THE GEOLOGY OF THE WOODSTOCK AND MILLVILLE AREAS, NEW BRUNSWICK

by

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THE GEOLOGY OF THE WOODSTOCK AND MILLVILLE AREAS,
NEW BRUNSWICK

Doctor of Philosophy Thesis F.D.Anderson

The Woodstock and Millville areas are in the continuation of the New England Province of the Northern Appalachians. The oldest exposed rocks are sedimentary and are presumed to be Ordovician in age. Overlying these are Silurian sediments, which contain the iron and manganese deposits of the Woodstock area. The Ordovician and Silurian sediments indicate deposition in an unstable marine geosynclinal environment.

Granite and allied rocks intruded the Silurian and older strata during the Devonian period. Resting unconformably on the older rocks are flat-lying, coarse clastic, continental sedimentary rocks of Pennsylvanian age.

The Silurian and older rocks were highly folded and contorted as a result of compression from the southeast and a horizontal couple along northeast-southwest lines - with the southeast side moving southwestward.

The last ice-sheet moved in over the areas from the north-northwest.

GEOLOGY OF THE WOODSTOCK AND MILLVILLE MAP AREAS, NEW BRUNSWICK

INTRODUCTION

Location

The Woodstock and Millville map areas are in the west central part of New Brunswick, about thirty-five miles northwest of Fredericton. The Millville area lies between latitudes 46°00' and 46°15', and longitudes 67°00' and 67°30, the Woodstock area lies immediately to the west, between latitudes 46°00' and 46°15', and longitude 67°30' and the International Border.

The combined map areas are about equally divided between the counties of Carleton and York. They comprise an area of about 650 square miles.

The town of Woodstock is situated on the west bank of the St. John River, in the east central part of the Woodstock area. The village of Millville is in the central part of the Millville area, on the banks of the Northeast Branch of the Nackawic River.

Accessibility

The Woodstock and Millville areas are readily accessible by motor road and railway.

The Woodstock area has by far the better road coverage. The Trans-Canada Highway follows along the west bank of the St. John River the length of the area. The map area is also cut from east to west by Highway Number 5, which joins the towns of Woodstock and Houlton, Maine.

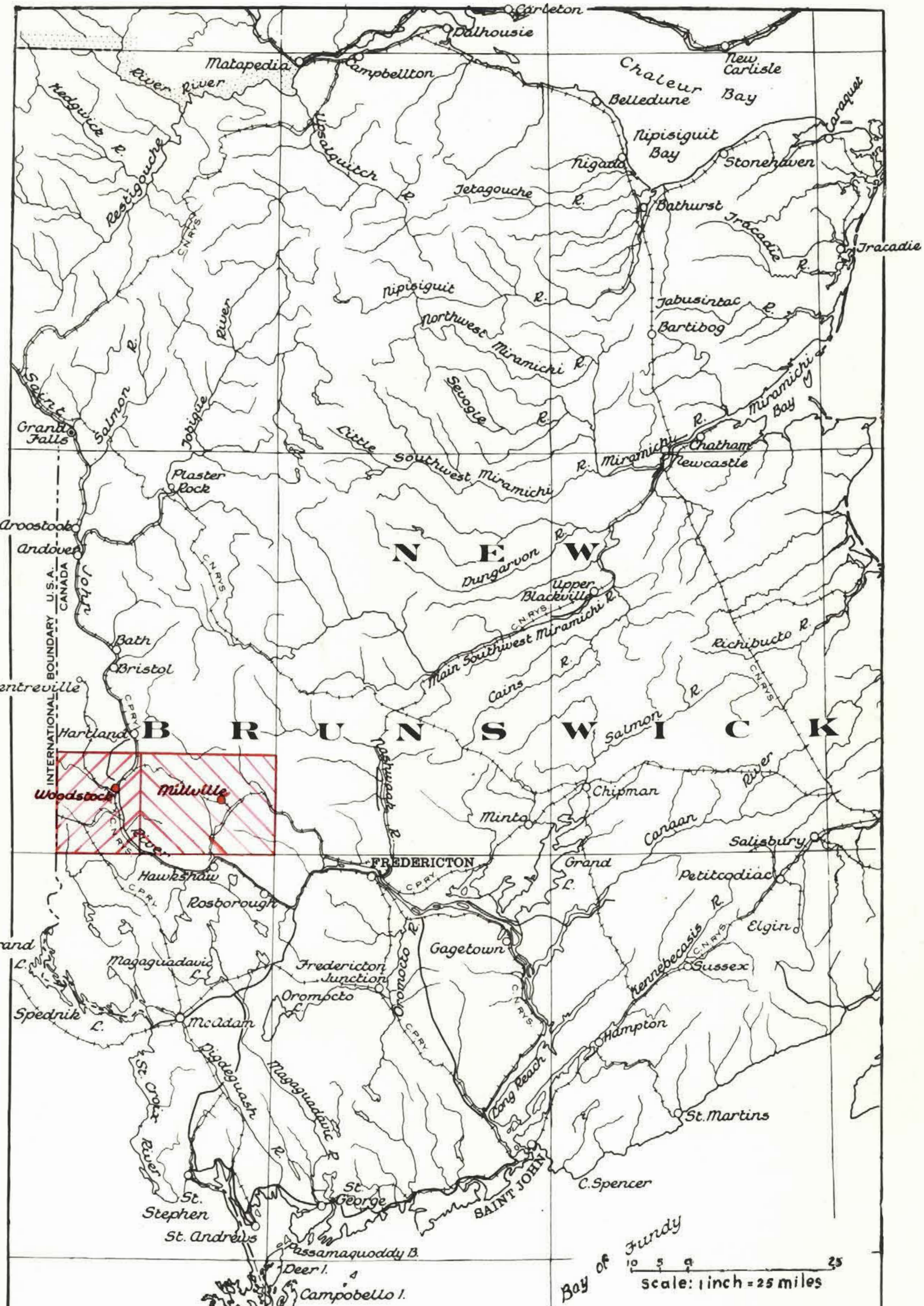

Figure 1. Index map showing the locations of the Woodstock and Millville areas.

Several secondary roads lead off these main highways to the settlements of the rich farming districts west of the St. John River. The Canadian National Railways and the Canadian Pacific Railways have railroads criss-crossing the area.

The Millville area is fairly well covered by a network of roads, except in the northeast section of the map area. Highway 24, between Fredericton and Hartland, runs through the village of Millville, and cuts across the eastern half of the area in a northerly direction. There are secondary roads leading from this highway to several small farming communities. A good gravel road connects Woodstock and Millville. The Gibson Branch of the Canadian Pacific Railways, from Fredericton to Woodstock, traverses the area in an approximate east west direction.

The St. John River is perhaps the only water course in the areas on which canoes may be used without much difficulty in the open season. Other streams, such as the Meduxnekeag, Nackawic, and Keswick Rivers, are very swift in the spring at highwater, with a large number of rapids, but in the summer or dry season there is seldom sufficient water to make the use of a canoe possible. At the source of many of the streams there is usually a chain of lakes or deadwaters, but the margins of these bodies are invariably quite swampy and the use of a canoe is impractical; they are also relatively inaccessible and can be reached only by poor trails or cross-country traverse.

Field Work

The writer spent the summers of 1950, 1951, and 1952, mapping the bedrock of the Woodstock and Millville areas, while employed by the

Geological Survey of Canada. During those years he was ably assisted in the field by J.M. Walroth, G. M. Mann, D. M. Morrison, L. E. Swayne, J. I. MacDonald, M. F. Moore, R. J. Wallace, J. M. Patterson, J. N. L.J-P. Charette, and G. C. Oland.

The field mapping was done on aerial photographs, on a scale of 4 inches to 1 mile. The information placed on the photographs in the field was then transferred, with proportional dividers and a sketchmaster, to a base map, the scale of which was 2 inches to 1 mile. Final map scale is 1 inch to 1 mile.

During the summer of 1951, in conjunction with a regular mapping program, the iron and manganese deposits of the Woodstock area were mapped in detail on a scale of 1 inch to 200 feet, using a plane table for the larger deposits, and pace compass method for the smaller deposits. Other mineral deposits in the area were mapped using either pace and compass methods and aerial photographs or base maps compiled by the New Brunswick Department of Lands and Mines.

Previous Work

The earliest geological investigations in the areas was undertaken by C. Jackson in 1837. Jackson was followed by several others including A. Gesner in 1842, J. Robb in 1849, C. H. Hitchcock in 1862, H. Y. Hind in 1865, and C. Robb in 1866. In 1874 the iron bearing rocks of Carleton County were examined by R. W. Ells.

During the years between 1880 and 1883, geological exploration was carried out by W. Broad and G. F. Mathew under the direction of L. W. Bailey. Two maps on a scale of 1 inch to 4 miles and a report followed the three years field work. During the time Broad, Matthews and Bailey were mapping the bedrock, R. Chalmers was busy studying the surface geology of the region. Maps and reports of Chalmers findings were published by the Geological Survey of Canada.

Upon completion of investigations by Broad, Matthews, Bailey, and Chalmers, very little in the nature of geological explorations were undertaken until 1935. In that year, J. F. Caley surveyed the topographic features and mapped the bedrock of a large part of Carleton County and adjoining York County for the Geological Survey of Canada. In the course of this mapping he covered an area of about 800 square miles, between latitudes 46°00' and 46°30', and longitudes 67°15' west to the International Border. The results of this survey are contained on a map, on a scale of 1 inch to 2 miles, and in a memoir.

PHYSICAL FEATURES

General

New Brunswick lies within the northeastern continuation of the New England Physiographic province of the Appalachian Highlands. The New England province includes the Green Mountains of Vermont, the White Mountains of New Hampshire, and the Highlands of Maine. New Brunswick has several physical subdivisions (see Figure 1); Alcock[1] has indicated these subdivisions, and his descriptions, in part, follow.

"New Brunswick falls naturally into four topographic divisions, whose boundaries, however, in most places are not sharply defined. The first, which may be regarded as the main axis of the province, is known as the Central Highlands, an upland region developed largely on resistant granitic, volcanic, and metamorphic rocks. It trends northeasterly through the central part of the province and is made up of ridges and hills most of which have flat summits. Its elevation varies considerably but most of it has an average height of about 1000 feet.

To the northwest of the Central Highlands is a second division, which may be termed the Northern Upland. It stands at an elevation of 800 to 1000 feet above sea-level and is developed on folded Palaeozoic strata. The upland presents a remarkably uniform, flat-topped surface whose regularity is broken only by a few peaks and ridges rising slightly above the general level and valleys such as those of the St. John and Restigouche, which are deeply entrenched in it.

The third division, the Eastern Plain, lies to the east of the Central Highlands and makes up almost one-half of the province. It is a region of low relief, rarely more than 600 feet high, sloping gently to the Gulf of St. Lawrence. Its underlying rocks are mostly flat or gently dipping Carboniferous sediments.

The fourth division, termed the Southern Highlands, lies along the Bay of Fundy. It is mainly an upland belt of ridges of which the most important is the flat-topped Caledonia Mountain belt of Albert, Kings,

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[1]Alcock, F. J.: The Appalachian Region; Geological and Economic Minerals of Canada, Geol. Surv., Canada, Econ. Geol. Series No. 1, Chpt. 3, pp. 100-101 (1947).

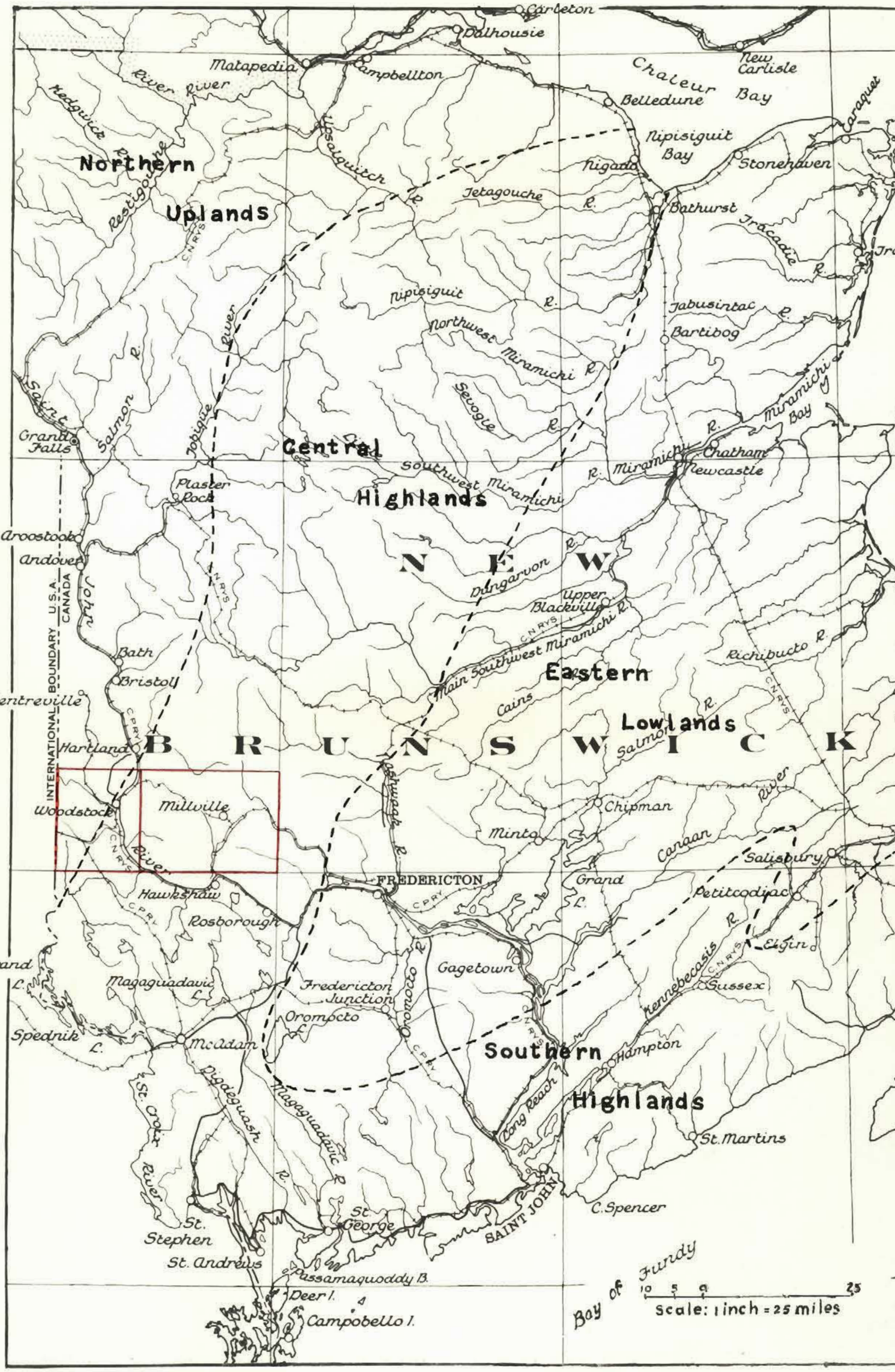

Figure 2. Map showing the physical subdivisions of New Brunswick

and St. John counties, which reach a maximum elevation of 1350 feet southeast of Markhamville. To the southwest in Charlotte county, the belt merges into the Central Highlands."

The Woodstock and Millville areas lie on the border between the Northern Upland and the Central Highlands, as a result of this the areas present a very diversified topography. The topography of the areas reflect largely the nature of the underlying bedrock. Gently rolling farmland, typical of the Northern Upland in this region, has been developed on the easily eroded slates in a large part of the Woodstock area west of the St. John River. The remainder of the areas is in the Central Highlands, and is underlain by resistant sedimentary, metamorphic, and igneous rocks, and being heavily wooded forms a sharp contrast to the gently rolling farmland of the former district.

The boundary between the Northern Upland and the Central Highlands in the Woodstock area, and also in most other areas, is obscure; roughly it follows the contact between easily eroded Silurian rock and older more resistant strata.

The average elevation of the Northern Upland in the Woodstock area is about 500 feet. The surface of the Upland in this area is gently rolling and when viewed from a distance presents a fairly regular horison, and broken only by the occasional prominence of resistant rock. (see Figures 3 and 4). The drainage pattern appears to have been well established on the upland surface before glaciation; however, action has since disrupted normal stream flow in several places. Uplift in fairly recent times has resulted in the stream valleys being deeply incised on the gently rolling surface of the upland.

The Millville area and the southeastern part of the Woodstock

Figure 3. Panoramic view of the Woodstock area, looking north, showing the deeply incised valley of the Meduxnekeag River in the foreground, and Iron Ore and Moody Hills in the left background. Iron Ore and Moody Hills are the location of iron and manganese deposits.

area may be considered to be in the Central Highland subdivision. Because of the large differences in the lithology of the bedrock underlying this region there is great diversity in physical features. However, when viewed from a distance the skyline is even and only rarely is there a knoll of resistant rock above the general level of the horizon. There are large expanses of gently undulating uplands bordering the valley of the St. John River and extending eastward and northward to the valley of the Keswick River. The Uplands are broken only by the broad valley of the Nackawic River. The upland area is at an elevation of about 500 feet along the valleys of the major streams and rises to about 750 feet in the interstream areas.

The Nackawic River is developed on easily eroded granite; the sedimentary rock bordering this granite was metamorphosed by the intrusion and is now much more resistant to erosion than the surrounding rock (see Figures 6 and 7). As a result the metamorphic rocks form very prominent northeast trending ridges, whose average elevation is about 750 feet, attaining at some points an elevation of over 1200 feet.

The land is rugged in the north-central and northeastern parts of the Millville area. Underlying this part of the area is a mixture of intrusive, sedimentary, and extrusive rocks. It is a land characterized by conical hills and narrow ridges. Between the hills and ridges the country is generally quite flat and often occupied by peat bogs, swamps, muskeg, and deadwaters marking the heads of several streams. Lakes are usually found where the valleys are narrow between ridges, and also amidst groups of hills. Local relief often exceeds 400 feet.

Figure 4. View from Oak Mountain looking to the northeast, showing the even skyline of the Woodstock area.

Figure 5. View from ridge one mile east of Ayers Lake. Hill in centre is composed of volcanic material.

Figure 6. Millville area, looking north from a ridge near Upper Hainesville. Hill in middle distance is composed of metamorphosed pre-Silurian strata. Valley in left background is underlain by Devonian granite.

Figure 7. Millville area, looking north from a ridge east of Lower Caverhill. Low ground in middle distance is underlain by pre-Silurian strata. Hills in background are composed of pre-Silurian metamorphosed rocks and are along the southeast contact of the Pinder-Keswick granite.

The region within which the two areas under study are located may be described as maturely dissected, ressurected, complex mountain area.

Drainage

The Woodstock and Millville areas lie entirely within the drainage basin of the St. John River.

The St. John River has a drainage area of about 21,600 square miles. This extends over parts of northern Maine, adjacent parts of Quebec, and a large part of western New Brunswick. Of the total drainage area about 65 per cent is in Canada, and of this 65 per cent, 11,250 square miles or a little over 50 per cent is in New Brunswick. The length of the St. John River from its source, at Little Lake Saint John in Northern Maine, to its mouth at Saint John, where it empties into the Bay of Fundy, is about 420 miles. The total fall of the river from Little Lake Saint John to tidewater at Fredericton is 1,578 feet. The river is at various stages of development along its course, with features of early to middle youth prominent along the upper reaches, while features of middle to late youth are evident along the lower part. The river has had a very complex history, the story of which has yet to be unraveled.

Glaciation has not changed the course of the St. John River to any great degree. Effects of glacial damming may be strikingly observed at Grand Falls, where a falls of 75 feet has been formed as a result of blocking of the former channel and rerouting of the river. The Reversing Falls at Saint John is also the result of blocking of the former river channel, coupled with the high tides of the Bay of Fundy.

Figure 8. Looking south along the east bank of the St. John River, four miles above Woodstock. The St. John River is visible in the centre background.

Figure 9. Meduxnekeag River, 4 miles above Woodstock.

Where the St. John River flows across the Woodstock area its characteristics are those of late youth. No flood plain has yet been developed, and the river is just able to carry away the material supplied to it by its tributaries. Exposures of bedrock and rapids along this part of the river indicate that a large part of the energy of the river is yet to be expended in downcutting.

Terraces are a prominent feature along the valley of the St. John River. There are at least two sets, and indications can be seen of a third, and possibly a fourth, set of terraces along the river in the Woodstock area. They may be readily seen at Grafton and in the vicinity of Northampton on the east side of the river; and between Woodstock and Bull Creek on the west side. These terraces and the falls that occur along the tributaries of the St. John in the area, may be taken as evidence of uplift (or a lowering of base level) of the region.

The most important tributary of the St.John in the Woodstock area is the Meduxnekeag River; it has its source in nearby Maine, and empties into the St. John at Woodstock. From its source to mouth the distance covered is about 40 miles.

The valley of the Meduxnekeag is deeply entrenched in the rolling upland of the district and therefore forms a very noticeable feature of the landscape (see Figures 3 and 9). In places the valley walls are over 250 feet high. The river is generally still in a youthful stage with several rapids and two falls. The first falls is about 6 feet high and is near the mouth of the river at Woodstock, where the water flows over highly resistant greywackes and slates. The second is at Jackson Falls, about 10 miles from Woodstock, and at this place the river cascades over highly contorted calcareous slates for a descent of about

Figure 10. Falls on Gibson Millstream, one-half mile below road from Woodstock to Kilmarnock Settlement. The rock are inclined pre-Silurian greywacke and slate.

Figure 11. Bull Lake in the east central Millville area. The Lake is shallow, and the bottom is covered with organic material.

20 feet in a distance of 200 feet. If we are justified in interpreting these two falls as 'nick points' they indicate at least two periods of rejuvenation of the region in comparatively recent times.

Other tributaries of the St. John River in the Woodstock area appear to have had similar histories as that of the Meduxnekeag River. Acker Brook, Gibson Millstream, Bull Creek, and Hayes Brook, to name but a few, have deeply incised valleys and two distinct falls or cascade sections along their courses. (see Figure 10). The relative resistances to erosion of the bedrock underlying each of these streams vary considerably, also the flow of water of each stream is considerably different; if such factors are taken into consideration, then the falls on these streams are at corresponding distances from their confluence with the St. John River as are the falls on the Meduxnekeag River.

The main tributaries of the St. John River in the Millville area are the Nackawic and the Keswick Rivers. Other streams are too small to be of much consequence, except perhaps the Mactaquac River whose headwaters, consisting of large swamp sections, are located in the southeastern part.

