STRUCTURAL GEOLOGY

OF

THE ANTIGONISH - POMQUET AREA

ANTIGONISH COUNTY, NOVA SCOTIA

by

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S.B., Massachusetts Institute of Technology

(1941)

SUBMITTED IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

(1951)

Signature of Author____________________

Department of Geology
January 12, 1951

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I INTRODUCTION

Introductory Statement

The present investigation is primarily concerned with a detailed study of the structures in, and underlying, the Windsor group, of Mississippian age, in the vicinity of Antigonish Harbour, Antigonish, Nova Scotia. Included in this report is much material from papers of other investigators, particularly M.I.T. students, who have worked in the same general area. Reports of M.I.T. students include theses and unpublished papers worked out in connection with the Summer Camp held at the Nova Scotia Center for Geological Sciences at Crystal Cliffs, Antigonish County, Nova Scotia.

Field work by the writer was undertaken during the summers of 1949 and 1950.

Acknowledgements

The author wishes to express his gratitude to Dr. Donald J. MacNeil of St. Francis Xavier College, Antigonish, and Drs. Robert R. Shrock and Walter L. Whitehead of M.I.T. for their kind encouragement and valuable advice, both in the field and in the laboratory. Jean Puech, with whom the writer tramped during the five weeks spent in the area in 1949, is to be especially thanked. The list of student associates who contributed their time and advice must include Maurice Stacey, Terence Podolsky, Robert Leonard, Claude Hill, Russell Shorey, Loring Lee, and Walter Sims.

Lastly, the writer wishes to express his thanks to the Nova Scotia Department of Mines and the Nova Scotia Research

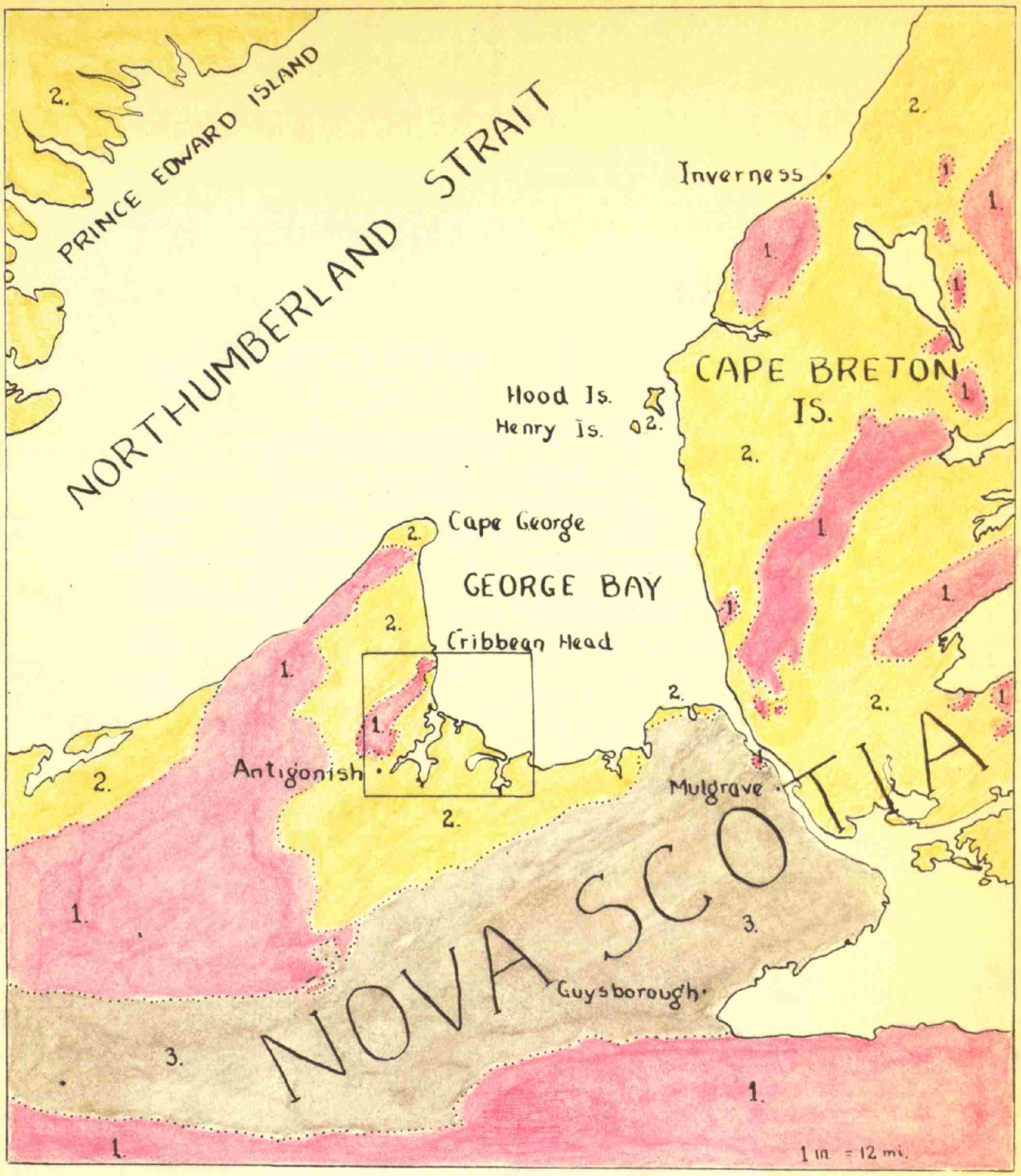
Foundation for their generous help with maps, aerial photographs, and finances.

Location and Area

The map area is located along the south-west end of George Bay in Nova Scotia. It includes the northern two-thirds of the West Antigonish topographic sheet. The southern boundary is just south of the main highway from Antigonish to Mulgrave, referred to as the "telegraph road" in old reports. The area examined measures 12 miles east-west, and 11.5 miles north-south with the north-east portion covered by George Bay; approximately 92 square miles are emergent today. The area is easily reached by means of the Sidney branch of the Canadian National Railways which connects Antigonish with New Glasgow and Truro to the south and west, and Mulgrave and Sidney to the north and east. The main highway from New Glasgow to Mulgrave passes through the area, and numerous good and bad dirt roads intersect the area.

Mapping

Aerial photographs were available during most of the time spent in the field. Brunton and pacing methods were used to tie in outcrops with features readily visible in the aerial photographs. The geologic map which accompanies this report was produced as an overlay to the preliminary topographic sheet which has been made up from aerial photographs by the Photogrammetry Division of the Nova Scotia Research Foundation.



LOCATION OF

ANTIGONISH - POMQUET

MAP AREA

LEGEND

1. Pre-Carboniferous, Crystalline
2. Carboniferous Sediments
3. Devonian and/or L. Mississippian

Apologia

Laboratory work on specimens from this area, both paleontological and petrographic, has not been completed. Names of fossils identified by the writer are not included in this report since they are unconfirmed, but from necessity they have been used to identify beds of Windsor limestones. Likewise, some field work remains to be completed. In the event that the U. S. Army does not exercise its option on the writer, this thesis may be considered a preliminary report on the Antigonish sedimentary basin.

Previous Work

The earliest work which dealt in great detail with the area under consideration was done by Hugh Fletcher, in 1887.[1] In discussing the earliest rocks present, he stated;[2]

"The syenite" (actually a granodiorite in present terms) "of Williams Point, Antigonish, and of the eastern side of the harbour, may be Pre-Cambrian, but is perhaps more likely of the same age as that which cuts the lower Cambro-Silurian rocks of James River." (which would place these rocks as Ordovician) and (the granodiorite of Williams Point) "is unconformably capped by gray Carboniferous limestone, largely quarried, full of fossils - Leperditia okeni, Cyrtoceras, Conularia, and Dentalium - and containing galena."

Rocks in the area of "Cambro-Silurian" age have been divided into three groups by Fletcher, as follows;[3]

1 Fletcher, H., 1887. Report of Geological Surveys and Explorations in the Counties of Guysboro, Antigonish and Pictou, Nova Scotia, from 1882 to 1886. Geol. Surv. of Canada.
2 Fletcher, H., 1887, p. 17p.
3 Fletcher, H., 1887, p. 18p.

"1. The lower flinty slates, quartzites and "whin"-like rocks of James River and Eigg Mountain;

"2. The soft reddish and olivaceous slates of Baxter's Brook and Brian Daly's Brook;

"3. The reddish and gray sandstones, grit and conglomerate of Bear's Brook."

Fletcher proposed that the "isolated hill-range of sedimentary and volcanic rocks,...west of the shore road from Antigonish to Morristown, including the Antigonish Sugar Loaf and the hills behind Ogden Pond"[1] be included in the lower group, that is, group number 1., above.

Into the middle "Cambro-Silurian" group, number 2., Fletcher proposed that the rocks described below be placed.

"At the head of a branch of North River, is a considerable breadth of gray and light-colored fragmental shales and slates, perhaps volcanic tuffs; and numerous similar outcrops in the neighboring branches,..... greenish-gray, massive slate and quartzite or sandstone, and reddish-pink and gray, slaty felsite and quartzite. Lower down, and below the highest outcrops of Carboniferous limestone, are felsitic rocks and a beautiful red syenite passing into almost pure quartzite or quartz-porphyry."[2]

No member of the upper group is noted in the area in the report of Fletcher, and next in age are the Carboniferous rocks. Fletcher divided these into three groups.[3]

"These groups are:

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1 Fletcher, H., 1887, p. 18p.
2 Fletcher, H., 1887, p. 23p.
3 Fletcher, H., 1887, p. 69p.

"G 1m. Carboniferous Conglomerate

G 1. Carboniferous Limestone

G 2. Millstone Grit."

Areas, described below, have been assigned by Fletcher to the G 1m. group, Carboniferous conglomerate.

"Indian-red coarse conglomerate and sandstone, and red and green marl, apparently of great thickness, occupying a broad belt in Ogden Brook, associated with gray beds containing coal. On the shore, near Cribbean Head, the conglomerate which overlies the "Cambro-Silurian" strata is red, gray and greenish, friable and thick bedded, with bands of reddish argillaceous shale and rusty sandstone, enclosing fossil plants and trunks of trees."[1]

Into the G 1. group, Carboniferous limestone, have been placed the following areas:

The "Blue Cape limestone....Antigonish to Morristown;" "On the west point of Pomquet Island nearest the breakwater, gray, greenish-gray and reddish, fine, micaceous sandstone dips 334° - 45°. Further north, greenish and gray arenaceous shale and sandstone show impressions of fossil plants. On the shore, westward from Bayfield Wharf, the first rocks seen are gray fine sandstone and arenaceous shale, rusty in spots, and blackened with carbonized plants..." "The coal and underclay found near the mouth of Pomquet Harbour..." "Up Pomquet River, above the bridge at the telegraph road, ledges and cliffs of gray and reddish-gray fine soft argillaceous sandstones and flags, with green layers, rippled and wavy...full of plants,

1 Fletcher, H., 1887, p. 71p.

"chiefly Calamites and Cordiates, partly converted into coal in thin layers or films..."[1]

Also placed in the Carboniferous limestone by Fletcher are: "A reported discovery of coal among these strata in a brook on the west side of South River, at John Fraser's, above the iron bridge at the head of the tide, proved, on examination, to be a bed of gray sandstone, full of large carbonized trunks of Lepidodendron and Calamites, mineralized throughout by coal and pyrites in layers." "The cliffs of the shore at Monk's Head show large exposures of gypsum, limestone, red marl and clay, fine red-spotted sandstone, with large patches of nut and egg-conglometare. The sandstone has been quarried for building, and was used in the abutments of the iron bridge at South River." "These rocks, particularly gypsum, are also found on Antigonish Harbour, below this bridge, as far as the mouth." Carboniferous limestone strata occur, with doubtful, variable dip, in South River..." "Reference has already been made to the fossiliferous limestone which caps the syenite on Williams Point and the east side of Antigonish Harbour." "In the Beech Hill brooks, the frequent exposures consist of limestone and gypsum, overlain by red sandstone and marl, with dark bluish-gray papery shale, dipping usually at a low angle." "On the shore at MacIsaac Point, near Morristown, gray flaggy and shaly limestone, about seven feet thick, veined with calcspar and pink and white heavy-spar, rests upon highly inclined reddish and greenish grit or conglomerate and is overlain by a much greater thickness of brecciated limestone."[2]

1 Fletcher, H., 1887, p. 80p - 82p.
2 Fletcher, H., 1887, p. 83p - 84p.

And lastly Fletcher assigns a few areas to the uppermost group, the Millstone Grit.

"The possibility that certain small areas of the upper rocks in the Antigonish basin, about.....Bayfield, may be Millstone Grit, has already been stated...."[1]

Fletcher's field work and his descriptions were exceedingly accurate and outcrop locations shown on his maps are nearly always perfect.

In 1889, Sir William Dawson published his Handbook of Canadian Geology; part of this three volume book may be considered a text book in geology, and part of it dealt with the geology of Canada. It was here that the Carboniferous system in Nova Scotia was divided into:

1. Horton series, or Lower Carboniferous shales and conglomerates.

2. Windsor series, or Lower Carboniferous limestone.

3. Millstone Grit.

4. Coal formation.[2] (Shown in ascending order)

Further work was done by Ami in 1900 in an attempt to fix ages and correlations of the Carboniferous system, and the Riversdale formation was of his naming.[3]

Daly in 1901 published a short paper dealing with the physiographic provinces of Nova Scotia and New Brunswick.[4]

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1 Fletcher, H., 1887, p. 86p.
2 Dawson, J.W., 1889. Hand Book of Acadian Geology, Montreal.
3 Ami, H. M., 1900. Notes on some of the formations belonging to the Carboniferous system in Eastern Canada. Can. Rec. Sci., Vol. VIII, p. 149 - 163.
4 Daly, R. A., 1901. The Physiography of Acadia. Museum of Comp. Zool., Bull., Vol. XXXVIII, p. 73 - 103

Daly recognised two main erosion cycles, one ending in the Cretaceous and the other in the Tertiary. The Cretaceous peneplain is represented in the upland areas, namely the Antigonish to Morristown metamorphic ridge of this map area, while the Tertiary cycle is represented by the lowlands of the Carboniferous rocks.

M. Y. Williams made a very detailed report on the Arisaig-Antigonish district in 1914.[1] Williams has proposed several name changes, and has in many cases substituted local names for formation names of older geologists. He has retained the formation names of James River and Baxters Brook, and has substituted Malignant Cove for Bears Brook of Fletcher's "Cambro-Silurian" group.[2] The term Browns Mountain group was used for this entire sequence, and on the basis of fossil content and conformable stratigraphic succession, the entire group was removed from "Cambro-Silurian" and placed in the Lower Ordovician, where it stands today.[3] It is worth noting that the fossils used for correlation were associated with iron deposits none of which occur in the Antigonish-Pomquet area.

New names for the Carboniferous formations were introduced by Williams on a local basis. The Lower Carboniferous conglomerates and grits were named the McAras Brook formation; the limestone, red sandstone, shale, and gypsum series overlying the McAras Brook formation were named the Ardness formation; The Millstone Grit of Fletcher was now termed the Listmore formation.[4] These names are of interest in reading the older

1 Williams, M. Y., 1914. Arisaig - Antigonish District, Nova Scotia, Mem. 60, Can. Geol. Surv.
2 Williams, M. Y., 1914, p. 53.
3 Williams, M. Y., 1914, p. 54 - 55.
4 Williams, M. Y., 1914, p. 30 - 33.

literature and maps of Williams, and of his time, but they are not used for formation names in this report.

Next in chronological line for review is J. W. Goldthwait's Physiography of Nova Scotia. The contribution of this paper to the Antigonish-Pomquet area is discussed under section III of this paper, GEOGRAPHY AND PHYSIOGRAPHY.

The greatest single contribution to Nova Scotian geology is Bell's monumental paper Horton - Windsor District, Nova Scotia, Memoir 155 of the Canadian Geological Survey, published in 1929. Although the type area in the vicinity of Windsor, N.S. is some 115 miles from Antigonish, the general description of the Horton and Windsor sediments of the type sections holds exceedingly well for all Nova Scotian sediments of like age. Indeed, the only variations are locally in the fossil record and in stratigraphic succession, where gentle upwarping or downwarping and proximity to old shore lines have produced depositional changes and facies changes within the individual sections and from basin to basin.

Bell has divided the Windsor into two faunal zones, with a number of subzones. Since use has been made of this information in unscrambling the structures near Antigonish, the breakdown of zones and subzones is given below:[1]

"Upper Windsor. Zone of Martinia galatea

Subzone E. Characterized by Caninia dawsoni and Chonetes politus.
Subzone D. Characterized by Productus semicubiculus.
Subzone C. Characterized by Dibunophyllum lambi and Nodosinella priscilla.

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1 Bell, W. A., 1929. Horton - Windsor District, Nova Scotia, Mem. 155, Can. Geol. Surv.

"Lower Windsor. Zone of Composita dawsoni.

Subzone B. Characterized by Diodoceras avonensis.
Subzone A. Basal limestone."

