The Structure and Succession at North Sydney and Sydney Mines, C. B.—By Loran A. DeWolfe, M. A., *North Sydney.*

(*Read 14th March, 1904*)

CONTENTS.

INTRODUCTION.

Origin of paper.—The following paper is extracted from a thesis accepted in part fulfillment of the requirement for the degree of Master of Arts at Dalhousie University in 1903. The field work was done during the autumn of 1902 and the folllowing winter; and it and the preparation of the results have been conducted under the general direction of Dr. J. E. Woodman, who also assisted in revising the manuscript for the press.

[Contributions from the Science Laboratories of Dalhousie University; Geology and Mineralogy.]

(Communicated by Dr. Woodman).

Location of field.—The territory covered by the study lies along the northwest side of Sydney harbor. It extends from the mouth of Leitch's creek on the west, through North Sydney and Sydney Mines on the east, to Cranberry Head; thence northwest along the shore of Spanish bay to the entrance of Big pond; thence southwest to Sawmill lake, and to the Intercolonial railway track where it crosses. It thus embraces roughly an area ten miles by two.

General stratigraphy.—The strata belong wholly to the Carboniferous period; lying on the northwest side of an anticline of these rocks which runs northeast from the pre-Cambrian of George's river end of the Coxheath hills, and plunges northeast as well.

This fold dies out in Sydney harbor; and its strata on the north leg change as one goes eastward, from a normal northeast gradually to an east-west and finally a northwest strike. At the extreme east side of the extension of the fold, there arises an imperfect synclinal basin, containing the coal seams of Sydney Mines, and freeing the strike of the beds from any influence of the anticline.

From the west end of the field studied, and beyond, eastward one and one-half miles to Limestone creek, the strata have been considered as belonging to the Lower Carboniferous limestone, equivalent to the Windsor series of Fletcher, on the mainland. From Limestone creek to Stubbart point, about six miles, has heretofore been mapped as Millstone Grit [vide Brown; also Geol. Surv. Can., No. 653, Sydney sheet, 134]. The boundary between this and the overlying Coal Measures, which extend thence eastward to the ocean at Cranberry Head, about four miles, is very arbitrary as it has been defined up to the present.

Topography.—The surface of the land presents little marked topographic variation. That underlain by the Windsor series is low for the most part. While the same series on the peninsula to the south, lying between the two arms of Sydney harbor, shows sinkhole topography and blind streams, there are none here. The Millstone Grit section is undulating but in general more elevated than the others. In some places it rises sharply from the harbor to a height of one hundred and eighty feet, and its average elevation is about one hundred. Between Sawmill lake and Limestone creek, at an elevation of one hundred and thirty feet, two square miles are covered with swamp and bog. Although low land occurs on all sides in adjacent territory, the ground here remains wet throughout the year.

In the Coal Measures the average elevation is approximately eighty feet. Owing, however, to the much greater exposure to marine action, the shore cliffs are higher than farther west.

Special interest attaches to the topography of the land north and northwest of Cranberry Head. From Black point the surface slopes down to Big pond. The shores of this body, beside which the Nova Scotia Steel and Coal Company have built their furnaces, are low and in some places even swampy. On the north side of the pond is the new colliery (Sydney No. 3). Stretching down to the shore on the east is a level bog, covering about three square miles. This swamp evidently was once the bed of a post-glacial lake, in all probability somewhat above sea level. A shore section of the bog shows that it rests in part, at least, upon bedrock. How much the shore has been cut back by wave action at this point, and where the initial shoreline of subsidence stood, it is impossible to say. But the bed of the lake, then probably filled up as now by vegetation, was brought practically to sea-level; and in three places the cross-section of the bog is exposed to marine erosion. Headlands on either side of the swamp have also suffered rapid loss by this agency. But where the erosion is most rapid—at Cranberry Head and Black point—the cliffs are lowering; for the land as a whole slopes inland and toward the bog rather than seaward.

Here, then, was formerly a lake, surrounded by gently sloping glacial debris, which itself lies for the most part as a thin mantle upon the bedrock. It was of irregular outline, with at least three coves on three of its sides. These now reach to the shore line, and the sea occupies what was once their ends. The three coves are represented by (1) the sections exposed on the shore between Black point and Cranberry Head; (2) the shore of Big pond; and (3), the deepest, at Lloyd's cove, to which the sea at times has access.

An additional ten or fifteen feet would have admitted the sea to the whole of this lake basin. In that event, Cranberry Head and Black point would stand out as islands.

Shoreline phenomena.—According to the classification of Dr. F. P. Gulliver, the shore as a whole is in an adolescent stage of development, following depression. Proof of this depression hardly need be stated in detail—the presence of estuaries like Sydney harbor itself may be accepted as sufficient evidence. It may be said, parenthetically, that no positive data have been gathered showing recent elevation here.

The adolescence is shown by the forelands of Allen point and Jackson point, by South bar on the Sydney side of the harbor, by bay bars at Lloyd's cove and Big pond, and by shore swamps near Limestone creek. Finally, the rapid wearing away of the cliffs shows that maturity has not been reached. Indeed, the mouth of the harbor is still in a somewhat earlier stage in its cycle than the shore nearer the head of the estuary.

Glaciation.—The whole of the field has been glaciated, and the topography reflects in a general way a pre-glacial relief, subdued by filling up hollows and planing down eminences. The general evenness of resistance is shown by the scarcity of inland outcrops.

Striations are rare, because of the post-glacial weathering of the surface wherever unprotected by soil. At upper North

Sydney they strike N. 38° E., and are crossed by later ones running N. 58° E. One mile to the west, striae run N. 40° E. The drift itself does not show by its contours the direction of ice motion; but at upper North Sydney the surface is profusely covered with granite boulders, whose source may have been anywhere between north and southwest of this spot.

Glacial origin must be ascribed also, in part, to Sydney harbor. The upper part of Southwest Arm is deeper than the seaward part, or than the main harbor; and apparently shows a true fjord character. The channel of this arm is from fifty-four to sixty feet deep, while the main mouth of the harbor is only forty. Not until one passes the mouth of the harbor and reaches the open water of Spanish bay is depth found equal to the deeper parts within the arm. The channel of what may conveniently be called the old Sydney river, continues for four or five miles out to sea, deeper than the general bottom. While this may indicate only submergence of a normal river valley, it may also have resulted in part from gouging, as part of Southwest Arm evidently has originated.