The histories of these tributaries appear to be much the same as those of the Meduxnekeag, Gibson Millstream and others, but do not have the narrow deep valleys that are so prominent with the other streams. The position and the development of the Nackawic and Keswick Rivers have been influenced to a great extent by the structure and the nature of the underlying bedrock. Differences in the attitudes and lithology of the bedrock are reflected in several places by the somewhat erratic courses of the Nackawic and its tributaries. Although the valleys are not very wide at any section along the upper parts of the

Figure 12. Ayers Lake viewed from a ridge one mile east of the Lake.

Figure 13. Deadwater on the Northeast Nackawic River 2 miles north of Taffy Lake. Hill in background is composed of volcanic material.

Nackawic River they narrow considerably when passing through resistant rocks, such as are encountered at the granite contact a few miles to the north of Temperance Vale. The Northeast Nackawic is developed on an intrusive mass of easily eroded granite, because of this the valley is broad with gentle slopes; however the walls of the valley are steep, being protected by the resistant metamorphosed rocks of the contact zone of the sediments. In the lower part of the valley, between Pinder and the mouth of the stream the Nackawic has cut a narrow course into the valley floor. Here it is apparent that the river has been rejuvenated and has cut down as much as 50 feet into the granite underlying the region.

The upper parts of the Nackawic and its branches are dotted with lakes, deadwaters, and waterfalls, the whole drainage pattern of the district having been disrupted by glaciation. (see Figures 11, 12 and 13).

Along the upper reaches of the Keswick River the valley is at its widest. The eastern side of the valley is steep but the western side generally has a much more gentle slope; towards the southwest, i.e. towards the headwaters of the Northeast Nackawic River, the slope of the land is practically negligible. There is little interuption between the two valley systems along the upper reaches, and it appears quite possible that they were formed by one pre-glacial stream. At Barton, where the Keswick passes over the contact between granite and metamorphosed sediments, the valley of the river narrows considerably. From Barton south for several miles the Keswick has cut a gorge, in places as much as 100 feet deep, through fluvioglacial material.

The headwaters of the Keswick and its tributaries, are dotted with deadwaters, water falls, lakes, and several swamps.

There are two important swamps in the Millville area in view of their economic potential. These are peat bogs, the largest is perhaps the one near Taffy Lake, north of Millville. The other is around the headwaters of the Mactaquac River a few miles north of Lower Caverhill. Neither of these peat bogs has been commercially exploited, although their existence has been known for several years[1].

Glaciation

The effects of glaciation are evident though not spectacular in almost every part of the two areas under study. The region is covered with a mantle of drift, and it has been estimated that till soils make up 90 per cent of the soil cover[2].

Measurements made on the glacial striae, the position or trend of eskers, and other features of glaciation in the areas, indicate that the ice moved over the region in a southeasterly direction. Several times during the retreat of the glacier, the front was more or less stationary, at these times when ablation and accumulation were balanced, meltwaters deposited large thicknesses of sand and gravel in the valleys leading away from the ice front. It has been postulated that for a short period of time the ice front was stationary across the northern part of the

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[1]Chalmers, R.: Surface Geology shown on the Fredericton and Andover Quarter-Sheet Maps, New Brunswick; Ann. Rept. Part M, Vol. XII, Geol. Surv., Canada, p. 34 (1902).

[2]Stoobe, P. C.; and Aalund, H.: Soil Survey of the Woodstock area, N. B.; Dept. of Agriculture, Canada, Pub. 747, Tech. Bull. 48 (1944).

Woodstock area[1]. There are irregular mounds of gravel and circular depressions - some of which are filled with water - about one mile north of Lower Wakefield, a short distance west of the St. John River; these features were examined by H. A. Lee of the Geological Survey of Canada, and he suggested them to be ice margin features. This locale near Lower Wakefield represents part of the stationary ice front that probably stretched in a east-west direction across the countryside.

The terraces along the St. John River are composed of outwash materials. The Keswick River has large thicknesses of sand and gravel along the Barton-Hayne section in the southeastern part of the Millville map area, which are undoubtedly outwash products. Several other streams in the areas had their valleys clogged with outwash materials and as a result the drainage was disrupted over the whole of the region.

Three eskers were found in the country examined, all in the Millville area. The first was about 4 miles northwest of the town of Millville, and about 1 mile west of Cloverdale. The trend is southeasterly, paralleling Highway 24. Throughout, its course is sinuous and its cross-section semi-circular. With some variations its height and width are about 30 feet and 100 feet, respectively.

The second esker is about 7 miles southeast of Millville and about 1 mile north of Lower Caverhill, at the headwaters of the Mactaquac.

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[1]Lee, H. A.; personal communication

This esker also has a sinuous southeasterly course of about 4 miles in length. The height and width vary considerably, but on the average it is about 30 feet high and a 100 or so feet wide. The road southwest from Staples Settlement cuts across the lower part.

A third, and comparatively small esker was found in the southeasternmost part of the area, about 1 mile west of Springfield. The trend of this esker is northwest-southeast, parallel to the course of other glacial features in the area. Its course and cross-section are typical. The height is about 20 feet, width about 60 feet, and length a little less than a mile.

The first two eskers have been exploited for gravel, but because of their location and the abundanse of sand and gravel in the deposits of outwash materials in the valleys, only local use is made of its products. The location and size of the third and last esker has made even local use of its materials uneconomical.

GENERAL GEOLOGY

General Statement

The consolidated rocks which underlie the Millville and Woodstock areas belong, as far as can be determined, to the Palaeozoic era. Fossils have served to date as Silurian about half of the bedrock of the Woodstock area. Although no fossils were found in the sedimentary rocks of the remainder of the two areas, it has been generally accepted by previous workers in the region that these rocks are Palaeozoic and pre-Silurian in age. Unconformably overlying both Silurian and pre-Silurian strata in the northern parts of the areas are coarse clastic sediments, which, because of their lithologic similarity to rocks of known age immediately to the north, are here placed in the Carboniferous system.

Intruding the pre-Silurian sediments are masses of granitic, syenitic and gabbroic rocks which appear to belong to the Devonian period. Dykes and sills of diabase and diorite, also apparently Devonian in age, intrude both the Silurian and pre-Silurian strata.

Volcanic rocks have been found in various localities in both areas. The age of these rocks is uncertain. They have been mapped as Devonian, but they may belong in part to the Carboniferous era.

Several difficulties are encountered in the study of the stratigraphy, thickness, and other aspects of the Silurian and pre-Silurian strata in the region. Bailey, in 1885[1], wrote as follows:

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[1]Bailey, L. W.: Report of Explorations and Surveys in Portions of the Counties of Carleton, Victoria and Northumberland, New Brunswick; Annual Report Part G, Geol. Surv., Canada, p. 13 (1885).

"In the study of the geology of the Silurian district two main difficulties are to be contended with. Of these, one arises from the slight diversity in the nature of the rocks to be studied, which as a consequence, present nearly the same aspect over wide areas, and the second, from the profound disturbances which they have undergone. It is thus well-nigh impossible to determine with anything like certainty, either the order of succession or the relative or total thickness of the several subdivisions of the system."

Although in this instance Bailey confined his remarks to the Silurian, it can be safely said that they apply equally to the pre-Silurian.

The beds and banks of the streams in the areas offer the best opportunity for obtaining exposures of bedrock. Road and railroad cuts also occasionally present good outcrops; but it is possible to travel for miles along the streams and the traffic routes without encountering any outcrop. Except along the crest of the larger hills, rock exposures in the interstream area are rare. Considerably less than one per cent of the total land area under study is exposed bedrock.

The rock name greywacke as used in this dissertation is defined as a dark coloured sedimentary rock, composed of sand grain size angular (in many places subrounded) fragments of quartz, feldspar, rock, and minor amounts of other minerals in a silty matrix. The feldspar content of the rock is commonly over 10 per cent. Many of the thin sections examined have the compositions of a subgreywacke as defined by Pettijohn[1]- i.e. less than 10 per cent feldspar, and a large percentage of subrounded quartz fragments, and rock fragments, set in silty matrix.

The term argillite is used to identify "A thick bedded

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[1]Pettijohn, F. J.: Sedimentary Rocks; Harper & Brothers, New York; p. 243 (1948)

argillaceous sedimentary rock without distinct slaty cleavage or fracture"[1]. The rock name slate is applied to aphanitic sedimentary rock " - having the property of easy fissibility along planes independent of the original bedding, whereby they can be parted into thin plates indistinguishable from one another in lithological character"[1].

Grit as used refers to an angular coarse grained sedimentary rock, the grain size being about that of coarse sand. In some occurrences the rock could be more aptly described as a fine conglomerate or a coarse greywacke.

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[1] Rice, C. M.: Dictionary of Geological Terms; Edward Brothers, Inc., Ann Arbor, Michigan; (1949).

TABLE OF FORMATIONS

ERA	PERIOD	EPOCH	LITHOLOGY
Cenozoic	Quaternary	Recent	river sands and gravels
		Pleistocene	sands and gravels, glacial drift and outwash
		-unconformity-	
Palaeozoic	Carboniferous	Pennsylvanian	chocolate-coloured and red conglomerate, grit, sandstone and shale; recomposed granite
		-unconformity-	
	Devonian		granite, granodiorite, syenite, diorite, quartz diorite, gabbro, diabase sills and dykes
	Devonian?		extrusions of andesite and basalt
		-unconformity-	
	Silurian		(C) buff and grey-green sandstone, slate and greywacke; intercalated dark grey calcareous slate (B) grey-green, grey, green and red slate; sandstone, greywacke, manganiferous iron formation; minor limestone and conglomerate (A) grey-green sandstone, slate greywacke; minor conglomerate and limestone
		-unconformity-	
	Pre-Silurian		grey-green slate, argillite, greywacke; minor limestone and grit biotite gneiss, mica schist, chlorite schist, hornfels

DESCRIPTIONS OF FORMATIONS

Pre-Silurian

Distribution. Pre-Silurian rocks underlie the greatest part of the Millville and Woodstock areas. At their western boundary these rocks abut against Silurian sediments; the contact is roughly along a line drawn diagonally across the Woodstock area from the northeast corner to the south central part. Eastward from the Silurian to the large granitic mass which cuts northeasterly across the Millville area, the areas are underlain almost entirely by pre-Silurian rocks.

A second fairly large area of pre-Silurian rocks is found in the southeast corner of the Millville area. This section is bounded on three sides by granite. Its relationship to other areas of pre-Silurian is uncertain.

Other small areas of pre-Silurian rocks are roof pendants in the various granitic and syenitic masses of both areas, and inliers in the Silurian of the Woodstock area.

In the north central part of the Millville area and in several places in the Woodstock area (notably near the contact with the Silurian), the pre-Silurian rocks have been cut by intermediate to basic intrusions. In the northern part of the Millville area and in the southern part of the Woodstock area, the pre-Silurian is associated with volcanic material of uncertain age.

The similarity of rock types and the scarcity of outcrop made it impossible to determine the stratigraphy or the thickness of the pre-Silurian - if limits were to be placed on the thickness of this rock group they would be about 3000 feet minimum and 40,000 feet maximum.

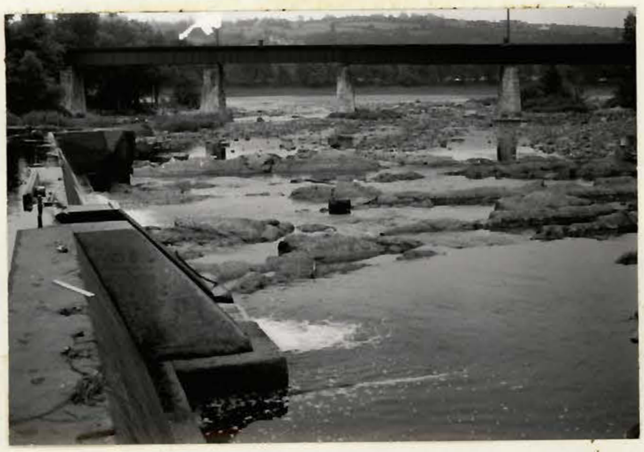

Figure 14. Pre-Silurian greywacke above railway bridge at Woodstock. The beds dip towards the observer, one of the few places where the pre-Silurian have low dips.

Figure 15. Pre-Silurian slate and greywacke below the falls on Gibson Millstream shown on Figure 10. Another locality where comparatively gently dipping pre-Silurian strata was found.

Lithology. Greywacke, slate and argillite comprise the bulk of the exposed pre-Silurian sediments. Limestone, grit and conglomerate are important locally, commonly as lenticular bodies of not more than 10 or 20 feet in thickness and a few hundred feet in length.

The greywacke is usually a grey-green, fine to medium-grained rock; it is arranged in beds which range in thickness from a few inches to several feet. Graded bedding is common and readily discernible. Microscopically the greywacke is composed of quartz, feldspar, and a few rock fragments in a silty fine-grained matrix. The quartz fragments, which make up to 75 per cent of the rock, are angular to subrounded, and range in size up to 1.3 mm (see Figure 16).

Interbedded with the greywacke are the finer-grained slates and argillites. These fine-grained sediments are in beds ranging from a fraction of an inch to several feet in thickness. The slates vary in colour from a light grey to dark green; and in several places, appear to have been a varved clay. Exposures of the slate along the road between East Newbridge and Central Waterville, in the western part of the Millville area are very distinctly varved. The beds are alternately light grey and green, about one-quarter of an inch thick, and upon close examination show a grain gradation.

The argillites tend to be darker in color than the greywackes and slates. They break with a conchoidal fracture.

The slates in the central part of the Millville area on Maple and Howland ridges, are dark grey, carbonaceous, and thin bedded. A few narrow beds of argillite and greywacke were noted interbedded with these dark grey slates.

Limestone, of exceptional quality, was found about 1 mile west of Central Waterville in the west half of the Millville area. The limestone is

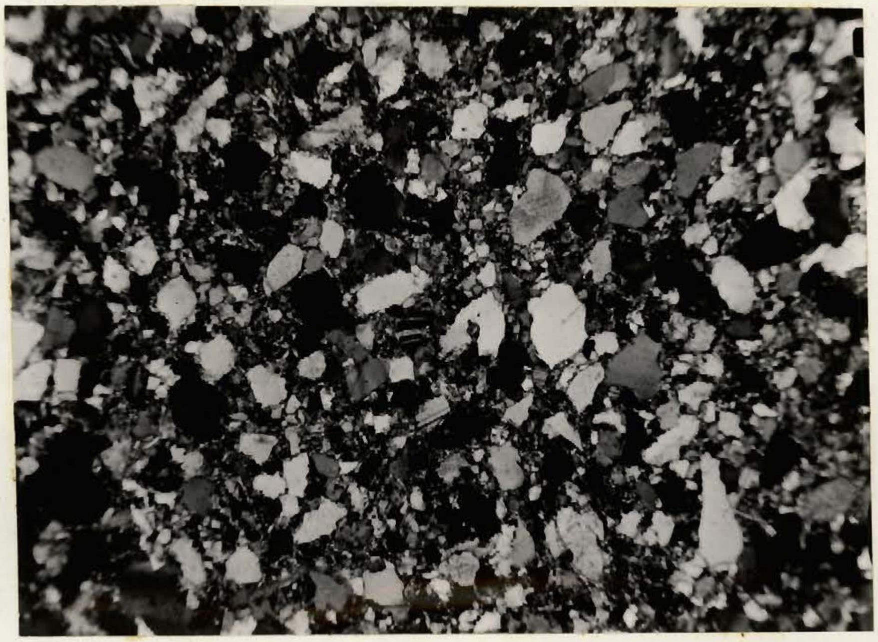

Figure 16. Greywacke, about 2 miles northeast of Northampton. Note fragments of feldspar near centre of figure. Crossed nicols, X 26.

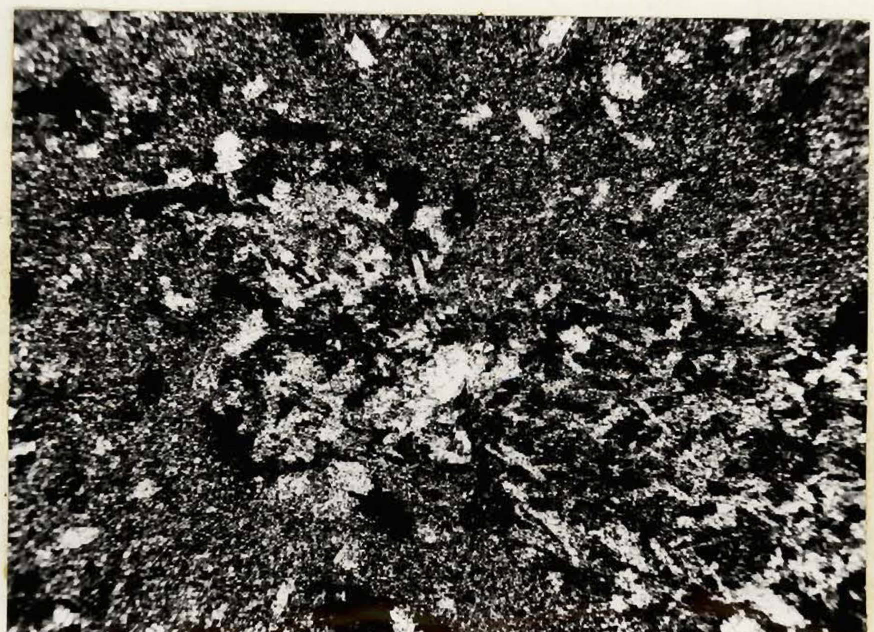

Figure 17. 'Spotted' slate, near road one mile northwest of Upper Springfield. Crossed nicols, X 26. The spot is that area of coarser-grained material in the centre and lower right corner of the figure.

associated with slightly calcareous slates and a narrow lenticular bed of conglomerate. The conglomerate is not exposed at the surface but was found in diamond drill cores in the course of the exploration of the limestone. Beds of limestone several inches thick, and associated with calcareous slates, were found on the east side of the Nackawic river near the settlement of Norton Dale. These limestones have very limited extent and are of a much lower quality[1] than that of the Waterville deposit. No other beds of limestone or calcareous rock were found in the pre-Silurian, in these areas. The limestone will be discussed later in detail in the section dealing with the Economic Geology of the areas.

Metamorphism. The pre-Silurian sediments have been metamorphosed by the intrusion of the many bodies of granite and syenite that are found throughout the Millville and Woodstock areas. The contact metamorphic zone is relatively narrow; usually less than one-quarter of a mile. The zone comprises gneiss, schist, hornfels, and injected lit-par-lit granite. Small areas of gneiss and schist are also found within the boundaries of the main intrusives as xenoliths.

The composition of the gneiss is not uniform but the constituents are essentially quartz, potash and plagioclase feldspars, biotite and muscovite, and here and there garnet and cordierite. The above minerals are arranged in alternate bands, up to 2 inches wide, rich in light and dark constituents.

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[1] 110th Annual report, Dept. of Lands and Mines of the Province of New Brunswick, pp. 39-40 (1946).

The schist is composed largely of small flakes of muscovite and biotite with variable amounts of quartz and feldspar. The flakes of mica are generally not more than one-eighth of an inch across but larger flakes, up to one-half inch, were noted in the xenoliths near Campbell Settlement, in the western part of the Millville area.

The effects of the granite intrusion on the pre-Silurian sediments may be fairly well observed along the road between Campbell Settlement and South Waterville, and about 1 mile north of the former. Generally, the sediments display little, if any, contact metamorphism beyond one-quarter of a mile of the contact.

'Spotted slates' are exposed in the eastern part of the Millville area, along the road between Upper Springfield and Lower Caverhill, about 1 mile northwest of the first named place. The slate is within one-half mile of the granite and is probably the result of contact metamorphism. The slate is dark grey, fine-grained rock, weathering to light grey, with small black coloured ovoid knots, one-eighth of an inch across, scattered throughout. Microscopically, the rock is composed of mica, principally muscovite, with smaller amounts of biotite, quartz and chlorite. The 'knots' consist of concentrations of secondary mica and chlorite, with random orientation (see Figure 17).

Green chloritic schists have been developed from the slates and argillites probably as a result of shearing, near the mouth of Acker brook in the northeast corner of the Woodstock area, along the Nackawic river about 1 mile above Norton Dale in the central Millville area.

There are exposures of a metamorphosed rock, for which no name is here suggested, on a hill about one and a half miles northwest of the town of Millville. Megascopically, the rock is light grey, almost white, fine-grained, and rust stained. There is no evidence of bedding or other primary structures. The rock is severely shattered; it is difficult to obtain a hand specimen on which a measurement of more than two inches can be made. Microscopically, the rock is composed largely of quartz and kaolin, both in angular fragments, and set in a very fine-grained matrix or groundmass of quartz and sericite. The fragments measure about 1 mm by 3 mm. The rock has the appearance of having been rhyolite flow breccia. The age of the rock is unknown; because of its metamorphic character it is included in the pre-Silurian.

Near Wickham in the southern Woodstock area, pre-Silurian thinly bedded slates are heavily stained with manganese oxide. The slates also contain a fair amount of iron as assays of the rock gave the following results[1].

Iron................................9.65 per cent

Manganese..........................2.08 per cent

On a fresh surface the beds of slate are alternately light and dark green. Because of the fine-grained nature of the rock, it was not possible to determine either the mineralogy or the disposition of the iron and manganese. The writer believes the iron and manganese are hydrothermal and directly associated with the intrusion of a nearby diorite mass. There is a coating of manganese oxide along the joints, and on the exposed surfaces of the diorite. North and south, along the strike of the slates, the rocks are typical pre-Silurian grey-green slates.

Structure. The structure of all the rocks in the area will be discussed later in the section dealing with Structural Geology.

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[1]Assayed by J. T. Donald & Co. Ltd., Montreal Quebec, for the Department of Lands and Mines, Fredericton, New Brunswick.

Origin. The nature of the pre-Silurian sediments would suggest that they were derived from a non-granite terrane. The land supplying the material was probably composed of dark coloured sedimentary, metamorphic, and basic igneous rocks. Because of the similarity of the pre-Silurian rocks over large areas and the scarcity of outcrop, the writer was unable to determine any lateral thickening or coarsening of the sediments, so consequently the source of the pre-Silurian rocks could not be located.

The Woodstock and Millville areas are located well within Schuchert's New Brunswick geanticline[1], and Kay's Magog Belt[2]. The lithology of the pre-Silurian sediments does not coincide with the type of rock that would be expected to be found within the boundaries of the above features. The pre-Silurian in the areas contain no volcanic material, this alone would take it out of the Magog Belt as defined by Kay. The greywacke, slates, and argillites, do not agree with the type of sedimentation found on such rising and/or positive areas as geanticlines.

