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GEOLOGY OF NICTAUX-TORBROOK MAP-AREA, ANNAPOLIS AND KINGS COUNTIES, NOVA SCOTIA

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W. G. Smitheringale

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By
W.G. Smitheringale

D E P A R T M E N T O F

M I N E S A N D T E C H N I C A L S U R V E Y S

C A N A D A

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GEOLOGY OF NICTAUX-TORBROOK MAP-AREA, ANNAPOLIS AND KINGS COUNTIES, NOVA SCOTIA

INTRODUCTION

Location and Access

The map-area lies about 70 miles west-northwest of Halifax and straddles part of the Annapolis Valley of Nova Scotia. It covers about 425 square miles.

Provincial highway No. 1 and the Dominion Atlantic Railway line from Truro to Digby are the principal routes of access. A grid of paved and gravel roads covers most of the map-area. Logging roads provide access to the unpopulated southeastern third.

Industrial Significance

Most of the population is concentrated within the Annapolis Valley, the adjacent upland area containing only scattered communities.

Middleton, the largest town in the map-area, is the centre of trade and commerce. Lawrencetown and Kingston are other important communities. A large military installation, Greenwood air-base, is situated on the flat valley bottom near Kingston.

The main industry within the map-area is agriculture, although the valley commerce is partly supported by fishing along the nearby Bay of Fundy coast, by small logging operations on the uplands, and by heavy summer tourist traffic. At present the map-area is not important from a mining standpoint although previous to 1914 the Nictaux-Torbrook iron beds, which occur within the map-area, were the main source of Nova Scotia's small iron-ore production.

Previous and Present Investigation, and Acknowledgments

Pioneer work in the area was done by Dawson (1860)[1]. Over 30 years later, more detailed work was begun by Bailey (1894, 1896), whose reports were accompanied by an 8-miles-to-the-inch map of southwestern Nova Scotia. Fletcher (1904) made a preliminary map of the area on the scale of 25 chains to the inch. A detailed survey of the Nictaux-Torbrook deposits was made by Woodman (1909). Frechette (1912) made a magnetometer survey of the Torbrook district. Hayes (1916) compiled a brief account of the petrology of the iron beds. From 1920 to 1923, Fairbault carried on detailed field work in the area. Fairbault's results were later compiled by E. H. Lovitt[2] and were used by him as the basis for an investigation conducted during the field season of 1932 under the direction of T. L. Tanton.

Extensive explorations have been conducted by mining companies formerly active in the district. At various times holes have been drilled by the Nova Scotia Department of Mines. Records of these operations are in the annual reports of the Nova Scotia Department of Mines and a complete summary up to the year 1907 is in Woodman's (1909) report. The most recent investigation of the iron beds was conducted by the Torbrook Iron Ore Mines Limited during 1956 and 1957.

The field work for the present report was done during the summers of 1956, 1957, and part of 1958. The author acknowledges the able assistance of L. B. Thompson and A. Buzas during these field seasons. Fairbault's plotting sheets were of great help in the field for locating outcrops and some of the granite contacts on the accompanying map were drawn directly from Fairbault's maps after spot field checks.

Physical Features

The map-area is divided into four elongated morphological units, each of which trends northeastward. From southeast to northwest these are: South Mountain, which covers half the map-area; Annapolis Valley and North Mountain, each covering almost a quarter of the map-area; and the Bay of Fundy, which cuts across the northwest corner.

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[1] Dates in parentheses are those of publications listed in the References at the end of this section.

[2] Lovitt, E.H.: unpublished report, Geol. Surv., Canada.

South Mountain - South Mountain is a glaciated upland, with elevations chiefly between 600 and 700 feet and a maximum elevation of 850 feet. The maximum local relief is about 250 feet. About 10 per cent of this upland is lake and swamp, and streams are numerous. It is drained by Nictaux and Annapolis rivers which flow north into Annapolis Valley, and by Lahave River which flows southeast across the province to the Atlantic Ocean. Near the northwest edge of the South Mountain upland the woods are thick and there is much underbrush, especially in areas that have been logged or farmed in the past. In the central part of the upland the woods are more open. In many areas the surface consists of coarse glacial debris, so that even in the thinly wooded and non-swampy areas, foot travel may be slow.

Although scattered outcrops are present in the interlake areas, the best exposures are along the lake shores. Allowing for short portages, most of the lakes are accessible by canoe and 4-wheel-drive vehicle.

Annapolis Valley - Annapolis Valley runs northeasterly through the north half of the map-area. It varies in width from about 3 1/2 to 5 1/2 miles. The valley floor is generally flat except where it is dissected by small streams. Approximately 75 per cent of the valley floor is between 50 and 100 feet in elevation. Most of the valley is under cultivation, although some is covered by thick bush. The main physical feature is Annapolis River which flows from South Mountain into the valley in the northeast corner of the map-area and then follows a meandering course southwestward. The meander belt is less than 3/4 mile wide. Bedrock exposures are few, and occur only in the banks and beds of Annapolis River and a few of its tributaries.

The north slope of South Mountain, between the valley floor and the South Mountain upland, is dissected by four large, and many small, consequent streams. The four large streams - all with their headwaters far back on the South Mountain upland - are South Annapolis, Fales, Torbrook, and Nictaux rivers. All streams have cut deep gulleys into the slope, thereby exposing the best bedrock sections in the map-area. The interstream areas of the slope, partly cleared farmland and partly bush-covered, are almost devoid of outcrops.

North Mountain - The southeast side of North Mountain forms a prominent escarpment along the northwest side of Annapolis Valley. Generally, the top of this escarpment has an altitude of about 700 feet. From its top the land rises gently northwestward to the crest of North Mountain. The altitude of the crest ranges from 750 to 850 feet. Northwestward from its crest, North Mountain forms a flat, gently sloping surface extending about 3 miles down to the shore of the

Bay of Fundy. Part of this slope is farmed but the remainder is covered with bush and small timber. Outcrops are continuous along the Bay of Fundy shore and are plentiful along the escarpment and in the beds of the numerous consequent streams flowing down the north slope. Along the crest of the mountain and in the interstream areas, outcrops are scarce.