Throughout the field, small lakes are abundant. Sawmill, or Pottle's, with an area of about five square miles, is the largest. The lakes all have a longer diameter northeast and southwest, parallel with the harbor front, and with the general direction of the glacial striae in the district. This attitude, taken with other evidence, such as the location of lakes along contacts of strata, appears to point to a glacial origin. About a mile east of Pottle's lake is a small pond and bog, called Ferris lake. It is connected with the former by a strip of swamp about 300 feet wide, probably at an earlier time part of a lake or brook bed. Ferris lake itself is in most parts but four or five feet deep, and over most of its extent is merely a wet bog. The whole area is about one square mile, of which water occupies scarcely 300 square yards. Some of the lakes are kettle holes, while others may be due to an unequal distribution of drift, creating new lines of drainage or diverting old ones.

References.—The following papers and books have been used in preparing this paper:—

Brown, Richard.

'71. The coal fields of Cape Breton.

Dawson, Sir J. W.

'78. Acadian Geology, 3rd ed.

Fletcher, Hugh.

:00. The Sydney coal fields [pamphlet, Geol. Surv. Can., accompanying three revised geological sheets.]

Gilpin, Edwin, Jr.

'86. Cape Breton Carboniferous. Nov. Scot. Inst. Nat. Sci., proc. and trans., vi, pp. 289-298.

'88. Ditto. vii, pp. 24-25, 100-117.

'89. Ditto vii, pp. 214-226.

Robb, Charles.

'74. Report on explorations and surveys in Cape Breton, Nova Scotia. Geol. Surv. Can., rep. for 1873-74, pp. 171-188.

'76. Ditto, rep. for 1874-75, pp. 166-266.

PART 1. DESCRIPTIVE GEOLOGY.

LIMESTONE SERIES.

Classes of rocks.—The study resulting in the present paper ended on the west arbitrarily at the railroad track, from the necessity of establishing an end somewhere. Thus the whole of the limestone series did not come into the field. The strata observed, however, can be conveniently grouped into three classes: —(1) a very calcareous shale; (2) a much less calcareous sandstone; (3) beds of marl and impure limestone, containing large but very variable amounts of lime. The shale, digested in HCl. leaves an insoluble residue of clay amounting to about 75%. The sandstone contains from 75% to 90% silica. The marl leaves a much smaller residue than the shale.

Inland observations.—These rocks are all exposed in a railway cutting immediately south of Limestone brook. They lie conformably, showing good contacts between the sandstones and calcareous shales, and dip 30° N. The sandstone here breaks into large flags suitable for building purposes. Ripple marks exposed on the under surface, wherever the underlying shale has fallen away, show wind from the south. At another horizon, a mile away, markings show an east wind.

The direction of dip here is important, as well as the amount, which is greater than in the Coal Measures to the east. The strata are under the immediate influence of the granitic core of the Boisdale hills to the southwest.

From this cut downward along Limestone brook, the ground is low and swampy, and gives no outcrops. On Fletcher's recent map (:00) this brook is given as the boundary line between the lower series and the Millstone Grit, except for about half a mile where limestone is given on both sides. Finding no exposures, I am unable to verify his conclusions. At the mouth of the brook, however, the contact is at least two hundred feet southwest of its stated position, for grit is exposed throughout that distance. The map also indicates fossils near the bank of the brook, nearly a mile from its source. I was unable to find there any exposures of bedrock; but a large slab of drift sandstone contains some fossils.

Section along shore.—For about a mile eastward from the mouth of Leitch's creek, the banks are low and give no cliffs; but the glacial debris is shallow, and the rock frequently outcrops on the beach. These exposures show a calcareous sandstone with a laminated shaly structure, the rock crumbling easily. It is possible that these strata alternate with concealed limestones and marls, as farther east.

Eastward toward the top of the series the cliffs become higher and more continuous. Beds of calcareous sandstone, calcareous red and green marl, and gray compact limestone alternate rapidly. The sandstone varies in compactness and texture, some breaking into slabs of several square feet, but scarcely one-fourth to one-half inch thick, while others form large cubical or rhombohedral blocks. The last varieties are especially well mottled with streaks and lenses of carbonaceous matter, so regularly arranged as to give considerable relief to the usual monotony of color in the cliffs. All the sandstones are red or brown, except a six-inch bed of hard gray rock, almost a quartzite, which overlies one of the gray limestone strata. Some of the flagstones are well ripple-marked, the wind having come from the east, and contain fine worm-like trails, too indistinct to ascribe to any particular origin. Rain-prints are also exposed on these beds. The weathering is often irregular, in one instance the softer black carbonaceous matter having entirely disappeared, leaving a skeleton rock.

The calcareous marl exhibits all degrees of cohesion between clay and shale. A bed of gypsum lies between two of marl; and the overlying stratum of the three is practically all clay, and contains a few small bedded stringers of fibrous gypsum, each about one-fourth inch thick. The limestone is of a slate-gray color, compact in texture, but not gritty.

Succession.—A section of this formation is more difficult to get than of either of the others. The lower part consists of about 200 feet of laminated, shaly, micaceous sandstone, with a considerable proportion of lime. In some parts the rock may fairly be called a limestone. Above this a nearly continuous section of 179 feet in vertical thickness, beginning at the bottom and ending with the Millstone Grit, is as follows:—

red shale	2 ft.	
gray limestone	2	
gray, hard sandstone	—	6 inches.
mottled brown calcareous sandstone	20	
red calcareous marl	10	
gypsum	8	
clay marl with gypsum stringers	10	
limestone	2	
marl	8	
thin bedded flaggy red sandstone	20	
marl	10	
brown rippled sandstone	20	
green marl	8	
flaggy sandstone	15	
limestone and marl	12	
mottled sandstone	20	
ironstone	12	
	179 ft.	6 inches.