The lithology of the pre-Silurian sediments would place its tectonic environment in several of the different environments arranged by Krumbein, Sloss, and Dapples[3].

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[1] Schuchert, C. : Orogenic Times of the Northern Appalachians; Geol Soc. America, Bull. Vol. 41, p. 704 (1930).

[2] Kay, M. : North American Geosynclines; Geol. Soc. America, Mem. 48, p. 49 (1951).

[3] Krumbein, W. C., Sloss, L. L. and Dapples, E. C.: Sedimentary Tectonics and Sedimentary Environments; Am. Assoc. of Petroleum Geol., Bull. Vol. 33, pp. 1859-1891 (1949).

These possible tectonic environments are as follows:

1. Unstable shelf - fluvial-lacustrine-eolian.

2. Intracratonic basin - infraneritic[1].

3. Geosynclinal - epineritic and infraneritic.

From the above information it could be postulated that the pre-Silurian sediments were deposited in one of the following places:

1. Unstable shelf of the New Brunswick geanticline.

2. Intracratonic basin in the New Brunswick geanticline.

3. In a geosyncline - either the St. Lawrence geosyncline of Schuchert or the Magog Belt of Kay.

If we follow Kay's definitions of geosynclines, then because of the absence of volcanics in the pre-Silurian strata then they must have been deposited in a miogeosyncline - such a miogeosyncline could have existed along the northwest border of the New Brunswick geanticline (assuming that the northwest border of the New Brunswick geanticline is placed a few tens of miles southeast from the position outline by Schuchert).

Age. The pre-Silurian strata are the oldest known rocks exposed in the Woodstock and Millville areas. As there were no fossils found in these rocks a more precise determination of the age must be arrived at by some other means. Fossils, tentatively identified as Ordovician graptolites[2], found about 50 miles to the southwest of the areas appear to be in the same lithologic belt as that of the pre-Silurian sediments of the areas under study. L. W. Bailey assigned a Cambro-Silurian age to the belt of sedimentary

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[1] Epineritic - marine environment less than 120 feet deep.
Infraneritic - marine environment between 120 and 600 feet.

[2] Boucot, A.: U. S. Geological Survey; personal communication.

rocks which is now called pre-Silurian[1]. As it now stands, the pre-Silurian rocks consist of sedimentary rocks that were deposited at some time after the Precambrian and before the Silurian, most probably during the Ordovician period.

Silurian

Distribution. Silurian sediments underlie slightly more than half of the Woodstock area. No sediments were identified as Silurian age east of the contact between the Silurian and the pre-Silurian in either the Woodstock or Millville areas.

The greatest part of the Silurian beds consist of slates; these are grey, grey-green, red, or dark grey color. The composition ranges from arenaceous to highly calcareous. The bedding is well-defined and the beds are generally not more than one quarter of an inch thick. Interbedded with the slates are sandstones, greywackes, limestones, conglomerates, and manganiferous iron formation.

Silurian - pre-Silurian Contact. The contact between the Silurian and the pre-Silurian is not exposed. However, abrupt changes in the lithology and attitudes of the rocks occur in several places in distances of about 500 feet, it is here that the contact has been placed.

Along the road one mile west of Teeds Mill, the pre-Silurian rock exposed is a highly indurated grey-green slate with interbedded greywacke; the strike of the bedding is about 105 degrees and the dip is approximately vertical. About 2000 feet west of this exposure are outcrops of Silurian type soft, thinly bedded dark grey calcareous slate, with interbeds of green arenaceous slate. The strike of these rocks is about 25 degrees. Although

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[1] Bailey, L. W. : op.cit. (1885).

Figure 18. Pre-Silurian slate and greywacke along the St. John River south of Woodstock. A nose of an anticline - the plunge is about 45 degrees away from the observer.

Figure 19. Vertical view of steeply dipping calcareous slates of Zone C of the Silurian exposed at Oakville (This figure is a close-up of the strata in the area covered by Figure 29).

the land between the Silurian and pre-Silurian rocks at this place has been cleared there is no break in the contour of the land that would indicate the presence of different underlying rock types. However, east of this locality the land is quite rugged and heavily wooded, and is ill-suited for agriculture; westward, farms and clearings are numerous, the calcareous rocks of the Silurian contributing markedly to the fertility of the soil.

Breaks in the rock types similar to that described above are to be found south from Teeds Mill. Along the road east from Debec, outcrops of pre-Silurian hard slate and greywacke are found within 500 feet of thinly bedded calcareous slates of the Silurian. Strikes of the bedding of the two rock types differ by about 60 degrees.

Near the railway tracks about one-half mile east of Debec, there is a bed about 30 feet thick of grit and conglomerate. The conglomerate contains quartz, slate, greywacke, argillite, and cherty material in calcareous matrix. The quartz pebbles range in size up to 2 inches in diameter, the slate pebbles measure as much as 2 inches by 5 inches. With the grit are beds of thinly bedded calcareous slate, with a strike of about 35 degrees and a dip of about 90 degrees; the grit by graded bedding show the tops to be to the west. The conglomerate and grit were at or near the base of the Silurian.

Silurian and pre-Silurian rocks are exposed within 1000 feet of each other about 1 mile southeast of Debec; in this locality there is also a marked difference in the lithology and attitude between the two rock types.

In the bed of a small brook which flows northward to join the Meduxnekeag river about one mile west of Woodstock, there is an exposure of Silurian slate. The slate is thinly bedded, dark grey, and calcareous.

It is severely contorted and cut by numerous calcite veins. The brook valley follows, for about 2 miles, a marked break in the topography - gently rolling farmland to the west and steep sloped, heavily wooded country to the east. This break may be well observed in the aerial photographs of the region, and can be extended for about one mile northeasterly from the Meduxnekeag river. The break is interpreted as reflecting a fault following the contact between the Silurian and pre-Silurian systems.

North of Woodstock the contact between the Silurian and pre-Silurian is covered by younger sediments.

Probable Succession. The division of the Silurian in the Woodstock area is here made to define the limits of all occurrences of ferruginous and/or maganiferous rocks, in doing this three distinct zones are recognised. The contacts between the zones have not been observed, however, all zones appear to be conformable with one another. With the possible exception of Zone A in contact with the pre-Silurian, these three zones may not have any stratigraphic significance, and may thus represent facies changes in one stratigraphic horizon. Because of folding and faulting within the Silurian and general scarcity of outcrop, no satisfactory estimates on the thickness of the system can be given. The three zones into which the Silurian is divided are as follows:

C Dark grey calcareous slates interbedded with buff weathering, grey-green sandstones, arenaceous slates and greywackes.

B Mainly grey-green, grey, and green slates with interbedded grey-green sandstones, greywackes, and, rarely, limestones. Lenticular bodies of manganiferous hematite and thin beds of red slate are also found in this zone.

A Grey-green slates, sandstones, and greywackes, with minor limestones, grits and conglomerates.

Zone A. These rocks occur along the contact with the pre-Silurian. They, in part, form the base of the Silurian in the area. Conglomerates, which are found at several horizons in this zone, contain pebbles of slate, greywacke, and argillite, which closely resemble pre-Silurian rock types.

The bulk of the material of this zone is grey-green slates. Interbedded with the slates are grey-green sandstones and greywackes. Limestone beds, usually not more than a few inches thick, are found interbedded with the slates. Dark grey, somewhat calcareous slates are also found in this division. Grit and conglomerate also form a minor lithologic type of Zone A, and occur in narrow lenticular beds, not more than 30 feet thick, which are exposed over distances of not more than 200 feet. In no case did two exposures of conglomerate appear to be on a similar stratigraphic horizon, and in no case did the conglomerate rest on rocks that could be regarded as pre-Silurian.

Zone B. The limits of this zone have been placed so as to include all occurrences of manganiferous and ferruginous rocks in the area. It is distinctly less calcareous than Zone A, but appears to be conformable with it.

The best exposures of the rocks of Zone B, are along the Meduxnekeag River and the Canadian National Railway track, south and east of Belleville. The rocks are generally grey-green slates, with interbeds of light grey and green slates, not more than one inch thick. The slates are quite sandy and commonly grade into sandstone and greywacke. Limestone is rare. A bed of limestone, at least 3 feet thick, was noted on the south slope of Moody Hill in association with iron formation.

Fossils were found[1] in grey-green slates on the north bank of the Meduxnekeag River about 1 mile below the bridge at Belleville. These fossils were identified as Monograptus sp., cf. M. clintonensis (Hall), and indicate the

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[1]Caley, J. F.: The Geology of the Woodstock area, Carleton and York Counties, New Brunswick; Geol. Surv., Canada, Mem. 198 p. 9 (1936).

Silurian age of the rock.

Fossils were also found in a conglomerate along the northern border of the Woodstock area, about three and a half miles north of the village of Jacksonville. The conglomerate occurs in association with iron formation, and is composed of pebbles and fragments of hematite, red and green slate, chert, quartz, and fossil material, bound in calcareous cement. The fossil material was examined in the offices of the Palaeontological Division of the Geological Survey of Canada, and was identified as crinoid stems and Favosites gothlandicus (Fought); the latter indicates a Silurian age for the containing beds.

The iron and manganese-rich rocks in this zone include red slates, manganiferous hematite, and green slates, all of which on the weathered surface are heavily coated with black manganese oxide. The slates are all thinly bedded, the beds are usually not more than one-quarter of an inch thick.

An occurrence of red slate with interbedded hematite was found on the northwest slope of Oak Mountain in the southern part of the Woodstock area. The actual extent of the ferruginous rocks is unknown because of the heavily wooded character of the country; however, exposures and the composition of the soil show that it is at least 100 feet wide and 500 feet long. The hematite is in beds about one foot thick and is quite fissile. The weathered surfaces of the rocks are coated with a layer of manganese oxide.

The hematite appears to be definitely sedimentary and in no way related to nearby intrusive rocks. Pre-Silurian strata are exposed in the vicinity but not in visible contact with the ferruginous rocks. Although this occurrence of hematite may be of pre-Silurian age its lithology is similar to the ferruginous material of Zone B of the Silurian system and as such it could be an outlier of that Zone.

Other iron and manganese deposits in the area are described later in the section dealing with economic geology.

Zone C. The last division of the Silurian in the area is the relatively more highly calcareous rocks of Zone C. They are exposed in the northwestern part of the area and are conformable with the rocks of Zone B. They consist largely of dark grey calcareous slate, with interbedded buff weathering grey-green sandstone, slate, and greywacke. The best exposures of the rocks of this zone are along the Meduxnekeag River.

The dark grey slates are very thinly bedded, highly contorted, (see Figure 19) and 'shot' with calcite veins. The sandstone, slate and greywacke are interbedded with the dark grey slate, but appear in greater and greater quantities than the dark grey slate as Zone B is approached.

Origin. There are no pebbles or fragments of granite, nor is there arkose in the Silurian strata of the Woodstock area; so it must be assumed that these rocks were derived from a non-granite terrane. The source rock area for the Silurian sediments was probably similar to that which supplied the pre-Silurian sediments, that is, composed of dark coloured sedimentary, metamorphic, and basic igneous rocks. As is the case of the pre-Silurian strata no lateral coarsening or thickening of Silurian rocks could be determined for use in locating the source of the sediments.

Use is made of Krumbein, Sloss, and Dapples[1], tectono-environmental classification, in determining the conditions of deposition of the Silurian rocks, and the following environments of deposition are suggested.

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[1]Krumbein, W. C. , Sloss, L. L., and Dapples, E. C.: op.cit. (1949).

1. Stable shelf - infraneritic

2. Unstable shelf - transitional, epineritic, infraneritic

3. Intracratonic - infraneritic

In view of the present knowledge of the Appalachians the presence of a stable shelf is remote.

As mentioned previously the Woodstock and Millville areas lie well within Schuchert's New Brunswick geanticline and Kay's Magog Belt. By moving the northwest border of the New Brunswick geanticline a few tens of miles to the southeast, tectonic conditions of unstable shelf and transitional, epineritic, and infraneritic environments could be obtained along the border of the geanticline.

An intracratonic basin with infraneritic environment could have existed within the New Brunswick geanticline, and thus provided the environmental conditions as indicated by the Silurian strata.

Volcanic rocks of Silurian age[1], are exposed in the area adjoining the Woodstock area to the north. Although there are no volcanic rocks in the Silurian system of the Woodstock area, the volcanic rocks may be in the same horizon and thus satisfy conditions of Kay's Magog Belt - as far as the presence of volcanic rock is concerned; however, the Silurian sediments here are miogeosynclinal rather than eugeosynclinal.

Devonian

The bulk of the igneous rocks in the Woodstock and Millville area has not been assigned to the Devonian system. Though no proof of a Devonian age of these rocks is found within these areas, their similarity to and continuity

[1] Caley, J. F.: op. cit. p. 10 (1936).

with rocks of known Devonian age in other areas are considered, by the writer, to be reasonably adequate proof of the Devonian age assigned.

Extrusives

Volcanic rocks occur in the southern part of the Woodstock area near Oak Mountain; and in the north central part of the Millville area. There is also a small area of basic volcanic rock exposed in the latter area, about one and a half miles south of Norton Dale.

The volcanic rock near Oak Mountain is a dark green, fine-grained andesite; it occurs in massive, porphyritic, and amygdaloidal facies. Amygdules and a suggestion of flow banding in an exposure along the road about one-half mile east of Oak, indicate the volcanic origin of the rock. The amygdules are typically ovoid, about 6 mm long, and are composed of calcite. Phenocrysts, where visible to the naked eye, appear to be either rectangular crystals of a white feldspar or a dark brownish-green mineral.

Under the microscope the rock is seen to be composed usually of phenocrysts of soda-rich plagioclase feldspar, in a felty, pilotaxitic textured groundmass of feldspar laths of composition of about An_{35}, and a highly altered ferromagnesian mineral. There are exposures of a light grey fine-grained rock on the eastern slope of Oak Mountain, containing phenocrysts of a pyroxene (identified as augite), and a highly altered plagioclase feldspar. These phenocrysts are set in a cryptocrystalline groundmass which is now white mica, chlorite, magnetite. In some thin sections there is a relic pilotaxitic texture; this rock may at one time have been either an andesite or basalt.

The age of these volcanics is not definitely known. In the bed of Pokomoonshine brook, on the west side of Oak Mountain, the contact between Silurian rocks and what appears to be amygdaloidal andesite was

Figure 20. Basalt, about one mile north of Ayers Lake. Crossed nicols, X 26.

Figure 21. Amygdaloidal basalt, one mile south of Ayers Lake. The Amygdules are calcite. Crossed nicols, X 26.

described by Bailey as follows[1]:

> " - there are, in the valley of the brook referred to, [Pokemoonshine brook], ledges of a very hard greenish-grey vesicular rock, containing dark-brown prismatic crystals of augite, as well as beds of white weathering felspathic quartzite; these being in turn overlapped by the ribboned calcareous slates which here represent the Silurian system."

The writer was unable to locate the exposure described by Bailey. It would appear that these volcanics are pre-Silurian, partly from Bailey's description, and partly because the outcrops of andesite are flanked by (though not in visible contact with) pre-Silurian sediments.

Basic extrusive rocks are exposed in the north central part of the Millville area, and are both andesites and basalts of massive, porphyritic, and amygdaloidal facies, (see Figures 20 and 21). The rocks are generally dark green, fine-grained, with rectangular phenocrysts of white feldspar. Amygdules, where found, are composed of white to light pink calcite. Bedding or banding was absent in all exposures examined by the writer.

Microscopically the rock was seen to be holocrystalline, varying in texture from pilotaxitic, felty to trachytic. The feldspar was plagioclase, varying in composition from An_{40} to An_{55}. The ferromagnesian mineral, where it could be observed, is found to be basaltic hornblende, and is usually altered to chlorite. Magnetite is fairly abundant.

The age of these volcanic rocks is uncertain. There is evidence that they are, in part, late Silurian or early Devonian. In the adjoining area to the north there are exposures of conglomerate covered conformably by sandy slate. The conglomerate contains pebbles of an amygdaloidal andesite, which appears to be related to the volcanics of the Millville area. The sandy

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[1]Bailey, L. W.: op. cit. p. 17 (1885).

slate contains fossils which have been placed in the Devonian. No pebbles of igneous rocks have been found in the conglomerates of the Silurian or pre-Silurian in the region. Hence, it would appear that these volcanic rocks are late Silurian or early Devonian in age.

Lying horizontally on the volcanic rocks in the northern part of the Millville area are coarse clastic sediments of Carboniferous age; the material for these sediments was derived in part from the underlying extrusive rocks. Elsewhere in New Brunswick where this association has occurred, it has been shown that the volcanic rocks are of Carboniferous age[1].

There are two exposures of a dark green rock along the road about one and a half miles south of Norton Dale in the central part of the Millville area. The rock is quite soft and fine-grained, and contains some amygdules and phenocrysts. The amygdules are composed of calcite, and are about 5 mm across; the phenocrysts are of white feldspar, roughly rectangular in outline, and rarely over 3 or 4 mm long. Under the microscope the rock was too highly altered to allow the identification of the original mineral constituents; alteration products include chlorite, magnetite, antigorite, and sericite. The texture appears to have been pilotaxitic. The rock was probably an andesite or basalt. The age of the rock is unknown; however, because of its lithology it has been included here with the Devonian, but might well be pre-Silurian.

Intrusives

The relationships between the various types of intrusive rocks are unknown. It is possible that they may all belong to the same period of igneous

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[1] Muller, J. E.: Geology and Coal Deposits of the Minto and Chipman Areas, New Brunswick; Geol. Surv., Canada, Memoir 260, p. 11 (1951).

activity. They will be dealt with in the order of their areal importance.

GRANITE, GRANODIORITE, SYENITE. The acidic intrusive rocks that occur in the Millville and Woodstock areas are either part of, or related to the great granite batholith that cuts diagonally across central New Brunswick from southwest to northeast. In order to facilitate the study of these rocks the main granite mass and the related stocks have been given names according to their position in the areas under study as follows (see Figure 30 Page 79):

1. Pinder-Keswick
2. Springfield
3. Oak Mountain
4. Gibson

Pinder-Keswick. The Pinder-Keswick granite underlies about 25 per cent of the Millville area. It is irregularly elongate from 2 to 6 miles wide, and cuts diagonally across the eastern half of the area, from near Cullerton and Pinder in the southwest to the headwaters of the Keswick river in the northeast. This granite mass is a tongue of the central New Brunswick batholith that underlies about half of the adjoining area to the south.

Over most of its areal extent the Pinder-Keswick granite occupies a low belt along which flow parts of the major streams (Nackawic and Keswick Rivers). The adjacent highlands are occupied by other rock types. It is only in the northeast corner of the area that the granite underlies the higher points of ground. Because the granite has been deeply weathered it is difficult to obtain a fresh piece for study. The stream beds are normally the only places where relatively fresh rock may be found. About one mile to the northwest of Temperance Vale in the south central part of the area, erosion has not removed the relatively soft, deeply weathered granite to any extent, consequently this has led to parts of it being mapped as a separate unit under 'recomposed granite'; the discussion of which will appear later. The only aplite dyke cutting any of the granite masses in the areas is found in the recomposed granite northwest of Temperance Vale.

The Pinder-Keswick granite ranges in colour from light grey to pink, and in grain size from medium to coarse; it is in part porphyritic. Within the boundaries of the intrusive the minerals present are essentially the same, but their relative proportions differ in different parts of the granite mass. Minerals present in almost all of the specimens examined are quartz, orthoclase, microcline, perthite, plagioclase feldspar from An_5 to An_{25}, zircon, and commonly sphene, chlorite and magnetite. One or more of biotite, hornblende, and muscovite, were also identified in the specimens. (see Figure 23).

The bulk of the rock of this intrusive is a biotite granite, coarse-grained, and generally pink coloured. Quartz, feldspar and biotite are readily visible to the naked eye. Microscopically, the rock was seen to be hypidiomorphic granular. Plagioclase feldspar was generally zoned. In many places, the rock has been altered, the feldspars are all clouded with sericite and kaolin, and the biotite is replaced by chlorite and magnetite.

A biotite granite exposed in the bed of the Nackawic River near the highway bridge at Cullerton contains phenocrysts up to 2 inches long of pink potash feldspar. Porphyritic biotite granite was also found near the Keswick River above Barton.

Specimens of the intrusive taken from the northernmost exposures in the area show that the rock there has the composition of a granodiorite. There has been a considerable increase in zoned plagioclase, biotite, and hornblende, with a corresponding decrease in quartz and potash feldspar.

Figure 22. Biotite granite; in railway cut about ½ mile north of Barton. Crossed nicols, magnification X 26.

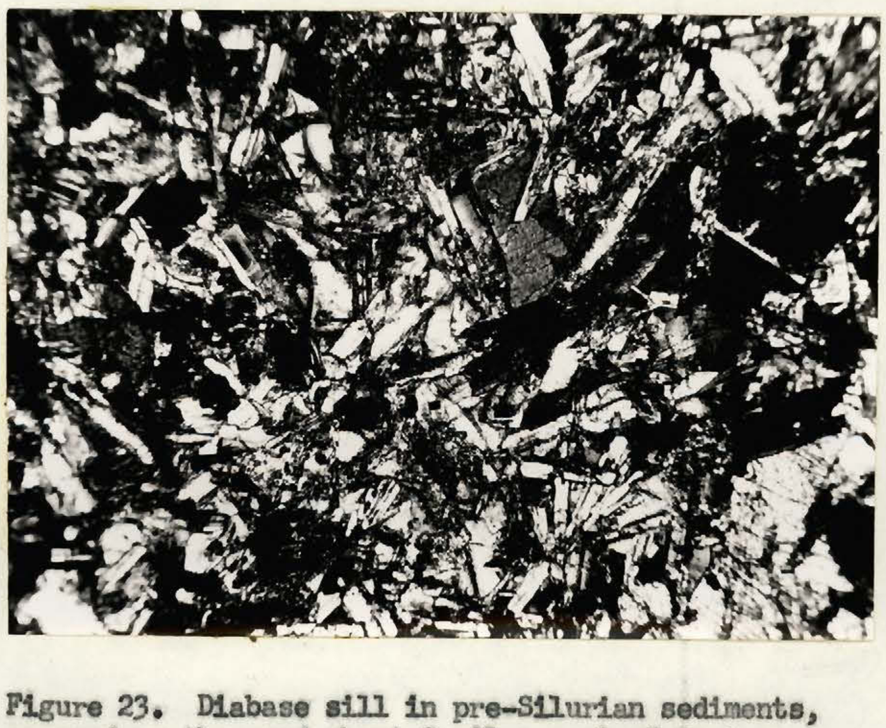

Figure 23. Diabase sill in pre-Silurian sediments, exposed on the road about 2 miles east of East Newbridge. Crossed nicols, magnification X 26.

