CANADA

DEPARTMENT OF MINES AND RESOURCES

MINES AND GEOLOGY BRANCH

BUREAU OF GEOLOGY AND TOPOGRAPHY

GEOLOGICAL SURVEY

MEMOIR 245

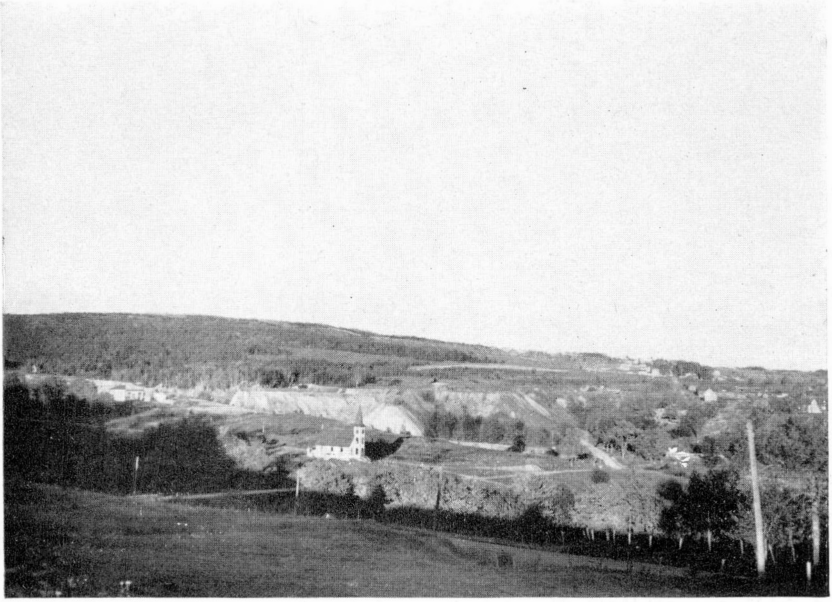
LONDONDERRY AND BASS RIVER MAP-AREAS, COLCHESTER AND HANTS COUNTIES, NOVA SCOTIA

BY

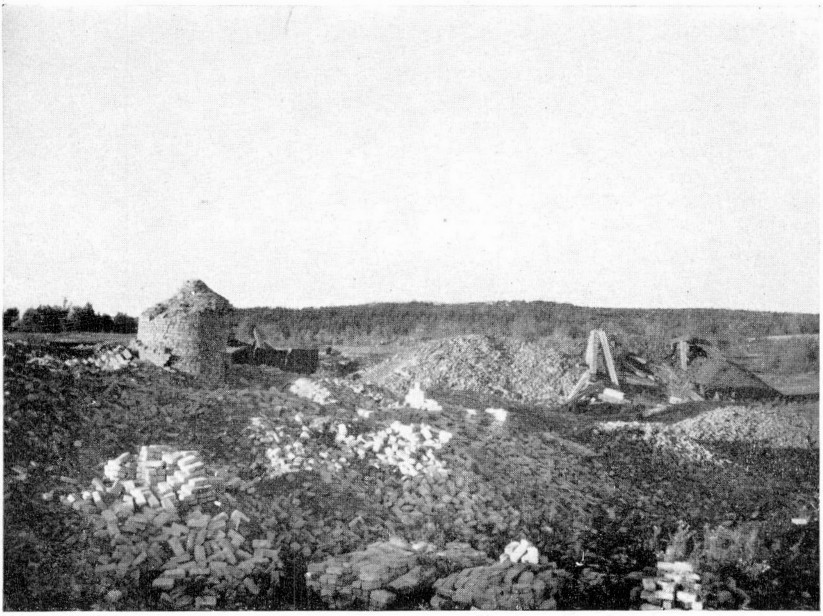
L. J. Weeks

OTTAWA
EDMOND CLOUTIER, C.M.G., B.A., L.Ph.,
KING'S PRINTER AND CONTROLLER OF STATIONERY
1948

Price, 25 cents No. 2480



A. Londonderry in 1941, showing the slag heaps on the banks of Rockland River. The nearer stream is Great Village River. The present village is to the right of the picture. (Page 37.)



B. Londonderry blast furnaces in 1941. On the right are remains of the trestle used to convey ore to the furnaces, and surrounding these timbers is part of a pile of ore. (Page 37.)

CANADA
DEPARTMENT OF MINES AND RESOURCES

MINES AND GEOLOGY BRANCH
BUREAU OF GEOLOGY AND TOPOGRAPHY

GEOLOGICAL SURVEY
MEMOIR 245

LONDONDERRY AND BASS RIVER MAP-AREAS, COLCHESTER AND HANTS COUNTIES, NOVA SCOTIA

BY

L. J. Weeks

OTTAWA
EDMOND CLOUTIER, C.M.G., B.A., L.Ph.,
KING'S PRINTER AND CONTROLLER OF STATIONERY
1948

Price, 25 cents

No. 2480

CONTENTS

CONTENTS—*Concluded*

Illustrations

PREFACE

Londonderry and Bass River map-areas cross Cobequid Bay and Minas Basin in the Bay of Fundy region, Nova Scotia. The geological formations range in age from those of the steeply folded pre-Carboniferous Cobequid complex and intrusive granites in the north to the relatively undeformed or flat-lying Triassic sediments and basic lavas that occupy a wide fringe along either shore of Cobequid Bay. North and south, respectively, of these younger rocks are representative sections of Pennsylvanian and Mississippian strata.

Little geological mapping has been attempted in these areas since 1900 and earlier years, when attention was directed chiefly to studies of the Carboniferous formations. Interest in the various mineral deposits has, however, been maintained to the present. From these deposits has come most of the manganese and iron produced in the province, as well as quantities of gypsum and other industrial minerals.

The present report is an outcome of investigations commenced in 1938 when, with war on the horizon, an inventory of possible economic reserves of iron and manganese ores became expedient. Special attention is, consequently, given to the Londonderry iron district, and to manganese deposits in the limestone of the Pembroke formation. Field studies by the author have, in addition, provided significant new data on the geological and structural relationships of the various formational groups, and on the nature of the contact between the rocks of the Cobequid complex and the Pennsylvanian strata.

GEORGE HANSON,
Chief Geologist, Geological Survey

OTTAWA, February 6, 1947

Londonderry and Bass River Map-Areas, Colchester and Hants Counties, Nova Scotia

CHAPTER I

INTRODUCTION

GENERAL STATEMENT

Londonderry and Bass River are names applied to two adjoining map-areas on the east arm of the Bay of Fundy, lying between latitudes 45°15′ and 45°30′ north, and longitudes 63°30′ and 64°00′ west. Together they comprise an area of about 430 square miles, within which has been mined almost all the manganese and the larger part of the iron produced in Nova Scotia. Whether these deposits had been mined to completion became a matter of increasing concern as war clouds gathered in the late thirties. In 1938, J. C. Sproule of the Geological Survey commenced work on the Londonderry and Bass River quadrangles, and after Sproule's resignation, in 1939, the writer continued this work. The field seasons of 1939 and 1943, together with parts of those of 1940, 1941, and 1944, were devoted to this area, and previous to this report an account of the Londonderry iron deposits and preliminary geological maps of Londonderry and Bass River areas were published[1].

ACKNOWLEDGMENTS

During the above field seasons Messrs. A. H. Watt, J. R. Nutter, G. R. Reynolds, J. E. Blanchard, S. M. Bancroft, E. A. Walker, J. A. Winterbourne, R. A. Cameron, C. M. Little, and J. S. Scott ably discharged their duties as field assistants.

W. A. Bell of the Geological Survey identified the Mississippian and Pennsylvanian fossils collected by the writer, and in addition very kindly spent some days with him in the field in 1944.

Prof. A. E. Flynn of the Nova Scotia Technical College spent some days in the field with the writer in 1943, and ran a series of observations with the Hotchkiss Superdip Magnetometer across the iron-bearing carbonate bodies of the Londonderry iron district. This, together with his many helpful suggestions on other matters, is gratefully acknowledged.

The writer is much indebted to Messrs. George Coolan and Frank Farnan for information and help during the investigations of the old mine workings of the Londonderry district.

[1] Weeks, L. J.: Geol. Surv., Canada, Paper 44-10 and Maps 45-25 and 45-26.

PREVIOUS GEOLOGICAL WORK

Probably the earliest geological description of the rocks of this area[1] is that of Abraham Gesner[2], published 2 years before he left Nova Scotia to become the Provincial Geologist for New Brunswick. In his descriptions, Gesner proved himself familiar with the more isolated parts of the then unknown Cobequid Mountains; and although his geological interpretations in general have long since been superseded by others based on a more mature science of geology, yet in other instances he was able, armed only with the weapons of an infant science, to define relationships that stand firmly to this day.

Sir William Dawson, in the first edition of "Acadian Geology," 1855, assigns the rocks of Cobequid Mountains to a metamorphic group of probable Devonian or Upper Silurian age. The Mississippian and Pennsylvanian rocks lying to the south of these mountains are correctly grouped as Carboniferous, taking, thereby, a step farther than Dr. Gesner who classified them, together with the rocks of the mountains themselves, as Red sandstone, including his Coal formation. Sir William referred the Triassic sandstone to the New Red sandstone, and his delimitation thereof, in even the first edition, is very little different from that known today. Subsequent editions of "Acadian Geology," in 1868, 1878, and 1891, added very little to the geology of this particular area.

In the 1870's, Hugh Fletcher commenced the systematic geological mapping of Nova Scotia on a scale of 1 inch to 1 mile. His chief interest, however, lay with the Carboniferous rocks, particularly the Coal Measures, and earlier groups were seldom accorded the detailed study that he lavished on these later strata. Cobequid Mountains he considered to be underlain by Devonian sediments cut by granite, diabase, and other intrusive bodies. On the south flank of the mountains, he termed the overlying sediments Carboniferous conglomerate. The island of Pennsylvanian beds protruding through the Triassic on the lower Economy River, he grouped with the sediments of the mountains. South of Cobequid Bay, he mapped rocks of the Windsor group correctly as Carboniferous limestone, but grouped the Horton rocks in the Devonian. The presence of many little structural and stratigraphical details on his maps, details that could quite excusably have been overlooked, testifies to the general excellence of his mapping.

In 1916, Sidney Powers[3] published the first detailed study of the Triassic of Nova Scotia, most of his investigations, however, being conducted to the west of the Londonderry and Bass River map-areas.

The various mineral deposits and occurrences within the area have attracted attention from the earliest times. Most, if not all of the investigators, accepted the regional geology as outlined by their predecessors, and devoted themselves to descriptions of the mineral deposits.

---

[1] Here and elsewhere in the report "the area" refers to that of the adjoining, combined Londonderry and Bass River map-areas.

[2] Gesner, Abraham: Remarks on the Geology and Mineralogy of Nova Scotia; Gossip and Coade, Times Office, Halifax, 1836.

[3] Powers, Sidney: The Acadian Triassic; Jour. Geol., vol. xxiv, Nos. 1, 2, and 3 (1916).

CHAPTER II

GENERAL CHARACTER OF THE REGION

ACCESSIBILITY

Both Londonderry and Bass River map-areas straddle Cobequid Bay, the eastern extension of Minas Basin, and the northern part of each area may be reached by road from the southern part only by a quite circuitous route through Shubenacadie and Truro, a distance of some 100 miles or more.

The main line of Canadian National Railways cuts across the northeast corner of Londonderry map-area. No. 2 paved highway follows the north shore of Cobequid Bay across both map-areas, and good secondary roads give access to all other parts of the area except Cobequid Mountains, which are in general accessible only by means of wood roads.

TOPOGRAPHY

The area may be divided topographically into three subdivisions, the Cobequid highlands, the Carboniferous uplands, and the Triassic lowlands. These will be discussed separately.

COBEQUID HIGHLANDS

Cobequid Mountains are 10 to 14 miles wide and extend from Cape Chignecto on the west to the Carboniferous lowlands of Pictou county on the east. The top of the range is flat and featureless, lying between 900 and 1,000 feet above sea-level, with a few knobs protruding above these levels. The southern face of the mountains is quite abrupt, and remarkably straight for long distances. The northern face, which lies beyond the area, is less steep and less straight.

South-flowing rivers leave the mountains in deep, steep-walled gorges, the bottoms of which are usually a series of cascades or falls for some miles into the highlands. Nearer their headwaters, these streams flow in shallow valleys through drift-covered terrain, and commonly expose no bedrock. Lakes are fairly common on the featureless top, and swampy areas are relatively abundant.

Near the south face of the mountains, the gorges of the major streams display at least three definite erosional slopes. The youngest, which is being actively cut at present, is very steep, and in places on Economy and Portapique Rivers is essentially vertical. Some 200 feet below the flat top of the range, this steep slope changes abruptly to one of intermediate grade, which, about 100 feet higher, changes rather less abruptly to a lower slope. The upper limits of this lower slope are usually lost in the transition to the flat top, and it has not been possible to delimit a further change, although such is suggested in one or two places in the valley of Economy River.

Economy River leaves the mountains in a fall more than 100 feet high, succeeded to the north by some miles of smaller falls and cascades. Bass and Portapique Rivers have no great fall at the southern edge of the mountains, and although their streams are somewhat smaller in volume of water their gorges are deeper for a greater distance into the mountains.

THE CARBONIFEROUS UPLANDS

Apart from a considerable difference in elevation, the terrain in this subdivision differs much in general character from that of both the Cobequid highlands on one side and the Triassic lowlands on the other. The outstanding characteristic of this terrain is its variability, underlain as it is by Carboniferous rocks that vary in degree of hardness from relatively soft limestones and shales through sandstones and conglomerates of intermediate hardness to relatively hard and almost slaty shales.

The rocks of Cobequid Mountains are everywhere bounded on the south by Pennsylvanian rocks, usually conglomerate. The foot of what might be termed the south face of the mountains varies in elevation from about 350 feet to 450 feet above sea-level. Farther south the conglomerates are in many places succeeded by hard shales where elevations may be as much as 550 feet above the sea. On the south side of Cobequid Bay, maximum elevations of the terrain underlain by Horton shales and sandstones are in excess of 500 feet above sea-level. There rolling hills and relatively deep valleys, but in general without steep gorges, are very characteristic, but no elevations reach those of the flat, featureless erosion surface of Cobequid Mountains, nor is the presence of such a dissected peneplain suggested anywhere in this Carboniferous terrain.

THE TRIASSIC LOWLANDS

Cobequid Bay is bounded on both sides by soft sandstone and conglomerate of Triassic age. These rocks in general extend much farther from the bay on the north side than on the south, where in places they form only a fringe less than a mile wide overlying the older rocks. On the north, in addition to the wider belt bordering the bay, a belt of these rocks more than a mile wide lies north of an area of Pennsylvanian rocks on Economy River, and joins the main belt just east of Bass River. With the exception of basalt (trap) flows, the effect of which on the topography will be discussed separately, the Triassic rocks possess a remarkably even degree of hardness, which in most instances is much less than that possessed by the Carboniferous rocks of the region. The general level of the terrain underlain by Triassic sedimentary beds is, therefore, lower than that of that underlain by Carboniferous rocks. Whereas rolling hills are common, an examination of sea-cliffs on both sides of the bay, many of which are cut in glacial till to depths of 25 or 40 feet or more, would suggest that such a rolling topography may be due to overburden, and that the bedrock surface may be relatively flat and low. The highest observed exposure of Triassic sandstone was 250 feet above sea-level, at the contact with Carboniferous rocks on a small brook a mile north of East Mines station. On the other hand, the highest exposure at a point well removed from contact with harder rocks was on the road from Great Village to Lornevale, 1 mile north of the former village and 2½ miles from the coast, where sandstone and conglomerate outcropped 160 feet above sea-level. Exposures of sandstone underlying the Triassic basalt and protected by it from erosion would, of course, be included with the trap highlands.

THE TRAP HIGHLANDS

Extrusions of Triassic basalt have been reduced by erosion and faulting to a number of small, separated bodies, only two of which, Gerrish and Portapique Mountains, are of a sufficient size to affect the local topography. Both these mountains have a similar structure; flows of basalt, originally flat-lying, have been displaced by faults striking east-west and north-south, and during the movement have taken up a final position with a low dip to the west. The harder trap rock has resisted erosion and protected the softer underlying sandstone, resulting in two wedge-shaped hills with the thick part of the wedge facing east. The eastern slope of the hills is steep, in places precipitous, whereas the western slope follows the dip of the basalt. Portapique Mountain rises slightly more than 550 feet, and Gerrish Mountain somewhat more than 600 feet above sea-level. Neither of these hills reaches the elevation of the peneplained surface of Cobequid Mountains.

DRAINAGE

In general the area is one of small streams. On the north side of Cobequid Bay, five streams—Economy, Bass, Portapique, Great Village, and Folly Rivers—rise to the north of the map-area, and, therefore, well within Cobequid Mountains. The total length of the longest of these is probably not much more than 15 miles. Two of these streams, Economy and Bass Rivers, after reaching the Triassic lowlands continue their more or less straight courses through ridges of harder, older rocks. Carr Brook, a much smaller stream, also cuts through the ridge of Riversdale shales en route from soft Triassic rocks on the north to similar rocks south of the ridge. These streams are believed to be superposed on the present land surface from courses established when these "islands" of harder rock were covered by the softer Triassic rocks.

Within the mountains these major streams have deep youthful valleys, which retain these characteristics to within a mile or so of their headwaters. The upper 3 miles of Economy River has a very mature cross-section down to a local base level that extends downstream to about 1 mile below its junction with the stream from Economy Lake, where a body of diabase acts as a dam. Several falls are developed over this diabase and the stream then enters a gorge that becomes deeper and steeper to where the stream leaves the mountains in Economy Falls.

The lower part of East Economy River flows through what is probably a subsequent valley, formed by the capture of a north-south stream paralleling Economy River, which was unable, because of its smaller size, to cut through the hard ridge of Riversdale shales exposed beneath the Triassic beds.

No streams of any size appear on the south side of Cobequid Bay. Tennycape and East Noel Rivers are actually large brooks, and neither receives much water from beyond the south limits of the map-area. This lack of large streams is due to the fact that the divide lies only 3 to 6 miles south of the shoreline. The district to the immediate south of the area is drained, in the western part by Walton River, flowing westerly to its outlet on Cobequid Bay at Walton, and in the eastern part by Kennetcook and Fivemile Rivers, which discharge respectively into Avon and Shubenacadie Rivers. All three of these are subsequent streams, and flow through valleys underlain by soft Windsor beds, their valleys being bounded by harder Pennsylvanian and Horton sedimentary rocks.

THE SEA-COAST

Cobequid Bay and Minas Basin, eastward extensions of the Bay of Fundy, divide the mapped area into north and south parts. These two bodies of water together comprise an inland sea with an area of some 400 square miles, and are connected with Bay of Fundy by Minas Channel, which at its narrowest point is about 3 miles wide. A tidal difference, which is probably not exceeded elsewhere in the world, is found in Minas Basin and Cobequid Bay. Goldthwait[1]

[1] Goldthwait, J. W.: Physiography of Nova Scotia; Geol. Surv., Canada, Mem. 140, p. 130 (1924).

estimates that 2 cubic miles of water travels through Minas Channel every 6 hours. The writer considers this figure to be nearer the minimum than the average.

Within the area mapped this inland sea is almost entirely bounded by coarse sandstone and conglomerate of Triassic age. In a few places Horton rocks are exposed on the sea-shore, but are generally overlain higher up the cliff by Triassic rocks. On the headlands, sea-cliffs as much as 100 feet high, but averaging perhaps 20 feet, are cut in the sandstone and its overlying glacial till. On some headlands, such as those on each side of the mouth of Portapique River, low cliffs are cut entirely in glacial debris. The estuaries of rivers and large brooks are bounded by saltmarsh, often of considerable extent, and composed of material deposited by tidal action throughout many centuries. Where the saltmarsh is dyked, to prevent it being over-run by spring tides, very desirable farm land is acquired.

At low tide, numerous sandbars are exposed in Cobequid Bay, and in the sheltered estuaries their place is taken by mud-banks. In places, as between Portapique and Highland Village, the saltmarsh is being removed by the same tidal agencies that deposited it there originally. Cliffs 8 to 10 feet high are cut in the deposits of mud and vegetation, and each storm moves the cliff inland appreciably. The low cliff cut in glacial till to the east of Portapique River estuary was cut inland about 5 feet each winter from 1940 to 1943. There is thus every reason to believe that the sandstone cliffs are being cut inland at a very appreciable rate, although probably much more slowly than at Portapique. Exceptionally high spring tides, coupled with gales and probably aided to some extent by floating ice, are the active agents. Where the face of the cliff is composed entirely of material of an equal degree of hardness, the cliff remains vertical by slumping, the dips of the sandstone being generally quite low. Where a somewhat harder bed lies higher up in the cliff face, caves and overhanging ledges are formed.

The material garnered from this corrasion is generally swept by strong tidal currents into the middle of the bay, where the coarser material remains largely in the form of sandbars. The finer material is deposited in part in the quieter estuaries, where thick deposits are built up during the neap tides to be torn out for redisposition by the ensuing spring tides, and in part is carried out through Minas Channel. The incoming tide into Minas Basin, although not crystal clear, is nevertheless quite clear, but the outgoing tide, bringing mud picked up in countless stream mouths, is a rich chocolate-brown. Wind during high tide increases the amount of mud carried in suspension. Freshets following a period of heavy rainfall may clean the bottoms of the streams of all mud, carrying it into the bay for redistribution by the tides. Thus the finer products of erosion are continually being moved about. Each day a small part reaches a position where it will not again be disturbed, but a very large part is moved to a place from whence it will again eventually be put into suspension, and another small part is completely removed from the bay.

CHAPTER III

GENERAL GEOLOGY

GENERAL STATEMENT

Cobequid Mountains are underlain by pre-Carboniferous sedimentary and volcanic rocks that, together with the intrusive rocks cutting them, are referred to as the Cobequid complex, and are the oldest rocks in the region.

Paralleling these mountains on the south, but separated from them by a belt some 10 miles wide underlain by younger rocks, Mississippian shales and sandstones of the Horton group are exposed along the axis of the so-called Walton anticline on the south side of Minas Basin and Cobequid Bay. Directly overlying the Horton, and in contact with its rocks throughout, are Mississippian limestones, calcium sulphate beds, and shales of the Windsor group.

Basal Pennsylvanian sandstone and conglomerate, of probable Riversdale age, overlap on the south flank of Cobequid Mountains in two localities, whereas red and grey sandstones and shales of definite Riversdale age protrude through the later Triassic in a lenticular ridge between Upper and Lower Economy. Those sections of the south flank of the mountains not overlapped by basal Pennslyvanian rocks are upfaulted against sandstones, conglomerate, and shales, also of Pennsylvanian age and believed to belong to either the Cumberland or Pictou groups, or to both.

Unconformably overlying the Pennsylvanian beds are coarse, red conglomerate and sandstone of Triassic age that at one time filled Minas Basin and Cobequid Bay. Volcanism during this period is represented by basalt flows that now remain as isolated remnants, usually much higher in relief than the other Triassic rocks, and probably represent the youngest consolidated rocks in the region.

The country has been well glaciated, and the drift mantle is usually thick, as much as 40 feet being commonly observed on sea-cliffs.

THE COBEQUID COMPLEX

The Cobequid complex may be divided into older rocks of two distinct lithological groups, whose age relations are uncertain, which will be referred to as the shale group and the volcanic and sedimentary group, and a series of younger intrusive rocks, ranging in composition from granite and granite-gneiss to diabase, that cut both of the older groups.

SHALE GROUP

Distribution

Rocks of the shale group occur underlying Cobequid Mountains on the west side of the area mapped and along the north side of this area as far east as Matheson Brook. From Economy River to Matheson Brook, however, these rocks do not continue to the south side of the mountains, but are succeeded at varying distances south of the north boundary of the area by rocks of the volcanic and sedimentary group. It is quite possible that they occur in other parts of the district, but could not be differentiated from similar rock types of the volcanic and sedimentary group.

TABLE OF FORMATIONS

Cenozoic	Quaternary	Recent	Tidal alluvium Lake deposits
		Pleistocene	Stratified gravels Glacial drift
Mesozoic	Triassic		Basalt Annapolis formation
Palæozoic	Pennsylvanian	Pictou (?) group	Sandstone, conglomerate
		Cumberland (?) group	Sandstone, shale
		Riversdale group	Sandstone, shale
	Mississippian	Windsor group	Upper Windsor Anhydrite, gypsum Tennycape formation Anhydrite, gypsum Pembroke formation Macumber formation
		Horton group	Cheverie formation Horton Bluff formation
	Devonian (?)		Intrusive rocks
	Pre-Carboniferous	Cobequid complex	Shales Volcanic and sedimentary rocks (possibly younger than the shales)

Lithology

On a northwest branch of Portapique River, the mouth of which is about 100 feet from the mouth of Gamble Brook, a very good section of the shale group is exposed north of the granite body. Here it may be described as consisting of grey, reddish brown weathering, well-bedded, slightly sandy shales. On this stream they dip uniformly to the south at angles varying between 45 and 70 degrees. Similar rocks are exposed at the extreme headwaters of Matheson Brook, their most easterly extension within the area, and on Portapique River just south of the north boundary of the area. On Bass River, north of the main granite mass, well-bedded, grey shales, which are, however, less sandy and darker grey, are assumed to be the westward continuation of these rocks. Here again the rocks dip uniformly to the south.

At the headwaters of Economy River and north of Economy Lake, the sediments are somewhat lighter in colour and not as well bedded as farther east. Dips on Economy River and its branches, Murphy Brook and Chain Lake Brook, as those farther east, are uniformly to the south, but those at the headwaters of Economy River are very flat, some being as low as 5 degrees. On

Murphy Brook, a short distance north of its mouth, dense, grey, sandy shale contains small oval plates of graphitic material that possibly represents plant remains of some kind.

On West Economy River and Peleg Brook the sediments are dark grey shales, in some places slaty. Here, as elsewhere, dips are uniformly to the south. Although Fletcher indicates the presence of fossil plant remains in this section, the writer was unable to find any material that could be identified as of vegetable origin.

Rocks of the shale group are in contact on West Economy and Economy Rivers with rocks of the volcanic and sedimentary group. Although the attitude of rocks of the shale group is everywhere quite apparent, and although the tops of the beds can occasionally be determined as right side up, similar determinations for rocks of the volcanic and sedimentary group can rarely be made. It so happened, however, that one such determination was made on a grey massive shale exposed about 1,000 feet south of the most southerly outcrop of rocks of the shale group on West Economy River. The southern rocks at this locality strike at an angle of about 30 degrees to that of rocks of the shale group, and the tops of the beds face northwest whereas those of the shale group face southeast. On the basis of this determination an east-west fault is assumed to lie between the two groups, thereby preventing the determination of their relative ages.

On East River of Five Islands, the shale group is represented by a series of dark grey, well-bedded shales, intimately cut by masses and dykes of diabase, and by minor granitic intrusion. Near the headwaters of the west branch of Beaver Brook greywacke and coarse shale are assumed to belong to the same group.

Age

No fossils were found in the shale group. Norman[1], however, in 1932 found fossils in similar rocks while mapping the Oxford area immediately to the north. These were identified by E. M. Kindle of the Geological Survey as *Monograptus?* sp., *Chonetes* sp., *Anoplotheca hemispherica,* and *Orthis tenuidens,* and the assemblage was referred to the Silurian. The writer, while working near Bridgeville in Pictou county in 1943, was struck by the close resemblance between rocks underlying the Carboniferous limestone there, rocks that have always been considered Silurian in age, and the members of this group, particularly those on the tributaries of Portapique River. A correlation with the Silurian cannot, however, be considered conclusive until fossils of the same age are discovered.

VOLCANIC AND SEDIMENTARY GROUP

Distribution

In general, rocks of the volcanic and sedimentary group may be said to underlie all those parts of Cobequid Mountains within the area that are not underlain by intrusive rocks or by rocks of the shale group. They are found on the south face of the mountains from the eastern limit of work as far west as Beaver Brook, but are succeeded by rocks of the shale group on the west branch of this brook. They extend as far north as the granite masses everywhere except on Matheson Brook, and on Economy River are found north of the Economy-Bass River granite batholith. As mentioned

[1] Norman, G. W. H.: Geol. Surv., Canada, personal communication.

previously, some narrow bands of grey shale found within the volcanic and sedimentary group may belong to the shale group, but no means of identifying them as such has been found.

Lithology

The rock types found in this group are grey-black to pearl-grey, poorly bedded to completely unbedded, fine-grained sedimentary rocks or volcanic ash beds; poorly bedded to well-bedded, grey and red shales; light grey to white quartzite or silicified tuff; chlorite schist showing varying degrees of alteration, and believed to be volcanic in origin; fine-grained, light grey conglomerate or volcanic breccia, containing pebbles or small bombs up to 5 millimetres in diameter; and black, graphitic schist. This assemblage is cut by basic intrusive rocks, many of which, if observed in isolated exposures, can only be differentiated with difficulty, if at all, from some of the rocks they cut.

