Technical and Bibliographic Notes / Notes techniques et bibliographiques

The Institute has attempted to obtain the best original copy available for filming. Features of this copy which may be bibliographically unique, which may alter any of the images in the reproduction, or which may significantly change the usual method of filming are checked below.

- [x] Coloured covers / Couverture de couleur
- [ ] Covers damaged / Couverture endommagée
- [ ] Covers restored and/or laminated / Couverture restaurée et/ou pelliculée
- [ ] Cover title missing / Le titre de couverture manque
- [x] Coloured maps / Cartes géographiques en couleur
- [ ] Coloured ink (i.e. other than blue or black) / Encre de couleur (i.e. autre que bleue ou noire)
- [ ] Coloured plates and/or illustrations / Planches et/ou illustrations en couleur
- [ ] Bound with other material / Relié avec d'autres documents
- [ ] Only edition available / Seule édition disponible
- [x] Tight binding may cause shadows or distortion along interior margin / La reliure serrée peut causer de l'ombre ou de la distorsion le long de la marge intérieure.
- [ ] Blank leaves added during restorations may appear within the text. Whenever possible, these have been omitted from filming / Il se peut que certaines pages blanches ajoutées lors d'une restauration apparaissent dans le texte, mais, lorsque cela était possible, ces pages n'ont pas été filmées.
- [ ] Additional comments / Commentaires supplémentaires:

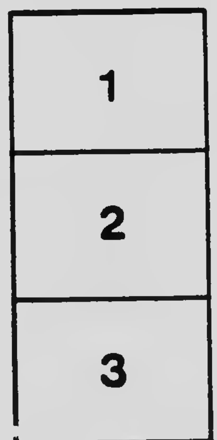
L'Institut a microfilmé le meilleur exemplaire qu'il lui a été possible de se procurer. Les détails de cet exemplaire qui sont peut-être uniques du point de vue bibliographique, qui peuvent modifier une image reproduite, ou qui peuvent exiger une modification dans la méthode normale de filmage sont indiqués ci-dessous.

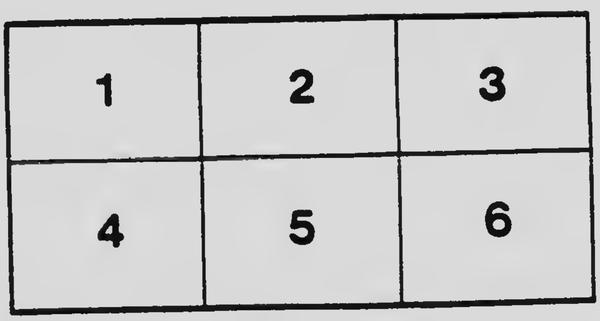
- [ ] Coloured pages / Pages de couleur
- [ ] Pages damaged / Pages endommagées
- [ ] Pages restored and/or laminated / Pages restaurées et/ou pelliculées
- [x] Pages discoloured, stained or foxed / Pages décolorées, tachetées ou piquées
- [ ] Pages detached / Pages détachées
- [x] Showthrough / Transparence
- [ ] Quality of print varies / Qualité inégale de l'impression
- [ ] Includes supplementary material / Comprend du matériel supplémentaire
- [ ] Pages wholly or partially obscured by errata slips, tissues, etc., have been refilmed to ensure the best possible image / Les pages totalement ou partiellement obscurcies par un feuillet d'errata, une pelure, etc., ont été filmées à nouveau de façon à obtenir la meilleure image possible.
- [ ] Opposing pages with varying colouration or discolourations are filmed twice to ensure the best possible image / Les pages s'opposant ayant des colorations variables ou des décolorations sont filmées deux fois afin d'obtenir la meilleure image possible.

This item is filmed at the reduction ratio checked below /
Ce document est filmé au taux de réduction indiqué ci-dessous.

10x	12x	14x	16x	18x	20x	22x	24x	26x	28x	30x	32x
							✓				

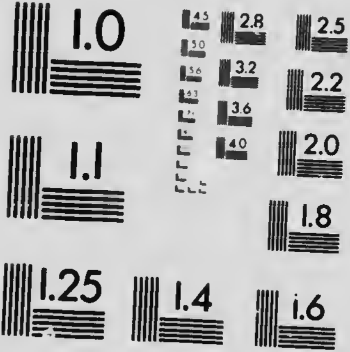

1
2
3


1
2
3


1
2
3
4
5
6

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



CANADA

DEPARTMENT OF MINES

HON. LOUIS CODERRE, MINISTER; A. P. LOW, DEPUTY MINISTER.

GEOLOGICAL SURVEY

R. W. BROCK, DIRECTOR.

MEMOIR 36

No. 33, GEOLOGICAL SERIES

Geology of the Victoria and Saanich Map-Areas, Vancouver Island, B.C.

BY

Chas. H. Clapp

OTTAWA

GOVERNMENT PRINTING BUREAU

1913.

CANADA

DEPARTMENT OF MINES

HON. LOUIS CODERRE, MINISTER; A. P. LOW, DEPUTY MINISTER.

GEOLOGICAL SURVEY

R. W. BROCK, DIRECTOR.

MEMOIR 36

No. 33, GEOLOGICAL SERIES

Geology of the Victoria and Saanich Map-Areas, Vancouver Island, B.C.

BY

Chas. H. Clapp

OTTAWA

GOVERNMENT PRINTING BUREAU

1913.

No. 1293

CONTENTS

Page

ILLUSTRATIONS.

Geology of the Victoria and Saanich Map-Areas, Vancouver Island

INTRODUCTION.

GENERAL STATEMENTS AND ACKNOWLEDGMENTS.

The elucidation of the geology of the Victoria and Saanich map-areas is of especial interest since it is representative of the igneous geology of the whole of Vancouver island, and indeed of the entire coast of British Columbia. Here, in a small and readily accessible area, are presented many of the principal geological features of the entire region, and many of their details may here be worked out. This could be accomplished in other more mountainous and less accessible parts of the coast region only with a great deal of expense and time. The object of the survey was to make a fairly thorough study of the area and prepare a detailed geological map. The results are given in this report and on the accompanying detailed geological maps. The report presents rather fully the facts gathered during field and office work.

The writer is indebted to many of the residents of Vancouver island for information and assistance, and in particular to the owners of the numerous mineral claims and to the companies exploiting the various mineral deposits.

The report is based on the detailed geological field work carried on during the summer of 1910. In this work the topographic maps—the Victoria and Saanich sheets—prepared by Mr. R. H. Chapman in 1909, were used as field maps. These maps were prepared on a scale of 1:48,000 (1 inch = 4,000 feet), but for use in the field were enlarged photographically to a scale of 2 inches = 1 mile. Both the topographic maps and the accompanying geological maps are published on the reduced scale of 1:62,500 (about 1 inch = 1 mile). In the field a fairly accurate outcrop and drift map was prepared, virtually every outcrop being examined. In order to make [illegible] map more intelligible a bed-rock map and a drift map have been prep[illegible] from it for publication. Approximately three months, from June 20 until September 15, were spent in the field doing detailed work, but reconnaissances over the area had been previously made in 1908; and in 1909, Mr. J. A. Allan worked on the extreme northwestern part of the Saanich map-area, on Saltspring island. During the detailed work of 1910 the writer was very ably assisted by Mr. John D. McKenzie and Mr. Alexander G. Haultain.

LOCATION AND AREA.

The Victoria and Saanich map-areas, as may be seen on the accompanying index map (Fig. 1), are situated in the extreme southeastern portion of Vancouver island. They consist of two fifteen minute rectangles between longitudes 123° 15′ and 123° 30′ and latitudes 48° 15′ and 48° 45′, the Victoria map-area being the southern rectangle and the Saanich map-area the northern. Their total land area is about 150 square miles and includes the city of Victoria and adjacent region, the Saanich peninsula, the southeastern part of Saltspring island, and several smaller islands in Haro straits. The following political divisions of Vancouver island are embraced by the map-areas—North and South Saanich, Lake and Victoria districts, and the

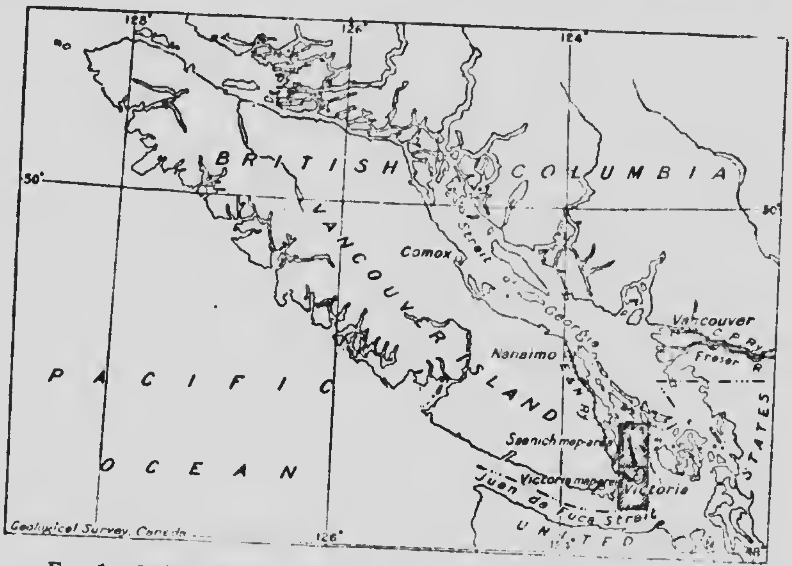


Fig. 1. Index showing location of Victoria and Saanich map-areas.

larger part of Highland and Esquimalt districts. Victoria, the capital of British Columbia, is the only city of the map-areas. According to the 1911 census its population is 31,620. The principal towns are Esquimalt, adjoining Victoria on the west, Oak Bay, adjoining Victoria on the east, and Sidney, on the east shore of the Saanich peninsula, near the northern end.

The area has many wagon roads, and is traversed by two railways, the Esquimalt and Nanaimo, and the Victoria and Sidney. An electric tramway has been projected along the Saanich peninsula. The roads and the large amount of cleared land make the area very accessible, and since the rock outcrops are abundant the geology may be done with a minimum amount of physical labour.

PREVIOUS WORK.

Very little detailed geological work had been done in the Victoria and Saanich map-areas previous to the present examination, although Victoria has been visited by a number of geologists who have written short papers covering the geology, especially the glacial geology, of Victoria and vicinity. In the seventies, Selwyn, Richardson, and Dawson made reconnaissances in the neighbourhood of Victoria, and the results of their work were published in the Reports of Progress of the Geological Survey of Canada for 1871-72 and 1876-77. Dawson's conclusions are given also in several papers published on the physical, glacial, and general geology of British Columbia. In 1908, the writer made a general reconnaissance over the southeastern part of Vancouver island, including the larger part of the Victoria and Saanich map-areas, the results being published in the Summary Report for 1908 and in a preliminary report on the geology of southern Vancouver island, Memoir No. 13, Geological Survey, Canada, 1912. In 1909, Mr. J. A. Allan, who was associated with the writer, made a rather detailed examination of Saltspring island, the southern part of which is included in the Saanich map-area. His results were published in the Summary Report for 1909.

BIBLIOGRAPHY.

A complete bibliography of all the literature of value bearing on the geology of southern Vancouver island has been given in the preliminary report on southern Vancouver island, and the following list includes merely those publications bearing directly on the geology of the Victoria and Saanich map-areas.

ALLAN, J. A.—Saltspring island, and east coast of Vancouver island. Summary Report for 1909, Geol. Survey, Canada, pp. 98-102.

BAUERMANN, H.—On the geology of the southeastern part of Vancouver island. Quart. Jour. Geol. Soc., Vol. XVI, 1859, pp. 198-202

CLAPP, CHARLES H.—Southeastern portion of Vancouver island. Summary Report for 1908, Geol. Survey, Canada, pp. 52-60.

Geology of the Victoria and Saanich map-areas, Vancouver island, B.C. Summary Report for 1910, Geol. Survey, Canada, pp. 102-109.

CLAPP, C. H., and SHIMER, H. W.—The Sutton Jurassic of the Vancouver Group, Vancouver island. Proc. Boston Soc. Nat. Hist., Vol. XXXIV, 1911, pp. 425-438.

CLAPP, C. H.—Preliminary report on the geology of southern Vancouver island. Memoir No. 13, Geol. Survey, Canada, 1912.

DAWSON, G. M.—On the superficial geology of British Columbia. Quart. Jour. Geol. Soc., Vol. XXXIV, 1878, pp. 89-123.

Additional observations on the superficial geology of British Columbia and adjacent regions. Quart. Jour. Geol. Soc., Vol. XXXVII, 1881, pp. 272-285.

Notes on the Cretaceous of the British Columbian region. The Nanaimo Group. Am. Jour. Sci., 3rd Series, Vol. XXXIX, 1890, pp. 180-183.

On the later physiographical geology of the Rocky Mountain region in Canada. Trans. Royal Soc. of Can., Vol. VIII, 1890, Sec. 4, pp. 3-74.

Geological record of the Rocky Mountain region in Canada. Bull. Geol. Soc. of Am., Vol. XII, 1901, pp. 57-92.

RICHARDSON, JAMES.—Coal fields of the east coast of Vancouver island, Rept. of Prog., 1871-72, Geol. Survey of Canada, p. 73.

Report of coal fields of Nanaimo, Comox, Cowichan, Burrard inlet and Sooke, B. C. Geol. Survey of Canada, Rept. of Prog., 1876-77, pp. 160-192.

WHITEAVES, J. F.—On the fossils of the Cretaceous rocks of Vancouver and adjacent islands in the Strait of Georgia. Geol. Survey of Canada, Mesozoic Fossils, Vol. 1, Part II, 1879, pp. 93-190.

On some additional fossils from the Vancouver Cretaceous, with a revised list of the species therefrom. Geol. Survey of Canada. Mesozoic Fossils, Vol. I., Part V., 1903, pp. 309-416.

SUMMARY AND CONCLUSIONS.

GENERAL GEOLOGY.

The oldest rocks of the Victoria and Saanich map-areas being of lower Mesozoic age—chiefly lower Jurassic and probably upper Triassic—are members of the Vancouver group. They are nearly 25,000 feet in thickness, and are subdivided on the bases of distribution, lithology, and structure into Vancouver volcanics, Sutton formation, and Sicker series, the latter including the Sicker volcanics and the Sicker schists. The Vancouver volcanics, which comprise the great bulk of the Vancouver group, consist of a series, accumulated largely under submarine conditions, of flow and pyroclastic rocks of medium basicity, chiefly andesites, with intrusive porphyrites. They have been metamorphosed and, near intrusive granitic rocks, partially recrystallized and replaced, forming silicified and feldspathized varieties, amphibolites, and garnet-diopside-epidote rocks. They are also seamed with veins of quartz and of quartz and epidote, and in places are impregnated with metallic sulphides, chiefly pyrite. Intercalated in the Vancouver volcanics are numerous lentils of crystalline limestone, which constitute the Sutton formation. They were formed by the accumulation of marine organisms that apparently lived on the shores of volcanic islands, built during the eruption of the Vancouver volcanics. They have been metamorphosed with the volcanics not only into crystalline limestones, some of which contain diopside and wollastonite, but also into silicified and mineralized varieties and even into garnet-diopside-epidote rocks. The Sicker volcanics, andesites, and augite andesites, closely resemble the Vancouver volcanics, but are more metamorphosed and mineralized and are interbedded with schists not only of volcanic but of fragmental sedimentary origin. The schists of volcanic origin are chiefly chlorite schists, while those of sedimentary origin, although partly tufaceous, are slaty and quartzose schists. The rocks of the Vancouver group have been greatly deformed, largely during an upper Jurassic period of mountain building, into large folds with steep limbs, striking nearly N. 60° W., complicated by small folds and even by contortions. Largely owing to their deformation the rocks are also greatly fractured, sheared, and faulted.

During and following the deformation, the rocks of the Vancouver group were invaded and partly replaced by plutonic rocks, which now underlie the greater part of the Victoria and Saanich map-areas. These may be subdivided into three main types, which were irrupted in a definite sequence as follows: Wark gabbro-diorite gneiss, Colquitz quartz diorite gneiss, and Saanich granodiorite. In addition, there are minor types, which form dykes and small masses, consisting of granodiorite porphyrites, diorite porphyrites, and gabbro-diorite porphyrites, these last being injected into the Sicker series only, and hence called the Sicker gabbro-diorite porphyri... The Wark and Colquitz gneisses although intruded separately, form virtually a single batholith, occurring in the southern part of the map-areas, which, since its component rocks are apparently primary gneisses, was probably irrupted during the deformation. The principal rock of the Wark type is a gabbro-diorite gneiss, which has, however, unfoliated gabbro and salic gabbro facies. It has been considerably metamorphosed by the younger irruptive rocks, into types in which large, poikilitic hornblendes are conspicuous. The Colquitz gneiss is a foliated quartz diorite, having a biotite granite facies, and is in places conspicuously banded, its light and its dark minerals occurring in separate bands, varying in width from a fraction of an inch up to several feet. The Saanich granodiorite, which forms a relatively large batholith, underlying the Saanich peninsula, in the central part of the Saanich map-area, and also several smaller stocks, is a fairly normal, chiefly unfoliated, granodiorite, with dioritic contact facies. The dykes and masses of granodiorite and diorite porphyrites, which are transitional, occur chiefly near the periphery of the Saanich granodiorite bodies and were injected during and following the irruption of the Saanich granodiorite. The relation of the Sicker gabbro-diorite porphyrites to the other irruptive rocks is indefinite. However, all belong to one general period of irruption and are correlated with the upper Jurassic, Coast Range batholith.

Resting unconformably upon the irruptive and metamorphic rocks and confined to the northern and northeastern part of the Saanich map-area is a series at least 6,000 feet thick of fragmental sedimentary rocks, conglomerates, sandstones, and shales of upper Cretaceous age, called the Nanaimo series. As shown by the rapid lateral and vertical gradation of the sediments and by the presence of marine organisms and vegetable (coaly) material the series was apparently deposited under varying conditions, both marine and terrestrial, in a down-warped basin between Vancouver island and the mainland. The sediments have been greatly deformed, probably in post-Eocene time, and now they occur in a closely folded synclinal basin, the Cowichan basin, striking about N. 60° W., and overturned to the southwest so that the rocks have a general northeast dip. The major syncline is complicated by a few smaller folds and by many minor ones or wrinkles, especially near its southern boundary. The northern boundary of the basin is a thrust fault and many smaller faults also occur. To the northeast of the Cowichan basin are found the lower parts of a smaller faulted syncline and, in the extreme northeastern corner of the map-area, the southwestern limb of another large syncline, the Nanaimo basin.

In the southwestern part of the Victoria map-area is a thick series of basic volcanic rocks, the Metchosin volcanics, that were formed largely under marine conditions during upper Eocene time. They are chiefly ophitic basalts, including flow and pyroclastic types, with intrusive diabases. They were greatly deformed during the post-Eocene deformation.

During a later Tertiary erosion cycle following the post-Eocene deformation, all of the rocks of the map-areas were peneplained. The peneplain was subsequently uplifted and before the Glacial period was largely reduced to a lowland, although numerous monadnocks survived, and in the upland districts of the map-areas small portions of the peneplain also.

During the Glacial period the map-areas were twice overridden by glaciers, chiefly by the southward flowing Strait of Georgia glacier, which occupied the depression between Vancouver island and the mainland. As a result, the greater part of the map-areas is covered with superficial deposits of various kinds, consisting largely of glacial detritus. These deposits are subdivided according to their lithological character and origin into the Admiralty till, deposited during the first epoch of glaciation, the Admiralty; the Maywood clays and Cordova sands and gravels, deposited during the inter-glacial epoch, the Puyallup; the Vashon drift, deposited during the second and lesser epoch of glaciation, the Vashon; and the Colwood sands and gravels deposited during the recession of the Vashon glaciers.

Following the retreat of the younger glaciers the region was uplifted about 250 feet to its present position. During the present cycle alluvium has been deposited in lakes and swamps which formed in the poorly drained hollows of the drift mantle and in dammed glaciated valleys; and at the shore the uplifted superficial deposits have been retrograded to form steep wave-cut cliffs, and beaches, spits, and bars of coarse sand and gravel.

ECONOMIC GEOLOGY.

The mineral resources of the map-areas are entirely non-metallic. The deposits being exploited at present are the Sutton limestones, for lime, Portland cement, and flux; the Maywood clays for common brick and drain-tile, for mixing with the Nanaimo clay-shales from Comox in the manufacture of sewer-pipe and fireproofing, and for mixing with the Sutton limestone in the manufacture of Portland cement; the Cordova and Colwood sands and gravels for concrete, filling, and for similar purposes; and the Metchosin volcanics, and, to a small extent, the other metamorphic and crystalline rocks, for crushed stone. A deposit of infusorial or diatomaceous earth is also known, but is not at present utilized, although it appears to be of fair quality and to occur in considerable amounts. There has been considerable unsuccessful prospecting for coal and also for metals, chiefly for gold and copper, and it is unlikely that these substances occur in commercial quantities.

GENERAL CHARACTER OF DISTRICT.

TOPOGRAPHY.

GENERAL ACCOUNT.

Regional.

The Victoria and Saanich map-areas occur in the extreme southeastern portion of Vancouver island. Vancouver island is one of the border ranges of North America, and is separated from the mainland by the submerged northern portion of a great marginal depression of North America. This depression, known as the Pacific Coast downfold,[1] extends from the Gulf of California to north of Queen Charlotte islands, above sea-level in California, Oregon, and Washington, but with the southern and northern ends submerged. It is flanked on either side by great mountain ranges, those of British Columbia being the Coast Range to the east, and the ranges of Vancouver island and Queen Charlotte islands to the west. The Vancouver range, which virtually constitutes Vancouver island, trends N. 55° W. The entire island is 290 miles long and 50 to 80 miles wide, the total area being about 20,000 square miles. It is, as stated, separated from the Coast range of the mainland by the submerged northern end of the Pacific Coast downfold, which is occupied from south to north by Haro, Georgia, Johnstone, and Broughton straits, and Queen Charlotte sound. It is separated from the mainland to the south, that is from the Olympic mountains of Washington, by a smaller transverse downfold striking about N. 70° W., now occupied by the strait of Juan de Fuca.

The Vancouver range is composed of a heterogeneous group of deformed rocks having a general northwest strike, which were apparently reduced to a subdued surface and then uplifted and greatly or maturely dissected. Looking across the upland of Vancouver island one can still see in the wide, relatively smooth interstream areas, the outlines of the subdued surface. In the southern part of Vancouver island this surface, before uplift, was nearly a plain, that is a peneplain, and only a few rounded hills, monadnocks, composed of especially resistant rocks, remained a few hundred feet above the general level. This peneplain was developed during a Tertiary erosion cycle and will be called the Tertiary peneplain. In the central part of the island, however, the surface was one of considerable relief with larger and higher monadnocks and small ranges of mountains. The present elevation of the uplifted Tertiary peneplain is less than 1500 feet near the southern coast, but increases rapidly to the northeast so that in the central part of

[1] Willis, Bailey—Tacoma Folio, No. 54, U.S. Geol. Survey, 1899.

the island the elevation of the uplifted subdued surface is about 4,000 feet, while the old residuals are now, since uplift, 5,000 to 7,000 feet above sea-level, a few peaks being even higher. As stated, the uplifted peneplain and subdued surface was maturely dissected. This occurred during a pre-Glacial erosion cycle, presumably by its own rivers revived by the uplift. These rivers consisted of large transverse streams with tributaries which followed belts of the less resistant rocks. In the southeastern portion of the island the dissection although the region is largely underlain by rocks of the same character, was carried to a further stage, that of late maturity to old age, so that the outlines of the Tertiary peneplain were entirely destroyed and another subdued surface was developed several hundred feet lower than the old surface and averaging now about 100 feet above sea-level. Along the coast are relatively narrow areas underlain by sedimentary rocks, which are less resistant than the crystalline rocks forming the larger part of the island, and which were, therefore, during the pre-Glacial cycle, reduced to a lowland also. It seems as if at some time following mature dissection in this same pre-Glacial cycle, the southeastern part of the island was depressed in part below sea-level, drowning the valleys, but leaving the higher elevations above sea-level as islands and promontories, and thus forming the irregular drowned coast characteristic of that part of the island.

During the Glacial period the island was apparently smothered by a thick ice-cap, which smoothed and rounded all the mountains under 4,000 or 5,000 feet high, while the pre-Glacial valley heads in the higher mountains were excavated by local glaciers, so that these higher mountains now have characteristic serrated summits. Valley glaciers occupied and scoured out the larger valleys, converting some of them, chiefly the transverse valleys running southwestward from the main range to the Pacific, into fiords, and deepening some of the interior valleys into large lake basins. The valley glaciers flowing eastward from the east slope of the Vancouver range joined with the larger and more numerous glaciers flowing westward from the ranges of the mainland and formed an extensive piedmont glacier which occupied the downfold between the Vancouver range and the ranges of the mainland. The southward flowing portion of this piedmont glacier, called by Dawson[1] the Strait of Georgia glacier, overrode the lowland developed by the pre-Glacial cycle in southeastern Vancouver island, removed virtually all surface soil, and smoothed off the angularities produced by normal erosion. A second period of glaciation, following an interglacial period during which the rocks below a present elevation of about 250 feet were covered by stratified drift, partially eroded this drift. A recent uplift of about 250 feet has caused a partial recovery from the former depression which,

[1] Dawson, G. M., "On the later physiographical geology in the Rocky Mountain region in Canada." Trans. Royal Soc., Canada, vol. 8, 1890, Sec. 4, p. 29.

as mentioned above, resulted in the drowned coast of southeastern Vancouver island, and has initiated the present marine cycle. During this cycle the stratified drift has been retrograded to form steep cliffs some 250 feet high, while the coast, where composed of the crystalline rocks, presents the initial irregularities of the drowned surface.

Local.

The greater part of the Victoria and Saanich map-areas consists of the subdued surface or lowland developed, as mentioned, during the pre-Glacial cycle, in the southeastern part of Vancouver island. Surmounting this lowland from 100 to 900 feet are numerous but relatively small monadnocks, and in the northwestern parts of the Saanich map-area, in the southwestern part of the Saanich map-area, and northwestern part of the Victoria map-area, are uplands which also remain above the lowland. These uplands are transitional in character between the lowland and the upland of the Vancouver range formed, as mentioned, only by the mature dissection of the previously uplifted Tertiary peneplain. In the upland portions of the Saanich and Victoria map-areas the dissection reached a further stage, one of late maturity, in which virtually all of the uplifted peneplain was destroyed, although the region retained considerable relief. It was upon the lowland that the stratified drift was deposited in the interglacial period, the lowland having been previously scoured off by the southward flowing piedmont, Strait of Georgia glacier, so that the elevations are now knob-like, with relatively smooth rounded outlines. During the second period of glaciation the stratified drift was partially eroded, leaving long, esker-like ridges, some of which occur in the lea of the monadnocks, and in some of the eroded hollows in the drift mantle, lakes have been formed. In the upland portions of the map-areas the scouring action of the glaciers, especially of the valley glaciers confined between the sides of deep valleys, is more evident. Here there are small lakes in deepened rock basins, and in the southwestern part of the Saanich map-area is a small fiord.

The partial recovery from the former depression has brought the land into its present position, and the uplifted stratified drift is being rapidly retrograded during the present marine cycle, producing steep cliffs with attendant sand spits and coarse boulder beaches. This type of shore-line, although still in a submature stage, is in marked contrast with the very youthful shore-line where there was no drift cover or where it has been removed, and where the coast consists of hard rocks. This latter type of shore-line presents all the irregularities of the original glaciated surface with many minor irregularities such as dyke or shear-zone chasms, formed by wave-pecking of the weaker portions of the rocks.

The larger part of the Victoria and Saanich map-areas is, however, below sea-level. In the Saanich map-area a lowland, some 2 to 3 miles wide and 14 miles long, with a north-south trend, remains above sea-level, forming the Saanich peninsula, which is separated from the Vancouver range to the west by a wide, fiord-like inlet called Saanich inlet. Only the northeastern part of Saanich inlet is included in the Saanich map-area. The upland mentioned as occurring in the northwestern part of the Saanich map-area is the southern part of a large island called Saltspring island, and it surmounts steeply a channel about 1½ miles wide with an east-west strike which separates Saltspring island from the Saanich peninsula. The eastern part of the Saanich map-area is a part of the Pacific Coast downfold and is largely under water, although numerous ridges with a general northwest-southeast trend remain above sea-level as islands. Also the entire central and southern part of the Victoria map-area, where the Pacific Coast downfold and the transverse Juan de Fuca downfold are confluent, is below sea-level. The northern part of the Victoria map-area is indented with two irregular inlets, drowned, glaciated valleys, that are separated by a roughly diamond-shaped peninsula about 3 miles in width. The eastern inlet is the harbour of the city of Victoria and the western inlet is Esquimalt harbour.

DETAILED ACCOUNT.

Upland.

As already mentioned, the upland of the Saanich and Victoria map-areas, formed, as described, by the late mature dissection of the uplifted Tertiary peneplain, occurs in two localities: in the northwestern part of the Saanich map-area, which constitutes the southern part of Saltspring island, and in the southwestern part of the Saanich map-area and northwestern part of the Victoria map-area which comprises the larger part of Highland district. In the Highland district the dissection has been accomplished by more numerous streams, that is, is finer textured than on Saltspring island, so that the upland of the Highland district is characterized by several hills, while southern Saltspring island consists virtually of one, much larger, rather flat-topped hill or mountain mass.

It is probable that the up-lifted Tertiary peneplain in the Highland district was virtually entirely destroyed by the erosion during the pre-Glacial cycle, although it is possible that the gently sloping benches on the sides of the highest hill in the district, Mt. Wark, at an elevation of near 1,000 feet above sea-level, represent the peneplain. This conclusion is still further strengthened by the fact that most of the hills of the district, some of which are slightly flat-topped, have an elevation of somewhat less than 1,000 feet. If the uplifted Tertiary peneplain had an elevation of about 1,000 feet, Mt. Wark must have surmounted it by about 450 feet, since the summit of Mt. Wark is 1,445 feet above sea-level. There are, however, no other evidences of old monadnocks.

The dissection has been accomplished by numerous rather small streams which were well adjusted to the less resistant parts of the crystalline rocks. The varying resistance of the rocks is apparently due to a corresponding variation in the size and number of the joints and shear planes striking chiefly in a north-south direction, to the foliation of the rocks, which strikes nearly N. 55° W., and to the alteration and weakening of the rocks near intrusive and, in some instances, fault contacts. As a result, the valleys and a few ridge-like hills have a general north-south and northwest trend, and in the northern part of the Highland district there is a pronounced and nearly straight valley which follows a contact striking about N. 70° W.

As already mentioned, the effect of glaciation is very evident in the Highland district where the valleys have been considerably deepened, although not greatly widened, especially the north-south valleys, possibly because the glacial movement was in general from north to south. In the deepened rock basins formed by glacial scour are small lakes, such as Prospect lake in the eastern part of the Highland district and Fizzle lake in the western part. Local deflections of the valley glaciers took place, and it may be that the six small lakes occurring at nearly regular intervals around the base of Mt. Wark, coll[illegible]ed in rock basins formed by valley glaciers deflected by Mt. Wark. These six lakes, beginning with the northernmost ar[illegible] proceeding in a clock-wise direction, are called Durant, Heal, Mud, For[illegible] [illegible]orna, and Fourth lakes. Durant lake occurs in the pronounced valley, which, as mentioned, has been developed along the contact striking N. 70° W.

Terminating the upland, along the northern boundary of the Highland district is a small fiord-like inlet, called Tod inlet, another result of a glacially deepened valley. Tod inlet, however, differs from a typical fiord in that one of its shores, the eastern, is comparatively low. It opens to the northwest into Saanich inlet which in its southern part, to the west of the Victoria and Saanich map-areas, is a typical fiord, relatively narrow with steep and high rock walls. In its northern part, however, Saanich inlet is broad with low shores, the eastern shore being, as already mentioned, the Saanich peninsula.

The other upland locality, southern Saltspring island, is, as described, virtually a single mountain mass with rather simple and rounded outlines. It is composed essentially of foliated crystalline rocks with a northwest-southeast strike, and of more resistant intrusive rocks which occur in bodies elongate in the direction of foliation. Consequently, the numerous small str[illegible]ms which drain the mass run in deep northwest-southeast ravines in the foliated rocks. The resistant intrusive rocks now form small knobs which surmount the comparatively wide, plateau-like summit of the is[illegible]nd, and probably surmounted the Tertiary peneplain, at the time of uplift, by 300 to 500 feet. The present elevation of the plateau-like summit which may represent the uplifted Tertiary peneplain, is from 1,400 to 1,600 feet above sea-level, while the hard rock knobs are about 1,900 feet above sea-level.

The southernmost knob, called Mt. Tuam, is 1940 feet high, and is the most conspicuous elevation of the Victoria and Saanich map-areas, although the northernmost knob, occurring at the northern boundary of the Saanich map-area, is slightly higher.

Along the southern shore of the island, separated from the crystalline rocks to the north by a fault having a strike about N. 80° W., is a narrow strip underlain by soft sedimentary rocks, which extend to the south below the waters of the channel separating Saltspring island from the Saanich peninsula. The upthrow side of the fault is the northern, but the initial scarp formed by the faulting was probably destroyed by erosion at the time of the uplift of the Tertiary peneplain. Since uplift, however, the relatively soft sedimentary rocks have been more rapidly eroded than the crystalline rocks, so that a new scarp has been formed along the old fault-line. A scarp produced in this manner, after the initial fault scarp has been destroyed during a previous erosion cycle, is called a fault-line scarp. That of southern Saltspring island is fairly steep, a slope of about 25 degrees, mounting from sea-level to 1900 feet within a horizontal distance of 4000 feet. As in the Highland district, all the rock surfaces have been smoothed by glacial scour and are frequently covered by glacial drift.

Monadnocks.

The larger number of the monadnocks which surmount the lowland of the Victoria and Saanich map-areas, are from 100 to 200 feet above the general level, but a few larger ones are from 500 to 900 feet above it. The monadnocks seldom correspond with the outlines of the various rock formations, but have survived where the rocks were less fractured and sheared or less altered. For example, Mt. Newton, the largest monadnock of the region, situated in the central part of the Saanich peninsula, is composed of a granitic rock, which is a part of a much larger rather uniform body. The greater portion of this large body has been reduced to a lowland, but that part composing Mt. Newton has remained in relief on account of its superior resistance due to the comparative absence of fractures, shear-zones, and alteration.

Mt. Newton is like most of the other monadnocks, roughly conical in outline, smoothed and rounded by glaciation. Its base is about 3 miles in diameter, and its summit is 1000 feet above sea-level and about 900 feet above the lowland. Another similar, but smaller monadnock, Bear hill, occurs in the southern part of the Saanich map-area, and is 718 feet above sea-level. Still another farther to the south in the Saanich map-area, known as Saanich hill, has an elongate outline, corresponding with the northwest-southeast trend of its component rocks. It is 732 feet above sea-level. The most conspicuous elevation of the Victoria map-area is the steep-sided monadnock occurring in the extreme north central part, called

Mt. Douglas or Cedar hill. Its summit is 723 feet above sea-level. O the smaller monadnocks of the Victoria map-area, Christmas hill, 337 fee above sea-level, and Mt. Tolmie, 388 feet above sea-level, situated respect ively 3 and 2½ miles north of the city of Victoria, and Gonzales hill, 215 fee above sea-level, situated about 2 miles east of Victoria, are the most con spicuous. Several more or less isolated elevations occur in the western par of the Victoria map-area also, near the boundary of the upland portion Of these the largest are Mill hill and Seymour hill, respectively, about 620 feet and 460 feet above sea-level.

The northern end of the Saanich peninsula is composed of thick-bedded sandstones, which have an east-west strike and a steep dip northward. They are more resistant than the sheared and altered granitic rocks which underlie the larger part of the peninsula, and have, therefore, been left in relief and form a more or less continuous ridge corresponding in strike with its component rocks. The ridge is highest in its central part where it is about 460 feet above sea-level. It is here dissected by a transverse valley, so that the name Saddle hill has been given to it.

Lowland.

As may be surmised from the mention of the numerous monadnocks of varying sizes which surmount the lowland, the lowland itself is not flat, but, except where covered by drift deposits, is characterized by small irregular valleys and by a great number of glacially smoothed rock ledges. The valleys are well adjusted to the weaker parts of the rocks, shear zones, and joint planes, and frequently follow the contacts of the various rock formations, even where the contacts are irregular. The lowland is drained chiefly by numerous intermittent wet-weather streams, there being no larger rivers. Only the largest stream of the region, Colquitz river, about 4 miles long, situated in the north-central part of the Victoria map-area, and flowing in a general southward direction, has a continuous flow. In the other larger streams the flow disappears in places. In the northwestern part of the Victoria map-area are two streams of this type having a southeastward flow, Mill stream and Deadman river.

As stated, a large part of the lowland has been covered by drift, which was partially eroded during a second period of glaciation. In the eroded hollows in the drift mantle, lakes have collected, of which the largest lake of the region, Elk lake, situated in the south-central part of the Saanich map-area, is a type. Elk lake is slightly over 2 miles long in a north-south direction and its maximum width is about 1 mile. It furnishes the present water supply for the city of Victoria. Two similar, but much smaller lakes, less than one-half mile long, Lost and Swan lakes, are situated in the north central part of the Victoria map-area. Lakes also occur in rock valleys, which have been partially dammed by drift. In some instances the natural dam has been strengthened artificially in order to conserve the water. Of this type are Thetis lake and other smaller lakes in the northwestern part of the Victoria map-area. Some of the basins in the drift mantle, presumably the shallower ones, which may have at one time held small lakes, have been filled with alluvium and are now marshes.

As previously stated, in the lea of some of the monadnocks, such as Mt. Douglas and Mt. Tolmie, the drift was protected from erosion during the second period of glaciation, so that it now forms esker-like ridges or trains extending south from these monadnocks. The largest of these drift trains is that of Mt. Douglas, which is nearly a mile long and 80 to 100 feet high. Similar drift ridges, 100 to 200 feet in height, about half a mile wide, and 2 to 3 miles long, nearly straight, with their axes parallel to the glacial movement, approximately S. 25° E., occur in the southeastern part of the Saanich peninsula, but in these instances the cause of protection from erosion during the second period of glaciation is not clear. Since the recent uplift the drift deposits have suffered but little erosion, although in some instances, notably in the western part of the Victoria map-area, they have been terraced. In this locality the drift forms a wide, flat plain, from 200 to 250 feet above sea-level, known as Colwood plain. It is probably a delta deposit, as it occurs at the mouth of a wide east-west valley, which extends for 40 miles across the southern end of Vancouver island, and was apparently formed during glacial recession, since near its inner border it contains several kettle or ice block holes, the largest of which are 600 to 800 feet across and 80 feet deep.

Shore-lines and Islands.

As described above, it was apparently the depression of the glaciated and drift-covered lowland, with numerous monadnocks, followed by a partial recovery, which formed the present irregular shore-line of the region and the numerous islands. The larger initial irregularities of the shore-line, such as Saanich peninsula and Saanich inlet, and Victoria and Esquimalt harbours, have been already mentioned. The drowned valley, the outer portion of which forms Victoria harbour, also extends inland from the head of Victoria harbour for about 3 miles, where it is called Portage inlet. The islands occur in the eastern part of the map-areas along the western border of the submerged Pacific Coast downwarp. With two exceptions they consist of hard rock monadnocks, such as Portland and Moresby islands in the northern part of the Saanich map-area and Chatham and Discovery islands on the eastern boundary of the Victoria map-area. Some of the islands of this type are composed of thick-bedded resistant sandstones, like those of Saddle hill, and are, therefore, ridge-like, with a general northwest to westerly strike, corresponding to the strike of their sandstones. Since the sandstones have steep dips, there is little difference in the opposite slopes of the islands.

Islands of this nature, notably Coal, Domville, and Gooch islands, occur chiefly in the east-central part of the Saanich map-area. A small portion of Pender island, which is also of this type, is included in the northeastern corner of the Saanich map-area. Here the dip of the sediments, which is to the northeast, is moderately low. Hence the southwestern coast of the island, which is parallel to the strike, but at right angles to the dip, is, as is characteristic of ridges composed of resistant beds with a low dip, very steep, as much as 60 degrees in places, with a height of 300 to 400 feet.

The two islands which were noted as being exceptions to the prevailing monadnock type, James and Sidney islands, occur in the east-central part of the Saanich map-area. James island is composed wholly of, and Sidney island largely of the esker-like stratified drift ridges which were protected from erosion during the second period of glaciation, such as occur in the eastern part of the Saanich peninsula.

The shore has been subjected to a weak to moderately strong erosion during the present marine cycle. The initial shore-line must have been rather simple, with smooth, flowing outlines where the crystalline rocks were drift covered, but with many small rounded and smoothed irregularities where the glaciated rock surfaces were not drift covered. During the present marine cycle the uplifted drift deposits have been rapidly retrograded, forming sea-cliffs 200 to 250 feet high, with sand spits and bars, and, where wave erosion has been especially powerful, developing a nearly straight shore-line. The southern shore of James island is of this type.[1] Here the retrograded drift has been carried northward, forming spits extending north from the southern shore of the island. Opposite the western spit is a similar spit on the east shore of Saanich peninsula, and it is probable that as the two spits grow in size they will eventually join to form a bar or tombolo[2] tying James island to the Saanich peninsula. In the present stage the two spits form, what has been called by Gulliver, an uncompleted tombolo. Sea cliffs occur also along the east shore of Saanich peninsula and the east and west shores of James and Sidney islands, long spits extending northward from these islands. In the western part of the Victoria map-area the delta forming Colwood plain also has been retrograded. The retrograded material has been carried northward, presumably by shore currents, and has developed a bay bar over a mile long, which nearly closes a lagoon or bay apparently formed by the depression of a valley in the drift surface. To the south a similar but much smaller bay bar, less than 1000 feet in

[1] An idea of the rapidity of the retrogression of this shore is shown by a wire fence, which three years previous to 1910 was built to the edge of the cliff. By 1910 24 feet of the fence had been undermined and had consequently fallen, apparently not all at once but gradually as this part was retrograded uniformly with the rest of the cliff. It is improbable that the entire shore-line is being retrograded at a rate of 6 feet a year, but the rate is doubtless more than a foot.

[2] Gulliver, F. P., Shore-line topography. Proc. Am. Acad. Arts and Science, vol. 34, 1899, pp. 149-258.

length, virtually closes in a small lagoon. It looks as if this lagoon had been formed by the depression of a valley that was eroded along the southern boundary of the delta adjacent to a ridge of crystalline rocks, which project eastward from the retrograded delta and form a rocky point about a mile long, called Albert head.

In some instances, notably along the east shore of the Saanich peninsula and along the southern shore of Sidney island, the drift has been retrograded beyond the underlying rocks. Along the east shore of Saanich peninsula the hard rocks form merely small, rather sharp points, but along the south shore of Sidney island the drift has been largely removed, and a very irregular shore-line is the result. This type of shore-line is in marked contrast to the retrograded type, being still in a very young stage, while the latter is in a much more advanced stage, that of early maturity. When a young shore-line is developed in this manner, that is by the sea being brought against resistant rocks through the retrogression and removal of a less resistant covering, it is analagous to the valley of a superimposed river. Such a river is one that having reached an advanced stage while eroding the soft mantle of a more resistant rock, is then placed upon or "brought against" more resistant rock in which it must first develop a valley which is in a young stage. To emphasize this analogy, and to show the origin of this type of shore-line (see Plate III) the term contraposed (placed against) might be employed.

The larger part of the coast of the Victoria and Saanich map-areas is composed at present of resistant rocks, and the shore-line developed on them is still in a very young stage, similar to the southern shore-line of Sidney island. Virtually none of the initial irregularities of the depressed glaciated rock surface have been destroyed. On the contrary, as already mentioned, minor irregularities, such as small coves and wave chasms have been developed by wave action on the shear zones, joints, dykes, and interbedded softer rocks. In the more exposed places, however, on shores of low relief, narrow benches have been cut. The hard rocks themselves have not been beached, but since the submaturely retrograded drift deposits frequently occur between headlands of hard rock, in the protected places of the headlands narrow beaches composed of the material of the retrograded drift deposits are found.

CLIMATE AND VEGETATION.[1]

Because of the controlling influence of the Japan current on the climate of the Canadian Pacific coast the temperature of southeastern Vancouver island, especially of the coast lowland portion included in the Victoria and

---

[1]See McCurdy, Arthur W., "The Climate of Victoria," Nat. Geog. Mag., vol. 18, 1907, pp. 345-348.

Saanich map-areas, is remarkably uniform and temperate. The average temperature is about 40° F. in winter and 55° F. in summer, and the extremes of temperatures are comparatively small. In marked contrast to the rest of the Canadian Pacific Coast region the Victoria and Saanich map-areas have a light rainfall on account of the high mountain ranges in the paths of the prevailing and moisture-bearing winds—the Olympic mountains of Washington to the southwest, the Vancouver range to the west and northwest, and the coast range of the mainland to the north. The average rainfall at Victoria, which is probably representative of the whole area, is 32·5 inches per year. The greater part of the rain falls during the winter, while the summer is comparatively very dry.

The region was once heavily forested and covered by a thick undergrowth, except in certain parts of the drift-covered areas, such as Colwood delta, where, owing to the coarse and gravelly nature of the drift, the permanent water level was too deep to support heavy vegetation. The forest trees were largely conifers, but oaks are prevalent on the coarse gravelly drift deposits. Except in the upland portion of the map-areas, the conifers have been cut for timber, and the land has been cleared and is now under cultivation. The eroded hollows in the drift mantle, where the sub-soil is usually clay, are especially productive. Market truck and some grain is grown, but small fruit, in great variety, is the chief agricultural product.

GENERAL GEOLOGY.

GENERAL STATEMENT.

REGIONAL.

Vancouver island is composed of deformed metamorphic volcanic and sedimentary rocks, intruded and replaced by numerous irregular bodies of granitic rocks, and fringed along both coasts with fragmental sediments, which rest unconformably upon the older metamorphic and granitic rocks. Covering the hard rocks to a greater or less degree is a mantle of drift, which although partly stratified consists largely of glacial detritus. The metamorphic rocks are largely of lower Mesozoic age, presumably upper Triassic and lower Jurassic, but they may include some Palæozoic members. Apparently the oldest rocks, considered provisionally as of late Palæozoic (Carboniferous) age, are a series of slates and quartz schists extending across the southern end of the island, called the Leech River formation.

Apparently unconformable upon the Leech River formation, although separated from it largely by faults, are the lower Mesozoic rocks, which comprise the larger part of Vancouver island and constitute the Vancouver group. These rocks consist chiefly of metamorphosed basic volcanics, principally meta-andesites. Associated with meta-andesites, occurring chiefly in small intercalated lentils, is a formation of limestones called the Sutton formation. Also in the southwestern part of the island there is a thick horizon of calcareous rocks, apparently free from volcanic members, called the Nitinat formation. Besides the limestones, there is associated with the meta-volcanics a series, the Sicker series, of stratified slaty and cherty rocks, composed partly of volcanic material. These rocks and their associated volcanics have been greatly metamorphosed and converted into schists.

All of the above-mentioned rocks are intruded and partly replaced by batholithic and "minor intrusive" rocks. The batholithic rocks are chiefly granodiorite with marginal facies of diorite, and in the southeastern part of the island also gabbro-diorite and quartz diorite gneisses. All of the batholithic rocks are closely related and appear to have been irrupted during the same general period of intrusion, but they may be subdivided into four types that were irrupted in a definite sequence, apparently as follows: Wark gabbro-diorite gneiss, Colquitz quartz diorite gneiss, Beale diorite, and Saanich granodiorite. It is probable that the "minor intrusives," acid and basic porphyrites, were irrupted during the same general period of intrusion also, chiefly accompanying the Saanich granodiorite.

Unconformable upon an erosion surface of the metamorphic and granitic rocks, and confined for the greater part to the east coast of the island is a thick conformable series, the Nanaimo series, of fragmental sediments, conglomerates, sandstones, and shales, with some coal. It is largely of upper Cretaceous age but the uppermost portion may be lowermost Tertiary (Eocene) age. The Nanaimo series has been deformed, in general, into broad open folds with a northwest-southeast dip, but in places it is closely folded, overturned to the southwest, and broken by reversed and overthrust faults.

Along the southern coast is a thick series of basalts of upper Eocene age that are called the Metchosin volcanics. They have been deformed and intruded by small bodies or stocks of gabbro, the Sooke gabbro, which ranges from a basic to an alkaline gabbro and even to a true anorthosite. The alkaline types are confined to small masses and veins intrusive into the normal gabbro.

Along the west coast of the southern part of the island, confined to small narrow basins, is a series of sediments of Miocene age, the Carmanah and Sooke formations. These sediments, largely coarse conglomerates and sandstones, were deposited under marine conditions and are the remnants of a once more extensive Miocene coastal plain.

In Pleistocene times Vancouver island was covered by a thick ice cap, and large glaciers fed by valley glaciers from the ice caps of Vancouver island and the mainland filled the Straits of Georgia and Juan de Fuca. The resulting glacial till remains on the upland, but in the larger valleys and on the coast lowlands the drift although consisting largely of glacial detritus is stratified, having been deposited by river, lake, and marine agencies. A second, but lesser period of glaciation followed the deposition of the stratified deposits so that they have been partially eroded and covered with a younger glacial till. A recent uplift of some 250 feet has taken place bringing the coastal lowlands, with their covering of stratified deposits, largely of marine origin, to their present position, some 200 to 400 feet above sea-level.

LOCAL.

Only the metamorphic varieties of the rocks of the Vancouver group, presumably of lower Mesozoic age, occur in the Victoria and Saanich map-areas. They have been subdivided, chiefly on the basis of their lithological character, into the Vancouver volcanics, Sutton formation, and Sicker series. The Vancouver volcanics, which are the principal formation, consist largely of metamorphic volcanic flow rocks of medium basicity, meta-andesites; although meta-basalts, some of which originally contained olivine, are also found. Interbedded with the flow rocks are amygdaloids and fragmental volcanics, tuffs and agglomerates, and cutting them all are dykes and sills of volcanic porphyrites, chiefly basalt porphyrite. All of the volcanics have been metamorphosed and greatly altered, and some of them have even been recrystallized or replaced forming various metamorphic types such as silicified and feldspathized varieties, amphibolites and garnet-diopside-epidote rocks. They are also seamed with veins of quartz, and of quartz and epidote, and in places are impregnated with metallic sulphides, chiefly pyrite.

The Sutton formation is composed of crystalline limestone or marble and occurs as numerous lentils intercalated in the Vancouver volcanics throughout their entire thickness. The lentils are small, only one of them, extending from Esquimalt harbour west to Colwood plain, being over a mile long. The crystalline limestones are grey or greyish blue to white, compact to medium grained, and where unmetamorphosed are composed almost entirely of calcium and magnesium carbonates, the former greatly predominating. The only impurities are small amounts of argillaceous and carbonaceous matter and pyrite. Near the intrusive granitic rock the Sutton limestones have been contact metamorphosed into light coloured, coarsely crystalline marbles carrying diopside and wollastonite, and even into garnet-diopside-epidote rocks and silicified and mineralized varieties.

The Sutton limestones and Vancouver volcanics are in general contemporaneous and conformable, the limestones probably having been built by marine organisms that lived on the shores of volcanic islands formed during the eruption of the Vancouver volcanics. However, the actual contacts between the two formations are intrusive, the volcanics cutting the limestones, which frequently occur as inclusions in the volcanics.

