CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

MEMOIR 260

GEOLOGY AND COAL DEPOSITS OF MINTO AND CHIPMAN MAP-AREAS, NEW BRUNSWICK

BY

J. E. Muller

OTTAWA
EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
KING'S PRINTER AND CONTROLLER OF STATIONERY
1951

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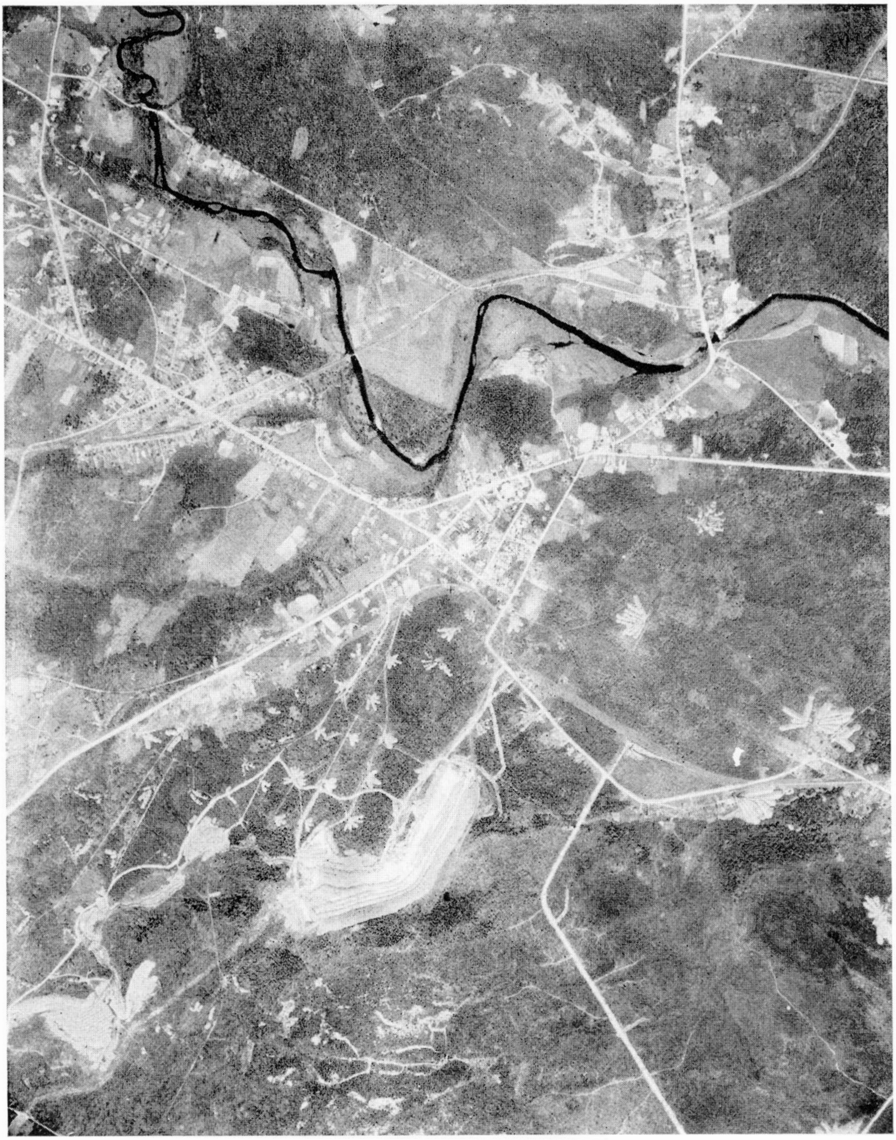

Vertical air view of Minto (in northwest, upper left corner), Rothwell (in centre), and Newcastle Bridge (northeast corner). The picture shows some strip-mines, with their successive ridges of waste material. The old shafts are marked by elongated shale dumps, branching out star-like from the shaft openings. Some of the dumps are covered by new vegetation and hardly visible. (Photo A8221-53 by Royal Canadian Air Force, July 2, 1945.)

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PREFACE

The Minto coalfield of New Brunswick has the distinction of being the first on the Atlantic seaboard of North America to be developed for export trade, coal having been shipped from there to New England as early as 1639. It is also unique in that its production throughout a long mining history has been from a single seam and this so thin as, in most coalfields, to be considered impractical to mine, but in this instance compensated for by its relative accessibility and lack of structural disturbance.

In the present report, the author deals with the geology of the two adjacent map-areas in which mining operations on the Minto coal seam have been of principal economic interest. The report includes a detailed estimate of the probable and possible coal reserves, based largely on the results of detailed mapping by the Provincial Geologist within the area of Pennsylvanian coal measures. Particulars are also given of the character of the coal, its analysis, and its thickness as determined from numerous workings and bore-holes.

The report and geological maps are a revision of Memoir 151, on Minto Coal Basin, New Brunswick, by W. S. Dyer, published in 1926. Not only are present data on the coal seam much more complete, but the recent field work by Dr. Muller has provided additional information on the stratigraphy of the two map-areas and, in particular, on the succession of formations in this southwestern part of the great Pennsylvanian basin of central and eastern New Brunswick.

GEORGE HANSON,

Chief Geologist, Geological Survey of Canada

OTTAWA, April 17, 1950

Geology and Coal Deposits of Minto and Chipman Map-Areas, New Brunswick

CHAPTER I

INTRODUCTION

GENERAL STATEMENT

The Minto coalfield fringes the northern shores of Grand Lake, in the central part of New Brunswick's Pennsylvanian basin. It lies within the limits of the adjoining map-areas Minto (East Half) and Chipman (West Half), comprising a combined area[1] of about 400 square miles lying between latitudes 46° and 46°15′ and between longitudes 65°45′ and 66°15′.

Old records in Boston, Massachusetts, indicate that coal was exported from the Grand Lake area as early as 1639, and some coal has probably been mined more or less continuously ever since. The present production is in the neighbourhood of 500,000 short tons a year, and represents practically all of the coal production of the province. There is only one seam of bituminous coal, averaging 18 to 24 inches in thickness, and occurring near the surface over large areas. The coal is produced from open pits, to a depth of about 40 feet, and from underground workings, entered by slopes or shafts, to a depth of about 100 feet. A little additional coal is produced from small slope-mines, driven into the outcrop of the coal in the banks of streams, or in abandoned strip-mines, and worked by only a few miners.

The considerably increased production in recent years has caused rapid depletion of the known coal reserves of the field. The main purpose of the present investigation was to establish the general distribution of the coal seam on the basis of geological field evidence and available mining and drilling data. The resulting maps may serve to guide prospecting for new mining areas and to assist in estimating the coal reserves of the area.

ACCESSIBILITY

The area can be reached by motor roads from Fredericton, Moncton, and Sussex. Near Grand Lake and Salmon River, where all mines and settlements are, it is well serviced by secondary roads; Minto and Chipman are connected by a paved highway. Farther from the lake there are few settlements, but lumber roads facilitate access to more remote parts.

Chipman is a station on the Canadian National Railways transcontinental line; at present this line is only used for freight, and a branch from Harwood Ridge to North Minto serves the mines in that vicinity. Both Minto and Chipman are also on a Canadian Pacific Railway line that extends from Norton to Devon, a suburb of Fredericton. This line serves the coal mines of South Minto, and what mining is being done in the Chipman area.

[1] This combined area will be referred to in this report as 'the area'.

ACKNOWLEDGMENTS

During the field work in the summer of 1948 the writer was ably assisted by Messrs. W. E. Hale and A. Hale.

Dr. W. J. Wright, Provincial Geologist, gave much helpful advice and assistance. His compilation of coal data on mining-block maps was a most important source of information. A vertical variometer (magnetometer), loaned by the Provincial Department of Lands and Mines, was used by the writer to make some magnetic surveys over the area of extrusive rocks.

Special thanks are also extended to officials of the Avon Coal Company, Miramichi Lumber Company, Welton and Henderson Limited, and to Messrs. W. Benton Evans and Gerald H. King, for valuable information and plans placed at the disposal of the writer.

The writer is also much indebted to Dr. B. R. MacKay of the Geological Survey, who visited him in the field, and gave all possible advice and co-operation.

PHYSICAL FEATURES

The area mapped is part of the Eastern Plain of New Brunswick, the site of a great area of nearly flat-lying Pennsylvanian strata. During at least part of Pleistocene time it was completely covered by ice, as indicated by the presence of boulder till and polished, striated rock surfaces.

The retreating ice left a smooth, gently undulating and slightly furrowed terrain, with low, rounded ridges composed of harder sandstones or volcanic rocks and shallow depressions underlain by shale. These furrows show a definite linear arrangement, following the general northeast trend of the rock formations, along which the ice apparently moved. They are partly filled by boulder till, exposed in some of the strip-mines. On the shores of Grand Lake, accumulations of boulders washed out from this till occur at several places. In some of these accumulations, the boulders are all derived from underlying sedimentary bedrock, but in other places they are mainly of intrusive rocks that may have been transported considerable distances. The latter are commonly larger than the sedimentary boulders, ranging from 1 foot to more than 10 feet in diameter.

Most of the glacial striæ on the bedrock surface indicate movement to the southwest, and, although other directions were noted, the writer was not able to verify two periods of different ice movement, as postulated by Dyer (1926, p. 5)[1].

In the southeastern part of the area, the following, shallow, southwest trending depressions may be observed, commencing in the southeast:

(1) Cumberland Creek and Cumberland Bay, continuing across Grand Lake to the depressions occupied by Keyhole and Maquapit Lakes (beyond the area).

(2) Coal Creek and the Northeast Arm of Grand Lake, with Flowers Cove on the west side of the lake.

(3) The depression occupied by Wilson Brook and the north parts of Salmon Bay and Newcastle Bay, to Yeamans Brook.

(4) Redbank Creek, Salmon River from Chipman to Iron Bound Cove, and Perley Brook.

(5) Salmon River, from below Gaspereau Forks to Briggs Corner, and Salmon Creek.

[1] Dates, etc., in parentheses are those of references in bibliography at the end of this chapter.

Salmon River cuts across from one linear depression to another in a series of sharp bends. From Gaspereau Forks, the river follows an old flood-plain in which loose sand deposits have been accumulated at levels high above the present river. This flood-plain continues up the valley of Gaspereau River, and probably dates from the Glacial times when the ice receded and this valley was one channel of drainage. Other streams occupying these depressions have commonly cut through boulder till in parts of their middle courses. Their lower courses are bounded by mud flats, with few rock outcrops, and widen gradually into an arm of Grand Lake.

In the northwestern part of the area there are southwest trending ridges, but a general southeast slope towards Grand Lake was here the main factor governing drainage. Thus the main streams in this part, Little River and Newcastle Creek, with their tributaries, have an irregular, dendritic pattern. They are in a youthful stage, with narrow valleys 25 to 100 feet deep, and with outcrops along most of their courses. In the harder sandstones of the Minto and Sunbury formations they have formed incised meanders.

Most of the area is wooded, mainly with spruce and scattered patches of poplar. Heaths and swamps cover much of the poorly drained inter-stream areas.

PREVIOUS GEOLOGICAL WORK

The first published account of geological investigations in the Grand Lake area was by Abraham Gesner, Provincial Geologist for the province of New Brunswick. In his five annual reports, dated from 1839 to 1843, he gives considerable attention to "the great New-Brunswick coal-field". Gesner assumed, optimistically, that the entire basin of Pennsylvanian strata, occupying an area of more than 5,000 square miles in this province, would yield a limitless quantity of coal. Although he stated that the thinness of the seam prevented successful mining, he expressed the belief that lower seams would be found by drilling. The log of one bore-hole, drilled at "Salmon River Coal Mines" in 1839, and given in Gesner's third report, records, apart from the surface seam, a seam of shale and coal 8 feet thick at a depth of 262 feet. But the presence of such a seam has not been confirmed since.

Gesner never published a map, but J. Robb compiled a first geological map of the province from Gesner's notes and his own observations. This map was included in a report on the argicultural possibilities of New Brunswick by J. F. W. Johnston (1850).

J. W. (later Sir William) Dawson, in the first edition of his 'Acadian Geology' (1855), devoted most of the chapter on the "Coal-field of New Brunswick" to the albertite deposits of the Hillsborough area, which he believed to be structurally distorted coal. Of the coal formation overlying the Albert bituminous shales he admitted that, though thin seams were worked in some places on a small scale, no really valuable bed of coal was known and that prospects of any future discovery were by no means promising.

In 1865 L. W. Bailey published a report, with map, on the geology of southern New Brunswick. In this report the term 'coalfield' is replaced by 'Carboniferous basin' for the entire Pennsylvanian area, indicating a better understanding of its actual coal resources.

