STRUCTURE AND PETROLOGY OF THE BARITE DEPOSIT AT BROOKFIELD, COLCHESTER COUNTY, NOVA SCOTIA

by

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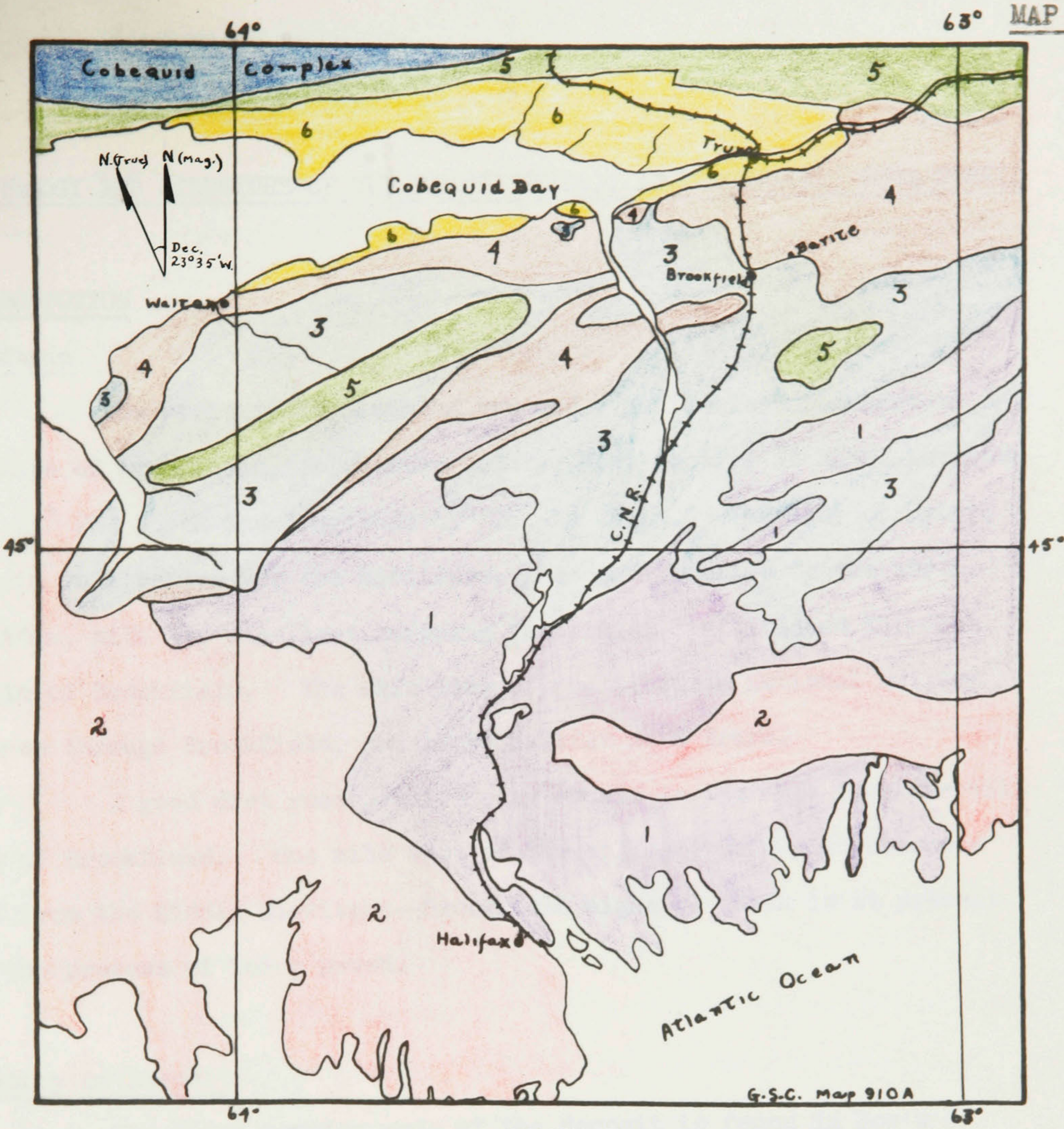
"The earth not only contains within
her bosom, substances the most
necessary and indispensable to
supply the wants of man; but also
exhibits in her vast museum, the
most certain and imperishable re-
cords of her own history, written
in characters not to be mistaken
by the most humble, destroyed by
the most powerful, nor blotted out
even by time itself."

Abraham Gesner (1836)



SCALE -I inch to I2 miles

GEOLOGICAL MAP
OF
CENTRAL NOVA SCOTIA

LEGEND

TRIASSIC		**PRE-CARBONIFEROUS**	
6	conglomerate, sandstone, shale.	1	Meguma Series. slates, etc.
CARBONIFEROUS PENNSYLVANIAN			
5	sandstone, shale, coal, conglomerate.	C	Cobequid Complex. volcanics.
MISSISSIPPIAN			
4	Horton Group-sandstone, red shale.		
3	Windsor Group-limestone, shale, gypsum.		
DEVONIAN			
2	granite, gabbro.		

PETROLOGY AND STRUCTURE OF THE BARITE DEPOSIT AT BROOKFIELD, NOVA SCOTIA

INTRODUCTION

Location

The property is situated two and a half miles northeast of the village of Brookfield, Colchester County, Nova Scotia, at about Latitude 45° 15' 20" North and Longitude 63° 14' 18" West. The city of Truro, a main rail centre for the Maritimes, lies twelve miles to the north. Halifax, with its excellent shipping facilities, is situated 54 miles south of Brookfield. The main line of the Canadian National Railway passes through Brookfield, and links Halifax with Truro.

A good dirt road permits easy access to the area from the village of Brookfield. One mile east of the village, this road branches off from the Middle Stewiacke--Brookfield highway, which is at present in the process of being paved.

History of Deposit

The first mention made of the deposit is found in How's Mineralogy of Nova Scotia, published in 1869.

Fletcher, in his report for the Provincial Government published in 1891, also makes a brief note of the deposit.

However, it was not until 1944 that serious consideration was given to economic possibilities of the ore body. During that year, Canadian Industrial Minerals Limited, of Walton, N.S., had the property under option, and they put down three diamond drill holes with a total depth of 426 feet. This company evidently did not think it feasible to develop the deposit, for the drilling program was abandonned.

In 1945 an exploratory company called Maritimes Exploration

Limited was formed to do exploratory work in the Maritime Provinces. During 1945 this company put down five more diamond drill holes on the property.

In 1948, Maritime Barytes Limited was formed to drill the Stewiacke Valley area. This company realized the economic possibilities which the property offered, and during 1948 inaugurated a program of diamond drilling which has been carried on intermittently to the present date. To date, this company has drilled 28 holes, with a depth totalling 6,155 feet.

As a result of the favorable assessing of the deposit, much preliminary work has been carried out since 1948 in preparing the property for operation. A poor dirt road of about two miles in length originally linked the property to the Middle Stewiacke--Brookfield highway. This dirt road has been greatly improved and extended, and several bridges have been built.

The outcrop of ore has had the overburden bull-dozed off, and an area of outcrop approximately 150 feet by 75 feet is now exposed. A powder house has been constructed, as well as a storage building of about 40 feet by 20 feet in size. Construction of a mill was begun late in 1950, and installation of machinery began in January, 1951. The property is expected to come into production in May, 1951.

The writer was engaged by the Geological Survey of Canada to carry out a mile-to-the-inch mapping program of the Truro, Nova Scotia map sheet during the summer field season of 1950. It was while engaged in this project that the barytes deposit was examined.

Purpose and Method of Examination

The examination of the barite property was carried out in an attempt to ascertain the origin and extent of the deposit.

At the present time, due to the existing international tension, Canada's mineral deposits are beginning to play an increasingly important role in industry. Deposits which previously were deemed uneconomical to mine are being profitably exploited by their owners. Barite is steadily becoming more in demand on the world market. Therefore, a deposit of extreme pureness such as is found at Brookfield should be able to compete favorably with other producers of barite on the international market. Although a relatively small amount of drilling has been carried out to date, an ore body of sufficient size to warrant further development has been outlined.

The field work consisted of a detailed examination of the area within a radius of one-half mile of the deposit. In considering the regional features, a much larger area has been referred to, based on personal investigation and also on previous reports of the area.

The purpose of the laboratory investigation was to determine the genesis of the ore, and to study the relation of the barite to the host rock. A study was made of a suite of specimens, but only the results which have direct bearing on the problem have been included in the report.

Acknowledgements

The writer wishes to thank Dr. T.H. Clark, under whose guidance the paper was prepared. Gratitude is due to Mr. C.O. Campbell, an officer of Maritime Barytes Limited, and Professor of Geology at Dalhousie University, Halifax, who kindly provided much unpublished information on the area. The assistance rendered by Dr. L.J. Weeks, of the Geological Survey of Canada, is also appreciated. My wife, Edythe Stevenson, willingly assisted in typing and arranging the thesis.

Glacial striae on Horton sandstones.
Striae Brook, near Brookfield, N.S.

PHYSIOGRAPHY

Topography

The dominant topographical characteristic of the region is a very disorderly grouping of ridges and valleys which tend to follow the general strike of the strata. Both the Horton and Windsor series in the area have been folded and faulted in a very complex manner, having yielded to pressures which a more resistant type of rock might have withstood. As a result of this deformation, the surface most peculiarly shows a series of small anticlinal hills having a maximum elevation of 250 feet above the intervening synclinal valleys.

The hills are almost oval in form, similar to that of the drumlins which occur farther south in the province. However, evidence secured by diamond drilling indicates that only a shallow mantle of glacial drift covers rock making up the hills. Furthermore, the elongation of these hills tends to follow the strike of the rocks, and not the direction of glacial movement. The gracefully curving profiles of the ridges are due to the smoothing off action of the ice, which tended to flow over and around the obstructing summits, gradually filling with drift such small irregularities as it encountered.

The shales, limestones, sandstones, and gypsum beds of the Horton and Windsor series display little evidence of glacial movement, either in grooved surfaces or in dispersal of drift. Only one occurrence of glacial striae is known within a five mile radius of the property. These striae occur on resistant Horton sandstones, at the base of a small falls on Striae Brook (see Map 3 and Plate 1).

One of the most interesting features of the area is the peculiar karst topography which is frequently found where beds of gypsum and anhydrite underlie the surface. Round funnel-like depressions

Differential erosion of gypsum.
Shubenacadie River, N. S.

and saucer shaped hollows, some of them occupied by pools of water with no visible outlet, show that the gypsum is being rapidly dissolved by ground water. Decay reaches down to the ground water level, which is in some instances 100 feet below the surface. Caverns may form beneath the surface, and the roof, eventually weakened, may collapse. Great care must be taken in travelling through country where this type of topography occurs, as one may easily stumble into one of these depressions, especially where the underbrush is thick.

Numerous interesting examples of differential erosion of gypsum may be seen throughout the area (see Plate 2). In spite of its extreme softness, gypsum displays remarkable resistance to erosion by wind and water.