Of these rocks, only the black graphitic schist has a definable area of occurrence. It has been found only near the south face of the mountains in the eastern part of the area, and is in many places, but not everywhere, the first rock encountered on entering them from the south.

Thin sections were made from a number of specimens from this group, none of which was known definitely to be from rocks of sedimentary origin. Under the microscope, those sections cut from clastic rocks indicated by the extreme angularity of their constituent grains that they were probably made from specimens of volcanic tuff. Highly chloritized rocks, generally termed "greenstone" in the field, and believed to be volcanic in origin, did not display in thin section features diagnostic of either an extrusive or a pyroclastic origin. Large, shadowy masses of variable texture and composition could be recognized in a general mass of chlorite, but whether they represented fragments in a breccia, or altered phenocrysts in a porphyry, could not be determined.

Black, graphitic schist, as previously mentioned, occurs commonly near the contact of rocks of the Cobequid complex with Carboniferous rocks on the south. The rock is very fissile, and usually very friable, almost approximating a fault gouge. Graphite, which gives the rock its colour, occurs as a thin coating on the parting planes of the schist. In no place is it exposed over a width greater than 20 or 30 feet, and is usually in contact on the north with grey, massive, sedimentary rocks. The schist is believed to represent a zone of considerable shearing in rocks originally similar to those found to the immediate north of it, and may be considered as a link in the chain of evidence favouring a fault on the south side of the mountains.

Age

The relationship between the rocks of this group and those of the shale group could not be determined. Although the rocks of the shale group dip uniformly towards those of this group, in no place is it obvious that the contact is not along a fault, and in one place, previously referred to, the evidence definitely favours a fault contact.

The writer has found no fossils in the assemblage. In similar rocks Fletcher records on his maps occurrences of fossil plant remains, but specimens from such localities observed by W. A. Bell were not determinable.[1] Detailed studies of the Nictaux-Torbrook area in western Nova Scotia by T. L. Tanton of the Geological Survey in 1932 disclosed the presence of a thick group of volcanic rocks lying near the contact of, if not between, the Devonian sediments

[1] Bell, W. A.: Geol. Surv., Canada, personal communication.

and the Gold-bearing (Meguma) series of Precambrian age. Tanton[1] believes these volcanic rocks to be associated with the Devonian rocks rather than with the Precambrian. At Nictaux and Torbrook the main batholith of Nova Scotia invades the Devonian sedimentary rocks, and because of this relationship a late Devonian age is given to these granitic rocks.

An accumulation of circumstantial evidence might be construed to indicate, first, that rocks of the shale group are Silurian, and secondly, that they are older than rocks of the volcanic and sedimentary group, both groups being older than the Cobequid granites. Similarly, it might be suggested that an analogy exists between the fossiliferous Devonian rocks of Nictaux and Torbrook, which, together with volcanic rocks at or near their base, are cut by batholithic intrusions, and the hitherto unfossiliferous sedimenatry rocks of Cobequid Mountains, which are likewise associated with volcanic rocks and cut by batholithic intrusions. The writer considers the question of the age of these rocks still unsettled.

INTRUSIVE ROCKS

Distribution

The main body of granite and granite-gneiss extends from the headwaters of Beaver Brook to a mile or so east of Gamble Lake, a distance of some 12 miles, and has a maximum width of 2 miles south of Economy Lake. A mile or so east of its eastern end, a small boss a mile in diameter is exposed on Portapique River. About 3 miles east of this, and just within the limits of the map-area, is the southernmost part of what is probably the largest body of granitic rocks in the Cobequids. This body, or the contact zones surrounding it, is exposed with few gaps along the north side of the area as far as the east boundary.

A body of aplite of unknown width outcrops on Economy and West Economy Rivers, for about half a mile above and below their confluence. A small body of similar rock was found on Economy Lake about 1,000 feet north of the granite.

Quartz porphyry and quartz feldspar porphyry, believed to be intrusive, but which may be of extrusive origin, outcrop on West Economy River and its north-east tributary, and on the outlet brook of Economy Lake.

Diabasic intrusions of varying composition are quite commonly found cutting all of the previously mentioned rocks of the Cobequid complex, but actually they are more abundant in certain districts than in others. Dykes and small bodies of these rocks appear to be most plentiful on East River of Five Islands, along and near Bass River, and from Great Village River to the east boundary of the area.

Granitic Rocks

Granite and Granite-gneiss

The largest body of granitic rocks is that extending from Beaver Brook some 14 miles to Gamble Brook, and consisting of a considerable variety of rock types. In appearance these rocks grade from coarse, massive granites to granite-gneiss; from rocks with a grain size of 10 millimetres to those of about 1 millimetre; and from pink to quite grey. In composition not as much variety is encountered, the rocks grading from alaskite through hornblende granite to granodiorite and quartz diorite. There is evidence that some, if not all, of the more basic types owe their origin to the assimilation of volcanic material by normal granite magmas. No biotite was observed in thin sections cut from rocks of this Economy-Bass River body, but it occurs in other granitic stocks in the area.

[1] Tanton, T. L.: Geol. Surv., Canada, personal communication.

Some doubt might arise as to such a variety of rock types being the product of one period of intrusion. The granite-gneiss exhibits, in each thin section made from it, ample evidence of having undergone stresses in excess of those experienced by the more massive intrusive rocks, stresses that vary in their effects from mylonitization, production of mortar structure, and even complete recrystallization; and this evidence is accepted as proof that the gneissoid rocks are not necessarily of a different age from the more massive types. On the other hand, variations in composition cannot be so easily dismissed. Microscopic evidence, which will be described later, indicates that the more basic members of this intrusive group owe their present composition to the assimilation, while molten, of basic volcanic material. Such evidence could not be found in thin sections of intermediate intrusive rocks, nor was it marked in all thin sections made from basic members of the group.

To the east of this elongated granite mass, and separated from it by little more than a mile, a small body of similar rocks is exposed on Portapique River. A typical specimen from this intrusion carried appreciable biotite, and was identified as a hornblende-biotite granite.

Some 3 miles to the east of the Portapique River stock, and along the trend of the main Economy-Bass River batholith, is the southern edge of a large granite body that continues to the east of the area, on or near its north boundary. North of East Mines a specimen was collected of a true biotite granite, the rock consisting essentially of orthoclase, oligoclase, quartz, and biotite. Rock of similar composition was not found elsewhere in the area.

Contact Effects. Surrounding most of the granite bodies in aureoles of varying widths, and in places lacking, are zones that represent either alteration of the surrounding rocks by the granite magmas or intimate admixtures of the two rock types. These were mapped as contact zones, and divided into three general classes.

The most common class is that in which granitic rocks intrude the older rocks in a plethora of dykes and sills, the individuals of which are commonly less than 100 feet across. Actually such intrusive rocks exhibit no true contact phenomena other than a decrease in grain size of the intrusive rocks, and a slight tendency to the formation of pegmatites. Usually, however, the intruded rocks exhibit phenomena of the second class type, in which granitization, either complete or partial, has occurred. Lit-par-lit injections are not uncommon in such cases, the granitic material being nearly, if not always, pegmatitic. One zone, extending from Great Village to Rockland Rivers, exhibits phenomena of this class, without, however, exposure of the responsible granite body, and apparently represents a dome-like aureole.

Contact effects of a third class were recognized in very few places, but may be much more common than can be proved. They consist of the assimiliation by granitic magmas of basic volcanic material, resulting in a rock of the appearance and general composition of a diorite or gabbro. A body of such rock surrounded by granite outcrops on the south side of Newton Lake. It was mapped in the field as a coarse diabase, but in the thin section was determined to consist essentially of coarsely crystalline actinolite containing poikilitically enclosed plagioclase and fine intergrowths of untwinned calcic oligoclase. As the occurrence is surrounded by granite, as the amphiboles are secondary, and as the rock has been recrystallized, the assumption appears sound that the origin of this rock is as outlined above.

East of Bass River, and bordering the main granite mass on its southeasterly side, occurrences were noted of what was termed in the field "fine-grained grey granite." This rock is quite massive, has a granitic texture, is finer than the main granite mass (having a grain size of about 5 millimetres), and is not exposed in contact with other granitic types or with the older rocks. Thin sections cut from the rock showed a very high proportion of actinolite, which had replaced plagioclase in places. Although much less basic in composition than the rock described from Newton Lake, it is assumed to have had a similar origin.

Aplite

Fine-grained, sugary textured, granitic rocks, essentially free of mafic minerals, were observed at a number of places in the area, but in only two localities were they extensive enough to map. On East River of Five Islands, on Bass River, on Economy Lake, and on a northeast branch of Portapique River aplite occurs as dykes and as small bodies cutting the members of the volcanic and sedimentary group. On Economy and West Economy Rivers above and below their junction aplite is exposed, with one or two interruptions, for a mile. In none of these occurrences, regardless of size, does the grain size increase to over 5 millimetres, usually is less than 3 millimetres, and the narrower dykes are aphanitic. In thin section the rocks are seen to consist essentially of feldspar and quartz, with less than ½ per cent of mafic or opaque minerals. Two stages of crystallization were apparent in most of the thin sections studied, the second stage consisting mostly of myrmekitic and micrographic intergrowths of quartz and feldspar filling the interstices between much larger crystals of orthoclase and quartz of the first stage. Other intergrowths are radiating, and many are quite haphazard in form. In thin sections cut from two aplite specimens, respectively from the Economy River intrusion and from a small body on Economy Lake, plagioclase in the intergrowths was identified as albite or albite-oligoclase. These rocks are believed to be related to the main granitic intrusions.

Acid Porphyries

No means has been found to identify these rocks as of intrusive rather than extrusive origin. They are, however, regarded as probably intrusions because they have invariably been found within areas underlain in general by rocks of the shale group, rather than by those of the volcanic and sedimentary group; and also because the porphyry bodies occupy irregular areas that do not seem to conform with those of the enclosing sedimentary rocks.

The porphyries occur in a rather extensive area lying just to the north of the area on West Economy River, on a northeast branch of this stream, and on Chain Lake Brook, extending into the area on the second of these streams. Smaller bodies were observed on the outlet stream of Economy River, and on Bass River just within the area.

Both quartz porphyry and quartz-feldspar porphyry occur, often both within the same body. The rocks consist essentially of a very fine groundmass of quartz and feldspars, containing phenocrysts of quartz or of quartz and feldspar up to 10 millimetres in size. Both orthoclase and albite have been noted as phenocrysts. The quartz phenocrysts show resorption embayments.

These rocks were in no place observed in contact with other rocks, and although their intrusive origin is accepted by the writer, it has not been established definitely.

Basic Intrusive Rocks

Fresh, diabasic intrusive rocks are found cutting members of the slate and volcanic and sedimentary groups. They are, on the whole, rather evenly distributed, but are very common on Great Village and Rockland Rivers north of the mine workings; on Bass and Folly Rivers; on Economy River, including the upper part that cuts through rocks of the slate group; and on East River of Five Islands. No diabase was observed cutting rocks of the slate group on Portapique River and its northeast branch, and diabase was rarely observed on Portapique River south of the south contact of the slate group, or on Matheson and Cumberland Brooks.

Lithology

In appearance the diabases are commonly fresh, fine- to medium-grained, dark grey to almost black rocks, and are usually quite massive. The plagioclase is commonly bytownite, nearly labradorite, but in one diabase from Economy River, where it cuts members of the shale group, it is andesine. The mafic mineral is usually an amphibole, but on Economy River, just below the junction of West Economy River, a diabase was found to contain augite, quite fresh or with only slight chloritization in places. The amphibole is usually actinolite. Almost all thin sections examined showed an ophitic or poikilophitic texture.

Age of the Intrusive Rocks

On the basis of evidence within the area mapped, the major and minor intrusive rocks are younger than those of the shale and volcanic and sedimentary groups, and older than Pennsylvanian strata lying to the south of, and in places on top of, the mountains. Mention has been made of the possibility of correlating the volcanic and sedimentary group with the Devonian of the Nictaux-Torbrook basin, which is believed to have volcanic members at or near its base. Correlation of the Cobequid granite with the granites cutting the Nictaux-Torbrook Devonian rocks, cannot, however, be considered a *fait accompli,* although further research on the age of all Nova Scotia granites may indeed verify such an assumption.

In 1925, Bell[1] found Upper Windsor fossils, including *Productus avonensis* and *Phillipsia eichwaldi,* in silicified, but not otherwise metamorphosed, argillite, on Harrington River some 7 miles west of the area and well within Cobequid Mountains. About ¼ mile south of this occurrence sheets and tongues of quartz porphyry and diabase intrude quartzites and argillites that, although they carry plant remains, cannot be correlated definitely with any age group, but resemble in many respects those rocks carrying Windsor fossils. Although this may be taken as strong evidence that at least the minor intrusive rocks are post-Windsor in age, it is somewhat nullified by Bell's observation that the dips of the Windsor rocks were much less steep than were those of the rocks cut by these intrusions. Although it is quite conceivable that the Windsor rocks are flat-lying, because they occur in the trough or crest of a fold, yet the writer considers it equally possible, if not more probable, that they represent an outlier of Carboniferous rocks on the already folded pre-Carboniferous rocks of Cobequid Mountains. Such outliers, of uncertain age, but ascribed to the Lower Pennsylvanian, occur within the area mapped and will be described later. Also, it may be considered quite possible that the minor intrusions of Cobequid Mountains are much later in age than are the batholithic intrusions, and may indeed be, and cut rocks whose age is, Carboniferous.

Alcock[2], in the Saint John area of New Brunswick, found small granitic bodies intruding the Mispek group, of Pennsylvanian or Mississippian age, usually in the form of sills. Major granitic intrusions in the same area are ascribed res-

---

[1] Bell, W. A.: Geol. Surv., Canada, personal communication.

[2] Alcock, F. J.: Geology of Saint John Region, N.B.; Geol. Surv., Canada, Mem. 216, pp. 35-36 (1938).

pectively to the Devonian and to the Precambrian. As there would appear to be some foundation for an assumption that Cobequid Mountains are more closely related geologically to the highlands of southern New Brunswick than they are to the rest of Nova Scotia, such age determinations in the Saint John area should be regarded with interest. Such a comparison would immediately support the possibility that the minor intrusions, particularly the acid porphyries, are later in age than are the main batholithic intrusions.

In summary, the main batholithic intrusions of Cobequid Mountains may be tentatively ascribed to the Devonian, and a similar, or Carboniferous, age may be admitted for the minor intrusions.

HORTON GROUP

Distribution

Rocks of the Horton group were recognized only on the south side of Cobequid Bay and Minas Basin, where they are exposed in a belt of varying width between the overlying Triassic sediments or the sea on the north and the overlying Windsor sediments on the south. This belt of Horton sediments, which has been termed by numerous writers the "Walton anticline", is about 1 mile wide at the mouth of Tennycape River, and gradually expands to a width of about 5½ miles south of Stirling Brook.

Bell, in his monographic description of the Mississippian of central Nova Scotia[1], divides the Horton into two formations, a lower, the Horton Bluff formation, consisting of dark grey, arenaceous and argillaceous shales and grey, feldspathic sandstones and grits; and an upper, the Cheverie formation, consisting of grey arkose and red shale. Bell admits the impossibility of everywhere separating these formations, and the writer concurs inasmuch as only in the very excellent and well exposed section on Tennycape River could the approximate boundary be established, and there the separation was made mainly on lithological grounds, although it was verified by floral remains. For this reason, the two formations are not indicated separately on the published map. Those Horton beds in contact to the south with rocks of the Windsor group may be safely assumed to be of Cheverie, or Upper Horton age, but not all rocks on the north side of the belt are Lower Horton, as there is reason to believe that Cheverie rocks are exposed just south of the Triassic in the vicinity of Densmore's Mills.

Lithology

In describing the lithological characteristics of rocks of the Horton group, necessity demands that the description be based more on geographical than on stratigraphical positions, a demand that is much more insistent in the broad easterly extension of the Horton belt, with its widely scattered and generally poor exposures, than it is in the western part, which is narrower but includes a few excellent sections.

The section at Tennycape, already mentioned, lies between the contact of the Horton with the unconformably overlying Triassic, about halfway between the highway bridge and Cape Tenny in the estuary of Tennycape River, and the contact of the Horton with the apparently conformably overlying Windsor rocks on Tennycape River about a mile south of the highway bridge. The northern half of this section, provided it is examined at low tide, is mostly exposed, but the southern part is concealed at intervals. About 600 feet south of the highway

[1] Bell, W. A.: Horton-Windsor District, Nova Scotia; Geol. Surv., Canada, Mem. 155 (1929).

bridge a synclinal axis, along which some faulting has occurred, is exposed, and 600 feet farther south is an anticlinal axis. It is proposed to give a detailed description of the section from its most northerly exposures, just south of the Horton-Triassic contact, to the synclinal axis. Farther south the section is faulted and incomplete, and details would be relatively meaningless. In the following description the thicknesses of beds given are true thicknesses, and are based on a survey made with a steel tape.

Section South and Southwesterly along East Side Tennycape River and Estuary from Most Northerly Exposure of Horton Rocks

Item	*Description*	*Thickness* Feet
1.	Shales, fine-grained, grey; with some slates	70
2.	Slate, black, graphitic; with thin beds of grey shale	70
3.	Paper shales, black, graphitic	25
4.	Slate, black, graphitic; in bands 1 inch to 9 inches wide separated by beds of grey shale 6 to 9 inches wide	4·5
5.	Paper shale, black, graphitic	26·5
6.	Slate, black, graphitic, or paper shale interbedded with grey shale, the latter predominating in bands up to 1 foot wide	10·5
7.	Slate, black, graphitic	14
8.	Slate interbedded with black, graphitic shale and with grey shale	18
9.	Slate, black, graphitic	11
10.	Shale, grey, thick bedded	27
11.	Slate, black, graphitic, with concretions about 1 foot in diameter, together with a few thin beds of grey shale	42
12.	Shale, grey	4·5
13.	Slate, black	14
14.	Shale, grey, with thin interbands of black slate	16
15.	Slate, black, graphitic	16
16.	Shale, grey	6·5
17.	Slate, black	14·5
18.	Shale, light grey to rose-grey and buff	19
19.	Slate, black	24·5
20.	Limestone, grey	1
21.	Slate, black	39
22.	Shale, grey	23·5
23.	Slate, black	18
24.	Shale, grey, calcareous	3·5
25.	Slate, black	30
26.	Arkose, light buff to pink, grain size up to 1¼ millimetres; contains quartz and orthoclase	18
27.	Slate, black	13
28.	Arkose, light buff to pink	35
29.	Slate, grey	15
30.	Arkose, light buff to pink	2·5
31.	Concealed (concealed areas are measured stratigraphically on the basis of dips at their ends)	87
32.	Shale, black, graphitic, paper	27
33.	Slate, black, with thin beds of grey shale	22
34.	Slate, black; differs inasmuch as the thin beds of grey shale are slightly more numerous	30
35.	Concealed	84
36.	Shale, grey; with a few inches of black slate next to item 35	1·5
37.	Slate, black, graphitic	32
38.	Slate, black, with beds of grey shale	37
39.	Sandstone and arkose, ripple-marked, grey	6
40.	Slate, black, with beds of grey shale	9
41.	Arkosic sandstone, fine, with thin beds of conglomerate	13
42.	Slate, black, and black shale	3·5
43.	Concealed	25·5
44.	Slates and shales, black and grey, slatiness decreasing upwards	108

Item	*Description*	*Thickness* Feet
45.	Sandstone, coarse, grey to pink, with narrow bands of conglomerate with 5-millimetre pebbles; some feldspar grains	11
46.	Shales, grey, with some slate	11·5
47.	Small drag-fold, and passibly a fault	3
48.	Shales, grey, and slates	39
49.	Fault in contorted shales and slates; displacement believed to be small and to fault out part of the section.	
50.	Slate and shale, grey	71
51.	Closely folded minor synical axis; item 52 goes downward stratigraphically (*See* Plate II A).	
52.	Slate and shale, grey	11
53.	Closely folded minor anticlinal axis; items 54 to 78 go upward stratigraphically.	
54.	Shales and slates, grey	76
55.	Concealed	31
56.	Shales and slates, grey, poorly exposed	69
57.	Slate, black, graphitic	2
58.	Concealed	116
59.	Shale, grey	15
60.	Strike fault; item 59 moved east, relative to item 61; vertical displacement, if any, unknown.	
61.	Sandstone, fine, grey, thin bedded, becoming coarser upwards	50
62.	Sandstone, grey, of variable grain with beds of mudstone less than 1 foot thick	32
63.	Sandstone, hard, massive, with thin bands of conglomerate carrying quartz pebbles up to 3 millimetres in size	19·5
64.	Sandstone, coarse, red, mostly 1 millimetre in grain size, but carrying pebbles up to 5 millimetres in diameter	5
65.	Sandstone, hard, grey	7·5
66.	Shale, grey, sandy, becoming less sandy upwards	15
67.	Sandstone, fine and coarse interbedded	8
68.	Sandstone, with thin beds of shale, grading upward to shale with thin beds of sandstone	14
69.	Sandstone, fine, friable, with some quite coarse beds and a few beds of sandy shale.	38
70.	Shale and sandy shale, fine, grey	32
71.	Sandstone, grey.	24
72.	Sandstone, coarse, friable, reddish, with ferruginous cement	26
73.	Shale, grey.	39
74.	Sandstone, coarse, reddish.	52·5
75.	Brecciated zone, but no fault plane visible	8·5
76.	Sandstone and sandy shale; overturned here	50
77.	Shale, grey, grading upward into fine, sandy shale	38
78.	Sandstone, massive.	15
79.	Synclinal axis and a strike fault, direction and amount of displacement unknown.	

(Structure section C-D shown on the Bass River map (No. 867A), although drawn about a mile east of the Tennycape River section, is nevertheless based upon this description.)

With the exception of item 52, the tops of all the beds face south. The sum of the above thicknesses is 2,107·5 feet, from which should be subtracted twice the thickness of item 52, leaving a stratigraphic thickness of 2,087·5 feet in this section. To tie the section geographically, the south side of the west end of Tennycape wharf is at the north side of item 32; and the south side of the highway bridge is vertically over the north end of item 59. It should be mentioned that the difference between black, graphitic slate and black, graphitic paper shale is one of degree only, depending on the thickness of the cleavage plates, and, commonly, where one term is used for an entire item the other term might well have been used for parts of it.

About 550 feet stratigraphically south of the syncline and fault in item 79 is an anticline, south of which the beds again face south and apparently continue to do so until they dip under Windsor beds about 2,000 feet stratigraphically above the anticline. That the fault in item 79 is of some magnitude is suggested by the fact that of five sandstone beds north of the syncline that might be expected to recur between the two folds, only three do so.

In the 2,000 stratigraphic feet between the above-mentioned anticline and the Windsor beds to the south considerably less than half of the complete section is exposed. Grey, ripple-marked sandstones and sandy shales predominate, and brownish mudstones are often interbedded with them. The latter rock appears devoid of bedding, and is usually broken into small angular pieces that may easily be pried loose from the mass. Some of these mudstones are so unconsolidated that when mixed with water they are easily ground into mud. At one or two places considerable brecciation, accompanied in one instance by drag-folding, suggests that faulting has occurred, but the fault planes were not visible.

At the contact with Windsor beds, the Macumber formation quite conformably overlies a fine-grained, reddish to grey, platy sandstone or arenaceous shale, and these characteristics also apply to the topmost Horton beds exposed at the Scott, Faulkner, Tennycape, and Stephens manganese mines, where in each case the ore was found near this contact.

The base of the Cheverie formation cannot be located with accuracy, and indeed it is doubtful if the contact between the Horton Bluffs and Cheverie formations is other than gradational, but it is probable that the contact lies at or near the bottom of item 26, the lowest arkose bed. Therefore, in the measured section 532·5 feet of sediments belong in the lower, or Horton Bluffs formation, and 1,555 feet in the upper or Cheverie formation. Taking into consideration the 550 feet of sediments between the anticline and the syncline on Tennycape River and subtracting twice that thickness, or 1,100 feet, from the total, and without considering the possible effects of faulting, there would appear to be about 3,000 feet of Cheverie sediments in this entire section, underlain by an unknown thickness of Horton Bluffs sediments, of which 532·5 feet are exposed south of the Triassic (Annapolis formation).

As must be apparent from the above section, recognizable horizon markers are lacking. The presence of arkose in a section would suggest that it and the rocks above it are of Cheverie age, but arkose is found only in a narrow belt paralleling the highway (and the Triassic contact) and extending about ½ mile south of it, from Densmore's Mills to Lower Selmah, occurring on Shad Brook, King Creek, Mungo Brook, and on two of the unnamed four brooks to the east of the latter. Between this belt and the Windsor beds to the south the Horton has its greatest width, some 4½ miles, and could it be proved that the beds dip continuously to the south throughout, a Cheverie age could be assumed for almost all the Horton in the area. But this area of greatest width unfortunately has few rock exposures, and the underlying structures are, consequently, imperfectly known. Black slate and paper shales are not diagnostic of the lower Horton, and from the Tennycape section, they do not appear to occur in the upper parts of this group. Their almost complete absence from inland rock exposures may, however, be due to the fact that they are among the softest and most easily eroded rocks in the area, and might, consequently, be present in considerable thickness without being exposed.

Rock exposures are fairly plentiful along East Noel River for 1½ miles upstream from the shore highway, and this section is probably the best in the area except for the Tennycape section. With the exception of a bed of red, shaly mudstone, 70 feet thick, about ½ mile south of the highway, all the exposed beds are grey, and range from fine shales to sandy shales.

The section on Mungo Brook, although composed of smaller outcrops more poorly exposed than those on East Noel River, extends farther south and, presumably, higher stratigraphically. Here, although the beds are predominantly grey, are some red shales and sandy shales, and on the east fork of the river is the only observed outcrop of black paper shale not otherwise noted near the Tennycape section. Nearby this paper shale are some massive, black, carbonaceous shale beds that may be related to an exposure of low-grade coal on Selmah Brook, and which will be discussed in a later chapter. They may well be correlatives of the black slates in the Tennycape section, but are quite different in appearance, lacking the fine slaty partings of the latter.

Near the Windsor contact, on streams flowing southerly into Fivemile River south of the area, the Horton rocks are usually a reddish, often micaceous, sandy shale, and similar rocks are found just north of the Windsor contact in a down-faulted block near the village of Selmah.

Where the Horton belt expands to its greatest width, south of a line joining Densmore's Mills and Stirling Brook, the dips of the beds decrease considerably as the Windsor contact is approached, dips of less than 10 degrees being quite common, and in a few places the beds are horizontal. Rocks on the northern side of this area of greatest width are comparatively steeply folded, and are believed, as was mentioned before, to be upper Horton in age. Although rock exposures are almost lacking in the middle of this belt, it is quite possible that the unusual width of the Horton rocks may be due to the flattening of the beds to the south, and not entirely to repetition by folding.

A short distance west of the Tennycape mine is a northwest-trending fault, originally located by Hugh Fletcher, in which the movement has been downward on the northeast side. Very few exposures of Horton rocks occur between the Tennycape River section and this fault. The Parker mine lies in a syncline of Windsor rocks in Horton shales, a syncline that if produced eastward to the Tennycape River section would probably underlie the Triassic rocks. West of the Tennycape mine fault, exposures on Rennie and Wilcox Brooks are grey shales and slates with steep dips to the north, underlain on the first-named brook by an arkosic quartzite of granitic detritus. North of the highway on these two brooks, and in the coves at their mouths, several small, closely spaced folds are visible (*See* Plate III).

Age

The Horton is of Mississippian age, and in Nova Scotia is the oldest Carboniferous group. It is succeeded by the Windsor group, also of Mississippian age, in apparent structural conformity. Bell[1] is of the opinion that the break between the Horton Bluffs and Cheverie formations is of greater importance faunally, even though gradational in character, than the break between the Horton and the Windsor groups.

WINDSOR GROUP

The Windsor group comprises a series of soft, marine sediments, which occur in a number of infolded basins of older rocks in central and eastern Nova Scotia. South of Cobequid Bay, Windsor rocks extend almost completely across the area, being bounded on the north by the uppermost Horton beds. North of Cobequid Bay, lower Windsor rocks occur surrounded by Triassic at Glenholme, and upper Windsor limestone protrudes through Riversdale beds at Upper Economy. The Lower Windsor has been divided into five formational units, which will be described separately.

[1] Bell, W. A.: Op. cit., pp. 44, 45.

MACUMBER FORMATION

Definition

The name Macumber is proposed by the writer for a formation of well-bedded, grey to buff, fine limestone overlying conformably the topmost sandstones and sandy shales of the Cheverie formation, and underlying with apparent structural conformity, but with slight evidence of an erosional break, a massive red limestone conglomerate of the Windsor group for which the name Pembroke formation will be proposed.

