in eastern Cordilleran and other areas interpreted as shelf or miogeosynclinal deposits (Nelson, 1961a,b; 1962. McGugan, 1963, McGugan and Rapson, 1963. Harker and Thorsteinsson, 1960. Wilson and Langenheim, 1962).

Rocks petrographically similar to those of the crinoidal carbonates of the Upper Division occur in many other upper Paleozoic deposits, and have also been interpreted as being of shallow-water origin (Stauffer, 1962; Carozzi and Soderman, 1962).

The precise limits of the depths at which such crinoidal limestones were originally deposited cannot be defined. Hyman (1955, p. 112) notes that modern stalked crinoids are found mostly between 600 and 15,000 feet, but "in a few restricted places may ascend into shallow water around 50 meters". Carozzi and Soderman (1962, p. 412) suggest that crinoidal "bioaccumulated" limestones formed "in shallow depressions of the sea bottom". These authors point out, in addition,

that the establishment of a crinoid population (colony or garden) appears to require an "undisturbed substratum" below wave base, where reworking and sedimentation are at a minimum. Such conditions could obtain either in deep waters or in sheltered water bodies of moderate to shallow depths.

Despite the evidence of current action mentioned above, present locally in parts of the sections of the Upper Division, petrographic evidence and the state of preservation of certain fossil assemblages precludes the inference of lengthy or vigorous transportation of the allochems of the majority of clastic limestones. Crinoid plates, for instance, appear fresh and unabraded, with fine surface sculpture preserved. Fine-grained limestones, with few or no coarse allochems, probably represent lithified lime-muds unlikely to have accumulated in strongly agitated waters. In present day seas, such deposits are formed in shallow, warm water at low latitudes (Newell and Rigby, 1957, p. 31, among others).

Striking evidence supporting a contention that quiet water deposition obtained for at least part of the sedimentation period of the Upper Division carbonates is given by the brachiopod bed in the Azure Lake section in which well-preserved long, slender productid spines, and large articulated spiriferid shells are found.

Petrographic, paleontological and other data thus point to a shallow depositional site which was intermittently agitated by marine currents. An estimate of the magnitude of currents capable of moving calcareous allochems of rocks similar to those of the Upper Division of the Sicker Group has been made by Stauffer (1962, p. 384, 386). This author calculated that tidal currents of ½ to

2 knots (similar to those now observed on the Bahama banks) would suffice to transport limestone particles of 1 to 10 mm. diameter. Hjulstrom's (1939) curve relating particle size to water velocities, used in this calculation, is applicable to particles of average density. Because echinoderm plates are porous calcite (Hyman, 1955, p. 50), particles composed of them are of less density than the average detrital particle (Carozzi and Soderman, 1962, p. 412). Thus, currents of Bahaman magnitude, or not much greater, conceivably could transport crinoidal debris of the maximum size observed in the Upper Division limestones (20 to 25 mm.).

The distinctive facies of the Upper Division of the Sicker Group typical of the China Creek-Saltspring belt (thin-bedded chert and siliceous limestone, with small to large lenses of medium to coarse-grained crinoidal limestone) suggests contemporaneous occurrence within the same region of different environments of deposition, and not successive dominance of one regimen over another, strikingly different one. If a shallow-water, bank-type accumulation of the coarse calcareous lenses is assumed, as seems consistent with the evidence for the larger bodies of a similar character in the other Paleozoic belts, the thin-bedded siliceous parts of the sequence would then represent inter-bank, quiet-water deposits. The siliceous content of these beds remains to be explained; an attempt at explaining this phenomenon is contained in the following paragraphs on the subject of silicification of the Sicker Group rocks as a whole.

The prominence of siliceous sediments in upper Paleozoic sequences of the Cordilleran region has been the cause of comment

by many authors (e.g. White, 1959, p. 70. Bissell, 1959, p. 151). Bissell concluded that chert is a syngenetic or diagenetic deposit, the silica being derived from a variety of possible sources such as weathering, volcanic activity, halmyrolysis of submarine volcanic materials, and siliceous organisms.

Krauskopf (1959, p. 16, 17) in a discussion of the geochemistry of silica, concluded that primary precipitation of gelatinous silica by sea water "can take place only locally, where volcanic activity under the sea or near shore supplies solutions with abnormally high concentrations of silica". In summarizing the possible origins of "bedded cherts and nodular cherts far from volcanic centres", Krauskopf postulates three mechanisms other than accumulation and alteration of the skeletons of siliceous organisms.

The three mechanisms are: adsorption on suspended matter; diagenetic alteration by saturated interstitial solutions; and replacement by introduced silica-bearing solutions (post-diagenetic). The adsorption process apparently would add silica to sediments in only small amounts (maximum of 4.5 per cent, Bien, Contois and Thomas, 1959, p. 20, 34). In modern carbonate deposits, silicification is lacking, so this process is not early diagenetic (Ginsburg, 1957, p. 91). Dapples (1959, p. 49, fig. 8) concludes that chert "is a product of diagenesis formed during the stage of early burial", which he regards as an intermediate grade of diagenesis.

Although siliceous sediments with laminae rich in sponge spicules are present in certain beds of the inter-bank sequence of the Cowichan Lake area, most of the siliceous strata of the region contain no visible remnants of originally siliceous organisms. It

is therefore concluded by the writer that most of the cherty strata and nodules of the Sicker Group are the product of intermediate diagenesis. A possible exception is the occurrence of cherty tuffs in the Lower Division, for which Fyles (1955, p. 15) presents conclusive evidence of syngenetic or diagenetic origin. The intense volcanic activity of the region during deposition of this sequence may have periodically yielded sufficiently high silica concentrations to have provided conditions for primary silica precipitation.

CONCLUSIONS

The writer's conclusions as to environments of deposition for the rocks of the Sicker Group are as follows:

1) The volcanic-sedimentary complex of the Lower Division represents deposition in moderately deep waters of a basin or gulf on the continental borderland. The depositional basin was probably bounded on the west by a volcanic land or volcanic archipelago, the tectonic activity of which decreased with time during the period of basin subsidence. Abundant source material for the silica in cherty sediments of this sequence as available, in the form of volcanic and organic products. The majority of chert probably was produced diagenetically.

2) The carbonate and carbonate-chert sequences of the Upper Division mark the establishment of a markedly different regimen in late Sicker time. A general shoaling, with the formation of some islands within the former basin, is indicated. Extensive bryozoan communities, established on muddy bottoms, acted as sediment-trapping mats. The subsequent stabilized patches of bottom-sediment enabled colonization by communities of crinoids and other invertebrates. Accumulation of crionoidal debris in bank-type bodies of small to large dimensions ensued. The shoal waters, with their higher temperatures and salinities, and accompanying prolific organic activity, resulted in physico-chemical and biochemical precipitation of calcium carbonate, and the deposition of lime muds in certain areas. Extensive land areas and volcanic centres must at this time have been few or far-removed from the region.

3) Interbank areas, extensive in the south, rare in the north, were the sites of deposition of fine-grained, mainly biogenic particles in depths below wave base. The dark colours, and preservation of finely disseminated organic matter, indicate dominant reducing conditions during deposition and diagenesis.

4) The formation of chert in both the carbonate lenses and bedded carbonate-chert sequences is considered to have been mainly diagenetic. The chert formation would have probably been enhanced by episodes of slow subsidence and/or slow accumulation of sediment, permitting maximum concentrations of silica below the sediment-water interface.

5) The regional pattern for Permian deposition in this part of the Cordillera is thus indicative of eugeosynclinal conditions, modified from place to place and from time to time by deposition of materials similar to those of the shelf and miogeosyncline. In a region of variable tectonic activity, this is not an unexpected paradox (see White, 1959, p. 70, 71). The overall aspects of Permian sedimentation are not, in the writer's opinion, entirely compatible, however, with the views of Bissell (1959, p. 175, 176) who stated that Lower Permian (Wolfcampian to lower Leonardian) sediments of the Fraser Belt "are composed almost entirely of shelf carbonates, mostly biostromal to clastic varieties". The shallow-water, "shelf" type sediments of the western part of the Cordillera, although lithologically similar to those of the stable to moderately unstable areas bordering the craton, appear to the writer to represent only transitory phases within the major trough-like accumulations of the eugeosyncline.

SYSTEMATIC PALEONTOLOGY*

Phylum PROTOZOA

Subphylum SARCODINA

Class RHIZOPODA

Order FORAMINIFERA

The paucity and poor state of preservation of the fossils belonging to this group in the Sicker Group have prevented firm identifications of the specimens.

The most common of the few foraminifers found belong to the genus Tetrataxis. At least two species appear to be present. Detailed morphology has not been determined. The genus occurs in Upper Division rocks of all three Paleozoic belts, as is noted in previous sections of this report.

Fragmentary or poorly oriented sections of a fusulininid genus have been found in thin sections from the Horne Lake and Cowichan areas. In determinable features, these fossils resemble the form identified by Skinner (personal communication to Danner, 1962) as Pseudofusulinella (among other possibilities). A representative specimen from the writer's collections is illustrated in Plate V, Figures 4, 5. A different, undetermined genus occurs in the basal sandstone of the Azure Lake section (Plate IV, Figure 6).

A schwagerinid has been identified in thin sections from Horne Lake and Cowichan areas. These fossils are tentatively assigned to the genus Schwagerina. Three specimens are shown in Plate V, Figures 1-3.

*Fossils described are in the Paleontology collection, Geology Department, University of British Columbia, Vancouver, B.C. The prefix "UBC" is used in citing their catalogue numbers.

Order RADIOLARIA

One thin section, from the upper part of the Lower Division in the Horne Lake area contains radiolarian fossils, not as yet generically or specifically identified. These fossils are illustrated in Plate V, Figures 8, 9.

Phylum BRACHIOPODA

Class ARTICULATA

Superfamily PRODUCTACEA Waagen 1883

Family DICTYOCLOSTIDAE Stehli 1954

Subfamily HORRIDONIINAE Muir-Wood and Cooper 1960

Genus HORRIDONIA Chao 1927

Current interpretations of the genus Horridonia by different authors are not entirely compatible; certain fundamental problems remain to be resolved. The original definition by Chao (1927, p. 24; expanded in 1928, p. 62) has been emended by Muir-Wood and Cooper (1960, p. 292-293) and Gobbett (1961, p. 43), whose views do not coincide. Chao's original definition is as follows (1929, p. 24): "Characterized by strong median sinus and fold, slightly convex brachial valve and a few but very stout hollow spines". It was emended as follows (Chao, 1928, p. 62):

> "Forms belonging to this subsection /of Productus / such as Pr. horridus, Pr. timanicus Tschern. etc., possess essentially the same characteristic outline of typical Productus, but without either plicae or wrinkles. The median sinus and fold are rather pronounced and the surface is marked only by irregularly distributed, strong and erect spines. Some indefinite plicae are sometimes present, indicating occasional survival of the plicae making impulse".

The taxonomic history of the genus is well covered by Muir-Wood and Cooper (1960) and Gobbett (1961), so will not be repeated here. The essential differences in current points of view may be summarized as follows. Muir-Wood and Cooper would exclude from Horridonia forms which do not bear cardinal spines on both pedicle and brachial valves.

This procedure is followed because these authors interpret the original genosyntypes (Productus horridus Sowerby, and P. timanicus Stuckenberg) and the genolectotype (P. horridus Sow; Schuchert and LeVene, 1929) as having cardinal spines on both valves. Gobbett interprets P. timanicus in such a way as to preclude the presence of cardinal spines on the pedicle valve. He therefore includes within Horridonia not only forms which have cardinal spines on both valves, but also those which possess only brachial cardinal spines. Neither of these two opinions as to what constitutes the genus Horridonia conflicts with Chao's original generic definition, which does not mention cardinal spines.

Muir-Wood and Cooper's definition of Horridonia thus includes as synonymous the genus Sowerbina Fredericks, 1928, (genotype P. timanicus) but will not accommodate Sowerbina Fredericks emend. Dunbar 1955, for Dunbar interpreted P. timanicus in the same way as Gobbett does. On the other hand, Gobbett's concept of Horridonia embraces both of these interpretations of Sowerbina.

Nelson (1962, p. 197) describes "horridonid" brachiopods with cardinal spines only on the pedicle valve; these he regards as possibly belonging to a new genus. They certainly do not fit into the emended definitions of Horridonia proposed by either Muir-Wood and Cooper or by Gobbett.

The problem of defining Horridonia satisfactorily is thus a question of whether to make the definition broad or narrow. The present writer's opinion is that Gobbett's broad definition is preferable, because of the unresolvable conflict in interpretation of Stuckenberg's original illustrations of P. timanicus (see Gobbett, 1961, p. 48). It

may also be desirable to expand it further to include such forms as the species described by Nelson, and even species, yet to be described, which bear no cardinal spines but are otherwise identical to species included under Horridonia. Such a course would not conflict with Chao's original definition of the genus.

All of the valid species of Horridonia have been grouped by Gobbett into the two old species H. horrida (Sowerby) and H. timanica (Stuckenberg). The present writer considers that a new species of Horridonia, rather than a new genus, is required for Nelson's forms with cardinal spines restricted to the pedicle valve.

The main reasons for this conservative approach to the taxonomy of this group of fossils are as follows. Adequate preservation of such surface features as the spines, and minute crinklings or pustules, used in discriminating between some of the forms mentioned above, is a relatively rare phenomenon. Hence, in the identification of fossils of this group on which details of the surface sculpture are not preserved, the taxonomist must rely on features which are diagnostic only of the genus (e.g., shape, sulcus, costae, internal features and lack of rugae). Secondly, because of the probable effects of environment on the external morphology of the productids, it is felt that such features as spines should be given less emphasis in taxonomy; variations in spine pattern should perhaps be utilized only for discriminations at the specific level or lower. On the other hand, internal features of Gobbett's two species of Horridonia, are remarkably similar; this is strong evidence of direct, genetic affinity.

Muir-Wood and Cooper (1960, p. 293) recognize no United States species of Horridonia. They indicate that the geographic distribution

of the genus is known to include Europe, Britain, Russia, Asia, the Arctic, and, questionably, Australia. Gobbett (1961, Fig. 1) illustrates the geographic range of the genus in Europe, Britain, Russia and the Arctic. His two species are shown to have different distributions. Horridonia horrida, he suggests, is a European and British species; H. timanica, on the other hand, he considers to be a Russian and Arctic species (p. 42). As for their stratigraphic occurrence, H. horrida is regarded as an upper Permian (Zechstein) form (p. 46), in contrast to H. timanica, which is stated to range from upper Carboniferous to upper Permian (p. 50).

The presence of the species described below, from the North American Cordilleran region, combined with the occurrences of the genus in the Yukon reported by Nelson, shows that the geographic range of the genus is not as restricted as that suggested by Gobbett and by Muir-Wood and Cooper.

The stratigraphic sequence of species of Horridonia, postulated by Gobbett, suggests that H. horrida may be derived from H. timanica. Assuming that Gobbett's statements are valid, an evolutionary trend toward greater development of cardinal spines may be postulated.

HORRIDONIA sp. A

Plate IV, Figures 1, 2, 3, 4.

1963 Horridonia sp. A, YOLE, pl. II, Figs. 11, 12.

Description: Ventral valve strongly convex, with long, narrow prominent sulcus extending from umbo to anterior margin. Umbo large, inflated, curved over hinge line. Beak small, pointed. Venter gently tapering,

widening anteriorly. Umbonal slopes and flanks of venter steep. Auricles convex; full lateral extent not visible. Hinge slightly more than one third distance from posterior to anterior extremity. Shell surface almost completely exfoliated; remnants finely pitted to pustulose. Faint, coarse, low plications on flanks and venter anterior to hinge line. Sparse, scattered spine bases? on venter. No spine bases visible along cardinal margin.

Brachial valve shallowly concave in one small remnant observed; no other features of brachial valve seen.

Internal features and shell structure of one specimen were examined by means of serial sectioning and a thin section. The adductor ridge, characteristic of the genus (Gobbett, 1961, p. 43) is wide, strongly elevated above the valve floor, with almost flat top and steep subparallel sides. The shell is thick. Its microstructure, evident in the sections, includes faint lamellar elements and coarse fibrous-appearing material, with the long axes of the "fibres" perpendicular to the shell structures. (Figure 56).

Measurements (in mm.):

UBC Nos.	Length Straight	Length Curved	Width	Width Hinge Line	Height	Ratios W/LS	Ratios W/LC	Ratios LS/LC
20200	55+	100+	45+	40+	35	1:1.2	1:2.5	1:1.8
20201	47?	90+	40	35+	30	1:1.1	1:2.25	1:1.9
20202	42+	70+	42	40+	30?	1:1.0	1:1.7	1:1.7
20204	49	80+	45	36+	-	1:1.1	1:1.8	1:1.6

Material: All of the measured specimens are partially recrystallized shells, freed from a matrix of coarse, crinoidal limestone. Other specimens in collections from various localities are not complete enough for measurements.

Discussion: The specimens from which the above description is derived show little or none of the surface sculpture and ornamentation of the shells. The species cannot, therefore, be certainly placed in any of the described species of Horridonia. The visible features, however, show that the species is in external features similar to Pleurohorridonia? elongata Cooper, from the Lower Permian of Oregon (Cooper, 1957, p. 37-38, pl. 7C, figs. 30-33). Cooper's species is slightly smaller than the one described above. H. texana King, from the "Middle" Permian (Word) of Taxas, though similar in size, appears to be more triangular in longitudinal outline than the Vancouver Island species (King, 1931, p. 85-86, pl. 21, figs. 25a, b, c).

Disregarding cardinal spine patterns, Horridonia sp. A very closely resembles Pleurohorridonia scoresbyensis Dunbar from the Upper Permian? of Greenland, and forms from the Upper Pennsylvanian? of the Yukon assigned to this species by Nelson (Dunbar, 1955, p. 89, pl. 11, figs. 1-10; pl. 12, figs. 1-13, 17-19; Nelson, 1961b, p. 35, pl. 28, figs. 9-10). Similarly, specimens of Sowerbina granulifera (Toula) from northeast Greenland Lower Permian rocks described and illustrated by Dunbar (1962, p. 6, pl. 1, figs. 6-7) may be compared to Horridonia sp. A. Certain specimens assigned by Gobbett to H. timanica (Stuckenberg) are closely comparable to the Vancouver Island species on the basis of pedicle valve morphology alone (Gobbett, 1961, pl. 4, figs. 1b, c, 2b, c, pl. 5, figs. 1, 2, 9, 10, 13).

The internal characteristics of the Vancouver Island species are perhaps the most critical for diagnostic purposes. As can be seen in Gobbett's illustrations of H. timanica (pl. 5, figs. 1, 2), the adductor ridge of this species is more pronounced, and more highly

elevated than that of H. horrida (pl. 5, fig. 7). Nelson (1963, pers. comm.) has investigated the development of the adductor ridge in specimens of Horridonia from the Yukon. He suggests that his Middle Pennsylvanian specimens are characterized by a subdued rounded adductor ridge. Permian (Leonardian) specimens have a strongly elevated, flat topped adductor ridge with steep sides; the sides of the ridge of some specimens become strongly concave in transverse profile. In the Vancouver Island specimens of Horridonia sp. A, the sides of the adductor ridge are high, and flat to gently concave in transverse profile. Nelson has also noted the presence of coarse fibrous structure in the Yukon shells, this being more prominent in the Pennsylvanian specimens. In summary, it can be stated that in development of the adductor ridge, Horridonia sp. A resembles H. timanica, and Lower Permian species of the genus from the Yukon. In shell structure it appears to have characteristics intermediate between those of Pennsylvanian and Permian species of the Yukon.

Although precise comparisons with previously defined species of Horridonia cannot be made because of poor preservation, or lack of detailed information on internal features, the Vancouver Island species, (Horridonia sp. A) may eventually be found to be conspecific with one of the species mentioned above. Until specimens in which the preservation is adequate for precise comparison are available, the writer prefers to designate the species as above. It should be kept in mind that Horridonia sp. A might also belong to a new species.

Occurrence: Most of the specimens assigned to Horridonia sp. A are from limestone talus at Locality 61-24-TF, north side of Horne Lake. One fragmentary specimen was obtained from the Buttle Lake area, Locality 62-61A-8F, in the upper half of the Buttle Lake Formation, south of

Marble Peak.

J. T. Dutro (1962, pers. comm. to W. R. Danner) identified Horridonia? in a collection from limestones of the Bald Mountain peninsula, east end of Cowichan Lake. The specimen is not available for examination so no comparisons can be made.

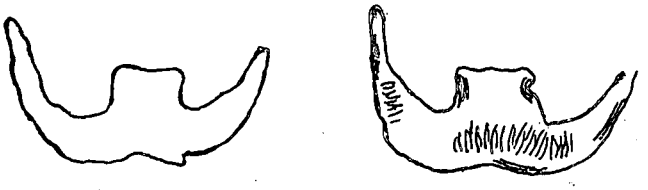

Figure 56. Cross sections, pedicle valve, Horridonia sp.A Spec. UBC 20203. Prominent, steep-sided adductor ridge shown in both sections. Right hand section shows distribution of coarse fibrous and fine laminar types of shell structure. XI.

HORRIDONIA sp. B

Plate IV, Figure 5

Description: Medium-sized, transverse in shape. Pedicle valve strongly convex. Umbo strongly tapering, curved over hinge line. Beak not visible, probably small and pointed. Narrow, shallow sulcus, originating close to beak. Auricles prominent, convex, extending well out from the lateral margins. Valve surface smooth, but appears coarsely pseudopunctate where exfoliated. Coarse spines set in single row close to

hinge line and on auricles, extending posterolaterally. Few spines scattered over venter; one possibly extends laterally straight from the auricles.

Brachial valve and interior features not seen.

Measurements: Measurements on the one specimen available are: Length 37 mm.?, Width, hinge line - 60 mm., Width, mid-length - 45 mm. The spines are 1.5 mm. thick at their bases, with gentle taper toward the tips; several have lengths of over 25 mm.

Material: The only specimen available (UBC 20096) is crushed, incomplete, and contained in black, fine-grained dolomitic limestone.

Discussion: The preservation of the one specimen available makes precise identification impossible. However, enough features are revealed to show that it is distinctly different from Horridonia sp. A. The spine patterns cannot be compared because no spines are preserved on the available specimens of Horridonia sp. A. The shape of H. sp. A is more elongate and a relatively narrower hinge line is evident.

Horridonia sp. B resembles some of the fossils assigned to Pleurohorridonia scoresbyensis Dunbar (Dunbar, 1955, pl. 11, fig. 1; pl. 12, figs. 1-3). As the features of the brachial valve are not known for the Vancouver Island species, an exact comparison cannot be made. Horridonid fossils illustrated by Nelson (1962, pl. 1, figs. a-c) show spine distribution on the pedicle valve similar to that of Horridonia sp. B. As the brachial valve and surface texture of the Vancouver Island fossil is not preserved, and the Yukon species illustrated by Nelson appears to differ in shape, a closer comparison of the two species is not possible. Certain resemblances to fossils assigned to Horridonia

horrida (Sowerby) by Gobbett (1961, pl. 3, figs. 1a, 6; pl. 5, fig. 7) are also displayed by Horridonia sp. B.

As with Horridonia sp. A, this species cannot be assigned with certainty to any described Horridonia. It may represent a new species. Until additional material with better preservation of critical features is available, it is considered desirable to refer to the fossil as Horridonia sp. B.

Occurrence: The specimen was obtained from the upper part of the Buttle Lake Formation (Unit 11), at Locality 61-35-5F, at the type section (see Figure 6).