The geology of the Maritime Provinces became a direct concern of the Geological Survey of Canada after their entry into Confederation in 1868. The Progress Reports of 1866-1869 include a report by C. Robb, containing some general information on Pennsylvanian stratigraphy in other parts of the basin. The report by Bailey and Matthew (1870-1871) also mentions the "coal basin" and lists fossil plants. In the following years the same authors made more detailed investigations of the Grand Lake coal area, and the results of these were published in the Progress Reports for 1872-1873.

In the last of these reports most stratigraphic divisions used in the present memoir can be recognized. The "Middle Carboniferous" seems to be equivalent to the Minto formation; it is subdivided into: (1) Barren grey beds (200 feet) and (2) Productive Measures (200 feet). The "Upper Carboniferous" is also called "Upper Coal formation" (200 feet), and corresponds with the present Hurley Creek formation and younger beds. Some terms are used rather loosely: "Lower Carboniferous" seems to indicate in most places Mississippian, but in some instances is used for the Barren grey beds. In the "Lower Carboniferous" are also included the volcanic flow of Newcastle Creek, with underlying conglomerate, and the volcanic rocks of the Cumberland Bay area. Several pages are devoted to descriptions and detailed sections of the exposures in the cliffs of Newcastle Creek. Outcrops on Salmon River and the branches of Salmon Creek are also mentioned, and the coal occurrences and exposures of pre-Carboniferous rocks on Coal Creek. These latter outcrops are regarded as evidence of the shallowness of the Carboniferous basin. The report also describes fifteen small mine workings, all apparently comparable to present-day workings (*See* Plate II A). According to the estimate of these authors the coal reserves of the Grand Lake area amounted to 154,948,147·2 (*sic*!) short tons.

In 1872 and 1873, two borings were made at Newcastle Bridge by the Provincial Government, and were described by R. W. Ells (1873 and 1876). The second hole reached pre-Carboniferous slates at a depth of 218 feet, without encountering a second coal seam. A third hole, "a little more than two miles south of No. 2", missed the coal seam, although it seems to have begun in the red beds overlying the coal.

Bailey's next report on the area (1880) contains little new information. In it the belief is expressed that the "great bulk of the sediments composing the central Carboniferous basin of the province are of Millstone Grit age"; on this basis the higher members of the Carboniferous system (in which the coal seams of Nova Scotia coalfields occur) would not be represented. In 1880, a geological map, by Bailey, Matthew, and Ells, was published on a scale of 1 inch to 4 miles. Stratigraphic subdivisions for the Minto-Chipman area comprised: Devonian (now Coal Creek formation); Lower Carboniferous (Newcastle Creek Formation, overlying volcanic flow, and the younger flow of the Cumberland Bay area); and Middle Carboniferous (Minto, Hurley Creek, and Sunbury Creek formations).

The reports of Bailey and Poole (1903) on the Carboniferous of the province, with special reference to workable coal, do not contain new data except for the logs of three bore-holes, drilled by the Provincial Government. One hole near Minto and one on Salmon River reached pre-Carboniferous rocks, but no second coal seam was found.

In 1922, the Minto coal area was mapped for the Geological Survey of Canada by W. S. Dyer (1926). The results are published in a memoir illustrated by two geological maps covering the same area as that of the present report.

Dyer introduced the names Coal Creek formation, Newcastle Creek formation, and Grand Lake formation, and the first two of these have also been used in the present report. Dyer's map shows the areas underlain by Coal Creek, Newcastle Creek, and Grand Lake formations and by a "basaltic extrusive", and drill-holes and coal outcrops in the area. He did not map the subdivisions of the Grand Lake formation, although he mentions them in his memoir. Thus the structural relations of the area remained somewhat uncertain. Dyer's memoir also includes a statement on the palæontology and correlation of the Minto flora by W. A. Bell of the Geological Survey, in which the Minto beds are correlated with the lower part of the coal measures at Sydney, Nova Scotia. The coal reserves of the Minto area were estimated by Dyer at 235,200,000 long tons.

In more recent years, the Provincial Geologist, Dr. W. J. Wright, has compiled a useful set of maps on a scale of 1 inch to 400 feet, covering mining blocks of 2 by 2½ miles. These blocks are the basis for the provincial leasing system of mining rights. The maps show all available information on mine workings, including positions of bore-holes, elevations and thicknesses of the coal seam, and structural contours on the seam. They were of great value to the writer in preparing the maps for the present report.

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CHAPTER II

GENERAL GEOLOGY

GENERAL STATEMENT

About one-third of the province of New Brunswick is underlain by flat-lying to gently undulating, continental sediments of late Carboniferous age. This Pennsylvanian basin has roughly the form of a triangle, with one side along the Gulf of St. Lawrence and Northumberland Strait, and with the opposite corner at Oromocto Lake in the southwest.

The Pennsylvanian beds blanket a folded complex of Mississippian and pre-Carboniferous rocks, but do not completely conceal their general structural trend. This trend is evident in a few ridges of older rocks, which outcrop in 'windows' through the Pennsylvanian blanket, and also in the structural relations of the Pennsylvanian formations themselves.

Ever since A. Gesner, the first Provincial Geologist, referred to this basin as "the great New Brunswick coal field" high hopes have at times been entertained as to its possibilities as a coal producer. However, although the sediments are correlative with part of the coal measures in Sydney, Nova Scotia, conditions of sedimentation were apparently unfavourable for the formation of workable coal seams. Outcrops of coal are known throughout the basin, but a thickness of more than 2 feet is seldom encountered.

As the Minto-Chipman area is the only coal mining district of importance in the basin, its geology has been more thoroughly studied than that of other parts, but is probably representative of the whole basin. In this area, the pre-Pennsylvanian Coal Creek formation reaches the surface in a northeast trending uplift, and is probably nowhere more than 500 feet below the surface. The Pennsylvanian succession has at its base a group of conglomerate and volcanic rocks, varying in thickness and character, and missing in many places. The overlying beds are mainly sandstones, shales, and conglomerates, and can be subdivided into fairly constant lithological units. One coal seam occurs in the upper part of the Minto formation, in the southern part of the Minto map-area, and the central part of the Chipman map-area. Another, higher seam occurs in the northwest corner of the Chipman map-area, but very little is known about it. A second volcanic flow with associated dykes occurs in the upper part of the Pennsylvanian series.

In recent geological maps of New Brunswick the flat-lying strata in the southern part of the Pennsylvanian basin are commonly referred to as Petitcodiac group, a name introduced by W. J. Wright in 1922. The basal part of this group as defined by Wright, in most places conspicuous by its heavy conglomerates and red colours, was included in the Hopewell group by G. W. H. Norman (1941). As there may be some doubt whether these basal beds have the same age throughout the Pennsylvanian basin, the names Pictou and pre-Pictou(?) are used here instead. The names Minto, Hurley Creek, and Sunbury Creek are introduced here for formational subdivisions of the Pictou group.

TABLE OF FORMATIONS

Period or epoch	Formation or group		Thickness Feet	Lithology
Recent?				Sand deposits along Salmon River
Pleistocene				Boulder till
Unconformity				
Pennsylvanian	Pictou group			Trachyte, quartz-porphyry
		Sunbury Creek formation	300	C. Light red, light green, and grey sandstone and conglomerate B. Grey sandstone, shale, coal A. Grey sandstone, quartz and shale-pebble conglomerate
		Hurley Creek formation	150	Red and green sandstone, conglomerate, and shale
		Minto formation (upper part)	50–150	Grey sandstone, shale, and conglomerate; coal
		Minto formation (lower part)	150	Grey sandstone, quartz-conglomerate
Transgressive overlap or disconformity				
Pennsylvanian or (?) earlier	Pre-Pictou (?)		0–80	Purple-grey basalt and andesite
		Newcastle Creek formation	0–50	Red conglomerate, tuff
Unconformity				
Ordovician?	Coal Creek formation			Green phyllites, foliated sandstone; some sandstone and shale

COAL CREEK FORMATION

The oldest rocks in the area are exposed along Coal Creek over a distance of about 3 miles in the Chipman map-area, and were named after this stream by Dyer (1926). They are mainly highly folded, light green to green-grey phyllites and foliated sandstone, but include some unmetamorphosed sandstones and shales. Beds stand nearly vertically in the almost continuous exposures on Coal Creek and its tributaries, and although lower dips may be observed locally, they are mostly due to slumping. The strike varies around north 60 degrees east, and Coal Creek follows this general direction.

Pyritic phyllites are the most common rock in the formation. They have a glossy green bedding surface, and contain many minute cubes of oxidized pyrite. The beds cleave readily into thin brittle plates along bedding planes; in some places it was observed that an incipient schistosity had formed at a sharp angle to the bedding planes. Under the microscope, sections normal to the bedding exhibit a fine aggregate of parallel muscovite flakes, and a fair abundance of quartz grains, the latter recrystallized and drawn out in streaks parallel with the bedding. This matrix of quartz and mica bends around the larger crystals of pyrite, which have been replaced by calcite and limonite and commonly carry rims of secondary quartz. Some of the pyrite cubes have been sheared into fragments. Thin sections cut parallel with the bedding show a multitude of small rutile needles in the quartz-mica matrix.

Metamorphism has been less effective in the sandy beds. Their surfaces have no glossy sheen, and fissility is much less pronounced. Pyrite crystals are larger, up to a few millimetres in size, and are unaltered. A thin section cut normal to the bedding shows predominant quartz, but little strained or recrystallized, together with many clots of calcite and only a little mica. The mica flakes are larger than in the phyllites, and form thin films between layers of quartz grains.

Numerous quartz veins occur in the Coal Creek formation, and most of them strike and dip with the enclosing strata. Their thicknesses vary from a few inches to about 1 foot. According to Dyer (1926), they contain considerable pyrite locally, and smaller amounts of chalcopyrite, galena, and biotite. Tales of the presence of gold on Coal Creek are still current among the local population. Dyer gives the following account of the matter:

"A few years ago it was rumoured that the quartz contained gold in quantity. A company was formed and stock was sold, but very little work was done and the proposition was soon forgotten. During the summer (1923) samples of a vein which had been worked at the time were sent to Ottawa for analysis. They were found to contain a trace of gold, and silver to the amount of 0·02 ounce to the ton."

Near the southwest end of the outcrop on Coal Creek, the formation is cut by a dyke of orthoclase porphyry. The contact of this intrusion is vertical, and trends about north 30 degrees west, normal to the strike of the phyllites. A soft, white gouge occurs at the contact and may be due to weathering or shearing. The dyke rock is purplish red, with small white crystals of feldspar. Under the microscope many decomposed crystals of orthoclase can be seen, occasionally with Carlsbad twins, about 0·5 to 1·0 mm. long, in a matrix of what appears to be devitrified glass. The aplitic marginal phase of the dyke is light grey, and is composed predominantly of quartz, in crystals up to 0·5 mm. in size, together with some orthoclase and plagioclase, and plentiful muscovite.

The outcrop of the Coal Creek beds is marked on Bailey's and Dyer's maps as a narrow strip along this stream. However, exposures of phyllites occur for considerable distances up some of the south tributaries of this stream, and thus the outcrop area is greater than was originally believed, and Coal Creek possibly follows its northwest boundary. It might be suggested that the course of the stream and the formation boundary are determined by a fault, but because of the lack of exposures directly northwest of the stream this could not be ascertained.

The Coal Creek 'ridge' of pre-Carboniferous strata, trending in the general direction of pre-Pennsylvanian folds and reaching the surface through the Pennsylvanian cover, is comparable to the ridge of Mississippian and older strata that separates the main Pennsylvanian basin from its outlier in the Moncton-Sussex area. It indicates that the pre-Pennsylvanian folded complex, exposed southeast of the basin, continues in the same fashion under the shallow cover of Pennsylvanian strata.

The age of the Coal Creek formation is uncertain. No fossils have been found in it and the writer can offer no satisfactory lithological correlation with pre-Carboniferous rocks in adjacent areas. Bailey (1873, p. 208) mentions their similarity to rocks near Hampstead and Enniskillen, to which he attributes a Devonian age. On his map of 1880, however, the Coal Creek rocks are shown as Devonian, but those of Hampstead as Cambro-Silurian (Ordovician)[1].

NEWCASTLE CREEK FORMATION

The oldest rocks of Carboniferous age in the area comprise a red, basal boulder-conglomerate, overlain by tuff, and a flow of lava. Dyer mapped the conglomerate and the lava separately, and named the former after the stream, Newcastle Creek, that affords best exposures of both. This practice has been followed by the present writer.

The outcrop area of the Newcastle Creek conglomerate is small, as the formation is exposed only at the bottom of stream channels in two small, structurally elevated areas. Besides its numerous good exposures on Newcastle and Hurley Creeks and their tributaries, the formation is only known from a few outcrops on the left bank of Salmon River, south of Chipman. Strata overlying the pre-Carboniferous rocks on Coal Creek, and assigned to this formation by Dyer, more probably represent the basal part of the Minto formation.