Glaciation and Post-glacial Deposits

During Pleistocene time the area was covered by a continental ice-sheet which moved in a southeasterly direction, bringing granite erratics into the area from New Brunswick. Glacial striae trend about N10°W to N30°W. According to Hickox, (1959), a local ice-sheet advanced northwestward from the centre of the southern Nova Scotia peninsula after the retreat of the continental ice-sheet.

In post-glacial time Annapolis Valley was filled with several hundred feet of fluvial, glacio-fluvial, and marine sediments.

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GENERAL GEOLOGY

Bedrock of the map-area comprises sedimentary, minor volcanic, and intrusive rocks of Palaeozoic age, unconformably overlain by sedimentary and volcanic rocks of Triassic age.

The Palaeozoic sedimentary and volcanic rocks are divided into five formations ranging in age from Ordovician to Lower Devonian. In order of decreasing age these are the Goldenville, Halifax, White Rock, Kentville, and Torbrook formations. The sediments in these formations are predominantly shales, slates and minor quartzites. The Lower Devonian strata include sedimentary iron beds.

The Goldenville-Halifax contact is probably conformable. The contacts between the Halifax, White Rock, Kentville, and Torbrook formations are gradational. The latter four formations represent more or less continuous accumulation, from Ordovician through Lower Devonian time, of about 19,000 feet of marine-shelf sediments and minor volcanics.

In late Lower or Middle Devonian time the Palaeozoic strata were affected by the Acadian orogeny. The main structural element of the map-area resulting from this orogeny is a northeast-trending, closed, symmetrical syncline called the Torbrook syncline. Tight folds occur in the trough of this syncline but its limbs contain few folds, although here and there isoclinal folding is inferred. In addition to folding, the rocks developed a strong, nearly vertical cleavage. The folded and cleaved rocks were intruded by numerous mafic sills and dykes. Faulting then occurred and was followed, and possibly accompanied by, the intrusion of the central southern Nova Scotia granite batholith and numerous outlying stocks. Some faulting occurred after the intrusion of the stocks.

Near the granite contacts the sediments have, in places, been metamorphosed to schists and gneisses which grade into spotted slates farther from the contacts.

A Triassic sequence, 5,800 feet thick, unconformably overlies the Palaeozoic rocks. It consists of three conformable formations: the lower Wolfville formation and the middle Blomidon formation, both sedimentary, and seven conformable basalt flows which are referred to as the North Mountain basalt.

Table of Formations

Era	Period or Epoch	Formation and Thickness (feet)	Lithology
Mesozoic	Triassic	North Mountain basalt 1,200±	Basaltic lavas
		Conformable contact	
		Blomidon 1,600±	Siltstone, arenaceous shale and minor claystone
		Conformable contact	
		Wolfville 3,000±	Sandstone and arkose
Unconformity			
Palaeozoic	Upper or Middle Devonian	Southern Nova Scotia batholith	Granitic rock
		Intrusive contact	
		Mafic sills and dykes	Gabbroic rock
	Intrusive contact		
	Lower Devonian	Torbrook 4,800±	Fossiliferous quartzite, marine shale and siltstone; minor shaly limestone, and iron-formation
	Gradational contact		

Upper Silurian	Kentville 2,000± to 3,800±	Marine shale, siltstone, and slate; minor fossiliferous beds
	Facies	change
Upper Silurian or earlier	White Rock 200± to 2,000±	(a) Shale, siltstone, and slate; minor quartzite; (b) Rhyolite and basalt (c) Shaly siltstone and quartzite Commonly either a and c or a and b are present
	Facies	change
Ordovician	Halifax 10,000±	Siltstone and slate
	Conformable contact	
Ordovician or earlier	Goldenville	Quartzite; minor slate

Description of Formations

The oldest rocks in the area are those of the Meguma group. This group is divisible into two formations, the older Goldenville and the younger Halifax.

Goldenville Formation

Distribution - Exposures of the Goldenville formation are scarce, except along the upper part of the west branch of South Annapolis River, where they are most abundant. Scattered outcrop and abundant rubble are present 0.5 to 1.0 mile south of the Canaan road in the area around the creeks forming the head of the east branch of South Annapolis River. The structure within the Goldenville formation is not known well enough to estimate its thickness.

Lithology - The Goldenville rocks are hard, medium grey to dark brown-grey, fine-grained, quartzites. Some are massive but more characteristically indistinct bedding is recognizable by bedding fractures spaced 4 to 18 inches apart and by faint colour changes. The quartzites are metamorphosed and impure. Biotite is ubiquitous, feldspar is common, and muscovite is present in places. In exposures near the granite contact the quartzites are slightly schistose.

Structural Relations - Structural data is scarce in the Goldenville formation. Several outcrops show steeply dipping beds and several show open folds plunging from a few degrees to 30°NE.

Age - The Meguma group is considered by Weeks (1957) to be Ordovician or earlier. In this report the Halifax formation is interpreted as Ordovician, therefore the Goldenville formation is interpreted as Ordovician or earlier.

Halifax Formation

Thickness - The only part of the map-area in which both top and bottom of the Halifax formation are exposed, is in the northeast corner, along South Annapolis River. Assuming there are no structural complications, the thickness there is about 10,000 feet. As, however, the structure in this part of the map-area is not well known, the accuracy of this figure is uncertain.

Lithology - The Halifax rocks can be described in terms of one general type, although variations in detail are numerous. The

general type consists of thinly interlaminated, medium to light grey, fine-grained quartzite and dark grey, argillaceous siltstone[1]. The quartzite laminae average about 1/8 inch in thickness whereas the siltstone laminae are generally thinner. Both types of laminae are characteristically irregular in thickness and laterally discontinuous. The thickness of the quartzite laminae commonly varies in a 'pinch-and-swell' fashion, thereby giving the laminae semi-lenticular shapes. The quartzite laminae commonly constitute from 50 to 75 per cent of the rock. The Halifax rocks generally have moderate to strong slaty cleavage.

