GEOLOGY OF THE BRANCH-POINT LANCE AREA

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by

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Abstract

This thesis is concerned with the largest of the Cambrian occurrences on the Avalon Peninsula in southeast Newfoundland, that in the Branch - Point Lance area, on the western shore of St. Mary's Bay. The area is, in general, a gently rolling, marshy, drift-covered expanse, behind steep sea cliffs, and has a land area of approximately forty-five square miles.

The oldest formation considered in this report is the supposedly late Precambrian Random quartzite, which disconformably underlies definite Cambrian strata throughout the area. Cambrian rocks begin with the thin conglomerates, sandstones, and shales of the Bonavista formation, which are followed by the limestones and shales of the Smith Point formation. Lower Cambrian strata end with the red and green shales at the base of the Redland Cove formation.

The red and green shales of the upper part of the Redland Cove formation contain a Paradoxides bennetti fauna, and are hence of early Middle Cambrian age. These are overlain by the dark-grey shales and calcite-rich tuffs of the Deep Cove formation, which contains the Paradoxides hicksi and Paradoxides davidis zones. Middle Cambrian strata end with the siltstones of the Big Head formation.

The Upper Cambrian Elliot Cove formation, of interbedded shales, siltstones, and sandstones, is the youngest consolidated sedimentary deposit in the area.

Sills, dykes, and two small stocks, of gabbroic composition, intrude the Cambrian strata, and are affected by later folding and faulting.

The strata, in general, are thrown into simple, north-northeast trending, open folds, with northwest-dipping axial

planes, and doubly-plunging axes, probably the result of the Devonian Acadian orogeny.

Faults in the area are steep and transverse to the regional strike, with right-lateral strike-slip displacements, and are younger than the folding.

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Foreword

This thesis, presented for the degree of Master of Science at Memorial University of Newfoundland, is the product of field work carried out during the summer of 1961. Financial assistance for this field work was provided by the National Research Council, and by the Geological Survey of Canada; this assistance is gratefully acknowledged here.

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CHAPTER I

INTRODUCTION

Location and Geography

Cambrian rocks occur in two main sections of the peninsula between St. Mary's and Placentia Bays in southeastern Newfoundland, one on the eastern side and one on the western. The present thesis deals with the eastern occurrence, which is the larger. The thesis area lies within north latitudes fifty-three degrees fifty minutes and fifty-four degrees eight minutes, and west longitudes forty-six degrees forty-five minutes and forty-seven degrees, and contains approximately 206 square miles, over half of which are ocean-covered.

The area under consideration contains two villages, Branch and Point Lance, the former, with a population of about 700, being the larger. Both are mainly fishing communities, although some farming and cattle-raising is carried on. Branch is linked to the line of settlements along the east shore of Placentia Bay by a good gravel road, and a branch road, of inferior quality, connects Point Lance with civilization. Outlying parts of the area are accessible either by boat, or along the many footpaths. Travel across country is fairly easy, as the area consists mostly of bog, with scattered spruce thickets, or "tucks".

In general, the Branch - Point Lance area is characterized by steep sea cliffs, behind which the country is a more or less rolling, rather featureless plain, cut by several large streams, and covered by marsh grass and occasional black spruce thickets. The sea cliffs form a semi-continuous line from Redland Point to Jigging Cove, broken only by sand and pebble beaches where the major streams enter the sea. These cliffs range in elevation from a few feet to more than 400 feet, and attain their maximum height in the red and green shales of the Lower and Middle Cambrian, and where resistant gabbro sills form a cap rock over more easily eroded dark-grey shales and siltstones. The latter situation accounts for the 450 foot prominence known locally as Fox Knob.

The cliffs are broken in five places by beaches. The largest, and most spectacular of these, is the sand beach at Point Lance, which is a little over a mile long. The other four beaches, at Gull Cove, Red Cove, Branch, and Beckfords River, are smaller, and composed of coarse pebbles.

The inland part of the area is, in the main, occupied by a fairly flat, rolling, marshy plain, covered by Pleistocene glacial deposits, and marked by low hills and ridges underlain by resistant gabbro. Relief varies from 300 feet to 500 feet, with few steep slopes. Along Branch River, and to the north, the country is covered with spruce and fir, interspersed with barrens and swamps, and here, again, relief is low.

The area is dissected by a number of streams, all of which flow southward into St. Mary's Bay, and, in general, follow the northeast-southwest trend of the bedding. The larger streams reach the sea in low beaches, the smaller plunge over the sea-cliffs, at some places in spectacular waterfalls. The two main streams, Lance and Branch Rivers, follow the bedding for most of their courses. Lance River, in its upper reaches, flows almost transverse to the strike, but here it is still flowing on drift; as soon as it reaches bedrock, its course changes to follow the bedding.

In the southern, marshy portion of the area, outcrops are confined largely to the coastline, and to the lower portions of the river valleys. Only a few protruberances, of gabbro, occur inland. However, on the barrens north of Branch River, outcrops are fairly common, and the Random quartzites, in particular, outcrop in long, rocky ridges.

Previous Geological Work

The Branch-Point Lance area has not been the scene of extensive geological endeavours. Beyond brief visits by A. Murray in 1868 and J. P. Howley in 1869, little work of a geological nature was carried out there until 1955, when R. D. Hutchinson, of the Geological Survey of Canada, made a preliminary survey. This, except for a Durham University expedition in 1959, has been the only attempt at detailed mapping in the area.

The history of geology in Newfoundland is generally considered to have begun with the endeavours of J. B. Jukes, M. A., of St. John's College, Cambridge, who, at the request of the Newfoundland Government, conducted a survey of the Island during the years 1839 and 1840. In his report, Jukes makes no mention of the Branch-Point Lance area, and it seems fairly certain that he did not visit it. However, he divided the "aqueous or stratified rocks of Newfoundland" into four main formations, which are given, in descending order, in Table 1:

Table 1

After Jukes (1843)

1. Coal formation (a) Upper Portion
   (b) Lower or Red Portion

1A. Magnesian Limestone

2. Upper Slate Formation
   (a) Belle Isle slate and gritstone
   (b) Variegated shales

3. Lower Slate Formation
   (a) Signal Hill sandstone
   (b) St. John's slate

4. Gneiss and Mica Slate Formation

Red and green shales of the Lower Cambrian at Chapel Arm, Trinity Bay, similar to those in the Branch area, are placed in the variegated shale member of the Upper Slate formation; hence, it seems probable that the Cambrian strata in the Branch area would have been placed in this division, had Jukes known of their existence. However, from observations made at Placentia, North Harbour, and Colinet, some thirty miles north of the Branch-Point Lance area, he concluded that "the whole of the peninsula between St. Mary's and Placentia Bays is composed of the Lower Slate formation", and makes no mention of any younger rocks.

In 1859, the Branch area made a spectacular entrance into geological literature with the publication in the Quarterly Journal of the Geological Society of London of a report by J. W. Salter on fossils from North America. The greater part of this report deals with specimens of a Paradoxides, sent to the Bristol Institution by a Mr. Bennett, who collected them in the vicinity of Branch. This Paradoxides was the first Lower Palaeozoic fossil identified in Newfoundland, and served to establish the presence of that zone in this country.

The next organized attempt at a geological survey of Newfoundland came in 1864, when A. Murray, of the Geological Survey of Canada, was sent to the Island, at the request of the Newfoundland Government. Murray continued his geological investigations on the Island until 1883. In 1869, J. P. Howley was appointed Assistant Geologist; he succeeded Murray in 1883 and continued work until 1909. The results of the work of these two men were assembled and published in collected form in two volumes, the first covering the period from 1864 to 1880, the second from 1881 to 1909.

Murray began work on the Avalon Peninsula in 1868, and succeeded that year in dividing the rocks there into three series, which are given, in descending order, in Table II:

Table II

After Murray (Report for 1868)

Lower Silurian Series

Intermediate Series

Laurentian Series

The rocks of the Branch area, which was visited during the summer of 1868, he included in his Lower Silurian Series. Murray's visit to Branch seems to have been marred by inclement weather. However, he mentions the well-cleaved, fossiliferous, red and green shales near Branch, the presence of numerous diabase dykes, and the many small faults near the beach. He also mentions the diabase sills and black shales south of Branch, and at Gull Cove.

In 1869, J. P. Howley was assigned the task of studying further the formations of the Avalon Peninsula. In the report for that year, it becomes apparent that Murray's Lower Silurian Series contained an appreciable thickness of the present-day Precambrian strata, as well as the Cambrian. Howley visited the Branch area during that year, and his work, coupled with that of Murray during 1868, led to the conclusion that "the whole of the western shore of St. Mary's Bay seems to be occupied by Primordial Silurian rocks". Murray's description of these rocks is as follows;

"The lower members exposed ——— here consist of red and green sandstones, with slaty and arenaceous divisions," (Musgravetown Group) "with a remarkable band of whitish, hard, and compact quartzite at the top." (Random formation). "——— at Red Head River these strata were found to be succeeded by a solid bed of fossiliferous limestone of a red colour," (Smith Point formation) "overlaid by red and green slates holding Paradoxides, which ——— constitute the cliffs, for the most part, to Branch Head."

On the basis of field work accomplished in 1868 and 1869, Murray concluded that the Primordial Silurian rocks of the peninsula between St. Mary's and Placentia Bays were divided into "at least two troughs, one towards the shores of Placentia Bay, the other towards St. Mary's Bay." It is with the latter trough that the present study is concerned.

From 1869 to 1955, barring occasional expeditions to the several excellent fossil localities in the area, very little geological work was carried out on the western shore of St. Mary's Bay. The fossil-collecting expeditions, it is true, inspired at least two papers, and many new species were described, but no mapping programs of note were undertaken. In 1955, R. D. Hutchinson, of the Geological Survey of Canada, conducted a preliminary survey of the area. The results of this survey have not yet been published.

Mr. Fletcher, of Durham University, made geological observations in the area while on a University expedition in 1959. His report may appear as a thesis, but at the present time none of his results are available.

General Geology

The area under consideration forms a southwestern part of the Avalon Peninsula, in southeastern Newfoundland. This peninsula, in general, lies on the southeast flank of the Newfoundland Appalachian geologic province (A. J. Eardley, 1951, p. 187), and is characterized by structures which, in common with those of the rest of Newfoundland, and, indeed, of all Appalachia, have a general northeast trend, and are reflected in a remarkable parallelism of bays, peninsulas, rivers, and ridges. The bedrock consists mainly of Precambrian sediments and volcanics, with occasional synclinal or downfaulted remnants of Cambrian strata. The present report deals with the largest of these Cambrian remnants, that in the Branch - Point Lance area, on the western shore of St. Mary's Bay.

The oldest formation considered in this report is the white Random quartzite, which overlies Precambrian strata of the Musgravetown group, and underlies definite Cambrian strata, throughout the area. Overlying the Random formation, and in disconformable contact with it, Lower Cambrian strata begin with sandstones and conglomerates, followed by limestones and red and green shales. Middle Cambrian strata consist, from the base upward, of red and green shales, dark-grey shales, a remarkable lens of tuff, and dark-grey siltstones. The Upper Cambrian of the area is formed of interbedded sandstones, siltstones, and shales. Intrusive rocks are also present, and consist of diabase sills and dykes, and two small gabbro stocks. The stratigraphic relationships are shown in Table III (p. 10).