Springfield. The Springfield granite, exposed in the extreme southeast part of the Millville area, is essentially part of the Pinder-Keswick granite. In fact, the two bodies are joined in the adjoining area to the south. It is therefore part of the central New Brunswick granite batholith.

The Springfield granite is well exposed near the settlement of Springfield, the Mactaquac River, and along the highway in the vicinity of Brewer Mill. Although similar in composition to the Pinder-Keswick granite, the writer did not find any exposures of the Springfield granite in which the rock was porphyritic or contained hornblende. The Springfield granite contain either muscovite or biotite, and non-porphyritic. Neither inclusions nor xenoliths were found in any of the exposures examined.

Oak Mountain. Exposures of granite and allied rocks were found in the vicinity of Oak Mountain in the southern part of the Woodstock area. The intrusive has an areal extent of about 18 square miles, of which about 8 square miles is in the Woodstock area.

There is a considerable diversity of rock types within the boundaries of the intrusive, and it may well be that there has been more than one intrusion, but due to the lack of exposures, this possibility could not be explored further.

The rock exposed on the slopes of Oak Mountain has a composition near that of a quartz diorite. Quartz makes up less than 10 per cent of the rock. Pyroxene, identified as aegerine-augite, forms about 10 per cent, and the remainder of the rock is taken up by plagioclase feldspar which has been too highly altered for identification, magnetite, some pyrite and chlorite. Northward from Oak Mountain the rocks exposed become more acidic; with granophyric facies near the central and northern parts, where exposed along the road between Flemington and Speerville. The whole of the intrusive appears to have been highly altered. Neither biotite nor muscovite was recognized, shreds of hornblende and relic structures of the same mineral were found here and there in some of the thin sections examined. Generally the feldspars were too highly altered to permit their determination.

Metamorphism of the host rock has been relatively low. Specimens of greywacke and slate xenoliths taken from an exposure immediately south of the road between Flemington and Speerville, about one and a half miles from the former place, show no new minerals resulting from the intrusion of the magma. The contacts between the xenoliths and the granite are sharp.

There is no mineralization of any significance that can be shown to be associated with the intrusion of the Oak Mountain stock. A reported occurrence of gold was made several years ago on the northeast slope of Oak Mountain. However, the relation of this reported occurrence and the stock is unknown. The gold occurrence will be described later, in the section dealing with the Economic Geology.

<u>Gibson</u>. The Gibson granite mass underlies about 6 square miles of the eastern part of the Woodstock area, about 4 miles southeast of the town of Woodstock. The Gibson granite is probably a stock of the central New Brunswick batholith.

The granite is best exposed along the banks of Gibson Millstream, where it forms the walls of gorges up to 75 feet high. Along this stream the rock is light to dark pink, coarse-grained, hornblende granite. In this section the feldsparswere seen to be all highly altered and the hornblende almost entirely changed to chlorite.

Along the St. John River, the granite contains numerous xenoliths, and is also highly altered, and cut here and there by diabase dykes. Cordierite has been found forming up to 10 per cent of the rock. The ferromagnesian minerals in the rock are generally so highly altered that their original identities are obscured.

In the northern section of the stock, the composition of the rock is different. The amount of quartz has decreased in some cases to such an extent that it was considered an accessory rather than an essential constituent of the rock. In other exposures there is a marked increase in the amount of ferromagnesian minerals, and the quantity of potash feldspar has decreased. Rock types were found whose composition would place them in the syenite and granodiorite classes. No feldspathoids were noted in any of the thin sections examined. The feldspars and the ferromagnesian minerals in the northern section of the stock, as in other parts of the mass, were all highly altered, in fact, so much so that their identification in most instances was impossible.

The Gibson stock is unique in that all of the base metal deposits found in the Woodstock area appear to be genetically related to it. Around the perimeter of the stock and in a roof pendant within the main granite body, are copper, lead and zinc sulphide deposits. The more important of these deposits are described later in the section dealing with the Economic Geology of the areas under study.

DIORITE, QUARTZ DIORITE, GABBRO. Intrusive bodies of diorite, quartz diorite, and gabbro were found in the north central part of the Millville area and in the vicinity of the contact between the Silurian and the pre-Silurian in the Woodstock area. In some cases the geological map shows large areas to be underlain by basic intrusive rock, in particular, that area about 6 miles northeast of Millville. This part is underlain by

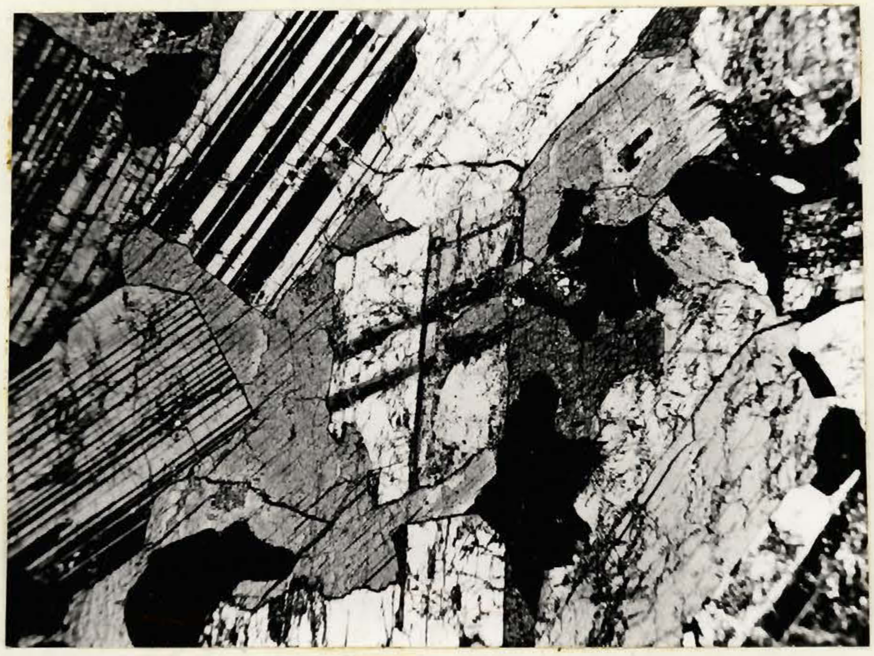

Figure 24. Gabbro, one mile northwest of Colter Lake. Note subophitic texture and the basal section of amphibole to the right of centre in the figure. Crossed nicols, X 26.

Figure 25. Diorite, one mile southwest of Colter Lake. Feldspar are largely twinned, and appear white or grey in the figure, the remainder is highly altered ferromagnesians. Crossed nicols, X 26.

several intrusive bodies of basic rock, their extrusive equivalents, and sedimentary rock of an earlier or similar age. Because of their small areal extent, the extrusive and sedimentary rocks could not be satisfactorily mapped as individual units.

The basic intrusive rocks in the northern section of the Millville area range in composition from a quartz diorite (here and there approaching a granodiorite with up to 20 per cent quartz) to gabbro. They are generally medium-grained, but both coarse and fine-grained phases were noted. The rocks were equigranular and several specimens displayed ophitic to sub-ophitic textures (see Figure 24). Colour varies to a considerable extent; in the vicinity of Ayers Lake and Indian Lake the rock is usually reddish from iron oxide stain; in the vicinity of Colter Lake region the rock is free from the iron oxide stain and is light to dark-green in colour.

In thin-sections of the diorite, quartz diorite, and gabbro, the feldspars were found to be of the plagioclase variety and were quite fresh. Compositions of the feldspars varied between An_{15} and An_{65}. Ferromagnesian minerals were considerably more altered than the feldspars; however, those determined in the specimens examined included augite, basaltic hornblende and possibly diallage and hypersthene (see Figure 25). Potash feldspar was found in some of the specimens taken from near Ayers Lake. Other minerals identified were magnetite, chlorite antigorite, and apatite.

There is a small area underlain by diorite about 3 miles west of Millville. It is a dark green, medium to coarse-grained rock, composed of a highly altered plagioclase feldspar, a pyroxene that is probably pigeonite, chlorite and magnetite.

There is a dark green, medium to coarse grained structureless rock exposed in the southern part of the Woodstock area near Wickham, a few miles west of Speerville. The rock has been highly altered and its original mineral composition is obscured. Relic structures indicate that a large proportion of the rock was once composed of plagioclase feldspar and a ferromagnesian mineral. It is possible that this rock is or was either a diorite or gabbro.

Immediately south of the town of Woodstock along the St. John River and in a railway cut just south of the town limits, there are exposures of a dark grey-green rock. Here again the rock is too highly altered to permit microscopic identification of the original minerals. The general megascopic appearance and the presence of certain relic structures in thin sections suggest that the rocks are of a basic composition near to that of a diorite or gabbro.

One mile north and two miles north of the town of Woodstock are two small areas of a dark green, medium to fine-grained rock whose composition would place it in the diorite class. Megascopically, the rock was seen to contain amygdules filled with white and pink calcite. Lighter green ovoid 'blotches', up to 18 inches across, were noted in several outcrops of the rock. The 'blotches' appear to have slightly more feldspar and to be finer grained than the main body of rock. The ovoids may be partially digested fragments of the chilled border. Angular fragments similar in composition to that of the surrounding rock were common, and it is possible that the rocks in this section north of Woodstock represent either an andesite flow breccia, or a contact breccia of an intrusive dioritic mass.

A silver deposit worked in the latter part of the last century by the R. K. Britton Mining Company, is located about one mile north of these basic rocks. It seems possible that the two are genetically related. The silver deposit will be described in the section dealing with the Economic Geology of the areas.

DIABASE. Intruding the pre-Carboniferous rocks in the Millville and Woodstock areas, are numerous sills and dykes of diabase. Ranging in width from 5 to about 50 feet, these diabase intrusives are most commonly found as sills cutting the pre-Silurian sediments of the Western part of the Millville area, and along the St. John River in the Woodstock area. A diabase dyke was found intruding the Silurian on the northern slope of Moody Hill, about 4 miles northwest of Woodstock. A sill of diabase, about 20 feet wide was found in contact with Silurian rocks about 2 miles northwest of Green Lake in the western part of the Woodstock area. Diabase dykes were also found cutting the Gibson granite stock.

The diabase is generally a dark green rock, fine-, medium-, and occasionally coarse-grained. The sills and dykes are typically fine-grained at the contacts and medium- to coarse-grained in the centre. Microscopically, the rock was seen to be invariably ophitic to subophitic in texture (see Figure 23, page 50). The feldspar, which was plagioclase, usually had a composition of about An_{55}. The most common ferromagnesian mineral was pigeonite; other pyroxenes present in most of the thin sections examined included hypersthene and diopside. Magnetite was always present, in quantities ranging from 1 to over 10 per cent.

In two of the thin sections examined the feldspar had been albitised and the ferromagnesian mineral altered or replaced by chlorite and magnetite.

The actual length of any one of these bodies has not been established; however, immediately south of Bull Lake, in the Millville area, a diabase sill was followed for over one-half mile. Several of the sills are undoubtedly longer than this.

AGE OF THE INTRUSIVES. The granites are believed to be Devonian in age, because of their similarity to and continuity with Devonian rocks of other areas. In southwestern New Brunswick and in adjoining parts of Maine, the Perry formation, whose Late Devonian age has been established from its plant remains, rests unconformably on granite, and granite pebbles are found in its conglomerate beds[1]. In the Millville and Woodstock areas the granite intrudes pre-Silurian rocks and pebbles of the granite are abundant in the Carboniferous conglomerates of the area. The granite has also been found intruding sedimentary rocks of Silurian age[2]. It therefore appears fairly certain that the granites of the areas under study are either Early, Middle, or Late Devonian in age.

The relationships between the granites and the more basic quartz diorite, diorites, and gabbros, is unknown. Because such suites of rocks are common and closely associated in time and space in other areas, it appears logical that all these rocks belong to the Devonian period. If the volcanic rocks in the northern part of the Millville are Late-Silurian or Early-Devonian in age, as was suggested earlier, and if the diorites, and gabbros are the intrusive equivalents of these volcanics (and this seems to be quite possible) then an Early Devonian age postulated for the basic intrusions is satisfactory.

The diabase sills and dykes have been found cutting pre-Silurian ans Silurian sediments and Devonian granite but they have not been found intruding the Carboniferous sediments. Diabase pebbles are found in the

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[1]Bastin, E. S. and Williams, H. S.; Eastport Folio, Maine; Geological Atlas of the United States, No. 192, U. S. Geol. Surv., p. 10 (1914).

[2]Bastin, E. S. and Williams, H. S.; op. cit. p. 15 (1914).

conglomerates of the Carboniferous, there are no such pebbles in the conglomerates of the Silurian and older rocks. This makes the diabase sills and dykes pre-Carboniferous and post-Silurian. It is possible that there are two ages of diabase, one pre-granite and a second post-granite. The writer believes that the diabase sills and dykes are Devonian in age, and were intruded almost at the same time or shortly after the intrusion of the granite.

Carboniferous

Recomposed Granite. The Pinder-Keswick and the Springfield granites are deeply weathered in several places. The deeply weathered granite crumbles to the touch, and where it is found in quantity it is quarried and used as road metal. The largest area underlain by this weathered granite, extends for about 5 miles along the northwest contact of the Pinder-Keswick granite west of Temperance Vale; other such smaller areas of weathered granite are found in the Springfield granite near Brewers Mills.

Some of the weathered granite may have undergone transportation. However, the coarseness and angularity of the grains, in the exposures examined, indicate that the distance transported was very short - not more than a few hundreds of yards. Because of this the writer has called the deeply weathered granite, 'recomposed granite'[1].

About one-half mile northwest of Temperance Vale there have been large pits or quarries dug in the recomposed granite. These excavations afford some very good cross-sections of the granite, and in many cases the original jointing may be observed (see Figures 26 and 27). Sand grains and silt

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[1]Pettijohn, F. J.: Sedimentary Rocks; Harper & Brothers, New York; p. 259, (1948).

Figure 26. Recomposed granite in quarry northwest of Temperance Vale.

Figure 27. Recomposed granite in quarry northwest of Temperance Vale. Close up of part at Figure 26.

have been deposited along several flat-lying joints by percolating groundwaters, creating the impression that the granite is disposed in beds a few feet thick and is in reality an arkose.

In one of the pits of deeply weathered granite examined by the writer, an aplitic dyke was left standing by the quarrymen because of its resistant character (the quarrymen call such rock bullrock). The dyke had at one time evidently intruded the granite, but because of its fine grain the aplite has remained fairly firm. If the recomposed granite were in reality an arkose or had undergone transportation, it does not appear possible that as a sedimentary rock it could have been sufficiently indurated to withstand the intrusion of the aplite. Therefore the recomposed granite is in place, and represents deep weathering of the underlying granite. The aplite dyke has a strike of about 160 degrees and the dip is essentially vertical. The recomposed granite is reddish, coarse-grained, and the interstitial character of the quartz is clearly discernible in the exposures. The feldspar is now largely kaolin, the ferromagnesian is biotite and appears to be little altered. Lineation of the biotite was observed in one exposure. The strike of the lineation was about 30 degrees and the dip about 50 degrees to the southeast. Nowhere in any of the exposures was there a suggestion of cross-bedding. The lineation of the biotite is in a fine-grained phase of the recomposed granite. The fine-grained granite butts against a coarse grained phase, the contact is almost vertical and strikes at about 30 degrees. It is difficult to imagine how such relations could be developed in a relatively unconsolidated sedimentary rock.

In other parts of the areas where the granite has been deeply weathered, the extent and depth of weathering was not sufficient to permit its being mapped separately. The depth of weathering in the Temperance Vale region in many places exceeds 20 feet whereas in other sections only 1 or 2 feet have been found. In all exposures where the underlying true granite could be observed the contact between the true granite and the recomposed granite was gradational.

The recomposed granite is considered to be Carboniferous, but the age is not definitely known. The following information may be considered when assigning an age to this rock. The granite upon which this recomposed granite was developed, and now rests, was apparently unroofed in the early part of the Carboniferous period. Not sufficient time has elapsed since the retreat of the last continental ice sheet to allow for the disintegration or weathering of the granite, nor has the climate been such as to allow such weathering to take place. Therefore the recomposed granite was formed before the Pleistocene. It is probable that the recomposed granite has been forming since the granite was unroofed in Carboniferous times. However, there is a possibility that the recomposed granite was formed in a single period and preserved by burial until recent times. In any case it represents a pre-Pleistocene regolith, which may be as old as the Carboniferous.

Clastic Sediments. Nearly flat-lying, coarse clastic sediments are exposed in the extreme north central part of the Millville area, and west of the St. John River in the northeastern part of the Woodstock area. These sediments are non-marine in origin and consist of reddish pebble, cobble and boulder conglomerates, with brick-red and chocolate-coloured sandstones and shales. The conglomerates make up the bulk of the exposed rock. The shales and the sandstone in several places show patches of light green colour, which represents deoxidation of the rock. The conglomerate is composed of well rounded fragments of greywacke, slate, quartz, granite and other older sedimentary and igneous rock types. The fragments range in size from a quarter of an inch up to 12 inches, the average is about one and a half inches. The Carboniferous sediments are not well cemented or indurated, therefore fractures pass around the grains or fragments. Earlier sediments are well cemented and for the most part highly indurated and fractures pass through the grains and fragments.

The clastic sediments of the Carboniferous exposed in the Woodstock and Millville areas have been placed in the Carboniferous period, because of their continuity and similarity with rocks of known Carboniferous age in adjacent areas in New Brunswick. Fossils were found by the writer, at, or near, the base of the Carboniferous in the adjoining area to the north. These fossils were identified in the offices of the Palaeontological Division of the Geological Survey of Canada as Estheria, and resemble those found in the Pictou Group of the Pennsylvanian of Nova Scotia[1]. The lithology of the Carboniferous under study compares favourably with that of the Pictou Group; the Carboniferous rocks of the Millville and Woodstock areas are continuous with the fossiliferous strata of the adjoining area to the north, therefore the Carboniferous of this part of New Brunswick is here assigned to the Pictou Group of the Pennsylvanian.

The presence of Estheria indicates that the enclosing sediments were probably deposited in a continental shallow fresh-water basin. It has been found that the size and propagation of living estherians is a function of their habitat and climate. The conditions for optimum growth

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[1]Bell, W. A.: Personal communication.

are a temperate climate, continental shallow fresh water, where water temperatures reach 20 to 30 degrees Centigrade in the warm season[1]. The fossil estherians found by the writer are of a comparatively large size and thus indicate that optimum conditions, probably as outlined above, existed at the time of their formation.

The sediments are generally flat-lying and hence have been little disturbed since their deposition; however, dips that exceed 50 degrees have been found in Carboniferous strata a few miles to the north of the areas under study. Although the contact between the Carboniferous sediments and older rocks has not been observed in the Millville and Woodstock areas, the difference in the attitude of the rocks certainly indicates that the Carboniferous overlies unconformably all earlier formations.

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[1]Kobayashi, T.: Fossil Estherians and Allied Fossils; Journal of the Faculty of Science, University of Tokyo; section 2, Vol. IX, pt. 1, p. 38 (1954).

Figure 28. An anticline from the isoclinally folded Silurian of Zone B. The rock is grey-green slate. The anticline is located along the Canadian National Railway track, about 2 miles southeast of Belleville.

Figure 28

STRUCTURAL GEOLOGY

General

The structural features that are most readily apparent from a preliminary examination of the Millville and Woodstock areas are first, the distinct northeasterly direction maintained by the major rock units, regardless of whether they are sedimentary or igneous in origin; and second, the broad open fold exhibited by pre-Silurian rocks in the west central part of the Millville area.

The general scarcity of outcrops, the similarity of the sedimentary rocks over large areas, and the complete lack of marker horizons have proved to be insurmountable obstacles in the preparation of a complete structural and historical geological picture of the areas under study. Where rock exposures are reasonably abundant, notably along stream banks and road cuts, detailed examinations have shown that the northeasterly trend of the sedimentary strata is complicated by innumerable isoclinal folds, which have in places, been cross-folded and faulted. The deformation of the rocks, coupled with erosion to the present time, produces a pattern which, without almost continuous outcrop, is impossible to interpret over any distance. In interpreting the structure of the bedrock of the areas, the writer has supplemented information obtained in the field with information from aeromagnetic and topographic maps of the Woodstock, Millville, and adjoining areas. Figure 30, with the use of trend lines, shows the writer's interpretation of the bedrock structure of the areas under study. For clarity and ease of interpretation, the topography, and about 40 per cent of the attitudes of the sedimentary rocks obtained in the field have been omitted from the drawing.

Cleavage

Cleavage is found in both the pre-Silurian and Silurian rocks of the areas. No partings which could be taken to be secondary foliation are found in the Carboniferous strata.

The cleavage of the pre-Silurian rocks, except in a few isolated occurrences is parallel to the bedding, and therefore strikes in various directions in different parts of the areas. Where the cleavage was found to be at a considerable angle to the bedding, it was taken to be axial plane cleavage and used to determine the nature and attitude of the folding. There are only three places in the pre-Silurian rocks, and these are in the Millville area, where the angle between the cleavage and the bedding was large enough to determine the nature of the fold. The first locality is about one mile north of South Waterville; the second, about one mile north of Woodstock Road; and the third, about one mile west of Indian Lake. Little use could be made of these cleavage-bedding relationships in determining the major structures of the areas, because of the intervening distances, and because it could not be determined whether the cleavage was related to the initial folding, or caused by later forces.

The strike of the cleavage in the Silurian rocks is, with very few exceptions, north-northeasterly, regardless of the strike of the bedding. In several places in the Silurian strata, most notably in Zone A, cleavage-bedding relationships were used to determine the nature and attitude of folds. In Zones B and C of the Silurian system, the strike of the bedding is northeasterly, so the bedding and cleavage are generally parallel.

As in the case of the pre-Silurian strata, it could not be determined whether the cleavage was related to the initial folding of the Silurian rocks, or caused by later deformation.