Of these characteristic fossils, only Martinia galatea and Composita dawsoni have been identified by the writer in the Antigonish-Pomquet map area. No cup corals of any species have been seen by the writer, although a single specimen was reported found in the limestone which forms the tight syncline three-quarters of a mile north of Antigonish by a geology student from St. Francis Xavier College; its identification is not known.[1] The table of zonal distribution of fauna from Bell's report has been used whenever possible. One point is worth further investigation. Bell has noted two species of Schizodus, which occur in subzones A and B. In the Antigonish area the writer has found an unidentified species of Schizodus which is very useful for correlating beds, but which occurs in the Upper Windsor, as it also does on Hood Island, off Cape Breton Island.[2]

A second publication by Bell in 1944 closes out the evolution of formation and group names used in this map area.[3] A new group name is introduced, the Canso group, the Mabou formation of Norman,[4] which by Bell's definition,

"comprises non-marine red and gray shales and sandstones that overlie the marine Windsor group or non-marine rocks of equivalent age."[5]

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1 Information from Dr. Donald J. MacNeil, Antigonish, N.S.
2 Norman, G. W. H., 1935. Lake Ainslie Map-Area, Nova Scotia. Mem. 177, Can. Geol. Surv.
3 Bell, W. A., 1944. Carboniferous Rocks and Fossil Floras of Northern Nova Scotia, Memoir 238, Can. Geol. Surv..
4 Norman, G. W. H., 1935, p. 42.
5 Bell, W. A., 1944, p. 5.

The Canso group covers an area in the eastern portion of the area mapped for this report, and presents a magnificent section along the Pomquet River, particularly just to the south of the Antigonish-Mulgrave road. The writer has visited this section and will mention it briefly later in this report. A more detailed description will be presented shortly by Walter Sims, who is working on this subject for his Master's degree at St. Francis Xavier College in Antigonish.

A. O. Hayes in reporting the possibilities of potash in Nova Scotia, includes a section, written by E. R. Pohl,[1] concerning the Windsor rocks in the Antigonish basin. Pohl, in giving a broad description of the structure of the basin (which is larger than the writer's map area) states:[2]

"Despite the heavy glacial covering frequent outcrops of bedrock allow of a good composite understanding of the general stratigraphy and structure. Upon a broad conception of the occurrence of the Windsor series in this district they occupy a large downwarped basin the edges of which have been truncated by subsequent erosion. That the extent of the Windsor beds was previously much greater is attested by the presence of an isolated outlier of these rocks resting by normal relations upon the Horton to the north of Antigonish. Almost invariably the strike of the basal Windsor beds of the district is tangential and the dip radial concavely to the center of the basin. The

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1 Pohl, E. R., 1928. Windsor Rocks of the Antigonish Basin and Knoydart District, p. 85 - 91 of publication by Hayes, A. O., 1930. Report on the Potash Possibilities of Nova Scotia, Part 2, Annual Report of the Mines, Province of Nova Scotia.
2 Pohl, E. R.: Op. cit., p. 88 - 89.

"simplicity of this synclinal structure is essentially continuous with the exception of complicated crumbling and intricate displacement."

The writer is in agreement with this general description but will expand the exceptions listed as "complicated crumbling and intricate displacement" into a definite system of tilt-blocks in the basement rocks. Further reference to Hayes publication is made later in this report.

Other papers on economic geology have been published which have reference to limestones in the map area of this paper. Foremost among them is the report by M. F. Goudge written in 1934.[1] Chemical analyses of many of the limestones in the area were made but are not discussed in this report. Still other papers, two by J. P. Messervey and one by G. V. Douglas give valuable information as to the structures involved in several limestone and marl quarries.[2]

In addition to the papers already mentioned, there are seven separate reports on some part of this map area, which have been written by students at the Summer Geology Camp at Crystal Cliffs. Some are theses for degrees at M.I.T., and are preserved in the library at M.I.T. and in the record of the Summer Camp at Crystal Cliffs. Others are short problems in geology and are preserved only in the records of the Summer Camp. The paper by R. W. Decker has been formally published,

1 Goudge, M.F., 1934. Limestones of Canada, Their Occurrence and and Characteristics, Part II, Maritime Provinces. Can. Dept. Mines.

2 Messervey, J. P., 1943. Marl Deposit, Lanark, Annual Report on Mines, Province of Nova Scotia.
Messervey, J. P., 1945. Limestone Deposit, South Side Antigonish Harbour, Ann. Report of Mines, Prov. of N.S.
Douglas, G. V., 1943. Limestone, Antigonish Harbour, Ann. Report on Mines, Prov. of Nova Scotia.

and may be found in the Annual Report on Mines, 1949, Province of Nova Scotia.

The first of these papers, by Barker, et al,[1] states that the basal Windsor rocks north of Crystal Cliffs are overthrust onto the Horton sediments with unknown displacement, and that early Paleozoic metamorphic rocks slightly further to the north, are also overthrust to the north-west, in this case onto Horton sediments. The writer does not agree to either of these suggestions. There are two normal faults between the two suggested by Barker, et al, not mentioned in their report, but the contacts they have mentioned would seem to be normal overlap of younger sediments upon older rocks, in each case the contact being an angular unconformity. The first contact can be seen at MacIsaac Point. Here three thin bedded layers, Sharpstone conglomerate, gray shale and red shale separate the Windsor basal limestone from the steeply dipping Horton sandstones. These delicate beds, separating the two Carboniferous groups would have been crushed and disrupted if any kind of faulting had taken place. The other "overthrust contact" is buried by glacial drift. If this is an overthrust contact, the metamorphic ridge behind Crystal Cliffs must be a Horst of sizeable proportions. The contact is nowhere visible along the west border of the metamorphic ridge, but regular variations in the attitude of these beds, the Horton group, supports the theory

1 Barker, F., Butterworth, J. A., Holden, R. N., Wetzel, J. H., and Wiberg, L. E., 1948. Structural Geology of the Coast North of Crystal Manor (now Crystal Cliffs), Antigonish. Annual Report of Summer School of Geology, Antigonish, Nova Scotia.

of overlap, and to the writer, rules out the possibility of an overthrust fault.

In the summer of 1948 a magnetometer survey was made across the Antigonish anticline.[1] This anticline is the high ridge running from the summit of Williams Point in a south-west direction out of the map area. Three traverses were made: 1) using station intervals of 200 feet from the base of Williams Point, easterly to the summit, 2) along the Antigonish - Mulgrave highway, using station intervals of from 500 to 1,500 feet, and 3) south along the Sherbrook road (from the town of Antigonish south along the very west margin of the map accompanying this report) using station intervals which varied from 200 to 1,100 feet.

The results are interesting to the structural picture of the area and are quoted below;[2]

Traverse 1 - Williams Point. "Here the anomaly indicated a steady rise of the granite (granodiorite - writer), with the sediments lapping up against it, from the subsurface beneath the Williams Point road to the point where it outcropped on the mountain top....The measurements indicated a continuous slope of granite to the peak which was considered to be the axis of the anticline."

Traverse 2 - Antigonish - Mulgrave highway. "..a complete cross section of the anticline was carried out. The same marked

1 Bartholomew, F. L., Gokhale, B. V., and St. Germain, S. A., 1948. Nova Scotia Magnetometer Surveys, Annual Report Summer School of Geology, Antigonish, Nova Scotia.
2 Bartholomew, et al., Op. cit., p. 6 - 8.

"peak in the anomaly was observed. The anomoly is the most significant obtained and has been interpreted as follows:

1. The slope of the flank of the anticline in this area rises gently, the subsurface granite not rising as abruptly as was indicated in the Williams Point area. A greater surface distance to the peak of the anomaly (axis of anticline) was encountered which amounted to several times that of the Williams Point area.

2. The magnetic intensity on the axis at this point was approximately one-half that of the Williams Point area, indicating considerable pitching of the anticline.[1]

3. After passing the peak, the anomaly dropped abruptly in approximately 1,000 feet, the total amount that it had risen in approximately 2 1/2 miles (13,200 feet). This would seem to indicate either a fault or some form of sharp contact. Conforming with the geological information available and the surface features which involve a steep slope at that region,[2] there is also the possibility that the data indicates a cliff of an ancient, submerged, granitic island covered by sediments..."

Traverse 3 - Sherbrook road. "Two observations can be made with respect to the work:

1. The surface of the buried granite appears to be irregular showing fairly well defined and well separated highs.

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1 Pitching to the south-west; other major structures in the area appear to be pitching to the north-east - writer.

2 About 3/4 mile west of bridge over South River at Lower South River - writer.

"2. There is reason to believe that the anticline has pitched to such a depth that further measurements across the extension of its axis toward the west would give little or no anomaly. This conclusion is based on a difference of anomaly equal to one-third of the high in the Williams Point area."

Two theses were written on the Horton group during the summer of 1948. Alderman made a detailed study of the Lower Horton conglomerate, particularly in the Ogden Brook,[1] which is included in the map area of this report, and some of his work is incorporated in this paper. Although the writer is familiar with the Ogden Brook, the map details have been taken from Alderman's paper, with only a few minor changes. Decker's paper was on the Upper Horton sediments, and although it has already been published, much of it is directly applicable to this map area.[2]

Still another paper was done on the Horton group during the summer of 1948. A rather complete analysis of the sandstone at Cribbean Head was performed by Irving Breger.[3] Although Cribbean Head is slightly off the map area, to the north , the sandstones from this point correlate with sandstones in the map area in two places; in the Upper Horton

1 Alderman, S. S. Jr., 1948. The Lower Horton Conglomerate of Cape George, Nova Scotia. S.B.Thesis, M.I.T.
2 Decker, R. W., 1948. A Study of the Upper Horton Sediments in Northern Nova Scotia and on Cape Breton Island, S.B. Thesis, M.I.T. Annual Report on Mines, Province of Nova Scotia, 1949.
3 Breger, I. A., 1949. A Partial Analysis of Horton Sandstone from Morristown Point, Nova Scotia. Annual Report of Summer School of Geology, Antigonish, Nova Scotia.

sediments in the Ogden Brook and to the north-west towards Big Marsh, and in the Upper Horton sediments found just north of the Antigonish Sugar Loaf, in the North River bed.

Two papers were written in 1949 affecting some part of the Antigonish - Pomquet area. French's paper concerns the geomorphology of the northern portion of the map area,[1] but does not throw any light on the structures of the map area beyond that of Goldthwait in his Physiography of Nova Scotia.[2]

The other paper, by Jean Puech, is mainly concerned with the contact of Mississippian rocks with underlying rocks.[3] The writer accompanied Puech during the summer of 1949, when the south-east margin of the metamorphic ridge was rather thoroughly explored from Crystal Cliffs to Antigonish. The description of the fault system from this paper of Puech's is an important part of the structure of the Antigonish basin, and free use of information from Puech's paper will be made.

A table of formation and group names used in this report is shown on the following page. The formation name - Ainslie - for an Upper Horton sandstone, is described in two reports from Cape Breton Island, but the writer is not sure of its origin.[4]

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1 French, E. R., 1949. Geomorphology of the Cape George - Arisaig Area. S.B. Thesis, M.I.T.

2 see III GEOGRAPHY AND PHYSIOGRAPHY.

3 Puech, J., 1949. Mississippian Overlap Near Cape George. S.M. Thesis, M.I.T.

4 Eastern Gulf Oil Co., 1928. Preliminary Report on Geology and Oil Exploration in Cape Breton Island, N.S. Annual Report on Mines, Province of Nova Scotia.

4. Norman, G.W.H., 1935.

Table of Group and Formation Names

of Sedimentary Rocks Found in the Antigonish-Pomquet Area

ERA	PERIOD	GROUP	FORMATION
PALEOZOIC	Lower Pennsylvanian	Riversdale	
	Upper Mississippian	Canso	
		Windsor	
	Lower Mississippian	Upper Horton	Ainslie s.s.
		Lower Horton	
	Ordovician (?)	Browns Mountain	Malignant Cove
	Lower Ordovician		Baxters Brook
			James River

II SUMMARY AND CONCLUSIONS

Early in the Mississippian period, tectonic events 15 to 20 miles west of the map area, caused uplift and the beginning of rapid erosion of the area now known as the Pictou-Antigonish highlands. Detritus was washed eastward into the Antigonish basin, and deposited as thick basal Horton conglomerates and coarse sandstones within the map area. The metamorphic ridge of today was then low lying, and the low line of igneous rocks along the eastern shore of Antigonish Harbour were large and prominent hills. These sediments were deposited on a large outwash plain, whose outermost edge was in contact with the sea. Instability along this advance edge gave rise to a transitional environment in which shales, eolian sandstones, and a thin limestone were interfingered with the coarser Horton sandstones.

In late Horton time, faulting took place along a N 40° E line, from the Antigonish Sugar Loaf past Crystal Cliffs, allowing a large block of Ordovician metamorphic rock to be tilted up through the Horton sediments, and down towards the north-west. Activity along the main scissor-like fault, and associated faults, continued through the end of the Horton period. The south end of the block was being uplifted, with large fault displacement taking place to the north. Horton sediments lying upon the western edge of the active block were folded into a large anticline and syncline parallel to the fault.

In Upper Mississippian time, downwarping of the Antigonish basin caused it to be inundated by the Windsor sea, at which time the well known series of limestones, evaporites, and red siltstones was deposited. The igneous hills east of Antigonish Harbour sank into the sea along with the deeper part of the basin to the east, and by late Upper Windsor were covered by the sea and sediments. Gentle upwarp in the Upper Mississippian caused the retreat of the Windsor sea, and the Canso and Riversdale sediments were deposited in the lowest portion of the Antigonish basin. There is no evidence that these rocks were deposited over the western edge of the map area.

At some point in post-Riversdale history, possibly late Pennsylvanian, a second block is thought to have faulted, much as the first block did, causing Windsor sediments to be brought up from depths level with the Riversdale sandstones at Monk Head, and possibly forming the synclinal structure in the Pomquet River area. The direction of this fault is not known. Evidence from the magnetometer survey indicates that it very nearly parallels the fault visible to the west. The Pomquet River syncline may be evidence of a more northerly direction for this fault, or may indicate the presence of a third, and even more deep-seated fault, running parallel to the first two.

From the material presented in the following pages, the writer concludes that Carboniferous sediments of the Antigonish basin are underlain by a block faulted basement. Successive blocks in an easterly direction lie at greater depths. The greatest displacements are at the north end of the faults, and the greatest uplift is at the southern end of these blocks. Faulting has progressed in time from west to east. Surface expression of tectonic events increases toward the west, as thinner sediments fail to conceal the activity of the underlying basement rocks.

III GEOGRAPHY AND PHYSIOGRAPHY

According to Goldthwait, we may divide the Antigonish-Pomquet map area into two natural physiographic provinces;[1] the metamorphic and resistant ridge running from the Antigonish Sugar Loaf north 40° east to the sea being a detached portion of the highlands of Pictou and Antigonish counties, and the remaining areas being lowlands. Included with the highland area is the intrusive knob just to the west of Captain Pond, although Williams Point is not included in the highland area by Goldthwait.

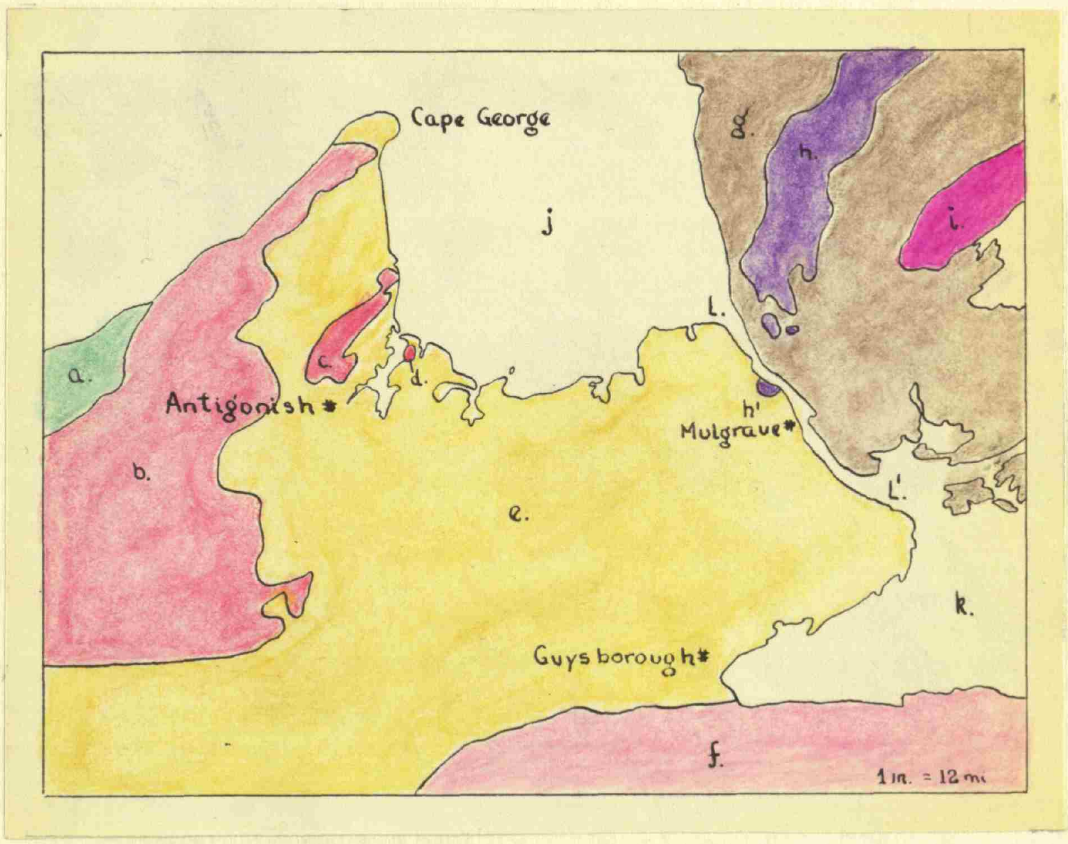

Figure 1. Physiographic provinces surrounding the Antigonish basin of Carboniferous sedimentation. Taken from Goldthwait's Map.[2]

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1 Goldthwait, J. W., 1924. Physiography of Nova Scotia, Mem. 140, Can. Geol. Surv. p. 28 and 56.
1 Goldthwait, J. W., 1924, Map.

a. Cumberland - Pictou lowland.

b. Pictou - Antigonish highland.

c. Metamorphic outlier of Pictou - Antigonish highland.

d. Granite outlier of Pictou - Antigonish highland.

e. Antigonish - Guysborough lowland.

f. Southern upland.

g. Lowlands of Cape Breton Island.

h. Craignish Hills.

i. North Mountain.

j. George Bay.

k. Chedabucto Bay.

l - l'. Strait of Canso.