The Sicker series consists of volcanic rocks and interbedded schists both of volcanic and of sedimentary origin, occurring in the northern part of the Saanich map-area. The volcanic rocks are meta-andesites, largely augite andesites, and both flow and fragmental types occur. They closely resemble the meta-andesites of the Vancouver volcanics, but are distinguished by their greater schistosity and mineralization and by their interbedded sedimentary rocks. The schists consist of slaty and quartzose schists, largely of sedimentary origin although partly tufaceous, and chlorite schists of volcanic origin. In addition some of the acid porphyrites intrusive into the Sicker series pass into quartz-chlorite-sericite or talc schists and into biotite schists not always distinguishable from the quartzose schists derived from sedimentary rocks. Both the schists and the volcanics have been more or less mineralized and replaced by magnetite, pyrite, chalcopyrite, and pyrrhotite, and cut by quartz and calcite veins carrying pyrite and chalcopyrite.

All of the rocks of the Vancouver group have been greatly deformed doubtless largely during the upper Jurassic period of mountain building. The general strike of the rocks, which on account of their massive character were, for the greater part, presumably warped into large folds, is about N. 55° W. to N. 65° W., and the dips are usually steep. However, the rocks of the Sicker series have been closely folded and contorted while even the

Vancouver volcanics and Sutton limestones have been involved in small folds. The rocks, especially those of the Sicker series, have also yielded by fracturing, shearing, and faulting.

During and following this upper Jurassic period of deformation all of the rocks of the Vancouver group were invaded by batholiths of granitic rocks and their accompanying minor intrusives. The granitic rocks may be subdivided into three main types, irrupted in a definite sequence as follows: Wark gabbro-diorite gneiss, Colquitz quartz diorite gneiss, and Saanich granodiorite. The minor intrusives, most of which accompanied the irruptions of the Saanich granodiorite, consist of dykes and small injected bodies of basic and acid porphyrites, and may be subdivided into granodiorite porphyrites, diorite porphyrites, and gabbro-diorite porphyrites, the last type being called the Sicker gabbro-diorite porphyrites.

The Wark and Colquitz gneisses form virtually a single batholith in the northern part of the Victoria map-area and southern part of the Saanich map-area. The Wark gneiss is a dark greenish rock of medium to coarse grain and gneissic texture, consisting essentially of light greenish weathering plagioclase (labradorite-andesine) feldspar, and hornblende, and since it is intermediate in composition between a gabbro and a diorite, is classed as a gabbro-diorite. In the southeastern part of Highland district, however, the Wark gneiss is represented by an unfoliated rock which consists of labradorite, feldspar, and augite, and is consequently a true gabbro. It, in turn, has a facies in which the calcic feldspar predominates and in which olivine is an essential constituent. The normal gabbro-diorite is not only gneissic but considerably altered and more or less metamorphosed, especially near the contacts with younger granitic rocks, where certain metamorphic varieties with large and frequently poikilitic hornblendes, or varieties in which recrystallized hornblende greatly predominates, have been developed

The Colquitz gneiss is a grey, medium grained rock of gneissic to schistose texture, consisting essentially of altered plagioclase (andesine) feldspar, quartz, hornblende, and biotite, and is classed as a quartz diorite At one locality, however, the gneiss is a biotite granite. It has also certain acid and basic or rather, salic and femic facies. The salic facies is light coloured, consisting essentially of quartz and feldspar, while the femic facies is dark, consisting almost entirely of hornblende. The facies commonly occur interbanded, the separate bands, or masses, varying in size from a fraction of an inch up to several yards in width, and thus producing a conspicuously banded gneiss. The banded gneiss is apparently a primary feature of the Colquitz gneiss, which was presumably irrupted during the mountain-building movements.

The youngest granitic rock, the Saanich granodiorite, forms a relatively large batholith underlying the Saanich peninsula, a stock underlying the southwestern part of Esquimalt peninsula, and several other small stocks.

It is a light coloured, medium grained rock, frequently having a somewhat gneissic texture and consisting essentially of feldspar, quartz, accessory hornblende, and usually biotite. The feldspar is of two varieties, orthoclase and plagioclase (andesine), the latter frequently occurring in rectangular crystals which weather greenish, while the former is interstitial and usually weathers pink. The granodiorite contains also numerous small rounded segregations, darker coloured than the normal rock and consisting chiefly of plagioclase and hornblende. Near its contacts the granodiorite passes into quartz and quartz-bearing diorites, and also into feldspathic and monzonitic diorites.

The granodiorite porphyrites form dyke-like and irregular intrusive bodies, that, for the greater part, are confined to the periphery of the Saanich batholith. They are light coloured porphyritic rocks characterized by a dense to fine grained groundmass, which consists essentially of quartz and both plagioclase and orthoclase feldspar, and phenocrysts of quartz and plagioclase, the quartz phenocrysts being absent in some varieties. Those porphyrites which are intrusive into the Sicker series have been dynamo-metamorphosed and pass into schistose varieties and even into quartz-chlorite and biotite schists.

The more basic types of the granodiorite porphyrites grade into diorite porphyrites. The diorite porphyrites usually form fairly well defined and regular dykes, from a few inches up to 70 feet in width, largely confined to the vicinity of the contacts of the Saanich batholith and the Esquimalt stock. They are greyish green, porphyritic rocks, with an aphanitic groundmass and phenocrysts of feldspar and also of hornblende and sometimes of augite.

The Sicker gabbro-diorite porphyrites form large masses, apophyses, and dykes which are intrusive only into the Sicker series. They are dark green, holocrystalline rocks, consisting essentially of plagioclase (labradorite-andesine) and hornblende. They vary greatly in texture from fine to medium grained porphyritic rocks with feldspar phenocrysts which frequently have a tendency to a radial arrangement, to very coarse grained varieties without a pronounced porphyritic texture. Some of the porphyrites are also foliated. They vary also in composition, some, especially the coarse grained rocks, consisting almost entirely of hornblende, while others are distinctly feldspathic.

Although the Wark and Colquitz gneisses form virtually a single batholith yet the Colquitz gneiss is distinctly intrusive into the Wark gneiss, the contacts being marked by wide zones of shatter breccias and numerous aplitic and pegmatitic apophyses of the Colquitz gneiss. Also the Wark gneiss is cut by large masses of quartz diorite, which are usually parallel to the foliation. The Saanich granodiorite is clearly intrusive into the Wark gneiss and doubtless is younger than the Colquitz gneiss. It brecciates the

Wark gneiss, forming extensive areas of "contact complex," consisting of shatter breccias and networks of granodiorite and aplite apophyses in the gabbro-diorite gneiss. The granodiorite porphyrites are distinctly intrusive into the rocks intruded by the Saanich granodiorite, and in many instances are clearly intrusive into the granodiorite itself. Frequently, however, their contact relations with the granodiorite are not clear, and some of them intrusive into the Sicker series, are apparently older than the granodiorite. The diorite porphyrites are younger than all the granitic rocks and also than the granodiorite porphyrites. The relations of the Sieker gabbro-diorite porphyrites with the other irruptive rocks are not clear, since they have not been seen in contact. They are apparently younger, but, on the other hand, they are seemingly magmatically related to the augite andesites of the Sicker series, and hence may be older.

All of the irruptive rocks have been more or less foliated, the gneisses greatly. The strike of the foliation is predominantly northwest-southeast, generally nearly N. 55° W., but varies widely. The rocks are also greatly jointed and fractured, and in places sheared. They are altered and, especially near the shear zones, are mineralized and cut by small and irregular quartz and quartz-epidote veins, but contain no mineral deposits of commercial value.

Resting unconformably upon the rocks of the Vancouver group and upon the irruptive rocks, is a conformable series of fragmental sediments of upper Cretaceous age, that is called the Nanaimo series. The series occurs only in the northern and northeastern portions of the Saanich map-area. It consists of conglomerates, sandstones, and shales, the sandstones predominating. Also thin coaly streaks and lenses, of no commercial value, are found near the lower part of the series. The rocks, although firmly indurated and extensively folded, are not appreciably metamorphosed though the shales have in places a slaty appearance and are cut by quartz or calcite veinlets and more rarely have been partially replaced by calcite.

The stratigraphic succession of the series cannot be determined since rocks of the same character do not form persistent beds, but both laterally and vertically pass rapidly into other rocks. Neither can their detailed structure be determined. However, in general, the rocks occur in two synclinal basins. The southern, called the Cowichan basin, is closely folded, strikes about N. 60° W., and has probably been overturned to the southwest so that the rocks have a prevailing dip to the northeast. A few smaller, and many minor folds occur, especially near the southern boundary of the basin. The northern boundary is a strike, thrust fault. Many smaller faults, both strike and dip faults, occur. To the northeast of the Cowichan basin are the lower parts of a smaller faulted synclinal basin, and the southwestern limit of another large synclinal basin, the Nanaimo basin, is found in the extreme northeastern corner of the map-area. The total thickness of the sediments involved in the deformation must be at least 6,000 feet.

The upper Eocene, Metchosin volcanics, occur only along the western border of the Victoria map-area. They are all basic, chiefly basalts and diabases, the latter occurring as dykes in the basalts. The basalts vary from coarse porphyritic and ophitic varieties to amygdaloids, and contain fragmental varieties, some of which are very coarse grained. One of the tuff beds, a few yards west of the western boundary of the map-area, is fossiliferous, containing upper Eocene gastropods. The Metchosin volcanics have been deformed, and more or less metamorphosed and altered, but not to nearly so great an extent as those of the Vancouver group.

The greater part of the Victoria and Saanich map-areas is covered with superficial deposits of various kinds, which consist, however, largely of glacial detritus. They may be subdivided according to their lithological character, and mode and time of deposition into the Admiralty till, deposited during an epoch of glacial occupation; the Maywood clays and Cordova sands and gravels, deposited during an interglacial epoch; the Vashon drift, deposited during a second and lesser epoch of glacial occupation; the Colwood sands and gravels, deposited during a stage of glacial retreat; and valley and swamp, and beach alluvium deposited during Recent time. The Admiralty till consists largely of an unstratified or rudely stratified yellowish grey, sandy clay with subangular to rounded pebbles and boulders, and is found only in a few localities in the crevices and small irregular hollows of the glaciated crystalline rocks. The Maywood clays consist chiefly of bluish or yellowish grey, sandy and carbonaceous clays, with numerous, irregularly distributed pebbles and boulders of crystalline rocks. They are well stratified and frequently contain layers of sand and gravel, and lignite is reported. They occur at the base of the interglacial deposits, resting upon the Admiralty till or upon the glaciated rocks, and are found throughout the map-areas usually at elevations of less than 100 feet, although they are found up to elevations of 220 feet. Their average thickness is probably nearly 100 feet. The Cordova sands and gravels conformably overlie the Maywood clays, and form low ridges in the southeastern part of Saanich map-area and eastern part of the Victoria map-area. They consist of yellowish, medium to coarse grained sand, with lentils and interbeds of gravel, and towards the base, of sandy clay. Scattered irregularly through the deposit are a few rather small, glacial boulders. The deposits are well stratified and frequently cross-bedded. Their average thickness is about 200 feet. The Vashon drift covers the greater part of the map-areas, mantling the interglacial deposits. However, below elevations of 250 feet, except in restricted localities, the mantle is thin, seldom more than 3 or 4 feet thick, and it frequently thins out completely or is represented only by large glacial boulders strewn on the surface. Above elevations of 250 feet the superficial deposits are composed chiefly of Vashon drift, probably mixed, however, with Admiralty till. The average thickness of the Vashon drift is probably not more than 10 or 15 feet. It is composed largely of an unsorted mixture of coarse yellow sand, gravel, and clay, with numerous large, glacial boulders. In places the finer portion of the drift is rudely stratified, and in the upland portions of the map-areas it is composed largely of a coarse rubble of the underlying rocks. The Colwood sands and gravels occur in the western part of the Victoria map-area and form a delta deposit, 200 feet thick, of cross bedded coarse sands and gravels, that was built at the mouth of a wide east-west valley near the ice front, during the last glacial recession. The swamp and valley alluvium consists of black muck, fine clays and silts, and in one instance of impure diatomaceous earth, largely deposited in the poorly drained hollows of the drift mantle. The beach alluvium consists of the coarse sands and gravel beaches, formed during the present marine cycle by the retrogression of the glacial and interglacial deposits, previously uplifted about 250 feet to their present position.

TABLE OF FORMATIONS.

Recent		Beach alluvium. Valley and swamp alluvium.
Glacial.		
Vashon epoch	Colwood sands and gravels	Deposits of glacial retreat.
	Vashon drift	Deposits of glacial occupation.
Puyallup epoch	Cordova sands and gravels Maywood clays	Interglacial deposits.
Admiralty epoch	Admiralty till	Earlier glacial deposits.
Upper Eocene	Metchosin volcanics	Ophitic basalt flows, tuffs and agglomerates with intrusive diabase dykes.
Upper Cretaceous	Nanaimo series	Unmetamorphosed conglomerates, sandstones and shales.
Batholithic and minor intrusives.		
Upper Jurassic and possibly Lower Cretaceous	Sicker gabbro-diorite porphyrite	Masses and dykes. Relative age doubtful.

	Diorite porphyrite....	Dykes.
	Granodiorite porphyrite.............	Masses and dykes of quartz and feldspar porphyrites. In part, may be older than Saanich granodiorite.
	Saanich granodiorite..	Batholith and stocks of granodiorite with contact facies of quartz, quartz bearing and monzonitic diorites.
	Colquitz quartz diorite gneiss...........	Batholith of quartz diorite gneiss with salic and femic facies.
	Wark gabbro-diorite gneiss...........	Batholith of gabbro-diorite gneiss, with unfoliated and salic gabbro facies.
Vancouver group.		
Jurassic sic...	Sicker schists........	Slaty and quartzose schists and chlorite schists.
	Sicker volcanics......	Metamorphic andesites and augite andesites, flows and tuffs.
Lower Jurassic, may include Triassic......	Sutton formation.....	Lentils of crystalline limestone in Vancouver volcanics.
	Vancouver volcanics..	Metamorphic andesites, basalts and olivine basalts, porphyries, amygdaloids, tuffs and agglomerates, and intrusive dykes and sills of basalt and andesite porphyrite.

DESCRIPTION OF FORMATIONS.

VANCOUVER GROUP.

The great bulk of the pre-batholithic rocks of Vancouver island are of lower Mesozoic age—Triassic and Jurassic—and have been named by Dawson[1] the Vancouver group. All of the pre-batholithic rocks of the Victoria and Saanich map-areas may be considered as belonging to the Vancouver group and are classified on the bases of distribution, lithology, and structure as Vancouver volcanics, Sutton formation, and Sicker series, including the Sicker volcanics and the Sicker schists. It is probable that some of the Vancouver volcanics occurring in the vicinity of Victoria and Esquimalt are Palæozoic in age, but they cannot be distinguished from those of lower Mesozoic age.

Vancouver Volcanics.

Under the name of Vancouver volcanics are grouped and mapped those volcanic rocks of the Vancouver group, which are not included in the Sicker series. They comprise the great bulk of the rocks of the Vancouver group, and form a fairly definite lithological and structural unit.

Distribution.

In the Victoria and Saanich map-areas there are several localities underlain by the Vancouver volcanics, the individual localities being separated by masses of intrusive granitic rocks. The largest area of the volcanics forms a belt which extends across the southern part of the Saanich peninsula. On the west shore of the peninsula, near Tod inlet, the belt is over 2½ miles wide, and on the east shore, at Cordova bay, over 3 miles wide, with an outlier 2 miles to the southeast near Gordon Head. However, the belt narrows in its central part, in the neighbourhood of Elk lake, to less than a mile. Along the south shore of Shoal harbour, on the east coast of Saanich peninsula, near the northern end, there is another area of the volcanic rocks, which doubtless extends southeast below the water, because similar rocks are exposed on Sidney and the D'Arcy islands. Two areas of somewhat more metamorphosed volcanic rocks occur in the vicinity of Victoria. The smaller one, to the east of Victoria, extends from Oak bay to Beacon hill, and the larger, west of Victoria, occurs in the vicinity of Esquimalt harbour, extending as far north as Thetis lake and westward to Colwood plain. Another much smaller area occurs at Knockan hill, and other very small and unmapped masses occur in the intrusive granitic rocks.

The less fractured portions of the Vancouver volcanics are fairly re-

[1] Dawson, G. M., Ann. Rept. 1886, Geol. Survey, Canada, p. 10 B.

sistant to erosion, forming small monadnocks surmounting the general lowland, and are consequently well exposed. The rocks are well exposed also along the shores. Hence the general outlines of the volcanic areas are well defined, although much of the detail of the boundaries is obscured by drift.

Lithological Characters.

The Vancouver volcanics are basic, chiefly andesites and basalts. Flow, fragmental, and injected types are present and include amygdaloids, porphyries, tuffs, breccias, and basic porphyrites. All of the rocks have been metamorphosed and some of them recrystallized. They are also seamed with veins of quartz, and of quartz and epidote, and in places impregnated with metallic sulphides, chiefly pyrite.

Meta-Andesite.

Macroscopic.—The most common rock type is a meta-andesite. Macroscopically the meta-andesites are greenish rocks, frequently of porphyritic texture, with an aphanitic groundmass and phenocrysts of feldspar and altered hornblende. The colour is usually dark green or greyish green, but the finer grained, sometimes silicified varieties are light green, and some more weathered varieties are reddish or purplish brown. The groundmass always predominates over the phenocrysts, which are usually small, seldom over 2 or 3 mm. in diameter. The meta-andesites have been sheared and altered and their green colour is due largely to secondary chlorite. In some instances irregular patches of light yellowish green epidote occur. The rocks are also cut by veinlets of quartz, epidote and calcite, and are commonly impregnated with pyrite.

Microscopic.—The groundmass is seen microscopically to consist essentially of small, lath-shaped crystals or microlites of andesine feldspar and hornblende, the latter being largely altered to chlorite. The only important accessory mineral is magnetite, which occurs in fine grains in relatively small amounts. The granularity of the groundmass varies from microaphanitic to decimillimetre grained. The original texture of the groundmass is frequently obscured by alteration, but the feldspar laths usually have a diverse arrangement with hornblende in the interstices. More rarely the two minerals are intergrown irregularly. The phenocrysts are of andesine and altered hornblende. They are usually of medium size, 1 mm. to 3 mm. in diameter, and at times are numerous, although, as mentioned, the groundmass is always dominant. The degree of alteration is large, and besides chlorite, mentioned above, the secondary minerals, calcite, epidote, zoisite, sericite, kaolin, quartz, and pyrite and limonite are common. Hematite and magnetite are sometimes apparently secondary minerals. More rarely in the normal meta-andesites the original hornblende has altered to uralite or actinolite.

Certain textural varieties of the normal meta-andesites occur, chiefly amygdaloids. The amygdules are seldom large, although frequently numerous, and are composed chiefly of chlorite, calcite, and more rarely of quartz. Taxitic, or eutaxitic, varieties occur, which, although flow rocks, contain fragments of similar composition but of different texture. Flow lines also are sometimes observed and are usually contorted and broken by very small faults.

Meta-Basalt.

Macroscopic.—Some of the volcanics, notably those of D'Arcy islands and the northern portion of the belt extending across the southern part of the Saanich peninsula, are more basic in composition than the meta-andesites and are classed as meta-basalts. They are similar in macroscopic appearance to the meta-andesites except that the phenocrysts of the dark coloured minerals are more numerous.

Microscopic.—The groundmass consists essentially of labradorite feldspar, altered augite, although sometimes unaltered remnants of augite occur, and presumably hornblende. As in the meta-andesites, magnetite, or possibly ilmenite, is the only important accessory. The granularity and texture of the groundmass is similar to that of the meta-andesites, although in some instances augite includes labradorite ophitically. The phenocrysts are labradorite, ca. Ab. 40 An. 60, and pyroxene, usually augite, although in one instance the pyroxene appears to be orthorhombic, apparently a non-pleochroic hypersthene. The phenocrysts are slightly larger than those of the meta-andesite, averaging 2 to 4 mm. in diameter, but they are not more numerous, the groundmass of the meta-basalts predominating. The meta-basalts are altered in a similar manner to the meta-andesites, the common secondary minerals being chlorite, serpentine, epidote, calcite, sericite, and quartz.

Inclusions of a similar composition, but of finer grain occur in the meta-basalts of D'Arcy islands. The inclusions are sometimes fairly numerous and vary from 1 inch to 18 inches in diameter.

Meta-Olivine Basalt.

Macroscopic—About one-fourth mile northeast of the head of Tod inlet there occurs a peculiar phase of the meta-basalts which apparently originally contained essential olivine. It is a dark greenish to purplish grey rock, with an aphanitic groundmass and fairly numerous small phenocrysts of an opaque, red, micaceous mineral (iddingsite) and a few phenocrysts of green weathering feldspar.

Microscopic—The essential minerals of the groundmass are labradorite ca. Ab. 45 An. 55, augite, and iddingsite, the last being apparently a pseudomorph after olivine. Magnetite is the only accessory mineral.

The groundmass is fairly fine, approximately decimillimetre grained, and the labradorite occurs in diversely to sub-radially arranged laths with subrounded grains of augite and flakes of iddingsite. The phenocrysts are plagioclase, probably labradorite, augite, and originally probably olivine now replaced by iddingsite, described in more detail in the next paragraph. The degree of alteration is moderate, the augite being altered very slightly, the feldspar phenocrysts considerably, but the feldspar of the groundmass slightly. The olivine, however, if originally present is entirely replaced. Except for the formation of iddingsite the alteration is similar to that of the normal meta-basalts and the secondary minerals are the same.

This iddingsite differs from that which has been heretofore described in that it does not appear to be uniform in composition. Near their centres, the grains are colourless with a very low birefringence, but with the other optical and crystallographic characters of iddingsite. Near the periphery of the grains and along cleavage cracks, are flakes of a typical, bright, brownish red iddingsite with a strong pleochroism and high birefringence, having the same orientation as the colourless centres. The central part of the grains is clouded with magnetite and is occasionally partly replaced by calcite or associated with it (See Plate V).

Since the central part of the grains is colourless and of low birefringence, it is probably a different mineral from typical iddingsite and may be a colourless serpentine of low birefringence, possibly antigorite. This occurrence, therefore, strengthens the conclusion, which has been previously stated,[1] that iddingsite is a lamellar serpentine coloured by red oxide of iron. In this instance the red oxide formed only on the outside of the grains and along cracks, where the iron was most readily oxidized. It is possible that the clouds of magnetite in the centre of the grains represent the partially oxidized iron of the original mineral from which the iddingsite was derived. From the occurrence and appearance of the iddingsite, one would consider it to be a pseudomorph after olivine, and the irregularity in its composition, as well as its crystallographic character strengthens this conclusion.

FRAGMENTAL VARIETIES.

Macroscopic.—Associated with the flow rocks are numerous fragmental volcanics. They vary from fine grained tuffs to agglomerates, consisting of angular fragments of volcanic rocks up to a few feet in diameter, (See Plate VI). They are rarely stratified, although on the shore north of Gordon Head in Victoria district there is a rudely stratified volcanic breccia, with apparently water-worn fragments, so that the breccia resembles a conglomerate composed entirely of volcanic detritus. The fragmental volcanics frequently weather to a red or purplish colour, while the more

[1] Iddings, J. P., Rock Minerals, N.Y., 1911, pp. 381 and 481.

dense, included fragments are green. Some of the amygdaloids and more altered phases of the normal andesites are also red weathering, but in general the red weathering fragmental varieties are in striking contrast to the green weathering flow types. However, this feature is not so pronounced in the Victoria and Saanich map-areas as in other parts of southern Vancouver island. Instead, in several of the fragmental volcanics, notably those exposed on the shore of Cordova bay and on Senamus island (in Saanich inlet), the matrix is dark green or is partly replaced by nodules of yellowish green epidote.

Microscopic.—The fragments are seen on microscopic examination to be mineral as well as rock fragments. The rocks are similar mineralogically to the flow types, but are invariably more feldspathic. They are more altered, original femic minerals being very rare, while the secondary minerals include besides chlorite, epidote, calcite, and sericite, which are also characteristic secondary minerals of the flow-types; kaolin and hematite, frequently in large amounts. Pyrite and limonite and quartz are also secondary products of these fragmental volcanics which have undergone much contact metamorphism.

Injected Types. Andesite and Basalt Porphyrites.

Macroscopic.—Many dykes and sills occur in the Vancouver volcanics and are related to them in origin. The dykes cutting the flow rocks are readily overlooked as they resemble the flow types macroscopically, but are conspicuous where they cut the fragmental varieties and intercalated limestones. The dykes are, as a rule, more basic then the flow rocks and include both andesite and basalt or dolerite porphyrites, the latter predominating. The porphyrites are dark green in colour, with an aphanitic to fine grained groundmass consisting of lath-shaped feldspars and dark femic minerals, with a few medium sized phenocrysts of feldspar, augite, and altered hornblende. The dykes in the limestone are commonly impregnated with pyrite and cut by calcite veinlets.

Microscopic.—The mineral composition is seen on microscopic analysis to be similar to that of the flow rocks. The essential constituents of the groundmass are plagioclase, ranging from labradorite, ca. Ab. 40 An. 60, to andesine, slightly more acid than Ab. 50 An. 50, augite, and originally hornblende. The accessory minerals are chiefly magnetite and ilmenite. The feldspars of the groundmass occur in diversely arranged laths, with interstitial and rarely poikilitic hornblende and augite. The phenocrysts are labradorite, andesine, augite, and hornblende. They are of medium size and subordinate in amount to the groundmass. With the exception of those that cut limestone, the porphyrites are less altered than the flow rocks, but the same secondary minerals are present, uralite, chlorite, epidote, sericite, and calcite.

Metamorphism.

As aleady mentioned, and as may be seen from the microscopic descriptions, the Vancouver volcanics are all greatly metamorphosed. The metamorphism, resulting in the alteration described above, the secondary minerals being chiefly uralite, chlorite, epidote, calcite, and sericite, is similar to that which takes place under conditions of moderate to shallow depths and moderate temperature. It has probably taken place in large part during the folding and shearing that the volcanics have undergone during periods of mountain building movements. However, near the contacts with the intrusive granitic rocks, the volcanics have been greatly contact metamorphosed and pass into the various metamorphic types described below.

Silicified and Feldspathized Varieties.

Macroscopic.—The most common type of the contact metamorphosed volcanics is one which is characterized by the presence of secondary quartz and feldspar. Macroscopically this type is a green, usually a light green, holocrystalline, but very fine grained rock, with a siliceous appearance. In some instances altered feldspar, having the appearance of original phenocrysts, is seen. The rock is commonly sheared and cut by veinlets of quartz, and less frequently of calcite. The rock is also partly replaced by quartz and other secondary minerals, feldspar, epidote, and calcite. The replacements are irregular in shape, and in the less metamorphosed stages form well defined lenses in the unreplaced rock. Pyrite also impregnates the rock, and, altering to limonite, stains the weathered rocks deep brown.

Microscopic—Microscopically the rock is seen to consist largely of secondary minerals. Andesine feldspar is usually the only original mineral, and it sometimes occurs as phenocrysts or fragments in a more altered groundmass, thus indicating the original texture of the rock. Frequently indications of the original texture are entirely wanting, the rock consisting of irregular fine grained aggregates of primary and secondary minerals. Besides quartz and secondary feldspar, presumably an acid plagioclase, the secondary minerals include uralite, chlorite, epidote, sericite, and calcite, as well as pyrite and limonite.

In places, as in the rock cut on the Esquimalt and Nanaimo railway east of Parsons Bridge station, the normal contact metamorphosed type passes into a grey, holocrystalline, rather fine grained rock, with a pronounced foliated texture, accentuated by veinlets of quartz. It is microscopically seen to consist of plagioclase, quartz, and hornblende, with secondary minerals, and cannot be distinguished from the fine grained, greatly foliated phases of the intrusive Colquitz quartz diorite gneiss.

AMPHIBOLITES.

Macroscopic.—In some instances, notably in the vicinity of Mi hill in Esquimalt district, the contact metamorphosed volcanics have bee converted into typical amphibolites. They are dark, finely crystallir and usually foliated rocks, cut by quartz veinlets, frequently parallel t and accentuating the foliation. At times larger feldspars are seen whic apparently are original phenocrysts.

Microscopic.—On microscopic examination the amphibolites ar seen to consist essentially of pale green hornblende and recrystallized feld spar, oligoclase, with a pronounced foliated texture. Quartz and magnetite ilmenite are accessory and epidote, chlorite, and sericite are secondary, bu are not present in large amount. In the more greatly contact metamor phosed varieties, quartz and acid plagioclase occur in larger amounts replacing the older minerals.

Chemistry.—The following is an analysis of a typical amphibolite with analyses of Massachusetts and Ontario amphibolites given for com parison.

	I.	II.	III.
SiO_2	51·60	51·25	50·83
Al_2O_3	15·00	16·53	18·64
Fe_2O_3	1·85	1·81	2·84
FeO	8·48	7·67	5·97
MgO	7·15	5·87	4·90
CaO	7·63	9·32	7·50
Na_2O	3·09	3·35	4·22
K_2O	0·70	0·78	1·83
H_2O-	1·95	0·19	1·40
H_2O+		1·26	
TiO_2	2·00	1·84	1·10
P_2O_5	0·18	0·31	undet.
MnO	0·24	0·28	0·10
	99·87	100·46	
CO_2			0·11
Cl			0·03
S			0·01
			99·48

Specific gravity, 2·95

I. Iron Mask mineral claim, south slope of Mill hill, Esquimalt district. M. F. Connor, analyst.

II. Amphibolite collected by B. K. Emerson, Palmer Center, Mass. W. F. Hillebrand, analyst. U.S. Geol. Surv. Bull. 419, 1910, p. 21.

III. Amphibolite collected by F. D. Adams and A. E. Barlow, Maxwells crossing, Glamorgan township, Ontario. Geol. Survey, Canada, Memoir No. 6, 1910, p. 104.

The norm of the Vancouver amphibolite is as follows:—

Quartz..........	1·86	Diopside........	9·95
Orthoclase.......	3·89	Hypersthene.....	24·14
Albite...........	26·20	Magnetite..	2·78
Anorthite........	25·02	Ilmenite.........	3·80
		Apatite..........	0·31

Class II.

$$\frac{Sal}{Fem} = \frac{57 \cdot 0}{41 \cdot 0} < \frac{7}{1} > \frac{5}{3}$$

Dosalane

Order 5.

$$\frac{F}{Q} = \frac{55 \cdot 1}{1 \cdot 9} > \frac{7}{1}$$

Germanare

Rang 3.

$$\frac{K_2O + Na_2O}{CaO} = \frac{63}{90} > \frac{3}{5} < \frac{5}{3}$$

Andase

Subrang 5.

$$\frac{K_2O}{Na_2O} = \frac{7}{50} < \frac{1}{7}$$

Beerbachose, very near Andose

Its mode as calculated from the chemical analysis and mineral composition as determined by the Rosiwal method is as follows:—

Hornblende................................	60·5
Oligoclase (Ab 77 An 23)	26·0
Quartz....................................	9·0
Magnetite.................................	1·2
Ilmenite..................................	1·8
Apatite...,..............................	0·1
Epidote...................................	0·9
Sericite..................................	1·0

The calculated analysis of the hornblende is given below, with the analysis of the hornblende separated from the Palmer Center, Mass., amphibolite given for comparison.

	I.	II.
SiO_2	42·4	44·09
Al_2O_3	13·9	10·68
Fe_2O_3	1·7	2·72
FeO	12·1	12·96
MgO	11·9	10·75
CaO	10·4	11·58
Na_2O	1·2	1·19
K_2O	1·0	0·88
H_2O	2·1	1·91
TiO_2	1·7	1·73
P_2O_5	0·15	0·10
MnO	0·3	0·33
	98·85	99·12
Sp. gr.		3·217

I. Calculated analysis of hornblende from Vancouver amphibolite.

II. Hornblende separated from Palmer Center amphibolite, W. F. Hillebrand, analyst, Bull. 419, U.S. Geol. Surv., 1910, p. 21.

From the data given above and from the analyses of other amphibolites[1] it is seen that the Vancouver amphibolite, in common with the greater number of amphibolites which have been described, differs from an ordinary igneous rock of the sub-alkaline group, having about 50 per cent of silica, in its low alumina, ferric oxide and potash, and high ferrous oxide, magnesia and incidentally, water and titanium. Nevertheless, the norm of the amphibolite corresponds with that of unmetamorphosed igneous rocks, chiefly diabases and basalts.[2]

GARNET-DIOPSIDE-EPIDOTE VARIETIES.

Rarely the volcanics have been metamorphosed into rocks characterized by the presence of garnet, diopside, and epidote, and in some instances the original rock has been completely replaced by these minerals. They are

[1] See F. W. Clark: Analyses of Rocks and Minerals from the Laboratory of U.S. Geol. Survey, Bull. 419, 1910. Most of the amphibolites given in this reference are described by B. K. Emerson in Geology of Old Hampshire county, Mass., Mon. XXIX, U.S. Geol. Survey, 1898. H. Rosenbusch, Elemente der Gesteinslehre, 1910, p. 532.

[2] H. S. Washington. Chemical Analyses of Igneous Rocks, Prof. Paper No. 14, U.S. Geol. Survey, 1903, p. 285.

identical with similar rocks derived from the contact metamorphism of limestones. They are restricted in their occurrence to those localities where a relatively large amount of mineralization has taken place, which in the Victoria and Saanich map-areas are the Penton claim situated in the southern part of South Saanich district, one-half mile east of Tod inlet, and the Iron Mask mineral claim situated in Esquimalt district, on the south slope of Mill hill.

Macroscopic.—The principal type is a massive, fine grained rock, light reddish brown to light green in colour, consisting of andradite garnet, diopside, and epidote, with quartz, calcite and epidote veinlets; and mineralized to a greater or less extent with pyrite, chalcopyrite, and magnetite. In some varieties garnet and diopside are absent, the rock consisting of epidote, and sometimes, chlorite, with quartz and calcite.

Microscopic.—The principal type is seen on microscopic examination to consist of andradite garnet in large irregular grains, and diopside in small prismatic grains with interstitial and vein-like epidote. Quartz also occurs in the interstices and frequently includes poikilitically the older minerals, especially garnet. Garnet with quartz and epidote sometimes occurs in veinlets in the diopside, and diopside grains are occasionally included in the garnet. Later veinlets of calcite cut all the other minerals. The apparent order of crystallization is, therefore, diopside, garnet, epidote, quartz, and calcite, although the formation of the first three minerals is, in general, contemporaneous.

Chemistry.—The following is an analysis of a typical specimen collected on the Iron Mask mineral claim, Mill hill, Esquimalt district. M. F. Connor, analyst.

SiO_2	42·86
Al_2O_3	7·19
Fe_2O_3	14·24
FeO	4·28
MgO	2·96
CaO	26·30
Na_2O	0·27
K_2O	0·33
H_2O	1·00
TiO_2	0·30
P_2O_5	0·21
MnO	0·50
	100·44
Sp. gravity	3·44

The following mode[1] and approximate analyses of the garnet, diopside, and epidote have been determined by the Rosiwal method, by calculation from the analysis, and by comparison with analyses of the same minerals occurring under similar conditions.

Andradite	45·0
Diopside	31·0
Epidote	19·0
Quartz	4·0
Calcite	1·0
Apatite	0·3
Chlorite	0·2

	Andradite.	Diopside.	Epidote.
SiO_2	35·0	50·0	38·0
Al_2O_3	5·5	0·3	25·0
Fe_2O_3	25·0	4·4	9·0
FeO	0·5	12·0	1·5
MgO	....	9·2	....
CaO	33·0	21·0	23·0
Na_2O	....	0·8	....
K_2O	....	1·0	....
H_2O	0·5	....	3·5
TiO_2	....	0·6	0·3
MnO	0·5	0·6	0·2

The origin of these garnet-diopside-epidote varieties is discussed under mode of origin (see page 47).

MINERALIZATION.

Along shear zones in the Vancouver volcanics the rock has usually been more or less impregnated with pyrite and occasionally, chalcopyrite. The mineralization is more pronounced in the contact metamorphosed phases, especially in the amphibolite and garnet-diopside-epidote varieties. The latter especially is replaced by metallic minerals, chalcopyrite, pyrite, and magnetite.

STRUCTURAL RELATIONS.

INTERNAL.—The various effusive varieties of the Vancouver volcanics are apparently conformable, flow and fragmental varieties occurring interbedded with each other. Although the fragmental varieties indicate explosive eruptions, no occurrence resembling an ancient and denuded

[1] Its norm, of course, does not agree with that of any known igneous rock.

volcanic neck was observed. However, the dykes of andesite and basalt porphyrites probably represent old lava channels. Although only relatively few dykes were observed, they may be fairly numerous for they are easily overlooked. Only the largest and best defined dykes are shown on the accompanying maps.[1]

On account of their massive and metamorphic character the attitude of the Vancouver volcanics can seldom be determined by direct observation. The rocks of the two northern areas have a general strike parallel to that of the belts which they underlie, that is about N. 60° W. The dips are apparently high, nearly vertical in the few cases where they could be determined. Occasionally, as on the shore of Cordova bay, north-south or northeast-southwest strikes are recorded, which indicate that the volcanics are involved in smaller folds.

The general strike of the volcanics in the vicinity of Victoria and Esquimalt seems to be more nearly east and west, approximately N. 80° W., and the dip nearly vertical. In this locality the original bedding is almost completely obscured but the rocks are foliated, and the foliation and bedding appear to be virtually conformable. In some instances, near Gonzales hill, in Victoria district, and Seymour hill, in Esquimalt district, the foliation, as shown on the accompanying map, is nearly north-south, which indicates that small folds occur in these localities also.

The volcanics are jointed, greatly faulted, and sheared. The jointing is seldom regular, although in some of the fine grained tuff beds, slaty cleavage has been developed, and on the D'Arcy Islands sheet jointing was observed. The sheared volcanics are commonly silicified and mineralized as described above and are cut by veins of quartz, quartz and epidote, and calcite, and rarely by veins of pyrite.

Since the attitude and detailed structure of the Vancouver volcanics are not known it is impossible to calculate their thickness. It must, however, be very great as the maximum width of the areas underlain by the volcanics, measured at right angles to the strike, is over 30,000 feet, and as the dips of the volcanics are high, the thickness may, therefore, be conservatively estimated as 10,000 feet.

EXTERNAL.

Relations to Other Members of the Vancouver Group.—The Vancouver volcanics and the Sutton formation, which consists of intercalated limestones in the volcanics, are in a general way conformable, the limestones probably occurring throughout the entire thickness of the volcanics. As described under Sutton formation (see page 43) the contacts

[1] Several dykes were noted cutting the intercalated Sutton limestones, but since the limestone masses are themselves small it is impossible to represent the dykes on the accompanying map, even approximately.

are, however, usually intrusive. The Vancouver volcanics are not seen in contact with the Sicker series in the area of the Victoria and Saanich map-sheets. However, the two are considered to be conformable, since the Sicker series contains volcanic members similar to those of the Vancouver volcanics, and since the structural relations of the two formations are the same.

Relations to Younger Formations.—All of the granitic rocks of the Victoria and Saanich map-areas, as well as their accompanying minor intrusives, are intrusive into the Vancouver volcanics. At the contacts, the volcanic rocks are brecciated and cut by apophyses of the granitic rocks, and also by irregular dykes of aplite, granodiorite porphyrite, and diorite porphyrite. In addition, near the contacts and over large areas also, the volcanics have been greatly metamorphosed by contact agencies into the various contact metamorphic and mineralized types described above.

The sedimentary rocks of the Nanaimo series rest unconformably upon the Vancouver volcanics, coarse basal conglomerates occurring near the base of the series made up largely of detritus from the rocks of the Vancouver group.

The mode of origin and age and correlation of the Vancouver volcanics is so closely associated with that of the intercalated Sutton limestones that the origin and age and correlation of the two formations is discussed together in the following section (see page 44).

Sutton Formation.

Intercalated with the Vancouver volcanics are numerous lentils of crystalline limestone or marble. It is probable that all of the limestone lentils of southern Vancouver island are of the same or nearly the same age, and they have been grouped into one formation, called the Sutton formation, from the type locality, on the south shore of Cowichan lake, 3 miles west of Sutton creek. Here the limestone contains fossils determined to be of lower Jurassic age.[1]

DISTRIBUTION.

The limestone lentils constituting the Sutton formation have in general a wide distribution throughout the area underlain by the Vancouver volcanics, but in the Victoria and Saanich map-areas they are largely confined to the two largest occurrences of the Vancouver volcanics, one, the belt extending across the southern part of the Saanich peninsula and the other, the area in the vicinity of Esquimalt harbour. There are two localities of Sutton limestone associated with the volcanic rocks of the first area, one in the vicinity of Tod inlet,

[1] C. H. Clapp, Memoir No. 13, Geol. Survey, Canada, 1912, p. 68.

where there is a lens about three-fourths of a mile long with a maximum width of about 250 yards, and the other at Cordova bay where limestone is exposed along the shore for about 100 yards, although intricately involved with volcanic rocks. There are three large lenses of limestone in the vicinity of Esquimalt harbour. One of them is the largest mass of limestone that has been measured in southern Vancouver island. It is over one-fourth mile wide and $1\frac{1}{2}$ miles in length, and extends west from Esquimalt harbour to Colwood plain. The other two large lenses occur respectively one-fourth mile north and $1\frac{1}{4}$ miles west of Esquimalt harbour. Six other small lenses which are shown on the accompanying geological map also occur associated with the volcanic rocks [illegible] Esquimalt harbour.

On the north side of Kno[illegible] hill there is a faulted lens of limestone associated with the small area of volcanics found in this locality. It has a maximum width of 75 feet and a length of about 1,400 feet. Other limestone lentils occur, which are not directly associated with the Vancouver volcanics since they form isolated lenses in the intrusive granitic rocks. The largest of these isolated lenses occurs about a mile northwest of Thetis lake in Highland district. It is 800 feet long, with a maximum width of about 150 feet. Two other occurrences are mapped, one near Pike lake in Highland district, and the other on the north shore of Victoria harbour, exposed in a small cove, locally called Lime bay. Several other patches of limestone occur, too small to map, since they are hardly more than inclusions in the Vancouver volcanics and intrusive granitic rocks.

Lithological Characters.

Macroscopic.—The Sutton limestones are all crystalline. They are chiefly grey to greyish blue, and even white, compact and medium grained marbles. They weather characteristically, developing solution hollows with smooth surfaces and small knob-like protuberances. When banded they weather differentially accentuating the banded texture. They are very frequently brecciated, and re-cemented by calcite veinlets. When not contact metamorphosed they are apparently very pure carbonates, although pyrite commonly occurs disseminated through the marbles in minute cubical grains.

Microscopic.—On microscopic examination the marbles are seen to consist essentially of calcite, or magnesian calcite, occurring in small grains, sometimes microscopic in size, that are firmly cemented together. Accessory or secondary constituents are, in many of the purer limestones, virtually absent. In others small amounts of argillaceous and carbonaceous matter occur.

Chemistry.—The following analysis is of one of the purer limestones of the Sutton formation.

Calcium carbonate, $CaCo_3$	95·35
Magnesium carbonate, $MgCO_3$	2·85
Ferric oxide Fe_2O_3 } Alumina Al_2O_3 }	0·16
Insoluble mineral matter	1·95
Sulphur S.	tr.
Phosphorus P.	tr.
	100·31

Sample from Rosebank Lime Company's quarry, one-half mile west of Esquimalt harbour. Analyst, F. G. Wait, Chemist, Mines Branch, Dept. of Mines.

The following analysis is furnished by Mr. Adolph Neu, formerly chemist with the Vancouver Portland Cement Company, and is an average analysis of the purer limestones from the quarry at Tod inlet:—

Calcium carbonate, $CaCO_3$	97·5
Silica, SiO_2	1·1
Iron oxide, Fe_2O_3	0·8
Magnesia, MgO	trace
Specific gravity	2·6

METAMORPHISM.

Near the contacts with the intrusive granitic rocks the marbles are coarser grained and correspondingly lighter coloured. Ordinarily calcite is the only essential mineral, but the accessory minerals are more numerous and in larger amounts. Diopside is the most common of the accessory minerals. It occurs in small irregular grains and has frequently been altered into a white to dark weathering, opaque serpentine. At one locality in Highland district, about one-half mile west of Fizzle lake and about 500 feet west of the boundary of the Saanich map-area, the marble contains irregular lenses and masses of white weathering wollastonite, which, being more resistant than calcite, is left in relief on the weathered surface. When present the original argillaceous matter has been recrystallized to sericite, and magnetite as well as pyrite is usually present.

The limestones have been metamorphosed also into garnet-diopside-epidote rocks that are identical with those which as described have apparently been formed by the contact metamorphism of the Vancouver volcanics. Farther west this type of metamorphism is fairly common, but in the Victoria and Saanich map-areas at only one locality, about one-half mile west of the head of Esquimalt harbour, were these rocks observed associated with pure limestones.

In some instances the marbles have been metamorphosed to a greyish white, cherty rock, consisting of a fine grained mixture of calcite, quartz, and sericite, and possibly feldspar. The rock is cut by veinlets of calcite and quartz containing pyrite, which mineral occurs also disseminated through the rock in small grains, frequently in considerable amount.

Structural Relations.

Internal.

Since the Sutton limestones occur in isolated lentils, the structure of the Sutton formation cannot be accurately determined. In general, however, it is the same as that of the Vancouver volcanics, since the two formations are so intimately related. The formation has, therefore, a general strike of N. 65° W., with steep dips. The individual lenses apparently correspond with the strike of the limestones. The greater number have, therefore, a northwest-southeast strike ranging from N. 55° W. to N. 80° W. The strike of the limestones exposed on the shore of Cordova bay is, however, N. 15° W., and two of the small lentils situated in the vicinity of Esquimalt harbour—those to the northwest of the head of the harbour—have north-south and N. 30° E. strikes. Where they can be observed or inferred the dips are in all cases steep, and usually to the southwest.

The limestones are usually greatly fractured and even sheared and slickensided. The fracturing or jointing is seldom regular, although some parallel sheet jointing is observed, notably in the large limestone mass extending from Esquimalt harbour to Colwood plain. The slickensides are produced by small faults probably of no very great throw. The Knocham Hill lentil is broken by two transverse faults, large enough to be shown on the accompanying map, having approximately a N. 25° E. strike, and producing a horizontal displacement of the limestone of about 75 to 100 feet.

As in the case of the Vancouver volcanics the thickness of the Sutton formation cannot be calculated. It may, however, be assuredly estimated as more than 1,000 feet.

External.

Relation to Vancouver Volcanics.—The Sutton formation, as already stated, occurs as limestone lentils in the Vancouver volcanics. Since the limestone lentils occur distributed throughout the entire thickness of the Vancouver volcanics, and since it has been shown[1] that some of the contacts of the limestones and volcanics are conformable, the two formations are considered to be contemporaneous in general. Nevertheless the actual contacts are intrusive, the volcanics forming irregular dykes

[1] Memoir 13, Geol. Surv. Can., 1912, p. 65.

and apophyses in the limestones (See Plate VII A) while the limestones frequently occur as inclusions in the volcanics. The character of the contacts, which are usually extremely irregular, is shown by the sketch map of the limestone exposed on the shore of Cordova bay (See Plate VII B) (Fig. 2). Intrusive contacts are observed also between the volcanic rocks themselves, and merely indicate that intrusive types occur intermingled with the limestones as well as with one another, and do not indicate that the limestones are an older formation or necessarily occur near the base of the Vancouver volcanics.

Relation to Younger Formations.—The Sutton formation has been intruded by the granitic rocks, the Wark diorite gneiss, Colquitz quartz-diorite gneiss, and Saanich granodiorite. These never cut unaltered limestones, but cut the contact metamorphosed varieties described above. However, apophyses of diorite gneiss occur in slightly altered limestone lentils in the granitic rocks, and in one instance at Colwood plain a nearly pure limestone is cut by a granodiorite porphyrite dyke.

No fragments of the Sutton limestones occur in the unconformably overlying sediments of the Nanaimo series, but some of the lower sandy shales of the series are calcareous, suggesting that they may have been formed in part from the detritus from the Sutton limestones.

Mode of Origin of Vancouver Volcanics and Sutton Formation.

At the type locality of the Sutton formation, at Cowichan lake, the limestones were evidently formed by the accumulation of marine organisms. It is probable that the Sutton limestones of the Victoria and Saanich map-areas are also of a similar origin, and indeed, in a few instances, fragments of poorly preserved fossils have been found, but the larger part of the limestones have been recrystallized to such an extent that any fossils which they may have contained have been entirely destroyed.

Since the Sutton limestones are of marine origin and are intercalated in the Vancouver volcanics, it is to be presumed, therefore, that the volcanics were largely submarine. The comparative rarity of tuffs and breccias and of interbeds of terrestrial material adds weight to this conclusion. The occurrence of angular and unstratified tuffs suggests that some of the old vents were above sea-level and formed islands. Also there are found in the volcanics a few conglomerates composed of rounded volcanic fragments, which imply that these volcanic rocks had been subjected to marine erosion on the shores of old volcanic islands. It was on these supposed volcanic islands that the organism which built the Sutton limestones lived; and since the fauna is very provincial, and since no interbeds of sedimentary material other than limestone occur with the Vancouver volcanics, it is probable that the volcanic islands were far from the mainland to the east.

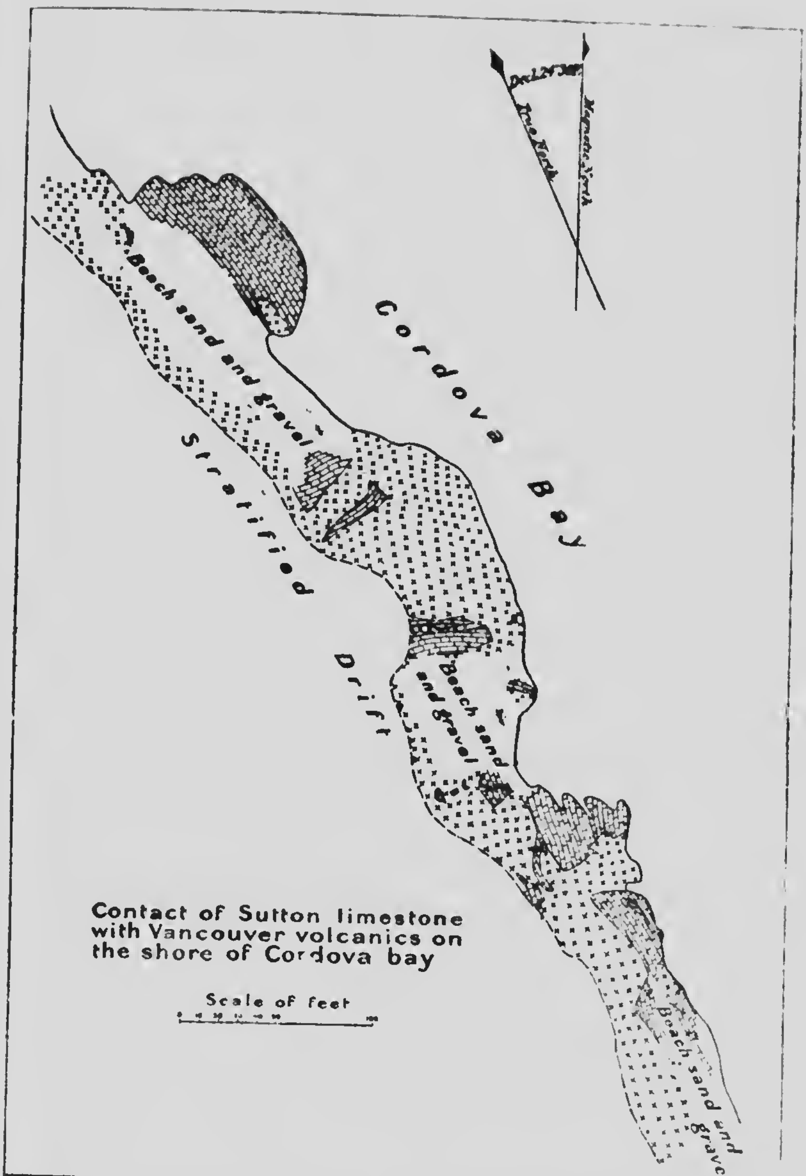


FIG. 2. Sketch map of the contact of Sutton limestones with Vancouver volcanics on the shore of Cordova bay, showing intrusive nature of volcanics.