Subfamily DICTYOCLOSTINAE Stehli 1954

Genus ANTIQUITONIA Miloradovich 1945

The definition of the common dictyoclostid genus Dictyoclostus Muir-Wood (1930, p. 103) has been emended several times. Dictyoclostus sensu stricto is apparently now represented only by European, British and Russian Lower Carboniferous species (Muir-Wood and Cooper, 1960, p. 269). One of the species groups separated from Dictyoclostus sensu lato is now referred to as the genus Antiquitonia Miloradovich (1945, p. 496). Externally the latter is distinguished by the presence of a row of spines on the flanks, commonly set on a rounded ridge (Muir-Wood and Cooper, 1960, p. 270). As is the case with many productids, should the spine pattern not be visible, the differentiation of species of Antiquitonia from those of related dictyoclostid genera is a difficult problem.

Most of the described species of Antiquitonia are from Lower Carboniferous horizons of Europe, Asia, Africa, Australia. A few

Pennsylvanian and Permian species from North America have been described or cited. Whether this apparent paucity of North American occurrences is a result of a lack of well-preserved specimens, or is truly indicative of poor representation of the genus on this continent is not presently known.

ANTIQUITONIA SULCATA Cooper

Plate II, Figures 7, 8, 9.

?1902 Productus inflatus McChesney. TSCHERNYSCHEW, p. 612, pl. 28, figs. 1-6.
?1931 Productus hessensis KING, p. 68, pl. 11, figs. 3-6.
1957 Antiquitonia sulcata COOPER, p. 35, pl. 5C, figs. 18-22.
?1960 Dictyoclostus cf. D. neoinflatus Licharew. HARKER and THORSTEINSSON, p. 55, pl. 17, figs. 1-2.
?1962 Dictyoclostus neoinflatus Licharew. DUNBAR, p. 17, pl. 1, figs. 8-9.
1963 Antiquitonia sulcata Cooper, YOLE, pl. II, fig. 18.

Description: Subquadrate in outline, pedicle valve with slightly convex umbo. Roundly geniculated one-third of length from beak, through 90 degrees or more; umbonal angle about 90 degrees; lateral slopes steep; beak not visible, probably projecting over hinge line. Sulcus originates at geniculation, reaches maximum depth at anterior end of geniculation, narrowing slightly in anterior one-third of length; flat to shallowly rounded bottom, gently convex sides; 15 mm. wide, 3 mm. deep near anterior margin. Flanks steep. Auricles slightly convex; full lateral extent not seen. Surface reticulate in umbonal region. Remainder of valve costate; 3 to 5 costae in 5 mm. at mid-length; costae rounded, wider than intervening spaces, crossed by fine, transverse lirae. No bifurcation or intercalation of costae visible; several costal pairs unite in the sulcus, reducing numbers of costae

in anteriorly narrowed portion. About 10 stout spines around auricles and across anterior half of valve, in slightly asymmetric pattern. Spines near auricles arranged on obscure concentric fold or wrinkle.

Brachial valve, and interior features, not seen.

Measurements (in mm.):

UCB Nos.	Length Straight	Length Curved	Width	Width Hinge Line	Height
20054	40+	58+	45?	43+	21?
20053	35+	63+	43?	43?	25?

Material: The two partial pedicle valves on which the above description is based occur in dark dolomitic limestone. One other fragment of a pedicle valve, on which no significant measurements were possible, is present in the collection.

Discussion: Cooper did not mention spines on the venter of his specimens from the lower Permian of Oregon. The specimens from Vancouver Island agree in other respects with Cooper's definition of the species.

Harker (in Harker and Thorsteinsson, 1960, p. 55), described and illustrated specimens from the Lower Permian of Grinnell Peninsula under the name of Dictyoclostus cf. D. neoinflatus Tschernyschew and certain Arctic forms assigned by other authors to Productus inflatus McChesney. The latter two species are included in the genus Antiquitonia Miloradovich (1945, p. 496). Harker's illustrations (1960, pl. 17, figs. 1-2) suggest that his Dictyoclostus cf. D. neoinflatus is conspecific with the Vancouver Island and Oregon species Antiquitonia sulcata Cooper. Specimens from the lower Permian of northeast Greenland, illustrated by Dunbar (1962, pl. 1, figs. 8-9), and referred

to as Dictyoclostus neoinflatus Licharew, may also be conspecific with A. sulcata. Tschernyschew's (1902, pl. 33, fig. 1) figures of Productus uralicus indicate a similar, but larger, species. Illustrations of "Productus inflatus McChesney" by Tschernyschew (1902, pl. 28, figs. 1-6) indicate that this Russian species is closely comparable to Antiquitonia sulcata.

Occurrence: Antiquitonia sulcata was collected from the fossiliferous horizon (Unit 11) about 350 feet below the top of the type section Buttle Lake Formation, Locality 61-35-5F. "Productus" cf. P. uralicus Tschern. from the Cowichan Lake area (Fyles, 1955, p. 19) may also belong to this species.

Family ECHINOCONCHIDAE Stehli 1954

Subfamily ECHINOCONCHINAE Stehli 1954

Genus ECHINOCONCHUS Weller 1914 sensu lato

The definition of the genus Echinoconchus has been restricted by Muir-Wood and Cooper (1960, p. 243) so as to include only Lower Carboniferous forms. New genera have been erected for Pennsylvanian and Permian species (Muir-Wood and Cooper, 1960, p. 243-248). Echinoconchus inexpectatus Cooper, specimens of which from Vancouver Island are described below, differs from Echinconchus as redefined by Muir-Wood and Cooper. The spine pattern and lateral ridges which extend around the auricles are characteristics of the Vancouver Island and Oregon species which do not agree with those of Echinoconchus. E. inexpectatus differs in the same features, and in having a less massive cardinal process, from Muir-Wood and Cooper's genus Bathymonia (ibid., p. 244). From

their Calliprotonia (ibid., p. 246) it is distinguished by the extension of the lateral ridges to the cardinal extremities, where sharp, angular deflection of the ridges occurs. The only other echinoconchid species known to the writer and displaying this type of lateral ridge is Echinoconchus pelliceus Chronic (Newell et al, 1953, p. 85, pl. 15, figs. 1-3), from the Lower Permian (Wolfcamp) of Peru. The latter species was questionably assigned by Muir-Wood and Cooper (op. cit., p. 247-248) to Calliprotonia.

The present writer concludes that E. inexpectatus Cooper and E. pelliceus Chronic may represent a new genus. However, until such time as further work on the echinoconchids has clarified the status of Muir-Wood and Cooper's taxonomic revision of Enchinoconchus, it is considered preferable to assign these two species to Echinoconchus sensu lato.

ECHINOCONCHUS INEXPECTATUS Cooper

Plate II, Figures 11, 12, 13.

?1902 Productus fasciatus Kutorga. TSCHERNYSCHEW, 1902, p. 631, pl. 24, figs. 5-6; Text figs. 72-74.
1957 Echinoconchus inexpectatus COOPER, p. 48, pl. 8C, figs. 13-26.
1963 Echinoconchus inexpectatus Cooper, YOLE, pl. II, fig. 17.

Description: Shell thin; transverse to elongate oval in outline; concavo-convex. Greatest width anterior to mid-length; hinge line about two-thirds of width.

Pedicle valve moderately convex; greatest convexity in umbonal region. Umbo large, with steep flanks. Beak small and pointed, curved slightly to strongly over hinge line. Surface sculpture of broad,

concentric bands, with short, steep, anterior slopes. Bands 3 to 5 mm. in width on venter, narrowing laterally. Each band with three or more rows of fine, closely spaced, prostrate spines; spines more or less quincunxially arranged in posterior parts of bands, finer and more irregularly arranged in anterior portions. Spines up to 0.15 mm. at base, 3 mm. long, slightly tapering, ornamented with fine, transverse ridges. Interior not seen.

Brachial valve gently concave, except for short, steep lateral and anterior margins. Cardinal extremities flattened into small, triangular auricles. Sculpture and ornament as in pedicle valve, with concentric bands up to 2 mm. in width on visceral disc. Interior with slender, trilobed cardinal process. Median septum narrow, extending at least half valve length. Prominent lateral ridges, thickened into buttresses adjacent to cardinal process, and extending along hinge border to cardinal extremities, thence anteriorly to about mid-length.

Measurements (in mm.):

Specimen	Length (Pedicle)	Length (Brachial)	Width	Width Hinge Line	Auricle Angle (degrees)	
UBC 20039	25	20	32+	23	120	
UBC 20040	26	21	30+	20	123	
UBC 20041	-	22	30+	20	119	
UBC 20042	25+	22+	35+	20	-	
UBC 20043	35	23	30?	18	121	
UBC 20037	30	-	32	-	-	
UBC 20044	21?	15?	29?	20?	-	
USNM 125551	27.8	21.8	30.4	-	-	(Holotype)
USNM 125357	25	20.9	25.5	-	118	(Paratype)
USNM 125359	-	20.5	26	17	124	(Paratype)

Material: Most of the specimens are incomplete and are slightly to severely crushed in the bedding planes of dark dolomitic limestone. Measurements of three of Cooper's Oregon specimens are added for

comparison.

Discussion: The external features of the Vancouver Island specimens are almost identical to Cooper's fossils from Oregon; the internal features of the Oregon specimens were not described. Parts of the description given above, therefore, emend Cooper's original description of this species.

Cooper (1957, p. 49) considered Echinoconchus inexpectatus to be very similar to the European, Russian, Arctic and Asian species, E. fasciatus (Kutorga), from which it was thought to differ only in dimensions and shape. The similarities in external appearance between the two species are apparent in comparisons of E. inexpectatus with illustrations of E. fasciatus by Tschernyschew (1902), which suggest almost identical exterior characteristics, and in Licharew, 1939 (pl. 21, figs. 7 a-c) and Sarycheva and Sokolskaya, 1952 (pl. 18, fig. 122).

Occurrence: On Vancouver Island this species has so far been found only in Unit 11 of the type section of the Buttle Lake Formation.

Family BUXTONIIDAE Muir-Wood and Cooper 1960

Subfamily BUXTONIINAE Muir-Wood and Cooper 1960

Genus KOCHIPRODUCTUS Dunbar 1955

This genus was proposed by Dunbar (1955, p. 107) to replace the preoccupied name Tschernyschewiella Fredericks (1924, p. 20). Frederick's generotype, Productus porrectus Kutorga 1844, was discarded by Dunbar in favour of his species K. plexicostatus. According to

Muir-Wood and Cooper (1960, p. 260), this change is invalid; the latter authors therefore reinstated P. porrectus as generotype.

Muir-Wood and Cooper interpreted the genus to include Productus peruvianus d'Orbigny 1842, Buxtonia saranaeana Fredericks 1933, and P. longus Meek 1877, in addition to the generotype and Dunbar's K. plexicostatus. Certain Arctic productid species, including some identified as P. porrectus, and K. plexicostatus were discussed by Harker and Thorsteinsson (1960, p. 59) and placed in synonymy with K. freboldi (Stepanow).

All of the species mentioned above, referrable to Muir-Wood and Cooper's redefined Kochiproductus, occur in Permian strata. One occurrence in beds of questionable Middle Pennsylvanian age in Peru has been reported for K. peruvianus by Newell et al (1953, p. 83).

KOCHIPRODUCTUS n. sp.

Plate I, Figures 1, 2, 3, 4, 5, 6, 7, 8.

1963 Kochiproductus n. sp. YOLE, pl. I, figs. 4, 5.

Diagnosis: Large Kochiproductus, subquadrate in outline, with large brushes of auricular spines on pedicle valve and simple, non-anastomosing costae.

Description: Pedicle valve moderately convex, greatest convexity in umbonal region. Greatest width along hinge line. Tapering venter, widening anteriorly. Umbo broad, with moderately steep slopes; curved over hinge line. Beak small and pointed, projecting short distance beyond hinge line. Sulcus broad, shallow, originating about one-third shell length from beak. Auricles triangular, slightly convex, small

in relation to overall shell size. Surface coarsely costate, with about five costae in 10 mm. at mid-length. Costae pinch and swell under the influence of weakly developed, concentric rugae, resulting in reticulation on the umbo, and interrupted costae anteriorly. No visible bifurcation or anastomosing of costae anterior to umbo. Short, erect spines scattered over valve, usually at nodes on costae; especially numerous in sulcus and near anterior margin. Longer spines near hinge line, culminating in a spectacular brush on each auricle; 15 to 20 spines in each brush, with individual spines up to 35 mm. long, directed posterolaterally. Very fine concentric striations over shell surface. Interior not seen.

Brachial valve rectangular in outline. Flat to slightly concave in visceral disc; steep, concave rim around lateral and anterior borders; posteriolateral borders flatten out into triangular auricles. A broad, gentle median fold in anterior half of some specimens. Whole surface reticulate, with rounded depressions marking interspaces between costae and rugae. Rugae most prominent on visceral disc, developing into low wrinkles on auricles. Few short, scattered spines. In interior, narrow, low median septum extends one-half to one-third of valve length; small antron near posterior end. Large, trilobed cardinal process, with well-developed shaft; not strongly recurved. Lateral ridges moderately developed, extending almost to auricles. No muscle areas or brachial ridges seen.

Measurements (in mm.):

Specimen	Length Straight	Length Curved	Width	Width Hinge Line	Length (Brachial)
UBC 20002	60+	-	65	70	50
UBC 20001	63+	83+	85	-	-

Specimen	Length Straight	Length Curved	Width	Width Hinge Line	Length (Brachial)
UBC 20006	70+	-	-	-	60?
UBC 20003	-	-	100?	-	-
UBC 20005	50+	-	77	-	-
UBC 20008	-	-	-	72	-

Material: All of the specimens are crushed and flattened to some degree, and occur in dolomitic limestone. Other fragmentary specimens are present, but significant measurements on these were not possible.

Discussion: The species described above appears to have close affinities with the fragmentary fossil described by Cooper (1957, p. 47, pl. 4B, fig. 7), from the Lower Permian of Oregon. Cooper referred his species to Kochiproductus cf K. porrectus (Kutorga). The information on the Oregon specimen is too incomplete for certain comparison, but it seems probable that it and the Vancouver Island specimens described above are conspecific. Tschernyschew's illustrations (1902, pl. 55, fig. 1; pl. 56, fig. 4; text figs. 75-77) of Russian specimens assigned to K. porrectus indicate that they are remarkably similar in visible features to Kochiproductus n. sp. of Vancouver Island. The anterior fringe on some of Tschernyschew's specimens, the shorter median septum of the brachial valve, and apparent lack of the prominent brush of auricular spines, are characters by which the two species appear to differ.

Another similar form is Buxtonia victorioensis King (1931, p. 80, pl. 19, figs. 1-4) from the middle Permian of Texas (Leonard-Word). Not enough of the spine pattern and internal details of the Texas species are available to make closer comparisons.

If Kochiproductus freboldi (Stepanow) is interpreted broadly, as by Harker and Thorsteinsson (1960, p. 59), such as to include certain forms previously assigned to K. porrectus (Kutorga), the species described above and Cooper's Oregon specimen may belong to K. freboldi. However, the illustrations of the latter which the writer has available suggest that this is not the case. K. freboldi and K. plexicostatus Dunbar are characterized by an astomosing costae, not present in the Vancouver Island species or K. porrectus (Kutorga).

The present writer believes that the Vancouver Island species should be named as new. The species which it most closely resembles are not well enough defined with respect to spine pattern and internal details to be precisely compared.

Occurrence: The specimens identified from Vancouver Island all occur in dark dolomitic limestone of Unit 11 approximately 350 feet below the top of the Buttle Lake Formation at the type section.

Family OVERTONIIDAE Muir-Wood and Cooper 1960

Subfamily OVERTONIINAE Muir-Wood and Cooper 1960

Genus KROTOVIA Fredericks 1928

The two specimens described below are tentatively assigned to this genus on the basis of their size, shape and pedicle valve ornament. In all of these features, the specimens appear to agree with Fredericks' (1928, p. 779-780) definition , and Muir-Wood and Cooper's (1960, p. 188) interpretation of the genus. According to the latter authors (ibid.,) "the genus is still imperfectly known". The specimens available from Vancouver Island are incomplete and poorly preserved, preventing more precise identification.

KROTOVIA? sp. A

Plate I, Figure 9

Description: Pedicle valve small, subcircular in outline, hinge line equal to greatest width. Moderately convex. Narrow swollen umbo, overhanging the hinge line. Small, triangular flat? auricles; auricular angle about 90 degrees. Surface ornament of short, erect spines, in apparently irregular pattern. Anterior marked by low, elongate pustules or subdued costae. Other features, including brachial valve, not seen.

Measurements: The one pedicle valve available (UBC 20065) has a length of 9, width of 10 mm. It is preserved in dolomitic,fine-grained limestone.

Discussion: The visible features of this shell are similar to Krotovia barenzi, from the Lower Permian of Novaya Zemlya, described by Milorado-vich (1935, p. 139, pl. 5, fig. 12). It is slightly smaller than the

Lower Permian fossil from central Oregon, described by Cooper (1957, p. 32, pl. 10C, figs. 12-17) as Krotovia aff. K. barenzi (Miloradovich).

Occurrence: The single specimen available comes from Locality 61-35-5F, in Unit 11 of the Buttle Lake Formation.

KROTOVIA? sp. B

Plate III, Figure 15

Description: Pedicle valve small, strongly convex, but not geniculated. Complete outline not seen, but probably elongate oval. Swollen, tapering venter, non-sulcate. Cardinal extremities not seen. Surface smooth, except for few, fine, scattered, circular to oval pustular spine bases.

Measurements: Length 7+ mm., width 9 mm. on the only specimen, UBC 20094. Preserved in fine grained calcareous sandstone of Locality 61-34-5F.

Discussion: This fossil, although of the same size as Krotovia? sp. A, appears to be of distinctly different shape, and the spines are less numerous and more widely spaced. The closest comparable form known to the writer is that referred by Tschernyschew (1902, p. 616, pl. 29, fig. 3; pl. 63, fig. 9) to Productus curvirostris Schellwien (included within the genus Krotovia by Muir-Wood and Cooper, 1960, p. 188). Tschernyschew's Russian species appears to be slightly larger, but has similar proportions, shape and ornament. The available material is insufficient for complete identification or description.

Occurrence: The partial pedicle valve described above is from Locality 61-34-3F, in the basal sandstone (Unit 1) of the Buttle Lake Formation of the type section.

Family LINOPRODUCTIDAE Stehli 1954

Subfamily PAUCISPINIFERINAE Muir-Wood and Cooper 1960

Genus MUIRWOODIA Licharew 1947

This linoproductid genus is characterised by its marked sulcus, strong geniculation, and symmetrically arranged halteroid spines, together with distinctive internal features (Muir-Wood and Cooper, 1960, p. 322). As is the case in many productid genera, the spines are rarely preserved, but the distinctive spine pattern can sometimes be ascertained from the spine bases. The specimen described below is partially exfoliated, with not enough of the shell remaining to show the spine bases. In other features visible, however, it is very closely comparable to several described species of Muirwoodia. It is assigned tentatively to the genus until additional material is obtained to corroborate or refute the identification.

MUIRWOODIA? sp.

Plate I, Figure 10

Description: Partial pedicle valve only. Probably subrectangular outline. Greatest width along hinge line. Venter moderately convex, geniculation and trail not preserved. Prominent narrow sulcus, originating anterior to beak. Surface capillate, capillae (see Muir-Wood and Cooper, 1960, p. 14) numbering about 30 in 10 mm. Umbonal slopes moderately steep, extending onto slightly convex, triangular auricles.

Other features, and brachial valve, not seen.

Measurements: Width (from half-width) 32 mm. Length 17+ mm., on single

specimen available (UBC 20046), a pedicle valve.

Discussion: This species has superficial resemblances to Muirwoodia transversa Cooper (1957, p. 39, pl. 5A, figs. 1-13), and to Muirwoodia mammatus (Keyserling), described by Stepanow (1937, p. 177, pl. 2, figs. 5-7) from Spitzbergen, by Tschernyschew from Russia (1902, p. 631, pl. 35, figs. 4-6) and by Harker and Thorsteinsson (1960, p. 58, pl. 16, figs. 1-5) from Grinnell Peninsula, and to Muirwoodia greenlandica Dunbar (1955, p. 103, pl. 16, figs. 1-18), from Greenland. All of these species are very similar, and may belong to one species group. They differ slightly in visible features from the Vancouver Island Muirwoodia? sp. only in dimensions and coarseness of ornamentation.

Occurrence: The single specimen is from Unit 11 of the Azure Lake section of the Buttle Lake Formation.

Superfamily SPIRIFERACEA Waagen 1883

Family SPIRIFERIDAE King 1846

Genus NEOSPIRIFER Fredericks 1919

Discussion: Neospirifer is differentiated from Spirifer Sowerby 1818 in having strongly fasciculate, rather than simple costae. However, according to Dunbar (1955, p. 131), "the distinction is not clear-cut, for in S. striatus (Martin) (type species of Spirifer), and related species, costae occasionally split into three instead of two branches and a moderate degree of fasciculation is commonly visible near the beaks". Within other spiriferid genera, and even species, fasciculation of the costae appears to be a variable characteristic. Dunbar's discussion of Spiriferella keilhavii (von Buch) (Dunbar, ibid., p. 139)

illustrates this problem; within this species, all gradations between non-fasciculate and clearly fasciculate types of costation occur.

Dunbar's remarks on S. keilhavii and on Spirifer striato-paradoxus Toula (Dunbar, ibid., p. 132) also show that shape of the shells is not a reliable criterion for specific differentiation in this group. Each of these two species, at least, include specimens whose cardinal extremities are either rounded-obtuse or acute and alate.

The specimens described below have partially fasciculate costal ornamentation. Internally, they display the generic characteristics of Neospirifer as interpreted by such authors as Sarycheva and Sokolskaya (1952, p. 190-191; fig. 166), R. E. King (1931, p. 115), and Stehli (1954, p. 340, text fig. 43).

NEOSPIRIFER n. sp.

Plate II, Figures 1, 2, 3, 4, 5, 6

1963 Neospirifer? n. sp. YOLE, pl. II, figs. 15, 16

Diagnosis: Large, transverse, mucronate Neospirifer, with incomplete fasciculation of the relatively coarse costae, and bearing a spiralium of about twelve volutions in each coil.

Description: Shell large, impunctate, wider than long, with straight hinge line, mucronate cardinal extremities, and greatest width at hinge line.

Pedicle valve moderately convex, greatest convexity in umbonal region. Beak sharply pointed, strongly incurved over wide, strongly concave interarea. Interarea flattens laterally from delthy-

rium, and is marked by transverse striations. Delthyrium large, triangular, open in all specimens on which it was observed. Prominent sulcus originates at beak, where it is narrow and deep; broader and more shallow anteriorly. Surface costate; costae rounded, weakly fasciculate, in bundles of three, the median one of the triad being the largest; fasciculation most obvious near umbo, becoming obscure anteriorly, and laterally; three to five bundles of costae in 10 mm. at mid-length. In sulcus, five or six costae at anterior margin, of similar size to those on flanks. Internally, strong dental plates, bounding delthyrial cavity, converging anteriorly and ventrally. Thick apical callous spreads anteriorly and laterally to cover a large portion of the posterior half of the shell interior; callous thinned in median area below dental plates.

Brachial valve less convex than pedicle. Beak small, slightly incurved over narrow interarea. Notothyrium wide, triangular; no chilidial plates seen; prominent, narrow dental socket grooves border notothyrium. Surface ornamentation apparently similar to that of the pedicle valve. Narrow rounded fold, nearly smooth near beak, costae anteriorly. Internally shell margin thickened and produced into strong, converging socket plates below notothyrium. Small apical callous, merging into low platform immediately below notothyrium, on which a low fibrous cardinal process occurs. Spiralium of at least twelve volutions in each coil.