The Cambrian strata occur in a large doubly-plunging downfold, the southern portion of which is lost under the Atlantic Ocean, leaving barely enough to ascertain the doubly-plunging nature of the fold. This large downfold contains several major anticlines and synclines, with northeast trending axes, and numerous minor folds. Faults in the area are vertical, and one, at least, shows evidence of strike-slip displacement.

CHAPTER 2

STRATIGRAPHY and PETROGRAPHY

New Formational Names Introduced in this Thesis

It may be noted here that three new formational names are used in this report. The introduction of new terms into an already cluttered literature needs some justification; this will be given in brief here, and treated more fully in the sections dealing with the formations in question.

The name Redland Cove formation is used instead of the existing Brigus (G. Van Ingen, 1914), and Chamberlains Brook (B. F. Howell, 1925) formations, since the division between the latter units cannot be made in the thesis area, except on palaeontological grounds.

The Deep Cove formation replaces B. F. Howell's (1925) Long Pond and Kelligrews Brook formations, since it represents a distinct lithologic unit, and, again, subdivision would have to be based on palaeontology.

The name Manuels formation, proposed by G. Van Ingen (1914) to include the whole of the Middle Cambrian of southeast Newfoundland, and redefined by R. D. Hutchinson (1956) to refer to the Middle Cambrian strata above the Chamberlains Brook formation, cannot be used in the present area, since here the sequence is clearly divisable into two units, neither of which closely resembles the type Manuels formation. These units are here named the Deep Cove and Big Head formations.

In all other cases, existing names have been used. The complete stratigraphic sequence is given in Table III (p. 10).

AGE	ZONE (or group)	FORMATION	LITHOLOGY
Recent and Pleistocene			alluvium, till, and outwash deposits
Upper Cambrian		Elliot Cove	sandstones, siltstones, paper shales 750'+
Middle (?) Cambrian	*P. forchhammeri* zone (?)	Big Head	dark-grey, micaceous siltstones 500'+
Middle Cambrian	*P. davidis* zone *P. hicksi* zone	Deep Cove	dark-grey shale, tuff and volcanic breccia 230'- 460'+
Middle Cambrian and Lower Cambrian	*P. bennetti* zone	Redland Cove	red and green shales, with calcareous and manganiferous nodules in lower portions 1050'
Lower Cambrian		Smith Point	pink limestone, red and green shale 162'
Lower Cambrian		Bonavista	conglomerate, sandstone, and shale 0' 6" - 7'
Precambrian		Random	white quartzites and quartzose sandstones 26' - 220'
Precambrian	Musgravetown Group		red, green, and grey sandstones

Random Formation

Name

The name Random formation is here applied to a sequence of white, quartzose sandstones, which lies between the sandstones and shales of the Precambrian Musgravetown group (not studied in this survey), and the red sandstones and conglomerates at the base of the definite Lower Cambrian. The name was proposed by C. D. Walcott and J. P. Howley in 1900, to apply to "the terrane between the Signal Hill" (formation) "and the Cambrian" (quoted by A. O. Hayes, 1948); that is, to the youngest Precambrian sequence in southeast Newfoundland. Walcott (1900) gives three measured sections of this sequence, at Smith Point, Hickmans Harbour, and Hearts Delight Harbour, in the Trinity Bay area. Since only one of these, that at Hickmans Harbour, lies on Random Island, and since this best shows the characteristic quartzitic quality of the interval, it must be considered to be the type section for the formation. Walcott's description of the formation is given in the following table:

Table IV

After Walcott (1900)

"The section, as measured by Mr. Howley, is as follows, downward:

Cambrian

Random formation

1. Reddish grey, quartzitic sandstone	1½'
2. Light greenish grey flaggy sandstone	3'
3. Hard grey quartzitic sandstone	5½'
4. Micaceous grey and greenish flaggy sandstone.....	68'
5. Grey sandstone	16'
6. Greenish and bluish grey slaty arenaceous beds, breaking up into fine shales in places	26'
7. Pale pinkish quartzite, in layers 1' to 3' thick	25'
8. Reddish brown hard sandstone	21'
9. Massive bedded white quartzite	10'
10. Massive and thin bedded hard grey sandstone and shale	90'

11. Dark grey flaggy sandstones ....55 '
12. Massive bedded white quartzite ....63 '
13. Massive bedded, reddish grey, quartzitic
    sandstone ....31 '
                                                  415 ' "

Since 1900, the term Random formation has consistently been used to refer to a white quartzite, with interbedded sandstone and shale, which extends over large areas of southeast Newfoundland, and which lies either at the base of the Cambrian or at the top of the Precambrian, depending on the beliefs of the authors (see p. 17).

Distribution

The Random formation is believed to underlie definite Cambrian strata throughout the Branch-Point Lance area. It outcrops in the sea-cliffs at Redland Point, and in small streams between there and the St. Bride's-Branch road. North of the road it outcrops in Branch River, Beckfords River, and on the coast at Jigging Cove. On the barrens north of Branch it forms a prominent ridge, clearly visible on aerial photographs, and displaced in at least two localities by faults. Elsewhere, the formation is presumably concealed beneath drift and river alluvium.

Lithology and Thickness

Rocks of the Random formation, within the Branch-Point Lance area, consist of white, locally cross-bedded, silica-cemented sandstone (quartzite), with intercalated lenses, stringers, and thin beds of shale and sandstone, cemented by argillaceous and calcareous material. The best section of the formation is that exposed in the sea-cliffs at Redland Point, but this is inaccessible. Accordingly, the next best section, in the valley of Beckfords River, will be described first. Here the Random formation is clearly divisable into three parts or members; a basal quartzite member, an intermediate sandstone-shale member, and an upper quartzite member.

The basal quartzite member is not well exposed, the outcrops occuring sporadically in the river bed. Both the base and the top of this member are concealed. From the scattered outcrops available, however, the member is seen to consist of white, light-grey weathering, very pure, recrystallized quartzite. The rock is made up almost entirely of quartz grains, with some chalcedony grains, and occasional fragments of white mica and magnetite. The quartz grains are small, sub-angular to well-rounded, and are cemented by silica, which crystallized in optical continuity with the grains.

The intermediate sandstone-shale member in the Beckfords River section consists of thinly interbedded, very fine-grained, laminated, dark-grey, quartzose sandstone, and dark-grey shale. The sandstone is composed of sub-angular to sub-rounded quartz and chalcedony grains, with some plagioclase feldspar, set in a matrix which is in part calcareous, in part argillaceous. Where the cement is calcareous, the calcite occurs in large crystals, each of which surrounds several quartz grains, giving a poikilitic texture to the rock. These sandstone beds often show graded bedding on a very small scale, and grade into the more argillaceous beds. Even in the latter, however, occasional isolated quartz grains make their appearance.

The upper quartzite member is well exposed in Beckfords River. This is similar to the lower member, except that it is cross-bedded, and is more completely recrystallized, at least in its upper portion, which consists almost entirely of quartz. The lower portion contains occasional discs of black shale, ranging up to 8 millimetres in diameter, and arranged parallel to the cross-bedding in the quartzite. This member develops upward out of the interbedded sandstones and shales by decrease in argillaceous material and in carbonate cement. The latter is entirely absent in the upper parts of the member.

The formation is approximately 220' thick in the Beckfords River section. In the two other outcrop areas of the formation north of the Branch - St. Brides road (in Branch River, and on the ridges north of Branch), the formation closely resembles the sequence in Beckfords River; it can be divided into the three members described above, and silica predominates as the cementing material in the two quartzitic members. The thickness, however, varies greatly, and the grain size decreases. On the ridges north of Branch, only the upper quartzite member is exposed; this was estimated to be over 100' thick. In Branch River, the thickness of the whole formation does not exceed 50'.

South of the road, the formation outcrops at Redland Point, and in small brooks north of the point. Here the quartzite has undergone little or no recrystallization, and calcareous and argillaceous cements increase in importance. The three members can be distinguished only in the gully west of Green Hill Brook; they may exist elsewhere, but the outcrops, except at Redland Point, are too small to allow a safe interpretation. No detailed study could be made at Redland Point, because of the difficulty of reaching the pertinent area of the cliff face. However, the quartzite there seems to be much thinner, and less pure than that in Beckfords River. Sub-angular to sub-rounded quartz grains predominate, it is true, but they are joined by shale fragments up to ½ inch long, and occasional grains of sodic plagioclase; all these sand-size constituents are usually embedded in an argillaceous or calcareous matrix, which constitutes 20 to 50 percent of the rock. Pure quartz sandstone, like that in Beckfords River, except that it has a calcareous cement, occurs only in thin stringers and lenses. The thickness of the formation here was estimated at 26'.

In the gully west of Green Hill Brook, where the three members of the Random formation can be discerned, the sequence as a whole is less pure than in the Beckfords River section. The two quartzite members contain appreciable amounts of argillaceous material, and the sandstone-shale member is less definitely quartzose. Here, the formation is 31' thick.

Thus, the Random formation in the Branch - Point Lance area attains its maximum thickness in the northeast, where it is predominantly a very pure, silica-cemented sandstone, and thins rapidly toward the southwest and west, where it loses its state of high purity, as calcareous and argillaceous materials replace silica in the matrix.

Relations to Underlying and Overlying Rocks

At no place within the area is there evidence to suggest an unconformity at the base of the Random formation. There is certainly no angular discordance, and evidence for a disconformity is lacking. Indeed, the contact is, in places, almost gradational, the sandstones of the Musgravetown group increasing in quartz content as the base of the Random formation is approached. The lower contact of the Random formation is therefore tentatively regarded as being conformable (see Figs. I, III).

The contact between the Random formation and the basal beds of the Cambrian (the Bonavista formation) outcrops in several excellent exposures. At all these points, evidence points to the contact being disconformable. In Beckfords River, the Random quartzite is overlain by a basal conglomerate, which fills pockets in the quartzite. This same situation holds on the long ridges of the Random formation outcropping on the barrens north of Branch. At Redland Point, the contact is not so obviously disconformable, the quartzite being overlain by interbedded sandstone and shale; but here, again, the sharpness of the contact, and the abrupt change in the type of the deposits, suggest a disconformity. R. D. Hutchinson (1956) found evidence for a disconformity at Cape Dog, to the north of the Branch - Point Lance area, and again between Cuslett and St. Brides, to the west of the area, where Cambrian rocks fill a channel in the Random formation.

Origin

Few definite conclusions regarding the origin of the Random formation can be made. The presence of cross-bedding, and the purity of the formation, suggest a shallow-water origin, and the increase in grain size to the east suggests that the source area lay in that direction. It is the writer's opinion that the sequence is a marine, shallow-water deposit, and that the argillaceous facies to the west represents the offshore equivalent of the eastern quartzitic facies. However, it is equally possible that the formation originated as a delta-plain deposit, the highly quartzitic portions representing areas of marine transgression into valleys or low-lying portions of the deltas. A more detailed study of the formation is needed before such conclusions can be drawn with certainty.