Distribution

Rocks of the Macumber formation have been traced from east to west across the two map-areas, a distance of 24 miles, and in addition have been observed at several scattered localities to the west, the most distant being the Macumber manganese mine at Cheverie, 14 miles west of the area. East of the Macumber mine, and west of the area, rocks of this formation were noted at the Feuchtwanger manganese mine, south of Pembroke, at the Stephens manganese mine at Walton (west of the village), and at the Jennison manganese pit at Walton (east of the village). At the Pembroke barite quarry, situated about halfway between the Feuchtwanger and Stephens manganese mines, and on the same general stratigraphical horizon, the Macumber was lacking in places, but numerous angular fragments of it occurred near the base of the overlying Pembroke limestone conglomerate. Within the area, the formation has been traced, by scattered exposures, from the Tennycape manganese mine to a point south of Minasville. Farther east, no exposures were recorded for 8 miles, where the Macumber was observed just east of Hennigar. From this point to the eastern boundary of the area scattered exposures leave very little doubt as to its continuity.

General Description

Lithologically the Macumber formation is readily recognizable. Its excellent bedding, with an easy parting along the bedding planes, together with its high lime content, distinguish it from all of the non-calcareous Horton rocks and from most of the Windsor limestones. Although in colour it varies from buff to grey, yet these distinctions are subtle; the bluff might be described as a light brownish grey, whereas the grey is much lighter in tone than is common in grey shales.

At the Macumber mine, red and grey Horton sandstones and sandy shales are overlain by 6 feet of red clay or mudstone, also referred to the Horton, and this member is succeeded by the Macumber formation, which has a thickness of 6 feet. Above the Macumber beds, at the base of the succeeding Pembroke formation, is a zone of indeterminate thickness consisting of angular blocks from the Macumber formation, cemented together by the reddish massive limestone of the Pembroke limestone conglomerate. At the base of this zone some fragments of Macumber rocks are 10 feet across, but less than 20 feet stratigraphically above it they have become a minor constituent of the conglomerate.

As mentioned above, the Macumber formation is lacking at the Pembroke barite quarry, although it is represented by fragments in the Pembroke conglomerate and is exposed a few hundred yards to the southeast of the quarry. Some 2 miles east of the quarry, at the Stephens manganese mine, the Macumber has a thickness of 25 feet in the No. 8 open-cut, the only place at this mine where both the top and bottom of the formation are exposed. Here, as at the Macumber mine, the base of the Pembroke formation contains numerous angular fragments of Macumber rocks, but these are usually only a few inches across, with a maximum size of perhaps a foot.

At the Tennycape mine the Macumber has a measured thickness of 16 feet, and again many angular and subangular fragments of it are present near the base of the overlying Pembroke formation.

East of the Tennycape mine no measurement of the thickness of the Macumber formation could be obtained, but it is believed to be in keeping with those made to the west, including the possibility that, as at the Pembroke quarry, the formation may be lacking at one or more localities.

Age

In the Windsor district, some 30 miles southwest of the area, Bell describes the lowermost member of subzone A of the Windsor group in terms that leave very little doubt but that it is the Macumber formation. In that district, as in this, the formation is non-fossiliferous. There is evidence, some of which has already been presented, that an erosional interval followed the deposition of the Macumber, and as this formation rests quite conformably on the Horton, it might be suspected that it represented the top of the Horton rather than the base of the Windsor, and that the Horton-Windsor contact lay at the top of the Macumber. In at least one locality the Macumber has either been removed entirely, or, which is less probable, was not deposited there. In all localities fragments of easily recognizable Macumber rocks occur in the overlying Pembroke conglomerate. Against this possibility, however, is the angular to subangular form of all the fragments found in the Pembroke, the fact that even the largest blocks of Macumber cemented together by Pembroke limestone have no fine detritus of Macumber material between them, and the complete lack of limestone in the strata of undoubted Horton age, whereas such rocks are exceedingly common in those of the Windsor group. This would suggest that the forces breaking up the Macumber were violent and short-lived, possibly occurring beneath the surface of the Pembroke sea. The writer, therefore, in the absence of definite contrary proof, accepts Bell's age of lowermost Windsor for strata equivalent to the Macumber formation.

PEMBROKE FORMATION

Definition

The name Pembroke is proposed by the writer for a formation of massive, red to grey-brown limestone, finely to coarsely conglomeratic in places, and containing lenticular beds of calcareous sandstone and mudstone. It overlies the Macumber formation and underlies the lowermost of the Windsor gypsum and anhydrite beds.

Distribution

The Pembroke has been traced for the same distance as has the Macumber, namely, from the Macumber mine at Cheverie to the eastern boundary of the area. In addition, it has been recognized in the Windsor outlier that protrudes through the Triassic rocks near Glenholme, and at a manganese mine about 6 miles east of Truro and some 25 miles east of the area.

In the eastern part of the area, where the Windsor lies in a synclinal basin in the valley of Fivemile River, the Pembroke does not outcrop on the north limb of the syncline, but its presence is indicated by good exposures on the south limb.

General Description

The best section of the Pembroke formation is that supplied by the drill core of hole No. 15 of the Pembroke barite quarry, which is the only hole that commenced above the upper contact of this formation. This section shows more sandstone than was found in these beds either east or west of Pembroke but as all or most of it is quite calcareous, and as the most calcareous parts of the Pembroke usually contain pebbles or grains of siliceous rocks, these calcareous sandstones might be regarded as parts of the formation in which the proportion of lime to siliceous grains is lower than usual. No calcareous clay or mudstone was found in the core from the drill hole at the Pembroke quarry, but it may have been present in parts of the section that yielded no core. Although this drill hole did not reach the lower contact of the Pembroke, yet the position of this contact may be computed with fair accuracy from its location in three adjacent holes, Nos. 5, 6, and 7A. The computed position in hole No. 15 is 1 to 10 feet stratigraphically below the bottom of the hole. The section of Pembroke beds in this drill hole is given below, in normal sequence.

Description	*Thickness*[1] Feet
Gypsum or anhydrite	15·5
Sandstone, buff; veinlets of gypsum	1·6
Gypsum (including a cavity in gypsum)	8·25
	25·3
Pembroke Formation	
Limestone conglomerate, brown	3·5
Core missing	6·0
Limestone conglomerate, brown and red	10·1
Sandstone, calcareous	1·3
Limestone conglomerate, grey	25·0
Sandstone and conglomerate, calcareous	13·8
Limestone conglomerate	0·9
Core missing	4·3
Sandstone, brown, calcareous	6·0
Core missing	2·6
Sandstone, brown, calcareous	6·9
Core missing	1·6
Limestone conglomerate, sandy	5·2
Core missing	3·5
Limestone conglomerate, sandy	2·6
Sandstone, brown, calcareous	2·2
Core missing	3·9
Sandstone, coarse, brown, calcareous	3·5
Sandstone, fine, brown, calcareous	1·6
Core missing	1·6
Limestone, brown	0·9
Core missing	3·0
Bottom of hole	
Computed depth of Horton-Windsor contact, stratigraphically below bottom of hole, probable figure taken	5·0
	115·0

At the Stephens manganese mine, on the west side of Walton River at Walton, the basal beds of the Pembroke are exposed. They consist of coarsely

[1] The thicknesses given above are computed from the drill intersections on the basis of a 30-degree dip to the beds.

crystalline limestone containing angular fragments of the Macumber formation, and rounded pebbles and grains of older rocks, most of which are believed to be derived from pre-Carboniferous formations. The limestone conglomerate is buff to red weathering, usually reddish on a fresh surface. The included rounded pebbles consist of granite, vein quartz, red, sandy shale, which is possibly derived from Horton rocks, thinly bedded, grey slate, grey quartzite, and slightly silicified sandstone, the last also possibly a Horton derivative.

At the Tennycape manganese mine, the Pembroke formation is a red-brown to buff conglomerate consisting of a fine, massive, limestone matrix containing fragments, usually angular, of Macumber rocks ranging in size from ½ inch to 2 inches, and rounded pebbles or grains of pre-Macumber rocks up to 1 millimetre in size. Sixty feet stratigraphically above the base of the Pembroke is a bed of dull brown, unbedded, calcareous mudstone, of unknown thickness, but not less than 6 feet. The top of the Pembroke is not exposed on this property, but at one time the overlying gypsum bed could be seen in an area now covered by the mine dump. Taking into consideration all factors, including the present extent of the dump, the Pembroke at Tennycape mine has a thickness of less than 350 and more than 66 feet.

At the Faulkner and Scott mines the Pembroke consists of reddish limestone conglomerate, the fragments in which are largely derived from the Macumber formation. The thickness at the Faulkner mine, on the basis of widely separated exposures, is less than 400 feet and in excess of 50 feet.

South of Morton Reynold's farm at Minasville, the base of the Pembroke had been quarried as a source of lime. Here only 6 or 8 feet of the formation is exposed, and consists of a coarse, boulder conglomerate cemented by a grey to red-grey limestone. The boulders are well rounded, up to 6 and 8 inches across, and consist mostly of vein quartz and quartzite, whether the latter is derived from the Horton or the Precambrian Gold-bearing group could not be ascertained, but the presence of vein quartz suggests that all were derived from the latter. No fragments of Macumber rocks were visible in the conglomerate, and it is quite possible that the Macumber is missing in this vicinity.

With the exception of small exposures near a road running northeast from Hennigar, and on an abandoned farm 2 miles to the southeast, the Pembroke does not outcrop for some 15 miles east of the Minasville exposure. In the valley of Fivemile River the Pembroke is exposed on the south limb of a syncline occupying that valley, and there consists of a greyish conglomerate of pebbles from pre-Windsor rocks and angular fragments of Macumber rocks in a matrix of grey to red-grey limestone. The thickness cannot here be determined with accuracy, owing to the lack of dip determinations, even though both top and bottom are exposed at points a half mile apart along the strike, but it does not appear to be at variance with values obtained farther west.

A small exposure of what is believed to be Pembroke conglomerate was observed in the bed of Debert River, beneath a bridge about half a mile south of the highway. The rock is a red-grey limestone containing fragments of a shaly limestone, on the basis of which the correlation was made.

LOWER SULPHATE BED

Overlying the Pembroke formation, and underlying the Tennycape formation, is a bed of anhydrite and gypsum that can be traced from the Pembroke barite quarry to the eastern limit of the area. Although it was not seen in the limited Windsor section on Debert and Folly Rivers, north of Cobequid Bay, yet Fletcher on his map indicates its presence there by the gypsum symbol, which may represent an observed exposure, or may represent karst topography, which he believed to be due to gypsum. The writer, however, observed neither exposures nor any signs of karst topography, so that this sulphate member is omitted from this northern section, even though both the Pembroke and Tennycape formations were recognized there. In the Selmah fault block, the presence of the sulphate bed is indicated by several exposures and some very excellent karst topography.

Although almost all exposures are gypsum, yet the bed is believed to consist primarily of anhydrite, and to be altered by surface waters to gypsum in zones whose extent and trend are governed by the extent to which it is accessible to ground-water circulation. The bed is about 100 feet thick on Fivemile River.

Karst Topography

Although karst topography is well known as a surface manifestation of gypsum and limestone beds, yet, as the gypsum beds, and by inference their accompanying formations, were traced, often in considerable detail, for miles across the area without encountering any exposures, some mention should be made of the forms encountered and what was accepted as a surface expression of underlying sulphate beds.

The sulphate beds were traced by running a plane-table traverse along one side of a bed, and from this a series of pace and compass traverses north and south across the bed in lines spaced about 500 feet apart. Although these traverses were begun with the intention of locating type examples of karst topography, it soon became apparent that many less perfect forms, particularly when found in juxtaposition with each other or in conjunction with the occasional outcrop of gypsum, had almost as much merit in delimiting the boundaries of the sulphate beds as did the ideal examples, which are rare.

The topographical expression of a sulphate bed depends on two variables, the depth of the water-table and the thickness of the overburden. Typical karst topography is encountered only where the water-table is low, permitting rapid vertical descent to rain water, and where the overburden is thin or, as in some places, lacking. Such forms are found on the second sulphate bed due south of Minasville, south of the old O'Brien quarry 1 mile west of Noel Lake, on the Hennigar-Densmore's Mills road about a mile north of Hennigar, and on the banks of Fivemile River. In all these localities the water-table is in excess of 20 or 30 feet below the surface, and rain water passed quickly downwards through fissures that continually enlarged, forming funnel-shaped chimneys commonly with a narrow ridge of gypsum between them. Such drift as overlay the bedrock will be found at the bottom of the chimney, and if excessive will fill the chimney and thus eliminate the expression of this form. In areas of such deep drift the topography is distinctly knobby. The chimneys are filled with glacial debris, but this debris has sunken 10 to 15 feet, leaving the till, which is still supported by the inter-chimney ridges, at that much greater elevation. Occasional exposures are bared on the sides of these depressions near the bottom.

With a decrease in the depth of the water-table, and a corresponding decrease in the rapidity of vertical circulation, the chimneys become bowls, and finally, in places where the water-table reaches the surface, solution may lower the level of the gypsiferous belt as much as several feet below the terrain of the adjacent rocks. This latter feature was noted with some reserve, and in no instance was regarded as proof of the presence of gypsum without the corroborating evidence of a more acceptable topographic form or an exposure.

As a rather massive limestone formation underlies the sulphate bed on its north side, it might be supposed that some of the more northern topographic forms, which have been accepted as evidence of the continuity of the sulphate rock, were in reality formed by solution of the limestone. Particular attention was paid to this limestone, and in no place was any solution form suggestive of the presence of anhydrite or gypsum encountered, and only one instance of large-scale solution found. At the Faulkner manganese mine, situated about 1,000 feet from and 150 feet above Tennycape River, a bowl-like depression 15 feet deep and 40 to 60 feet across, with a subterranean outlet, was found in the limestone of the Pembroke formation.

All in all, karst topography was found to be a very useful tool in tracing beds across country where outcrops are scarce and lacking for long distances.

TENNYCAPE FORMATION

Definition

The name Tennycape is proposed for a formation of soft, red, fine, sandy shales overlying the lowermost sulphate bed of the Windsor group in the Avon-Shubenacadie River district. The formation is believed to be overlain by the second sulphate bed of the Windsor.

Distribution

Rocks of this formation have not been traced or observed beyond the limits of the mapped area, and within the area are believed to be continuous from the eastern limits to south of the Tennycape manganese mine. In the Selmah fault block, although not observed, they are assumed to overlie the sulphate beds, and they occur in the Windsor outlier on Folly and Debert Rivers.

Because of the very soft nature of these sediments exposures are rare, and are limited to the bed of Tennycape River, where the only fair section is exposed, to the bed of Fivemile River and one or two tributaries, and to the Glenholme district where they occasionally form cliffs on Folly and Debert Rivers and also are exposed by excavations for the highway.

General Description

The most outstanding characteristic of the rocks of this formation is their uniformity in composition, grain size, and appearance. Although they protrude through the Triassic rocks in the Glenholme district, and although the latter often displays very fine, red, sandstone facies, yet no difficulty is encountered in distinguishing the two formations, as no oversized grain has ever been found in the Tennycape rocks, and even the finest Triassic sandstones contain many oversize grains.

Although the colour of the Tennycape formation is referred to as red, grey rocks may also be observed, but are believed to be due to later reductive processes, as in many instances the colour was found to apply to irregular masses and not to any definite bed.

The bedding is usually quite apparent, but not due to banding nor variation in grain size. The rock parts easily into tabular blocks, and although joints also cross the bedding planes at an angle, little difficulty is experienced in determining which is which. The jointing is usually separated by open fractures, whereas bedding planes are incipient partings along which the rock will separate under the impact of a hammer blow.

Most of the exposures are under water, occurring in the beds of streams, and usually in the slower parts of a meandering stream. This is due to the fineness of the grain size and to the fact that the rocks do not break down into debris but wear away on the surface into material of such fineness that spring freshets are quite capable of removing all of it. Such exposures are, of course, continually saturated, and a fragment squeezed in the hand will be forced through the fingers as a fine mud. If the normal rock is dried, however, no amount of soaking thereafter will cause it to behave in this fashion.

The unsatisfactory, but, nevertheless, best available section on Tennycape River would indicate that the Tennycape formation is at least 600 feet thick, and that this figure is close to the total.

The formation was not observed by Bell in the Windsor area. In age it would overlie item (a) of subzone A of the Lower Windsor[1].

SECOND (?) SULPHATE BED

About 2 miles south of Moose Brook and Minasville are exposures and topographic expressions of a flat-lying bed of anhydrite and gypsum, which, as indicated by two exposures about 100 feet apart, overlies the Tennycape formation. Some doubt must be expressed, however, whether this superposition is due to stratigraphic conformity, or whether this sulphate bed is the lower one thrust on top of the Tennycape.

The two exposures mentioned occur on Robinson Brook, one of flat-lying Tennycape shale in the bed of the stream, the other of gypsum in an almost vertical cliff rising above the stream a short distance south. Although no bedding is visible in the sulphate beds, yet their configuration to the contours indicates that they also are flat-lying. No deformation or other indication of the presence of a fault between these formations is apparent, suggesting that the two rock types constitute a normal stratigraphic succession.

Against this, however, is the presence, just south of the east side of the area, on Fivemile River, of a grey limestone that apparently overlies the Tennycape without any intervening sulphate bed. Also there is the fact that both the sulphate bed and the Tennycape formation consist of rocks that with saturation by water would become greasy or soapy, and might easily permit an overthrust of major proportions to take place without any appreciable deformation of the involved rocks.

On the other hand, it is not to be supposed that the sulphate beds have the continuity of clastic sediments. The lowermost sulphate bed, although continuous across the southern part of the area, is believed to be lacking in the Glenholme district, and it is quite possible that the second bed, although of considerable thickness south of Minasville, does not occur in the section at Fivemile River. The writer believes that this is so, and that the grey limestone observed south of the area on Fivemile River overlies the Tennycape rocks without an intervening sulphate bed.

UPPER WINDSOR

Hennigar District

On the farm of Albro Miller, Hennigar, a small quarry is excavated in grey, almost massive, fossiliferous limestone. Near the road west from Hennigar is an exposure of grey, well-bedded, non-fossiliferous limestone, and just south of a farm 3 miles east of Hennigar, and reached by a road from Upper Kennetcook, are exposures of red and grey limestone. None of these limestones was

[1] Bell, W. A.: Op. cit., p. 46.

encountered in the lower Windsor sections to the east and west, and they occur a relatively short distance south of the lower sulphate bed of lower Windsor age.

Fossils from the Albro Miller quarry were examined by Bell, who determined the following species:[1] *Pugnax dawsonianus* (Davidson); *Productus (Diaphragmus) tenuicostiformis* Beede; *Martinia galataea* Bell; *Productus lyelli* Verneuil; *Productus subfasciculatus* Bell; and *Dielasma davidsoni* (Hall and Clarke). From these Bell considers the age of the rocks to be early upper Windsor.

With the exception of those obtained from the Albro Miller quarry, no identifiable fossils were found in the other enumerated exposures, but as those rocks do not fit into the known lower Windsor sequence, and as they can be geographically a unit, they are included in the upper Windsor. An assumed fault is shown on Map 874A between the lower and upper Windsor, no basis for which was observed other than that a considerable part of the lower Windsor section is missing between the two groups and may be best explained by the presence of a faulted contact. Further work to the south of the area would probably give considerable information on the relationships between these two sub-groups.

Upper Economy District

Beds varying in composition from quite massive, grey, granular limestone to thinly bedded, grey, shaly limestone protrude through the Pennsylvanian rocks north of Upper Economy, and are quarried at one place on the road from there to Pleasant Hills. A collection of fossils from near the Pleasant Hills road was submitted to Bell at the same time as those from Hennigar. He identified *Camarotoechia atlantica* Bell; *Buxtonia cogmagunensis* Bell; and *Bellerophon* sp.; and considered the age to be late upper Windsor.

PENNSYLVANIAN

BASAL PENNSYLVANIAN

Throughout most of its length within the area mapped the south face of Cobequid Mountains is the topographical expression of a fault by which the older, mountain sediments and extrusives have been lifted relative to the Pennsylvanian rocks to the south, but at the extreme east and extreme west of the area rocks believed to be of Pennsylvanian age rest with a large angular unconformity directly on rocks of the Cobequid complex.

On Folly River the contact is exposed within 6 feet, and the base of the Pennsylvanian sediments to the south is composed of a conglomerate consisting largely of fragments, angular to subangular, of greenish volcanic rocks, similar to those in situ north of the contact, embedded in a finer chloritic matrix, probably derived from the weathering of the same rocks. The conglomerate, containing pebbles of diorite, granite, quartz, and greenstone, extends for 1,000 feet south of this contact to a visible fault, movement along which has resulted in a sheared and broken zone 100 feet wide. South of the fault the rocks are brown sandstones and conglomerates, similar to those found in juxtaposition with the Cobequid complex along most of the south face of the mountains.

On the high ground bordering Folly River on its west bank, and about ½ mile north of the contact between rocks of the Cobequid complex and the Pennsylvanian conglomerate described above, a small area of flat-lying grey

[1] Bell, W. A.: Geol. Surv., Canada, personal communication.

conglomerate is exposed in a railway cutting. Although the contact of this conglomerate and the rocks of the Cobequid complex that surround it are not exposed, yet the attitude of the conglomerate relative to the steeply dipping Cobequid rocks nearby leaves very little doubt but that the conglomerate is of Carboniferous or later age.

Both this outlier of conglomerate and the conglomerate lying unconformably against the south face of the mountains are believed to be representative of the lower Pennsylvanian beds. The fault, which along the south side of most of Cobequid Mountains separates the pre-Carboniferous from later, Pennsylvanian rocks, here lies to the south of the basal Pennsylvanian beds, separating them in turn from younger Pennsylvanian sediments.

Flat-lying conglomerate, overlain by brownish sandstone, is also exposed on the eastern tributaries of Portapique River, and in one locality overlies steep-dipping sediments of the Cobequid shale group. These rocks are also believed to represent the earliest period of Pennsylvanian deposition.

At the extreme west of Bass River map-area an unconformable overlap between grey conglomerate and pre-Carboniferous sediments may be observed on Beaver Brook. Here, as on Folly River, the lowest beds of the conglomerate are composed of boulders derived from the underlying Cobequid rocks, but unlike the Folly River occurrence, it is not apparent where, to the south, the Cobequid fault actually extends, as the rocks immediately south of the overlap contact are very similar to those found elsewhere south of the Cobequid fault.

None of these basal Pennsylvanian rocks has yielded any fossils. W. A. Bell, who spent some days with the writer in 1944 studying the Pennsylvanian succession, expresses the opinion that they may be Riversdale, but does not exclude the possibility that they may be of Canso age.

RIVERSDALE GROUP

A ridge of shales and sandy shales, bounded on all sides by Triassic rocks, parallels No. 2 highway on its north side, and extends from Little Bass River to Lower Economy, a distance of 7½ miles.

To the south of this ridge Triassic sandstones and conglomerate overlie the shales in what is apparently a normal overlap; to the north similar Triassic rocks are downfaulted against the shales. Near its east end the ridge is traversed diagonally by a narrow belt of Upper Windsor sediments, which apparently underlie the shales. W. A. Bell ascribes a Riversdale age to them on the basis of freshwater lamellibranchs observed near Lower Economy. That they are near the base of the Pennsylvanian is suggested by the fact that they are underlaid by Upper Windsor strata and, by inference, by rocks of the Cobequid complex, exposed farther east at Bass River.

Lithologically, both red and grey beds are present, the former usually shales and the latter showing gradations from shale to sandy shale. The only continuous section, that on the sea-shore at Lower Economy, is 2,200 feet long, and displays a thickness of 920 feet of sediments. Both ends of the section are concealed by Triassic sandstone and conglomerate.

LATER PENNSYLVANIAN ROCKS

Pennsylvanian rocks lie to the south of the Cobequid fault throughout its extent within the area mapped. Although their age is somewhat in doubt, they are believed to have been laid down in post-Riversdale time. They have been divided on lithological grounds into two map-units (*See* Maps 867A and 874A) that may or may not represent separate parts of Pennsylvanian time, and may be of either Cumberland or Pictou age.

GREY SANDSTONE AND SHALE

Distribution

This older assemblage of later Pennsylvanian rocks forms part of a belt that lies south of the Cobequid fault and varies in width from a little more than ½ mile at the west to 2¼ miles at the eastern boundary of the area. The belt is bounded on the south by another fault, with downthrow on the south, separating these rocks from Triassic sediments and volcanic rocks. Where members of the grey sandstone and shale division occur they are bounded on the south by this latter fault, and extend north for varying distances. Three occurrences were noted. The most westerly is quite narrow, being less than ½ mile wide, and extends from near Carr Brook, along this southern fault, to Pleasant Hills. The second occurrence extends from just east of Pleasant Hills to the road from Portapique to Lornevale, a distance of 7 miles, and on the west or upthrow side of the Bass River north-south fault extends completely across the Pennsylvanian belt to the Cobequid fault. The most easterly occurrence is about 3 miles long and lies about 1½ miles east of the second.

General Description

The rocks of this division are predominantly grey, but include some thin red beds, usually of shales. In grain size the rocks vary from fine shales, through sandy shales to fine, even-grained sandstone. No conglomeratic phases were observed.

The best section, that on Bass River between the north limit of Triassic rocks and the south side of the mountains, is unsatisfactory. Exposures are not plentiful, and as the stream parallels a nearby north-south fault the large local variations in observed strikes would indicate that auxiliary faulting has developed from it. Consequently, no credence could be placed on any estimate of thickness based on this section.

On Miller Brook, however, a short distance east of the Bass River fault, some 1,000 feet of shales and sandstones are exposed in a very incomplete section of these rocks. Bell, during his aforementioned short visit with the writer, identified two plant species from this assemblage, *Neuropteris pseudogigantea?* Potonie and *Lepidostrobophyllum lanceolatum* (Lindley and Hutton), and stated that the former indicated a correlation with late Cumberland or the early part of the Pictou group. These fossils were found on Saltspring Brook, very close to the top of the grey shale and sandstone division, so that it is quite possible that rocks of this division and of the succeeding red sandstone and conglomerate represent both Cumberland and Pictou groups. It does not follow, however, that the line of division between these groups coincides with the lithological boundary selected by the writer for the purposes of mapping.

RED SANDSTONE AND CONGLOMERATE

Rocks of this map-unit, which everywhere (except for a very short distance on Bass River) are bounded on the north by the Cobequid fault and on the south by either rocks of the grey shale and sandstone division or by Triassic rocks, consist essentially of dull red-brown, coarse sandstone to conglomerate. Grey beds are occasionally present, but are distinctly subordinate, and in many sections are completely lacking. The sandstone members commonly carry streaks of conglomeratic material. Pebbles in the conglomerate consist usually of rocks identifiable as pre-Carboniferous, although it is possible that Horton rocks are represented. No fossils were found in these rocks, but plant remains discovered just below them are of either late Cumberland or early Pictou age.

TRIASSIC

Triassic rocks lie in a large synclinal basin, most of which is now covered by Cobequid Bay, Minas Basin, and the Bay of Fundy, and extend from some 15 miles east of Truro to the western tip of Nova Scotia on Brier Island. Remnants of this syncline are found on the south coast of New Brunswick, and the whole is probably continuous with Triassic basins existing in the New England States and farther southwest. Sidney Powers has written[1] the most complete account of the Triassic rocks in Nova Scotia. He divides them into the Annapolis formation, which underlies the North Mountain basalt, the basalt itself, and the Scott Bay formation, which overlies the basalt. The Annapolis formation he divides into a lower Wolfville sandstone member, and an upper Blomidon shale member. He does not correlate the basalt at Gerrish Mountain, near Lower Economy, with the North Mountain basalt, but considers it to be a local flow near the top of the Wolfville sandstone member.

ANNAPOLIS FORMATION

Distribution

Sandstones and conglomerates of the Annapolis formation fringe the south side of Cobequid Bay and Minas Basin in a narrow belt, in a few places lacking; and the north side in a much wider belt, in places 7 miles wide. Protruding through this latter belt are three areas of older rocks, all of which are bounded on the north by an east-west fault, believed to be the same fault in each case.

General Description

Lithologically the Annapolis sediments grade from fine, but never even-grained, sandstone to coarse conglomerate containing boulders that are several feet across. The strata are everywhere red, but may vary locally from brick-red to reddish brown. The constituent grains are cemented in part by calcite, and in part by iron oxides. The quartz grains composing the matrix are usually quite angular, whereas the pebbles are subangular to round, being usually bounded by fracture faces, although the corners are rounded. On the Hants county shore the contact with the underlying Horton rocks is exposed at a number of places, and material above that contact may readily be traced to the Horton. Well above this contact, pebbles of quartzitic rocks appear to predominate, and may have originated from either the Gold-bearing group in the south or from the Cobequid or Caledonian Mountains, the latter in southern New Brunswick, in the north. Some felsitic types of pebbles could, so far as is known, have an origin only in the north. The dips are usually low, when unaffected by local deformation, and the structure is a low syncline whose axis lies under Minas Basin and Cobequid Bay. Faulting in these rocks is discernible only where underlying or overlying rocks are moved into juxtaposition with them, and will be discussed following the description of the overlying basalt.