The extreme dissection of the surface indicates that the sculpturing was done mainly by rivers and small streams, which are numerous throughout the entire region. Glaciation played but a minor role in the formation of the existing topography.

Vegetation

Much of the area is covered by a thick growth of spruce, birch, and poplar. Most of the larger trees have been removed, and dense underbrush has sprung up in many regions. A small percentage of low-lying land is quite boggy, and covered with marsh-grass. Areas which are suitable for farming have been cleared, but many of these farms are being allowed to revert to their natural condition.

Economy of Area

The valley of the Stewiacke River, which runs just south of the area, consists of fair farm soil. However, north of the river, a lime-deficiency in the sandy soils developed on Horton rocks makes profitable farming impossible in many sections. Many abandoned farms in the area bear evidence of this fact. Lumbering at one time formed the chief means of livelihood for the people, but readily accessible stands of timber are rapidly becoming scarce, due to over-cutting and forest fires.

Extensive trapping has depleted most of the fur bearing animals in the region. A few beaver are found in the larger rivers and ponds, and these hardy animals appear to be increasing in number. Red fox are plentiful, as well as the occasional bob-cat. Porcupines do a great deal of timber damage, and during 1950 more than two thousand dollars was paid out in bounties on these animals. White-tailed deer, ruffed grouse, wood-cock, and the occasional black bear makes the area a hunter's paradise. However, most of the streams and rivers have been fished out.

GENERAL GEOLOGY

The area herein described lies within a ten mile radius of the barite property, and forms part of the lowlands of Hants and Colchester counties which surround Minas Basin on the north, east, and south. The rocks are entirely sedimentary, and range in age from lower Carboniferous (Mississippian) to Triassic.

Being part of the Appalachian Province, the entire region has been subjected to multiple orogenies. Canadian geologists claim that the Acadian part of Canada was folded during the Devonian, with other orogenies during Windsor and Pennsylvanian times.

Schuchert (1930, pp. 701-724) says that all of the intense Acadian folding and intrusion of Devonian times produced a complex that was peneplained across, and is now overlain by thousands of feet of Mississippian sediments and Pennsylvanian clastics. The Windsor marine sediments found in the neighborhood of the property were laid down by a shallow arm of the Windsor sea, on top of fresh-water Horton sediments. As an erosional disconformity exists between the Windsor and Horton formations, it is understandable how Fletcher (1892) made the error in calling the Horton sediments Devonian.

Relatively severe folding continued intermittently throughout Carboniferous time. Pennsylvanian clastics were deposited conformably on the Windsor series. No Pennsylvanian rocks are found in the immediate vicinity of the barite property, but Pennsylvanian sandstones and conglomerate do occur a few miles east of Truro (see Map 1). The writer found evidence in these sediments of extensive and repeated block faulting, though the faulting has no recognizable definite pattern.

Field evidence indicates that Nova Scotia was again deformed during Permian time by the Appalachian Orogeny.

The region has therefore been affected by three separate periods of deformation. Unfortunately, the evidences of these have been largely obscured by glaciation. Only along high river banks, such as are found on the Shubenacadie River, can one readily see the intricate manner in which the area has been deformed.

The area is probably best known for its deposits of gypsum, of upper Mississippian age, which occur extensively throughout the entire region wherever Windsor sediments are found. Several of these deposits were in commercial operation late in the last century, but no use is being made of them to-day.

Several limestone quarries were formerly employed in producing lime for enrichment of the land. The use of present day fertilizers has caused the abandonment of this practice. Some lime was also used in the reduction of iron ores found within the area.

In 1881, work was begun on a lead deposit at Smithfield, about six miles east of Brookfield. There was some production in 1884, and a small smelter was erected for extracting the lead from the galena. Metallurgical difficulties could not be overcome and for this reason the property became inactive after 1889. Total production is not known, but it is only in the neighborhood of a few hundred tons.

Several small workings of limonite within the area were formerly in production about the turn of the century. A vein of limonite occurs about 200 yards east of the barite deposit at Brookfield. Fletcher (1892, p. 177) states that 1000 tons of iron ore were shipped from this limonite deposit in 1888.

A vein of barite occurs six miles east of Brookfield, about 3000 yards north of the Stewiacke River. Prior to 1868, twelve hundred tons of ore were taken from this deposit (Fletcher, 1892, p.192).

An interesting fact is that practically all mineralization within the area occurs along or near the contact between the lower Mississippian sandstones and the basal beds of the upper Mississippian sediments. In some instances, as at Smithfield, the ore is found in, and often replaces, the overlying limestone-conglomerate.

STRATIGRAPHY

Regional Geology

The rock formations within a radius of ten miles of the barite property consist almost entirely of Carboniferous sediments laid down in Mississippian time. The main rock types are sandstones, shales, and arkoses of the Horton group, overlain with apparent structural disconformity by the less resistant limestone, gypsum, and conglomerate beds of the marine Windsor Group.

A narrow band of Pennsylvanian sandstones is found along the eastern border of the area. These sediments are similar in appearance and composition to the underlying Horton Group sandstones, and can be divided from them only on a paleontological basis, as no structural unconformity exists between the Mississippian and Pennsylvanian strata.

A narrow strip of red sandstone of Triassic age is found along the south shore of Cobequid Bay. This formation is easily recognized by its distinctive brick-red color. It is separated from the underlying Horton sandstones by a well-marked angular unconformity.

The area has been covered by a shallow mantle of glacial drift, seldom exceeding 25 feet in depth.

Description of Formations

A generalized geological column for the region, extending from Cobequid Bay on the north, to an east--west line through Brookfield on the south, is given on the following page.

TABLE OF FORMATIONS

ERA	PERIOD	GROUP	FORMATION AND ROCK TYPE
CENOZOIC	QUATERNARY	Recent	Tidal alluvium Lake deposits
		Pleistocene	Glacial drift Stratified gravel
MESOZOIC	TRIASSIC		Red sandstones
PALEOZOIC	PENNSYLVANIAN	Riversdale	Sandstones, shales, conglomerate
	MISSISSIPPIAN	Windsor	Upper Windsor limestone Anhydrite, gypsum Tennycape formation red, sandy shales Anhydrite, gypsum Pembroke formation limestone, conglomerate Macumber formation buff to grey limestone
		Horton	Cheverie formation grey arkose, red shales Horton Bluff formation grey arenaceous shales, feldspathic grits and sandstones

Horton Group

The Horton Group is Mississippian age, and in this area is the oldest Carboniferous group.

Bell divides the Horton into two formations (1929, p.30). The lower consists of the Horton Bluff formation, made up chiefly of argillaceous and arenaceous dark grey shales and feldspathic, grey sandstones and grits. The upper formation, called the Cheverie Formation, consists of red shale and grey arkose.

The writer has found that in this area it is very difficult, in fact almost impossible, to separate the two formations by lithological characteristics. However, it may safely be assumed that those Horton beds which are in immediate contact with the overlying Windsor group to the south are of Cheverie age.

Horton Bluff Formation

This formation outcrops in a low anticline belt, called the Walton anticline, whose axis runs through the southern part of the area.

The Horton Bluff formation may be divided into a basal feldspathic sandstone or arenaceous member, and an upper arenaceous shale member. In the latter, the more purely argillaceous beds occur in a basal member, and the top member has numerous thin beds of feldspathic quartzite.

Composition of the basal beds is in direct relation to the underlying rock. Where the latter is of slate, the lowermost Horton bed is a breccia of the underlying rocks imbedded in a paste of the same material. These underlying slates are weathered for several tens of feet, weathering that took place before the Horton was deposited. The effect of this weathering was to oxidize the iron and to remove the carbon, producing purplish or reddish shales.

Where the composition of the underlying rock is that of a granite, the basal Horton is composed dominantly of brecciated granite minerals. Above the breccia the stream-deposited feldspathic grits and arenaceous shales, so characteristic of the Horton formation, were laid down.

The middle members of the Horton Bluff formation contain many beds of laminated, finely arenaceous silts and argillaceous shales, with which are associated thin ironstone bands, ironstone concretions, spheroidal calcareous concretions, and occasional thin argillaceous limestones.

The upper beds of the upper member of the Horton Bluff formation comprise a thick accumulation of fine siliceous, micaceous, arenaceous groups in alternating succession with more argillaceous beds or feldspathic sandstones.

Ripple marks and cross-bedding are prominent in the Horton Bluff formation.

W.A. Bell has made a thorough study of the Horton Bluff formation, and from evidence gathered (1929), has concluded that a fluviatile environment under a pluvial climate was essential for the deposition of the formation. The climate is judged to have been a temperate insular one.

The source of sediments was upland masses lying in a southwesterly direction. The mineralogical composition of the sediments points to the great belt of the Devonian granite batholith end of the Precambrian rocks that stretches for 120 miles to the southwest.

Cheverie Formation

The Cheverie formation cannot in all cases be distinguished from the underlying Horton Bluff formation, as in many instances the contact is gradational. Yet the heavy arkose and red muds in the Cheverie point to important climatic and tetonic changes at the close of the Horton Bluff epoch.

The basal Cheverie is composed of grey arkose grits with a subordinate amount of chocolate, or chocolate and green, variegated argillo-arenaceous shale, as well as occasional beds of micaceous-arenaceous shale of a green-black color. The dominant constituents of the arkose are angular fragments of translucent quartz up to

15 mm. grain, and angular orthoclase fragments of same dimensions. Biotite and muscovite are also often present in large flakes. The binding material is grey kaolinite. Pebbly lenses may be traced occasionally in the arkose.

The uppermost strata of the formation are dominantly purple red to chocolate arenaceous shales with thin interlayered zones of greenish black micaceous arenaceous shales.

Current ripples and cross-bedding are widely found in the Cheverie. Pronounced current cross-bedding is often observed in the grits and feldspathic sandstone. Channelling of the grit beds into underlying shales is also common. Sun cracking occurs occasionally in arenaceous soil beds.

The same features that denoted a fluvial environment for the Horton Bluff formation are repeated in the Cheverie formation. Climatic changes have been the main control in the chemical and textural features of the sediments. An accelerated rise of the positive areas bordering the subsiding basin in which Horton sediments were being deposited probably occurred.

That the temperature was higher than in Horton Bluff times is evidenced by the thorough oxidation of the Cheverie. True arid conditions were lacking, as there are no deposits of alkaline salts. The climate was probably of a temperate semi-arid type with a seasonal rainfall.

The material comprising the Cheverie is of fresh granite debris, and evidence points to a south westerly source, as in the case of the Horton Bluff formation.

Although the Cheverie formation is in erosional disconformity with both the Horton below and Windsor above, the break between the

Fault contact between Horton -- Windsor series.
Little River, N.S.

Horton and the Cheverie is possibly of greater importance than that between the Cheverie and Windsor.

Windsor Group

The Windsor Group comprises a series of marine sediments. The Brookfield area lies at the eastern end of a synclinal basin that extends westward to the Shubenacadie River valley and beyond. Its northern boundary is structurally the Walton anticline whereby Horton Bluff and Cheverie strata underlie the surface. On the south, a fault line limits the Windsor against Horton rocks.

