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PAPER 64-13

SILURIAN STRATIGRAPHY AND ORDOVICIAN-SILURIAN RELATIONSHIPS IN SOUTHWESTERN NOVA SCOTIA

(Report, 3 figures and 2 plates)

F. C. Taylor

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ABSTRACT

Recent mapping on various scales has delineated the areas of Silurian rocks, comprising the White Rock, Kentville, and New Canaan Formations. The White Rock Formation, which overlies the Lower Ordovician Halifax Formation, is the most widespread and the most diverse. In the northeast it is a simple, thin (100-500 feet), completely sedimentary unit of slate and quartzite, whereas in the southwest it is a thick (13,000-15,000 feet) complex unit of mafic and silicic volcanic rocks, slate, siltstone, quartzite, and conglomerate. In the central part it shows characteristics of both extremes. The sparsely fossiliferous Kentville Formation (Ludlovian) consisting of slate, siltstone, and shale, 1,600-3,500 feet thick, occurs only in the central and northeastern parts. The New Canaan Formation, possibly more than 1,000 feet thick, occurs in the northeast. Consisting of siltstone, slate, breccia, and andesite, it is conformable with the Kentville Formation.

The absence of a defined Ordovician-Silurian boundary obscures Ordovician-Silurian relationships, but on structural grounds no Taconic effects are evident. However, because of lithologic changes and thickening southwestward of the White Rock Formation it is apparent that, although the area lies outside the deformation belt, the Taconic orogeny did exert influence over southwestern Nova Scotia in so far as sedimentation and volcanism are concerned.

SILURIAN STRATIGRAPHY AND ORDOVICIAN-SILURIAN RELATIONSHIPS IN SOUTHWESTERN NOVA SCOTIA

INTRODUCTION

Recent mapping in southwestern Nova Scotia by the Geological Survey (Crosby, 1962; Smitheringale, 1959, 1960; and Taylor, 1961a, 1961b, 1962)* has delineated the areas underlain by Ordovician and Silurian rocks. The completion of this mapping permits an analysis of the results to determine whether or not this part of the Appalachians was involved in the Taconic orogeny and to establish the Silurian stratigraphy in this part of Nova Scotia.

The area forms a part of the Atlantic (southern) Upland of Nova Scotia and extends from Wolfville southwestward to beyond Yarmouth, a distance of more than 125 miles. An extensive cover of glacial and glacio-fluvial debris exists throughout most of the area and good exposures are limited to places where erosion has been effective, that is, along stream valleys and, in the southwest, along the coast.

Geological investigations in this part of Nova Scotia were started in the 19th century and include a long list of contributors, the chief ones being Dawson (1855), Honeyman (1878), Bailey (1898), Ami (1900), and Faribault (1909). These men established a broad regional picture of the geology of the area, but did not recognize for the most part the extensive distribution of pre-Devonian rocks that overlie the Meguma Group.

In 1949 Crosby (1962) commenced 1-mile mapping in Wolfville map-area and later, 1957 to 1959, Smitheringale (1959, 1960) mapped Nictaux-Torbrook and Digby map-areas on the same scale. During this period Hickox (1958) mapped some of the same area in conjunction with a glacial geology study.

Reconnaissance studies (1 inch to 4 miles) by the writer Taylor, 1961a, 1961b, 1962, completed geological mapping along the west side of Nova Scotia. While engaged in these studies the author visited both the Nictaux-Torbrook and Wolfville map-areas. The areal distribution of the pre-Devonian rocks in southwestern Nova Scotia is now known, although the scale of geological investigation varies from one area to another.

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*Names and/or dates in parentheses refer to publications listed in the References.

GENERAL GEOLOGY

Rocks in southwestern Nova Scotia range in age from probable Late Cambrian to Triassic. The oldest rocks, the Meguma Group, consist of two formations, the lower Goldenville Formation and the upper Halifax Formation of Early Ordovician age. The former is predominantly greywacke whereas the latter is primarily slate. These formations are overlain by Silurian strata, which show a great diversity of rocks of both sedimentary and volcanic origin. The Silurian rocks are overlain by fossiliferous Lower Devonian (Torbrook Formation) sedimentary rocks in two separate map-areas (Smitheringale, 1959, 1960).

During the Acadian orogeny these rocks were folded into north- to northeast-trending folds and were intruded by granite. The Silurian and Devonian rocks are only present in the cores of synclines formed at that time.

Following a period of erosion Carboniferous strata were deposited unconformably on the Devonian and earlier rocks. These are limited to the northeastern part of the area under discussion. Along the northwestern side of southwestern Nova Scotia, Triassic sedimentary and volcanic rocks lie unconformably on all the older rocks.

Rare, small, basic intrusive plutons, chiefly sills, some pre-granite and some post-granite (a few possibly as young as the Triassic) occur locally.

The Silurian of southwestern Nova Scotia is represented by the White Rock, Kentville, and New Canaan Formations. These formations occur in six localities, which from north to south are: Wolfville map-area, Nictaux-Torbrook map-area, Digby map-area, along the Sissiboo River, at Cape St. Mary and in the Yarmouth district.