Metamorphic Varieties.

The origin of most of the metamorphic phases of the Vancouver volcanics and Sutton limestones is clear. Undoubtedly the common alteration of the Vancouver volcanics and, in most cases, the crystallization of the Sutton limestones, took place under conditions of moderate to shallow depths and moderate temperature, largely during periods of dynamic metamorphism. Also the silicified and feldspathized phases of the Vancouver volcanics, and the silicified and the diopside and wollastonite bearing phases of the Sutton limestones have clearly been the result of contact metamorphism. Unquestionably the amphibolites and garnet-diopside-epidote rocks are also the products of contact metamorphism, but the nature of the original rock and the character of the metamorphism is not always clear.

Amphibolites.

Amphibolites are attributed to the metamorphism of basic igneous rocks and of limestones. Their formation by the contact metamorphism of limestone has been very fully described by Emerson[1] and by Adams and Barlow.[2] On Vancouver island amphibolites derived from limestones and from basic volcanics both occur.[3] The two types are virtually identical, except that those derived from the volcanic rocks frequently retain some evidence of an original igneous texture. The similarity in the composition of the two types is shown by the chemical analyses given above, the Massachusetts and Ontario amphibolites having been derived from limestones while the Vancouver amphibolite has almost certainly been derived from a basic volcanic rock. The Vancouver amphibolite is remarkably similar to those amphibolites described by Emerson, notably to the Chester amphibolite, which, as Emerson states, may in part be of eruptive origin. The origin of the various amphibolites of Vancouver island, since both types occur, must be determined by field relations; and these relations indicate that the amphibolites of the Victoria and Saanich map-areas have been formed largely if not entirely by the contact metamorphism of the Vancouver volcanics.

Garnet-Diopside-Epidote Varieties.

The development of garnet-diopside-epidote rocks by the contact metamorphism of limestones has been recognized in many parts of the world. It is also rather generally recognized at present that these rocks

[1] B. K. Emerson, Geology of Old Hampshire county, Mass. Mon. XXIX, U.S. Geol. Surv., 1898, pp. 66-306.

[2] F. D. Adams and A. E. Barlow, Geology of the Haliburton and Bancroft Area, Memoir No. 6, Geol. Surv., Can., 1910, pp. 101-112.

[3] Memoir No. 13, Geol. Surv., Can., 1912, pp. 46, 56, and 64.

may result from the contact metamorphism of relatively pure limestones, which presumably through the agency of hot gaseous emanations received additions of silica and iron from the invading magma, in sufficient amount to combine with the lime and magnesia of the limestones to form andradite garnet, diopside, and other silicate minerals. It has been shown that garnet-diopside-epidote rocks are fairly abundant in southern Vancouver island and, in most instances, have resulted from the contact metamorphism of pure limestones.[1] It is, therefore, quite certain that the garnet-diopside-epidote rocks associated with the pure limestone occurring one-half mile west of the head of Esquimalt harbour, are the result of the contact metamorphism of this limestone.

However, there is no limestone associated with the garnet-diopside-epidote rocks, previously described, from the Iron Mask and Penton mineral claims. Instead, the rocks are associated with meta-volcanics in such a way as to indicate that they were derived from the meta-volcanics by contact metamorphism. On the Iron Mask claim the garnet-diopside-epidote rock occurs in a shear zone in the meta-volcanics, which have been largely metamorphosed into amphibolites[2] and near the shear zone greatly silicified, mineralized, and traversed by numerous quartz veinlets. There are no large masses of granitic rocks exposed within a distance of one-half mile, but in the immediate vicinity of the shear zone are large, irregular apophyses of the Colquitz quartz diorite gneiss. The shear zone, which is 2 to 3 feet wide, striking N. 25° W. and dipping nearly vertical, is now largely occupied by a vein-like mass or replacement, 18 inches wide, of the garnet-diopside-epidote rock and associated chalcopyrite, pyrite, and magnetite.

On the Penton claim the garnet-diopside-epidote rock is developed at the contact of the Saanich batholith and sheared and schistose meta-volcanics. The contact phase of the batholith is the monzonitic contact facies of the Saanich granodiorite. The contact metamorphosed rock is largely a fine grained rock consisting of epidote, quartz, and calcite, and a large area of the meta-volcanics is irregularly mineralized, chiefly along shear zones, by pyrite and chalcopyrite. But near the actual contact is developed a mass of fine grained magnetite, 12 feet thick, with which the garnet-diopside-epidote rock occurs. Other instances of the close association of garnet-diopside-epidote rocks with meta-volcanics, have been noted farther west on Vancouver island, on the Sterling and Glen Apa claims on the upper Koksilah river, in Helmcken district, and on the divide between Cottonwood creek and Chemainus river in Cowichan Lake district.[3]

The origin of these garnet-diopside-epidote rocks is still open to doubt, since they may represent old limestone inclusions in the meta-volcanics,

---

[1] Memoir No. 13, Geol. Survey, Canada, 1912, pp. 45, 64, and 166.
[2] See p. 34.
[3] Memoir No. 13, Geol. Survey, Canada, 1912, p. 164.

for, as has been shown,[1] the limestones and volcanics have in places ve complex and intimate relations. It is even possible, although very impro able, that the amphibolites of the Iron Mask claim are metamorphic lim stones. In the field, however, it seems as if the garnet-diopside-epidote roc were replacements of the sheared country rocks, which in most instances a clearly of volcanic origin.

As may be seen from a comparison of the analyses of the amphiboli phase of the meta-volcanics, which probably does not differ greatly fro the composition of the original volcanic rock from which it was derived, an of the garnet-diopside-epidote rock, the change in composition caused by th contact metamorphism is very great.

	1.	2.	3.
SiO_2	51·60	42·86	123
Al_2O_3	15·00	7·19	209
Fe_2O_3*	11·27	19·00	25
MgO	7·15	2·96	242
CaO	7·63	23·30	32·7
Na_2O	3·09	0·27	1140
K_2O	0·70	0·33	212
H_2O	1·95	1	195
TiO_2	2	0·30	667
P_2O_5	0·18	0·21	85·8
MnO	0·24	0·50	

* All iron figured as Fe_2O_3.

(1.) Amphibolite (meta-volcanic) Iron Mask mineral claim, south slope of Mill hill, Esquimalt district. M. F. Connor analyst.

(2.) Garnet-diopside-epidote rock, Iron Mask mineral claim, south slope of Mill hill, Esquimalt district. M. F. Connor, analyst.

(3.) $\frac{\text{Amphibolite}}{\text{Garnet-diopside-epidote rock}} \times 100$

Since the details of the change cannot be read directly from the analyses, as there has doubtless been a change of mass in the formation of the garnet-diopside-epidote rock, the change in composition can best be shown by the "straight line" method of comparing analyses of unmetamorphosed and metamorphosed rocks.[2] The "straight line" diagram, Fig. 3, is obtained

---

[1] See page 43 and Fig. 2.

[2] W. J. Mead, Economic Geology, vol. 7, 1912, pp. 141-144

by plotting the product of 100 and the quotient obtained by dividing the per cent of each constituent in the original rock by its per cent in the metamorphosed rock. "This represents for each constituent the number of grains of altered (metamorphosed) rock required to contain the amount of that constituent originally present in 100 grains of fresh (unmetamorphosed) rock." On the diagram "the relative behaviour of the several oxides can at once be obtained by the position of the points on the line. If any constituent is assumed to have remained constant during the alteration (metamorphosed), all of the constituents whose points fall to the right have decreased in absolute amount and the constituents whose points fall to the left have increased." It is seen on the diagram (Fig. 3) that alumina and potash, constituents that are not liable to be changed in their amount during metamorphism, and water and magnesia as well, all fall near 200. It is probable, therefore, that 100 grains of the original amphibolite have, through the addition of other constituents, produced about 200 grains of the garnet-diopside-epidote rock. It is also seen that if this supposition is true, there has been an addition of silica and notable amounts of iron, lime, and manganese, and a marked loss in soda. The changes in titanium and phosphoric acid are probably not significant, since these constituents occur in such small and varying amounts in the original rocks. It is thus seen that the conversion of the meta-volcanics into the garnet-diopside-epidote rocks differs from the similar conversion of limestones, in that during metamorphism, notable amounts of lime, as well as of iron, manganese, and silica have been added to the original rock.

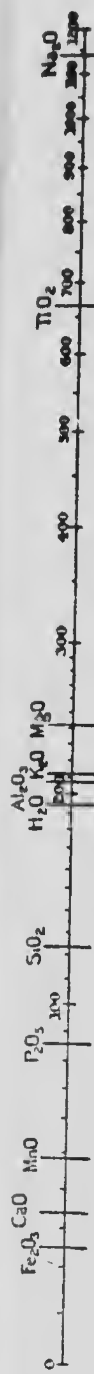


FIG. 3. Straight line diagram, illustrating change in composition of Vancouver meta-volcanics (amphibolites) by contact metamorphism to garnet diopside epidote rock.

The development of andradite garnet in igneous rocks is uncommon, but has been noted by Brock[1] in the Boundary Creek district in meta-volcanics, and even in granodiorite, both of which were intruded by younger granitic rocks; and by Kemp and Gunther[2] in a quartz porphyry intrusive into limestones at White Knob, Idaho. In both instances it appears as if a large part of the constituents of the garnet was introduced by solutions which

[1] Brock, R. W., Geol. Survey, Canada, Summary Report for 1902, pp. 108 A, 109A.

[2] J. F. Kemp and C. G. Gunther, Trans. Am. Inst. Min. Eng., vol. 38, 1907, pp. 269-296.

must have carried large [illegible] ants of both iron and lime. As noted, the addition of silica and [illegible] contact metamorphosed rocks has been well established, but the [illegible] on Vancouver island and those in the Boundary Creek district [illegible] White Knob, indicate that lime may also be added. In all these [illegible] ver, the irruptive rock cuts, in the immediate vicinity, large [illegible] estone. It is very probable therefore, as suggested to the wr[illegible] Lindgren, that the irruptive magma has assimilated limestone, s[illegible] olutions emanating from the magma are abnormally rich in lime

Age and Correlation of [illegible] and Sutton Formation.

From purely struc[illegible] age of the Vancouver volcanics and Sutton limestones ma[illegible] tely determined as lower Mesozoic, since they are pre-batholithic, t[illegible] pre-upper Jurassic, and probably younger than the Leech River formation which occurs to the west of the Victoria map-area, and which is considered to be Carboniferous. However, to the west of the Victoria and Saanich map-areas, certain fragmental and schistose volcanics occur that are conformable with the Leech River sediments, and hence are probably of Palæozoic age. It is very questionable, however, whether any of the volcanics of the map-areas should be correlated with these. Also, a belt of limestone lentils may be traced from Saanich inlet to Cowichan lake, where one of the limestone lentils contains a lower Jurassic fauna[1] that has been called the Sutton Jurassic. The lithological characters and structural relations of all the limestones in the belt are similar, and the volcanic rocks with which they occur are virtually continuous, so that the limestones and volcanics of the belt are doubtless of nearly the same age, that is, lower Jurassic. All of the limestones and associated volcanics of the Victoria and Saanich map-areas are related structurally and lithologically, although those in the vicinity of Victoria and Esquimalt are more metamorphosed than those of the southern part of the Saanich peninsula. Nevertheless it is most probable not that the former rocks are older than the latter, but rather that the former rocks have suffered greater contact metamorphism, because of the number and size of the granitic bodies intrusive into them. Therefore all of the limestones and associated volcanics of the Victoria and Saanich map-areas are considered to be of the same general age and are grouped into the same formations, the Sutton limestones and the Vancouver volcanics, which are members of the Vancouver group.

In northern Vancouver island, where the Vancouver group was first defined, Dawson found similar volcanic rocks with intercalated limestones

[1] C. H. Clapp and H. W. Shimer. The Sutton Jurassic of the Vancouver Group, Vancouver island. Proc. Boston Soc. Nat. Hist., vol. 34, 1911, pp. 436-438.

and argillites, which contain fossils referable to the Alpine Triassic.[1] It is seen, therefore, that the Vancouver group contains Triassic as well as lower Jurassic members. Hence it seems probable, that although part of the limestones and associated volcanics of the Victoria and Saanich map-areas are of lower Jurassic age, some of them may be of Triassic, presumably upper Triassic, age.

Sicker Series.

Exposed in the northern part of the Saanich map-area are a series of schists and interbedded volcanic rocks. The schists are of both volcanic and sedimentary origin. The series is pre-batholithic in age and apparently conformable with the Vancouver volcanics. Its volcanic members are similar to the Vancouver volcanics but are distinguished by their greater schistosity and mineralization, and by their interbedded sedimentary rocks. The series was first met with in 1908, and has been called from its typical occurrence on Mt. Sicker the Sicker series[2]. On the accompanying geological map the series has been subdivided into the Sicker schists and Sicker volcanics, but with the exception of their lithological characters the two members are described together.

Distribution.

The rocks of the Sicker series occur at the southern end of Saltspring island, and to the southeast on Russell, Portland, and Moresby islands. They are very well exposed along the shores of the various islands, but are not well exposed inland so that many of their boundaries are poorly located or are assumed.

Lithological Characters.

As mentioned, the rocks of the Sicker series include volcanics and sedimentaries, many of which are probably tufaceous. All of the rocks have been metamorphosed, many of them greatly, so that the sedimentaries and some of the volcanics have been converted into various types of schists. In many instances the origin of the schists is doubtful, so that they have not been subdivided into sedimentary and volcanic members, but have been distinguished in mapping from those volcanics which are less schistose and which are not intimately involved with rocks clearly of sedimentary origin.

Sicker Volcanics.

The volcanic rocks of the Sicker series are largely meta-andesites. They are, as mentioned, very similar to the meta-andesites of the Vancouver volcanics, and both flow and fragmental types occur.

---

[1] G. M. Dawson, Ann. Rept. Geol. Survey, Canada, 1886, pp. 7 B-11 B.
[2] Clapp, C. H., Memoir No. 13, Canadian Geological Survey, 1912, p. 71.

Meta-Augite Andesite.

The principal volcanic rock of southern Saltspring island is a metamorphosed porphyritic augite andesite, the augite phenocrysts having been largely replaced by hornblende. The type is identical with that which farther west occurs in large areas and which has been mapped with the Vancouver volcanics.

Macroscopic.—The meta-augite andesites are dark green porphyritic rocks with an aphanitic groundmass and fairly numerous, and relatively large—up to 2 cm. in diameter—phenocrysts of dark green hornblende, which sometimes have a nucleus of light green augite. Within the limits of the Saanich map-area the rock is sheared and sometimes has a schistose texture.

Microscopic.—The groundmass consists of a fine mat of amphibole (probably uralite) needles and andesine feldspar, with accessory magnetite. The phenocrysts are chiefly of pale green, weakly to moderately pleochroic hornblende, and, as seen macroscopically, often with a nucleus of augite. The hornblende is secondary after augite, but since it is a compact variety, such as would form only under conditions of high temperature and pressure, it is probable that it formed under magmatic conditions. In addition there are also a few small phenocrysts of andesine feldspar. The rock is usually greatly altered and the chief secondary minerals are uralite, chlorite, epidote, sericite, and calcite.

Meta-andesite.

Macroscopic.—The principal type of the Sicker volcanics of Portland and Moresby islands is a sheared porphyritic meta-andesite. It is green in colour, with an aphanitic groundmass and small phenocrysts of feldspar. It is greatly sheared and altered and is traversed by numerous quartz and epidote veinlets.

Microscopic.—On microscopic examination the groundmass is seen to consist of andesine and secondary amphibole, chiefly uralite, with accessory magnetite. The andesine predominates so that the groundmass is distinctly feldspathic. The phenocrysts are chiefly andesine, and are of medium size and subordinate in amount to the groundmass. The rocks are greatly altered, the more altered type consisting of an aggregate of andesine with uralite, chlorite, epidote, and quartz. Sericite and calcite also are present in smaller amounts.

Fragmental and Taxitic Varieties.

Fragmental and taxitic varieties of both the augite andesites and feldspathic andesites are found. They are similar in composition to the normal flow rocks, but differ in texture. The fragmental varieties are chiefly rather fine grained tuffs, no coarse agglomerates being noted. The taxitic varieties are chiefly flow-breccias, fragments of andesite being enclosed in andesites of identical composition but of slightly different grain or texture.

Sicker Schists.

The Sicker schists include slaty and quartzose schists largely of sedimentary origin and chlorite schists probably of volcanic origin. Some of the porphyrites intrusive into the Sicker series are also schistose, especially the granodiorite porphyrites, which pass into quartz-chlorite-sericite or talc schists, and biotite schists which cannot be distinguished from the quartzose schists that have probably been derived from sedimentary rocks.

Slaty Schists.

Macroscopic.—The most common type of schist clearly of sedimentary origin is a grey to nearly black, fine grained slaty rock, laminated in colour and foliated in texture.

Microscopic.—The essential constituents are seen microscopically to be quartz in fine, sub-angular grains, averaging about 0·2 mm in diameter and carbonaceous, quartzo- , and argillaceous material. Plagioclase feldspar is ordinarily present in small angular grains and is sometimes an essential constituent. Accessory and secondary minerals cannot be readily distinguished from each other; they include biotite, chlorite, epidote, calcite, and sericite as well as pyrite and limonite. The presence of feldspar and biotite, chlorite and epidote suggests that the rocks in which these minerals are abundant are partly of volcanic origin.

Rocks of the type described above pass into more schistose varieties, quartz-talc schists, graphitic schists, and other types which have been previously described.[1] The more extreme types of metamorphism are less common within the limits of the Saanich map-area than they are farther west.

Chlorite Schists.

Dark green schistose rocks, consisting chiefly of green chlorite and altered feldspar occur with the other schists and are apparently of volcanic origin, as they appear to be extremely metamorphosed phases of the meta-andesites.

Mineralization.

Both the Sicker volcanics and Sicker schists are more or less "mineralized," the chief metallic minerals being, in the order of their relative abundance, magnetite, pyrite, chalcopyrite, and pyrrhotite. In the schists, especially near intrusive porphyrites, the mineralization is especially rich, and certain of the impregnated and replaced schists have

[1] Memoir No. 13, Geol. Survey, Canada, 1912, pp. 75-77.

been prospected slightly in the search for copper ore. Pyrite and chalcopyrite bearing quartz and calcite veins are found also.

Structural Relations.

Internal.

The volcanic and sedimentary members of the Sicker schists are conformably interbedded as is clearly exposed along the northwest shore of Portland island. The Sicker schists as a whole are doubtless conformable and apparently interbedded with the Sicker volcanics, although in the Saanich map-area most of the schists lie to the south or southwest of the volcanics. However, on the east shore of southern Saltspring island, north of Isabella point, there are two small areas of schists apparently interbedded with the volcanics; and on Russell island and near the northern point of Moresby island, schists are exposed which occur to the northeast of the volcanics.

The rocks of the Sicker series have been closely folded and frequently wrinkled into small folds and contortions (See Plate VIII). The small folds and contortions are best exposed along the south shore of Saltspring island and the northwest shore of Portland island. They vary greatly in shape from those having rounded crests and troughs to those having angular crests and troughs. Many of the smaller folds are closed, but open, flat-topped folds occur also. The dynamic forces which have caused this extreme type of folding have developed also the foliation or schistosity which is usually, but not always, parallel to the bedding.

The general strike of the series is nearly N.60° W. and varies but slightly. The dips are chiefly steep, very commonly nearly 90 degrees. On southern Saltspring island and on Russell and Portland islands the prevailing dip is to the northeast, but on Moresby island it is to the southwest. The structure of the series is, however, too complicated for the larger folds to be determined, so that the stratigraphic succession of the volcanics and schists and their thickness cannot be determined. The sedimentary rocks apparently occur near the upper part of the series, since farther west along Chemainus river they grade into relatively unmetamorphosed sediments.[1] If this is true, the rocks of southern Saltspring island and Russell and Portland islands have been overturned. Since the belt underlain by the Sicker series is over 15,000 feet wide and as the dips of the strata are high, the thickness of the series may be safely estimated as at least 5,000 feet.

The series has also been faulted extensively. The faults are chiefly strike faults and are probably compression or reversed faults. They are accompanied by a large amount of shearing and slickensiding, frequently developing extensive shear-zones. In most instances it is impossible to

[1] Memoir No. 13, Geol. Survey, Canada, 1912, p. 82.

determine the amount of displacement of the faults; but it is probable that the total displacement is not proportional to the large amount of shearing. Transverse faults also occur, and are seen along the southern shore of Saltspring island and the southwest shore of Moresby island. They are usually of small displacement and are not marked by extensive shear zones. Besides the smaller faults described above, large boundary faults occur, which bring the rocks of the Sicker series into contact with those of the Nanaimo series. These faults, which are described further in connexion with the structural relations of the Nanaimo series (see page 99), are chiefly strike faults, but transverse faults also occur, as on Russell, Portland, and Moresby islands.

As noted, the Sicker series are cut by numerous quartz and quartz-epidote veinlets. These were formed in part before the deformation of the Sicker series took place as some of them have been contorted and sheared with the rocks which they cut.

External.

Relation to the Other Members of the Vancouver Group.—The Sicker series is, as mentioned, considered to be conformable with the Vancouver volcanics. By the gradation of their sedimentary rocks into unmetamorphosed sediments it is suggested (see page 54) that the Sicker series occurs near the upper part of the Vancouver group, and may overlie the Vancouver volcanics. There are, however, certain objections to this conclusion.[1]

Relation to Younger Formations.—The Sicker series have been intruded by the Saanich granodiorite and accompanying minor intrusives, granodiorite porphyrites, and Sicker gabbro-diorite porphyrites. The only body of intrusive granodiorite occurs in the western part of Moresby island. Near its contacts with the Sicker volcanics, it includes large blocks of the volcanics elongated in the direction of foliation, and also apophyses of it extend into the volcanics. The granodiorite porphyrites forms an intrusive mass into the Sicker series in the southeastern part of Saltspring island. It was apparently intruded during the deformation of the Sicker series, since portions of it are schistose. The gabbro-diorite porphyrite forms large and irregular intrusive bodies, which are usually elongate in the direction of the foliation of the Sicker series, and which occur on Saltspring, Portland, and Moresby islands.

The Nanaimo series unconformably overlies the Sicker series; and in a few instances as exposed on Russell and Portland islands, basal conglomerates of the Nanaimo series, composed of the detritus of the Sicker rocks, rest directly upon the Sicker series. In other instances the contacts between the Nanaimo and Sicker series are faults. Those of southern Saltspring

[1] Memoir No. 13, Geol. Survey, Canada, 1912, p. 83.

island, occurring near the southern and eastern shores, are strike and probably reversed faults of considerable displacement. Strike faults occur also in the northern part of both Portland and Moresby islands separating the Sicker from the Nanaimo series. On Russell island the unconformable contact of the Sicker and Nanaimo series is displaced by a transverse fault, and transverse faults occur also on Moresby island. The fault which traverses Portland island, having a general north-south strike, separates the rocks of the two series, and in its northern portion is apparently conformable with their foliation and bedding. But in its central and southern portion it cuts across the foliation of the Sicker series, although it may conform to the strike of the Nanaimo series.

Mode of Origin.

The Sicker series have been seen to consist of volcanic rocks, largely andesitic, with schists, largely of sedimentary origin. Even the sedimentary rocks, however, are probably in part tufaceous. The sedimentary and volcanic rocks are interbedded, but the sedimentary rocks predominate in apparently the upper part of the series. The rocks have been closely folded, greatly metamorphosed and mineralized, and intruded by granitic rocks and porphyrites. The metamorphism has been in part dynamic, but the extreme metamorphism and mineralization which has converted the volcanic rocks into chlorite schists, and sedimentary rocks into quartz-talc and graphitic schists has been due in large measure to contact and thermal agencies active during the intrusion of the granitic and porphyritic rocks, notably the gabbro-diorite porphyrites.

Age and Correlation.

The Sicker series is pre-batholithic in age, that is, pre-upper Jurassic, and is doubtless conformable with the Vancouver volcanics. It is, therefore, one of the members of the Vancouver group, and may be, as suggested, one of its higher members. If the series is one of the higher members, it is probably lower or middle Jurassic in age, if not, it may be either Triassic or Jurassic.

Summary of Internal Relations of Vancouver Group.

It is seen that the Vancouver volcanics, Sutton formation, and Sicker series compose what is apparently a conformable group, all having the same structural relations and occurring contiguous to one another. The thickness of the group is very great, at least 16,000 feet, if the estimated thicknesses of the various formations are, as is believed, conservative minimum estimates. If the thickness of the Nitinat formation,[1] which is considered

[1] A calcareous formation, occurring in the vicinity of Nitinat lake. Memoir No. 13, Geol. Survey, Canada, 1912, p. 44.

to be a member of the Vancouver group, is also added, the total thickness of the Vancouver group is considerably more than 20,000 feet,[1] and is doubtless near 25,000 feet.

BATHOLITHIC AND MINOR INTRUSIVES.

Intrusive into the rocks of the Vancouver group, are batholiths and stocks of plutonic rocks, and smaller masses of injected rocks. The plutonic or batholithic rocks, although irrupted during the same general period of batholithic intrusion, may be subdivided into three main types, irrupted in a definite sequence. These types are, in the order of their irruption, Wark gabbro-diorite gneiss, Colquitz quartz diorite gneiss, and Saanich granodiorite. The smaller masses of injected rocks, or, as they are called, the minor intrusives, were irrupted during the same general period. They consist of dykes and small injected bodies of basic and acid porphyrites. They are of three principal types, granodiorite porphyrites, diorite porphyrites, and gabbro-diorite porphyrites. These last, which have been previously described with the Sicker series,[2] are virtually restricted in their occurrence to the Sicker series, and are, therefore, given the distinctive name of Sicker gabbro-diorite porphyrites.

In the following description, the distribution and lithological characters of each of the types are first described separately, and then the structural relations, mode of origin, and correlation of all the types, are considered together.

Wark Gneiss.

Distribution. (With Distribution of Colquitz Gneiss.)

The Wark and Colquitz gneisses are very intimately involved and form virtually a single batholith, extending for 15 miles across the northern part of the Victoria map-area and the southern part of the Saanich map-area. The batholith attains its greatest width in Highland district, where it is about 7 miles wide. The gneisses are well exposed in the western portion of the map-areas, but in the eastern portion the exposures are largely confined to the shores and to the low monadnocks that surmount the drift covered lowland of southeastern Vancouver island. The Wark gneiss is typically exposed on Mt. Wark in Highland district, and Wark has, therefore, been chosen as its distinctive geographic term. The Colquitz gneiss has been given the geographic name Colquitz, after the largest stream in the Victoria map-area. The boundaries of the batholith are well located where the rocks are exposed, but only inferred where the rocks are drift covered. On the whole, however, the boundaries are fairly accurately determined. The

[1] Given as minimum thickness in Memoir No. 13, Geol. Survey, Canada, 1912, p. 91.
[2] Memoir No. 13, Geol. Survey, Canada, 1912, p. 78.

boundaries between the two types of gneisses are frequently poorly located because of the lack of exposures. In general, however, they follow the foliation of the rocks, so that the general size and shape of the individual masses is fairly well shown on the accompanying geological map. As may be seen on the map, and as has been mentioned above, the two types are intimately involved. The Colquitz gneiss is intrusive into the Wark gneiss and forms in general lenticular masses elongate in the direction of foliation, that is nearly N. 60° W. There are also areas where the Wark gneiss is so minutely and intricately brecciated by the Colquitz gneiss, and by the Saanich granodiorite as well, that they can be mapped only as contact breccias.

Lithological Characters.

Gabbro-Diorite Gneiss, Normal Phase.

Macroscopic.—The principal rock type of the Wark gneiss is a gabbro-diorite gneiss. It is a dark greenish rock, of medium to coarse grain and of gneissic texture. It consists essentially of light greenish weathering feldspar and hornblende. The feldspar usually predominates, but the relative proportion of feldspar and hornblende varies, and some varieties contain approximately 75 per cent of hornblende. With the essential minerals are varying amounts of quartz and biotite. The rock is commonly cut by quartz veinlets and impregnated slightly with pyrite.

Microscopic.—Microscopically, the essential constituents are seen to be plagioclase feldspar and hornblende. The feldspar varies from labradorite ca. Ab. 45 An. 55, in certain rocks, to andesine ca. Ab. 60 An. 40, in others, but in the individual grains of any single facies there appears to be but little tendency to a zonal change of composition. The hornblende is a rather pale green, common variety of negative character, with a moderately strong pleochroism, ranging from light yellowish green to bluish green. Some of the grains contain a small nucleus of augite, partly and irregularly replaced by hornblende. This fact suggests that a large part of the hornblende may be secondary after augite. The accessory constituents are quartz, biotite, magnetite, titanite, and apatite. The amount of quartz varies greatly, in some facies being as high as 15 per cent, while in many others it is absent. It always occurs in the interstices of the other minerals, and may be largely secondary, having been formed during the contact metamorphism of the Wark gneiss by the intrusive Colquitz gneiss and Saanich granodiorite. The original texture of the rock has been partially destroyed, and the original minerals are now fractured and crushed, and more or less elongated in the direction of foliation. Since its foliation the rock has also been altered considerably, developing the following secondary minerals: biotite, chlorite, epidote, serpentine, sericite, kaolin, and limonite. Also veinlets of quartz, sericite, and calcite are common.

Chemistry.—The following analysis is of a typical quartz-free member of the Wark gneiss, collected from a road cut, one-half mile south of Mt. Tolmie, in Victoria district. M. F. Connor, of the Mines Branch of the Department of Mines, is the analyst. With the analysis are given for comparison the average compositions as calculated by Daly[1] of diorite, excluding quartz diorite, and of gabbro, excluding olivine gabbro.

	Wark gneiss.	Average diorite.	Average gabbro.
SiO_2	48·68	56·77	49·50
Al_2O_3	18·05	16·67	18·00
Fe_2O_3	3·41	3·16	2·80
FeO	6·44	4·40	5·80
MgO	2·82	4·17	6·62
CaO	10·00	6·74	10·64
Na_2O	3·18	3·39	2·82
K_2O	1·60	2·12	0·98
$H_2O\pm$	2·40	1·36	1·60
TiO_2	0·80	0·84	0·84
P_2O_5	2·01	0·25	0·28
MnO	0·20	0·13	0·12
	99·59	100·00	100·00
Specific gravity	2·91		

The norm of the Wark gneiss is as follows:—

Quartz	1·62	Diopside	6·25
Orthoclase	9·45	Hypersthene....	11·94
Albite	26·72	Magnetite	4·87
Anorthite	30·30	Ilmenite	1·52
		Apatite	4·34

Class II.

$$\frac{Sal}{Fem} = \frac{68\cdot 1}{28\cdot 9} < \frac{7}{1} > \frac{5}{3}$$

Dosalane

Order 5.

$$\frac{F}{Q} = \frac{66\cdot 5}{1\cdot 6} > \frac{1}{7}$$

Germanare

Rang 3, near rang 4.

$$\frac{K_2O + Na_2O}{CaO} = \frac{68}{109} < \frac{5}{3} > \frac{3}{5}.$$

Andase

Subrang 4.

$$\frac{K_2O}{Na_2O} = \frac{17}{51} < \frac{3}{5} > \frac{1}{7}$$

Andose, near Hessose

[1] Daly, R. A., Average Chemical Compositions of Igneous Rock Types. Proc. Amer. Acad. Arts and Science, vol. 45, 1910, pp. 209-240.

The actual mineral composition or mode, as determined by the Rosiwal method, aided by calculation of the chemical analysis, is as follows:—

Orthoclase	7·3
Labradorite, Ab 47, An 53	53·4
Hornblende	31·8
Biotite	4·1
Magnetite	2·3
Apatite	1·2

Since there are too many variables or unknown quantities the composition of the hornblende and biotite cannot be determined. Assuming that the biotite is of average composition, which assumption will not introduce a very large error since biotite occurs in such small amount, the composition of the hornblende may be approximately calculated as follows:—

SiO_2	44
Al_2O_3	3
Fe_2O_3	5
FeO	18
MgO	8
CaO	12
Na_2O	1
H_2O	2
TiO_2	2
P_2O_5	4
MnO	1

This calculation indicates that the hornblende must be relatively high in ferrous iron and phosphoric acid, and relatively low in alumina and magnesia.

It is seen from the chemical analyses given above that the Wark gneiss differs in composition from the average gabbro in its higher alkalies and lower magnesia. These differences are caused by the presence of a more alkaline feldspar than is characteristic of a true gabbro, and of a magnesia-poor hornblende. The rock is, therefore, not a true gabbro but is transitional into a diorite. Also its norm, andose, is more characteristic of diorites than of gabbros. The distinction made between gabbro and diorite is chiefly in the alkalinity of the feldspar, although the preponderance of pyroxene in gabbro and amphibole in diorite is recognized also. The dividing point in the feldspar is virtually that between labradorite and andesine, that is Ab. 50 An. 50. In the Wark gneiss the feldspar ranges to either side of this dividing point, although it is slightly more calcic in the rock analysed. The hornblende is in part primary, although augite may have been present in much greater amount in the original rock. Therefore, while having strong gabbro affinities the Wark gneiss is also allied to a diorite, and is classed as a gabbro-diorite gneiss.

Fine Grained Phases.

Fine grained phases of the Wark gneiss occur associated with the normal gabbro-diorite gneiss especially near the contacts with the intrusive Colquitz gneiss and Saanich granodiorite. They form segregations or inclusions in the normal rock, sometimes several yards in width. In places they form bands parallel to the foliation, but more commonly they form irregularly shaped masses, which frequently are elongate in a direction transverse to the foliation. In a few instances, as on the shore south of Gordon head in Victoria district, small dyke-like masses of the fine grained rock occur in the normal coarser grained gneiss. Some of these masses have apparently been broken and their fragments separated several

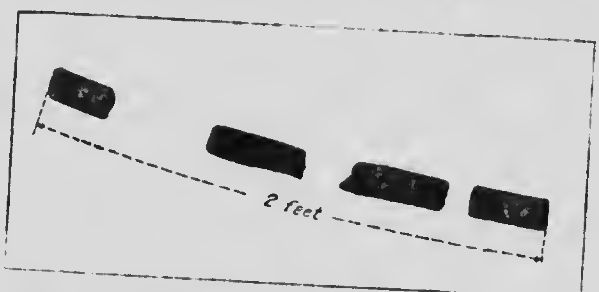


Fig. 4. Fine grained, dyke-like segregation in the Wark gneiss, apparently broken and pulled apart by movement in the Wark gneiss while still in a viscous condition.

inches from each other by movements in the normal rock, while it was still in a plastic or viscous condition[1] (See Fig. 4). In a few instances, also, apophyses of the normal coarser grained gneiss cut the inclusions or segregations of the fine grained rocks.

Macroscopic.—The fine grained phases of the Wark gneiss are darker in colour, as well as finer grained, than the normal gneiss, and are commonly more foliated, passing into a hornblende schist or amphibolite.

Microscopic.—On microscopic examination they are seen to consist of the same minerals as the normal gneiss. In them, however, in addition to the other secondary minerals, secondary hornblende, fibrous amphibolites, and secondary feldspar, probably albite, have been developed. The minerals

[1]Compare with broken amphibolite inclusions in red gneiss, described and figured by Adams and Barlow, Memoir No. 6, Geol. Survey, Canada, 1910, p. 76.

occur in small euhedral grains, elongated in the direction of foliation, thus developing a pronounced gneissic to schistose texture.

GABBRO.

Associated with the normal gabbro-diorite gneiss and occurring in large masses notably in the southeastern part of Highland district to the northeast of Thetis lake, is a typical gabbro, with a salic gabbro differentiate.

Macroscopic.—The gabbro is dark coloured and of medium to coarse grain, but is not foliated. It consists of green weathering feldspar and dark coloured pyroxene, which resembles hornblende since it has a good cleavage.

Microscopic.—On microscopic examination the gabbro is seen to consist of labradorite ca. Ab. 40, An. 60 and augite, with accessory magnetite and apatite. Some of the feldspars are euhedral and are included ophitically in the augite. The alteration of the gabbro is similar to that of the Wark gabbro-diorite gneiss, although, as a rule, it is of less degree and serpentine is perhaps a more common alteration product.

SALIC GABBRO.

Macroscopic.—The salic differentiate of the gabbro is a light grey rock of medium to coarse grain, consisting chiefly of glassy unweathered feldspar and augite.

Microscopic.—The essential minerals are bytownite ca. Ab. 20, An. 80, augite, and olivine. Magnetite is the only recognizable accessory mineral. The bytownite and olivine are euhedral and the augite and magnetite interstitial. Also the augite and magnetite occur intergrown with each other in a very intricate manner, the augite surrounding and including the magnetite (See Plate IX). The rock is only slightly altered, the secondary minerals being biotite, chlorite, serpentine, magnetite, calcite, and sercite.

GABBRO-DIORITE WITH RECRYSTALLIZED HORNBLENDES.

Macroscopic.—During the contact metamorphism produced by the intrusion of the Colquitz gneiss and Saanich granodiorite, the Wark gneiss was more or less recrystallized and certain characteristic metamorphic varieties were developed. One of the most common of these has part of the hornblende recrystallized to large rectangular grains up to 1 cm. in diameter. The recrystallized hornblendes occur in irregular but elongate patches, and associated with them, in their interstices, are relatively coarse grained quartz and feldspar (See Plate X).

Microscopic.—The mineral composition is similar to that of the normal gabbro-diorite gneiss, but the texture is very different. It varies from mosaics of fine grained, anhedral hornblende and plagioclase to large euhedral hornblendes which include poikilitically numerous small and irregular grains of altered plagioclase, while quartz and some clear feldspar are interstitial (See Plate VIII B). As indicated, the plagioclase is greatly altered but the hornblendes are comparatively fresh. From their character and occurrence there can be little doubt that the hornblendes are secondary.

Poikilitic Phases.

A peculiar phase of the gabbro-diorite with recrystallized hornblendes is fairly common in Lake and Highland districts near contacts with the Colquitz gneiss. In this phase the hornblende forms very large crystals up to several centimetres in diameter, which are seen even macroscopically to include poikilitically the older minerals, especially altered feldspar.[1]

Femic Facies.

Near contacts with the intrusives rocks are hornblende-rich facies of the gabbro-diorite gneiss. They vary from fine grained to coarse grained rocks, the latter being largely recrystallized, and virtually identical with the coarse grained hornblendites of the Colquitz gneiss. They differ from the normal gabbro-diorite gneisses chiefly in the large amount of hornblende which they contain.

Microscopic.—On microscopic examination the hornblende-rich facies are seen to consist, as would be expected from their macroscopic appearance, chiefly of recrystallized hornblende and altered feldspar. The hornblendes are not, as might be expected, all the same, but vary from light green slightly pleochroic varieties of negative character to dark brownish green strongly pleochroic varieties of positive character. The alteration products are similar to those of the normal gabbro-diorite gneiss, but the recrystallized hornblendes are but slightly altered. They are, however, frequently crushed into diversely orientated aggregates of small fragments of larger grains.

Colquitz Gneiss.

Distribution.

As already described, the Colquitz gneiss is intrusive into the Wark gneiss, and the two gneisses together form virtually a single batholith extending across the northern part of the Victoria map-area and the southern part of the Saanich map-area.

---

[1] See U. Grubenmann, Die Krystalline Schiefer, Part 1, 1904, p. 80.

Lithological Characters.

Quartz-Diorite Gneiss.

Macroscopic.—The principal rock type of the Colquitz gneiss is a quartz-diorite gneiss. It is a grey rock of medium grain and of gneissic to schistose texture, consisting chiefly of altered feldspar, quartz, hornblende, and biotite.

Microscopic.—The essential minerals of the rock are acid andesine ca. Ab. 70, An. 30, quartz, green hornblende and biotite. Orthoclase is also present but can seldom be distinguished from the andesine feldspar. The accessory minerals are magnetite and apatite and more rarely titanite. During foliation the original texture of the rock has been largely destroyed, but in places primary euhedral feldspars are poikilitically included in hornblende grains, which may, however, be secondary. Quartz is largely interstitial. In general the grains are anhedral and elongate in the direction of foliation. The rock, since foliation, has been altered moderately to chlorite, epidote, sericite, and kaolin, and is frequently cut by veinlets of quartz, sericite, epidote, and calcite.

Chemistry.—The following analysis by M. F. Connor, of the Mines Branch of the Department of Mines, is of a typical specimen of the Colquitz quartz-diorite gneiss collected on Smiths hill, Victoria district, from the rock cut made for the Victoria city reservoirs. With it is given the analysis of the average quartz diorite as calculated by Daly.[1]

	Colquitz gneiss	Average quartz diorite.
SiO_2	64·04	59·47
Al_2O_3	15·83	16 52
Fe_2O_3	2·16	2·63
FeO	2·40	4·11
MgO	2·72	3·75
CaO	3·60	6·24
Na_2O	3·52	2·98
K_2O	1·43	1·93
$H_2O\pm$	1·60	1·39
TiO_2	0·30	0·64
P_2O_5	1·56	0·26
MnO	0·15	0·08
	99·31	100·00
Specific gravity............	2·74	

[1] R. A. Daly, Average chemical composition of igneous rock types. Proc. Am. Acad. Arts and Science, vol. 45, 1910, pp. 209-240.

The norm of the Colquitz gneiss is as follows:—

Quartz	30·24	Hypersthene	9·04
Orthoclase	8·34	Magnetite	3·25
Albite	29·34	Ilmenite	0·61
Anorthite	8·62	Apatite	3·40
Corundum	5·41		

Class II.

$$\frac{Sal}{Fem} = \frac{82\cdot 0}{16\cdot 3} < \frac{7}{1} > \frac{5}{3}$$

Dosalane

Order 3.

$$\frac{P}{Q} = \frac{43\cdot 3}{30\cdot 2} < \frac{5}{3} > \frac{3}{5}$$

Quarfelic

Rang 2.

$$\frac{K_2O + Na_2O}{CaO} = \frac{71}{13} > \frac{5}{3} < \frac{7}{1}$$

Domalkalic

Subrang 4.

$$\frac{K_2O}{Na_2O} = \frac{15}{56} < \frac{3}{5} > \frac{1}{7}$$

Dosodic.

If there were only 0·9 per cent of apatite in the norm, as there is in the actual mode, the norm of the rock would fall into the dosodic subrang (4), called sitkose of the alkalicalcic rang (3) instead of into the dosodic subrang (4) of the domalkalic rang (2), which subrang is not given any name by the inventors of the quantitative classification.

The actual mineral composition of the Colquitz gneiss as determined by the Rosiwal method, aided by calculation of the chemical analyses, is approximately as follows:—

Quartz	30
Orthoclase	6
Andesine Ab. 70, An. 30	46
Hornblende	8
Biotite	7
Magnetite	2
Apatite	1

The composition of the hornblende and biotite cannot be determined, but the hornblende must be characterized by high alumina and phosphoric acid, and low lime.

It is seen from the analyses given above that the Colquitz gneiss differs from the average quartz diorite in its high silica and phosphoric acid, and in its low ferrous oxide, magnesia, and lime, and slightly lower potash. As seen from the norm and mode these differences are chiefly due to the very large amount of quartz in the rock. This large amount of quartz in a rock containing so much iron, magnesia, and lime and so little potash, is abnormal, as is shown by the fact that its norm corresponds with those of only a few abnormal rocks. Only two rocks are listed by Washington[1] that fall into the same norm as the Colquitz gneiss, a quartz-keratophyre from Baraboo Bluffs, Wisconsin, and a felsophyre from Fabbiasco, n. Lugano, Piedmont. But the chemical composition of neither of these rocks closely resembles that of the Colquitz gneiss. Only one rock is known which is classified as sitkose. It is from Indian river, Sitka, Alaska, and was called by Becker[2] a "pyroclastic diorite," but is considered by all other geologists who have examined it, as a sedimentary greywacke.[3] With the exception of this large amount of quartz the Colquitz gneiss is, however, a fairly typical quartz diorite, with orthoclase feldspar less than 8 per cent[4] and predominating andesine feldspar of medium basicity. The Colquitz gneiss is best considered, therefore, as a quartz-rich quartz diorite gneiss, and not as a granodiorite.

BIOTITE GRANITE GNEISS.

Macroscopic.—There is a facies of the Colquitz gneiss, however in which the feldspar is predominantly orthoclase and which is, therefore, best classified as a granite. It occurs to the southwest of Saanich hill in Lake district. It is similar in appearance to the normal quartz-diorite gneiss, but contains both light green and white weathering feldspar and the dark constituent is biotite.

Microscopic.—This facies of the Colquitz gneiss is seen on microscopic analysis to consist essentially of orthoclase, albite-oligoclase, quartz, and greenish-brown biotite, with accessory magnetite, titanite, and apatite. These minerals occur in irregular interlocking grains, the biotites being in parallel arrangement thus giving the rock a marked foliated texture. The rock is but slightly altered to epidote and sericite.

BANDED GNEISS, LIGHT COLOURED OR SALIC BANDS.

The most striking feature of the Colquitz gneiss is its banded character. The light and the dark minerals occur in separate bands, which vary in width from a fraction of an inch (See Plate XI) up to 4 or 5 feet, while more irregular femic and salic masses are several yards in width.

Macroscopic.—The light coloured or salic bands are light greenish grey to white in colour, fine to medium grained, although coarse grained varieties occur, and gneissic to schistose in texture. They consist chiefly of quartz and feldspar, but narrow streaks of altered, dark femic minerals are seen, accentuating the foliated texture. In some instances dark minerals are virtually absent, and then the rock, although foliated, has a uniform

[1] H. S. Washington. Chemical Analyses of Igneous Rocks. Prof. papers No. 14 and No. 28, U.S. Geol. Survey, 1903 and 1904.

[2] G. F. Becker, 18th Ann. Rept. U.S. Geol. Survey, Part III, 1898, p. 45.

[3] A. Knopf. Sitka Mining District, Bul. 504, U.S. Geol. Survey, 1912, p. 13.

[4] Lindgren gives 8 per cent of orthoclase as the upper limit of quartz diorite. Am Jour. Science, Ser. 4, vol. 9, 1900, p. 277.

appearance. The salic bands are cut by veinlets of quartz, sericite, and calcite, and pyrite frequently occurs in disseminated grains. At one locality, on the north slope of Knockan hill in Lake district, the rock contains a relatively large amount of pyrite, and the pyritic rock has been prospected in search for ore. The pyrite has altered to limonite, which has stained the feldspar bands of the rock pink. These pink feldspar bands are interlaminated with bands of white quartz and greenish chlorite, and, as a result, since the colours are soft and dull, the appearance of the rock, especially of a polished surface, is very beautiful. The rock is, however, too greatly fractured and foliated to be quarried into blocks large enough to be valuable as an ornamental stone.

Microscopic.—The essential minerals are quartz, orthoclase, or microperthite, and oligoclase ca. Ab. 75, An. 15. The microperthite is an irregular intergrowth of orthoclase and albite, the former greatly predominating. The accessory minerals are very small in amount and at times are almost absent. They consist of hornblende, biotite, magnetite, titanite, and apatite. The minerals are apparently of two generations. The older, chiefly feldspar, occur in relatively large, irregular to lens-shaped grains that are fractured, strained, and altered. The younger minerals occur in smaller anhedral grains, that are unaltered but foliated, and have apparently been derived through the crushing and recrystallizing of the original minerals. The degree of alteration varies from moderate to large, and the following secondary minerals have been formed: actinolite, epidote, chlorite, sericite, and kaolin, as well as the quartz, sericite, and calcite veinlets, and pyrite and limonite.

Chemistry.—The following analysis is of a typical specimen of the salic facies of the Colquitz gneiss, collected from a small hill, 1 mile north of Prospect lake in Lake district. The analyst is M. F. Connor, of the Mines Branch, Department of Mines.

SiO_2	75·02
Al_2O_3	13·90
Fe_2O_3	0·45
FeO	0·40
MgO	0·10
CaO	0·10
Na_2O	1·16
K_2O	3·06
H_2O+	5·37
TiO_2	0·95
P_2O_5	0·04
MnO	0·15
	0·10
	100·70
Specific gravity	2·63

The norm of the rock is

Quartz	34·38	Hypersthene	0·60
Orthoclase	31·69	Magnetite	0·70
Albite	25·68	Ilmenite	0·15
Anorthite	5·00	Apatite	0·31
Corundum	1·22		

Class I.

$$\frac{Sal}{Fem} = \frac{98 \cdot 0}{1 \cdot 8} > \frac{7}{1}$$

Persalane.

Order 4, near Order 3.

$$\frac{F}{Q} = \frac{62 \cdot 4}{34 \cdot 4} > \frac{5}{3} < \frac{7}{1}$$

Brittanare, near Columbare

Rang 1.

$$\frac{K_2O + Na_2O}{CaO} = \frac{106}{18} > \frac{7}{1}$$

Liparose.

Subrang 3.

$$\frac{K_2O}{Na_2O} = \frac{57}{49} < \frac{5}{3} > \frac{3}{5}$$

Liparose, near Alaskose.

By the recalculation of the chemical analysis and by the Rosiwal method the actual mineral composition or mode is determined to be as follows:—

Quartz	36
Orthoclase	31·5
Oligoclase Ab. 85, An. 15	30·5
Hornblende	0·5
Biotite	0·5
Magnetite	0·7
Apatite	0·3

The chemical analysis is similar to that of a quartz-rich granite, but is lower in iron and magnesia and higher in lime than most granites containing 75 per cent of silica. This variation is due, of course, to the small amount of femic minerals present in the rock and to the presence of oligoclase feldspar with orthoclase, rather than albite, which is found ordinarily in normal granites.

DARK COLOURED OR FEMIC BANDS. (HORNBLENDITES.)

Macroscopic. Interlaminated with the light coloured, salic bands are the complementary dark coloured, femic bands. They are of dark green rocks, of fine to coarse grain, consisting essentially of hornblende, and may, therefore, be classified as hornblendites. The larger bands and masses are virtually always coarsely crystalline, and in the large masses northwest of Prospect lake single crystals of hornblende occur that are 2 to 3 feet long and 2 to 3 inches wide. The hornblende crystals in the coarsely crystalline phases have a parallel arrangement, but the foliation of these phases is not nearly so pronounced as in the finer grained phases or in the salic bands or normal Colquitz gneiss. The finer grained phases also contain considerable feldspar which is frequently absent in coarse grained hornblendites.