Folds

The pre-Silurian rocks, the oldest exposed strata in the areas, have undergone the greatest amount of deformation. The degree of deformation may be most readily observed along the St. John River, below the town of Woodstock. There the rocks have apparently undergone several periods of deformation, and the strata are for the most part disposed in steeply plunging, commonly vertical, isoclinal folds. The distances between the axial planes of most of the folds are less than 200 feet. The strike of axial planes of the isoclinal folds are about east-west.

The pre-Silurian rocks in the west central part of the Millville area, although probably subjected to the same forces as those along the St. John River, are not as severely deformed. The bedded greywackes, slates, and argillites have been isoclinally folded; the axial planes of the folds are essentially vertical and the plunge is nearly horizontal. The rocks maintain a remarkably uniform attitude for several miles in a southeasterly direction. Towards the central part of the area the strike of the rocks swings from southeast to northeast. The pre-Silurian strata in this region thus have the outline of a very large fold (see Figure 30, page 79).

The Silurian rocks have not been subjected to as many periods of deformation as the pre-Silurian, nevertheless, in a few places they are highly contorted.

In places the contact between the Silurian and the pre-Silurian has, as described earlier, been faulted. In other sections the contact appears to have been folded, as can be seen by its sinuous course east of Debec Junction on Plate 1. In general the Silurian strata have been isoclinally folded. The axial planes of the folds are essentially vertical, but several were noted dipping steeply to the northeast. The plunges of the folds range between 0 and 35 degrees, and are generally to the southwest. In many cases, notably along the Meduxnekeag River, the plunges of the folds change, between the limits given, in distances less than 1 mile. This was taken to indicate that here had been some cross-folding because there is no evidence of any faulting that could have caused the change in the plunges.

Highly contorted strata are commonly found in place of the isoclinally folded strata; particularly in Zone C in the northwest part of the Woodstock area. The rocks in this part of the area are generally thinly laminated highly calcareous slates, and are quite incompetent. They deformed plastically under pressure, rather than being bent mechanically into folds and fractured as is the case with the more competent, less calcareous strata. The folding in the calcareous strata in the northwest part of the Woodstock area is flow-folding as opposed to flexure-folding in other parts, notably in Zones A and B. The flow-folding may be very well observed near the settlement of Oakville (see Figure 29).

The Carboniferous rocks in the areas for the most part flat-lying. However, dips exceeding 50 degrees have been measured a short distance to the north in an adjoining area. Therefore, some tilting or folding took place at some time after the deposition and consolidation of the Carboniferous sediments. The forces which acted to produce post-Carboniferous deformation were relatively weak in comparison to those which acted in pre-Carboniferous times.

Figure 29. Flow folding of the calcareous slates of Zone C of the Silurian near Oakville. Figure 19, page 37, is a close up of these rocks.

Faults

Faulting probably plays a larger role in the distribution of the rock types in the Woodstock and Millville areas than the geological map of the areas would lead one to believe, but there is seldom any evidence of large scale faulting to be found in the rock exposed. The similarity of the strata over large areas also makes it difficult to determine where, and if, there has been a displacement. Topographic breaks and anomalies on aeromagnetic maps have been coupled with what meagre information could be obtained in the field, to locate or at least assume the location of three major faults in the areas.

The first fault was located by a topographic break northeast of Ayers Lake in the north central part of the Millville area. There is a narrow, steep walled valley trending to the southeast; it is occupied for about 3 miles by a small brook, and starts about 1½ miles north-northwest of Ayers Lake. The valley is flat-bottomed and usually not more than a few hundred feet wide. The top of the southwest valley wall may be as much as 200 or 300 feet above the valley floor, whereas the northeast wall is rarely over 20 or 30 feet high. The walls of the valley have the appearance of being fault-line scarps. Rock exposures found a few hundred yards apart on the escarpments on opposite sides of the valley did not display any features which would indicate the proximity of a large scale fault. The difference in rock types found in several places on opposite escarpments could easily be explained without assuming the existence of a fault in the intervening valley. Normal contacts would have sufficed.

The extent of the fault was assessed with the aid of aerial photographs beyond Ayers Lake region, as far as Taffy Lake northeast of

Millville - a total distance of assumed faulting of about nine miles. Although, as it has been pointed out, no evidence for faulting was found in the rock exposures, the break in the topography is so prominent, and so persistent, that it is without any doubt, caused by a bedrock structure, which in all probability is a fault.

The largest assumed fault in the areas cuts northeasterly across the central Millville area. It is at least 15 miles long, and has no topographic expression, therefore it has not been placed on the geological map (Plate 2), however, its position can be noted on Figure 30, page The fault was first noted on the aeromagnetic map (Figure 31), where it shows up as an anomaly.

The southeasterly trending belt of high magnetic intensity in the west half of the Millville area (see Figure 31), is believed to be caused by magnetite in swarms of diabase sills in the pre-Silurian strata. The isograms of this belt of high magnetic intensity are snubbed and elongated in a northeast-southwest direction. It is along this northeast-southwest anomaly that the fault is postulated. The anomaly along this assumed fault is also believed to be caused by the presence of magnetite in diabase. The fault has provided the channelway along which the diabase melt could travel to enter between the beds of the pre-Silurian sediments.

Much of the bedrock in the vicinity of this northeast-southwest anomaly is highly contorted. Variations in the attitudes of the rocks were also found to be more common in the neighbourhood of the elongated isograms. Because of the slight lithological differences in the rocks in the region of the assumed fault, and the lack of any marker horizons, no displacement of the strata could be observed.

The writer has traced the elongated isograms of this fault on aeromagnetic maps for at least 40 miles northeast, and 10 miles southwest of the Millville area - making a total distance of 75 miles. If there is a fault along the whole of the length of the elongated isograms then it constitutes one of the major breaks of the bedrock in New Brunswick.

A break in the topography less than a mile northeast of Millville is also assumed to be an expression of a break in the bedrock. This is a low terrace about six feet high, facing southeast and cutting southwesterly across Howland Ridge. While the escarpment is not prominent when viewed at ground-level, it is very distinct in the aerial photographs of the district.

The fourth assumed fault is along the Silurian - pre-Silurian contact in the Woodstock area. Aerial photographs show a marked break in the topography, which runs north-northeast - south-southwest for about 4½ miles along the postulated contact between the two rock systems, a short distance to the west of the town of Woodstock. The break consists of a line of demarcation between gently rolling farmland to the west and steep sloped, heavily wooded country to the east; the topographies are typical of areas underlain by Silurian and pre-Silurian rocks respectively. A brook follows the line for about two miles. For about two hundred feet along the bottom of the brook, one-quarter of a mile south of its confluence with the Meduxnekeag River, bedrock is exposed and consists of dark grey calcareous slates of Silurian age. The slates are highly contorted and cut by numerous calcite veins with random orientation. This was taken to indicate the presence of a nearby fault. No evidence was found by which movement along the assumed fault could be determined.

Elsewhere smaller breaks occur both in the bedrock and in the topography but they were generally too small to map. However, two of these smaller faults found in the Woodstock area bear mentioning. The first is a bedding plane fault in the pre-Silurian near Teeds Mill. The strike of the fault is slightly east of north and the dip is about 45 degrees west. The second fault is in Zone B of the Silurian system about 1 mile northwest of MacKenzie Corner; the strike of this fault is northerly, similar to that of the Teeds Mill break, and the dip is also west about 50 degrees. Striations on the fault surfaces indicate that both faults are of the reverse type. It is not known which side moved, consequently it is not known whether the faults are the result of under thrusting from the east or over thrusting from the west.

Origin of Deformation

The forces required to produce the deformation of the rocks of the Millville and Woodstock areas, must have been of various magnitudes and directions. Experimental evidence has shown that it is possible to develope a series of isoclinal folds with parallel axial planes either by compression or by a couple being applied to the strata. In the case of compression, axes of the folds are at right angles to the compressing force; and in the case of a couple the axes of the folds are aligned so that there is an acute angle between the axes and the direction of the coupling or shearing force[1].

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[1]Mead, W. J.: Notes on the Mechanics of Geologic Structures; Journal of Geology, vol. 28, p. 510 (1920)

Willis, B.: Mechanics of Appalachian Structure; U. S. Geological Survey 13th Annual Report, pt. 2. (1893).

The rocks of the areas under study, because they are isoclinally folded, must have been subjected to either a compressing force or a shearing force, or both.

Alcock[1] postulated that the forces deforming the pre-Silurian rocks in the Northern Appalachians acted along northwest-southwest lines, probably originating in the southeast and thrusting to the northwest. This theory would conform very well to the development of isoclinal folds in the pre-Silurian rocks of the Woodstock and Millville area; that is, the folds were formed as a result of lateral compression acting along a northwest-southeast line. Isoclinal folding of the Silurian strata could have been accomplished in the same way, and at the same time the pre-Silurian strata became more tightly compressed.

Following the folding of the Silurian areas, and probably contemporaneously with the intrusion of the granite, the rocks were subjected to a shearing force or couple acting along northeast-southwest lines. This couple was instrumental in forming the large drag fold with the isoclinally folded pre-Silurian rocks of the west central Millville area, the steeply plunging folds of the pre-Silurian along the St. John River, and the development of flow cleavage and cross-folding of the isoclinally folded Silurian beds. The pattern of faulting in the pre-Silurian and Silurian rocks conforms with the pattern that would be produced by the action of a horizontal couple applied along northeast-southwest lines as postulated above[2]. The large fault cutting northeasterly across the

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[1]Alcock, F. J.: see Schuchert, C.: op. cit. pp. 722-723 (1930).

[2]Mead, W. J.: op. cit. (1920).

Millville area would then be a shear fracture; the fault in the vicinity of Ayers Lake would represent a tension fracture, with movement normal to the walls of the fracture, which appears to be the case; the fault along the Silurian - pre-Silurian contact would also represent a shear fracture; the smaller reverse faults found near Teeds Mill and MacKenzie Corner would then fall into the pattern of thrust faults.

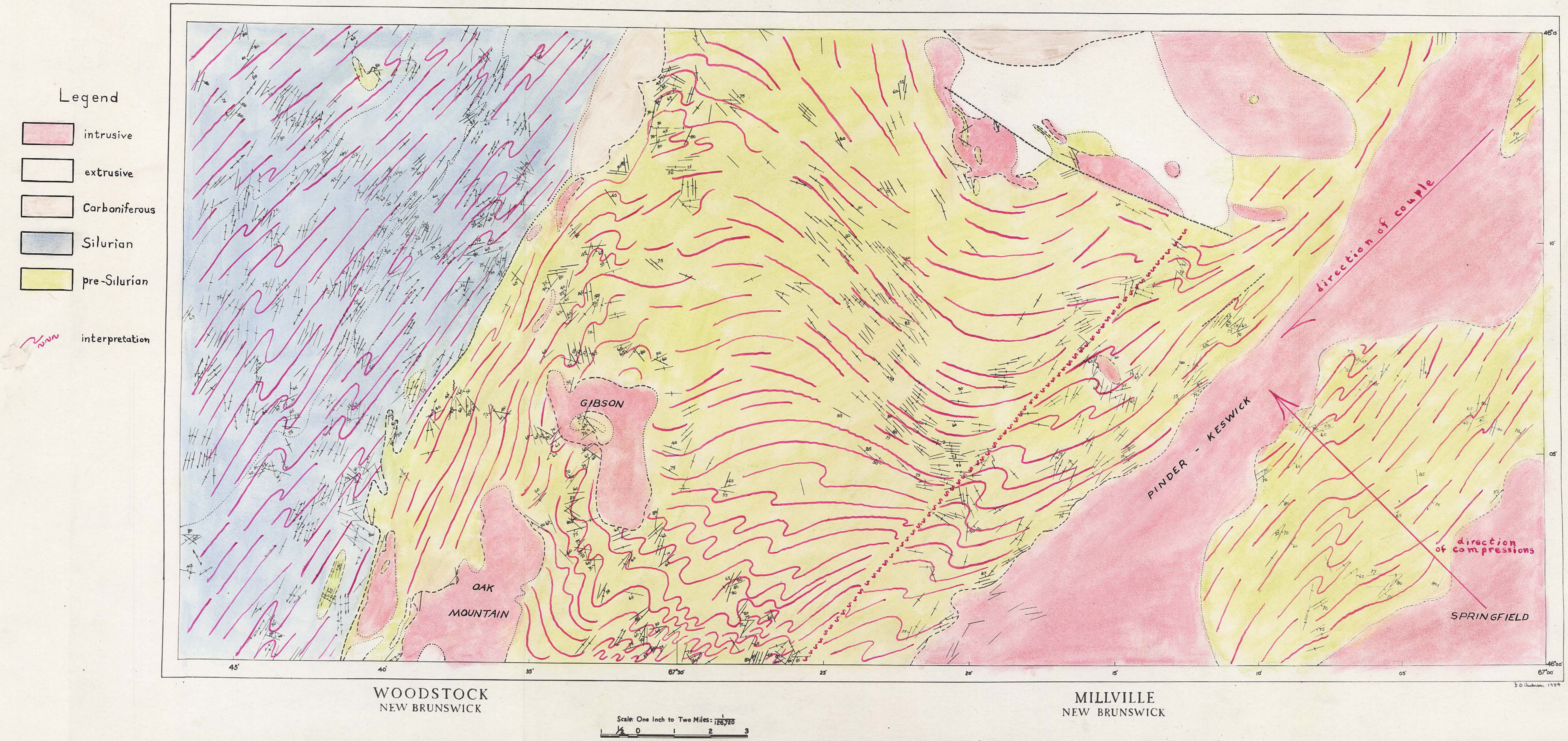
Summary

The structural history of the areas is then (1) lateral compression of the pre-Silurian strata to produce isoclinal folds whose axes were in a northeast-southwest direction, (2) lateral compression of both Silurian and pre-Silurian rocks again in a northwest-southeast direction to produce isoclinal folds in the competent Silurian strata, flow-folding in the incompetent strata, compression of the pre-Silurian into tighter folds with some buckling no doubt taking place, and the folding of the Silurian - pre-Silurian contact. The general structure of the areas was at that time a series of isoclinal folds whose axes lay in a northeast-southwest direction. (3) A shearing force or couple then acted along a northeast-southwest line with the southeast side moving southwestward. As a result the isoclinally folded pre-Silurian of the western Millville area was then deformed into a large drag fold, and numerous lesser drag folds were developed on the flanks of this major drag. Along the St. John River and in the southwestern part of the Millville area the pre-Silurian strata were crumpled and contorted as they were pushed against the rigid igneous intrusive mass lying to the southwest. The crumpling and contorting of the rocks is evident by the numerous and steeply plunging, in many case vertical, isoclinal folds.

These areas were again tilted and in some places probably slightly deformed at some post-Carboniferous time.

Figure 30

Figure 30: Structure Map of the Woodstock and Millville Areas.



AFTER G.S.C. MAPS 1406 AND 1476

WOODSTOCK
NEW BRUNSWICK

Isomagnetic lines (total field)
100 gammas
Magnetic depression contour

Scale: One Inch to Two Miles = 1/126,720

MILLVILLE
NEW BRUNSWICK

Figure 31. Aeromagnetic Map of the Woodstock and Millvile Areas.

HISTORICAL GEOLOGY

The oldest rocks exposed in the Woodstock and Millville areas are of pre-Silurian age. These rocks were probably deposited in a shallow sea during the Ordovician period.

The pre-Silurian sediments were deformed during the Taconian disturbance that marked the close of the Ordovician period. The forces acting in this disturbance were probably compressional and followed a northwest-southeast line, the forces originating in the southeast. The pre-Silurian strata were bent into a series of northeasterly-trending isoclinal folds by this disturbance.

Following the Taconian disturbance there was a long period of erosion and during early Silurian time much of the Appalachian region was above sea-level. By the Middle Silurian the Appalachians were again under the sea. The arenaceous and calcareous slates, the greywackes, limestones and other sediments found in the Silurian strata of the Woodstock area were deposited at this time. There was only minor local volcanic activity along this part of the Appalachians at this time - which resulted in the deposition of iron and manganese-rich sediments in small lens-shaped bodies. The Silurian period ended with the Caledonian disturbance, when the Silurian sediments were raised above sea level in a broad arch.

The seas again invaded the northern Appalachian district in Early Devonian time. During this epoch there was much local volcanic activity - notably in the Chaleur Bay district and possibly in the region of the Woodstock and Millville areas.

At the close of the Early Devonian and on into the Middle Devonian, there was an orogeny, called the Acadian disturbance. The Northern Appalachians underwent their greatest deformation during this time. It was during this orogeny that the Silurian rocks of the district were isoclinally folded and the pre-Silurian strata were further compressed. The forces acting were apparently similar to those which were active during the Taconian disturbance at the close of the Ordovician. It was probably during the Acadian disturbance that the granite and other igneous rocks were intruded. Contemporaneously with, or very shortly after, the emplacement of the granite batholiths of central New Brunswick, forces acted to produce a couple which bent the isoclinally folded pre-Silurian sediments in the western Millville area into a large drag fold, with numerous lesser drag folds on the flanks, and caused the crumpling and contorting of the pre-Silurian along the St. John River. As was mentioned earlier, the faults in the Silurian and pre-Silurian rocks were probably a result of this couple. The development of flow-cleavage and the overall northeasterly-trending schistosity so prominent in the Silurian strata of the district could also be attributed to this couple.

Intrusion of the diabase sills and dykes apparently followed the period during which the couple or shearing forces were active. There were probably spaces formed between the layers of sedimentary rock that were bent and deformed by the coupling action, and along these spaces the diabase melt could travel. Because of the competency of the greywackes and argillites the greatest number of openings could be expected in the pre-Silurian of the west central Millville area, rather than in the incompetent slates of the Silurian system in the Woodstock area. Therefore there are swarms of diabase sills and a few dykes in the pre-Silurian rocks and only the isolated diabase sill or dyke in the Silurian strata. As discussed earlier, in the section on Structural Geology, the diabase melt probably travelled along the northeast-southwest fault to enter the pre-Silurian strata in the west central Millville area.

Following the Acadian disturbance, this part of the Northern Appalachians underwent a period of subaerial erosion. With the possible exception of a possible invasion of the sea during the early part of the Carboniferous period, as is evidenced by the Lower Carboniferous, or Mississippian, sediments in other parts of the province, there is no evidence of any pre-Pleistocene submergence of the land since the Devonian. The youngest consolidated rocks in the areas have been assigned to the Pictou Group of the Pennsylvanian epoch. These sediments are coarse clastic rocks, red in colour, facts which strongly suggest that they are terrestrial sediments[1].

The Pennsylvanian sediments were tilted and, as the attitudes of the rocks in the adjoining areas to the north indicate, they experienced minor folding. The folding and tilting of the Carboniferous are the only expressions of the Appalachian revolution found in this part of the Appalachians, and are the last events recorded for the Palaeozoic era.

It must be assumed that the Northern Appalachians underwent an extremely long period of subaerial erosion following the Pennsylvanian epoch, as there are no sedimentary deposits in the region to indicate otherwise - with the exception of coarse terrestrial and shallow water sediments that were deposited around the Bay of Fundy during the Triassic period.

Earlier, reference was made to the even skyline of the areas

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[1] Krumbein, W. C., and Sloss, L. L. : Stratigraphy and Sedimentation; W. H. Freeman and Company, San Francisco, p. 371 (1951).

under study. This even skyline has been interpreted as remnants of a peneplain probably as old as the Cretaceous period. Several erosion surfaces have been recognised in other parts of the Northern Appalachians, reflecting successive periods of uplift and erosion in the geological past. The last notable uplift occurring in Pliocene time.

The areas underwent glaciation during the Pleistocene epoch. Local ice-caps probably moved out from the high ground of the Central Highlands and other high areas in the region to merge into the continental ice-sheet. Striae and the position of eskers in the Woodstock and Millville areas indicate that the last ice-sheet moved over the district from north-northwest to south-southeast. As the ice-sheet retreated, large quantities of fluvio-glacial material were deposited in the valleys of the streams. The fluvio-glacial material, and material shoved into the valleys by the ice-sheet, disrupted drainage that had been well established in the Pliocene epoch.

Under the weight of the continental ice sheet the region had subsided. As the ice melted the land slowly rose, and numerous terraces were formed in the fluvio-glacial material along the valleys of the major streams. The land has not as yet fully emerged to its former level as the region still has a drowned coast line.

ECONOMIC GEOLOGY

IRON AND MANGANESE

General Statement

The iron and manganese deposits occur mainly in rocks of Zone B of Silurian age, and consequently are found only in the Woodstock area. The deposits are all sedimentary in origin and lenticular in outline. Minor occurrences of iron and manganese were noted within the boundaries of the pre-Silurian strata, but because of their limited extent and the relatively low grade they are not included in descriptions which follow.

The more important deposits of iron and manganese lie to the west and northwest of the village of Jacksonville, and minor occurrences are known 1 mile west of McKenzie Corner, 2 miles west of Belleville on the Meduxnekeag River, 1 mile northeast of Union Corner, and 1½ miles south of Richmond Corner.

During the course of field work in the season of 1951, the writer examined four deposits of iron and manganese in detail, and prepared maps, with the use of a plane table and pacing, on a scale of 1 inch to 200 feet, for final compilation on a scale of 1 inch to 400 feet. The two most important of the deposits examined were those of Iron Ore and Moody Hills, which lie respectively about 1 mile northwest, and half a mile west of Jacksonville. These deposits are shown on the accompanying map (Plate 3) as Area 3. The other two deposits are 2½ miles north-west and 3½ miles north of Jacksonville respectively; they are designated on the map (Plate 3) as Area 1 and Area 2.

The iron and manganese deposits near Jacksonville have been known for over 100 years, and were mined intermittently from 1848 to 1884. About 70,000 tons of ore were smelted[1], and the iron obtained was reportedly used for mail plating of gunboats of the British navy[2].

In 1868 the deposits were examined by H. Y. Hind[3], and six years later by R. W. Ells[4]. In 1884 mining operations ceased.

In 1931, S. C. Perry and W. J. Wright, of the New Brunswick Department of Lands and Mines, made a plane table survey of the area of the old workings, showing the outline of the old workings and indicating the zones of ferruginous rock[5].

The presence of Manganese in the ores was recognized from the time of the earliest operation, but no attempt was made to recover that metal.

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[1] Lindeman, E. and Bolton, L. L.: Report on Iron Ore Occurrences in Canada; Dept. of Mines, Canada, Mines Branch, No. 217, vol. 2, p. 162 (1917).

[2] Hitchcock, C. H.: 2nd Annual Report, Natural History and Geology of Maine, (1863).

[3] Hind, H. Y.: A Preliminary Report on the Geology of New Brunswick, Fredericton (1868).