Variations from the general type occur in silica content, composition, colour, thickness, and shape of the laminae. Thus siltstone laminae vary from dark grey, siliceous siltstone, to black, slightly or even non-siliceous, argillite. Quartzite laminae vary from fine-grained quartzite with almost no impurities to extremely fine-grained, argillaceous quartzite. In fact, in many outcrops both light and dark grey laminae are siltstones that only differ from one another in grain size and silica content. The thickness of quartzite laminae ranges from 1/16 inch or less to 1 inch. Siltstone laminae vary from paper-thin to 2 inches thick. Black, argillaceous, paper-thin partings commonly constitute a third type of laminae. However, in some outcrops they are clearly very thin varieties of the thicker, dark-coloured laminae in the same outcrop. Their presence as a third component is noticed when they occur within both quartzite and siltstone laminae. Although both thin and thick laminae are generally irregular they have, in places, a constant thickness over several tens of feet. Quartzite laminae may constitute about 10 per cent to as much as 90 per cent of the rock.

Although siltstone laminae and argillite partings are commonly dark grey or black on the weathered surface, they are locally buff or rusty red. There, the outcrop as a whole is buff-coloured, even on 'fresh' surfaces. On the southeast limb of the Torbrook syncline a 500-foot wide band of buff slates can be traced by widely scattered outcrops for 4 miles along strike. In the Digby area, (Smitheringale, 1959), similar colouring in Halifax slates is known to be a secondary

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[1] The shades of grey referred to are those of the weathered surface; and, in fact, it is the weathered surface that best shows the features of these rocks. On the fresh surface the laminations are not as distinct, as the quartzite laminae, which usually contain argillaceous impurities, are almost as dark as the siltstone laminae.

feature, and not due to any peculiarity in the composition of the slate. Accordingly, this band of buff slate is not interpreted as having petrological significance.

On Nictaux River, 3.5 miles upstream from the bridge at Nictaux Falls, and on the west branch of South Annapolis River, 0.25 mile upstream from Canaan road, Halifax slates contain small disseminated pyrite cubes. In both these localities the rock is predominantly slaty, argillaceous siltstone with few quartzite laminae.

The lower 2,000 feet of the Halifax formation only outcrops in about a dozen localities, all in the northeast corner of the map-area. In each, the siltstone component is more abundant and distinctly less siliceous than in the 'general type'.

Structural Relations - In some outcrops, lenticular parts of quartzite laminae, (described above under Lithology), show small scour and fill features. Bedding within the fill is defined by paper-thin, black argillite laminae. This bedding may be truncated, indicating tops of beds, but this is rare.

Ripple-marks, etc., are not sufficiently abundant to give a consistent indication of current directions. For example, at the old sawmill on Hutchinson Brook, a mile northeast of Morristown, groove casts indicate a southwesterly current direction. However, within 25 feet stratigraphically from these features, ripple-marks indicate a current direction at right angles to this.

On Torbrook River, 1.6 miles upstream from the road running east from Bloomington, and in other scattered localities, invertebrate fossil trails occur in typical Halifax slate.

Although the Goldenville-Halifax contact can be accurately located, it is not exposed. As the Goldenville quartzites near the contact are not bedded, it is not known whether or not the Halifax lies conformably on the Goldenville. Elsewhere in Nova Scotia the contact is probably conformable.

Age - The Halifax formation contains few fossils. More than 60 man-hours were spent splitting slate with cleavage parallel or nearly parallel with bedding, but only four specimens were found. These are from the extreme northeast corner of the map-area on Hutchinson Brook by the old sawmill, a mile east of Morristown by road. The specimens were taken from different horizons within 30 feet downstream from the old millpond dam. All four specimens are dentritic graptolites to which an Ordovician age has been tentatively assigned.

White Rock Formation

Thickness - The White Rock formation ranges in thickness from about 200 to 2,000 feet.

Lithology - The formation has an extremely varied lithology. The most complete section, exposed on Fales River, is given in tabular form below.

Table I

Lithology of White Rock Formation Exposed Along Fales River

Description	Thickness (feet)	Comments
Two massive, white to pink quartzite members with red-weathering, shaly siltstone between	600	'Upper part' of White Rock formation (map-unit 3c)
fault contact		
Argillaceous quartzites in 4- to 12-inch beds; bedding distinct	400	Fault at top of sequence is not of major significance (map-unit 3a in part)
Discontinuous outcrop of vessicular basalt, with minor chert, intruded by sills; mafic	400	'Basalt member' (map-unit 3a in part)
Light grey, predominantly aphanitic volcanic rock with approximate composition of rhyolite	110	May be a tuff at this locality but in other places it shows distinct flow features; 'Rhyolite member' (map-unit 3a)
Base not exposed		

Although the Fales River exposures provide the most complete section of the White Rock formation, the foregoing section is by no means representative. Siltstones are normally much more abundant in the middle and lower parts of the formation than they are at Fales River. Other changes in lithology and thickness occur both northeast and southwest of Fales River.

The rhyolite member can be traced by discontinuous outcrops and rubble zones southwest of Fales River on both limbs of the Torbrook syncline. In fact, it is the most persistent member in the entire map-area. On both limbs of the syncline southwest of Fales River, light grey, massive quartzite members, varying in thickness from a few feet to 250 feet, occur with siltstones in a section extending stratigraphically from 600 feet below the rhyolite member to 800 feet above the basalt member. These quartzites are laterally discontinuous. In places at least two quartzite members are present.

This volcanic-quartzite unit, which includes map-unit 3b and part of 3a, cannot be traced northeast of Fales River. Rather, in the northeast part of the map-area all but the upper part of the White Rock formation (3c) is composed of red-weathering, slightly siliceous to siliceous, generally non-laminated siltstone. There the upper part is similar to the upper part on Fales River except that it thins toward the northeast. On South Annapolis River it is 400 feet thick.

The distinctly bedded, argillaceous quartzite unit overlying the basalt member is apparently restricted to the Fales River section.

Southwest of Fales River the massive white to pink quartzite members of map-unit 3c cannot be traced beyond the South Tremont - Rockville Notch road. Red-weathering siltstone rubble is present at a point 0.6 mile east of South Tremont, but southwest of this point, rocks resembling map-unit 3c are lacking. In fact, southwest of this point the siltstones of the White Rock formation and those of the lower part of the overlying Kentville formation are indistinguishable except where quartzite members are present above the volcanic members of the White Rock formation.