The high metamorphic ridge reaches its highest elevation at three points; the summit of the Antigonish Sugar Loaf is approximately 760 feet, and two other peaks reach this same elevation on the parallel with Fairmont. The North River cuts through the saddle between these two high areas at an elevation slightly over 500 feet. From the Fairmont highs the metamorphic ridge plunges northward and to the east, until it is truncated by the sea just north of MacIsaac Point. This ridge is dissected by streams which are cutting back into it from either side, in deep "V"-shaped cuts.

On the western side of this highland area, the Horton sandstones and conglomerates of Lower Mississippian age lap against the older quartzites and baked shales. In the Fairmont area these Horton sediments lie at an elevation of slightly over 450 feet, and their contact with the metamorphic ridge also plunges to the north-east, reaching 150 feet in the

Ogden Brook area. In the north-west section of the map area, the Horton sediments form a hill reaching 400 feet in elevation, and drop at a steady rate towards the north-east and the waters of George Bay. This surface can not be attributed to present day erosion, for both the Ogden Brook and the stream flowing eastward from Big Marsh cut deep valleys through the Horton sediments.

The south-east border of the metamorphic highland is delineated by large normal faults. The main fault runs from about a half-mile north of Sugar Loaf, north 40° east, until it disappears into a rift valley directly behind MacIsaac Point. Undoubtably it reaches, and extends well out into George Bay, but recent sediments cover its path for the last half mile. The displacement of this fault is approximately 600 feet at its mid-point and 1,200 feet at its northern end. Several minor faults run essentially parallel to it and form the contact with Horton and Windsor groups of Antigonish basin. Many minor cross faults are seen along the sea-cliffs north of Crystal Cliffs and at Monk Head. Slumping may have a big hand in these small faults, although several are definitely associated with the major fault systems.

The Carboniferous sediments filling this basin reach elevations against the metamorphic ridge of approximately 250 feet. The northward plunge of this contact is only slight compared with the plunge of the Horton-metamorphic contact on the west side of the ridge, and may be due entirely to erosion. Upper Horton sediments in the southern area of the

North River reach elevations of 300 feet, but nowhere do Windsor rocks reach higher than the 250 foot contour. From the fault contact eastward to Antigonish Harbour the Carboniferous sediments form low rolling hills. Streams run east-west through these lowlands, except where they follow the fault trace, and their courses meander, cutting into glacial debris and soft gypasum hills. The glacial debris covers this lowland area to depths averaging about 40 feet, and in at least one place, are over 100 feet thick. A well drilled for Dr. Frazer at Mahoney Beach traveled through 102 feet of clays and glacial boulders before reaching limestone, which is thought to be bed rock in this region. Another drilled water well, located between Ogden Pond and the shore road, was lost at 90 feet in quick sand and slime. The low lying hills bordering the west shore of Antigonish Harbour are almost entirely glacial till. Except for the gypsum cliff along the north bank of the North River estuary, there is one outcrop of rock along the shore from Crystal Cliffs to the limestone outcrop on the west side of Williams Point.

The next physiographic feature is the row of low-lying, intrusive peaks which, starting at the summit of Williams Point, trend north 40° east to the granite knob west of Captain Pond. The highest point on Williams Point lies at an elevation of 250 feet. The granodiorite breaks through the Windsor limestones to form the summit, but the limestones surround this igneous cap, and undoubtably at one time covered it completely. The granite peaks near South Side of Antigonish Harbour are capped by limestones, although they form surface outcrops along the shore. The large granite mass near Captain Pond is essentially bare of limestones, although the Windsor sediments reach to within 50 feet of its 150+ feet summit, and may surmount it, hidden by scrub growths and recent debris. A large mass of granite boulders north of Dunn's Beach, and visible at low tide, may indicate still another granite peak, buried at the present time. It is difficult to explain these igneous fragments as being products of stream or shore current, or wave deposition. Their size and angularity would suggest that they are not far from their source. In this line of igneous peaks, the limestones maintain a slight plunge to the north-east.

The remainder of the map area, the eastern half, is one physiographic unit; flat, low-lying and swampy, and on the whole, drainage is haphazard and without any definate pattern. There is one small area, just east of South River, where the stream drainage is of interest. Here several small streams flow north 40° east, and several more flow south 40° west. The writer did not uncover any outcrops in this area to prove the argument that the direction of stream flow is controlled by the bedding of the Windsor sediments which are thought to underly the area of possible consequent stream drainage.

Along the shore lines there are several features of interest. Across the mouths of Antigonish and Pomquet Harbours, and cutting off Ogden Pond, large sand bars have developed. From the shape of the Harbours behind them it may be seen that the area has recently undergone submergence, drowning slightly the rivers which empty into these harbours. Two cliff areas are also present. The structural complexity at Monk Head forms a cliff of over 50 feet at that point, and at Crystal Cliffs the Windsor rocks dip into the sea forming an even higher cliff which is undergoing very rapid erosion at the present time.

The land bordering the roads is generally farm land, with wood lots to the rear. Vast areas have fallen into disuse and are being overgrown by spruce growths. The soil is a red-brown color and varies from a good loam to sand and clay fields, with the red clay covering perhaps as much as 75% of the cleared land. On the lower slopes of the hills are large stands of medium sized spruce trees, and on top of the metamorphic ridge, in addition to the spruce, hard wood trees thrive. These are mainly hard maple and beech trees; no oak trees were spotted and the white birch trees have a definite affinity for the gypsum beds. Birch die-back has already killed off many of the birch trees in the area. The spruce trees seem to préfer the sedimentary regions, but in cut over and burnt over areas, they extend out over the metamorphic rocks. The line between spruce and hardwoods shows up well in aerial photographs but can not be relied upon for geological mapping. A few balsam and hemlock trees are mixed up with the spruce groves, and likewise a few white pines.

Fishing and farming, and combinations of both, are the two main occupations of the inhabitants within this area. Efforts to get farmers to spread lime and marl on their fields from nearby deposits should be encouraged.

IV STRATIGRAPHY AND SEMINENTATION

General Statement

The sediments of this map area fall into two divisions. The earliest sediments are those of the Browns Mountain group which make up the metamorphic ridge running from the Antigonish Sugar Loaf to Morristown. Excepting recent and glacial deposits, all other sedimentary rocks within the map area are Carboniferous in age.

Browns Mountain Group

Following the nomenclature of Fletcher and Williams, the earliest formation in the Browns Mt. group is the James River formation, of Lower Ordovician age. According to Fletcher these are "flinty slates, quartzites and "whin"-like rocks." Most of the metamorphic area of this report fits this description. A small area along the North River fits the description of the Baxter's Brook formation, which is the middle Browns Mt. formation, consisting of "soft, reddish and olivaceous slates." And in a small area along the stream bed of the stream which flows north east into Ogden Pond, and on a parallel with Mahoney Beach, the metamorphic rocks fit the description of the upper formation of the Browns Mt. group, the Bear's Brook formation of Fletcher, and the Malignant Cove formation of Williams. Here red and green nucleii in a green quartzite are all that remain of the anchient conglomerate. The borders of the old pebbles have been recrystallized and the entire mass oriented optically, platey minerals parallel. Sufficient work has not been done to map accurately the group at this time.

Carboniferous Rocks

The earliest Carboniferous rocks are those belonging to the Horton group. Their lower contact is either a fault contact with the Browns Mt. group (two such contacts are visible in the area) or an unconformable overlap on the Browns Mt. group. This overlapping contact is not actually seen in any place in this map area, but the inference is strong that it exists. Resting upon the Horton, both conformably, and with an angular unconformity, is the Windsor group, the only truly marine sediments of the Carboniferous in this area. Along the Williams Point to Captain Pond line of igneous rocks, the Windsor sediments overlap unconformably igneous granites and granodiorites of uncertain age.

Overlying the Windsor group is the Canso group, non-marine beds of Upper Mississippian age. No contacts between Canso and Windsor are exposed in the map area, but the contact is located just south of the telegraph road, in the Pomquet River bed, where it is obscured by overburden and gypsum. And lastly, lying above the Canso are the Lower Pennsylvanian sandstones of the Riversdale group, and again no contacts are known. The coal seam near Pomquet is taken as the lower limit of the Riversdale in this report and the inference is strong that the contact is conformable. The writer must admit that with all his digging around on the bottom of Pomquet Harbour, and along the shore in the vicinity of the coal seam, the contact was never seen. If the inferences can be accepted, then sedimentation was taking place continuously from early Mississippian times to early Pennsylvanian times.

Horton Group

Lower Horton sediments in the Antigonish-Pomquet map area are located in three places; on the west and east side of the metamorphic ridge in the Ogden Brook area, and in a small pocket of Lower Horton sediments in the North River region. Puech included a larger patch of Lower Horton sediments on the east side of the Browns Mt. ridge.[1] A careful examination of these rocks by the writer was made during the summer of 1950. Their description at the Ogden Brook outcrop and on the shore is similar to the rocks of lower Upper Horton age described by Alderman[2] and Decker[3] and they have accordingly been moved up the section of the Horton group for this report. A small patch of Lower Horton conglomerate can be seen in the stream which flows north into Ogden Brook; its western edge is thought by the writer to overlap the metamorphic rocks for a short strip, between the two normal faults which dilineate the rest of this Horton area.

The oldest outcrop of Lower Horton basal conglomerate is to be found in the Ogden Brook, west of the metamorphic ridge. The deep red-brown conglomerate is poorly sorted here, with stream-rounded boulders and cobbles up to three feet in diameter, and added small rounded pebbles and coarse sand filling the spaces. Alderman has measured this section carefully and assigns a figure of 2,200 feet for the Lower Horton in this region.[4] The conglomerates are very similar throughout the

1 Puech, J., 1949, map.
2 Alderman, S. S. Jr., 1948.
3 Decker, R. S., 1948, '49.
4 Alderman, S. S. Jr. 1948, p. 15.

entire thickness, diminishing in size of included cobbles and stones as the upper limit is approached. The stones are everywhere stream worn, although semi-angularity testifies that this stream action was not continued for a long time.

Upper Horton sediments cover the north-west region of the map area. They are also exposed in the North River area, and along Rights River in the west border area near Antigonish. They are characteristically interbedded sandstones and conglomerates along the Ogden Brook exposures. Employing the tectono-environmental classification proposed by Krumbein, Sloss, and Dapples, the Ogden Brook Horton sediments may be placed in the catagory, or group of sediments laid down in a continental environment. This group is characterized by the mutual operation of wind and streams on alluvial plains, combined with occurrences of lakes and ponds, and with coloration being affected by oxidation.[1] Alderman measured an even mile of Upper Horton in the Ogden Brook section.

A different lithofacies for Horton sediments of the same age is found along the shore north of Morristown, and in the South Lake Creek bed in the extreme north-west corner of this map area. By stratigraphic relationships it is known that these two sections are of the same age. The environment of the shore section is typical of a transitional environment, characterized by interfingering and gradation, sandstones varying from quartzose to sub-graywacke, micaceous, carbonaceous, or calcareous shales, with limestones usually subordinate.[1]

1 Krumbein, W. C., Sloss, L. L., and Dapples, E. C., 1949. Sedimentary Tectonics and Sedimentary Environments. Bull. Am. Assoc. Pet. Geol., November, Vol. 33, No. 11.

The shore sequence of Upper Horton sediments was described and measured by Decker, with results listed in descending order, as follows:[1]

"Basal Windsor limestone	
Limey conglomerate	5'
Ainslie sandstone	500
Shales	100
Pink limestone	10
Conglomerate shale cycles	150
Micaceous sandstone	600
Marine shales	200
Gray sandstone (Cribbean Head)	80
	1,645'

A further point should be discussed before assigning Horton sediments from the map area to a particular point in the stratigraphic column. This is the question of provenance. Aldermans study of the Ogden Brook Horton has shown that the coarse clastic materials were derived from highlands to the west and southwest.[2] Decker's paper confirms the opinion that Horton sediments were derived from not too distant highlands, and deposited as a giant alluvial fan which reached the sea, and whose border deposits were naturally somewhat changed in places by encroachment of this sea, in this case George Bay.[3] Imbricate structures in the Upper Horton of Ogden Brook, and in the Lower Horton of the North River clearly show that water deposition of these sediments was from the west and southwest. Figure 2, on the following page, shows possible source areas for clastic fragments of the Horton group. It is worth noting that of all the pebbles noted in the Horton group in the Ogden Brook, none are foreign to sources marked 1 - 4 on Fig. 2.

1 Decker, R. W., 1949, p. 140.
2 Alderman, S. S. Jr., 1948, p. 16.
3 Decker, R. W., 1949,.

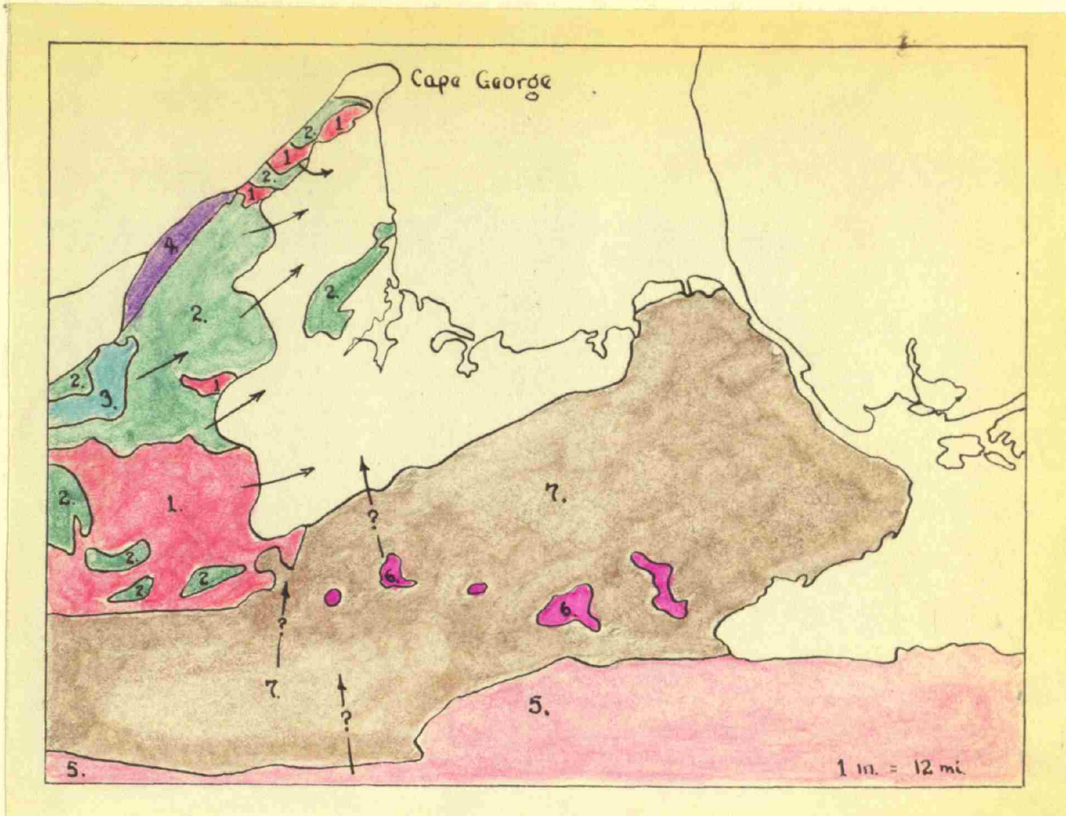


Figure 2. Possible source rocks for clastic materials found in sediments of the Horton group in the Antigonish-Pomquet map area.