In the Newcastle Creek area the conglomerate as well as the overlying lava flow disappears towards the south. In a bore-hole, drilled in 1944 by the Provincial Government at North Minto, on the bank of Newcastle Creek and about 2 miles south of the nearest outcrop of conglomerate and lava, no trace of either rock was found. Their non-occurrence had also been noted in two bore-holes drilled at Newcastle Bridge in 1872 and 1873 (R. W. Ells, 1873 and 1876). The conglomerate seems thus to occur in the anticlinal area bounding the Minto coalfield to the north, but disappears on its south limb. Similarly, it may pinch out on the north limb of the 'Hardwood Ridge anticline', as suggested in Structure-section A-B of the Map 1003A.

The lowest outcropping beds of the formation consist of a brick-red conglomerate with many boulders and pebbles of vein-quartz, together with boulders of diverse metamorphic rocks. They are probably derived from the Coal Creek formation, which may underlie the Newcastle Creek at shallow depths. The general appearance of this conglomerate is very

[1] The Hampstead area was remapped for the Geological Survey of Canada in 1948 by Dr. G. S. MacKenzie of the University of New Brunswick. He informed the writer that a specimen of the Coal Creek phyllites submitted to him resembled certain rocks in the Hampstead map-area, namely those of the 'Pale Argillite division of the Charlotte group'. Dr. MacKenzie regards this non-fossiliferous division as probably Ordovician, as it is more severely deformed than fossiliferous rocks of Upper Silurian age occurring in the vicinity.

similar to that of the 'Demoiselle' (Hopewell) conglomerate in Albert county. Its exposures show in many places the undercutting that is so typical of the mushroom-like cliffs at "The Rocks".

Higher in the section, the conglomerate becomes finer, and about 200 feet upstream from the mouth of Hurley Creek, in a sharp bend of Newcastle Creek, it is overlain by a series of tuff beds, with an occasional bed of bentonite. The unweathered tuff is hard and greenish grey; its weathered surface is brick-red. The tuff contains fragments, up to about 1 inch, of older tuff, quartz, quartzite, and green phyllite, and under the microscope the brown to grey matrix contains globules of glassy material, altered to a crypto-crystalline substance with strong double refraction. One bed of soapy bentonite about 6 inches thick was found at this locality. A thin section from a hard layer of this bed showed mostly indeterminable small fragments, probably of volcanic glass, with some hornblende crystals and rock and quartz fragments.

The exposure of the Newcastle Creek formation on Salmon River, down the bank from the garages of the Provincial Highway Department, and about 1½ miles south of Chipman, is of different character. Here a 20-foot bank exposes very hard, angular quartz-conglomerate, with a purple to grey-green matrix, interbedded with some thin-bedded to massive, dark green sandstone. This is overlain by 5 feet of crumbly ironstone with quartz pebbles scattered in the basal part. These beds grade upward into about 4 feet of grey chert containing rusty veins and exhibiting an indefinite columnar jointing. In thin section all these rocks appear to contain a large amount of coarse to very fine angular fragments and shards of quartz. The chert on top, directly overlain by Minto sandstones, also consists mainly of fine quartz fragments. This rock seems to be similar to the 'ganister' of some British coalfields.

On Coal Creek the pre-Carboniferous phyllites of the Coal Creek formation are directly overlain, at the southwest end of their exposure, by a series of irregularly bedded, coarse, dark green sandstones, with dark brown specks, and thin-bedded, chocolate-brown to green siltstone and shale. At the base is 1½ feet of quartz-conglomerate, with pebbles up to 3 inches in diameter. These beds are overlain by the Minto formation and may grade into it. Lithologically they bear more resemblance to the Hurley Creek formation, but as they contain no beds of volcanic material they are considered to be the basal part of the Minto formation. However, it is not impossible that they are the equivalent of the Newcastle Creek formation, as was assumed by Dyer. According to him, the Newcastle Creek formation is missing at the other end of the series of Coal Creek outcrops, east of Chipman map-area, where the pre-Carboniferous beds again disappear beneath Pennsylvanian strata.

BASALTIC TO ANDESITIC LAVA

The extrusive rock that overlies the Newcastle Creek formation was termed a dolerite by Bailey and Matthew (1873) and basaltic extrusive by Dyer (1926). On Dyer's map it is shown as three separate patches, on Newcastle and Hurley Creeks, on the highway north of Hardwood Ridge, and on the upper end of Doherty Creek. Although few new outcrops have been found, they are interpreted by this writer as representing one single, larger area of extrusive rock, occupying the centre of a very shallow structural uplift, the 'Hardwood Ridge anticline'. Magnetic anomalies were observed in several runs with a vertical variometer across the area of this uplift.

The extrusive rock may not extend far laterally beyond its present outcrop area. To the south it disappears within 2 miles, as indicated by the previously mentioned bore-hole in North Minto. To the northwest, a fairly sharp flexure in the overlying beds, dipping about 30 degrees to the northwest, may indicate its northern limit (*See* Structure-section A-B, Map 1003A). Magnetic observations and loose blocks of lava indicate that the Hardwood Ridge flow extends for some distance into Chipman map-area. Blocks of lava also occur in large quantity at the point where the road east from Briggs Corner turns south. It is possible that these blocks were abandoned there by Pleistocene ice and that they were derived from exposures in the bottom of Salmon River, now covered by drift.

The apparently elongated, narrow shape of the area occupied by the lava flow might be explained by eruption from a northeast trending fissure, along which some faulting may have occurred. In pre-Minto time, the extrusive rock may have been a hard ridge, elevated above the general land surface. As such it would have protected the Newcastle Creek conglomerate against erosion while in adjacent areas erosion proceeded below the level of this formation. Minto beds might later have been deposited against the sides, and on top, of the ridge. Such a sequence of events could explain why the Newcastle Creek and extrusive rocks occur only in the core of the Hardwood Ridge anticline.

The extrusive rocks of Cumberland Bay, included by Bailey and Dyer with this same lava, appear to overlie the Sunbury Creek formation, and will be described later.

On Newcastle Creek, the conglomerate and tuff of the Newcastle Creek formation are overlain by a thick lava flow. In one place, a little less than a mile downstream from the mouth of Hurley Creek, about 2 feet of lava is exposed just above the stream bed, and is overlain by conglomerate. The main flow is not exposed there but occurs nearby, and apparently overlies the conglomerate. Bailey and Matthew (1873) mention a similar section in this vicinity, where a lower bed of "dolerite" 10 feet thick and a higher one about 50 feet thick (partly covered) are separated by 25 feet of soft gravelly shales. Farther north, on Hurley Creek, north of the railway trestle, a cliff of lava 80 feet high was measured by the writer.

The lava is commonly a dense, hard, purplish grey rock, exposed in steep cliffs on Newcastle and Hurley Creeks and tributary creeks. In many places it is layered, and may resemble a sedimentary rock. Under the microscope it reveals a mass of highly altered feldspathic material, occurring as indeterminable and mainly equidimensional grains. Small grains of olivine show chalcedony in their centres and growths of iddingsite in globular masses, with biotite-like cleavage and pleochroism. In addition, it contains fine magnetite, needles of apatite, and grains of epidote. Although this rock is too altered to be classified accurately, the presence of olivine suggests olivine basalt.

On Hurley Creek, near the Canadian National railway trestle, the upper part of the flows is porphyritic and amygdaloidal. It contains flesh-coloured phenocrysts of plagioclase and calcite amygdules in a dense, purplish grey matrix. In thin section, the feldspar shows alternating wide and very narrow lamellæ, twinned according to the albite and pericline laws. One individual, measured with the universal stage, appeared to be andesine, about An_{45}. The matrix consists of feldspar, magnetite, poikilitic diopside, and iddingsite. Another specimen from the same locality contains amygdules filled with calcite. The feldspar of this sample occurs in nearly quadratic or short rectangular shape, is highly altered, and may be partly potash feldspar. These rocks are tentatively classified as andesite, or possibly intermediate between andesite and trachyte.

A thin section of a specimen from the lava blocks at Briggs Corner shows a predominance of fresh plagioclase laths with smaller grains of magnetite and olivine, very small needles of diopside, and some glass and calcite.

Altogether, most of the specimens of this lava that were examined revealed too great alteration of the feldspars to permit their determination, and in fresher material the feldspar microlites proved difficult to identify. On the basis of the information available, however, it seems probable that the Hardwood Ridge lava flow is partly basalt and partly andesite, with gradations into trachyte.

AGE OF THE NEWCASTLE CREEK FORMATION AND OVERLYING LAVA

The age of the Newcastle Creek conglomerate and of the lava that overlies it has not been definitely established. It seems probable, however, that the extrusion of the lava followed with little delay the deposition of the conglomerate and associated tuffaceous beds, and that, consequently, the question of their age may be dealt with together.

On the one hand, it might be assumed that the conglomerate is equivalent in age to lithogically similar conglomerate of the Hopewell group of southeastern New Brunswick. If so, a considerable interval of erosion must intervene between the extrusion of the overlying lava and the deposition of the succeeding Minto formation, which is of Pictou age, an interval during which the Cumberland and at least most of the Riversdale groups of Pennsylvanian age were laid down in Nova Scotia and parts of New Brunswick (Bell, 1943). Indeed, there is apparently here good evidence for such an unconformity, as in places the basal Minto beds directly overlie the pre-Carboniferous Coal Creek formation. Further, it has already been shown how the Newcastle Creek conglomerate and lava of the Hardwood Ridge area may have formed a prominent ridge during this period of erosion, with Minto beds gradually overlapping it from areas of pre-Carboniferous phyllites.

On the other hand, it is now known that further volcanic activity occurred in the Cumberland Bay area in post-Minto, Pictou time. The extrusive rocks there are more acidic than those of Newcastle Creek and Hardwood Ridge, but seem to belong to the same volcanic sequence, and might justify the assumption that all these volcanic rocks are of Pictou age. On this basis, the apparent disconformity in places at the base of the Minto formation might be attributed to transgressive overlap of the Minto onto local, relatively thin deposits of conglomerate and lava rather than to any prolonged period of erosion in pre-Minto time. Such an explanation would not be inconsistent with the erratic distribution and varied local accumulation of such continental and volcanic deposits, nor with the fact that no recognizable lava fragments were observed in the basal Minto beds. It would, however, suggest that, in lieu of possible correlation with the Hopewell group, the Newcastle Creek conglomerate may be much younger, perhaps of early Pictou age or, alternatively, of pre-Pictou but post-Hopewell age, and as such correlative with some lower member of the Petitcodiac group of the Hillsborough and Maringouin areas of south-eastern New Brunswick.

MINTO FORMATION

The name Minto formation is introduced here for a series of strata, predominantly grey, and comprising sandstones, shales, siltstones, conglomerates, and a coal seam about 18 to 24 inches thick. These beds may be subdivided locally into a lower part of mainly conglomerate and coarse- to medium-grained sandstone, and an upper part of mainly fine sandstone, shale, and coal.

The formation seems to correspond with the "Middle Carboniferous" of Bailey and Matthew (1873), who made a similar subdivision into "Barren grey beds" for the lower part and "Productive measures" for the upper part. In the terminology of Dyer (1926), the entire Minto formation would constitute only a part of the Grand Lake formation, which Dyer subdivides into Lower, Middle, and Upper members. The Lower member is equivalent to the lower part of the Minto formation as here defined; the Middle member includes the upper part of the Minto and the Hurley Creek formation of this report; and the Upper member is the present Sunbury Creek formation.

LOWER PART OF MINTO FORMATION

The lower part of the Minto formation occupies the axial part of the Hardwood Ridge anticline, and occurs also in the Salmon River and Coal Creek uplift areas. Its thickness, as determined from the 1944 bore-hole in North Minto, is about 180 feet and seems to be about the same in older borings.

The basal layers of the formation are exposed on Newcastle Creek, Coal Creek, and Salmon River. On Newcastle Creek they overlie the lava flow. Locally, the beds at the contact are hard, grey-green rocks, with a crystalline lustre due to impregnation with carbonates. In the outcrop, they have a weathered selvage about half an inch thick, within which the carbonates have been dissolved and a dark brown, ferruginous substance is left as a matrix of the sandstone. In other exposures, along the stream, poorly sorted conglomerate, with a crumbly, dark brown matrix of similar ferruginous material, overlies the lava.

In the Coal Creek area the lower part of the Minto formation rests directly on the Coal Creek phyllites. There the following section was measured:

	Thickness Feet
Sandstone, coarse, dark green with dark brown specks, in thick, irregular beds..............................	10
Siltstone, chocolate-brown to green, thin-bedded, alternating with fine, hard, dark green sandstone, in 2-inch beds...	10
Sandstone, coarse, green, massive........................	5
Sandstone, coarse, green-grey, and conglomerate, with angular quartz-pebbles up to 3 inches in diameter.....	1·5
Underlying beds: phyllites, red-grey weathered, striking north 58 degrees east and dipping vertically.	