Structure and Stratigraphy - Crosby (1951) described the White Rock formation in Wolfville map-area as follows: "The White Rock formation comprises quartzite and slate. The formation is essentially two massive quartzite beds with slate between them. The top of the upper quartzite bed and the base of the lower quartzite bed mark the stratigraphical limits of the formation ..... Known thicknesses

of the formation vary within the Wolfville map-area from about 100 feet to more than 450 feet." If Crosby's description of the White Rock formation is applied to the Fales River section the base of the formation would have to be placed at the bottom of map-unit 3c. However, lithology of the bedded argillaceous quartzites and of the quartzite-volcanic sequence that underlies map-unit 3c is completely foreign to the Halifax formation. Therefore, the Halifax - White Rock contact in Nictaux-Torbrook map-area cannot be defined in terms of Crosby's description of the White Rock formation in Wolfville area. After consideration of the relationships in the Wolfville, Nictaux-Torbrook and Digby map-areas, the most consistent interpretation is obtained by placing the contact either at the bottom of the lowest quartzite or volcanic member, or at the top of the thinly interlaminated, light and dark grey 'Halifax type' slates, whichever location is stratigraphically the lowest. The accompanying map is drawn on this basis.

The above definition of the Halifax - White Rock contact, i.e. of the top of the Halifax formation, is not as ambiguous as it might appear. The reason for placing the top of the Halifax at the bottom of the lowest quartzite or volcanic member, even though laminated slates occur stratigraphically above that member, is that laminated slates similar to those in the Halifax formation do, in places, occur in both the White Rock and Kentville formations.

However, the important point is that the entire Halifax - White Rock sequence is conformable and, except for the volcanic members, represents continuous deposition.

The base of the rhyolite member is exposed only at a point 1.2 miles south of South Tremont and 1,000 feet northeast of the county line. There the rhyolite lies disconformably on an erosion surface. Because the trace of the rhyolite member there and elsewhere throughout its length is parallel with the strike of the beds in the underlying slates and quartzites, this disconformity is interpreted as having only local significance.

The gradational Halifax - White Rock contact is exposed on South Annapolis River in the vicinity of the sharp bend 1,900 feet due south of Factorydale. There, light and dark grey interlaminated slates of the Halifax formation grade into non-laminated shales and slates of the White Rock formation.

Mode of Origin - The discontinuous quartzite members in the lower part of the White Rock formation and the lateral facies change in both the lower and upper parts suggest deposition in a basin in which conditions of sedimentation at any one time varied from one

locality to the next. The chert lenses between the basalt flows exposed on Fales River suggest a subaqueous origin for these volcanic rocks. The White Rock formation is probably a marine-shelf deposit.

Crossbedding is present in only a few localities within the White Rock formation. Other indications of the source and direction of transportation of the White Rock sediments are lacking.

Age - Unidentifiable fossil remains occur near the northwest edge of a 250-foot-thick quartzite member, 3,200 feet S26°E from the school house at Inglisville. Fossils are not known to occur elsewhere in the White Rock formation. However, as it is underlain by the Ordovician Halifax formation and overlain by the Silurian Kentville formation, the White Rock formation is probably Silurian.

Kentville Formation

Thickness - The approximate thickness of the Kentville formation, measured along Fales River, is 2,000 feet. However, southwest of Fales River, where all but the volcanic rock - quartzite component of the White Rock formation becomes indistinguishable from the Kentville formation, about 3,500 feet of strata between the top of the volcanic rock - quartzite beds and the base of the Torbrook formation have been assigned to the Kentville formation.

Lithology - The most complete section of the Kentville formation is exposed in discontinuous outcrops along Fales River, beginning 1,200 feet downstream from the dam at Rockville Notch and continuing for 2,000 feet farther downstream. It is described in Table II.

Table II

Kentville Formation Exposed Along Fales River

Description	Thickness (feet)	Comments
No outcrops	400	Kentville-Torbrook contact lies somewhere in this zone
Strongly cleaved, purplish weathering, moderately siliceous shale	small outcrop	
No outcrops	100	
Pale grey, purplish grey, and greenish grey, very fine-grained, soft, non-siliceous, argillaceous slate; occasional interbeds of more siliceous slate and black slate	100	Purplish colour and possibly some other shades are due to weathering
No outcrops	150	
Alternating laminae of fine-grained, medium grey, argillaceous quartzite and dark grey, argillaceous shale; individual laminae of both rock types range from 1/16 to 1/2 inch in thickness; proportion of quartzite laminae varies from less than 25% to about 50%	450	One bed contains small black calcite nodules

Table II (cont.)

Description	Thickness (feet)	Comments
No outcrops	200	
Strongly cleaved, black, argillaceous shale	75	Only indication of bedding is a 4-foot by 2-foot lens of dark grey, finely crystalline limestone; Silurian graptolites occur stratigraphically below limestone
No outcrops	200	White Rock - Kentville contact lies somewhere in this zone

In the creeks southwest of Fales River are scattered exposures of Kentville rocks. Strikes are consistent in this region and a fairly complete section of the Kentville formation can be obtained by projecting between these creeks and Fales River.

The lower half of the Kentville formation consists chiefly of dark grey, slightly siliceous slate and alternating thin laminae of medium grey, impure quartzite and dark grey argillite. The upper half of the Kentville, at least between Fales River and Spinney Brook, consists predominantly of greenish grey, non-siliceous, sparsely laminated slates. These slates do not outcrop southwest of Spinney Brook. Thus on Torbrook River the rocks along the projected strike of the upper Kentville formation are similar to those of the lower Kentville, i.e. they are predominantly medium to dark grey, in places laminated, moderately siliceous siltstones. This is interpreted as a facies change in the upper Kentville beds rather than displacement of the section by faulting.

Stratigraphy - Because the upper part of the White Rock formation becomes indistinguishable from the lower part of the Kentville formation southwest of South Tremont, the former is shown

on the map as undergoing a lateral facies change to the southwest, thereby merging with the Kentville formation. The only remaining recognizable part of the White Rock formation is the quartzite-volcanic rock unit. The upper stratigraphic limit of this unit which represents the top of map-unit 3a in this region, is defined by the uppermost quartzite member. As the stratigraphic position of the quartzite members varies, map-unit 3a is also mapped as undergoing lateral facies changes and locally merging with the Kentville formation. Thus, southwest of Fales River the White Rock-Kentville contact is represented locally by lateral facies changes. Northeast of Fales River the contact is not exposed. However, it is presumably conformable although not necessarily gradational.