[4] Ells, R. W.: Report on the Iron Ores of Carleton County, New Brunswick; Geol. Surv., Canada, Rept. of Prog. 1874-75, pt.vii, pp.97-104 (1876).

[5] Wright, W. J. and Perry, S. C.: Unpublished Manuscript Map, New Brunswick Dept. of Lands and Mines, Plate 32-1 (1932).

Iron Ore Hill[1]

General. Iron Ore Hill lies about one mile northwest of Jacksonville. The manganese is found in a highly contorted manganiferous iron formation, which outcrops along the crest of Iron Ore Hill. These deposits were worked at one time for the iron content of the rock. Exposures are rare except along the walls of the pits of the old workings. The lack of outcrop has rendered it difficult to determine, with any accuracy, the width of the manganiferous material, the grade, and the stratigraphy of the deposit. The deposit is readily accessible by road, and the land in the vicinity is cleared and under cultivation.

Geology. Low-grade manganiferous hematite interbedded with red and green slates comprise much of the rock of this deposit. These rocks have been folded into a series of steeply-plunging anticlines and synclines. Small faults and slickensided surfaces were observed in several places, but major dislocations were not noted.

Due to lack of exposures, the writer was unable to observe all parts of the ferruginous zone, but an early report[2] mentions that the beds of hematite reach a thickness of 16 feet. The width of the zone in which the beds of hematite occur varies considerably; the writer noted it to be as much as 200 feet in places.

The folds plunge steeply towards the northwest; the dip of the

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[1]The remainder of the section on iron and manganese is taken in part from Topical Report No. 1, prepared by the writer for limited distribution by the Geological Survey of Canada (1954).

[2]Ells, R. W.: op. cit. (1876).

beds on the limbs of the folds is also steep, and overturning of the beds is frequently seen. The strikes of the beds vary considerably, but the overall trend is to the northeast.

Veinlets of quartz, carrying pyrite and chalcopyrite, cut the bedding of the hematite and slates along the crests of the numerous folds. The amount of sulphides with these quartz veins is insignificant, and should have little, if any, bearing on the development of the deposit for iron and manganese.

Beyond the limits of the old workings the structure of the hematite and slate beds is unknown, and there are no exposures of bedrock to indicate further extensions of the deposit. Such information may be obtained only by an intensive exploration program involving diamond drilling and trenching. Although there is some magnetite in the deposit it is too irregularly distributed to allow satisfactory use of magnetometer.

Character of the 'Ore'. Hematite and interbedded slates are the host rocks for the manganese minerals. Although the cryptocrystalline character of the rock prevented the identification of the minerals in thin sections and polished sections, the presence of the metal is made evident by the assays (see Table 1) and the dense black coating of manganese oxide on exposed surfaces.

The hematite occurs in a dark red, fine-grained, very finely laminated rock (see Figure 32), containing detrital quartz, chlorite (daphnite ?), calcite, and small amounts of magnetite. Paralleling the laminae of low-grade hematite are bands up to 1 centimeter thick, and elongated pods or 'wheatstones' of a light pink, fine-grained carbonate (see Figure 33), which effervesces with dilute hydrochloric acid (5 per cent), and has optical properties that lie between those of calcite and rhodochrosite.

Figure 32. Iron formation. Thinly bedded manganiferous hematite from a metamorphosed section of the Iron Ore Hill deposit. The lighter bands in the figure are composed largely of mangano-calcite and quartz, with minor amounts of chlorite and magnetite. Plain light, X 26.

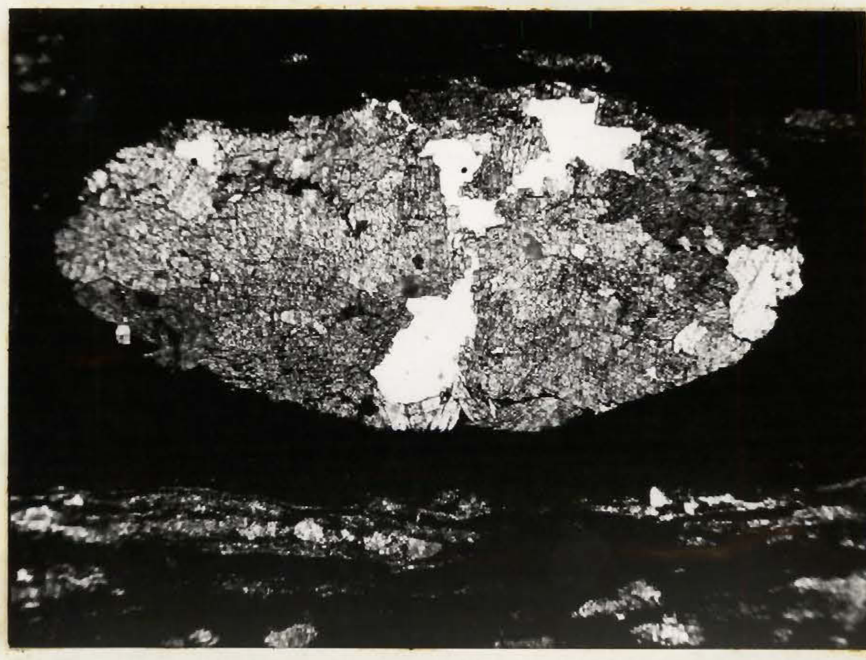

Figure 33. Iron formation. Wheatstone of mangano-calcite in manganiferous hematite of the metamorphosed section of the Iron Ore Hill deposit. Plain light, X 26.

The weathered surfaces of the bands and pods are heavily coated with black manganese oxide.

The red and green slates are all heavily stained with a coating of manganese oxide on the weathered surfaces. In thin section detrital quartz was the only mineral identified, for the other minerals in the slates are too fine-grained to be identified by conventional means with a petrographic microscope.

Manganese ores of a similar character to those described above are found in an adjoining area in the State of Maine. The manganese minerals identified in these ores, some of them with the aid of X-ray studies, included braunite ($3\ (Mn, Fe)_2O_3 . MnSiO_3$), and bementite ($8MnO . 7SiO_2 . 5H_2O$) and manganiferous carbonate[1]. It is probable that these manganese minerals are also present in the hematite deposits of the Woodstock area.

Metamorphism. The low-grade manganiferous hematite and interbedded slates have undergone considerable change along the crests of several folds. The bands are elongated pods of the fine-grained carbonate have been recrystallized, but are still manganiferous, because exposed faces of the carbonate crystals are black with a coating of manganese oxide. The width of the bands in the metamorphosed rock is approximately half of those in the unaltered rock. The optical properties of the metamorphosed carbonate are approximately the same as those of the unaltered materials - between those of calcite and rhodochrosite.

The hematite of the metamorphosed areas conains minerals similar to those found in the unaltered parts of the deposit but in different proportions. The main difference appears to be in the relative amounts

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[1]White, W. S.: Occurrence of Manganese in Eastern Aroostook County Maine; U. S. Geol, Surv., Bull. 940E (1943).

of magnetite, as the metamorphosed zones contain much more of that mineral. No manganese minerals were identified in thin sections made of the metamorphosed hematite or slate, although both are heavily stained with manganese oxide on exposed surfaces.

The fissile finely laminated green slate, interbedded with the hematite, has been transformed into a dense, dark green, rock. Study of thin sections of this rock indicates that the original mineral constituents have been reconstituted and that the laminae of the rock are either quartz-rich or chlorite-rich. Considerable calcite and magnetite are also present in these rocks. The red slates do not appear to have undergone any noticeable change.

The hematite and slate beds are cut by many quartz and quartz-calcite veinlets; on the exposed surfaces the latter are coated with a thin layer of manganese oxide. Small veinlets of pyrite were also noted cutting the laminae of the hematite.

There may have been an introduction of manganese from an outside source into the low-grade hematite of the metamorphic areas, as assays taken from several areas indicate. In Table 1, (page 101), sample 51-4 is from a channel across a succession of interbedded slate and hematitic beds on the limb of an anticline; sample 51-5 is taken from the crest, or metamorphosed section, of the same anticline, and from the same beds. The latter sample has at least 10 per cent more manganese than the former.

Moody Hill

General. Moody Hill is about half a mile southwest of Iron Ore Hill (see Plate 3, Area 3). The deposits of iron and manganese are located on the southward slope of the hill, and are readily accessible, for a road from Iron Ore Hill runs along its east side. The southern part of the hill may be reached by a road between Jacksonville and Hartford. The old workings are found in the open bush that covers a large part of the hill.

Bedrock exposures are relatively plentiful at and near the crest of the hill. Overburden is generally quite thin, commonly not more than 3 or 4 feet, except in the saddle between Iron Ore and Moody Hills, where it may be as much as 20 feet.

Geology. The manganese deposits of Moody Hill consist of several lenticular, manganiferous, ferruginous zones that are 10 to 100 feet in width and may be hundreds of feet in length. There are indications that many of these ferruginous zones are repeated by folding and faulting.

The rock assemblages are similar to those observed on Iron Ore Hill. More outcrops were noted and the different rock types appear to have the following relationships:

Younger - green slate, red slate, red and green slates with interbedded hematite.

Older - dark grey calcareous slates.

All the rock types listed above, with the exception of the calcareous slates, are heavily stained with manganese oxide. The manganese occurs largely in beds of low-grade manganiferous hematite, which range in thickness from a fraction of an inch to six feet.

Although there are numerous outcrops at and near the crest of the hill, they are rare on the slopes, and in many cases the walls of the old pits offer the only sources of information as to the statigraphy and structure of the deposits. It is apparent that the structure of the Moody Hill deposits is for the most part complex. On Plate 3, trend lines are used to indicate the possible complexities of the deposits.

Locally the strikes of the bedding vary considerably, but the general trend of the beds is to the northeast. Dips are generally of a high order but may be as low as 30 degrees. Schistosity strikes northeast with almost vertical dips.

There are indications that faulting is important from a structural standpoint, but little direct evidence was obtained. The one fault shown on the accompanying map was located by a study of the topography and of the distribution of rock types nearby. Topographic breaks, slickensided surfaces, and minor displacement of beds were observed in other parts of Moody Hill, but the lack of continuity of these features did not permit accurate interpretation.

Character of the 'Ore'. The ore of the Moody Hill deposits is laminated, fine-grained, low-grade, manganiferous hematite with interbedded manganiferous slates, and is similar to that of Iron Ore Hill. Analyses of this material show the presence of considerable manganese, but in lesser amounts than found in similar material of Iron Ore Hill.

Pods and narrow bands of fine-grained manganiferous carbonate, which were noted in the hematite of Iron Ore Hill, also occur in the hematite of this deposit. The manganese occurs in much the same manner as in the unaltered parts of the Iron Ore Hill deposit. Metamorphosed areas, such as were found in the other deposit, were not noted here.

The manganese content of Moody Hill ores compares favourably with that of the ores of Iron Ore Hill, but in general the orebodies are narrower and lack the continuity displayed at Iron Ore Hill.

Assays of the material from Moody Hill deposits are given in Table 1.

Area 1

A small exposure of manganiferous hematite was found in a pit about 1½ miles north of Iron Ore Hill (see Plate 3). The pit was dug in a ferruginous zone of less than 200 feet. The occurrence is in the middle of a small hardwood grove within a few hundred yards of gravel road, about 2½ miles north-northwest of Jacksonville.

The exposed rocks comprise several thin beds of a fine-grained, low grade hematite interbedded with grey and green slates. Four of the largest hematite beds were up to 16 inches wide. Impure limestone was found in the vicinity but its relationship to the ferruginous zone is unknown. All the rocks are contorted and broken, with a strong northeasterly schistosity. The strike of the bedding, where observed, is mainly conformable to that of the schistosity, and the dips are all steep. A layer of black manganese oxide coats all the exposed rock. No data could be obtained on the stratigraphy, but it appears that the deposits pinch out a short distance to the south.

The manganese content of the material is considerably less than that found at Iron Ore Hill and Moody Hill, but the mode of occurrence of the minerals appears to be the same.

Analyses of the ore from Area 1 is given in Table 1.

About 500 feet east of Area 1 is a zone of ferruginous slates about 250 feet wide. This zone contains much red slate and numerous narrow stringers of hematite. One half mile south of this zone, is another 10-foot ferruginous zone containing beds of hematite, the largest of which is 8 inches thick. The rocks in both of these localities are heavily stained with manganese oxide. It appears quite possible that these zones respresent the northward extension of the Iron Ore Hill deposit.

Area 2

Ferruginous rocks outcrop about $3\frac{1}{2}$ miles north of Jacksonville at a point about 200 yards west of the highway (see Plate 3). A pit approximately 300 square feet in area and 15 feet deep was dug in the iron formation, apparently for exploratory purposes at about the same time as the operation of the Iron Ore and Moody Hills deposits. The land in the vicinity of the deposit is cleared, but due to the stony nature of the soil it is not under cultivation.

The stratigraphy of the deposit has been determined to a limited extent and the various rock types appear to have the following relationship and thicknesses, from oldest to youngest:

(1) Dark grey calcareous slate.................... 50 feet
(2) Red slates ....100 "
(3) Red slates with interbedded hematite .... 20 "
(4) Grey, sandy slates .... 2 "
(5) Conglomerate ....150 "
(6) Red and greenish grey slates .... 60 "
(7) Thinly bedded limestone .... 20 "

The conglomerate is composed of fragments and pebbles of hematite, red and green slate, grey slate, cherts, quartz, and fossil material bound in calcareous cement. The fossil material was examined in the offices of the Palaeontological Division of the Geological Survey of Canada and identified as crinoid stems and Favosites gothlandicus (Fought); the latter is indicative of the Silurian age. The conglomerate varies considerably in thickness and appears to be lenticular; interbedded with it are several bands of manganiferous hematite, measuring from a fraction of an inch to 10 inches in thickness.

The main deposit of manganiferous hematite is confined to a zone about 20 feet wide (bed No. 3 above). The deposit is composed of red slates and hematite. The hematite is in narrow beds up to 16 inches thick, and is similar to the manganiferous hematite described in the other deposits. Red slates comprise the greater part of this ferruginous zone. Light-pink coloured, fine-grained, manganiferous carbonate, first described in the Iron Ore Hill deposit, is also present in the hematite of this deposit in the form of elongated pods and bands.

The structure of the bedrock of this area does not appear to have been complicated either by folding or by faulting. The strike of the bedding and the schistosity are approximately parallel and trend northeastward. Dips of both bedding and schistosity are steep.

An assay of material from this deposit is given in Table 1 (page101).

Assumed Extent of the Iron and Manganese Deposits

The rock assemblages of each of the iron and manganese occurrences in the Woodstock area are similar. The iron and manganese-bearing rocks outcrop in a definite pattern that follows the structure of the enclosing strata of Zone B of the Silurian system. There may be only one ferro-manganiferous horizon, but this is doubtful; it is more probable that there is a number of lenticular bodies of iron and manganese-rich rock scattered through and along a belt about 2 miles wide and up to tens of miles long.

The ferro-manganiferous strata of Iron Ore Hill cannot be safely assumed to extend for more than a few hundred feet beyond the limits of the old workings. The contorted structure and the lack of outcrop in the vicinity make any forecasts of their continuity purely hypothetical. A southward extension towards Moody Hill and, in particular, a junction with these latter deposits, must be based on information gained from either trenching or diamond drilling. The same remarks apply to a northward extension of the strata toward Area 1.

The Moody Hill deposit comprises several bodies of ferro-manganiferous rock, none of which may be extended beyond the outcrop area with any accuracy. Information derived from the outcrops indicates that these deposits are contorted as much as, if not more than, those of Iron Ore Hill. A northward extension of iron and manganese-bearing strata toward Iron Ore Hill must be proved by exposed rock or diamond drill cores; as both of these are lacking no attempt has been made to indicate on the map the continuity of the ferro-manganiferous beds between the two major occurrences.

The ferro-manganiferous beds of Moody Hill have been traced to within one-quarter of a mile of the Meduxnekeag River. Almost continuous outcrop along the river bank, and in railway cuts within 100 yards of the river, do not show the presence of such beds. The rocks along the river and railway are grey-green slates, dark grey calcareous slates, and limestone breccia.

The iron and manganese horizon of Area 1 may be traced, by outcrops and soil fragments, to a small pit about 2,500 feet to the northeast. Between this pit and Area 2 there are no outcrops, and the soil cover appears to be quite thick, therefore information of any extension of the ferro-manganiferous beds to the northeast must be based on further exploration. The writer believes, however, that approximately 500 feet north of the before-mentioned pit the manganiferous zone pinches out, and that the deposits of Area 2 lie stratigraphically above it.

There is no evidence in the vicinity of Area 1 from which the ferro-manganiferous strata could be assumed to extend any distance southward toward Iron Ore Hill; it appears unlikely that the two deposits are in the same stratigraphic position, although the rock assemblages of each are very similar. About 500 feet to the east of Area 1 there is a zone of ferruginous rocks about 250 feet wide. About one-half mile to the south of this zone there is an outcrop of manganiferous hematite, and it is possible that these two areas are related and that they represent the northward extension of the Iron Ore Hill deposit.

The iron and manganese rocks of Area 2 appear to be lenticular, and, as mentioned earlier, are believed to lie stratigraphically above those of Area 1. No attempt has been made to assume an extension of the strata of ores between Areas 1 and 2.

Reports written on the occurrence of iron ore in this part of New Brunswick, and observations made in the field by the writer, indicate that the belt of manganese and iron-rich rocks may extend for tens of miles northeasterly from Area 2, but little if any detailed information is available.

Origin of the Iron and Manganese Deposits

The iron and manganese deposits of the Woodstock area are of sedimentary origin. The associated, thinly bedded, calcareous slates, limestones, and fossiliferous strata show that the iron and manganiferous rocks were probably deposited as marine sediments, in shallow water a considerable distance from shore.

It has been suggested by Caley[1], that the iron and manganese concentrations in the rocks are the result of chemical precipitation accompanying volcanic activity. No volcanic rocks are directly associated with the deposits, but extrusive rocks occur in other parts of the region within a radius of 10 miles. These volcanic rocks are regarded as being in the same stratigraphic sequence as that of the iron and manganese-rich rocks.

White[2], and later Miller[3], studying similar manganese deposits in Maine, were inclined towards the view that the manganese was derived from the subaerial weathering of an adjacent landmass and deposited as geosynclinal sediments. Miller, however, does believe that volcanic activity during the Silurian time may have played a role in the formation of the deposits.

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[1]Caley, J. F.: op. cit., p. 19 (1936).

[2]White, W. S.: op. cit., pp. 142-144 (1943).

[3]Miller, R. L.: Manganese Deposits of Aroostook County, Maine; Maine Geol. Surv., Bull. 4, pp. 33-36 (1947).

Due to the limited amount of geological information available on the surrounding region, it is difficult to prove or disprove any one theory of the genesis of these deposits. Where the stratigraphy of the manganese and iron-rich rocks could be observed, there appears to be a disturbance in the normal sequence of deposition, as is evidenced by the conglomerate bed in Area 2; this disturbance could have been caused by volcanic activity. The lenticular shape and the relatively small area extent of the individual deposits indicates that they were deposited in small restricted basins, and it is not what one would expect if the manganese and iron-rich material was derived solely from the subaerial weathering of an adjacent landmass and deposited as geosynclinal sediments. Exposures of volcanic rocks in the adjoining area to the north, placed by Caley in the Silurian, are coated with a layer of manganese oxide on the weathered surface. From the observations made above the writer favours the suggestions on the origin of the manganese and iron-rich rocks as put forward by Caley.

Reserves of Iron and Manganese

The lack of subsurface data and the scarcity of bedrock exposures have been the limiting factors in the estimation of iron and manganese reserves in the Woodstock area. The reserves of the two larger deposits, that is, Iron Ore and Moody Hills, have, however, been calculated.

The manganese and iron deposits are sedimentary and may, therefore, be assumed to extend for a distance below the surface comparable to their lateral extent, but the complex structure and the apparent lenticular shape of the deposits, make it necessary to limit the assumed depth in the estimations of reserves; this depth has been taken at 100 feet.

Assays of the iron and manganese-rich rocks of the Iron Ore and Moody Hills indicate that there is at least 15 per cent iron and 10 per cent manganese across the width of the old workings; in places, this width may be as much as 200 feet. It is probable that further exploration of the deposits will reveal that the average grades of iron and manganese are higher than 15 and 10 per cent respectively.

Estimated reserves of possible 15 per cent iron and 10 per cent manganese ore are as follows:

Iron Ore Hill .... 1,500,000 tons

Moody Hill .... 800,000 tons[1]

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[1]Comprises the total of the estimated tonnages of the larger orebodies of Moody Hill.

Assays of the Manganese and Iron Deposits of the Woodstock Area

Table 1

IRON ORE HILL

Sample	Iron %	Manganes %	Phosphorous %	Sulphur %	Width Feet
51-4	22.42	12.18	0.56	0.23	8
51-5	19.10	22.38	0.51	0.10	11
51-6	14.74	16.84	0.38	0.02	10
51-7	22.22	14.99	0.86	0.13	10
51-8	17.94	10.48	0.39	0.12	10
568	20.91	18.53	1.28	trace	10
569	15.05	14.10	0.56	0.25	8
570	30.00	9.30	1.02	0.02	12
571	27.47	10.80	0.89	0.03	11.5
579	25.48	14.69	0.96	0.09	28
581	24.95	10.28	0.86	0.13	7

MOODY HILL

51-3	26.06	12.26	0.69	0.02	11
583	31.51	12.15	1.08	0.02	5.5
584	26.97	14.84	1.09	0.02	4.5
584	24.85	11.10	0.87	0.03	4
586	26.06	11.25	0.88	0.03	5
587	23.63	14.25	1.25	0.04	5
588	22.02	12.08	0.87	0.05	5

AREA 1

51-1	13.88	6.97	0.28	0.02	7

AREA 2

51-2	20.50	8.86	0.49	0.03	15

Note: Numbers preceded by '51' are of samples assayed by the Mines Branch, Department of Mines and Technical Surveys, Ottawa; other numbers are of samples taken in 1939 by the Department of Lands and Mines, New Brunswick, and assays by J.T.Donald & Co., Ltd., Montreal, Quebec.

COPPER LEAD AND ZINC

General Statement

There are numerous occurrences of copper, lead and zinc sulphides around the Gibson granitic stock, about 3 miles southeast of the town of Woodstock. In a very few known cases these sulphides are concentrated in sufficient quantities to warrant more than a superficial examination; no deposit as far as can be ascertained, has ever been economically worked.