Age and Correlation

The age of the Random formation has long been a controversial topic among geologists working in southeast Newfoundland. C. D. Walcott (1900) originally referred it to the Precambrian - "the Random terrane is believed to be the upper member of the Avalon series" - apparently because of its conformable contact with the Precambrian, and the presence of a disconformity between it and the red and green shales of the Lower Cambrian. Later workers questioned the presence of this disconformity. A. O. Hayes (1948), in particular, states that both contacts are conformable, and that "the persistence of the white quartzite lying conformably below the red and green shales, and the nodular limestone of the Lower Cambrian in nearly every locality where the formation is preserved suggests a Lower Cambrian age". E. R. Rose (1948), indeed, goes so far as to discard the term Random formation, including the white quartzites in the Lower Cambrian Brigus formation. R. D. Hutchinson (1953), working in the Harbour Grace area, found that the quartzite - red shale contact was there disconformable and that the Random formation is, therefore, of late Proterozoic age. Other workers referred to the Random as being either late Proterozoic or early Cambrian in age. Christie (1950) classes it as "Lower Cambrian or earlier".

The Random is, virtually, an unfossiliferous formation; hence the dilemma. Walcott and subsequent workers, it is true, found annelid trails in shaly and arenaceous portions of the formation, but these do not permit an age determination. Therefore, it has become customary to date the sequence on the basis of the presence or absence of an unconformity at its upper contact. The validity of this criterion is obviously questionable, since an unconformity must transect time lines. In the case of the Random formation, the use of the unconformity is doubly questionable, since in some localities the formation has an apparently conformable upper contact, while in others the contact is disconformable. However, in accordance with the time-honoured tradition, the Random formation is here tentatively assigned a late Proterozoic age, because of the presence of a disconformity between it and the Cambrian.

The Random strata in the Branch - Point Lance area are correlated with similar rocks on Random Island and on the adjacent mainland (Hayes, 1948), on the eastern and southern shores of Trinity Bay (Hutchinson, 1953), on the Burin Peninsula, and in other parts of St. Mary's, Placentia, and Trinity Bays. They may, perhaps, be equivalent to all, or part, of the Blackhead formation of the St. John's area, but are probably younger.

The Random formation is similar in lithology and stratigraphic position to the upper part of the Morrison River formation (Weeks, 1954) on Cape Breton Island, and may, perhaps, be correlated with it.

Bonavista Formation

Name

The name Bonavista formation is here applied to a thin sequence of conglomerate, sandstone, and shale, which lies between the Random quartzites and the Smith Point limestone throughout the Branch - Point Lance area. The name was proposed by G. Van Ingen in 1914, to apply to the Cambrian beds directly overlying the Random formation. Van Ingen divided the Lower Cambrian of southeast Newfoundland into two formations, the Bonavista and the Brigus formations, the former consisting of red and green shales with limestone nodules, the latter of red shales only. A distinctive horizon of red limestone within the Brigus formation was called the Smith Point member. However, since the boundary between the two formations is based on a change from red to green shales, since it is difficult to recognize this boundary in isolated outcrops, and since the Smith Point member outcrops in most of the Cambrian localities in southeast Newfoundland, it has become customary to use the limestone sequence as a marker horizon, the beds below it being referred to the Bonavista formation, and those above it to the Brigus formation (see Hutchinson, 1956). In accordance with this usage, the Smith Point member has been elevated to the rank of formation. This usage is adopted in this report.

Distribution

The Bonavista formation, being very thin, does not outcrop extensively in the area. However, it is believed to overlie the Random formation throughout the area, as it can be identified at all localities where exposure permits. It outcrops at Redland Point (see Fig. III), on the barrens north of Branch, and in Beckfords River. At these localities, it forms a thin layer between the Random and the Smith Point formations, hardly worthy to be called a formation. However, since it represents the equivalent of a thick sequence to the north, it is so designated here.

Lithology

The formation displays two distinct facies within the Branch - Point Lance area. In the southern part of the area, at Redland Point, it consists of interbedded red sandstone and shale; in the north, at its outcrops in Beckfords River, and on the ridges north of Branch, the formation is thinner and definitely conglomeratic.

The southern facies is best exposed on Redland Point. Here the Random formation is overlain by a thin sequence of interbedded red sandstone and shale. The sandstones commonly show cross-bedding, and consist for the most part of sub-angular to sub-rounded quartz grains, with minor amounts of sodic plagioclase and rock fragments, set in a silty matrix rich in haemetite. They form thin beds and lenses, alternating with red shales.

The northern facies is best exposed in Beckfords River. The Bonavista formation here is a medium-grained conglomerate, containing rounded pebbles averaging approximately ½ inch in diameter. The pebbles consist of quartz and quartzite, derived, in all probability, from the quartzite members of the underlying Random formation; and of quartzose sandstone and siltstone, derived from the intermediate member of the Random formation, and perhaps from pre-Random rocks. The conglomerate is cemented by calcareous material, which is red in the upper portions. On the ridges north of Branch, the lithology is similar to that in Beckfords River, but the conglomerate is finer-grained.

Thickness

The Bonavista, as has been noted, is a very thin formation. Measurements were taken at Redland Point, Beckfords River, and at several localities on the ridges north of Branch. At Redland Point, the following section, given from top to bottom, was obtained:

Table V

Measured section of the Bonavista formation at Redland Point

Smith Point formation

Bonavista formation

Red shale, with interbeds of red sandstone 1" to 3" thick	1' 4"
Red, cross-bedded sandstone	0' 5"
Interbedded red shale and sandstone, individual beds ranging from 1" to 4" in thickness	5' 0"
Total	6' 9"

Random formation

The Bonavista formation here rests on a flat surface at the top of the Random formation. North of Branch, however, the conglomerate fills slight depressions in the Random formation, and the thickness varies from 6" to 2'.

Relations to Underlying and Overlying Rocks

The contact relations of the Bonavista formation vary within the map area. The lower contact is exposed in three places. At Redland Point there is no apparent unconformity, but the sharpness of the contact, the thinness of the Bonavista formation, and the abrupt change from quartzite to red sandstone and shale deposition suggest, but do not prove, a break in the sequence. In Beckfords River, and on the ridges north of Branch, the Bonavista formation fills slight depressions in the Random quartzite, and is composed largely of pebbles derived from the quartzite, proving the presence of a disconformity.

The upper contact is exposed only at Redland Point and in Beckfords River. At the former locality there is a fairly sharp break between the Smith Point and the Bonavista formations. However, the base of the Smith Point contains lenses and stringers of red shale, and red and white sandy limestone, suggesting that the upper contact is gradational in the Redland Point section. In Beckfords River, the thin conglomerate of the Bonavista formation is overlain directly by Smith Point limestone. The red limestone fills small depressions on top of the conglomerate, occupies the interstitial spaces in its upper portion, and forms part of the calcareous cement throughout. For these reasons, the upper contact in the Beckfords River section is regarded as disconformable.

Origin

It is the writer's opinion that the Bonavista formation within the Branch - Point Lance area represents the sediments deposited in a shallow sea, the sandstone-shale facies to the south being the offshore equivalent of the northern, conglomeratic littoral deposits. The constituents of both facies are derived mainly from the underlying Random formation, and the source area, as suggested by the directions of increase in coarseness of the formation, probably lay to the north or east.

In detail, it is suggested that the constituents of the conglomeratic facies, although they may have originated as stream or residual deposits on the old erosion surface, were rounded, sorted, and distributed as the sea covered the area. It is further suggested that the advancing sea did not reach the northern part of the area until the beginning of Smith Point time, since the conglomerate is cemented, in part, by the red calcareous material of the overlying formation, and the limestone-conglomerate contact is disconformable. The southern section, however, has a gradational upper contact, and hence was covered before Smith Point time, and received the finer sediments from the land area to the north or east. The climate in this land area was probably tropical, producing red soils, which were not reduced in the shallow sea or tidal-flat in which they were deposited.

Age and Correlation

No fossils were found within this formation. However, since it disconformably overlies the Random formation, and since by its stratigraphic position and lithology it may be correlated with the earliest Lower Cambrian beds elsewhere in southeast Newfoundland, it is tentatively assigned a Lower Cambrian age. This tentative assignment holds only for the area under consideration, since the Bonavista formation, being, in places, a basal conglomerate deposited in an advancing sea, must be assumed to transgress time.

The Bonavista formation in this area is correlated with the red and green shales, red sandstones and conglomerates which occur between the Random and Smith Point formations throughout southeastern Newfoundland. This correlation is made on the basis of similarities in lithology and stratigraphic position, and is therefore subject to correction.

Smith Point Formation

Name

The Lower Cambrian sequence throughout most of southeast Newfoundland contains an excellent marker horizon, in the shape of a series of red, wavy-bedded limestones and red shales. As noted in the discussion of the Bonavista formation, G. Van Ingen applied the name Smith Point to this horison, giving a type section in Smith Sound, Trinity Bay, and including it as a member in his Brigus formation. Other authors, however, raised the member to formation status, using it as a marker horizon in the subdivision of the Lower Cambrian strata. This latter usage is followed here.

Distribution

The Smith Point formation outcrops throughout the area in stream beds, on the coastal cliffs, and as low ridges on the barrens north of Branch. Frequently, when no outcrop is seen, the prescnce of the formation is indicated by large, angular blocks of red limestone, which sometimes occur in such quantities as to make travel up the minor streams extremely difficult. The formation is best exposed on Redland Point (see Figs. II, III); here, however, the height and steepness of the cliffs make study hazardous. It outcrops again in the brooks between there and the St. Brides - Branch road, on Branch River and its tributaries, on the ridges north of Branch, in Beckfords River, and in the cliffs at Jigging Cove, where, again, high cliffs make close study difficult.

Lithology

The Smith Point formation is composed of red, wavy-bedded limestone, and red, green, and purple shale. The most complete exposure of the formation occurs on Redland Point; here the Smith Point may be divided into three members - a basal limestone member, a shale member, and an upper limestone member.

The basal limestone member grades downward into the sandstone and shale of the Bonavista formation. At the base, the member is composed of thinnly interbedded pure white limestone and calcareous red sandstone and shale. This grades upward into red limestone, which composes most of the unit. Red shale occurs as thin beds, lenses, and nodules throughout the upper half, and gives the limestone its peculiar wavy-bedded appearance. This phenomenum is probably due to solution of the limestone semicontemporaneous with its formation, the shale beds, or insoluble residues, sinking into the cavities so formed. The wavy appearance of the shale beds in the limestone members is even more pronounced in outcrops of the formation elsewhere in the area.

The shale member (see Fig.II) makes up most of the Smith Point formation in the Redland Point section. It is composed of red, green, and purple shale, with thin beds of limestone, red at the base and green at the top, which increase in number as the top of the member is approached. These limestone beds range from 2" to 6" in thickness, and, by increasing in number, provide a gradual transition between the shale and the upper limestone members. Within the shale member, there seems to be a distinct rhythm of deposition, the sequence green shale, purple shale, red shale, limestone bed being repeated regularly throughout, each completed cycle attaining a thickness of about 10', except near the top, where the interval is much shorter, the green shales being usually absent.