Age - The Kentville formation is sparsely fossiliferous. Fossil collections were identified by Cumming (1957). Graptolites from the Fales River section are *Monograptus nilssoni* (Barr) and *M. colonus* (Barr). This fauna is of Silurian (Ludlovian) age.

Graptolites also occur in slightly siliceous argillaceous shale that outcrops on Torbrook River 0.8 mile upstream from the old Phinney Mill road, east of Bloomington. They are *Monograptus* sp. cf. *tumescens* Wood, also of Ludlovian age.

A fauna of "probable Silurian" age was collected from olive-grey upper Kentville slates in a gravel pit at the junction of Messenger Brook and the main road east-northeast from Torbrook. Cumming identified the following forms:

Kionoceras sp. cf. *angulatum* (Wahlenberg)
Modiolopsis sp.
? Seyphocrinites sp.
? Actinopteria sp.
crinoid columnals.

Torbrook Formation

Thickness - The most complete section is along Spinney Brook, although there the upper 1,500 feet of strata are not exposed. The thickness of the Torbrook formation on Spinney Brook is about 4,800 feet.

Lithology - The lithology of the Torbrook formation is varied. Between Fales and Torbrook rivers the most abundant rock types are shale and shaly siltstone that are variably siliceous. Both types are dark to medium grey, or reddish. Light grey to purplish

quartzite beds, 1 inch to 6 inches thick, are intercalated with the shale and siltstone. Also numerous are quartzite members up to several tens of feet thick. They are grey, sometimes fossiliferous, and are made up of beds 4 to 18 inches thick. About 1,100 feet from the base of the formation is a 300-foot-thick limy section which thins towards Torbrook River. This section comprises black, limy shale and thin-bedded, dark grey, in part fetid limestone containing black argillite partings.

In the region between Torbrook Mines and Nictaux River, beds of quartzitic iron-formation up to 10 feet thick occur on both limbs of the syncline. In places these beds are highly fossiliferous. Hematite is the most abundant iron mineral in the northeast parts of these beds, but magnetite predominates in the southwest parts where the entire section is more highly metamorphosed. The two main beds are known as the 'Shell' and 'Leckie'.

In the vicinity of Nictaux River, and southwest of it, the Torbrook formation is distinctly more siliceous than to the northeast. Torbrook rocks exposed along Nictaux River are predominantly dark grey, moderately siliceous to siliceous, slaty siltstones, some of which contain beds 1 inch to 3 inches thick of buff-weathered, limy, fossiliferous siltstone. A minor, although very distinctive component of this section, is a light grey, greenish brown mottled, fine-grained, silty quartzite which occurs in beds 6 to 24 inches thick. A few light grey quartzite beds, 2 to 6 inches thick, are also present. The increased silica content is probably due to the combined effects of a variation in the composition of the original sediments and a higher degree of metamorphism. The latter can be related to the proximity of the granite contact.

Structural Relations - Rocks of the Torbrook formation in the trough of the Torbrook syncline are exposed along Nictaux River. The axis of the syncline crosses Nictaux River about a mile northwest of Bloomington. Its exact location, however, is obscured by complex isoclinal folding in the Torbrook formation. The folds plunge up to 20° NE and SW and have amplitudes unknown, but more than 10 feet.

One mile southwest of Nictaux River the Torbrook formation is cut across its strike by an elongated granite stock. On the southwest side of this stock near the headwaters of Jones Brook, about a mile east of East Inglisville, fossiliferous siltstones, metamorphosed almost to hornfels, are crumpled into many folds of about 3 to 10 feet amplitude. The fold axes plunge 15 to 20° NE. This is the approximate position of the axis of the Torbrook syncline.

Apart from several major faults (discussed under Structural Geology), faulting within the Torbrook formation is not evident in the present exposures. However, maps of the iron-formations made when these beds were well exposed by mining operations, show numerous faults striking northwest to west across the beds. These faults produce offsets up to 100 feet in both right- and left-handed directions (Frechette, 1912).

The Kentville-Torbrook contact is best exposed on Spinney Brook 700 feet downstream from the road running east-northeast from Torbrook. It is gradational through a stratigraphic zone about 40 feet thick and is marked by an increase in silica of the slightly siliceous shales of the upper Kentville formations, and by the appearance of quartzite beds 1/2 inch to 6 inches thick interbedded with the shale.

Origin - The varied lithology and fauna of the Torbrook formation indicate deposition in a changing environment. The lower 1,100 feet exposed on Spinney Brook consists of shale, siltstone, and fossiliferous quartzite. Although interbedded, the quartzite and shale beds are, in general, fairly well sorted, whereas the siltstone beds are poorly sorted. The quartzites contain marine brachiopods. This lithology reflects deposition in a marine-shelf environment subjected to currents of variable strength. The 300-foot-thick section of dark grey, in part fetid limestone and black shale, which overlies the lower 1,100 feet, was deposited in a highly reducing environment protected from currents; possibly in a local, stagnant basin. The next 900 feet are predominantly grey siltstone and represent a normal marine facies. The uppermost 500 feet exposed on Spinney Brook consist of red-weathering siltstone with minor quartzite. Some of the quartzite shows small-scale crossbedding and the siltstone rarely contains terrestrial plant remains. The scarcity of the latter suggests that they are not in place but were transported to their present site. These beds were deposited in a near-shore marine environment. The presence of marine brachiopods in the Shell bed, and plant remains in the hanging-wall shale of the Leckie bed 0.25 mile west of Torbrook Mines indicate that the iron beds are also a near-shore marine facies.

Crossbedding is rare in the Torbrook formation and other indications of current direction are lacking.

Age and Correlation - The age of the Torbrook formation is Lower Devonian. This was determined by Cumming (1957) who reported the following forms obtained from fossils collected from more than twenty localities.