WHITE ROCK FORMATION

Definition

Quartzite rocks immediately above the Halifax Formation were named "Whiterock quartzite" by Faribault (1909) in Gaspereau (Wolfville) map-area. Faribault (1920) later correlated lithologically similar quartzite outcropping at Chegoggin Point north of Yarmouth with these rocks. The formation was not well defined, however, until Crosby (1951) mapped the Wolfville area. He changed the name to "White Rock Formation" and described it as follows.

Table I

Table of Formations

Era	Period or Epoch	Formation	Lithology
Mesozoic	Triassic		Sandstone, arkose, siltstone, shale, conglomerate, basalt
	Unconformity		
Palaeozoic	Mississippian		Sandstone, shale, arkose, conglomerate, limestone, gypsum, anhydrite
	Unconformity		
	Middle Devonian		Granite
	Intrusive contact		
	Early Devonian	Torbrook	Fossiliferous siltstone and quartzite, shale, siltstone, minor shaly limestone, and iron-formation
	Gradational contact		
	Late Silurian	New Canaan	Breccia, siltstone, slate, andesite
		Kentville	Slate, siltstone, shale
	Silurian and earlier	White Rock	Quartzite, slate, siltstone, rhyolite, andesite, basalt, tuffs, conglomerate
	Early Ordovician	Halifax	Slate and siltstone
	Conformable contact		
	Early Ordovician or Late Cambrian	Goldenville	Greywacke, minor slate

"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 are the limits of the formation..."

Southwest of the Wolfville area, Smitheringale (1960) found that the above definition could not be applied unless bedded argillaceous quartzites, quartzite, and volcanic rocks were included in the Halifax Formation. As these rocks are foreign to the Halifax Formation he therefore redefined the White Rock Formation so as to place the lower 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." Smitheringale commented further (p. 15): "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." This definition has been found to be satisfactory for placing the lower contact of the White Rock Formation elsewhere to the southwest.

Distribution and Thickness

Rocks of the White Rock Formation are present in widely separated localities all along the northwestern side of Nova Scotia from Wolfville map-area to Yarmouth. The thickness of the formation increases southwestward from about 100 to 500 feet in Wolfville map-area to about 200 to 2,000 feet in the Nictaux-Torbrook area, to as much as 2,300 feet in the Digby area. The formation is thickest, however, in the Yarmouth district where, although the top is not known, between 13,000 and 15,000 feet of strata overlies the Halifax Formation.

Lithology

The lithology of the White Rock Formation becomes increasingly complex in passing from the type area, near Wolfville, to the most southerly exposures near Yarmouth. In the type area it consists solely of two massive quartzite beds separated by slate, whereas in the Yarmouth district it consists of quartzite, slate, conglomerate, and greywacke, along with both silicic and mafic volcanic rocks. The only distinctive rock type is massive quartzite, commonly white or light coloured, which does not occur in any other formation in southwestern Nova Scotia.

Quartzite — In the Wolfville area the lower quartzite bed is commonly the thinner of the two and ranges from 14 to 87 feet thick. The upper bed on the other hand ranges from 30 to 92 feet thick. Both beds locally contain thin beds of slate. In the Nictaux-Torbrook area the two quartzite beds cannot be traced southwest of Fales River (Smitheringale, 1960). However, in this area light grey, massive quartzite members, ranging in thickness from a few feet to 250 feet, occur in a zone stratigraphically below the two quartzites mentioned above. The light grey massive quartzite members are laterally discontinuous, and in places at least two members are present.

In the Digby area the two quartzite beds are present. The upper one, 75 feet thick, of medium grey, massive quartzite, outcrops 1,300 feet above the top of the Halifax Formation. A rubble zone of white to pink quartzite suggests the presence of the second bed at the base of the formation. A single outcrop of quartzite is present 1 mile southeast of Mistake Lake in the Sissiboo River area, but its stratigraphic position is not known.

At Cape St. Mary several thin and discontinuous beds of quartzite are present just above the top of the Halifax Formation. Farther southwest at Chegoggin Point similar quartzite, which forms at least four beds ranging from 12 to more than 80 feet thick, occurs about 2,700 feet above the base. Another bed of quartzite, 21 feet thick, occurs near Overton, about 9,000 feet above the base of the formation. East and southeast of Yarmouth similar quartzite lies 6,000 to 6,100 feet above the Halifax Formation.

From the above observations, therefore, it can be seen that the quartzite beds are discontinuous and occur at different horizons in relation to the base of the formation.

These quartzites are almost everywhere white, pale yellow to pale brown or pinkish, equigranular, and tough. Locally finely disseminated argillaceous material gives them various shades of grey. They are chiefly massive, although in many places they are well bedded, with beds ranging from a fraction of an inch to 4 feet thick. Colour banding is locally common. Rare current-ripple marks are present in the Wolfville area 5,000 feet north of White Rock Mills and 4,000 feet east of Deep Hollow road along a small north-flowing brook. The only other primary structure is rare crossbedding in the Nictaux-Torbrook area and at Cape St. Mary, where it occurs in two of the quartzite beds.