Microscopic.—A light greenish brown, moderately pleochroic, common hornblende is the only essential constituent of the coarse grained hornblendites. However, the hornblende grains frequently include small grains of augite. In the finer grained phases andesine feldspar is also an essential mineral. The accessory minerals are in greater amount than in the normal Colquitz gneiss, and are chiefly magnetite and apatite, but in the fine grained phases titanite also occurs. The coarse grained hornblendites are chiefly euhedral so that their foliation cannot be detected microscopically, but the fine grained varieties are chiefly anhedral and foliated. The hornblendites are only moderately altered, although the secondary minerals are numerous, including biotite, serpentine, chlorite, epidote, zoisite, calcite, and sericite. Pyrite and limonite also are common in the coarser grained phases.

Chemistry.—The following analysis is of a coarse grained hornblendite collected to the northwest of Prospect lake in Lake district. M. F. Connor, of the Mines Branch, Department of Mines, is the analyst.

SiO_2	38·80
Al_2O_3	12·50
Fe_2O_3	6·57
FeO	8·20
MgO	13·10
CaO	11·42
Na_2O	1·60
K_2O	0·81
H_2O+	2·85
TiO_2	1·69
P_2O_5	1·26
MnO	0·23
	98·94
Specific gravity	3·16

The norm of the rock is as follows:—

Orthoclase	5·00	Diopside	19·64
Albite	7·34	Olivine	22·02
Anorthite	24·46	Magnetite	9·28
Nepheline	3·41	Ilmenite	3·04
		Apatite	2·79

Class III.

$$\frac{Sal}{Fem} = \frac{40\cdot 2}{56\cdot 8} < \frac{5}{3} > \frac{3}{5}$$

Salfemane

Order 5.

$$\frac{L}{F} = \frac{3\cdot 4}{36\cdot 8} < \frac{1}{7}$$

Gallare

Rang 4.

$$\frac{K_2O + Na_2O}{CaO} = \frac{35}{88} < \frac{3}{5} > \frac{1}{7}$$

Auverngnose.

Subrang 3.

$$\frac{K_2O}{Na_2O} = \frac{9}{26} < \frac{3}{5}$$

Auverngnose.

The mode or actual mineral composition as determined by the Rosiwal method, aided by the chemical analysis, is as follows:—

Hornblende	85·2
Augite	8·0
Magnetite	5·5
Apatite	1·3

Assuming that the augite has an average composition, which does not introduce a large error since it occurs in such relatively small amount, the composition of the hornblende may be determined approximately as follows:—

SiO_2	42·8
Al_2O_3	14·6
Fe_2O_3	3·3
FeO	7·3
MgO	14·9
CaO	11·4
Na_2O	1·9
K_2O	1·1
H_2O	0·5
TiO_2	1·1
P_2O_5	0·8
MnO	0·3
	100·0

Apophysal Phases. Aplites.

Macroscopic.—Cutting both the Wark and Colquitz gneisses and the Vancouver meta-volcanics as well, are numerous aplitic and pegmatitic apophyses that are doubtless related to the Colquitz gneiss. The aplites are light coloured, sometimes white, fine grained, gneissic rocks, consisting essentially of quartz and feldspar.

Microscopic.—The feldspar, which predominates over the quartz, consists of plagioclase, probably albite-oligoclase, and a microperthite, composed chiefly of orthoclase, irregularly intergrown with albite. The accessory minerals are hornblende, magnetite, titanite, and apatite, and occur only in small amounts. The aplites are considerably altered to sericite, chlorite, and epidote. Pyrite also is nearly always present, and weathering to limonite, has stained the weathered surfaces of the aplites brown. Some of these brown stained aplite veins have been mistaken for mineralized quartz veins, and have been prospected.

Pegmatites.

The pegmatites are nearly white, coarsely crystalline, unfoliated rocks consisting chiefly of white weathering feldspar, orthoclase and albite, muscovite, and a relatively small amount of quartz.

Saanich Granodiorite.

Distribution.

The Saanich granodiorite forms a relatively large batholith which underlies the greater part of the Saanich peninsula, and a small batholith or stock which underlies the southwestern part of the Esquimalt peninsula. Small satellitic stocks also occur on Moresby and Sidney islands, and to the west of the head of Esquimalt harbour. The Saanich batholith which underlies nearly the whole of Saanich peninsula, extends north from Elk lake nearly to Saddle hills, a distance of about 11 miles, and is at least 4 miles wide. However, it is probable that the batholith extends east under water to at least the east shore of Sidney islands. Although no rock exposures occur on James island which lies between the peninsula and Sidney island, it is probably underlain by the Saanich batholith. The batholith is known to extend farther west since it is exposed on the west shore of Saanich inlet, and even for 3 miles inland. Its greatest length, about 15 miles, is, therefore, probably in a northwest-southeast direction, corresponding with the greatest length of the Wark-Colquitz batholith and to the general strike of the Vancouver group. The rocks of the Saanich batholith are very well exposed along both shores of the Saanich peninsula. These, less fractured, consequently more resistant, are also well exposed inland, forming several of the monadnocks surmounting the lowland of southeastern Vancouver island, notably Mt. Newton and Bear hill. The larger part of the batholith, however, is covered by a thick mantle of stratified drift. But there are enough exposures to indicate its general outlines and as shown on the accompanying map its boundaries are for the greater part fairly well located.

The satellitic stock on Moresby island is well exposed along the western shore and there are enough outcrops in the interior of the island to indicate its general outline. Along the west shore of the island, south of the stock cutting the Sicker volcanics, there are numerous granitic apophyses which indicate the presence of a larger body of granodiorite to the west, under Moresby passage.

The Esquimalt stock is well exposed along the south shore of Esquimalt peninsula, and it also forms small monadnocks, so that its outlines are well defined. Two outliers of the stock occur, one to the east, on the east shore of Victoria harbour, south of the Victoria outer wharf, and the other to the west, on Fishguard Light island and on the west shore of Esquimalt harbour. The long axis of the stock, which is over 3 miles long, has, therefore, a general northwest-southeast strike also.

Lithological Characters

Granodiorite. (Normal.)

Macroscopic.—The Saanich granodiorite is a light coloured, medium grained rock, with a characteristic granitic, and frequently somewhat gneissic texture, which is rarely pronounced. The weathered surface is in general much lighter coloured than the freshly broken surface. The rock consists of feldspar and quartz, with essential hornblende and sometimes biotite, and accessory magnetite. Pyrite is also a common constituent and may be original. The feldspar in some varieties weathers both pink and greenish white, the latter occurring in euhedral crystals. The hornblende frequently occurs, especially near contacts, in large euhedral crystals, that give the rocks a characteristic porphyritic or "speckled"[1] appearance. The granodiorite usually contains also numerous small rounded segregations or inclusions of a darker colour and of more femic composition.

Microscopic.—On microscopic examination, the essential minerals of the granodiorite are seen to be plagioclase, orthoclase, frequently microperthitically intergrown with a little albite, quartz and common green hornblende, and in some varieties greenish brown biotite, which is always present, at least as an accessory mineral. The accessory minerals are magnetite, pyrite, titanite, and apatite. The plagioclase, which is the chief feldspar, is largely andesine, and is usually zonal, the composition varying from Ab. 55 An. 45, to Ab. 90 An. 10. The average composition is near Ab. 65 An. 35. The texture of the rock is subhedral, with euhedral grains

[1] James Richardson. Report of Progress, 1871-72, Geol. Survey, Canada, p. 90.

of hornblende and andesine, and interstitial quartz, some plagioclase, orthoclase, and microperthite. The quartz and potash feldspars are sometimes graphically intergrown. Quartz more rarely occurs in large grains, which include the euhedral andesine crystals. The original minerals have been fractured, strained, and even distorted. They are also moderately altered, the hornblende altering to biotite, chlorite, and epidote and the biotite to chlorite. The feldspars are partly altered to and replaced by sericite, kaolin, and calcite. Veinlets of quartz, sericite, and calcite also occur traversing the granodiorite.

Chemistry.—The chemical composition of a rather basic phase of the Saanich granodiorite is given below:—

	I.	II.	III.	IV.
SiO_2	62·64	65·10	59 —68½	64·62
Al_2O_3	17·75	15·82	14 —17	15·90
Fe_2O_3	1·64	1·64	1½ — 2½	1·47
FeO	3·44	2·66	1½ — 4½	3·05
MgO	2·53	2·17	1 — 2½	2·13
CaO	4·44	4·66	3 — 6½	4·87
Na_2O	3·53	3·82	2½ — 4½	3·48
K_2O	2·14	2·29	1½ — 3½	2·43
$H_2O\pm$	1·65	1·09		1·29
TiO_2	0·60	0·54		0·52
P_2O_5	0·25	0·16		0·11
MnO	0·14	0·05		0·07
Ba.				0·06
	100·75	100·00		100·00

Specific gravity, 2·71.

I. Saanich granodiorite, south shore of Shoal harbour, North Saanich district, M. F. Connor, Mines Branch, Dept. of Mines, analyst.

II. Average composition of granodiorite. R. A. Daly, Proc. Am. Acad. Arts and Sci., Vol. 45, 1910, p. 223.

III. Limits of variation of granodiorite. W. Lindgren, U.S. Geol. Survey, 17th Ann. Rep. Part 2, 1896, p. 35.

IV. Mean of five analyses of typical granodiorites from the Sierra Nevada of California, selected by H. W. Turner, Journ. of Geology, Vol. 7, 1899, p. 150.

The norm of the Saanich granodiorite is as follows:—

Quartz	19·74	Hypersthene	10·52
Orthoclase	12·23	Magnetite	2·32
Albite	29·87	Ilmenite	1·22
Anorthite	20·29	Apatite	0·62
Corundum	2·35		

Class II.

$$\frac{\text{Sal}}{\text{Fem}} = \frac{84\cdot5}{14\cdot7} > \frac{5}{3} < \frac{7}{1}$$

Dosalane.

Order 4.

$$\frac{F}{Q} = \frac{62\cdot4}{19\cdot7} > \frac{5}{3} < \frac{7}{1}$$

Austrare

Rang 3.

$$\frac{K_2O + Na_2O}{CaO} = \frac{79}{73} < \frac{5}{3} > \frac{3}{5}$$

Tonalose.

Subrang 4.

$$\frac{K_2O}{Na_2O} = \frac{22}{57} < \frac{3}{5} > \frac{1}{7}$$

Tonalose.

The mode or actual mineral composition, as obtained by the Rosiwal method, aided by a recalculation of the chemical analysis, is as follows:

Quartz	24
Orthoclase	10
Andesine Ab. 65 An. 35	44
Hornblende	10
Biotite	9
Magnetite	1·5
Titanite	0·4
Apatite	0·6

There are too many unknown quantities to calculate the compositions of the hornblende and biotite with any assurance. The hornblende, however, must resemble that of the normal Colquitz gneiss, since it must be characterized by high alumina and ferrous iron, and low lime.

It is seen from the data given above that the Saanich granodiorite is somewhat more basic than the average granodiorite, leaning toward a quartz diorite. With the exception of alumina and magnesia, all of the oxides fall well within the limits of variation of granodiorite as given by Lindgren, and the magnesia is virtually the same as Lindgren's higher limit. The reason for the presence of the high alumina in the Saanich granodiorite is not entirely clear. It is not due, however, to the presence of a more calcic and aluminous feldspar than is common in granodiorites, as there is not sufficient lime to form such a feldspar, nor do the optical characters of the feldspar indicate that it is more calcic and aluminous than andesine. The high alumina may be due in part to the altered character of the granodiorite, but, as indicated, is probably due chiefly to the presence of an alumina-rich hornblende. The rock is, therefore, best classed as a granodiorite and not as a quartz diorite. This conclusion is further supported by the fact that the specimen analysed, chosen for its comparative freshness, is slightly more basic than the average rock of the Saanich batholith, and yet even it contains 10 per cent of the potash feldspar,[1] so that the average rock of the Saanich batholith is a typical granodiorite, having all those characteristic features of granodiorite which are given by Lindgren[2] and corresponding exactly with Turner's[3] description: "Granodiorite, when typical, is composed of plagioclase (oligoclase-andesine, but usually andesine) > quartz > orthoclase. Biotite and green aluminous amphibole are abundant constituents, but are variable in their relative amounts, and at times only one of these ferro-magnesian elements is present. Magnetite, titanite, and apatite are nearly always present as accessories. The rock is usually evenly granular in texture and of a light grey colour." Therefore, the composition of the average Saanich granodiorite doubtless corresponds fairly closely to the average composition of the Sierra Nevada granodiorites, given in the above table.

Esquimalt Phase.

The granodiorite of the Esquimalt stock and of the small stock at the northwest end of Esquimalt harbour contains on the whole a smaller amount of femic minerals than the normal Saanich granodiorite. It is also more altered, so that the original femic minerals are almost completely replaced by secondary minerals, chiefly chlorite and epidote. The rock has, therefore, both macroscopically and microscopically, a more salic appearance than the average Saanich granodiorite. Finer grained phases are also more abundant than in the Saanich batholith. They are characterized microscopically by stout laths of oligoclase-andesine diversely arranged, irregular grains and flakes of hornblende and biotite, and interstitial quartz and orthoclase.

Contact and Hybrid Phases.

Near its contacts the granodiorite becomes more dioritic and passes into quartz and quartz bearing diorites, and also into feldspar-rich, quartz-poor rocks, which are best considered as quartz-bearing feldspathic diorites,

[1] Lindgren gives 8 per cent as the lower limit of orthoclase in granodiorite. Am. Jour. Sci., Ser. 4, vol. 9, 1900, p. 277.

[2] Op. cit.

[3] H. W. Turner. The granitic rocks of the Sierra Nevada. Journ. of Geology, Vol. 7, 1899, p. 151.

although some of them are monzonitic in character. The quartz diorites differ from the normal granodiorites in their lack or small amount of potash feldspar. Their feldspar, which usually has a pronounced zonal structure, varies from labradorite Ab. 45 An. 55, to oligoclase Ab. 80 An. 20. The texture of these rocks is more porphyritic than that of the normal granodiorites, hornblende and part of the feldspar occurring in large euhedral crystals while the quartz and the rest of the feldspar is usually interstitial. In a few instances quartz occurs also in large phenocrysts. The feldspar-rich varieties are similar in texture to the quartz diorites, but contain a smaller amount of quartz and femic minerals. Orthoclase, usually microperthitically intergrown with albite, is present in these rocks, sometimes in sufficient amount for the rock to be classified as a monzonite or monzonitic diorite. One of these monzonitic diorites found in contact with the garnet-diopside-epidote rock of the Penton mineral claim in South Saanich district, a mile east of Tod inlet, contains essential augite. This rock is similar to those rocks farther west that are in contact with metamorphic limestones, and frequently contain a large amount of pyroxene. The pyroxene has apparently been formed by the recrystallization of material derived from assimilation of the limestone, so that the rocks are considered to be true hybrid or mixed rocks.[1] All of the contact phases are as a rule more altered than the normal granodiorite, epidote being an especially prominent alteration product.

Along some of the contacts of the granodiorite with the intruded Vancouver meta-volcanics, certain peculiar rocks have been developed which are intermediary in composition between the granodiorite and the meta-volcanics. As might be expected they are greatly altered and of rather indefinite composition and texture. They are fine to medium grained and chiefly feldspathic, with more or less quartz and secondary femic minerals.

SEGREGATIONS.

Macroscopic.—Throughout the granodiorite, but occurring more abundantly near the contacts, are numerous, small rounded segregations, which are composed of a fine grained, dark groundmass with a few small phenocrysts of feldspar and hornblende. Their contacts with the granodiorite are well marked, but crystals of the one penetrate into the other, and since their mineral composition is related to the granodiorite, they are considered to be segregations and not inclusions.

Microscopic.—The essential minerals of the segregations are andesine-oligoclase, Ab. 60 An. 40 to Ab. 80 An. 20, and hornblende, with biotite and sometimes quartz. Magnetite is the chief accessory and is sometimes present in relatively large amount. The groundmass of the

[1] Memoir No 13, Geol. Survey, Canada 1912. p. 104

segregations has a rather characteristic texture as it is composed of lath-shaped feldspars and prismatic hornblendes with poikilitic biotite and interstitial quartz. The alteration products are similar to those of the granodiorite, chiefly chlorite, epidote, and sericite.

APOPHYSAL PHASES.

Apophysal phases of the Saanich granodiorite, chiefly aplites, cut the normal granodiorite and contact phases. They are light coloured, fine grained rocks consisting essentially of albite, orthoclase or microperthite, and quartz with accessory biotite, hornblende, and pyrite. They are similar to the aplites of the Colquitz gneiss but are distinguished by the absence of crushing and foliation, even the quartz having a sharp extinction, and by the fact that the minerals are not interlocking although they occur in anhedral grains.

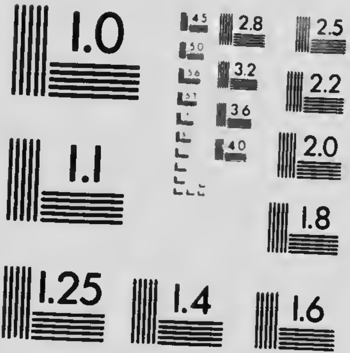
Granodiorite Porphyrites.

DISTRIBUTION.

The granodiorite porphyrites form dyke-like and irregular intrusive bodies that for the greater part are confined to the periphery of the Saanich batholith. One of the largest bodies occurs in the western part of North Saanich district, east of Coal point, and appears to be intrusive into the normal granodiorite. It is exposed along the shore, south of Coal point, and inland it forms several large ledges, so that its general extent and outline is fairly well shown on the accompanying map. Another large body occurs on the east shore of Saanich peninsula, west of Shoal harbour, and several smaller bodies are exposed along the shore between Shoal harbour and Sidney. The largest body occurs on Southern Saltspring island and is intrusive into the Sicker schists and volcanics. Its greatest length, which is over a mile, is in the direction of the foliation of the Sicker series, that is about N. 50° W. The dykes which occur in both the granodiorite and the rocks which it intrudes, are irregular and are traceable for only a short distance, their extent being necessarily exaggerated on the accompanying map. The dykes are well exposed along the shore, where the rocks are cleaned by the waves, but inland, where the rocks are covered with moss and lichens, very few dykes have been noted, although they doubtless occur. Two dykes were noted in the Victoria map-area, one on the shore south of Esquimalt P. O., intrusive into the granodiorite of the Esquimalt stock, and the other exposed near the northeastern boundary of the Colwood delta, intrusive into a pure limestone of the Sutton formation.

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



Lithological Characters.

The granodiorite porphyrites are porphyritic rocks characterized by a dense to fine grained groundmass consisting essentially of quartz with both plagioclase and orthoclase feldspar, and phenocrysts of quartz and plagioclase, quartz phenocrysts being absent in some varieties. They are, therefore, strictly dellenite porphyries or porphyrites, but since they are very closely related to the granodiorite, and vary somewhat in character, grading from very acid quartz porphyrites to the quartz bearing diorite porphyrites, described later, they are called granodiorite porphyrites.[1] For purpose of description they may be subdivided into those characterized by both quartz and feldspar phenocrysts, and those with feldspar phenocrysts only.

Quartz-Feldspar Porphyrite.

Macroscopic.—The quartz-feldspar porphyrite, which is the most common type, is a light greenish grey rock with an aphanitic to fine grained groundmass and medium sized phenocrysts of white weathering feldspar, colourless quartz, and prismatic hornblende. The rocks vary from phases in which the phenocrysts are few to those in which the phenocrysts are dominant. Some of the coarser grained rocks contain irregular darker coloured segregations composed of a fine grained groundmass of lath-shaped plagioclase feldspar and hornblende, with a few small phenocrysts of the same minerals.

Microscopic.—Under the microscope the phenocrysts are seen to be albite-oligoclase, Ab. 90 An. 10 to Ab. 80 An. 20, quartz, and an olive to brownish green common hornblende. Many of the quartz phenocrysts are rounded or deeply embayed (See Plate XII). The groundmass consists of very fine, irregular to euhedral grains, rarely intergrown micrographically, of albite-oligoclase, orthoclase, quartz, and hornblende, the latter being usually accessory. Magnetite and pyrite are the only other accessory minerals, and the pyrite may be secondary. The porphyrites are slightly to greatly altered, the alteration being usually rather large. The hornblende is usually replaced by biotite, chlorite, and epidote, and the other secondary minerals are sericite, calcite, and limonite.

Feldspar Porphyrites.

The feldspar porphyrites are similar to the quartz porphyrites in both their macroscopic and microscopic appearance except that they do not have quartz phenocrysts. Also they are somewhat coarser grained with more

[1] The term granodiorite porphyry (porphyrite) was first proposed by Lindgren, to designate "minor intrusive masses and dykes having a composition of granodiorite combined with a porphyritic holocrystalline groundmass." Am. Jour. Science, Series 4 vol. 9, 1900, p. 281.

calcic feldspars and a larger percentage of hornblende. By a further decrease in quartz and an increase in hornblende and in the basicity of the feldspar, these feldspar porphyrites grade into the diorite porphyrites. The feldspar porphyrites are also greatly altered, the alteration products being the same as those of the quartz-feldspar porphyrites.

METAMORPHISM AND SCHISTOSE VARIETIES.

Macroscopic.—As noted, the alteration of the granodiorite porphyrites is usually large, the chief secondary minerals being biotite, chlorite, epidote, sericite, calcite, and limonite, but, except where they are intrusive into the Sicker series, the porphyrites have rather rarely been metamorphosed by contact or dynamic agencies. Where they are intrusive into the Sicker series, the porphyrites are dynamo-metamorphosed and pass into schistose varieties. Macroscopically the schistose varieties are similar to the normal granodiorite porphyrites, except that they have a more or less pronounced schistose texture and are as a rule cut by numerous quartz veinlets, and are greatly mineralized.

Microscopic.—Microscopically the mineral composition is seen to be the same as that of the normal granodiorite porphyrite, even the secondary minerals being the same. However, the secondary minerals are more abundant, biotite and chlorite predominating, and actinolite is usually present also. The phenocrysts are strained, broken, and crushed, the crushed quartz phenocrysts forming lens-shaped mosaics. The groundmass consists of anhedral grains of quartz and feldspar, and secondary minerals, the biotite, actinolite, and sericite being elongated in the direction of foliation.

Quartz-Chlorite and Biotite Schists.—Farther west the schistose varieties grade into quartz-chlorite-sericite or talc schists in which the original porphyritic texture has been obliterated; and which cannot be distinguished from similar schists derived from sedimentary members of the Sicker series. In southeastern Saltspring island the schistose porphyrites pass into a biotite schist. It is a dark reddish brown to green, fine grained schist composed of quartz, feldspar, and light greenish brown biotite, with lesser amounts of calcite, epidote, sericite, pyrite, hematite, and kaolin.

Diorite Porphyrites.

DISTRIBUTION.

The diorite porphyrites form fairly well defined and regular dykes, from a few inches up to 70 feet in width, that are confined for the greater part to the vicinity of the contacts of the Saanich batholith and the Esquimalt stock (See Plate XII B, page 78). The dykes cut both the granodiorite and intruded rocks and also the granodiorite porphyrites. They are best exposed along the shore, where, in a few instances, they may be traced for 100 or 200 feet. They can seldom be traced inland, but doubtless occur there, although they are seldom seen. In only two localities are the dykes numerous enough to form a "dyke complex," one at Ountze head in Esquimalt, and the other south of Outer Wharf in Victoria. They are relatively numerous along the west shore of Saanich peninsula north of Tod inlet, and along the east shore of the peninsula north of Sidney.

Lithological Characters.

Macroscopic.—The diorite porphyrites are greyish green porphyritic rocks, with an aphanitic groundmass, and phenocrysts of feldspar and fewer phenocrysts of hornblende and sometimes augite. The phenocrysts are usually medium sized, and vary in amount, so that in some varieties the groundmass is dominant while in others the phenocrysts are dominant, the phenocrysts usually being in slightly greater amount than the groundmass. Analagous to the granodiorite porphyrites, the porphyrites which have been previously called andesite porphyrites[1] are called diorite porphyrites in order to indicate their relation not only to the granodiorite porphyrites but to the granodiorites and quartz diorites.

Microscopic.—The phenocrysts are seen microscopically to be plagioclase feldspar, hornblende, and augite. The plagioclase ranges from a basic andesine ca. Ab. 50 An. 50 to acid oligoclase ca. Ab. 90 An. 10, and has usually a pronounced zonal structure with a wide variation in composition. Augite phenocrysts, especially in the dykes associated with the Esquimalt stock, are sometimes absent, and in a few dykes, hornblende phenocrysts are absent. The groundmass consists essentially of andesine ca. Ab. 65 An. 35, which is in excess, common green hornblende, and augite and usually quartz and orthoclase, which are in relatively large amounts in those varieties transitional into the granodiorite porphyrites. Magnetite and apatite are accessory minerals. The groundmass varies in texture. In the more femic facies the feldspar occurs in diversely arranged, lath-shaped crystals with interstitial hornblende, while in the salic facies the grains are anhedral with spherulites and micrographic intergrowths of quartz and feldspar. The rocks are usually considerably altered, the chief secondary minerals being epidote, chlorite, sericite, and calcite.

Sicker Gabbro-Diorite Porphyrites.

Distribution.

The Sicker gabbro-diorite porphyrites form large masses, apophyses, and dykes which are intrusive only into the Sicker series. They are, therefore, confined to Saltspring, Portland, and Moresby islands. The large

[1] Memoir No 13 Geol. Survey, Canada, 1912, p. 106; also in the writer's Summary Report for 1908, 1909, and 1910.

masses are usually elongate in the direction of foliation of the Sicker schists, so that the largest body, which is the central one of southeastern Saltspring island, is over 3 miles long, but only about half a mile in width. The southernmost body of Saltspring island has, however, a roughly square-shaped outline, although large apophyses extend from it into the schists parallel to their foliation. The dykes also are usually parallel to the foliation of the Sicker series.

The gabbro-diorite porphyrite is the most resistant rock in the belt underlain by the Sicker series. It forms, therefore, bold ledges and monadnocks and is consequently well exposed. Hence the outlines of the various masses are in most instances well or fairly well located.

Lithological Characters.

Macroscopic.—The gabbro-diorite porphyrites are dark green, holocrystalline rocks consisting essentially of feldspar and hornblende. They vary greatly in texture from fine to medium grained porphyritic rocks, with feldspar phenocrysts, which frequently have a tendency to a radial arrangement—"rosette tendency"[1]—to very coarse grained varieties without a pronounced porphyritic texture. In general the fine grained porphyritic phases form the smaller dykes and the contact zones of the larger masses, while the coarse grained phases are found only in the large stock-like masses, such as the southernmost mass of Saltspring island. Some of the porphyrites are also gneissic to schistose. They vary also in composition, some, especially the coarse grained rocks, consisting almost entirely of hornblende, while others are distinctly feldspathic. Besides the essential minerals magnetite, or ilmenite as it appears microscopically, is readily detected macroscopically, and quartz also is frequently seen. Numerous quartz veins up to several feet in width invariably cut the gabbro-diorite porphyrites. They contain also, in relatively large amounts, disseminated grains of pyrite and chalcopyrite.

Microscopic.—On microscopic examination the phenocrysts and essential minerals of the groundmass and of the coarser grained non-porphyritic rocks, are seen to be labradorite-andesine ca. Ab. 40 An 60 to Ab. 60 An. 40, and bluish green to pale green hornblende, which has frequently a nucleus of augite, so that it appears as if the hornblende had in part resulted from the alteration of the augite. Quartz occurs in the groundmass in the coarse grained varieties in the interstices of the larger grains of feldspar and hornblende. It is usually micrographically intergrown with orthoclase and possibly albite. Ilmenite is the chief accessory and apatite is also present.

[1] Cf. "Rosette" gabbro porphyrite. Memoir No. 13, Geol. Survey, Canada, 1912, p. 80.

It is seen from this description that the porphyrites range in composition from a gabbro to a diorite, the feldspar varying from acid labradorite to basic andesine, and although hornblende is always the chief femic constituent it has been formed in part from augite. They are, therefore, best designated as gabbro-diorite porphyrites.

Alteration and Metamorphism.

The gabbro-diorite porphyrites are usually greatly altered and sheared. The feldspar has been replaced by sericite and saussurite, and the hornblende has gone over to a fibrous uralite and chlorite. The ilmenite is always surrounded by a thick layer of leucoxene and has sometimes been completely replaced. Epidote and calcite are very common secondary minerals and occur in replacements and veinlets.

In the more sheared varieties the rock resembles a dark green schist. The porphyritic and igneous character of the rock is, however, usually preserved. The feldspars have been twisted and broken and their edges frayed, and have been replaced by epidote and calcite. Recrystallized feldspars are common also. The alteration of the hornblende is similar to that described except that chlorite is more abundant. Even in the most altered varieties the micrographic intergrowth of quartz and feldspar, and leucoxene are present, and furnish convenient ear marks for distinguishing the sheared Sicker gabbro-diorite porphyrite from the sheared Sicker augite andesite, the two rocks resembling each other closely.

Structural Relations of the Batholithic and Minor Intrusives.

Internal.

Foliation.

All of the intrusive igneous rocks have been more or less foliated, some of them slightly, but others, such as the Wark and Colquitz gneisses, greatly, the gneisses in places even being contorted. The general strike of the foliation of the Wark and Colquitz gneisses is about N. 55° W., which corresponds with the greatest length of the batholith and with the strike of the intruded Vancouver volcanics. In detail, as shown on the accompanying map, the strike of the foliation varies greatly, usually following the contacts of the Wark and Colquitz gneisses with each other and with the invaded rocks. Ordinarily it lies in the northwest-southeast quadrants. Also the Sicker gabbro-diorite porphyrites and those granodiorite porphyrites which are intrusive into the Sicker series are in places greatly foliated, passing, as mentioned, into schistose phases. The strike of their foliation corresponds with that of the Sicker series, the intruded and intrusive rocks having been foliated in some instances at apparently the same time.

JOINTING AND SHEARING.

All of the intrusive rocks are greatly jointed and fractured, the joints and fractures, although numerous, being usually small and irregular. Only the Saanich granodiorite has regular and large joints; although all of the batholithic rocks are broken by joints which have a persistent north-south strike. This phenomenon has apparently determined the strike of many of the valleys that traverse the batholithic rocks. The rocks have also been more or less sheared, often greatly, developing wide shear zones. These usually correspond in strike with the foliation and have, therefore, a general northwest-southeast strike. Transverse fractures also occur along which more or less movement has taken place, since the foliation on one side of these fractures frequently does not correspond with that on the other side. The fracturing and shearing in the Victoria and Saanich map-areas has been so great as to render the granitic rocks unfit for building purposes. Along the shear zones they are more or less mineralized and cut by small and irregular quartz and quartz-epidote veins, which are of no commercial value.

RELATION OF TYPES TO EACH OTHER.

Wark and Colquitz Gneisses.—As stated, the Wark and Colquitz gneisses form virtually a single batholith, but the Colquitz gneiss is clearly intrusive into the Wark gneiss. The Wark gneiss is cut by masses of the Colquitz gneiss, usually the salic facies, some of which are several hundred feet in width. These masses are usually parallel to the foliation, but many of them are cross-cutting. Also the contacts of the Colquitz gneiss with the Wark gneiss are marked by wide zones of contact shatter-breccias and by numerous apophyses of the quartz diorite. Some of the zones are so wide that they are shown on the accompanying maps—southeast of Elk lake in Lake district, and at Mt. Tolmie and along the shore south of Cadboro bay in Victoria district—as contact complexes. The contact zones are frequently sheared and foliated and, as mentioned, their strike is usually parallel to the foliation. Also the angular inclusions or xenoliths of the gabbro-diorite gneiss in the quartz diorite gneiss have been pulled out into long dark femic bands, which resemble the femic bands of the banded Colquitz gneiss, but in part perhaps differ from them by being occasionally broken or cut across the foliation by the quartz diorite.

Both the Wark and Colquitz gneisses are cut by veins or dykes of the apophysal phases of the Colquitz gneiss. These are, of course, most prominent in the dark coloured gabbro-diorite gneiss and vary from a fraction of an inch up to several hundred feet in width. Although cross-cutting apophyses occur, they are usually injected parallel to the foliation, and are foliated themselves parallel to their walls. In some instances the apophyses, parallel to the foliation, are so numerous as to convert the gabbro-diorite gneiss into a banded gneiss. It is also probable that some of the quartz in the

Wark gneiss, which, as described, is virtually always confined to the interstices between the apparently older minerals, is secondary, having infiltrated into the gabbro-diorite gneiss during the intrusion of the quartz diorite gneiss. The relatively few dykes of pegmatite that have been noted are, as described, unfoliated, and while usually parallel to the foliation are sometimes cross-cutting.

Wark Gneiss and Gabbro.—The relation of the gabbro and salic gabbro mass in the Highland district with the normal Wark gabbro-diorite gneiss is not known. Since the gabbro is not foliated to any great extent, apparently it is younger and, therefore, intrusive into the gabbro-diorite gneiss. There are, however, no distinct intrusive contacts; but instead the gabbro and salic gabbro, of which there is very little, grade irregularly into the Wark gneiss which in that locality is more basic and less foliated. This in turn grades imperceptibly into normal gabbro-diorite gneiss.

Banded Colquitz Gneiss.—The banded Colquitz gneiss, in particular that type with the wide, coarse grained, femic bands or masses, is more or less restricted in its occurrence to the contacts with the intruded Wark gneiss. As described, its salic and femic bands vary in width from a fraction of an inch to 4 or 5 feet, and the larger more irregular masses to several yards. The length of the individual bands is more or less proportional to their width, the proportion being about 1 to 10. Some of the bands, especially the narrower and finer grained, gradually pinch out (See Plate XI A), but others, notably the wider, coarse grained, end abruptly and irregularly. The sides of the bands are usually straight or broadly curved. Rather frequently, however, they are irregular, and in places the bands are contorted and off-set by minor faults. The contacts b[illegible] the bands while usually well marked and persistent, that is with[illegible] irregularities except those due to foliation, are not sharp in deta[illegible] crystals of one band are intergrown with those of the contiguous b[illegible]n places, notably west of Prospect lake, in Lake district, and northwest of Lost lake in Victoria district, the Wark gneiss appears to be cut not only by salic apophyses of the Colquitz gneiss but by coarse grained hornblendite apophyses, which seem to be intrusive and cross-cutting and which have a structure symmetrical with their walls. The relations, however, are so complex and the resemblance of the supposed hornblendite apophyses to the recrystallized Wark gneiss is so close that the intrusive nature of the hornblendite masses cannot be positively affirmed.

Saanich Granodiorite and Wark and Colquitz Gneisses.—The Saanich granodiorite is clearly intrusive into the Wark gneiss and doubtless is younger than the Colquitz gneiss also. It brecciates the Wark gneiss where the two rocks are in contact, as in the eastern part of Esquimalt peninsula and in the southern part of Victoria, and forms extensive areas of "contact complex" consisting of shatter breccias and networks of granodiorite apophyses in the gabbro-diorite gneiss (See Plate XIII A). The xenoliths of gabbro-diorite gneiss in the contact shatter-breccias are chiefly angular to sub-angular in outline, although some of them are rounded. They vary in size from minute fragments to large sheet-like blocks, 2 to 3 feet in thickness and several feet, at least 20, in width and length. Most of the xenoliths show but little change from the original gabbro-diorite gneiss, but some have been recrystallized to a rock of coarser grain, which frequently has a central nucleus of the original finer grained rock. In a few instances also the xenolith has been infiltrated by quartz and feldspar, thus forming a rock intermediate in composition between the gabbro-diorite and the granodiorite. In places the shatter-breccia has apparently been foliated and the xenoliths have been pulled out into bands, which resemble those of the Colquitz gneiss.

The Saanich granodiorite is not in contact with the Colquitz gneiss, but since the latter is foliated, while the former is not, the latter is presumably the older. It is also very probable that many of the aplitic and pegmatitic apophyses in the Colquitz gneiss are related to the Saanich granodiorite, which is almost certainly intrusive into the Colquitz gneiss as well as into the Wark gneiss.

Saanich Granodiorite and Contact Phases.—The relation of the contact phases of the Saanich granodiorite—the quartz and monzonitic diorites—to the normal granodiorite is clear. As stated, they are confined to the contacts and in addition they are cut by large masses of the normal granodiorite. In common with the granodiorite they are cut also by apophyses of aplite and pegmatite.

Saanich Granodiorite and Granodiorite and Diorite Porphyrite.—The granodiorite porphyrites also are, as mentioned, restricted in their occurrence to the vicinity of the contacts of the Saanich granodiorite, except those with the Wark gneiss, and are chiefly confined to the granodiorite itself. They are distinctly intrusive into the ocks intruded by the granodiorite, and in some instances are clearly intrusive into the granodiorite itself, forming large irregular masses and dykes. Frequently, however, the contact relations of the two rocks are not clear, and farther west some of the granodiorite porphyrites, which are intrusive into the Sicker series, are apparently older than the Saanich granodiorite.

The diorite porphyrites are younger than the batholithic rocks and the granodiorite porphyrites, cutting them all in well defined, regular dykes. (See Plate XIII B.)

Sicker Gabbro-Diorite Porphyrite.—The relations of the Sicker gabbro-diorite porphyrites with the other irruptive rocks are not clear, since these have not been seen in actual contact. Farther west the gabbro-diorite porphyrites appear to be younger than the granodiorite porphyrites that are intrusive into the Sicker series. It may be, therefore, that the gabbro-diorite porphyrites are younger than the other irruptive rocks, but if so their restriction to the Sicker series is remarkable, as is also the fact that they are apparently magmatically related to the augite andesites of the Sicker volcanics.

SEQUENCE OF IRRUPTION.

From the structural relations given above, the sequence of irruption of the batholithic and minor intrusives of the Victoria and Saanich map-areas, from oldest to youngest, is seen to be as follows:—

Wark gabbro-diorite gneiss.
Colquitz quartz-diorite gneiss.
Saanich granodiorite.
Granodiorite porphyrites (some may be older than the Saanich granodiorite).
Diorite porphyrites.
Sicker gabbro-diorite porphyrites.

EXTERNAL.

RELATION TO OLDER FORMATIONS.

The batholithic rocks and accompanying porphyrites are intrusive into all the formations of the Vancouver group, developing relatively narrow zones of shatter-breccias along the contacts of the batholiths and sending apophyses and porphyrite masses and dykes into the invaded rocks for long distances. In the vicinity of the contacts the invaded rocks are traversed also by numerous quartz veins and lenses. As stated, the Saanich granodiorite changes in character along the contacts, developing the contact and hybrid phases described above, and is accompanied by the minor intrusives. The invaded rocks also have been changed, being contact metamorphosed into the various types that have already been described.

The batholiths now occupy large volumes formerly occupied by the rocks of the Vancouver group and have, therefore, apparently replaced them, but in such a manner as not to disturb their attitude greatly. That this attitude affected the position of the batholiths is shown, however, by the conformity of the larger axis of the batholiths to the axes of deformation of the invaded rocks.

RELATION TO YOUNGER FORMATIONS.

The Saanich granodiorite and its accompanying minor intrusives are all unconformably overlain by the sediments of the Nanaimo series. As mentioned, the unconformity, which is well exposed, is marked by coarse basal conglomerate composed partly of fragments of the granodiorite and porphyrites.

Mode of Origin of Batholithic and Minor Intrusives.

Intrusion.

The batholithic and minor intrusives have crystallized from a molten state under deep-seated conditions. As mentioned, they were irrupted into the rocks of the Vancouver group and have replaced them, appare[illegible]ly in a relatively quiet manner without disturbing them greatly. The invading batholiths, even during their last active stages, shattered the invaded rocks along their contacts into angular fragments. Near the present contacts great numbers of these fragments occur in the intrusive rocks, but they disappear within a few yards. They may have been shattered to smaller fragments and assimilated by the intrusive rocks, while still in a magmatic condition, for of this there is, as noted, some evidence in certain localities, or else they have sunk in the intrusive magmas to abysmal depths.[1] It is by this last method that Daly supposes that batholiths have replaced large volumes of the rocks into which they were intrusive.

Differentiation.

All the batholiths of the Victoria and Saanich map-areas were not irrupted at the same time, but during two main periods, that have been called the Wark and Saanich periods.[2] During the first period the Wark and Colquitz gneisses were irrupted, but independently, thus dividing the Wark period into two sub-periods, the second sub-period being characterized by the irruption of a more salic magma than that irrupted during the first. The close structural and lithological relationships of the Wark and Colquitz gneisses show, however, that they are closely related in origin also, and are doubtless differentiates of the same parent magma.

A similar subdivision into two sub-periods characterizes the Saanich i[illegible]ive period, but the first sub-period, during which the femic rock, the P[illegible] diorite,[3] was irrupted, is represented in the Victoria and Saanich map-areas only by the contact phases of the Saanich granodiorite.

Also the rocks irrupted during the Wark and Saanich periods are closely related structurally, and, except that those of the Wark period are gneissic, are similar lithologically. It is probable, therefore, that the Wark and Saanich magmas are themselves differentiates of the same parent magma, the Wark magma being more femic than the Saanich magma.

---

[1] R. A. Daly. Mechanics of Igneous Intrusion. Three papers Am. Jour. Sci., vol. 15, 1903, p. 269; v[illegible]l 16, 1903, p. 107; vol. 26, 1908, p. 17.

[2] Memoir No. 13, Geol. Survey, Canada, 1912, p. 110.

[3] See Memoir No. 13, Geol. Survey, Canada, 1912, p. 99.

The association of sub-alkaline rocks of varying composition, like those of the Wark and Saanich batholiths, exhibiting also a similar sequence of irruption from femic to salic, has been found to be very common wherever igneous rocks have been studied.[1] The association and the sequence of irruption is very generally accepted to be due to some kind of magmatic differentiation. Since the principal rock types, the Wark gabbro-diorite gneiss, the Colquitz quartz diorite gneiss, and the Saanich granodiorite have been separately and more or less independently intruded in large masses, the differentiation producing the various types must have been deep-seated.[2] However, since the parent magma was apparently subdivided into the Wark and Saanich magmas, each of which independently underwent further differentiation under deep-seated conditions, it seems probable that this differentiation did not take place in the same magma chamber. On the other hand, it looks as if the Wark and Saanich magmas, after differentiation from the parent magma, were irrupted from the primary magma chamber into separate chambers, where each underwent its further differentiation independently, producing the sub-types which themselves were irrupted into their present position independently.

It also appears as if the three principal types were still further differentiated apparently "in place,"[3] giving rise to those variations of the principal rock types that have been described. Under this hypothesis the fine grained phases and some of the femic facies of the Wark gneiss as well as the Wark gabbro and salic gabbro, would not be intruded independently from the normal gabbro-diorite, and their structural relations support this conclusion. In the same relation are the normal quartz diorite and biotite granite of the Colquitz gneiss, and the various types of granodiorite and the segregations of the Saanich granodiorite. Most probably the contact phases of the Saanich granodiorite also are differentiates in place, although they may be related to the Beale diorite, which appears to have been intruded separately from the granodiorite.[4]

Metamorphism.

As stated, the other facies of the Wark gneiss that have been described, the gabbro-diorite gneiss, with recrystallized and poikilitic hornblendes and the coarse-grained femic facies, appear to have been the result of metamorphism subsequent to their intrusion and probably to their crystallization. The secondary or metamorphic nature of the gabbro-diorite

---

[1] Cf. A. Harker. The National History of Igneous Rocks, Macmillan, 1909, pp. 125-131.

[2] Primary or "deep magmatic" of Brogger. W. C. Brogger. Eruptingestein des Kristianiagebietes, vol. 1, 1894, pp. 178-179.

[3] Cf. W. G. Brogger Loc. ci.

[4] See Memoir No. 13, Geol. Survey, Canada, 1912, p. 108.

gneisses with large and poikilitic hornblendes can hardly be doubted since they are confined to the contacts of the Wark gneiss with the intrusive Colquitz gneiss and Saanich granodiorite, especially with the former, and since the hornblendes are as described doubtless secondary. The coarser grained hornblende-rich facies of the Wark gneiss are considered to be the result of metamorphism also, since they too are largely confined to the contacts of the Wark gneiss, and since their chief constituent, hornblende, is likewise secondary, being similar in its relations and character to the hornblendes of the types described above, although it is not characteristically poikilitic and is not associated with quartz.

The gneissic texture of the rocks of the Wark-Colquitz batholith and the virtual absence of rocks with a pronounced gneissic texture in the Saanich batholiths, although all the batholiths were intruded during the same general period, may be best explained by supposing the Wark-Colquitz batholith to have been intruded during the orogenic movements, which generally accompany or precede batholithic intrusion, the movements having ceased before the Saanich batholith was intruded. All of the batholithic rocks have been somewhat dynamo-metamorphosed by late orogenic movements, probably during the Laramide revolution.

ORIGIN OF BANDED COLQUITZ GNEISS.

The origin of the banded texture of the Colquitz gneiss is a problem of considerable geological interest since it throws light on one of the most important problems of geology, the origin of gneisses. It is, therefore, discussed in some detail. Gneisses are doubtless formed in many different ways, and many explanations have been proposed to explain their origin. In this instance there is no question as to whether the Colquitz gneiss was originally igneous or sedimentary. Its lithological character, chemical composition, and geological structure all prove conclusively that it was igneous. We have, therefore, a somewhat simpler problem, the origin of banded gneisses of igneous origin. There are several ways in which banded gneisses can be formed, for example, by the injection of one igneous rock along the foliation planes of another and by the pulling out of xenoliths or inclusions in a viscous magma. Examples of banded gneisses formed by these two methods have already been mentioned, for instance, the Wark gneiss has been intruded along its foliation planes by numerous apophyses of quartz diorite, thus forming a banded quartz diorite gneiss, and the xenoliths of Wark gneiss in the Colquitz gneiss have been pulled out into long bands and even the contact breccias have been foliated. Many, possibly most, of the banded gneisses of the Victoria and Saanich map-areas have been formed by this last method, especially those characterized by large, coarse grained hornblendite masses, which may represent recrystallized and stretched xenoliths of Wark gabbro-diorite. The stretched xenoliths would be fine grained, if not recrystallized, because of the granulation due to stretching, and fine grained bands occur in the Colquitz gneiss, with central coarser grained portions, which closely resemble the Wark gneiss.

However, it is probable that the wide areas of laminated and comparatively fine, well banded gneiss have been formed by some other method than those just described. To explain the origin of such banded gneisses, two principal hypotheses have been proposed: one that the gneisses represent igneous rock bodies, even of the size of large batholiths, that after complete solidification have been "extremely metamorphosed through dynamic and hydrothermal agencies by orogenic crushing and its attendant processes"[1] (such as batholithic and dyke intrusions); and the other that the banding is a primary structure developed before the igneous rock was completely solidified. Gneisses having developed in the latter way are called primary gneisses,[2] in distinction from those formed by the first method, which may be called metamorphic or secondary gneisses. The first hypothesis is the older and is accepted by nearly all geologists as being effective in producing at least a foliated or gneissic texture, but its effectiveness in forming banded gneisses is now held in some doubt. The hypothesis of primary gneisses was perhaps first clearly and confidently stated by Lawson[3] to explain the vast areas of banded gneisses in the vicinity of Rainy lake, Ontario. Since then primary gneisses have been described by many leading geologists in both Europe and North America, notably in Ontario and Quebec, by F. G. Adams and A. E. Barlow, in the Central Alps by E. Weinschenk, and on the island of Skye by A. Geikie and J. J. H. Teall and A. Harker, and most recently in Connecticut and New York by G. F. Loughlin and G. S. Rogers. The criteria for distinguishing primary gneisses from secondary gneisses have very recently been summarized by J. D. Trueman in an excellent thesis on "The value of certain criteria for the determination of the origin of foliated crystalline rocks"[4] as follows:—

"*Field Evidence.*—Banding in apophyses from the gneiss parallel to the walls and at an angle to the schistosity of the enclosing rock; dykes of pegmatite belonging to the same magmatic series as the gneiss and either parallel to the gneissic structure and foliated with it or cutting the gneissic structure and undisturbed; lack of sharp contact between the acidic and more basic portions of the gneiss, indicating high temperature during the solidification of the different bands; presence of inclusions of foreign rock, which are but slightly deformed, in a matrix of well-banded

---

[1] R. A. Daly. The Okanagan Composite Batholith. Bull. Geol. Soc. Am. vol. 17, 1906. pp. 329-376.

[2] See J. P. Iddings, Igneous Rocks, Wiley & Sons, 1909, pp. 242-245.

[3] A. C. Lawson, Ann. Rep. Geol. Survey, Canada, 1887-88, p. 139 F.

[4] Trueman, J. D., Jour. of Geology, vol. 3, 1912, p. 231.

gneiss; presence of distinct bands of widely different composition, none of which may show evidence of shearing; flow-like curves of the banding some of which may close in a circle."

"*Mineralogical Evidence.*—Presence of minerals formed characteristically only from igneous melts and arranged in a manner impossible for formation from solid rocks by metamorphism: e.g., nepheline and olivine; textures due to crystallization from an igneous melt."

Applying first the criteria of field evidence to the Colquitz gneiss, we have seen that apophyses of the Colquitz gneiss, which are foliated parallel to their walls, but not banded, cut not only the Wark gneiss and Vancouver meta-volcanics, but the intrusive Colquitz gneiss as well, and that the apophyses while usually parallel to the foliation sometimes cut across it. The few dykes of pegmatite, referable to the Colquitz magma, are, as mentioned, unfoliated and occur both parallel to and at an angle to the foliation. The contact between the salic and femic bands is not sharp. Some of the inclusions of Wark gneiss and Vancouver meta-volcanics in the Colquitz gneiss are angular and but slightly deformed, but in most instances, especially the inclusions of Wark gneiss, they have been pulled out into elongate masses, which, as mentioned, are in some instances virtually identical with the femic bands in the normal gneiss. The salic and femic bands are of widely different composition, but are usually more or less foliated, although some of coarse grained hornblendites are only slightly foliated. The contacts between the salic and femic bands, although usually straight or forming gracefully sweeping broad curves, are, in places, contorted and off-set by minor faults.

Applying the criteria of the mineralogical evidence to the Colquitz gneiss, we note that the minerals present in the banded gneiss are all found in both igneous and metamorphic rocks. However, the orthoclase and albite of the Colquitz gneiss are microperthitically intergrown in a manner identical to that of the microperthite of the Saanich granodiorite. It is probable that microperthite, which is generally considered to be some kind of eutectic mixture, forms only on crystallization from a melt. Also the plagioclase feldspar of the salic bands of the Colquitz gneiss has a zonal growth, a feature not characteristic of metamorphic textures.[1] It is also seen, however, that the minerals of the salic bands are apparently of two generations, those of the second period of formation fine grained and apparently derived through the crushing and recrystallization of the coarse grained and apparently original minerals.

The value of these various criteria is a more or less debatable question, as Trueman has shown in the case of texture. He arrives at the conclusion that while evidences of igneous texture are more or less conclusive of the

[1] V. Grubenmann. Die Kristallinen Schiefer, Part I, 1904. p. 77.

primary origin of gneisses, metamorphic texture is not necessarily an evidence of metamorphic origin, since, as may be the case, later or continued dynamic movements may have developed this texture in primary gneisses. In the case of the Colquitz gneiss, we have clear evidence, not only of movements taking place during its crystallization, since inclusions of Wark gabbro-diorite have been pulled out into bands, but also since the younger Saanich granodiorite is in places somewhat foliated, of movements after its intrusion and crystallization. But when nearly all of the criteria, given above, are applicable to any gneiss, its origin is almost certain. It is seen in the case of the Colquitz gneiss, that all of the criteria are applicable to a greater or less degree, so that its primary origin is almost certain, unless we hypothecate a complete remelting of the rock after crystallization.