Dalmanella sp. cf. D. planoconvexa Hall
Dalmanella sub carinata Hall
Spirifer sp. cf. S. murchisoni Castelnau
Spirifer cf. arenosus Conrad
Spirifer cf. gaspensis Billings
Spirifer cf. pellico Archiac et Verneuil or Acrospirifer
Rensselaeria sp. cf. R. mainensis Williams
Rhipidomella sp. cf. R. oblata Hall
Rhipidomella sp. cf. R. vanuxemi Hall
Rhipidomella sp. cf. logani Clarke
Atrypa sp.
Palaeopina sp.
Phacops sp.
Strophostylus ? cf. globosus Hall
? Onchus sp.
Tentaculites cartieri Clarke
Zygobeyrichia sp. cf. Z. devonica Jones and Woodward
Syngoporia ? sp.
Stropheodonta (Leptostrophia) magnifica Hall
Leptostrophia cf. perplana Conrad
Zaphrentis sp.
? Hipparionyx
Meristella sp.
Platyceras chapmani Williams and Breger
Modiomorphia sp.
Grammysia canadensis Billings
Homalontus sp.
Bellerophon trilobatus Sowerby
Favosites sp. indet.
Strophonella sp.
Stropheomena sp.
? Athyris
Paleochara or Polypora sp.
Stenoscisma sp.
Eatonia sp.
Chonetes novascoticus Hall
? Stenoscisma
? Antispirifer sp.

The Torbrook formation correlates with the Lower Devonian siltstones and quartzites in Digby map-area. Cumming (1959) stated ".... Lower Devonian fauna from Bear River (Digby map-area) is in general similar to the Lower Devonian fauna of the Gasperaux Sheet (west half) ..... Minor differencesbetween these two faunas may be explained by local environmental and facies differences."

Mafic Intrusions

Numerous bodies of mafic rock intrude the Palaeozoic rocks. Most of these are sill-like, but some are discordant. They range in thickness from a few feet up to 250 feet. Some can be traced by discontinuous outcrops for distances exceeding 1,000 feet. They are gabbroic in composition, fine to medium grained, and in places have a diabasic texture. Chilled margins and baking of the intruded rocks are common.

Age - These mafic rocks intrude all formations from the Halifax to the Torbrook, inclusive. However, on Eel Weir Brook, on Jones Brook, and in the spillway of the Nictaux River power dam near Wamboldt Lake, small mafic sills and dykes are intruded by granite. The age of the mafic rocks is thus post-Lower Devonian and pre-granite.

Granitic Rocks

Granitic rocks (9) underlie the southeast half of the map-area. They are part of the large batholith that underlies central southern Nova Scotia.

Lithology - At least six petrographically distinct types of granitic rock occur in the map-area. The distinction between these types was made in the field on the basis of megascopic characteristics. They have not yet been studied in thin-sections and are not differentiated on the accompanying map.

Type 1: The southeastern and southwestern parts of the map-area are underlain by a type that can be traced beyond the map-area and that appears to be the main type of the southern Nova Scotia batholith. It is a light grey, coarse-grained, porphyritic rock. The following composition and texture is characteristic:

Quartz: 20 to 30%; predominantly coarse grained
Biotite: 5%; medium grained
Feldspar: 65 to 75%; medium to coarse grained, in groundmass; also as hypidiomorphic to automorphic orthoclase phenocrysts up to 7.5 cm in greatest dimension; these phenocrysts comprise up to 5% of rock

Type 2: A second type occurs north of type 1 in the area of East Allen, Cloud, La Have, and Randall lakes. It is light grey, medium to coarse grained, and porphyritic. The following composition and texture is characteristic:

Quartz: 25%; medium grained
Biotite: 5 to 10%; fine to medium grained
Feldspar: 65 to 70%; predominantly medium grained, in groundmass; also as orthoclase phenocrysts up to 2.5 cm in greatest dimension; these phenocrysts rarely comprise more than 2% of rock

Type 2 differs from type 1 in that it is distinctly finer grained and contains fewer and smaller phenocrysts.

Type 3: Here and there, within areas chiefly underlain by types 1 and 2, are small bodies of fine-grained aplite composed of various proportions of quartz, feldspar, biotite, and minor muscovite. A few irregularly shaped bodies contain 1 to 2% hypidiomorphic to allotriomorphic orthoclase phenocrysts with a large dimension of up to 0.7 cm. More commonly this aplite is not porphyritic and occurs as stringers.

Type 4: A granitic rock with a distinctive texture outcrops between Trout Lake and Nictaux River. It is composed of: medium-grained quartz, 20 to 30%; medium-grained feldspar, 25 to 45%; biotite, less than 5%; minor muscovite; and orthoclase phenocrysts, 30 to 50%, ranging in size from 0.3 by 1.0 by 1.0 cm, to 0.6 by 2.5 by 2.5 cm. These abundant automorphic phenocrysts are characterized by their parallel alignment.

Type 5: This type has a limited distribution at the edge of the main batholith in the area south of Inglisville and East Inglisville and between Inglisville and West Inglisville. It is pink, medium grained, and seriate.

Type 6: Directly west of Nictaux Falls are three small stocks of grey, medium-grained, seriate, biotite granite. Type 6 is finer grained and contains more biotite than type 5.

Marginal Zones and Stocks - The rock forming the stocks and the marginal zone (1 mile wide), of the main batholith between Alpena and South Annapolis River is slightly but not distinctly different from type 1. It is coarse grained, locally porphyritic, and has a composition similar to that of type 1. It is light grey but in some localities the feldspar is weathered red, thereby giving the rock a pink colour. It differs from type 1 in having a slightly finer grained groundmass and fewer and smaller phenocrysts. In this respect it might be considered to be a coarse-grained variety of type 2. Because of its uncertain relationships it has not been considered as a separate type.

Numerous inclusions of schistose meta-sedimentary rocks occur within granitic rocks in the vicinity of Fox and Banks Lakes, north of Shell Camp Lake. Aeromagnetic data suggest that similar hybrid rocks (7b) constitute a bulbous, north-trending belt between Fox and Banks lakes and South Annapolis River.

Structure - Contacts between the various types of granite are not well exposed. Nevertheless, several of these contacts can be located accurately, although their nature cannot be discerned.

The contact relationships between types 1 and 2 are unknown. Type 3 commonly occurs as small dykes intruding types 1 and 2. Type 4 intrudes type 1 but its relationships to types 2 and 3 are unknown. The nature of the contact between types 1 and 5 is uncertain although it appears to be gradational. Type 5 does not occur in contact with types 2, 3, or 4. Type 6 is isolated from the other types.