Slate and Siltstone — The slate in the type area ranges in thickness from 18 feet to approximately 350 feet. It is indistinguishable from the slate of the Halifax Formation there and elsewhere.

Southwestward the lithology becomes much more diverse. For example, along Fales River is the section described in Table II. Siltstone is normally more common in the middle and lower parts of the formation than in this section. Northeast of Fales River, red-weathering slightly siliceous to siliceous non-laminated siltstone, 400 feet thick along South Annapolis River, comprises the lower part of the formation; volcanic rocks are unknown.

Table II

Lithology of White Rock Formation Exposed Along Fales River
(after Smitheringale, 1960)

Description	Thickness (feet)	Comments
Two massive, white to pink quartzite members with red-weathering, shaly siltstone between	600	'Upper part' of White Rock Formation
	fault contact	
Argillaceous quartzites in 4- to 12-inch beds; bedding distinct	400	Fault at top of sequence is not of major significance
Discontinuous outcrop of vesicular basalt, with minor chert, intruded by sills; mafic sills	400	'Basalt member'
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'
	Base not exposed	

In the Digby area, weakly laminated dark grey 'featureless' arenaceous siltstone is the dominant rock type. Besides the quartzite previously mentioned, about 10 feet of basic volcanic rock occurs in the section close to the base of the upper quartzite (Smitheringale, field notes on file, Geol. Surv. Can.).

Along Sissiboo River, the White Rock Formation consists mainly of andesite and tuff. Sedimentary rocks are rare, possibly owing to a scarcity of outcrop. The few sedimentary rocks exposed are grey-green slate with minor amounts of grey to light grey, fine- to medium-grained quartzite in beds 1/2 inch to 2 inches thick.

At Cape St. Mary, mafic and acidic volcanic rocks are intercalated with quartzite and well-bedded grey slate. Volcanic members range from 15 to 80 feet thick, the sedimentary units from less than a foot to 130 feet thick.

It is in the Yarmouth district where the White Rock Formation contains the greatest variety of rocks. Slate, argillaceous quartzite, conglomerate, and greywacke, as well as the distinctive White Rock quartzite, comprise the sedimentary rocks. Slate, much of it identical to that of the Halifax Formation, forms the largest part and totals about 2,500 feet. In places quartzite interbeds are common. Argillaceous quartzite is the lowest, most exposed rock type near Pembroke Shore, where 500 feet of it is present. Smaller amounts occur elsewhere in the formation.

Conglomerate occurs at Cape Fourchu and on strike along the coast near Overton. It is intercalated with the volcanic rocks and probably wedges out to the north. Conglomerate is not known on the east limb of the Yarmouth syncline. Boulders and cobbles are composed of mafic volcanic rocks, rhyolite, the distinctive White Rock Formation quartzite, biotite greywacke, and small amounts of vein quartz. The matrix is composed in part of volcanic debris and in part of siliceous material; in general where sedimentary fragments predominate the matrix is siliceous and where volcanic boulders predominate the matrix is of volcanic origin.

Greywacke constitutes only a small part of the formation and shows neither continuity nor appreciable thickness.

Volcanic rocks form the largest part of the White Rock Formation in the Yarmouth district and are 9,000 to 11,000 feet thick. Of these probably no more than 600 feet is rhyolite. Mafic volcanic rocks comprise the largest part of these rocks. In places andesites, showing amygdules, flow-top breccias, and rare pillow structures are present, whereas elsewhere low-grade metamorphism has converted the rocks to schists. Tuffs form a considerable part of the mafic rocks, and a band of these rocks, approximately 500 to 800 feet thick, extends with minor breaks from Cape Fourchu (East Cape) to west of Bunker Lake. These rocks are well bedded and locally show graded bedding and volcanic bombs. They may be subaerial in origin.

The rhyolites are chiefly flows, but include some tuffs. In places they are intrusive and occur as sills.

General Stratigraphy

Representative columnar sections of the White Rock Formation are shown on Figure 1.

The White Rock Formation is therefore not a simple rock unit as represented in the type area, but a complex unit consisting of many rock types, which reflect a complex history of sedimentation, volcanism, and erosion.

The stratigraphy within the White Rock Formation is not well known. Except for the Wolfville and parts of the Nictaux-Torbrook areas, strata useful as horizon markers show little continuity. This, coupled with poor exposures and lack of fossils, prevents accurate correlation from one locality to another.

The most readily recognized rock unit is the quartzite-slate member that forms the entire White Rock Formation in the Wolfville area. There the two quartzite beds, although not of constant thickness and not separated by a uniform amount of slate, can be readily traced throughout the area. The same horizons are recognizable in the Nictaux-Torbrook area as far southwest as the Annapolis-Kings county line. This quartzite-slate member may be represented again in the Digby area, but there the slate component is a siltstone 1,250 feet thick compared with no more than 400 feet to the northeast. In the Yarmouth district the quartzites at Chegoggin Point and near Overton may represent the quartzites of this member even though separated by about 7,000 feet of strata. Probably 6,350 feet of this is rock of volcanic origin, although 5,800 feet is drift covered along the coast. The remainder, about 650 feet, is sedimentary rock, predominantly slate, which corresponds fairly well with thicknesses of sedimentary rocks in this member elsewhere.