[1] Powers, Sidney: The Acadian Triassic; Jour. Geol., vol. xxiv, Nos. 1, 2, and 3, 1916.

TRIASSIC BASALT

Distribution

The youngest formation of consolidated rock in the area consists of a continuous series of basic volcanic flows that occur as erosional remnants where faulting has dropped them among the older rocks. Although no Triassic rocks are exposed above the volcanic flows, Power, as mentioned before, believes these particular flows occur within the Annapolis formation, near the top of the Wolfville sandstone, and that they cannot be correlated with the North Mountain basalt, which extends for 125 miles from Cape Blomidon to Brier Island. Undoubtedly no rocks suggestive of the Blomidon shale occur below these basic flows, and such would undoubtedly be expected 17 miles from its type locality. Also, the general structure of the Triassic basin, as depicted by the North Mountain basalt, is such as to lead to the belief that the basalt within this area is lower stratigraphically than that of North Mountain.

The two largest occurrences of Triassic basalt cap the tops respectively of Gerrish Mountain, just west of Lower Economy, and Portapique Mountain, just east of Upper Bass River. Both these features display a steep east face where erosion has undercut the softer sandstone underlying the basalt, and a gentle west slope that approximates the natural dip of the basalt. Two other occurrences, one on Callaghan Brook and the other on Little Bass River, are limited in extent, and do not stand out in relief.

The Portapique Mountain basalt occurrence supplies the information for the solution of the structural problem presented by these isolated remnants of extrusive rocks. This solution, although verified by facts observed near the other three occurrences, could not be derived *in toto* from any or all of them. The Triassic rocks to the south of the area of Pennsylvanian strata occupy a belt that varies in width from 1 mile to 3½ miles. This belt forms a graben, downfaulted on the north against Cumberland or Pictou rocks, and on the south against Riversdale and older rocks (where the fault can be traced), and across about half the area, from Bass River to Glenholme, against Triassic rocks (where the fault cannot be traced). After its formation the graben was cut by a series of north-south faults into blocks that were depressed on their western sides and elevated on their eastern sides. More of these north-south faults are probably present east of Portapique Mountain, but only one can be recognized, as it has brought Windsor rocks to the surface on the west side of the fault.

General Description

The Triassic basalts vary from brownish grey to black, weathering usually a dull brown, and from aphanitic to a grain size of about 3 millimetres. The upper parts of flows are commonly amygdaloidal, and under the microscope show vesicles filled or partly filled with crytocrystalline to fibrous chlorite. Dark to light brown glass is present in all the rocks examined microscopically, and in some slides makes up about 40 per cent of the rock. The plagioclase varies from labradorite, An_{60}, to labradorite-bytownite, An_{70}. The mafic mineral is a pyroxene, and was determined in a number of slides to be diopside. A little olivine, altered in part to antigorite, was observed in one thin section.

Near the top of Gerrish Mountain and a few hundred yards west of the area, the old, now unused, highway follows a ledge on a basalt cliff some 70 feet below the present highway, which is on top of the mountain. Between the two roads, in the cliff face, two and possibly three flows are exposed, although their actual contacts are poorly displayed. A specimen collected from within 2 feet of the top of the lower flow showed a distinct porphyritic texture under the microscope, the "phenocrysts" having a length of 0·5 millimetre, whereas the groundmass had a rather uniform grain size of 0·2 millimetre. Six feet above the base of the overlying flow the basalt had a uniform grain size of 0·5 millimetre, and 20 feet above the base, and very close to the middle of the flow, this same body had a uniform grain size of 3·0 millimetres.

Concentrations of magnetite, a ubiquitous accessory mineral in these rocks, are known, and attempts have been made to mine one on the east side of Gerrish Mountain. The zeolitic type of amygdule so common in the North Mountain basalt appears to be lacking in these flows.

PLEISTOCENE

The area is everywhere, but not uniformly, covered with a mantle of glacial debris, usually boulder clay. The thickness of this mantle varies from 30 or 40 feet, displayed in sea-cliffs cut in the deposits, to almost nil on the high flat tops of Cobequid Mountains. In any district the glacial till indicates the character of the underlying formations, and this predominance of locally derived material was used extensively by Fletcher in drawing his contacts. Material from adjacent formations to the north will be found in smaller amounts, and occasionally stray boulders will be encountered that must have travelled many miles.

On the plateau surface of Cobequid Mountains evidence of glaciation is indicated by erratic boulders, many of considerable size. Their distribution is somewhat haphazard and although no particular attempt was made to map them they were noticeably more plentiful in that area underlain by granite and extending east, west, and south from Economy Lake. Although outcrops of bedrock are scarce, and lacking for long distances on this surface, yet the till exposed in the few prospect pits dug near Matheson Brook was only a few inches to a foot or so thick. Below the till a coarse soil graded into decomposed bedrock within a depth of 10 to 15 feet. The evidence furnished by these pits would suggest that the ice-sheet was less active and, therefore, much thinner on top of the mountains, at least near Matheson Brook, than on the uplands and lowlands to the south.

Glacial striæ were not observed by the writer, nor are any indicated on Fletcher's maps. This no doubt is due to the soft character of the sediments to the south of the mountains, and to the localization of exposures to stream gorges within the mountains. The general direction of movement of the ice was from north to south, with local variations, depending on topography, at the close of the glacial period. Such local movement would probably still be to the south on the north side of Cobequid Bay and Minas Basin, but may have been to the north on the south side.

CHAPTER IV

FAULTS

It is proposed in this chapter to discuss in some detail the different systems of faults encountered in the area, based on the considerable evidence provided in the northern half. North of Minas Basin and Cobequid Bay the faults fall naturally into two systems, an earlier east-west, and a later north-south, system. South of this body of water there is some evidence that the north-south faults continue across the bay, and that east-west faults are possibly also represented. In addition, two other systems, striking northeast and northwest respectively, were encountered.

EAST-WEST FAULTS

The east-west faults have the most profound effect, not only on the geology, and the occurrence of mineral deposits, but on the life and intercourse of the people in the district, as one of them, the Cobequid fault, is responsible for the existence of Cobequid Mountains. Three of these east-west faults are clearly recognized, and to simplify reference to them they will be given names. The fault that extends along the south face of Cobequid Mountains has already been referred to in this report as the Cobequid fault. Another fault, some 1 to 3 miles south of the Cobequid fault, marks the contact between the northern belt of Pennsylvanian sediments and the Triassic rocks, and will be called the Portapique Mountain fault after an eminence about 1½ miles east of Upper Bass River where the existence of this fault was first proved. A third fault, 1½ to 3½ miles south of the Portapique Mountain fault, follows the north side of outliers of pre-Carboniferous, Windsor and Riversdale rocks, and will be called the Gerrish Mountain fault, after a high basalt ridge lying mainly just west of the area at Lower Economy. An assumed, approximately east-west, fault running through Hennigar, near the south boundary of the area, has already been referred to in describing the Upper Windsor of the Hennigar district. The fault is extended across a terrain practically devoid of outcrops in order to explain a gap in the normal Windsor succession whereby Upper Windsor fossils are found in rocks lying very close to those of the lowest parts of the lower Windsor. The existence of this fault may be admitted with some confidence, but its position as mapped is pure assumption.

THE COBEQUID FAULT

In an earlier paper on the Londonderry Iron Deposits[1] the writer expressed the view that if a fault existed on the south face of the mountains it must be pre-Carboniferous in age. This statement was based on field work to that date, during which the unconformable overlaps of the Carboniferous strata on the Cobequid complex on Folly River and Beaver Brook had been observed, but the definite evidence of a faulted contact between the Cobequid Mountain rocks and the Carboniferous on Bass River and on a number of smaller streams had

[1] Weeks, L. J.: Londonderry Iron Deposits; Geol. Surv., Canada, Paper 44-10 (1944).

not then been seen. Later the lithological differences, though not pronounced, between the Carboniferous rocks near the two overlaps and those near the faulted contacts were noted, and afforded the explanation for a fault that across most of the area separated the mountain rocks from the Carboniferous, but which at the extreme east and west of the area included some Carboniferous north of the fault. On Bass River the Cobequid fault is marked by a zone of broken and mylonitized rocks some hundreds of feet wide. This is the most clearly recognizable evidence of faulting, but on many other streams rocks of the Cobequid complex collected near the south face of the mountains at the exposure nearest to those of Carboniferous age exhibited in thin section a degree of mylonitization and other results of deformation not encountered in similar rocks farther north.

The Cobequid fault extends from Cape Chignecto, on the west, to the coalfields of Pictou county, where Carboniferous sediments overlap on the east end of Cobequid Mountains and lie on both sides of the fault. It may be suggested that the Pictou coalfield marks a hinged zone in this fault, and that the relative movements are reversed farther east, as pre-Carboniferous rocks there lie to the south of the Pennsylvanian formations instead of to the north as in the Cobequid Mountain region. The writer has nothing to add to this suggestion and does not believe that previous field work in the Antigonish highlands has brought forth conclusive evidence either way.

THE PORTAPIQUE MOUNTAIN FAULT

The middle of the three main east-west faults extends across the map-area and separates rocks of the Cumberland or Pictou group, on the north, from Triassic rocks on the south. The existence of the fault was proved by exposures of Carboniferous sediments and Triassic basalt very close to each other on the north side of Portapique Mountain and a little farther apart on the north side of Gerrish Mountain. The attitude of the basalt is indicated on the southeast corner of Portapique Mountain where the Annapolis sandstone dips beneath the basalt at a low angle to the west. As in the Cobequid fault, the downthrow side of this fault is on the south.

THE GERRISH MOUNTAIN FAULT

The Gerrish Mountain fault, as in the case of the two just described, is believed to extend completely across the area, but can be traced only where Triassic rocks are downfaulted against older formations. This means that across about one-half of the area, where Annapolis sediments are downfaulted against earlier Annapolis beds, the fault cannot be traced. The presence and direction of movement of this fault, the latter opposite to that of the first two faults, were first proved on the east side of Gerrish Mountain, where the west-dipping basalt is displaced eastward nearly a mile, on the north side of the fault. A fault was also suspected on the north side of the Riversdale belt, and there seemed to be evidence favouring it in the dips of the Triassic rocks north of the Pennsylvanian contact, but this had been regarded as inconclusive. In the light, however, of the fault on Gerrish Mountain, in which movement was downward on the north side, the continuity of this fault eastward along the north side of the Riversdale belt may now be considered as well established.

At Bass River an outlier of Cobequid complex protrudes through the Triassic rocks and, although exposures are very scarce, evidence of considerable brecciation and deformation is visible on the north side of the belt, in the bed of West Bass River. North of Glenholme, although evidence of deformation is lacking in the Windsor beds near what is assumed to be the continuation of the Gerrish Mountain fault, yet the attitudes and relative elevations of the red Tennycape shales are such that they must either overlie the Triassic rocks to the north or be separated from them by a fault. The latter alternative is, of course, the only one tenable.

Opposite relative movements along the Portapique and Gerrish Mountains faults have resulted in a graben structure for the intervening block. Such a structure would indicate a zone of tension and would not support the theory that Cobequid Mountains could have been overthrust onto the Pennsylvanian formations.

NORTH-SOUTH FAULTS

The repetition of basalt flows at four places in the graben between the Portapique Mountain and Gerrish Mountain faults can be explained in only two ways, in the light of observed evidence. The four occurrences may lie at different horizons, or the four occurrences may represent the same flow, and be downfaulted in blocks whose western sides have dropped relative to their eastern sides. The first alternative cannot be lightly discarded. No positive evidence mitigates against such a supposition; and the negative evidence consists only of the fact that nowhere in the area is more than one series of basalt flows suspected. However, as there is positive evidence in favour of the second alternative, which is based on the presence of north-south faults, such evidence will be considered as more conclusive.

The presence of a north-south fault lying to the west of the Portapique Mountain basalt body is well indicated by the displacement of the Cobequid fault between Bass River and a small stream to the east of it. The course of the fault is shown by exposures of basaltic and sedimentary (Annapolis) rocks on Bass River, and the fault is assumed to cut off the end of the small body of Cobequid rocks at the village of Bass River. The data obtained from this fault along Bass River were then used in assuming the positions of similar faults believed to lie west of the basalt bodies on Little Bass River and Callaghan Brook. A similar fault is believed to lie west of the Gerrish Mountain basalt, but it is outside the area and was not mapped. A fifth north-south fault is assumed to lie east of, and form the eastern boundary of, the area of Windsor rocks on Folly and Debert Rivers.

The possible continuation of only one of these faults, that at Bass River, has been found on the south side of Cobequid Bay. This fault was located while following a gypsum bed east of Noel Lake, and much of the detail of the displacement was obtained from mapping karst topography. As this fault apparently had its downthrow on the east, as do the north-south faults north of the bay, it may also belong to the same system. One other fault observed on the south side of the bay just west of Tennycape mine has a downthrow on the east side, and, though given a northwest direction on the map may belong to the north-south system. This fault was first mapped as a northwest fault by Hugh Fletcher. The writer verified its existence, but had very little evidence for its direction beyond an intensely brecciated zone in the Triassic rocks just east of the outlet of Rennie Brook. Because the location of this zone of brecciation seemed to verify the direction Fletcher had given to this fault, and as no evidence for any other direction was observed, Fletcher's original mapping was retained. The fact that the Triassic-Horton contact is apparently very little, if any, displaced by this fault would lead to the belief that most of the movement along it had occurred in pre-Triassic time, and that the brecciated zone mentioned above might have been caused by minor movements in Triassic or post-Triassic time. If this is so the fault could hardly be included with those of the north-south system, movements along which are believed to have been mainly, if not entirely, in post-Triassic time.

NORTHEAST AND NORTHWEST FAULTS

Two northeast-trending faults, with upthrow on the southeast, were located south of Minasville by tracing gypsum beds. The direction of the western of these two faults is well established, as the fault cuts off the southern gypsum bed, which is practically horizontal and does not occur east of the fault on the upthrow side. The displacement caused by these faults is not large, and other similar faults may exist without having been detected.

Between Stirling Brook and Maitland a segment of Windsor rocks is down-faulted among Horton rocks by a major northwest fault, whose existence and direction are well established, and a northeast fault, whose existence, but not direction, is also well established.

In the Windsor fault block the normal Windsor succession is observed striking east and dipping south at a low angle from the contact with Horton rocks just south of Selmah. Although the Pembroke limestone and Tennycape shale are not exposed, their positions may be assumed from the distribution of the Macumber limestone and the lower sulphate bed, both of which are well exposed. On Stirling Brook an east-west anticlinal axis in Horton rocks trends directly toward the supposed position of the Tennycape formation, and toward the southern part of the exposed sulphate bed. A fault with downthrow on the east is thus clearly indicated between these groups.

Some 4 miles to the southeast, on Fivemile River, the existence of a fault with downthrow on the east is determined within narrow limits, and, although little is visible to throw light on its direction, it is assumed to be the continuation of the fault at Stirling Brook, particularly as the latter fault is known by the location of Horton and Windsor exposures to have a southeasterly trend.

About a mile west of Maitland Horton rocks may be observed striking west toward Windsor rocks a few hundred yards away, which have similar strikes. The presence of another fault on the southeast side of the Windsor block seems necessary to explain these relationships. The direction of this fault, however, can vary considerably from that indicated on the map, and still satisfy the known data. It is shown in its indicated position because there seems to be no sign of the continuity of the sulphate beds east of the road south from Selmah, which the writer believes indicates that the fault lies very close to the gypsum exposures on that road. The relative ages of these two faults are not known.

CHAPTER V

MINERAL DEPOSITS

GENERAL STATEMENT

Although mining and quarrying activity within the area is at present confined to one quarry producing limestone for agricultural purposes, yet traces, minor concentrations, and in some cases major concentrations are known of minerals of some economic value. During the past century, some 2,000,000 tons of iron ore, 5,000 tons of manganese ore, and smaller but considerable amounts of gypsum and limestone have been mined or quarried within the limits of the area. Vein barite was mined during the last century a few miles west of the area north of Cobequid Bay, and massive barite is now being mined a few miles west of the area south of the bay. Traces of copper, lead, and zinc are known in the rocks of Cobequid Mountains, but little or no development has been done on them.

IRON

The outstanding occurrence of iron within the limits of the map-area is that of the Londonderry district, where primary ankerite bodies of considerable size have been altered in part to bodies of limonite acceptable as ore. Up to 1908 about 2,000,000 tons of ferrous minerals were mined and smelted in the district. Iron is also found in veins and small masses of specularite in the rocks of Cobequid Mountains; in small concentrations of magnetite in Triassic basalt; and in ferruginous shales somewhat concentrated by surface waters in Horton rocks adjacent to their contact with Windsor rocks. These occurrences will be discussed individually.

THE LONDONDERRY IRON DISTRICT

(*See* Plate I)

References

Fletcher, Hugh.: Geol. Surv., Canada, Ann. Rept. 1892, vol. V, pt. P.

Gilpin, E., Jr.: The Iron Ores of Nova Scotia; Trans. Can. Soc. of Civil Eng., vol. V, 1891.

Lindeman, E., and Bolton, L. L.: Iron Ore Occurrences in Canada; Mines Branch, Dept. of Mines, Canada, Pub. No. 217, vol. 11, pp. 169-174 (1917).

N.S. Dept of Mines: Ann. Repts. for 1874, 1875, 1877, 1884, 1904, 1905, and 1907.

Woodman, J. E.: The Iron Ore Deposits of Nova Scotia; Mines Branch, Dept. of Mines, Canada, Rept. No. 20 (1909).

Introduction

The iron ore of the Londonderry district consists of enrichments by surface waters of numerous lenticular masses of ankeritic carbonate that occur in a complex of sedimentary and volcanic rocks within and near the south flank of Cobequid Mountains.

A detailed examination of these deposits was undertaken in 1941 and 1943 during the geological mapping of the Londonderry and Bass River map-areas.

During the latter season the examination was limited to that part of the district lying between Pine and Totten Brooks, and a large-scale plane-table map of that area was prepared. None of the old workings was entered, and knowledge of the ores themselves was gleaned largely from material in a large dump near the site of the old blast furnace, which presumably represented economic ore at the time operations ceased.

Location and Extent

The Londonderry iron district lies in Colchester county, Nova Scotia, on the south flank of Cobequid Mountains, and mainly within the southern 1½ miles between Portapique and Debert Rivers, which flow south from the mountains about 14 miles apart. The main line of the Canadian National Railways crosses this belt slightly to the east of its middle, and about 4 miles east of the village of Londonderry. Only two roads cross the belt from south to north, following respectively the valleys of Great Village and Folly Rivers. A good secondary road, termed the Base Line road, follows the south side of the belt from Matheson Brook to Weatherbe Brook. All parts of the belt are, however, accessible by wood roads, many of which could at small expense be made suitable for mechanized transport.

History

The following outline is gathered largely from Woodman's report, with additional information from early reports of the Nova Scotia Department of Mines.

In 1849 the first commercial operations were commenced by the Acadia Iron Works, utilizing six Catalan forges and a puddling furnace. In 1852 a charcoal blast furnace was put into operation and continued intermittently until 1875. In 1870 the first steel plant was inaugurated, and shortly thereafter Dr. Siemens made here his first experiments in the direct conversion of iron into steel. In 1877 the first coke ovens were built, and the use of charcoal discontinued. In 1874 the properties were purchased by the Steel Company of Canada, which went into liquidation in 1899. In 1902 the Londonderry Iron and Mining Company acquired the property and continued operations until about 1908, since when no mining or smelting has been done in the district.

It is difficult to ascertain from the early reports what specific parts of the district were being mined at any one time in its history. It is probable, however, that the earliest workings were located on the west bank of Great Village River, in that section known as the "Old Mountain"; that during a later period of the district's history work was confined largely to the area between Martin and Cumberland Brooks and, to the west of the latter, a section known as "West Mines"; and that during the last phase of activity work was commenced at East Mines, east of Folly River, and continued at Old Mountain, with some activity at West Mines.

Topography

The iron deposits lie within the southern mile or so of Cobequid Mountains, and roughly parallel the southern, straight, steep face. The topography of this section, which has been described earlier in this report, is believed to have a direct bearing on the enrichment of the iron ores.

General Geology

The iron deposits lie entirely within the southern, and possibly younger, group of sedimentary and volcanic rocks that underlie the south flank of

Cobequid Mountains from Bass River on the west to at least as far east as Totten Brook. The rock types are grey-black to pearl-grey, poorly bedded to massive, fine-grained sedimentary rocks or bedded volcanic rocks; poorly bedded to well bedded grey shales; light grey to white quartzite or silicified tuff; chlorite schists showing varying degrees of alteration, and believed to be volcanic in origin; fine-grained, light grey conglomerate or volcanic breccia containing pebbles or small bombs up to 5 millimetres in diameter; and black, graphitic schist. Graphitic schist has been found only near the south contact of the mountains, and is in many places the first rock encountered on entering them.

In addition to the rock types enumerated above, the assemblage is cut by basic intrusive rocks and by dykes and masses of intermediate composition, many of which when seen in isolated exposures can only be differentiated with difficulty, if at all, from some of the rocks of the group they cut. Basic rocks, although plentiful near the iron deposits, are not commonly found cutting the actual rocks in which the deposits occur. On the other hand, intrusive bodies of intermediate composition have been identified at only two localities, both of which are within the zones containing iron carbonates. On Pine Brook, a few hundred feet north of a zone of iron carbonates, well-bedded shales are intruded by a light grey, dense rock determined under the microscope to consist of a mass of fine quartz crystals and a few small flakes of biotite lying in a finer groundmass of mainly sericite with some carbonate. Rock similar to this has been found on high ground to the immediate west of the workings of Old Mountain mines, but no relationships with surrounding rocks could be determined.

Batholithic intrusive rocks, mainly granite, cut the volcanic and sedimentary rocks, but such occurrences have not been observed within half a mile of the iron deposits.

Mine Workings

In the interval between the inauguration of mining in the district, nearly a century ago, and cessation of operations in 1908 activities were extended to three principal areas. Although it is not always, or even often, possible to determine at what period any particular work was done, yet the excellent series of plans and sections submitted by J. E. Woodman in his report of 1909 give a clear impression of the total extent of the workings in 1906, when he visited the district. These will be discussed from west to east.

West Mines

The West mines include those workings between Martin and Cumberland Brooks, and those on the west side of the latter. Work apparently began in these sections about 1874, and was continued until operations in the district ceased.

West of Cumberland Brook work was carried out, and then discontinued, at a relatively early date. Three levels were driven into the hill from the brook valley, the upper one being about 1,000 feet long. Two bodies of ore were mined, the most westerly lying between the surface and the upper level about 800 feet from the portal, and the more easterly between the surface and slightly below and about 300 feet from the portal of the intermediate level. As work was usually discontinued downward when unaltered carbonates were encountered, it would appear that the line separating enriched ore and unaltered carbonate lay about 150 feet below the surface of the hill.

Between Martin and Cumberland Brooks more concentrated mining has been done than in any other section. One level, No. 5, is a tunnel driven through the ridge a distance of about 4,300 feet, with portals in each brook valley. Altogether three adit levels, Nos. 5, 6, and 7 (numbered downwards), open out into Cumberland Brook Valley, and four, Nos. 2, 5, 6, and 7, into the valley of Martin Brook. The levels are about 100 feet apart vertically, with none between Nos. 2 and 5 levels. For inter-level hoisting, three shafts were sunk in the line of workings, each reaching the lowest level at that place. The Jamme shaft, about 600 feet west of Martin Brook, reached three short blind levels below No. 7; the McClellan shaft, about halfway between the brooks, was sunk to a depth of one level below No. 7; and the Dufferin shaft, 1,425 feet east of Cumberland Brook, reached two levels below No. 7. In addition, a number of shallow air shafts reached the upper levels only.

The mineable ore apparently extended to quite varying depths in different parts of the section between the brooks. It reached its greatest depth about 600 feet west of Martin Brook, in workings tapped by the Jamme shaft, where ore was stoped to 300 feet below stream level. This ore shoot was apparently small, as it was mined for less than 150 feet from the shaft. At 1,500 feet west of Martin Brook unaltered carbonate was found apparently closer to the surface than at any other point, mining having been carried to a depth of only 50 feet below the surface. Beginning just west of the Jamme shaft is a zone 1,200 feet long in which no mining was done below 150 feet from the surface. Between there and Cumberland Brook, however, mining was extended over large sections to depths of 150 feet below brook level, and, according to Woodman, did not in all cases bottom in unaltered carbonates.

Old Mountain Mines

This section, in which some of the earliest, as well as the latest, work was performed, lies on the steep west bank of Great Village River about 3,000 feet north of the bridge on the Base Line road. Although not generally included in this group, and not connected with it by underground workings, for convenience the openings on Cook Brook will also be dealt with in this part of the report.

The Cook Brook workings consisted of three levels, each with two openings, one on the west side of the valley and one on the east. The workings were not extensive, the upper and longest level being driven 600 feet on the west and 450 feet on the east. The intermediate level was apparently exploratory and was driven only a few feet on the west and about 150 feet on the east. The lowest level, because it had to surface considerably downstream from the ore zone, was quite long on both the east and west, but apparently just reached the ore zone. It is not known how much ore, if any, was obtained from these workings, but there are no indications of a narrow-gauge railway to the workings, suggesting that production had been small.

On the west bank of Great Village River six adit levels were driven, Nos. 1 and 2 being at the same elevation, but unconnected. Of the others, No. 3 is the only one of any extent, Nos. 4, 5, and 6 being exploratory holes driven a short distance into the hillside.

No. 1 level was driven 900 feet into the hill from a point 250 feet above the river, and apparently was not at any point more than 50 feet below the surface, which flattens after the steep slope from the river. Mining was carried out along this level, mainly from a series of open-cuts from which the broken ore was dropped through chutes into the level and drawn to the portal. Caved ground is quite extensive along this level, indicating that mining was carried almost to completion between the level and the surface.

No. 2 level has its entrance about 600 feet north of that of No. 1 and, as mentioned, at about the same elevation. The workings extend about 1,000 feet west of the portal. No open-cuts were made above the workings, but the latter may be traced quite easily on the surface by a succession of slumps.

No. 3 level lies about 80 feet below No. 2, and is connected with it by one hoisting shaft near the west end. One large open-cut was apparently mined by discharging into this level in a section not tapped by No. 2. The adit is in such a condition as to suggest that with a small outlay the mine could be entered, and indeed it was entered as late as 1938, but the portal has since caved.

Below No. 3 in the north and No. 1 in the south are Nos. 4, 5, and 6 levels. These are driven 300, 120, and 40 feet respectively into the hillside, but are not connected with workings of a productive nature. It is understood that work was being done on these levels when operations ceased.

East Mines

The East Mines district lies about 5 miles east of the village of Londonderry, and at one time was connected with East Mines Station on the Canadian National Railway by a full-gauge railway, which was used to transport the ore to Londonderry for treatment. Work was apparently commenced in this district quite late in the history of the mines, and was being carried out when operations ceased. At the East mines there were two sets of openings, the westerly, called the Gory Brook workings, connected directly with the full-gauge railway line, and the easterly, or Weatherbe Brook openings, connected with the Gory Brook workings by a narrow-gauge railway. In addition, the roadbed for another railway was being constructed to a point about 1 mile west of Gory Brook when work ceased. No workings were driven at the latter point.

Gory Brook Workings. The main opening of these workings was on the hillside directly north of a loading trestle at the end of the full-gauge railway. From the adit, levels were driven north 700 feet to the ore zone, from which point 1,500 feet of east-west workings were cut in the ore. Several open-cuts exist along the ore zone, two at least of which must have been mined by discharge into the workings below. Seventy-five feet below the workings tapped by this adit is another level whose workings have an east-west extent of 3,000 feet, and which was apparently entered from another opening on Slack Brook, about ½ mile west of Gory Brook. Ore from this level, however, was handled from the Gory Brook adit, being hoisted to the upper level in a shaft near the ore and north of the Gory Brook portal. Apparently this lower, or Slack Brook, level was driven mostly in unaltered carbonates with small pockets of ore.

Weatherbe Brook Workings. These workings are on Weatherbe Brook, about ½ mile east of the Gory Brook workings. Two parallel zones, about 1,200 feet apart, were tapped from the main adit on the brook, the northern zone being worked almost entirely from underground workings and the southern by large open-cuts and underground workings. Ore was won in places at a depth of 150 feet below the surface, but deeper levels apparently did not find any. It is believed that a dump at Londonderry of some thousands of tons of ore was derived either from the Weatherbe or the Gory Brook workings, as it is piled where it would have been dumped from the full-gauge railway over which East Mines ore was brought to the furnaces.

Ankerite Quarries

Although the early operators did not consider ankerite an ore, yet that material was quarried extensively for use as a flux in the furnaces, in lieu of limestone that would add no extra iron to the melt. The ankerite was obtained from two localities, one at Old Mountain and one at East Mines.