Stratigraphy

The Windsor Group is a well-defined unit of marine deposits, laid down under peculiarly restricted environmental conditions. There are present four or five distinct stages of calcium sulphate deposits, each greater than 40 feet thick, separated by varying amounts of brick-red argillaceous shale, fossiliferous limestone, and thin magnesian sandy shales. In amount, the gypsum may make up 20 per cent of the total volume, with red shale 55 per cent and calcareous beds 25 per cent.

Environmental Factors

Certain salient factors enter into the local problem of environment. Such are abnormally high temperatures combined with shallow waters and aridity, culminating at intervals in salinities wholly inimical to the existence of a bottom animal-life. These, as evidenced from the vertical and horizontal distribution of anhydrite and gypsum deposits within the Windsor series, were recurring conditions of widespread extent in the Windsor seas. Gypsum depositing seas prevailed at various places and times over a region of at least 40,000 square miles. The prevalence of oölites at various horizons within the

Windsor is evidence of shallow waters. In the Brookfield area the lower Windsor sea transgressed over a flat alluvial plain underlain by earlier continental Mississippian sediments without the development of appreciable basal conglomerate.

Red mudstones and shales make up nearly one-half of the total mass of sediments and are barren of fossils. Extreme muddiness of the waters would prevent animal life. A rhythmic precipitation of red shale and gypsum with fossiliferous calcareous beds occurred.

Weeks (1948, p. 8) has divided the lower Windsor into five formational units. The writer has found this division to be suitable for the lower Windsor in the Brookfield area, and therefore proposes to accept this nomenclature for the different formations. A brief description of each formation, in order of decreasing age, follows.

Macumber Formation

This Macumber formation consists of a well bedded, grey to buff, fine-grained limestone overlying disconformably the topmost sandstones and sandy shales of the Cheverie formation (see Plate 8). Intermittent outcrops of the Macumber formation were traced by the writer from Black Rock on the Shubenacadie River eastward to the lead-zinc mine at Smithfield, a distance of almost 20 miles. A small outcrop of this formation appears about 300 yards west of the barite deposit at Brookfield.

The Macumber formation is distinguished from the non-calcareous Horton rocks and from most of the Windsor limestones by its high lime content. It also has excellent bedding, in places being highly drag folded. Its color varies from buff to grey. Measurements at Black Rock indicated the Macumber to be at least 26 feet thick.

The upper beds of the Macumber have been broken up into

Erosional disconformity between Macumber and
overlying Pembroke formations.
Black Rock, Shubenacadie River, N.S.

angular blocks, cemented together by the overlying reddish calcareous Pembroke conglomerate.

No evidence of fossils in the Macumber formation could be found. An erosional interval probably followed the deposition of the Macumber, as is evidenced by the fragmental blocks of Macumber limestone in the basal Pembroke beds.

Pembroke Formation

The Pembroke formation is a 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 with apparent structural conformity, and with slight evidence of an erosional break (see Plate 4).

The basal beds of the Pembroke consist of coarsely crystalline limestone containing angular fragments of the Macumber formation, and rounded pebbles and grains of older rock, most of which are derived from pre-Carboniferous formations. The limestone conglomerate is buff to red weathering. The included rounded pebbles consist of granite, vein quartz, red, sandy shale, and grey slates, quartzites, and sandstones.

The upper beds of the Pembroke appear to consist of a dull brown, unbedded, calcareous mudstone.

Lower Sulphate Bed

Overlying the Pembroke formation is a bed of anhydrite and gypsum, which appears to lense out intermittently. The bed is believed to consist originally of anhydrite, and to be altered by surface waters to gypsum. In many cases this bed, due to lack of outcrop, could be traced only by the development of karst topography.

Tennycape Formation

The Tennycape formation consists of soft, red, fine, sandy shales overlying the lowermost sulphate bed.

The most outstanding characteristic of Tennycape rocks is their uniformity in composition, grain size, and appearance. No over-sized grains occur. Reducing processes in many instances have altered the red shales to a grey color.

Bedding is usually apparent in the Tennycape formation.

Second Sulphate Bed

A second sulphate bed appears to overlie the Tennycape formation. However, some doubt exists as to whether this superposition is due to stratigraphic conformity, or whether this sulphate bed has been thrust on top of the Tennycape. No fault plane between the two sulphate beds has been observed.

Small anticline in Pembroke conglomerate.
Five Mile River, N.S.

STRUCTURE

Folding

The Carboniferous formations within the map area have been affected by broad, folding movements. An example of the effect of this folding on the topography is apparent in the broad anticline called Truro Heights which lies between Brookfield and Truro. It is probable that both the Carboniferous sediments and the underlying Precambrian rocks were affected in this folding. Numerous other smaller anticlines and synclines, considerably altered in surface expression by erosion, lead to the conclusion that the country has undergone several periods of severe folding on a large scale.

A second type of folding of a minor order has deformed the soft Windsor strata. Commonly these folds are recorded in the topography by small, synclinal hills of limestone. In other instances, especially along the banks of streams, anticlinal structures have been exposed in the limestone (see Plate 5).

The date of the folding of the Carboniferous strata was pre-Triassic, as evidenced by the unconformable contact and attitude of the overlying Triassic beds. No appreciable folding movements are thought to have occurred between the Mississippian and Pennsylvanian periods, for contacts of basal Pennsylvanian strata with Windsor beds elsewhere in the province indicate no appreciable folding movements during the interval between the two periods. However, a folding disturbance of early Pennsylvanian time is recognized in the Pennsylvanian sandstones in the Riversdale area, about eight miles east of Truro. It is possible that both Horton and Windsor series were affected by this disturbance.

It is noted that beds of sediments lying close to areas of

Fault in Horton series.
Victoria Park, Truro, N.S.

gypsum are commonly deformed. This is due to the volumetric expansion consequent upon a change from anhydrite to gypsum. Anhydrite is readily converted to gypsum upon the addition of ground water. Due to the resulting increase in volume, the gypsum tends to be deformed in the direction of least resistance. Flowage occurs laterally to a certain extent, but all gypsum beds are more of less lens-shaped, and lateral expansion is limited by the enclosing beds of the more resistant sandstones and shales. Hence, vertical expansion tends to occur, with the overlying beds becoming warped into minor folds.

It is rather difficult to estimate the size and extent of such folds, but it is evident that deformation caused by the formation of gypsum is considerable. Areas of folding up to almost one quarter mile in width have been attributed to this cause. Individual folds sometimes occur up to about 25 feet in height and several hundreds of feet in width.

Faulting

Carboniferous strata throughout the map area are cut by numerous faults with small stratigraphic displacements (see Plate 6). Surface erosion has, in many instances, largely destroyed the topographic expression of these faults. In many instances, however, they form the loci of local drainage gullies, and control in part the channels of many larger streams. It would appear that Little River, immediately south of the barite property, flows in such a channel.

The normal faults within the area are characterized by high angles of dip, and are in some cases accompanied by wide brecciated fault zones. The general trend of these faults lies in a northeast direction, although exceptions to this rule occur.

The most prominent fault within the map area in relation to the ore body is readily distinguishable by surface expression (see Plate 7). This fault strikes 70° true, and the resulting fault line is extremely straight. The barite lies at the western terminus of the fault, while a small deposit of limonite occurs about 200 yards east-northeast of the barite, within the fault zone. Approximately one mile from the barite deposit, on a bearing of 70° true, several further occurrences of limonite of no commercial value have been found. Therefore, it is possible that the fault continues in a northeast direction for a much greater distance than is observable from topographic expression.

Gypsum is also thought to have played a part in local faulting. When subjected to differential pressure, it tends to force its way into the surrounding sediments because of its extreme plasticity. Entrance into the sediments is made along paths of least resistance, which is along bedding planes. Pressure is exerted vertically as well as horizontally. The overlying beds are subjected to stress up to the rupture point, whereupon fracturing occurs. The resulting faults are small in magnitude but are accompanied by extreme brecciation.

All faults within the area are of post-Windsor age, because both Horton and Windsor strata have been equally affected. Field evidence indicates that extreme faulting occurred during the Pennsylvanian period, evidenced by the extreme block-faulting in the Pennsylvanian sediments east of Truro. The Triassic sandstones along the south shore of Cobequid Bay have likewise been cut by numerous faults which also affect the underlying Horton sandstones.

Local Geology

The barytes deposit outcrops on the summit of a hill 200 feet in height, which has its steeper slope facing south, overlooking

Little River (see Map 2). As is general throughout the area, the surface is covered with considerable glacial drift material, making a detailed examination of the structure extremely difficult.

A narrow intervale of Windsor sediments extends throughout the area in a general east--west direction. Little River flows westward through this intervale, and by means of small, repeated meanders, has developed a flat surface on the valley floor.

It is probable that this intervale is the result of an east-west striking block fault, formed perhaps in Pennsylvanian time, when much of the country underwent block-faulting. If this were so, the Windsor sediments in the down-faulted block would have been protected from glacial scour to a certain degree by the more resistant Horton sandstones to the north of the intervale.

A clearly defined fault zone marks the southern contact of the Windsor-Horton formations. At several places along this zone, gypsum beds of the Windsor formation are found in direct, faulted contact with Horton sandstones (see Map 3). The fault zone runs parallel to the south bank of Little River to a point approximately two miles east of the barytes deposit. Here, on the steep south bank of the river, an erosional disconformity appears between the Horton shales and the overlying basal Windsor limestone. The disconformity is marked by a fault zone, approximately eighteen inches thick, of mud and fault breccia (see Plate 3).

The contact strikes northward across Little River, and gradually swings back in a westward direction, parallelling the north bank of the river. The contact is marked in several places by falls, where it crosses small streams. These falls are formed by differential erosion between the resistant Horton sandstones and the soft, Windsor limestones. Evidence of a fault contact between the two formations is not apparent on the north side of the river.

BARYTES IN CANADA

Production

Prior to 1940, the production of barytes in Canada was relatively unimportant. The total output from 1885 to 1933, inclusive, amounted to only 41,027 short tons. No further production occurred until 1939. Deposits in Nova Scotia have been the main source of supply, with a production between 1866 and 1925 of 31,689 short tons (Campbell, p. 299, 1942).

In 1940 work was begun on a deposit of barytes at Walton near Pembroke, Hants County, Nova Scotia. Drilling outlined an ore body containing well over 1,000,000 tons of ore. A mill was constructed, and eight months after discovery, the first shipment of 2,500 long tons of milled barytes was made to Trinidad, B.W.I. Since 1941, this deposit has provided the chief source of barytes mined in Canada.

The following tables were obtained from the Department of Mines Annual Report on Mineral Production of Canada for 1949.