Ironstone contact beds.—The last twelve feet of the limestone formation consists of a hard and somewhat felspathic rock, light flesh in color, and containing a variable quantity of hematite. The corresponding rocks on the opposite side of the harbor contain more iron. The surface of the exposures softens and crumbles to a depth of half an inch.

No topoографhic change marks the contact of the two formations. The exact contact is, indeed, concealed. On the map sheet of the geological Survey of Canada (Sydney sheet, 134), Limestone brook is regarded as the dividing line; but at its mouth it is well into the Millstone Grit. Here Limestone creek, the tidal portion of the brook, makes in for about 200 feet with a depth of eight to ten feet, after which it shoals to two or three feet and swings westerly, almost parallel with the harbor. This brings the mouth of the brook proper about 800 feet from harbor front.

"MILLSTONE GRIT."

Succession.—For want of data based upon sufficiently wide field study, the various formations are retained in this paper as designed by Fletcher's map (Geol. Surv. Can., Sydney sheet, 134), even though the reasons for delimiting them in precisely that way are not clear. Within the so-called "Millstone Grit," the succession upward is as follows, ending on the east at Stubbert's point:—

coarse grit and conglomerate	500	feet.
measures hidden	200	
conglomerate	5	
fine laminated sandstone	10	
conglomerate	30	
sandstone	10	
conglomerate	2	
sandstone and arenaceous shale	115	
measures hidden	1,000	
sandstone	400	
arenaceous shale	30	
conglomerate	5	
sandstone	300	
measures hidden	900	
coarse sandstone, in part a breccia	200	
underclay	2	
coal (Ingraham seam)	2	
shale and sandstone	41	
red marl	3	
conglomerate	8	
coarse sandstone	280	
fine "	100	
arenaceous shale	6	
sandstone	60	
	4,209	ft.

Conglomerates.—At the base of this formation, the texture is on the average slightly coarser than is the case higher up. Some strata grade into finer or coarser beds, but in most instances the contact is an abrupt one. Not far above the base, a few strata of mixed conglomerate and breccia have been found, interbedded with fine sandstone. The rocks at this point are very ferruginous, in some spots sending out small streams of rusty water. The pebbles are almost entirely quartz. Sharp angular pieces and rounded pebbles occur together, such as one often finds upon the beaches of to-day. There is usually a sharp line of demarkation between the conglomerates and sandstones, showing that the conditions of deposition changed somewhat abruptly. The mixture of angular and rounded pebbles suggests the proximity of a cliff at the time of deposition.

It is difficult to determine the thickness of the conglomerate, as only parts of the beds are exposed, but the best estimate possible gives thirty feet as the total.

Coal.—Throughout the whole upper half of the formation coal seams occur, ranging from one-fourth to two inches in thickness.

About 386 feet below the base of the Coal Measures is a bed of shale, the first encountered in the Millstone Grit. It contains both arenaceous and argillaceous varieties, and a thin layer of red marl. The lower shale grades upward into sandstone, and this again into shale, twenty-five feet thick. At the base of this shale lies the Ingraham seam of coal, which, however, is not exposed on the sea cliff. I am informed by old residents that this coal measured two feet, and was worked many years ago for local supply. It has long since been abandoned. A section of the associated beds at this horizon would be as follows, in ascending order:—

underclay	2	feet.
coal (Ingraham seam)	2	
arenaceous shale	6	
sandstone	10	
arenaceous shale	15	
argillaceous shale	10	
red marl	3	
coarse gritty sandstone and conglomerate..		

The total thickness of shale here amounts, then, to thirty-six feet. This "Ingraham seam" is not to be confused with the "Ingraham mine", to be mentioned later.

A new occurrence of coal has recently been reported. Mr. John Redmond, Upper North Sydney, while boring for a well on his farm, struck what is reported to be a two-foot seam. The land is under lease by Rev. Father MacPherson, of Little Bras D'Or. His brother informs me that the new discovery consisted of two feet of good coal, which with shale, clay, etc., makes a belt of six feet. No openings have been made, so that no information can be given at first-hand. If the occurrence is real, it is noteworthy as showing coal at a greater distance below the Coal Measures than has heretofore been recorded in this part of the Sydney basin.

Fossils.—Vegetable remains occur at many horizons, the most abundant being Calamites. None have been found erect. Indistinct remains of Sigillaria are also numerous. In a few places may be seen a net-work of leaves, sticks, etc., irregularly washed together; but none distinct enough to show structure. Impressions of large stems more than a foot in diameter occur, but so nearly obliterated as to leave only a coating of rust, without any detail of the original form.

Variation in dip.—Throughout this formation the dip changes considerably. At Limestone creek it is about 40° N.; but eastward along the shore it becomes less, the average for three miles being about 12°, and turns eastward. In the vicinity of North Sydney and from there to Cranberry Head the dip is northeast, becoming constantly less until in the Coal Measures it is only 6°.

Back from the shore there are few exposures, most of those found being in railway cuts. As these are not far from the water, their dips are the same as in corresponding cliff exposures. On Fletcher's map an outcrop is recorded as being near the railroad, one mile east of North Sydney Junction, with a dip 25° E. There appears to be no bedrock here; but a large boulder was found, thrust up above the ordinary level, and its strata in the attitude described.

A dip section, to be accurate, would run northeast and southwest, with a curve southward in the western part.

COAL MEASURES.

Contact strata.—Although the boundary between the two formations have been placed at Stubbart point in maps heretotofore published, there are many strata of coarse sandstone above it, and several small coal seams below. The sandstones, are, however, not so massive as those in the lower group, and the however, not so massive as those in the lower group, and the coal seams outcropping on the coast are unimportant as regards thickness and amount. The boundary has been placed, then, where a change occurs from beds prevailingly arenaceous to beds prevailingly argillaceous; and while its exact position may be a matter of debate, its general location may be regarded as established.