Two quarries were operated at Old Mountain, the largest in a steep cliff face of the west bank of Great Village River, and a little to the south of the mine workings there. The quarry cutting was some 30 feet wide, with a difference of elevation between top and bottom of about 120 feet. The bottom of the quarry was about on the level of the roadway along the west river bank. The second Old Mountain quarry is on the flat top of the hill, and although originally operated as an open-cut quarry was finally connected to the underground workings of No. 1 level. It is of interest that although normal ankerite was obtained from the quarry, yet the mine workings below it obtained some enriched ore.

At East Mines one of the eastern open-cuts of the Weatherbe Brook workings is marked on Woodman's plan as "ankerite open-cut". It is assumed, although no other mention is made of it, that the material from this cut was used as flux, as was the material from the quarries at Old Mountain mines. This open-cut is located on a relatively flat piece of land, about 400 feet east of Weatherbe Brook, and is surrounded on three sides by open-cuts from which iron ore apparently was obtained.

Prospected Areas

In addition to those sections in which actual mining was performed, some work of an exploratory nature has been done in various other parts of the district, both by the companies operating the Londonderry mines prior to 1908 and by individuals and companies at later dates. A summary of this work and the results, if any, will be given in order from west to east.

Matheson Brook Section

Matheson Brook is about 1½ miles west of Cumberland Brook. In 1942, two parties prospected the immediate environs of the brook, one under Mr. Bernard Sky, operating for himself, and one under Mr. George Coolan, operating for the Dominion Steel Company.

The first-named party sank two shallow pits ⅜ mile apart, east and west, on Whetstone Brook, a tiny eastern tributary of Matheson Brook, and 1 mile north of the Base Line road at Mr. W. Carroll's farm. In the western pit, about 200 feet from the confluence of the two brooks, was a vein of oxidized iron carbonates about 6 inches wide and striking north. The eastern pit showed some oxidized carbonates on the dump, but no vein could be found in the pit.

Coolan's party sank several shallow pits on the flat top of the mountain about ½ mile west of Matheson Brook, and about a mile north of the Base Line road, and in addition drove a short adit into the hillside on the west bank of the brook at a point where the flat top of the mountains gives way to steep slopes down to the lower land to the south. The first-mentioned pits were purely exploratory, and, so far as is known, nothing was found. The short adit was driven at a point where several stringers of specularite were visible on the cliff, and a few more stringers were exposed in the adit, but nothing to approximate commercial ore.

Derry Hematite

About ½ mile north of Old Mountain mines, and on the steep north bank of a tributary of Great Village River, a body of flinty black hematite was discovered lying between the almost vertical contact of fine-grained diabase on the north and sedimentary rocks on the south. An open-cut was sunk 10 or 15 feet on the outcrop of the ore, and an adit driven to intersect the body from a point farther down the hillside. A borehole was then drilled at an angle of about 45 degrees to intersect the orebody at a depth of around 200 feet, at which depth the diabase was entered without encountering any ore. No further work was done.

Section Between Great Village and Folly Rivers

Of this section, Woodman says: "Although the iron-bearing zone has long been known to extend through the country between Old Mountain and East Mines, little has been done to explore it. A few short drifts, such as the Drummond, Ferguson, and Boutilier levels have been run, but no attempt appears to have been made to follow the ankerite and siderite for any distance. This may be because of an evident scarcity of brown and black ores, compared with the abundance in earlier years on Old Mountain and thence westward.

"On the hill between the two branches of Great Village River[1] are a number of shallow pits as well as short levels. Thence eastward a few pits have been sunk to ore; but there is no underground development, except on Weigh-house brook.... The extent of this is not known, but it is not great."

With the exception of two caved adits, one at the head of a small brook entering Rockland River just north of Londonderry, and the other at the head of the middle of three forks of a branch of West McElman Brook, there are few signs today of any work having been performed in this section. The first-mentioned brook may be the "Weigh-house Brook" of Woodman, no brook being known by that name today.

Pine Brook-Totten Brook Section

Pine Brook lies a little over ½ mile east of Weatherbe Brook, and Totten Brook about ¾ mile east of it. This section, therefore, is a direct continuation eastward of the East Mines district.

A large body of ankerite was discovered early in the century near the top of the steep east bank of Pine Brook and about ¾ mile north of the continuation of the Base Line road. About 500 feet east of this exposure a small open-cut into a hillside showed the body at this point to have a width of at least 70 feet, with scattered isolated exposures nearby indicating that the width might be greater. On the steep bank of Pine Brook, and 45 feet below the first-mentioned exposure, a short adit was driven into the hillside, and apparently mostly in ankerite. The length of this level is not known, but it would appear from the size of the dump to be about 80 to 100 feet long. The writer was informed by local farmers and by Mr. Coolan that this section was being developed when operations ceased over the entire district.

About ½ mile east of Pine Brook, at the point referred to above, and extending eastward almost ½ mile to Totten Brook is a low, linear swamp 200 to 400 feet wide, having an elevation only a few feet above Totten Brook, and known locally as Peter Totten Meadow. Exposures of massive iron carbonates, both with and without oxide enrichment, had been discovered along the steep north side of the meadow, and several trenches and one small open-cut were dug in them. Where enrichment has occurred the ore was of good grade, and the small amount of it hauled to the furnaces was of considerably better grade than that obtained from East Mines.

So far as is known, no other prespecting has been done in the district.

[1] Great Village River and Rockland River, on the Londonderry map (No. 874A).

Iron Deposits

The deposits of iron ore are apparently[1] oxide enrichments, by surface waters, of lenticular masses of iron-bearing carbonates, of which ankerite, a calcium-magnesium-iron carbonate, is most common. Owing to the inaccessibility of the deeper workings, carbonate below the zone of oxidation and enrichment has not been observed by the writer, and is described by Woodman merely as "spathic ore and ankerite" (siderite and ankerite), terms that may be used to cover the possible carbonates present in depth, or, on the other hand, to indicate more precisely that both are present and have been observed.

In general the unenriched carbonates have no possibilities as ore. This statement, however, may be amended to admit that a body of siderite of large size and free of ankeritic impurities (two conditions that are not at present known to exist in this district) may be classed as a low-grade ore of iron.

A possible use, other than as an ore, exists, however, for ankerite. During the period of production at Londonderry no limestone was used in the furnaces as a flux, ankerite being used exclusively for this purpose. Limestone, of course, added no iron to the melt, whereas ankerite, carrying 10 per cent or more of metallic iron, often added considerable amounts of this metal, and apparently was as satisfactory as a flux.

Primary Carbonate Bodies

The primary carbonate bodies lie in close proximity to, and almost strictly parallel with, the post-Pennsylvanian fault marking the south face of Cobequid Mountains. The bodies are a series of roughly parallel lenses whose boundaries in detail are exceedingly irregular. Fragments of country rock occur throughout the carbonate mass, but show no signs of having been brecciated to their present shape. The carbonate crystal grain varies from quite sugary, with about ½ millimetre grain size, to coarsely crystalline. The width of the carbonate bodies varies from mere stringers to masses 50 to 100 feet across. There are no signs in the carbonate of banding or other structures such as might indicate bedding inherited from replaced sedimentary rocks.

The above features, together with the fact that at no place were clean fissure walls found bordering the carbonate, suggest that although access was undoubtedly provided originally by fissures yet the actual formation of the carbonate took place by replacement of the rock bordering the fissures. The coarse grain of the carbonate in places cannot be considered as detrimental to such a theory, as occurrences of equally coarse-grained carbonate are known elsewhere to be entirely the result of replacement.

The deepest workings, and in fact all workings that were sunk below the zone of enrichment, bottomed in unaltered carbonates. This fact alone may be considered as strongly favouring a hypogene origin for the carbonate bodies, and such a theory was also held by Woodman. He, however, mentions one fact that might militate against such a theory, although it does not sway him, namely, that he was unable to find carbonate crossing the beds of brooks, even where well exposed on the slopes above them. The writer paid particular attention to this statement when traversing streams that cut across the ore zones, and found that no stream had a completely solid section of rock across such zones. When it is remembered that the carbonates are much softer than the country rocks of the mountains and much more soluble, the flat statement that massive carbonate bodies do not cross the brooks cannot be accepted.

[1]The possibilities of the enrichment being due to processes other than those of surface waters will be discussed on page 53.

Granting a hypogene origin for the carbonate bodies, the actual source of the carbonatizing solutions is not immediately apparent. The assumption is that the solutions emanated from some not too distant igneous mass during its period of intrusion. Although in parts of the iron belt granite is either exposed nearby or its proximity is suggested by other features, yet in other equally productive sections the nearest known granite is several miles away. The diabasic intrusions are not at all plentiful in the carbonate zones, in fact certain sections of the iron belt are almost unique in the complete absence of such rocks. The minor intrusions of intermediate composition, however, have only been definitely established in the Pine Brook section, and are believed to exist in the Old Mountain section. Mention has been made of the difficulty, barring actual exposure of an intrusive contact, of differentiating these rocks from some of the volcanic rocks, and it may be assumed that rocks of this type are more plentiful than can be definitely stated. Thin sections taken from the only known intrusive body show the presence of carbonate as a very late interstitial mineral, but with nothing to suggest that it has replaced an already consolidated rock. The writer, however, considers these facts suggestive of a relationship rather than as conclusive evidence of such.

As was mentioned previously, the composition of the carbonate below the zone of oxidation and enrichment is not known. It would be of considerable value to know whether it is ankerite and whether the known occurrences of siderite are the result of supergene processes; or whether mixtures of ankerite and siderite made up the primary bodies. The reasons will be clear, because if the former is true no bodies of siderite (which as mentioned above might be considered a low-grade ore) will be found below the zone of groundwater enrichment, whereas if the latter is true lenses of siderite might go to any depth reached by the carbonates as a whole.

Mention should be made of two accessory minerals occurring in the carbonates. Pyrite is occasionally present in tiny euhedral crystals. That it is not present in any quantity is shown by extremely low percentages of sulphur in the various analyses quoted in Woodman's report. The other mineral, specularite, is extremely plentiful in places. It occurs as veinlets, seams, and isolated needle-like forms. Under the microscope it appears in part to have been deposited simultaneously with the carbonates, and in part to be a little later. The former relationship, if well substantiated, would alone indicate a hypogene origin for the primary carbonate bodies.

Enrichment of the Carbonate Bodies

The weathering of the carbonate bodies, the subsequent transportation downward of iron-rich solutions by percolating surface waters, and the later deposition in the carbonate bodies of various iron oxide minerals from these solutions, gave origin to lenses in the carbonate that could profitably be mined as ores of iron. The products of this supergene enrichment are mostly forms of limonite, together with small amounts of hematite, and possibly some siderite. Mention will be made in this section also of occurrences of specularite as a minor primary constituent of the carbonate, mainly because such occurrences definitely "enrich" the rock, and might conceivably be plentiful enough in any one place to raise an otherwise low-grade carbonate to the status of an ore.

When it is remembered that mining operations were pursued in this district for about 80 years, it is inevitable that a number of terms descriptive of the ores should come into local usage, and be well understood by those familiar with the district, although having a very inexact application if used in any other mining district. Where no confusion can exist, these local terms will be retained in the description of the ores.

Types of Ore. Paint ore is yellow-brown, earthy, ochreous limonite, and is found on or within a few feet of the surface. Bottle ore is hard, black, botryoidal limonite or goethite,[1] and was found either as residual bodies in the soil overlying orebodies, or as cavity fillings in the rock close to the bedrock surface. Red ore is, as might be suspected, red, earthy hematite, and was rather uncommon. White ore is siderite sufficiently free from ankerite to be classed as low-grade ore. Specular ore or specularite occurs as thin, platy deposits in cracks in the carbonate, and also as needle-like aggregates in solid carbonate. Woodman states that it is a surface mineral only and is not found at any depth, a statement that is somewhat out of keeping with its known high temperature origin. Brown ore and black ore are terms used in Woodman's report, which the writer finds rather confusing, as specimens of ore satisfying both these descriptions have been found to be essentially the same, namely, a hard sintery mass of limonite replacing, almost completely, the carbonate that originally made up the rock.

Bottle ore and paint ore, as mentioned, were found only close to the surface, and generally over the whole mined extent of the district, but the former was particularly plentiful in that part of West Mines between Cumberland and Martin Brooks. Bottle ore carried about 57 per cent iron and paint ore 35 to 38 per cent.

Of the specular ore, Woodman (p. 152) says:

"Another fairly superficial ore is the specular. Doubtless it should be called specular hematite, but its streak is brown rather than red, often even yellowish, and it contains a variable percentage of water. There is need of a variety name to designate such a mineral. The specular ore is fine to coarse, and occurs in form from thin filaments and stringers in other ore up to large pockets of many tons. Like the bottle ore it is one of the most recent formations, but it is in far larger amounts than the former and does not line cavities but forms a dense mass. It is developed locally, owing to causes which are not apparent. In some instances it is near igneous rock, which, however, long antedates its formation. In others it has no environment which might be used as a clue. Thus, analyses of the Totten Brook old workings at East Mines show a comparatively large percentage of specular ore, while westward toward Slack Brook there is little, limonite being the oxide. In this case proximity of igneous rocks might at first sight appear to account for the change to specular ore. But in the western part of the property now worked—Cumberland Brook and West Mine—the ore west of the brook consists of a mixture of ankerite, siderite and specular iron.... In this case intrusives could under no circumstances have influenced the ores...."

Specularite is a high temperature mineral, and as such may be produced by primary igneous activity, by hydrothermal alteration, or by deep-seated metamorphism. At Londonderry, specularite is in part contemporaneous with, and in part slightly younger than, the primary carbonate bodies. The latter circumstance, however, cannot be considered as proving that the specularite is not in all cases related to the primary carbonate bodies in origin. Considering all these circumstances, it is difficult to see why this mineral should be limited to zones near the surface. However, as the writer has in no case had access to parts of workings other than those near the surface, Woodman's statement that

[1] An analysis for combined water was made by the Mineralogical Section, Geological Survey, on a specimen of bottle ore found on a West mine dump. The results showed the mineral to be intermediate between limonite and goethite, the combined water content being 12·3 per cent.

it so occurs must be accepted. Regarding his statement that it is a hydrous variety of specularite with a brownish streak, the writer has often obtained such a streak, but in no case has been convinced that the specimen tested was free from limonite, which could be deposited between the lamellæ of the specularite and be secondary after it; in all cases the rock surrounding the specularite contained considerable limonite.

As Woodman remarks, specularite is very common in the Pine Brook-Totten Brook district, particularly in the old workings on Peter Totten Meadow. It has been observed in fair amounts in dump rock on Cumberland Brook, and may well be much scarcer in the intervening sections than at these extremes. The writer would suggest that the non-proximity of intrusive rocks on the surface does not necessarily indicate that such intrusive rocks are not nearby in depth, and it may well be that the zones showing abundant specularite in the carbonate are in reality closer to the parent source of the carbonate (and specularite) than are those zones in which the mineral is less common.

Apparently otherwise unenriched carbonate may contain enough specularite to class the rock as a whole as an ore, as Woodman mentions on the west side of Cumberland Brook. This would be the only case in which such a classification could be applied to the carbonate where unaffected by supergene enrichment. If a hypogene origin is accepted for the specularite, as it must be, Woodman's statements notwithstanding, there is no reason other than local structure why such concentrations of specularite in the carbonate could not be encountered at any depth regardless of the level of supergene enrichment. With the meagre information at hand regarding the occurrence of this mineral, it would be exceedingly difficult, if not impossible, to anticipate such concentrations.

Another ore having local extent is the red ore, formed by enrichment of the carbonate bodies by red hematite. Woodman does not discuss any occurrence of this material, but mentions its presence. The writer found such an ore in place in the open-cut on Peter Totten Meadow, a vertical body of red ore consisting of hematite with some limonite lying against a similarly oriented body of black-brown limonite. Some enrichment by hematite was also observed in an open-cut about 1,000 feet east of Pine Brook, but there the hematite was present only in sufficient quantity to give a red colour to the rock.

The above-mentioned enriching minerals, although of considerable interest, and in some places the producers of very superior ore, did not by any means supply the bulk of the mined material in the district. This bulk consisted of what was known as black or brown ore, and was nearly pure limonite, the original carbonate having been almost lost in the enriching process. It differed from the paint ore, which was distinctly a surface product, in being quite hard and non-ochreous, and in addition was often porous. With the exception of fragments from dumps, no such ore can be seen in any of the exposed mine workings today, but a band of such ore is exposed in the prospect open-cut on Peter Totten Meadow, in juxtaposition, as has been mentioned, to a band of red ore. So far as it is known from the descriptions of mine workings, similar material was mined in depth in all the mines, and finally, in the deepest workings, gave way to unaltered carbonate.

In a discussion of supergene enrichment processes, it should be proper to mention processes of supergene de-enrichment, which also took place, but fortunately on a very small scale. By this is meant the deposition in an already slightly limonitized carbonate rock of fresh iron-calcium-magnesium carbonate, containing less iron than the rock that it replaced. Such processes may be suspected from the examination of hand specimens of brownish to black ankerite containing euhedral crystals of white carbonate, and are proved by the microscopic examination of thin sections taken from them. The dark ankerite is found to have minute films of limonite deposited along cleavage and fracture planes, and this material is replaced by fresh white carbonate containing no such limonite. It is also conceivable, and in one place thought possible, that such a process could replace the compound carbonates with siderite, thus resulting in a deposit with a higher iron content than the material replaced.

Chemistry of Enrichment. Iron carbonates may be enriched by two processes—by oxidation of iron carbonate to limonite, which increases the iron content of the rock per ton, but leaves unaltered the iron content per cubic foot; and by replacement of all the carbonates present by limonite. Microscopic seams of limonite have been observed following cleavage and fracture lines in ankerites taken from near the surface, and it is assumed that during the solution of iron from the upper parts some oxidation to limonite occurs, the results of which are left in the rock. The point may be raised whether those rocks that are almost entirely limonite may not have been produced by oxidation rather than by replacement. Specific gravity determinations were made on two specimens, one being a surface ankerite composed roughly of 92 per cent carbonates and 2½ per cent limonite, the other specimen being a highly enriched ore composed of about 8 per cent carbonates and 89 per cent limonite. The results showed the ankerite to have a specific gravity of 2·9 and the limonitic rock of 3·1. If enrichment were the result only of oxidation of iron carbonate to limonite, accompanied by solution of such calcium and magnesium carbonates as were present, the resulting rock would have a specific gravity considerably below that of the ankerite, so it is quite evident that considerable iron is added to the rock in the enrichment process in addition to any that may be left there by oxidation of the iron carbonate.

The agents by which iron is dissolved and transported are: (*a*) sulphuric acid derived from the weathering of pyrite, and possibly from sulphate deposits such as gypsum; (*b*) organic acids derived from decomposing vegetable matter; and (*c*) carbon dioxide derived mainly from the atmosphere, but also from the decomposition of organic matter.

Pyrite, although present as a primary mineral in the carbonate bodies, occurs in quantities too minute to permit its being considered as a possible source of sufficient sulphuric acid to account for the extensive solution that has occurred. That some solution by sulphates has taken place is suggested by Woodman's statement that a considerable increase in the amount of sulphur present in the ore was noted in the lowest levels west of Cumberland Brook.

The possibility of overlying gypsum beds supplying sulphate solutions for the transport of the iron must also be considered very slight. Rocks of Windsor age, the only gypsiferous group in the Maritime Provinces, do occur on the flat mountain top north of Five Islands, and some 20 miles west of Londonderry, but no indications of such rocks have been seen elsewhere on the mountains, nor do gypsum beds occur there. Finally, had sulphate solutions been at all active in transporting the iron, the consequent deposition of the iron would give rise to considerable masses of other sulphates, particularly calcium sulphate, by the replacement of calcite by limonite, whereas such sulphur-bearing minerals are extremely rare.

Organic acids, smilarly, cannot be considered as a principal factor in the solution of the iron. A swampy, wet terrain, such as would be required for the formation of large quantities of organic acids, cannot be assumed to have existed on the mountains so close to their edge. And conversely, if the south face of the mountains had been elsewhere at the time of enrichment, or if the area to the south of the mountains had been filled to their level by later sediments, then the differences of relief required to promote water circulation to the depths at which enrichment is encountered would be lacking.

No such objections, however, can be raised against a theory of solution of the iron by carbonic acid. Iron is soluble as the bicarbonate, and, as it existed already as the carbonate, a smaller amount of carbon dioxide would be required to effect its solution than would be necessary had it existed in any other form. The supply of the solvent material would be unlimited, as it existed in the atmosphere, and the presence of secondary carbonates of calcium, magnesium, and iron in some of the slightly enriched ankerites indicates that such solution was occurring, because secondary carbonates are precipitated only from bicarbonate solutions.

Iron as the hydrous oxide or carbonate is precipitated from a bicarbonate solution by release of pressure; by contact with organisms requiring carbon dioxide in their life processes; by the admixture of certain organic acids; and by encountering a mineral salt whose basic radical is exchanged for the iron in the bicarbonate solution.

As a bicarbonate solution is essentially a solution of one molecule of the carbonate in the presence of one molecule of carbonic acid, the latter being carbon dioxide in aqueous solution, it can be clearly seen that any lessening of the pressure on the solution will result in the dissolution of the carbon dioxide, leaving the much more insoluble carbonate in the water. Such a release of pressure may be obtained when the solutions reach the surface by way of a spring, or when, after seeping downwards through dense rock with some hydrostatic column behind them, they reach a broken or fractured zone where circulation is freer. Such a zone need not be anywhere near the surface to effect a release of pressure sufficient to de-carbonatize the solutions.

The precipitation of iron by contact with organisms cannot be considered as a method by which the bulk of the iron was precipitated, nor can such precipitation occur through the admixture of organic acids, although both processes undoubtedly were responsible for the formation of minor amounts of limonite in the upper parts of the enriched zones.

Precipitation of iron by molecular exchange is in effect replacement, and undoubtedly played a large part in the formation of the limonite deposits. Undoubtedly both the calcium and the magnesium carbonate in the ankerite underwent such replacement, as both minerals are almost lacking in the better grade limonite ores. It is unfortunate that ores from the deepest zones of enrichment are not available today, at least with any certainty as to their original locality, as without them it is impossible to outline the actual processes by which the limonite came into its present positions.

Although the iron precipitate from a bicarbonate solution is essentially in the form of the carbonate, the change to limonite occurs in most cases almost coincidental with the original precipitation. In fact, unless the change takes place immediately, the resulting carbonate is very likely to remain as such unless and until acted upon by oxidizing solutions.

Effect of Topography on Enrichment. The general topography of the district has already been described. The details, however, vary considerably in different parts, and will be outlined in an attempt to derive a relationship between topography and character of enrichment. The discussion will, of necessity, involve the consideration of factors on which but little information is at present available, but will serve to indicate that, in the writer's opinion, topographic conditions have had a prime bearing on the formation of the iron ores; that enrichment by limonite is found at depths that in places are considerably in excess of that of the present water-table; and that such enrichment in hitherto unworked orebodies may reasonably be considered to go to similar relative depths.

From Matheson Brook to Martin Brook the south face of the mountains is much steeper and more rugged than elsewhere. Cumberland Brook crosses the ore zone at about 520 feet above sea-level, and Martin Brook at about 550 feet.

Between Martin Brook and Great Village River the south face of the mountains smooths out a bit, and as rocky cliffs are absent Cook Brook does not make much of an indentation in the mountain block. In the vicinity of Great Village River, however, the face of the mountains locally becomes quite rocky and steep—the river cutting a deep gorge across the ore zone at about 350 feet above sea-level. The west bank of this river is much steeper and higher than the east bank, having about a 30 per cent grade for 1,000 feet from the river.

Great Village and Rockland Rivers are too close together to have any pronounced highland between them, but along the line of the ore zone the inter-stream area rises in places to almost 200 feet above the rivers.

Between Rockland and Folly Rivers the slope of the south mountain face is considerably lower than to the west, and in places is cultivated all the way to the relatively flat top of the upland. Saltspring, West McElman, and McElman Brooks cut fairly deep gorges, the last named having the deepest, crossing the ore zone 300 feet above sea-level. The gorge cut by Folly River is, however, remarkable for its very steep walls, more so on the east than on the west, although the elevation of the river where it crosses the line of ore is not very different from that of McElman Brook.

From Folly River to Pine Brook the south face of the mountains has about the lowest slope in the entire district. In this section alone, the Pennsylvanian conglomerates occur at elevations almost as high as those of the rocks of the mountains themselves. Slack, Gory, and Weatherbe Brooks flow from the mountains through very shallow gorges, or no gorges at all. Pine Brook, however, occupies a very deep and narrow gorge, with particularly steep walls on the east.

East of Pine Brook the slopes of the mountain face increase considerably to Debert River, where the south mountain slopes are almost as rugged as they are in the West Mines section.

The deepest enrichment was encountered in the West Mines section, between Cumberland and Martin Brooks, and particularly in the immediate proximity of these brooks. In this section the relief was more pronounced for a long distance than in any other, though precipitous slopes are lacking. In these workings, apparently wherever ankerite was encountered above the limit of downward enrichment it was sufficiently enriched to be classed as ore.

At Old Mountain mines, although the slopes of the south face of the mountain are slightly less than in the West Mines section, yet the precipitous west bank of Great Village River is much steeper than any valley slope at West Mines. Here the conditions of enrichment are different from those of West Mines. Bodies of carbonate outcropping on the precipitous slope and on the flatter ground near the edge of the slope are in places not enriched at all, and were quarried as ankerite. Good, enriched ore was obtained farther back from the precipitous slopes, but the depth of enrichment is not known as mining was not carried to the bottom of the enriched zone.

At East Mines the zone of enrichment was determined to have a shallower depth than in any other section of the district. Also, some carbonate bodies were not enriched and were quarried as ankerite. Here the topography is flatter than elsewhere on the south side of the mountains. It is of interest to recall that when operations closed at East Mines a railway was being constructed to a hitherto unoperated part at the west end of the section, and a short distance from the steep slope down to Folly River. It may be assumed that the railway was not being constructed without some ore having been discovered, even though its exact location cannot be determined today. The topographical conditions in this new section would be strikingly similar to those at Old Mountain mines, in so far as the gorge of the river is concerned.

East of Pine Brook the steep brook valley sides have slopes again similar to those at Old Mountain mines. Here again are large bodies of ankerite, on and above the slopes that have undergone very little enrichment. Farther east, in the Peter Totten Meadow section, there has been considerable enrichment in places, but no information exists as to its possible depth. However, in spite of a rather abrupt south face of the mountains south of Peter Totten Meadow, drainage conditions are not quite similar to those at West Mines where the ground rises continuously from the south face of the mountains to the ore zone, whereas from Peter Totten Meadow the ground to the south rises about 75 feet before it begins to slope toward the south face of the mountain.

The relationship between ruggedness of topography and depth of the water-table is quite apparent, as is also the relationship between the latter and the depth of secondary enrichment. Apparently, however, a few other factors enter into the enrichment of these ores. Ankerite, or unaltered carbonate, is found, and has been quarried as such, only in places where the water-table may be considered to be either exceptionally high or exceptionally low, in other words, where there is very little relief, and where the relief is almost precipitous. The deepest zones of enrichment were encountered where the relief, although considerable, was not excessive. The reasons for these phenomena are self-evident. To obtain enrichment by deposition of oxides from iron-bearing solutions requires not only a circulation of those solutions, but a moderately slow circulation. A speeding-up of the rate of circulation would result in the solutions passing through the carbonate rock without deposition. These factors should have an important bearing on any search for new enriched orebodies, and will be discussed later.

It may be apropos to refer here to the prevalence of botryoidal limonite, or bottle ore, in that section known as West Mines. This type of ore, which was found almost entirely as a cavity filling, and only in quantity in this section, was deposited when iron-bearing solutions seeped into open spaces. Such openings in the carbonate rock would postulate earlier solution processes, which may be construed to indicate that these were active over a deep vertical range. Such an explanation would suggest an exceptionally low water-table in this section, and this is in keeping with the exceptionally low levels of enrichment encountered. The prevalence of this mineral at or near the surface might, therefore, be considered as an indication that a considerable zone of enrichment exists at that locality. Botryoidal limonite, however, is not known to be plentiful elsewhere.

Mineralogy of the Ores. It is proposed to limit discussion under this heading to those ores collected in place by the writer, and whose relationships are definitely known. This limits the number of specimens for study to those collected in the Pine Brook-Totten Brook section. A suite of specimens collected there was analysed by the Bureau of Mines, Ottawa, and it is proposed from these analyses to compute the mineralogical composition of each specimen. The analyses are given below:

—	I	II	III	IV	V	VI	VII	VIII
	%	%	%	%	%	%	%	%
Insoluble	4·50	1·74	1·94	0·16	0·11	0·18	0·39	0·32
Fe	10·05	10·77	13·33	12·72	57·35	23·60	13·75	35·09
CaO	27·99	29·10	22·46	30·21	0·50	33·58	29·00	15·29
MgO	12·01	12·02	9·03	11·01	0·36	0·80	9·80	1·86
CO_2	41·74	41·80	40·84	41·88	3·98	26·72	39·14	34·22

I—massive carbonate on crest of high bank Pine Brook; II—massive carbonate 900 feet east of Pine Brook; III—carbonate in open-cut 1,000 feet east of Pine Brook; IV—carbonate stained red with hematite, open-cut 1,000 feet east of Pine Brook; V—dark brown or black ore from open-cut, Peter Totten Meadow; VI—red ore, open-cut Peter Totten Meadow; VII—carbonate from north side of V and VI; VIII—black and specular ore, dump of open-cut, Peter Totten Meadow.