FINAL STATISTICS OF BARITE PRODUCTION FOR 1948

	NOVA SCOTIA	ONTARIO	BRITISH COLUMBIA	CANADA
Tons	94,068	47	1,632	95,747
Dollars	1,056,590	473	16,317	1,073,380

PRELIMINARY ESTIMATE OF BARITE PRODUCTION FOR 1949

	NOVA SCOTIA	BRITISH COLUMBIA	CANADA
Tons	38,400	1,315	39,715
Dollars	483,400	13,150	496,550

PRODUCTION AND IMPORTS OF BARITE FOR CANADA

	PRODUCTION		IMPORTS	
Year	Tons	Dollars	Tons	Dollars
1940	338	4,819	2,622	64,922
1941	6,890	74,416	3,431	81,620
1942	19,667	188,144	2,536	68,196
1943	24,474	279,253	1,686	43,239
1944	118,719	1,023,696	1,824	47,913
1945	139,589	1,211,403	1,150	32,531
1946	120,419	1,006,473	1,546	42,904
1947	128,675	1,380,753	1,737	51,060
1948	95,747	1,073,380	1,263	39,613
1949#	39,715	496,550	899	30,825

Imports for 11 months only.

Mode of Occurrence

Canadian barytes occurrences are predominately vein deposits. An exception occurs in the Five Islands deposit, in Colchester County, Nova Scotia, where a great deal of the barytes occurs as irregular, pockety masses, in a breccia of slate and quartzite of Carboniferous or earlier age, occupying depressions between ridges of similar rocks. These brecciated masses, however, tend to give way to vein like bodies as soon as the underlying bed rock is reached. It would appear that the ore has been derived from ascending solutions from the syenite which underlies the Devonian sedimentaries. Thus, the Five Islands deposit has a similar origin to other occurrences of barytes in Nova Scotia. All other deposits in Nova Scotia, Ontario, and Quebec are of the true vein type.

There is considerable difference of opinion regarding the source of the barium in many of the world's important barytes deposits. The deposits in Missouri, Georgia, Kentucky, and Tennessee, in the United States, and those in the United Kingdom and Germany, yielding the bulk of the world's barytes production, are all associated with sedimentary rocks, chiefly limestones or dolomites, or, as in the case of the American deposits, with clay representing a disintegration product of such rocks. A common genetic relationship may be assumed for all these deposits, but whether the barytes was derived by downward leaching from the enclosing limestone or dolomite, or was deposited from ascending solutions upon fissures in these rocks, is uncertain.

According to Tarr (1919, pp. 46-47), the source of the barium in the Missouri deposits is to be sought in "ascending heated waters of igneous origin". A similar origin might be postulated for other barytes deposits occurring in carbonate rocks or their derivatives, although the igneous source of the ascending solutions may not always be apparent.

It is not necessary to regard the barite as having a hydrothermal origin. In the case of deposits in sediments such as limestone, etc, the barium may have been derived by leaching from underlying crystalline rocks by vadose waters, with the subsequent deposition of barium sulphate upon circulating channels in the overlying sediments. In such case, the barium has possibly gone into solution as the chloride or carbonate, and has been deposited as the sulphate when the waters commingled with others carrying gypsum or other sulphates derived from the sediments (Butler, 1919, pp. 581-609).

The average content of barium oxide in the igneous rocks of the lithosphere is 0.10%. The barium of these rocks is contained mainly in the feldspars and micas. The sedimentary rocks contain much less barium; 0.05% barium oxide in the shales examined; 0.05% in the sandstones; none in the limestones. Many spring waters and mine waters carry barium. Thus, even though igneous contain by far the greater amount of barium, one must not preclude the possibility of sedimentary rocks having furnished the barium in a deposit. On account of a low solubility ratio, barytes may readily be deposited, under proper conditions, from solutions containing barely perceptible traces of barium. Barium is commonly contained in vadose waters in sedimentary rocks (Lindgren, 1913, pp. 89, 191).

Thus, it would appear that many barytes deposits of vein type have derived their barium content from the rocks in which they occur, whether sedimentary or crystalline. In the case of a vein extending downward through limestone into an underlying rock of crystalline character, the barium may conceivably have been derived from either or both of the above mentioned rock types.

Canadian barytes deposits differ greatly from those in the United States. There the barytes occurs as nodules and irregularly shaped masses, in a residual clay, the decomposition product of dolomite. Mining is an open pit operation. Two varities of barytes occur: "hard crystalline", and "soft". The soft variety is preferred on account of its texture and ease of grinding and bleaching.

Canadian barytes exhibit marked dissimilarities from district to district. In general, Nova Scotia barytes is soft and opaque, with a coarsely crystalline, platy structure. Texture is seldom regular. The color range is from cream to white.

The principal mineral impurities present in Canadian barytes are small amounts of sulphides (chalcopyrite, pyrite, sphalerite, and galena), calcite, fluorite, siderite, and sulphates of lime and strontium.

Sources and Uses of Barium

The minerals barytes (barium sulphate) and witherite (barium carbonate) are the only known economic sources of the element barium. Of these, only barytes is found in commercial quantity in North America. In addition to being utilized in the finely ground state, barytes forms the raw material for the production of lithopone and various barium chemicals. Metallic barium is of no present industrial importance.

Barytes

Barytes, sometimes called "barite", or "tiff" when pure, is barium sulphate ($BaSO_4$) and contains 65.7% of barium oxide (BaO) and 34.3% of sulphur trioxide (SO_3) (Lindgren, 1913, p. 441).

Barytes is a heavy, white, opaque or translucent mineral. Its specific gravity is about 4.5. The average hardness is 3. It is brittle, and may possess cleavage. The translucent varieties have vitreous to resinous and often pearly lustre.

Much of the crude barytes ore mined contains impurities in the shape of sulphate or carbonate of lime, silica, alumina, calcium fluoride, and strontium sulphate. In addition, sulphide minerals, such as galena, chalcopyrite, sphalerite, and pyrite, may also be present. Crude commercial barytes runs from 90 to 95% $BaSO_4$. Lithopone and barium chemical manufacturers impose penalties of so much per unit for each percentage below a stipulated grade. Ore running less than 90% barium sulphate is not commonly acceptable to these industries, and in addition, a low maximum content of iron and alumina, lead, silicate, and fluorite, is demanded. Much of the barytes ore of commerce is stained pink or brown by oxide of iron and has to undergo bleaching with H_2SO_4 in order to render it white enough for certain trades. Off-color in some cases is inherent, and cannot readily be removed by bleaching.

Barytes is a widely distributed mineral. The foremost producing regions are in the United States, Germany, the United Kingdom, Belgium, France, Italy, and Spain.

In Canada, concentration has been practiced at Lake Ainslie and Walton, in Nova Scotia, and also in Northern Ontario.

In the trade, two types of barytes are recognized, "hard crystalline" and "soft". The former is spathic in character, and is hard and coherent, while the soft has a milky appearance, and is more or less friable. The soft type is preferred for grinding, as it yields the best grade of ground barytes on account of its texture, and because impurities in it can be more readily removed by treatment with acid. The hard variety, on the other hand, is employed in the manufacture of lithopone and barium chemicals.

Barytes is valuable in industry because it is a white, heavy, chemically inert, and cheap mineral. The market price of crude barytes is largely dependent on the ease with which it can be ground, and that of ground barytes, on its color, fineness, and chemical purity.

The barytes of commerce is:

(1) Crude Barytes--- The natural mineral as mined, or after it has been washed to remove clay or earth and, where necessary picked or jigged to remove admixed rock.

(2) Ground Barytes--- The fine powder obtained by grinding the cleaned crude ore. Crude barytes that is of the required degree of whiteness needs only to be ground fine. Much of the ore mined, however, is stained pink or brown by iron oxide and must be bleached by H_2SO_4. Ground barytes that is not pure white is used as pigment in

dark paints, and as a filler in rubber goods, and as heavy paper material. Ground barytes that has been bleached is known as "prime white" or "floated" barytes. It is chiefly used as a pigment in paints (white) and as a filler in paper.

Barium Chemicals

The term "barium chemicals" is used to designate various salts or compounds which are manufactured by chemical processes from the mineral barytes.

Blanc fixe: Blanc fixe is prepared by precipitating $BaSO_4$ from a solution of a soluble barium salt, such as $BaCO_3$, by means of H_2SO_4. It is the best grade of $BaSO_4$ for pigment purposes. It is used in the manufacture of white paints, rubber goods, linoleum, oilcloth, and glazed paper. It is also used in X-ray photography as an indicator.

Barium carbonate: Barium carbonate is a white powder, obtained by treating a solution of barium sulphide with soda ash. Barium carbonate is used in ceramics; in the manufacture of optical glass; as a pigment; enamelling of iron ware; and a rat poison.

Barium chloride: This is a white salt, made by roasting crude barytes with calcium chloride. Barium chloride is used in the production of blanc fixe. Also used as a water softener; as well as being employed in the leather industry. All barium salts have poisonous properties.

Other barium chemicals are: Barium nitrate, barium chromate, barium monoxide, barium hydroxide, barium peroxide, barium chlorate, barium phosphate, barium sulphide, barium acetate, barium bromide, barium cyanide, barium ethylsulphate, barium fluoride, barium iodide, barium manganate, barium sulphocyanate.

Manufacture of Barium Chemicals

As raw material for the manufacture of barium chemicals, the best washed, soft barytes is preferred. The hard crystalline type, however, can be used. The crude barytes is first crushed to pea size, mixed with pulverized coal, and roasted in a rotary reduction furnace. The barium sulphate is reduced to barium sulphide.

Lithopone

Lithopone is a white powder consisting of a mixture of 70% barium sulphate, and 30% zinc sulphide. Lithopone is used extensively as a white pigment. It is also employed as a filler in rubber, paper, linoleum, and oilcloth.

Use of Barite in Diamond Drilling

Barite has a growing use as a heavy drilling mud in the oil industry. In diamond drilling, mud must be weighted by the addition of some material which will give a non-corrosive liquid of low viscosity and high specific gravity. Some of the substances which have been used for this purpose in past years are pulverized iron, iron oxide, flour, lead, and mercury. In recent years barite has replaced all of these, due to its low cost, high specific gravity, inertness, non-toxic qualities, and cleanliness.

The mud is prepared by mixing finely ground barite with about an equal volume of water to give a liquid of specific gravity of about 2.5. To prevent the barite from settling out, a small amount of some colloidal suspending material, such as bentonite, is added to, or ground with, the barite. Specifications for barite to be used for this purpose are given in the following table.

	Specification
Specific Gravity	4.2 (minimum)
Fineness	98% (minimum) through 325 mesh(I.M.M.)
Barium Sulphate content	93% (minimum)
Water-Soluble content	0.1% (maximum)

The water-soluble content may exceed 0.1% if the material dissolved has no harmful effects. Color of material is a matter of little or no importance (Campbell, p. 309).

At the present time, the most promising outlet for the product appears to be as weighing material in the oil-drilling industry. Some 186,000 tons of ground barite are used annually for this purpose in North America and the West Indies, with Trinidad accounting for 25,000 to 30,000 tons.