1. Lower Ordovician granite, monzonite, and rhyolite.

2. Browns Mt. group; sandstone, slate, argillite, quartzite, volcanic rocks, schist.

3. Arisaig series of Silurian age; shales and impure limestones, rhyolite (reworked fragments from conglomerate).

4. Red slates and sandstones of Knoydart formation.

The source areas shown above were elevated during late Devonian and early Mississippian times providing ample materials to fill the Antigonish basin with detritus. Other possible sources, although quite distant, or low-lying, include:

5. Slates and quartzites of the Meguma series.

6. Granitic rocks, protruding as isolated islands in the

7. Sedimentary rocks marked Horton on Map 910A, Geological Map of the Maritime Provinces, but which are in part Devonian. Lower Horton sediments in this area could also be source rocks for Upper Horton sediments, providing upwarp had taken place during the intervening time.

All data for Figure 2 was taken from Map 910A, 1949, Geological Map of the Maritime Provinces, published by the Geological Survey of Canada.

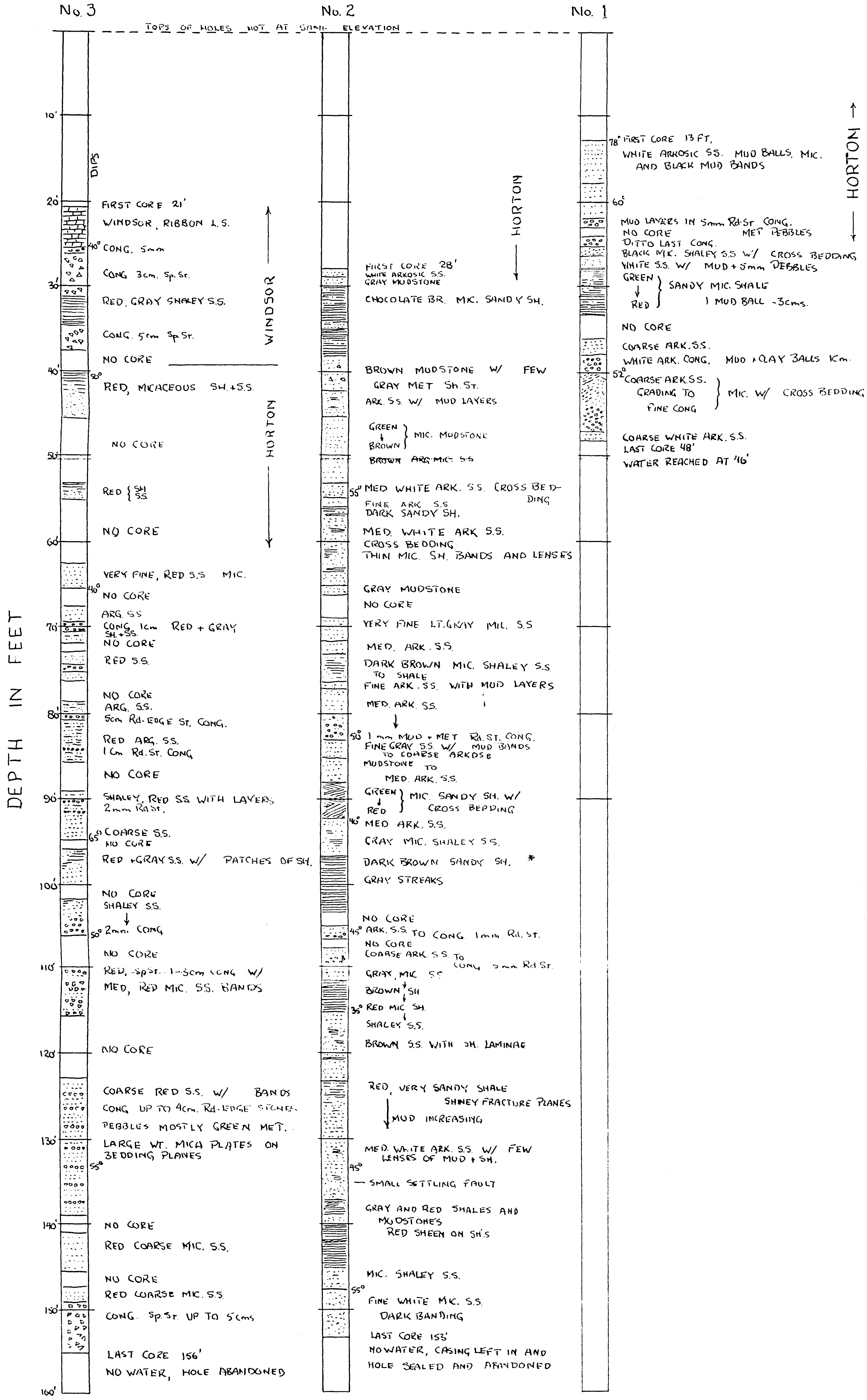
The section along the Ogden Brook represent continuous deposition throughout Horton times, and can be classified as stream and river deposits, delta deposits, and channel deposits. In the small triangle east of the metamorphic ridge, and northwest of Crystal Cliffs the Horton sediments represent a section similar in appearance to the Ogden Brook section, fluviatile deposits of interbedded conglomerates and sandstones. This small Horton deposit is bordered by two faults; to the west is rests unconformably against Ordovician metamorphic rocks, and to the east it is bordered by fine red sandstones.

This Horton east of the main fault is best seen along the shore north of MacIsaac Point from the main fault trace, underlying a group of fishing shacks in the rift valley, south to the Windsor contact . Here the rocks vary from red to white in color, with coarser graywackes and conglomerates showing a preference for white and gray coloring, and the finer arkoses, siltstones, and shales being predominately red. The sandstones often show a positive reaction to acid, and thin sections show clearly the calcite cement. The beds are often crossbedded in large lenticular beds, and in other places show wedge shaped crossbedding. A thin section of one specimen from this area showed quartz fragments to be badly frosted, and the rock composition that of a pure quartz sandstone. Small lenses of this character can be attributed to wind action. It is proposed that this section correlates with the lower Ainslie sandstone and shale section which directly underlies it.

South of the area just described, and on the Crystal Cliffs property, three wells were drilled for water and the cores were saved. These wells reached depths of 48', 153' and 156', water being found only in the shallowest hole. The wells are far enough apart in relation to their depth so that there is no common section due to the steep dips of the beds, from 40° to 78°. The basal Windsor limestone is in the very top of number 3 well, and overlies with a 10° angular unconformity Horton sediments which are not representative of the Ainslie sandstones, rather of the micaceous sandstone, shale and conglomerate cycles further down in Decker's shore section. The Horton section represented by these well cores is approximately 238' thick, and may be reconstructed by placing core #3 uppermost, core #2 below this, and core #1 at the bottom; there will be minor gaps. The log from these wells is shown on the following page.

In keeping with this trend of descending in the Horton section as we progress south, the next outcrop of Upper Horton, found in the North River area, is even lower down in the Upper Horton section. As the North River swings through and around a point of metamorphic and igneous rocks, its southern branch runs over Lower Horton conglomerates, and further south, Log of Crystal Cliffs Well Cores

LOG OF WELL CORES
CRYSTAL MANOR
ANTIGONISH, N.S.



N McL. SAGE JR.

upstream, the Upper Horton is exposed in odd patches along the stream bed, lying at odd and widely varying attitudes. The Upper Horton section in this area is representative of the Cribbean Head gray sandstones and carbonized tree fragments, a thin layer of black, possibly marine shales, and white micaceous sandstone. The black bituminous shale contains unidentified branches and floral remains; no fish scales such as are found in the South Lake Creek near Big Marsh were noted. Minor anticlinal and synclinal folds are seen along the stream bed, and in the white micaceous sandstone two major joint systems are noted: 1) N 65° W and 2) N 55° E. The sediments in this Horton section could not have been derived locally from the metamorphic and granitic rocks which surround it, for they contain large flakes of white mica; the quartz and feldspars could conceivably have been derived locally from the igneous rocks which intrude the Browns Mt. group, but probably not in such large quantities as are here present. The direction of transport and deposition can not be determined from the Upper Horton at this point, but the Lower Horton sediments in the same area show that stream action which deposited them was from the south-west. Directly to the south-west and lying at an elevation of 760' is the Antigonish Sugar Loaf.

The final outcropping of Horton sediments is actually off the map area, a half-mile north-west of the town of Antigonish. These appear to be very Upper Horton sediments in that they are directly and conformably overlain by Windsor limestones. The contact shown on the large geological map which is part of this report is actually confused by several faults which extend through both Windsor and Horton sediments. Further work needs to be done in this area, but the writer considers that they represent tangential faulting along the periphery of the Antigonish basin. Another half-mile along Rights River, and visible from the railroad bridge and the Hawthorn Street road bridge, (not shown on the map of this report) a limestone bed can be seen in the red terrestrial deposits which are typical of the Upper Horton. The exposed section along the stream bank measured as follows, in descending order:

Conglomerate, sandstone and shale	unknown
Red stained limestone	24"
Conglomerate, pebbles up to 1 cm.	5"
Limestone	1.5"
Conglomerate, pebbles up to 1 cm.	2+"
Limestone	5"
Section hidden, but further conglomerate and sandstone outcrop below.	

The writer's interpretation is that this represents the contact of the Windsor and Horton groups. Terrestrial sediments were being dumped into the sea down the Rights River valley, and limestones were being deposited by the encroaching sea. On a facies basis, the Windsor limestones are interfingered with the Horton red beds, but on a time basis the change from Horton group to Windsor group is not sharp, and Windsor red beds and Horton red beds are undistinguishable.

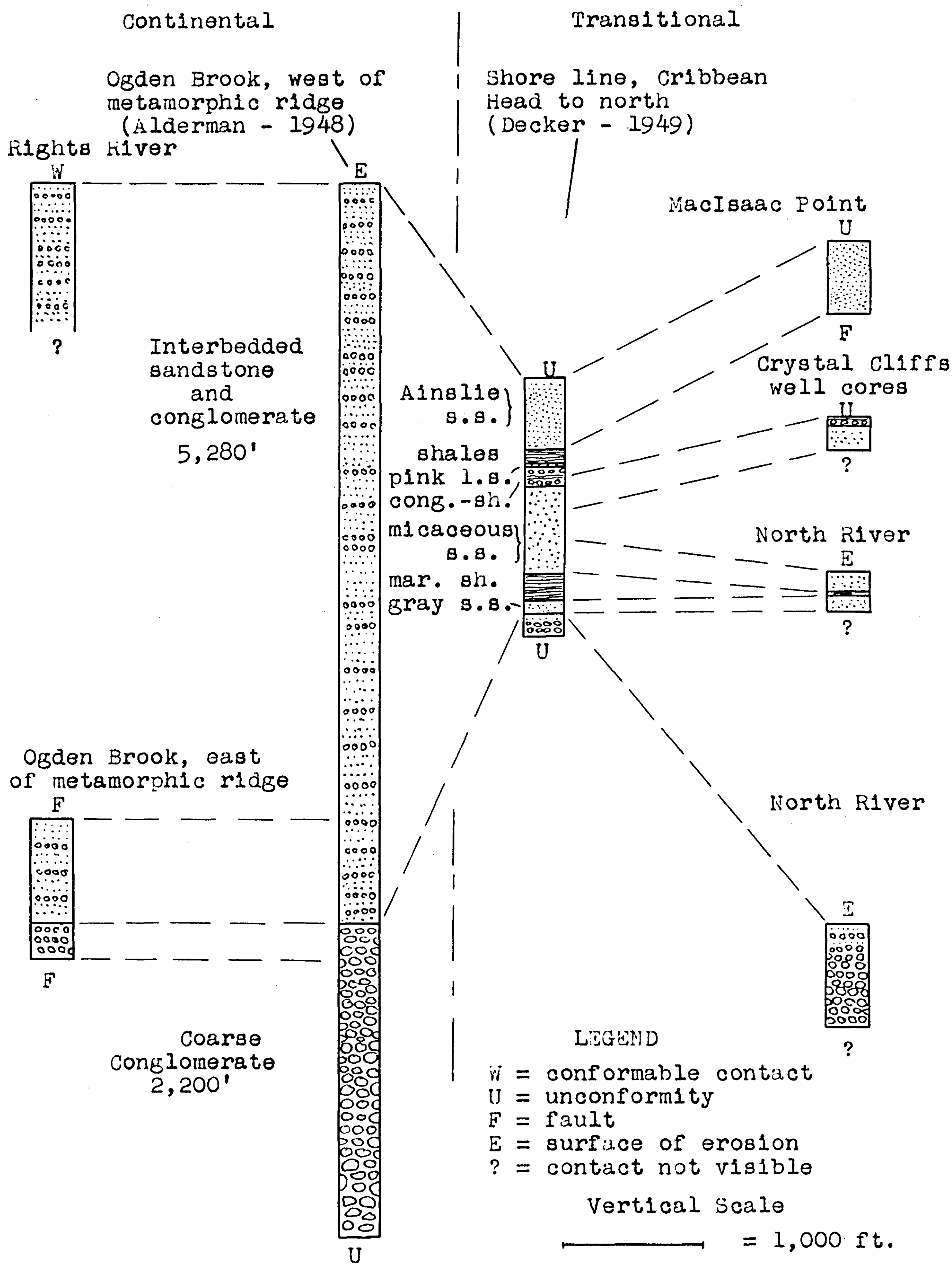
The writer is ready to admit that this contact may lie entirely within the Upper Horton and represent a local marine phase of the Horton. More field work in this area may give a more definite answer to the problem.

In summary, the Horton group represents terrestrial deposits of conglomerates, sandstones, and shales, laid down on a large alluvial plain, or fan, whose furthermost limits were in contact with the sea. Along this border area facies changes are found which represent swamp and marsh conditions, lagoons and stream channels, and periods of time when wind action was most prominent. The materials were chiefly derived from the west and south-west, from the older sediments and igneous rocks in those regions. Local contributions from the metamorphic ridge in the center of this area were minor. During Lower Horton times and for most of Upper Horton times this ridge must have been at low elevations, probably completely submerged until late Upper Horton times, for Horton sediments appear to have washed over it, and settled down along its eastern flank.

Contributions of sharpstone pebbles from the metamorphic ridge in late Upper Horton times to the conglomerates lying close to this crystalline mass, testify to the first upheaval and tectonic activity of this metamorphic mass in Horton times.

A generalized section and a rough correlation of Horton sediments within the map area is given on the following page. For a more detailed description of these sediments, the reader is referred to the papers of Alderman, Decker, and Puech.

GENERALIZED SECTION - HORTON GROUP - WEST MAP AREA



Windsor Group

With a single exception, Windsor contacts with older rocks are marked with an unconformity, although this is only angular unconformity in the Crystal Cliffs to MacIssac Point region. In the North River area the basal limestones overlie Lower Horton conglomerates. Just south of the Antigonish Sugar Loaf and to the south-east along the southern border of the metamorphic ridge, the Windsor limestones overlie a sharpstone conglomerate, which in turn lies directly on the older Browns Mt. group. On the row of igneous peaks from Williams Point to Captain Pond Windsor limestone overlaps directly upon these older rocks but the limestone does not represent the basal Windsor, rather limestones of Bell's Subzone "B". The single conformable contact of the basal Windsor limestone is thought to be along Rights River, about a mile north-west of Antigonish, and already described on page 38 of this report.

Two basal Windsor contacts are sketched on the following pages; a third is shown in the #3 well core from the Crystal Cliffs area on page 36 of this report. The sharpstone conglomerate, which is more often than not present, consists of sharp angular fragments from the Browns Mt. group of metamorphic rocks which is the major topographical feature of the area today. The fragments are of gray-green quartzite, green baked shale, and locally of pink granitic rock. The thickest conglomerates are found south of the metamorphic ridge, exposed by a small fault and stream cut in that region. Often overlying the conglomerate is a thin layer of red and gray clays and siltstones. The red color appears to be from recent staining through circulation of waters from the red Horton sediments, but may well be a primary coloring.