The ore minerals of the deposits usually consist of at least two of the following - chalcopyrite, galena, and sphalerite, and are invariably associated with pyrite. The sulphides are found most commonly in veins with a quartz-calcite gangue; some replacement of the wallrock by the sulphides has been noted. The host rocks are pre-Silurian greywackes and slates. Mineralization is undoubtedly genetically related to the Gibson stock, and as such it is presumed to be Devonian in age.

Dominion No. 1

This deposit consists of lead and zinc sulphides which occur along a fault zone; the enclosing rocks are slates and greywackes. The property is located about 2 miles to the southeast of Woodstock, and about 1 mile east of the St. John River. A shaft was sunk on the ore zone to a depth of 65 feet, between the years 1925 and 1927[1]. At the time the writer

[1] Alcock, F. J.: Dominion No. 1 - Lead Property at Woodstock; Geol. Surv., Canada, Economic Geology series No 8; pp. 70-71 (1930).

visited the property the shaft was partially caved in and filled with water. Only the dump and surface exposures could be examined satisfactorily. Several reports have been written on the property and the information presented here has been taken from these reports and supplemented with personal observations.

The slates and greywackes in the vicinity of the shaft strike north 20 degrees east and dip 70 degrees northwest. The fault parallels the strike of the slates and greywackes but dips in the opposite direction at 70 degrees southeast. The slate, where cut by the fault, has been altered to a chloritic material and is partially replaced by the sulphides[1]. The sulphides are confined largely to the fault zone and are found in veins with a quartz-calcite gangue and as replacement bodies. The zone of mineralization varies from 12 to 48 inches with an average of 36 inches. The mineralized fault zone is quite narrow in the greywacke but after passing into the slate it widens out considerably[2], indicating that the slate is much more favourably disposed to mineral deposition than the greywacke. The vein has been proven for a distance of about 50 feet[3]. Two more veins, (possibly the same as the mineralized vein in the shaft), have been found 60 feet and 150 feet south of the shaft. These veins carried pyrite but no galena, sphalerite or chalcopyrite. A vein of

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[1] Wright, J. D.: unpublished report, (1940) (for A. W. Kyle).

[2] Wright, J. D.: op. cit., (1940).

[3] Claudet, H. H. unpublished report; Files New Brunswick Dept. of Lands and Mines, (1930).

quartz with pyrite but no other visible sulphides, was found in the bed of Connell Brook about 1000 feet south of the shaft area.

The ore minerals present, in the order of their abundance, are sphalerite, pyrite, galena, and chalcopyrite. The order of deposition was apparently pyrite, sphalerite, chalcopyrite, and galena, the two latter were probably deposited contemperaneously.

Assays of the ore vary considerably, probably the most representative assay is of a bulk sample of 422 pounds taken from the shaft, and considered to be an average run of ore. The results of this assay were as follows[1]:

Gold	0.005 oz/ton
Silver	1.00 oz/ton
Lead	5.16 per cent
Copper	0.57 per cent
Zinc	7.53 per cent

In 1930 H. H. Claudet reported that an average assay across 3 feet at 15 feet below the surface gave the following results:

Gold	trace
Silver	2 oz/ton
Lead	5.58 per cent
Copper	0.4 per cent
Zinc	7.14 per cent
Iron	8.35 per cent

J. D. Wright in an unpublished report states that an assay of 12 pounds of vein material from the shaft was as follows:

Gold	0.10 oz/ton
Silver	5.00 oz/ton
Lead	1.57 per cent
Copper	3.44 per cent
Zinc	8.00 per cent

Because of the small size of the deposit, the owners did not consider it to be of economic value, and ceased development work.

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[1] Report on the Flotation and Concentration of Copper-lead-Zinc Ore from the Dominion No. 1 Mine Woodstock, N. B.; Dept. of Mines, Bureau of Mines, Canada, (1940).

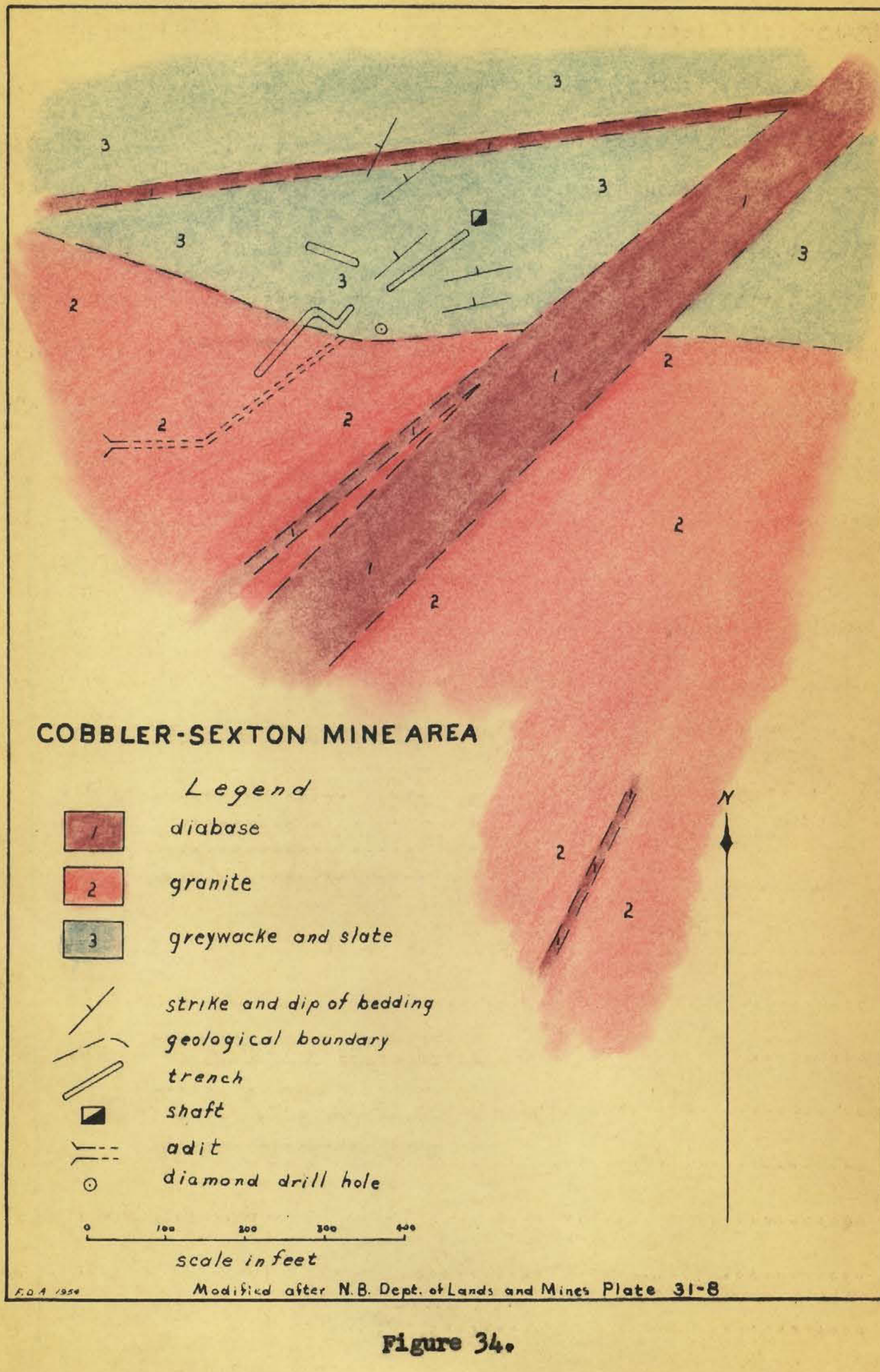
COBBLER-SEXTON MINE AREA
Legend
diabase
granite
greywacke and slate
strike and dip of bedding
geological boundary
trench
shaft
adit
diamond drill hole
0 100 200 300 400
scale in feet
N
Modified after N.B. Dept. of Lands and Mines Plate 31-8

Figure 34.

Cobbler - Sexton

This deposit consists of a concentration of copper sulphides in quartz veins. The veins occur in the neighbourhood of the contact of the Gibson granitic stock with a roof pendant of slates and greywackes. Several diabase dykes cut the granite and the sediments in the immediate vicinity of the deposit (see Figure 34).

The property is about 4 miles south of the town of Woodstock on the east side of the St. John River. The deposit was first seriously thought of as a potential producer of copper ore at about the turn of the century. In about 1906 an adit was driven into the side of the hill following the vein system for a distance of about 275 feet. The vein system was faulted off, and work was abandoned with no attempt being made to locate the displaced ore zone[1].

The principal mineral sought in the ore was chalcopyrite. It occured with pyrite and minor amounts of galena and sphalerite; assays made on the ore also reported minor amounts of gold and silver. The chalcopyrite occured in 'pockets' in the quartz veins.

Bull Creek

Copper ore was mined on this property between the years 1854 and 1858. It is situated about 4 miles south of the town of Woodstock on the west side of the St. John River near the mouth of Bull Creek. The shafts were sunk along the contact between the slates and greywackes and the Gibson granite stock. A considerable amount of exploration and development work has been undertaken on the property, as is evidenced by a plan of the old workings (see Figure 35). The main shaft was reported sunk to a depth of 125 feet

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[1] Hovey, J.: personal communication. Mr. Hovey is a long time resident of the area, and directed the mining of the Cobbler-Sexton.

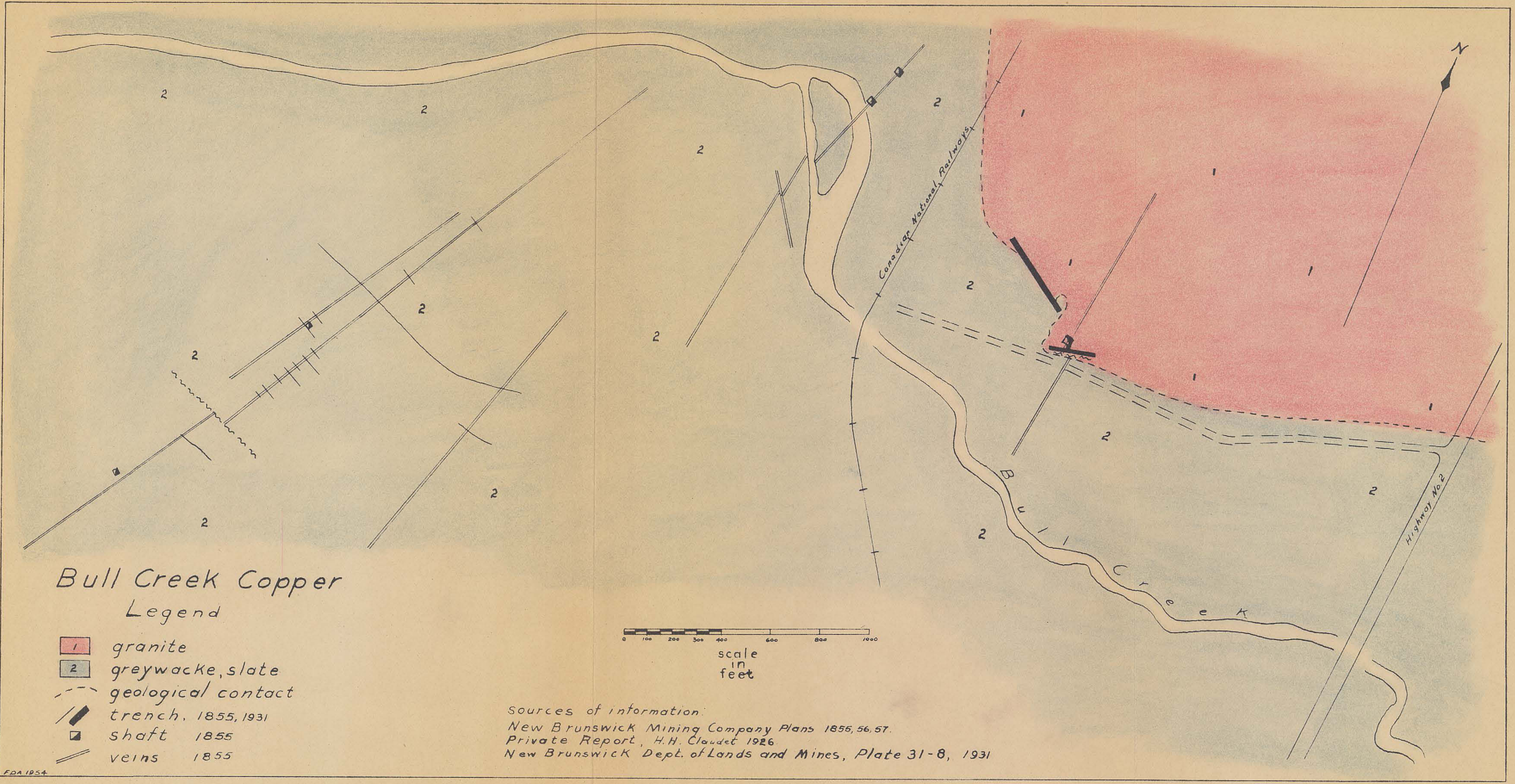
Bull Creek Copper
Legend
1 granite
2 greywacke, slate
geological contact
trench, 1855, 1931
shaft 1855
veins 1855
0 100 200 300 400 600 800 1000
scale in feet
Sources of information:
New Brunswick Mining Company Plans 1855, 56, 57.
Private Report, H.H. Claudet 1926
New Brunswick Dept. of Lands and Mines, Plate 31-8, 1931
Canadian National Railways
Bull Creek
Highway No 2
N
FDA 1954

Figure 35

The ore was quartz mineralized with chalcopyrite and pyrite[1]. Indications are that the mineralization was spotty, with, probably, small pockets of high grade copper ore.

Wright Brook

Galena, sphalerite with minor amounts of chalcopyrite, and pyrite are found in quartz veins and disseminated in a fine-grained greywacke, on the south bank of Wright Brook about 1 mile from its mouth. This brook joins the St. John River directly opposite the town of Woodstock. Diabase dykes cut the slates and greywackes near the deposit. Development work in 1949 consisted of a small amount of diamond drilling and a pit from which about 1000 cubic feet of rock has been removed. This work did not give very encouraging results and as far as is known the property was abandoned. The deposit is vein type with some replacement of the greywacke. Mineralization is undoubtedly related to the intrusion of the Gibson granite about 4 miles to the south.

SILVER

The only property in the region worked exclusively for silver was that of the R. K. Britton Mining Company, located about 4 miles north of Woodstock on the west side of the St. John River. The mine, which is said to have had a shaft over a hundred feet deep with two levels, is now completely concealed by caving and fill. Mining was reportedly started in 1889 and continued until 1891 or 1892, and during this time about $250,000 worth of silver was extracted from the ore[2]. The host rock of the deposit

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[1]Bailey, L. W.: The Mineral Resources of the Province of New Brunswick; pt. M, Annual Report. Geol. Surv., Canada, Vol. X, p. 25 (1899).

[2]Shaw, B. L., and Shaw, K. E.: personal communication. (Messrs. Shaw are long time residents of the area).

are greywacke and slate. Examination of the surface exposures and the dump gave little evidence of the type of ore mined but apparently it was in the form of quartz-calcite veins about 18 inches wide and the ore mineral was primarily argentiferous galena, associated with pyrite. The ore had an assay of:[1]

Silver	..............................4.5 oz/ton
Lead	..............................2.5 per cent
Gold	..............................trace

The origin of this deposit is unknown but it is probably genetically related to the intermediate to basic intrusions in this part of the area.

GOLD

Gold has been found in minute quantities associated with the base metal deposits in the areas; it was also reported in assays from the silver property of the R. K. Britton Mining Company. Separate occurrences of gold have been reported in the vicinity of Oak Mountain in the southern part of the Woodstock area. The region in which the gold was reported is covered with very large boulders of white milky quartz, and it is supposedly in this quartz that the gold was found. The writer examined the area with considerable care but found no trace of gold. Some very small amounts of chalcopyrite and pyrite were noticed in the quartz boulders. No quartz was found 'in situ'.

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[1] Shaw, B. L., and Shaw, K. E. personal communication (Messrs. Shaw are long time residents of the area.).

LIMESTONE

General Statement

Agriculture is the major industry in the Woodstock and Millville areas, and as such is of prime importance in the economy of the inhabitants. Ground limestone or 'lime', as it is often referred to, plays a very important role as a fertilizer, contributing to the maintenance and production of an agricultural district; thus, deposits of workable limestone are always of importance in a farming community.

The largest quantity of calcareous rocks in the region is undoubtedly the calcareous slates of Silurian age which outcrop over a large portion of the Woodstock area. The economical use of the majority of the slates for their lime content is impractical because of their impure character. Intercalated with the calcareous slates are several lenticular beds of fairly pure limestone, but these beds are usually of such limited extent that they could not be commercially exploited.

The largest and the purest deposit of limestone located to date occurs in the relatively non-calcareous strata of the pre-Silurian. This deposit is near Central Waterville in the west central part of the Millville area. There are no other limestone deposits of any consequence in the pre-Silurian of the areas under study.

Ivy Corner

This deposit of limestone is in the southern part of the Woodstock area, immediately south of the road between Ivy Corner and Limestone about one-half a mile east of the first named place. The pits and quarries that made up the old working are all filled. There are no exposures of bedrock in the immediate vicinity of the deposit; examination of the property by the writer was limited to the soil cover and the old dumps. The material quarried was apparently a dense, black or dark grey, limestone, containing a fair amount of shell fragments and crinoid stems, all of which were either too imperfect or fragmentary to permit identification. There was no trace of internal structure in the limestone, but from the location of the pits and by conversations with long time residents, it was ascertained that the limestone conformed with the structure of the enclosing rocks. The bed of limestone forming the deposit was about 100 feet wide and about one-quarter of a mile long.

Limestone was quarried from this deposit in the early part of the 1800's. Some of the material was crushed and used locally as fertilizer, other was slaked and used in mortar in the construction of barracks for the United States Army, in nearby Houlton, Maine[1]. Because of poor drainage, work was suspended on the deposit about 100 years ago[2], and as far as is known was not resumed.

Central Waterville

The deposit is composed of two lenticular beds of limestone separated by a few feet of slate, enclosed in slates and greywackes, all of which appear to be pre-Silurian in age. The deposit is about 100 feet east of the road between Temperance Vale and Woodstock and about 4 miles from the former place, and 14 miles southeast from the latter. The history is

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[1]Carson, A.: personal communication, (Mr. Carson is a longtime resident of the area).

[2]Bailey, L. W.: op. cit., p. 300 (1885).

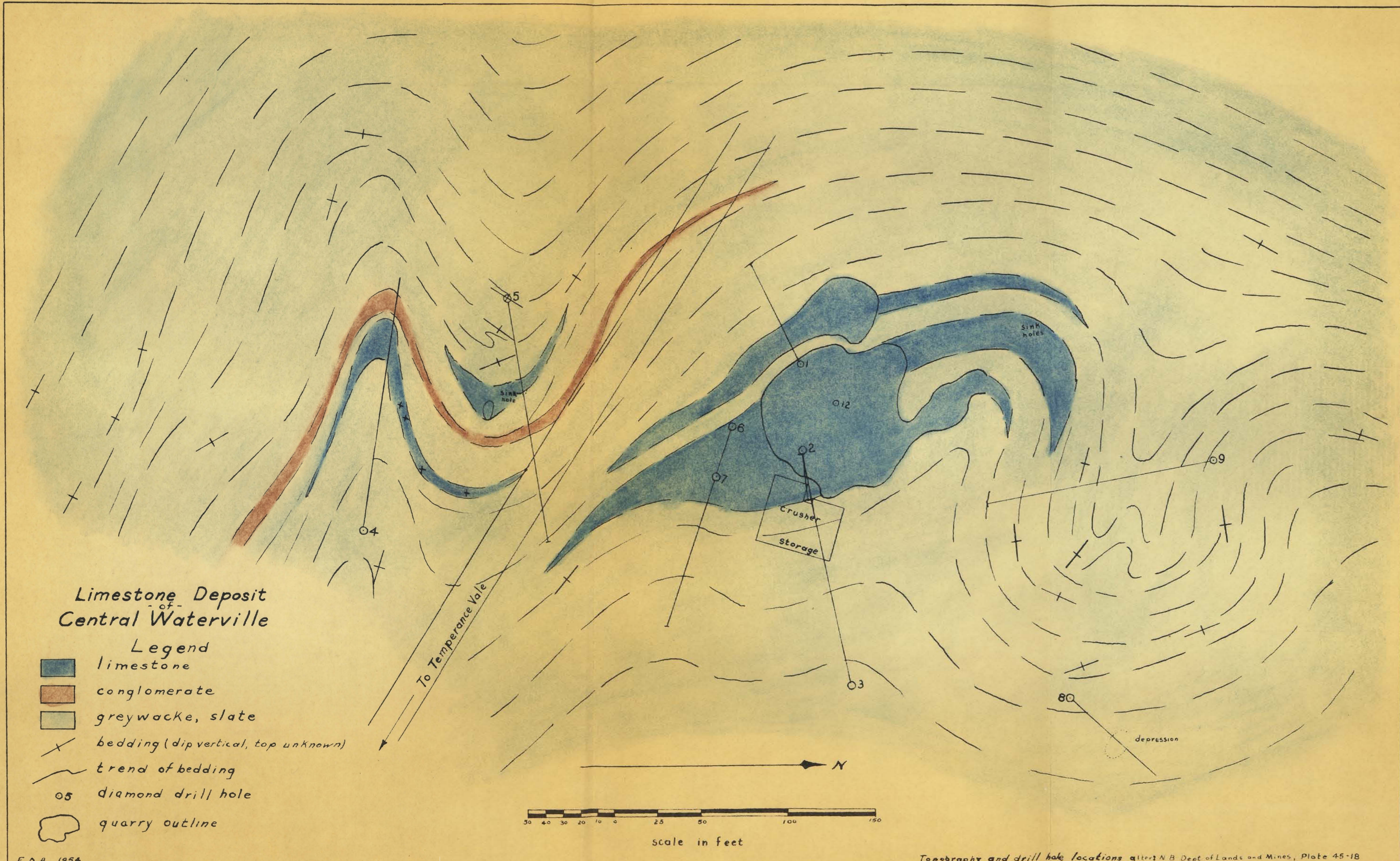
Limestone Deposit
-of-
Central Waterville
Legend
limestone
conglomerate
greywacke, slate
bedding (dip vertical, top unknown)
trend of bedding
diamond drill hole
quarry outline
To Temperance Vale
sink hole
sink holes
Crusher
Storage
depression
N
50 40 30 20 10 0 25 50 100 150
scale in feet
F.D.A 1954
Topography and drill hole locations after N B Dept of Lands and Mines, Plate 45-18

Figure 36.

uncertain, but it has been known since at least 1884, when it was investigated by L. W. Bailey[1]. No serious work was apparently done on the deposit until around the time of World War 1. From then until the present time the property has changed ownership several times. Under the direction of several people the limestone was pulverized and used locally as fertilizer, but for various reasons, largely either poor management or the lack of capital, the working of the deposit has not proved to be economically feasible for the owners.