Dyer believed that the conglomerate at the base was part of the Newcastle Creek formation, but in the present report it is regarded as part of the Minto formation. Though some difference exists between the basal beds of the Minto formation on Newcastle Creek and those on Coal Creek, this is to be expected, as the underlying formations are in the one creek a lava flow, and in the other, pre-Carboniferous phyllites. Apparently considerable detritus from the phyllites and their enclosed quartz veins has entered into the composition of the basal Minto beds on Coal Creek. This may explain why these sediments are so similar to those of the Hurley Creek formation, as the latter also contain abundant schist fragments.

The basal Minto beds are overlain by an irregular succession of coarse sandstones and interbedded conglomerates. These are well exposed near Camp Wegesegum on the east bank of Salmon River and were encountered between depths of 238 and 274 feet in the North Minto bore-hole. Pebbles such as those of the conglomerates are also scattered in some abundance through the enclosing, coarse to gritty, grey sandstone. They are well rounded, vary to about 1 inch in size, and consist mainly of quartz and quartzite, with minor amounts of schist pebbles. The log of the North Minto drill-hole also indicates beds and lenses of dark carbonaceous shale in this section.

These beds grade upward into a more regular succession of predominantly sandstones, well exposed on the banks of Little River, Newcastle Creek, Salmon River, and a few smaller streams. Outcrops occur generally in small and larger bluffs on the tops of the banks; the lower parts of the slopes are commonly covered with a talus of sandstone slabs, and outcrops at stream level are less common. It is significant that all larger streams have incised meanders, with amplitudes up to about half a mile where they pass over these strata. Similar meanders are also found on a grey sandstone member of the Sunbury Creek formation, but do not occur on other formations. The writer believes that these meanders are diagnostic for the Minto sandstone or similar sandstone members in younger Pennsylvanian formations. They may prove to be useful for future regional mapping of the Pennsylvanian basin.

The sandstones are grey, medium- to coarse-grained, commonly crossbedded rocks. They fall apart easily into slabs, 1 inch to 3 inches thick, and break readily along the edges of grains and pebbles.

UPPER PART OF MINTO FORMATION

The upper part of the Minto formation contains the Minto coal seam, and is, consequently, represented in all mining areas at the surface, or under a cover of Hurley Creek beds. It occurs on the limbs of the Hardwood Ridge and Salmon River uplifts, in the centre of the Coal Creek uplift, and covers a large irregular area around Minto. In the North Minto bore-hole the thickness of these strata beneath the coal seam is 66 feet, if their base is placed at a depth of 99 feet. An additional 20 to 40 feet are estimated to lie between the coal seam and the base of the overlying Hurley Creek formation, so that the total thickness of this part of the Minto formation is about 100 feet.

There is no sharp boundary between lower and upper parts of the Minto formation, and in the area north of the Hardwood Ridge anticline it is questionable whether mapping of these two separate units is possible or the attempt to do so justifiable. There the two seem to merge, and their aggregate thickness probably decreases. However, in the mining areas, where subdivision is possible on slight lithological differences, the separate mapping of these two units is useful in defining as accurately as possible both the areas underlain by the seam and the line of outcrops of the seam.

The basal strata of the upper part of the Minto formation are well exposed on the Grand Lake shore between Newcastle Creek and Flowers Cove. They are buff to grey-green, crossbedded sandstones, with scattered pebbles and with many plant stems, commonly *Calamites*, lying on the bedding planes. This fossil driftwood may be several feet long, and is replaced by coaly material and iron sulphides. Pyrite and marcasite also occur in small, elongated concretions, but in the outcrop these are oxidized, leaving rusty coloured cavities on the bedding plane.

The basal beds are overlain by grey, fine-grained, thin-bedded to massive sandstone, shale, and siltstone, which enclose the coal seam. Thus, on Newcastle Creek, downstream from the highway bridge, pebbly sandstone with sulphides is overlain by grey siltstone and shale, and coal is exposed on the top of the bank. In many places the bedding surfaces of the upper Minto beds are stained black, or are covered with finely powdered carbonaceous material. The coal seam is commonly underlain by about a foot of soft, sticky, blue-grey fire-clay. In the areas south of Minto, along the Grand Lake shore, the coal seam is overlain by soft, fissile shales, as can be seen in several old strip-mines. The shales directly above the seam contain abundant, well-preserved fossil plants. They can be collected easily on the waste dumps of strip- and shaft-mines, but only freshly dug material will yield good specimen material. The shale disintegrates into small pieces and becomes a light grey clay after short exposure to the atmosphere. As the shales are soft and weather easily it is obvious that the upper part of the Minto formation is poorly exposed except in strip-mines and on a few cut-banks. In the New Zion area, hard, fine, massive sandstone beds overlie the coal seam, and render stripping operations more expensive, as the sandstone has to be blasted before it can be removed. Coarse sandstone overlies the coal seam in the Chipman area, and may be an important reason for the lesser development there. A greenish grey sandstone, with brown specks giving it a 'salt and pepper' appearance, is also characteristic of certain beds in this part of the formation. Under the microscope this rock appears to consist of about equal amounts of quartz, quartzite, and small fragments of schist and tuff. The brown specks seem to be fragments of tuff, similar to rocks of the Newcastle Creek formation and possibly derived from it.

The Minto formation occupies a narrow belt north of the Hardwood Ridge anticline; its narrowness is partly due to relatively steep dips of the strata, up to 35 degrees, and partly to a probable decrease in thickness. In the few places where the coal seam could be found, it was generally about 2 inches thick. In the north part of the area the formation is well exposed on the two branches of Salmon Creek and on Dorsey Brook. The following incomplete section was measured on the North Branch of Salmon Creek, directly under the power-line crossing:

	Thickness Feet
Sandstone, medium-grained, grey-green, irregularly bedded	5
Sandstone, fine-grained, grey-green, in flat-surfaced flags 1 inch or less thick	10
Sandstone, coarse-grained, green-grey, massive to poorly bedded, with pebbly layers; pebbles are mainly quartz and shale	15
Covered interval	9
Shale, purple, locally light green, soft and chunky	11
Shale and silty shale, olive-green to grey, thin-bedded to chunky, as 'coal rock'	12
Siltstone, olive-green to blue-grey, rusty weathering, micaceous, poorly bedded and brittle, with iron sulphide concretions	1·5

The horizon where the coal seam should occur may be near the bottom of this section, or may overlie it; most probably the Minto seam is missing in this area.

PALÆONTOLOGY AND CORRELATION

The age of the Minto coal seam and, therefore, of the Minto formation, was established by W. A. Bell in 1926, through the determination of plants collected by W. S. Dyer (1926). This determination was confirmed by Dr. Bell in an examination of a collection made by the writer. The flora indicates correlation with part of the coal measures in Sydney, Nova Scotia, which belong to the Pictou group.

The following plants were determined from Dyer's collection (1926, p. 18):

Alethopteris serli (Brongniart)
Annularia radiata (Brongniart)
Annularia sphenophylloides (Zenker)
Asolanus camptotaenia Wood
Asterophyllites longifolia (Sternberg)
Asterotheca miltoni (Artis)
Calamites carinatus Sternberg
Calamites suckowi Brongniart
Cordaites principalis (Germar)
Cordaianthus rhabdocarpi (Dawson)
Corynepteris sternbergi (Ettingshausen)
Diplothmema furcatum (Brongniart)
Lepidodendron cf. *alternans* Sauveur
Lepidodendron cf. *binerve* Lindley and Hutton
Lepidodendron plicatum Dawson
Lepidostrobus squamosus Dawson
Mariopteris latifolia (Brongniart)
Mariopteris muricata (Schlotheim)
Neuropteris gigantea var. nov. (= *N. aculeata* Bell)
Neuropteris loshii Brongniart (non Lesquereux) aff. *N. flexuosa*
Neuropteris scheuchzeri Hoffman
Neuropteris tenuifolia (Schlotheim)
Oligocarpia brongniarti Stur
Pecopteris oreopteridia (Schlotheim)
Polypterospermum ornatum Kidston
Samaropsis bisectum (Dawson)
Sigillaria tessellata Brongniart
Sigillaria tessellata var. *eminens* Dawson
Sphenophyllum cuneifolium (Sternberg)
Sphenophyllum cuneifolium forma *saxifragaefolium* (Sternberg)
Sphenophyllum emarginatum Brongniart
Sphenophyllum myriophyllum Crépin
Sphenopteris bella (Stur)
Sphenopteris gracilis Brongniart
Sphenopteris laurenti Andrae
Sphenopteris obtusiloba Brongniart

From these fossils the conclusion was reached that the Minto coal seam represented a zone at about the top of the Middle Coal Measures of Britain, or the top of Zone B^3 of Zeiller in the French Valenciennes basin. Although correlation with the United States is more difficult, the flora indicates probably topmost Pottsville or basal Alleghany, more probably the latter. Compared with the Sydney coalfield, the coal seam is probably not far removed from the horizon of the Tracy seam. In his report of 1938 on the Sydney coalfield, Bell states that this seam falls in the lower part of the *Linopteris* zone, the second subdivision of the Pictou group.

The following species were determined by Dr. Bell from a collection made by the writer:

Alethopteris serli (Brongniart)
Annularia stellata (Schlotheim)
Asolanus camptotaenia Wood
Cordaites principalis (Germar)
Lepidodendron dawsoni Bell
Mariopteris latifolia (Brongniart)
Mariopteris nervosa (Brongniart)
Myriotheca desaillyi Zeiller
Neuropteris aff. *flexuosa* Sternberg
Neuropteris rarinervis Bunbury

Neuropteris scheuchzeri Hoffman forma *angustifolia* D. White
Oligocarpia gutbieri Goeppert
Pecopteris (Asterotheca) miltoni (Artis)
Pecopteris (Senftenbergia) plumosa forma *dentata* (Brongniart)
Samaropsis cornuta (Dawson)
Sphenopteris sp. cf. *nummularia* Gutbier
Sphenophyllum cuneifolium (Sternberg)
Telangium? potieri (Zeiller) Kidston

Dr. Bell offers the following remarks on the age of this flora:

"The above flora is considered to indicate a Westphalian C age. The containing beds are thus equivalent to a part of the *Linopteris obliqua* zone of the Sydney coalfield. The few species, for example *Asolanus camptotaenia* and *Myriotheca desaillyi*, which have been collected only from higher horizons at Sydney, occur elsewhere in beds of Westphalian C age and do not invalidate the above conclusion."

According to its fossil flora, the Minto, together with younger formations of the area, has, therefore, been included in the Pictou group. This is in contrast with the mapping in nearby areas, where, for lack of diagnostic fossils, the flat-lying Pennsylvanian strata have been included in the longer ranging Petitcodiac group, though they are probably mainly, if not entirely, of Pictou age.

HURLEY CREEK FORMATION

The name Hurley Creek formation is introduced here for a succession of predominantly red shales and sandstones, and pinkish conglomerates with a more varied pebble content than those of the Minto formation. The name derives from a branch of Newcastle Creek, where the formation outcrops. Better exposures occur in other streams, but their names have been pre-empted for formations elsewhere.

The Hurley Creek is roughly equivalent to the 'Upper Carboniferous' map-unit of Bailey and Matthew (1873), which may, however, include some beds assigned in this report to the Sunbury Creek formation. In Dyer's memoir (1926), the beds of this formation form the upper part of his "Middle member" of the grand Lake formation.

Hurley Creek beds occur in synclinal areas between the Hardwood Ridge, Salmon River, and Coal Creek anticlinal areas. On the northwest limb of the Hardwood Ridge anticline they occur in a narrow zone, but in the southern part of the areas mapped the formation is much more extensive, and may be considerably thicker. Exact figures of the thickness cannot be obtained from borings or natural sections, but the total thickness is estimated at 150 to 200 feet.

Outcrops of this formation generally form low banks bordering the streams, or the stream beds may be bare rock. Due to the alternation of soft sandstone and shale these outcrops are commonly slumped and partly covered by red mud and debris. Unlike the Minto sandstones the Hurley Creek beds are nowhere exposed away from the stream at the upper edge of the valleys.

The base of the Hurley Creek and its contact with the Minto formation are exposed in only a few places. In a strip-mine of the Avon Coal Company near Grand Lake (*See* Structure-section A-B, Map 1003A) grey Minto shales grade into red shales at about 20 feet above the Minto coal seam. These red shales may represent the base of the Hurley Creek formation.