The shale member, as noted above, grades upward by increase in the frequency of the limestone beds into the upper limestone member. The boundary is drawn at the first appearance of entirely red limestone in the sequence. The lower part of the upper limestone member, then, consists of interbedded limestone and red shale, and is similar to the shale member, except that the limestone beds are entirely red, and more frequent. As the upper half of the member is approached, the shale beds decrease in thickness, and the member consists of massive red limestone.

Elsewhere in the area, the three members of the Smith Point formation cannot be distinguished, possibly due to incompleteness of the outcrops. Exposures show only one limestone bed, probably the upper, and there is a distinct possibility that only one is present over parts of the area. However, the scarcity of outcrops makes it difficult, if not impossible, to be certain. The section at Jigging Cove could not be reached for close study, but, viewed from some distance, it seems to contain only one limestone bed. Where the shale interval is exposed, it cannot be distinguished from the shales of the overlying Redland Cove formation, except where the relations of the outcrop to one or other of the limestone members is known.

Thickness

The Smith Point formation is exposed in its entirety only at Redland Point, and measurements of the thickness were made here only. The section there is given in Table VI:

Table VI

Measured section of the Smith Point formation at Redland Point

Redland Cove formation	
Smith Point formation	
Upper limestone member	40'
Shale member	115'
Lower limestone member	7'
Total	162'
Bonavista formation	

The cyclic nature of the bedding in the shale member is illustrated by the following detailed section (thicknesses are estimations only):

Table VII

Detailed section of portion of the shale member of the Smith Point formation, taken at Redland Point

Top

Limestone	0'3"
Red shale	1'0"
Greenish-red shale	3'0"
Limestone	0'3"
Greenish-red shale	8'6"
Limestone	0'3"
Red shale	1'0"
Greenish-red shale	10'0"
Limestone	0'3"
Red shale	1'0"
Greenish-red shale	8'0"

Bottom

Relations to Underlying and Overlying Rocks

The contact relationships of the Smith Point formation vary within the area. The lower contact is well exposed on Redland Point, where the base of the lower member contains thin beds of shale, and red and white sandy limestone, suggesting a gradual change from red sandstone and shale to limestone deposition. In Beckfords River, however, the limestone fills depressions and interstitial spaces in the underlying conglomerate, and the contact is regarded as disconformable.

The upper contact is well exposed only on Redland Point, and is there drawn at the top of the upper limestone member, this being the last appearance of massive red limestone in the Lower Cambrian sequence. The contact is fairly sharp, but no evidence of an important break in deposition could be found; the presence of wavy red shale interbeds in the upper half of the limestone member, and of thin limestone stringers and nodules in the overlying Redland Cove formation suggest that there is no significant break between the two units.

Origin

The presence of marine fossils, and the lack of a break between the Smith Point formation and the overlying marine rocks indicate that it is a marine deposit. Any further statements as to the nature of the source area, method of transport, or nature of the basin of deposition are not so well grounded in fact.

Since the sequence is composed entirely of very fine-grained material, it may be postulated that the source area was low, with sluggish streams delivering only mud and silt to the sea. The position of the source area remains problematic; however, the outcrop pattern of the Smith Point sequence over southeast Newfoundland indicates that the present area lies near the eastern boundary of deposition, and the source area, therefore, lay, in all probability, to the east.

The red colour of the sequence may be a reflection of the climate in the source area - warm, tropical climates usually produce red soils. However, it may also mean erosion of red rocks, of which there are plenty in the underlying Musgravetown group, or oxidation after deposition. The writer inclines to the first suggestion.

The limestone of the Smith Point sequence is probably of biochemical origin, and may have been spread over the sea floor by wave and current action. The presence of thin shale residues in the two limestone members indicates that periods of limestone solution were fairly common, and, possibly, these increased in length near the top of these members, resulting in the deposition of the shale member, and the lime-free shales of the Redland Cove formation. Fluctuations between solution and deposition could also account for the cyclic shale member (see W. D. Brueckner, 1951; E. Seibold, 1952).

The presence of green shale in the sequence may be due to several possible factors; they may be caused by short, periodic climatic changes in the source area, by reduction of iron oxides during transport, by introduction into the basin of deposition at places or times when organic material was present in sufficient quantities to establish reducing conditions, or by reduction during diagenesis.

Fossils

The Smith Point formation contains a meagre fauna of poorly preserved hyolithids, brachiopods, and cryptozoans. These usually occur in the limestones, and are most abundant in the upper member. The poor state of preservation makes specific identification difficult, and no attempt at such identification will be made in this report.

Age and Correlation

The fauna of the Smith Point sequence do not permit definite dating. However, on the basis of its stratigraphic position and correlation with similar strata elsewhere in southeast Newfoundland, it is tentatively assigned a Lower Cambrian age.

The formation in the Branch—Point Lance area is correlated, on the basis of similarities in lithology and in stratigraphic position, with similarly named strata elsewhere on the Avalon, Burin, and Bonavista Peninsulas in southeast Newfoundland.

Redland Cove Formation

Name

The name Redland Cove formation is here proposed for a sequence of red and green shales, with calcareous and manganiferous nodules, which overlies the Smith Point limestone throughout the Branch - Point Lance area. The type section for the sequence is at Redland Cove, about 1½ miles west of the village of Point Lance.

Distribution

Red and green shales outcrop sporadically in a belt running from Redland Cove, west of Point Lance, northward to Branch River, and thence southeastward and eastward toward Branch. The cliffs from Branch Head to Beckfords River are composed of this formation, as is the shore in the vicinity of Jigging Cove. As with the other formations, the best outcrops occur on the coast; inland, the formation is exposed only in river beds and in occasional small protuberances in the more barren, less marshy areas. The sequence is best exposed in Redland Cove, where the whole formation, except for a covered interval of about 50', may be studied (see Fig. III).

Lithology

The Redland Cove formation is composed of red and green shales, with occasional limestone stringers, and scattered manganiferous and calcareous nodules. In its type section, at Redland Cove, the formation may be divided into five members.

The lowermost member, directly overlying the Smith Point limestone, consists predominantly of red shales, with thin beds of green shales, and occasional stringers and scattered nodules of limestone. The member outcrops in high cliffs at the base of

Redland Point, and detailed study is difficult.

The second member is more accessible. It consists of a mappable unit of green shale, with a two-foot thickness of red shale in its lower half. Below this red bed, the green shale contains numerous manganiferous nodules, and is sparsely fossiliferous. The red bed, also, is replete with manganiferous nodules. Above the red bed, the green shale is free of nodules, and is highly fossiliferous.

The third member, like the first, consists of red shales, with beds and lenses of green shales. Calcareous nodules and stringers, and manganiferous nodules, howevër, are no longer in evidence.

The fourth member is composed of a mappable unit of fossiliferous green shale, and is overlain by the fifth, and last, member, of red shales, with beds and lenses of green shales increasing in importance in its upper half, which underlies the dark grey shales of the Deep Cove formation.

Individual members can be recognised only in the shore sections, where outcrops are excellent. In these sections, the two mappable green shale units can always be recognized; away from the coast, however, the division is impossible, due to the scarcity of outcrop. Minor changes occur within the units throughout the area; the nodular red shale bed of the second member at Redland Cove does not occur elsewhere in the area, and all units vary somewhat in thickness. On the whole, however, it is believed that the five members described above persist throughout the area, although they can be recognized only where outcrop is continuous.

Thickness

The total thickness of the Redland Cove formation at its type locality is estimated to be approximately 1050'. In the following section, given from top to bottom, measurements listed for the second, third, and fifth members are accurate; those given for the first and fourth members are estimations:

Table VIII

Measured section of the Redland Cove formation at its type locality

Fifth member;	red shale, with green beds and lenses	190'
Fourth member;	green, highly fossiliferous shale	100'
Third member;	covered interval	50'
	red shale, with green beds and lenses	168'
Second member;	green, highly fossiliferous shale	47'
	red shale, with manganiferous nodules	2'
	green, fossiliferous shale, with manganiferous nodules ..	24'
First member;	red shales, with thin green beds and lenses, and occasional limestone stringers and nodules	470'
Total	....	1051'

No accurate measurements for this formation were obtained elsewhere in the area.

Relations to Underlying and Overlying Rocks

The Redland Cove formation has apparently conformable upper and lower boundaries. The basal member conformably overlies the upper limestone bed of the Smith Point formation; thin beds and nodules of limestone in this member point to a gradual change from limestone to shale deposition.

The upper boundary, also, is gradational. The upper part of the fifth member consists mostly of green shale, which grades almost imperceptibly into the dark grey shales of the Deep Cove formation.

Origin

The possible causes of red shale deposition have been listed above (see p. 28), and may, perhaps, be reviewed briefly here; they indicate either a tropical climate in the source area, erosion of pre-existing red rocks, or oxidation during diagenesis. The general conditions of deposition must have remained fairly similar to those of Smith Point time, with the exception that calcareous material could not exist in the basin of deposition, due, perhaps, to a slight decrease in water temperature. The source area was still low-lying, supplying mud and silt to the sea.

The presence of green shales in the formation may be due to a variety of causes. Since the green shales are fossiliferous, whereas the red shales are not, it is possible that a surplus of organic material may have caused the establishment of reducing conditions at certain places and times within the basin. The ferric iron in the muds would then be reduced to the ferrous state, giving the green colour. Changes in the amount of organic material present could be due to changes in the rate of sedimentation, water currents, temperature, or any of a dozen factors. However, the green colour may also be due to periodic climatic changes in the source area, or to diagenetic changes.

Fossils

The green shale members and beds of the Redland Cove formation are usually highly fossiliferous, containing numerous trilobite remains. The red shale beds are unfossiliferous.

The lower member of the formation is sparsely fossiliferous, as far as could be ascertained from the few outcrops accessible. No definitely identifiable remains were obtained from this unit.

The green shales of the second member are highly fossiliferous, containing a well preserved, though slightly distorted, Paradoxides bennetti fauna. In the lowermost beds, below the red nodular shale horizon, Paradoxides eteminicus Matthew predominates. However, specimens of Paradoxides regina Matthew, and Agraulos sp. were also found. The red shale bed itself is unfossiliferous. Above the red shale bed Paradoxides bennetti Salter and Paradoxides lamellatus Hartt appear, the former being the more abundant.

The two latter forms, together with an unidentified species of Agraulos, continue to appear almost to the base of the Deep Cove shales, the last identifiable fossil, Paradoxides bennetti, being found about 100' below the contact.

Age and Correlation

The fossils mentioned indicate that the red and green shales of the Redland Cove formation, at least from the base of the second member upwards, represent the Paradoxides bennetti faunal zone, the lowermost Middle Cambrian zone in the Atlantic faunal realm. It is possible, but not definite, that the lowermost member still belongs in the Lower Cambrian.

The Redland Cove formation, on the basis of its fossil content and lithology, can be correlated with Lower and Middle Cambrian strata elsewhere in southeast Newfoundland. The red and green shales of the first member possibly correspond to beds of the Brigus formation outcropping elsewhere in southeast Newfoundland. The remainder of the formation, encompassing as it does the Paradoxides bennetti zone, is correlated with the

Chamberlains Brook formation of B. F. Howell (1925).