In computing the theoretical mineral composition of the specimens from the above data, several assumptions were made, which may be considered to be largely true. It was assumed that calcium and magnesium existed only as the carbonate, and that the balance of the CO_2 left after computing $CaCO_3$ and $MgCO_3$ belonged to an iron carbonate molecule. The computation thus far, with one exception to be mentioned later, left all the CO_2 used up and with a surplus of iron that was assumed to be either limonite or hematite according to the nature of the material. In the former case water, which was not determined in the original analysis, had to be computed to satisfy the limonite. In all cases empirical formulæ were used. The results are as follows:

—	I	II	III	IV	V	VI	VII	VIII
	%	%	%	%	%	%	%	%
$CaCO_3$	49·8	51·9	40·0	53·9	0·9	60·0	51·7	27·3
$MgCO_3$	25·2	25·2	18·9	22·1	0·7	1·7	20·6	3·9
$FeCO_3$	17·7	17·9	....	15·8	8·5	nil	14·8	52·7
Insoluble	4·5	1·7	1·9	0·2	0·1	0·2	0·4	0·3
Limonite	2·5	3·7	....	8·5	89·1	....	11·0	16·2
Hematite	....	....	....	....	....	33·7	....	....
Total	99·6	100·4	....	100·5	99·3	95·6	98·5	100·4

In analysis No. III there was not sufficient iron to satisfy the CO_2 remaining after $CaCO_3$ and $MgCO_3$ were computed. It was evident that some other metal existed in this specimen, as some limonite was visible in the sample. A spectrographic analysis showed this particular sample to be high in manganese, which probably existed as the carbonate, freeing some iron to exist as limonite.

In analysis No. VI it was assumed that all the iron oxide was present as hematite. The low total of 95·6 shows that this was not so, and that some of the iron oxide was limonite, which with the extra water it would require would have brought the total to nearer 100 per cent.

Analyses Nos. I, II, III, IV, and VII were made of rocks that were essentially the carbonate with some added limonite. Excluding No. III, the results of which were unsatisfactory because of an unknown amount of manganese, the mineralogical computation of the other four analyses are striking in the similarity of proportions between the carbonates of iron, magnesium, and calcium. Reducing these percentages to molecular proportions, the carbonate present in these rocks would appear to conform closely to the formula $4CaCO_3.MgCO_3.FeCO_3$. True ankerite has the formula $2CaCO_3.MgCO_3.FeCO_3$, and, therefore, these carbonates should be more correctly termed ankeritic limestones; but as ankerite is a term of long standing in the Londonderry field, and particularly as these proportions have been worked out on the carbonates of only a small area of the district, the term ankerite will be retained for the compound carbonates.

Analysis No. VIII was made of a rock termed black and specular ore. Actually, although mostly black, it is not a true black ore, as the primary fabric of carbonate remains. The rock is essentially carbonate cut by stringers of specularite, and with limonite deposited throughout the carbonate. This mineral assemblage is then replaced on a small scale by a white carbonate that contains little, if any, iron, and probably is close to calcite. The analytical results show that the calcium carbonate content is about half, and the iron carbonate about three times, as great as those of the normal carbonate. Some of the calcium carbonate can, no doubt, be accounted for by the secondary, iron-low carbonate that replaces the somewhat enriched carbonate, thus reducing still further the amount of calcium carbonate that existed in the original carbonate of the rock. This would place the original carbonate in the siderite class, and, if so, it is the only occurrence of which the writer is definitely aware. Unfortunately, rock of this type could not be located in situ, but it was quite plentiful on the dump. It might be mentioned that the sample was composed of small pieces from a large number of fragments, and is more truly representative than would be one or two large pieces.

Theories of Origin. Throughout the foregoing discussion it has been assumed that the enrichment of the ores took place by supergene processes, a theory of origin that the writer believes is unassailable in the light of surface examination, and data on sub-surface features derived from the study of reports by earlier writers. However, it is only fair to point out possible errors in the observations of investigators who may thus have overlooked features that might favour a theory of enrichment by hydrothermal processes.

If enrichment had taken place through the agency of hot water solutions from below, we should expect the following features to be apparent in the ore-bodies: (*a*) no parallelity, other than by merest chance, between the bottom of the zone of enrichment and the surface of the ground; (*b*) a gradual decrease in degree of hydration of the iron oxides in depth; (*c*) the occurrence of iron oxide deposits beyond the limits of the carbonate bodies, if enrichment had occurred subsequent to the introduction of the carbonate bodies; and (*d*) the persistence of the iron oxide ores to any depth to which the carbonate bodies extend, if enrichment had been contemporaneous with the formation of these bodies.

Regarding parallelity between the bottom of the enriched zone and the surface of the ground: (*a*) it is true that in only one section, West Mines, was mining carried to any considerable depth and to the bottom of the enriched zone, and even here Woodman notes that over a short part of the belt east of Cumberland Brook ore was exposed in the bottom workings. True, in this section the apparent bottom of the enriched zone is definitely parallel with the surface of the ground, being much deeper in absolute elevation near Cumberland and Martin Brooks than in the interstream area, but a proponent of a hydrothermal origin for the ores might claim that such relationships were unique for this section, due to local causes not necessarily holding in other parts of the district, and that had deep mining been carried on elsewhere, such relationships would not have been found. It might also be claimed that the zone of enrichment, like that at Flin Flon, which is hydrothermal in origin, dipped steeply for a short distance, and then raked off at a low angle for some distance before again plunging steeply, and that the miners missed entirely the flat-lying continuation of the ore and believed they had reached its bottom. It is impossible, of course, without first-hand information from underground, to completely refute such a claim. The section, however, was the most thoroughly mined part of the district, and the miners were employed largely on a contract basis, by which they were paid only for ore that they delivered at the portal. They were very adept at following any lead of ore, but they may have been equally hesitant about going far into what they believed was barren carbonate.

No mention has yet been made of the fact that the bottom of the enriched zone was also encountered at East mines, and that there, also, the bottom was parallel, roughly, with the surface of the ground. The workings at East mines were relatively shallow, unenriched carbonate being encountered closer to the surface than in other sections, and because of this, it may be claimed that they were not worked sufficiently to yield positive data regarding the distribution of ore. Again, this might possibly be true, but the workings, although not continuous to any great depth, were quite extensive laterally, and it seems probable that downward extensions of the ore would have been found.

Regarding the degree of hydration of the oxide ore, and its decrease at depth (*b*), very little can be offered to disprove it. In none of the many analyses quoted by Woodman is a figure given for combined water. In deposits of iron oxides formed by hydrothermal processes, as the temperature at time of formation increased with depth the deposited oxide would be expected to change from limonite to goethite to hematite. Paint ore and bottle ore, being strictly surface manifestations, should be excluded from any consideration of such changes. Woodman refers to the brown and black ores as limonite only, but whether he arrived at that designation by analysis or by inspection is not known. Also, he makes no differentiation in degree of hydration between ores near the surface and those at the deepest depths attained. The writer, whose examination of ores was limited to those occurring at the surface, found limonite and a mixture of limonite and hematite in adjacent bodies at Peter Totten Meadow. The possibility must be admitted that Woodman's nomenclature was based largely upon inspection of the ores and may be in error, and that ores from the deepest workings are less hydrated than those occurring nearer the surface. Pending, however, the discovery of more conclusive evidence for a hydrothermal theory, his classification should be accepted.

The succeeding two features of hydrothermal deposition, (*c*) and (*d*), are more or less related, being reciprocals of each other, and will be discussed together. With the exception of specularite, which is rather common in parts of Cobequid Mountains as a fissure filling in sedimentary and volcanic rocks, and the Derry hematite, which probably is hydrothermal in origin, no bodies of iron oxides are known to exist except within the carbonate bodies. However, again the evidence is negative, and a lack of known occurrences cannot be taken as proof that none exists. Further, a remote possibility exists that miners missed downward extensions of the zone of enrichment at West Mines.

There are undoubtedly loopholes in a theory of supergene enrichment, but all postulate a large number of coincidental factors at variance with relationships observed by the writer and previous investigators. Acceptance of a hydrothermal theory of origin for the ores could have very little effect in promoting interest in the locality; it would affect only the life of the district, once operations were commenced. Underground work of any extent should without doubt settle this question conclusively.

Results of Detailed Work in the Pine Brook-Totten Brook Area

In 1943 it was decided that work of a detailed nature should be carried out on some section of the Londonderry district that might be considered to have future economic possibilities. That section lying between Pine and Totten Brooks was chosen because: (*a*) large bodies of ankerite were known to exist there; (*b*) occurrences of enriched ore were known; (*c*) there were no underground workings to jeopardize any future workings; and (*d*) the operators of the Londonderry mines were carrying on a prospecting program in the section when work closed down.

Outline of Work

A transit line was run from Pine Brook, following as closely as possible the line of carbonate bodies, to Totten Brook, and eastward some 2,000 feet from the latter brook to the first of two small lakes draining into Debert River. On this control line a plane-table map was constructed on a scale of 200 feet to the inch, with 5-foot contours. The area mapped by plane-table is about 800 feet wide and 6,400 feet long, and wood roads, outcrops, prospect workings, and streams were located by stadia.

While this work was in progress, Professor A. E. Flynn of the Nova Scotia Technical College very kindly ran a series of observations across the possible ore zones with a Hotchkiss Superdip Magnetometer. For this purpose six lines were cut out at right angles to the supposed trend of the ore, and stakes were driven at 50-foot intervals on these lines. Three lines crossed known occurrences of ankerite (one occurrence carrying enrichment of ore grade), and three lines were run across sections where the presence and location of carbonate bodies were unknown. It was hoped to obtain information from the observations on the known occurrences that could be applied to those sections where no data were at hand, and thus further the knowledge of their extent.

Description of Section

Work was started from Pine Brook, which where crossed by the iron carbonate bodies hugs the east side of a valley 150 to 200 feet wide. Rock is exposed plentifully in the brook bottom, but not continuously, and is composed mostly of volcanic rocks of intermediate composition, with some sedimentary rocks cut by a small, fine-grained, intrusive body. Dykes and stringers of ankerite are plentiful, but probably do not exceed a foot or so in width. There is no sign of a body or bodies of ankerite of any size crossing the brook, but, as mentioned previously in this report, there are gaps in the completed rock section ample to allow such bodies to cross should they exist.

The east bank of Pine Brook is quite steep, and in one or two places almost precipitous for 600 feet east of the brook where the elevation is 185 feet above it. Four hundred and fifty feet east of the brook, and 115 feet above it, is a short prospect adit driven into ankerite. On the hill above the adit, 550 feet east of the brook, is a rounded exposure of ankerite with numerous very narrow seams of specularite through it. North and south, this exposure has an unobstructed width of 16 feet, but nearby small exposures indicate that the width of solid ankerite may be as great as 30 feet. No non-carbonates are exposed here. East and west the exposure has a length of 40 feet, and extends eastward almost to the top of the steep slope. Fifty feet east of this exposure, and on a slight down grade, is another small exposure of ankerite. The slight down grade is followed to the east by a short flat, and then by an up grade until an elevation 225 feet above Pine Brook is attained at a small prospect open-cut 1,000 feet east of the brook. Scattered outcrops of ankerite are found between the top of the first rise and the open-cut. In the cutting, ankerite is exposed for a width of 70 feet, no other rock being present. On the west side of the knoll into which the cut is made, scattered outcrops, only of ankerite, show that the possible width of carbonate may be 120 feet.

To the east of the knoll into which the open-cut is driven, and 25 feet lower in elevation, is a swamp about 150 feet wide, on the east side of which is a hill of drift about 30 feet high. This drift-covered terrain extends eastward in slightly rolling country for 1,200 feet, although a small knob of volcanic rock sticks through the mantle 700 feet east of the swamp.

Two thousand three hundred feet east of Pine Brook this flat, rolling country gives way, with a rather steep drop, into the western end of a long swampy depression lying about 175 feet higher than Pine Brook, and known locally as Peter Totten Meadow. This depression, in so far as its flat, swampy characteristics extend, is about 2,200 feet long, east and west, and varies in width from 100 to 400 feet. Near the eastern end it is crossed by Totten Brook, which forms a small pond in the meadow, but enters and leaves the meadow by steep-walled gorges.

The north side of the meadow rises steeply, but not precipitously, and was rising less steeply at the northern edge of the mapped area some 400 feet north of the meadow where the elevation was about 100 feet above the meadow floor. The south side of the meadow is in places precipitous, being bounded by a rocky ridge 75 to 90 feet high, which extends west to the western end of the meadow. Fletcher called the rocks in this ridge intrusive, and they may be in part of that origin, but in some places definite characteristics of volcanic rocks were observed. Totten Brook flows from the meadow through a narrow gorge in this ridge, and from the top of the ridge a few hundred feet south of the meadow the country slopes uniformly to the south.

For 2,200 feet east of the outlet of Totten Brook from Peter Totten Meadow this ridge maintains its high, rocky characteristics and a narrow depression 200 to 400 feet wide lies on the north of it. This depression is none the less marked because the divide between Totten Brook and Debert River lies in it only 1,000 feet east of Totten Brook. In this depression, and 1,600 feet east of Totten Brook, is a small circular lake 300 feet in diameter, and about 1,000 feet east of this lake, in the same depression, is another slightly larger lake. These lakes, together with the pond where Totten Brook crosses the meadow, suggest, very strongly, sink-hole lakes in their general appearance, although they are all choked to a shallow depth with vegetation. The two easterly lakes drain into Debert River, and on aerial photographs the depression in which they lie may be traced considerably to the east of the eastern lake, although the plane-table work was carried only to the western one.

About 700 feet east of the western end of Peter Totten Meadow a small brook enters the meadow from the north. On the east bank of this stream considerable trenching was done at some time. No rock is exposed, but pieces of ankerite may be found in the rubble.

Six hundred and fifty feet east of this brook, and 700 feet west of where Totten Brook enters the meadow, is a small open-cut some 30 feet deep cut into the rather steep north bank of the meadow. A section of rock about 70 feet wide, north and south, is exposed here, the only rock seen being carbonates or their oxide enrichments. On the west side of the cut, and poorly exposed due to slumping of the walls of the cut, are two bands displaying oxide enrichment in juxtaposition. The southern band is a dark brown limonite (analysis No. V, previously given), and to the north of it is a bright red hematite and limonite enrichment of carbonate (analysis No. VI). The total widths of these bands are not determinable, but are not less than 7 feet.

Magnetometric Work

As mentioned, six series of observations were made on north-south lines using a Hotchkiss Superdip Magnetometer. In principle this instrument consists of a magnetic needle on a horizontal axis, to which axis is also attached an auxiliary arm, the angle between which and the magnetic needle may be adjusted. The auxiliary arm, being acted upon only by gravity, may be adjusted relative to the needle so as to completely nullify the effect of the earth's magnetism, in which case, and only at that station where this adjustment was made, the magnetic needle will come to rest anywhere within the circle. In practice the angle between the auxiliary arm and the needle is changed a small amount from this exact position so that the effect of the earth's magnetism is almost, but not quite, nullified. The result is that extremely small variations in the earth's magnetism give very large differences in readings of the needle. It was hoped that a large variation over a short distance would be encountered on going from country rock to carbonate rock or vice versa; or that the country rock and carbonate rock would give uniform, but differing, readings. There seemed to be some basis for the first hope, inasmuch as large variations had been obtained by Professor Flynn at the contacts of limestone and other rocks, but very little basis for the second as no magnetic minerals were known in either rock group. The results were decidedly inconclusive, inasmuch as opposite results were obtained on two of the three lines over known carbonate bodies. They were interesting, however, in that decided variations were obtained in places along all lines, which might be taken to indicate the presence of a structure, or structures, the character of which is unknown. A more complete description of the results of these magnetometric surveys is given by the writer in an earlier report.[1]

Ore Possibilities of the District

It is proposed here to discuss in rotation from west to east the various sections of the Londonderry iron district, and the possibilities that can be said to exist in each of there being undeveloped ore bodies. The paucity of information in certain sections will be apparent, and opinions expressed for those sections should be treated with the reservation that they may be changed by any additional information, however slight.

Matheson Brook to Cumberland Brook

In this section very little prospecting was ever done, although a few slumped pits are visible on the flat mountain top between the two brooks. Mining was, of course, carried on in that part of the section available to levels driven from Cumberland Brook. In 1942 two parties did considerable work in four limited localities, and possibly had an equivalent amount of work been more generally distributed, information of a more definite character might have been uncovered.

Woodman reports that the zone of possible ore is wider in this section than in any other. By this he probably means that float and stringers have been located over a greater north-south distance here than in other parts of the district. He does not mention the occurrence of bodies of mineable size other than those that were actually mined, and no such bodies are apparent in the excellent section exposed on Matheson Brook, although on this brook, as on others, the section is not so complete as to exclude the possibility of their existing. On the flat mountain top, both east and west of Matheson Brook, outcrops are extremely scarce, and over large areas completely lacking, but the drift mantle is thin wherever prospecting operations have been carried out.

---

[1] Weeks, L. J.: The Londonderry Iron Deposits, Colchester County, Nova Scotia; Geol. Surv., Canada, Paper 44-10 (1944).

No reason is known why carbonate bodies could not exist in this section, and if their presence were proved, the topography, particularly on the Matheson Brook side, is such as is considered favourable for deep zones of enrichment.

West Mines Section

Regardless of whether or not carbonate bodies still exist in this section, it would be considered very inadvisable that they be developed. Mining has been carried on in this section to such an extent that any future underground work must be extremely hazardous. It is also believed that the section was mined practically to completion, at least in so far as enriched deposits go.

Old Mountain Section

Although considerable mining has been done in this section, it was limited to a zone that did not extend far below the flat top of the mountain, and the lowest workings of any extent were more than 100 feet above the bottom of Great Village River. No. 3 level (the lowest level of any extent) was entered in September 1938 by J. C. Sproule of the Geological Survey. He observed ore of different widths on several faces, the ore varying from black and brown to paint.[1] The presence of such ore might be taken as an indication that the bottom of enrichment had not been reached, and indeed such would be expected from an examination of the topography there. It is doubtful, however, if these points would be stressed were it not for the fact that the workings could, if interest were taken, be entered relatively cheaply and the exact character and disposition of the ore examined in detail.

Great Village River to Folly River

Very little is known of the potentialities of this section. Prospecting has been confined to a few short levels and a number of shallow pits, and the results of this work are not recorded. Outcrops, except in stream bottoms, are extremely scarce or even lacking. However, indications of carbonates are found in all the traversing streams except Saltspring Brook, and might possibly have been missed on that stream. Topographically the section could be considered to be unfavourable for deep enrichment should carbonate bodies be present, and taken as a whole this is probably true. In one part of the section, however, due to local characteristics, conditions for such processes may be considered to be much more favourable than they are in the remainder. The ridge separating McElman Brook from Folly River is $\frac{3}{4}$ mile wide, and although the south front of the mountains between these streams is devoid of appreciable relief, yet these streams have cut such deep valleys through the mountains that the east-west relief along this narrow block is comparable with that in those sections of deep enrichment. Prospect pits west of No. 4 highway, and about 1,200 feet north of the bridge over the railway, have, according to Sproule (1938), ankerite piles on their dumps, which would indicate the presence of carbonate bodies. Such a position is almost exactly in the line joining carbonate indications on McElman Brook with the southernmost similar indications on Folly River.

Folly River to Pine Brook

Included in this section are the East mines, and the ore possibilities of that section are not discussed for reasons put forward in the case of West mines, namely, that unrecorded underground work has been carried on to an extent

[1] Sproule, J. C.: Geol. Surv., Canada, information from notes taken in 1938.

that would render any future work extremely hazardous. To the west and to the east of the East mines lie two sections, on the east bank of Folly River and on the west bank of Pine Brook, that merit some attention.

About ½ mile of undeveloped country lies between the western workings of East mines and Folly River. The east bank of this stream is appreciably steeper and more rugged than the west bank, and the general relief of this section is comparable with that of Old Mountain mines facing Great Village River. Disregarding the low relief to the south of East mines, and which is found also to the south of this part of the section, the east-west relief is considered ample to give rise to a relatively deep zone of enrichment, subject of course to the limitations of such a zone at West Mountain in that the steeper parts of the slopes were underlain by practically unaltered ankerite.

As was mentioned previously, a narrow-gauge railway to this part of the section was under construction when operations ceased. This is of interest, particularly as there are no records of development work, indicating that some ore or indications of ore must have been found there.

Between the eastern end of the East mines workings and Pine Brook is about ½ mile of rolling country followed by a steep declivity into the brook valley. Outcrops are scarce or lacking, both on the top and on the gorge sides. No signs of prospecting have been observed. The remarks about the east side of Folly River would also apply here.

Pine Brook to East of Totten Brook

Near the crest of the east bank of Pine Brook, and 550 feet from the brook, ankerite is exposed for a clear width of 16 feet, and a somewhat obstructed width of at least 30 feet. One thousand feet east of the brook the ankerite has a clear width of 70 feet, and a width indicated by isolated exposures of at least 120 feet. In neither case is the bounding country rock exposed at these limits, but in the latter case such an outcrop occurs 120 feet to the south of the southernmost outcrop of ankerite. In addition to these two main exposures, a sufficient number of small ones are found between them to indicate that the carbonate may be continuous. In the brook bottom below the first exposure is a zone of considerable width showing ankerite stringers cutting the country rock, but no massive carbonate is found, although it may still exist there in debris-covered sections.

Using only the narrower positive width of 16 feet, assuming a possible depth of 200 feet, making proper allowances for the slope of the bank toward the brook, and using a figure of 11 cubic feet per ton for ankerite, it would appear that there may be 220,000 tons of ankerite within 1,000 feet east of Pine Brook. The conservatism of the figures used in the computation is apparent. Of this body of ankerite, the amount, if any, that has undergone enrichment to ore grade cannot be estimated. Based on experiences elsewhere in the district, one could almost safely assume that enrichments would not be lacking. That the ankerite exposed on the steep slopes would not be enriched is to be expected from observations made at Old Mountain, where similar topographical conditions hold. It might, however, be expected that enrichment would have taken place at the open-cut 1,000 feet east of the brook, and indeed the iron content of the carbonate is here slightly, but only slightly, higher than at the top of the steep slope. These possibilities can only be decided by exploration.

Between the prospect open-cut 1,000 feet east of Pine Brook and that on Peter Totten Meadow, 2,500 feet to the east of it, there are no exposures of carbonate, although such rock may be, on the evidence of dump rock, safely assumed to exist at a point where some trenching was done 600 feet west of the latter point. However, it seems highly improbable that the country between two clear exposures of carbonate, each 70 feet wide, should be entirely lacking in such rock when the trends of the bodies are known to be toward each other. In the opinion of the writer, it may be safely assumed that carbonate bodies do exist in this intervening country.

As mentioned, enrichments that might constitute ore are found in the meadow workings. No estimate can be made of the extent of this enrichment. Its presence, however, indicates that conditions favourable to enrichment were present, and no reason exists for supposing that such enrichment should be limited only to the place where it was found.

A description has been given of a linear topographical depression extending from the west end of Peter Totten Meadow to some thousands of feet east of it. Variations in magnetic dips were found on the south side of this depression on two lines of observations, and at a point on another line west of the depression but in line with it. Observations on one line across the depression gave no such variation. This depression may be due: (*a*) to a normal fault with a downthrow on the north, and not sufficiently old to have its surface expression yet removed; (*b*) to a belt of harder rocks on the southern, steeper side (Fletcher maps an intrusive belt on the south side of the meadow); or (*c*) to a belt of softer rocks underlying the depression, which have been eroded or dissolved, leaving lower ground. That the depression may be due to a fault must not be discounted. Such an origin may account for the variations in magnetic dips along the south side of the depression. These variations could be as easily explained by the third alternative (*c*), however. The main faulting along the south side of Cobequid Mountains occurred after the deposition of the Pennsylvanian sediments. Such faulting could presumably have occurred at a date sufficiently recent to permit the surface expressions of the fault to still remain. Against such a theory, however, is the fact that although the south side of the depression is undoubtedly steeper and rockier, yet normal glacial action, by sweeping clear the north-facing ridge and depositing material on the south-facing ridge, might account for such conditions.

There is no essential difference in the rocks north and south of the depression. Rocks believed to be of volcanic origin have been found on both sides, and although fine-grained intrusive rocks may occur on both sides, such are not considered plentiful enough or sufficiently resistant to account for the depression. The note above on glacial action would also apply here, and it is possible that were the north slope stripped of debris, there would be no essential difference in the steepness of the two sides.

The above considerations lead, by process of elimination, to the possibility that the depression is caused by the erosion or solution of softer rocks. Such rocks, particularly if solution is considered as a means of erosion, would be carbonate. Against this theory may be mentioned the fact that although in general the carbonate bodies exhibit the erosional features of limestone and to a lesser extent of gypsum, yet such pronounced topographic expression has not been heretofore found on a carbonate body or bodies. The writer considers that determination of the character of the rocks underlying this depression should be one of the first demands made on any exploration program in the section.

Uses of Ankerite

It was mentioned earlier in this report that during operations at Londonderry ankerite was quarried as such, and charged into the furnaces in the place of limestone. The magnesium content was not considered detrimental, and the ankerite had the advantage that such iron as it contained was added to the iron in the melt.

In computing the charge for a blast furnace magnesium is added to calcium, the total being treated as calcium. This takes care of a magnesium content up to from 5 to 10 per cent of the limestone. The Londonderry ankerites vary considerably in their magnesium content, but in the Pine Brook-Totten Brook section did not go above 12 per cent magnesium. Whether such an amount of magnesium would be detrimental to a furnace charge could be determined only by experiment. And even if such a content should be considered detrimental, the disadvantages of using such rock as a flux should be weighed against the advantages of adding some almost phosphorus-free iron to the melt.

Recommendations

In discussing the ore possibilities of the region, it was apparent that at a number of localities limited deposits of iron ore might reasonably be expected to exist. In only one of these, the Pine Brook-Totten Brook section, does it appear reasonable that if carbonates do exist they are in rather large quantities. The amount of enrichment to be encountered in any unexplored carbonate body cannot be estimated in advance.

The writer would recommend that the Pine Brook-Totten Brook section be considered as a source of furnace flux, from which some iron will be obtained, with the hope and reasonable expectation that enriched bodies of unknown size will be encountered during its development. The most reasonable method of exploration, both in time and money, would be a diamond-drilling program along the supposed carbonate belt.

SPECULARITE DEPOSITS

Specularite, in addition to its association in many places with the ankerites of the Londonderry district, is commonly found as veins and veinlets in the volcanic and sedimentary rocks of Cobequid Mountains. It has not been observed in the grey slates toward the north of the map-area.

Occurrences of this mineral have been prospected slightly about 2 miles north of Broderick's Hotel at Lower Five Islands (west of the area); on Chain Lake Brook to the north of the area; and on West Economy River about ¼ mile above its junction with Economy River. The writer has seen the first- and last-mentioned occurrences.

The specularite occurs in veinlets up to ½ inch wide, and as a coating on both sides of small fractures. Although its shiny appearance, and its habit of dusting off onto any available rock fragment give it at times undue prominence, leading to the impression that much more is present than is actually the case, no occurrence was seen that had any economic possibilities, nor is it expected that any such will be found.

MAGNETITE DEPOSITS

Gerrish Mountain

Magnetite has been long known to occur as segregations in the basalt or trap flows of Triassic age. The material is massive magnetite, and although not analysed, appears of excellent grade. Were it not known to occur in the trap as pockety concentrations, it might be regarded as a possible source of ore. The possibility exists that a small operation with an assured market might be economically feasible, armed with the foreknowledge that the deposit is strictly limited in size.

One occurrence is on the east slope of Gerrish Mountain, a few feet stratigraphically above the contact of the trap with underlying Annapolis sandstone, and about 200 feet east of the west boundary of the area. Two shallow pits were sunk on this deposit some 50 or more years ago, and Woodman examined it in 1906, furnishing one analysis, as follows:[1]

	Per cent
Fe	56·09
SiO_2	17·18
Al_2O_3	0·10
CaO	0·35
MgO	2·02
P	0·21
S	0·50

Bass River

During the recent thirties a deposit of magnetite was discovered on Bass River, by H. K. Langille and H. B. Betts. The writer made two unsuccessful attempts to find the showing, accompanied, on one of them, by a man who had visited the property some years before. As no first-hand information can be offered, a short report issued by the Nova Scotia Department of Mines will be quoted.[2]

"Messrs. H. K. Langille and H. B. Betts held areas for iron ore on Big Bass River, Colchester County. The properties are located approximately three miles north of the village of Bass River in the centre of a tongue of Devonian rock about one mile in width. This tongue is bounded on the south by Carboniferous conglomerate, and on the north by granite and syenite.