This conclusion is further substantiated by the occurrence not only of salic, but of what appear to be femic, hornblendite apophyses in the Wark gneiss, a fact which if true, indicates that the intrusive magma had split into the femic and salic facies before it became too viscous for the facies to be injected into the invaded rock. These facies were evidently pulled out into the femic and salic bands by movements in the viscous magma.

Saanich Granodiorite and Minor Intrusives.

The close magmatic relation of the granodiorite and diorite porphyrites to the Saanich granodiorite and to each other is shown by their close structural relation, by the lithological similarity of the normal granodiorite porphyrite to the Saanich granodiorite, and by the transition from the normal granodiorite porphyrites to the diorite porphyrites. There are three significant structural features of the porphyrites. First, they are restricted to the vicinity of the contacts of the Saanich batholith. Second, their period of irruption was long, since some of the granodiorite porphyrites are apparently older than the Saanich granodiorite, while others are certainly younger: and all are followed by the diorite porphyrites. Third, they are injected bodies, as is shown by their dyke-like forms and porphyritic texture. Since the granodiorite porphyrites and Saanich granodiorites are magmatically related, the porphyrites are quite certainly differentiates from the Saanich magma. It is probable that further differentiation of the "porphyrite magma" gave rise to the two transitional and yet complementary types, the granodiorite and diorite porphyrites. Whether or not the differentiation was "deep seated" or "in place" is indefinite. In their structural relation the porphyrites are chiefly later than the granodiorite, and, therefore, conform to the general sequence of irruption of batholithic and the accompanying minor intrusives.

Whether or not the Sicker gabbro-diorite porphyrites conform to this sequence is not known, as its relations to the other intrusive rocks are indefinite. It appears to be magmatically related to the augite andesite of the Sicker volcanics rather than to the batholithic rocks. Also some of the masses have apparently been foliated along with the Sicker series. However, this foliation may have been produced during the post-Eocen deformation, which was competent to produce the foliation, since it is known to have produced a large amount of deformation in the closely associated Nanaimo series. Also the gabbro-diorite porphyrites cut the schistose granodiorite porphyrites and, as mentioned, may be related to the younger diorite porphyrites of Texada island. Hence it would seem as if the Sicker gabbro-diorite porphyrites also conformed to the general sequence of irruption of batholiths and their accompanying minor intrusives.

Thus, as has been pointed out,[1] the irruptive cycle, represented by all of the igneous rocks of the Victoria and Saanich map-areas, the metavolcanics of the Vancouver group, the gneisses and granodiorites of the batholithic intrusives, and the porphyrites of the minor intrusives, conforms to the general irruptive cycle,[2] which consists of three phases of igneous activity in the following sequence: the volcanic phase, the batholithic phase, and the phase of minor intrusives.

Age and Correlation.

The batholiths are intrusive into lower Jurassic rocks (Vancouver group) while upper Cretaceous sediments (Nanaimo series) rest unconformably upon them. They are, therefore, correlated with considerable certainty with the other batholithic rocks of Vancouver island and with the Coast Range batholith of the mainland of British Columbia, which is considered to be chiefly upper Jurassic in age. Most of the other batholithic rocks of Vancouver island are identical with those of the Victoria and Saanich map-areas. The Coast Range batholith is composed of rocks similar to those of the Wark-Colquitz and Saanich batholiths and it is also made up of separate intrusions, and is, therefore, strictly speaking, a composite batholith.[3] Large composite batholiths of similar rocks are very numerous all along the Pacific coast of North America. Most of them were irrupted during the same period of batholithic intrusion. This period, however, apparently occurred at an earlier date in Alaska (middle Jurassic) and at a later date (lowermost Cretaceous) in California. Associated with the batholithic rocks are minor intrusives of similar porphyries or porphyrites to those of the Victoria and Saanich map-areas, and they have, doubtless, the same general structural relations.

---

[1] Memoir No. 13, Geol. Survey, Canada, 1912, p. 112.

[2] See A. Harker. The Natural History of Igneous Rocks, Macmillan, 1909, p. 95.

[3] R. A. Daly, Classification of Igneous Intrusive Bodies. Jour. Geol., vol. 13, 1905, p. 504.

NANAIMO SERIES.

The unmetamorphosed sedimentary rocks of the southern part of Vancouver island, which are referable in large part to the Cretaceous, have been grouped together, since they could not be definitely subdivided, and have been called the Cowichan group.[1] The rocks belonging to the Cowichan group, which occur in the Saanich map-area (none occurring in the Victoria map-area) all belong to one conformable series or formation that has been named and described by Richardson, Whiteaves, and Dawson as the Nanaimo series[2] and by the writer[3] as one of the subdivisions or formations of the Cowichan group, since it could not be further subdivided even in the detailed geological mapping of the Saanich map-area. However, during 1911 in the detailed geological mapping of the Nanaimo map-area the name Nanaimo was extended to embrace the entire conformable series of sedimentary rocks of the Nanaimo map-area, which series has been definitely subdivided into various members or formations. It seemed best, therefore, to call the conformable series of sedimentary rocks not the Nanaimo formation but the Nanaimo series,[4] which term, for the sake of uniformity in the final reports, is employed in this report also, although, as stated, the series cannot be further subdivided in the Saanich map-area.

Distribution.

The larger part of the rocks of the Nanaimo series that are found in the Saanich map-area occur in a single basin called the Cowichan basin by Richardson.[5] They are found on the northern end of Saanich peninsula, and in a narrow strip along the opposite shore, at the southern end of Saltspring island. From these occurrences they extend southeast to the International Boundary, forming several of the islands east of Saanich peninsula, the larger being Piers, Coal, Domville, and Gooch islands. The southeasternmost exposures are found on Bare and Low islands, and along the northeast shore of Sidney island.

Pender island, a portion of which is included in the extreme northeastern portion of the Saanich map-area, is composed of rocks of the

---

[1] C. H. Clapp, Summary Report, 1909, Geol. Survey, Canada, p. 89, and Prelimin. Report on Southern Vancouver Island. Memoir 13, 1912, Geol. Survey, Canada. p. 124.

[2] James Richardson. Report on the Coal Fields of Nanaimo, Comox, Cowichan, Burrard Inlet, and Sooke, B.C. Geol. Survey, Canada. Report of Progress. 1876-7., pp. 160-192.

J. F. Whiteaves, Mesozoic Fossils, Vol. I, Part II, Geol. Survey, Canada, 1879, pp. 94-96.

G. M. Dawson, The Nanaimo group. Am. Jour. Sci., vol. 39, 1890, pp. 180-183.

[3] C. H. Clapp, Summary Report, 1910, Geol. Survey, Canada. p. 107; Memoir 13, 1912, Geol. Survey, Canada, p. 134.

[4] C. H. Clapp, Summary Report, 1911, Geol. Survey, Canada, p. 96.

[5] James Richardson, Geol. Survey, Canada, Rept. of Progress. 1876-77, pp. 187-188.

Nanaimo series, which belong, however, to the eastern part of the Nanaimo basin. Between Pender island and the islands of the Cowichan basin small areas of the rocks of the Nanaimo series occur on Saltspring, Russell, Portland, and Moresby islands, lying directly upon the older crystalline rocks. Also a small remnant patch of sandstone of the Nanaimo series is found lying on the crystalline rocks three-fourths mile from the southern shore of Saltspring island at an elevation of about 1,400 feet.

The rocks of the Nanaimo series although on the whole less resistant than the older crystalline rocks, having been worn down to a lowland as described under topography, have in the Saanich map-area a nearly equal or greater resistance than the more altered and fractured portions of the crystalline rocks. Consequently the harder beds form low ridges of moderate elevation where the rocks are fairly well exposed. They are also exceptionally well exposed along the shores of the Saanich peninsula and various islands. Their boundaries with the crystalline rocks have, therefore, been located with considerable accuracy. However, by far the larger part of the sedimentary rock basins in the Saanich map-area is under water so that the stratigraphic succession and thickness of the series, and the detailed structure of the basins cannot be determined.

Lithological Characters

The rocks of the Nanaimo series consist of conglomerates, sandstones, and shales, the sandstones predominating. Some thin coaly streaks and lenses occur associated with carbonaceous shales interbedded with sandstones, especially in the lower part of the series. There are in the Saanich map-area no distinctly calcareous rocks.

Conglomerates.

The conglomerates usually consist of fairly well rounded, waterworn assorted fragments of the various crystalline rocks of the vicinity in a sandy matrix. They ordinarily range from coarse conglomerates, with fragments up to a foot in diameter, to fine grained phases, and from phases in which there is very little matrix to those in which the matrix is dominant. They form thick massive beds, the thickest horizon, 300 feet, occurring on Pender island. However, the conglomerate at this locality contain numerous thin lenticular beds of coarse grained sandstone.

The basal conglomerates are usually coarse, with rounded to angular fragments up to 4 or 5 feet in diameter, of the crystalline rocks directly underlying them, and the sandy matrix is usually subordinate. They vary in thickness from 1 or 2 feet to 25 feet, and in a few places are absent. The pebbles of granodiorite and intrusive porphyrites are chiefly rounded, while those of the schists and volcanic rocks of the Sicker series are frequently angular. Where the basal conglomerate is composed largely of the latter type of fragments, especially on Portland and Moresby islands, the fragments vary greatly in size and occur jumbled closely together at all angles, there being no appearance of sorting during deposition.

SANDSTONES.

The sandstones are commonly medium to coarse grained and yellow to grey or greyish green in colour. Fine grained, laminated sandstones occur, but, as a rule, the sandstones are uniform in appearance and no colour lamination is seen. They are uniform in composition also. Quartz is the most abundant constituent, and occurs with other minerals and even with small rock fragments, as angular to sub-rounded grains in an argillaceous or more rarely calcareous matrix. The matrix is usually subordinate. The other minerals present are, in about the order of their relative abundance, feldspar, chiefly plagioclase, muscovite, biotite, chlorite, epidote, and more rarely serpentine, magnetite and other iron oxides, and calcite. Calcite occurs also in veinlets.

The sandstones are commonly massive, forming with conglomerates, thick bedded strata. They grade into arenaceous shales through thin bedded shaly sandstones, and the arenaceous shales are very commonly interbedded with numerous thin beds of sandstone a few inches thick, and seldom more than a foot or two apart. Many of the sandstones are concretionary, with numerous concretions ranging from an inch up to several feet in diameter (See Plate XIV). The cement of the concretions is ferruginous and calcareous. Cross-beddings, sun-cracks, and ripple marks are rarely seen. Where exposed to solution by salt water and to wave and wind action the sandstones have been fantastically weathered and "honeycombed," the softer and more soluble portions having been abraded, leaving the harder and less soluble streaks and patches in relief.

SHALES.

The shales are arenaceous, and frequently carbonaceous, varying from olive grey to dark grey or black in colour. Where they have undergone the greatest deformation they are slaty in appearance and are frequently traversed by quartz or calcite veinlets and more rarely are impregnated by pyrite. They are composed chiefly of small angular quartz grains in an argillaceous and carbonaceous matrix. Calcite is frequently present in the groundmass although rarely in large amounts, and then only as replacements. Muscovite also occurs in small quantities.

The shales seldom have a well developed shaly parting, but are relatively massive; although the finer grained less arenaceous shales weather into small flakes. Far more commonly, however, the shales weather concentrically. Sandstone concretions, lenses, and interbeds are numerous and the shales exposed on the east shore of southern Saltspring island contain concretions or lentils up to 3 feet in diameter of a compact, black calcareous rock, which is virtually an argillaceous limestone. The shales seldom or never grade imperceptibly into sandstones, but are nevertheless frequently replaced by sandstones, often abruptly, the sandstones evidently representing filled up channels which were eroded in the shales during deposition. Such examples of contemporaneous erosion and deposition are fairly frequent.

Occasionally the shales or finer grained sandstones contain bark impressions and thin coaly seams or lenses which are rarely more than a foot thick and none of which are known to be persistent. The carbonaceous matter is mixed with a large amount of argillaceous material also and is almost always impregnated with pyrite, which has decomposed near the surface, forming sulphur and limonite, which stain the weathered outcrops of the coaly lenses yellow.

Metamorphism.

The rocks of the Nanaimo series although firmly indurated and extensively folded are not appreciably metamorphosed. The shales have undergone the greatest change, and they have merely taken on a slaty appearance or have been cut by quartz or calcite veinlets, and more rarely have been partially replaced by calcite.

Structural Relations.

Internal.

The greater part of the Nanaimo series exposed in the Saanich map-area occurs, as already mentioned, in the Cowichan basin. In general the rocks of this basin form a closely folded syncline, striking about N. 60° W., that has probably been overturned to the southwest, so that the rocks have a general dip to the northeast. A few smaller folds and many minor ones or wrinkles occur in the major syncline, especially along the southern boundary of the basin. The northern boundary of the basin is a thrust fault, and many smaller faults also occur. The rocks of the syncline occur on the southern end of Saltspring island and the northern end of Saanich peninsula and extend southeast to Bare and Low islands. To the northeast of the major syncline, chiefly on Saltspring, Russell, Portland, and Moresby islands, are found the lower parts of a smaller faulted syncline; and the southwestern limb of another large syncline is found in the extreme northeastern corner of the map-area on Pender island.

Stratigraphy.

The thickness of the sediments of the Nanaimo series found in the Saanich map-area is at least 6,000 feet and probably more. Their stratigraphic succession and detailed structure cannot be determined on account of the absence of horizon markers, due to the rapid lateral and vertical gradation of the sediments and because it is impossible to trace the faults and axes of folding, since a large proportion of the basins are under water. There is a general tendency for the rocks to grow finer grained upward, but in some places, as at the northern end of Saanich peninsula, there is a thick horizon composed chiefly of shale below a conglomerate horizon which in places rests directly on the crystalline rocks. Also thick horizons of coarse conglomerate are found apparently in the upper part of the series. The general succession of beds in the lower part of the series is illustrated by the following section of a bore-hole put down at the northern end of Saanich peninsula between James point and Saddle hills, only about 1,000 feet north of the contact with the underlying crystalline rocks.

	Thickness.		Depth.	
	Ft.	ins.	Ft.	ins.
Sandstone	46	6	46	6
Black carbonaceous shale	9	2	55	8
Sandstone	1	4	57	
Carbonaceous shale	51		108	
Sandstone	60		168	
Very coarse grained sandstone	5		173	
Sandstone	7		180	
Sandy shale	5		185	
Carbonaceous shale	3		188	
Sandstone	55		243	
Sandstone and "quartz" (quartz veinlets ?)	18		261	
Sandstone	4		265	
Carbonaceous shale	7	6	272	6
Sandstone	7	6	280	
Sandy shale	11		291	
Carbonaceous and sandy shale	19		310	
Sandstone	1		311	
Carbonaceous and sandy shale and small lenses of conglomerate	44		355	
Sandy shale	3		359	
Carbonaceous shale	3		361	
Sandy shale	4		365	
Sandstone	18		383	
Sandy shale	65		448	
Carbonaceous shale	4		452	
Sandy shale with lenses of carbonaceous matter	52		504	
Carbonaceous shale and thin sandstone layers	17		521	

	Thickness.	Depth.
	Ft. ins.	Ft. ins.
Sandy shale	1	522
Carbonaceous shale	21	543
Sandstone	39	582
Carbonaceous shale	61	643
Grey shale	2	645
Sandstone	25	670
Sandstone and shale	65	735
Coarse grained sandstone	21	756
Sandstone and shale	42	798
Shale, with slaty appearance	8	806
Sandstone	85	891
Sandy shale	14	905
Sandstone	3	908
Carbonaceous shale	7	915
Sandstone	11	926
Sandy shale	4	930
Carbonaceous shale	55	985
Sandy shale	5	990
Carbonaceous shale	10	1000
Sandy shale	27	1027
Sandstone	12	1039
Carbonaceous shale	3	1042
Sandstone and carbonaceous shale	12	1054
Sandstone	13	1067
Carbonaceous shale	15	1082
Sandstone	2	1084
Black carbonaceous shale with slaty appearance	2	1086

End of bore.

Folding and Faulting.

The evidence in the Saanich map-area upon which the synclinal structure of the rocks of the Cowichan basin is based is not complete, but the structure is more or less inferred from that to the west which is more readily determined.[1] At the northern end of the Saanich peninsula the rocks have a general northward dip, which increases to the north so that near the central part of the supposed syncline on Arbutus and Piers islands it becomes nearly vertical. On southern Saltspring island the beds which are exposed dip to the north against the crystalline rocks, but are apparently

[1] Memoir 13, Geol. Survey, Canada, 1912, p, 129.

the lower beds of the syncline since they contain conglomerates with coarse, angular fragments of the underlying crystalline rocks. Since the Nanaimo series dips against the crystalline rocks, the contact is evidently a fault and probably a thrust fault. To the west on Mt. Tzuhalem the crystalline rocks are capped with basal conglomerates of the Nanaimo series, but on Saltspring island the cover of sedimentary rocks has been entirely removed with the exception of the small remnant patch of sandstone, a few feet in diameter, resting on the crystalline rocks at an elevation of almost 1,400 feet. The thrust fault, as well as the syncline, probably extends to the southeast, the fault and axis of the syncline being below the water of Satellite channel and Shute and Moresby passages, north of Piers, Knapp, Pynn, and Yellow islands and south of Black, Hood, Portland, and Moresby islands.

The southern limb of the syncline is fairly well exposed, and, as mentioned, it is complicated by several minor folds or wrinkles, and some of the shale horizons are even conterted, as is well shown along the southern shore of Piers island. Minor but more open folds are exposed also along the north shore of Saanich peninsula and the south shore of Coal island. In all of these localities the sediments are broken by small faults. A much larger but open syncline and corresponding anticline is determined by the attitude of the beds exposed on the small islands between Saanich peninsula and Coal island. Hill and Domville islands form the southwest limb of another syncline while Gooch and Comet islands form the northeast limb. There are also two small synclinal infolds of the Nanaimo series in the crystalline rocks south of the main syncline. They are exposed on the east and west sides of Saanich peninsula. The dip of the rocks in these infolds varies from 70 to 90 degrees to the north and the northern boundaries are possibly faults.

The sediments exposed on the east shore of Saltspring island, and on Russell, Portland, and Moresby islands are deformed also, on the whole to a greater extent than those of the major syncline. Strike faulting is especially prevalent on these islands, although the faults are probably of rather small displacement.

Jointing.—The jointing of the rocks of the Nanaimo series is in general irregular. At times it is parallel, and where the rocks have been weathered along the joint planes the parallel sheet jointing has, at a distance, the appearance of bedding. Along the northern shore of Piers island the jointing in a sandy shale is regular, there being two sets of parallel joints having a northwest strike but with opposite dips of about 45 degrees. The joints have, therefore, broken the shale into nearly rectangular blocks, with a face varying in size from 3″ × 8″ to 12″ × 36″. The sandy shale has been weathered along the joints, [illegible]ening them slightly, so that the jointed shale has, at a distance, the appearance of an artificial wall (See Plate XV). In general the jointing is not only irregular but extreme, rendering the rocks in most instances unfit for building stone. Also, where exposed to wave action the rocks where greatly fractured have been eroded, forming small joint chasms with nearly vertical walls, and small coves.

EXTERNAL.

Relation to Older Formations.—The Nanaimo series rests unconformably upon the volcanic and sedimentary rocks of the Vancouver group and upon the igneous rocks of the batholithic and dyke intrusives. In several instances the unconformity is directly observed, as on the west shore of Saanich peninsula, between Coal and Boulder points and on Russell, Portland, Moresby, and Sidney islands. There are also, as described, fragments of the underlying rocks in the sediments of the Nanaimo series.

It has been found elsewhere on Vancouver island that the Nanaimo series was deposited on an erosion surface of considerable re''[1] Small irregularities in the unconformable surface are seen in the exposed unconformities in the Saanich map-area and much larger ones are inferred by the occurrence in certain places of the shale horizon below that one which corresponds with the basal conglomerate in other places.[2] It is not probable, however, that in the Saanich map-area the amount of relief in the unconformable surface is as great as in other parts of Vancouver island. It is doubtless much less than 1,000 feet.

MODE OF ORIGIN.

The Nanaimo series as shown by its fauna is partly of marine origin,[3] probably estuarine, since it was deposited on a surface of considerable relief, and under varying conditions, shown by the rapid lateral and vertical gradation of the sediments. The series also contains land plants and some coal, most probably of fresh water accumulation. Hence conditions of fresh or at least brackish water, that is terrestrial conditions, alternated with marine conditions. The lithological character of the sediments, the sandstones and conglomerates being composed of angular to sub-angular fragments and of a large percentage of easily decomposed minerals such as feldspar, indicates a very rapid accumulation and deposition in relatively small basins, where the detritus was not subject to severe wave action.

AGE AND CORRELATION.

From the large collection of fossils from the Nanaimo series of Vancouver island the series has been correlated with the Chico of the

[1] Memoir 13, Geol. Survey, Canada, 1912, p. 133.
[2] See page 98.
[3] J. F. Whiteaves, Mesozoic Fossils, vol. 1, Geol. Survey, Canada, Part V, 1903, p. 312.

California Cretaceous and approximately with the Pierre of the Great Plains. Comparatively few fossils have been collected from the series in the Saanich map-area since here they are not abundant and are rather poorly preserved. However, a sufficient number have been collected and determined to show that the fauna is identical with that of the type locality of the Nanaimo series, that is of the vicinity of Nanaimo. The following fossils have been identified:—

Tellina sp. North shore, Saanich peninsula.
Trigonia, cf. *evanbana*, Meek. Moresby island.
Inoceramus sagencis, Owen. Piers island.
Inoceramus cf. *barabini*. Piers island and north shore Saanich peninsula.

These sediments of the Saanich map-area under consideration are, therefore, definitely members of the Nanaimo series and consequently upper Cretaceous in age.

The formations of the Saanich map-areas, however, cannot be exactly correlated with those occurring at Nanaimo,[1] but the lowermost ones are best correlated at present with the middle formations at Nanaimo.

The Nanaimo series were deformed doubtless at or near the close of the Eocene period, at the same time that the upper Eocene, Metchosin volcanics were folded. There seems to have been no widespread deformation on the Pacific coast at the close of the Cretaceous, corresponding with the Laramide revolution of the interior, for, as Arnold[2] points out, with one exception at San Diego, California, the unconformity between the Eocene and the Chico (equivalent to the Nanaimo) is not angular, but, as far as the stratigraphic evidence goes, the two formations represent an apparently uninterrupted period of sedimentation. This conclusion has been confirmed in general by the writer's work of 1910 to 1912 in British Columbia; for although there were local movements throughout the deposition of the Nanaimo sediments, and doubtless an uplift without much folding at the close of the Cretaceous, since definitely lower Eocene sediments are not known in the region, the first pronounced deformation took place after the close of Eocene sedimentation and volcanism.

METCHOSIN VOLCANICS.

Distribution.

In the Victoria map-area the Metchosin volcanics, which farther to the west form a broad belt 5 to 7 miles wide extending to the west coast, occur only along the western border, west and south of the Colwood delta.

---

[1] Clapp, C. H., Summary Report for 1911, Geol. Survey, Canada, p. 96.
[2] Arnold, Ralph. Tertiary faunas of the Pacific Coast, Journ. of Geol., vol. 17, 1909, p. 512.

Typical and well exposed examples of these rocks occur around the shore of Albert head.

Lithological Characters.

The Metchosin volcanics are all basic, principally basalt and diabase, the latter occurring as dykes in the basalt. The basalt varies texturally from coarsely porphyritic and ophitic basalts to amygdaloids. Fragmental varieties also occur, and some of them are very coarse grained. All of the rocks have been more or less altered and metamorphosed.

Meta-Basalt.

Macroscopic.—The principal rock type is a more or less porphyritic rock with a dark greyish green, aphanitic groundmass. Where more affected by surface alterations and oxidation the groundmass frequently has a pronounced purplish tint. In the groundmass are seen also dark green patches of chlorite and less frequently lighter green masses of epidote or serpentine. When porphyritic the rock contains phenocrysts of white weathering feldspar and dark green, altered femic minerals. The phenocrysts are usually subordinate to the groundmass in amount. They are usually small, averaging 2 or 3mm. in diameter, but are sometimes as large as 1 cm. The rocks are fractured, sometimes greatly, and are frequently cut by calcite and epidote veinlets.

Microscopic.—The phenocrysts are labradorite, ca. Ab. 40 An 60, augite, and doubtless originally olivine, although in no instance has olivine been actually seen. Its presence is, however, indicated by the occurrence of characteristic masses of serpentine and limonite and also of iddingsite, apparently formed by the alteration of olivine. The labradorite phenocrysts, which are the more numerous, are comparatively unaltered, although in some instances they have been clouded. The augite phenocrysts are smaller, and more altered. In one instance a light green pyroxene, possibly hedenbergite, was noted in association with the augite.

On microscopic examination the groundmass is seen to consist of essential labradorite and augite, with an intersertal texture in the coarser grained varieties. The groundmass varies greatly in grain, from a relatively coarse decimillimetre grain to microcrypto crystalline, and in some instances is partially glassy. The labradorite occurs in small needles which have a tendency to form radiating groups. The augite not only occurs intergrown with the labradorite but also interstitial to it and in irregular small grains. Magnetite is the only accessory mineral, although pyrite is usually present, but is probably secondary.

The secondary minerals are chiefly chlorite and serpentine, replacing the groundmass and the phenocrysts of femic minerals. Saussuritic and sericitic minerals occur clouding the feldspar. Calcite and epidote also occur in small irregular replacements and in veinlets. Other secondary minerals are a light brown mica, limonite, and rarely uralite.

AMYGDALOIDAL META-BASALT.

The amygdaloidal meta-basalts are similar in appearance and composition to the normal meta-basalts, and except that they contain amygdules are similar in texture also. The amygdules are commonly of calcite, and more rarely of serpentine, epidote, and quartz. They are seldom large, averaging 1 or 2 mm. in diameter. The calcite amygdules show microscopically that the calcite sometimes occurs in radial groups frequently with concentric growth lines.

TAXITIC VARIETIES.

Other types of effusive meta-basalts are banded and brecciated, the banding being very evident in the field because the bands are of slightly different colour, due primarily to a corresponding difference of texture. The brecciated basalts, called flow-breccias, include small square-shaped fragments of basalt exactly similar in composition to the enclosing rock. The inclusions are at times very abundant. This feature is most strikingly seen on the weathered surface, the little blocks being in slight relief.

FRAGMENTAL VARIETIES.

Fragmental volcanics occur along the southern shore of Albert head. They range from fine tuffs, consolidated ash-beds, to very coarse agglomerates. The tuffs are dark green, fine grained fragmental rocks, consisting of basaltic detritus, altered more or less to serpentine and chlorite, and cut by veinlets of calcite. In the field they are frequently seen to be stratified, but evidence of stratification or sorting is seldom seen in the hand specimen or microscopically. One of the tuff beds on the south shore of Albert head, a few yards west of the boundary of the Victoria map-area, contains large numbers of upper Eocene gastropods.

The agglomerates are composed of rounded to angular fragments of meta-basalts in a matrix of basaltic detritus. The fragments are identical with the neighbouring finer grained and amygdaloidal meta-basalts and vary greatly in size, the largest having a diameter of about 10 feet. The coarse agglomerates show no stratification and their fragments are angular to subangular. The finer grained agglomerates are frequently stratified, and their fragments are subangular to rounded and appear to be waterworn.

DIABASE.

Macroscopic.—Intrusive into the Metchosin volcanics are numerous dykes of diabase. They are fine to medium grained rocks, dark green on fresh fracture but weather into rounded masses of a lighter, brownish colour. Where the rocks are well exposed they are, therefore, quite easily distinguished from the effusive basalts. On the weathered surface of the coarser grained varieties the diabase texture of the rock is conspicuous, white narrow laths of feldspar occurring in a dark crystalline matrix.

Microscopic.—The essential minerals of the diabase are labradorite, ca. Ab. 40 An. 60, and augite with an intersertal to ophitic texture. The accessory minerals are magnetite and doubtfully olivine. The larger grains of labradorite and augite are comparatively unaltered but the finer grained portions of the groundmass are altered to and partially replaced by serpentine, chlorite, and epidote. The serpentine may in part be the result of the alteration of original olivine.

Metamorphism.

The basalts have not suffered as great metamorphism as might at first be thought. They have been largely altered to greenstones, the femic minerals having gone over to a greater or less extent to chlorite and serpentine. The feldspars are, however, usually unaltered, only the more decomposed surface rock showing much clouding of the larger feldspar grains by secondary minerals. The character of the alterations is such as would be produced by aqueous solutions under surface conditions of low temperature and pressure.

Structural Relations.

Internal.—The Metchosin volcanic formation is made up of several basalt flows interbedded with the fragmental varieties, both of which are cut by numerous diabase dykes which are, however, identical in composition with the flow rock. The coarser agglomerates do not always occur as distinct interbeds, but along the south shore of Albert head form large irregularly-shaped areas. Except where separated by horizons of fragmental rocks, the individual flows cannot be distinguished since their contacts are obscure and seldom traceable, doubtless because of the metamorphism the formation has undergone. Neither can the dykes, although they are well defined, often with fine-grained chilled contacts, be traced for any considerable distance both because they pinch out, and because of the subsequent deformation of the formation.

The formation has suffered considerable deformation, which took place at or near the close of Eocene time. In many instances, particularly in the tuffs and agglomerates, direct evidence of folding is seen in the inclination and contortion of the beds. Otherwise it is very difficult to determine with any assurance the strikes and dips of the beds and thus work out the structure due to folding, and to calculate the thickness of the formation. The formation has a general northwest-southeast strike, but the dips are both to the northeast and to the southwest, varying up to 60°. Shear zones, often wide with well defined slickensided walls, are common. Hence it is probable that the rocks did not bend into closed folds but by shearing and faulting yielded to the larger of the forces causing the deformation. On account of the uniformity of the formation it is virtually impossible to determine the amount and direction of the displacement, which produced the shear zones. The formation is greatly fractured also and seamed with quartz, epidote, and calcite veinlets. In quarrying the rock breaks along the fractures and seams, and has apparently no decided rift.

An accurate determination of the thickness of the formation is not possible. The thickness of that part of the formation exposed in the Victoria map-area may not be very great, but the thickness of the whole formation has been estimated as 5,000 feet.[1]

External.—The Metchosin volcanics are not seen in contact with any other bed-rock formation of the Victoria map-area, as the contact is covered by the thick deposit of sand and gravel of the Colwood delta, but they are less altered than any of the other volcanic rocks. To the west of the area they are separated from the Leech River slates to the north by a profound and extensive fault,[2] and are intruded by the Sooke gabbro. They are also overlain unconformably by sediments of Miocene age, the Sooke and Carmanah formations.

Mode of Origin.

The Metchosin formation was formed largely by the accumulation of successive basaltic flows. The irruptions were probably for the greater part of a quiet nature from numerous fissures. Actual vents are doubtless represented in many cases by the diabase dykes which cut the basalt. That the irruptions were in part explosive is fully substantiated by the occurrence of agglomerates and tuffs, and it is possible that the irregular masses of coarse agglomerate represent the pipes or necks of old volcanic cones.[3]

The entire absence of sediments in the Metchosin volcanics suggests that they were built up in deep water far removed from any continental mass. But the occurrence of water-worn fragments in the agglomerates and of marine organisms in the tuff beds indicates that enough lava was irrupted to form a platform which reached nearly to the surface of the water, on

---

[1] Memoir No. 13, Geol. Survey, Canada, 1912, p. 92.

[2] Memoir No. 13, Geol. Survey, Canada, 1912, pp. 92-93.

[3] On the south shore of Albert head, a few hundred feet west of the boundary of the Victoria map-area, there appears to be a denuded old volcano, which is described in the writer's preliminary report on Southern Vancouver island, Memoir 13 Geol. Survey, Canada, 1912, p. 91.

which were built the cones which actually projected above sea-level. The probable conditions existing at the time of formation were, therefore, similar to those existing during the formation of the Vancouver volcanics.

Age and Correlation.

The Metchosin volcanics, which were previously considered to be doubtfully Jurassic or Triassic,[1] are now known to be of upper Eocene age. Interbedded with the normal basalts on the south shore of Albert head, a few yards west of the boundary of the Victoria map-area, and well exposed at low tide only, is a bed of tuff, 3 feet in thickness, which is crowded with upper Eocene gastropods.[2] Doubtless other fossiliferous tuffs occur in the volcanics but have not yet been discovered.[3] The conformability of the tuffs with the flow rocks and the other fragmental varieties of the series is unquestionable.

Similar basalts containing similar fossiliferous tuffs occur south of the Strait of Juan de Fuca, and have been described by Arnold[4] and Weaver[5]. Both Arnold and Weaver correlate the Olympic peninsula basalts with the Tejon (upper Eocene) of California. Since identical fossils occur in both basalt formations there is no question but that the Metchosin volcanics and those of the Olympic peninsula, called by Arnold the Crescent formation, are the same. Weaver believes the Crescent basalt to have a thickness of only from 1,500 to 2,000 feet, but there are exposed sections of the Metchosin basalts which are over 2,000 feet, with neither the top nor the base of the series exposed, and since they have been deformed and underlie a belt 5 to 7 miles wide, 5,000 feet seems to be a conservative estimate of their thickness.

SUPERFICIAL DEPOSITS.

With the exception of Highland district, the greater part of the Victoria and Saanich map-areas is covered with drift. The drift is varied in character, having been deposited by various agencies, but by far the larger part is primarily of glacial origin. With other features, such as glacial grooving and erosion, the drift records two epochs of glacial occupation and two corresponding epochs of glacial retreat. These two epochs of glaciation have been

---

[1] Memoir No. 13, Geol. Survey, Canada, 1912, pp. 94-95.

[2] The determination of the age of these gastropods was made by Dr. Charles E. Weaver of the Washington Geological Survey, who has studied similar rocks with the same fossils on the Olympic peninsula.

[3] The fossiliferous tuff was not found until June, 1912.

[4] Arnold, Ralph, Reconnaissance of the Olympic Peninsula; Bull. Geol. Soc. Am., vol. 17, 1906, pp. 460-461.

[5] Weaver, Charles E., Preliminary Report on the Tertiary Palæontology; Bull. No. 15, Washington Geol. Survey, 1912, pp. 12-14.

previously noted[1] and have been called by Willis, from his studies in Puget Sound region, the Admiralty and Vashon epochs, the interglacial epoch being called the Puyallup. Since there is little question but that the glacial and interglacial epochs recorded in the superficial deposits of the Victoria and Saanich map-areas can be correlated with those of the Puget Sound region, the names proposed by Willis are used in this report. Distinguishing also the post-Glacial from the Glacial deposits we may subdivide the superficial deposits as follows:—

- Post-Glacial epoch—
  - Beach alluvium.
  - Valley and swamp alluvium.
- Vashon glacial epoch—
  - Stage of glacial retreat.
    - Colwood sands and gravels.
  - Stage of glacial occupation.
    - Vashon drift.
- Puyallup interglacial epoch—
  - Cordova sands and gravels.
  - Maywood clays.
- Admiralty glacial epoch—
  - Admiralty till.

Distribution and Character of Deposits.

Admiralty Till.

The Admiralty till, which is the oldest of the superficial deposits, can be clearly distinguished only in a few localities, notably in the vicinity of Victoria, and is best exposed in the newer street-cuttings in the vicinity of the Empress Hotel and to the east of the hotel. Here it occurs in the crevices[2] and small irregular hollows of the glaciated crystalline rocks. The till is seldom more than a few feet in thickness, and averages, where noted, from 1 to 3 feet. Being present in such small amounts it cannot be shown on the accompanying map of the superficial deposits. It is probable, however, that some of the glacial drift occurring above an elevation of 250 feet, not distinguished on the map from the Vashon drift, is

---

[1] Dawson, G. M., Trans. Royal Soc., Canada., vol. 8, 1890 sec. 4, pp. 43-44.

Willis, Bailey, Drift Phenomena in Puget Sound. Bull. Geol. Soc. Am., vol 9, 1898, pp. 112-162.

Willis, Bailey, and G. O. Smith, Tacoma Folio No. 54. U.S. Geol. Survey, 1899.

LeRoy, O., Geol. Survey, Canada. Pub. 996. 1908, p. 27.

[2] G. M. Dawson. On the Superficial Geology of British Columbia. Quart. Jour. Geol. Soc., vol. 34, 1878, p. 95.

referable to the Admiralty epoch; but it cannot be distinguished from the Vashon drift.

The Admiralty till varies from an unstratified, hard, yellowish grey, sandy clay, with subangular to rounded pebbles up to 6 inches in diameter, to a coarser yellow clayey sand, that is rudely stratified and contains scattered pebbles and subangular boulders.

PUYALLUP INTERGLACIAL DEPOSITS.

The deposits formed during the Puyallup interglacial epoch are chiefly well stratified clays, sands, and gravels, and lignite is reported near the base of the deposits on the shore of Cordova bay, but has not been seen by the writer. In general the clays occur near the base of the deposits and the sands and gravel near the top, and so the deposits may be subdivided for purposes of description and mapping into the Maywood clays and Cordova sands and gravels. However, since the two formations are not only conformable but transitional in both lateral and vertical directions, and since good exposures and sections are confined to the shorecliffs and occasional road-cuttings, post-holes, and clay pits or sand and gravel banks, the two formations cannot be separated in mapping with a very high degree of precision. The separation is further hindered by a thin but fairly p[illegible] covering of Vashon drift, which is represented on the accompanying m[illegible] only where well developed. Nevertheless, since the two formations are so different in their economic value, topography, soil covering and consequently vegetation, an attempt has been made to map them separately.

Maywood Clays.—The Maywood clays, which occur near the base of the interglacial deposits, are found throughout the Victoria and Saanich map-areas, usually at elevations of less than 100 feet above sea-level. However, in several places, especially near the larger monadnocks, they are found at elevations between 100 and 220 feet above sea-level, and apparently have never been covered with the Cordova sands and gravels. They are especially well developed in the vicinity of Victoria and are best exposed in the clay pits in the northern part of Victoria near Maywood P.O., and hence are called the Maywood clays. The country underlain by the Maywood clays is usually low, gently rolling or flat, the only pronounced elevations being the monadnocks whose slopes are in some cases covered by the clays. The surface is still further diversified by the valleys of small intermittent streams.

The Maywood clays are chiefly bluish or yellowish grey, sandy clays with numerous, irregularly distributed, subangular to rounded undecomposed pebbles and boulders of the crystalline rocks of the region. They are, however, well stratified, and frequently contain layers of sand and occasionally gravel. The clays are frequently carbonaceous and plant remains and impressions are very common, and, as mentioned, lignite is reported to occur in them. Besides the plant remains the clays contain numerous impressions and occasionally shells of marine organisms, chiefly small molluscs.

The Maywood clays sometimes rest upon the Admiralty till, but more commonly rest directly upon the glaciated surfaces of the underlying crystalline rocks. They vary greatly in thickness according to the irregularities in the underlying rock surface. Their maximum thickness is at least 100 feet and perhaps much more, for as they probably extend below sea-level, they doubtless average nearly 100 feet. They are overlain conformably by the Cordova sands and gravels and unconformably by the Vashon drift.

Cordova Sands and Gravels.—The Cordova sands and gravels form the low ridges in the eastern part of South Saanich, Lake, and Victoria districts, and on James and Sidney islands. As has been described, they were left in relief by the erosion of the wide valleys between them during the second period of glaciation, and some occur in the lea of the larger monadnocks. They are, as mentioned, usually long and straight and relatively narrow with an esker-like cross section, being from 2 to 3 miles long, about one-half mile wide, and 100 to 200 feet high. However, in the northeastern part of Victoria district they form a ridge with a comparatively wide and smooth summit. They overlie the Maywood clays, the contact being marked by a series of springs; and their lowest elevation is sometimes but a few feet above sea-level. Their highest elevations average about 220 feet, but elevations of 300 to 350 feet are found on the ridge east of Elk lake, and similar sands are exposed in the lea of Mt. Douglas at nearly 500 feet above sea-level. The sands and gravels are well exposed in numerous sand and gravel banks and in the steep cliffs along the shore, being especially well exposed along the shore of Cordova bay south of Cowichan head and northwest of Gordon head, and have, therefore, been called the Cordova sands and gravels.

The Cordova formation consists chiefly of yellow to greyish yellow, medium to coarse grained, and usually pebbly sand, with irregular lentils and interbeds of gravel, and towards the base, interbeds, sometimes 10 to 15 feet thick, of sandy clay and in one or two instances of stiff blue clay. Scattered irregularly through the deposit are a few rather small glacial boulders. The sand is composed chiefly of angular quartz grains, but epidote and other minerals, chiefly in small rock fragments, are present. The pebbles are chiefly of the granitic rocks and are rather small and subangular to rounded. They are usually fairly fresh, but, in some instances, the coarser grained granitic pebbles have been entirely decomposed, doubtless by the vadose waters which circulate much more freely in the Cordova sands than in the Maywood clays. The deposits are capable of forming steep, almost vertical cliffs but are only slightly indurated. Although they are well stratified the sands are usually cross-bedded, with dips, most frequently to the south, of 5° to 10° and sometimes more, and instances of contemporaneous erosion and deposition also are numerous. Marine organisms occur in the Cordova sands and gravels, having been found on the east shore of James island about 70 feet above sea-level in a 2-foot bed of sandy clay. The fossils are, however, very fragile, a large part of the calcium carbonate having been removed by circulating waters.

The Cordova sands and gravels are commonly strewn with large glacial boulders which are not found in the deposits. These are doubtless referable to the Vashon drift, which frequently mantles the Cordova formation. The maximum thickness of the formation is presumably nearly 300 feet, while the average is about 200 feet. In some instances, as along the south shore of James island, over 150 feet of the formation is shown in one exposure.

Vashon Drift.

The Vashon drift covers the greater part of the Victoria and Saanich map-areas, mantling the interglacial deposits. However, below elevations of 250 feet, except in restricted localities, the mantle of Vashon drift is thin, seldom more than 3 or 4 feet thick, and it frequently thins out completely, so that over large areas it is absent or is represented only by the glacial boulders which occur strewn over the surface of the interglacial deposits, especially over the Cordova sands and gravels. The boundaries of the Vashon drift areas are very indefinite and the drift is shown on the accompanying map only where it attains a significant thickness, materially changing the character of the surface topography, soil, and vegetation, and where it is consequently easily recognized. Above elevations of 250 feet the larger part of the drift mantle is composed of the Vashon drift. It is probable, however, that this drift is mixed with more or less of the Admiralty till from which it is indistinguishable. The maximum exposed thickness of the drift is about 20 feet, but it doubtless attains a much greater thickness in places, presumably in the higher portions of the map-areas where it may exceed 100 feet. Its average thickness, where shown on the map, is, however, probably less than 10 or 15 feet.

The Vashon drift is ordinarily an unsorted mixture of coarse yellow sand, gravel, and clay, with numerous and comparatively large undecomposed boulders, chiefly of the granitic rocks. The boulders are sub-angular to rounded, and although striated boulders are found they are not conspicuous. In some places the finer portions of the drift are rudely stratified. Near the surface it is usually oxidized to dark brown, and passes into a dark, sandy, and gravelly loam which usually covers it. In the higher parts of the map-areas the drift is coarser with a much larger percentage of a coarse rubble of the underlying rocks, and the large boulders are usually derived from the immediately underlying formation, and have apparently not been carried any great distance. The drift mantle is thin and it fails to cover numerous small rounded outcrops, which cannot always be distinguished from the large boulders. This is especially true on Saltspring island where large areas are covered by drift composed of coarse, angular fragments of the Sicker schists.

In the Victoria and Saanich map-areas the Vashon drift seldom or never forms distinct and characteristic topographic fractures such as moraines, eskers, and so forth, but merely forms a mantle covering either the crystalline rocks or the interglacial deposits. It has, of course, filled up the hollows and minor depressions in the surface upon which it lies. Its own surface is, however, marked by small irregularities, such as low rounded hills and undrained shallow basins, many of which, especially in Highland district, hold lakes or have been filled with swamp alluvium.

Colwood Sands and Gravels.

In the western part of the Victoria map-area occurs a thick deposit of sand and gravel, which forms a nearly smooth plain, Colwood plain, 2 to 3 miles wide and from 200 to 250 feet above sea-level. On it, especially to the southeast of Colwood station, are well defined terraces (see Plate XVI A) up to 20 feet high. Also near its inner border are several kettle or ice block holes, the largest of which are shown on the topographical map and which are 100 to 800 feet across and 10 to 80 feet deep. In its central part the plain terminates to the eastward in a comparatively gentle slope to sea-level, three-fourths of a mile long, but in its southern part it is terminated abruptly by a steep cliff, 240 feet high, in places almost vertical, formed as already described by the retrogression of the sand and gravel during the present marine cycle.

The deposit consists chiefly of coarse sands and gravels, the proportion of each being almost equal. The sand is composed largely of quartz and rock fragments, in fine to very coarse angular to subangular grains. The pebbles and boulders consist chiefly of the granitic rocks and of the Metchosin volcanics, although about 15 per cent have been derived from the Leech River slates. They are undecomposed and subangular to rounded, the largest boulders averaging about 18 inches in diameter, although there are a few much larger boulders several feet in diameter. There are no interbeds of clay, but in places there are large clay concretions, probably cemented by calcite. But although capable of standing in steep cliffs, the deposit is not in general indurated. It is well stratified with pronounced delta structure, the larger part of the deposit consisting of fore-set beds, with dips of 15 to 25 degrees to the southeast. These are capped with 10 to 15 feet of top-set beds of horizontally stratified coarse gravels (See Plate XVI B).

The deposit overlies about 40 to 50 feet of sandy clay, probably the Maywood clays, the contact being marked by numerous springs. Except in the kettle holes and a few other shallow basins, the deposit is not covered by any younger deposit and even the soil covering is very thin. Its thickness is, therefore, very nearly 200 feet.

Swamp and Valley Alluvium.

In the undrained hollows in the drift mantle, and in many of the preglacial valleys in the upland regions, which were partially dammed by drift deposits, and hence became poorly drained, are deposits of black carbonaceous mud or muck and fine grained siliceous clays or silts. Also in the valley north of Prospect lake, in Lake district, there is exposed near the surface a deposit of impure diatomaceous earth. These deposits were all doubtless deposited during post-Glacial or Recent times in the standing water of small lakes and ponds. Some of these are only partially filled, and are now swamps, while others are completely filled up, or have been drained artificially. Also along the east shore of Saanich peninsula, north of Cowichan head, are old tidal flats and salt marshes back of narrow beaches, barrier beaches, which protected them from erosion. They are now fairly dry and support more or less vegetation, and either the old marshes have been filled up with muck or silt, or else they have been uplifted slightly, so that they are no longer flooded during high tide.

Beach Alluvium.

As described under shore-lines, a large part of the sand and gravel of the drift deposits that have been retrograded during the present marine cycle now forms coarse sandy and gravel beaches between rock headlands, or has been built by shore currents and waves into spits and bay bars, which are shown on the accompanying map.

Structure.

The sequence of the various superficial formations, as well as their general structure, has already been given. All of the formations are essentially flat lying, resting unconformably upon the underlying indurated rocks and filling up the inequalities in them. Four marked unconformities are noted in the superficial deposits themselves, between the Admiralty till and Maywood clays, between the Maywood clays or Cordova sands and gravels and the Vashon drift, between the Maywood clays and Colwood sands and gravels, and between the Pleistocene deposits and the Recent alluvium. Besides these there are numberless local unconformities caused by cross stratification and contemporaneous erosion and deposition.

The detailed structure of the formations is also shown by Figures 5 and 6 and by the following sections.

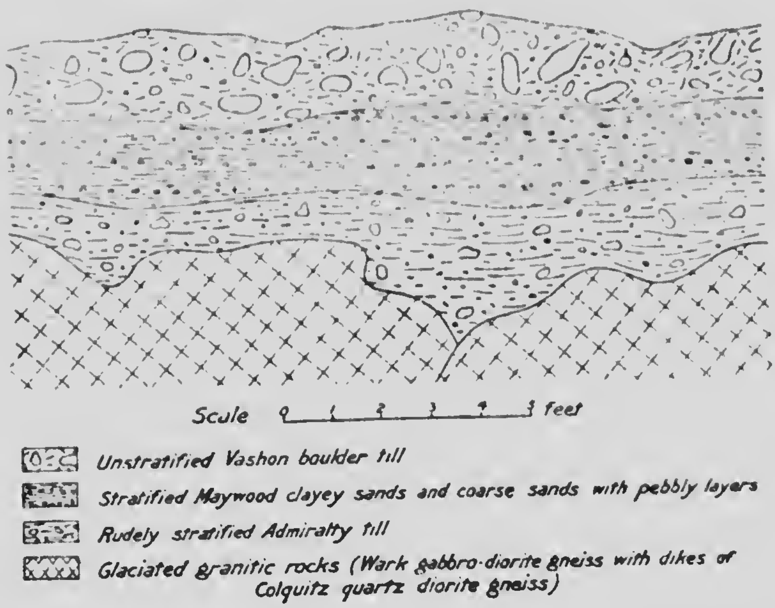


FIG. 5. Section exposed in road-cut in southeastern part of the city of Victoria, illustrating relations of the superficial deposits.

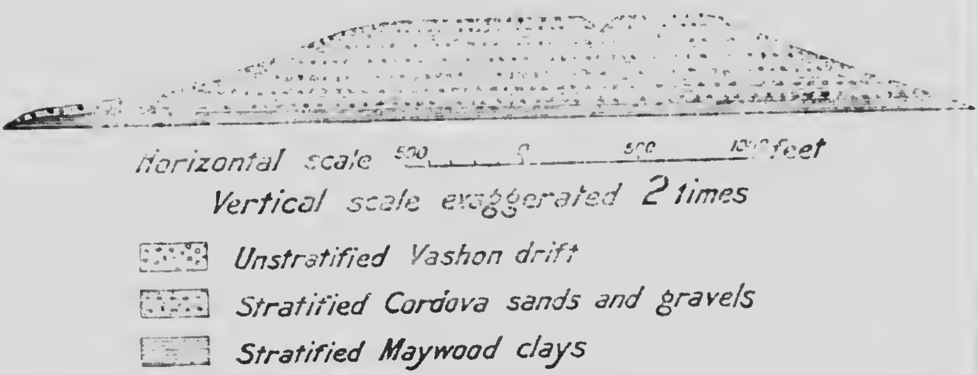


FIG. 6. Section exposed along the south shore of James island, illustrating relations of the superficial deposits.

Section of cliff on east shore of Saanich peninsula, one-fourth mile north of Cowichan head.

Thickness. Feet.	Character and structure of material.	Formation.	Elevation above sea-level
1	Surface loam.		144
4	Light grey clay.		143
4	Sandy clay, with a few rounded pebbles.		139
8	Pebbly sand, pebbles one-fourth to 2 inches in diameter, few granodiorite pebbles up to 6 inches in diameter.		135
8	Cross bedded yellowish grey sand, with a few small pebbles.		127
5	Cross bedded pebbly sand, with small lenses of fine grey sand.	Cordova sands and	119
4	Cross bedded grey sand.	gravel	114
6	Sand and gravel, pebbles up to 2 inches in diameter.		110
3	Fine grey sand, upper sand rests unconformably upon lower gravel.		104
10	Sandy gravel.		101
15	Cross bedded greyish yellow sand.		91
18	Clayey sand.		78
5	Yellow, ferruginous pebbly sand, coarse grained near base, horizontally stratified.		58
15	Yellow ferruginous sand, cross bedded, dips 5° to 10° to S.		53
8	Blue sandy clay, horizontally bedded.	Maywood	38
30	Unexposed to shore.	clays	30

Section exposed in sand and gravel pits at Spring Ridge, North Victoria.