Measurements (in mm.):

Specimen	Length Straight	Length Curved	Length Sub-Hinge Line	Width	Thickness
UBC 20013	20+	53?	20	72	-
UBC 20028	-	-	-	77	-

Measurements (in mm.):

Specimen	Length Straight	Length Curved	Length Sub-Hinge Line	Width	Thickness
UBC 20027	30+	45?	29	84	-
UBC 20024	38	60	29	84	-
UBC 20015	50	60	-	55+	-
UBC 20022	30?	35?	21	84	-
UBC 20025	-	-	22	60+	-
UBC 20021	35+	55?	26	55+	-
UBC 20023	29+	-	-	74	-
UBC 20026	40	75	29	70+	-
UBC 20014	60	85+	45	80	27+
UBC 20017	38	-	28?	64	-
UBC 20018	50+	-	36?	80+	-

Material: All specimens listed are from dolomitic limestone; most are incomplete, but preservation is otherwise fair to good.

Discussion: The North American form most similar to this species appears to be Spirifer (Neospirifer) huecoensis King, (1931, p. 116, pl. 38, figs. 2-3). The Texas species differs from Neospirifer n. sp. in its less alate shape, less pronounced umbo and beak, and shorter dental plates.

Neospirifer condor (d'Orbigny), a Permian and Permo-Carboniferous species of widespread distribution, differs from Neospirifer n. sp. in its more pronounced fold and sulcus, in shorter dental plates, greater number of volutions in the spiralia, and in slightly different surface sculpture (Chronic, in Newell et al, 1953, p. 60, pl. 10, figs. 10-12; R. E. King, 1930, p. 113, pl. 35, figs. 8-10). A specimen from the Lower Permian of Spitzbergen, assigned by Stepanow (1937, p. 141, 179, pl. 7, fig. 3) to Neospirifer condor, is externally very similar to Neospirifer n. sp.

Similarities to certain specimens assigned by authors to Neospirifer cameratus (Morton) are also evident; examples are in

Miloradovich, 1935 (p. 128, pl. 4, figs. 708), and Tschernyschew, 1902 (p. 531, pl. 5, figs. 1-9; pl. 6, fig. 8; pl. 11, figs. 2-4; pl. 40, fig. 6). Identifications of N. cameratus from Permian horizons are, however, open to question; many such assignments have been removed from Morton's species (see Branson, 1948, p. 426). Certain Arctic forms previously referred to this species have been included in the synonymy of Spirifer striato-paradoxus Toula by Harker (in Harker and Thorsteinsson, 1960, p. 67, pl. 19, figs. 1-7). From the latter species, the Vancouver Island Neospirifer n. sp. differs in having coarser, less strongly bundled costae, fewer costae in sulcus, and lack of growth varices; in addition, each spiralium coil of Neospirifer n. sp. bears about twelve volutions, in contrast to the much larger number present in Spirifer striato-paradoxus (Dunbar, 1955, p. 131).

From typical North American forms of Neospirifer cameratus (Morton), the Vancouver Island species is easily distinguished by its more alate shape, fewer and stronger costae, and less pronounced bundling of costae (cf. Shimer and Shrock, 1944, pl. 125, figs. 5, 6).

The differences cited above, and the lack of descriptions of internal details of many of the superficially similar forms, combined with the present uncertain status of some of the named species lead the writer to believe that the Vancouver Island species described above should be regarded as new.

Occurrence: Neospirifer n. sp. occurs in Unit 11 of the Buttle Lake Formation location at the type section. Superficially similar forms have also been recognized in the same formation at Locality 61-33-10F, on the ridge east of Azure Lake.

NEOSPIRIFER sp.

Plate III, Figure 11

1963 Neospirifer sp. YOLE, pl. I, fig. 9

Internal molds of one pedicle valve (UBC 20070) and a portion of a brachial valve (UBC 20071) of a small brachiopod probably belonging to Neospirifer were found in the basal sandstone of the Buttle Lake Formation (Locality 61-34-3F). The shells are strongly costate, with the costae prominently fasciculate in the anterior halves. The sulcus and fold are narrow; both appear to be weakly costate, but preservation is inadequate for full description. Measurements made on the more or less complete pedicle valve are: Length - 13 mm., Width - 26 mm. Not enough material is present for adequate comparison with other material. However, the pedicle valve (UBC 20070) appears identical in external appearance to a fossil from the Lower Permian of Novaya Zemlya, referred by Miloradovich (1935, p. 150, pl. 6, figs. 37-38) to Spirifer cameratus Morton. A small specimen, referred by Tschernyschew (1902, pl. 5, figs. 1, 2) to Morton's species also shows distinct similarity to the Vancouver Island fossils. Tschernyschew's "S. cameratus" has, however, since been placed in synonymy with Neospirifer posstriatus (Nikitin) (see Branson, 1948, p. 430).

Genus BRACHYTHYRINA Fredericks 1929

BRACHYTHYRINA cf. B. UFENSIS (Tschernyschew)

One partial pedicle valve of a large, broad ribbed spiriferid (UBC 20056), from Unit 11 in the type section of the Buttle Lake Forma-

tion resembles Brachythyrina ufensis (Tschernyschew) in visible features. The fossil measures over 45 mm. long, over 44 mm. wide; a shallow sulcus with medial furrow is bounded on the flanks by broad, subdued costae. Remnants of a broad spiralium with many volutions are visible. The closest comparison that can be made is with the specimen figured in Tschernyschew's (1902) fig. 3, pl. 39. Closely comparable external characteristics are also shown by a fossil from Novaya Zemlya assigned to B. ufensis by Miloradovich (1935, p. 150, pl. 6, fig. 36). From the fossil illustrated by Nelson (1961b, pl. 28, fig. 2), under the name "Spirifer" sp., cf. S. ufensis Tschernyschew, the Vancouver Island specimen differs in having a less elevated umbo.

Somewhat similar fossils, though less well-preserved, occur also at Locality 61-33-10F, in the Buttle Lake Formation, east of Azure Lake.

Genus SPIRIFERELLA Tschernyschew 1902

Recent discussions of the characteristics of this genus, and the problems of specific distinctions are given in Dunbar (1955, p. 142) and Harker and Thorsteinsson (1960, p. 70). From these authors' work, it is apparent that the Arctic species of this genus cannot be easily distinguished, especially when only external features are available for study. Harker and Thorsteinsson (ibid., p. 71) summarize their conclusions, based on specimens from Grinnell Peninsula, as follows: "By selecting the more extreme forms it is fairly easy to separate them into two groups; one group includes the more elongate shells with angular sulcus and fairly simple ribs, the other group comprises the more transverse shells with more complex rib pattern. These two groups

correspond respectively with S. saranae sensu lato and S. keilhavii sensu lato of Einor 1939, p. 126-154. There are some intermediate forms and it is probable that there would be a completely intergrading series if more material was available".

The species represented in the writer's collections from Vancouver Island is herein referred to Spiriferella saranae sensu lato, following the interpretation of Harker and Thorsteinsson.

SPIRIFERELLA SARANAE (de Verneuil) sensu lato

Plate III, Figures 1, 2, 3, 4.

1902 Spiriferina (Spiriferella) saranae (de Verneuil). TSCHERNYSCHEW, pl. 12, fig. 4: pl. 40, fig. 5; text figs. 41-46.
?1955 Spiriferella? sp. undet. DUNBAR, pl. 27, figs. 15-16.
1960 Spiriferella saranae (de Verneuil) s.l. HARKER and THORSTEINSSON, p. 71, pl. 22, figs. 1-8; pl. 23, figs. 3, 4, 8.
?1961b Spiriferella saranae (de Verneuil). NELSON, pl. 29, figs. 1-3.
?1962 Spiriferella draschei (Toula). DUNBAR, p. 3, pl. 2, figs. 1-14.
1963 Spiriferella cf. S. saranae (de Verneuil). YOLE, pl. 1, figs. 6, 7.

Description: Shells medium to large sized, thick, especially in apical region, longer than wide (incomplete preservation of some specimens suggests widths equal or greater than length). Hinge line apparently straight, but not completely preserved in the Vancouver Island specimens.

Ventral valve moderately convex. Interarea high, height about one-third of shell length, concave. Delthyrium not seen. Prominent sulcus, narrow, steep-sided, with narrow flat or slightly arched bottom near beak; becomes broad and shallow, with less steep sides, anteriorly; sides smooth or marked by faint, fine costae. Five,

possibly six, strong costae on each flank, the two bounding the sulcus being the most prominent. No fasciculation of costae evident. Interior shows small median muscle field depression, surrounded by thick secondary? shell growth, a continuation of the extremely thick apical shell filling. Other features not visible.

Brachial valve not seen.

Measurements (in mm.):

Specimen	Length Straight	Length Curved	Width
UBC 20068	38+	57+	40?
UBC 20069	36+	49+	42
UBC 20154	30+	-	42
UBC 20155	51+	-	42?
UBC 20157	37+	45+	25+
UBC 20156	33+	48+	26+

Material: The specimens consist of partial pedicle valves in all cases, poorly preserved by partial silicification in coarse crinoidal limestone. The preservation does not permit observation of shell surface features, and detail of the costation may be partially obscured.

Discussion: While in shape the specimens appear similar to Spiriferella keilhavii (von Buch), as described and illustrated by Dunbar (1955, p. 139, pl. 25, figs. 1-9; pl. 26, figs. 1-11; pl. 27, figs. 1-14), they differ from it in having a deeper, more angular sulcus, and in the simple costae. Dunbar illustrates a Spiriferella? sp. undet (ibid., pl. 27, figs. 15-16), from the Permian of Spitsbergen, which closely resembles the Vancouver Island specimens. The Spitzbergen form was originally assigned to S. keilhavii by Tschernyschew and Stepanow (1916, pl. 11, figs. 3a-c). The sulcus and costal type shown on the

Vancouver Island specimens, seem to agree best with Harker and Thorsteinsson's interpretation of Spiriferella saranae, mentioned in the generic discussion. Because of the apparent variations in shape and degree of costal fasciculation present in the genus and described species, the assignment of the Vancouver Island specimens to S. saranae sensu lato, seems most suitable until further work has clarified the definition of the species.

Spiriferella saranae from the Permian of the Yukon (Nelson, 1961b, p. 129, figs. 1-3), and Spiriferella draschei (Toula) from the Permian of northeast Greenland (Dunbar, 1962, p. 8, pl. 2, figs. 12-14), although not identical to the Vancouver Island specimens, may conceivably fall within the broad definition of S. saranae accepted by Harker and Thorsteinsson (1960). Information on these two forms is not sufficient to make accurate comparisons.

Occurrence: Two of the Vancouver Island specimens, UBC 20068, 20069, are from the upper 75 feet of the Buttle Lake Formation, Unit 21 of the type section. The remainder are from the upper part of the same formation, southeast of Marble Peak, Localities 61-61A-7F and 8F.

Genus PTEROSPIRIFER Dunbar 1955

PTEROSPIRIFER? sp.

Description: From two poorly preserved brachial valves, a partial description is all that is possible. The shells are wide, alate, with a prominent non-plicate fold. About 10 to 12 subangular plicae occur on each side of the fold, the four or five nearest to the fold being most clearly defined. The hinge line is the widest part of the shell. A slightly concave, subparallel-sided interarea arches more strongly under the small, inconspicuous beak. In one specimen (UBC 20059), remnants of an extensive apical callosity, and a medial, strongly impressed, elongate muscle field, are visible. No surface micro-structure is preserved on the specimens available; the shells appear to be impunctate.

Measurements (in mm.):

Specimen	Length	Width
UBC 20095	12+	30
UBC 20167	12+	52

Material: Specimen UBC 20095 is an internal mold, and UBC 20167 a silicified valve, the former occurring in the basal sandstone of the Buttle Lake Formation, the latter in coarse crinoidal limestone of the same unit.

Discussion: The lack of complete fossils prevents certain identification of this species; its general resemblance to species included within Dunbar's genus Pterospirifer warrant only tentative assignment

to that genus. The visible features indicate close resemblance to P. cf. P. alatus (Schlotheim), described by Harker and Thorsteinsson (1960, p. 68, pl. 20, figs. 13-14). From P. alatus (Schlotheim), as illustrated and described by Dunbar (1955, p. 129, pl. 22, figs. 19-25), the Vancouver Island fossils differ in their lack of a median groove on the fold.

Occurrence: Specimen UBC 20095 was found in Unit 1, in the basal sandstone of the Buttle Lake Formation type section. The other fossil, UBC 20167, was collected from the upper part of the same formation at Locality 61-33-10F, east of Azure Lake.

Subfamily INGELARELLINAE Campbell 1959

Campbell erected this subfamily to include three spiriferid genera with external characteristics related to those of the genus Martiniopsis Waagen 1883. His diagnosis (1959, p. 332) is as follows:

> "Spiriferidae of very variable size; hinge line variable in length but always less than the maximum width of the shell; cardinal extremities rounded; fold and sulcus present or absent; commissure rectimarginate to parasulcate and sulciplicate; cardinal areas invariably present on each valve; delthyrium partly obstructed by narrow dental ridges; lateral slopes smooth or bearing up to six deep rounded plications; shell substance in two layers -- a very thin 'epidermoidal' layer and a thick inner fibrous layer; outer layer bearing shallow pits of variable shape; teeth supported on well-developed dental lamellae; ventral adminicula diverge at variable angles; dorsal adminicula range in length from one-third the length of the valve to absent; crural plates strong; spires with about twelve to twenty-five volutions; no jugum present".

The three genera comprising the subfamily are Martiniopsis Waagen 1883, Notospirifer Harrington 1955 and Ingelarella Campbell

1959; they are distinguished on the basis of: presence or absence of fold and sulcus; presence or absence of dorsal adminicula; shape and arrangement of surface pits.

Genus INGELARELLA Campbell 1959

Type species: Ingelarella angulata Campbell 1959 (p. 345, pl. 56, figs. 4a-c; pl. 57, figs. 4-6). Generic diagnosis:

> "Shells small to large in size; fold and sinus present, but variably developed, and each with or without a median furrow; lateral slopes smooth or exhibiting varying degrees of plication; pedicle umbo usually high; hinge about two-thirds the maximum width of the valve; shell formed of two layers, the outer usually being of the order of 1/25 mm. thick, and carrying a series of fine semi-quincuncially disposed short linear depressions; dental lamellae and ventral adminicula present, the latter never lying completely lateral to the folds bordering the sinus; sockets long; crural plates and dorsal adminicula always developed; descending lamella robust, and spires directed postero-laterally".

The fossils described below have all the characteristics of Ingelarella, with the exception of some of the internal features, such as the spiralia, which are not preserved on the Vancouver Island specimens. Although strong evidence for their affinity with Campbell's Australian genus can be cited, until more completely preserved material is obtained, the Vancouver Island specimens can only tentatively be referred to Ingelarella. According to Campbell (1959, p. 341-342, fig. 4) the genus occurs without question only in Eastern Australia, New Zealand, Tasmania and Argentina, in Permian beds. A possible representative of the genus occurs in the Salt Range, Pakistan.

The fossils tentatively assigned to Ingelarella, are morphologically divisible into three groups, which are here treated as

"species". They all occur in the same bed, and the variations expressed by them may actually be of intraspecific character. Campbell's (1959, p. 344) I. angulata, for instance, shows great variations in shape, size and development of plicae. The main differences between the groups described below are in these same features, but in addition, the size of the surface pits and length of adminiculae appear to be significantly different in the three forms described. There are not enough specimens available to use statistical measures for significance of the variables. Provisionally, therefore, the three groups are described as "species". The fossils are all single valves, and many are incomplete. They occur in a fine to medium grained sandstone. Thus the evidence on hand suggests that this is not a life-assemblage; though the shells have obviously not been subjected to strong abrasion, they have probably been transported prior to deposition.

INGELARELLA? sp. A.

Plate III, Figures 13-14. Plate V, Figure 16.

Description: Medium to large in size, biconvex, thin-shelled, transverse oval in outline.

Pedicle valve moderately convex. Hinge line less than maximum width. Cardinal extremities obtuse. Umbo moderately elevated above hinge line, lateral slopes concave in outline, umbonal angle slightly obtuse. Anterior commissure parasulcate. Shallow, almost flat-bottomed sulcus, extends into broadly rounded tongue, set off from lateral slopes by prominent troughs. Lateral slopes each have

6 to 7 low, rounded to subangular plications, diminishing in prominence laterally from sulcus. Few faint, concentric rugae. Ventral adminicula (Campbell, 1959, p. 336) consist of long, subparallel plates, extending slightly more than 1/3 of shell length from umbo, probably converging posteriorly. Shell surface finely pitted; pits about 0.4 mm. average length, and about 10 occur in 1 mm. of valve width; arrangement semi-quincuncial.

Brachial valve transverse oval in outline. Small, pointed, incurved beak. Prominent, steep-sided fold, gently convex on summit. Lateral slopes with 5 to 6 rounded plicae, the 3 closest to the fold being most prominent on each side. Growth varices or rugae irregularly developed, being most numerous and closely spaced anteriorly. Dorsal adminicula, slightly diverging, extend 1/3 of valve length from umbo. A short median septum (myophragm? of Campbell, 1961, p. 172, etc.) extends less than half of length of muscle field between adminicula.

Measurements (in mm.):

Specimen	Length	Width	Width Hinge Line	Length Adminicula	Length Surface Pits
UBC 20075 (p.v.)	30	40	34?	12	-
UBC 20077 (b.v.)	27	34	22	8	-
UBC 20083 (b.v.)	23+	32+?	-	-	0.4-0.6

Material: An internal mold of an almost complete pedicle valve (UBC 20075), an internal mold of a partial brachial valve (UBC 20077) and an external mold of a partial brachial valve (UBC 20083) are the only specimens available. They are preserved in calcareous sandstone; all are partially crushed.

Discussion: The material and preservation of the specimens is not adequate for precise comparisons with previously described species. However, general comparisons with some of Campbell's Australian fossils are possible. The most closely comparable species is Ingelarella angulata Campbell (1959, p. 345, pl. 56, figs. 4a-c; pl. 57, figs. 1-5). The size range of the latter species includes that of the specimens from Vancouver Island. In all other discernible features, Ingelarella? sp. A. agrees with Campbell's species, except for the greater number of plications in the Vancouver Island specimens. Ingelarella? sp. A. differs from I. denmeadi Campbell (1961, p. 171, pl. 23, figs. 7-12) in being smaller, thinner shelled, and in having a less prominent fold and sulcus; plications appear to be more numerous on the Vancouver Island specimens. The only other described fossil with strong similarity to Ingelarella? sp. A. is one referred to by Miloradovich (1935, p. 136, pl. 6, fig. 33) as Meekella? sp. indet., and compared by him to M. striato-costata Cox. The single illustration provided by Miloradovich shows a brachial valve, almost identical in appearance to one of the Vancouver Island specimens (UBC 20077).

Because of the small amount and inadequate preservation of the Vancouver Island material available at the present time, it is considered insufficient for the erection of a new species. The observable differences between Ingelarella? sp. A. and previously described species, and geographic separation from the localities of the latter, suggest that a new species may be necessary to accommodate it.

Occurrence: All specimens are from Unit 1, the basal sandstone of the Buttle Lake Formation, Azure Lake section.

INGELARELLA? sp. B

Description: Medium to large in size, subpentameral outline.

Pedicle valve moderately convex, with greatest convexity in umbonal region. Umbo raised high (about 1/3 of valve length) above hinge line; lateral slopes slightly concave in outline, umbonal angle slightly obtuse. Anterior commissure uniplicate to very faintly parasulcate. Very shallow, almost imperceptible sulcus becomes evident about 1/3 of distance from umbo to anterior margin; a medial, broad groove or trough is present. The lateral slopes are non-plicate, or marked by extremely subdued, low, rounded plications, visible only near the lateral and anterior margins, and numbering about 6 on each side of sulcus. Few, faint rugae. Ventral adminicula slightly less than 1/3 of valve length, slightly diverging anteriorly. Shell surface finely pitted; average length of pits 0.6 mm., with about 10 in 1 mm. width, arrangement semiquincuncial.

No brachial valves seen.

Measurements (in mm.):

Specimen	Length	Width	Width Hinge Line	Length Adminicula	Length Surface Pits
UBC 20078 (p.v.)	29	36	32?	-	0.5-0.7
UBC 20076 (p.v.)	26	32	30?	7	- -

Material: The two specimens are molds, one external (UBC 20078), the other internal; both are incomplete pedicle valves. They are preserved in fine-grained sandstone.

Discussion: This species differs from Ingelarella? sp. A in having a highly elevated umbo, in the lack of, or very faint development of, plications on the lateral slopes, and in the longer surface pits. It

bears certain resemblances to smooth-shelled forms of I. angulata Campbell, and to smaller specimens of the species I. mantuanensis Campbell (1960, p. 1118, pl. 137, figs. 2-3; 1961, p. 185, pl. 24, figs. 1-2) and I. ingelarensis (Campbell, 1960, p. 1115, pl. 135, figs. 1-3; pl. 138, fig. 4). However, both of the latter species are considerably larger on the average, and have more strongly divergent adminicula; the size and density of the surface pits of these two species have not been described. The specimens of I. angulata which do fall within the size range of the Vancouver Island specimens are of more rounded outline, have less numerous plications (when these are developed), and show much greater divergence of the adminicula.

As with the other species tentatively assigned to this genus, Ingelarella sp. B cannot be precisely compared, or named, with the inadequate material at present available. It is clearly distinct morphologically from I.? sp. A; with greater numbers of the specimens, it is possible, however, that a gradational series including these two species would be recognisable.

Occurrence: All of the available specimens are from Locality 61-34-3F, in the basal sandstone (Unit 1) of the Buttle Lake Formation, Azure Lake section.

INGELARELLA? sp. C

Plate III, Figure 12.

Four specimens of smaller dimensions than the two species described above are grouped together here as a separate taxon. It is possible that some or all of these may represent juvenile forms of one of the above described species.

Description: Small, subcircular in outline, biconvex, with uniplicate anterior commissure.

Pedicle valve moderately convex. Umbo high, with lateral slopes straight in outline, fairly steep, extending laterally to small, flattened triangular auricles. Shallow sulcus, possibly medianly furrowed. Lateral slopes nonplicate, or marked by very faint plicae, 4-5 on each side of sulcus. Few irregularly spaced rugae. Ventral adminicula long, about 1/3 to 1/2 of shell length, subparallel in umbonal region, slightly convergent anteriorly. Interarea, high, triangular, oblique to plane of commissure. Delthyrium wide, triangular. Dental lamellae well-developed.

Brachial valve gently convex. Umbo slightly elevated over hinge line, with lateral slopes gently concave in outline. Cardinal angles obtuse. Low, gently convex fold evident in anterior two-thirds of valve length with broad, shallow median furrow. Lateral slopes very faintly plicate, with four or more plications on each side.

Surface pits relatively long, most over 0.5 mm., and spaced about 10 in 1 mm. of width.

Measurements (in mm.):

Specimen	Length	Width	Width Hinge Line	Length Adminicula	Length Surface Pits
UBC 20079 (b.v.)	20	24	20?	6	-
UBC 20080 (p.v.)	19+		24	12	-
UBC 20082 (p.v.)			25?	-	0.5-0.9
UBC 20081 (p.v.)	22	26?		7	-

Material: The specimens are all molds, three being internal and one (UBC 20082) an external mold, of partial single valves. They are preserved in sandstone.

Discussion: This species may be referrable to I. angulata Campbell (1959, pl. 56, figs. 2a-c, 4a-c), the smaller specimens of which it resembles. The plication of Campbell's specimens is coarser than that evident on I.? sp. C. The surface pits of I. angulata have not been measured and recorded by Campbell. Not enough material is available to precisely identify or define I.? sp. C at the present time.