In the east limb of the Yarmouth syncline only one quartzite is present. Its stratigraphic location in relation to the base of the White Rock Formation suggests it is the lower quartzite of the quartzite-slate member. If this is correct, then the slates outcropping along the east side of Yarmouth Harbour are correlative with those exposed along the coast near Overton on the west limb of the Yarmouth syncline. The upper quartzite on the east limb would be stratigraphically above the highest bed exposed.

Smitheringale (1960) found that a rhyolite was the most persistent member of the White Rock Formation in Nictaux-Torbrook map-area. He was able to trace it on both limbs of the Torbrook syncline from Fales River to the western limit of the formation in this area, a distance of 15 miles. The only place where the base of this rhyolite is exposed is 1.2 miles south of South Tremont and 1,000 feet northeast of the Annapolis-Kings county line. There the rhyolite lies disconformably on an erosion surface. Smitheringale considered this relationship as a local disconformity.

This rhyolite member does not occur in the Digby area, but a similar rock type occurs at Cape St. Mary and in several horizons in the Yarmouth district. At Cape St. Mary rhyolite lies unconformably on Halifax slates. (The significance of this relationship is discussed later in this report.) In the Yarmouth district only one of the rhyolite horizons could be considered correlative with the rhyolite of the Nictaux-Torbrook area as only one rhyolite occurs below the quartzite-slate member. This particular rhyolite occurs only on the east limb of the Yarmouth syncline and extends for 5 miles from southeast of Yarmouth airport northeastward to Brooklyn. Its base is nowhere exposed.

Smitheringale (1960) was able to establish that siltstones in the upper part of the formation undergo a lateral facies change southwest of Fales River and locally merge with the Kentville Formation.

Contacts

Possible correlations are shown in Figure 2. Although the contact between the White Rock and Kentville Formations is not well exposed in the Wolfville area, Crosby (1962) agreed with Faribault (1909) that the two formations are conformable there. To the southwest Smitheringale (1960) found that the upper part of the White Rock Formation is indistinguishable from the lower part of the Kentville Formation southwest of South Tremont. Therefore he considered that the former had undergone a lateral facies change to the southwest and merged with the Kentville Formation. Northeast of Fales River the contact is not exposed, but not necessarily gradational.

In the Digby area the contact is gradational, for only the presence of rare Upper Silurian (Ludlovian) brachiopods led Smitheringale (1959) to correlate part of the 'featureless' siltstone zone with the Kentville Formation. The lower part and the quartzites below the fossil beds are therefore probably the counterparts of the quartzites of the White Rock Formation in the Nictaux-Torbrook and Wolfville areas.

Age

Except for a few unidentifiable remains collected by Smitheringale (1960) from near Inglisville no fossils are known in the White Rock Formation. However the overlying Kentville Formation is sparsely fossiliferous along Fales River, Torbrook River, and Messenger Brook. These fossils are Silurian (Ludlovian) in age, so that the White Rock Formation is either Ordovician or Silurian or both. As the upper part of the White Rock Formation merges with the Kentville Formation which contains Upper Silurian fossils (Smitheringale, 1960, p. 19) this part of the White Rock Formation is probably also of Silurian age. The conformable relationship of the lower part of the White Rock Formation with the Halifax Formation, however, still allows its interpretation as Ordovician.

Origin

A complex rock unit such as the White Rock Formation is a reflection of a complex geological history. The distinctive quartzite that shows rare current-ripple marks, crossbedding, excellent sorting, and well-rounded shapes points to shallow-water deposition. The slates, which for the most part are indistinguishable from the Halifax slates, were probably formed under similar conditions. The tuffaceous volcanic rocks and the coarse conglomerates in the Yarmouth area also are indicators of shallow-water deposition. Carbonate lenses between basalt flows in the Nictaux-Torbrook area (Smitheringale, personal communication) suggest in part a subaqueous origin for the volcanic rocks of this area. A similar origin is suggested by rare pillow structures in the Yarmouth and Middleton districts. The lateral facies change in the Nictaux-Torbrook area and discontinuous quartzite members all indicate deposition in a shallow sea in which conditions of sedimentation varied from one locality to the next. The occurrence of volcanism would certainly bring about many complications during sedimentation.

Some tuffs in the Yarmouth area, notably on Cape Fourchu and Green Island are probably subaerial. These are the stratigraphically highest rocks in the Yarmouth district.

Too few current indicators are known to speculate on the direction of transport of sediment in the White Rock Formation. No evidence as to the source of the sediment, with the exception of the conglomerate, is available at present and may be lacking. The slates and siltstones are probably derived from the same source as the Halifax Formation.

The polymictic conglomerate, showing coarse grain and poor sorting, was undoubtedly formed during the period of volcanism and may be the result of subaerial erosion and stream or alluvial deposition. Deformation has destroyed the primary structures in this rock.