Thickness. Feet.	Character and structure of material.	Formation.	Elevation above sea-level.
1	Surface loam.		110
7	Rudely stratified boulder clay, sand and gravel, with numerous large glacial boulders 2 to 4 feet diameter. Upper 1½ feet oxidized and partly decomposed.	Vashon drift	109
12	Yellow sand, with pebbly layers and lenses of gravel, cross bedded, and exhibiting contemporaneous erosion and deposition.	Cordova sands and gravel	102
10	Gravel with sandy layers strongly cross bedded.		90
2+	Yellow to blue sandy clay well stratified.	Maywood clays.	80

Glaciation, and Mode of Origin of Superficial Deposits.

From the character of the superficial deposits it is seen that they are composed largely of glacial detritus, so that a discussion of their origin is so closely linked with a discussion of the glaciation of the Victoria and Saanich map-areas that the two topics are treated together. From the wide-spread distribution of glacial till on the upland of Vancouver island and from the severe glaciation of the upland, mountains nearly 5,000 feet high having been rounded, it is seen that Vancouver island was at some time during the Glacial period nearly smothered by a thick ice-cap. Valley glaciers filled the larger valleys, and those flowing eastward from the east slope of the Vancouver range joined with the larger and more numerous glaciers flowing westward from the ranges of the mainland and formed an extensive piedmont glacier which occupied the downfold between the Vancouver range and the ranges of the mainland. The southward flowing portion of this piedmont glacier, called by Dawson[1] the Strait of Georgia glacier, overrode the lowland of the Victoria and Saanich map-areas, removed virtually all of the surface soil, and smoothed off the angularities of the pre-Glacial rock surface.

---

[1] G. M. Dawson. On the later physiographical geology in the Rocky Mountain region in Canada. Trans. Royal Soc., Canada, vol. 8, 1890, sec. 4, p. 29.

The results of the severe abrasion of the hard rocks by the glacier are most striking, and have been described and figured by several geologists.[1] The rocks are not only smoothed, but are striated and grooved, the grooves even in the crystalline rocks exposed along the shore south of Victoria and also along the shores of Esquimalt peninsula and Cordova bay, attaining a width of 3 to 4 feet and a depth of 1 to 5 feet (see Plate XVII A); while the Nanaimo sandstones of the islands in the northern part of the Saanich map-area are traversed by grooves up to 10 feet in width and 3 feet deep. The striations and grooves are not confined to the flat surfaces but occur as well on the sloping and vertical surfaces of the ledges, in some cases the rocks being actually undercut. These features, and curved and spreading striations as well, indicate the remarkable flowage or "plasticity" of ice when under great pressure. Also the smaller ledges have been worn into "boat-bottomed shapes," roches moutonnées, with their long axes in the direction of glacial movement, their smaller or bow end being pointed in the direction from which the glacier came, while their stern ends are frequently broad and craggy, portions of the ledges having been broken and "plucked" away by the onward movement of the glacier. In many instances, however, the stern or lee ends of the ledges have also been striated and polished. The softest rocks have, of course, suffered the greatest amount of abrasion, leaving rounded ledges of the harder rocks in relief, and many of the rounded points of the shore south of Victoria are of this nature.

The general direction of the movement of the Strait of Georgia glacier over the lowland of the Victoria and Saanich map-areas seems to have been nearly south, or a little to the west of south.[2] Locally, owing to the influence of topography, the movement appears to have varied considerably from this general direction. As has been pointed out,[3] the influence of the topography varied at successive stages of glaciation, and, as a result, cross striations were produced. The direction of the grooves varies only from 10 to 20 degrees from south, but the direction of the striations which frequently cross the grooves showing that they are younger, varies much more, those noted ranging from S. 54° E. to S. 35° W. This fact indicates that while

---

[1] Notably H. Bauerman, On the Geology of the south-eastern part of Vancouver Island, Quart. Journ., Geol. Soc., vol. 16, 18[illegible], p. [illegible].
G. M. Dawson, Superficial Geology of British Columbia, Quart. Journ., Geol. Soc., vol. [illegible], 1878, pp. [illegible]2-95.
T. C. Chamberlain, The Rock-Scourings of the great ice invasions, U. S. Geol. Survey, 7th Ann. Rept., pp. [illegible]5-218, 1888.

[2] Dawson in his paper "The Superficial Geology of British Columbia," Quart. Jour. Geol. Soc., vol. 21, 187[illegible], p. 92, gives the direction of movement as S. 11° W.

[3] G. M. Dawson, Quart. Jour. Geol. Soc., vol. 34, 1878, p. [illegible].
T. C. Chamberlain, 7th Ann. Rept. U. S. Geol. Survey, 18[illegible], pp. 290-297.

the glaciers were thick and advancing the minor topographic features were overridden and had little effect on the glacial movement, but became effective during the stages of glacial retreat, inducing local changes in the movement.

In the upland portions of the Victoria and Saanich map-areas, however, the topography affected the glaciation much more, although the upland was doubtless deeply buried, as is indicated by the rounding of even the highest hills and by the general southward movement of the glaciers, shown by the striations and marked glaciation of the north-south valleys. However, at least the lower part of the glacier, or glaciers, since it is probable that valley glaciers flowing from the Vancouver Island ice-cap mingled in these localities with the Strait of Georgia glacier, were deflected locally by the larger elevations such as Mt. Wark, and followed the valleys, deepening them considerably and widening them somewhat, especially the north-south valleys, converting them into small lake basins and even into fiords.

The only deposit of the Victoria and Saanich map-areas that was clearly deposited during this period of glaciation is the Admiralty till. It was doubtless much more extensive than appears at present and probably furnished a large part of the material of the deposits formed during the Puyallup interglacial period, and, as mentioned, doubtless occurs on the upland mingled with the Vashon drift. It was deposited directly by ice, some of it being clearly a ground moraine, but part of it was apparently deposited in water, probably below sea-level, as it is slightly modified and directly overlain by the marine interglacial (Maywood) clays.

On the retreat of the glaciers of the Admiralty epoch the land stood at least 200 feet lower than it is at present, as is shown by the occurrence of marine fossils in the interglacial deposits up to virtually that elevation. Hence the pre-Glacial lowland must have been submerged below sea-level forming estuaries. In these estuaries, under conditions of comparative quiet and of moderate temperature, shown by the abundant remains of animal and vegetable life, the Maywood clays were deposited. The glaciers had not, however, completely disappeared from the region as the irregularly distributed pebbles and large erratic glacial boulders found in the clays were doubtless dropped by floating ice.

During the later stages of the interglacial epoch when the Cordova sands and gravels were deposited, either shallower water prevailed or else the rivers and streams issuing from the glacial front, perhaps advancing at this time, were more heavily loaded with coarser detritus. It is probable that both explanations are correct, for this stage was evidently one of varying conditions, as shown not only by the rapid vertical gradation of the Cordova sands and gravels, and their horizontal and cross stratification, but from the fact that in certain localities there seems to have been no deposition of thick beds of sand and gravel. Evidence of interglacial streams in the Victoria map-area may be furnished by the occurrence of pot-holes at various localities, but it is more probable that these pot-holes were formed during glacial occupation, presumably during the Admiralty epoch, by glacial streams falling through crevasses in the glaciers. Northwest of Hospital crossing in Esquimalt district there are 3 pot-holes worn in the Vancouver meta-volcanics, the largest being 3 feet wide by 4 [illegible] (See Plate XVII B). Another pot-hole was noted in the [illegible] part of Victoria district, one-half mile southeast of Brookan hi[illegible] pot-holes are reported on the west shore of Cadboro bay. The latter part of the interglacial epoch was probably a stage in which there were [illegible] estuaries and isolated lake basins, advancing glacier ends, and, accompanying them, swift streams, with floating ice, both carrying coarse detritus.

The interglacial epoch was brought to a close by the second glacial advance, the Vashon glacial epoch. At this time the Vashon drift was deposited largely by ice alone, but since some of it is rudely stratified, it was doubtless in part deposited by water, either by streams flowing beneath the glacier or issuing at its front. The Vashon glaciation was far less intense than the Admiralty glaciation, for the Vashon drift is seen to rest upon the hard glaciated rocks only in the upland portions of the map-area, while in the lowland portions it rests always upon the stratified interglacial deposits, the Vashon piedmont glaciers apparently being unable to remove the covering of the unconsolidated interglacial deposits. However they eroded portions of these deposits, chiefly the Cordova sands and gravels, thus forming large, relatively flat, and poorly drained areas, underlain by the Maywood clays. The Cordova sands and gravels in the lea of the steep-sided monadnocks, such as Mt. Douglas, were protected by the monadnocks from erosion, and now extend southward from them in the long, ridge-like trains. The other esker-like ridges of the Cordova sands and gravel also escaped erosion although the reason for their escape is not clear. That they are the erosion remnants of a once more extensive deposit and are not constructional features of the sands and gravels, is indicated clearly by the section exposed along the south shore of James island, Fig. 7, which shows that the outlines of the present surface of the ridges and of the Vashon drift cut sharply across the bedding of the sands and gravels. The axes of these ridges, which are virtually parallel, are the best indication of the direction of the Vashon glacial movement in the eastern part of the map-areas, which must have been fairly persistent and nearly S. 25° E.

To judge from the absence of moraines composed of the Vashon drift the retreat of the Vashon glaciers must have been fairly rapid.[1] Nevertheless, one large delta, the Colwood sands and gravels, was formed at the

[1] Dawson arrives at the same conclusion. Royal Soc., Canada, vol. 8, 1890, sec. 4, p. 45.

front of the retreating glaciers. It was evidently formed by a heavily loaded stream issuing from a large valley glacier which occupied the pronounced east-west valley, called the Leech River valley[1], that extends for nearly 40 miles across southern Vancouver island. That the deposit was formed near the front of the ice during glacial recession is fully substantiated by the presence of large ice-block holes near its inner border. It is possible that the Colwood delta was deposited in a lake ponded by a glacial tongue occupying the present Royal Roads. But since an uplift of at least 200 feet is known to have taken place presumably after the retreat of the Vashon glaciers, and since the elevation of the Colwood delta is now only 250 feet above sea-level, it is most probable that it was deposited in salt water. The absence of fossils may be confidently explained by the coldness of the water and the rapid deposition of coarse detritus. It is probable, therefore, that the highest elevation of the Colwood delta, about 250 feet, represents the amount of uplift of the region in post-Glacial time.

The origin of the recent alluvial deposits has already been sufficiently indicated.

Age and Correlation.

There is, of course, little question as to the general age of the superficial deposits. The Admiralty till and Vashon drift were clearly deposited during two epochs of glaciation separated by an interglacial epoch, during which marine sediments, the Maywood clays and Cordova sands and gravels, that contain the following Pleistocene fossils,[2] were deposited:—

Cardium islandicum.
Leda fossa.
Saxicava rugosa.
Natica clausa?
Balanus crenatus?

The Colwood sands and gravels were clearly deposited during the recession of the Vashon glaciers, which probably took place during the transition between Pleistocene and Recent times. In Recent times the swamp and valley and beach alluvium has been deposited.

As has already been stated, the two glacial epochs of the Victoria and Saanich map-areas are correlated with the two glacial epochs which have been recognized in other parts of the North Pacific coast, those of Puget Sound region having been called the Admiralty and Vashon epochs. The features of the superficial deposits of the Victoria and Saanich map-areas agree very closely with those of the Tacoma quadrangle[3] (map-area) and

[1] Memoir No. 13, Geol. Survey, Canada, 1912, p. 22.
[2] G. M. Dawson, Quart. Jour., Geol. Soc., vol. 34, 1878, p. 98.
[3] B. Willis and G. O. Smith, Tacoma Folio, No. 54, U.S. Geol. Survey, 1899.

the glacial histories as indicated by the deposits of the two regions are virtually the same. Therefore, the glacial and interglacial epochs of these two regions, which are only 80 miles apart, are correlated with much certainty. The superficial deposits of the Puget Sound region are largely referable to the Vashon epoch but comparatively little is known concerning the history of the Admiralty epoch. Apparently in the Puget Sound region the Vashon glaciation was the most extensive,[1] but there is no question but that in the coast region of British Columbia the Admiralty glaciation was by far the more extensive and intense.[2] It appears, therefore, as if the glaciation of the Puget Sound region during the Vashon epoch was accomplished chiefly by piedmont glaciers fed from the ice-caps of the Cascades and Olympic mountains. The Vashon epoch[3] has been correlated with the last epoch of glaciation of the central and eastern parts of North America, the Wisconsin. In the Puget Sound region the Admiralty till and interglacial deposits are frequently weathered, suggesting that they were long exposed before the Vashon glaciations. But in the Victoria and Saanich map-areas the till is unweathered, and only the granitic rocks in the coarser water-bearing sands of the Cordova formation are decomposed. However, there must have been a long interval between the Vashon and Admiralty epochs, but the Admiralty epoch cannot at present be correlated with any certainty with one of the pre-Wisconsin glacial epochs of central and eastern North America.

STRUCTURAL GEOLOGY.

The detailed structure of the rocks of the Victoria and Saanich map-[illegible] cannot be determined since the metamorphic rocks of the Vancouver [illegible] have been extremely deformed and intruded and replaced by large [illegible]thic masses of granitic rocks, and since it is impossible to trace single folds and faults or to accurately correlate exposures widely separated by drift, water, or granitic rocks. Therefore, all that can be given here is the general structure of the map-areas, the minor details of the folding, faulting, and intrusive and unconformable contacts having been already given in the description of the various formations.

In the present attitude of the rocks of the Victoria and Saanich map-areas evidences of two periods of pronounced deformation are recorded. During the first period, the upper Jurassic, the rocks of the Vancouver group were deformed, and intruded and replaced by the granitic rocks; during the last, the post-Eocene, the Nanaimo series and the Metchosin volcanics were

[1] J. Harlon Bretz, Terminal moraine of the Puget Sound glacier. Jour. of Geol., vol. 19, 1911, p. 171.

[2] This conclusion was reached by Dawson also from his more general studies. Royal Soc., Canada, vol. 8, 1890, sec. 4. pp. 43-45.

[3] G. M. Dawson, Royal Soc. Canada, vol. 8, 1890, sec. 4, p. 54. J. Harlon Bretz, oc. cit.

deformed, being folded against the older rocks, which do not appear to have been greatly deformed during this period, although they were doubtless sheared and faulted. The result of these periods of deformation has been to form three roughly parallel belts of "stratified rocks,"[1] having a strike near N. 65° W., thus conforming with the general trend of the whole island, and separated by broad, possibly anticlinal areas of the granitic rocks. The southern and central belts consist entirely of rocks of the Vancouver group, but the northern belt contains in addition rocks of the Nanaimo series.

The "stratified rocks" of the southern belt, which extends from Gonzales point, east of Victoria, to the western boundary of the map-area, north of Colwood, are not continuous, but are separated by intrusive masses of granitic rocks and by the thick deposit of the Colwood sands and gravels. They consist of the Vancouver volcanics, Sutton limestones, and Metchosin volcanics. The relation of the first two formations is well established. They doubtless are a conformable series, having a general N. 65° W. strike, with steep dips, usually to the southwest. The relation of the Metchosin volcanics with the Vancouver volcanics and Sutton limestones cannot be directly determined as the contact is covered by the Colwood sands and gravels. However, the contact is almost certainly a fault, the eastward extension of the profound fault which, farther west, separates the Metchosin volcanics from the Leech River slates.[2]

The central belt, which extends from Cordova bay to Saanich inlet, is composed entirely of Vancouver volcanics and Sutton limestones, having a general N. 60° W. strike, with nearly vertical dips. At Gordon head, the southern contact of the volcanics with the Wark gneiss is apparently a strike fault. The two formations cannot be correlated exactly with the same rocks of the southern belt.

The northern belt is much the largest, having a width of at least 5 to 10 miles, and much more if considered as embracing the Nanaimo series of Pender island. It consists, as mentioned, not only of rocks of the Vancouver group but rocks of the Nanaimo series as well. The rocks of the Vancouver group are the Vancouver volcanics and Sicker series, probably conformable, and the latter possibly overlying the former. The Vancouver volcanics occur along the southern border of the belt and the Sicker series along the northern border, the two being separated by a synclinal basin

[1] The term "stratified rocks" is used in the same sense as it was used by F. E. and C. W. Wright, "to include those formed (1) by sedimentation, such as shales, sandstones, conglomerates; (2) by precipitation and sedimentation, as limestones and cherts, and (3) by volcanic activity, as the lava and tuff beds." Bull. 347, U.S. Geol. Survey, 1908, p. 32. Nevertheless, the term "stratified rocks" connotes, at least, rocks formed by sedimentation or precipitation only, and a new term to include all the surface-formed rocks is desirable.

[2] Memoir No. 13, Geol. Survey, Canada, 1912, p. 92.

of the Nanaimo series. Both the Vancouver volcanics and Sicker series have a general N. 60° W. strike with nearly vertical dips and are interrupted and partially replaced by small intrusive masses of Saanich granodiorite of granodiorite and diorite porphyrites, and of Sicker gabbro-diorite, porphyrite. As described, the Sicker series consists of the Sicker schists and Sicker volcanics, conformably interbedded. If, as is presumed, the schists overlie the volcanics, the series is apparently bent into a closed anticline striking about N. 60° W., and slightly overturned to the southwest, since along their southern boundary, on Saltspring, Russell, and Portland islands, the schists occur to the southeast of the volcanics although the general dip is steep to the northeast, while along their northern boundary, on Moresby island, a small area of the schists occurs to the northeast of the volcanics, which dip steeply to the southwest. As noted, the rocks of the Sicker series are also contorted and broken by both strike and dip faults and traversed by shear zones.

Most of the rocks of the unconformably overlying Nanaimo series occur in a closely folded, synclinal basin, striking N. 60° W. to N. 80° W. and overturned to the southwest, so that the prevailing dips are moderately steep to the northeast. The southern boundary of the basin is the contact with the underlying Vancouver volcanics and Saanich granodiorite and is complicated by small faults, and by two small infolds of the Nanaimo sediments in the older rocks. Also small folds involving the sedimentary rocks only, occur in the southern part of the basin. The northern boundary of the basin is apparently a strike, thrust fault of considerable throw, the eastward extension of the similar fault occurring farther west at the head of Cowichan bay and north of the Cowichan valley. The occurrence of the fault on southern Saltspring island is virtually assured since there the sediments are in contact with the Sicker schists and dip steeply against them. The throw of the fault may here be estimated as at least 1000 feet. It is probable that this fault extends to the southeast below the waters of Satellite channel and Shute and Moresby passages, separating the upper horizons of the Nanaimo series, occurring on Piers, Knapp, Pym, and Hill islands from the lower horizons and the underlying rocks, occurring on Portland and Moresby islands.

To the northeast of the fault is another, smaller basin, of which only remnants remain, on the east shore of Saltspring island and on Russell, Portland, Moresby, and several smaller islands. This basin is probably synclinal also, but it is complicated by many minor folds and faults, and the rocks have a general northeastward dip. The sediments on the east shore of Saltspring island are crumpled against the Sicker volcanics, the actual contact between the two formations doubtless being a strike fault. The sediments on Portland and the neighbouring small islands appear to form a dome-shaped anticline, broken, however, by two strike faults in the northeastern part of Portland island and by a larger transverse, north-south fault extending across the central part of the island. This fault brings the Nanaimo series which occurs on its east and downthrown side against the Sicker series on its west side. The sediments on Russell and Moresby islands have a general monoclinal structure, dipping to the northeast at comparatively low angles, 10 to 20 degrees. They are, however, broken by strike and by dip faults, probably of small displacement, like that exposed on the south shore of Russell island, which is a normal fault, striking N. 10° E. and dipping 65° N.W. with the upthrown side to the east and with a displacement of not more than 15 or 20 feet, yet bringing the underlying Sicker schists against the basal measures of the Nanaimo series. Many of the contacts between the Nanaimo series and the Sicker series on Moresby island are also faults but are apparently of no great displacement. It is probable that the basin, like the larger basin to the south, is terminated to the northeast by a strike, thrust fault, occurring below the waters of Swanson channel and between Moresby and Pender islands. The presence of the fault is indicated by the occurrence of what is considered to be the same fault only a few miles to the northwest on Saltspring island between Burgoyne bay and Fulford harbour.[1] This fault is the eastward extension of the north boundary fault of the Cowichan basin in Comaiken and Somenos districts. In these districts the Cowichan basin consists of two large, closely folded synclines striking ca. N. 70° W. overturned to the southwest, both having their northern limbs broken by strike, thrust faults, with the upthrown side to the north.[2] This structure is apparently duplicated in the Saanich map-area, although only remnants of the northern syncline remain.

Still farther to the northeast of the supposed fault below the waters of Swanson channel, on Pender island, is the southwestern limb of another large syncline, which is the southern of two large synclines along the southern boundary of the Nanaimo basin.

The granitic rocks which separate the three belts of "stratified rocks" form in general two large batholiths and several minor stocks. One batholith, the southern, occurs between the southern and central belts, and consists of the Wark and Colquitz gneisses. The other, the northern batholith, occurs between the central and northern belts and consists of Saanich granodiorite. The longer axis of both batholiths corresponds with the strike of the rocks of the Vancouver group, that is ca. N. 60° W., into which the batholiths were intruded, possibly along anticlinal axes. Since large volumes of the rocks of the Vancouver group are now missing, although their presence is indicated by remnant masses or "roof pendants" in the

[1] J. A. Allan, Summary Report, 1909, Geol. Survey, Canada, p. 100.
C. H. Clapp, Memoir No. 13, Geol. Survey, Canada, 1912, p. 131.

[2] Memoir No. 13, Geol. Survey, Canada, 1912, p. 129.

batholiths, the rocks must have been replaced by the batholithic rocks; and since their attitude has not been greatly disturbed, they must have been replaced in a relatively quiet manner.

The granitic rocks, although irrupted during the same general period, were not all irrupted at the same time, so that some of the bodies are intruded and replaced by others. Thus in the southern batholith which is composed of two rocks, the Colquitz gneiss is clearly intrusive into the Wark gneiss and now forms a series of irregular or rudely lenticular masses in the batholith that are elongate in the same general direction as the whole batholith. The northern batholith is composed almost entirely of one rock, the Saanich granodiorite, but the granodiorite also forms smaller masses which are intrusive into the southern batholith and into the rocks of the Vancouver group occurring in the southern and northern belts of "stratified rocks." Also small bodies of granodiorite and diorite porphyrite and of Sicker gabbro-diorite porphyrite occur injected into the rocks of the Vancouver group and to less extent into the batholithic rocks themselves.

The granitic rocks are more or less foliated, the younger only slightly, but the older, the Wark and Colquitz gneisses, greatly, their foliation corresponding in general with the axis of the Wark-Colquitz batholith. Also the Sicker gabbro-diorite porphyrites and those granodiorite porphyrites which are intrusive into the Sicker series are in places greatly foliated, their foliation corresponding with that of the Sicker series.

HISTORICAL GEOLOGY.

It is probable that at the close of the Palæozoic era a pronounced change of conditions occurred in southern Vancouver island. The fine grained sediments, represented to the west of the Victoria and Saanich map-areas by the Leech River slates, were no longer deposited in shallow seas, for during the greater part of lower Mesozoic times extensive volcanism took place, presumably under submarine conditions. Thick flows of moderately basic lavas, the Vancouver volcanics, were poured out upon the sea-floor from numerous fissures and in places eruptions of a more explosive nature occurred. Doubtless near these centres the accumulating volcanics attained a thickness sufficient to reach above sea-level and formed islands. On these islands marine organisms lived and built extensive shell and coral deposits, which have since been metamorphosed into the crystalline limestones of the Sutton formation. At some time during the accumulation of the volcanic rocks a change of conditions brought about the deposition of fine grained sediments with the volcanics; thus forming the rocks of the Sicker series. It is possible that this change took place towards the close of the period of volcanism, and that closely following it the rocks that had been formed during the volcanic period, that is the Vancouver group, were deformed.

At the time of deformation the thickness of all the rocks of the Vancouver group must have been nearly 25,000 feet. Possibly on account of this heavy, extra load upon the earth's crust in this region, strong crustal movements were initiated. They began a long period of deformation, a part of the more extensive deformation which affected the entire Pacific Coast region of North America in upper Jurassic and lower Cretaceous times. During this period the rocks of the Vancouver group were greatly deformed, the main axis of deformation corresponding with the present trend of the island, that is in the Victoria and Saanich map-areas about N. 60° W. It is probable that the forces acted from the southwest, folding the rocks of the Vancouver group against the old crystalline rock buttress, now forming the axis of the Selkirk and Columbia Mountain ranges. During and closely following the deformation, batholiths of granitic rocks were intruded into rocks of the Vancouver group, metamorphosing them, and apparently replacing large volumes of them. Those granitic rocks irrupted during the deformation were foliated and pulled out into bands, the Wark and Colquitz gneisses, while the younger rocks, the Saanich granodiorite and its accompanying porphyrites, were intruded into them and to some extent brecciated and replaced them.

The irruptive rocks were subsequently exposed by erosion during the cycle initiated by the deformation, and upon an erosion surface of moderate relief composed of the irruptive rocks and of the rocks of the Vancouver group, a series of fragmental sediments, the Nanaimo series, were deposited in upper Cretaceous times. The sediments were derived chiefly from the underlying irruptive and metamorphic rocks and were deposited in a marine basin between Vancouver island and the mainland, which basin was probably one of deformation and was depressed at least as early as the upper Jurassic folding. The deposition took place under varying conditions, since the different beds vary rapidly in both vertical and lateral directions, and it is probable that marine conditions alternated with those of fresh and brackish water. At the close of their deposition the sediments in the vicinity of the Victoria and Saanich map-areas were at least 6,000 feet thick, while a few miles to the north they were doubtless nearly 10,000 feet thick. Their original extent in the Victoria and Saanich map-areas is not known, and they may have covered the larger part of the present lowland.

During the deposition of the Nanaimo series local movements occurred, and at the close of sedimentation, presumably near the beginning of Eocene time, volcanism took place in the southern part of the area, and extensive basalt flows were poured out on the sea floor from numerous fissures, and in places eruptions of a more explosive nature occurred. As during the Mesozoic volcanism, the accumulating volcanics, the Metchosin, attained a thickness sufficient to reach above sea-level and formed islands. On the shores of the islands lived the upper Eocene gastropods found in the tuff beds, and there also the basaltic detritus was subject to wave action. At the close of the period of volcanism the Metchosin volcanics and the Nanaimo series were both extensively folded and faulted, the main axis of deformation being about N. 70° W. It is probable that the forces causing the deformation acted from the northeast, doubtless having their origin below the basin of deformation between Vancouver island and the mainland, that was partially filled by the upper Cretaceous sedimentation and by Eocene sedimentation from the mainland.

This post-Eocene deformation initiated a new erosion cycle, which has been called the Tertiary cycle, although the erosion was probably accomplished during the Miocene period. During the Tertiary cycle all of the rocks of the map-areas were reduced to a peneplain although a few low monadnocks may have survived, possibly represented now by the upper portions of Mt. Wark and by the higher elevations of southern Saltspring island. During this cycle a large part of the detritus was deposited off the southern and western coasts of the island and formed a coastal plain. None of these coastal plain sediments, however, the Carmanah and Sooke formations, are found in the Victoria and Saanich map-areas.

The Tertiary cycle was closed and a new cycle, the pre-Glacial cycle, was initiated by an uplift of the Tertiary peneplain that probably took place during early Pliocene or possibly late Pliocene or early Pleistocene[1] times. During the pre-Glacial cycle the uplifted peneplain was largely destroyed and the region reduced to a lowland, although numerous but relatively small monadnocks survived. In the northwestern part of the Saanich map-area—southern Saltspring island—and in the southwestern part of the Saanich map-area and northwestern part of the Victoria map-area—Highland district—the uplifted peneplain was only late maturely dissected so that in these districts the peneplain is still partially preserved on the remaining upland.

The pre-Glacial cycle was brought to a close by the advent of the Glacial period during which the Victoria and Saanich map-areas were twice overridden by glaciers. During the first epoch of glaciation, called the Admiralty, the southward flowing Strait of Georgia glacier overrode the pre-Glacial lowland of the Victoria and Saanich map-areas, sub-maturely glaciating it. The upland portions of the map-areas were thickly covered with glacial ice, which had a general southward flow, so that even the highest hills were rounded while the north-south valleys in particular were maturely glaciated, and converted into small lake basins and even into fiords. Either before the advent or directly following the retreat of the earlier and larger glaciers the whole region was depressed, part of it below sea-level, so that during the interglacial epoch, the Puyallup, the preglacial lowland was

[1] Cf. Ralph Arnold, Jour. of Geology, vol. 17, 1909, pp. 528-531.

covered by marine and delta deposits composed largely of glacial detritus, the Maywood clays and Cordova sands and gravels. During the later and less intense epoch of glaciation, the Vashon, the interglacial deposits were partially eroded by the smaller glaciers, which upon their apparently rapid retreat left the deposits partly covered by a younger drift; and by a large delta deposit, the Colwood sands and gravels, that formed at the front of the retreating glaciers.

Doubtless soon after the retreat of the later glaciers the present marine cycle was initiated by an uplift of some 250 feet, which, however, was not sufficient to offset the earlier depression, so that the valleys of the sub-maturely glaciated lowland are still below sea-level, as are the maturely glaciated, larger, north-south valleys of the upland, the fiords. During the present marine cycle, the uplifted Glacial deposits have been sub-maturely retrograded to form the steep cliffs with their attendant beach deposits characteristic of the present shore-line; while inland many of the hollows in the drift mantle have been filled or partially filled with alluvium.

CORRELATION.

The pre-batholithic rocks of the Victoria and Saanich map-areas are chiefly if not entirely of Mesozoic age, but may include Palæozoic members, since schistose volcanics in other parts of Vancouver island are apparently ir[illegible]ded with sedimentary rocks probably of Palæozoic (Carboniferous) age, such as the Leech River slates. However, the great bulk of the pre-batholithic volcanic rocks of southern Vancouver island are of Mesozoic age. It has been previously supposed that the more metamorphosed of the volcanic rocks and intercalated limestones of southern Vancouver island, and indeed of the coast region of British Columbia, might be of Palæozoic age, chiefly because poorly preserved fossils in some of the limest[illegible] resembled Palæozoic species. It has been shown[1] that in one instance on Vancouver island, at Cowichan lake, the fossils in one of the limestones associated with the volcanics, first thought to be Palæozoic, are lowermost Jurassic. These fossils resemble the poorly preserved forms, that have been thought to be Palæozoic, occurring in other limestones both on Vancouver island and elsewhere in the coast region of British Columbia. Therefore, since the structural relations and lithological character of all of the batholithic volcanics and associated limestones of Vancouver island and of the coast region are similar, and since all of the definitely determined fossils in them are either Jurassic or Triassic, they are all best considered, provisionally, as conformable and of lower Mesozoic—Triassic and Jurassic—age, and consequently members of the Vancouver group as defined by Dawson.[2]

[1] Memoir No. 13, Geol. Survey, Canada, 1912, pp. 68-71.

[2] G. M. Dawson, Northern Vancouver island and adjacent coasts. Ann. Rept., 1886, Part B, Geol. Survey, Canada.

If this correlation be true the great bulk of the pre-batholithic rocks of the Coast region are Mesozoic, although there are occasional infolds of Palæozoic sediments, and associated volcanics.

As stated the batholithic rocks of the Victoria and Saanich map-areas are correlated on account of their structural and lithological similarity with the other batholithic rocks of Vancouver island and of the Coast range of British Columbia. From the evidence available on Vancouver island the date of their irruption can be placed only between lower Jurrassic and upper Cretaceous. On the mainland the irruption can be placed more definitely as upper Jurassic and possibly lower Cretaceous, so this date is given to the irruption of the batholithic rocks of the Victoria and Saanich map-areas. Farther north, however, in Alaska, the granitic rocks were largely irrupted during the middle Jurassic, while in California, lower Cretaceous is considered to be the date of irruption. The succession of separate irruptions, the older irruptives having been foliated and completely crystallized before the next younger rock was irrupted, a conclusion drawn from the occurrence of extensive shatter breccias, indicate, however, that even in one locality the period or epoch of batholithic intrusion was of very long duration. Nevertheless in the Victoria and Saanich map-areas it was doubtless confined to the upper Jurassic and possibly lowermost Cretaceous.

The rocks of the Nanaimo series occurring in the Victoria and Saanich quadrangles can be correlated definitely with the rest of the Nanaimo series of Vancouver island and vicinity, not only by their lithological and structural resemblance and continuity but by the fossils they contain. The formations, however, cannot be exactly correlated with those occurring at Nanaimo[1], but the lowermost ones are best correlated at present with the middle formations at Nanaimo. As mentioned, from the evidence obtained from a large number of fossils the Nanaimo series has been correlated with the Chico of the California Cretaceous, and approximately with the Pierre of the Great Plains.[2]

The Metchosin volcanics are definitely correlated with the Crescent basalts of the Olympic peninsula, since both formations contain identical upper Eocene fossils.[3] It is probable also that the coast basalts should be correlated with the Eocene basalts of the east side of the Cascades, the Teneway basalts of Smith.[4]

As noted, it is probable that both the Metchosin volcanics and the Nanaimo series were folded at the same time, presumably at or near the

---

[1] C. H. Clapp, Summary Rept., 1910, Geol. Survey, Canada, p. 96.

[2] G. M. Dawson, Am. Jour. Sci., ser. 3. vol. 39, 1900, pp. 180-183.

[3] See Ralph Arnold, "Reconnaissance of the Olympic Peninsula." Bull. Geol. Soc. Am., vol. 17, 1906, p. 460, and Charles E. Weaver, Tertiary Paleontology of Western Washington Bull. No. 15, Washington Geol. Survey, 1912, pp. 12-15.

[4] Smith, G. O., Geology and Physiography of Central Washington, Prof. Paper 19, U. S. Geol. Survey, 1903, pp. 15-16.

close of the Eocene. At least before the deposition of the Carmanah formation, considered by Merrian[1] and Arnold[2] to be of Oligocene-Miocene age, and by Weaver[3] to be of lower Miocene age, the deformed Metchosin volcanics had been deeply eroded, enough to expose the gabbro stocks irruptive into them and to obliterate any sign of a scarp along the profound fault separating the Metchosin volcanics and the Leech River formation of supposed Carboniferous age. The post-Eocene deformation was of the first order and in general was wide-spread, being noted by Smith[4] in central Washington and by Arnold[5] in Oregon and California. Although the deformation was very intense in places, the intense deformation was extremely localized in the vicinity of southern Vancouver island, as noted by Arnold in California. Even in the Puget Sound region, in the vicinity of Tacoma, sedimentation appears to have gone on continuously from the Eocene to the Neocene[6], although Weaver[7] notes that the time interval following the Eocene is characterized by a marked evolution of the marine faunas. Also the Eocene sediments of the Fraser delta region and even the upper Cretaceous of Texada island are comparatively undisturbed and only partially consolidated.

As described, the superficial deposits of the Victoria and Saanich map-areas were formed during two epochs of glaciation and an interglacial epoch of considerable length, during the recession of the younger glaciers and during Recent times. The two Glacial epochs and the interglacial epoch are correlated quite certainly on account of their similarity and proximity with those previously recognized in other parts of the North Pacific coast and called by Willis and Smith,[8] from their studies in the Puget Sound region, the Admiralty and Vashon glacial epochs and the Puyallup interglacial epoch.

---

[1] Merrian, J. C., Note on two Tertiary Faunas from the rocks of the southern coast of Vancouver island, Bull. Univ. of Calif., Dept. of Geol., vol. 2, 1896, pp. 101-108.

[2] Arnold, Ralph, Tertiary Faunas of the Pacific Coast, Journ. of Geol., vol. 17, 1909, Table of Correlations, p. 532.

[3] Weaver, Charles E., Tertiary Palæontology of Western Washington, Bull. No. 15, Wash. Geol. Survey, 1912, pp. 17-20.

[4] Smith, O. S., Geology and Physiography of Central Washington, Prof. Paper 19, U.S. Geol. Survey, 1908, p. 22.

[5] Arnold, Ralph, Tertiary Faunas of the Pacific Coast, Journ. of Geol., vol. 17, 1909, pp. 518-519.

[6] Willis, Bailey, Tacoma Folio No. 54, U.S. Geol. Survey, 1899, p. 3.

[7] Weaver, Charles E., Bull. 15, Washington Geol. Survey, 1912, p. 25.

[8] B. Willis and G. O. Smith, Tacoma Folio, No. 54, U.S. Geol. Survey, 1889.

ECONOMIC GEOLOGY.

The mineral resources of the Victoria and Saanich map-areas are entirely non-metallic; and include lime, cement and flux, clay, sand and gravel, infusorial or diatomaceous earth, and crushed stone. There has been more or less prospecting for coal and also for metals, chiefly for gold and copper.

GOLD AND COPPER.

Several types of deposits in the Victoria and Saanich map-areas have been prospected for gold and copper, entirely without success. Those which have been prospected for gold are chiefly aplite or pegmatite veins of quartz and feldspar, sometimes carrying small amounts of pyrite, and rarely of chalcopyrite. The true nature of these veins, which are really apophyses of the Colquitz quartz diorite gneiss and of the Saanich granodiorite, has apparently not been recognized by the prospectors. For, since the feldspar has altered to sericite, it resembles, on the weathered surface, white milky quartz, so that the veins have the appearance of ordinary quartz veins. Their true character is still further concealed by the brown limonite stains on their weathered surfaces. Such veins as these elsewhere have not been shown to contain gold in commercial quantities. Hence it is not likely that those of the Victoria and Saanich map-areas are gold bearing and their prospecting should be discouraged.

True quartz veins are common in the Sicker-gabbro-diorite porphyrite, some of them of rather large size. However, they are all very low grade, seldom carrying more than a few small grains of chalcopyrite and of well crystallized pyrite, hence are of no commercial value.

The most common type of those deposits prospected for both gold and copper are shear zones in the various metamorphic and granitic rocks that have been silicified and impregnated and partially replaced by metallic minerals, chiefly pyrite. They occur in all of the granitic rocks, chiefly in the Wark and Colquitz gneisses, near intrusive aplite or pegmatitic apophyses, and are doubtless one of the "after effects" of the granitic intrusions. In all cases the mineralization is insignificant and in spite of dark weathered outcrops the deposits are of no commercial importance.

The mineralization of the shear zones in the metamorphic rocks is greater, especially those in the Sicker schists of Saltspring and Moresby islands and in the Vancouver meta-volcanics near intrusive granitic rocks, the latter having been prospected on the west shore of Tod inlet. In every case, however, the resulting deposit is too small, too irregular, and of too low grade to be of any commercial value.

Typical contact deposits, also, have been developed in the Vancouver meta-volcanics and Sutton limestones, near the intrusive granitic rocks.

One-fourth mile west of the head of Esquimalt harbour one of the small lentils of Sutton limestone is in contact with a small stock of Saanich granodiorite. The limestone is contact metamorphosed, chiefly silicified, but at one place has been converted into a garnet-diopside-epidote rock, containing a small irregular body, about 15 feet by 4 feet on the surface, of magnetite and a little chalcopyrite.

On the south slope of Mill hill in the Esquimalt district, on the Iron Mask claim, a small deposit of metallic minerals occurs in a shear zone in the Vancouver meta-volcanics, which have been largely metamorphosed into amphibolites and near the shear zone greatly silicified, mineralized, and traversed by numerous quartz veinlets. There are no large masses of granitic rocks exposed within a distance of half a mile, but in the immediate vicinity of the shear zone are large, irregular apophyses of the Colquitz quartz diorite gneiss. The shear zone, which is 2 to 3 feet wide, is at one place occupied by a vein-like mass or replacement, 18 inches wide, of a garnet-diopside-epidote rock, which is associated with and partly replaced by massive metallic minerals, chiefly magnetite, pyrrhotite, pyrite, and chalcopyrite. The order of crystallization of the gangue and metallic minerals is indefinite, but chalcopyrite has apparently replaced part of the gangue and is interstitial to the garnet and occurs also in veinlets.

In South Saanich district, a mile west of Tod inlet on the Penton claim, a large area of the Vancouver meta-volcanics is irregularly mineralized by pyrite and chalcopyrite, chiefly along shear zones, near the contact with the Saanich batholith. At the actual contact, however, a mass 12 feet thick of fine grained magnetite, with a little chalcopyrite, has been developed and is associated with a garnet-diopside-epidote rock.

It has been shown[1] that the garnet-diopside-epidote rocks were probably formed from the limestones and volcanics by emanations from the intrusive granitic rocks, carrying silica, iron, manganese, and lime. In many widely separated localities, and in other parts of Vancouver island, as well, deposits similar to those described above have been formed by similar emanations that have doubtless carried also sulphides of iron and copper which they deposited as magnetite, pyrrhotite, pyrite, and chalcopyrite, in the contact metamorphosed rock. Since the close association of the garnet-diopside-epidote rocks and the metallic minerals in the deposits described above indicates that both were formed by the same agencies it is probable that these deposits are similar in their mode of origin to those in other parts of the world, and are typical contact deposits. They are of the type that developed near the intrusive granitic rocks,[2] and is characterized by a high percentage of magnetite and pyrrhotite, although the "Iron Mask" deposit, formed farther than the others from the main contact with the

[1] See page 46.
[2] See Memoir No. 13, Geol. Survey, Canada, 1912, p 159.

granitic rocks, contains a higher percentage of chalcopyrite. The deposits, although interesting as illustrating contact deposits, are, however, too small and irregular and too low grade to be of economic value.

COAL.

The occurrence of small seams and lenses of coal in the measures of the Nanaimo series, notably at James and Coal points and at the southern base of Saddle hills in North Saanich district, and on the south shore of Coal island and on the east shore of Portland island, has attracted considerable attention, chiefly on account of the proximity to the productive coal seams of the Nanaimo and Comox districts, and also on account of the lithological similarity of the measures to those of the productive districts. One or two attempts have been made to mine the exposed seams and some diamond drill boring has been carried on, but without successful results. The conditions are not favourable; for although the measures are well exposed along the shores of various islands, no thick or extensive seams are known to occur. An exact correlation of the measures of the Saanich map-area with those of the Nanaimo district cannot be made, yet it is probable that the measures of the Saanich map-area correspond with those above the coal horizon in the Nanaimo district, in which, in spite of extensive prospecting, no commercial coal has ever been found. If the horizon of the Nanaimo coals does occur in the map-area, it must be very near the base of the measures, and since the measures are fully 6,000 feet thick and have been so closely folded and faulted that the dips are high, it must occur at great depths. Besides, the folding and faulting themselves are so great as to almost preclude mining. Therefore, the probability is very slight of finding coal which could be mined profitably in the Saanich map-area.

LIME, CEMENT, AND FLUXES.

The crystalline limestones of the Sutton formation are the most valuable of the mineral resources of the Victoria and Saanich map-areas since they yield excellent material for the manufacture of lime and Portland cement, and for fluxing. They occur as relatively small lentils in the Vancouver volcanics, chiefly in the vicinity of Esquimalt harbour and at Tod inlet. Most of the lentils are of little value on account of their small size, the metamorphic character of their limestones, and the numerous porphyrite dykes which cut them, but the largest and purest lentils furnish abundant material and are the basis of a considerable lime and cement industry in the vicinity of Esquimalt harbour and at Tod inlet.

The purer limestones are grey to greyish blue, and even white, compact to medium grained marbles, frequently brecciated but firmly recemented by calcite veinlets. They are very pure carbonates and, as a rule, are low in magnesia, although magnesia occurs in very variable amounts and is in places troublesome. As may be seen from the following analyses they are low in insoluble material (argillaceous and carbonaceous matter) and virtually free from phosphorus. Sulphur in the form of pyrite is in variable amount but is usually very low. Consequently they are suitable for the manufacture of lime and cement, and for flux in lead and iron smelting, even when it is proposed to utilize the slag for the manufacture of slag cement.

ANALYSES OF SUTTON LIMESTONES.

	1.	2.
Calcium carbonate $CaCo_3$	95·35	97·5
Magnesium carbonate, $MgCO_3$	2·85	trace
Ferric oxide, Fe_2O_3 / Alumina, Al_2O_3	0·16	0·8
Insoluble mineral matter, chiefly silica, SiO_2	1·95	1·1
Sulphur, S	trace	
Phosphorus, P	trace	
	100·31	99·4
Specific gravity		2·6

(1.) Sample from Rosebank Lime Company's quarry, one-half mile west of Esquimalt harbour. Analyst, F. G. Wait, chemist, Mines Branch, Dept. of Mines.

(2.) Average analysis of the purer limestones from the quarry at Tod inlet, furnished by Mr. Adolph Neu, formerly chemist with the Vancouver Portland Cement Company.

Several quarries have been opened for the purpose of obtaining limestone for the manufacture of lime, and quarries are at present operated near the west shore of Esquimalt harbour by the Rosebank Lime Company, and by Thomas Atkins, and near the Esquimalt and Nanaimo railway about $1\frac{1}{4}$ miles west of Esquimalt harbour by the Silica Brick and Lime Company.[1] The Silica Brick and Lime Company also manufacture hydrated lime and sand-lime brick, the sand being obtained from the Colwood sands and gravels.

The Vancouver Portland Cement Company, whose plant is situated on Tod inlet in South Saanich district, is the only company manufacturing Portland cement.[2] The clay which is mixed with the limestone is obtained from the Maywood clays on the same property. The capacity of the

[1] For a description of the plant and character of the product, see Rept. Min. of Mines, B.C., for 1907, pp. L155-L157.

[2] For a description of the plant, see Rept. Min. of Mines, B.C., for 1904, pp. G256-G260.

plant is about 500,000 barrels, and during 1911 over 420,000 barrels of cement were produced, valued in the neighbourhood of $650,000.[1]

Since 1910, the Tyee Copper Company have opened a quarry near the Esquimalt and Nanaimo railway, one-half mile west of Stewart station and one-fourth mile north of the head of Esquimalt harbour, to obtain flux for their smelter at Ladysmith.

CLAYS.

The only deposits of the Victoria and Saanich map-areas in which clays are four[illegible] the Nanaimo series and the superficial deposits. The clays of econo[illegible] v[illegible]ue, however, are confined [illegible]he superficial deposits, the shales of the [illegible]mo series being invariably sandy and suitable only for brick and drain-tile, [illegible]ich can be made more easily and more cheaply from the superficial clays. The superficial clays are confined largely to the Maywood formation (clays) occurring at the base of the Puyallup interglacial deposits, although interbeds of similar clays, not at present exploited, occur in the overlying Cordova sands and gravels. The commercial clays of the Maywood formation occur in beds up to 10 or 15 feet thick, and have a wide distribution throughout the Victoria and Saanich map-areas, occurring wherever the formation is well developed. They are chiefly yellowish grey, sandy clays, although fairly plastic, with a moderate air-shrinkage. Fat blue clays, not utilized at present, also occur, usually underlying the sandy clays, and, in places, resting directly upon the glaciated rock surfaces. Disseminated through the clays are glacial pebbles and boulders of crystalline rocks, rarely more than 2 or 3 feet in diameter. The clays contain more or less vegetable matter, usually plant remains deposited with them and now lignitic in character. They are all of rather low fusibility and their points of incipient fusion and viscosity are very near together. Throughout the map-areas the clays are fairly uniform in their physical characters and, as shown by the following analyses, in their chemical composition also.

No. Location.	Silica, SiO_2	Alumina, Al_2O_3	Iron oxide, Fe_2O_3	Lime, CaO	Magnesia, MgO	Alkalies, Na_2O and K_2O	Water and loss.	Fusibility Seger cone.	Specific gravity.
1. Brethour's road, Sidney	60 0	20 8	7·6	4 5	0·7	....	5 1	3	....
2. Sidney Brick and Tile Co.'s clay pits....	60 2	15·5	9 4	5 3	1·5	....	6 8	....	....
3. Atkins's lot, Esquimalt	63 6	19·0	7 6	3·6	0·2	....	6·0	3	....
4. Vancouver, Tod inlet, South Saanich	65	10	14	5	1·1	trace	....	....	2 1

Nos. 1–3, inclusive, analyst, Herbert Carmichael, Rept. of Minister of Mines, B.C., for 1908, p. 188.

No. 4, furnished by Adolph Neu, formerly chemist with Vancouver Portland Cement Co.

[1] Rept. Min. of Mines, B.C., for 1911, p. K28.

The clays are used for the manufacture of common brick at Victoria and Sidney, and on Sidney island. The numerous pebbles which they contain cause considerable trouble in the moulding and burning of the brick, since only the larger ones are picked out by hand and the clays are not finely ground or screened. At Sidney island the bricks are moulded by the stiff-mud process, but at all the other plants the wet-mud process is used for moulding the brick, although at Victoria drain-tile is moulded by the stiff-mud process in an auger machine. The bricks are dried in open yards, except on Sidney island where a waste steam tunnel drier is used. They are burned in updraft scove kilns, although drain-tile are burned in a round down-draft kiln at Victoria. The Maywood clay is used also by the British Columbia Pottery Company, in Victoria west, to increase the plasticity of the shale, brought from the Comox coal mines, and used for the manufacture of sewer-pipe and fireproofing, and by the Vancouver Portland Cement Company at Tod inlet in the manufacture of Portland cement.

SAND AND GRAVEL.

Sand and gravel for concrete and ordinary filling, road material, sand-lime brick, and for other similar purposes, is quarried extensively from the superficial deposits of the Victoria and Saanich map-areas. The largest deposit from which both sand and gravel may be readily obtained is the Colwood delta. This is quarried by the British Columbia Sand and Gravel Co. and the Royal Bay Sand and Gravel Co., who operate banks on the Colwood shore of the Royal Roads, and by the Silica Brick and Lime Co. near the Esquimalt and Nanaimo railway, south of Mill hill in Esquimalt district. It was quarried extensively, especially the coarse top-set beds, near the Esquimalt and Nanaimo railway also, for ballast in the construction of the railway. The deposit consists of cross-bedded sands and gravels (fore-set beds of the Colwood delta) overlain by horizontally bedded coarse gravels (top-set beds). The sand consists of quartz, epidote, and rock fragments, the approximate percentage of each being respectively, 70, 10, and 20 per cent. The grains are angular and fine to coarse grained, varying in size from 0·1 mm. to 3·0 mm., the fine sand averaging 0·3 mm. and the coarse sand 1·5 mm. The gravels consist of pebbles of the various rocks of the region, granitic rocks about 40 per cent, Vancouver and Metchosin metamorphic volcanics about 40 per cent, Leech River slates about 15 per cent, and Nanaimo sandstones about 5 per cent. The pebbles are undecomposed, subangular to rounded, and vary in size from coarse sands to boulders 18 inches in diameter. Their average diameter is about 3 inches and that of the boulders is about 10 inches. The proportion of sand to gravel varies; where the deposit is quarried on the shore of Royal Roads, sand forms about 50 per cent of the deposit, pebbles up to 6 inches in diameter, 40 per cent, and boulders, 10 per cent; but in the quarries of the Silica-Brick Company sand forms about 85 per cent of the deposit which there conta .s no boulders. The deposit is exceptionally free from other materials, the only rejected material being clay concretions which occur up to 4 inches in diameter. On the shore of Royal Roads where the deposit is worked for sand and gravel, the sand and gravel is quarried by hydraulic giants and carried in flumes to screens where it is sized into two grades of sand and two or three grades of gravel (see Plate XVIII), as follows: fine sand, 20 to 25 per cent; coarse sand, 15 to 40 per cent; fine (pea) gravel, 5 per cent; medium (nut) gravel, 20 to 35 per cent; coarse gravel, 10 to 15 per cent; and cobbles, 5 per cent. In the manufacture of sand-lime brick only the sand of the deposit is used, the pebbles and clay concretions being eliminated by dry screening through 25 and 50 mesh screens.