Age - About 3/4 mile west of Nictaux South, at the north end of the pond near the headwaters of Jones Brook, the contact between a large stock and fossiliferous beds of the Torbrook formation is exposed. The stock intrudes beds within 100 feet along strike of a fossil locality. In many other localities granitic rock shows intrusive relationships to rocks mapped as the Torbrook formation on the basis of structure and lithology. According to this evidence the granitic rocks are post-Lower Devonian.

In the Geological Survey laboratories an age determination of 363 million years was obtained on biotite from granitic rock of type 1 from the northwest corner of Mistake Lake. This indicates a Late Devonian age according to the time scale proposed by Kulp (1959).

Wolfville Formation

The Wolfville and Blomidon units have recently been raised to formational status by Klein (1959b). Previously they were considered as members of the Annapolis formation. Klein discarded the term Annapolis as a rock-unit name.

The Wolfville formation unconformably overlaps the Palaeozoic rocks of South Mountain. The contact follows approximately the southeast side of Annapolis Valley. Although the greater part of Annapolis Valley is underlain by this formation, exposures are few. They are scattered along the bed of Annapolis River and in several creeks running off South Mountain. The most northwesterly exposures are about a mile north of Highway No. 1, along the brook that crosses

Highway No. 1 approximately a mile west of Wilmot Station. On this brook - 600 feet upstream from the east-northeast-trending cross-road a mile north of Highway No. 1 - the Wolfville-Blomidon contact can be located within 5 feet, although it is not exposed. The minimum thickness of the Wolfville formation is about 3,000 feet.

The exposures of the Wolfville formation along Annapolis River consist predominantly of reddish brown and pale greenish grey arkose. The rock contains between 10 and 50 per cent (average 25 per cent), medium- to coarse-grained, subrounded grains of quartz, and minor quartzite and dark-coloured rock fragments. Weathered, fine-grained feldspar is abundant in the silty matrix, and locally, fine-grained biotite constitutes 10 per cent of the rock. In places, beds of fine-grained quartz sandstone and siltstone are interbedded with the arkose. Both red and grey varieties occur in the same outcrop. The colour boundaries are not a bedding feature although in places they follow the indistinct bedding planes. In many beds colouring is patchy, with red patches occurring in predominantly grey zones, and vice versa.

Outcrops in the creek northwest of Wilmot Station are predominantly fine-grained, red-brown quartz sandstone with about 50 per cent quartz and rock grains. A few beds of coarse-grained sandstone, in places approaching quartz-pebble conglomerate, are also present.

Structural Relations - The Wolfville formation unconformably overlies Upper Devonian and older rocks. Bedding strikes approximately northeast to east-northeast and dips 4 to 12°NW. Beds are not folded or metamorphosed.

Mode of Origin and Age - Current-direction indicators in the Wolfville formation within the map-area are not numerous enough to be of use. However, the components of the medium- to coarse-grained arkose must have had a nearby source. The large quartz grains suggest the coarse-grained granitic rocks of South Mountain as a probable source. That the source of these components was local is suggested by the presence of a fine-grained, biotite-rich facies of the arkose in the vicinity of the three fine-grained, biotite-rich, granitic (type 6) stocks that are exposed to the southwest of Nictaux Falls. According to Klein (1959a) the Wolfville formation is fluviatile in origin.

The age of the Wolfville formation is Triassic (Powers, 1916; Klein, 1959b).

Blomidon Formation

The Blomidon formation underlies the slope at the base of the North Mountain escarpment. It is approximately 1,600 feet thick.

Lithology - The Blomidon formation comprises red and grey siltstone, arenaceous shale, and minor claystone.

The formation within a few feet of the Wolfville-Blomidon contact is exposed in the creek northwest of Wilmot Station. At this point is consists of deep red-brown shale with minor lenses of grey shale up to 1/4 inch thick. The shale contains mica flakes but no visible quartz. One lens of fine-grained argillaceous sandstone is present.

In the north central part of the map-area, where the road 0.7 mile east of Dodge Road crosses Wiswal Brook, a 45-foot-thick section of the Blomidon formation is exposed. It comprises reddish brown, arenaceous, blocky shale, containing irregular and discontinuous bands of light grey shale. These bands are 1/4 inch to 3 inches thick and occur in groups up to 1 foot thick. The groups are spaced 2 to 15 feet apart. Rounded and frosted quartz grains up to 1/8 inch in diameter, constitute up to 50 per cent of the rock. The strata with the grey bands are more arenaceous and could be called argillaceous sandstone. Some other beds, less arenaceous than average, could be called claystone.

About 50 feet of the Blomidon formation immediately underlying the North Mountain basalt, is exposed at the head of the creek northwest of Wilmot Station. The top of this section is light grey clay containing a little fine-grained quartz. Beneath this is about 35 feet of red, arenaceous to non-arenaceous claystone with a few grey lenses.

On the Clarence-Outram road, near the west edge of the map-area, the top 85 feet of the Blomidon formation is completely exposed and a 100-foot section below this is partly exposed. The total section consists of interbedded sandstones, siltstones, and claystones, with all gradations between these types. The sandstones are most abundant. Typical colours are pale red, dark reddish brown, light grey, and yellowish to greenish grey. The top 35 feet of the section is predominantly grey, with red and brown beds. It is less arenaceous than the lower 150 feet which is predominantly red. Near the top of the section, small-scale crossbedding, ripple-marks, mud-cracks, raindrop imprints, and cube-shaped voids that may be molds of former salt crystals, are present in siltstones and claystones. Fossil plant

fragments occur at horizons about 25 feet and 35 feet from the top of the section.

The Blomidon formation conformably overlies the Wolfville formation, but the nature of the contact within the map-area is unknown. According to Klein (1959a) the Wolfville and Blomidon formations interfinger in the Annapolis-Cornwallis Valley.

According to Klein (1959a) the Blomidon formation is lacustrine in origin. Its age is Triassic (Powers, 1916; Klein, 1959b).

North Mountain Basalt

The North Mountain basalt forms North Mountain. It is approximately 1,200 feet thick.

Within the map-area the North Mountain basalt comprises seven conformable flows. These fine- to medium-grained rocks are dark brownish grey, dark greenish grey, and light brownish red. Some flows are abundantly amygdaloidal with several species of zeolite minerals as fillings. Chalcedony and zeolites occur as fissure fillings.