In summary, the White Rock Formation is chiefly a shallow-water marine deposit that formed during a period of volcanism. Current action at certain times and in certain places was sufficient to sort the sediment so as to produce the distinctive quartzite.

KENTVILLE FORMATION

Definition

The Kentville Formation, named by Ami (1900), has been redefined by Crosby (1951) as "those sedimentary rocks, slate with minor siltstone, that overlie, apparently conformably, the White Rock Formation, and are conformably overlain by the New Canaan Formation." As the New Canaan Formation has not been recognized beyond Wolfville map-area this definition is not applicable elsewhere. Smitheringale (1960) considered all the strata between the White Rock Formation and the Lower Devonian Torbrook Formation as Kentville in the Nictaux-Torbrook area. Although the recognition of the Kentville is more difficult in the Digby area he adopted the same approach. Therefore it seems advisable to modify Crosby's definition to read: The Kentville Formation comprises those sedimentary rocks, mainly slate with minor siltstone, that apparently conformably overlie the White Rock Formation, and are conformably overlain by the New Canaan Formation or the Torbrook Formation.

Distribution and Thickness

The Kentville Formation is mappable in Wolfville and Nictaux-Torbrook map-areas and is also present in Digby map-area. It ranges in thickness from 1,600 feet in the Wolfville area to 2,000 feet along Fales River in the Nictaux-Torbrook area. Southwest of Fales River, Smitheringale assigned 3,500 feet of strata, which lie between the top of the volcanic rock-quartzite beds of the White Rock Formation and the base of the Torbrook Formation, to the Kentville Formation.

Lithology

The rocks of the Kentville Formation consist chiefly of siltstone and slate with lesser amounts of argillaceous quartzite, argillite, and shale. In the Wolfville area Crosby (1962) found the Kentville rocks to be lithologically indistinguishable from those of the Halifax Formation. Much of the rock in the Nictaux-Torbrook area consists of medium to dark grey, in places laminated, moderately siliceous siltstones. The upper part of the formation, between Fales River and Spinney Brook, is formed by greenish grey, sparsely laminated slates, which do not occur farther southwest. In their place are rocks similar to those in the lower part of the Kentville Formation. This relationship has been interpreted by Smitheringale as a facies change. In the Digby area a 'featureless' siltstone with rare limy, arenaceous lenses is correlative with the Kentville Formation.

Contacts

The Kentville Formation is conformably overlain by the New Canaan Formation (Crosby, 1962) in Wolfville map-area. In Nictaux-Torbrook and Digby map-areas it is conformable and grades into the Lower Devonian Torbrook Formation by an increase in silica content and by the appearance of quartzite.

Age

Although no fossils are known in the Kentville Formation in the Wolfville area, Crosby assigned it to the Silurian because it is overlain conformably by the New Canaan Formation, which contains Silurian fossils. Fossils from the Kentville Formation of the Nictaux-Torbrook area, which have been identified by Cumming (1957) as Silurian (Ludlovian) in age, are:

Monograptus nilssoni (Barr)
M. colonus (Barr)
M. sp. cf. *tumescens* (Wood)

Other "probable Silurian" fauna are:

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

The following sparse collection from the Digby area, from 1,200 feet below the base of the Torbrook Formation, was also assigned a Silurian (Ludlovian) age (Cumming, 1959):

Orthoceras sp.
Hormotoma sp.
Plectonotus cf. *trilobatus* (Sowerby)
Nuculites cf. *cawdori* (Sowerby)
Camarotoechia sp.
Nucula sp.
Delthyris cf. *crispa* (Davidson)

Where fossil evidence is present the formation is of Silurian (Ludlovian) age and therefore it is probable that the Kentville in the Wolfville area is of the same age.

Origin

The Kentville Formation in the Wolfville area is so much like the Halifax Formation that Crosby (1962) considered it to have been formed under similar conditions, that is in a shallow marine environment. The fossil evidence from Digby and Nictaux-Torbrook map-areas confirms this interpretation.

NEW CANAAN FORMATION

Definition

Crosby (1962) introduced the name "New Canaan" for a formation of "marine sedimentary breccia containing fragments predominantly of volcanic origin, and minor dark grey siltstone, slate, and possibly lava, conformably overlying slates of the Kentville Formation in the New Canaan district..."

Distribution and Thickness

This formation has only been mapped in Wolfville map-area, but a brief examination by the present author shows that it extends into the adjoining area to the west. Crosby estimated that it exceeds 1,000 feet thick, although nowhere is the top known.

Lithology

Breccia, consisting of fragments of volcanic rocks and fine-grained sedimentary rock in a calcareous matrix, forms the largest part of the formation. Many fine-grained fragments may be of pyroclastic origin.

Dark grey siltstone and slate comprise a small part. Andesite flows occur to the west of the Wolfville map-area but in general flow rocks are scarce.

Contacts

The New Canaan Formation is structurally conformable with the underlying Kentville Formation. An increase in the slate content in the lower part downwards to the contact with the Kentville Formation suggests the two units grade into one another.