About 20 feet of purple-red to chocolate-brown, poorly bedded to massive, chunky shale, siltstone, and fine sandstone are exposed in a large shale pit between Chipman and Redbank. The shales are used by a brick manufacturing plant in Chipman. These beds are probably close to the contact with green-grey Minto sandstone, exposed a short distance west of the pit in the road ditch. In the upper part of the pit, crumbly beds of coarse sandstone and conglomerate overlie the shale and sandstone. Similar shale and sandstone, with overlying conglomerate, are also exposed on Hurley Creek, on the North Branch of Salmon Creek, on Little River, and on the east shore of Salmon River, south of the power-line crossing. The whole section of the Hurley Creek formation consists of such red shales, sandstones, and pink-grey conglomerates, and the beds seem to become generally coarser in the higher parts of the formation. The contact between conglomerates and underlying shale beds is commonly marked by good springs. In some places the shales and sandstones contain poorly preserved plant fossils. The characteristic red colour may change locally to green, or the rock may be mottled red-green, as is common with sedimentary rocks coloured by iron oxide. In places the red shale and sandstone contain concretions of iron oxide, ranging from well-rounded oolites or pisolites to irregular lumps, up to about half an inch in diameter. In the upper part of Redbank Creek, a thin layer of limonitic pisolites was observed embedded in red shale and sandstone. An assemblage of oolites and larger concretions was seen on the shore of Grand Lake, near Wiggins, where they had been washed out and concentrated by wave action on the beach.

Macroscopic and microscopic examination of both sandstones and conglomerates reveal an abundant detritus of quartzites, schists, and volcanic rocks, including green pebbles of schists and basic extrusive rocks, and pink pebbles from acidic extrusions. The latter are responsible for the general pink colour of the conglomerates. In many red sandstones, fragments of green schist are most abundant, and in thin section many grains of epidote were observed with the quartz and schist grains.

SUNBURY CREEK FORMATION

Although future work in adjacent areas may prove the existence of several Pennsylvanian formations overlying the Hurley Creek formation, all post-Hurley Creek beds are here included in one unit, the Sunbury Creek formation. The name is derived from Sunbury Creek, a tributary to Newcastle Creek, which rises near Sunbury, a station on the Canadian National railway in the northwest corner of Minto map-area. The stream affords good exposures of the various members of the formation.

The Sunbury Creek strata may be equivalent to higher parts of Bailey and Matthew's (1873) "Upper Carboniferous formation", and is Dyer's (1926) Upper member of the Grand Lake formation.

Large tracts in the northwest part of Minto map-area, and in the southeast corner of the Chipman area, are underlain by the Sunbury Creek formation. The maximum thickness of 250 to 300 feet indicated on the structure-sections on the accompanying maps is a mere estimate, and depends on the slope of the pre-Carboniferous surface towards the northwest. On Cumberland Hill, where the formation is overlain by remnants of a flow of trachyte, its thickness seems to be little more than 200 feet.

The Sunbury Creek beds are not as well exposed as the older Pennsylvanian strata, and are similar lithologically to those of the Minto and Hurley Creek formations. Information on them is, therefore, incomplete and the following account may require revision later. Tentatively, the formation has been divided into Members A, B, and C, in ascending order.

The rocks of Member A are almost an exact replica of those of the lower part of the Minto formation. They are well exposed on the upper parts of Newcastle and Hurley Creeks, and a pronounced ridge of hard, grey beds marks their contact with softer Hurley Creek strata. In Chipman map-area, Chase Brook has formed falls over this ridge, a rare topographic feature in the area. The contact is also marked by several springs.

The beds of Member A consist of quartz-pebble conglomerate as well as grey, medium- to coarse-grained, crossbedded sandstone. The general evidence for their stratigraphic position overlying the Hurley Creek formation is the only means of distinguishing them from the Minto formation. The writer has considered the possibility of a fault along the above-mentioned ridge, bringing Minto above Hurley Creek beds. However, this is improbable, as on Newcastle Creek, in a direction at right angles to the ridge and the contact, Hurley Creek beds are exposed for a considerable distance in the stream, and grey sandstones occur on top of the banks.

Grey sandstones exposed in Cumberland Creek, in the south part of Chipman map-area, are assigned to this member. They appear to overlie red shales and variegated conglomerates of the Hurley Creek formation. No contact between the two was observed, but both are exposed alternately in the creek, which, apparently, follows the formation boundary. A grey shale-pebble conglomerate exposed in this creek may be the base of the formation.

In northwest Minto and southeast Chipman map-areas the beds of Member A grade into those of Member B, which are well-bedded, smooth-surfaced, medium-grained sandstones in about 2-inch slabs. Where broken they show a characteristic, sharply delimited, brown weathered selvage about $\frac{1}{4}$ to $\frac{1}{2}$ inch wide, beneath which the fresh rock is grey. This brown selvage is probably due to oxidation of finely disseminated iron sulphide. Concretions of pyrite or marcasite may also occur, and bedding planes may be covered with fine carbonaceous material. Grey, thin-bedded to massive shale and siltstone were also found, probably overlying the sandstone; on Mowatt Brook they contain a coal seam. The coal seam, which has been prospected in two places about $1\frac{1}{2}$ miles apart, is probably exposed on the two limbs of a very gentle fold. There are no signs of coal in the Sunbury Creek formation in the Cumberland Bay area, but flaggy, brown weathered sandstones, as described above, occur on Wasson Brook, just downstream from the railway bridge, and in several other places. On the north branch of Cumberland Creek, at 1 mile and 2 miles from the forks, grey shales similar to the 'coalrock' of the Minto or Sunbury Creek formations were observed; it is uncertain to which of the two formations they belong.

The third division, Member C of the Sunbury Creek formation, consists of green-grey, coarse- to medium-grained sandstones and conglomerates, with shale pebbles. The sandstones and conglomerates bear some resemblance to Hurley Creek beds, as they contain conspicuous pink grains, probably of acidic extrusive rocks. In the Cumberland Bay area, thin-bedded and chunky, purple-red shales occur on Wasson Brook a short distance upstream from the highway bridge. Red-brown, fine-grained sandstone occurs on a little brook about half a mile up from where it crosses the highway and railway at Granville. At both localities, these red beds may form part of Member C. The red shales of Wasson Brook apparently overlie the grey sandstones of Member B, as indicated by the northerly dip of the latter in the part of the stream beyond the map-area.

It may be pointed out that the sequence of the Sunbury Creek formation is similar to that of the underlying Pennsylvanian beds, Member A corresponding to the Lower Part of the Minto formation, Member B to the Upper Part, and Member C to the Hurley Creek formation. Although in this repetition of a similar sequence of strata only continental beds are involved, it is reminiscent of the cyclical repetitions in the coal measures in Illinois, where nearly identical sequences of partly marine and partly continental sediments are associated with each consecutive coal seam.

TRACHYTE AND QUARTZ PORPHYRY

On the tops of the hills in the Cumberland area are exposed remnants of a lava flow overlying the Sunbury Creek beds. Good outcrops occur only at a few places, and the best are those on the hill between the Dominion Telegraph road and the Canadian Pacific railway. There, a conspicuous little butte, visible from many places across Grand Lake, affords some relief to the generally flat-looking country.

The butte exposes a bluff, about 30 feet high, of purple, hard, dense, non-porphyritic lava, with distinct flow layers. Under the microscope, the rock appears to comprise about 80 to 90 per cent sanidine, in laths about 0·2 mm. long. Some of the laths show Carlsbad twinning, and all exhibit cryptoperthitic intergrowth with plagioclase. Interstices between the feldspar laths are mainly filled by a green to light brown, pleochroic mineral, probably aegirite. The slide shows a little iron ore, mostly hematite. The rock is classified as aegirite trachyte.

An exposure on the east side of Cumberland Hill shows a trachyte with pink sanidine phenocrysts of several millimetres diameter in a purple-grey matrix. The rock disintegrates into sharp, flat fragments, which form a talus below the outcrop. Microscopically this rock shows well-developed microperthitic sanidine in a groundmass of mainly sanidine with some quartz. The dark mineral, possibly aegirite, is nearly totally resorbed, leaving clusters of minute, partly green-yellow, pleochroic fragments.

In Cumberland Bay village, on the highway near the bridge, there is an outcrop of purple, slightly fractured, trachytic rock that may be a dyke. It can be traced for some distance westward, and the linear character of the outcrop, as well as the almost vertical attitude of the layers composing it, suggest a dyke rather than a flow. In thin section this rock shows irregular clusters of opaque material in a matrix of much altered feldspar, probably all a potash-bearing variety, and some interstitial quartz.

Another such 'dyke' occurs south of Cumberland Hill, along a poorly marked bush road (not shown on map). It is the most easterly patch of trachyte and quartz porphyry on the Chipman map. There a little ridge of orthoclase porphyry trends southwest for about 600 feet. The rock is dense, fractures conchoidally, and is green-grey on the fresh surface. It contains many pink phenocrysts of soda feldspar, about 2 mm. in diameter. A thin section shows phenocrysts of partly altered, microperthitic orthoclase or sanidine in a matrix containing irregular patches of quartz, laths of sanidine, and a fair amount of a green, indeterminate substance.

STRUCTURE

It has been mentioned that the Pennsylvanian strata in the area mapped are essentially flat-lying, with minor undulations bringing different parts of the thin, blanket-like formations to the surface. These structures show a very definite northeast alinement, in accord with the general trend of the Mississippian and pre-Carboniferous strata in adjacent areas. It is debatable whether this trend is due to deposition on an uneven surface, reflecting the pre-Pennsylvanian folds, or to later, post-Pennsylvanian folding.

The most conspicuous structure in the area is the Hardwood Ridge anticline. The flow of basaltic to andesitic lava outcrops in its core, and in the channels of Newcastle and Hurley Creeks the underlying Newcastle Creek formation reaches the surface. Farther southwest, the lower part of the Minto formation occupies the central part, and the Minto, Hurley Creek, and Sunbury Creek formations are exposed on its flanks. The northwest limb is comparatively steep, with northwest dips of about 30 degrees in places on Newcastle Creek; the southeast limb exposes irregular areas of the upper part of the Minto and Hurley Creek formations.

The lava flow does not reach far to the south beyond its present area of exposure, and the same may be true to the north. It may be that it is a narrow sheet elongated in northeast direction along a feeding fissure. Such a flow might, indeed, have formed a fairly prominent topographic ridge, against and over which continental Minto beds might have been deposited with an original depositional dip, and this dip might have been increased by differential compaction. Accordingly, the moderately steep dips on Hurley and Newcastle Creeks are not necessarily evidence of a fault, such as postulated by Dyer.

Another important anticlinal area is that of Coal Creek. Here the Coal Creek formation occupies the core of the structure, and farther southwest the lower and upper parts of the Minto formation appear in the central part. This anticline, too, has a definite northeast alinement, and here, too, a fault may bound the Coal Creek formation on the northwest, although actual evidence for this is lacking.

Between the Hardwood Ridge and Coal anticlines, is a smaller, Salmon River uplift, of irregular shape. Here, the Newcastle Creek formation is exposed in a small area on Salmon River, surrounded by the Minto formation.

The Sunbury Creek formation occupies a shallow syncline, the south limb of which extends beyond Chipman map-area. North-dipping strata may be seen on Cumberland Point and on parts of Wasson Brook. In the northwest part of Chipman map-area, the formation seems to be folded into a shallow syncline with adjoining anticlines (*See* Structure-section A-B), as indicated by the strata on Mowatt Brook. The structure elsewhere in the large area underlain by this formation is unknown. A gentle northwest dip of the pre-Pennsylvanian surface and consequent thickening of the Pennsylvanian cover has been assumed in Structure-section A-B of Map 1003A.

A southwest dipping flexure, trending about north 25 degrees west, is shown by the contours of the coal seam in Mining Block 28 (*See* Map 1005A). It is the only structural feature with a trend normal to the general regional trend that is known in either map-area, and may be the result of later movement along a transverse fault in the subsurface formations.

BORE-HOLES

Several holes have been drilled in the area to ascertain whether there might be another coal seam below the one exposed at the surface. Of these holes, the first of which was begun as early as 1837, many penetrated rocks underlying the Pennsylvanian sediments, but none gave any reliable indication of a second coal seam. Their logs were published by Dyer (1926, pp. 12-16), except that of the most recent one (No. 10), but are reprinted or noted here in so far as they give useful information. The numbers, except 1a, 1b, and 10, are those used by Dyer.

No. 1. East bank of Salmon River, north of Long Creek. Drilled in 1837-1839. Total depth, 403 feet. Ref.: Gesner, 1841; Bailey and Matthew, 1873, pp. 225, 230; Dyer, 1926. Contrary to Dyer, the writer believes that the hole penetrated pre-Carboniferous formations, probably at a depth of 162 feet. If this be so, the 8 feet of shale and coal at 262 feet should not be considered as a possible coal seam of the Minto formation. As the interpretation is uncertain, and the hole is close to No. 5, the log is not reproduced.