Manufacture of Ground Barytes

Producers of the best grade of ground barytes prefer soft barytes as raw material, while the harder crystalline ores are utilized principally as raw materials in the manufacture of lithopone or of barium chemicals. Hard, crystalline barytes may be made to yield a prime ground product if subjected to a lengthy grinding process, but the expense involved would be considerably greater than that involved in the grinding of soft ore. Crystalline ore, stained by iron oxide, does not respond to bleaching treatment as readily as the soft type.

No preliminary washing is required in vein type deposits. If sufficiently free of mineral impurities, the ore may be ground straight. If impurities are present, the ore may have to be concentrated, depending on the type of impurities, color of ore, etc. An ore containing fragments of brecciated country rock, and aggregates of other minerals, may have a large part of these impurities removed by a preliminary rough crushing, with subsequent hand picking and jigging. In other cases, the accessory minerals may be present in a finely divided form, disseminated throughout the ore, and may be removable only by an expensive concentration process.

Impure barytes ore usually undergoes a rough crushing, preceded or followed by hand picking, and is then jigged to remove remaining impurities. Impure crude barytes that cannot be brought up to a barium sulphate content of about 90%, by the above means, is of doubtful value, since the cost of additional concentration would be prohibitive.

The ore is wet-ground in burr mills. If a prime white grade of barytes is required, it is usually necessary to bleach the pulverized ores, by means of H_2SO_4.

Occurrences in Nova Scotia

Nova Scotia has supplied most of the barite produced in Canada, and contains the country's largest known reserves. The deposit discovered near Walton, Hants County, in 1940, has been proved by drilling to contain more than 3,000,000 tons, one of the largest known deposits of barite in the world. Production began there in 1941, and 6000 tons were shipped in that year; the amount produced in 1944 was 114,147 tons (Geology and Economic Minerals of Canada, 3rd Ed., Economic Geology Series No.1, Geological Survey p. 154-155).

The deposit lies in a limestone-conglomerate zone 200 feet thick, that locally forms the basal beds of the Mississippian Windsor group. This bed has been called the Pembroke formation by Weeks. Above the limestone-conglomerate is a Lower Sulphate bed, and below it are sandstones and argillite of the Horton group. The barite body is a replacement of the limestone-conglomerate on the flank of a syncline that is part of a large drag-fold. Faulting movements produced a zone of brecciation that served as a locus for the replacement. The deposit is now exposed at the surface, and its large area permits open-cut methods of mining.

The Walton deposit is probably related to Triassic igneous activity. A long dyke of supposed Triassic age, traverses Lunenburg and Shelbourne counties, and follows along the south shore of Nova Scotia. Similar Triassic dykes may be present, at depth, at places far removed from the Bay of Fundy.

Prior to the discovery of the Walton deposit the chief production of barite was from deposits at Lake Ainslie, Inverness county, Cape Breton Island. There the deposits are in veins traversing pre-Carboniferous rocks. For lengths of several hundreds of feet the veins have widths ranging from 8 to 18 feet, and locally have smaller veins parallel with them. Though the vein material is largely barite it contains, in places, considerable calcite and fluorite. Barite-bearing veins occur also at North Cheticamp, 40 miles north of Lake Ainslie.

Near Five Islands, on the north side of Minas Basin, still other barite deposits occur in a brecciated zone traversing folded slates and sandstones of Carboniferous or earlier age.

The following tables on barite production in Nova Scotia were obtained from the Annual Reports on Mines, Department of Mines, Nova Scotia, 1948 and 1949.

BARITE PRODUCTION IN NOVA SCOTIA

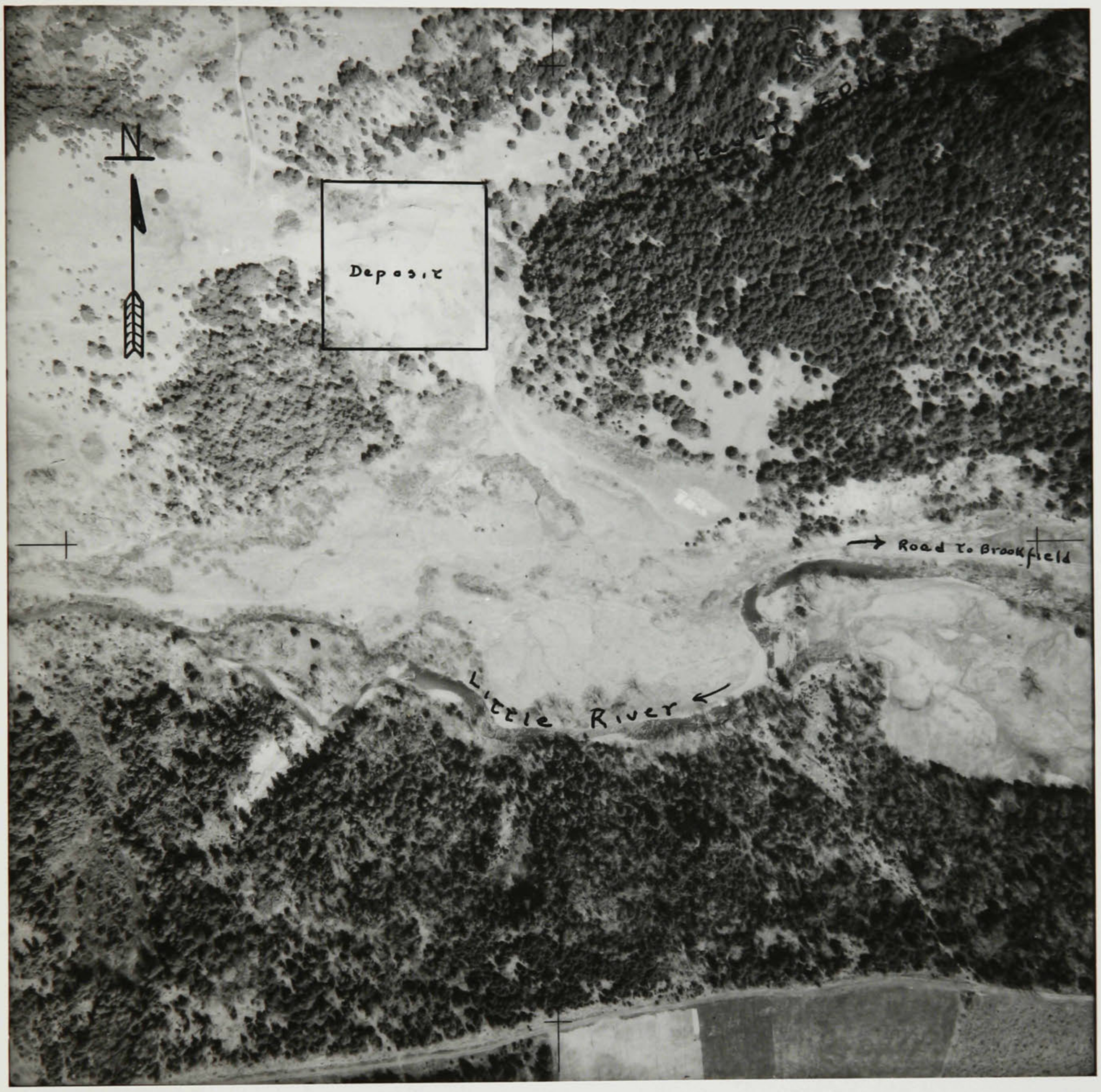
	1946	1947	1948	1949
BARITE (short tons)	115,699	131,190	96,533	43,347

BARITE PRODUCTION AT WALTON, HANTS COUNTY

Year	Tons Produced	Shipments (tons)	Men Employed	Total Man Days
1948	96,533	94,068	104	26,989
1949	43,347	45,618	69	17,657

Production of barium metal in Canada in 1948 totalled 2,552 pounds, valued at $7,988, compared with 568 pounds valued at $1,278 in 1947. The commercial production of barium metal was introduced in Canada by the Dominion Magnesium Company Limited at Haley, Ontario, in 1947.

The price of barium metal is about $3.00 per pound.



<u>Scale</u> : <u>1</u> inch equals 300 feet

Air photograph of barite property.
Brookfield, N.S.

THE BROOKFIELD BARYTES DEPOSIT

Structure

At the time of the writer's examination of the barite deposit, very little outcrop was exposed because of the heavy mantle of glacial drift which covers the area. Likewise, only scattered exposures of the Horton and Windsor country rocks were available for examination. As a result, deductions concerning the local structure had to be drawn in large part from data visible on air photographs. Sufficient diamond drilling has not yet been done to make possible the accurate outlining of the ore body.

The area within the immediate vicinity of the ore body is cut by numerous faults, which appear to follow no definite pattern. The barytes deposit is concentrated at the western terminus of the prominent fault which strikes north 70° east (see Plate 7). The ore body is found entirely within the Horton series, but in direct contact with the overlying Windsor limestone. The ore body dips northwest at about 60° and plunges east at approximately 45°. The steep dip to the northwest could be due to the influence of the previously mentioned fault.

The strike of the Horton sediments in the vicinity of the property is approximately east--west, with an average dip of 60° north. Insufficient drilling has been done to prove the definite existence of a fault surface underlying the main ore body, but it is entirely possible that such a fault does exist, as the deposit is in direct contact with the steeply dipping Windsor sediments to the south. A fault contact has been proven to exist between the Horton and Windsor formations at a point about one mile east of the deposit (see Plate 8).

Thus, it would seem highly probable that the ore occupies part of the crest of a sharp fold which plunges to the east, and which

Fault contact between Horton sandstones
and overlying Windsor limestones.
Looking north. Little River, N.S.

has been cut off on the north and south by two east--west striking bedding faults.

Further diamond drilling will undoubtedly disclose much vital information regarding the structure of the ore body. It is evident that both pre-ore and post-ore faults exist, but the complex fracturing of the property makes an accurate time determination of this faulting impossible.

To date, approximately 100,000 tons of first grade ore have been proven to exist above natural drainage.