The Chamberlains Brook formation can be distinguished on lithological grounds only in the Manuels area, in Conception Bay, where it consists of green slate, with a few limestone beds. Elsewhere, the <u>Paradoxides bennetti</u> zone occurs within a sequence of red and green shales, with no easily recognizable lithological break to mark its lower contact. If the formation is to be recognized in these areas, it must be on palaeontological grounds. The writer does not agree with this practice, and in this paper the <u>Paradoxides bennetti</u> zone is therefore given no formation name, but is included in the Redland Cove formation, which can be distinguished clearly on lithological grounds.

Deep Cove Formation

Name

The name Deep Cove formation is here proposed for a sequence of dark-grey to black, highly fossiliferous shales, which overlies the Redland Cove formation throughout the Branch - Point Lance area. The type area for the sequence is at Deep Cove, about two miles northeast of Branch. These shales contain a rather large lens of tuff, which is here named the Red Cove member of the formation, with a type section at Red Cove, three miles southwest of Branch.

Distribution

The dark shales of the Deep Cove formation are believed to overlie the Redland Cove shales throughout the area. The best exposure of the sequence is at Deep Cove, north of Branch, where, in low coastal cliffs, a complete section through the formation is easily accessible. Black shales of this formation also outcrop in Redland Cove, Red Cove, at Branch Head, at Big

Head, in Jigging Cove, and in several small exposures inland. These exposures, however, are either incomplete or inaccessible.

The tuff member is best exposed in Red Cove, where a complete section is available, again in low coastal cliffs. The member constitutes the cliffs from there almost to Branch Head, but the cliffs cannot be investigated closely. A thin bed of tuff, believed to represent the rapidly thinning northward extension of the member, occurs in the black shales east of the mouth of Beckfords River, and in Deep Cove. No other outcrops of the member are known.

Lithology

In the type area, at Deep Cove, the formation is composed of fine-grained, dark-grey shale, which grades upward, near the top of the unit, into thinly laminated, alternating dark-grey and black shales. Here, the formation contains a thin bed of very fine-grained, light blue-grey, calcite-rich tuff, which is believed to be the equivalent of the thicker tuffaceous member to the south.

In its outcrops east of the mouth of Beckfords River, the formation contains several thin beds of grey limestone, which exhibit gradational boundaries with the shale. Below these, the thin tuff bed outcrops, and is underlain by laminated, dark-grey and black shales. The lower portion of the formation is not exposed here.

The Deep Cove formation forms most of the coastal cliffs from Small Point to Branch Head. Here the formation consists, from the bottom up, of dark-grey shale, tuff, and dark-grey shale. The shale is similar to that at the other outcrops, except that the base of the upper shale bed contains numerous small mud pellets, probably indicating penecontemporaneous erosion, and a minor hiatus. At its other outcrops, the formation consists only of dark-grey shale; the tuffaceous beds and the limestones are not present.

The Red Cove member, at its type section, consists of interbedded, fine-grained, light blue-grey tuff and fine-grained, light-grey, volcanic breccia, with fragments up to two inches in diameter. The finer-grained beds consist of finely intermingled volcanic ash and calcareous material. The coarser beds contain angular blocks of amygdaloidal andesite, occasional fragments of a very fine-grained, acidic-looking volcanic rock, highly angular fragments of glassy pumice, and occasional pieces of volcanic glass. The amygdules in both the blocks and the pumice are filled with chalcedonic silica or calcite, or both, the order of crystallization being silica and then calcite. Usually, the glass fragments are partially or wholly devitrified, and the whole is set in a calcareous matrix.

Further north, at its outcrops in Deep Cove and near the mouth of Beckfords River, the pyroclastic sequence consists only of very fine-grained, light blue-grey, highly calcitic tuff, with no breccious horizons. The tuff here contains thin stringers of calcite, and much finely disseminated pyrite.

Thickness

A measured section of the formation, taken at its type area, is given below in Table IX:

Table IX

Measured section of the Deep Cove formation at its type locality

Big Head formation

Deep Cove formation

Laminated, dark-grey to black shales .... 59'

Table IX (cont'd)

Fine-grained, light blue-grey, calcite-rich tuff	0'6"
Dark-grey shale, laminated near the top	171'0"
Total	230'6"

Redland Cove formation

No other complete outcrop of the formation is known within the area. However, partial sections are available, and since these show the thickening of the Red Cove member, they will be given here. On the coast east of the mouth of Beckfords River, the section given from top to bottom in Table X was obtained:

Table X

Measured section of the Deep Cove formation east of the mouth of Beckfords River

Big Head formation

Deep Cove formation

Laminated, dark-grey to black shale, with several thin grey limestone beds	18'5"
Fine-grained, light blue-grey, calcite-rich tuff	2'0"
Laminated, dark-grey to black shale	4'0"
Covered interval of unknown thickness	
Total	24'5"+

Redland Cove formation

In Red Cove, no measurements could be obtained for the shale members of the formation. However, the tuff and volcanic breccia sequence here is approximately 460' thick, and consists of volcanic breccia beds 6" to 4' in thickness, separated by 1" to 6" thick beds of fine-grained fissile tuff.

Relations to Underlying and Overlying Rocks

Both the bottom and top of the Deep Cove formation reflect gradual changes in the type of deposition. The base of the formation is difficult to fix accurately, the grey-green shales of the Redland Cove formation undergoing a very subtle change in colour as the top of that formation is reached. The top of the formation, also, is transitional, beds of dark-grey shale appearing with the siltstones of the overlying Big Head formation.

The nature of the contacts of the tuff-breccia horizon with the underlying and overlying shales is difficult to ascertain. In localities where the tuff is fine-grained and thin, the contacts seem to be conformable. In Red Cove, the lower contact of the thick tuff sequence seems to be extremely irregular. The outcrop occurs in a steep cliff face, however, and close study is impossible. The upper contact here seems to be conformable, but the presence of mud pellets at the base of the overlying shales may indicate a minor disconformity.

Origin

No criteria indicative of the source of the sediments are apparent in the Deep Cove formation. However, the dark-grey to black colour of the shales is indicative of either a change in the climate of the source area, or of a copious supply of organic material in the basin of deposition. Since the formation is replete with fossil remains, the latter suggestion is the more likely. The presence of thin beds of limestone suggests that water temperature was fairly high. It is possible, of course, that the colouring effect of the slowly-decaying organic matter was aided by a change in the climate of the source area. Therefore, a possible combination of climatic change, with an increase in organic material, is here invoked to explain the gradual change from green to black shale deposition. The formation, in general, lacks ripple marks, mud cracks, and other indications of shallow water deposition, suggesting accumulation below wave base.

We have, then, fine-grained sediments from an unknown source area accumulating in an environment where bottom life was very abundant. This quiet sedimentation was interrupted by volcanic activity, which spread ash and coarser material over certain parts of the basin. The source of this material cannot be definitely ascertained, but the rapid thickening and coarsening of the tuff member in the Red Cove area suggests that the parent volcano was situated nearby. These volcanic ejectamenta are predominantly of a basic nature, but some acidic, perhaps silicified, fragments were noted, and the vesicles in the breccia fragments are filled with silica, of uncertain origin. The highly calcareous nature of the tuff lens is problematic; it may be due to the introduction of calcite during or after diagenesis.

After this period of tuff deposition, dark-grey to black shales again accumulated, and were gradually replaced by the siltstones of the Big Head formation, as the water depth decreased, or as slightly coarser clastics were supplied from a higher source area.

Fossils

The fossils of the Deep Cove shales may be divided into two groups; the lower three-fourths of the formation contains a *Paradoxides hicksi* fauna, while the upper fourth holds a *Paradoxides davidis* fauna.

The following fossils were found in the lower part of the formation:

Paradoxides hicksi Salter

Ctenocephalus terranovicus Resser

Bailella sp.

Bailiaspis sp.

Agraulos sp.

Conocoryphe sp.

and some agnostids

Fossils of the *Paradoxides davidis* zone were first encountered 60' below the base of the Big Head formation, in the Deep Cove area. Remains of the fossil are numerous from that point to the top of the Deep Cove formation. The following is a list of the fossils found in the upper part of the sequence:

Paradoxides davidis Salter

Bailiella baileyi (Dawson)

Conocoryphe sp.

and some agnostids

Therefore, it is assumed that the lower 170' of the Deep Cove formation represent the *Paradoxides hicksi* zone, while the upper 60' lie in the *Paradoxides davidis* zone.

Age and Correlation

The black shales and tuffs of the formation, on the basis of their fossil content, are of Middle Cambrian age, and may be correlated with the lower part of G. Van Ingen's Manuels formation, as the latter was redefined by R. D. Hutchinson in 1956. This redefined Manuels formation includes grey to black shales, with some limestone, and local volcanic flows and tuffs, and includes the *Paradoxides hicksi*, *Paradoxides davidis*, and *Paradoxides forchhammeri* zones. No fossils of the latter zone were found in the Branch - Point Lance area, and it is probably represented by all or part of the unfossiliferous Big Head formation.

The sequence may also be correlated with the Long Pond and Kelligrews Brook formations (B. F. Howell, 1925), which include, respectively, the Paradoxides hicksi and the Paradoxides davidis zones. Since, however, in the present area the palaeontological division is not marked by a lithologic change, the existing names cannot be used.

The Deep Cove formation, again on the basis of its fossil content, may be correlated with part of the Young's Cove formation of the Fortune Bay area (Widmer, quoted in Hutchinson, 1956). The Paradoxides hicksi zone is not found there, and is probably represented by an unfossiliferous interval, but the Paradoxides davidis zone does occur. The Deep Cove formation is also correlated with the Paradoxides hicksi and Paradoxides davidis beds of Cape Breton Island and Europe.

The only possible equivalent of the tuff lens is a series of pillow lavas, breccias, and slate beds, which outcrops in the Argentia area, thirty miles to the north, and overlies the Paradoxides davidis zone (McCartney, 1956). In the present case, the tuff occurs within the Paradoxides davidis zone, and so is not strictly equivalent in time to the Argentia beds.

Big Head Formation

Name

The name Big Head formation is here proposed for a sequence of micaceous siltstones and dark-grey shales, which overlies the Deep Cove shales throughout the Branch - Point Lance area. The type section for the formation is exposed at Big Head, about five miles east of Point Lance.

Distribution

The Big Head formation does not outcrop extensively in the area. It forms the sea cliffs from Big Head almost to Gull Cove, from Gull Cove Point to Small Point, and from Beckfords River to Jigging Cove Head, with minor interruptions in inlets where underlying rocks are exposed. It also forms part of the sea cliffs on the east side of Point Lance Point, but the height and steepness of the cliffs make close study difficult. Inland, the formation outcrops in Lance and Branch Rivers, and in several smaller streams and gullies.

Lithology

No complete, accessible section through the Big Head formation is known. However, it seems to consist almost entirely of dark-grey, micaceous siltstones, with thin interbeds of dark-grey shale. The siltstones occur in beds 2' to 6' thick, with mica flakes clearly visible on bedding and cleavage planes. Microscopically, they consist of well-rounded quartz grains, with muscovite and chlorite flakes, set in an argillaceous matrix. Near the top of the formation, the siltstones grade into the dark-grey to black shales at the base of the overlying Elliot Cove formation. Diabase sills occur in great profusion in the upper half of the formation.