The Cordova sands and gravels also are quarried for sand and gravel at Mt. Tolmie, in Victoria district, by the Mt. Tolmie Sand and Gravel Company, and at Spring Ridge in the northern part of Victoria by the corporation of Victoria. The materials are similar to those of the Colwood delta, but as a whole contain a larger amount of sand. The relative amounts of sand, gravel, and boulders in the deposit are shown at Mt. Tolmie by the approximate percentage of the total output of each of the products by dry screening—sand, through ¼ inch, 65 per cent; fine gravel, through ½ inch, 15 per cent; coarse gravel, through 1¼ inch, 15 per cent; cobbles, oversize 1¼ inch, 5 per cent. The sand and gravel produced at Mt. Tolmie is used for mortar, concrete, filling, and ballast. At the Spring Ridge pits an upper layer of sand, 10 to 14 feet thick, is used for mortar, while a lower layer of both gravel and sand, about 10 feet thick, is used for concrete and road material. In these pits the sand and gravel is overlain by 6 to 8 feet of Vashon drift, "hard pan," which has to be removed sometimes by blasting. It is used for filling.

The Cordova sands and gravels and also beds of sand and gravel in the Maywood clays and Vashon drift are quarried on a small scale at several places for local use, chiefly for the construction and repair of roads, and for railway ballast. Also the sand is used to temper the Maywood clays for the manufacture of brick.

DIATOMACEOUS OR INFUSORIAL EARTH.

A deposit of diatomaceous earth, or as it is commonly, although incorrectly, called, infusorial earth, occurs below the surface soil in the wide valley north of Prospect lake in Lake district. Its extent and thickness is not definitely known, but it must occur in considerable amounts, since it may be seen at intervals for at least half a mile north of Prospect lake, and is at least 2 or 3 feet thick. It is light grey, uniform in appearance, and free from grit. Microscopically, it is seen to consist of the siliceous tests of diatoms, largely broken to submicroscopic grains, although many straight columnar forms are present, mixed with a considerable amount of fine argillaceous matter. The following is a partial analysis by Mr. H. A. Leverin, of the Mines Branch of the Department of Mines.

	SiO_2	75·92
	Al_2O_3	8·23
	Fe_2O_3	3·43
	MgO	1·28
	CaO	1·85
	Na_2O	1·39
	K_2O	0·94
	CO_2	1·08
Combined	H_2O	5·40
		99·52

The deposit was doubtless formed in one of the post-Glacial lakes, which collected in the dammed, north-south glaciated valleys and of which Prospect lake is a shrunken remnant.

As may be seen from the description and analysis, the deposit is of a moderate degree of purity and is suitable for many of the varied uses to which diatomaceous earth may be put, such as polishing powders, absorbents, non-conductors, fertilizers, and many other products.

STONE.

No building stone is quarried at the present time in the map-areas. The older crystalline rocks, even the Saanich granodiorite, are too greatly fractured and sheared to yield good building stone. Some of the sandstones of the Nanaimo series, especially those occurring on Russell, Portland, and Moresby islands, would furnish stone of a fair quality, but they are considerably and usually irregularly fractured. Furthermore their steep dip makes the quarrying difficult and causes great variation in the exposed stone. Also sandstone, more readily quarried and of better grade, occurs farther to the north and west, and supplies the present demand.

Crushed stone is obtained from the Metchosin volcanics of Albert head by the British Columbia Trap Rock Company. The rock is a greyish green, somewhat altered, ophitic or diabasic basalt. It is uniform in composition, but varies in texture, from porphyritic to amygdaloidal, and from dense to fine grain. It is greatly fractured and seamed with quartz-epidote-veinlets, and breaks, in quarrying, along the incipient fractures, into rather large fragments. These are crushed and screened to various sizes, the approximate percentage of each being, ½ inch, 20 per cent; ¾ inch, 20 per cent;

1 inch, 30 per cent; and 1½ inch, 30 per cent. The dust from the crusher is saved, and is used with cement for facing. This crushed stone is of excellent quality for road metal and concrete, and for similar uses.

Crushed stone is obtained also within the city limits of Victoria, being chiefly quarried by the street department of the city for road metal. The finer grained phases of both the Wark and Colquitz gneisses are quarried, although the Wark (gabbro-diorite) gneiss is preferred. Neither of the two rocks furnishes crushed stone of good grade, the roads made from them being hard and dusty. However, the quarrying is not extensive, being merely incidental to the cutting of roads through rock out-crops and to the levelling off of small ledges. The Vancouver volcanics also are quarried locally for crushed stone, but the material obtained is of poor quality.

SOILS.

The soils of the Victoria and Saanich map-areas are all transported or drift soils and a mixture of the superficial deposits with decayed vegetable and animal matter, called humus. Consequently their character at any locality is directly dependent upon immediately underlying superficial deposit, being sandy or pebbly where underlain by sands or gravels, and clayey where underlain by clays. Thus the general character of the soils, and their distribution, is approximately shown on the accompanying map of the superficial deposits.

In general, the Maywood clays, which are sandy and contain interbeds of sand, form fairly loose, fine sandy loams, that are very fertile, although where the subsoil is stiff clay and the surface fairly flat, the soil must be drained. More rarely the soil is a heavy clay loam, and this too must be drained to become productive.

The soils formed from the Cordova sands and gravels range from fertile, fine sandy loams to dry, coarse sandy loams, which cannot hold much water and are subject to great changes of temperature and consequently are of poor fertility. The former soils occur where the subsoil is one of the interbeds of sandy clay that are found in the Cordova formation, and the latter are found where the subsoil is coarse sand or gravel.

The Vashon drift forms chiefly a rather coarse, sandy loam, with a considerable proportion of clay, and also numerous pebbles and boulders. The soil is fertile and supports a thick forest growth, which has not yet been cleared to much extent, nor has much land been prepared for cultivation, on account of the numerous pebbles and boulders, and because the country underlain by the Vashon drift is more hilly than that underlain by the Maywood clays.

The Colwood sands and gravels form a delta deposit, with a thick top-set of coarse gravel, and consequently their soil covering is thin, and consists of a gravelly, porous loam, that is comparatively sterile and supports but little vegetation. The country underlain by the top-set bed is, therefore, open and prairie-like and in marked contrast to most of the lowland of Vancouver island. Occasional small areas are, however, underl. 'n by fine silt, presumably deposited in shallow lakes that formed on the surface of the delta. The soil of these areas is consequently of much greater fertility, but since the subsoil is largely gravel, is apt to be dry.

The valley and swamp alluvium supports in its natural condition a heavy growth of swamp vegetation and where cleared and drained is productive, but is apt to become dry and light during the summer months.

INDEX

F

G

H

I

K

L

M

N

P

CLASSIFIED LIST OF RECENT REPORTS OF GEOLOGICAL SURVEY

Since 1910, reports issued by the Geological Survey have been called memoirs and have been numbered Memoir 1, Memoir 2, etc. Owing to delays incidental to the publishing of reports and their accompanying maps, not all of the reports have been called memoirs, and the memoirs have not been issued in the order of their assigned numbers, and, therefore, the following list has been prepared to prevent any misconceptions arising on this account.

Memoirs and Reports Published During 1910

REPORTS

Report on a geological reconnaissance of the region traversed by the National Transcontinental railway between Lake Nipigon and Clay lake, Ont.—by W. H. Collins. No. 1059.

Report on the geological position and characteristics of the oil-shale deposits of Canada—by R. W. Ells. No. 1107.

A reconnaissance across the Mackenzie mountains on the Pelly, Ross, and Gravel rivers, Yukon and North West Territories—by Joseph Keele. No. 1097.

MEMOIRS—GEOLOGICAL SERIES

MEMOIR 1. *No. 1, Geological Series.* Geology of the Nipigon basin, Ontario—by Alfred W. G. Wilson.

MEMOIR 2. *No. 2, Geological Series.* Geology and ore deposits of Hedley Mining district, British Columbia—by Charles Camsell.

MEMOIR 3. *No. 3, Geological Series.* Palæoniscid fishes from the Albert shales of New Brunswick—by Lawrence M. Lambe.

MEMOIR 5. *No. 4, Geological Series.* Preliminary memoir on the Lewes and Nordenskiold Rivers coal district, Yukon Territory—by D. D. Cairnes.

MEMOIR 6. *No. 5, Geological Series.* Geology of the Haliburton and Bancroft areas, Province of Ontario—by Frank D. Adams and Alfred E. Barlow.

MEMOIR 7. *No. 6, Geological Series.* Geology of St. Bruno mountain, Province of Quebec—by John A. Dresser.

MEMOIRS—TOPOGRAPHICAL SERIES

MEMOIR 11. *No. 1, Topographical Series.* Triangulation and spirit levelling of Vancouver island, B.C., 1909—by R. H. Chapman.

Memoirs and Reports Published During 1911.

REPORTS

Report on a traverse through the southern part of the North West Territories, from Lac Seul to Cat lake, in 1902—by Alfred W. G. Wilson. No. 1006.

Report on a part of the North West Territories drained by the Winisk and Upper Attawapiskat rivers—by W. McInnes. No. 1080.

Report on the geology of an area adjoining the east side of Lake Timiskaming—by Morley E. Wilson. No. 1064

MEMOIRS—GEOLOGICAL SERIES

MEMOIR 4. *No. 7, Geological Series.* Geological reconnaissance along the line of the National Transcontinental railway in western Quebec—by W. J. Wilson.

MEMOIR 8. *No. 8, Geological Series.* The Edmonton coal field, Alberta—by D. B. Dowling.

MEMOIR 9. *No. 9, Geological Series.* Bighorn coal basin, Alberta—by G. S. Malloch.

MEMOIR 10. *No. 10, Geological Series.* An instrumental survey of the shore-lines of the extinct lakes Algonquin and Nipissing in southwestern Ontario—by J. W. Goldthwait

MEMOIR 12. *No. 11, Geological Series.* Insects from the Tertiary lake deposits of the southern interior of British Columbia, collected by Mr. Lawrence M. Lambe, in 1906—by Anton Handlirsch.
MEMOIR 15. *No. 12, Geological Series.* On a Trenton Echinoderm fauna at Kirkfield, Ontario—by Frank Springer.
MEMOIR 16. *No. 13, Geological Series.* The clay and shale deposits of Nova Scotia and portions of New Brunswick—by Heinrich Ries, assisted by Joseph Keele.

MEMOIRS—BIOLOGICAL SERIES

MEMOIR 14. *No. 1, Biological Series.* New species of shells collected by Mr. John Macoun at Barkley sound, Vancouver island, British Columbia—by William H. Dall and Paul Bartsch.

Memoirs Published During 1912

MEMOIRS—GEOLOGICAL SERIES

MEMOIR 13. *No. 14, Geological Series.* Southern Vancouver island—by Charles H. Clapp.
MEMOIR 21. *No. 15, Geological Series.* The geology and ore deposits of Phoenix, Boundary district, British Columbia—by O. E. Le Roy.
MEMOIR 24. *No. 16, Geological Series.* Preliminary report on the clay and shale deposits of the western provinces—by Heinrich Ries and Joseph Keele.
MEMOIR 27. *No. 17, Geological Series.* Report of the Commission appointed to investigate Turtle mountain, Frank, Alberta, 1911.
MEMOIR 28. *No. 18, Geological Series.* The geology of Steeprock lake, Ontario—by Andrew C. Lawson. Notes on fossils from limestone of Steeprock lake, Ontario—by Charles D. Walcott.

Memoirs Published up to November 1, 1913

MEMOIRS—GEOLOGICAL SERIES

MEMOIR 18. *No. 19, Geological Series.* Bathurst district, New brunswick—by G. A. Young.
MEMOIR 31. *No. 20, Geological Series.* Wheaton district, Yukon Territory—by D. D. Cairnes.
MEMOIR 17. *No. 28, Geological Series.* Geology and economic resources of the Larder Lake district, Ont., and adjoining portions of Pontiac county, Que.—by Morley E. Wilson.
MEMOIR 35. *No. 29, Geological Series.* Reconnaissance along the National Transcontinental railway in southern Quebec—by John A. Dresser.
MEMOIR 33. *No. 30, Geological Series.* The geology of Gowganda Mining Division—by W. H. Collins.
MEMOIR 38. *No. 31, Geological Series.* Geology of the North American Cordillera at the forty-ninth parallel—by Reginald Aldworth Daly. Part I.
MEMOIR 29. *No. 32, Geological Series.* Oil and gas prospects of the northwest provinces of Canada—by W. Malcolm.

Memoirs in Press, November 1, 1913

MEMOIR 25. *No. 21, Geological Series.* Clay and shale deposits of the western provinces (Part II)—by Heinrich Ries and Joseph Keele.
MEMOIR 37. *No. 22. Geological Series.* Portions of Atlin district, B.C.—by D. D. Cairnes.

MEMOIR 23. *No.* **23**, *Geological Series.* Geology of the coast and islands between the Strait of Georgia and Queen Charlotte sound, B.C.—by J. Austen Bancroft.

MEMOIR 40. *No.* **24**, *Geological Series.* The Archæan geology of Rainy lake—by Andrew C. Lawson.

MEMOIR 32. *No.* **25**, *Geological Series.* Portions of Portland Canal and Skeena Mining divisions, Skeena district, B.C.—By R. G. McConnell.

MEMOIR 19. *No.* **26**, *Geological Series.* Geology of Mother Lode and Sunset mines, Boundary district, B.C.—by O. E. Le Roy.

MEMOIR 22. *No.* **27**, *Geological Series.* Preliminary report on the serpentines and associated rocks in southern Quebec—by J. A. Dresser.

MEMOIR 36. *No.* **33**, *Geological Series.* Geology of the Victoria and Saanich map-areas, B.C.—by C. H. Clapp.

MEMOIR 39. *No.* **35**, *Geological Series.* Kewagama Lake map-area, Quebec—by M. E. Wilson.

MEMOIR 26. *No.* **34**, *Geological Series.* Tulameen mining district, B.C.—by C. Camsell.

MEMOIR 20. *Geological Series.* Gold fields of Nova Scotia—by W. Malcolm.

MEMOIR 30. *Geological Series.* Basin of Nelson and Churchill rivers—by W. McInnes.

PLATE I.

Lowland developed during pre-Glacial cycle in southeastern Vancouver island, in the vicinity of Victoria; looking west to the upland, the maturely dissected Tertiary peneplain.

PLATE II.

Lowland of the Victoria map-area, with the Mt. Douglas monadnock; upper part of Esquimalt harbour to the right; looking east from Mill hill.

Contraposed shore-line Hard rocks overlain by retrograded Vashon drift and Maywood clays
South shore of Beacon Hill park, Victoria

A

B

A. Shear-zone chasm on the shore south of Cadboro bay, Victoria district, developed by wave action on a shear-zone in the Wark gneiss.

B. Small cove in the north shore of Shoal harbour, North Saanich district; developed by wave action on an interbed of sandy shales in the Nanaimo sandstones.

PLATE V.

Microphotograph of meta-olivine basalt, without crossed nicols, x 35, showing iddingsite

Andesite breccia of the Vancouver volcanics, east shore of Saanich inlet, Highland district.

A

B

A. Dykes of andesite porphyrite (Vancouver volcanics) cutting fractured marble of Sutton formation; Rosebank Lime Co.'s quarry, one quarter of a mile west of Esquimalt harbour.

B. Contact of Sutton limestones with Vancouver volcanics on the shore of Cordova bay, showing inclusions of limestone in the volcanics and dyke of andesite porphyrite cutting the limestone.

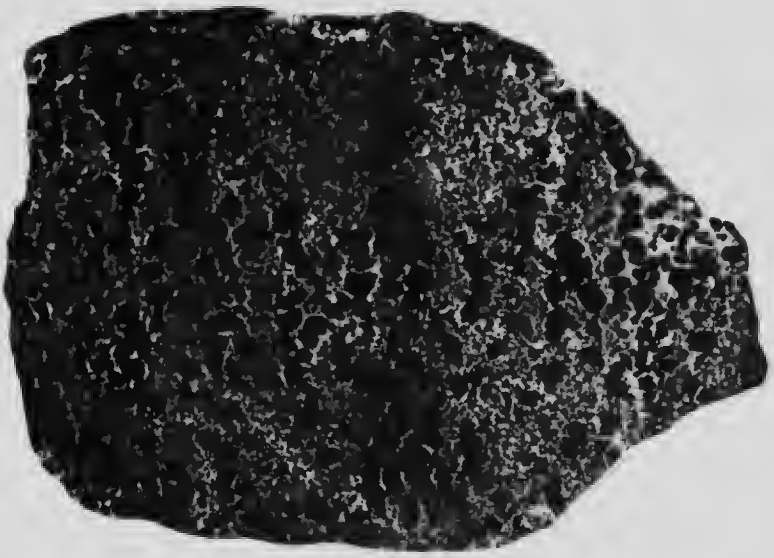
PLATE VIII.

Contortion in the Sicker slaty schists, south shore of Saltspring Island.

PLATE IX

Microphotograph of salic gabbro differentiate of Wark gabbro-diorite; with crossed nicols, x 35, showing magnetite black with rim of augite, intergrowth of magnetite and augite mottled area to right of large magnetite grain, bytownite feldspar, and accessory biotite

PLATE X.



A

B

A. Polished surface of Watts gabbro-diorite gneiss with [illegible] hornblendes [illegible]

B. Microphotograph of Watts gabbro-diorite gneiss with [illegible] hornblendes, [illegible] crossed nicols, x 16, showing poikilitic [illegible] of altered felspar and interstitial quartz

A

B

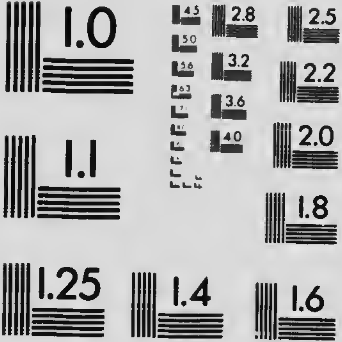
A. Polished surface of Colquitz quartz diorite gneiss showing banded structure, x ½.
B. Banded Colquitz gneiss, one half mile west of Strawberryvale post-office, Esquimalt district.

PLATE XII.

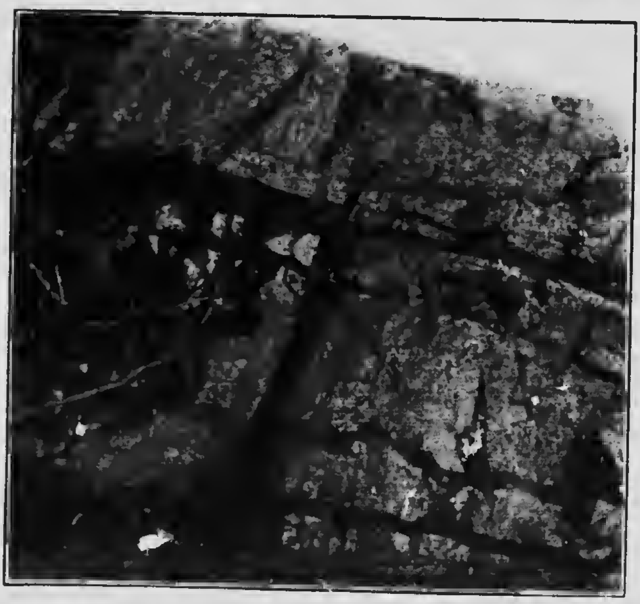
Microphotograph of granodiorite porphyrite; with crossed nicols, x 30, showing embayed and euhedral quartzes (clear grains), euhedral feldspars (clouded grains), and hornblende altered to chlorite, epidote, and magnetite, in a groundmass of quartz, feldspar, hornblende, and magnetite.

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



A



B

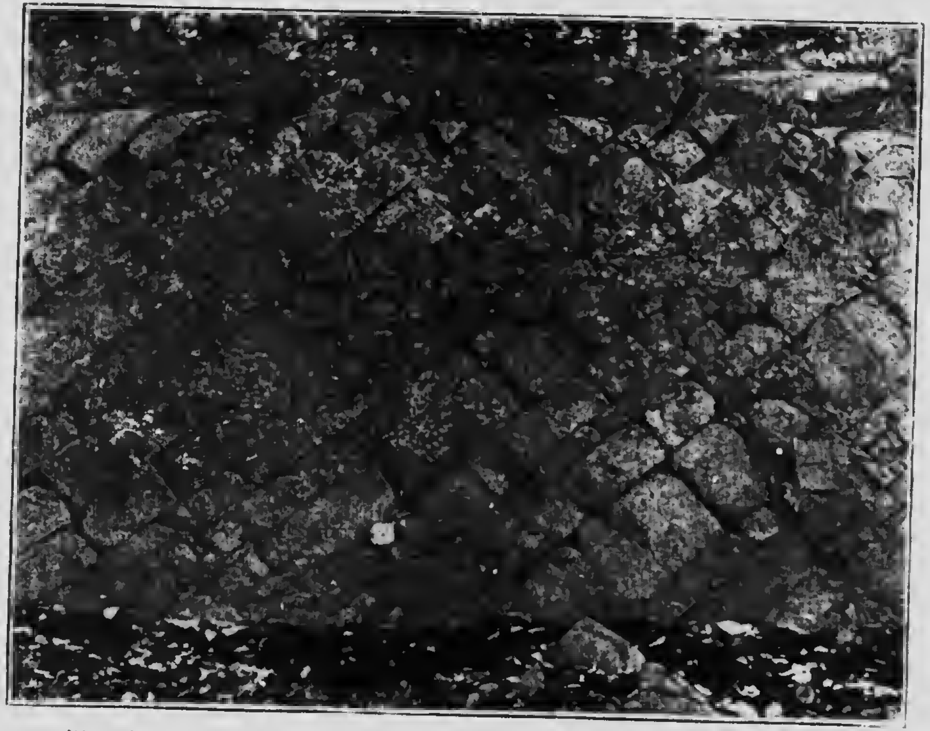
A. Shatter-breccia at contact of Wark gabbro-diorite gneiss and Saanich granodiorite, showing both angular and rounded xenoliths; ledge south of outer wharf, Victoria.

B. Diorite porphyrite dykes in Saanich granodiorite: southeast shore of Esquimalt peninsula.

PLATE XIV.

Concretionary sandstone of the Nanaimo series, Coal point, North Saanich district.

PLATE XV.



Block jointing in sandy shale of the Nanaimo series, north shore of Piers island.

A

B

A. Two terraces of Colwood delta, each about 15 feet high, Colwood plain.

B. Section of Colwood delta at British Columbia Sand and Gravel Co.'s bank, on the shore of Royal Roads, showing top-set and fore-set beds.

A

B

A. "Roche moutonée," at cross roads, one mile southeast of Swan lake. Victoria district, showing glacial grooving and striation.

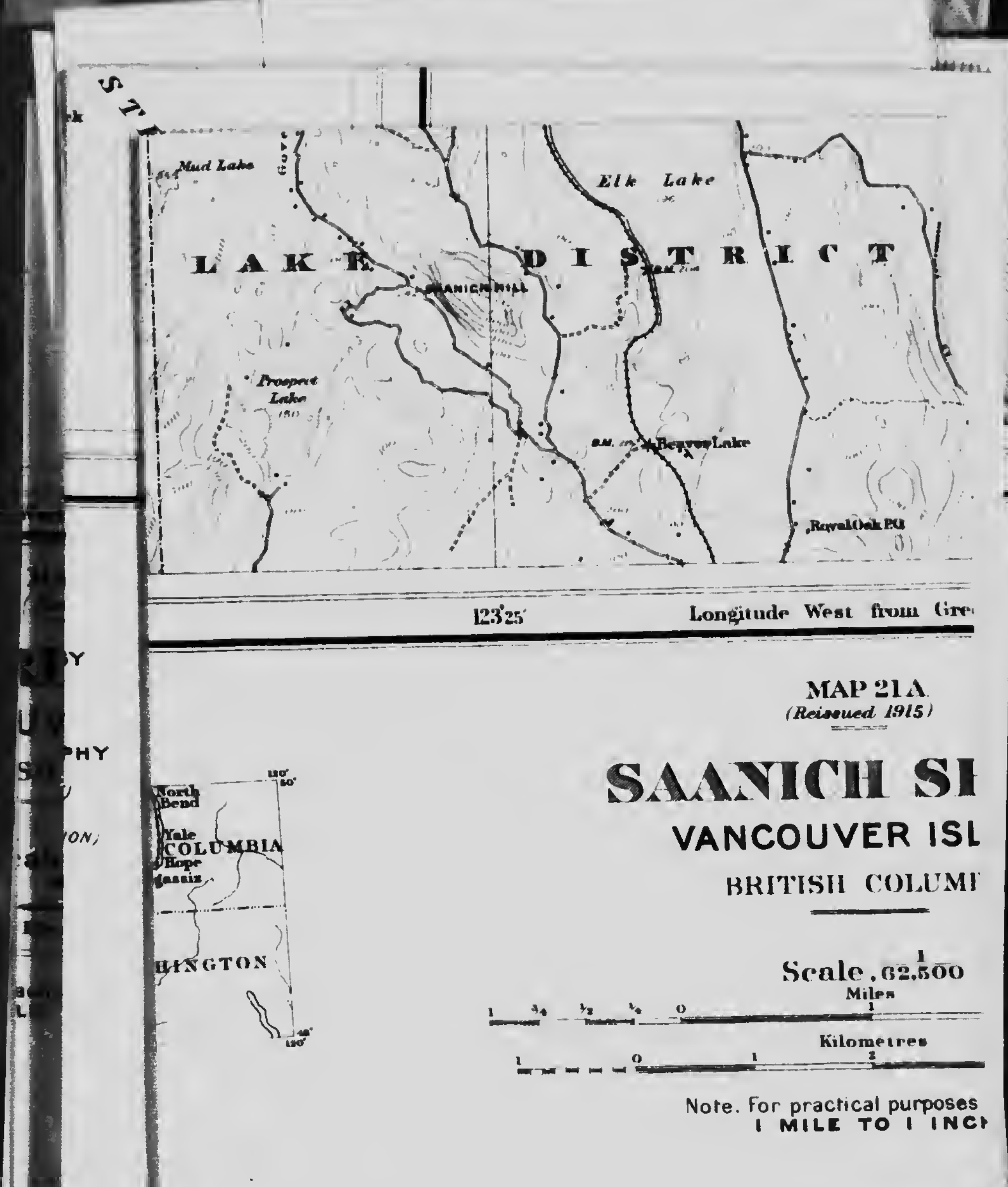
B. Pot-hole, near Hospital crossing, in Esquimalt district.

A

B

A. Hydraulicking Colwood sands and gravels; British Columbia Sand and Gravel Co., Royal Roads.

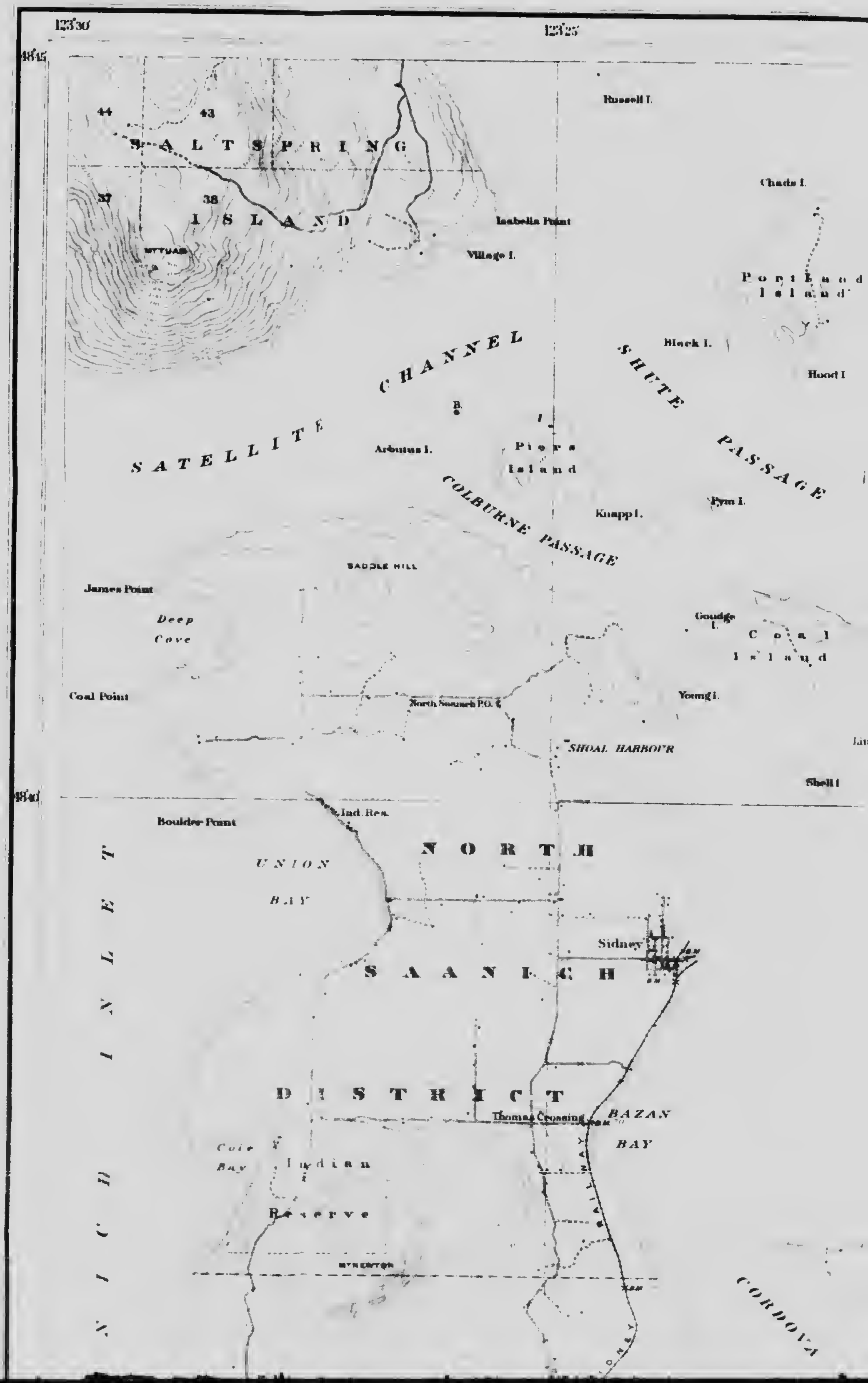
B. British Columbia Sand and Gravel Co.'s screening plant and bins at Royal Roads.



Mud Lake
Elk Lake
LAKE DISTRICT
SAANICH HILL
Prospect Lake
Beaver Lake
Royal Oak P.O.
123°25'
Longitude West from Gre
MAP 21A
(Reissued 1915)
SAANICH SI
VANCOUVER ISL
BRITISH COLUMI
Scale, 1/62,500
Miles
Kilometres
Note. For practical purposes
1 MILE TO 1 INCH
North Bend
Yale
COLUMBIA
Hope
HINGTON

Canad
Department of
HON L. CODERRE, MINISTER. R G M

GEOLOGICAL SUR

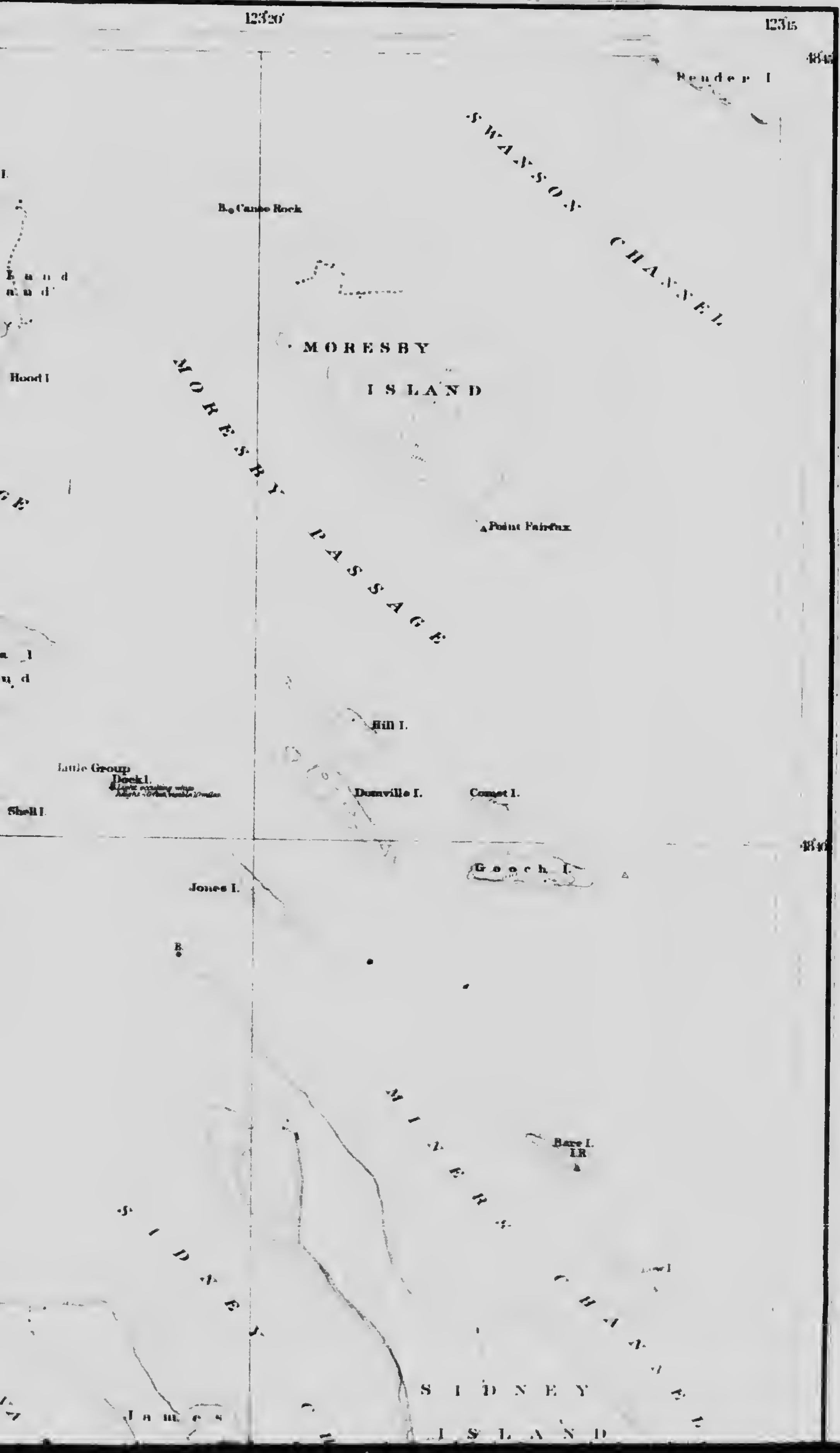


...nt of Mines

...G. Mc...DEPUTY MINISTER

...AL SURVEY

TOPOGRAPHY



LEGEND

Culture

Streets, roads and buildings

Private roads and roads not well defined

Trails

Railways

Bridges

Churches and schools

Cemeteries

Wharves

Lighthouses

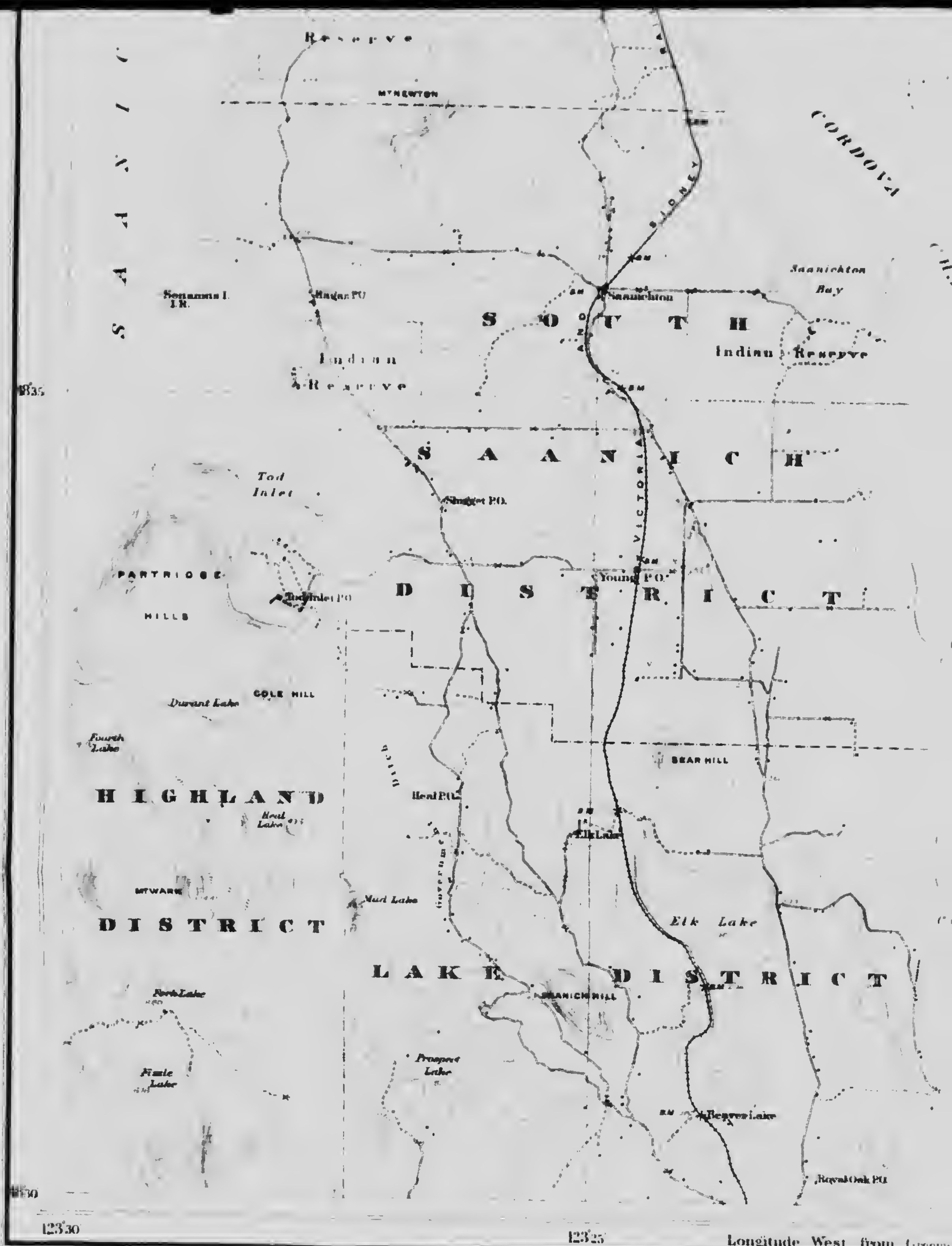
Beacons

Triangulation stations

Bench marks

District boundaries

Water



C. O. Senecal, *Geographer and Chief Draughtsman*
A. Dickison, *Draughtsman*

MAP 21A
Reissued 1915

SAANICH SH

VANCOUVER ISLA

BRITISH COLUMBIA

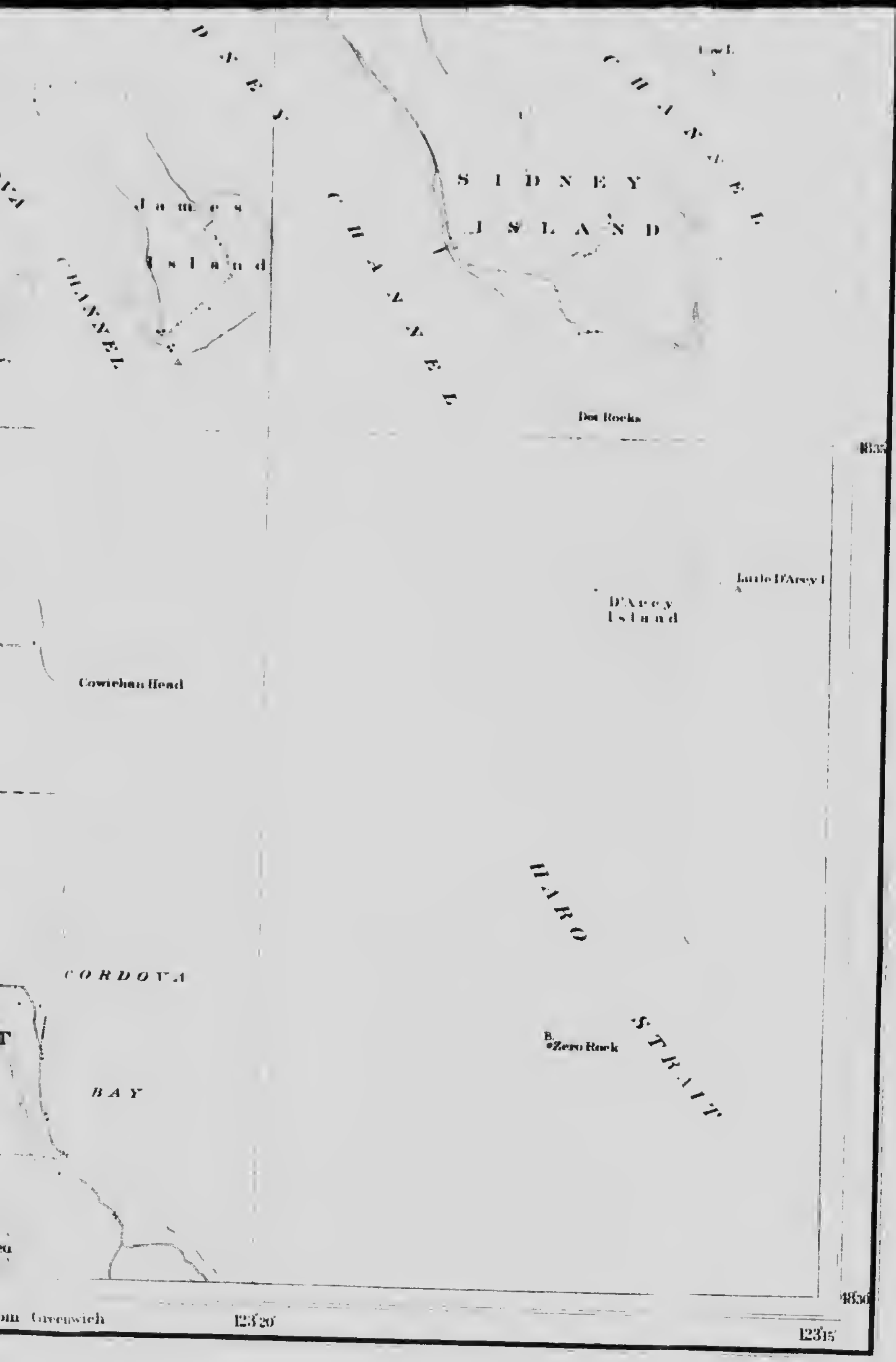
Scale $\frac{1}{62,500}$

Miles

Kilometres

Note For practical purposes as...
1 MILE TO 1 INCH

To accompany Memoir by C. H. Clapp



Bench marks

District boundaries

Water

Rivers and lakes

Watercourses with intermittent flow

Fresh marshes

Tidal flats

Springs

Relief

Contours
showing land forms and elevations above sea level interval 20 feet

Figures showing heights in feet above sea level

Sand

Geographical position by triangulation based on U.S.C. and G.S. stations "Gonzales" and "Discovery" near Victoria

Average magnetic declination 24°30' East

.915

SHEET

R ISLAND

LUMBIA

2.500

rposes assume
INCH

TOPOGRAPHY

R.H. CHAPMAN, (IN CHARGE)	909
K.G. CHIPMAN	909
S.C. McLEAN, TRIANGULATION	1909

B.
°Zero R

gitude West from Greenwich 123°20

MAP 73 A

Issued 1915

NCH SHEET

NCOUVER ISLAND

BRITISH COLUMBIA

Scale $\frac{1}{62,500}$

Miles

Kilometres

For practical purposes assume

1 MILE TO 1 INCH

GEOLO

C H CLAPP

TOPOGRA

R H CHAPMAN, IN CHARG

K G CHIPMAN.