Occurrence: The specimens described occur, together with the other ingelarellinids? and species of Rhynchopora, Squamularia, pelecypods and other fossils, in the basal sandstone (Unit 1) of the type section of the Buttle Lake Formation.

Subfamily PHRICODOTHYRINAE Caster 1939

Genus SQUAMULARIA Gemmellaro 1899

SQUAMULARIA? sp.

Plate III, Figure 16.

1963 Squamularia cf. S. rostrata (Kutorga). YOLE, pl. 2, fig. 20.

Description: Brachial? valves only; wider than long, transverse oval in outline. Gently to moderately convex. No fold. Umbonal angle slightly obtuse; umbo slightly inflated; beak not seen. Surface strongly lamellose, with spine fringes on lamellae. Spine molds of one specimen suggest double-barreled type.

Measurements (in mm.):

Specimen	Brachial valve? Length	Width	Width Hinge Line
UBC 20089	9	10+	8
UBC 20090	7	8	-
UBC 20091	9	11	8

Material: Poorly preserved single valves. The first two listed are in calcareous sandstone, the last in tuffaceous? limestone.

Discussion: Superficial similarity to several species is shown by the Vancouver Island fossils described above. With the few, poorly preserved specimens available, no precise determinations are possible.

The dimensions, shape and proportions of the specimens agree with the immature portions of brachial valves of S. rostrata (Kutorga) as figured by Cooper (1957, p. 59, pl. 10F, figs. 36-42). They also are closely comparable to smaller specimens of the same species illustrated

by Tschernyschew (1902, p. 575, pl. 20, figs. 14-18). Kutorga's original specimens, shown in Tschernyschew (ibid., pl. 15, figs. 4-5) are larger than the specimens under discussion. A somewhat similar species, S. lineata Martin, shown by Tschernyschew (ibid., pl. 20, figs. 9-13), is also larger than Squamularia? sp. and has a distinctly different shape.

Occurrence: Two specimens are from Unit 1 of the type section of the Buttle Lake Formation. The other is from limestone talus at Horne Lake, Locality 61-24-TF-8.

Superfamily PUNCTOSPIRACEA Cooper 1944

Family RHYNCHOSPIRINIDAE Schuchert and LeVene 1929

Subfamily RETZIINAE Waagen 1893

Genus HUSTEDIA Hall and Clarke 1893

Hustedia meekana (Shumard)

Plate II, Figure 10.

?1902 Hustedia indica (Waagen). TSCHERNYSCHEW, p.512, pl. 47, fig. 12.
1909 Hustedia meekana (Shumard). GIRTY, p.394, pl. 14, figs. 22-26a; pl. 21, figs. 5-8a; pl. 24, figs. 14, 14a; pl. 29, fig. 8; pl. 30, figs. 16-17.
1931 Hustedia meekana (Shumard). KING, p. 126, pl. 42, figs. 34-39.
1938 Hustedia meekana (Shumard). McKEE, p. 255, pl. 48, figs. 8-9.
1944 Hustedia cf. H. meekana (Shumard). CLOUD, in King et al., p. 64, pl. 18, figs. 9-11.
1953 Hustedia meekana (Shumard). COOPER, in Cooper et al., p. 65, pl. 20D, figs. 16-24.
?1953 Hustedia meridionalis CHRONIC, in Newell et al., p. 105, pl. 17, figs. 10-17.
?1955 Hustedia sp. Dunbar, p. 160, pl. 32, fig. 11.
1963 Hustedia cf. H. meekana (Shumard). YOLE, pl. 1, fig. 8

Description: Medium-sized for the genus; elongate oval shape, greatest width slightly anterior to the mid-length. Punctate shell structure.

Pedicle valve rostrate, moderately convex; shell strongly corrugated by 8 to 10 coarse, anteriorly flaring plications; median pair of plications lower than adjoining pair, remainder progressively lower toward lateral borders; plications narrowly rounded to subangular, with troughs between them of similar size and shape. Pedicle opening apical, subcircular. High interarea.

Brachial valve subcircular, slightly wider than long, gently convex; small pointed beak; short, narrow, inflated, incurved umbo. Plications seven, coarse; median three slightly higher than adjoining pairs; similar in other respects to those of pedicle valve.

Interiors not seen.

Measurements (in mm.):

Specimens	Length Straight	Length Brachial Valve	Width
UBC 20058	6	4	5
UBC 20059	10		9
UBC 20060	7.5		7

Material: Three partial shells, in dolomitic limestone of the Buttle Lake Formation.

Discussion: Species referable to H. meekana, as defined by Shumard and emended by Girty occur in Permian rocks of many areas of the western United States, Mexico, South America, Alaska and Arctic regions. Because of some confusion arising from Shumard's original description (see Girty, 1909, p. 394), some authors have assigned similar forms to new species (e.g., Chronic, 1953, p. 108). Girty (ibid., p. 391) suggested that H. indica (Waagen) might be conspecific with H. meekana.

Occurrence: The three specimens listed above are from Unit 11 in the type section of the Buttle Lake Formation. A fragmentary specimen probably referable to this species occurs in collections from Locality 60-H-2, Horne Lake.

Family SPIRIFERINIDAE Davidson 1884

Genus SPIRIFERINA d'Orbigny 1847 sensu lato

SPIRIFERINA? sp.

Description: From two partial valves, the following incomplete information is derived. Small, transverse shells, with no plicae on fold and sulcus. Flanks each with five subangular plicae. Shell structure not well preserved, definite punctation not seen; if present, punctae must be very fine.

Measurements (in mm.):

Specimen	Length	Width	
UBC 20158	5	8	Brachial valve
UBC 20159	6+	12	Pedicle valve

Material: Two incomplete valves from calcareous sandstone.

Discussion: The status of the various genera of punctate spiriferids is still a matter for discussion and further clarification (see Dunbar, 1955, p. 147; Stehli, 1954, p. 344-346; Campbell, 1959, p. 351-363; Branson, 1948, p. 511-514).

The specimens referred to above cannot be definitely assigned to a genus, because of the poor preservation and small number of specimens for study. They are tentatively assigned to Spiriferina, on the basis of external similarities to certain described species of that genus. One of the latter, S. multiplicata was described by Dunbar (1955, p. 147, pl. 29, figs. 1-9). Another similar species is S. hilli Girty, as described by King (1931, p. 122, pl. 42, figs. 1-6), which was compared to S. multiplicata (Sowerby). Girty's original description

of S. hilli (1908, p. 379, pl. 30, figs. 15, 15a-b) suggest a more elongate form with fewer lateral plicae.

Occurrence: Specimens have been found only in the basal sandstone (Unit 1) of the Buttle Lake Formation, at the type section.

Superfamily ROSTROSPIRACEA Schuchert and Levene 1929

Family ATHYRIDAE Phillips 1841

Genus CLEIOTHYRIDINA Buckman 1906

CLEIOTHYRIDINA sp.

Description: Parts of both valves of a slightly crushed shell, with interior filled with coarse calcite. Medium sized, subequally biconvex, probably transverse oval in outline. Pedicle valve slightly thicker than brachial, gently to moderately convex, with greatest convexity in umbonal region. Umbo closely overhanging the hinge line. No sulcus evident. No interarea. Surface lamellose, with lamellae 1/2 to 1 mm. apart. Brachial valve evenly convex, umbonal region not appreciably inflated. Surface sculpture as in pedicle valve, with spiny fringes visible in one part, spines extending up to 2 mm. from anterior edge of lamellae.

Other features not seen.

Measurements: In the single specimen available, UBC 20067, length 22 mm., width 18+ mm., thickness 11 mm.; greatest thickness about 1/3 of length from umbo. The specimen is incomplete, and is in fine grained dolomitic limestone of the upper part of the Buttle Lake Formation, Locality 61-35-5F.

Discussion: In all visible features, this specimen agrees with Cleiothyridina gerardi (Diener), as described from central Oregon by Cooper (1957, p. 61, pl. 11E, figs. 28-31); and from Russia by Tschernyschew (1902, p. 512, pl. 43, figs. 1-2); the Vancouver Island specimen is slightly larger. Another closely comparable species is C. pectinifera

(Sowerby) as interpreted by Dunbar (1955, p. 126, pl. 22, figs. 9-18), and Tschernyschew (1902, p. 511, pl. 43, figs. 4-6). The latter are of slightly more rostrate form, and smaller than the specimen described above. Certain specimens assigned to C. royssiana (Keyserling) by some authors (Fredericks, 1934, pp. 22-23, pl. 4, figs. 16-17, pl. 5, fig. 11; Stepanow, 1937, p. 181, pl. 9, fig. 8) also appear similar to the Vancouver Island specimen; the majority of forms identified with Keyserling's species (e.g., Tschernyschew, 1902, p. 518, pl. 43, figs. 11-12) are of much different shape than Cleiothyridina sp., however. A species (C. cf C. subexpansa (Waagen)) described by Harker and Thorsteinsson (1960, p. 73, pl. 24, figs. 1-2), from Grinnell Peninsula, is about twice the size of the Vancouver Island species.

Occurrence: The single specimen available is from Unit 11 of the Azure Lake section of the Buttle Lake Formation.

Superfamily CAMAROPHORIACEA Grabau 1936

Family CAMAROPHORIIDAE Waagen 1883

Genus LAEVICAMERA Grabau 1934

The genus was proposed by Grabau to include "smooth camarophoridae usually with a tuning fork type of spondylium" (1936, p. 87). Sarycheva and Sokolskaya (1952, p. 170) treated Laevicamera as a sub-genus of Camarophoria, and included within the sub-genus those forms which had a smooth surface, with no radial ribbing. Camarophoria was described as having a well-developed spondylium, and a cruralium-like structure, the "camarophorium", in the brachial valve. The internal features of Camarophoria are also described and illustrated by Licharew (1936, p. 58-61, fig. 2). The Vancouver Island fossil described below has internal features almost identical to those ascribed to Camarophoria by the latter author, but appears to differ in minor details from Laevicamera as described by Sarycheva and Sokolskaya. The genus has been reported from Permo-Carboniferous and Permian rocks of Russia, and from the Permian of China, Novaya Zemlya and Afghanistan (Branson, 1948, p. 381). Faunal lists suggest that forms belonging to the genus may also occur in Cordilleran regions of North America.

LAEVICAMERA n. sp.

Plate III, Figures 5, 6, 7, 8, 9, 10.

1963 Laevicamera n. sp. YOLE, pl. 2, figs. 13-14.

Diagnosis: Large, smooth, biconvex, triangular in outline. Prominent rounded-triangular fold in anterior half of brachial valve; shallow sulcus in anterior half of pedicle valve, geniculated into prominent tongue.

Description: Large, impunctate shell, triangular in outline. Biconvex. Apical angle about 90 degrees. Uniplicate anterior border.

Pedicle valve convex in umbonal region, blunt beak curved over brachial umbo. Pre-umbonal region flat; anterior half of valve shallowly concave, with shallow sulcus turning sharply into broad, rounded-triangular tongue. Surface perfectly smooth. Interior has long median septum, extending two-thirds of valve length, supporting a V-shaped spondylium over most of the distance. Small, stout teeth at corners of delthyrium.

Brachial valve moderately convex, thicker than pedicle valve, with broad poorly defined umbo. Broad, steep, rounded-triangular fold in anterior half of shell, occupying about two-thirds of anterior border. Median septum extends at least half of interior shell length, and supports a camarophorium (Kozlowski, 1929, p. 131; Licharew, 1936, p. 56). An intercamarophorial plate (Licharew, ibid.,) occurs in the upper part of the camarophorium, joining it to a flat or slightly concave hinge plate in the cardinal region. A small cardinal process, probably bifid, occurs as a roughened projection in the posterior part of the hinge plate. Prominent dental sockets at the lateral margins of the hinge plate. Shell surface smooth.

Immature specimens more rounded in outline, with convex lateral margins.

Measurements (in mm.):

Specimen	Length	Width	Thickness
UBC 20061	40+	39+	-
UBC 20062	35	50	27
UBC 20063	28+	28+	-
UBC 20064	25+	43	22

Material: All of the specimens are from the dolomitic lime-

stone of the Buttle Lake Formation, Locality 61-35-5F. One specimen was serially sectioned (UBC 20064), the results of which are shown in Figure 57.

Discussion: The only species known to the writer and which bears any resemblance to Laevicamera n. sp. is the Russian species L. pentameroides (Tschernyschew). (Tschernyschew, 1902, p. 510, pl. 22, fig. 1; pl. 23, figs. 1-3; Sarycheva and Sokolskaya, 1952, p. 172, pl. 48, fig. 268; Branson, 1948, p. 380). A fragmentary specimen from the Permian of China was assigned to this species by Grabau (1936, p. 68, pl. 10, fig. 2).

Laevicamera n. sp. differs from L. pentameroides in having a less elongate shape and less sharply defined, shorter fold, and in the lack of a prominent median groove on the tongue of the pedicle valve. The variation within L. pentameroides is not known. Hence it is considered preferable to regard the Vancouver Island fossils as a new species.

Occurrence: All of the specimens available are from Unit 11 of the Buttle Lake Formation type section.

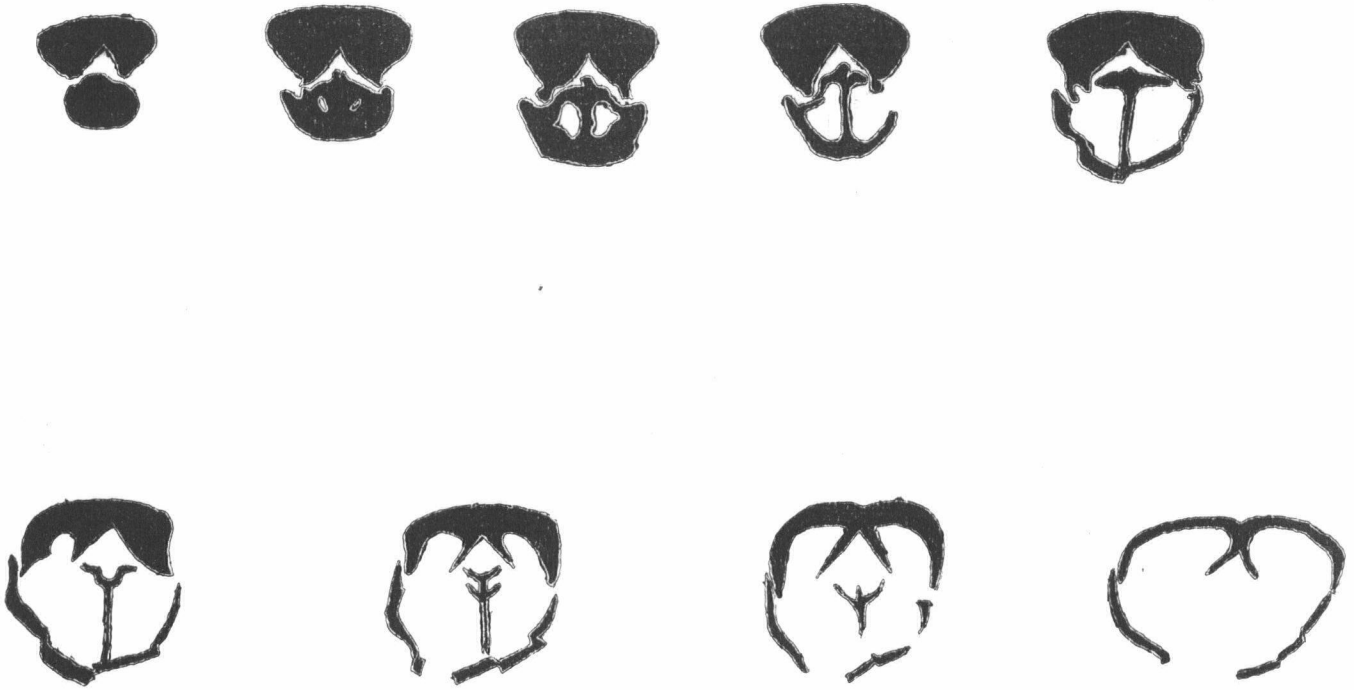

Figure 57. Serial sections of Laevicamera n.sp. Specimen UBC 20064. XI

Superfamily RHYNCHOPORACEA Moore 1952

Family RHYNCHOPORIDAE Muir-Wood 1955

Genus RHYNCHOPORA King 1865

RHYNCHOPORA n. sp.

Plate III, Figures 17, 18.

1963 Rhynchopora cf. R. magna Cooper, YOLE, pl. 2, fig. 19.

Diagnosis: Medium sized, subpentagonal shape, wider than long, with 4 to 5 plicae in sulcus, 5 to 6 on fold, 5 to 6 on flanks; plicae rounded to subangular.

Description: Shell of medium size for the genus, subpentagonal in outline, subcircular to rounded triangular in lateral profile. Length/width ratio about 0.7 to 0.85. Greatest width about mid-length. Greatest thickness anterior to middle. Strongly plicate, plicae rounded to subangular; about 17 plicae with 4 or 5 in sulcus, 4 or 6 on fold, 5 or 6 on flanks. Shell surface coarsely punctate.

Pedicle valve gently to moderately convex. Umbo slightly inflated. Umbonal angle slightly obtuse. Beak small, pointed, slightly incurved over hinge line. Sulcus shallow, evident only in anterior half of shell length, widens forward to occupy about half of anterior margin; extends dorsally into flattened tongue. Interior with long slightly diverging dental lamellae, reaching almost to mid-length.

Brachial valve gently convex in posterior 2/3 of length, strongly convex anteriorly. Umbo almost imperceptibly inflated. Beak obscure. Umbonal angle 90 degrees to slightly obtuse. Fold becomes evident only in anterior half of shell, where central plicae are stronger and more elevated than flanking ribs; at 2/3 of shell length from beak,

fold sharply geniculated to meet tongue. Interior with long, thin median septum, reaching about to mid-length. Apical structures not seen.

Measurements (in mm.):

Specimen	Length	Width	Thickness
UBC 20084 (b.v.)	11	17	-
UBC 20085	11	-	11
UBC 20086 (p.v.)	12	14	-
UBC 20087	12	16	9+

Material: All of the specimens are molds, preserved in the basal sandstone of the Buttle Lake Formation. Most are crushed to various degrees. In addition to the specimens on which measurements were possible, several fragmentary valves are present in the collection.

Discussion: This species does not appear to be identical to any of those described species for which adequate descriptions or illustrations are available to the writer. The closest comparable forms are R. nikitini Tschernyschew as illustrated by Stepanow (1937, p. 182, pl. 9, fig. 13) from Spitsbergen, and R. geinitziana (de Verneuil) figured by Miloradovich (1935, p. 134, pl. 5, fig. 7) from Barents Islands, Novaya Zemlya. The original descriptions of the latter two species have not been available to the writer. However, Dunbar (1955, p. 116) in his discussion of a Greenland species, states that de Verneuil's and Tschernyschew's species can be distinguished on the basis of plical shape; the former has angular ribs, the latter rounded ribs. The Vancouver Island specimens include some with broadly rounded plicae, and others with subangular plicae. According to Dunbar, R. nikitini

is also characterized by medial grooves on the anterior portions of the plicae. This feature was noted on one or two of the Vancouver Island specimens, but on others was not evident. Harker and Thorsteinsson (1960, p. 63-64) describe, without illustration, R. cf. R. nikitini; their species is smaller, but otherwise apparently closely comparable to Rhynchopora n. sp.

The Oregon species described by Cooper (1957, p. 54, pl. 9A, figs. 1-10; pl. 10D, figs. 18-31), as R. magna, is larger, less transverse in outline, and has a greater number of plicae (total number, and number in silcus and on fold) than Rhynchopora n. sp. A smaller species, R. variabilis Stuckenberg (1898, p. 342, pl. 3, figs. 13-14) has plicae similar in number and character to those of Rhynchopora n. sp.; in Tschernyschew's illustrations of Russian specimens of Stuckenberg's species however, the total number of ribs appears to be only 12 to 13, with 3 to 5 on the fold and sulcus.

The Vancouver Island species thus appears to have closest resemblances to the Russian species R. nikitini and R. variabilis. Not enough is known of the intraspecific variability of either of these species, nor of their internal features to be certain that the species described above is conspecific with either of them. In addition, certain features differing from the described characteristics of these two forms are seen on the Vancouver Island specimens. It is considered preferable that the latter should be described as a new species, while pointing out its close resemblance to the Russian forms.

Occurrence: The species has been recognized only in Unit 1 of the Buttle Lake Formation type section.

Superfamily DALMANELLACEA Schuchert and Cooper 1932

Family SCHIZOPHORIIDAE Schuchert 1929

Genus SCHIZOPHORIA King 1850

SCHIZOPHORIA sp.

Plate V, Figure 17.

Description: Small to medium sized, subpentameral in outline, subequally biconvex. Hinge line short, less than half shell width. Both valves costellate with 15 to 16 costellae in 5 mm. at mid-valve. Growth lamellae few in posterior half, numerous, closely spaced near anterior and lateral margins.

Pedicle valve gently convex in posterior half, flat to gently convex in anterior half of larger shells. Beak small, acute, erect to sub-erect. Sulcus broad, shallow, poorly defined, evident only in larger shells. Prominent interarea, 1/4 to 1/5 as high as wide, inclined at 40 to 60 degrees to line of lateral commissure. Delthyrium, wide, triangular, with acute delthyrial angle. Prominent diverging hinge teeth. Low ridge around postero-lateral borders of muscle field, may have been joined to thin dental lamellae, (not preserved in available specimens). Muscle field impressed in valve floor, extends about half of shell length from hinge line, and divided by a relatively broad, gently rounded median ridge; ridge is highest posteriorly.

Brachial valve gently to moderately convex, greatest convexity in umbonal region. Beak small, inconspicuous. Interarea

prominent, almost co-planar with commissure. Internal details not seen, but internal mold of one specimen suggests low median ridge in muscle field.

Measurements (in mm.):

Specimen	Length	Width	Thickness	
UBC 20185	21	22	4+	pedicle valve
UBC 20180	11+	15	6+	
UBC 20181	13	12	-	p.v.
UBC 20183	13	11+	5+	
UBC 20183	14	12+	4+	p.v.
UBC 20184	12	11	4+	p.v.

Material: The specimens are all silicified, and occur in coarse crinoidal limestone.

Discussion: In observed features, this species closely resembles S. juresanensis Tschernyschew (1902, p. 591, pl. 27, figs. 13-15; pl. 60, figs. 5-8; text fig. 61). The size range of the Vancouver Island specimens exceeds that indicated by Tschernyschew's illustrations; however, other species of S. show similar or greater size range. The characteristics of the inside of the brachial valve cannot be compared exactly to Tschernyschew's species, because of the limitations of the Vancouver Island material.

Another of Tschernyschew's Permian species, S. supracarbonica, (ibid., p. 593, pl. 63, figs. 7-8; text fig. 62), though similar in other features to the Vancouver Island species, has a bundled arrangement of costellae, not seen on Schizophoria sp.

From both of these species, the Vancouver Island forms differ in a tendency for the smaller forms to be more elongate in shape; the transverse shape is more accentuated in the larger specimens.

Species with certain resemblances to S. sp. have also been recorded from Pennsylvanian localities. S. texana Girty (1927, p. 432, pl. 27, figs. 1-8) has been found in Lower Pennsylvanian localities Texas, Idaho and Nevada (Lane, N.G., 1963, p. 379-392, pl. 43, figs. 9-19). The Vancouver Island species differs from S. texana in having usually a more pentagonal shape, and in the broader, non-tapering median ridge in the pedicle valve. No tendency toward elongate, rather than transverse, shape is suggested by Lane's graph (text fig. 1, p. 383) of the dimensions of his specimens. A Middle Pennsylvanian species, S. resupinoides (Cox), described by B. O. Lane (1962, p. 898, pl. 125, figs. 17-19) from the Atokan beds of Nevada, is larger than the Vancouver Island Schizophoria sp. and is characterized by a long, narrow median septum in the pedicle valve.