From the shore at Stubbart point the contact follows a more or less arbitrary line northwest to Little Bras D'Or lake. It is roughly traceable by a line of large sandstone boulders which are scattered in profusion over the ground, and whose presence has been attributed to the greater wearing away of the softer argillaceous rocks of the Coal Measures, and the consequent breaking down of the harder and topographically higher Millstone Grit. Conclusions here, however, must be based largely upon conjecture, as no exposures are to be found inland. On the geological map of the Survey (No. 134) the boundary curves considerably. This, and the curving of the coal seams, would be due largely to the basin-like structure, but also in part to topographic differences. Since the beds dip northeast at a low angle, rising ground would extend horizon outcrops noticeably to the southwest. The surface rises rather suddenly from the harbor, and slopes from the divide gradually toward Big pond, thus giving to the eroded edges of rock horizons a crescent shape.

Divergence of outcrops.—The separation of horizons at the surface is noticeable from the harbor to Big pond. This is due in part at least, to the differences in dip. On Sydney harbor the dip is six degrees, while at Big pond and Black point it averages four to five. This difference in beds so nearly flat cannot but have some influence upon the location of the outcrops of two horizons between which lies a constant thickness of rock. The same condition obtains south of the harbor, at Victoria mines and southeastward.

Succession.—Beginning at the lowest strata, on the east side of Stubbart point, and going northeastward to the highest rocks at Cranberry Head, the order is as follows:—

	ft.	in.
arenaceous shale	20	
marl and clay, with small coal seams	20	
underclay	2	
coal	—	10
sandstone	20	
shale	25	
coal (Stony seam; contains 6 inches of rock)	3	
shale	10	
sandstone	12	
shale	4	
sandstone	3	
shale	6	
impure limestone	—	6
red marl	10	
shale	30	
coal	—	6
shale	2	
sandstone	8	
coal	1	
argillaceous shale	20	

	ft.	in.
sandstone	2	
argillaceous shale	25	
marl	15	
arenaceous shale	5	
sandstone	15	
arenaceous shale	5	
measures hidden	20	
bituminous shale and coal, (Indian Cove seam)	5	
shale	4	
sandstone	15	
arenaceous shale	15	
limestone	3	
shale and red marl	6	
sandstone	2	
shale and red marl	17	
shale	2	
shale and red marl	12	
massive sandstone	20	
clay and shale	6	
coal	1	3
argillaceous shale	2	
sandstone	15	
arenaceous shale	6	
clay	2	
coal	—	8
argillaceous shale	2	
sandstone	26	
argillaceous shale	5	
arenaceous shale	26	
argillaceous shale and marl	36	
coal	—	10
shale	—	6
sandstone	25	
arenaceous shale	25	
argillaceous shale	15	
arenaceous shale	2	
argillaceous shale	2	
sandstone	2	

	ft.	in.
argillaceous shale	4	
limestone	—	8
sandstone	3	
argillaceous shale	15	
limestone	—	4
red marl	2	
green marl	5	
red arenaceous shale	6	
arenaceous shale	20	
sandstone	6	
marl	6	
clay	2	
coal	—	4
clay and shale	1	3
coal	1	
shale	8	
sandstone	6	
arenaceous shale	5	
sandstone	6	
argillaceous shale (erect trees and many plant remains)	6	
clay	2	
coal (Sydney Main seam)	6	
marl	15	
sandstone	20	
arenaceous shale	3	
sandstone	8	
shale	8	
limestone	2	6
marl and clay	3	
bituminous shale (with *Naiadites*)........	—	2
argillaceous shale	17	
bituminous shale (with *Naiadites*)	—	1·5
argillaceous shale	6	
sandstone	6	
argillaceous shale	15	
sandstone	15	
red marl	2	
shale	15	

	ft.	in.
coal (with calcareous underclay)	—	4
shale	3	
limestone	1	
shale	3	
limestone	2	
shale	26	
marl	4	
coarse sandstone	26	
shale (with erect *Calamites*)............	15	
limestone	—	4
shale	1	
blue sandstone	20	
arenaceous shale	4	
limestone	—	4
red marl	2	
arenaceous shale	3	
sandstone	15	
arenaceous shale	15	
argillaceous shale and red marl..........	26	
shale and underclay (*Stigmaria*)........	2	
coal	—	2
shale	4	
sandstone	4	
shale	4	
coal	—	2
shale	26	
sandstone	3	
clay	—	3
coal	—	3
shale	2	
coal	—	3
shale	1	6
coal	—	2
clay	—	2
coal	1	4
shale	4	
sandstone (quarry)	24	
shale and fire-clay	3	
coal	—	9

	ft.	in.
clay	—	3
coal	—	1
shale	6	
sandstone	24	
shale	20	
clay	—	6
coal	—	3
shale and underclay	5	
coal	—	4
shale	—	5
coal	—	7
sandstone	25	
clay	1	
coal	1	
strata mostly concealed	215	
argillaceous shale	20	
arenaceous shale	6	
argillaceous shale	10	
coal (Lloyd's Cove seam)	6	
blue marl	10	
arenaceous shale	2	
sandstone	5	
shale and underclay	1	
coal	—	6
black shale	—	6
coal	—	2
blue marl	8	
arenaceous shale	10	
blue marl	2	
coarse conglomeratic grit } Swivel	6	
sandstone } point	12	
sulphurous marl (upper ten inches almost red ochre)	6	
argillaceous shale (thinning out laterally into sandstone)	20	
gray fine sandstone	20	
red marl	2	
blue marl	5	
red marl	2	

	ft.	in.
limestone	5	
red marl	1	
argillaceous shale	50	
arenaceous shale	10	
argillaceous shale	5	
red marl	6	
blue marl	5	
red marl	10	
argillaceous shale	20	
sandstone	4	
arenaceous shale	5	
argillaceous shale	15	
red marl	5	
argillaceous shale	3	
clay	2	
coal (lower seam, Cranberry Head)......	1	
argillaceous shale	3	
sandstone	5	
argillaceous shale	11	
underclay	1	
coal (upper seam, Cranberry Head)	3	6
shale (to top of Cranberry Head).......	15	
	1,735 ft. 6in.	

Details of shore section.— Stubbart point stself is a salient of cross-bedded sandstone, which has been able to withstand marine action better than the shales overlying it and outcropping to the east of the point. Passing to the Stony seam, 88 feet above, the cliff was so covered with talus at the time of this study, that I was unable to examine the coal. Robb ('74) says that it has a fossiliferous limestone base. If so, this is the lowest occurrence within the Coal Measures, and none is known in the Millstone Grit.