Thickness

As has been noted, no complete section through the Big Head formation is known. Therefore, no accurate measurements could be made of the thickness of the formation. However, on the point east of the mouth of Beckfords River, a section approximately 500' thick was measured, without reaching the top of the sequence, which is here covered by the sea. Measurements of the outcrop width of the formation in the Deep Cove area indicate that it is approximately 600' thick there. Therefore, all that can be said with certainty is that the sequence is more than 500' thick, and is probably in the neighbourhood of 600'.

Relations to Underlying and Overlying Rocks

Both the base and the top of the Big Head formation are apparently conformable. The base is well exposed in Deep Cove, and on the coast east of the mouth of Beckfords River. At both these localities, the change from dark-grey shale to siltstone is gradual, the shale becoming silty as the base of the overlying formation is approached.

The top of the formation is well exposed in Little Harbour, and on the west shore of Gull Cove. Here, again, a transition zone exists, the siltstones gradually giving way to the interbedded sandstones, siltstones, and shales of the overlying Elliot Cove formation. The transition zone in both places, however, is obscured by diabase sills, which intrude both the upper part of the Big Cove, and the whole of the Elliot Cove formation.

Origin

Very little factual information can be given concerning the origin of the Big Head formation. The coarseness of the deposit suggests either derivation from a source area with a greater relief than that of Deep Cove time, or deposition in a shallower sea. The increase in relief of the source area may have resulted from erosion in a tropical climate, where an increase in rainfall after Redland Cove or Deep Cove time would, in the absence of vegetation, produce a rugged, badland-type topography, with resulting coarser deposits. This change in the amount of rainfall would also account for the grey colour of the sediments, since the ferric iron could not exist in the reducing environment then prevailing. However, the grey colour may also be due to a surplus of organic material in the basin of deposition, or to reduction during diagenesis.

Age and Correlation

The Big Head formation, except for some very vague worm trails, is unfossiliferous. Stratigraphically, the nearest fossils are those of the Paradoxides davidis zone in the underlying Deep Cove formation, and a few poorly preserved trilobites of the Olenus zone in the Elliot Cove sequence. The Big Head formation, then, can be said to lie between the Paradoxides davidis zone and the Upper Cambrian Olenus zone. It is, therefore, of late Middle Cambrian or early Upper Cambrian age, and may, indeed, straddle the contact between the two series. As will be seen below, however, the formation bears a strong lithological similarity to strata of the Paradoxides forchhammeri zone on Cape Breton Island, and hence is tentatively assigned a late Middle Cambrian age.

Because of its unfossiliferous nature, the Big Head formation is difficult to correlate with deposits in other areas. According to its stratigraphic position, however, it may be the equivalent of a series of pillow lavas, volcanic breccias, and dark slates, which outcrops to the north, in the Argentia area (W. D. McCartney, 1956). These are placed at the top of the Middle Cambrian by McCartney. Lithologically, the only possible equivalent to the Big Head formation seems to be the MacLean Brook formation, in the Mira Valley of Cape Breton Island. There, quartzitic siltstones and micaceous shales have been referred by several authors (G. F. Matthew, 1903; R. D. Hutchinson, 1952) to the

Paradoxides forchhammeri zone of the Middle Cambrian. This zone is not well represented in Newfoundland, its position being usually occupied by an unfossiliferous interval of dark-grey slate and sandstone at the top of G. Van Ingen's Manuels formation. This interval outcrops in the Harbour Grace area (R. D. Hutchinson, 1953), and elsewhere on the Avalon Peninsula, and is probably represented by the upper part of the Young's Cove formation of the Fortune Bay area. The Big Head formation, then, is tentatively correlated with the Paradoxides forchhammeri zone of Europe and eastern North America.

Elliot Cove Formation

Name

In 1914, G. Van Ingen proposed the term Elliot Cove series to refer to the Upper Cambrian rocks of southeast Newfoundland, and included in this series one formation, the Elliot Cove formation. Since it is not certain that the strata in the Branch - Point Lance area represent the entire assemblage of sediments deposited during the Upper Cambrian epoch, it seems best to restrict the term to formation status. The name is here applied to a sequence of shales, siltstones, and sandstones, which overlies the Big Head formation throughout, and form the youngest consolidated sediments in the area.

Distribution

Strata here assigned to the Elliot Cove formation outcrop in the troughs of the two major synclines in the area - the Point Lance and the Gull Cove synclines - and form a small portion of the coast north of Deep Cove. The best exposure of the formation occurs along the west shore of Gull Cove, where excellent outcrops and low coastal cliffs make detailed study relatively easy. The formation also outcrops in the small streams north of Gull Cove. In the Point Lance syncline, the sequence outcrops extensively in Lance River and its tributaries, and in the cliffs at Bull Island (see Fig. VII) and Point Lance Points, but no continuous section of the formation is available here. Only the very base of the formation is exposed on the coast north of Deep Cove (see Plate V).

Lithology

The Elliot Cove formation in the Branch - Point Lance area consists of interbedded dark-grey to black, highly fissile, paper shales; dark-grey, well-laminated shales; micaceous siltstones; and cross-bedded quartzose sandstones. The whole sequence is extremely pyritiferous.

The bulk of the formation is composed of shales. These are predominantly of two types; paper shales and laminated shales. The paper shales are dark-grey, extremely pyritiferous, and very fissile, and usually show a yellow-brown colour on the weathered surface. The laminated shales contain alternating, thin, dark-grey to light-grey layers, and are extremely micaceous. These show a distinctive bluish tint when exposed to marine erosion; otherwise, they weather to a yellowish-brown colour.

Interbedded with these shales are thin beds of sandstone and siltstone. These occur in beds, laminae, and lenses ranging from one-tenth of an inch to six feet in thickness, and are usually quartzose and cross-bedded. Individual beds display sinuous contacts with the underlying and overlying shales, and usually contain thin beds and partings of shale. Microscopically, the sandstones and siltstones consist predominantly of fine-grained, sub-angular quartz grains, and muscovite, with minor sodic plagioclase and biotite, and much disseminated pyrite.

The Elliot Cove sequence, as a whole, is marked by cross-bedding and ripple marks, and is replete with peculiar fossil-like impressions, which will be discussed in a later section (see p.50). Besides these, cut-and-fill structures were observed in the formation at several localities.

The whole sequence is intruded by numerous diabase sills, which will be considered later (see p. 51). The degree of contact metamorphism is slight, and does not go beyond a minor baking of the shales in the immediate vicinity of the sills. The sills occur in great profusion near the base of the formation, but decrease in abundance as the top is approached.

Thickness

The total exposed thickness of the sediments of the Elliot Cove formation, as measured on the west shore of Gull Cove, is approximately 750'. This thickness does not include the numerous diabase sills, which push the total to 1000'. A detailed section, taken near the top of the formation, is given below, from top to bottom:

Table XI

Detailed section of Elliot Cove formation, taken near the top of the sequence exposed in Gull Cove

Top of sequence covered by waters of Gull Cove	
Diabase sill	110'+
Shale, blue-grey, well-cleaved, with thin beds of sandstone; highly pyritiferous	107'
Diabase sill	2'
Shale, laminated, light-grey to dark-grey, with thin beds of cross-bedded, ripple-marked sandstone	22'

Table XI (cont'd)

Diabase sill	1'
Shale, blue-grey, with thin beds of sandstone..	25'
Diabase sill	1'6"

The remainder of the sequence is generally similar, except that the diabase sills increase in number and thickness as the bottom of the formation is approached.

Relations to Underlying and Overlying Rocks

The base of the Elliot Cove formation is well exposed on the west shore of Gull Cove, on the coast north of Deep Cove, and in Little Harbour. At all these localities, a transition zone exists, the dark-grey siltstones of the Big Head formation grading upward into dark-grey shales of the Elliot Cove sequence. The Upper Cambrian sequence is the youngest bedrock exposed in the area, and is overlain with angular unconformity by Pleistocene and Recent surficial deposits.

Origin

The existence of trilobite remains, coupled with the presence of cross-bedding, ripple marks, and cut-and-fill structures, indicate that the Elliot Cove formation is a marine, shallow-water deposit, possibly of the tidal-flat type. This suggestion is supported by the abundance of clastic mica, which, according to Lahee (1952, p.39), is indicative of "accumulation near the shore". Since the deposits are over 700' thick, a gradually subsiding basin of deposition, with sedimentation keeping pace with subsidence, must be postulated.

The position of the source area remains unknown, but the predominance of quartz and mica in the clastic materials suggests that it was probably composed of some combination of granites, gneisses, and schists. Since the deposits are fairly coarse-grained, and the fragments are, in the main, sub-angular in appearance, it is probable that the increase in relief of the source area, begun in early Big Head time, may have continued into and throughout Elliot Cove time. On the other hand, the coarseness of the sequence may be due simply to deposition above wave base, with no accompanying change in the source area.

Fossils

The Elliot Cove sequence in the Branch - Point Lance area is very sparsely fossiliferous. R. D. Hutchinson (1955, McCartney's unpublished map) found specimens of Olenus in dark-grey shale on the west shore of Gull Cove; the writer discovered one poorly preserved specimen of Olenus sp. in the same locality, but nothing identifiable elsewhere.

The sequence, as a whole, is marked by the presence of peculiar, elongate, sub-cylindrical, fossil-like bodies, which occur in the thin shale coatings at the top of the sandstone beds. Lithologically, they consist of low ridges of sandstone, which project slightly above the general level of the sandstone bed. No inorganic agent adequate to explain their formation is known; but neither is there any conclusive proof that they are of organic origin - they might belong to that category of structures commonly referred to as "worm tracks".

Age and Correlation

The presence of the trilobite genus Olenus indicates that the Elliot Cove formation is, in part, at least, of Upper Cambrian age. Since the specimens of the index fossil were found near the top of the sequence exposed in Gull Cove, it is possible that the underlying Agnostus pisiformis zone is represented by the lower unfossiliferous portions of the formation. In the Point Lance syncline, where the Olenus beds are overlain by a considerable thickness of unfossiliferous shales, siltstones, and sandstones, post-Olenus zones may be represented.

The distinctive cross-bedded and ripple-marked shales, siltstones, and sandstones of the sequence may be correlated with similar rocks on Random Island, on the adjacent shores of Smith Sound, and at Little Ridge, all in Trinity Bay, on the east shore of Conception Bay, and elsewhere on the Avalon Peninsula. These beds, lithologically very similar to the strata in the Branch - Point Lance area, have all been referred to the Upper Cambrian. The sequence may, furthermore, be correlated with all or part of the Salmonier Cove formation north of Fortune Bay, where the Olenus fauna has also been found (Widmer, 1950).

Intrusive Rocks

Since the author was mainly interested in the stratigraphy and palaeontology of the Cambrian sediments of the area, the intrusive rocks were given secondary consideration. Hence, the following discussion is, of necessity, not as complete as could be wished.