Occurrence: This species has been found only at Locality 60-H-2, Horne Lake.

Genus ORTHOTICHIA Hall and Clarke 1894

ORTHOTICHIA sp.

From insoluble residues of limestone from the Horne Lake area, Locality 60-H-2, a single specimen (UBC 20186) with the generic characteristics of Orthotichia was recovered. The silicified pedicle valve is elongate oval in outline with no trace of a sulcus. The shell surface is finely costellate. High, slender, slightly diverging dental lamellae, and a thin, triangular-shaped median septum are evident in the anterior portion of the shell.

The specimen is of smaller size and more elongate outline than O. hueconiana (Girty) as described by Stehli (1954, p. 293, pl. 17, figs. 7-12). The latter author considered Girty's species to be the only valid species of Orthotichia from Permian localities in North America; King's O. kozlowskii species from the Lower Permian of Texas (King, 1931, p. 45, pl. 1, figs. 14-15) was relegated by Stehli to the synonymy of O. hueconiana.

It cannot be determined from the information available whether the single specimen from Vancouver Island falls within the range of variation of O. hueconiana. It may represent a new species.

ORTHOTICHIA? sp.

In collections obtained from the Buttle Lake Formation, Unit 1 of the Azure Lake section, a single specimen with characteristics suggesting those of Orthotichia is present. The shell is of medium size, transverse oval in outline, with hinge line narrower

than maximum width. The pedicle valve is slightly convex, with a steeply inclined, flattened interarea. Beak not preserved. Thin dental lamellae descend to the floor of the valve from strong, diverging dental plates. A narrow, low median septum is visible in the posterior part of the shell.

The brachial valve is of moderate convexity. Beak and umbo not seen. Well-developed, diverging crural lamellae.

Exterior multicostellate, with about 15 costellae in 5 mm. anteriorly. Shell structure not discernible.

Length 23 mm., width 32 mm., thickness about 13 mm., hinge line about 16 mm.

The material available permits only a tentative generic assignment; referral to Orthotichia is based on the general exterior features and the presence of a median septum.

Superfamily ORTHOTETACEA Williams 1953

Family SCHUCHERTELLIDAE Stehli 1954

Genus DERBYIA Waagen 1894

DERBYIA? sp.

An internal mold of a single, incomplete pedicle valve (UBC 20093), questionably belonging to this genus, was found in the basal sandstone (Unit 1) of the Buttle Lake Formation type section. The length is approximately 30 mm. and the width about 38 mm. Remnants of a thin median septum in the centre of the muscle field are evident. The shell surface is multicostellate, with about 12 rounded costellae in 5 mm. of width near the antero-lateral extremities. Near the lateral margins, strong growth varices are present.

The material available suggests some similarity with Derbyia sp. described by Harker and Thorsteinsson (1960, p. 53, pl. 23, fig. 8), and certain other species. The Vancouver Island material is inadequate for more refined comparisons.

Phylum MOLLUSCA

Class PELECYPODA

Family NUCULANIDAE Stoliczka 1871

Genus NUCULANA Linck 1807

NUCULANA sp.

A medium sized nuculanid is represented by one specimen in the collection from Unit 1 of the type section of the Buttle Lake Formation. The specimen (UBC 20101) is a left valve, almost complete. The anterior margin is rounded, and the cardinal margin is concave posteriorly. The small, opisthogyrate beak is located about 1/3 of the shell length from the anterior extremity. The umbo is swollen. Escutcheon prominent. About 20 small, simple teeth are about evenly divided between the regions anterior and posterior to the beak. The surface is marked by about 40 fine concentric lamellae, whose short, steep dorsal borders suggest deep grooves. The valve has a length of 17 mm., height of 8 mm., and thickness of 4 mm.

The species is similar to N. bellistriata (Stevens) as illustrated by Shimer and Shrock (1944, p. 377, pl. 146, figs. 30-31). It is closely comparable to the Greenland specimens assigned by Newell (1955, p. 17, pl. 4, fig. 6) to N. speluncaria (Geinitz), and to the Western Australian N. darwini (de Koninck) described by Dickens (1957, p. 18, pl. 2, figs. 1-6). The latter is stated by Dickins to be similar to N. bellistriata (Stevens). Branson (1948, p. 633) apparently considers N. bellistriata (of authors, not Stevens) to be distinct from Stevens species. Lack of access to Geinitz's and de Koninck's original descriptions present closer comparisons.

Family?

Genus CHAENOMYA Meek 1865

Dickins (1957) discussed the differences between Chaenomya and Allorisma, and in an earlier publication (1956, p. 20), reviews the problems of taxonomy and classification of these genera.

CHAENOMYA? sp.

Plate III, Figure 19.

A single left valve of a shell tentatively assigned to this genus is present in the collection from Unit 1 of the Azure Lake section, Buttle Lake Formation. The shell is elongate, with truncated anterior margin, rounded posterior margin. The posterior is produced, with a distinct recurving of the back part of the dorsal margin. Umbo is slightly inflated, the swelling extending in diminishing prominence towards the postero-ventral extremity. The umbo is very close to the anterior end of the cardinal margin. Ornament of closely spaced concentric lamellae, with about 15 in 5 mm. posteriorly more in same distance elsewhere on the shell. Lamellae appear to have fibrous structure, probably giving rise to granular surface. No evidence of dentition or pallial line and muscle scars.

Measurements of the specimen give - Length 22 mm., Height 12 mm., Thickness 2+ mm.

With the material available, adequate comparisons cannot be made. However, superficial resemblance to Chaenomya sp. nov. Dickins (1957, p. 29, pl. 4, figs. 10-12), from the Lower Permian of Western

Australia, and to Allorisma elegans King as described by Newell (1955, p. 34, pl. 5, fig. 16) from Greenland specimens, is noted.

Family TRIGONIIDAE Lamarck

Genus SCHIZODUS Murchison and de Verneuil (King 1844)

SCHIZODUS sp.

Description: Rounded triangular outline. Prominent carina extending from umbo to posterior angle. No surface or interior features preserved.

Measurements (in mm.):

Specimen	Length	Height	
UBC 20161	32	30	Right valve, external mold
UBC 20162	32	20+	Right valve, internal mold
UBC 20163	36	30	Right valve, internal mold
UBC 20164	40	26+	Left valve, internal mold

Material: As indicated above, only molds of single valves are preserved. They were found in sandstone.

Discussion: Newell's illustrated (1955, pl. 1, figs. 6-8) specimens of S. obscurus (Sowerby), from Greenland, agree in all visible respects to the species from Vancouver Island. A Russian species, S. aff. S. obscurus Fredericks (1934, p. 16, pl. 1, fig. 10), although of similar dimensions, has a much less prominent carina and post-umbonal area than the Vancouver Island species. Fredericks (pl. 2, fig. 3) described under the name of Schizodus sp. a form which is much more similar to the Vancouver Island fossil. Another closely comparable species is S. kennedyensis Dickins 1956 (p. 30, pl. 5, figs. 1-10) from the Lower Permian of Western Australia. Dickins mentioned the similarity of his species to several other described forms, including S. obscurus.

The poorly preserved material from Vancouver Island permits only the general comparisons made above. The closest affinities appear to be with species related to S. obscurus (Sowerby). However, Sowerby's descriptions and illustrations are not available to the writer. It seems appropriate to leave the specific identification open until such time as better material and/or additional pertinent literature has become available.

Occurrence: The specimens are from Unit 1 of the type section of the Buttle Lake Formation.

Family AVICULOPECTINIDAE Etheridge 1906

Genus AVICULOPECTEN M'Coy 1851

AVICULOPECTEN? sp.

Two fragmentary valves of a medium sized pectinacean were collected from Unit 1 of the Buttle Lake Formation, Azure Lake section. The shells have coarse angular plications, and a few concentric rugae. The material is insufficient to make certain generic identification. A partially preserved structure in the umbonal region of one of the specimens suggests the presence of a resilifer or chondrophore, on the basis of which a tentative assignment to Aviculopecten is made.

The specimens are numbered UBC 20165 and UBC 20166. Comparisons with described species are not warranted with the material available.

Class GASTROPODA

Molds and partial shells of at least three types of gastropods occur in the basal sandstone of the Azure Lake section of the Buttle Lake Formation, in association with pelecypods, bryozoans, brachiopods and plant fragments. They are all small forms. Preservation is not considered adequate to attempt even generic identification. Small unidentified gastropods also occur in the fossiliferous beds of the Horne Lake and Cowichan Lake areas. Most are silicified and fragmentary.

Phylum COELENTERATA

Class ANTHOZOA

Order TABULATA Milne-Edwards and Haime 1850

Family CHAETETIDAE Milne-Edwards and Haime 1850

Subfamily CHAETETINAE Milne-Edwards and Haime 1850

Genus CHAETETES Fischer in Eichwald 1829

CHAETETES sp.

Two specimens (UBC 20177, 20178) from Horne Lake, from Unit 7, Mt. Mark section, and talus, are referrable to this genus. Both are fragmentary, silicified coralla, the largest having dimensions of 30 by 25 by 20 mm. The corallites are small; the largest measured has a diameter of 0.5 mm. Closely spaced tabulae are visible in part of one specimen. No detailed information on the species is yet available, so no comparisons are made at the present time.

Family FAVOSITIDAE Dana 1846

Subfamily MICHELINIINAE Waagen and Wentzel 1886

Genus MICHELINIA de Koninck 1841

The differences between Michelinia and Pleurodictyum Goldfuss 1829 (i.e., mainly in tabular pattern /Hill and Stumm, 1956, p. 466/). Tabulae were not seen in the specimens mentioned below, so assignment to M. is tentative only.

MICHELINIA? sp. A.

Three silicified specimens of partial coralla of this genus, probably representing the same species, have been collected. Two (UBC 20175 and 20179) are from Locality 62-56-1, Horne Lake, and the other (UBC 20176) occurs at Locality 62-52-3, Cowichan Lake area. The largest portion of a corallum reaches dimensions of 25 by 18 mm., with corallites of 3 mm. diameter maximum. The smaller fragments are about 7 mm. across, with corallites of 1.5 mm. maximum diameter. Both types of corallum, the one with small corallites, the other with large-sized corallites, occur in the same locality (62-56-1), so are regarded here as probably being variants of the same species. The state of preservation of these specimens is poor. Detailed analysis of the species has not been completed, so comparisons with described, superficially similar species is not warranted.

MICHELINIA? sp. B.

A single specimen (UBC 20186) of a corallum with corallites of distinctly larger average size than those of the species mentioned above, and very thin walls, was found in the limestones of Locality 60-H-2, Horne Lake. The corallite diameters are 5 to 7 mm., walls are 0.2 to 0.3 mm. in thickness. No tabulae are visible.

The material available is insufficient for precise comparisons with other described species. It may be noted, however, that a species with large (7 to 10 mm. diameters) corallites from the Yukon, M. harkeri Nelson 1962b (p. 957, pl. 37, figs. 8-11; text fig. 1e, f, 2e) has much thicker walls (0.5 mm.).

Family AULOPORIDAE Milne-Edwards and Haime 1851

Subfamily AULOPORINAE Milne-Edwards and Haime 1851

Genus CLADOCHONUS M'Coy 1847

CLADOCHONUS sp.

Plate IV, Figure 10.

A species of this genus has been identified in specimens (UBC 20097-20100) from Locality 61-35-5F (Buttle Lake), Locality 62-58-1F (Horne Lake) and Locality 62-48-2F (Cowichan area). The largest specimen is 30 mm. in length. Corallites are 5 to 6 mm. in length; diameters are from 1.5 at base to 2.5 at the calice. Calices open alternately at different sides, giving the corallum a zig-zag form. A Russian species, C. michelini Edwards and Haime, illustrated by Stuckenberg (1898, p. 354, pl. 5, figs. 15a-b) appears similar to the Vancouver Island Cladochonus sp. The longitudinal striations present on C. striatus Hill (1942, p. 70, pl. 2, fig. 11) from the Lower Permian of Western Australia, are not evident on Cladochonus sp. The corallites are shorter than those of C. shawi Wilson and Langenheim (1962, p. 514, pl. 89, figs. 3-10) from the Lower Permian of Nevada. The latter species also differs from Cladochonus sp. in having corallites which all face in the same direction; this may be an environmental variation, rather than a specific characteristic. The Vancouver Island material may well belong to a new species; the examination of more complete coralla, with better preservation is necessary before a more precise definition is possible.

Order RUGOSA Milne-Edwards and Haime 1850

In each of the areas studied, a few poorly-preserved solitary rugose corals have been found. A few of the silicified forms may yield diagnostic detail with serial sectioning. Until such detailed studies are completed, the forms present cannot be identified even generically with any confidence. The occurrence of such fossils is mentioned here only to complete the listing of main elements present in the fauna. Several different genera are undoubtedly present.

Phylum BRYOZOA

Generic names have been revised, where necessary, to conform with the Treatiseon Invertebrate Paleontology volume of Bryozoa (Bassler, 1953).

Subphylum ECTOPROCTA

Class GYMNOLAEMATA

Order TREPOSTOMATA

Suborder AMALGAMATA

Family STENOPORIDAE Waagen and Wentzel 1886

Genus STENOPORA Lonsdale 1844

STENOPORA PROLIFICA (Fritz)

Plate IV, Figure 7.

1932 Ulrichotrypa prolifica FRITZ, p. 94, pl. 1, figs. 1-3.
1963 Stenopora prolifica (Fritz), YOLE, pl. 1, fig. 10.

The observed zoarial and zooecial characteristics of the numerous specimens available agree in most respects with those described by Fritz. The oval zooecia measure 0.2 x 0.1 mm., with about 6 zooecia in 2 mm. longitudinally. The arrangement of both megacanthopores and micracanthopores is as regular as suggested by Fritz; Fritz's Figure 2 of Plate 1 illustrates the distribution of acanthopores as seen in the present specimens.

This species is very common in the writer's collections from Unit 11 (Specimens UBC 20105-20107, 20109-20111, 20115, 20116) and is also present in Unit 1 (UBC 20108), of the Azure Lake section of the Buttle Lake Formation. Preservation is good; most specimens are fragmentary zoaria, weathering out on the surface of dark dolomitic

limestone. The majority of specimens are flattened in the bedding planes, and some are crushed.

To the writer's knowledge, this species has not been described from other Permian localities, nor is it closely comparable to other described species of the genus.

Order CRYPTOSTOMATA

Family RHABDOMESIDAE Vine 1883

Genus STREBLASCOPORA Bassler 1952

STREBLASCOPORA PULCHRA (Fritz)

Plate V, Figure 10.

1932 Streblotrypa pulchra FRITZ, p. 97, pl. 1, figs. 6, 9-10.
?1943 Streblotrypa browni Etheridge. CROCKFORD, p. 147, pl. 3, figs. 3-6.
?1944 Streblotrypa marmionensis Etheridge. CROCKFORD, p. 168, pl. 5, figs. 10-11; text figs. 31-34.
?1961 Streblascopora delicatula SAKAGAMI, p. 52, pl. 25, figs. 7-10, pl. 26, figs. 1-18; pl. 27, figs. 1-5.

Fragments of this species, up to 20 mm. in length, are rare but distinctive elements of the bryozoan faunules of the areas studied. The characteristic arrangement of mesopores, in two longitudinal rows, with three to four pores in each row and sometimes an additional pore between the distal pair in sequence, is evident in all specimens. The oval zooecia, arranged in vertical rows, have apertures measuring about 0.2 x 0.15 mm.

The specimens (UBC 20112-20113, 20117) from the Buttle Lake Formation (Unit 11) are well preserved in dark dolomitic limestone. Fragments of this species have also been identified in thin sections of limestone from the Horne Lake area, Locality 62-57-4F (Unit 24 of the Mt. Mark section). In thin sections of limestones from the Cowichan area, Localities 61-38-13, 61-43-A3 and 62-48-2F, fragments questionably assignable to this species have been found.

Fritz (1932, p. 97) noted the similarity of her species to S. germana (Bassler). Crockford (1944a, p. 168; 1957, p. 80) places

S. germana in questionable synonymy with S. marmionensis (Etheridge), stating (1957, p. 81) that they appear "identical". The dimensions and micro-measurements of S. marmionensis (as given in Crockford, 1944a, p. 168, pl. 5, figs. 10-11; text figs. 31-34) are very similar to those of S. pulchra. The main differences seem to be in the absence of superior hemisepta in S. marmionensis, and greater range in the numbers of mesopores of the latter species. Crockford states (p. 109), however, the number of mesopores per interzooecial space is extremely variable. In addition, the hemisepta of S. pulchra are very poorly developed, as indicated by Fritz's illustration (pl. 1, fig. 10). Crockford (1943, p. 147) described S. browni (Etheridge), noting the "striking resemblance" to S. pulchra, from which it differed in slightly more widely spaced zooecia. From S. marmiomensis, Crockford distinguished S. browni on the basis of hexagonal ridges enclosing the interzooecial spaces of the latter species. The longitudinal ridges separating the zooecial rows of S. marmionensis are apparently sometimes sinuous (Crockford, 1944, p. 169), and in certain specimens assigned to this species (e.g., holotype, Crockford, 1944, pl. 5, fig. 11), this results in ridges almost identical in appearance to those said to characterize S. browni and S. pulchra. It thus appears to the present writer that these three species are not easily differentiated, and may in fact be synonymous. If Crockford's diagnosis of S. germana is correct, then this species also may be synonymous with S. browni Etheridge 1907.

The Japanese species S. delicatula Sakagami 1961 (p. 52, pl. 25, figs. 7-10; pl. 26, figs. 1-18; pl. 27, figs. 1-5) is described as differing from S. pulchra in the greater number of tubes in the axial bundle. Yet Sakagami states that the number of tubes varies

from 40 to 80, and certain of his illustrations (e.g., the longitudinal sections shown in pl. 26, figs. 5-6) show about the same number of axial tubes as does Fritz's specimen in her pl. 1, fig. 10 of S. pulchra. It thus seems possible that S. delicatula and S. pulchra are synonymous.

The close similarities between the species mentioned above are obvious. To clarify the status of these species, reference to type material is probably necessary. Until such precise comparisons can be made, the writer prefers to refer to the Vancouver Island species under Fritz's specific name.

Genus RHABDOMESON Young and Young 1874

RHABDOMESON sp.

Specimen UBC 20114, from the Unit 1 of the Buttle Lake Formation type section is a fragment of a zoarium assignable to this genus. It occurs in dark, fine-grained impure limestone, and is associated with numerous fragments of ramose and fenestrate bryozoans. The zoarium is 3 mm. long, 1.1 mm. wide, with an axial tube of 0.4 mm. diameter. Zooecial apertures measure approximately 0.2 x 0.1 mm.; their arrangement and spacing is not determinable on this poorly preserved specimen.

Small fragments of a similar species are evident in thin sections of limestones from the Cowichan area, Localities 61-39-1 and 62-48-2F.

In zooecial dimensions, diameter of axial tube, and general appearance, Rhabdomeson sp. is similar to R. mammillata (Bretnall),

as described and illustrated by Crockford (1944c, p. 166, pl. 14, fig. 14; text figs. 39-41).

Genus NICKLESOPORA Bassler 1952

Bassler (1952) erected the genera Nicklesopora and Saffordotaxis to include species which did not agree in acanthopore pattern with the genotype of Rhombopora. The latter characteristically has "micracanthopores around each aperture and a megacanthopore at the distal edge of each" (Bassler, 1953, p. G134). Nicklesopora lacks megacanthopores, and has "a single row of micracanthopores around each aperture" (Bassler, 1953, p. G133). The species discussed below cannot belong to Rhombopora sensu stricto, because of the lack of megacanthopores. The numerous scattered micracanthopores do not fit Bassler's definition of Nicklesopora, because of the irregularly distributed numerous micracanthopores around each aperture. The Vancouver Island form is questionably assigned to Nicklesopora, which, more than other described genera, has characteristics closely resembling those of N.? porifera. It may eventually be necessary to erect a new genus to accommodate N.? porifera.

NICKLESOPORA? PORIFERA (Fritz)

1932 Rhombopora porifera FRITZ, p. 96, pl. 1, figs. 4-5, 7-8.
?1961 Rhombopora? sp. indet. SAKAGAMI, p. 51, pl. 18, figs. 5-6.

A single specimen (UBC 20119) from Unit 11, Buttle Lake Formation, is referrable to this species on the basis of its micromeasurements and overall dimensions.

Rhombopora? sp. Sakagami appears very similar in the features described and illustrated by two sections only. Sakagami indicates (p. 51) that megacanthopores are "indistinct". The illustrations (pl. 18, figs. 5-6) do not show any megacanthopores; if they are actually not present, the similarity to N.? porifera is very close.

Genus CLAUSOTRYPA Bassler 1929

CLAUSOTRYPA SPINOSA Fritz

Plate V, Figure 12.

1932 Clausotrypa spinosa FRITZ, p. 97, pl. 1, fig. 11, pl. 2, figs. 3-4, 9.

Although Fritz found this species to be one of the most abundant in the collections from Buttle Lake, the present writer's collection apparently contain only rare fragments of the species. Some of the numerous indeterminate, less-well preserved ramose bryozoan fragments present may, however, include representatives of Fritz's species. Two specimens (UBC 20118, 20120) from the Azure Lake section, Units 1 and 11, Buttle Lake Formation, have been assigned to this species. In thin sections from Horne Lake (Localities 62-56-2, 62-57-4) and Cowichan area (Locality 61-38-1), transverse sections of a species of Clausotrypa, very similar, and perhaps identical, to C. spinosa have been recognized. Fritz compared her species to C. conferta Bassler, from the Permian of Timor, from which the Vancouver Island species was differentiated by a greater number of acanthopores.

From C. exillis Sakagami (1961, p. 52, pl. 25, fig. 6), C. spinosa is distinguishable by larger diameter and greater size of the zooecial apertures.

The two specimens from Buttle Lake area on which measurements can be made agree in all respects to the description given by Fritz. The zooecial apertures are oval, with average dimensions of 0.3 x 0.2 mm.

Order FENESTRATA Elias and Condra 1957

Family FENESTELLIDAE King 1850

Genus FENESTELLA Lonsdale 1839

FENESTELLA cf. F. PARVIUSCULA Bassler

Several specimens from the writer's collections have meshwork formulae similar to that of F. parviuscula Bassler 1929 (p. 76, pl. 17, figs. 8-13). The material consists of small fragments of zoaria, usually with only obverse surfaces visible. The only specimen on which significant measurements were possible (UBC 20122) has a partial meshwork formula 24/16//?/?. This is slightly different from that of F. parviuscula Bassler (20/18/18/18); it appears closer to that of a Texas species, F. cf. F. parviuscula Bassler, noted by Elias and Condra (1957, table 10), with a formulae 20-24/17-18//18/19-23.

The Vancouver Island specimen is from Unit 11 of the type section of the Buttle Lake Formation. Fritz (1932, p. 99) assigned a single specimen from the same area to Bassler's species.

Crockford placed F. parviuscula in the synonymy of F. horologia Bretnall 1926 (Crockford, 1957, p. 57), which suggests that F. cf. F. parviuscula should perhaps also be referred to Bretnall's species. A species from Japan described by Sakagami as F. nomatae Sak. 1961 (p. 34, pl. 15, fig. 3, text fig. 5) appears to fall within the range of variation of F. parviuscula, as indicated by Elias and Condra's table 10, 1957; it has a meshwork formula of 20-22/16-17//16-17/?.

FENESTELLA sp.

?1932 Fenestella cf. pulchradorsalis Bassler. FRITZ, p. 99.