The two next overlying seams, one six and the other twelve inches thick, are separated by sandstone which contains a number of Sigillaria trunks, six to eight feet in length. The sandstone grades laterally into shale, and thins out so that the coal beds converge, but they do not meet within the limits of the section.

Indian Cove seam.—About eighty feet of strata, in part concealed, separate the last named seam from the Indian Cove seam. This is four feet thick, has a micaceous underclay, and a bituminous shale roof. The roof is calcareous and fossiliferous, containing large numbers of shells of Cytherea. The seam is worked by the Sydney Coal company, under the name of the " Greener mine." The coal contains a large amount of pyrite, which has decomposed near the outcrop. The rusty water from the opening on the shore is rapidly cementing the beach material into a conglomerate. On the Big pond end of the same seam is the long abandoned Ingraham mine, which was worked nearly thirty years ago for local use. In the old trenches remaining from this early work, a considerable quantity of iron has been deposited, resembling ordinary bog iron in appearance.

Section to Lloyd's cove.—Above the Indian Cove seam, there is a continuous rock cliff almost to Lloyd's cove, a distance of about two miles, and representing a vertical stratigraphical height of 1125 feet, including 215 feet largely concealed, on the east end. The argillaceous and arenaceous layers alternate rather regularly, and contain a few thin limestones. The approximate proportion of each is :—sandstone 316 feet, shale 534 feet, marl 36 feet, limestone 10 feet, bituminous shale 3½ inches, coal 16 feet, concealed 215 feet.

To show the relative arrangement of these beds, a condensed section of this part of the field may be of interest. Sandstone, shale and marl are here grouped under the general term " strata." Indian Cove seam, with its fossiliferous roof containing Cytherea, etc., has been described. Above this the section is as follows :

	ft.	in.
strata	34	
limestone	3	
strata	65	
coal	1	3
strata	27	
coal	—	8
strata	90	
coal	—	10
strata	75	
limestone	—	8
strata	18	
limestone	—	4
strata	47	
coal	—	4
strata	1	3
coal	1	
strata (with erect trees)	33	
coal (Sydney Main seam)	6	
strata	54	
limestone	2	6
strata	3	
bituminous shale (with *Naiadites*)	—	2
strata	17	
bituminous shale (with *Naiadites*)	—	1.5
strata	59	
coal (with calcareous underclay)	—	4
strata	3	
limestone	1	
strata	3	
limestone	2	
strata (with erect *Calamites*)	71	
limestone	—	4
strata	25	
limestone	—	4
strata	63	
coal	—	2
strata	12	
coal	—	2
strata	29	3
coal	—	3

	ft.	in.
underclay	2	
coal	—	3
shale and underclay	1	6
coal } Chapel point	—	2
clay } Chapel point	—	2
coal } Chapel point	1	4
strata	28	
fireclay	3	
coal } Chapel point, upper seam	—	9
clay } Chapel point, upper seam	—	3
coal } Chapel point, upper seam	—	1
strata	50	6
coal	—	3
underclay and shale	5	
coal	—	4
shale	—	5
coal	—	7
sandstone	25	
clay	1	
coal	1	
concealed measures, of Lloyd's cove	250	

In this section there are eight beds of limestone, with a total thickness of ten feet, and nineteen coal seams with a total thickness of fifteen feet. Every seam possesses its underclay except one or two very thin layers; and Stigmaria rootlets abound. Hence it can scarcely be doubted that these seams for the most part have accumulated from vegetation in place. The term "strata," as used above, includes a few beds of underclay with rootlets, but containing no accompanying seam, showing that in some cases the vegetable matter was prevented from accumulating.

All the limestone layers are very similar in character, except the eight-inch one between the Indian Cove and Main seams. This is very compact and semi-crystalline, and of a brownish gray color. The others are coarse and bluish gray, somewhat crystalline and frequently brecciated. All rest upon shale, while all except one have shale or marl immediately overlying. In the exceptional case, sandstone is above limestone.

Fossils.—The strata next below the Main seam give the best illustrations of erect tree trunks, of any on this coast. There Sigillaria from one to three feet in diameter show eight to ten feet of their length through beds of sand and shale. I found none with roots attached, but in one case the trunk is easily traced into the shale overlying a seam. The trees visible in these beds taper rapidly. The original bark forms a thin layer of glossy coal, the interior being filled with shale or fine sandstone.

Fern-like leaves and petioles are abundant in the sandstone surrounding the erect trees, lying with so little distortion that they must have fallen into still water or soft mud, and have been buried before they became disarranged. In several cases, leaves appear in the inferior layers, but no branches; and in higher strata branches are found. The rising sediment may have killed the tree gradually, leaving it at last shorn of its leaves, but with branches intact. These fell later into sediment newer than that which had received the leaves. The time came, however, when the dead top fell also, and was borne away; for now the truncated bole stands with overlying masses of rock which contain no trace of the missing wood.

While the sediment must have accumulated comparatively rapidly, to bury trees before they could decay and fall, it did not prevent other trees from taking root and growing to a considerable size. For erect trees are found in the same cliff at but slightly different levels. They were probably swift growers, but perhaps tenaceous of life and slow to decay. These qualities would readily explain the conditions under which we now find them. That the bark decayed more slowly than the wood is evident from finding the former carbonized, while the space once occupied by the latter is now filled with sandstone, or less commonly clay or shale.

In all this section, sand beds are replaced laterally by shales, or thin out into them. The clay must have accumulated until the water was comparatively shallow, then sand spread over it, thinning out as depth increased. After this had gone on for some time, the sea bottom was depressed and into the deepening water only mud could be brought. The clay overspreading the sand and extending beyond it enclosed a wedge of sand similar in shape and situation to those now exposed.

Main seam.—This seam is not well exposed in the cliff, so that information concerning it had to be gained from the mines. It is six feet thick, overlain by soft flaggy gray shale containing particularly good plant remains. The following are especially abundant:—Neuropteris cordata, Cyclopteris acadiana, Pecopteris, Alethopteris, and leaves of Cordaites.