No. 1a. On Coal Creek, location on map of Bailey *et al.*, 1880. Drilled in 1866. Total depth, 96 feet. No log available. Ref.: Bailey and Matthew, 1873, p. 226; Bailey, Matthew, and Ells (map), 1880.

No. 1b. East bank of Salmon River, about 1 mile to the north of No. 1. Drilled in 1870-1871. Total depth, 217 feet. No log available. Ref.: as for No. 1a.

No. 2. On the slope of the hill rising southward from Newcastle Creek, and about 240 yards from the stream. Drilled by Provincial Government in 1872-1873. Total depth, 170 feet. Ref.: Ells, 1873; Bailey, 1902; Dyer, 1926.

Depth Ft.	In.	Minto Formation	Thickness Ft.	In.
4	0	Sandstone, fine-grained, shaly	4	0
16	5	Shale ('coal rock'), with thin bands of coal and pyrite	12	5
18	3	*Coal*, main seam	1	10
19	1	Shale and impure coal	0	10
23	7	Clay, fine	4	6
28	4	Sandstone, fine and shaly	4	9
31	4	Shale, fine ('coal rock')	3	0
34	1	Shale and fine clay, with pyrite	2	9
43	1	Sandstone, fine-grained, greenish and dark brown, with greenish and grey shale	9	0
108	6	Sandstone, fine-grained, grey and olive-green, micaceous	65	5
113	2	No core	4	8
141	5	Sandstone, grey and greenish grey, with grit bands and some pyrite	28	3
145	1	Shale, hard, dark grey, oily, with streaks of coal	3	8
150	5	Shale, grey	5	4
155	10	Sandstone, fine-grained, grey, micaceous	5	5
163	7	No core	7	9
171	7	Sandstone, fine-grained, grey	8	0

No. 3. On the north bank of Newcastle Creek, near highway. Drilled by Provincial Government, 1873. Total depth, 366 feet. Ref.: Ells, 1873 and 1876; Bailey, 1902; Dyer, 1926.

Depth Ft.	In.	Minto Formation	Thickness Ft.	In.
4	0	Sandstone, grey, flaggy	4	0
7	3	Fire-clay, grey shale, and sandstone	3	3
13	8	Sandstone, yellowish grey, micaceous, and fine grit	6	5
24	4	Sandstone, yellowish grey, and fire-clay	10	8
25	7	Conglomerate, grey	1	3
28	10	Sandstone, yellowish to dark grey, micaceous	3	3
30	0	Conglomerate, grey	1	2
31	0	Sandstone, grey	1	0
32	0	Conglomerate, grey	1	0
37	5	Sandstone, fine, grey	5	5
57	11	Sandstone, coarse, grey	20	6
76	8	Sandstone, fine, grey, the last 2 feet containing fossils and pyrite	18	9
83	0	Shale, grey	6	4
84	3	Sandstone, grey, micaceous	1	3
87	8	Shale, grey, micaceous	3	5
89	11	Sandstone, grey, and conglomerate	2	3
108	8	Sandstone, fine, grey	18	9
111	1	Quartz grit, coarse	2	5
113	1	Shale, grey	2	0
116	7	Sandstone, grey	3	6
120	7	Shale, dark grey	4	0
128	7	Sandstone, fine-grained, grey, shaly	8	0
136	2	Shale, fine	7	7
141	6	Sandstone, fine-grained, grey, micaceous and pyritic, with bands of fire-clay	5	4
150	9	Sandstone, fine, grey	9	3

Depth Ft.	In.	*Minto Formation*—Concluded	Thickness Ft.	In.
155	4	Sandstone, fine, grey, with plant remains and pyrite	4	7
160	4	Sandstone, coarse, grey, with plant remains, pyrite, and a band of conglomerate	5	0
178	2	Sandstone, very fine, greenish grey	17	10
188	7	Grit, coarse, grey	10	5
193	10	Sandstone, fine, dark grey	5	3
194	10	Conglomerate, grey	1	0
199	3	Shale, grey	4	5
217	5	Grit, coarse, grey, and conglomerate	18	2
		Coal Creek Formation		
249	9	Slates, grey, micaceous, with quartz veins and pyrite	32	4
257	11	Slates, dark reddish	8	2
263	5	Sandstone, grey, shaly	5	6
299	5	Slate, grey, with quartz veins	36	0
308	5	Slates, olive-green	9	0
333	9	Slates, grey, micaceous, with quartz and calcite	25	4
366	9	Slates, grey and bluish, with some pyrite	33	0

No. 4. On lakeshore road, 3 miles southeast of Minto. Drilled by Provincial Government, 1873. Total depth, 399 feet. Ref.: Ells, 1873; Bailey, 1902; Dyer, 1926.

Depth Ft.	In.	*Minto Formation*	Thickness Ft.	In.
2	0	Soil	2	0
47	0	Sandstone, grey, micaceous	45	0
55	6	Shale, grey ('coal rock'), and fire-clay	8	6
81	3	Shale, brown and red	25	9
82	6	Sandstone, grey	1	3
84	7	Clay, red, and shale	2	1
92	8	Shale, grey	8	1
101	5	Sandstone, grey	8	9
105	10	Shale, black and grey	4	5
112	4	Sandstone, grey	6	6
180	10	Shale, brown, red, and grey	68	6
217	5	Sandstone, grey, micaceous	36	7
260	8	Sandstone, purplish grey	43	3
		Coal Creek Formation		
263	3	Slate, hard, grey, sandy	2	7
399	3	Slate, blue, with quartz and calcite	136	0

No. 5. On east side of road leading north on point of land between Salmon River and Long Creek, about 500 feet from west end of bridge over Long Creek. The location was given to the Provincial Geologist, Dr. W. J. Wright, by Mr. Arthur Brown of Chipman. Mr. Brown remembered seeing the pieces of core lying about the site. Dyer located this hole erroneously at the site of drill-hole No. 1b. Drilled by Provincial Government, 1903. Total depth, 362 feet. Ref.: Dyer, 1926; files Provincial Geologist.

Depth Ft.	Depth In.	*Minto Formation*	Thickness Ft.	Thickness In.
8	0	Clay, red	8	0
12	0	Shale, blue	4	0
13	5	*Coal*	1	5
14	0	Fire-clay	0	7
18	0	Shale, blue	4	0
22	0	Sandstone, fine	4	0
77	0	Sandstone, dark-coloured	55	0
79	0	Shale, blue	2	0
85	0	Sandstone	6	0
95	0	Conglomerate	10	0
120	0	Shale, red and blue	25	0
152	0	Sandstone, light-coloured	32	0
156	0	Shale, red	4	0
201	0	Sandstone, bluish, fine-grained	45	0
202	0	Shale, red	1	0
213	0	Sandstone, light-coloured	11	0
217	0	Conglomerate	4	0
		Coal Creek Formation		
236	0	Shale and quartz	19	0
362	0	Hard blue rock and quartz	126	0

No. 6. On railway, 1½ miles west of Minto station. Drilled by Provincial Government, 1903. Total depth, 405 feet. Ref.: Dyer, 1926; files Provincial Geologist.

Depth Ft.	Depth In.	*Minto Formation*	Thickness Ft.	Thickness In.
30	0	Clay, red, and gravel	30	0
64	0	Sandstone, light-coloured	34	0
65	0	Shale, blue	1	0
70	0	Conglomerate	5	0
109	0	Sandstone, coarse, light-coloured	39	0
118	0	Conglomerate	9	0
120	0	Shale, blue	2	0
148	0	Sandstone, fine-grained, dark-coloured	28	0
155	0	Shale, hard, blue	7	0
163	0	Sandstone, light-coloured	8	0
166	0	Conglomerate	3	0
214	0	Sandstone, light-coloured	48	0
221	0	Conglomerate	7	0
224	0	Sandstone, light-coloured	3	0
228	0	Shale, blue	4	0
232	0	Sandstone, light-coloured	4	0
233	0	Shale, blue	1	0
237	0	Conglomerate	4	0
262	0	Sandstone, light-coloured	25	0
266	0	Conglomerate	4	0
274	0	Sandstone, light-coloured	8	0
275	0	Shale, blue	1	0
284	0	Sandstone, light-coloured	9	0
298	0	Conglomerate	14	0
		Newcastle Creek Formation?		
339	0	Sandstone, red, and quartz-pebble conglomerate	41	0
357	0	Sandstone, red	18	0
		Coal Creek Formation		
405	0	Hard blue rock and quartz veins	48	0

No. 7. In Rothwell, 1¼ miles southeast of Minto station. Drilled by Provincial Government, 1903. Total depth, 245 feet. Ref.: Dyer, 1926; files Provincial Geologist.

Depth Ft.	Depth In.		Thickness Ft.	Thickness In.
9	0	Clay, red, and gravel	9	0
19	0	Shale, red and blue, and sandstone	10	0
45	0	Shale, red and blue	26	0
46	6	Coal	1	6
53	0	Fire-clay and blue shale	6	6
69	0	Shale, red and blue	16	0
87	0	Sandstone, fine-grained, blue	18	0
189	0	Sandstone, coarse, light-coloured	102	0
224	0	Sandstone, fine-grained, light-coloured	35	0
245	0	Shale, red	21	0

No. 8. In Rothwell. Location not known. Ref.: Keele, 1914; Dyer, 1926. Not reprinted.

No. 9. 2½ miles northeast of Newcastle Bridge, near crossing of Old Postroad and Canadian Pacific railway. Drilled by Provincial Government, 1919. Total depth, 318 feet. Ref.: Dyer, 1926; files Provincial Geologist.

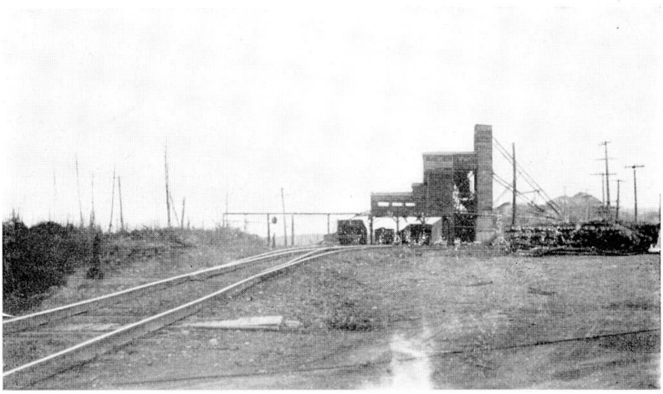
Depth Ft.	Depth In.		Thickness Ft.	Thickness In.
		Hurley Creek Formation		
15	0	Clay, red	15	0
57	0	Sandstone, red, and red shale	42	0
83	0	Shale, soft, red	26	0
		Minto Formation		
103	0	Shale, soft, red and blue	20	0
113	4	Sandstone, grey	10	4
115	0	*Coal*	1	8
117	0	Soapstone, soft (underclay)	2	0
127	0	Shale ('coal rock')	10	0
137	0	Sandstone, grey	10	0
139	0	Sandstone and shale	2	0
150	0	Sandstone	11	0
170	0	Sandstone and blue shale	20	0
202	0	Sandstone, coarse, and conglomerate	32	0
223	0	Sandstone, fine-grained	21	0
243	0	Sandstone, fine-grained, with thin bands of coal	20	0
254	0	Sandstone and conglomerate	11	0
275	0	Sandstone, fine-grained, with thin bands of shale	21	0
295	0	Sandstone, fine-grained	20	0
315	0	Sandstone, conglomerate, and coal rock	20	0
		Coal Creek Formation		
335	0	Slate, quartz, and phyllite, with thin bands of limestone	20	0
363	0	Slate, quartz, and phyllite	28	0
381	0	Feldspar, slate, and quartz	18	0

No. 10. Just south of dead-end road from North Minto across Newcastle Creek. Drilled by Provincial Government, 1944. Elevation of surface, 111 feet; final depth, 847 feet. Logged by Provincial Geologist, Dr. W. J. Wright (log slightly abbreviated).