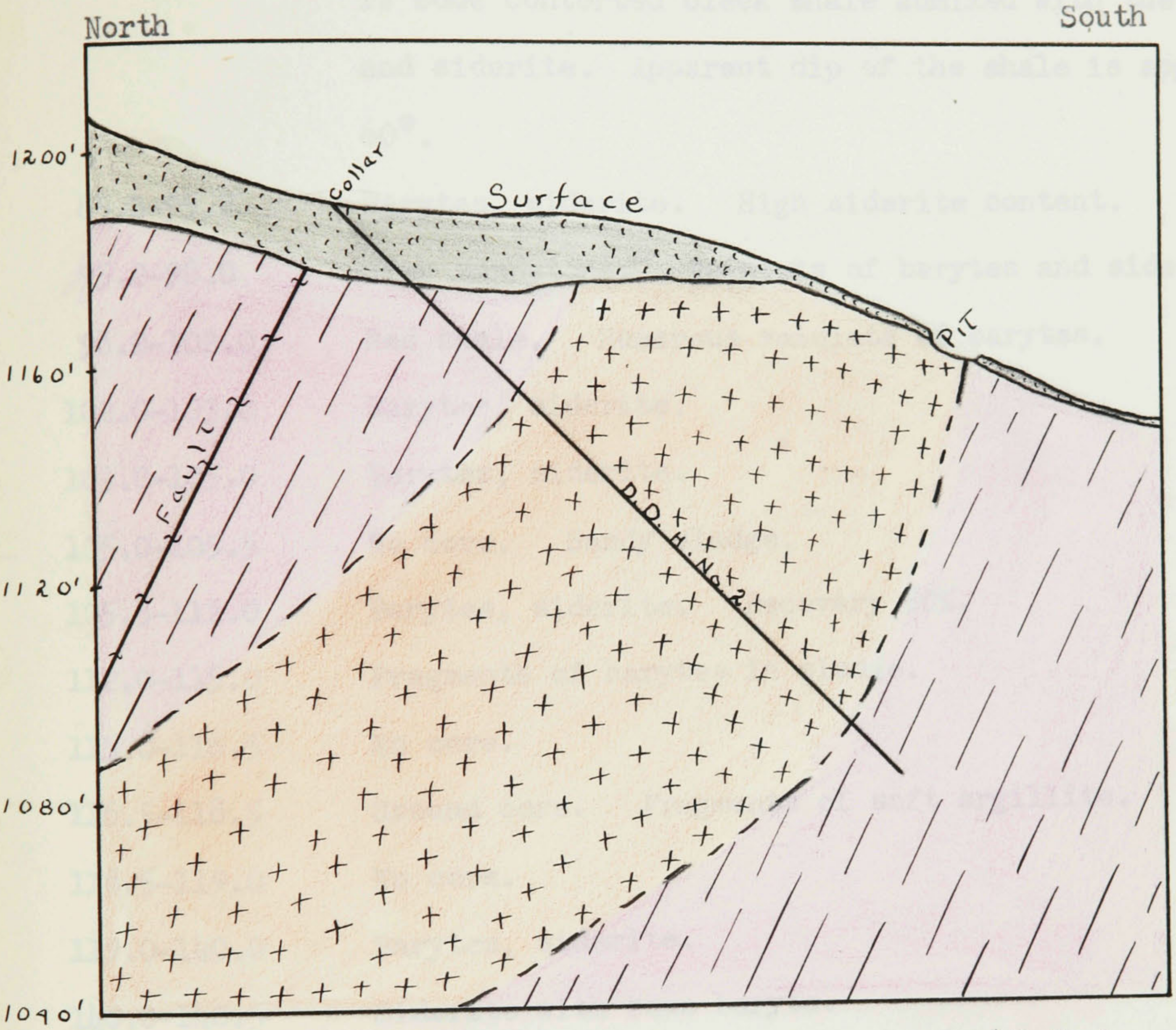
The following data was obtained from the log of the core of Diamond Drill Hole No. 2 (see Map 2).

Diamond Drill Hole No.2

Location	Latitude- North 31° Departure- East 71°
Elevation of Collar	1189.4 feet
Direction at Start	Bearing- 180° Dip- 45°

Depth in feet	Formation
0-25.0	Overburden.
25.0-39.0	No core. Sludge grey, sandy.
39.0-49.5	No core. Sludge red, sandy.
49.5-50.0	Broken pieces of red, grey argillite.
50.0-61.5	Barytes, siderite.
61.5-62.5	No core. Grey, sandy sludge.
62.5-63.5	Broken pieces of grey argillite.
63.5-65.0	No core. Red sandy sludge.
65.0-69.5	No core. Red, grey sandy sludge.
69.5-70.0	Barytes, siderite.
70.0-71.0	No core. Grey sandy sludge.

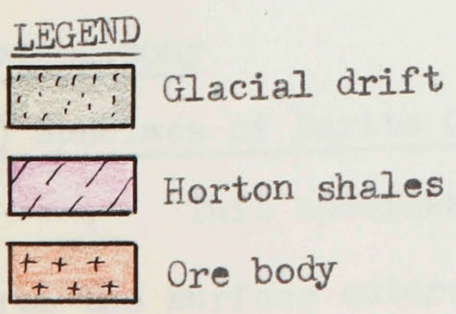
Text Figure No. 1



Scale : 1 inch equals 40 feet

Vertical Section Through Diamond Drill Hole No. 2

Showing Ore Body



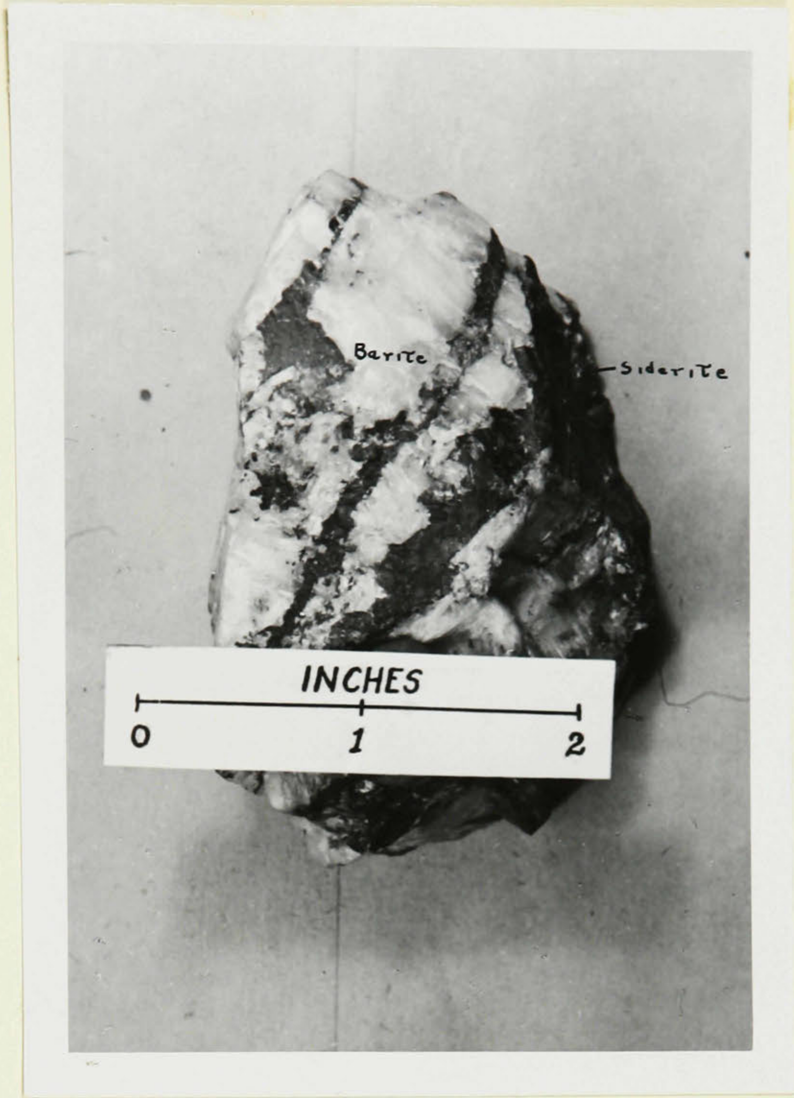
Depth in feet	Formation
71.0-85.0	Barytes, siderite. High siderite content. At 83.0-84.0 is some contorted black shale admixed with the barytes and siderite. Apparent dip of the shale is approximately 60°.
85.0-95.2	Barytes, siderite. High siderite content.
95.2-98.0	Grey sandstone. Veinlets of barytes and siderite.
98.0-102.0	Red shale. Numerous veinlets of barytes.
102.0-103.0	Barytes, siderite.
103.0-105.0	Barytes, siderite.
105.0-105.5	No core. Sandy sludge.
105.5-112.0	Barytes, siderite. Recovery 50%.
112.0-115.0	Fragments of barytes in sludge.
115.0-116.5	No core.
116.5-118.5	Ground core. Fragments of soft argillite.
118.5-119.0	No core.
119.0-140.0	Barytes, siderite.
140.0-140.5	Siderite with some baryte.
140.5-141.5	No core.
141.5-150.0	Ground core. Blocks of red shale.

Hole bottomed at 150 feet

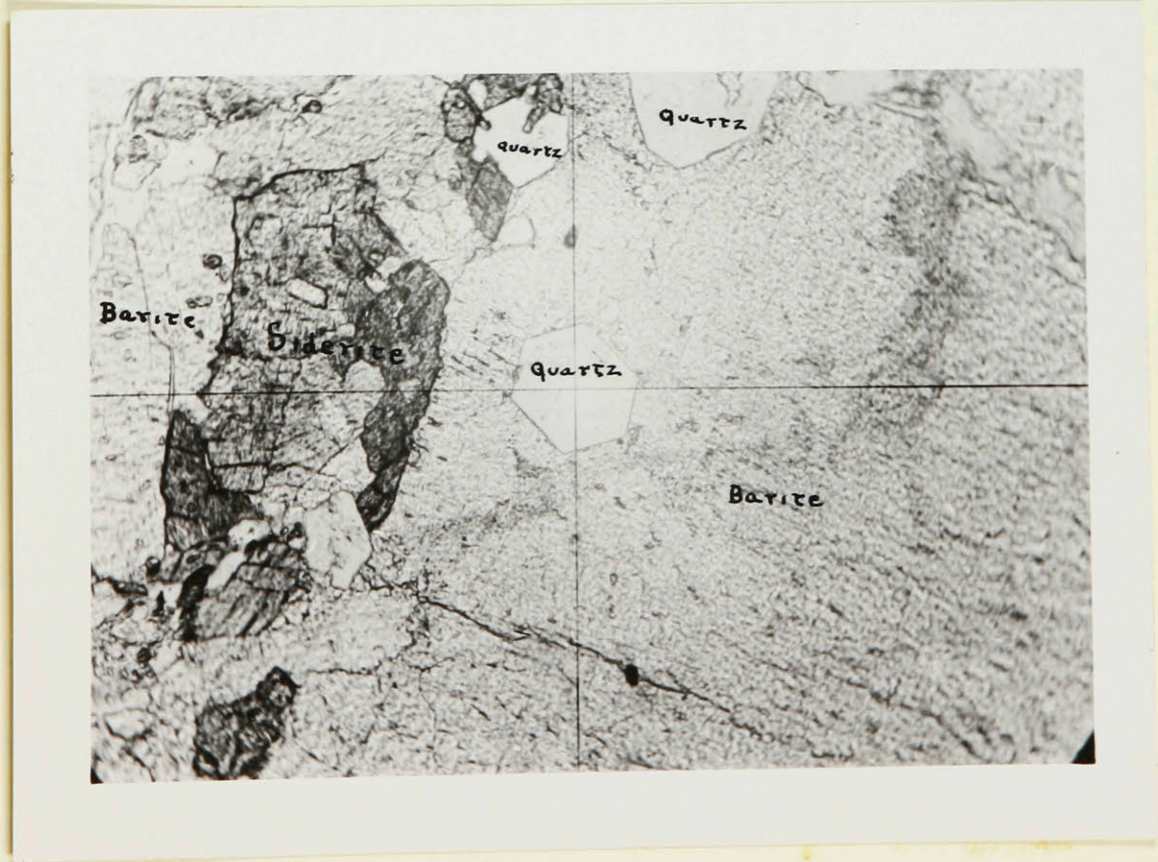
Petrography

1) Specimen of Barite Ore (see Plate 9).