Basic Sills

Distribution

Basic sills, of gabbroic composition, intrude strata of the Big Head and Elliot Cove formations throughout the area. Good exposures of the sills, which range in thickness from less than 1' to over 150', are present on Bull Island Point,

Point Lance Point, in Gull Cove, and on the coast north of Branch. The sills form almost the only outcrops in the interior, marshy portions of the area, where they occur in low ridges and protruberances, standing above the more easily eroded shales and siltstones. The sills are, in the main, confined to the Big Head and Elliot Cove strata, although occasional intrusions are known to occur in the Deep Cove shales.

Lithology

The sills may most conveniently be classed as olivine diabases or dolerites. In general, they display a sub-ophitic texture, and the major constituents are augite, highly altered andesine, and olivine, with minor amounts of biotite, chlorite, and pyrite. The sill to the north of the Bull Island fault (see Plate V) is especially rich in olivine; otherwise, the intrusives conform to the general picture. They display chilled border zones, and a thin zone of contact metamorphism parallels each.

The thicker sills are cut by numerous feldspar-rich bands and blotches, the bands ranging in thickness from one-tenth of an inch to five inches, and the blotches appearing as roughly circular bodies up to two feet in diameter. These aggregations consist of sericitized oligoclase, orthoclase, and perthite, with occasional fragments of biotite and pyrite. The bands seem to follow joints in the sills, and, although they show sharp contacts with the surrounding rock, do not exhibit chilled border zones, or other evidence of later intrusion.

The relationship of sills and feldspar bands presents a problem which cannot be satisfactorily answered. Both sills and feldspar bands are, in all probability, offshoots from the same parent, the feldspar bands representing a later stage in differentiation. This differentiation could have taken place in the sills themselves, or in the parent magma, after intrusion of the sills. The lack of chilled border zones seems to indicate that the bands were emplaced while the sills were still plastic, perhaps along incipient joint planes. The presence of feldspar-rich blotches seems to favour differentiation in the sills, the late, feldspar-rich liquids being forced in along developing fractures as portions of the rock cooled. But there is no definite layering in the sills, as would be expected if this suggestion were true. The question must, at present, remain unanswered.

Diabase Dykes

Distribution

Diabase dykes are fairly common within the area, intruding strata of the Redland Cove and underlying formations. Good exposures of these dykes occur in Redland Cove, Branch Cove, and at several places in the interior. At all these localities, the dykes exhibit a general northwest-southeast trend, and have steep dips.

Lithology

The dykes range in thickness from 6" to 20', and display chilled contacts, and thin zones of slight contact metamorphism. The intruded shales are usually jointed parallel to the contact with the dykes. Many of the dykes pinch and swell, and a few tongue out entirely, only to begin again some distance away.

These rocks may best be classed as diabases, using the term in the old English sense to refer to "a more or less decomposed dolerite" (Harker, 1956). They are all very highly altered, but seem to have consisted initially of plagioclase, of the andesine-labradorite range, olivine, biotite, and augite. The feldspars are highly sericitized, and the olivine is almost entirely altered to serpentine. Secondary minerals consist of pyrite, calcite, and chalcedonic silica. The calcite occurs in veins running across the dykes, and fills vesicle-like openings, where it is joined by chalcedony. The rock may have undergone some slight carbonatization, since in some slides the feldspar seems to be replaced by carbonates.

These dykes are, in all probability, closely related to the sills described above. They display a similar mineralogical composition, but no outcrops are known where sills and dykes occur together. Thus the actual relationships cannot be ascertained. It is assumed, from the similarity in mineralogy, that both sills and dykes are products of the same phase of intrusion; the restriction of the dykes to the Redland Cove and lower formations, and the occurence of the sills only in the uppermost Middle Cambrian and the Upper Cambrian beds, suggests that the dykes may represent the connecting links between the sills and some deep-seated intrusion. The tentative nature of this suggestion is obvious, and needs no comment.

Gabbro Stocks

Distribution

Two stocks of gabbroic composition are known in the area. The first of these outcrops approximately one-half mile north-west of Gull Cove, in stream beds and in small outcrops in the marsh. The second occurs just south of the Branch - St. Brides road, about two miles west of its intersection with the road to Point Lance. In both cases, outcrops are small, and the possibility exists that the so-called stocks may be portions of large sills.

Lithology

Both stocks are composed of gabbro. In both cases, the rock has a peculiar corrugated appearance on the weathered surface, possibly resulting from erosion of a type of flow-banding. Constituent minerals include augite, plagioclase of the labradorite variety, and biotite, with some magnetite and secondary pyrite. The texture is sub-ophitic.

The contacts of these bodies were not observed. They appear very similar in lithology to the sills, but differ from them in their peculiar corrugated appearance on the weathered surface, and in their larger grain size. The large areas covered by these bodies suggests that they are stocks; the Gull Cove body outcrops in semi-continuous exposures for almost one mile, directly across the regional strike (see Plate V); no sills of comparable size are known from the coastal sections. It is, therefore, concluded that these bodies are small stocks, possibly indicating the presence of a large basic intrusive underlying the area, and providing a possible source for the sills and dykes.

Age of the Intrusions

It is thought that the sills, dykes, and stocks described above belong to the same general phase of intrusion, and are hence of approximately the same age. Since no outcrops showing the contact relationships between the three types of intrusives are known, this conclusion is tentative.

Both sills and stocks intrude strata of the Upper Cambrian Elliot Cove formation. They are, therefore, late Cambrian or post-Cambrian in age. Also, both sills and dykes have been affected by the folding which, according to R. E. W. Neale et al (1961), took place during the Acadian orogeny, in the Devonian. The intrusives, then, were emplaced at some time between the late Upper Cambrian and the Devonian.

Gabbro intrusives are known from the Cambrian of the Argentia area (W. D. McCartney, 1956), where gabbro stocks intrude Middle Cambrian strata, and are thought to be late Middle Cambrian in age. On the Burin Peninsula, basaltic flows conformably overlie definite Middle Cambrian strata, and are classed as Upper Cambrian by D. H. Williamson (1956). The intrusives in the Branch - Point Lance area may, perhaps, be a part of this phase of igneous activity.

Quaternary Deposits

Accumulations of glacial drift, formed by glaciers active during the Pleistocene ice ages, and perhaps slightly reworked by water, now blanket almost the entire Branch - Point Lance area (see Figs. V, VI). These deposits vary widely in thickness, and consist of boulder clay, gravel, sand, silt, and isolated erratics. In places they rest directly upon polished bedrock. Most of the material comprised in the till is of local origin, derived from Cambrian and Precambrian formations within the map area. The bulk of these glacial deposits may be classed as ground moraine, since they lack conspicuous ridge-like forms; however, eskers are fairly common in the area (see Fig. V), and supply most of the gravel for road building. Vague bedding, visible here and there in the glacial deposits, suggests that they have undergone some water transport, but the complete lack of sorting indicates that this was probably of minor significance; the bedding may be due to solifluction.

Glacial striae are conspicuously absent in the area, probably due to the scarcity of outcrop, except in exposed coastal areas. However, roches moutonnees and crag-and-tail structures indicate that the ice moved, in general, from northeast to southwest.

A marine terrace, situated approximately 10' above present sea level, is known from several localities along the coast. This is covered with glacial debris (see Figs. IV, VI), and is followed downward by a recent terrace, situated at about present sea level. These marine terraces are reflected in several river terraces, well developed in the valleys of Branch and Lance Rivers. In Lance River, there are two such terraces, developed on glacial deposits, at elevations of approximately 6' and 10', respectively.

Recent deposits consist of peat bogs, developed on interior, poorly-drained portions of the glacial mantle, and beaches of cobbles, gravels, and sand, formed along the present strand line, in protected bays, where the sea has access to the Pleistocene glacial deposits (see Fig. VI).

CHAPTER III

STRUCTURAL GEOLOGY

General Statement

The Branch - Point Lance area lies on the east flank of the northern Appalachian folded belt. It is characterized structurally by large-scale open folds, high-angle faults, and very low-grade regional metamorphism. The simple fold pattern in the area suggests that only one period of deformation took place, but no evidence indicative of the time of orogeny, other than that it is post-Cambrian, is apparent.

Unconformities

Three definite unconformities are known to exist in the Branch - Point Lance area: the contact between the Random formation and the Bonavista sandstones and conglomerates is unconformable throughout the map area; the Bonavista - Smith Point contact is disconformable in the north; and the Upper Cambrian - Pleistocene contact is angularly unconformable throughout. These unconformities have already been discussed under the formations concerned, and need not be dealt with again here.

Folds

Folding in the area is, in general, of a fairly simple nature. The Cambrian rocks have been preserved in a large, northeast-trending, doubly-plunging downfold, the southern portion of which is lost under the waters of the Atlantic Ocean. Six major folds, and part of a seventh, are included in this downfold, as well as numerous minor folds. These folds will be described here, proceeding from west to east.

The westernmost, and the largest, of the major folds is the Point Lance syncline, the axial plane of which strikes approximately N 15 E, and runs from Lance Cove to Branch River, and beyond. This fold plunges slightly to the southwest along most of its length, but near Lance Cove the plunge is to the northeast. Numerous minor folds, with both north and south-plunging axes, are included in this syncline. On its western limb, in the vicinity of Redland Cove, the red and green shales are distorted by north-plunging folds, with axes trending approximately N 20 E to N 25 E, and plunging 20 degrees. The Upper Cambrian Elliot Cove formation, exposed in the centre of the syncline, is crumpled into numerous minor folds, the axial planes of which usually trend about N 15 E, and dip steeply to the northwest. The direction of plunge of these folds varies, some plunging north, others south.

The Point Lance syncline is bordered on the east by an anticline, the exact relations of which are not readily apparent, due to insufficient outcrop. At its exposure on the coast, near Big Head, the axial plane of the fold strikes N 20 E, and is vertical. The east limb of the anticline contains folds with horizontal axes, and axial planes which dip to the northwest at approximately 45 degrees.

The axial plane of the Gull Cove syncline, east of the Big Head anticline, strikes approximately N 10 E, and the axis plunges to the south at about 30 degrees. As in the Point Lance syncline, the Upper Cambrian strata are distorted by numerous minor folds.

The anticline bordering the Gull Cove syncline on the east outcrops only in the high cliffs east of Small Point, and could not be studied closely. It appears to plunge gently to the south. The southern portion of the adjacent syncline is well exposed in Red Cove (see Fig. VIII), where the fold is seen to plunge to the north at about 20 degrees. In exposures north of the Branch - St. Brides road, the plunge is to the south at about the same value.

The next anticline, of Branch Head, also outcrops in high cliffs; the plunge there is to the south.

The shore from Beckfords River to Jigging Cove, finally, is carved on the west limb of a south-plunging syncline, the axis of which runs beneath the waters of St. Mary's Bay.

In general, then, the axial planes of the folds trend north-northeast, and dip steeply to the northwest. The plunge of the folds averages about 25 degrees, and varies in direction from southward in the northern part of the area, to northward in the southern part.