Depth Ft.	Depth In.		Thickness Ft.	Thickness In.
22	0	Casing; no core	22	0
30	10	Grey shale ('coal rock')	8	10
32	5	*Coal*	1	7
33	0	'Coal rock'	0	7
33	4	*Coal*	0	4
35	8	Shale, grey, gritty, with black markings	2	4
37	0	Sandstone, fine-grained, massive, grey	1	4
37	7	Shale, grey, sandy	0	7
37	11	*Coal*	0	4
45	9	Shale, grey, core lost in part	7	10
49	6	Shale, grey, somewhat gritty	3	9
52	4	Sandstone, fine-grained, grey, massive	2	10
58	0	Sandstone, medium-grained, grey	5	8
61	0	Sandstone, coarse, grey	3	0
64	0	Sandstone, medium-grained, grey	3	0
64	2	Sandstone, grey, with black coaly parting	0	2
69	0	Sandstone, massive, medium-grained, grey	4	10
79	4	Sandstone, massive, medium-grained, grey, coaly	10	4
80	2	Sandstone, fine-grained, grey, with numerous coaly partings	0	10
92	0	Sandstone, medium- to coarse-grained, and quartz-pebble conglomerate	11	10
95	3	Sandstone, massive, coarse, grey, with occasional coaly partings	3	3
99	0	Sandstone and conglomerate, interbedded	3	9
116	0	Sandstone, massive, medium- to coarse-grained, grey	17	0
150	9	Sandstone, fine- to medium-grained, grey, with occasional grey shale partings	34	9
157	2	Shale, grey ('coal rock')	6	5
168	4	Conglomerate, grey, with coaly shale partings at 164 feet	11	2
192	4	Sandstone, massive, medium-grained, grey	24	0
198	9	Sandstone, massive, coarse, grey	6	5
198	10	Coal and pyrite in lens	0	1
238	2	Sandstone, massive, fine- to coarse-grained	39	4
243	0	Conglomerate, massive, grey	4	10
248	5	Lost core	5	5
249	0	Sandstone, massive, coarse, grey	0	7
250	5	Sandstone, fine-grained, grey, with nodules of black shale	1	5
257	6	Shale, dark grey	7	1
264	1	Sandstone, massive, coarse, grey	6	7
264	5	Conglomerate, grey	0	4
267	2	Shale, carbonaceous, with fine and coarse grey sandstone and conglomerate	2	9
270	0	Lost core	2	10
273	8	Sandstone, fine to coarse, grey, and conglomerate	3	8
274	9	Shale, soft, greenish grey; base of Pennsylvanian	1	1

Depth Ft.	Depth In.	*Coal Creek Formation*	Thickness Ft.	Thickness In.
279	7	Lost core	4	10
281	0	Argillite, greenish, chloritic; dip 70 to 90 degrees	1	5
283	10	Sandstone, massive, greenish grey, micaceous	2	10
285	7	Sandstone, massive, fine-grained, and chloritic argillite; dip 45 degrees	1	9
292	0	Core missing	6	5
293	0	Chloritic argillite; dip 20 degrees	1	0
293	4	Soft chlorite gouge	0	4
295	0	Chloritic argillite and quartz carbonate; dip 45 to 70 degrees	2	0
297	0	Core missing	1	8
298	0	Sandy argillite	1	0
307	0	Laminated argillite; dip 30 to 80 degrees; considerable quartz at 300 to 302 feet	9	0
311	0	Core missing	4	0
312	0	Quartz, broken, and talcose clay	1	0
318	5	Argillite, fairly massive, sandy; dip 60 to 90 degrees; some bedded quartz-carbonate veins	6	5
320	8	Core missing	2	3
322	0	Argillite, laminated, chloritic; dip 35 degrees	1	4
338	0	Argillite, massive, sandy, with many quartz veins; core incomplete; dip 45 to 60 degrees	16	0
378	6	Siltstone, light grey, micaceous, with quartz veins; core incomplete; dip 35 to 90 degrees	40	6
572	0	Shale and siltstone, dark grey to grey, with graphitic partings, quartz and carbonate veins; dip 70 to 90 degrees; core incomplete	193	6
665	0	Sandstone, fine, grey, with veinlets of quartz and dark shaly partings; dip 50 to 90 degrees; core incomplete	93	0
667	0	Schist, chloritic, with quartz-carbonate veins; dip 80 to 90 degrees	2	0
686	6	Sandstone, fine, grey; dip 75 to 90 degrees; core incomplete	19	6
847	0	Shale, grey, micaceous, and siltstone; partly graphitic; dip 50 to 90 degrees; core incomplete	160	6

A. Small level-mine in Coal Creek area.



B. Shaft-mine of Welton and Henderson, Minto.

C. Strip-mine of A. W. Wasson, with 'walking' diesel-electric drag-line.

CHAPTER III

COAL RESOURCES

MINING HISTORY

The coal resources of the Minto coalfield, New Brunswick's only active coal-mining area, are small if compared with those of Nova Scotia or the western provinces of Canada. However, the disadvantages of a single coal seam, with an average thickness of only 18 inches, are partly compensated for by the relative accessibility of the seam under a shallow overburden, and the absence of structural disturbances. These conditions have permitted the production of coal with a minimum of mechanization, and thus the capital investment per ton of coal produced is appreciably lower than in other coal-producing provinces.

Recent reports, prepared for the Royal Commission on Coal by the New Brunswick Coal Producers Association and by the New Brunswick Department of Mines, give a full account of mining conditions in the area, amplified by many tables. Production figures may also be found in the Annual Reports of the New Brunswick Department of Lands and Mines, and in the yearly "Coal Statistics" of the Dominion Bureau of Statistics. The mining history of the area was related in 1935 by two local mine managers (King and Johnson, 1935), and the following account is largely taken from their paper.

A reference in Massachusetts Colonial Records indicates that coal was exported from the Grand Lake area to New England as early as 1639. A monument in the village of Minto commemorates this export trade of coal as the first to be developed on the entire eastern coast of North America.

In May 1837, a bore-hole was started near the "Salmon River Coal Mines" and completed 2 years later. The hole penetrated to a depth of 403 feet, and 8 feet of shale and coal were reported at 250 feet. At this depth the hole was probably well into the Coal Creek formation, and the existence of this second coal seam has never been confirmed.

The first coal was probably mined by hand stripping in places where the overburden was thin, or from short levels in the banks of the streams where the coal seam was exposed. Bailey and Matthew (1873) describe fifteen such workings in the Minto area, mainly on Newcastle Creek. At present, small workings, probably very similar to those of the old mines, may be seen in the Coal Creek area (*See* Plate II A).

In 1890, a railway was built from Norton, on the then Intercolonial Railway from Sussex to Saint John, to Chipman. Some of the coal output could now be shipped by rail, although Chipman was not the main point of activity. The railway was extended in 1904 from Chipman to Minto, which village had been named after the then Governor General of Canada. In 1913, the line from Minto to Fredericton was completed.

The first vertical shaft with mechanical hoisting equipment was installed in 1892. In 1905, a steam-driven clam-shell was introduced by the J. S. Gibson Company for stripping the overburden from the coal.

During the first World War production rose from 55,000 short tons (1909-1913 yearly average) to 165,000 short tons (1914-1918 yearly average). In 1917, strip-mining was commenced by the Rothwell Coal Company and Harvey Welton, using steam shovels, and shortly afterwards by the Minto Coal Company, using a drag-line and, for loading, a steam shovel. The overburden in these mines ranged from 6 to 22 feet.

The largest underground mine at this time was operated by the Minto Coal Company, working an area in Block 23, directly south of the highway. The coal seam, which here had an average thickness of 28 inches, lay at a depth of 20 to 70 feet, and was mined by the room and pillar system. Natural drainage for most of this area was a valuable asset, facilitating mining operations. Main levels, 4 feet 6 inches high and 6 feet wide, were driven 425 feet apart. Shafts, 12 by 6 feet, were sunk at intervals of 600 feet. Ventilation at first was by natural draft, with air shafts halfway between mine shafts and air courses driven between the bye levels, but with the introduction of electric power, fans were installed. Each mine shaft had a 20-horsepower boiler and single-drum reversing hoist, and single-deck cages. On underground tracks 12-pound rails and steel mine-boxes of 800 pounds capacity were used.

In 1921, the Minto Coal Company erected an electric power plant to produce the power for longwall mining machines, which have been successfully operated by this company ever since. At one time a 325-foot longwall was carried beneath a brook, with only a few feet of strata intervening and without any appreciable amount of water entering the mine. The coal was cut by a chain machine and carried to the loading point with a shaker-conveyor. By this new system, the yearly production from one shaft was increased from about 30,000 to nearly 100,000 short tons. In 1923 this same company was the first to install a shaking screen, picking table, and crusher.

In 1924, a spur line was constructed from Hardwood Ridge, on the Canadian National railway, to North Minto to serve the mines in that area.

In 1931, the New Brunswick Electric Power Commission built an electric power plant on the Grand Lake shore, near Newcastle Landing. This plant supplies energy to a district within a 100 mile radius and consumes about 15,000 tons of coal yearly, of which each major operator furnishes a certain quota. After electric power became available, longwall mining machines and conveyors were also installed by the Avon Coal Company, Welton and Henderson, the Rothwell Coal Company, and the Miramichi Lumber Company. Advancing or retreating longwall systems are used, depending on the conditions of the roof. The Avon Coal Company, in its retreating longwall operations, used the 'panel system', driving roadways with a mounted track machine at intervals of 400 feet, forming blocks 400 by 450 feet. Crosscuts are then driven to form a longwall face.

From 1935 on, strip-mine operations (*See* Plate II B) have become increasingly important. Whereas, from November 1 to October 31, 1935, strip-mines produced 15,493 short tons, or 4·6 per cent of the total output, this was increased by 1941 to 112,922 short tons, or 21·2 per cent of the total. Although the total production decreased after the war, strip-mine production was still increasing in 1948, when it reached 276,377 short tons or 55 per cent of the total production. Stripping is done mostly by steam-driven cranes that are moved on rollers. In 1947, a modern diesel-electric self-propelling ('walking') drag-line, with a 123-foot boom, was introduced by the Avon Coal Company, and a similar machine is now used by A. W. Wasson (*See* Plate II C).

EXTENT AND THICKNESS OF THE MINTO COAL SEAM

The extent of the Minto coal seam, as determined from drilling, mining, and surface data, is indicated on Map 1005A accompanying this report. It is based mainly on data compiled by the Provincial Geologist on large-scale maps of the mining blocks. In areas where these maps give no information, the surface geology has been used to determine or estimate the position of the coal seam at the outcrop. Elevation contours of the coal seam are partly based on known elevations and have been extrapolated in unexplored areas. The map shows the areas where the coal lies beneath an overburden of less than 50 feet, and could be worked by strip-mining methods. The thickness of the coal seam, in some cases divided into upper and lower benches, with an interbedded shale band, is given for a number of places. These thicknesses are all from drill records, for the mine operators do not keep records of the coal sections in the workings.

MAIN MINTO COAL AREA

Map 1005A shows that the principal coal-mining area centres around the village of Minto, west of Newcastle Creek, in Mining Blocks 22, 23, 27, and 28. Here are the main operations of the Minto Coal Company, the Miramichi Lumber Company, the Avon Coal Company, the Rothwell Coal Company, Welton and Henderson, and the Newcastle Coal Company[1]. There are shaft-, slope-, and strip-mines. In most of the coal area only a thin cover of shales and sandstones of the Minto formation (upper part) overlies the coal seam, but in some parts red beds of the Hurley Creek formation form part of the overburden. The area is traversed by several glacial or preglacial river channels, from which the coal has been eroded and replaced by drift. The seam contains an interbedded shale band in many places, and probably this band was intersected in many drill-holes, though not recorded. A second shale band, 1 inch thick, is recorded in the coal of some drill-holes, but has been omitted on the map. It will be noticed that in the north part of this area a 'main seam', at most 2 feet thick, is separated by a few inches of shale from an underlying thin bench

[1] The holdings of the Minto Coal Company were acquired by the Miramichi Lumber Company in 1948.

about 6 inches thick. In the south part of the coal area, the main seam is overlain by a varying amount of shale and by another half foot of coal. In most places the interbedded shale is removed in a separate operation and both benches of coal are recovered. In the north, the seam rises and terminates against the Hardwood Ridge anticline. The thickness of the seam decreases in this direction, and the approximate boundary of coal in mineable thickness coincides roughly with this structure. Although most of the coal in this main coal area has been mined, and only a few small patches remain, stripping of the coal left in the older mines may still yield fair returns.

UPPER EIGHTEEN BROOK AREA

In the west part of the Minto map-area some coal occurs north of the Hardwood Ridge anticline at the head of Eighteen Brook. Some of it was stripped, but apparently little success attended the mining operations. No coal of commercial thickness seems to occur farther northeast along the northwest limb of the anticline.

SOUTHWEST COAL AREA

Potential tracts of coal occur in the west corner of the area. They occupy parts of Mining Blocks 12, 13, 17, 18, 19, 24, and 29, and are separated from the main Minto area by a mainly barren area west and south of New Zion. In this area some isolated patches of coal may have escaped erosion, but much drilling will be necessary to discover them.

Two stripping operations are in progress along the outcrop of the coal seam in the southwest coal area, one near Flowers Cove, Block 24, and one south of New Zion, in Block 18. Here, a 'main seam' about 1½ feet thick is separated by 12 to 18 inches of shale from an overlying seam about 6 inches thick. More mineable coal is known to occur between these two workings, and the remainder of the coal-outcrop zone (*See* Map 1005A) may contain several more promising tracts.