This specimen of barite ore was taken from a sample obtained from the surface outcrop which had been exposed by blasting. It represents typical material from the ore body.



(i) Specimen of barite ore with high siderite content.



(ii) Microphotograph of barite ore. Plain light. Magnification 40x.

Megascopic Characteristics

The barite in the hand specimen is pure white in color, and displays excellent orthorhombic cleavage. The siderite displays perfect rhombohedral cleavage. The texture of both minerals is coarsely crystalline, with the average grain size being about 10mm. in diameter. The siderite is disseminated throughout the barite in narrow, approximately parallel bands.

Microscopic Characteristics

The ore is of holocrystalline texture and fairly uniform grain size.

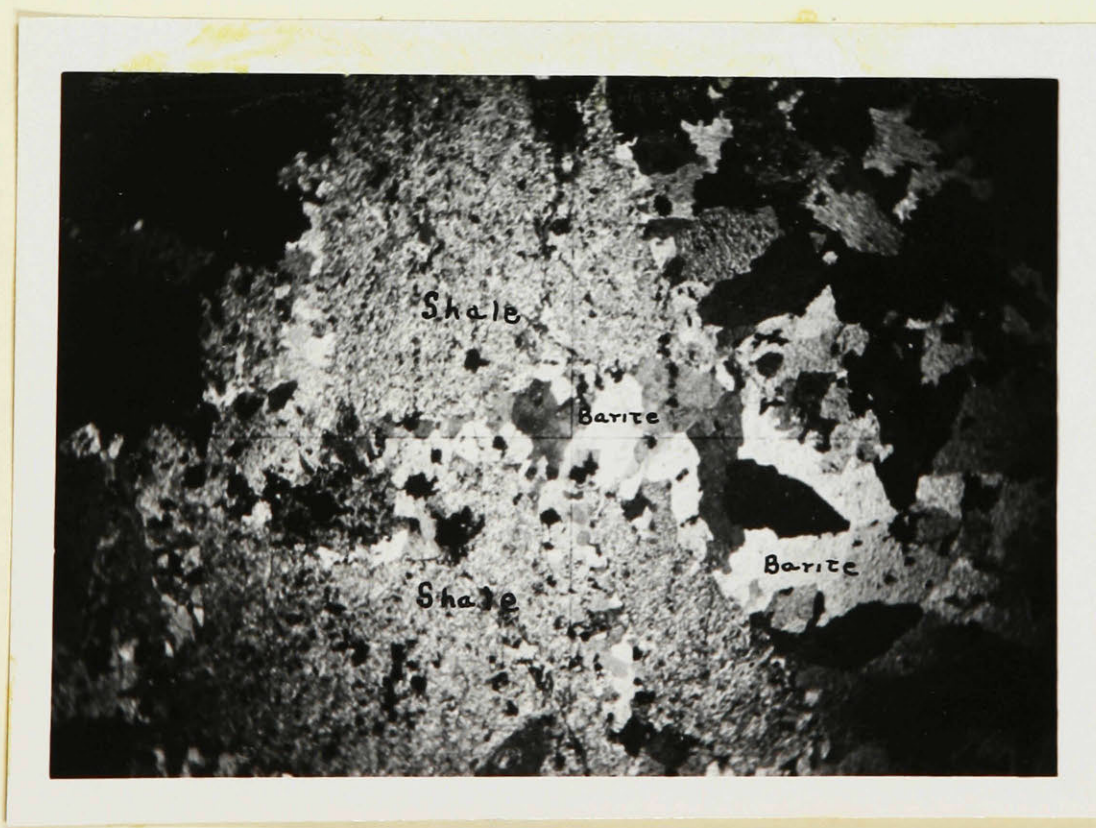
The barite is colorless in thin-section, with excellent orthorhombic cleavage. Relief is medium high, greater than balsam. Birefringence is rather weak, with a maximum interference color rarely above first order orange. Sections parallel to 100 give a positive biaxial figure.

The siderite is grey-brown in color with subhedral crystals possessing good rhombohedral cleavage. Relief is high when the long diagonal of the crystal is parallel to the vibration plane of the lower nicol, and moderate when the short diagonal is in this position. Siderite is characterized by its extreme birefringence, which ranges up to white of high order. Extinction is parallel to the cleavage traces. Interference figure is uniaxial negative.

Secondary quartz occurs as scattered euhedral crystals disseminated throughout the ore.

The barite and siderite are mutually intergrown, indicating a contemporaneous deposition from solution. The origin of the quartz crystals is more obscure. It is probable that the quartz came up in solution, and formed slightly subsequent to the deposition of the barite

(I) Specimen of barite ore in red shale.
Note brecciation of shale.



(ii) Photomicrograph of barite ore in red shale.
Crossed nicols. Magnification 40x.

and siderite.

The ore consists of approximately 80% barite, 19% siderite, and 1% secondary quartz.

2) Specimen of Barite Ore in Red Shale (see Plate 10)

This specimen was obtained from a section of drill core taken at a depth of 45 feet below the surface, at the contact of the main ore body with the red Horton shales.

Megascopic Characteristics

The red Horton shales are very fine-grained, and have been highly brecciated, the broken pieces having a diameter of approximately 2cms. The space between the brecciated particles has been filled with coarsely crystalline barite and siderite.

Microscopic Characteristics

The barite and siderite appear to have been deposited contemporaneously in fracture channels among pieces of red shale. Slight alteration of the red shales occurs along the contact between shale and ore.

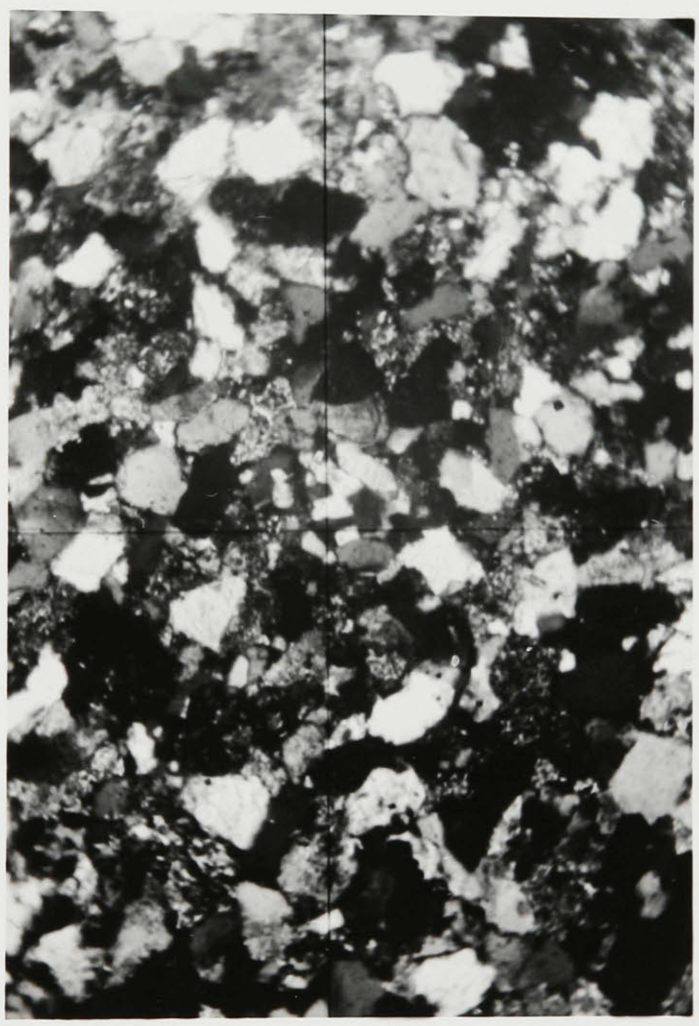
The barite and siderite are coarsely crystalline, while the shales are very fine-grained. Extremely fine bedding is visible in the brecciated pieces of shale. This bedding is discernible only upon insertion of the gypsum plate, when the crystals which make up the shale are found to be aligned.

3) Specimen of Horton Sandstone (see Plate 11)

This specimen of Horton sandstone was obtained from a section of diamond drill core taken 75 feet below the surface, in proximity to the ore body.

Megascopic Characteristics

The hand specimen is medium-grained in texture, and grey in



Photomicrograph of Horton sandstone.
Crossed nicols. Magnification 80x.

color. It appears to be a typical arkose, the dominant constituents being angular fragments of translucent quartz up to 2 mm. in diameter, and angular orthoclase fragments of the same dimensions. A small amount of calcite is also present as well as a barely noticeable amount of green chlorite. No bedding is visible in the section of drill core.

Microscopic Characteristics

The rock is of inequigranular texture. Individual grains of quartz and orthoclase feldspar are very angular, bearing evidence of mechanical disintegration with short transportation prior to deposition. The chief constituents of the rock are as follows;

Quartz	43%
Orthoclase	40%
Calcite	12%
Ilmenite	1%
Chlorite	1%
Pyroxene	1%
Sericite	1%
Not determined	1%

According to Pettijohn (1949, p. 258) such a mineral assemblage indicates the rock to be a typical arkose. The ilmenite present has been largely altered to leucoxene, while the feldspar bears evidence of extensive chloritization. The cementing material in the rock is a mixture of sericite, argillite, calcite, and colorless chlorite.

Origin of Deposit

The origin of the barium radical in the deposit is rather obscure. Analyses carried out on shales and sandstones show these rocks to contain 0.05% barium oxide respectively (Clarke, 1924, p. 30).

Spring waters also often carry barium. Therefore it is possible for the sandstones and shales of the Horton series to have provided the barium found in the deposit. Even though very small traces of barium were present in solution, deposition could have occurred, due to a low solubility ratio.

The barium is quite probably of hypogene origin, having come up as barium chloride, which is soluble in water. Chloride ion is Cl^-, and never possesses more than one negative charge. Barium ion is Ba^{++}. From these facts it follows that barium chloride ($BaCl_2$) dissociates, not into one barium ion (Ba^{++}) and one ($Cl_2^=$) ion, but into one barium ion (Ba^{++}) and two chloride (Cl^-) ions.

But in order for dissociation to occur, the rising waters containing barium chloride would have to come in contact with a solution containing a sulphate. Extensive beds of gypsum present in the area would provide a plentiful supply of calcium sulphate for this purpose.

As the water containing barium chloride mingled with the calcium sulphate solutions, the following reaction would occur:

$$CaSO_4 + BaCl_2 \longrightarrow BaSO_4 + CaCl_2$$

with barium sulphate being precipitated.

Barium sulphate is quite insoluble in water, and is as a result, almost completely removed from solution by precipitation. When removed, the double decomposition in which it was formed goes practically to completion.