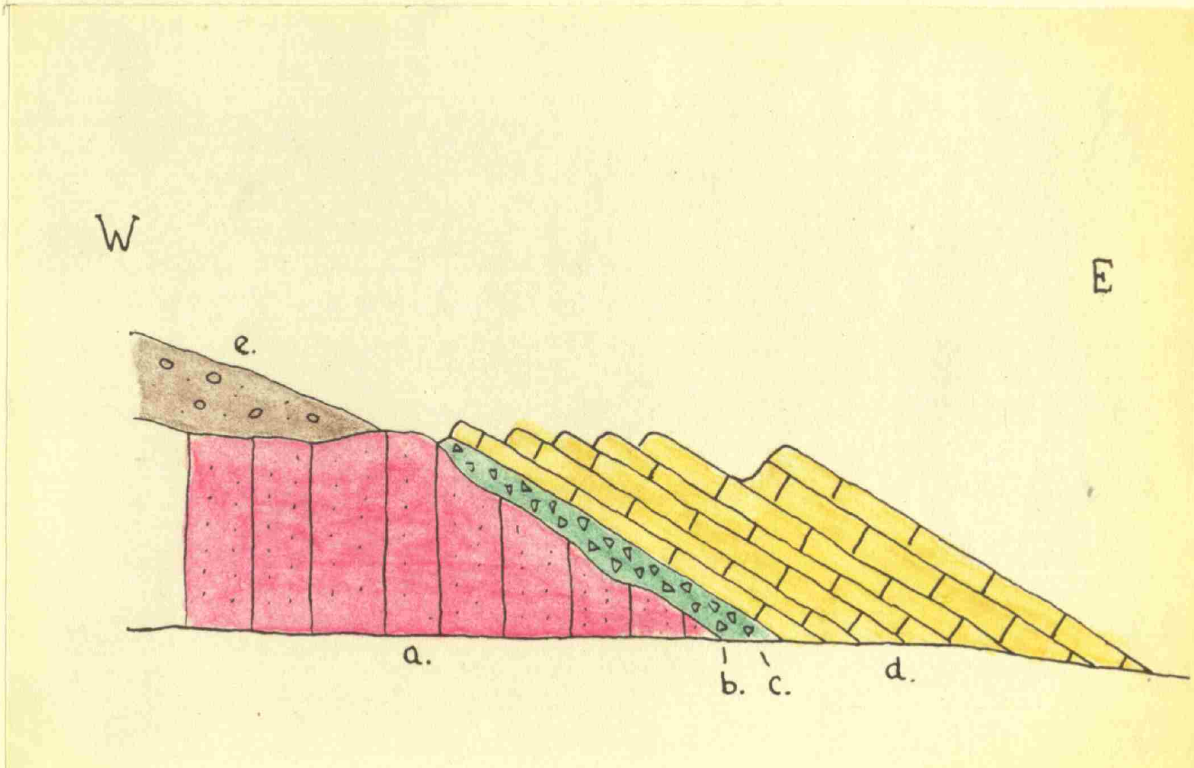


Figure 3. Most northerly Windsor-Horton contact on shore at MacIsaac Point.

a) Upper Horton red and white sandstones.

b) Surface of unconformity, variable.

c) Sharpstone conglomerate, locally thickening to fill small cuts and valleys in Upper Horton surface.

d) Basal Windsor limestone; massive, crystalline and varying locally in sand content.

e) Topsoil and overburden consisting of red clays and unassorted gravels.

Horizontal and vertical scale: 1 inch = 20 feet.

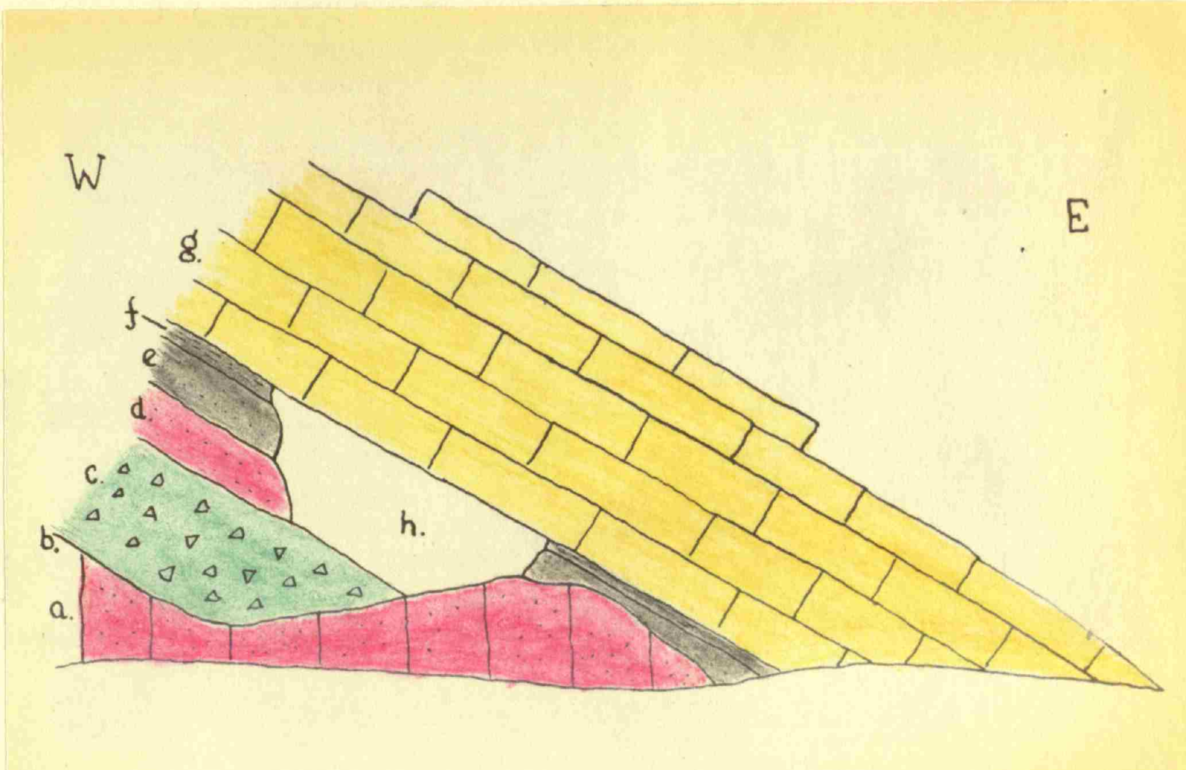


Figure 4. Windsor-Horton contact on shore, 1,200' south of most northerly Windsor exposure on MacIsaac Point.

a) Upper Horton red and white sandstones.

b) Surface of unconformity, uneven.

c) Sharpstone conglomerate, containing gray metamorphic pebbles from 2.5 to 5 cms. in diameter.

d) Fine grained red sandstone layer.

e) gray sandstone layer, fine grained.

f) Gray stratified clay.

g) Basal Windsor limestone, massive, sandy in places.

h) Small cave formed below limestone, where sandstones and clays have been washed out.

Horisontal and Vertical scale: 1 inch = 3 feet.

There is no continuous section of Windsor sediments within the map area of this report. To describe adequately the complete sequence of beds requires that outside deposits be introduced. On Hood Island, Windsor beds are standing vertically, and represent almost three-quarters of the Windsor known in the general area. Hood Island lies directly across George Bay from the area under discussion and it is thought by the writer to lie in the same depositional basin; certain beds across the bay correlate well between sections, notably those at Monk Head with those at Hood Island, and using it for a type section of Windsor rocks in the George Bay area, including Antigonish basin, seems a reasonable point at which to start. The lowest Windsor sediments are not represented at Hood Island, due to faulting; they are well represented at Crystal Cliffs and are described from this area. Limestone beds are lettered alphabetically, as they would be if encountered in a drill hole, the youngest limestone being A.[1]

Letter	Popular Descriptive Name	Described from
A	Botryoidal l.s.	Pomquet River and Cape Breton Is.
B I	Schizodus dol.	Hood Island
B II	none	Hood Island
B III	none	Hood Island
B IV	Giant Ripple l.s.	Hood Island
C	Columnar algal l.s.	Hood Island
D	none	Hood Island
E	Small algal l.s.	Hood Island
F	1st Oolitic l.s.	Hood Island
G	2nd oolitic l.s.	Hood Island
H	Canary l.s.	Crystal Cliffs
I	Ribbon l.s.	Crystal Cliffs

1 Private report of Dr. Walter L. Whitehead, about 1941.

The Hood Island section has already been described by Norman.[1] Many other geologists have visited the section and are familiar with it. In spite of this, beds from this Island are included in the generalized section of Windsor, and many are described below. Several thin sections were made from the various zones in each horizon although details of all these sections are omitted from this report, as are results of paleontological studies. The features described are the macroscopic features which serve as keys to the identification of individual limestone horizons.

The A limestone, Botryoidal, does not appear in the Hood Island section, nor is it apparent in the Antigonish-Pomquet map area. It is present, however, in the Pomquet River, south of the map area in contact (?) with the Canso group. It appears to be a series of very thin algal limestones, interfingered with shales.

Separating the A and B_I limestones is a section of red, maroon siltstones and shales. In this report the term siltstone is used for the thick maroon and gray beds which lie between the various limestone horizons. These red siltstone beds are very similar in character throughout the Windsor group. In places they have been compressed and form shaley areas, and in other zones gypsum has been deposited with them, making a red or gray, marly mass, with wide variations in composition. One part of the group, at least, is a true, fine grained sandstone, massive and well bedded and cemented. In general these are soft

1 Norman, G. W. H. 1935.

sediments, crossed by gypsum veinlets and non-resistant to weathering. It would be impossible to tell one red horizon from any other by known field methods.

The B_I, or Schizodus, limestone at Hood Island forms the outermost exposure of land, Cape Vertical. This limestone is in fact strongly dolomitized, with secondary dolomite seen replacing oolites and calcite crystals, and forms a resistant barrier to the rest of the section on its leeward side. It measures 44.5 feet in thickness, with minor variations along its length.[1] The basal nine inches is a black limey shale, thinly laminated. Above this lies from 8 to 9' of oolitic limestone, showing cross bedding, particularly on weathered surfaces. Throughout this lower zone are individual algal growths, cylindrical, about 1" in diameter and from 2 to 4" in height. Sides are vertical, with upper surface convex upward, formed by thin laminations of crystalline limestone. About 9' from the base lies a 16" bed containing the Schizodus, along with fragments of crinoids; this zone is the trade mark of the B_I horizon. The Schizodus is a Pelecypod, about 1 cm. in diameter, and they generally lie with their two valves spread open, convex, roundside up. They are visible in fresh or weathered surfaces and make not only excellent index features, but are consistent as a top and bottom feature. Another zone, rich in fossils, lies about 18' from the base. Above the Schizodus zone the rocks are generally crystalline, with small oolitic patches, and often showing nodular, more resistant cores of crystalline limestone, or dolomite, in the weathering surfaces.

1 Measurement of the Hood Is. section was made by Maurice Stacey, Claude Hill, and the writer during the summer of 1950.

The horizon is generally light gray in color, weathering to a tan or buff color.

The Schizodus limestone outcrops in two areas in the Antigonish region; between Captain Pond and Monk Head, and probably in the West River and tributaries south of the town of Antigonish. The Schizodus fossils could not be located in the last named area; the species may actually be missing at this point, or this may be a wrong identification.

The B_{II} and B_{III} limestone horizons embrace 6' of gypsum. Neither of them is important as a marker singly, since there are no distinguishing features for either bed. The sequence may perhaps be useful. The B_{II} limestone is 20" thick on Hood Island, light brown in color, weathering yellow; it is crystalline, containing neither oolite nor fossil. The B_{III} limestone is 26" thick, black, porus on the bottom, turning to red-yellow on top. The sand content increases noticeably in ascending this 26". Here again, no fossils or oolites. The B_{II} and B_{III} horizons have not been positively identified in the Antigonish area, but are believed to be present at Monk Head, at both ends of the structure.

The B_{IV} horizon is approximately 15' thick and has several diagnostic features. The lower 5.5' is of gray limestone stringers, suggestive of algal activity, with brown argillaceous limestone filling in around them. It does not appear fossiliferous, but in thin sections, foraminifera show up clearly, and the limestone is again undergoing dolomitization. Next follows a foot and a half of yellow, earthy, porus material, containing numerous Brachiopoda. The remainder of the bed is oolitic, showing cross bedding and displaying the giant ripple marks on the upper surface. These ripples marks have an amplitude of about 3.5 inches and a wave length of from 14 to 18 inches. They are readily visible on the top surface, but do not appear to have affected the deposition of the oolites much below this surface veneer. The duration of the event which caused these ripples was apparently short lived. The B_{IV} horizon is thought to be present in the Monk Head structure, although identification is hampered by the curious algal growth which covers the surface in place of the ripple marks.

The C horizon, 15' thick on Hood, also has several good identifying features. The basal 28" consists of small algal (?) heads of crystalline limestone, separated by softer argillaceous limestone; best seen on weathered surfaces. Above this are the columnar algal structures which lend their name to the C horizon. Shrock has described these as "conoidal algal columns" and a sketch of them is shown in his Sequence in Layered Rocks.[1] Between the columns shell fragments and foraminifera (?) have been cemented into place. Overlying the algal columns is 7' of oolitic and fossiliferous limestone. Approximately 3' from the top of this horizon is a layer of large concretions, about 6" high, roughly circular in plan, with a diameter equal to 12±". These concretions have a sandy, limey center and appear flattened on the bottom. The weathered oolitic limestone continues to the top of the horizon. The C horizon is definitely present at Monk Head; it forms the most eastern limestone outcrop of this structural unit.

1 Shrock, R. R., 1948. Sequence in Layered Rocks, McGraw-Hill. p. 287 and 292.

The D limestone is not particularly well known by the writer. Its exposure at Hood Island was almost obliterated by a slump of red topsoil and mud; at Monk Head its presence is only inferred by boulders and fragments. Despite these difficulties, the D limestone appears to be another algal biostrome, with a thickness of about 40". In the bank it appears yellowish on weathered surfaces. Barrel shaped limestone boulders lying on the beach, and buried in the sand, are thought by the writer to belong to this D limestone. These barrel-like objects are roughly 1.5 feet in diameter, 2 to 3 feet high, with crystalline outer surfaces, and stringy, firerous insides, much like the interior of an overripe turnip, or radish. The remainder of the filling was presumably of softer, perhaps argillaceous limestone, and has since weathered away.

The E limestone horizon has few index features, and is particularly difficult to identify in fresh surfaces. The bottom 10' of its total 12.5' is essentially a tan to gray crystalline limestone, which weathers yellow. The uppermost 29" is another algal biostrome of small columns. They fit together much like baby basalt columns, and their top surface looks like so many bakers buns in the baking pan; concentric limestone layers are convex upwards.

The F limestone, or 1st. oolitic, is 16.5' thick on Hood Island and the basal 12 to 13' is oolitic, light gray to black in color, and excepting single algal growths, does not appear fossiliferous. These single algals growths are widely spaced, columnar colonies about 5" high and 2.5" in diameter. Under the microscope, in section, they appear as thin laminae of $CaCO_3$, separated by layers of quartz fragments, small oolites, foraminiferal and limestone fragments. Above this zone, ascending the F limestone, are 18" of algal material, similar to the basal 28" of limestone C, 17" of oolitic, fossiliferous, and rippled limestone, and 9" of rotten, yellow, chalky limestone. In the troughs of the ripple marks shell fragments are plentiful.

The G limestone horizon, or 2nd. oolitic, is very similar to the F horizon. The basal section is made up of oolites and minute shell fragments. One of the individual cylindrical algal colonies was noticed. The bottom 10' of this bed is light gray, brown, or black in color. Above this lies 20±" of crystalline limestone, algal, and probably the oldest of the algal biostromes in the Windsor group in this basin of deposition. The upper 15" is again oolitic, yellow-gray in color. Naming the F and G limestones the 1st. and 2nd. oolitic limestones muct be done with caution, for most of the limestone horizons are oolitic at some point in the Hood Island section, and at Monk Head. But oolites are missing from these same horizons when they represent littoral or reef facies.

The H limestone has not been definitely recognised at Hood Island. There are fragments of a yellow limestone mixed up with the fault gouge which possibly are from this horizon. This limestone does outcrop directly in front of Crystal Cliffs, at the north edge of the bathing beach. It also outcrops at the base of some gypsum hills, east of Mr. McLean's farm at the sharp turn of the shore road near Mahoney Beach. The thickness is not known for certain at either of these outcrops, but 20' is a fair estimate. This limestone is characteristically yellow in color, fresh or weathered, hence its nickname, the Canary limestone. No fossils have been found in the Antigonish area. It is crystalline, and conglomeritic, with limestone fragments as pebbles in a limestone maitrix as large as 12 cms. in length. In the Mahoney Beach area the material in the limestone maitrix consists of silt balls. As the limestone weathers, the silt washes out, leaving an extremely porus rock, with a peculiar honey-combed appearance. The included silt is maroon red, and comparable to the red material which comprises the thick red series of siltstones of the Windsor group. The Canary limestone is reported to be fossiliferous on Cape Breton Island.[1]

The basal Windsor limestone in the Antigonish area, the I limestone, is also called the ribbon limestone, the sandy lamey, the laminated limestone, and by Fletcher, the Blue Cape limestone.[2] The basal 12±' of this is massive, crystalline, blue-gray to pinky limestone. Layering is 2 to 4" thick and this zone seems to be extremely competent. The next 45±' consists of pink to yellow, laminated and finely rippled limestone. This zone is extremely incompetent and is often seen in tight concentric folds, overlying the undisturbed massive basal limestone. Both these zones are quite sandy, although the sand content varies from outcrop to outcrop. Hematite crystals and dendritic manganese (pyrolusite) are common in the laminated

1 Eastern Gulf Oil Co., 1928. Preliminary Report on Geology and Oil Exploration in Cape Breton Island, N.S. Annual Report on Mines, Province of Nova Scotia.