"The rock formation in this place is a black quartzite of the iron bearing rocks similar to that of the Londonderry areas. Beginning at the 20 foot falls shown on the G.S.C. map the rock was traced west for over ¼ of a mile. The iron occurrence in the rock was in the nature of sulphides with inclusions of magnetite and was not a true iron bearing ore as they supposed. Samples of hematite taken from this district several years ago by Mr. Farney were analysed at the Nova Scotia Technical College and gave a return of 68 per cent iron. However, during the examination of the outcrops as exposed in the gorge on the river and on the banks to the west, no evidence was found of any hematite ore."

The deposit lies on the west bank of Bass River, within ½ mile north of the south contact of the Cobequid Mountain rocks, and within ½ mile of the river. To the immediate north of this limited area rocks of the volcanic and sedimentary group have been considerably altered by nearby granitic intrusions. The mineral associations would seem to indicate that the mineralized zones were also associated with this granite. If material of ore grade exists, further prospecting might be advised.

SELMAH IRON DEPOSIT

Selmah is a small village on the south shore of Cobequid Bay, about 2 miles west of the village of Maitland. The iron occurrence is about ½ mile southwest of the church at Selmah.

There are four very old pits on the property, three of which are spaced roughly along an east-west line 450 feet long, and the fourth about 350 feet south of the most westerly of the other three.

The occurrence was examined by J. E. Woodman[3] in 1906, and although his definitions of specific pits are somewhat vague, yet he found ore on the dumps of two of them. The iron content of samples from each was 56·880

[1] Woodman, J. E.: Op. cit., p. 131.
[2] N.S. Dept. Mines, Ann. Rept. 1938, p. 144.
[3] Woodman, J. E.: Op. cit., p. 136.

and 56·860 per cent respectively. He reports that the New Glasgow Iron, Coal and Railway Company sank one of the pits and found ore across a width of 8 feet at the bottom. He quotes several analyses made by that company, the average being: iron 44·0 per cent and silica 10·0 per cent. He states that the ore consisted of limonite and red hematite, with more of the former than of the latter.

At the time of the writer's visit no ore was found on any of the dumps, and only one contained material to suggest that that pit had bottomed in bedrock, namely, fragments of slightly ferruginous, micaceous, sandy shale. A local resident volunteered the information that rock from this dump had been used for road building, which may account for the fact that no ore was found on any dump, whereas Woodman reports the presence of some.

The deposit is in rocks of the Horton group very close to their contact with the overlying Windsor group. This particular zone has been proved particularly susceptible to supergene replacements by various minerals, and there is nothing in the observed relationships or in Woodman's descriptions to indicate that the ferruginous concentrations encountered here were not also supergene in origin. Lacking a terrain of considerable relief to cause an abnormally low water-table, it cannot be assumed that any iron deposits, even if of ore grade, will continue downwards more than a matter of tens of feet.

MANGANESE

GENERAL STATEMENT

A larger number of manganese occurrences has been found in this area than in any other area of similar size in Nova Scotia. In addition, the Tennycape mine had a total production about four times as great as its next, and only serious, competitor. The deposits in the area may be divided roughly into three general types, namely: replacement deposits in Windsor limestone; fissure fillings in shale; and nodular deposits in Triassic sandstone. Actually there is some evidence that the nodular deposits are basically similar in mode of origin to the replacement deposits, inasmuch as the nodules found in the red sandstone and conglomerate are in part, if not wholly, replacements of calcite cement or pebbles of limestone. Because, however, they differ greatly in their economic possibilities, they will be treated separately.

REPLACEMENT DEPOSITS IN LIMESTONE

Deposits of this type are found exclusively in the limestone conglomerate of the Pembroke formation, at or near its lower contact with the shaly limestone of the Macumber formation. The former, and probably both formations are part of the Windsor group. The manganese occurs as oxides in the form of nodules and lenses replacing the limestone conglomerate. Associated with the replacement deposits are fissure fillings of manganese oxides that occur in many places in the adjacent shaly Macumber limestone, but no nodular replacements have been observed in rocks of this formation. The replacement lenses have been known to attain considerable dimensions, one lens at the Tennycape mine yielding 1,000 tons of ore. They are in general, however, extremely spotty and difficult to predict. A description will be given of the various occurrences of this type in the area, all on the south side of Cobequid Bay.

Tennycape Mine

References

Bancroft, M. F.: Manganese Occurrences about Minas Basin, N.S.; N.S. Dept. Mines, Ann. Rept. 1937, pt. 2, pp. 13-33.

Fletcher, Hugh: Geol. Surv., Canada, Ann. Rept., vol. V, pt. 2, 1890-91, pt. P, p. 184; Sum. Rept. 1893, p. 42.

Flynn, A. E.: Survey of Minas Basin Manganese Deposits; N.S. Dept. Mines, Ann. Rept. 1939, pt. 2, pp. 101-113 (1940). Geophysical Survey, Minas Basin Manganese Deposits; N.S. Dept. Mines, Ann. Rept. 1940, p. 102. Concentration of Tennycape Manganese Ore; N.S. Dept. Mines, Ann. Rept. 1940, p. 107.

Geol. Surv., Canada, Ann. Rept. 1892-93, pt. A, p. 63.

Gilpin, E.: On the Manganese Ores of Nova Scotia; Roy. Soc., Canada, vol. 2, sec. 4, p. 10 (1884).

Hanson, George: Manganese Deposits of Canada; Geol. Surv., Canada, Ec. Geol. Ser. No. 12, p. 41 (1932).

How, Professor: Contributions to the Geology of Nova Scotia; London, Edinburgh and Dublin; Phil. Mag., 4th ser., vol. 31, p. 167 (1866).

Ingall, E.D.: Mineral Statistics and Mines; Geol. Surv., Canada, Ann. Rept. 1889, vol. IV, pt. S, p. 58 (minor ref.). Rept. Div. of Mines; Geol. Surv., Canada, Ann. Rept. 1892-93, pt. S, p. 88 (minor ref.). Manganese; Geol. Surv., Canada, Sec. of Mines, Ann. Rept. 1902, pt. S, p. 154.

Nauss, A. W.: The Origin and Economic Possibilities of Canadian Manganese Occurrences; manuscript report submitted to Research Council about 1940.

N.S. Dept. of Mines, Ann. Repts.: 1877, p. 46; 1880, p. 14 (minor ref.); 1881, p. 17 (minor ref.); 1883, p. 24 (minor ref.); 1884, p. 33 (minor ref.); 1886, p. 21 (minor ref.); 1889, p. 46 (minor ref.).

Penrose, R. A. F., Jr.: Manganese, Its Uses, Ores and Deposits; Ark. Geol. Surv., Ann. Rept. 1890, vol. 1, p. 518.

Smitheringale, W. V.: Manganese Deposits of the Maritime Provinces, Canada; manuscript report written in 1928.

Willimott, C. W.: Report of Observations in 1883 on some Mines and Minerals in Ontario, Quebec, and Nova Scotia; Geol. and Nat. Hist. Surv., Canada, Rept. of Prog. 1882-83-84, pt. L, p. 21 (1884).

General Information

The Tennycape mine was from 1880 to 1900 the largest producer of manganese ore in Nova Scotia. A few attempts have since been made to reopen it, but none of these has materialized, and no orebodies are known to exist.

The mine lies in the village of Tennycape, Hants county, about 1½ miles southwest of the highway bridge over Tennycape River. A fair wood road, passable to motor vehicles, connects the mine with the highway at R. Patterson's farm. The property is 2 miles from a small dock at Tennycape, and 7 miles from the gypsum-loading dock at Walton. There are no buildings nor mining equipment on it.

History and Production

The following account is largely by Smitheringale, as quoted by Hanson. The mine was first owned by a Mr. Hill and associates of Halifax, and in 1862 work commenced under the management of J. Brown. Early production was from boulders of manganese ore in the soil overlying the deposit. Open-cuts into the underlying limestone later provided a considerable quantity of ore. In the eastern open-cut a large lens yielded 1,000 tons of good ore between 1870 and 1875.

In 1877 J. W. Stephens of Tennycape bought the property, and during the following 15 years is said to have obtained an average annual production of about 200 tons. The production figures for all years are not given in the reports of the Nova Scotia Department of Mines, but between 1879 and 1889 the average annual recorded production was about 130 tons.

In 1895 Messrs. McVicar and Shaw bonded the property and did a little work, but later sold to a company the chief members of which were Messrs. Boak of Halifax, Barnes of Boston, French of Maine, and W. F. Jennison of Truro. Very little development work was done by this company.

During the winter of 1917-18 a Mr. Hassan dewatered and sampled the mine for an American company, but nothing further was done and the property has since lain idle.

It is probable that altogether about 4,000 tons of manganese oxides were produced from the property.

Description of the Property

The workings at the Tennycape mine fall into three main groups, namely: Nos. 1 and 2 open-cuts at the eastern end of the property, which, together with a number of pits and shafts, may be considered to be the main workings; No. 3 open-cut and one shallow shaft, lying 160 feet west of No. 2 open-cut; and Peddler's cave, a short horizontal adit 640 feet west of No. 3 open-cut, which, with a short inclined shaft from the brow of the hill above it, might be referred to as the western workings. Most of the production came from Nos. 1 and 2 open-cuts together with the underground workings associated with them.

The two eastern open-cuts are actually two deeper excavations in the bottom of what was originally one large cut that included both. Both are connected with the underground workings by raises, and are filled with water to 6 feet below the lowest point in their rims. They are separated by a ridge of loose material, possibly dump rock, and lie at the foot of a south-facing cliff in rock, 50 feet high. Prof. A. E. Flynn[1] has computed the amount of rock removed from these open-cuts to be 21,000 tons. He also has computed the tonnage of rock on the dumps to be 35,000 tons,[2] so that, including the recovered manganese, roughly one-half of the removed rock came from open-cuts Nos. 1 and 2.

The main shaft, said to be 165 feet deep, lies 90 feet south of the west end of No. 1, or the most eastern, open-cut. It is flooded to the same level as the open-cuts, in this case 8 feet below the collar. Although the timbers around the collar are badly decayed, and some slumping has occurred, the shaft may be usable at depth.

In addition, there are three slumped pits, probably shallow, within 200 feet east of No. 1 open-cut; and two slumped pits and one timbered but caved shaft within 140 feet west of No. 2 open-cut.

No. 3 open-cut is about 80 feet by 40 feet in plan, and at its northern extremity has been excavated to a depth of about 25 feet. A shaft of unknown depth, but accessible to 18 feet below the collar, is located within the cut and near its southern entrance. The timbers in this shaft are comparatively fresh, and it could not have been sunk at the same time that operations were conducted in open-cuts Nos. 1 and 2. Except for its limited depth and the absence of any indicated ore nearby, this shaft could be used again.

At the western workings an adit is driven 77 feet northerly into the base of a ridge 50 feet high. From the crest of the ridge an inclined shaft was sunk to intersect the adit, but missed it by 8 to 10 feet. The adit is locally known as Peddler's cave, and both it and the shaft are accessible for examination, although the portal of the adit is slumped, leaving a hole not much larger than a man.

---

[1] Personal communication.

[2] *See* References, Flynn, 1939, p. 112.

The full extent of the various underground workings is difficult to ascertain. As mentioned above, Flynn's figures show by subtraction that 18,000 tons of rock on the dump came from the underground workings. Actually the rock broken must exceed this figure considerably, as the writer is informed by Mr. W. J. Stephens of Tennycape that a large amount of mined rock was not hoisted, but was left in old stopes. Considering the limited spacial extent of the workings and the relatively large tonnage of rock broken, it is apparent that large vault-like spaces must have been left.

Geology

The Tennycape mine deposit lay on the north limb of a syncline in rocks of Horton and Windsor age, which is cut off about 1,000 feet to the southwest by a fault of considerable magnitude. The oldest rocks on the property are exposed at the top of the cliff north of Nos. 1 and 2 open-cuts, at the most northerly extension of a gash excavated in the cliff face. These rocks, of the Cheverie formation (upper Horton), are red, sandy, slightly micaceous shales, and dip 35 degrees south. Overlying these rocks is the Macumber formation, 16 feet thick and composed of shaly limestone, reddish to red-grey near the bottom, grading to yellowish brown and to buff higher in the section. This rock is well bedded, and is seen to be quite conformable with the Cheverie. Similar features were observed in No. 3 open-cut, but the actual contact is covered there.

Overlying the Macumber on the cliff faces back of the eastern cuts, and also about 55 feet from the portal in Peddler's cave are the red-brown to buff-coloured conglomerates and breccias of the Pembroke formation. Rocks of this formation consist normally of massive, commonly crystalline limestone matrix containing pebbles of pre-Macumber rocks up to 1 mm. in size, and fragments, usually angular, of the Macumber shaly limestone ½ inch to 2 inches long. Sixty feet stratigraphically above the base of the Pembroke, and exposed between Nos. 1 and 2 open-cuts and again at the eastern end of No. 1 cut, are small exposures of dull brown, unbedded, calcareous mudstone. This rock, although the youngest exposed on the property, is believed to be a local lens in the conglomerate, and to be followed by more conglomerate. Penrose[1] states that bodies of ore are sometimes separated by beds of clay, but does not state whether calcareous clay or not.

Although it is not at present exposed on the property, the lower sulphate bed of the Windsor group is known to overlie the Pembroke formation, and this is verified by Penrose who states that at the time of his visit gypsum was found to the south of the mine, in the valley of Rennie Brook. It is not possible to determine from Penrose's description just where the gypsum was found, but it may be assumed that it lay in an area now covered by dump. Taking into consideration the present extent of the dump, and assuming a constant dip of 35 degrees for the rocks, the Stephens formation must have a thickness at the mine not exceeding 350 feet.

In No. 3 open-cut Macumber shaly limestone is exposed along the southeast side of the excavation, which is a southwest-facing gash in the hillside. Similar rock is exposed in the shaft sunk near the entrance to the cut. On the northwest side is exposed red, slightly micaceous, sandy shales of the Cheverie formation, similar in all respects to the rocks underlying the Macumber south of the eastern open-cuts. Although the contact between these formations is not exposed, and indeed their exposures are no closer than 30 feet, yet by continuing the strike

[1] *See* References, Penrose, 1890.

of one toward the exposure of the other, a gap of only a few feet is seen to exist, in which gap the contact must lie. If the trend of this contact in the No. 3 cut be extended to the east, using the strikes in the eastern part of the cut for direction, it would lie 40 to 60 feet south of the approximate but highly probable position of the same contact in the cliffs north of No. 2 open-cut, which are only 80 feet to the east of the most easterly exposure in the No. 3 cut. Between Nos. 2 and 3 open-cuts is a draw in an otherwise continuous ridge. The probability exists that there is a fault between Nos. 2 and 3 open-cuts, that this draw is its topographic expression, and the horizontal displacement is 40 to 60 feet.

Pembroke limestone conglomerate is exposed at the mouth of Peddler's cave, and on the walls of the tunnel for 55 feet from the portal. Fragments contained in this rock are largely Macumber shaly limestone, and in general the size and distribution is much the same as is found in the same conglomerate at the eastern workings. At least 22 feet of Macumber rocks are exposed north of the conglomerate in the tunnel. The inclined shaft on the hill to the north of the tunnel is entirely cut in shaly limestone. Twenty feet below the collar the dip is 22 degrees to the south, but below that it steepens. Small blebs and stains of manganese were found in and on the dump rock in front of Peddler's cave, but none was seen in place in either workings.

A major fault lies about 1,000 feet southwest of the eastern open-cuts. This fault, which strikes about north 60 degrees west and has its downthrow on the northeast side, was first mapped by Hugh Fletcher, who indicated a horizontal displacement of 3,000 feet. Because of its distance from the deposits, it is not believed that this fault had any influence on the formation of the mineral deposits, and apart from it, and the fault between Nos. 2 and 3 open-cuts, there are no indications of faulting on the property.

Mineral Deposits

The deposits at Tennycape mine were composed essentially of pyrolusite, with minor amounts of manganite and psilomelane, associated with varying amounts of calcite, limonite, barite, and selenite. They occurred as lenses and blebs in the limestone conglomerate, and as fracture fillings in the shaly limestone. The ore was of remarkable purity, most of the output of the mine being of "chemical grade."

The best ore was found as nodules and pockets in the limestone conglomerate. One massive body, as mentioned above, yielded more than 1,000 tons of manganese minerals. Manganese was also found in the shaly limestone, and today manganese minerals may be seen as small stringers filling fractures in this rock on the cliff face back of the eastern open-cuts. These stringers lie along joint planes, fractures, and bedding planes. Very seldom, if ever, are rounded replacement nodules found in the conglomerate.

Pyrolusite was the most common manganese mineral, but a little manganite was also observed. The writer did not, however, identify any psilomelane, but as earlier writers have mentioned its presence, and as it admittedly will probably be found in the lower parts of the deposit, it is included among the manganese minerals.

The best ore was said to have been found in the lower 40 feet of the limestone conglomerate, or that part of the conglomerate immediately above the Macumber formation.

The manganese minerals replaced the limestone conglomerate, giving rise to lenticular and nodular bodies that may be unconnected with other nearby bodies. The shaly limestone on the other hand was not as amenable to replacement as the younger rock, and depositions within it were confined to the filling of openings that existed before the advent of the manganiferous solutions.

Ore on the Dump

As previously mentioned, Flynn computed that the dumps at the main eastern workings held 35,000 tons of rock. In the same paper he gives the results of sampling the dumps, and of attempts to concentrate these samples. The average manganese content of the rock on the dumps was computed to be 1·88 per cent. This would indicate a total manganese metal content of 660 tons for the entire dump, or slightly more than 1,000 tons of pyrolusite. Samples weighing 1·84 tons in all were treated by table concentration, a method that Flynn admits is not particularly satisfactory. A 31 per cent concentrate was obtained, the recovery, however, being only 7 per cent. It is possible that a more efficient method of concentration may be devised, but it is apparent that otherwise the manganese in the dump is of no commercial interest.

Recommendations

In considering recommendations for further work on this property, four facts should be borne in mind: (1) the mined-out orebodies at Tennycape were not continuous, one to the other; (2) the orebodies did not continue to depths incompatible with a theory of origin based on ground-water solution and deposition; (3) the discovery of new orebodies during the period of the mines activity might be said to be largely fortuitous, following work in the vicinity of either known orebodies or of residual manganese masses in the soil; and (4) during the mine's hey-day, at least 9 tons of rock were moved to obtain 1 ton of manganese.

The following corollaries are then apparent: the presence of a known orebody does not necessarily indicate that it continues an appreciable distance in any direction; no ore can be expected to any considerable depth; and a 9 to 1 ratio of rock to ore is equivalent to 11 per cent pyrolusite or, roughly, 6 per cent manganese, which is very low.

Under these circumstances, and particularly as no known concentration of oxides exists, no underground work can be advised. The amount and manganese content of the dump rock being known, the dumps may be considered as a possible source of limited manganese should economic conditions so warrant.

Faulkner Mine

References

Flynn, A. E.: Survey of Minas Basin Manganese Deposits; N.S. Dept. of Mines, Ann. Rept. 1939, pt. 2, p. 1.

Hanson, G.: Manganese Deposits of Canada; Geol. Surv., Canada, Ec. Geol. Ser. No. 12, p. 40 (1932).

Smitheringale, W. V.: Manganese Deposits of the Maritime Provinces; manuscript report written in 1928.

Location and History

The Faulkner mine lies 6,000 feet southwest of the highway bridge over Tennycape River, and is reached by a very poor wood road leading south from the extreme west end of the road that extends southwest from Minasville village.

The property was originally owned by Joseph Faulkner. About 1887 William Stephens operated it on lease and removed about 1,200 pounds of ore from surface workings. About 1907 Leonard Reynolds sank a 35-foot shaft from which he obtained more than a ton of good ore.

Workings

The 35-foot vertical shaft, sunk in 1907, can be descended safely by a ladder. Five old pits, now completely caved, lie less than 120 feet to the west and south of the vertical shaft, and 800 feet east of it is another caved shaft or pit. It is believed that all these caved workings were excavated in the earlier period of activity, about 1887. In addition, there is a cave hole in limestone shale, 40 feet long and 15 feet deep at its southern end, into which a small brook flows and disappears. Whether this opening is man made or is the result of solution of the limestone is not clear. There is no dump near it, and it is probable that it is a sink-hole.

Geology

The occurrence lies on the northern limb of a syncline of Horton and Windsor rocks at, and above, the contact of Macumber shaly limestone and Pembroke limestone conglomerate. Horton shales are not exposed on the property, but are assumed to lie a short distance south of the Macumber formation.

The Macumber formation consists here of a dull yellow to buff, bedded, shaly limestone dipping south at angles between 65 and 85 degrees. Most of the workings are along the contact between these rocks and the Pembroke formation, here a reddish limestone conglomerate, pebbles in which are largely derived from the shaly limestone. The Pembroke formation at the Faulkner mine is less than 400 feet thick, and is overlain, in the valley of Tennycape River to the south, by beds of gypsum.

Most of the manganese minerals observed on the dumps was pyrolusite, occurring as earthy fillings in narrow openings in the conglomerate. Well crystallized manganite was also observed, as was pyrolusite in crystals up to 1 inch long associated with dog-tooth spar (calcite) as vug linings.

Recommendations

Nothing on or near the property justifies an assumption that manganese orebodies exist there. No further work can be recommended.

Parker Mine

References

Fletcher, Hugh: Geol. Surv., Canada, Ann. Rept. 1892-93, pt. A, p. 63.

Flynn, A. E.: Survey of Minas Basin Manganese Deposits; N.S. Dept. of Mines, Ann. Rept. 1939, pt. 2, p. 6.

Hanson, G.: Manganese Deposits of Canada; Geol. Surv., Canada, Ec. Geol. Ser. No. 12, p. 44 (1932).

Ingall, E. D.: Geol. Surv., Canada, Sec. of Mines, Ann. Rept. 1902, pt. S, p. 155.

Penrose, R. A. F., Jr.: Manganese, Its Uses, Ores and Deposits; Ark. Geol. Surv., Ann. Rept. 1891, vol. 1, p. 522.

Smitheringale, W. V.: Manganese Deposits of the Maritime Provinces; manuscript report written in 1928.

Location and History

The Parker mine is located 3,600 feet northwest of Tennycape mine, and 2,400 feet southeast of Tenecape schoolhouse, from where it is connected by a poor wood road, impassable to motor vehicles.

The mine was worked about 1882 by William Stephens of Tenecape, who removed some 50 tons of very good ore. The workings consist of a water-filled pit some 90 feet in diameter, and two trenches 600 feet and 800 feet northeast of the pit.

Geology

The property lies on the axis of a syncline that probably plunges to the west. Fifty feet east of the pit an outcrop 30 feet long, north and south, exposes buff-coloured, Macumber, shaly limestone at each end with 6 feet of infolded, reddish, Pembroke limestone conglomerate in the middle. All observed pebbles in the conglomerate were derived from the shaly limestone. The pit lies on the westerly extension of the axis of the fold, and the entire width of limestone conglomerate, together with some shaly limestone, must have been removed. At the southwest corner of the pit is a small outcrop of reddish sandy shale, very similar to that found beneath the shaly limestone at Tennycape mine, and indeed the entire section would seem to correspond closely except that the Macumber appears here to be about 20 feet thick instead of 35 feet as at the Tennycape mine.

No rock is exposed in the two trenches to the northeast, but the rock on their dumps leaves very little doubt as to what was encountered. The more southerly trench has a dump composed of reddish, slightly sandy shale, similar to that found at the southwest corner of the pit, whereas the northern trench was dug in a reddish, very fine-grained and finely cleaved shale, almost a slate. The presence of Horton rocks to the northeast, and the apparent widening of the Pembroke formation to the east of its exposures, is the basis for the assumption that the syncline plunges to the west.

Recommendations

Fifty tons of ore are recorded as the production from this property. It would be difficult to estimate the amount of rock removed to obtain this tonnage, but it would appear as if the grade might have been satisfactory for a small operation, and that the operators ran out of ore in the Macumber formation.

If the syncline plunges to the west, as anticipated, it is possible more ore might be encountered near the surface while the fold is still shallow. It might be advisable to trace this syncline westerly for a short distance and examine its ore potentialities.

Scott Mine

References

Hanson, G.: Manganese Deposits of Canada; Geol. Surv., Canada, Ec. Geol. Ser. No. 12, p. 67 (1932).

Smitheringale, W. V.: Manganese Deposits of the Maritime Provinces; manuscript report written in 1928.

Location, History, and Workings

The Scott mine is 3,000 feet south of the back road in Minasville, on the farm of Arthur Laffin. It is reached by a poor wood road, extremely swampy in places.

The mine was operated on lease by Captain Scott about 1887. Two pits about 80 feet apart on the south bank of a small brook are accessible to a depth of 8 or 10 feet. In addition to these, an open-cut is said to have been excavated, but apparently is grown over. There is no record of production.

Geology

The deposit lies in Windsor rocks near their contact with those of the Horton group. In the more westerly of the two pits limestone conglomerate of the Pembroke formation is exposed, containing pebbles and fragments that apparently were derived from the underlying Macumber formation. Manganese stain was visible in a few places, but no blebs of oxides were observed. In the other pit the contact was observed between underlying shaly limestone of the Macumber formation and Pembroke rocks similar to those exposed in the first pit. The contact surface of the shaly limestone is crumpled into folds a few inches across, and the overlying Pembroke beds are badly broken at the immediate contact, and carry pebbles of the Macumber formation. A rock, believed to be a much weathered soft member of the Horton group, is exposed 30 feet east of this pit and at a somewhat lower elevation.

Recommendations

No further work can be recommended at this property.

OTHER OCCURRENCES

So far as is known, there are no other workings on occurrences of manganese minerals in the Windsor limestone of the area mapped. It should be borne in mind, however, that the contact between the Macumber and Pembroke formations, adjacent to which all the above described occurrences have been found, is not only continuous across most of the southern side of this area, but extends unbroken from Avon River near Summerville to Shubenacadie River near South Maitland. This contact is considered as a possible locus for concentrations of manganese minerals, although conditions particularly favourable for their occurrence are more limited. Such conditions will be discussed later, together with the origin of the ores.

Several occurrences of manganese minerals lie a short distance to the west of the area, and thus normally would not fall within the scope of this report, but it is proposed to include a description of what is considered the two most important of these occurrences, and certainly the two on which the most work has been performed. These are the Stephens mine, just to the east of Walton, about 4 miles west of the area, and the Macumber property at Cheverie, about 14 miles west of the area. These properties are included, not because it is considered that they have a better chance of producing manganese in the future, but because details were encountered in their examination that were to prove of great help in understanding those properties that have already been described.

Stephens Mine

References

Fletcher, Hugh: Geol. Surv., Canada, Ann. Rept. 1892-93, pt. A, p. 64; Sum. Rept. 1902, pt. A, p. 390.

Flynn, A. E.: Survey of Minas Basin Manganese Deposits; N.S. Dept. of Mines, Ann. Rept. 1939, pt. 2, p. 1.

Hanson, G.: Manganese Deposits of Canada; Geol. Surv., Canada, Ec. Geol. Ser. No. 12, p. 41 (1932).

Ingall, E. D.; Manganese; Geol. Surv., Canada, Sec. of Mines, Ann. Rept. 1902, pt. S, p. 155.

Smitheringale, W. V.: Manganese Occurrences of the Maritime Provinces; manuscript report written in 1928.

Willimott, C. W.: Geol. and Nat. Hist. Surv., Canada, Rept. of Prog. 1882-3-4, pt. L, p. 21.

Location and History

The Stephens mine is situated 3,200 feet southwest of the bridge over Walton River in the village of Walton, and may be reached by a short, fair wood road, passable to motor vehicles.

The mine was first worked by J. Brown from 1870 to 1875, and a few tons of very good ore are said to have been obtained. About 1885 R. J. Stephens removed some 10 to 20 tons of ore, and from 1902 to 1907 about 20 tons of ore were recovered by William Stephens.

Workings

The main workings will be described from west to east, and numbered in rotation for reference. Nearby allied projects of a minor nature will be included under the main numbers.

No. 1 group, at the extreme west of the property, apparently commenced as an open-cut into a low cliff face of limestone. Later, an inclined shaft was driven to the south at an angle of 41 degrees, and an attempt was made to intersect it by a vertical shaft 53 feet to the south. Both shafts are filled with water to within 4 feet of the collar of the lower, inclined shaft. It appears that these workings were among the last to be excavated on the property.

No. 2 working is a pit 10 feet in diameter and 8 feet deep, located 680 feet east of the No. 1 workings. It is sunk entirely in bedrock.

No. 3 group lies 50 feet east of the No. 2 pit, and consists of an open-cut 30 feet long in a low cliff face, at the bottom of which is a vertical shaft 16 feet deep. The shaft is completely timbered, so that no bedrock is exposed.