Age

Fossils present (Wilson, in Crosby, 1962) consist of:

Crinoid stems
Pentamerid brachiopod of the Conchidium type
Tabulate coral too worn to show spores if present
Brachiopod fragments

The presence of the Conchidium-like pentamerid indicates a Silurian age.

Origin

The above fossils are indicative of a marine, fairly shallow, warm-water environment. The fragmental character of most of the formation and the presence of flow rocks suggests near-shore deposition in a zone of volcanism.

STRUCTURE

FOLDS

Folds are the main structural element in southwestern Nova Scotia. Fold axes are approximately parallel to the long axis of the province and trend northeast in the northern part of the area and north-northeast in the southern part. In each of the six areas containing Silurian rocks, synclines have preserved the Silurian strata from erosion. These synclines lie in three roughly parallel belts, those in Wolfville map-area being the easternmost and that at Cape St. Mary the westernmost. The synclines in the other four areas are situated along the same arcuate middle fold belt.

In Wolfville map-area two interconnected southwest-plunging synclines are present. In the Sissiboo River area the syncline is inferred on stratigraphic grounds only. Only the northwest limbs of the synclines are present in the Digby and Sissiboo River areas because of the distribution of granite. At Cape St. Mary the southeast limb is drift covered.

The axial planes of all the synclines dip more than 70 degrees. In the Wolfville, Cape St. Mary, and Yarmouth areas the axes plunge gently southwest to south-southwest and in the Sissiboo River area to the north-northeast. Direction of plunge in the Nictaux-Torbrook and Digby areas is not known and there the folds may be horizontal.

FAULTS

Faults are not a prominent feature in western Nova Scotia. The known ones are primarily transverse faults, which with few exceptions (such as two shown on Smitheringale's (1960) Nictaux-Torbrook map) are of small displacement. None are known to predate the deposition of the Silurian rocks, but since the sole horizon marker in the Meguma Group is the Halifax-Goldenville formational contact, and as exposures are scarce, an element of uncertainty exists in regard to pre-Silurian faults.

MINOR STRUCTURES

Insufficiently detailed structural analyses of the pre-Silurian and Silurian rocks have been undertaken to determine whether minor structures and major structures in both rock units are congruent or not. However, as far as is known, structures in both groups of rocks are similar. Cleavage and schistosity are steeply dipping and minor folds and drag-folds are in harmony with the major structures. Axes of these small folds show shallow plunges either northward and southward, and in some places they are horizontal. Locally cleavage and drag-folds deviate from the regional trend, but these aberrant readings can be related to local features such as faults. Some small folds are overturned with axial planes dipping between 80 and 90 degrees.

ORDOVICIAN-SILURIAN RELATIONSHIPS

The relationship between the Silurian and Ordovician in south-western Nova Scotia is important as it determines whether the area was affected by both the Taconic and Acadian orogenies or only the Acadian. This relationship, however, is obscured by the fact that the stratigraphic location of the Ordovician-Silurian boundary cannot be established with certainty. Two possible locations are: the base of the White Rock Formation, or somewhere within the lower part of the same formation.

If it is assumed that the base of the White Rock Formation forms the Ordovician-Silurian boundary then the character of the Halifax-White Rock contact is of prime importance. The scarcity of outcrop is such that this contact is only known accurately in a few places. In the northeast Crosby (1962) described the contact as conformable, citing the following sequence exposed on the south side of the Gaspereau River dam:

Description	Thickness (feet)
White Rock Formation	
Slate, predominantly dark grey	(not measured)
Quartzite, pale yellow to pale brown	68
Slate	4
Quartzite, light grey	4
Slate, varicoloured	2.5
Quartzite, grey	4
Halifax Formation	
Slate, varicoloured	(not measured)

There the lower quartzite member is a darker colour than normally encountered and two thin beds of slate are interbedded with it near the base.

Faribault (1909) observed that the slates immediately beneath the White Rock Formation in this area showed several different colours, which changed along strike. Crosby (1962) and Bell (1929) consider these different colours to be of secondary origin due to oxidation and weathering. The age of the oxidation and weathering is unknown and could be post-Devonian and pre-Carboniferous. On the other hand it may be pre-Silurian. Although the strata of the Halifax and White Rock Formations on the Gaspereau River are parallel the presence of this weathering phenomenon and the abrupt lithologic change suggests the contact could well represent a paraconformity (Dunbar and Rodgers, 1957).

In the Nictaux-Torbrook area Smitheringale (1960) located the contact on South Annapolis River near 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. The quartzite that forms the base of the White Rock Formation in the Wolfville area is underlain in the Nictaux-Torbrook area by argillaceous quartzites, shales, and slates.

On Fales River, although the base of the White Rock Formation is not exposed, its lowest visible rhyolite member probably lies on the Halifax Formation, because only a few feet of drift separates the two formations.

Farther southwest along Bear River the Halifax-White Rock contact crosses the river about 0.5 mile northwest of Bear River Village. Smitheringale (1959) considered this contact to be gradational, and described the lower part of the White Rock Formation there as consisting of dark grey 'featureless' arenaceous siltstone and differing from the Halifax Formation by being slightly coarser grained and having few laminations. Along Bear River pink and white massive quartzite, known only by the presence of rubble, occurs at the base. The presence of this quartzite suggests that, as in the Wolfville area, this contact may also be a paraconformity.