2 Fletcher, H., 1887, p. 79p.

zone. Above these zones lies an intraformational sharpstone conglomerate, withlimestone pebbles up to 10 cms. long in a limestone maitrix. This conglomeritic zone completes the I horizon, and is about 30±' thick. This thickness varies considerably over short horizontal distances, and may be missing altogether at some outcrops, with additional thicknesses of non-conglomeritic limestone. 75 cms. above the base of the I horizon lies a fossil bed with small white pelecypoda (?) lying concave side up. So far, the remains have defied identification.

At this point in the discussion, it would be well if the lettered limestone horizons from this report could be placed definitely into Bell's subzones of faunal distribution.[1] Norman has reported Martinia galatea on Hood Island in beds above the 1st. oolitic limestone horizon, but not in this F horizon or any lying below it stratigraphically.[2] These observations are confirmed by the writer's and it would seem safe to assign lettered horizons A through E to the Upper Windsor, and lettered horizons F through I to the Lower Windsor.

Taking information from Norman's report again, nine fossil species were reported from the 1st. and 2nd. oolitic limestone horizons, eight of which can be placed in Bell's subzone "B". One species, Flemingra dispersa (Dawson) appears

1 Bell, W. A. 1929, p. 66 - 68.
2 Norman, G. W. H., 1935.

to be out of place, suggesting changes in the faunal distribution of this area. The report of the Eastern Gulf Oil Co.[1] lists seven fossil species in the Canary limestone, five of which Bell includes in subzone "B", and two of which are not fully identified, but which represent genera which are also included in subzone "B". It would seem then, that limestone horizons E, F, and G are members of Bell's subzone "B".

The fossils found in the ribbon limestone have yet to be identified from this area. The basal limestone may be in either subzone "A" or "B". The thickness of the sequence would seem to favor the basal limestone horizon I being placed in subzone "A", awaiting confirmed identification of diagnostic fossils.

The last horizon which may be assigned to a subzone with assurance of this placement being correct is the B_I horizon, or Schizodus horizon. Norman has reported four fossil species in this horizon from Cape Breton Island, of which three belong to the subzone "E".[2] The fourth species is the unidentified Schizodus, mentioned earlier in this report. From the material in Norman's paper, and from fossils collected from this horizon by the writer, the B_I horizon is identified as being a member of subzone "E", and because of stratigraphic relationship, the A horizon is also included in subzone "E".

This leaves six horizons from the Upper Windsor which have not been assigned to a subzone. On the basis of only a few unconfirmed fossils, the presence of foraminifera and algal

1 Eastern Gulf Oil Co., 1928.
2 Norman, G. W. H., 1935.

bands in the C - E horizons, the great number of Brachiopoda in the B_{IV} horizon, and a comparison of the generalized section with that of Bell's,[1] the most probable division of these six horizons into subzones is as follows: the B_{II}, B_{III}, and B_{IV} limestones belong to subzone "D", and the C, D, and E, horizons belong to subzone "C".

The Windsor section on the following page is to scale vertically, using known measurements from several areas. Each bed is a specific bed from a single location and in a sense, this section is more a composite section than a generalized one. Local variations from the section include thin limestone beds within the Lower Windsor Gypsum beds, and wide variations in the thicknesses and occurrences of gypsum beds. The section shown represents 1,937 feet of Windsor, excluding the underlying sharpstone conglomerate. This compares favorably with the thickness of 2,090 feet assigned to the Windsor of the Antigonish basin by the Hayes Report.[2]

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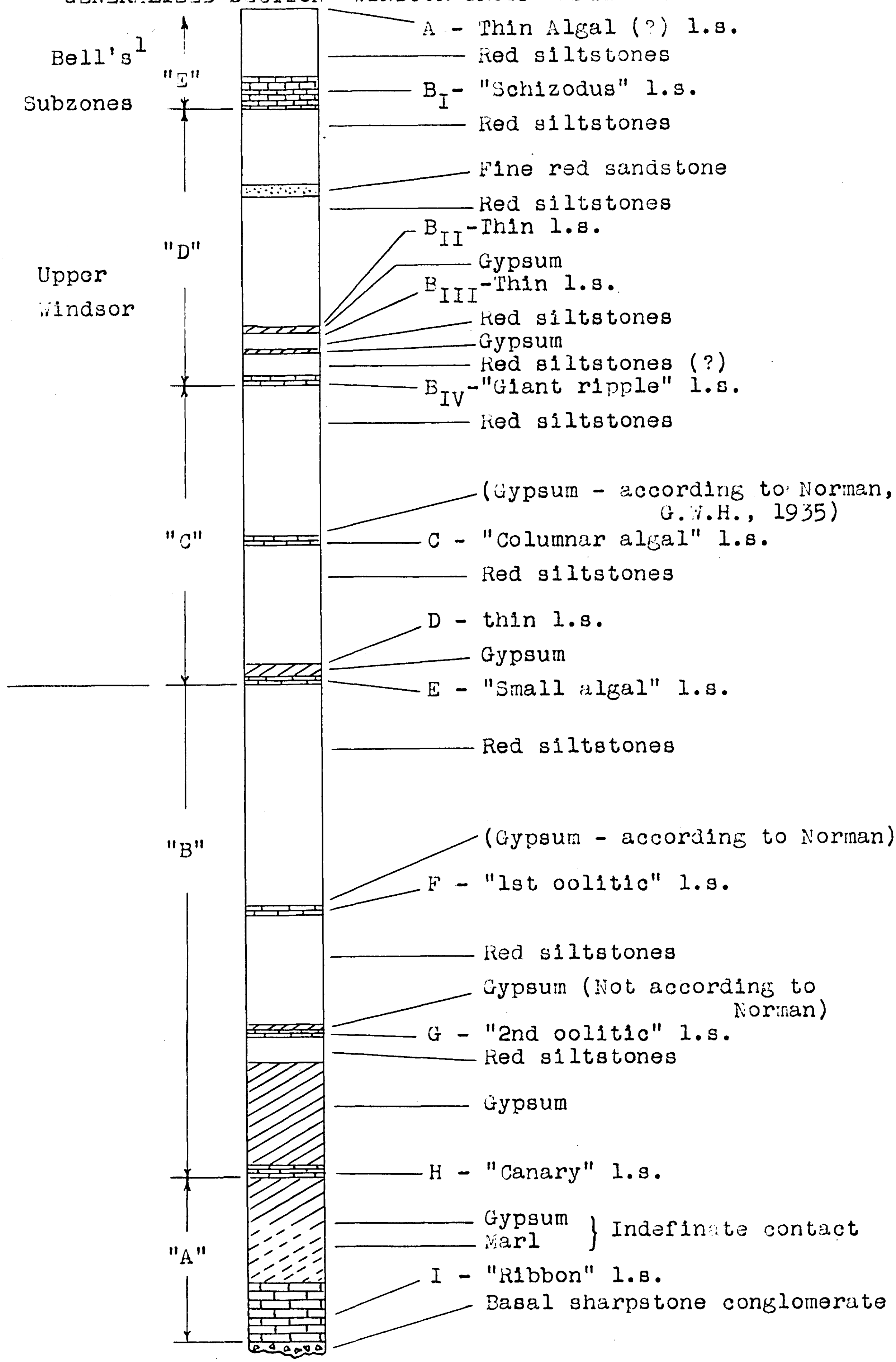
1 Bell, W. A., 1929, p. 55 - 56.
2 Hayes, A. O., 1930, p. 91.

GENERALIZED SECTION WINDSOR GROUP ANTIGONISH BASIN



1 Assignment to Bell's subzones unconfirmed.

One of the problems involved in the Antigonish basin is that each subzone of Bell's, with the possible exception of the "A" subzone, contains two or more limestone horizons containing fossil markers which at the present time have not been separated into individual faunal zones. Still another factor contributes to the difficulties of horizon identification.

In the Hood Island section, limestone horizons all appear to have been deposited under similar environmental conditions; shallow water, but not littoral. In the Antigonish basin there are three environments, although not too strongly developed.

The limestones along the west border of the map area, overlapping the metamorphic and Horton rocks, represent a littoral facies, high in sand and mud and low in fossils. This shortage may be due in part to the muddy water, and in part to the fact that fossils were not too numerous during the deposition of the basal Windsor. The limestones overlapping the igneous knobs from Williams Point to Captain Pond represent a reef-like facies. Sand and mud are at a minimum, although sharp granitic fragments give evidence of mechanical weathering of the intrusive rocks, and are found throughout these crystalline limestones. Unlike the shore limestones to the west, which contain horizons from subzones "A" and "B", the earliest fossils known so far around the igneous highs are from the "B" subzone. The only corals and Bryozoa found by the writer lie along this line of outcroppings, along with thick beds of comminuted shells, chiefly Brachiopoda, Pelecypoda, and Gastropoda, with only an occasional whole specimen. Lying directly east of this line of igneous rocks, the limestones appear to represent again the Hood Island type environment, shallow water, and being characterized by extroardinary algal colonies and oolitic limestones. The number of whole fossil specimens increases markedly, as does the amount of silt and mud contained in these limestones. No limestones from Bell's subzone "A" are known east of the igneous knobs and within the map area, but subzones "B" through "E" are represented. Assignment of subzones and lettered horizons to individual outcrops is not made in this report, since the work of identifying these beds is far from complete.

The origin of the Windsor sediments presents one last problem. The limestones, gypsum, and salt were derived from the Windsor sea, and this has been thoroughly discussed already by Bell.[1] The thick deposits of red shales, siltstones, and sandstones probably were derived much as were the Horton sediments, that is, from the western and southern highlands, which by Windsor times were much reduced in elevation. The very low elevation of these source areas is proved by the fact that not one single conglomerate or coarse sandstone bed is found in the Windsor group in the Antigonish area, excepting the Rights River basal Windsor contact. It is thought by the writer that much of the content of the Windsor red beds is reworked Horton sediments, derived from the halo of Horton sandstones, shales, etc., which surround the Windsor basin of deposition.

1 Bell, W. A., 1929, Chap. VI, p. 81 - 89.

Canso Group

The Canso group is represented in the eastern sector of the map area, in the vicinity of the Pomquet River. In fact, the best exposures are to be seen in the bed of this river. The rocks from this group outcrop along the river upstream and south off the map area for some distance, displaying a thick and ideally exposed section. In the map area it is generally red to deep maroon in color, though frequently gray and black. Typically this group is represented by paper thin, laminated shales, and fine grained sandstones, which are never very thick. Green shales are also not uncommon. Thin seams of coalified material and limey sands and shales complete the picture. Pseudomorphs of halite (?) are found just south of the telegraph road.

The lower contact of the Canso group, off the map to the south, and in the central map area, is hidden, but in all probability is conformable with Upper Windsor sediments. The upper contact has been taken as the coal seam on the shore of Pomquet Harbour and is assumed to be conformable. The coal seam is no longer visible on the shore, but the attitude of Canso beds below and Pennsylvanian beds above indicates a conformable contact. Local inhabitants, who are French speaking, explained to the writer that the seam was about 8" thick. Coal float is found along this shore, and has not been exposed to particularly deep burial.

Riversdale Group

Reddish white, to bright red sandstones and conglomerates of Lower Pennsylvanian age (?) outcrop in two areas; east of Monk Head along the shore, and in the south-east corner of the map, in a new railroad cut. These sandstones are particularly well exposed along the south, and harbour shore of the Monk Head peninsula, and are easily accessible by car. Here tree fragments are noted; they were not disturbed by the writer and it is expected that positive identification of the sandstones can be made from these fossils. The conglomerates contain small pebbles which do not attain a size of more than 1 to 1.5 cms; rounded stones outnumber the slightly angular ones.

Measurements from the map indicate thicknesses in excess of 1,000' for both the Canso and Riversdale groups. Neither section has been measured along the ground by the writer.

V IGNEOUS GEOLOGY

General Statement

There are six areas of igneous activity in this map area which are represented by outcrops. D_1, the dike rocks and possible flows on the northern end of the metamorphic ridge, D_2, the diabase intrusion into the Browns Mountain group in the vicinity of the Antigonish Sugar Loaf, D_3, the granodiorite which forms the core of Williams Point, D_4, the granite intrusion of the Browns Mountain group directly behind Crystal Cliffs, D_5, the granite in the North River area, and D_6, the granite intrusives exposed near Captain Pond and South Side of Antigonish Harbour. Volcanic activity is represented by sediments of the Browns Mountain group. The symbols D_x are plotted on the geological map which accompanies this report, indicating the nature of the outcrops, and have no other significance.

Along the shore, north of MacIsaac Point, the Browns Mt. group is frequently cut by dark, lamprophyre dikes, D_1, and possibly flows. These may be seen as far south as the Ogden Brook which cuts several of these dikes. They are characterized by euhedral plagioclase crystals, lath-shaped, penninite with its characteristic blue color replacing biotite, magnetite, pyrite, and high epidote and calcite. The epidote and calcite are probably in part due to hydrothermal solutions post-dating the dike formation, for areas surrounding the dikes are also rich in calcite and epidote, and the latter often appears as green, druse-like crystals covering the dike rock. These rocks can be distinguished readily from the surrounding quartzitic rocks and fragments of them have been identified in the basal Windsor sharpstone conglomerate. Since some of these outcrops appear to be flows, lying between Browns Mt. beds, the age of these dikes is thought to be similar to that of the Browns Mt. group, or early Ordovician.

The writer can contribute little to the question of the diabase, D_2. In fact, it is not mapped on the geologic map of this report because its boundaries are not known, and no specimens were picked up from areas suspected of being diabase. A gray-brown igneous rock does outcrop near the summit of the Antigonish Sugar Loaf, and along the southern slope, and has been mapped as diabase by Williams.[1] Williams has given its composition as approximately 50% plagioclase (An_{4-7}), 33% augite, 10% magnetite, with the remainder being alteration products, chiefly actinolite, chlorite and epidote, all replacing the augite. The texture is characteristically ophitic.[2] Diabase dikes along the Arisaig coast cut Lower Horton but not Upper Horton, and if there was only one period of diabase intrusion, as is suggested by Williams, then his age assignment of Middle Horton should be retained. The sample taken by Williams came from close to the Arisaig shore, and he noted an increase in quartz towards the south.[3] The outcrop of granodiorite at Williams Point, which Fletcher called syenite,[4] is similar to the diabase of Williams, southern, quartz rich variety, and has been studied by the writer.

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1 Williams, M. Y., 1914, Map.
2 Williams, M. Y., 1914, p. 122.
3 Williams, M. Y., 1914, p. 122.
4 Fletcher, H., 1887, p. 17p.

The Williams Point igneous rocks, D_3, have the ophitic texture of Williams' diabase. About 50% of the rock is plagioclase (An_{32}), about 20% quartz, 15% penninite replacing biotite, and 5% amphibole (actinolite?). Minor constituents are epidote, carbonates, pyrite, magnetite, and long apatite needles. The pyrite is greatly in excess of the magnetite. The plagioclase occurs as euhedral laths, and the quartz crystals, in groups of 8 to 12, surrounding and mixed with plagioclase crystals, are in optical orientation. The plagioclase crystals show epidote and carbonate inclusions, thought to be replacing the plagioclase, and their appearance is unmistakable so that fragments are easily spotted in the limestones which overlap this outcrop, and into which these weathered fragments have fallen. If cross country petrographic work could tie this granodiorite in with Williams' diabase, its age might be established as Mississippian. The weathering of this outcrop is much more severe than in the granites to be described shortly, and the writer is of the opinion that it is the oldest rock in the map area. Accurate placement of this outcrop will have to await further information.

The two granite areas west of Antigonish Harbour, D_4 and D_5, are very similar and probably represent the same intrusion. These two granites are coarse grained, pink rocks, with quartz averaging about 50%. Roof pendants and xenoliths may be seen at the outcrops and their intrusive nature is proved. Patch perthite makes up the bulk of the feldspar content, although minor amounts of pure albite are present (5%±), which is seen being replaced by orthoclase. Minor constituents include penninite replacing biotite, epidote, opaque minerals and apatite needles. The cataclastic nature of the rock is apparent, mortar structures are common along grain boundaries. The quartz also shows well developed lamellae. The fine grained red intrusive (?) area in the Browns Mountain group just above the fault contact in the North River appears to be an alteration of the metamorphics to a jasperite, perhaps associated with the granitic intrusion but not a fine grained granite. The high quartz content of these granite outcrops distinguishes them from the James River granite found to the west, and off the map area. The time of intrusion is approximately the same, and these granites may well be some phase of the same igneous period of activity.