Faults

The area is crossed by three, or possibly four, major transverse faults. The largest of these is the Bull Island fault, which is exposed on Bull Island Point, and again on Point Lance Point (see Plate V). The fault strikes approximately N 80 W, and dips vertically. Its presence is strikingly demonstrated on the west side of Bull Island Point, where Elliot Cove rocks are brought into contact with red and green shales of the Redland Cove formation. The actual fault plane is here hidden, but is exposed on Point Lance Point, where horizontal slickensides were observed, suggesting that the last movement along the fault, at least, was of a strike-slip nature. Exposures are not good enough to determine the apparent displacement, but this is estimated to be in the neighbourhood of 1500', since Elliot Cove strata abut against

Redland Cove rocks. The fault, then, may be classed as a transverse fault, with a right-lateral strike-slip displacement.

Two other major faults exist north of Branch, but no exposures of the actual fault planes are known. Both faults are clearly visible on aerial photographs, since the white quartzites of the Random formation, which stand out as ridges, are displaced. The southern, and the larger, fault strikes approximately N 80 W, and can be seen in Deep Cove, as well as on the ridges north of Branch. The actual fault plane not being exposed, the dip and the direction of actual movement cannot be ascertained. However, the southern block has apparently moved westward relative to the northern block, giving a horizontal displacement of 1000', and a perpendicular displacement of approximately 360'. The northern fault strikes approximately N 80 E, and can be seen on the ridges north of Branch and at Little Harbour. The fault has a horizontal displacement of 800', and a perpendicular displacement of about 275'. Apparent movement is such that the southern block has moved westward relative to the northern block. The actual nature of movement along both of these faults cannot be ascertained; however, the relationship of the displacement to the folded strata suggests that a strike-slip component was involved. If this is indeed the case, these faults, like the Bull Island break, may be classed as transverse, right-lateral strike-slip faults. Exposures do not permit a study of the relationships at the place where the faults meet.

It is possible that a fourth major fault runs across the area, in a general northwesterly direction, from the vicinity of Branch (see Plate V). This fault is inferred from the disruption of fold axes in the vicinity of Branch, and from the presence of numerous minor faults near that town, but has not been seen in actual outcrop.

Minor faults, with apparent displacements of up to 30' are numerous throughout the area, especially in the regions close to the major breaks described above. These, in general, run in a northwesterly direction, and dip steeply. Apparent movement varies from one locality to another. Such minor faults are well exposed on Bull Island Point, Point Lance Point, at Branch, and in Gull Cove.

All these faults are younger than the folds, since they displace fold axes, and cut across the folded strata with no change in strike.

Cleavage and Jointing

Strata of the area are not well jointed. Usually the joints, except in the sills, have a general northwesterly trend, and are confined to the vicinity of the diabase dykes, which they parallel. It is possible that the dykes have been intruded along the joint planes. Joints in the sills usually parallel the sill contacts.

The area has undergone very low-grade regional metamorphism; this is indicated by the presence of two sets of cleavages, the best-developed of which strikes approximately N 15 E, and dips vertically or steeply to the northwest. This is crossed by a less regular cleavage, which "intersects the oblique cleavage and the bedding at right angles, dividing the rock into splintery fragments". (A. Murray, Rept. for 1868). Both cleavages are developed only in the shales of the Smith Point and overlying formations; there is a vague cleavage in the Big Head siltstones, possibly belonging to one of the above sets.

It can be assumed that the main cleavage originated during the period of folding.

Age of Deformations

No evidence indicative of the exact age of the deformations is apparent in the Branch - Point Lance area. With regard to the folding, the writer can do no better than offer the following quotation from Neale et al. (1961):

> "Late Precambrian rocks of the Avalon Peninsula ...., together with disconformably overlying Cambrian to Lower Ordovician strata, are interpreted as being appreciably deformed only during the Acadian orogeny." (Devonian). This interpretation is based on the simple fold pattern of these rocks, which suggests only one period of major deformation, and on the fact that these rocks are cut by Devonian granites on the islands of Placentia Bay."

The faulting, as stated above, is younger than the folding, and is therefore, post-Devonian in age.

CHAPTER IV

GEOLOGIC HISTORY

The writer does not wish to present a detailed account of the geologic history of the Branch - Point Lance area, since such an account would, it is thought, be of a highly theoretical nature. However, a general summary may be of value; such a statement is given here.

The Precambrian Musgravetown group was not studied in detail; however, it is believed to have accumulated as a fluvial or delta-plain deposit. There is no apparent break between the group and the overlying Random formation; in fact, the more argillaceous portions of the Random closely resemble the Musgravetown strata, leading to the conclusion that the quartzites may represent merely "cleaned" Musgravetown sandstones, developed as lobes of the sea invaded low-lying portions of the delta areas. The fact that the more highly quartzitic facies of the Random formation is the thicker lends some support to this suggestion.

After deposition of the Random quartzites, the sea retreated, and a period of erosion began. The next advance, at the beginning of Bonavista time, covered the southwestern portion of the area before the northern; locally, at least, the advance was from the southwest. While the northern part of the area was still undergoing erosion, red silt and sand from a source area with a tropical climate accumulated in the southern part. Finally, near the beginning of Smith Point time, the sea covered the northern portion, giving the basal conglomerate atop the Random quartzites.

In this sea, fluctuations between limestone solution and deposition caused alternating deposition of lime-rich and lime-free beds, and, as the periods of limestone solution increased in intensity, the red and green shales of the Redland Cove formation were deposited.

Then, an increase in the content of organic material, coupled, perhaps, with an increase in the rainfall in the source area, gave a gradual change from red and green shale to dark-grey shale deposition, resulting in the Deep Cove shales. Near the middle of Deep Cove time, volcanic eruptions spread ash and breccia over the east-central portion of the area. After this interruption, dark-grey muds again accumulated, becoming intermingled with silty material as the end of Deep Cove time approached.

After Deep Cove time, there was a gradual increase in the overall coarseness of the deposits, indicating a probable increase in relief in the source area, and, possibly, an accompanying decrease in water depth in the basin of deposition. As the relief increased, the siltstones of the Big Head formation, followed by the sandstones, siltstones, and shales of the Elliot Cove sequence were deposited. This period of shallow water deposition continued throughout Upper Cambrian time, and may, possibly, have lasted throughout some or all of the Ordovician, the resulting strata having been lost by erosion in the Branch - Point Lance area, but preserved in Conception Bay (Bell Island).

The post-Upper Cambrian history of the area must, in the main, be inferred, for later periods are not represented. Deposition continued, then, for an indefinite period after the end of the Cambrian. At some time after the deposition of the Elliot Cove sequence, and before the Acadian orogeny of the

Devonian, the strata of the area were intruded by stocks, dykes, and sills of gabbroic composition. Then, in Devonian time, the sequence was disturbed by the Acadian orogeny, which produced all the folds described in Chapter III. The post-Devonian history of the area includes a period of faulting, but is otherwise probably one of continued erosion, lasting until the Pleistocene period, when ice sheets, moving southwestward from the central part of the Avalon Peninsula, spread till and outwash deposits over the eroded edges of the deformed Cambrian strata. Later modification, by wave and river action, gave the area its present aspect - a gently rolling, fairly marshy expanse (see Fig. V), behind steep, high, sea cliffs.

CHAPTER V

ECONOMIC CONSIDERATIONS

General Statement

The Branch - Point Lance area is not well-endowed with economic mineral deposits. Barite and, perhaps, galena are known to occur, but in insufficient quantities to warrant development. The limestone and peat deposits of the area may be extensive enough to encourage closer inspection, with a view to future development.

Barite

Barite occurs in thin veins on the coast south of Branch. The veins do not exceed three inches in thickness, and for this reason are not considered of economic importance.

Galena

Several fragments of galena were found in drift on the east shore of Gull Cove. Since the drift is mainly of local origin, it is possible that the galena occurs in bedrock in the vicinity. No outcrop was found, however, and hence estimations of the economic importance of the possible deposits cannot be made.

Limestone

The pink limestone of the area may be of use in the manufacture of cement, or for purposes of soil amendment. Analyses of these and similar limestones are now being made by the Newfoundland Department of Mines. The results should indicate the possible uses of the deposits.

Peat

The post-glacial deposits of the area include many peat bogs, some of large extent. At present, these are not used as a source of fuel, since a fairly adequate supply of firewood exists. A considerable reserve is present, however, for possible future use.

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Plate I

Fig. I: Contact between Musgravetown group (M) and Random formation (R), Redland Point.

Fig. II: Upper portion of shale member (S) and upper limestone member (L) of the Smith Point formation, Redland Point.

Plate II

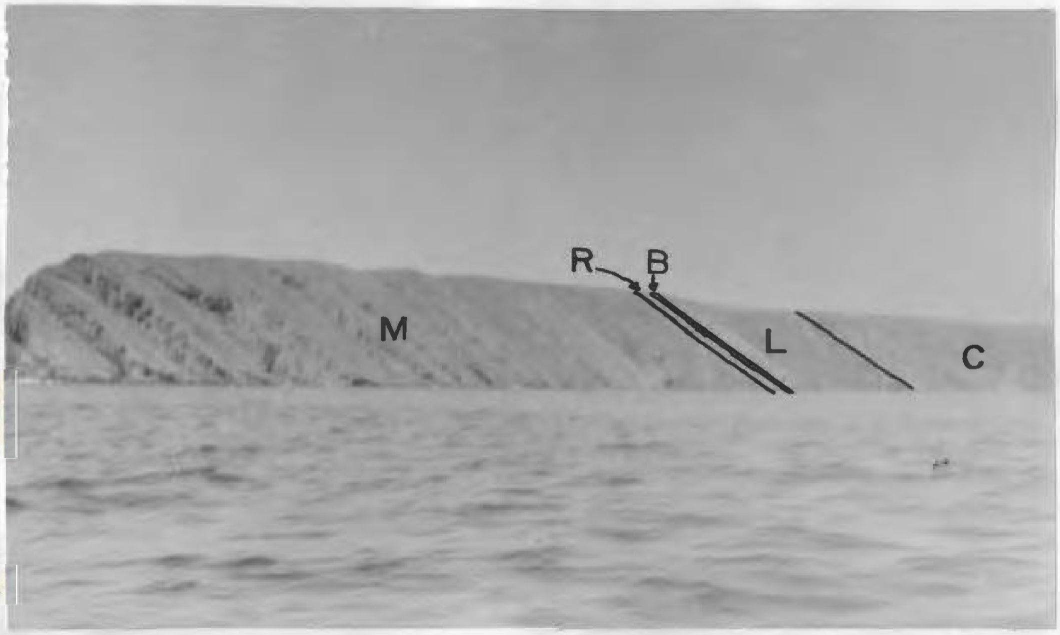

Fig. III: Upper Musgravetown group (M), Random formation (R), Bonavista formation (B), Smith Point formation (L), and lower Redland Cove formation (C), Redland Point.

Fig. IV: Marine terrace developed on folded Upper Cambrian strata, and covered with glacial debris, Gull Cove.

Plate III

Fig. V: Interior, marshy plain, with esker at lower left.

Fig. VI: Beach, marine terrace, and glacial deposits, at mouth of Beckfords River.

Plate IV

Fig. VII: Elliot Cove sandstones, siltstones, and shales, intruded by thin diabase sills, Bull Island Point.

Fig. VIII: Nose of north-plunging Red Cove syncline, in tuffs (lower left) and dark-grey shales (centre) of the Deep Cove formation, Red Cove.