Along Sissiboo River, outcrop is discontinuous and the contact is poorly defined. Thinly laminated Halifax slates are slightly arenaceous in the contact zone, where thin sills of diorite are common. Grey-green andesite and minor tuff form most of the lowermost part of the White Rock Formation. The contact is drawn at the base of the volcanic rocks. Structurally the contact is conformable and is probably gradational and represents continuous deposition except for interruptions by volcanism.

The contact is exposed in two places at Cape St. Mary. At the tip of the cape a schistose rhyolite lies unconformably on the Halifax Formation at a 10-to-20-degree angle (Plate I). The Halifax Formation shows no bleaching or weathering effects below the contact. A few pebbles of vein quartz and grey quartzite, up to 3 inches long, lie along the contact. The quartzite of these pebbles is similar to some of the quartzite of the White Rock Formation.

Along the north shore, east of the wharf, and 2,000 feet along strike from the first locality, the contact is well exposed at low tide. The top 6 inches to 1 foot of the Halifax shows a bleached weathered zone (Plate II). In part the Halifax beds are truncated at low angles, but elsewhere brecciated rhyolite overlying the Halifax Formation is conformable. The lowest foot of the White Rock Formation contains angular to subangular fragments of Halifax slate as much as 1 inch by 6 inches in size. In the lowest 5 feet, rare pebbles and cobbles, the largest 12 by 8 inches, are present. These consist of vein quartz, quartzite, rhyolite, and a carbonate breccia.

PLATE I.

Unconformity between Halifax Formation slate and White Rock Formation rhyolite at the tip of Cape St. Mary. The hammer is lying on the Halifax Formation with the base of the White Rock Formation at the head.

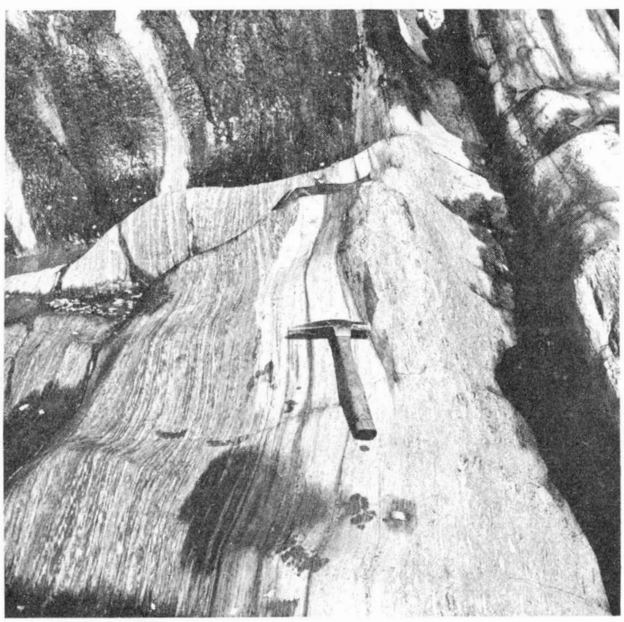

PLATE II.

Contact between the Halifax Formation (left) and the White Rock Formation east of the wharf at Cape St. Mary. The hammer is lying on the top 6 inches to 1 foot of the Halifax Formation, which is bleached, probably the result of pre-White Rock weathering.

Along the west side of Chebogue Point, slates typical of the Halifax Formation are indistinguishable from those considered to be part of the White Rock Formation. However, intercalated with the White Rock Formation slates are thin beds of volcanic rocks, probably tuffs. The contact is placed at the base of the stratigraphically lowest volcanic horizon. The contact there is conformable and gradational.

The evidence available, summarized in Table III, shows that in five of the seven localities where the contact between Halifax and White Rock Formations is exposed, it is conformable. In three of these, South Annapolis River, Sissiboo River, and Chebogue Point, it is also gradational. It may be gradational at Bear River also. At these last four places, continuous deposition from the Halifax to the White Rock is indicated.

The contact along Gaspereau River (Wolfville map-area) is possibly gradational also, as the lowest quartzite of the White Rock contains thin slate beds and is darker in colour than elsewhere. However, depositional conditions had changed, giving rise to a sorting action that produced the quartzite. Hence the possibility exists that a paraconformity is present in this area. It may be significant that the Wolfville area is the most easterly exposure of the White Rock Formation. Crosby (1962) pointed out that the quartzite beds thin to the southwest and suggested that each quartz sand bed was deposited nearer to an eastern shore than the finer sediments were.

There remains the unconformity at Cape St. Mary to be considered. The angular contact could be interpreted equally well as a fault, especially as the lowest member of the White Rock is a schistose rhyolite at this locality. However the presence of rounded fragments of vein quartz, quartzite, rhyolite, and breccia, along with a weathered zone at the top of the Halifax Formation points to an erosional unconformity.