The ionic reaction between barium chloride and calcium sulphate would be as follows:

$$Ba^{++} + 2Cl^- + Ca^{++} + SO_4^= \longrightarrow Ca^{++} + 2Cl^- + BaSO_4$$

As barium sulphate is an insoluble substance, its precipitation would drive the action to completion, and a deposit of barium sulphate would result.

Iron carbonate ($FeCO_3$) is also found in the ore. Microscopic examination of thin sections indicates contemporaneous deposition of siderite and barite (see Plate 9). It is probable that iron carbonate came up in solution, intermingled with barium chloride in solution, and was deposited along with the barium chloride. Lack of oxygen would prevent oxidation of the siderite to limonite.

Other impurities, such as aluminum silicates, make up less than 2% of the ore. A small amount of secondary, low temperature quartz is also present. Indications are that these impurities crystallized slightly later than the deposition of the barite and siderite, as several barite crystals have small fractures which are filled with quartz.

From examination of drill core, it is evident that the baryte-bearing solutions came up along, and were deposited in, fracture channels in the Horton sandstones and shales (see Plate 10). Thus, pre-ore faults must have been present in the Horton series. Diamond drilling has also proven the existence of post-ore faults.

That the solutions were of low temperature is indicated by the lack of alteration of the red Horton shales. Barytes seems to favor a sort of grey, Horton shale, but the ore is found in red shales as well.

Prospect for Production

The chief factors to be considered in mining a barytes deposit are:

(1) Accessibility of the deposit.

(2) Nearness to tide water in Nova Scotia.

(3) Nature of impurities in ore.

(4) Size and character of the ore body.

(1) Accessibility of the deposit

The deposit at Brookfield is readily accessible to trucks.

The property is only about three miles from Brookfield, which is situated on the main Truro--Halifax highway. Part of the road joining Brookfield with the deposit is paved, while the remainder is a good dirt road with a gravel surface.

(2) Nearness to tide water in Nova Scotia

The nearest shipping port on tide water is at Halifax, fifty-four miles south of Brookfield. Excellent facilities for transportation to Halifax via Canadian National Railway are available at Brookfield. An alternative means of transportation would be to truck the ore directly from the mill to Halifax.

(3) Nature of Impurities in ore

The nature of the impurities in the Brookfield ore is such that a white grade of barytes of more than 99% purity can be obtained by mechanical methods alone. At Walton, Nova Scotia, a product of such purity can be produced only by a costly chemical treatment, which consists of bleaching the ore with sulphuric acid.

In 1949, sample tests were run on an Aerofall mill by the Maritime Barytes Limited, to see if dry milling with magnetic concentration could be successfully carried out. The results were not satisfactory, and as a consequence it was decided to employ wet-grinding in conjunction with flotation. The company intends to wet-grind the ore to 325 mesh in a ball mill, pass the product through a classifier, and float the barium sulphate off by the flotation method.

The capacity of the mill will be 25 to 30 tons per day, with the finished product being 99% (plus) of pure white barium sulphate. No chemical agents are required to bleach the ore, as is often necessary due to discoloration caused by mineral impurities.

SAMPLE FLOW SHEET

Quarry
↓
Ore Bin
↓
Jaw Crusher
↓
Ball Mill
↓
Classifier
↓
Flotation
↓
Drier
↓
Bagger → to Brookfield

The extreme purity of the Brookfield ore is equalled by no other known barytes deposit of commercial value in Canada. Thus, a ready market for the ore is assured.

(4) Size and character of the ore body

Sufficient drilling has not been carried out to date to outline the ore body accurately. But an approximate tonnage of at least 100,000 tons of first grade ore has so far been proven to exist above natural drainage level. This figure will undoubtedly be increased considerably by further drilling.

The location of the deposit is such that it can be mined with a minimum of effort. Being situated on the side of a hill, the ore body is available for mining by open-pit quarrying methods. The ore can be dry-drilled by jackhammer, and powder consumption should be very light, because of the easy fracturing characteristics of the ore. Using 20% Polar No. 1 stumping powder, a consumption estimate would be about one stick per ton of ore broken.

The broken ore can then be loaded by mechanical methods into mine cars and so transported directly to the ore bin at the mill. An alternative method would be to transfer the ore to the bottom of the hill by chute, and then load the ore into mine cars which empty into the ore bin.

CONCLUSIONS

Although structural information is meagre due to drift cover, it is evident that faulting has played a major part in the localization of the ore body. The ore-bearing solutions came up along, and were deposited in, fracture channels in the Horton shales. Some replacement of the Horton shales by the barite has taken place. The ore favors a type of grey, sandy shale.

The barytes deposit appears to be of hypogene origin. Rising solutions containing barium chloride mingled with descending solutions containing calcium sulphate, and the barium chloride was deposited as barium sulphate, which is insoluble in water.

The principal impurity in the ore is siderite, which was deposited contemporaneously with the barite. Other impurities, such as aluminum silicates and secondary quartz occur in negligible amounts.

The extent of the ore body is well in excess of 100,000 tons, the greater part of which consists of first-grade ore from which a product of white barytes of more than 99% purity can be obtained without chemical leaching.

The deposit is ideally situated for both mining and milling.

In view of the present demand for barytes, the barytes deposit at Brookfield will undoubtedly prove to be of considerable economic value, both for the owners and for the province of Nova Scotia.

BIBLIOGRAPHY

Bateman, A.M. Barite and Witherite: Economic Mineral Deposits, Fourth Edition, p. 748, 1948.

Bell, W.A. Horton-Windsor District: Geol. Surv. of Can., Mem. no. 155, 1929.

Butler, B.S. Primary Sulphate Minerals in Ore Deposits: Economic Geology, vol. 14, no. 8, pp. 581-609, 1919.

Cameron, A.E.
Campbell, C.O. Barytes Deposit, Pembroke, Hants County, Nova Scotia: The Transactions of the Canadian Institute of Mining and Metallurgy and of the Mining Society of Nova Scotia, p. 292, 1942.

Clarke, F.W. The Data of Geochemistry (Fifth Edition): U.S. Geol. Surv., Bull. 770, 1924.

Canada Geology and Economic Minerals of Canada: Geol. Surv. of Can., Third Edition, pp. 154-155, 1947.

Mineral Production of Canada, Dept. of Mines, Annual Report, 1948-1949.

Non-metallic Minerals Used in the Canadian Manufacturing Industries: Dept. of Mines, Mines Branch Report, no. 305, p. 9, 1914.

Fletcher, H. Report on Geological Surveys in the Counties of Pictou and Colchester, Nova Scotia, 1892.

Goudge, M.F. Limestones of Canada, Their Occurrence and Characteristics: Canada, Dept. of Mines, Pub. 742, 1934.

How, H. The Mineralogy of Nova Scotia: A Report to the Provincial Government, 1869.

Ladoo, R.B. Barytes; Occurrence, Mining, Uses: Eng. and Min. Jour. Press, vol. 115, no. 7, pp. 319-324, 1923.

Lindgren, W. Mineral Deposits: pp. 89, 191, 1913.

McKinnon, A.H. Annual Report on Mines, Dept. of Mines, Nova Scotia, 1949.

Messervey, J.P. Barytes in Nova Scotia: Annual Report on Mines, Dept. of Mines, 1929, pt. 1, Pamph. 4, pp. 195-214, 1930.

Barytes, Lake Ainslie, Nova Scotia: Annual Report on Mines, Dept. of Mines, Nova Scotia, pt. 2, 1930.

Patterson, M.A. Annual Report on Mines, Dept. of Mines, Nova Scotia, 1948.

BIBLIOGRAPHY (cont'd)

Pettijohn, F.J. Sedimentary Rocks, p. 258, 1949.

Santmyers, R.M. Barite and Barium Products: U.S. Bur. of Mines, Inf. Circ. 6221, 1930.

Schuchert, C. Orogenic Times of the Northern Appalachians: Geol. Soc. America, Bull., vol. 41, no. 4, pp. 701-724, 1930.

Spence, H.S. Barium and Strontium in Canada: Mines Branch, Dept. of Mines, Pub. no. 570, 1922.

Stern, A.G. Role of Clay and Other Minerals in Oil-well Drilling Fluids: U.S. Bur. of Mines, Pub. Inf. Circ., no. 3556, 1936.

Tarr, W.A. The Barite Deposits of Missouri: Economic Geology, vol. 14, no. 1, pp. 46-67, 1919.

Tyrell, G.W. Principles of Petrology: Methuen, 1946.

Weeks, L.J. Londonderry and Bass River Map Areas: Geol. Surv. of Can., Mem. no. 245, 1948.

Weigel, W.M. Industrial Minerals and Rocks: Amer. Inst. of Min. Engineers, N.Y., chap. 4, 1937.

Winchell, A.N. Elements of Optical Mineralogy.
Vol. I - Principles and Methods, 1948.
Vol. II - Description of Minerals, 1947.
Vol. III - Determinative Tables, 1946.

LIST OF ILLUSTRATIONS

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Plates

Maps


BARITE DEPOSIT
BROOKFIELD - NOVA SCOTIA
SCALE: 1 INCH TO 40 FEET
ORE INTERSECTIONS IN DRILL HOLES PROJECTED VERTICALLY TO 1200' LEVEL.
WINDSOR LIMESTONES
HORTON SHALES
CONTACT
FAULT
BARITE
Dec. 23° 35' W
WINDSOR
CONTACT
HORTON
ASSUMED ELEVATION 1200'
PIT
PIT
OLD ORE DUMP
SMALL BROOK
HORTON
WINDSOR
CONTACT
1250
1210
1200
1190
1180
1170
1160
1150
1140
1120
1110
1100
1090
1080


LEGEND
Windsor Series Contact
Fault
Limestone
Gypsum
Grit-Conglomerate
Shale
Strike & dip of bedding
Glacial Striae
Highway
Wood Road
Brook
Barytes-in situ
SCALE - 1 INCH TO 1000 FEET
MAGNETIC NORTH
TRUE NORTH
HORTON
WINDSOR
Upper Brookfield Barytes Prospect
Shaft
Old Iron Mines
Gypsum
Grey S.S.
Red Shale
Little River
Fine Grey Grit
Brandy Brook
Wood Road to Camden
H. Nelson Farm
Farm
Small Lake
Striae Brook
Pond
Gypsum Mounds
Fault Zone
Grit
Graveyard
Camps
Gypsum sinks
Small Veinlets of Ankerite
Approximate position of Anticlinal Axis
Brookfield Village
C.N.R.
R.R. Station
Sutherlands Brook
Fine Grey Grit
Grey Grit
Old Gold Prospect
Trenches
Pits
Grit Conglomerate
Some dark Fossiliferous Slates
Old Mill Dam
Meadow
Coarse Grey Grit
Finely banded dark grey slates
Coarse Grey grit
Wood Road
Flat Marshy Land
BARYTES DEPOSIT
BROOKFIELD - NOVA SCOTIA
SHOWING HORTON - WINDSOR CONTACT