Forty feet east of No. 3 group an open-cut begins, and extends 120 feet farther east. This cut and a shaft at the bottom of it are referred to as the No. 4 group of workings. The open-cut is made partly by quarrying into a 13-foot cliff face, and partly by excavating to a depth of 12 feet below the normal land surface. The shaft at the bottom is now almost filled with rock debris, and apparently is inclined.

No. 5 consists of a depression 60 feet in diameter and about 12 feet deep, situated 80 feet south of No. 4 group shaft. The absence of a dump near this depression suggests that it may be a sink-hole, but as this could not be ascertained with certainty, it has been included with the other workings.

One hundred and ten feet east of No. 4 shaft is a pit 40 feet in diameter, 15 feet deep, and with what appears to be a caved shaft in the bottom. Just east of this excavation, which will be referred to as No. 6, is a dump 80 feet in diameter and 8 feet high.

No. 7 group consists of four pits, up to 40 feet in diameter, and not more than 8 feet deep. Although no dump is visible near the pits, they are believed to have been excavated, as bedrock is exposed on the sides of some of them.

No. 8 open-cut begins 390 feet east of No. 4 shaft and 20 feet east of the most easterly of the No. 7 group, and extends from there northeasterly 230 feet. The normal ground surface is quite level here, and the excavation has been carried down to 20 feet in places below this level. Near the western end is an inclined shaft, sunk from the bottom of the open-cut. The shaft inclines 35 degrees just east of south, and measures 58 feet along the slope. Several short levels are cut each way from the shaft, made apparently in the search for ore.

No. 9 open-cut and shafts are the most easterly of the Stephens mine workings, and, judging from the size of trees growing in the open-cut, they are probably the oldest. The cut is 160 feet long and begins 165 feet east of the east end of No. 8 open-cut. Two shafts were sunk within the cut, but neither is accessible. A washing plant for improving the grade of the ore was erected 120 feet north of the No. 9 workings, where a small earth dam makes a pond of a small swamp.

Roughly 10,000 tons of rock were moved in excavating these workings, and as the recorded recovery is 40 tons of ore, it seems reasonable that there must have been some unrecorded production. The average grade on the basis of the recorded production would be 0·4 per cent manganese oxide, or about 0·2 per cent manganese.

Geology

The oldest rocks on the property are reddish, fine, sandy shales of Horton age, exposed on the north side of No. 8 open-cut. Although not exposed elsewhere, these rocks follow closely the north side of the manganese-bearing horizon, and mark the foot-wall limit of possible ore. Overlying these shales is a fine, buff, well-bedded, shaly limestone of the Macumber formation, which in No. 8 open-cut has a thickness of 25 feet. Manganese minerals, pyrolusite with some manganite, are found as fracture fillings in this limestone, but rarely, if ever, as masses replacing it. The Macumber is apparently quite conformable with the Horton sandy shales, but fragments of it are plentiful in the overlying Pembroke limestone conglomerate. The latter rock is buff to red weathering, usually reddish on a fresh surface, and consists of pebbles and angular fragments of a variety of rock types, in a matrix of reddish limestone, often crystalline. In No. 8 open-cut the pebbles consist almost entirely of angular fragments of Macumber rocks. At No. 6 pit several pebbles of vein quartz and granite were found in the conglomerate. In No. 4 open-cut the included pebbles were predominantly buff, shaly, Macumber limestone, and a reddish, slightly calcareous clay or mudstone, a rock found in place only near the Macumber mine, and referred to later in describing that mine, and minor amounts of red, sandy, Horton shale, thinly bedded, grey slate, vein quartz, grey quartzite, and slightly silicified sandstone, the last possibly from the Horton. These pebbles show that a considerable range of pre-Windsor rocks were exposed and under erosion at the time of deposition of the Pembroke conglomerate.

The Pembroke conglomerate was the source of most of the manganese produced from the property, and blebs and irregular larger masses are today visible in it at numerous places in the workings. Near the old washing plant north of No. 9 workings is a barrel about half full of manganese ore obtained from the mine. Although largely fines, several pieces of relatively pure oxide are more than 5 inches in diameter, and probably were much larger before undergoing frost action for a quarter of a century.

In No. 8 shaft are a large number of leached fractures, some of which are large enough to admit a man, and which are lined with coarse crystals of dog-tooth spar (calcite). Near the bottom of the shaft such crystalline aggregates are in many places coated with crystalline pyrolusite about ½ inch thick. On removing the manganese coating, pure calcite is found in perfect crystal form beneath, and containing no manganese. In another place near the shaft bottom such calcite crystals are coated with earthy pyrolusite, and one broken crystal was found coated in such a manner as to suggest that the manganese had been deposited since the opening of the shaft.

In the eastern end of the property the water-table is very low, much below the deepest workings. No. 1 workings only are filled with water.

Conclusions

No large body of ore was found on the property. The tenor of the rock mined in early operations was very low, and it is improbable that further work would result in a greatly increased recovery per ton mined. Against this should be considered the fact that the water-table in the eastern part of the property is probably the lowest encountered among the limestone replacement deposits, and that, therefore, deposition by surface waters could continue to greater depths than in other properties. This again may result in a lowering of the grade through more distribution of a definite amount of oxide. No further work can be recommended.

Macumber Mine

References

Flynn, A. E.: N.S. Dept. of Mines, Ann. Rept. 1939, pt. 2, p. 4.

Hanson, G.: Manganese Deposits of Canada; Geol. Surv., Canada, Ec. Geol. Ser. No. 12, p. 56 (1932).

How, Professor: Lond. Edin. and Dub. Phil. Mag., 4th ser., vol. 31, 6, 166 (1866).

Ingall, E. D.: Manganese; Geol. Surv., Canada, Sec. of Mines, Ann. Rept. 1902, pt. S, p. 156.

Penrose, R. A. F., Jr.: Ark. Geol. Surv., Ann. Rept. 1891, vol. 1, p. 522.

Smitheringale, W. V.: Manganese Deposits of the Maritime Provinces; manuscript report written in 1928.

Location and History

The Macumber mine is on the farm of Leander Macumber, on the west side of a small bay, by which it is separated from the Government wharf at Cheverie. It is reached by a good farm road from the highway (the "Shore Road" from Walton to Windsor) at the east end of Manganese Hill. The old workings on the Macumber farm were originally known by two names, those nearest the sea being called the "Lake property", and those nearest the highway the "Brown property". The Brown pits and the earlier Lake pits were worked from 35 to 45 years ago, and the recovery of manganese ore is said to have been about 100 tons. In 1936 or 1937 Mr. Macumber sank a vertical shaft 19 feet at a point about 100 feet west of the sea-cliffs bounding his farm. Some ore was recovered.

Workings

The Brown workings lie 455 feet north of the highway, and immediately to the west of the Macumber farm road. They consist mainly of a small open-cut, some 60 feet long, excavated partly into the side of a hill and partly downward at the foot of the hill. The latter part is now a shallow pond. On the top of the hill, 20 to 30 feet above the pond, are a number of small slumped pits. Bedrock is exposed in the face of the open-cut, and in a few outcrops on top of the hill.

The old Lake workings are only visible today in an open-cut dug into the sea-cliff 350 feet north of the Macumber house and 1,300 feet from the highway. This open-cut is 80 feet long, east and west, 30 feet wide, and 25 feet deep at the inland end although partly filled there by rubble.

The Macumber shaft, situated 30 feet west of the west end of the Lake open-cut, is 19 feet deep, of which 8 feet is in bedrock, is 12 feet square at the collar, and 10 feet square at the bottom, and is soundly timbered (1940). About 66 tons of bedrock were excavated, from which the manganese minerals were removed by hand sorting and stored on the property. The weight of manganese oxide there was estimated at 3,000 pounds, which would indicate that the bedrock mined carried 2·4 per cent of manganese oxide.

Geology

The deposits lie on the west limb of a very shallow syncline of Windsor and Horton rocks. The dip usually ranges from horizontal to 5 degrees, but locally may be as high as 10 or 15 degrees. Northwest of the Macumber shaft on the sea-shore, fine-grained, red and grey, Horton sandstone is overlain by 6 feet of red clay or mudstone, which in turn is overlain by buff, shaly limestone of the Macumber formation. The Macumber is unbroken for 6 feet above its base, and then grades into a zone, properly belonging to the Pembroke limestone conglomerate overlying it, in which large angular fragments of the Macumber, some of which near the base of this zone are 10 feet across, are cemented together by red, crystalline limestone. The top of this zone is placed, with difficulty, at a point where fragments of the Macumber rocks cease being brecciated fragments, almost in situ, and become normal pebbles in a conglomerate. Overlying the Pembroke conglomerate, but separated in exposures from it by some hundreds of yards of water, are beds of gypsum and anhydrite.

The ore obtained from the Macumber shaft consisted essentially of pyrolusite with some manganite, and occurred in blebs and nodular masses up to 6 inches across. Small veinlets, usually of about 1 millimetre in width, were seen in some of the rocks on the dump. Below high tide, about 100 feet east of the shaft, nodular masses of psilomelane 1 foot across are visible in the conglomerate. Mr. Macumber, who referred to psilomelane as "hard manganese", was quite sure that it was not encountered in digging the shaft, but occurred only on the shore.

Recommendations

The material mined in the shaft was very low grade. The property, however, has several features to recommend it, were it possible to treat material of such grade. The conglomerate lies in a very shallow syncline, and, therefore, will have a wide lateral extent, within comparatively shallow depths. Other factors being satisfactory, the overburden, 10 to 15 feet thick, could be removed, and the conglomerate then quarried. Against such an operation is the confinement of the conglomerate to a surface width of 500 feet only at the Macumber pit. To the south, toward the highway, the width cannot be estimated as accurately on the basis of the few exposures. East of Macumber's shaft, the conglomerate is cut off by the sea.

There is no reason, however, to expect that grades to be encountered elsewhere in the conglomerate will be better than those encountered in sinking the Macumber shaft.

VEINS IN SANDSTONE AND SHALE

The second type of manganese deposits, that of fissure fillings in rocks other than limestone, has never been of great economic importance. Six occurrences are known where shafts or pits were sunk, from which the total recorded production is slightly in excess of 6 tons. Nor can any much larger production be expected. The veins vary in width from a fraction of an inch to about 1 inch, and even where the rock is much fractured, and all fractures filled with veins, the amount of rock proportional to vein material is always high. No further work can be recommended on any of the occurrences examined, nor is it thought possible that similar deposits of economic value remain undiscovered. A brief description will be given of the six occurrences where mining was done.

MacDonald Property, Minasville

References

Fletcher, Hugh: Geol. Surv., Canada, Sum. Rept. 1893, p. 42.
Hanson, G.: Geol. Surv., Canada; Ec. Geol. Ser. No. 12, p. 40 (1932).
Ingall, E. D.: Geol. Surv., Canada, Sec. of Mines, Ann. Rept. 1902, pt. S, p.156.

Penrose, R. A. F., Jr.: Ark. Geol. Surv., Ann. Rept. 1891, vol. 1, p. 522.
Smitheringale, W. V.: Manganese Deposits of the Maritime Provinces; manuscript report written in 1928.

General Description

The workings are on a vacant farm, formerly occupied by the MacDonald brothers of Minasville. They lie 2,100 feet due south of the highway bridge over Moose Brook in the village of Minasville.

The excavations were made by John Mosher about 1891, and a little ore was obtained. The workings consist of two slumped, dry pits, one water-filled shaft, and a trench 40 feet long. The rocks exposed belong to the Horton group, and consist of brown to red, thin-bedded to massive, usually much fractured shale and mudstone. No ore is visible near the workings, but some manganese oxides are piled near the house 200 yards away.

Minasville School

References

Hanson, G.: Geol. Surv., Canada, Ec. Geol. Ser. No. 12, p. 67 (1932).
Smitheringale, W. V.: Manganese Deposits of the Maritime Provinces; manuscript report written in 1928.

General Description

The Minasville School property is situated 1,000 feet south of the Minasville schoolhouse, which in turn is 1,300 feet east of the highway bridge over Moose Brook. It is reached by a poor wood road from the schoolhouse. The first work was done about 1887 by Mr. McPhee, and about 1900 or 1902 J. Wright sank two shallow shafts and recovered 5 barrels of "hard" ore.

The workings consist of two shafts in red, irregularly fracturing shale of Horton age. The western is at least 27 feet deep. No manganese minerals were found on the property, either in place or on the dump.

Thompson Property, Minasville

The Thompson property lies about 200 feet north of the southerly road running west from Minasville, and about 4,200 feet west of its junction with the highway there. There is no record of any production. The workings consist of a shallow open-cut, about 40 feet by 20 feet, in brownish red, fractured, and unbedded Horton mudstone. A stain of manganese is visible on some of the fracture surfaces.

Reynolds Property, Minasville

References

Hanson, G.: Geol. Surv., Canada, Ec. Geol. Ser. No. 12, p. 67 (1932).
Smitheringale, W. V.: Manganese Deposits of the Maritime Provinces; manuscript report written in 1928.

General Description

The Reynolds property is on the farm of Morton Reynolds, Minasville. The one shaft is located about 10 feet west of the laneway to the house, about 200 feet south of the road fronting the farm. The shaft was sunk by Dan McVicar about 1891, and about 3 tons of ore recovered.

Mr. Reynolds says the shaft is 50 feet deep on an incline. Thirty feet down is a drift to the east 30 or 40 feet long, cut on a manganese oxide-filled vein 3 inches wide.

The rock around the pit is reddish, fine-grained, micaceous sandstone without prominent bedding. Manganese oxides can be seen occupying tiny fractures in the sandstone.

Densmore Mills

References

Fletcher, Hugh: Geol. Surv., Canada, Sum. Rept. 1893, Ann. Rept. 1892-93, pt. A, 63.
Hanson, G.: Geol. Surv., Canada, Ec. Geol. Ser. No. 12, p. 67 (1932).
Smitheringale, W. V.: Manganese Deposits of the Maritime Provinces; manuscript report written in 1928.

General Description

The Densmore Mills property is in the village of Densmore's Mills about 3,000 feet east of the junction of the Hennigar road with the highway following the shore, and about 600 feet south of the highway. Mr. Maxwell Densmore says that the shaft was sunk about 60 feet in 1890 or 1895, and that a little manganese was shipped.

The rock is arkosic quartzite of the Horton group. No manganese minerals are visible, but a manganese stain may be observed on fracture faces.

Sea Cliffs, Lower Economy

References

Hanson, G.: Geol. Surv., Canada, Ec. Geol. Ser. No. 12, p. 66 (1932).
Ingall, E. D.: Geol. Surv., Canada, Sec. of Mines, Ann. Rept. 1902, pt. S, p.157.
Smitheringale, W. V.: Manganese Deposits of the Maritime Provinces; manuscript report written in 1928.

General Description

The Sea Cliffs occurrence lies in the sea-cliffs facing Minas Basin a few hundred yards east of the church at Lower Economy. It is claimed that several barrels of ore were produced there.

The rocks are shales and shaly sandstone of the Riversdale group. As the cliffs are being actively worn away, no sign of the previous operations is visible today. Thin seams of manganite and some manganese stain are, however, visible in these rocks.

DEPOSITS IN TRIASSIC ROCKS

Two instances are known where manganese oxides have replaced the cement in Triassic conglomerates. Although of no economic importance, the total output from both being slightly more than 2 tons, the occurrences are of interest in showing that manganese-bearing solutions wandered in places quite far afield from the rocks that supplied the manganese. A brief description will be given of the two occurrences.

Tennycape Estuary

References

Flynn, A. E.: N.S. Dept. of Mines, Ann. Rept. 1939, pt. 2, p. 1.
Hanson, G.: Geol. Surv., Canada, Ec. Geol. Ser. No. 12, p. 40 (1932).
Smitheringale, W. V.: Manganese Deposits of the Maritime Provinces; manuscript report written in 1928.

General Description

This deposit lies on the west bank of the estuary of Tennycape River, about 2,300 feet along the shore from the highway bridge over the river. There is no record of production, but a little ore is believed to have been obtained.

Horton shales, sandstones, and arkoses are exposed along the west side of Tennycape estuary for 1,900 feet from the highway bridge, then, after a gap of about 200 feet, low-dipping Triassic conglomerate forms the sea-cliff. The manganese occurrence, 200 to 300 feet north of the first Triassic exposure, lies, therefore, quite close to the base of these rocks.

The manganese is found in the form of pyrolusite between the pebbles of conglomerate. Above and below the manganese-bearing conglomerate the rock consists of rounded pebbles in a matrix of finer sand and pebbles. The manganese bearing part of the conglomerate section seems to be lacking in these finer detrital products, and the pebbles appear to rest in a matrix of pyrolusite. Although the pyrolusite occurs mostly as an interstitial mineral in conglomerate, several pebbles of pyrolusite were also found. Two of these, when broken, showed a core of reddish limestone. Calcite may be observed as an interstitial cement, both in the manganiferous conglomerate, where it is rather scarce, and in the adjacent conglomerates, where it is more plentiful. Both massive calcite and dog-tooth spar were observed.

The deposit was sampled in 1939 by A. E. Flynn. Analyses were made of a channel sample across a mineralized area 90 by 10 feet, and of a picked sample of ore. The results are as follows:

	Channel sample Per cent	Picked ore Per cent
Total Mn.	5·7	12·3
Total MnO2	7·6	17·3
Insoluble	78·4	70·0

The deposit was formed by the replacement of abundant calcite cement in a local phase of the Triassic conglomerate. The apparent pebbles of pyrolusite were indicated by the presence of limestone core in two of them to be incomplete replacements of pebbles of limestone in the conglomerate. Quite apart from this evidence, it is inconceivable that a fragment of a mineral as soft as pyrolusite could withstand transportation even a relatively short distance.

Although the occurrence is not considered to have present economic possibilities, yet, should a market be found for the material, that showing in the cliff face could be recovered and hand sorted with very little expenditure or equipment.

East Walton

References

Hanson, G.: Geol. Surv., Canada, Ec. Geol. Ser. No. 12, p. 45 (1932).

Smitheringale, W. V.: Manganese Deposits of the Maritime Provinces; manuscript report written in 1928.

Willimott, C. W.: Geol. and Nat. Hist. Surv., Canada, Rept. of Prog. 1882-3-4, pt. L, p. 21.

General Description

The deposit lies just south of the highway in East Walton, about halfway between Rennie and Wilcox Brooks, and on the farm of Mr. Wheadon. Work was done on the property prior to 1900 by a Mr. MacMillan, who is said to have recovered about 2 tons of ore.

The manganese is believed to have occurred interstitially in Triassic conglomerate immediately above its contact with Horton shales (*See* Plate II B). The old workings are caved, although the Horton-Triassic contact is exposed on the property through use of the conglomerate as road material.

ORIGIN OF THE MANGANESE DEPOSITS

A satisfactory theory of origin for the manganese deposits requires an explanation for: (*a*) the original source of the manganese metal; (*b*) the means by which it has been placed in solution and transported to the point of deposition; and (*c*) the reasons why it was precipitated where found and not elsewhere. It is proposed to discuss the factors controlling the solution and deposition of manganese ores, and to attempt a correlation between suitable related factors and conditions observed around the deposits.

Penrose believed the manganese to have been laid down in the Pembroke formation as the carbonate or oxide during normal sedimentary processes. Later the carbonate was changed to the oxide, all of which was then dissolved and re-precipitated in its present position. He believed the fragments of Macumber formation in the base of the Pembroke represented brecciation of the Pembroke, and that this was due to the chemical change, with attendant increase of volume, of the anhydrite beds overlying the Pembroke into gypsum beds. This increase in volume he regarded as directly responsible for both the heat and the pressure necessary to dissolve the manganese oxides and transport them to other places where conditions were suitable for concentrated deposition. From a chemical standpoint his theory is not sufficiently definite to warrant serious consideration. Structurally, it is also untenable. The anhydrite beds are now known to be hydrated to gypsum only in zones near the surface where adequate ground-water circulation is provided. Such chemical changes near the surface could be expected to cause deformation only of the overlying beds, and not of the solidly supported underlying beds, particularly the bottom of the underlying, thick, Pembroke formation. Indeed, this relationship would be expected to hold, regardless of the depth at which hydration took place.

Smitheringale believed that the manganese was derived from Carboniferous sediments and later volcanic rocks, and was removed from these by ground-water solutions. The concentration of the oxides in the Windsor limestone he ascribes to the natural susceptibility of limestone to replacement. He is the first to mention the possibility that sulphate waters, derived from the Windsor gypsum beds, may play an important rôle in the solution of the original manganese minerals, but does not discuss the chemistry of such processes.

Other writers uniformly ascribe the solution, transportation, and final deposition of the manganese to supergene agencies without being more specific as to actual processes.

Experimental data on the dissolution of manganese minerals, and on the precipitation of manganese from manganiferous solutions, are fairly complete, but, so far as the writer can learn, no work has been done on the solubility of the lower and higher oxides of manganese in calcium sulphate solutions, either neutral or acidified by the natural acids, carbonic and humic. It is suggested that experimental work along this line might give a strong clue as to the part played by the gypsum beds, which everywhere in this area directly overlie the Pembroke formation in which the largest concentration of manganese minerals is found. There seems to be a strong probability, based on experimental work with other sulphate solutions, that calcium sulphate in the presence of either or both of carbonic and humic acids may be a solvent of at least some manganese oxides, and should this be true, a means of concentrating manganese minerals near the base of the Pembroke becomes at once apparent. Such concentrations, if caused by solutions derived from the overlying formation, would postulate that the manganese should have been an original constituent, probably as a carbonate, of the Pembroke limestone. Manganese carbonate was determined by Penrose in these rocks at Tennycape mine, but the specimens were undoubtedly collected in the zone of surface-water circulation, where the presence of the carbonate cannot be accepted as proof that it was an original constituent of the limestone. To be considered as proof of such an origin, the specimen on which the determination is made should be collected from below the zone of supergene circulation, that is, in the case of the Tennycape mine, at a depth of at least 200 feet.

The occurrence of barite as an accessory mineral in some of the manganese occurrences (and probably others where it was not noted), and as a replacement mineral in the Pembroke formation at the Pembroke barite quarry, is also of considerable interest. Barium carbonate is relatively soluble in carbonic acid, yielding the bicarbonate, and such a solution would immediately precipitate barite if brought into contact with a sulphate solution, such as manganese sulphate. Whether barium carbonate is present as an original constituent of the Pembroke formation can likewise be determined in specimens of that formation obtained from below the zone of ground-water circulation.

COPPER

Prospecting for copper was done some years ago on Portapique River, about ½ mile north of where it leaves the mountains. Two pits were dug about ¼ mile apart on veins and stringers of calcite and ankerite in volcanic rocks, which carry small amounts of sulphide minerals including pyrite, chalcopyrite, and chalcocite. Nothing was seen at either occurrence to suggest that an ore deposit might exist.

LEAD

On a northeast branch of Portapique River, about 2¼ miles northwest of Lornevale, some prospecting has been done for lead minerals. Galena occurs as tiny crystals in the cleavage cracks of pearl-grey fissile slate of the Cobequid complex. Overlying these rocks in patches, and on the banks of the brook, are flat-lying conglomerates believed to be of Pennsylvanian age. Nothing was seen that would indicate the possible presence of an ore deposit.

GYPSUM

Although no gypsum has been produced for half a century from deposits within the area, the importance of this industry in Nova Scotia is shown by the 1939 production, which was more than 1,250,000 tons. All of this was quarried from Windsor sulphate beds.

The normal occurrence of calcium sulphate in these beds is in the form of anhydrite, a mineral having a relatively limited commercial application as compared with that of gypsum, which is formed by the hydration of anhydrite. This hydration occurs mainly through ground-water agencies, and as almost no weathered exposure of calcium sulphate is found except in the form of gypsum, the extent of this mineral in the deposit can usually be determined only by drilling. Some factors, however, have a bearing on the extent and rate of hydration, and such factors should be considered when examining an occurrence of calcium sulphate rocks.

The large quarrying operations being carried on at present elsewhere in the province appear to have one feature in common; the local water-table is quite low under the deposit. Either the gypsum occurs in considerable immediate relief, or local subterranean water channels result in a lowering of the water-table where the relief is small. It would appear that a rapid and voluminous circulation of water downward is a necessary adjunct for the hydrolyzation of anhydrite into gypsum.

Within the map-area, gypsum has been quarried at three localities: the Stephens quarry, about ½ mile southeast of the Tennycape manganese mine; the O'Brien quarry, ½ mile north of the road junction at Gormanville; and the Paint quarry, east of Noel Lake. Production was small from all of these, but that of the O'Brien quarry exceeded that of the others. The O'Brien and Paint quarries may have further economic possibilities.

Other occurrences, where a low water-table underlies a considerable area of sulphate beds, are believed to exist on the south side of Robinson Brook, south of Minasville, and on the banks of Fivemile River in the southeast corner of the area.

BARITE

Barite occurs in the Pembroke formation as an accessory mineral in the manganese deposits, and is found at Pembroke, a few miles west of the map-area, as an extensive replacement of this formation.

The deposit at Pembroke occurs on a small, minor syncline in the trough of a larger syncline in Horton and Windsor rocks, and just above the contact of these two groups. Although the origin of this barite is not definitely known, it would appear that the sulphate radical present in the barium sulphate probably was derived from the overlying calcium sulphate beds, and that the replacement was facilitated by ground-water circulation that brought into juxtaposition the sulphate and barium radicals. The origin of the barium radical may be considered problematical, but it may have existed as barium carbonate in the Pembroke formation. An analysis of a specimen of this formation from well below the zone of ground-water circulation may throw light on this matter.

If this outline theory of origin is tenable, further occurrences might conceivably be anticipated anywhere in the Pembroke where barium carbonate was an original constituent, and where the Pembroke was overlain by a sulphate bed. If the shallow, synclinal structure noted at the Pembroke quarry has any bearing on the replacement of the limestone, which is quite conceivable, it may be pointed out that a similar but less pronounced structure exists near the end of a road running 2 miles east from Hennigar.

LIMESTONE

Limestone was at one time quarried from the Pembroke formation about 1½ miles south of Minasville, and is today being quarried from exposures of upper Windsor rocks north of Upper Economy. The Pembroke formation, the most calciferous of the limestone horizons south of Cobequid Bay, usually contains pebbles and grains of siliceous rocks, thereby reducing its lime content. It is possible, however, that there are occurrences relatively free from non-limy material, and if so such occurrences could be considered a source of agricultural lime.

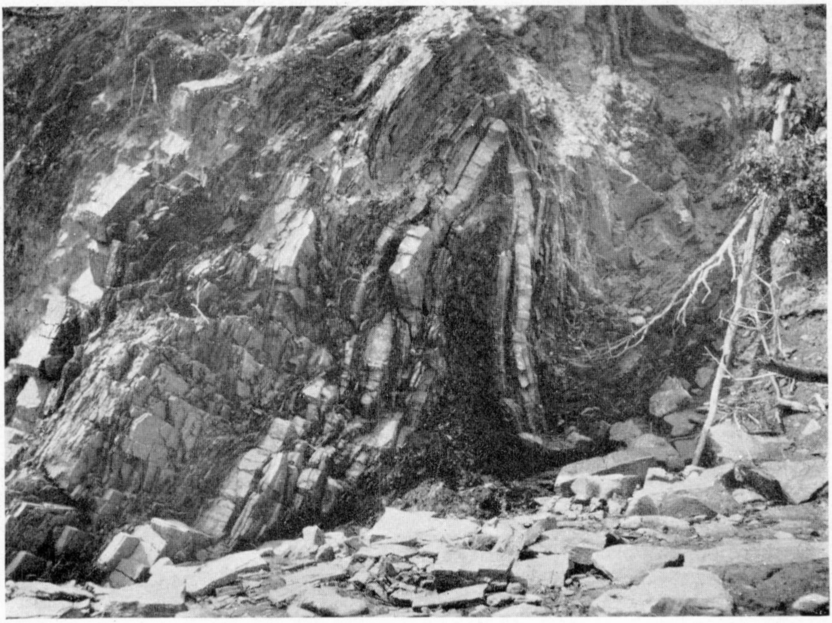
COAL

Although economic coal seams are lacking in the area, two occurrences of highly carbonaceous shale were examined.

An occurrence on a south branch of Selma Brook is said to have been used in a smithy some years ago. Very little of the deposit could be seen owing to slumping that had occurred in the shallow excavation from which it was extracted. Some fragments of highly carbonaceous shale were found in the brook below the workings, however, the largest of which was less than an inch in size.

About ½ mile south of Cobequid Mountains, 4 feet of steeply dipping carbonaceous shale is exposed in the bed of Cook Brook. A slumped pit on the west bank showed that the material had been prospected at some time. A sample of the material was burned with some dfficulty in a stove.

PLATE II



85846

A. Drag-fold in Horton shales, Tennycape estuary. (Page 17.)

85844

B. Unconformity between Annapolis conglomerate, above, and vertical Horton slates, below, East Walton manganese property. (Page 78.)

A. Syncline in Horton shales, Clement Cove. (Page 19.)

B. Close up of axis of above syncline. Fracture cleavage trends diagonally across beds on each side of axis, and illustrates how tops of beds may be indicated by such cleavage. (Page 19.)

INDEX