Details of section to Cranberry Head.—Fifty feet above the Main seam lies a limestone horizon two and one-half feet thick, and crystalline. Three feet of marl and shale separate it from two inches of black bituminous shale, containing a multitude of fish scales and shells of Naiadites. Twelve feet above is a second similar layer, in which the shells compose nearly the whole mass. The species represented are Naiadites elongatus and N. laevis. They are supposed to be proof of brackish water or lagoon conditions.

The shell beds are succeeded by shale with a little sandstone to a depth of fifty feet, which in turn is followed by four inches of coal with a calcareous underclay. Three feet above the coal lies one foot of limestone. The underclay could not have got its lime from washings from this bed, for in that case, the intervening shale would also be calcareous. This is not the case ; consequently the underclay must have accumulated its lime independent of the bed above.

From this level to the top of the visible layers at Cranberry Head, clay ironstone nodules become more abundant. In some beds, they make up nearly one-fourth of the whole material.

The strata at the particular horizon now reached are less uniform in their nature and arrangement than either above or below. Sandstone shades off laterally and vertically into arenaceous and argillaceous shales, and *vice versa*. These horizons then must represent a comparatively prolonged period of rest, during which the debris arranged itself according to coarseness—the coarser sand being deposited nearest shore, while finer and finer material was laid down as depth increased, until at last only the finest clay was deposited. As this went on, the cliffs wore back until they were so far from the earlier shore that the coarsest sand did not reach that water at all. Then only the finer sand, and at length clay, spread over the original coarse sand. This would produce a gradual change from coarse to fine material both seaward and upward, so that now sandstones and shales of all varying textures merge into each other.

Tracing the strata upward through three feet of shale and two feet of lime, another layer of shale follows containing erect Calamites. Nearly all the shale here and for a long distance above, is argillaceous. Changes usually take place suddenly from coarse sandstone to fine clay without the intermediate stages that one might expect. Next above the shale with Calamites, in addition to two thin bands of limestone, are twenty feet of blue gritty sandstone, very much cracked. Since there are no faults or folds here, or any other structure different from that of the preceding beds, it is possible that this sand owing to some peculiar conditions held more water at the time of deposition than the other beds. Later, the drying of the stone caused shrinkage cracks producing the effect now visible.

The next sixty feet of strata present evidence of deposition on a more uneven bottom or in the presence of more erratic currents than any other part of the whole field under discussion. Shales have been cut away and filled with sand, in a remarkable manner.

Proceeding to the next overlying strata, several small seams of coal are found distributed as in tabular section on pages 304 and 309. The sandstone overlying the sixteen-inch seam is a good building stone, a considerable quantity of which has been quarried for local use. It is rich in fossils of the genera Sigillaria and Lepidodendron. Here, too, I found a cast of the pith of a Calamodendron. It very much resembles the stem of Calamites, but is distinguished by the absence of leaf-scars. The Calamodendron, as now found fossil, appears to be the pith of a stem which had a thick bark and woody coating. This pith doubtless decayed first, and the hollow stem filled with sand or clay. Later the outer part disappeared, leaving a stone cast of the interior. Although this quarry stone contains numerous fossils, very few remain distinct enough to determine their species. Sigillaria trunks are found varying from two to eighteen inches in diameter.

Nearly all the coal seams have clay or shale above them. One, however, the last but two before Lloyd's Cove seam, is overlain by very coarse, gritty micaceous sandstone. Conditions succeeding the formation of this coal must have been somewhat different from those succeeding previous beds. The ordinary fine clay and shale usually overlying the vegetable matter came from the gentle filling up of swamps with fine material during a period of slow gradual subsidence. The coarse sandstone, on the other hand, must have been deposited in moving shallow water near shore. This may very likely have come about by a sudden but comparatively slight subsidence after the prolonged interval of rest during which the coal had accumulated. For, if depression had not been sudden, the water would not have attained sufficient depth to produce waves capable of moving and spreading out the coarse sand without any intervening layer of clay. Nor could the depression have been very great, for then the water would be so deep that coarse sand could not be carried out any distance over the sea-floor. A second possibility is the influx of sand from the action of storms breaking over the low bars into the lagoon behind. In this sandstone, false-bedding is extremely common, but with no particular current direction. Its presence indicates the probability of vertical oscillation rather than flooding as a source of the sand. Much of the material bears evidence of deposition in shore coves where current eddies would give more irregular bedding than would be possible on a straight shore.

Lloyd's cove making in directly over the measures just described, cuts off observation of the next 200 feet of strata. Crossing the cove, however, the section becomes continuous, remaining so to Cranberry Head—the end of the land surface of this district. Lloyd's Cove seam itself is cut off from view by detritus from the old workings. It is six feet thick, but is cut into three parts by two thin layers of clay. There are two slopes working at present on it, while it is cut at a depth of eighty feet in the "Princess" pit.

The next coal seam is separated from Lloyd's Cove seam by eighteen feet of shale. It contains only five inches of coal, divided into two bands by eight inches of soft shale. From here to Cranberry Head the strata consist largely of shale, with a few bands of sandstone and marl. The total thickness from Lloyd's Cove seam to the Head is about 300 feet. At the headland, two coal beds occur, with fifteen feet of shale and fireclay between them. The upper seam is three and a half feet thick; the lower, one foot. Under the lower seam are one foot of fine clay and two feet of fireclay with Stigmaria rootlets, the whole resting upon gritty shale. The fine shale overlying the upper seam is extremely rich in fossils and leaves of ferns and Cordaites, etc. No other rocks in the whole region except the roof of the Main seam can equal it in its fossils. Some of the plants found here are Sphenophyllum schlotheimii, Pecopteris arborescens, Odontopteris, Sphenopteris gravenhorstii, Pecopteris. Many Cordaites leaves here measure three inches across. About ten feet of strata still overlie the upper seam, before the top of the Head is reached. When the land wears back thirty feet more, however, not a trace of this coal outcrop will remain above water.