Farther south and west, the remainder of the area mapped is occupied by the Hurley Creek formation, and the presence of the coal seam beneath is almost certain. However, the greater overburden will probably prohibit economic extraction, and the thickness of the seam in this area is still unknown.

AREA BETWEEN NEWCASTLE CREEK AND SALMON RIVER

East of the main coal area and south of the Hardwood Ridge anticline, another large area of coal occurs between Newcastle Creek and Salmon River, mainly in Mining Blocks 27, 30, 32, 34, 35, 36, and 39. Much of this area is underlain by the Hurley Creek formation, and the coal occurs mainly at depths of more than 50 feet, thereby excluding the possibility of strip-mining except in the narrow marginal parts. Shaft-mining is also less attractive, as the average thickness of the seam is only 18, or at most 24, inches. Old workings are in evidence at many places along the margin of this area, but none was active in 1948.

More drilling might reveal some workable tracts in the area between Vance and Perley Brooks, where the overburden is light. However, the thickness of the seam in these parts is small and variable. The peninsula south of Newcastle Centre is possibly more promising, for it is nearer the main mining area where the seam is thicker.

IRON BOUND COVE AREA

A few scattered strip-mines in a small area north of Iron Bound Cove and Salmon River illustrate the northward pinching of the coal seam, which varies in thickness from 7 to 18 inches.

CHIPMAN AREA

The coal areas discussed thus far are separated from the Chipman area by Salmon River and the Salmon River uplift. A series of old strip- and shaft-mines lies east and south of this uplift. The coal averages 18 inches in thickness, and the overburden includes considerable hard sandstone, so that stripping operations are difficult and expensive. The coal seam is probably continuous with that of the Coal Creek area. In 1948, only one strip-mine, near Long Creek, was in operation.

COAL CREEK AREA

Coal occurrences along both sides of Coal Creek and the Northeast Arm of Grand Lake for about 6 miles are similar to those near Chipman. Here, too, the thickness varies around 18 inches. Numerous, old strip-mines and small slope-mines were worked in this area, but at present only a few, small, primitive slope-mines, employing less than a dozen miners, are in operation.

An area of assumed, near-surface coal deposits east of the old Dufferin settlement may be worth a few drill tests.

FUTURE DEVELOPMENT

It seems probable that future development will be mainly in the Southwest coal area. One operator has transferred his activities from Chipman to this area, and probably more shifts to the western blocks will occur when the Main Minto coal area nears depletion. The Southwest area has been tested only incompletely, and more drilling will have to be done in Blocks 13, 18, 19, the south parts of 12 and 17, and in the area west of these blocks to determine the coal reserves.

COAL RESERVES

PREVIOUS ESTIMATES

The reserves of the Minto coalfield have been estimated at various times with the following results:

—	Year	—	Acres	Short tons
L. W. Bailey and G. F. Matthew.....	1873	....	53,760	154,948,147·2
D. B. Dowling......................	1913	Cites above in metric tons		
W. S. Dyer.........................	1926	Actual coal..........	2,750	8,200,000
		Probable coal.......	25,600	61,000,000
		Possible coal........	67,200	166,000,000
			95,550	235,200,000
New Brunswick Department of Mines	1945	Probable coal........	33,282	69,474,900
		Possible coal.........	4,393	8,809,400
			37,675	78,284,300
New Brunswick Coal Producers Association........................	....	Actual reserve......	....	25,000,000
B. R. MacKay......................	1947	Mineable—		
		Probable coal......	33,282	89,814,000
		Possible coal.......	4,393	11,566,000
		Total coal..........	37,675	101,380,000
		Recoverable—		
		Probable coal......	16,641	44,907,000
		Possible coal........	2,196	5,783,000
		Total coal..........	18,837	50,690,000

As they are based on the latest data, the most recent of these figures may be assumed to be the best. Although MacKay used the same estimate of the coal-bearing area as that of the Provincial Department of Mines, he arrived at a larger figure for coal reserves by reckoning on greater tonnages per acre.

ESTIMATED AREA

Too optimistic reserve calculations may result from failure to take into account the amount of overburden. Yet, in the Minto area the depth of the coal is of prime importance in determining its recoverability. The area is different from most coalfields in having only one seam, and this with a thickness that would normally be considered insufficient for commercial production. It is mainly due to its occurrence near the surface over considerable areas that the seam can be mined profitably, and that certain parts of the seam must be included in the coal reserves of this country. But the factor of depth should be taken into account in calculating these reserves.

On the coal map accompanying this report, the areas of coal at a depth of less than 50 feet have been separated from those where the coal occurs at greater depths. These areas can be outlined readily from 25-foot interval contour maps of both topography and the coal seam. The total area of this seam within a depth of 50 feet, as well as the areas of strip- and shaft-mines, the latter divided into parts that lie at depths of less or more than 50 feet, was measured in each mining block with the planimeter. The results are tabulated in Table I. The aggregate area covered by the present Provincial Mining blocks is the area on which the estimates are based. Coal probably occurs beyond this area, and within the area of the Minto and Chipman maps, but too little is known to warrant its inclusion in the estimate of total available coal.

TABLE I

Mining block	Aréa of coal with less than 50 feet overburden (includes areas mined)	Areas worked by strip-mining (less than 50 feet overburden)	Areas mined with less than 50 feet overburden	Areas mined with more than 50 feet overburden
No.	Acres	Acres	Acres	Acres
11	550	15	-	-
12	160	-	-	-
13	530	-	-	-
16	320	-	-	-
17	280	10	-	-
18	940	135	-	-
19	220	-	-	-
21	60	-	-	-
22	640	105	125	500
23	920	140	435	-
24	340	85	-	-
26	20	-	-	-
27	610	-	160	375
28	1,070	140	500	500
29	480	25	20	-
30	800	-	20	-
31	50	-	10	115
32	1,050	5	140	145
34	930	-	-	-
35	380	-	-	-
36	600	-	-	-
38	250	-	-	-
39	940	45	-	-
40	1,060	20	-	-
41	320	-	-	-
42	80	-	-	-
43	210	35	10	-
44	800	30	5	-
45	500	40	-	-
47	700	100	55	50
48	760	85	-	-
49	290	15	-	-
90	950	-	-	-
91	1,650	5	-	-
Total.........	19,460	1,035	1,480	1,635

	Acres
Total area of coal at depth less than 50 feet, including areas mined	19,460
Area where coal has been extracted from depth of less than 50 feet (1,035 stripped; 1,480 mined)	2,515
Area remaining, presumably underlain by coal	16,945

According to this a combined reserve area of about 17,000 acres of coal may be expected within the mining blocks at a depth of less than 50 feet. As almost no coal has been mined at a depth greater than 100 feet, this may be taken as the depth limit of coal to be included in the reserves. The area of coal between 50 and 100 feet depth cannot be outlined and measured as readily as that between 0 foot and 50 feet. However, as dips of coal seam and terrain are gentle and fairly constant, these two areas may be assumed to be roughly equal. Thus, another 19,500 acres of coal are probably available at depths of between 50 and 100 feet. Of these, about 1,500 acres have been extracted, leaving a reserve of 18,000 acres.

TONNAGE PER ACRE

By using the data on past production and acreage of coal extraction, an average figure for the yield per acre of coal may be found:

Total production (1887-1948)	10,674,022 short tons
Total acreage mined	4,150 acres
Yield per acre	2,572 short tons

This yield per acre is in close agreement with a calculated yield of 2,625 tons per acre for a seam of 18 inches, assuming a weight of 80 pounds per cubic foot of coal. It seems, therefore, to be justifiable to use an average thickness of 18 inches and a yield of 2,625 short tons per acre for the calculation of the coal reserves of the field.

ESTIMATE OF RESERVES

MacKay (1947) referred to the reserves believed to occur at workable depths and with a certain minimum thickness of the seam as "mineable coal". For New Brunswick he sets the maximum depth at 500 feet and the minimum thickness at 18 inches (page 14). Of these mineable reserves he estimates that only 50 per cent will be recovered ultimately, and these are called "recoverable reserves". The same system has been adopted for the present report, but, as indicated before, the maximum depth of the seam has been reduced from 500 to 100 feet. The following tonnage of coal is estimated to occur within the mining blocks on Map 1005A:

—	Million short tons	
	Mineable	Recoverable
Coal at less than 50 feet depth	44	22
Coal at 50 to 100 feet depth	47	23

CHARACTER OF THE COAL

Run-of-mine samples of Minto coal from different strip- and shaft-mines have been analysed at various times by the Fuels Division of the Bureau of Mines, Ottawa. The following information has been taken from the reports of this organization that deal partly or entirely with the Minto coal.

Minto coal is generally a well-banded coal, with bright bands predominating. It is highly fractured, and disintegrates readily during mining, preparation, and transport. Pyrite occurs commonly in appreciable quantities.

According to the A.S.T.M.[1] classification, the rank of the Minto coal is 'High Volatile A Bituminous'. Thus, though it is of inferior grade, due to its high ash and sulphur content, it is of the same rank as coal from the mining areas of Nova Scotia. Tests have shown that by washing the coal a relatively clean coal may be obtained.

Table II shows the proximate and ultimate analysis, together with calorific values and ash softening temperatures of Minto coal from various mines in the field (*See* Map 1005A for locations). They were taken from the Analysis Directory of Canadian Coals, 1948, and represent in most instances an average of many analyses of samples from the same mine.

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[1] American Society for Testing Materials.

TABLE II

Operator	Mine	Location No.	Number of samples	Proximate analysis				Ultimate analysis					Calorific value B.t.u./lbs.	Ash softening temperature, degrees F.
				Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen		
Minto Coal Co. Ltd.	West Slope, No. 2C shaft	1	12	3·0	30·1	48·3	18·6	6·7	4·6	64·8	0·8	4·5	11,840	2,050
Miramichi Lumber Co. Ltd.	Northfield (Miramichi—Block II)	2	10	3·0	30·2	48·2	18·6	6·7	4·5	64·3	0·7	5·2	11,815	2,015
C. S. Yeamens	Lake Road No. 2	3	2	3·5	30·6	49·0	16·9	7·0	4·8	66·0	0·9	4·4	12,310	2,005
Rothwell Coal Co.	Rothwell (new and old, Block 18)	4	21	3·0	30·9	48·8	17·3	7·3	4·7	65·1	0·8	4·8	11,960	2,020
Minto Coal Co. Ltd.	Tweedie, C1, C2, C3—strip	5	21	3·0	30·0	49·8	17·2	8·3	4·5	64·5	0·8	4·7	11,825	2,045
Welton and Henderson Ltd.	Kelley (Lease 179)	6	72	3·6	29·8	46·9	19·7	6·7	4·5	63·4	0·8	4·9	11,550	2,030
Avon Coal Co. Ltd.	Shaft-mines and strip-mine	7	8	3·0	29·8	49·6	17·6	7·9	4·6	64·8	0·8	4·3	11,810	1,990
Newcastle Coal Co.	Shaft No. 2 (Lease No. 191)	8	12	3·5	30·5	48·8	17·2	6·8	4·6	64·9	0·9	5·6	11,930	1,995
McDougal Bros.	Shaft- and strip-mine	9	2	3·5	30·2	48·2	18·1	7·2	4·9	62·2	0·7	6·9	11,725	2,000
Harvey Welton Ltd.	Welton (Lease No. 181)	10	2	3·5	29·6	49·0	17·9	7·9	4·8	63·7	0·9	4·8	11,735	1,990
Myles and Wisely	Long Creek strip-mine and No. 1 slope	11	3	3·5	32·3	48·2	16·0	6·7	5·1	66·8	1·0	4·4	12,100	1,915
G. H. King	Elkin shaft	12	21	2·8	30·9	42·9	23·4	6·4	4·5	60·2	0·9	4·6	11,060	2,040
Pennlyn Coal Co. Ltd.	Broderick and Crossman strip-mines	13	2	3·0	30·7	46·4	19·9	10·3	4·2	60·6	0·8	4·2	11,250	2,025
Soft coal (weathered)														
McDougal Bros.	Shaft- and strip-mine	9A	2	10·0	29·7	53·7	6·6	2·4	5·5	68·7	0·9	15·9	12,120	2,250
Pennlyn Coal Co. Ltd.	Broderick and Crossman strip-mines	13A	3	10·0	29·3	52·0	8·7	3·9	5·6	67·3	0·9	13·6	11,845	2,100
Average analysis of hard coal			129	3·2	29·7	47·8	19·3	7·6	4·5	62·7	0·8	5·1	11,610	2,030
Average analysis of soft coal			7	10·5	29·6	53·1	6·8	2·6	5·6	68·4	0·9	15·7	12,075	2,280