Fritz tentatively assigned to this species several specimens from the Buttle Lake area, noting that in certain of their measurements, the fossils differed from those of Bassler's Timor species. The meshwork formula of F. pulchradorsalis Bassler 1929 (p. 74, pl. 16, figs. 10-13; pl. 18, figs. 1-4) is 13/10//15/0, while that of Fritz's species is 16/10//15-20/?. Elias (1937, p. 322, table 3) places F. cf. pulchradorsalis Fritz in the synonymy of the Upper Pennsylvanian species F. subrudis Condra 1902, which has a meshwork formula of 16/12//17-18/0.

In the present writer's collections from the Buttle Lake area, several specimens (UBC 20121, 20123, 20124, 20148, 20149) apparently similar to the group of species mentioned above occur. The meshwork formula appears to be 14-17/10-11//15-16/?. The zooecial spacing is 3 to 4 per fenestrule, as in Fritz's species. The reverse sides of these specimens do not show the granular texture mentioned by Fritz; however, this character does not seem to be of specific significance, as many species show a granular or finely pustular reverse surface (Elias and Condra, 1957). Fritz considered that the differences from F. pulchradorsalis visible in her species did not warrant the description of a new species. It is the present writer's opinion that the material in his collections is conspecific with Fritz's specimens, and that it does not belong in any of the species mentioned above.

The meshwork formula of Fenestella sp. and the other visible features suggest that it belongs to the group of F. basleoensis Elias and Condra (1957, p. 78, table 4). The number of fenestrules in 10 mm.

shown by the Vancouver Island species tends to suggest its relationship with the Upper Carboniferous species of Elias and Condra's species group. The other measurements are more closely akin to the Permian species of this group.

Certain of the specimens assigned here to Fenestella sp. have a coarse enough mesh to be very similar to F. basleoensis Bassler (14/18//16/12). However, none has features precisely comparable with Bassler's species. Fritz (1932, p. 99) found F. basleoensis "not uncommon" in one limestone slab from Buttle Lake area.

All of the specimens referred to Fenestella sp. are from Unit 11 of the Buttle Lake Formation type section, where they occur in dark dolomitic limestone of the Buttle Lake Formation. Small fragments of zoaria tentatively assigned to the species occur in limestones of the Horne Lake area, Locality 60-H-2.

Genus POLYPORA McCoy 1844

POLYPORA cf. P. CONSANGUINEA Bassler

Plate V, Figure 11.

?1932 Polypora consanguinea Bassler. FRITZ, p. 100.

Several large fragments (specimens UBC 20125, 20126) of zoaria displaying the typical measurements of P. consanguinea Bassler (1929, p. 79, pl. 19, figs. 5-10) are found in dolomitic limestone of Unit 11 of the type section, Buttle Lake Formation. The only difference discernable between these specimens and those described from the same area by Fritz (1932, p. 100) is that the branches are spaced 5 to 6 in 10 mm., rather than 5 in 10 mm., as in Fritz's specimen. Only a small portion of one of the fragments shows the obverse side, on which 5 rows of apertures can be seen; the spacing of the apertures appears to be approximately 15 to 16 in 5 mm., but this measurement cannot be made with any great degree of accuracy on this material.

This species is very similar to P. cyclopora Eichwald, as illustrated by Licharew et al (1939, p. 66, 73; pl. 13, figs. 9a, b), which appears to differ in having a slightly greater number of branches (6 to 7) in 10 mm. From P. montuosa (Laseron), described in Crockford, 1941, (p. 409, pl. 18, fig. 4; pl. 19, fig. 2; table 2), P. cf. P. consanguinea can be distinguished by its lower number of rows of zooecia, and more closely spaced zooecia. It differs from P. vancouverensis Fritz (1932, p. 100; pl. 2, figs. 1-2) a slightly finer mesh, and more widely spaced zooecial apertures.

POLYPORA cf. P. SYKESI (Koninck)

1932 Polypora sykesi (Koninck). FRITZ, p. 102.

One fragment (UBC 20127) of a zoarium from Unit 11 of the type section, Buttle Lake Formation, is questionably compared to this species. In its measurements it agrees with the specimens from the same area described by Fritz, and displays longitudinal striations on the reverse side, the only side seen. Branches number 8 in 10 mm., fenestrules 7 in 10 mm.

Genus PROTORETEPORA Koninck 1876

PROTORETEPORA cf. P. HAIMEANA (Koninck)

Plate IV, Figure 8.

1932 Phyllopora cf. haimeana Koninck, FRITZ, p. 103, pl. 3, figs. 1-4.

Several zoarial fragments in the collections from Buttle Lake area, with a maximum size of 50 x 35 mm., represent the same species as was tentatively assigned to Koninck's P. haimeana 1863a (p. 6, pl. 1, fig. 3) by Fritz (1932, p. 103, pl. 3, figs. 1-4). Most of the fragments show only the reverse side of the zoarium, but some display features of the obverse side. The fenestrules are round to slightly oval, numbering 5 in 10 mm. Branches number 5 to 7 in 10 mm., and are approximately 1 mm. thick. Four rows of zooecia are present. Zoocial apertures measure 0.2 x 0.15 mm., with 20 in 5 mm. Just before

branching occurs, 5 to 6 rows of zooecia may occur. A somewhat similar species, P. flexuosa Crockford (1957, p. 69, pl. 18, figs. 4-5), appears to have a slightly finer mesh, finer branches, more rows of zoocia, and wider spacing of the zooecia (12-13 in 5 mm.). Fritz considered that the Vancouver Island form might represent a new species. Reference to type material of P. haimeana and other similar species is probably required to determine the proper status of P. cf. P. haimeana.

The specimens (UBC 20128-20133, 20187) are all from the dolomitic limestone horizon of Locality 61-35-5F. They are oriented in the rock with the plane of the fronds parallel or subparallel to the bedding planes. Associated fossils are mainly small fragments of other fenestrate and ramose bryozoans.

Family ACANTHOCLADIIDAE Zittel 1880

Genus ACANTHOCLADIA King 1849

ACANTHOCLADIA MULTIPORA Fritz

Plate IV, Figure 9.

1932 Acanthocladia multipora FRITZ, p. 104, pl. 3, figs. 6, 9.

Several fragmentary zoaria of this species (UBC 20134-20138) were found in Unit 11 of the Buttle Lake Formation type section. Main stems are 1 to 2 mm. wide; branches taper distally from 1 mm. to 0.8 mm., and occur regularly along the main branch at centre to centre distances of 2.5 to 3.0 mm. Preservation of the obverse side is not good, but in at least one fragment, the 7 rows distinctive of the species are evident.

The zooecia apertures measure approximately 0.2 x 0.15 mm. The reverse side is smooth.

Fritz mentioned the external similarity of this species to A. rectifurcata Bassler, from Timor, from which it differs in greater number of zooecial rows. A. guadalupensis? Girty (1908, pl. 18, figs. 16-16b), appears similar in overall measurements to A. multipora, but the features of the obverse side are not known.

Genus PENNIRETEPORA D'Orbigny 1849

PENNIRETEPORA GRANDIS (Fritz)

Plate V, Figure 14.

1932 Pinnatopora grandis FRITZ, p. 104, pl. 3, figs. 5, 7.

Two specimens assignable to this species are present in the writer's collections. The main branch, or midrib, is 1.2 to 1.3 mm. in width, slightly less than the figure (1.5 mm.) given for the type material; the other measurements and observations are so close to those cited by Fritz that there seems to be no doubt that the same species is represented in both collections. Lateral branches are 0.7 mm. in width; pinnate branchlets 0.4 mm. wide are spaced 1.2 mm. (centre to centre) apart, with 5 in 5 mm. Zooecial apertures measure 0.2 to 0.3 x 0.15 to 0.2 mm., with 10 in 5 mm. The keel nodes and longitudinal striae on the obverse side mentioned by Fritz are evident on both specimens. The reverse side is faintly striated.

An Upper Permian species from Japan, P. iwaizakiensis Sakagami (1961, p. 46, pl. 24, fig. 3; text fig. 7) approaches P. grandis in width of midrib, but differs in having shorter distances between

branchlets, and greater number of zooecia in 5 mm. P. triporosa Crockford 1944c (p. 161, pl. 5, fig. 4; text fig. 49), has thinner branches (less than 0.67 mm.), and smaller apertures than P. grandis; the Australian species also has a strong tendency towards alternating, rather than opposite, branches.

One specimen from the Azure Lake section, Unit 11, (UBC 20139) and one from Locality 60-H-2, Horne Lake, (UBC 20140) comprise the representatives of this species. The former is associated with fragments of many other species of bryozoa in dolomitic limestone. The Horne Lake specimen is associated with other bryozoa and brachiopods in a coarse, crinoidal and tuffaceous? limestone.

Family SULCORETEPORIDAE Bassler 1935

Genus SULCORETEPORA D'Orbigny 1849

SULCORETEPORA sp.

Plate V, Figure 15.

A species of Sulcoretepora is a common fossil in limestones from locality 60-H-2, Horne Lake, where it is found on weathered surfaces of rock slabs, associated with many other bryozoans, brachiopods and other fossils.

The species has branches of maximum width 3.5 mm., and thickness 1.3 mm.; in the thickest branches, the number of rows of zooecia is 10. Bifurcation of the main branches reduces the width to 2.5 mm., and the rows of zooecia to 6 or 7. The zooecia are 0.2 to 0.23 x 0.1 to 1.5 mm. at the apertures; on the main branches, 9 to 10 occur in 5 mm.; on the narrower branches there are 7 to 8 zooecia in 5 mm. Two

specimens from Horne Lake (UBC 20141, 20142) show these external features well. Several random transverse sections in thin section probably also belong to this species. No longitudinal or tangential sections have yet been obtained.

A Lower Permian species from Japan, S. nipponica Sakagami (1961, p. 55, pl. 28, figs. 5-8; pl. 29, figs. 1-3; pl. 30, figs. 1-7) is somewhat similar to the Vancouver Island fossils. The Japanese species has fewer rows of zooecia (9), wider zooecial spacing (6-7 in 5 mm.) and larger apertures (0.31 x 0.17). "Sulcoretepora" meridianus (Etheridge) 1926, described and illustrated by Crockford (1944c, p. 156, pl. 4, fig. 6; text figs. 29, 30) has smaller branches, smaller apertures (0.16 x 0.11), and fewer rows of zooecia than Sulcoretepora sp. In "S". meridianus zooecia are more closely spaced (10-11 in 5 mm.).

Order CYCLOSTOMATA Busk 1852

Suborder CERAMOPOROIDEA Bassler 1913

Family GONIOCLADIIDAE Nikiforova 1938

Genus GONIOCLADIA Etheridge 1876

GONIOCLADIA INTERMEDIA Fritz

Plate V, Figure 13.

1932 Goniocladia intermedia FRITZ, p. 106, pl. 3, figs. 8, 10.

Several specimens (UBC 20143-20146) from Unit 11 of the Azure Lake section, and one (UBC 20147) from Locality 60-H-2, Horne Lake, are tentatively assigned to Fritz' species (1932, p. 106, pl. 3, figs. 8, 10).

The anastomosing branches, with rounded triangular cross-section, vary from 1 mm. to 2 mm. in width, and from 1.5 to 2.0 mm. in thickness. The size of fenestrules is variable. In some specimens, they are quite regular and measure 8 to 9 x 2.5 to 3.5 mm.; in other they vary in size from 20 x 3.5 and 6 x 4 mm. at the extremes, and from hexagonal to irregular in shape. In all the specimens observed, there are three rows of zooecia on each side of the median keel. The zooecia number 6 to 7 in 5 mm., in contrast to the more closely spaced apertures indicated by Fritz for G. intermedia (about 10 in 5 mm.). The apertures are circular to slightly oval in shape with diameters of 0.2 to 0.3 mm.

Fragments of zoaria showing the extremes of variation mentioned above occur in the same small slab of dolomitic limestone from Azure Lake. It is considered that they therefore represent intraspecific variants.

Only two specimens were available to Fritz, whose illustrations of these suggest rather poor preservation of the surface details. The specimens described above probably belong to Fritz's species, as they come from the same area and horizon, and have significant features in common.

Fritz stated that G. intermedia was closely similar to G. indica Waagen and Pichl, from the Salt Range, and to G. indicalaxa Bassler from the Permian of Timor.

A silicified fragment (UBC 20147) of a zoarium of a species possibly the same as that of the Buttle Lake area was found in limestone from Locality 60-H-2, Horne Lake. Micromeasurements similar to those given above are easily obtained on the specimen. The size and shape of the fenestrules are not determinable from this single fragment, but apparently do not fall outside of the range exhibited by G. intermedia.

Transverse sections of zoaria tentatively assignable to this species occur in thin sections from the Cowichan area, Localities 61-38-19, 61-39-1, 62-42-12, and 62-43A-3.

Family FISTULIPORIDAE Ulrich 1882

Thin sections of limestone from Localities 61-39-1, 62-43-12 (Cowichan area) and 62-56-2 (Horne Lake) contain fragments of massive bryozoans with fistuliporoid microstructure. No precise determinations have yet been possible for this material.

POSITION UNCERTAIN

Many fragments of bryozoans remain to be identified in these collections. Without doubt, many more genera and species than described above occur in this material and further work should yield additional valuable information.

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APPENDIX

The following are measured sections of the Upper Division of the Sicker Group, shown in diagrammatic form in Figure 6.

MT. MARK SECTION

Measured on cliff face, 1/2 mile southeast of Mt. Mark (Peak 3,165).

Overlying rocks: Vancouver Group - pillow basalt

Unit	Thickness (Feet)	Cumulative
26 Covered interval .	30	1525
25 Limestone, medium-to coarse-grained, crinoidal; cherty stringers, 1" to 1' thick, spaced from few inches to several feet; medium-bedded at base, thick to massive at top. Silicified crinoidal debris.	290	1495
24 Limestone, fine-to medium-grained, cherty to tuffaceous?, thin-bedded (2" to 4"); cherty stringers, 1/2" to 2", grey to bright red. Few coquinoid layers of partly silicified crinoidal debris, brachiopods, bryozoans.	85	1205
23 Limestone, slightly sandy, medium-to coarse-grained, light grey to green and maroon; tuffaceous? partings up to 1/2", spaced 1/2" to 6"; small-scale cross laminations. At top, several pebbly zones, 1" to 4" thick, 1' to 2' apart. Pebbles 1/4" to 2", green and maroon tuffs and tuffaceous limestone, and large productid shells.	55	1120
22 Covered interval .	30	1065
21 Limestone, fine-to medium-grained, light grey to greenish-grey, medium-to thick-bedded, with many closely spaced tuffaceous? partings; few stringers of grey chert, less than 1/2" thick.	25	1035
20 Covered interval. Underlain by medium-to coarse-grained diabase; sill-like intrusion, estimated at 200 feet thick. Base not seen.	10	1020

19		135 (Est.)	1010
Limestone, impure, brown weathering, as below.			
18		325	875
Limestone and calcareous tuffs, thinly, irregularly interbedded; grey, pale green and maroon fresh surface, dark grey-brown weathered surface. Basal 50 feet gradational into unit below, as light grey, crinoidal limestone beds 10 feet to 2 feet thick gradually diminish upwards. Molds of crinoidal and bryozoan debris etched into few thin layers.			
17		40	550
Limestone, medium-to coarse-grained, crinoidal, light grey to white weathered surface, light grey fresh surface.			
16		15	510
Limestone, tuffaceous, and calcareous tuff, dark grey to greenish grey, with dark grey-brown weathered surface. Lower contact gradational over few feet; upper contact sharp. Abundant bryozoans, few brachiopods.			
15		10	495
Limestone, medium-to coarse-grained, crinoidal, light grey weathered surface.			
14		80	485
Limestone, fine-grained, pale green to maroon, with dark grey weathered surface; thick to massive bedded, but numerous regular to irregular varicoloured tuffaceous partings give blocky to slabby split. Partially silicified bryozoans, corals and brachiopods in more impure layers; bryozoans mainly aligned in bedding planes.			
13		65	405
Limestone, medium-to coarse-grained, crinoidal, massive. Rare chert lenses near top. Dyke of fine-grained greenstone.			
12		5	340
Limestone, fine-grained, tuffaceous, buff and maroon, laminated, as in Unit 10 below.			
11		15	335
Limestone, medium-to coarse-grained, crinoidal, massive. Few large, silicified brachiopods.			
10		5	320
Limestone or calcareous tuff, laminated maroon and buff, fine-grained, medium bedded, with compositional banding 1/4" to 2". Scattered coarse crinoidal debris and bryozoans.			

9	105	315
Limestone, medium-to coarse-grained, crinoidal, with thin tuffaceous partings in upper part; abundant dark chert stringers in basal 50 feet, massive in upper part.		
8	135	210
Limestone, medium-to coarse-grained, light to medium grey, buff mottled, crinoidal; abundant cherty stringers in basal part, massive in upper part. Chert is in lenses, 1" to 6" thick, 2" to 2' apart, in zones up to 20 feet apart. Few partially silicified brachiopods.		
7	5	75
Limestone, fine-grained, tuffaceous, grey, green and maroon. Abundant brachiopods, few rugose solitary corals, one tabulate coral, crinoidal debris.		
6	20	70
Limestone, coarse-grained, crinoidal, thick bedded. Few brachiopods and corals.		
5	2	50
Limestone, fine-grained, tuffaceous. Abundant fossil debris in patches.		
4	13	48
Limestone, coarse-grained, crinoidal, grey, thick bedded. Few partially silicified brachiopods.		
3	5	35
Limestone, fine-grained, tuffaceous, green and maroon, medium-bedded. Abundant fossils, brachiopods, bryozoans, solitary corals.		
2	15	30
Limestone, coarse-grained, crinoidal, thick bedded, grey.		
1	15	15
Tuff, calcareous, maroon and green, thin to medium bedded, fossiliferous. Upper part coquina of brachiopods, bryozoans and solitary corals. Grades into overlying unit. Base not seen.		

Underlain by 100 foot covered interval, followed by fine-grained, green tuffs or tuffaceous sediments of Lower Division, Sicker Group.

FAIRSERVICE MOUNTAIN SECTION

Measured in series of gullies on northeast face of Fairservice Mountain, 3¼ miles southeast of Lake Cowichan Post Office.

Overlying rocks: Vancouver Group - fine-grained green volcanic rock.

Unit	Thickness (Feet)	Cumulative
33 Covered interval.	15	2580
32 Chert and limestone. Chert, black, thin to medium bedded, with lenses of limestone, fine-grained, grey, fossiliferous. Crinoidal debris, bryozoans, auloporoid and colonial tabulate coral, partially silicified. Contorted and cut by numerous calcite veinlets.	5	2565
31 Mainly covered. Spotty outcrops of thin bedded chert and minor limestone along strike to southeast.	675	2560
30 Limestone, medium-to coarse-grained, crinoidal; medium bedded at base, thick to massive at top; medium to dark grey, with light to medium grey weathered surface; highly siliceous in basal 10 feet and upper 20 feet. Few partly silicified brachiopods. (Schwagerinid present in thin section from this unit.)	112	1885
29 Chert, dark grey to black, thinly bedded.	10	1773
28 Covered interval - probably thin-bedded chert.	201	1763
27 Limestone, coarse-grained, crinoidal; breccia in part, with clasts of limestone and green, fine-grained volcanic rocks; massive. Few partly silicified brachiopods in basal 20 feet. Underlain by massive, fine-grained, green intrusive rock, sill-like? about 20 feet thickness exposed.	182	1562
26 Mainly covered. Scattered small outcrops of thin bedded chert and limestone, some brecciated.	93	1380

25 Chert and limestone, interbedded, thin to medium bedded, (2" to 1'). Chert dark grey to black, fine-grained to cryptocrystalline, colour-laminated in part. Limestone fine-to medium-grained, grey, with light to medium grey weathered surface; siliceous in part, grading into chert in places. Contorted in part.	145	1287
24 Limestone, coarse-grained, crinoidal, grey. Scattered bryozoan fragments in upper 2".	2	1142
23 Chert and limestone, thin to medium bedded, as above. Poorly exposed.	124	1140
22 Limestone, coarse-grained, crinoidal, grey. Scattered bryozoans. One small ribbed brachiopod. Underlain by green, fine-grained intrusive; about 10 feet exposed.	3	1016
21 Chert and limestone, thinly bedded, as above. Contorted.	52	1013
20 Limestone, coarse-grained, crinoidal, grey. Abundant ramose, bryozoans, one ribbed brachiopod, partly silicified (Fusulinid in thin section from this unit).	4	961
19 Chert and siliceous limestone, as above, thin to medium bedded. Contorted in part.	58	957
18 Covered interval.	65	899
17 Chert and limestone, as above, thin to medium bedded, with few lenses of grey crinoidal limestone up to 1' thick, several feet long. Some of siliceous limestone units show graded textures. Poorly exposed.	104	834
16 Limestone, coarse-grained, crinoidal, grey; few thin partings near top.	8	730

15	Chert and limestone, as above, thinly bedded. Contorted.	97	722
14	Limestone, fine-to medium-grained, grey, medium bedded (6" - 18"); minor dark grey to black chert interbedded.	20	625
13	Covered interval.	130	605
12	Limestone and chert interbedded. Limestone, fine- to medium-grained, grey, siliceous in part, grading into chert. Chert dark grey to black, fine-grained to cryptocrystalline, colour laminated in part. Beds 2" to 1'. Lenses of medium-grained crinoidal limestone, 6" to 1' thick, near top. Fucoid-like markings on upper surfaces of some cherty beds.	35	475
11	Covered interval.	15	440
10	Chert and limestone interbedded. Chert black, cryptocrystalline. Limestone fine-grained to very fine-grained, dark grey. Thin bedded (1" - 4"). Contorted. Underlain by green, medium-grained crystalline intrusive, of which 20 feet exposed.	20	425
9	Covered interval.	15	405
8	Chert and siliceous limestone, thinly interbedded, as above.	10	390
7	Covered interval. Underlain by 50', mainly covered, with rubble of green, medium-grained, crystalline intrusive rock near middle.	25	380
6	Limestone, very fine-grained, grey to grey-brown siliceous, thin to medium bedded, with partings ¼" - ½" of green argillite.	5	355
5	Covered interval.	20	350

4 Limestone, siliceous, thin bedded as above.	10	330
3 Chert and siliceous limestone interbedded, dark grey to black, fine-grained to cryptocrystalline, in beds 3" to 1'.	80	320
2 Limestone, medium-to coarse-grained, crinoidal, grey, medium to thick bedded. Few buff-weathering siliceous bands, 1" to 4" thick. Abundant partly silicified bryozoans in thin zones near base.	90	240
1 Chert and siliceous limestone thinly interbedded, as in Unit 5. Base not seen.	150	150

Estimated 200 feet covered between base of section and outcrop of massive volcanic rocks of Lower Division.

AZURE LAKE SECTION

Measured west-southwest from ridge 1.8 miles south of peak of Mount McBride.

Overlying rocks: Vancouver Group - pillow lavas and intrusive diabase.