Cranberry Head is about forty feet high, standing upon a sandstone base. Since water level on either side finds soft shales, these have worn away, leaving the outstanding firmer sandstone. The front of the head, too, is parallel with the strike, and the dip is directly seaward. These conditions give less chance for wave attack than would otherwise exist. Notwithstanding this, the head must eventually wear away. Brown, writing in 1871, said: "A block, 20 yards square and 15 yards high slipped off from Cranberry Head, forming an island." Although this was not very many years ago, no trace of the "island" now remains. Moreover, as the sea works landward, the cliffs are becoming lower; for here the land surface slopes away from the sea.

Black point.—Around Cranberry Head no new measures are exposed, for the shore either follows the strike or cuts back into beds already seen. At Black point, about a mile from Cranberry Head, are good exposures of coal and strata. The point is sandstone, much broken into cubical blocks, which aids the sea action in rapidly eroding it back. Three coal beds crop here. The lower is one and one-half feet thick, with a foot of fire-clay, resting upon sandstone. Above are six inches of fine clay and marl, then coarser shale ten feet to the middle seam, which is one foot thick. Sixteen feet higher is the third seam, three feet thick, with coarse sandstone above and clay and shale below. All these clays contain Stigmaria rootlets, while the sandstone contains Sigillaria and Calamites. Mr. Charles Robb says these Black Point seams are the same as those cropping at Chapel point. Their enclosing strata go far towards proving his conclusion to be correct. This is especially true of the coarse gritty limestone overlying a coal bed at each point. I have found no other coal seam without clay or shale immediately above. In default of this evidence, however, one would be disposed to call the Black Point beds new ones, owing to the increase in their thickness and in that of the intervening strata between the two places. But it is not hard to believe that such diversity could occur in that distance, for a difference of some inches in coal and of some feet in strata is often seen in the part exposed in one cliff. Moreover, the Indian Cove seam, for example, where it is now worked near the outcrop, is four feet thick; while in some other places it has been cut through in two feet. The Main seam presents undulative and varying thickness as it is worked at different points. With these facts in view, it is quite probable that the Black Point and Chapel Point seams are the same.

PART II. SUMMARY OF HISTORY.

The rocks included in the area under discussion are all sedimentary. Nearly all give evidence of deposition in shallow water. This could happen throughont such great depth only in the case of a slowing sinking land. There are a few indications of more rapid or sudden sinking, but rocks formed under suddenly changed conditions are a very small part of the whole deposit.

LIMESTONE SERIES.

Limestones.— The total thickness of strata from Leitch's creek to Cranberry Head is about 6400 feet. The lower beds at Leitch's creek are a laminated calcareous sandstone resting upon limestone. The presence of limestone containing marine fossils is proof of formation under the water of the open sea. After this condition had remained for some time the waters, which must have been shallow, became partly flooded with sand. Its deposition was probably slow, thus allowing it to be so thoroughly impregnated with lime. Since this sand now forms a bed nearly 200 feet thick, gradual depression must have taken place for a long time. At last some change in the supply of detritus brought clay instead of sand, now forming a bed of red shale two feet thick. This is succeeded by limestone which could have come from two sources. Either it could have been carried from some land reef of limestone by water containing carbon dioxide derived from decaying vegetation and deposited subaerially, by evaporation of water or by loss of carbon dioxide, or it may have been formed under the sea from shells. The presence of land or marine fossils would decide the question one way or the other. I have failed to find them, but Mr. Brown and Mr. Robb report marine fossils. This makes it an ordinary shell deposit. Re-elevation at last brought an end to the formation of limestone, and renewed the supply of sand which in turn was succeeded by clay as before. After a prolonged period of clay deposition the waters at length became clear, and gypsum was deposited.

Gypsum.—Two theories have commonly been advanced as to the origin of gypsum beds :—(1) formation by the action of sulphuric acid on limestone ; (2) precipitation from water solutions by other salts, or by partial evaporation. In the case before us either method could have operated. The rocks both above and below are limestones containing iron. The most fundamental compound of iron occurring in nature is ferric sulphide, iron pyrites. By oxidation or through organic influence, this iron is often changed to oxide or carbonate, and finally in a state of solution impregnates other rocks. The sulphur goes to form sulphuric acid. The presence of iron in these rocks points to a probable presence, then, of sulphuric acid. It being supplied, and the limestone already at hand for it to attack, gypsum could result just as we find it.

On the other hand, since it is so regularly bedded in material evidently accumulated under water in a territory of alternate elevation and subsidence, there is no valid objection to the precipitation theory. In some parts of the world, beds are undoubtedly of this origin, where they alternate with rock salt. The absence of an overlying salt bed here can be readily accounted for, from the evidence of seashore and marine deposition where water could not be sufficiently concentrated to precipitate its common salt. It is possible, moreover, that the land was never sufficiently elevated to form inland seas, where gypsum could be deposited as a result of evaporation. On the whole, the sulphuric acid theory would seem more probable.

A third method of gypsum formation is sometimes attributed (according to W. P. Blake—Trans. Am. Inst. Min. Eng., 1901, p. 715), to collections on dry arid surfaces after the manner of the *caliche*. Since the structure here, however, points to totally different conditions from those belonging to such formations, we may dismiss the subject.

Whether the gypsum was deposited by the concentration or sulphuric acid method, clearly it indicates, like the limestone, a temporary exclusion of the clay supply. Later this supply was renewed, forming the next layer of marl; which, however, was somewhat irregular, as proved by the stringers of bedded gypsum running through it.

The changes outlined above succeeded each other alternately for long periods, since lime, shale, marl, and sandstone alternate until an additional thickness of two hundred feet have accumulated. That it is all calcareous, indicates its deposition under sea water. Ripple marks and rain prints occur at different levels, while material in some cases is uniform for some considerable depth, proving slow subsidence. The occasional sudden change from lime to sand or shale, proves intermittent sudden changes of depositional conditions. This is further evident from ripple marks at a contact of fine shale and coarser sandstone in the railway cutting previously mentioned. The fine shale was deposited in comparatively deep water, or on a mud flat. With a sudden elevation, however, sand was laid down on the shore, for the ripple marks are in the first layer of sand overlying the shale.