The Captain Pond granite and South Side of Antigonish Harbour granites, D_6, are also pink, coarse grained rocks. The grain size is such that they must have been fairly deep seated. This fact alone would seem to place them earlier than Horton time, for the erosion interval does not appear long enough to remove thick Horton beds, perhaps partially metamorphosed, before Windsor times, when limestone and gypsum were deposited upon the east shoulders of these outcrops. The Captain Pond granite contains about 27% quartz, about 60% feldspars and runs as high as 10% biotite. The feldspars are kaolinized but the biotite has not undergone alteration to penninite as it has in the west shore granites. Apatite needles and a few opaque grains make up the rest of this granite. There is a zone in this granite which has little, or no biotite, where quartz occurs as a graphic intergrowth with orthoclase. No cataclastic structures were noted in these east side granites. Here again, the granite approaches even more closely the composition of the James River granite.

One other feature is worth noting. The intrusives into the Browns Mountain group appear to be narrow stocks, necks, and dikes. Across the river, or harbour, the igneous rocks occur as broad domes, or knobs, suggesting a batholithic origin. The controlling factor may very well have been the nature of the sediments which were intruded by these clearly intrusive rocks. If the granite masses across the harbour from each other are of about the same age, then it can be argued that the east side granites must have intruded softer sediments, either Devonian or Horton, which have been more quickly eroded than the Browns Mountain group. All the igneous rocks in the map area have been called pre-Carboniferous, and no further attempt to straighten out their ages is made at this time.

Along the west shore of Antigonish harbour, on the Captain Pond granite, a true arkose may be seen, lying in a small saddle of granite. To the north and to the south of this arkose, a well cemented tillite also overlies the granite. The age of the tillite is unknown, and the included granite and rock fragments have not been studied sufficiently to place them as to possible origin.

VI STRUCTURAL GEOLOGY

In order to gain an understanding of the structural geology of the whole area, several small areas will be discussed in detail. Areas have been chosen which show the major features of the west half of the map area. One of the areas selected, Monk Head, gives an indication of what may be the history of the east half of the map area. The Monk Head structure is itself complicated; Windsor limestone horizons which are the key to this structure do not lend themselves to easy identification, and the slumps of red mud and gypsum in this area have confused many of the good clues. The Pomquet River syncline also sheds some light on the possible structure underlying the east half of the map area.

The block diagrams and sketches on the following pages are not all to scale. It is hoped that they may help explain the relationships of the various sediments and the sequence of historical events which have taken place within the whole map area. Small areas are taken up in the following order:

1) The lower end of Ogden Brook.
2) The North River area, including the main fault.
3) The Old Gulf Road quarry area, south of the Sugar Loaf.
4) Williams Point.
5) The limestone deposit at South Side of Antigonish Harbour.
6) Monk Head.
7) The Pomquet River syncline.

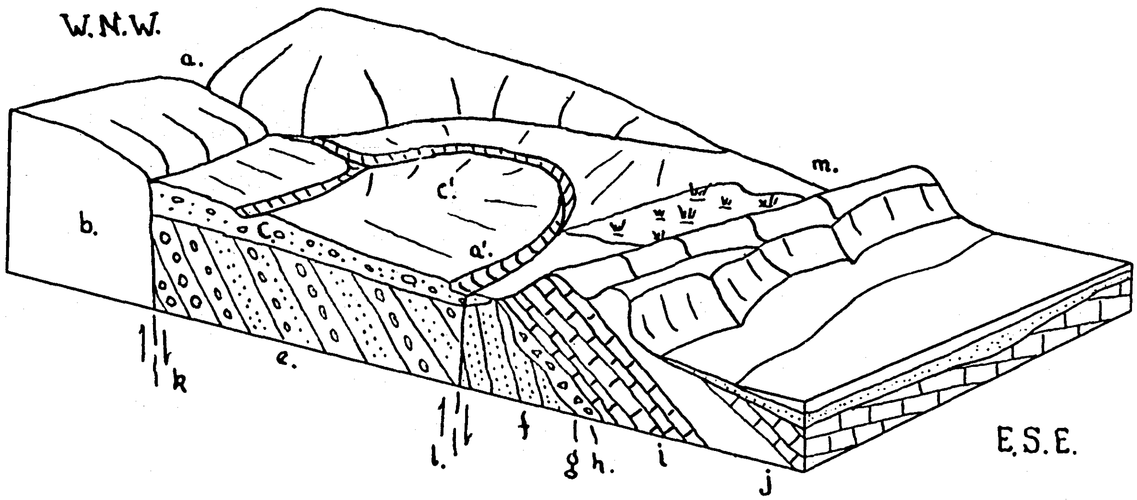

Figure 5. The Lower End of Ogden Brook.

a) to a') is the Ogden Brook, cutting a deep "V" valley through b) the metamorphic rocks of the Lower Ordovician Browns Mountain group. c) and c') represent recent deposits, glacial, stream and fanglomerate, which bury most of the Horton outcrops. e) represents a section of Horton ranging from late Lower to early Upper Horton, and f) are Upper Horton sandstones, which correlate with the Ainslie sandstones. g) is the surface of unconformity between Windsor and Horton, and h) the basal sharpstone conglomerate of Windsor age, underlying the basal limestone, i). j) represents the rapidly disappearing marl and gypsum which form the cormorant rookery at Crystal Cliffs, and the limestone shown above the gypsum in the bay, is the Canary limestone. k) is a normal fault which has brought the Browns Mt.

group above the Horton group, although, as has already been shown, Horton sediments probably covered these older rocks until late Horton times. Sharpstone conglomerates, with pebbles from this metamorphic complex, belonging to late Horton and basal Windsor rocks, place the age of this faulting as late Horton. 1) represents the major fault of the area, running north 40° east, and as far south as the Antigonish Sugar Loaf. Displacement has brought together sections which normally lie 1,000' or more apart. Since the beds are dipping at steep angles to the fault face, the vertical displacement must be 1,200' at a minimum. The northern end of this major fault is covered by recent gravels; the rift valley m) is the topographic expression of the fault north of Crystal Cliffs.

Another event of major importance has been the tilting of the Windsor and Horton sediments towards George Bay. Later activity of the faults may have contributed to the tilting, but downwarping of the sedimentary basin to the east probably had an even greater effect. Recent events include glaciation, uplift following the ice retreat, and slight submergence very recently.

Events from this area which are helpful in explaining the structure of the whole area may be summarized as follows:

1. Normal faulting, with over 1,200' displacement, occurring in late Upper Horton.

2. Post-Windsor activity of faults, and/or downwarping of sedimentary basin to the east.

3. Extensive uplift, either just preceding 1) or just following 1).

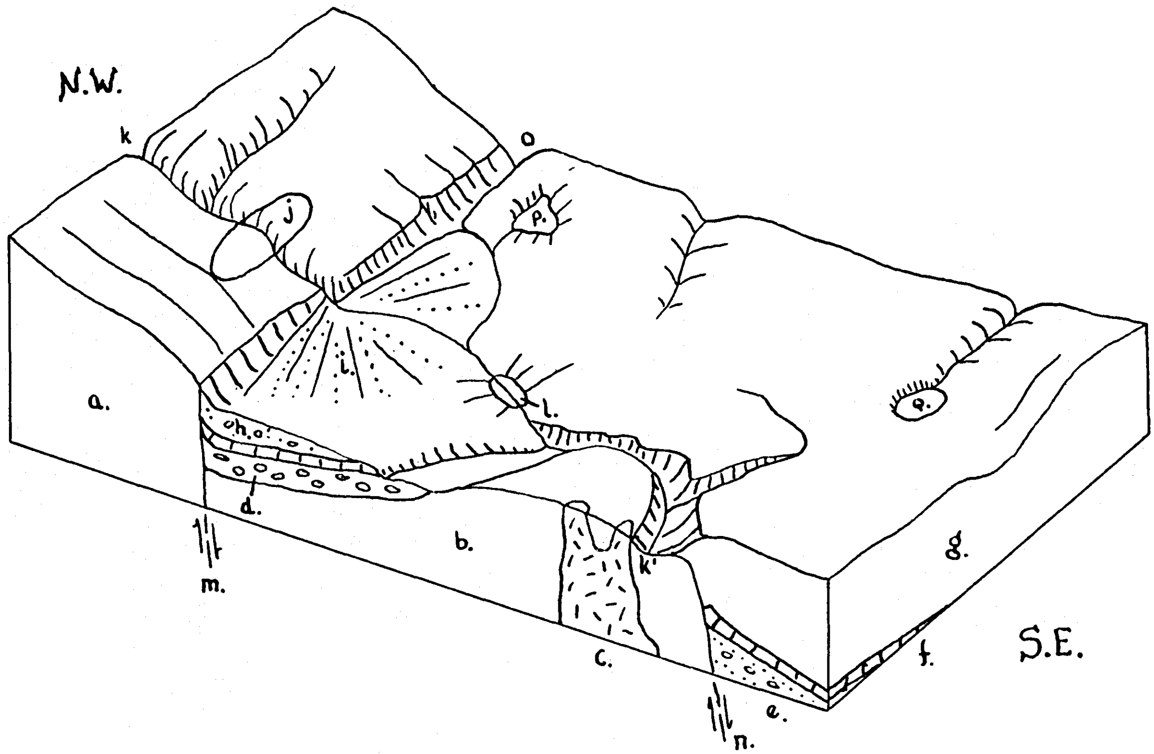

Figure 6. The North River Area.

a) is the metamorphic ridge formed by the Browns Mountain group. b) is the detached block of this same group with c), red granite intruding it. Roof pendants and xenoliths are to be seen in the stream bed and bank at point k'). d) is Lower Horton conglomerate, unconformably overlain by Windsor limestone f), the basal limestone, or I horizon. e) represents the Upper Horton, which is only a guess as to what underlies the Windsor in the area shown. g) represents the gypsum hills, and h) and i) are recent gravels and fanglomerate blanketing areas of the gypsum. j) is the outcrop of red, fine grained rock, jasperite, which has indurated the metamorphic rocks at this point, increasing their resistance to erosion, as shown by the twenty foot waterfall at this point. k) to k') is the north branch of the North River shown cutting a deep gorge through the metamorphic ridge and exposing Horton sediments through the small window at l). m) is the major fault running from Morristown, and n) is a minor fault associated with the large one. o) is the fault valley, 90 feet deep just north of this sector, and separating metamorphic rocks on the west from gypsum beds on the east. Displacement of the fault is about 500' at o). The two ponds p) and q) represent water filled sink holes in the gypsum. There are many such sinks not filled with water, and the region between p) and q) is typical of the more rugged karst topography of Windsor formations.

Since the major fault runs into the flanks of the Antigonish Sugar Loaf, upon whose sides no traces of the fault are found south of the end of the North River's south branch, it appears that the fault has had a scissor action, with major displacement at the northern end. The Windsor beds do not appear to dip as steeply into the Antigonish basin here as they do at Crystal Cliffs. Although shown on the sketch, the limestones are not seen in the field in fault contact with the Browns Mountain group; this contact is inferred from the relationship of the overlying gypsum, which is separated from the metamorphic rocks only by a stream flowing along the fault trace. Since the gypsum appears fresh, and does not contain outwash from the ridge to the west, some of the faulting in this area is presumed to be post-Windsor.

Important facts from this area which are useful to the understanding of the structure of the entire area are:

1. The major fault in this area has about 500' of displacement, and most recent movement has been post-Windsor.

2. The northward plunge of Windsor sediments is less marked than the northward plunge of Horton sediments which helps place the time of faulting as late Horton, as well as having post-Windsor movement.

3. Even more extensive uplift has taken place here than to the north, around Crystal Cliffs; the metamorphics stand 760' above sea level, and Windsor rocks are about 250' above sea level. Discounting erosion, post-Windsor uplift has been at least 250'.

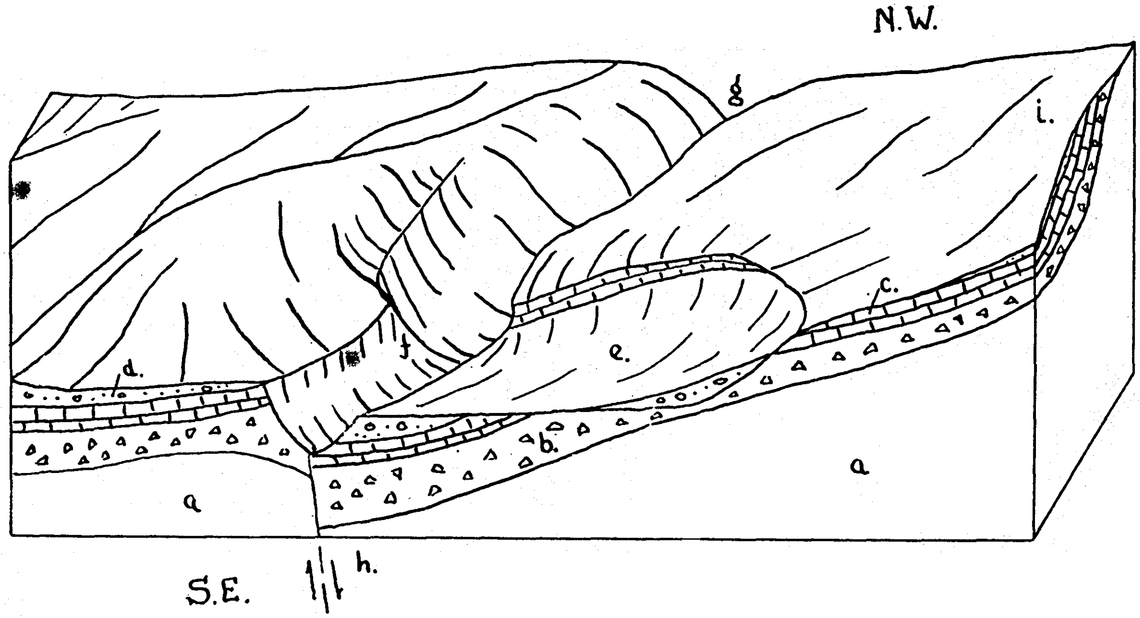

Figure 7. Old Gulf Road Quarry Area.

This area lies about a mile north of Rights River and a half-mile south-west of the Sugar Loaf. The stream is in fact a branch of Rights River and cuts through g), a steep, narrow gorge in the metamorphic rocks, shown as a). b) is a sharpstone conglomerate of basal Windsor age, lying directly upon the older rocks. c) is the basal Windsor limestone, overlain by recent gravels and topsoil d). The small cut at e) is the result of old limestone quarrying operations, and the area is now a heap of limestone rubble. f) represents the very steep south face of the river cut and is about at the location of a small cave, formed by fracturing out a sharpstone conglomerate chunk, and roofed by basal limestone. h) is a small reverse fault, with perhaps 50' of displacement near the cave. It seems

to run a long distance horizontally, and is apparently connected with the uplift of the Browns Mountain ridge, possibly in the late stages of this uplift and represents a relief fault.
i) is the slope running up to the Sugar Loaf summit. The contact shown in the sketch lies at about 200' elevation today. The limestone is scattered over the hillside in patches, but no where reaches higher than 300' elevation. The south end of the metamorphic ridge has apparently been uplifted further than the north end in both pre- and post-Windsor times.

The sharpstones in the conglomerate range in size from 2 to 5 cms. and are very nearly 100% green-gray quartzite and baked shale, representing very local origin. Here is more proof of late Horton uplift for this ridge.

Finally, what about the Horton itself? The writer and Jean Puech together did not find any Horton in the gorge which is the stream bed at this point. Material in the south bank, and underlying the sharpstone conglomerate may possibly be Horton; it is thought to be Browns Mountain by the writer, as it was by Puech.[1] Either Horton sediments were deposited at this point, and were eroded without trace before Windsor limestones were deposited, or this point was above the reach of Horton sedimentation . The writer supports the first view. The fact that Windsor limestones have stuck to this elevated position while Horton sediments did not, does not strengthen the argument, but does not condem it. The evidence that Lower Horton conglomerates were swept into the North River area from the south-west, and deposited at that point is very strong. These sediments would have passed

1 Puech, J., 1949, Map.

directly over the Old Quarry area, the area under discussion, when it was at a low elevation, if not below sea level. The writer offers support to this thesis in a map by M. Y. Williams which shows a single Horton outcrop in the same stream bed, exactly three-quarters of a mile north of this area, and at about 450 feet elevation.[1] The outcrop is not shown on the geological map accompanying this report, but when located in the field, will most certainly be added.

Eastward along the reverse fault the great wash of sediments from off the south slope of the ridge has buried most traces of limestone under thick gravels. The single outcrop of limestone found along the fault trace supports the fault thesis, but suggests that to the east the fault is normal. No measurement of displacement is possible.

Evidence form this area serves to fix the time of events of faulting and uplift of the metamorphic ridge. In summary:

1. Great uplift took place at the end of Horton times, allowing time for Horton sediments to be stripped off the south end of the ridge before Windsor limestones were deposited.

2. Faulting along the south edge of the metamorphic ridge may be due to relief from stress, or may be part of the general uplift.

3. Some 250' to 300' of uplift as a minimum has taken place since Windsor times.

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1 Williams, M. Y., 1914. Map.