Unit	Thickness (Feet)	Cumulative
22 Tuffaceous? sedimentary rocks, very fine-to fine-grained, varicoloured (dark green to dark grey, with purplish and rusty weathered surfaces), thinly bedded. Top not seen. Underlain by sill-like intrusion of medium-grained green crystalline rock, gabbroic or diabasic, estimated to be 500 feet thick.	unknown, possibly 200	1250?
21 Limestone, coarse-grained, light grey, with pale buff weathered surface, crinoidal, thick bedded, with irregular nodules and beds of light grey chert, 1 inch to 3 inches thick, in zones 5 feet thick. Few poorly preserved brachiopods.	75	1050
20 Limestone, coarse-grained, crinoidal, as above, with 3 foot zone of chert nodules and irregular thin beds (1" - 3") in the middle.	50	975
19 Limestone, fine-to medium-grained, light grey with buff weathered surface, thin bedded, with chert nodules and irregular beds as above.	5	925
18 Limestone, coarse-grained crinoidal.	25	920
17 Limestone, fine-to medium-grained, cherty as in Unit 18.	8	895
16 Limestone, medium-to coarse-grained, crinoidal, thick bedded, with few thin zones of chert nodules and thin beds in middle 10 feet.	45	887
15 Limestone and chert as in Unit 16 and 18.	7	842

14	20	835
Limestone, fine-to medium-crystalline, light grey, with pale grey-buff weathered surface, massive.		
13	45	815
Limestone, coarse-grained, crinoidal, light grey fresh and weathered surfaces, thick bedded, with scattered chert as above.		
12	50	770
Limestone, fine-grained, light grey with buff weathered surface, medium bedded, with abundant chert nodules and irregular discontinuous beds, 1 inch to 3 inches.		
11	60	720
Dolomitic limestone, fine crystalline, medium to dark grey, with abundant dark grey to black chert in irregular beds 1 inch to 6 inches thick, spaced few inches to few feet apart. Abundantly fossiliferous; spiriferid and productid brachiopods dominant in lower half, fenestrate and ramose bryozoans dominant in upper half, but coquina of brachiopods in ten-foot zone 20 feet from top.		
10	200	660
Limestone, fine-grained, light grey, with abundant grey chert in thin, even beds near base, irregular to "honeycombed" layers grading into lenses near top, 3 inches to 1 foot in thickness, giving whole unit a thin to medium bedded appearance.		
Underlain, with sharp contact, by fine-to medium-grained green crystalline intrusive rock, a sill-like body, gabbroic or diabasic, estimated to occupy about 750 feet perpendicular to bedding of limestone.		
9	40	460
Limestone, fine-to medium-grained, light grey with white weathered surface, with chert, light grey to dark grey, in pinching and swelling beds, 3 inches to 1 foot thick spaced 4 inches to 2 feet apart, giving whole unit a thin to medium bedded appearance.		
Underlain by tongue of green basic intrusion, 20 feet thick, which merges with main mass of intrusion 200 feet south.		
8	200	420
Limestone and chert as above in Unit 9.		
7	50	220
Covered interval.		

6 Limestone, coarse-grained, light grey crinoidal, thick bedded (1½ to 6 feet).	35	170
5 Limestone, medium-to coarse-grained, crinoidal, bedding thick, poorly defined. Few brachiopods and solitary corals near base, partly silicified.	55	135
4 Covered interval.	50	80
3 Limestone, fine-grained, argillaceous?,dark grey. Scattered bryozoans.	10	30
2 Covered interval.	10	20
1 Sandstone, fine-to medium-grained, calcareous, grey with chocolate-brown weathered surface, thin to medium bedded (2 inches to 1 foot); few thin pebble lenses near base. Contact with underlying unit sharp, gently undulating. Brachiopods, pelecypods, gastropods, solitary corals and few silicified fusulinids. Plant fragments, carbonized.	10	10

Underlying unit medium-to coarse-grained tuffs, mottled green and maroon, and coarse, green volcanic breccias, of Lower Division, Sicker Group.

PLATE I

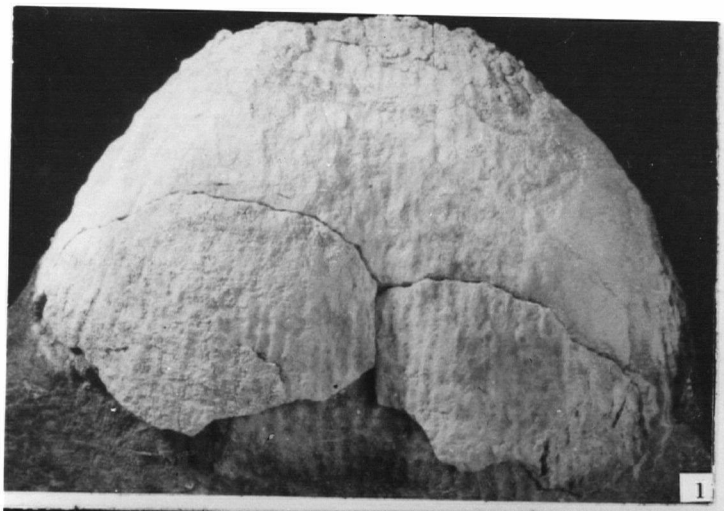
All specimens are from Unit 11 of the Buttle Lake Formation at the Azure Lake section. All figures are x 1 unless otherwise indicated.

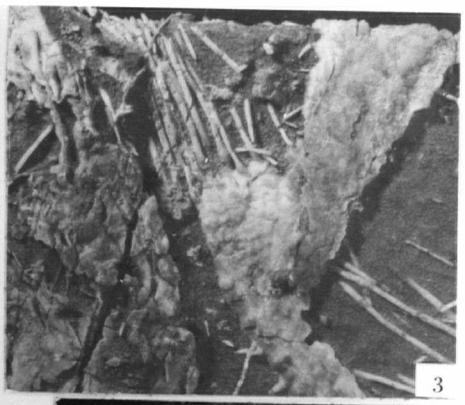
Figures 1 - 8, *Kochiproductus* n. sp.

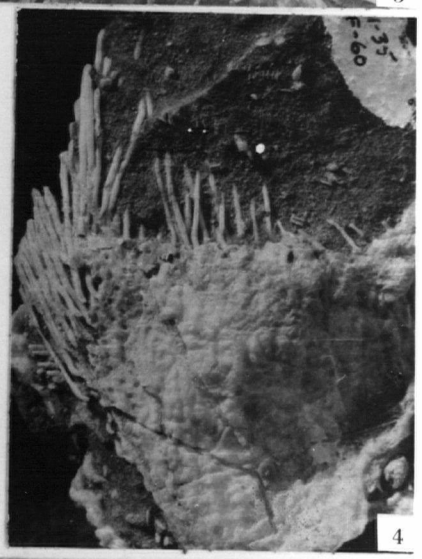
1. Pedicle view, Specimen UBC 20001.
2. Posterior view, UBC 20001.
3. Auricular spines, pedicle valve, UBC 20009.
4. Auricular spines, brachial view, UBC 20010.
5. Brachial valve, UBC 20002.
6. Cardinal process, UBC 20002, x 4.
7. Pedicle valve, with scattered surface spines, UBC 20005.
8. Cardinal process, median septum and antron, UBC 20011, x 3.

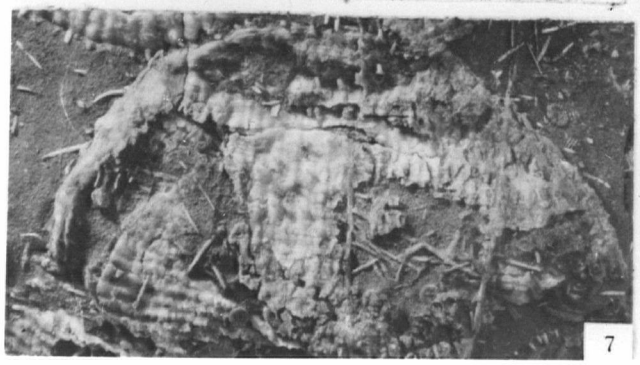
Figure 9, *Krotovia*? sp. A., interior pedicle valve, UBC 20065.

Figure 10, *Muirwoodia*? sp., pedicle view of partly exfoliated shell, UBC 20046.









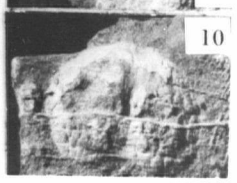


PLATE I

PLATE II

All specimens from Unit 11 of the Buttle Lake Formation, Azure Lake section. All figures x 1 unless otherwise indicated.

Figures 1 - 6, Neospirifer n. sp.

1. Internal view, pedicle valve and portion of brachial valve, Specimen UBC 20013.
2. Posterior view, UBC 20014.
3. Lateral view, UBC 20014.
4. Pedicle view, UBC 20029.
5. Pedicle view, partly exfoliated shell, UBC 20015.
6. Pedicle view, UBC 20016.

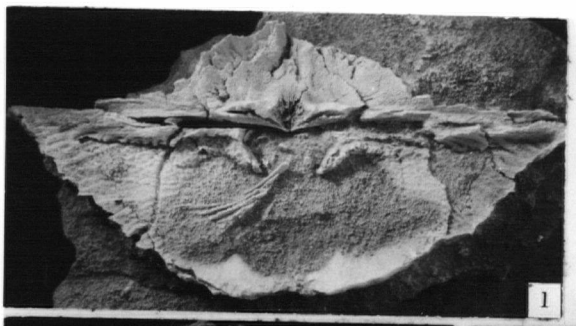
Figures 7 - 9, Antiquitonia sulcata Cooper.

7. Lateral view, UBC 20053.
8. Posterior view, UBC 20053.
9. Pedicle view, UBC 20054.

Figure 10, Hustedia meekana (Shumard), Pedicle view, UBC 20059.

Figures 11 - 13, Echinoconchus inexpectatus Cooper.

11. Pedicle view, UBC 20039, x 1.25.
12. Pedicle valve, partly exfoliated, showing spine rows, UBC 20037.
13. Interior view, pedicle valve, UBC 20039, x 1.5.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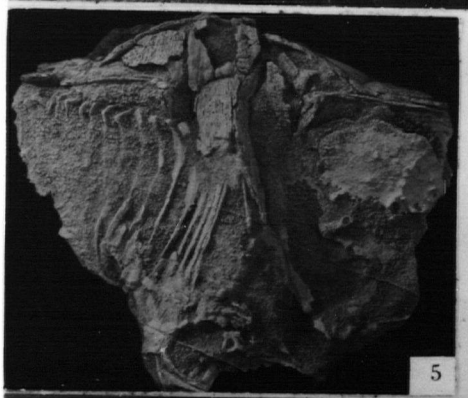
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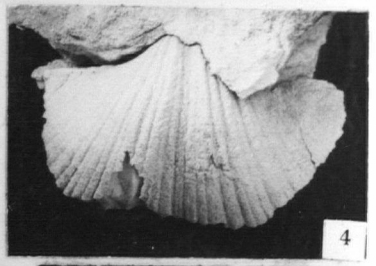
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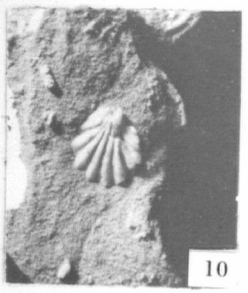
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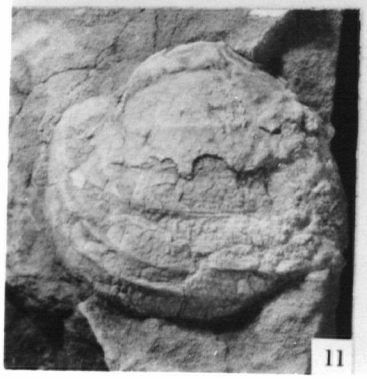
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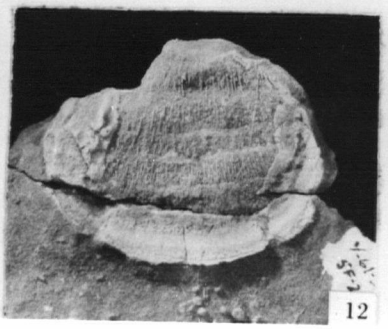
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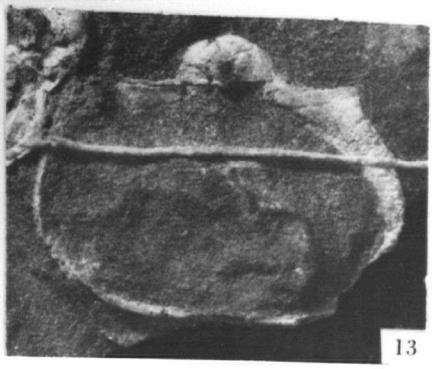

13

PLATE II

PLATE III
All figures x 1.

Figures 1 - 4, Spiriferella saranae (de Verneuil).

1. Pedicle view, Specimen UBC 20068, from Unit 21, Buttle Lake Formation, Azure Lake section.
2. Pedicle view, UBC 20069, Unit 21, Buttle Lake Formation, Azure Lake section.
3. Lateral view, UBC 20069.
4. Posterior view, UBC 20069.

Figures 5 - 10, Laevicamera n. sp.

5. Brachial view, UBC 20062, from Unit 11, Buttle Lake Formation, Azure Lake section.
6. Pedicle view, UBC 20062.
7. Anterior view, UBC 20062.
8. Posterior view, UBC 20062.
9. Lateral view, UBC 20062.
10. Pedicle view, UBC 20061, from Unit 11, Buttle Lake Formation, Azure Lake section.

Figure 11, Neospirifer sp., Pedicle view, UBC 20070, Unit 1, Buttle Lake Formation, Azure Lake section.

Figure 12, Ingelarella? sp. C, Brachial view, UBC 20079, from Unit 1, Buttle Lake Formation, Azure Lake section.

Figures 13 - 14, Ingelarella sp. A.

13. Part of brachial valve, UBC 20077, same locality as Fig. 12.
14. Pedicle view, UBC 20075, same locality as Fig. 12.

Figure 15, Krotovia? sp. B, pedicle view, UBC 20094, Unit 1, Buttle Lake Formation, Azure Lake section.

Figure 16, Squamularia? sp., external mold, brachial? valve, UBC 20095, Unit 1, Buttle Lake Formation, Azure Lake section.

Figures 17 - 18, Rhynchopora n. sp.

17. Pedicle view, UBC 20084, Unit 1, Buttle Lake Formation, Azure Lake section.
18. External mold, brachial? valve, UBC 20089, same locality as Fig. 17.

Figure 19, Chaenomya? sp., external mold, left valve, UBC 20160, Unit 1, Buttle Lake Formation, Azure Lake section.

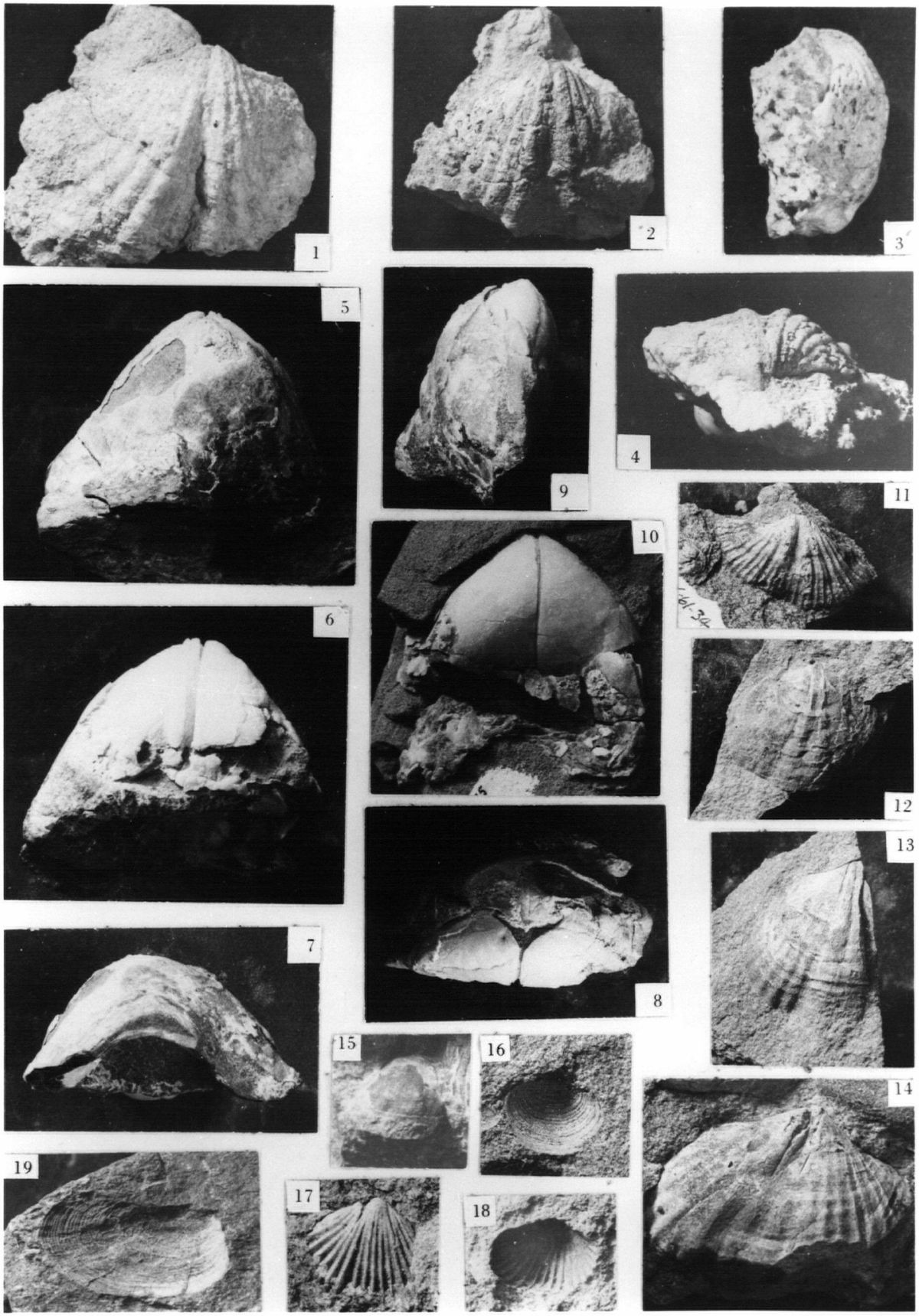


PLATE III

PLATE IV

All specimens except those of Figs. 1 - 4 and Fig. 6 are from Unit 11, Buttle Lake Formation, Azure Lake section. All figures except 6 and 11 are x 1.

Figures 1 - 4, Horridonia sp. A.

1. Lateral view, UBC 20200, from Horne Lake, talus below Mt. Mark section.
2. Posterior view, UBC 20200.
3. Pedicle view, UBC 20200.
4. Pedicle view, UBC 20201, same locality.

Figure 5, Horridonia sp. B, Part of pedicle valve, showing cardinal spines, UBC 20096.

Figure 6, Unidentified silicified fusulinid, UBC 20103, x 20, Unit 1, Buttle Lake Formation, Azure Lake section.

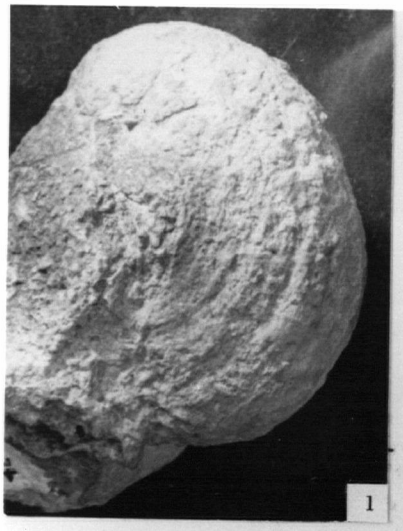
Figure 7, Stenopora prolifica (Fritz), UBC 20105.

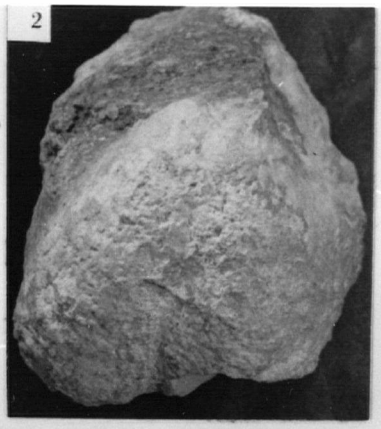
Figure 8, Protoretepora cf. P. haimeana (Koninck), Partial zoarium, reverse side, UBC 20128.

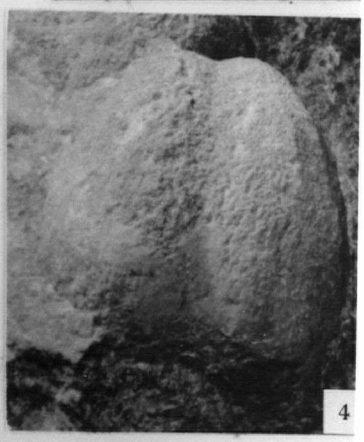
Figure 9, Acanthocladia multipora Fritz, part of zoarium, reverse side, UBC 20134, with other bryozoans.

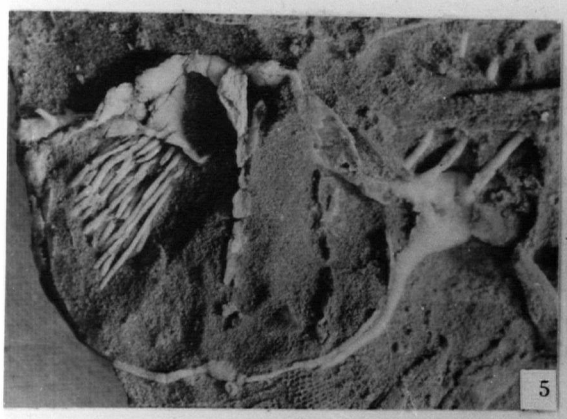
Figure 10, Cladochonus sp., UBC 20097, with bryozoans.

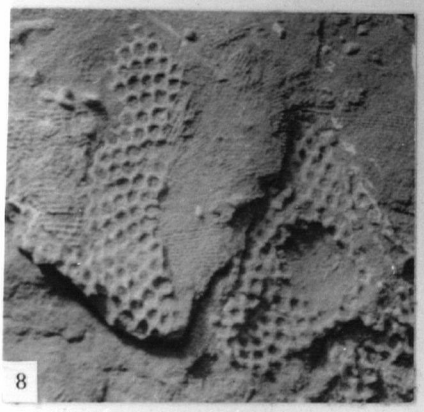
Figure 11, Southwest end of Azure Lake, view southwest. Section from which fossils of this plate (except Figs. 1 - 4) obtained is just over ridge crest in left background.

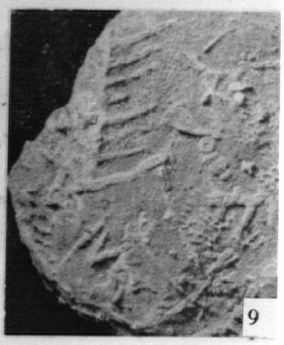












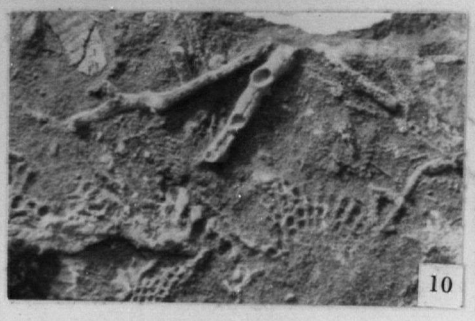


PLATE IV

PLATE V

Figures 1 - 3, Schwagerina? sp.

1. Specimen UBC 20188, thin section from Unit 25, Upper Division, Sicker Group, Mt. Mark section, x 15.
2. UBC 20189, thin section as in Fig. 1. x 15.
3. UBC 20190, same section as Figs. 1 and 2. x 15.

Figures 4 - 5, Pseudofusulinella? sp.

4. UBC 20191, thin section from Unit 23, Upper Division Sicker Group, Mt. Mark section. x 15.
5. UBC 20192, thin section from Upper Division, Sicker Group, Bald Mountain peninsula, Cowichan Lake area. x 15.

Figures 6 - 7, Unidentified fusulinid, UBC 20104, Unit 1, Buttle Lake Formation, Azure Lake section.

6. Axial section, x 15.
7. Sagittal section, x 15.

Figures 8 - 9, Radiolaria, from 190 feet below top of Lower Division, Sicker Group, Horne Lake, below Mt. Mark section.