The limestone of the deposit is white to light grey, and crystalline. The two beds making up the deposit are distinctly lenticular, ranging in width from 2 to 85 feet over a length of 200 feet. The beds dip essentially vertically, and are disposed in the shape of a vertical drag fold (see Figure 36). The trend of the deposit is northerly. The beds of limestone are separated by from 6 to 12 feet of dark grey slate and enclosed by dark and light grey slate and grey-green greywacke. The slates and greywackes are cut by numerous quartz-calcite veins.

Although the limestone is crystalline, the shape of the deposit and the severe deformation the rock has undergone have rendered it unsuitable to be quarried as dimension stone for the building trade. Pulverized, the limestone is admirably suited for agricultural purposes. Analyses made by the Canadian Pacific Railway Development Branch gave the

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[1]Bailey, L. W.: op. cit., p. 19G (1885).

following results[1]:

Silica..............................0.68 per cent
Alumina.............................0.27 per cent
Iron Oxide..........................0.25 percent
Calcium Carbonate...................98.27 per cent
Magnesium Carbonate.................
Sulphur Dioxide..................... trace

During the years 1945 and 1946, the Provincial Government diamond drill was engaged by a private concern to put down 12 holes on the property; the total amount of drilling done was 1597 feet[2]. A short description of the holes that appear in Figure 36, follows.

Hole	Bearing	Dip	Depth	Limestone		
				from	to	Thickness
1	S63W	45	91'	11'9"	38'5"	26'8"
2	N86E	45	21'	4'	20'	16'
3	N60W	45	194'	138'	194'	56'
4	N38W	30	191'	137'	139'	2'
				145'	172'3"	17'3"
5	N80E	35	175'	-	-	-
6	S72E	45	60'	20'	60'	40'
7	S72E	45	125'	0'	20'	20'
8	N80E	45	95'	-	-	-
9	S12E	45	190'	-	-	-
12	vertical		268'	0'	103'	103'
				152'	267'6"	15'6"

The quarry which has been established on the limestone in the past years is roughly circular in outline, with a diameter of approximately 100 feet. The proven area underlain by limestone is about 11,775 square feet. Tonnage has been estimated at about 1000 short tons per foot of depth. One drill hole, No. 12 of Figure 36, indicates that the limestone extends to a depth of at least 267 feet below the quarry floor.

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[1] 97th Annual Report, Dept. Lands and Mines of the Province of New Brunswick, p. 49, (1933).

[2] 110th Annual Report, Dept. Lands and Mines of the Province of New Brunswick, p. 37, (1946).

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PLATE I

LEGEND

CARBONIFEROUS
PENNSYLVANIAN
PICTOU GROUP

- 9 — Red conglomerate, sandstone

DEVONIAN

- 8 — Diabase sills, dykes
- 7 — Granite, granodiorite, syenite
- 6 — Diorite, quartz diorite, gabbro
- 5 — Andesite, basalt; may be wholly or in part Carboniferous; 5a, amygdaloidal facies; 5b, porphyritic facies

SILURIAN

- 2, 3, 4 — 2. Grey-green slate, sandstone, greywacke; minor conglomerate, limestone. 3. Grey-green, grey, green and red slate; sandstone, greywacke; manganiferous iron formation; minor limestone. 4. Buff and grey-green sandstone, slate, greywacke; intercalated dark grey calcareous slate

PRE-SILURIAN

- 1, 1a — Grey-green greywacke, slate, argillite; minor limestone, grit; 1a, metamorphosed equivalents; biotite gneiss, mica schist, chlorite schist

PALÆOZOIC

Drift-covered area
Rock outcrop
Bedding (horizontal, inclined, vertical, dip unknown)
Bedding (direction of dip known, upper side of beds known)
Cleavage (inclined, vertical, dip unknown)
Drag fold
Fault (assumed)
Glacial striæ
Quarry, mine
Mineral prospect or occurrence
Shaft
Adit

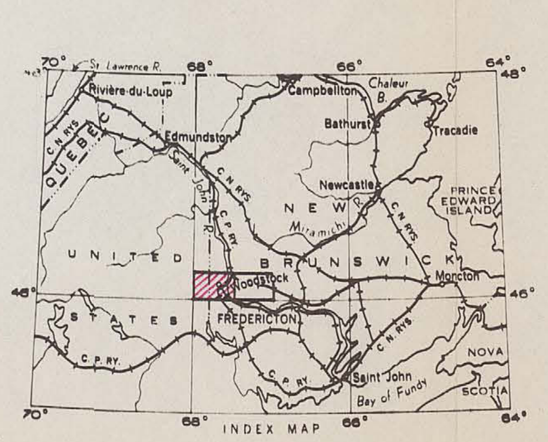
MINERAL OCCURRENCES

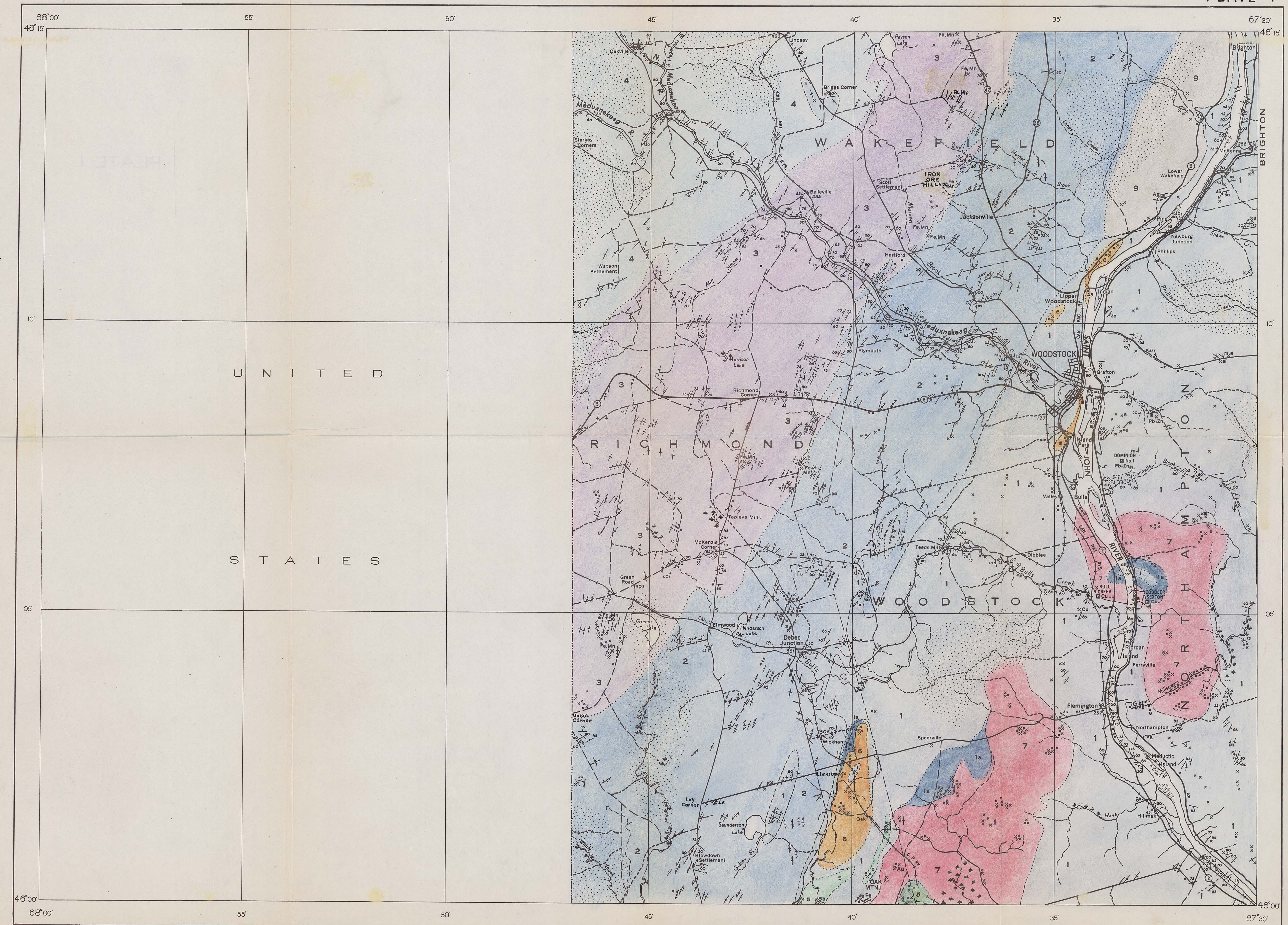
Silver	Ag	Iron	Fe
Gold	Au	Lead	Pb
Copper	Cu	Manganese	Mn
Zinc	Zn		

Geology by F.D. Anderson 1951, 1952

Main highway
Other roads
Trail
International boundary
Parish boundary
Marsh
Sand or gravel
Height in feet above mean sea-level ... 608

Approximate magnetic declination, 21° 10' West





WOODSTOCK
CARLETON COUNTY
NEW BRUNSWICK

Scale: One Inch to One Mile = $\frac{1}{63,360}$

Miles

LEGEND

PALÆOZOIC

CARBONIFEROUS
PENNSYLVANIAN
PICTOU GROUP

7	*Red sandstone, shale, conglomerate*
6	*Recomposed granite arkose*

DEVONIAN

\ × 5	*Diabase sills, dykes*
4	*Granite, granodiorite, syenite; xenoliths within the bodies are indicated by a strike symbol*
3	*Diorite, quartz diorite, gabbro*
2	*Andesite, basalt; may be wholly or in part Carboniferous; **2a**, amygdaloidal facies; **2b**, porphyritic facies*

PRE-SILURIAN

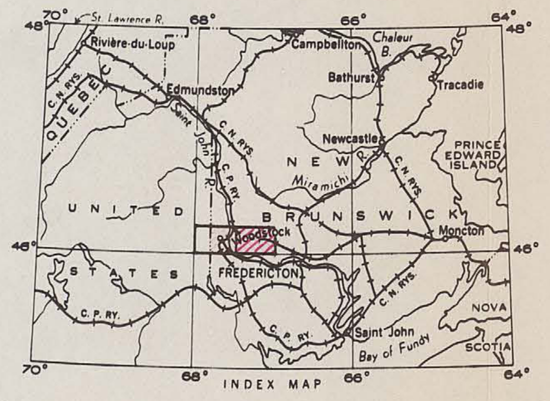
1 / 1a	*Grey-green greywacke, slate, argillite, minor limestone, grit; 1a, metamorphosed equivalents; biotite gneiss, mica schist; hornfels*

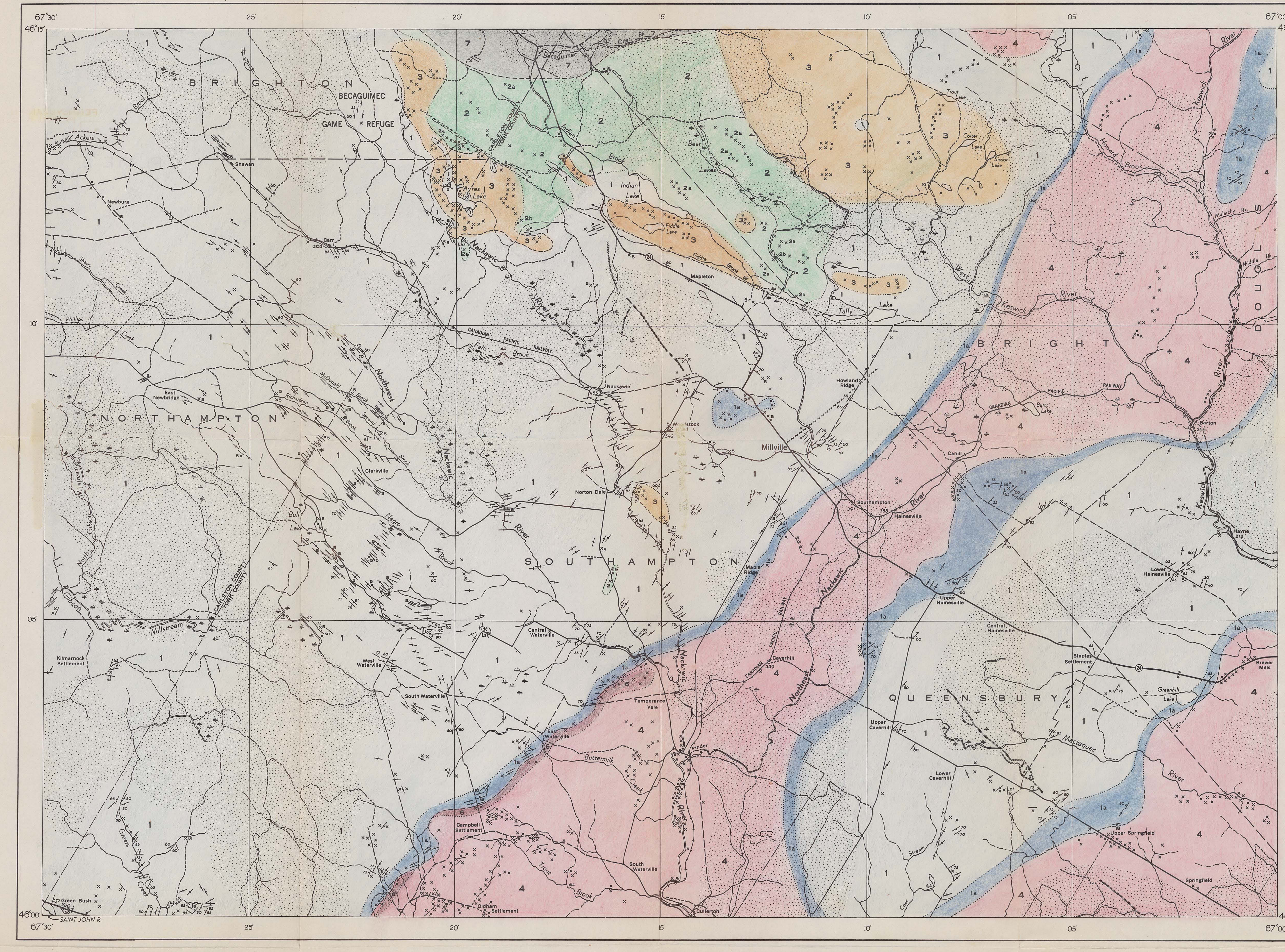
Drift-covered area
Rock outcrop . . . ×
Bedding (inclined, vertical, overturned, dip unknown)
Bedding (direction of dip known, upper side of bed unknown)
Cleavage (inclined, vertical, dip unknown)
Drag fold
Fault (assumed)
Glacial striae
Esker
Limestone quarry

Geology by F. D. Anderson, 1950, 1951

Main highway
Other roads
Trail
County boundary
Parish boundary
Marsh
Height in feet above mean sea-level . . . 614

Approximate magnetic declination, 21°32′ West





MILLVILLE

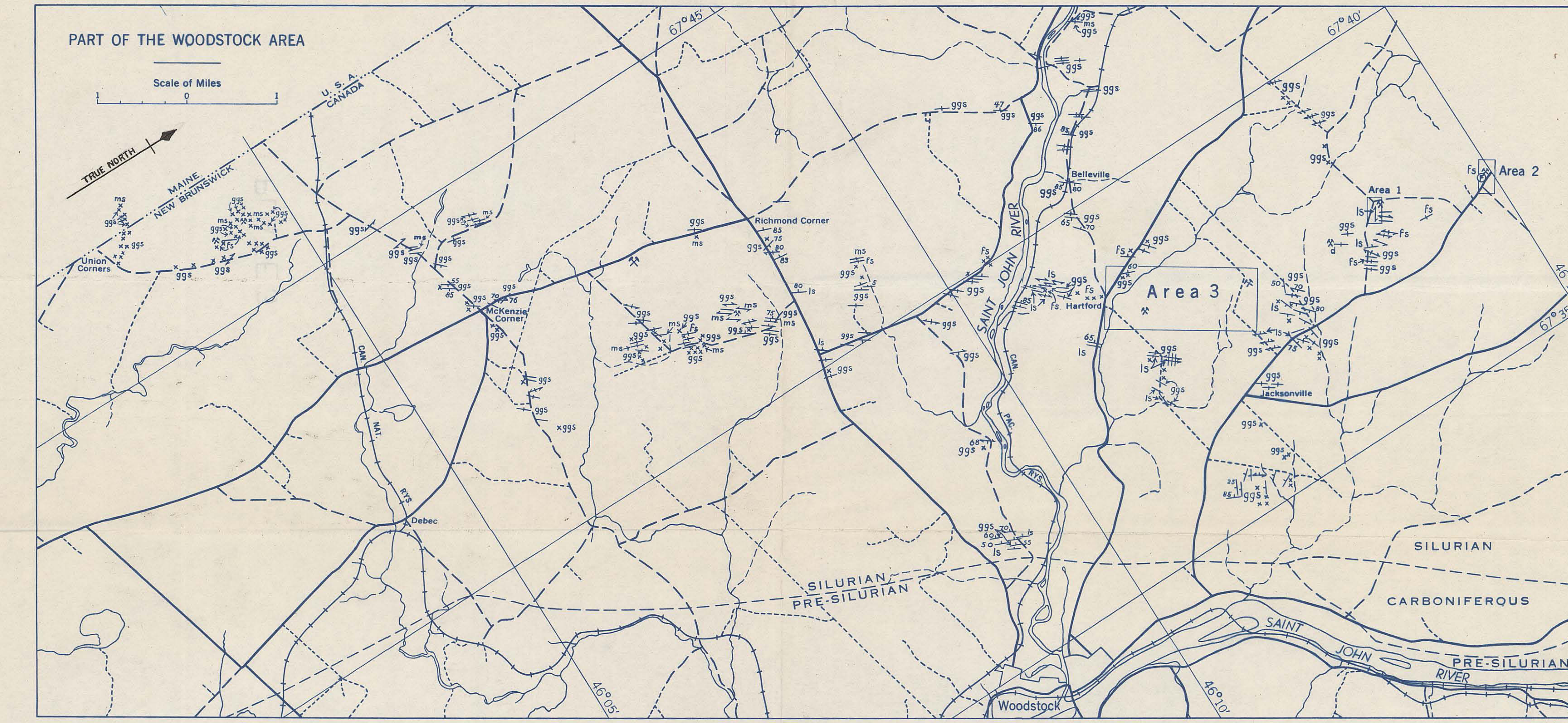
YORK AND CARLETON COUNTIES

NEW BRUNSWICK

Scale: One Inch to One Mile = $\frac{1}{63,360}$

Miles

1 ½ ¼ 0 1 2 3



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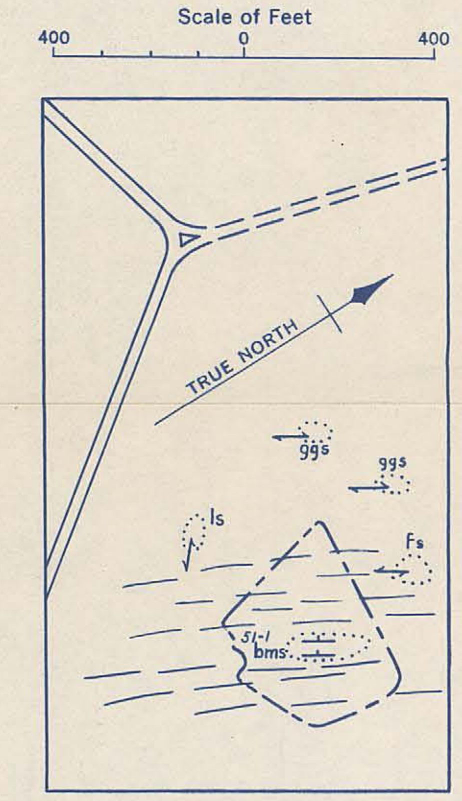

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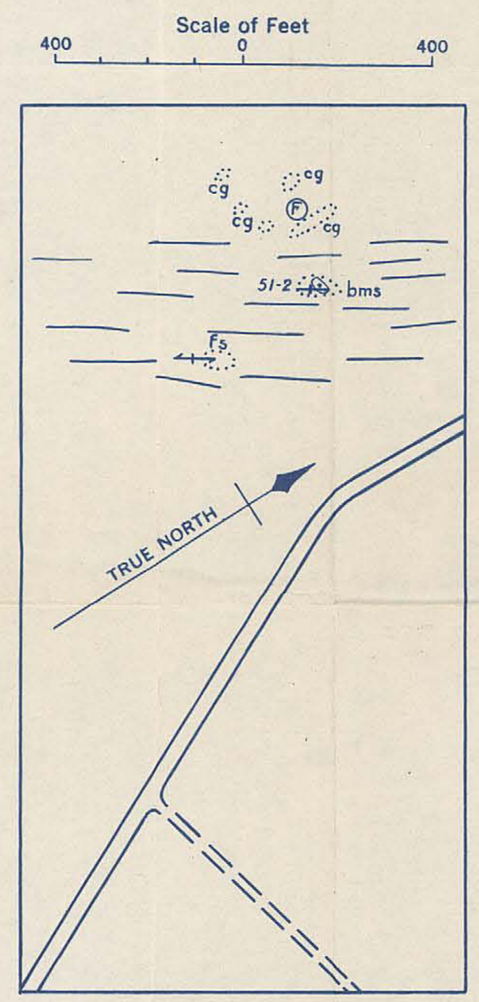

LEGEND

bms	*Banded manganiferous hematite*
ms	*Manganiferous slates*
fs	*Ferruginous slates*
ls, cg	*Limestone, calcareous slates, conglomerate*
ggs	*Green and grey slates, sandstones*
d	*Diabase*

Outcrop
Geological boundary
Strike and dip of bedding, direction of tops known, unknown, vertical, overturned
Assumed and indicated trend of bedding
Cleavage inclined, vertical, dip unknown
Fault
Fossil locality
Iron and/or manganese occurrence
Outline of old workings
Samples
International boundary
Boundary between field and woods

Geology by F. D. Anderson, 1951

AREA 3

Plane table survey