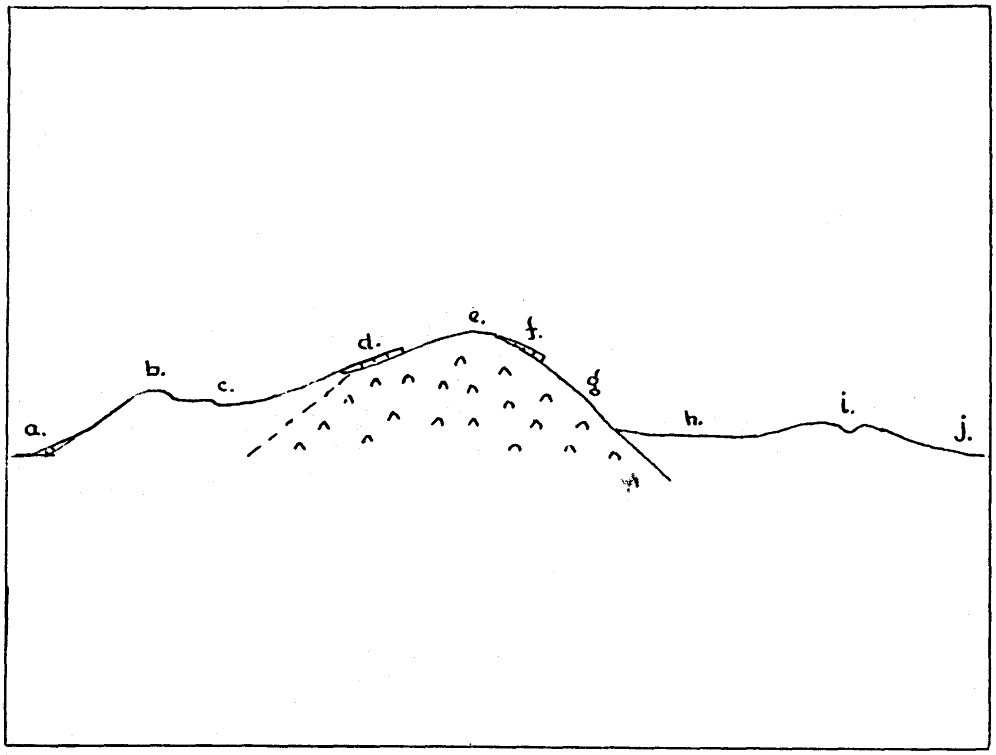
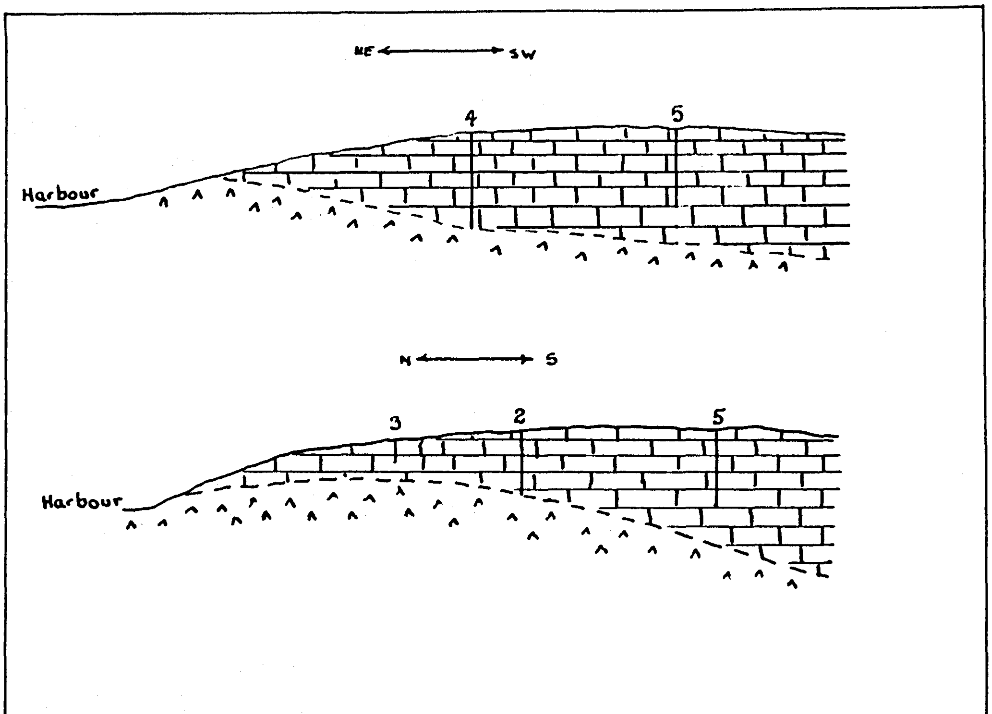


Figure 8. West-East Section Through Williams Point.

The section sketched above is exaggerated vertically. It represents the granodiorite mass outcropping at e), being over-lapped by Windsor sediments which dip radially outward and dis-appear under the Harbour at a) and j). The identity of the limestone at a) is not known. It contains limey mud balls, with shell fragments stuck in them and often acting as a core. These are thought to have been rolled down the slope of the grano-diorite, probably aided by wave action. The limestone here is dark, and crystalline. The ridge at b) is a prominent high area upon whose crest are built the Williams Point farm houses. The soil is red and clayey, and may either be Windsor siltstones or glacial in origin. The low point c) is caused by gypsum being washed out to form sinkholes, and by small streams cutting through soft beds. The c) area is typical karst topography and overlies the limestones which outcrop on the hill at d). The d) and f) outcrops contain fossils from Bell's subzone "B", including the only Bryozoa known in the area. Tiny razor edged slivers of the granodiorite are seen in thin sections of these limestones. They represent mechanical weathering, probably from extreme temperature changes, and indicate that this knob was at least at sea level during early Windsor time.

g) is a nearly flat face of granodiorite, dipping steeply and having the earmarks of a small fault scarp. To the north-east where the fault seems to go, only rolling gypsum hills can be seen. The high point i) is formed of gypsum, which is strewn about the east side of Williams Point and southward. The picture gained by the writer of this area is that Lower Windsor seas lapped around the edges of this igneous mass, which was slowly sinking into the water. By Upper Windsor this mass may have been completely submerged and buried by sediments, with the faster downwarp taking place to the east. Covering sediments have been eroded off, following the tilting of the block, of which Williams Point is a member, in post-Riversdale times. The fault indicated in Figure 8, and on the geological map section appears to be minor, but possibly is larger than expected. The anomolies picked up by the magnetometer survey on the telegraph road to the south indicate that this may be part of a major fault.



From Messervey, J.P., 1945. Limestone Deposit, South Side Antigonish Harbour.

Figure 9. Sections Through Limestone Deposit, South Side of Antigonish Harbour. (after J. P. Messervey, 1945)

The interesting point about this limestone outcrop is its great thickness. It overlaps a granite mass which is shown outcropping along the shore. The high elevations in this little area are all made by limestone. A complete analysis of the limestones drilled in this area may be found in the 1945 Annual Report on Mines, Province of Nova Scotia, with a short description of the area by Mr. Messervey. The report shows that #2 borehole passed through 60.6 feet of limestone before reaching granite, #3 through 23 feet of limestone, #4 through about 100 feet, and #5 through 85 feet. Granite fragments were encountered in most of the bore holes. This great thickness is hard to explain. The fossils collected to date and identified from this bed are subzone "B" fossils. If all the subzone "B" limestone horizons known in the area were stacked up together they would account for little more than fifty feet. The dip of these beds is gentle, about 20° towards the west.

There are several explanations which can be offered, but until more evidence is uncovered none is offered as the correst one. One explanation is that before tilting, the steep east, and present shore side of the granite offered a poor depositional base for the limestone, which slid off into a catchment basin to the side of the granite crest, forming excessive thicknesses of limestone. The core would show brecciated limestone were this the case. Another explanation is that the conditions in the basin allowed the 100' of limestone to be deposited normally. This seems unlikely since no other beds are known with such great thicknesses for this subzone. A third explanation is that fluctuations in the basement rock caused this area to be submerged during limestone deposition of the "A" and "B" subzones, but emergent during the intervening period, when gypsum and marl were deposited elsewhere. Since subzone "A" fossils are scarce to begin with, they might easily escape notice, particularly if buried by subzone "B" limestones. A single thin section of the granite from this point does not show any sign of disturbance, such as a large fault. There are a number of large limestone boulders along the shore showing brecciated dark fragments in a lighter calcite cement. Unless the cores produce evidence to the contrary, the writer favors the first solution offerd.

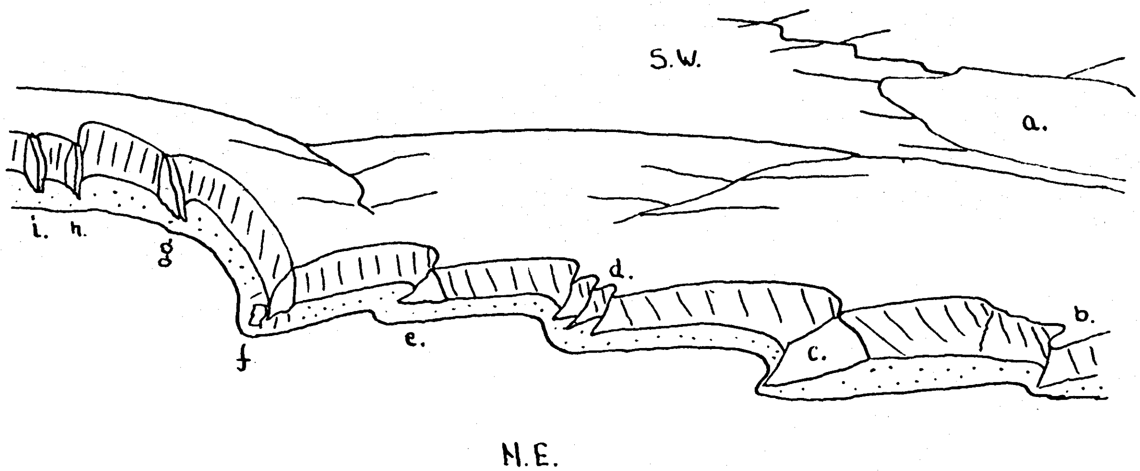


Figure 10. Monk Head.

The sketch shows the shoreline and outcrops at Monk Head with all the gypsum and clay debris removed. In the background at a) is Monk Pond, and in the foreground is the sea cliff. Literature on Monk Head does not indicate that its complicated structure has been worked out nor has sufficient note been made of its other interesting feature, the extraordinary algal colonies which occupy a prominent position in almost every limestone horizon. The best approach to the area is on the dirt road between Captain and Monk Pond. This entails a short hike on foot across the loose sandy beach, but the other road shown on the large map is deep rutted and not designed for a modern automobile. For that matter, neither is the last quarter mile of the preferred road.

The first outcrop, approaching from the west (right hand side of sketch) is at b) where three limestone horizons occur close together, at widely differing attitudes. The most competent bed, thought to be the B_{IV} horizon, strikes north 59° west, nearly paralleling the shore, and dips north at 74°. Its upper surface is covered by cabbage-like limestone heads, about 10" to 12" in diameter, and thought to be algal. Two, three, or four of these heads make up a cluster which are fastened to a single limestone stalk. The stumpy, and broad stalk-like bases are in turn fastened to the upper surface of the limestone bed. The total height of these algal colonies is about two feet. The thickness of the limestone beneath is not known, for red mud and overburden covers the upper edge of the outcrop. These algal heads are black, covered with a bituminous waxey substance with an encouraging petroleum smell. This outcrop may be seen at any tide, but low tide is required for exploring the rest of the section. The other two limestones mixed up at point b) are thought to be Upper Windsor. The thin 30" limestone stringer mixed up with gypsum contains Ostracoda and may actually be Lower Windsor.

Point c) is a durable limestone horizon, in contact above and below with undisturbed red silt stones. It strikes north 84° east and dips to the north at 68°. In this bed also, a large algal colony protrudes through the limestone, forming a smooth dome about 15 feet in diameter, and upon whose flanks the oolites have been washed and deposited like clastic fragments. This horizon is thought to be the 1st. or 2nd. oolitic limestone from the

Lower Windsor.

At point d) gypsum, red siltstone and thin limestone beds have slumped into the sea. The mass can be climbed over in dry weather only, and gives indication of faulting and folding, and defies identification.

At point e) a limestone horizon is in contact with gypsum and the whole mass has been sharply folded. The limestone dips to the north and is about at the axis of the anticline making up the Monk Head structure. This limestone is thought to be a subzone "B" member from the Lower Windsor.

The limestone at f), though overturned, and dipping north west is the same horizon as the limestone at g), which is right side up and dipping a bit south of east. This single horizon is thought to be Upper Windsor .

From g) to h), much out of proportion in the sketch, is a distance of 670', longer than portrayed. No outcrops are visible along this stretch, rather a high bank of clean, bedded and sorted sand which is classed as glacial outwash. h) represents an 8' yellow crystalline limestone, unidentified and without fossils, standing vertically and striking just east of north. Fifty feet beyond this bed lies fifty feet of gypsum, a 30" limestone marker, a few more feet of gypsum, and then the columnar algal limestone horizon, the C horizon from subzone "C", Upper Windsor. The algal columns so prominent on the Hood Island occurrence of this bed are directly in contact with the gypsum, probably faulted into position. The next outcrop beyond, save for a few feet of red siltstone, is from the

Lower Pennsylvanian. Here sandstones and conglomerates dip at gentle dips of from 8° to 10° towards the Windsor outcrops. The bank between these sections covers all possible traces of a large fault which must lie at this point.

Surface drainage patterns and lined up sink holes on the flat hill top behind Monk Head appear to follow the bedding lines of a plunging anticline. The writer interprets this Monk Head structure as an asymetrical, and steeply plunging anticline, formed by faulting taking place at depth below this structure. If the Monk Head area had gone up in faulting, and the Pennsylvanian area to the east down in faulting, the whole section being at depth, an asymetrical structure might be expected to result. It appears to be overthrust against the Pennsylvanian area, but the Monk Head structure could also be derived from normal faulting, provided it was covered to some depth.

Faulting and folding has taken place in the Monk Head structure at points b),d), e), f), and i). Displacements do not appear to be great within the complex, for instance, Upper Windsor is thought to lie at the flanks, while Lower Windsor occupies the center section, being exposed through erosion of the overlying Upper Windsor beds. This structure may in fact be a simple monocline with fracturing and faulting along its east edge. Beds bordering the postulated fault are not overturned towards the fault.

The Pomquet River Syncline.

The last local area up for discussion is the Pomquet River bed. The few outcrops along the river bed near its mouth in Pomquet Harbor, and those in the tributary to the west, show the structure here to be a plunging syncline, asymetrical, with the axial plane dipping to the west. The plunge appears to be about north, but may vary widely from this estimate as more outcrops are located. The east flank of the syncline dips gently, but the west flank is standing vertically. The writer interprets this structure as lying east of the fault, and very nearly over the down throw side of the deep seated fault which is running in a northerly direction, passing out into George Bay just east of Monk Head. The flat lying Canso beds east of Little South River along the telegraph road, and the west flank of the syncline make up a monocline which passes over the lip of the deep seated fault. The gently dipping Canso strata east of the fault represent the strata overlying the downthrown block which has now been tilted down to the west. The strata running together near the fault trace form the present Pomquet River syncline.

The summary and conclusions drawn from this investigation are given on pages 20 and 21.

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GEOLOGY
ANTIGONISH - POMQUET
NOVA SCOTIA
SCALE
2640' 0 1/4 1/2 1 2 MILES
SECTIONS
VERTICAL SCALE X 2.64
CARBONIFEROUS
PENNSYLVANIAN
P
MISSISSIPPIAN
CANSO
C
WINDSOR
W
UPPER HORTON
H1
LOWER HORTON
H2
PRE-CARBONIFEROUS
IGNEOUS
D1,2
METAMORPHIC
BM
OUTCROPS
CONTACT
APPROX. CONTACT
FAULT
COAL SEAM
TO LAKEVALE
TO CRIBBEAN HEAD
MORRISTOWN
MacISAAC POINT
CRYSTAL CLIFFS
OLDEN POND
JIM TOWN
MAHONEY'S BEACH
DUNNS BEACH
CAPTAIN POND
MONK POND
MONK HEAD
BIG MARSH
SOUTH LAKE CREEK
FAIRMONT
OLD GULF ROAD
SUGAR LOAF
OLD QUARRY
ANTIGONISH HARBOUR
WILLIAMS POINT
ANTIGONISH
SOUTH RIVER
LOWER SOUTH RIVER
TELEGRAPH ROAD
TAYLORS ROAD
POMQUET CHAPEL
POMQUET LAKE
POMQUET
POMQUET HARBOUR
SUMMERSIDE
HEATHERTON
MacKENNA POINT
POMQUET POINT
POMQUET ISLAND
TO BAYFIELD
TO MULGRAVE
45° 45'
45° 35'
62° 00'
55
50
61° 45
A A'
B B'
C C' C''
D D' D'' D'''
E E' E'' E'''