The fact that the basal part of the White Rock Formation in the Cape St. Mary area is a rhyolite may be significant. Rhyolite also overlies the erosion surface mapped in the Nictaux-Torbrook area (Smitheringale, 1960) within the White Rock Formation. The possibility exists that the hiatus, assumed by Smitheringale to be of local significance may have been more widespread and that during the period of deposition of the lower part of the White Rock in the Nictaux-Torbrook area erosion was active in the Cape St. Mary area. There is the remote possibility that the formation of conglomerate in the Yarmouth district may also be related to this hiatus. There, contact relationships are poorly defined owing to rhyolite intrusion, and precise relationships are indecipherable.

Another factor to be considered is the regional position of the Cape St. Mary rocks. They are the westernmost representatives of the formation, and assuming that sediment was derived from the east they may have been west of the area of deposition during early White Rock time.

Table III

Halifax - White Rock Contact Relationships

	Gaspereau River Crosby (1962) (Wolfville map-area)	South Annapolis River Smitheringale (1960) (Nictaux-Torbrook map-area)	Bear River Smitheringale (1959) (Digby map-area)	Sissiboo River (This report)	Cape St. Mary (tip of cape) (This report)	Cape St. Mary (east of wharf) (This report)	Chebogue Point (This report) (Yarmouth district)
BASAL WHITE ROCK FORMATION	Interbedded quartzite and slate	Non-laminated shale and slate	Dark grey, 'featureless' arenaceous siltstone	Metavolcanic rocks and andesite	Schistose rhyolite with a few pebbles of quartz and quartzite at base	Brecciated rhyolite with fragments of quartz, quartzite, rhyolite and Halifax slate at and near the base	Slate, thinly laminated with interbedded volcanic rocks
CONTACT RELATIONSHIPS	Conformable Disconformity(?)	Conformable and gradational	Conformable and gradational	Conformable probably gradational Outcrop not continuous	Angularly unconformable 10-to-20-degree angular relationship	Angularly unconformable Low angle to parallel	Conformable and gradational
UPPER HALIFAX FORMATION	Slate, varicoloured	Slate, light and dark grey, interlaminated	Slate, thinly laminated	Slate, thinly laminated, slightly arenaceous	Slate, thinly laminated	Slate, thinly laminated, bleached weathered zone at top	Slate, thinly laminated

The unconformity at Cape St. Mary is therefore interpreted as having local significance only, but its occurrence may be related to its geographic position and to the hiatus within the White Rock Formation previously recognized by Smitheringale (1960).

The dominance of a gradational and conformable contact between the Halifax and White Rock Formations shows that the Ordovician-Silurian boundary, although possibly at the contact, could equally well lie somewhere within the White Rock Formation. No structural discordance has been recognized within the White Rock Formation to mark the boundary. The only discordance known is an erosional unconformity near South Tremont, which Smitheringale (1960) considered as of local significance only. Therefore it is not yet possible to establish the stratigraphic location of the Ordovician-Silurian boundary.

As no significant structural discordance exists between the Halifax Formation and the White Rock Formation or within the White Rock Formation, and small-scale structures such as cleavage and drag-folds, so far as known, are similar throughout both formations, there is apparently no structural evidence of the Taconic deformation in southwestern Nova Scotia.

However, regardless of the structural conformity or the precise location of the Ordovician-Silurian boundary, from a stratigraphic aspect two facts are important. These, which are evident on Figure 2, are the change in lithology and thickening of the White Rock Formation. The simple quartzite-slate unit found in Wolfville area becomes a complex unit, dominated by volcanic rocks, to the southwest in the Yarmouth district. Accompanying this change in lithology is an increase in thickness from less than 500 feet in the Wolfville area to more than 13,000 feet in the Yarmouth district. These changes show that during the period of deposition of the White Rock Formation the southern parts of the present area had become a zone of active volcanism that was sufficiently mobile to accommodate this great outpouring of volcanic rocks.

In view of the absence of structural disconformity the area cannot be looked upon as forming a part of the main Taconic orogenic belt, but because of the lithologic variation and the great thickening southwestward it did not escape the influence of the Taconic deformation. It seems most probable that southwestern Nova Scotia formed a marginal zone, subject to sedimentational changes including volcanism, during the period of Taconic mountain building.

This is in contrast with Silurian-Ordovician relationships to the northwest in New Brunswick. There several investigators (Smith, 1957; Anderson and Poole, 1959; and Alcock, 1960) reported that Silurian rocks lie with angular unconformity on Ordovician rocks. Elsewhere in Nova Scotia the Silurian-Ordovician contact in the Pictou-Antigonish Highlands has recently been described by Maehl (1961) as a disconformity, although Benson, D.G. (personal communication), mapping in Hopewell map-area, which includes part of Maehl's area, considers the contact to be a slightly angular unconformity.

It would seem therefore that the eastern limit of Taconic deformation lies in the Bay of Fundy south of lat. 45°15'N, but may extend eastward from the north end of the Bay of Fundy so as to include the Ordovician of the Pictou-Antigonish Highlands. Southern Nova Scotia lies outside the zone of deformation, but it still felt the influence of the mountain building through the effects of sedimentation and volcanism.

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