8. UBC 20193, x 40.
9. UBC 20194, x 40.

Figure 10, Streblascopora pulchra (Fritz), UBC 20112, Unit 11, Buttle Lake Formation, Azure Lake section. x 2.

Figure 11, Polypora cf. P. consanguinea Bassler, UBC 20125, same locality as Fig. 10. x 1.

Figure 12, Clausotrypa spinosa, Fritz, UBC 20118, same locality as Fig. 10. x 1.

Figure 13, Goniocladia intermedia Fritz, UBC 20143, reverse side, same locality as Fig. 10. x 1.

Figure 14, Penniretepora grandis (Fritz), UBC 20140, from Horne Lake, basal 10 feet of Upper Division, Sicker Group, Mt. Mark. x 2.

Figure 15, Sulcoretepora sp., UBC 20141, same locality as Fig. 14. x 1.

Figure 16, Ingelarella? sp. A., external mold of partial brachial valve, showing surface pits, UBC 20083, Unit 1, Buttle Lake Formation, Azure Lake section. x 2.

Figure 17, Schizophoria sp., pedicle view, UBC 20181, Horne Lake, basal 10 feet, Upper Division, Sicker Group. x 1.5.

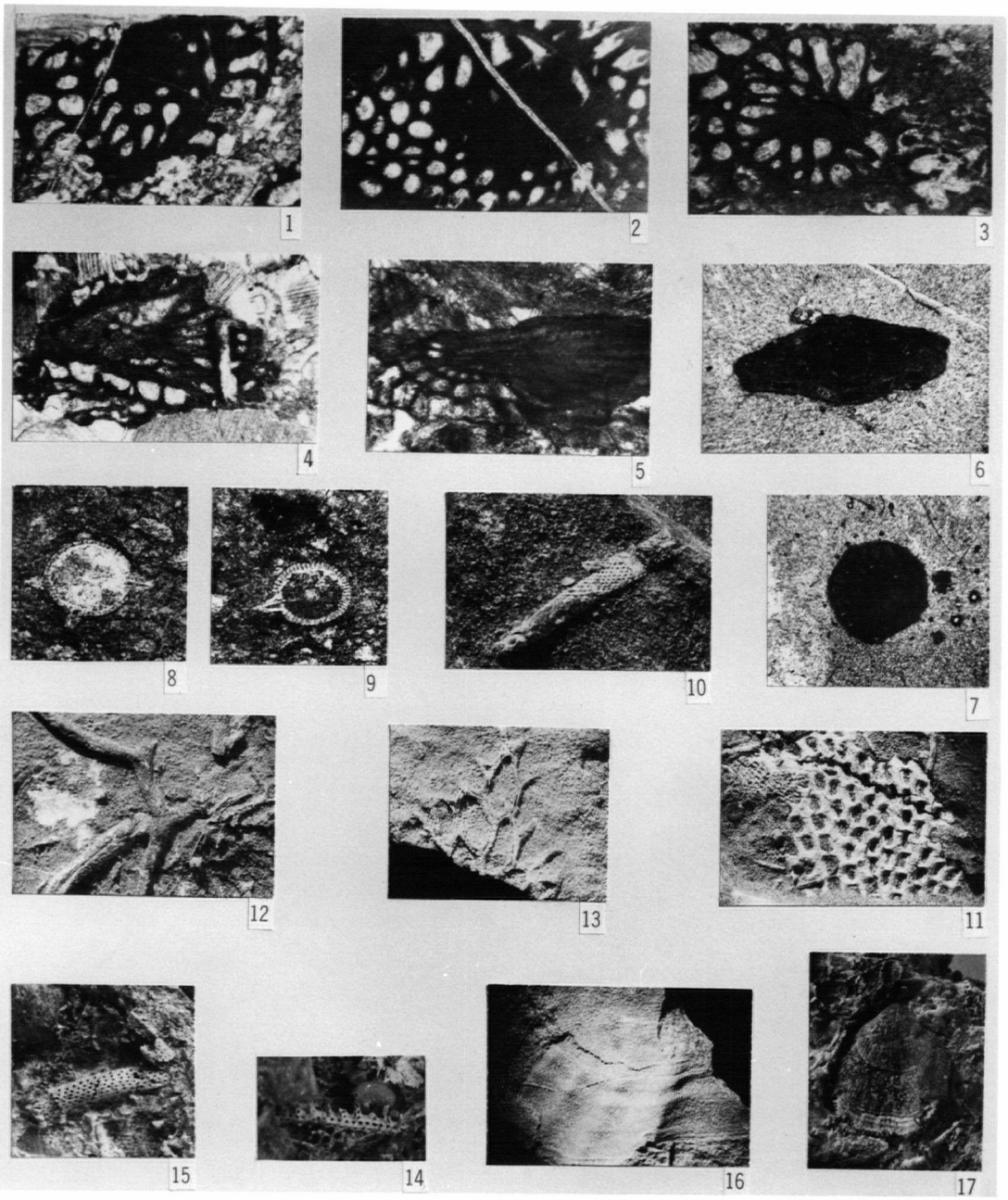


PLATE V

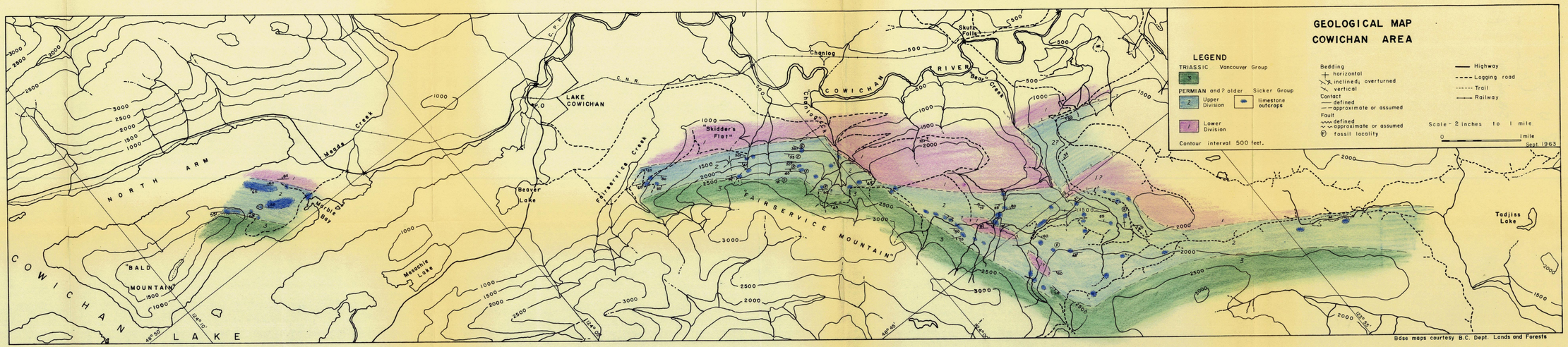
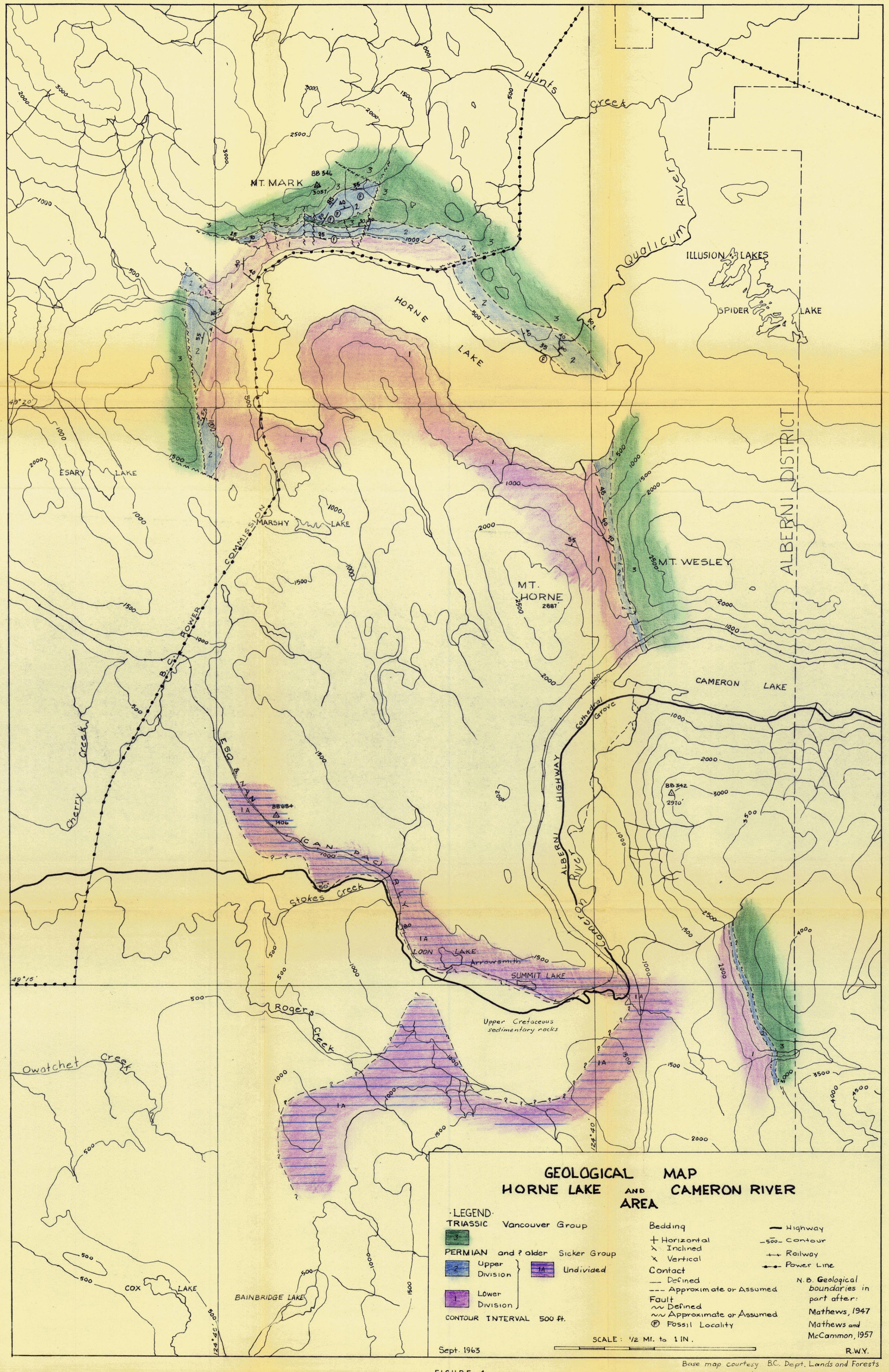

GEOLOGICAL MAP
COWICHAN AREA
LEGEND
TRIASSIC Vancouver Group
3
PERMIAN and ? older Sicker Group
2 Upper Division
limestone outcrops
1 Lower Division
Contour interval 500 feet.
Bedding
horizontal
inclined; overturned
vertical
Contact
defined
approximate or assumed
Fault
defined
approximate or assumed
fossil locality
Highway
Logging road
Trail
Railway
Scale - 2 inches to 1 mile
0
1 mile
Sept. 1963
Base maps courtesy B.C. Dept. Lands and Forests
NORTH ARM
COWICHAN LAKE
"BALD MOUNTAIN"
Marble Bay
Meade Creek
Mesachie Lake
Beaver Lake
LAKE COWICHAN
Fairservice Creek
"Skidder's Flat"
"FAIRSERVICE MOUNTAIN"
Chanlog
COWICHAN RIVER
"Bear" Creek
Skutz Falls
Tadjiss Lake
C.N.R.
C.P.R.
48°50'
124°10'
48°45'
124°00'
123°55'

FIGURE 3



GEOLOGICAL MAP
HORNE LAKE AND CAMERON RIVER AREA

·LEGEND·

TRIASSIC Vancouver Group

3

PERMIAN and ? older Sicker Group

2 Upper Division

1 Lower Division

1A Undivided

CONTOUR INTERVAL 500 ft.

Bedding
- + Horizontal
- Inclined
- Vertical

Contact
- Defined
- --- Approximate or Assumed

Fault
- ~~ Defined
- ~~ Approximate or Assumed
- Ⓕ Fossil Locality

Highway

-500- Contour

Railway

Power Line

N.B. Geological boundaries in part after:
Mathews, 1947
Mathews and McCammon, 1957

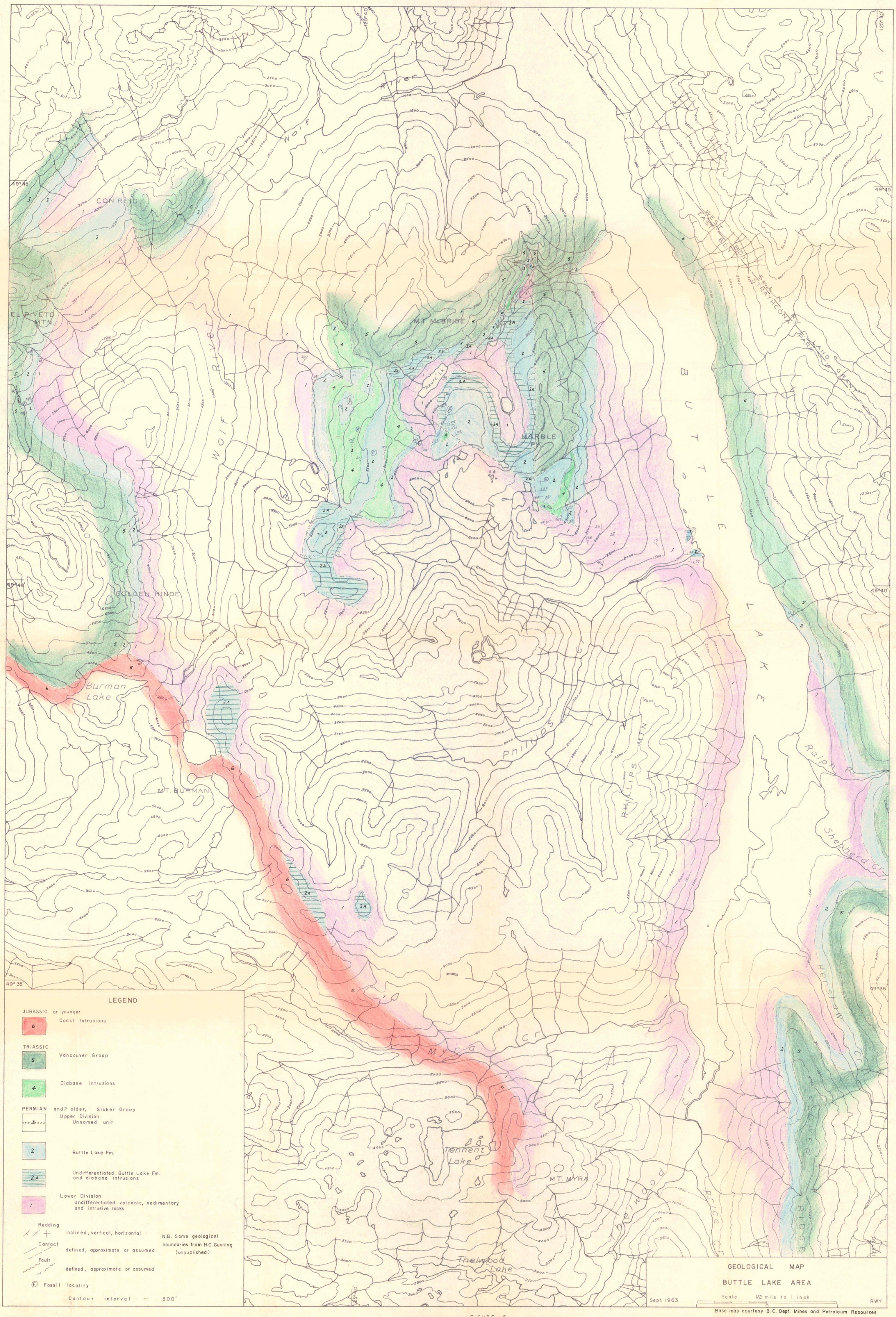
SCALE: 1/2 Mi. to 1 IN.

Sept. 1963

R.W.Y.

Base map courtesy B.C. Dept. Lands and Forests

FIGURE 4



LEGEND

JURASSIC or younger

6 — Coast Intrusions

TRIASSIC

5 — Vancouver Group

4 — Diabase intrusions

PERMIAN and? older, Sicker Group

Upper Division

-3- — Unnamed unit

2 — Buttle Lake Fm.

2A — Undifferentiated Buttle Lake Fm. and diabase intrusions

Lower Division

1 — Undifferentiated volcanic, sedimentary and intrusive rocks

Bedding — inclined, vertical, horizontal

Contact — defined, approximate or assumed

Fault — defined, approximate or assumed

(F) Fossil locality

Contour interval ~ 500'

N.B. Some geological boundaries from H.C. Gunning (unpublished)

GEOLOGICAL MAP

BUTTLE LAKE AREA

Sept. 1963 — Scale 1/2 mile to 1 inch — RWY

Base map courtesy B.C. Dept. Mines and Petroleum Resources

FIGURE 5

STRATIGRAPHIC SECTIONS of UPPER DIVISION of SICKER GROUP VANCOUVER ISLAND

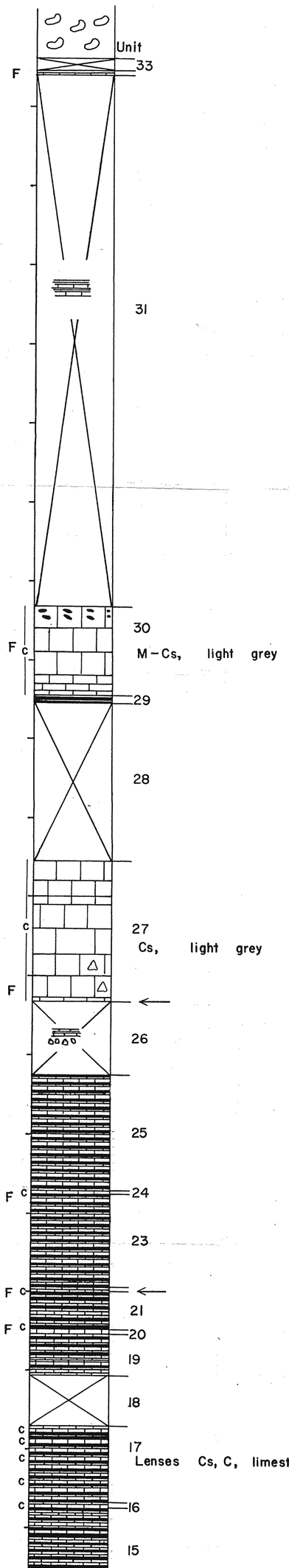
Vertical scale - 1 inch = 100 feet. Sept. 1963

LEGEND

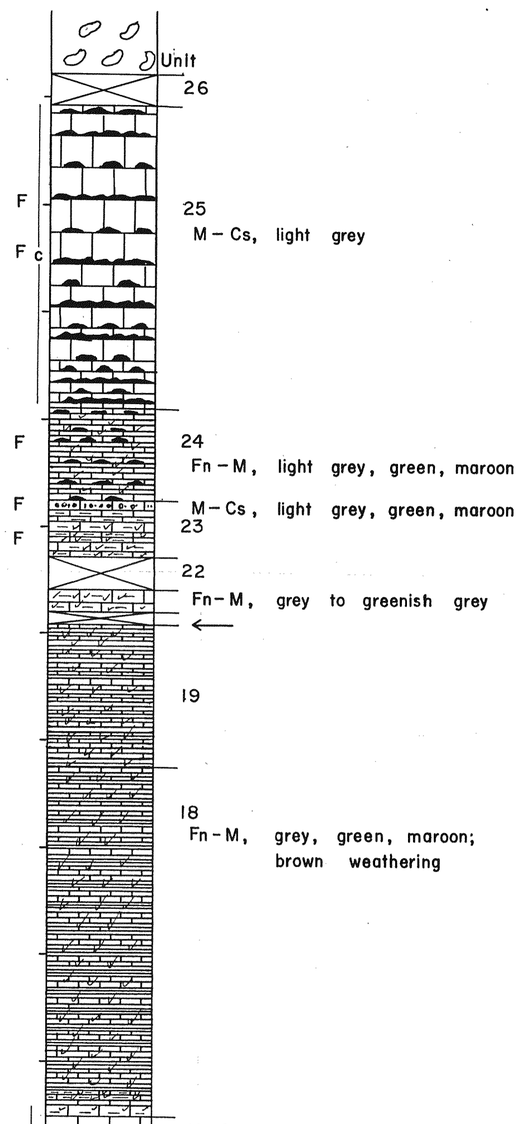
- non – calcareous clastic rocks fine grained probably tuffaceous
- tuffs, fine to coarse grained
- breccia
- pillow lavas
- Conglomerate
- Sandstone
- Limestone: thick-bedded (over 2') medium – bedded (6" – 2') thin – bedded (<6")
- Limestone, chert thinly interbedded
- argillaceous tuffaceous dolomitic
- Chert: thinly bedded
- Nodules irregular lenses
- covered interval

Fn fine grained
M medium grained
Cs coarse grained
c crinoidal
← basic intrusive rock
F fossils

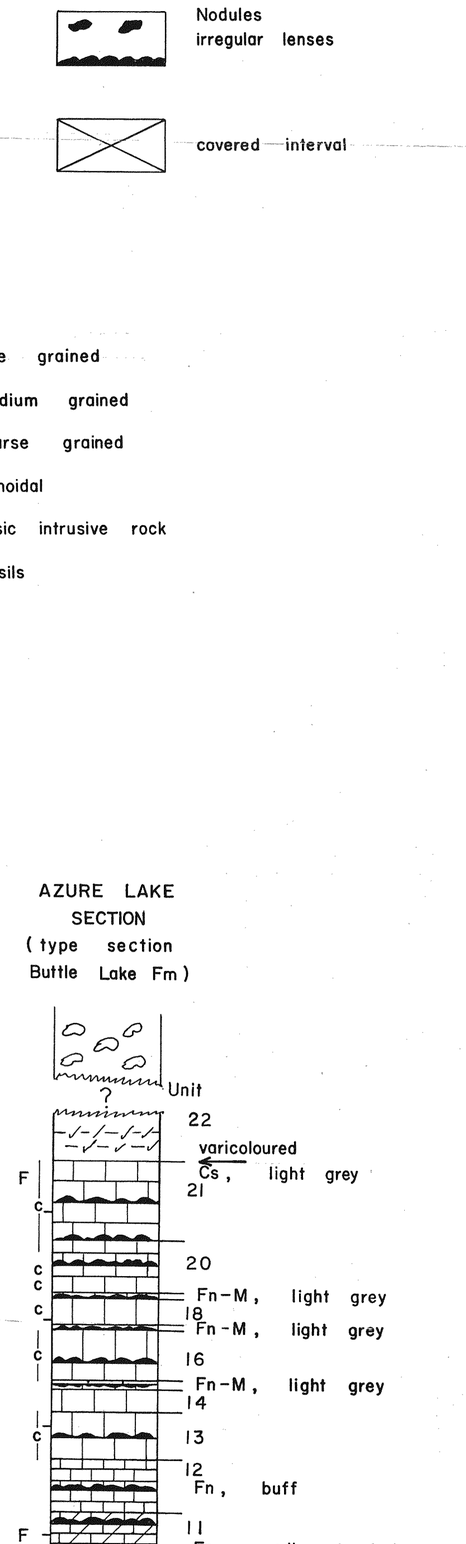
FAIRSERVICE MT. SECTION



MT. MARK SECTION



AZURE LAKE SECTION (type section Buttle Lake Fm)



RWY

FIGURE 6