The attitude of the North Mountain basalt is similar to that of the underlying Blomidon formation. The contact between the two formations, which follows the North Mountain escarpment at about the 500-foot contour, represents a slight erosional hiatus.

The age is Triassic (Powers, 1916; Klein, 1959b).

STRUCTURAL GEOLOGY

It is worth repeating that the entire stratigraphic section from the Goldenville formation through the Torbrook formation is conformable and apparently represents almost continuous deposition. The only break in this sequence occurs at the bottom of the volcanic unit within the White Rock formation. As this hiatus is not visible in either Wolfville or Digby map-areas it is not considered to be of regional importance.

Beds within the map-area generally strike northeast and dip vertically or steeply towards the axis of the Torbrook syncline. Cleavage also strikes northeast and dips steeply.

Folding

The main structural element in the area is the Torbrook syncline, whose axial trace passes through the community of Torbrook and trends about N45°E. The axial plane is almost vertical, but a steep southeast dip is suggested by cleavage which, with few exceptions, dips from 70°SE to vertical. Subsidiary folds, in the region of the trough, plunge both northeast and southwest but the direction of plunge of the main syncline is not known. Whatever the direction, the angle must be low.

On the southeast limb of the Torbrook syncline are a few northeasterly plunging folds in the Halifax formation. Their axial planes commonly dip steeply and their amplitude, where it can be determined, is in the order of 10 feet. Here and there throughout the map-area, beds that dip away from the axis of the Torbrook syncline occur where there is no visual evidence of folding. Except in one locality (see below), tops of beds face the synclinal axis, therefore beds that dip away from the synclinal axis are believed to do so because of local overturning rather than subsidiary isoclinal folding. However, as reliable determinations of tops of beds are few, and as those noted were not in beds with anomalous dips, the possibility of isoclinal folding cannot be ruled out. Moreover, it is possible that strong cleavage, such as that developed in the Kentville formation along Fales River, has destroyed visual evidence of folding. In only one locality, about a mile south-southeast from Nictaux South, top and bottom determinations associated with anomalous dips suggest isoclinal folding.

Faulting

At the east abutment of the old dam 3,500 feet upstream from the bridge at Nictaux Falls, an easterly trending fault cuts the northwest limb of the Torbrook syncline. East of Nictaux River this fault displaces the iron beds in the Torbrook formation. West of Nictaux River it displaces the volcanic unit in the White Rock formation and can be traced into the Halifax formation to about 1/2 mile west of Jones Brook. The fault dips steeply and has a right-hand strike separation of about 700 feet.

Numerous minor faults in the map-area trend, in general, northwesterly to due north. They have produced predominantly left-handed offsets of up to several hundred feet. They are most noticeable, and therefore have been mapped most abundantly where they displace mafic sills and dykes, and volcanic and quartzite members. About a mile southeast of Nictaux West, on Jones Brook, a fault with a small displacement cuts an apophysis extending from a nearby granitic stock.

In the vicinity of East Inglisville, on the northwest limb of the Torbrook syncline, the rhyolite member (3b) of the White Rock formation has been offset several thousand feet to the right. Two miles southeast of Torbrook, on the southeast limb of the syncline, the same unit has been offset several thousand feet to the left; moreover, the entire Kentville section has been repeated. In both these places, markedly elongated granitic stocks occur in the areas between the separated beds. On the southeast limb of the syncline the distribution of rhyolite and granitic rock is such that the displacement cannot be the result of simple dilation associated with the intrusion of the stock. Movement with a horizontal component parallel with the axis of the stock must have occurred. Although the evidence is not as conclusive, the same is probably true of the displacement on the northwest limb of the syncline.

The fact that, on both limbs of the syncline, the displacement of the northeast part relative to the southwest part is towards the synclinal axis, suggests the possibility of a transverse fault along which the northeast side has moved upward relative to the southwest side. As there is no displacement of the Kentville-Torbrook contact on the southeast limb, the direction of net slip in the plane of such a fault would have to be approximately parallel with the trace on that fault plane of the Kentville-Torbrook contact in the southeast limb of the syncline. No direct evidence of such a transverse fault was noted.

A second possibility is that these displacements occurred along two different faults, one with a right-hand, the other

with a left-hand component of horizontal movement. The accompanying map is drawn according to this interpretation.

It is probable that the elongated form of the two stocks between the severed beds is a result of these stocks being intruded along the faults that caused the displacements. If so, the large horizontal displacement of unit 3b occurred either before or during, but not after, the emplacement of the granitic rocks. However, faulting in other localities occurred after the intrusion of the stocks, as is shown by the faulted apophysis on Jones Brook.

By analogy to the two stocks discussed above, the shape of the other stocks rimming the main granitic body suggests that they too may have been intruded along fault zones.

ECONOMIC GEOLOGY

Iron

Between the communities of Torbrook West and Torbrook Mines are old pits and dumps that mark the sites of previous mining operations located along the Nictaux-Torbrook iron beds. These operations began in 1825 and the ore was smelted at Clementsport, N.S. Operations continued sporadically until 1916; then World War I curtailed shipments of ore which, at that time, was smelted in Europe.

The iron beds occur in the Torbrook formation on both limbs of the Torbrook syncline. One bed, several feet thick, occurs on the southeast limb. Two main beds which average about 5 feet in thickness, and several smaller beds, occur within a 200-foot-thick section on the northwest limb. In the northeast part of these beds, hematite is the main ore mineral, but to the southwest, near the granitic intrusives, magnetite is the ore mineral. (All are high in phosphorus.) The iron is sedimentary in origin.

The beds are narrow and dip steeply, thereby requiring underground mining; they are uneconomical by present standards.

Manganese

Several small, uneconomical manganese deposits are shown by Fairbault (1923) on his field maps. Most of these are bog deposits.

An exploration shaft, now caved, was sunk about 2 miles east-northeast from Harmony, along the contact between a mafic sill and siltstone of the White Rock formation (3). Loose material surrounding the shaft shows manganese-oxide stains but gives no suggestion of significant manganese concentrations.

In 1957 the Torbrook Iron Ore Mines Limited did some stripping on a small manganese showing about 2.5 miles south-southeast from Torbrook. The mineralization is associated with a basalt member of the White Rock formation.

Granite

Several granite quarries are currently in operation. The small production is consumed locally for tombstones.