At length these oscillatory movements ceased, and for a very long time slow and continual subsidence prevailed, without any intervening elevation. The depression was just rapid enough to allow accumulation to keep pace with the sinking sea bottom, so that shore or shallow water deposits are continuous for great depths. The advent of this permanent period of sinking marks the beginning of the formation of the Millstone Grit series.

Ironstone.—Between the Limestone and Grit is a bed of impure ironstone. It is possible that this was formed in part later than the adjoining beds as a bedded replacement deposit. The limestone being more soluble than the overling grit, would gradually dissolve away by water following the contact line. The grit is a coarse grained permeable rock, while the limestone is of much finer texture. Water leached from the overlying beds, then, soaked down and overspread the limestone surface, carrying away lime in solution. Iron compounds already existed in the limestone, while additional quantities would be brought in from the grit above. These were deposited in the form of iron oxide in the place previously occupied by lime. This is apparent from the fact that all the calcareous sandstones are red or brown from iron, while the overlying grit is gray as if leached ; and also that the rock containing the iron is silicious to clayey, similar to that containing the lime.

MILLSTONE GRIT.

Cross-bedded sandstones.— With the introduction of the Millstone Grit, variety ceases. In one or two cases an irregularity occurred, sufficient to accumulate beach detritus, which now appears as small beds of conglomerate. In general, however, sand was laid down in shallow water. It graduated from coarse to fine, both laterally and vertically, but the change was seldom abrupt. A few sudden depressions succeeded periods of rest, as is seen in comparatively fine sand resting on conglomerate. False bedding is common, and nearly always in the direction of the dip. Shore phenomena are also evident, from horizontal stems of Calamites, Lepidodendron, and Sigillaria, where they were probably thrown down as driftwood as at the present day. Now and again tangled masses of leaves and twigs occur as if brought there by some current.

Coal seams.—True coal seams are small and few. One often finds coal bands extending only a few feet, and not more than an inch thick. Since they usually contain no underclay, and are of limited lateral extent, they probably represent small masses of leaves and driftwood buried quickly. When true seams do occur, they possibly do not extend far, but have been formed in small restricted shore swamps, much after the manner of the thicker seams of the Coal Measures. The conglomerates contain more iron than the surrounding grit. A conglomerate layer, be it ever so small, usually exudes rusty water. This is due partly to the cementing iron, but is to be explained in part also by the fact that the more porous conglomerate acts as an underground drain by which the grit continues to be further leached of its iron.

The Ingraham coal seam is the only coal that has been worked in the Grit. It must have been formed during a period of temporary elevation of the bottom, or in a cove that had been shut off from the sea. If it had formed during a period of rest, when the land had risen merely by accumulation of detrities, the intervening beach stage with its conglomerate might be expected. This does not exist. The more probable view, therefore, is that since this bed has not been traced far, it is of small extent and formed in a large cove that had been closed up by a bay bar. As the land sank, the bar grew in height until a silting up of 25 feet of shale and underclay in addition to two feet of coal had accumulated. Then the sea again broke over the bar covering the whole area with coarse sand which now almost approaches conglomerate. No part of the bar, if such existed is now visible.

From here to the top of the Grit series no important change in the structure takes place. At Stubbart point, which has been fixed upon as the boundary between the Grit and the Coal Measures, alternations of shale and sandstone again appear. The oscillations which had marked the period of the Limestone series, but which had almost totally ceased during the formation of the Grit, were resumed. They continue throughout the deposition of the Coal Measures proper; but on the whole, greater elevations were attained here than in the other series, hence greater periods of growth of terrestrial vegetation.

COAL MEASURES.

Alternations of strata.—The alternations of sandstone and shale have already been commented upon. Since the rocks often contain erect trees and undistorted ferns, they must have been deposited in shallower but quieter water than those of the preceding series. The presence of small shells, mostly determined to be fresh water species, and the absence of purely marine limestone fossils, all go to show periods of vegetable growth and sediment deposited in inland swamps and lagoons. The beds of coal and shale often being covered with sandstone, however, may show subsidence or floodings at frequent intervals. Mr. Brown reports finding rill marks, rain marks, and footprints of land animals near Lloyd's cove and in shale overlying coal. These discoveries, with their distribution, prove the proximity of ancient shore lines.

All these beds in turn have had their period of depression beneath the sea, where the pressure of the ocean and the overlying strata has brought about those changes necessary to form solid shale, sandstone and coal. At last, however, they again were forced up by the orogenic activities which gave rise to the Coxheath and Boisdale hills, and became part of the great compound Sydney basin to the east.

DYNAMIC CHANGES.

Uplift against pre-Cambrian.—To the southwest of the Sydney district as a whole are two mountain cores of pre-Cambrian rocks. One of these forms the Boisdale hills, the other the Coxheath hills. Both were uplifted at the close of the Carboniferous. In some portions of the province, as Cumberland county, Permian strata have shared in the general deformation; or as in Pictou county, have been slightly deformed, but less than the Coal Measures. Thus there appears to have been a general orogenic disturbance at the close of the deposition of the Coal Measures, with less, and perhaps more local, warping during or after the Permian.

As no Permian is met in the Sydney district, the exact date of uplift cannot be fixed; but it is to be presumed that it was at the close of the Coal Measures, or Carboniferous proper.

The effect was to make a large syncline in the form of a partial basin, with its margins well defined on the northwest, west, southwest and south. This was broken up into subordinate basins largely by the influence of the two cores of old rocks referred to above. The Coxheath core most affected the area under discussion; and its effects may be seen in the northwest dip of the Carboniferous near the head of Sydney harbor, changing gradually to the normal northeast dip as one recedes from the source of influence.

Both the mountain cores gave to the enwrapping sediments the attitude of local anticlines, plunging sharply northeast, and dying out near the present shore of the island. These folds acted merely, however, as local interruptions to the general basin structure.

Absence of post-Carboniferous strata.—Except the Triassic area in the western part of the province, there are no rocks to be found between the Permian and the Pleistocene. In the Sydney district, as elsewhere, it is presumable that the land was above water constantly after the end of the Carboniferous. The evidence here is purely negative—absence of subsequent formations; but throughout the province as a whole, the drainage patterns made by the streams point to a very ancient emergence of the land.