S C McLEAN, TRIANGULA

Dep

HON L. CODERRE, M

G

SUPERFICIAL GEOLOGY

LEGEND

QUATERNARY

POST-GLACIAL EPOCH

7 Beach alluvium

6 Valley and swamp alluvium

VASHON GLACIAL EPOCH

5 Colwood sands and gravels (stage of glacial retreat)

4 Vashon drift (stage of glacial occupation)

PUYALLUP INTER GLACIAL EPOCH

3 Cordova sands and gravels

2 Maywood clays

ADMIRALTY GLACIAL EPOCH

1 Admiralty till

Canada
Department of Mines

...ODERRE, MINISTER. R.G. McCONNELL, DEPUTY MINISTER

GEOLOGICAL SURVEY

TOPOGRAPHY

LEGEND

Culture

Streets, roads and buildings

Private roads and roads not well defined

Trails

Railways

Bridges

Churches and schools

Cemeteries

Wharves

Lighthouses

Beacons

Triangulation stations

Bench marks

District boundaries

Maywood clays

ADMIRALTY GLACIAL EPOCH

Admiralty till
not shown on map

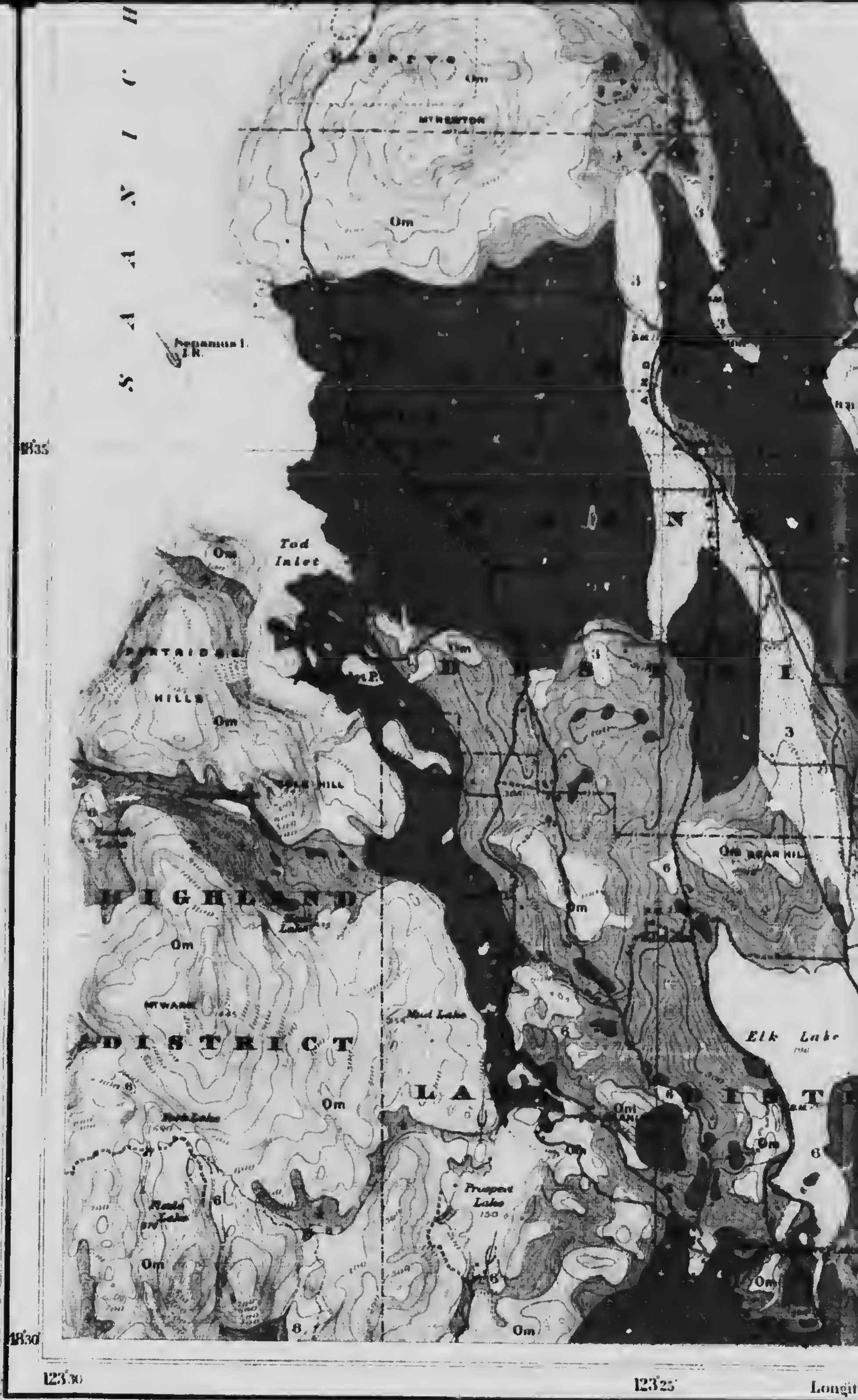
Rock outcrops

Om Om
Chiefly rock outcrops
but some drift

Symbols

Geological boundaries
position approximate

Glacial striae



C.O.Senécal, *Geographer and Chief Draughtsman.*
A.Dickison, *and* A.F.Clark, *Draughtsmen.*

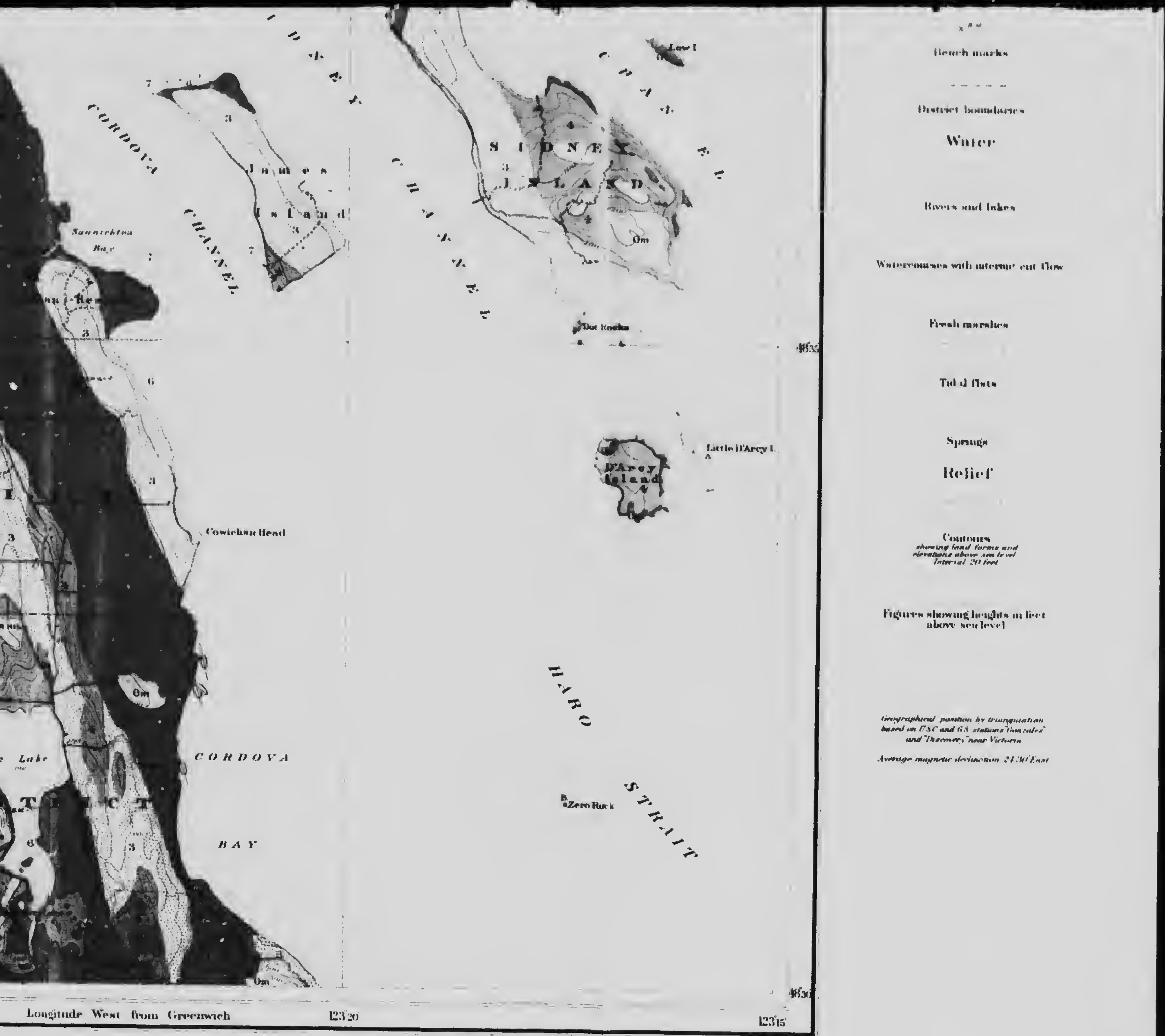
SAA

VANC

BR

Note. Fo

To accompany Memoir by C.H. Clapp



MAP 77 A
Issued 1915

AANICH SHEET
VANCOUVER ISLAND
BRITISH COLUMBIA

Scale $\frac{1}{62,500}$

Miles

Kilometres

Note. For practical purposes assume
I MILE TO I INCH

GEOLOGY

C.H. CLAPP.	1910

TOPOGRAPHY

R.H. CHAPMAN, IN CHARGE	1909.
K.G. CHIPMAN.	1909.
S.C. McLEAN, TRIANGULATION	1909

123°25' Longitude West from Greenwich

MAP 70A

Issued 191[illegible]

VICTORIA SHEET

VANCOUVER ISLAND

BRITISH COLUMBIA

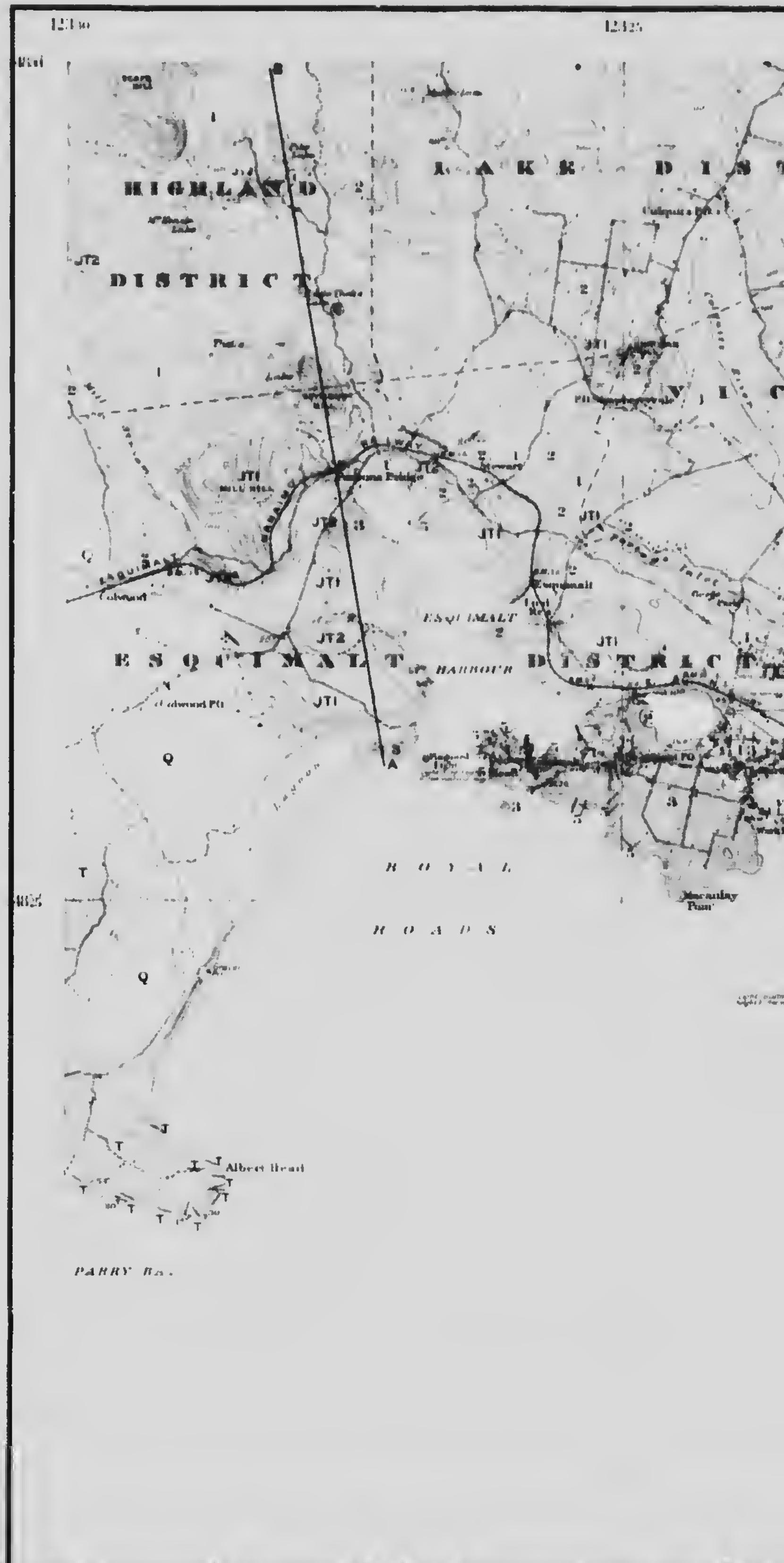
Scale, $\frac{1}{62,500}$

Miles

Kilometres

Note For practical purposes assume
1 MILE TO 1 INCH

GEOLOGY



LEGEND

QUATERNARY

Q — Superficial deposits
completely masking bed rock

TERTIARY — UPPER EOCENE

T — Metchosin Volcanics
basalt, tuff, etc.

Metchosin Volcanics
diabase dikes

UPPER CRETACEOUS

K — Nanaimo series
conglomerate, sandstone and shale

MESOZOIC — UPPER JURASSIC AND POSSIBLY LOWER CRETACEOUS

6 — Sooke Gabbro-diorite Porphyrite
masses and dikes

5 — Diorite Porphyrite
dikes

4 — Granodiorite Porphyrite
masses and dikes

3 — Saanich Granodiorite

2 — Colquitz Quartz Diorite Gneiss

1 G — Wark Gabbro-diorite Gneiss
G shows localities of gabbro and sub-gabbro differentiate

1·3 — Contact complex of Wark Gneiss with Saanich Granodiorite and Colquitz Gneiss

Symbols

Geological boundary
position determined

Geological boundary
probable error of location less than 100 feet

Geological boundary
probable error of location less than 500 feet

Geological boundary
position assumed

Fault
probable error of location less than 100 feet

Fault
probable error of location less than 500 feet

Fault
probable error of location greater than 500 feet

Dip and strike

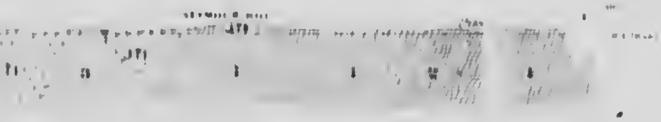
Vertical strata

Foliation, dip and strike

Foliation [illegible]

Canada
Department of Mines

GEOLOGICAL SURVEY



Structural section along line AB

TOPOGRAPHY

LEGEND

Culture

Streets roads and buildings

Private roads and roads not well defined

Trails

Railways

City and other tramways

Bridges

Reservoirs

Churches and schools

Cemeteries

Quarries

Wharves

Lighthouses

Beacons

Triangulation stations

Bench marks

International boundaries

District boundaries

MESOZOIC

UPPER JURASSIC

2

Colquitz Quartz Diorite Gneiss

J-T4

J-T3

JURASSIC OR TRIASSIC

J-T2

Sutton Formation
crystalline limestone

J-T1

Vancouver Volcanics

LOWER JURASSIC AND POSSIBLY TRIASSIC

VANCOUVER GROUP

J-T1

Vancouver Volcanics

Contact complex of Vancouver Volcanics with Saanich Granodiorite and Colquitz Gneiss

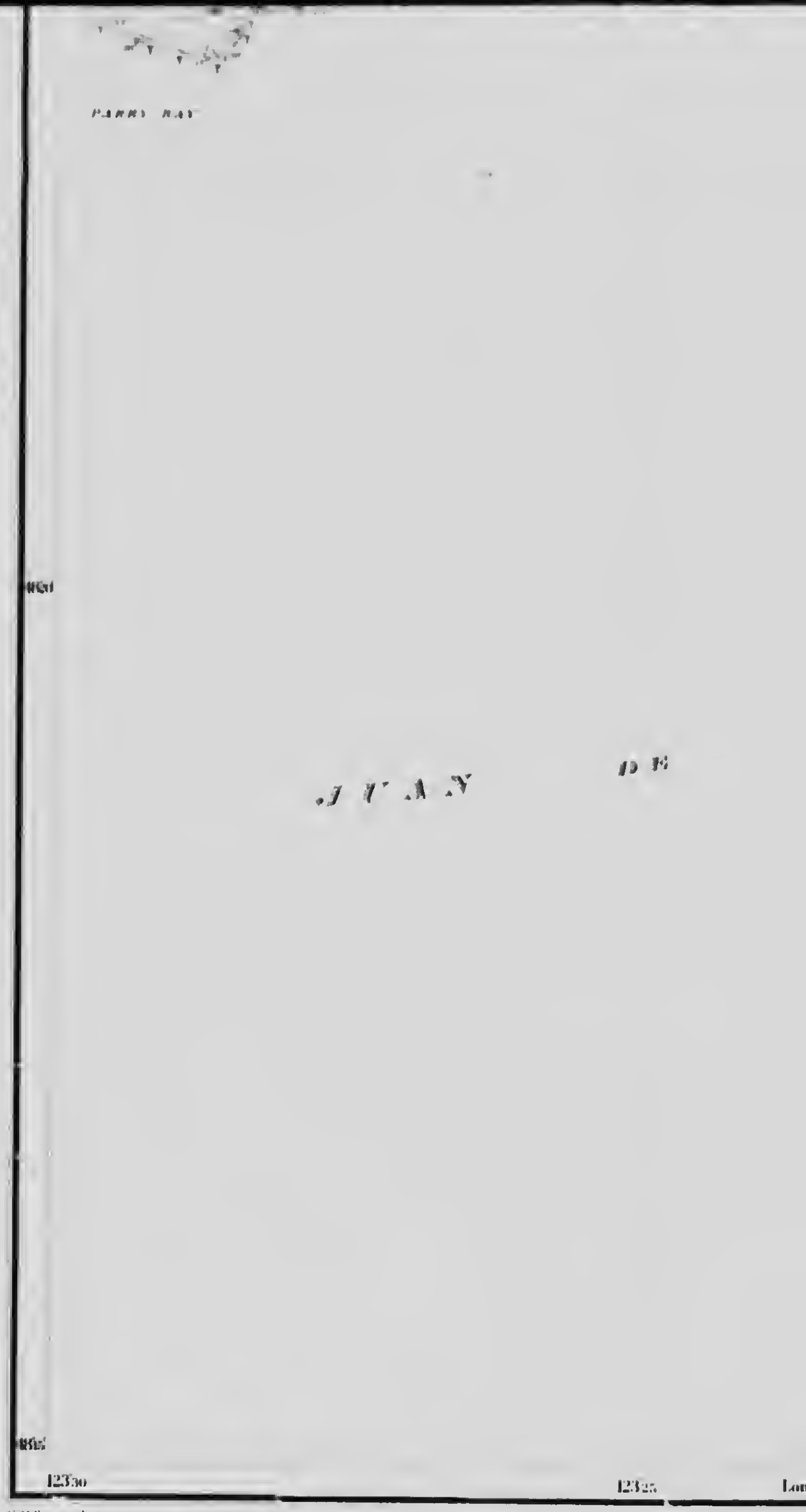
Dip and strike

Foliation, dip unknown or nearly vertical

Foliation contorted general strike and dip

F

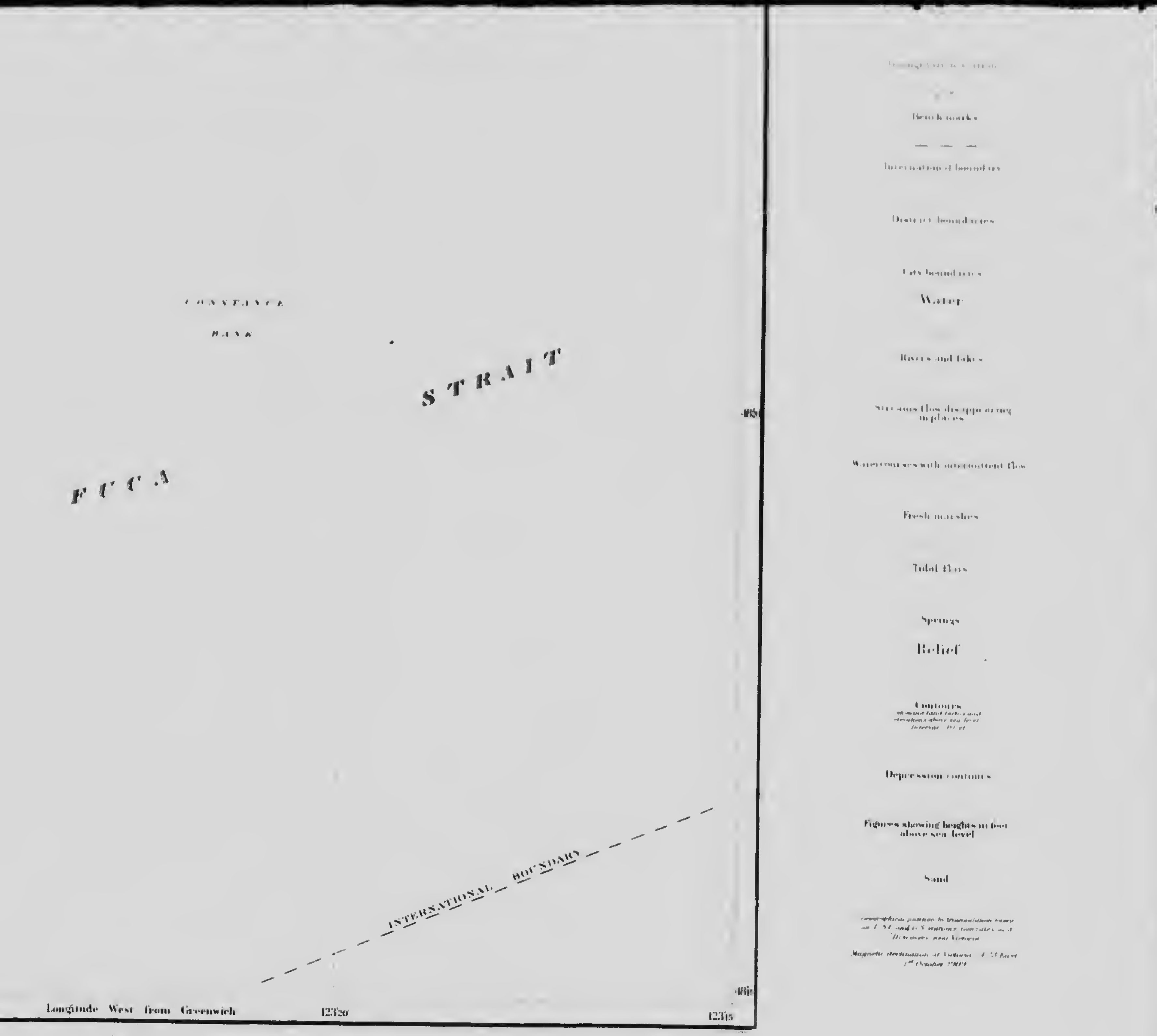
Fossil locality



C.O. Senécal, *Geographer and Chief Draughtsman*
A. Dickison, *and* N.F. Clark, *Draughtsmen*

VICT
VA

Note



MAP 70 A
Issued 1911

VICTORIA SHEET

VANCOUVER ISLAND

BRITISH COLUMBIA

Scale, $\frac{1}{62,500}$

Miles

Kilometres

Note for practical purposes assume
1 MILE TO 1 INCH

GEOLOGY

C.H.CLAPP. 1910

TOPOGRAPHY

R.H.CHAPMAN	(IN CHARGE)	1909
K.G.CHIPMAN		1909
S.C.McLEAN	(TRIANGULATION)	1909

MAP 72 A

Issued 1911

SAANICH SHEET

VANCOUVER ISLAND

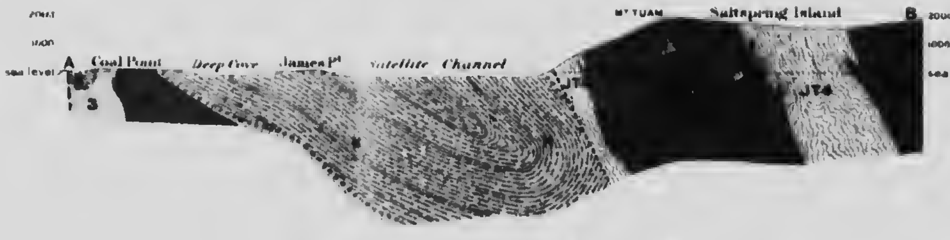
BRITISH COLUMBIA

Scale $\frac{1}{62,500}$

Miles

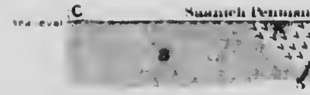
Kilometres

Note: for practical purposes assume
1 MILE TO 1 INCH



Structural section along line A B

Scale, horizontal and vertical



GEOLOGY

LEGEND

Symbols

TERTIARY

QUATERNARY

Q

Superficial deposits
completely masking bed rock

UPPER EOCENE

T

Metchosin Volcanic
basalt, tuff etc

T

Metchosin Volcanics
diabase dykes

UPPER CRETACEOUS

K

Nanaimo series
conglomerate sandstone and shale

Sicker Gabbro diorite Porphyrite
masses and dykes

5

Diorite Porphyrite
dykes

UPPER JURASSIC AND POSSIBLY LOWER CRETACEOUS

Granodiorite Porphyrite
masses and dykes

3

Saanich Granodiorite

2

Colquitz Quartz Diorite Gneiss

1 G

Wark Gabbro diorite Gneiss

I 3

Contact complex of Wark Gneiss with Saanich Granodiorite and Colquitz Gneiss

MESOZOIC

I 4

Geological boundary
position determined

Geological boundary
probable error of location less than 100 feet

Geological boundary
probable error of location less than 500 feet

Geological boundary
position assumed

Fault
probable error of location less than 100 feet

Fault
probable error of location less than 500

Fault
probable error of location greater than 500

Dip and strike

Vertical strike

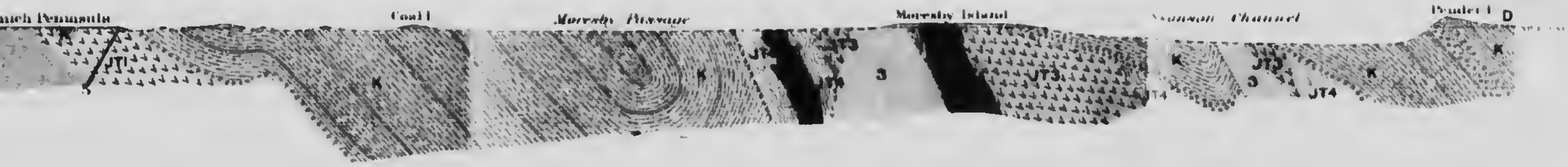
Foliation dip and strike

Foliation dip and strike

Canada
Department of Mines

...L. Coderre, Minister; R. W. Brock, Deputy Minister

GEOLOGICAL SURVEY



Structural section along line C D
Scale, horizontal and vertical, 62,500

TOPOGRAPHY

LEGEND

Culture

Streets, roads and buildings

Private roads and roads not well defined

Trails

Railways

Bridges

Churches and schools

Cemeteries

Wharves

Lighthouses

Beacons

Triangulation stations

Bench marks

District boundaries

Water

Rivers and lakes

[illegible] Porphyrite
[illegible] and dikes

[illegible]
less than [illegible]

3

Saanich Granodiorite

[illegible]
probable error [illegible]
greater than [illegible]

2

Colquitz Quartz Diorite Gneiss

Dip and strike

I G

Wark Gabbro diorite Gneiss
[illegible]

Vertical strata

I 3

Contact complex of Wark Gneiss with Saanich Granodiorite and Colquitz Gneiss

Foliation, dip and strike

Foliation, dip unknown or nearly vertical

MESOZOIC

UPPER JURASSIC AND POSSIBLY LOWER [illegible]

JURASSIC OR TRIASSIC

J-T4

Sicker Schists
slate and quartzose schists of sedimentary origin partly [illegible] and chlorite schists of [illegible] origin

Foliation, contorted general strike and dip

J-T3

Sicker Volcanics
andesite and [illegible] andesite flows tuffs etc

F

Fossil locality

LOWER JURASSIC AND POSSIBLY TRIASSIC

VANCOUVER GROUP

J-T2

Sutton formation
crystalline limestone

J-T1

Vancouver Volcanics
[illegible]

J-T1

Vancouver Volcanics
porphyrite dykes

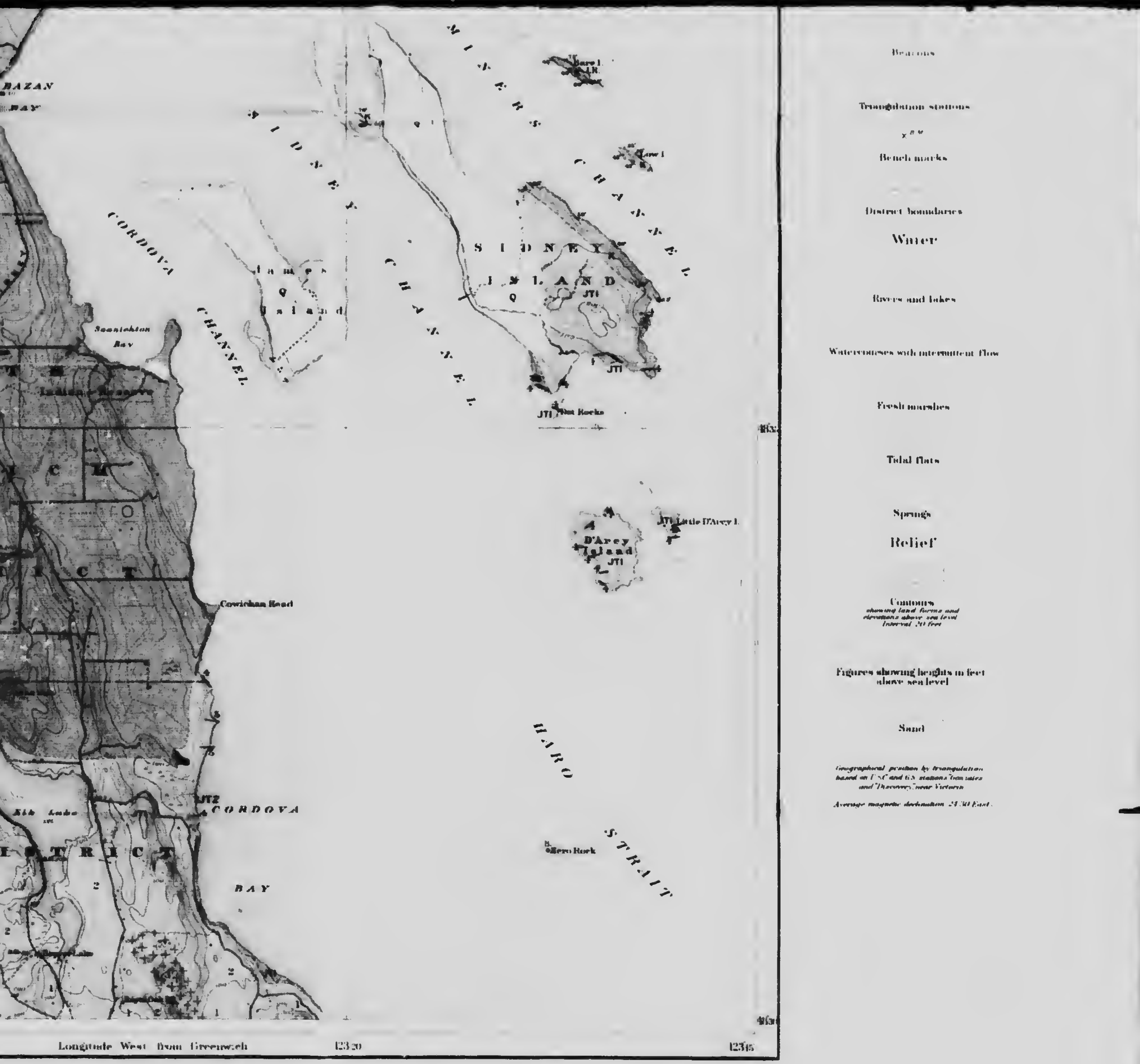
J-T

Contact complex of Vancouver Volcanics with Saanich Granodiorite and Colquitz Gneiss

Note — The relative age of the [illegible] porphyrite and of the Sicker schists and volcanics as compared with the age of other divisions [illegible] doubtful. Some of the dykes and masses of [illegible] diorite porphyrite may be older than the Saanich granodiorite.

C. O. Senecal, [illegible] and Chief Draughtsman
A. Dickison and A. F. Clark, Draughtsmen

[illegible]



MAP 72A
Issued 1914

SAANICH SHEET
VANCOUVER ISLAND
BRITISH COLUMBIA

Scale $\frac{1}{62,500}$

Miles

Kilometres

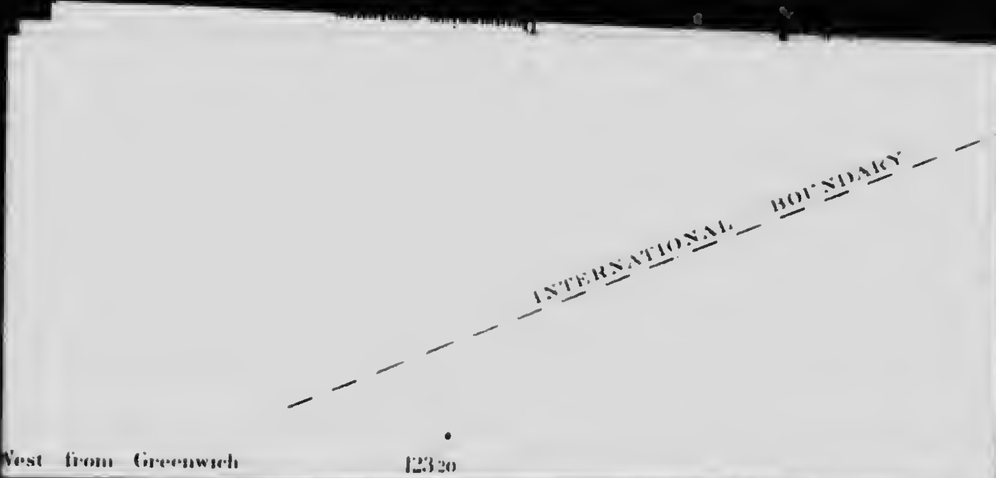
Note: for practical purposes assume
1 MILE TO 1 INCH

GEOLOGY

C.H. CLAPP 1910

TOPOGRAPHY

R.H. CHAPMAN
K.G. CHIPMAN



MAP 71A
Issued 1915

RIA SHEET

UVER ISLAND

SH COLUMBIA

cale, $\frac{1}{62,500}$

Miles

Kilometres

actical purposes assume
LE TO 1 INCH

GEOLOGY

C H CLAPP

TOPOGRAPHY

R H CHAPMAN IN CHARGE
K G CHIPMAN
S C McLEAN TRIANGULATION

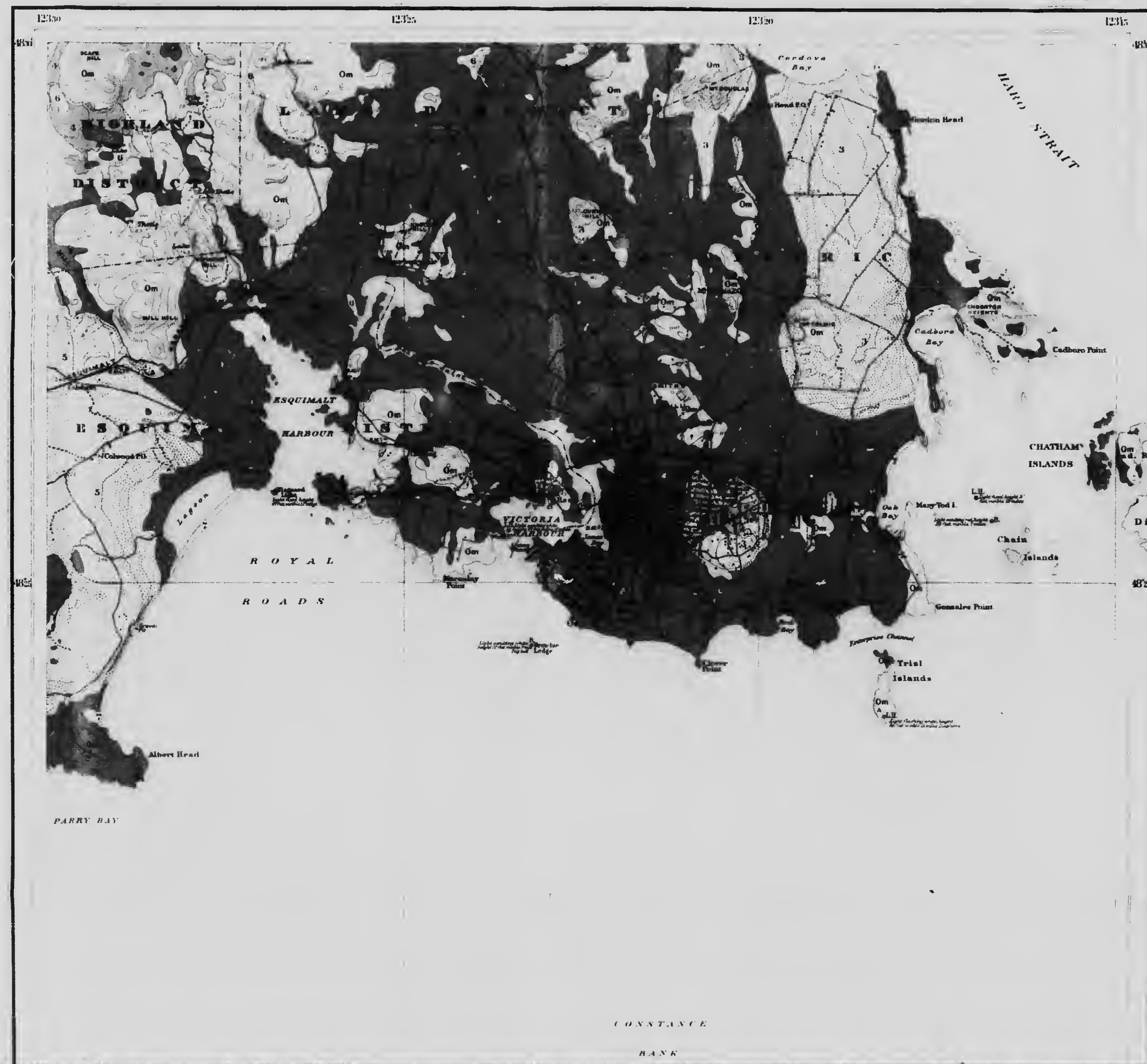
Canada
Department of Mines

HON. L. CODERRE, MINISTER; R. G. McCONNELL, DEPUTY MINISTER

GEOLOGICAL SURVEY

SUPERFICIAL GEOLOGY

TOPOGRAPHY



LEGEND

QUATERNARY

POST-GLACIAL EPOCH

7 Beach alluvium

6 Valley and swamp alluvium

VASHON GLACIAL EPOCH

5 Colwood sands and gravels *stage of glacial retreat*

4 Vashon drift *stage of glacial occupation*

PUYALLUP INTER GLACIAL EPOCH

3 Cordova sands and gravels

2 Maywood clays

ADMIRALTY GLACIAL EPOCH

1 Admiralty till *not shown on map*

Rock outcrops

Om Om Chiefly rock outcrops but some drift

Symbols

LEGEND

Culture

Streets, roads and buildings

Private roads and roads not well defined

Trails

Railways

City and mine tramways

Bridges

Reservoirs

Churches and schools

Cemeteries

Quarries

Wharves

Lighthouses

Beacons

Triangulation stations

Bench marks

International boundary

District boundaries

City boundaries

Water

PUYALLUP INTER-GLACIAL EPOCH

3 — ... sands and gravels

2 — Maywood clays

ADMIRALTY GLACIAL EPOCH

1 — Admiralty till (not shown on map)

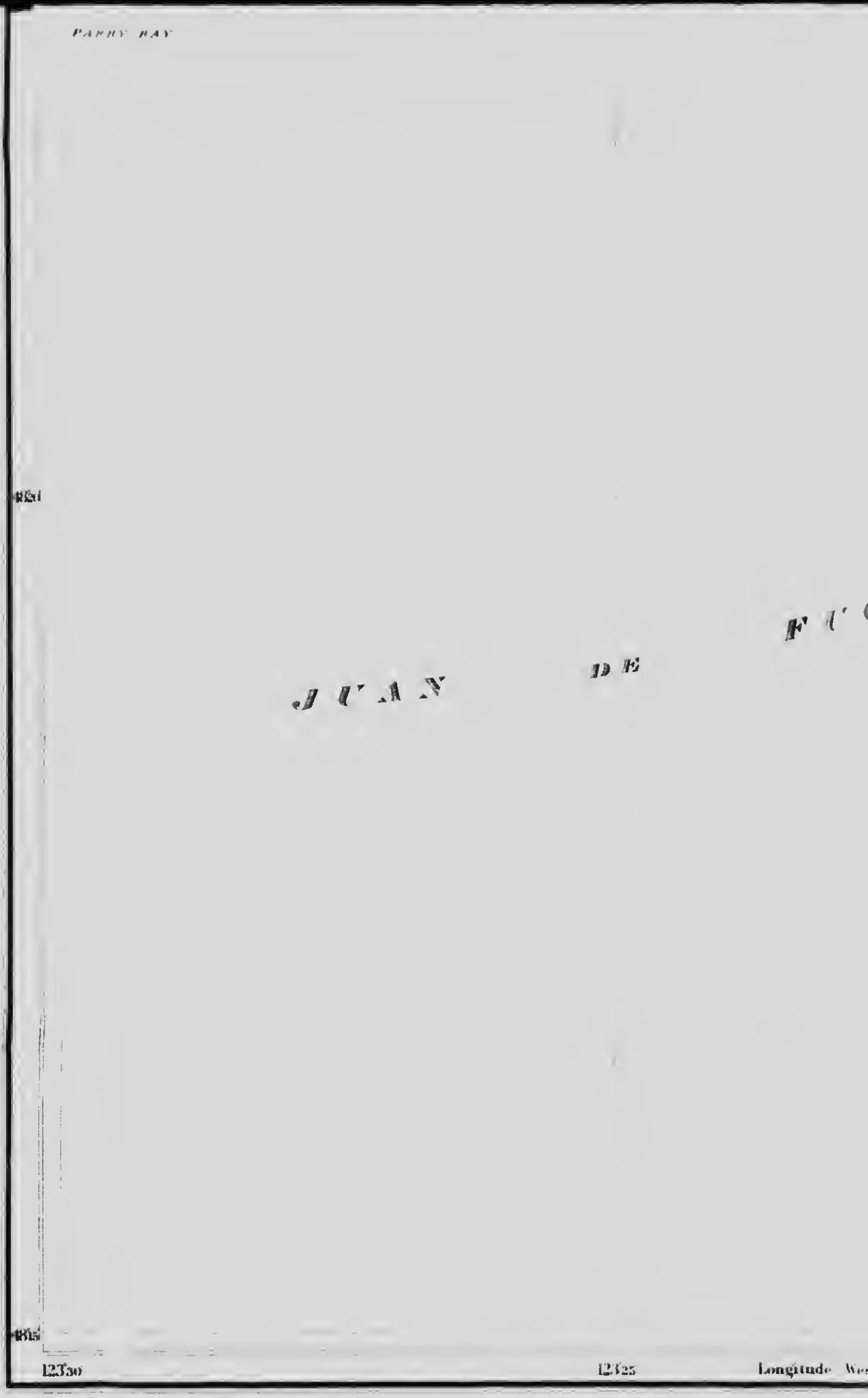
Rock outcrops

Om Om — Chiefly rock outcrops but some drift

Symbols

Geological boundaries *position approximate*

Glacial striae



C. O. Senecal, *Geographer and Chief Draughtsman*
A. Dickison, *and* V. F. Clark, *Draughtsmen*

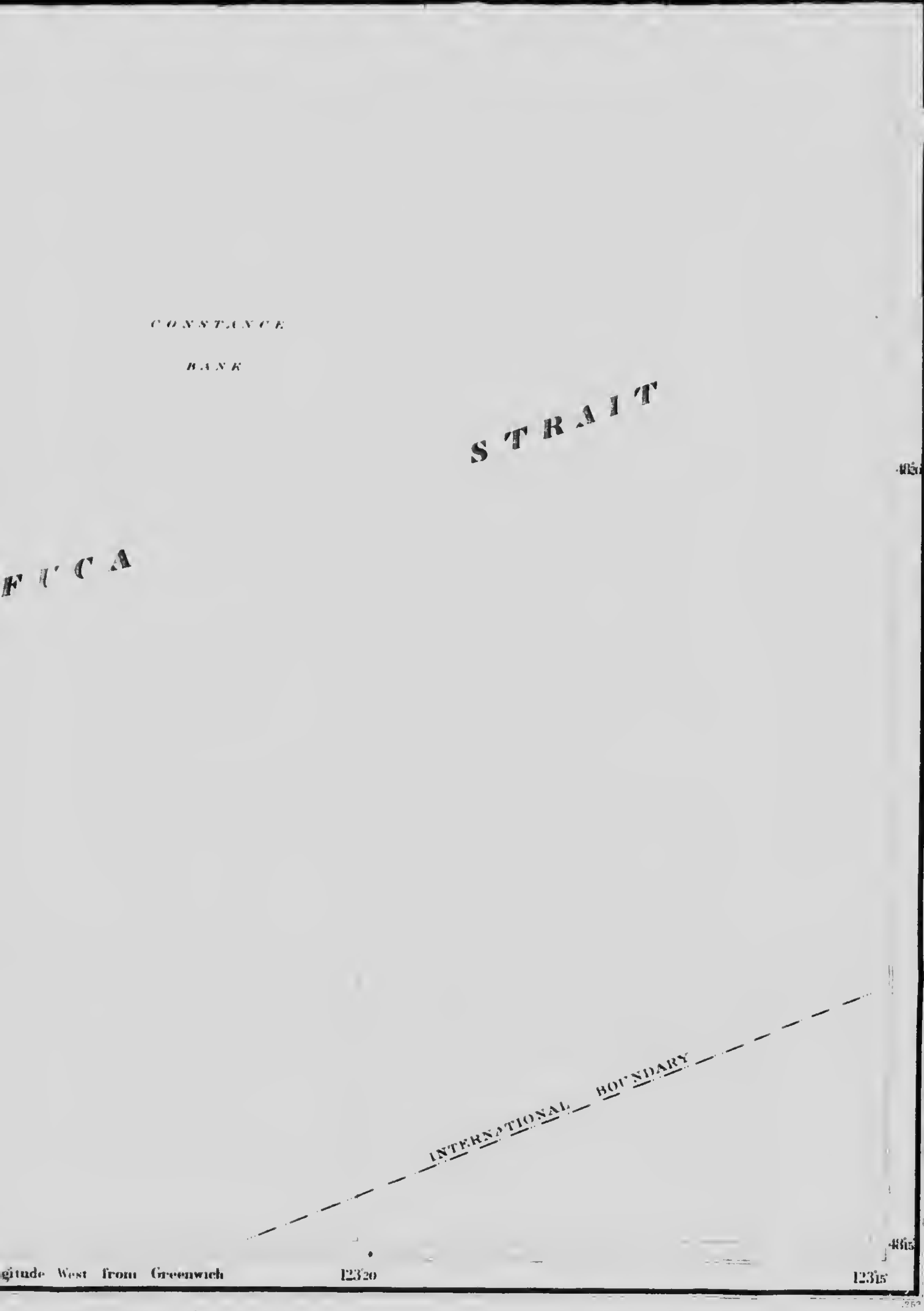
VICTORI

VANCOU

BRITISH

Scal

Note For practi
1 MILE



Triangulation stations

Bench marks

International boundary

District boundaries

City boundaries

Water

Rivers and lakes

Streams, flow disappearing in places

Watercourses with intermittent flow

Fresh marshes

Tidal flats

Springs

Relief

Contours
(showing land forms and elevations above sea level) Interval 20 feet

Depression contours

Figures showing heights in feet above sea level

Geographical position by triangulation based on U.S.C. and G.S. stations "Gonzales" and "Discovery," near Victoria.

Magnetic declination at Victoria 24°23' East 1st October 1909

MAP 71 A
Issued 1915

TORIA SHEET
NCOUVER ISLAND
BRITISH COLUMBIA

Scale $\frac{1}{62,500}$

Miles

Kilometres

e For practical purposes assume
1 MILE TO 1 INCH

GEOLOGY

C.H.CLAPP.

TOPOGRAPHY

R.H.CHAPMAN
K.G.CHIPMAN
S.C.McLEAN

Depression contours

123°25'

Longitude West from Greenwi

MAP 20 A
Reissued 1915

South
Bend

Yale
COLUMBIA
Hope

INGTON

VICTORIA SH

VANCOUVER ISLA

BRITISH COLUMBIA

Scale, $\frac{1}{62,500}$

Miles

Kilometres

Note For practical purposes ass
1 MILE TO 1 INCH

Canada
Department of Mine[s]

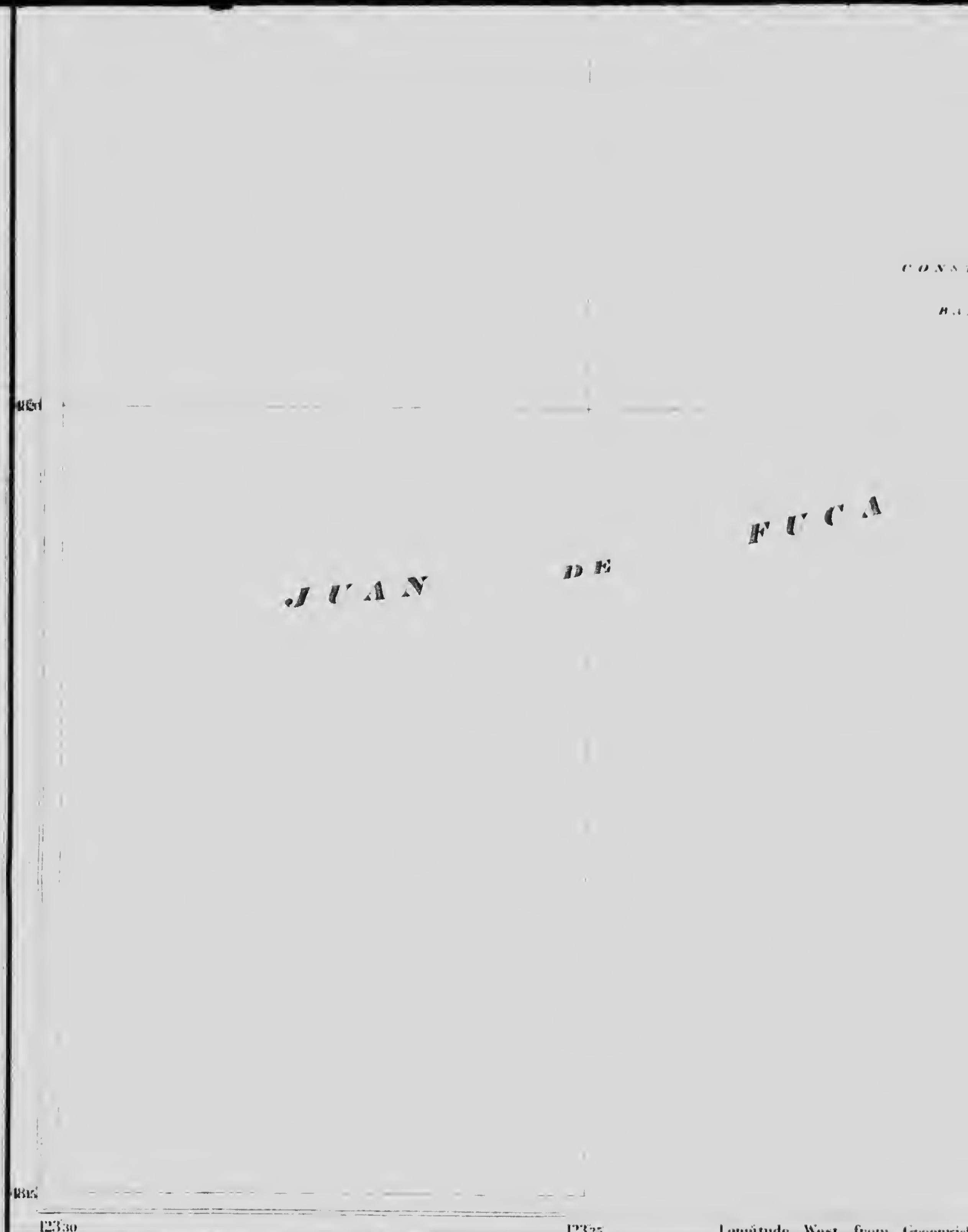
HON. L. CODERRE, MINISTER. R. G. McCONNEL, DE[PUTY MINISTER]

GEOLOGICAL SURVEY

...al
...f Mines
...NNEL, DEPUTY MINISTER

...URVEY

TOPOGRAPHY



C O Senecal *Geographer and Chief Draughtsman*
A Dickison, *Draughtsman.*

MAP 20 A
(Reissued 1915)

VICTORIA SHE

VANCOUVER ISLAN

BRITISH COLUMBIA

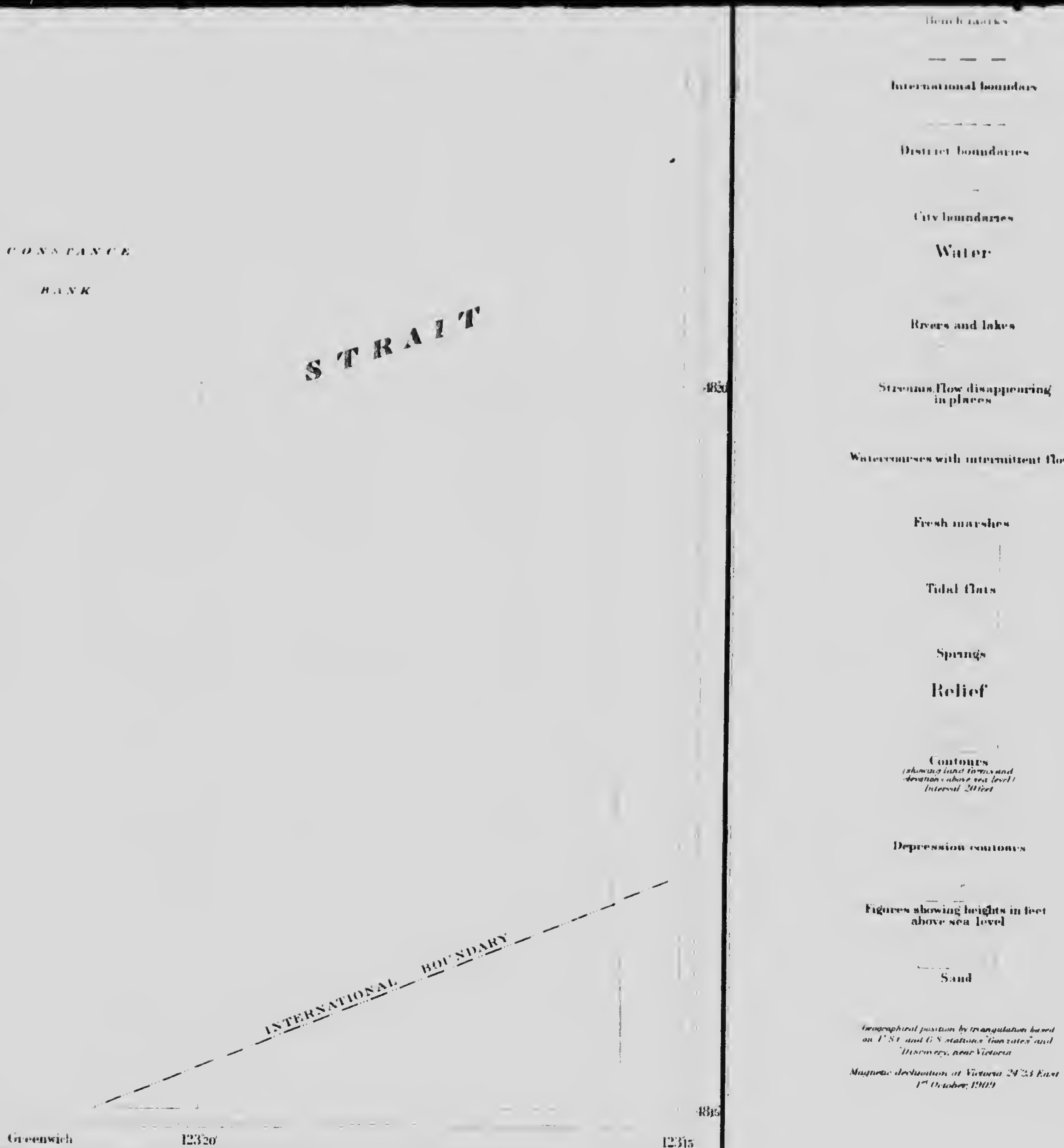
Scale, $\frac{1}{62,500}$

Miles

Kilometres

Note For practical purposes assum
1 MILE TO 1 INCH

To accompany Memoir by C.H. Clapp



SHEET

ISLAND

MBIA

00

oses assume
NCH

TOPOGRAPHY

R H CHAPMAN	NCHARGE	909
K G. CHIPMAN		909
S C McLEAN	TRIANGULATION,	909