VII.—The Geological History of the Gaspereau Valley, Nova Scotia.—By Professor Ernest Haycock, *Acadia College, Wolfville, N. S.*

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A line drawn across the eastern portion of King's County from the Bay of Fundy to the southeast county line, a distance of about eighteen miles in a southeasterly direction, will cross three distinct bands of country which, with slight local variations, run parallel with the coast and represent the soil and surface of that part of Nova Scotia bordering this bay on the southeast and draining into its waters.

From the shore the surface of the land rises for about four miles in gentle undulating slopes to the crest of the ridge, which marks the boundary of this northernmost band. At short intervals the brooks have cut deep trenches at right angles to the coastline, and these, from their steep sides and generally abrupt character, are locally known as vaults Thus the surface, though sloping but gently seaward, is very uneven and the drainage good. The soil is dark grey, thin and stony, scarcely concealing, in many places, the underlying rock, and largely made up of its more resistant constituents. Where not boggy the land is thus subject to drouth, and adapted to pasturage rather than to tillage.

The underlying rock is an ancient lava-flow, or a mass formed by successive lava-flows, and the peculiar features of the soil and surface are the natural results of the chemical and mechanical action of subaerial forces upon its gently sloping sheets.

From the crest of the ridge the surface drops suddenly away to an undulating plain but little above sea-level, about seven miles wide, made up of alternate strips of level marsh and smoothed and rounded ridges. When one leaves behind the rough roads, lined with the rail fences of stony pasture and hay lands or flanked by steep slopes with their scanty covering of spruce and fir, and emerges upon the crest of the ridge, this lovely plain lies spread out beneath like a picture. With white June clouds sailing across a blue sky, patches of shadow and sunlight sweeping across the squares and parallelograms of deep brown ploughed-land, pink and white apple-orchards and grass-green marsh to the purple slopes of tidal flats and blue sparkling waters of the basin, this plain presents a picture to the onlooker that is in the strongest contrast to the rough hard lines and sombre coloring of the land and life at his back; for the life necessarily reflects the character of the land whence it draws its sustenance.

Here again, to the underlying rock, hidden by its own debris except where tidal scour has swept away the crumbling fragments from the shore, is due the soil and surface that makes Cornwallis the garden of Nova Scotia. It is red sandstone, in some parts coarse and gravelly but mainly fine-grained, rapidly breaking up with rain and frost and forming a sandy loam particularly adapted to the growth of root-crops and fruit trees.

The southern edge of this plain meets the northern edge of a gentle slope which, within a mile or two, rises to an older loftier plain some five hundred or six hundred feet above the sea. Although carved and sculptured along its borders by water-courses, the uniform elevation of the detached ridges and the main mass, and the regular and even sky-line when viewed from the crest of the North Mountain opposite, point to it as a base-leveled and then elevated and dissected plain, and to the essential unity of the separated ridges and the central portion.

This third band stretches for about seven miles to, and then beyond, the southeast county line. Towards the eastern border of the county it descends somewhat and is abruptly truncated by the Avon River, forming the well-known Horton Bluffs. Its southwestern extension forms the central watershed of the province.

Within this strip the surface is generally level, with low hills, sluggish drainage and abundant lakes in the inner portions, steep slopes, rapid streams and deep water-courses along the borders.

The soil is more variable. Boulder-clay lies in thin sheets or in thick masses in some places on the North Mountain; it is more abundant in the Cornwallis Valley; but it reaches its greatest development along the bordering slopes and in the minor depressions of the elevated southern band. This deposit almost always forms deep and heavy but workable soils. Along the lower slopes it is made up in large part of debris dragged and pushed from the adjacent valley, and to that extent it possesses the fertility of the valley soils; but farther south the slates make up a larger and larger portion and the soils are correspondingly poorer. Where the boulder-clay is wanting, the underlying slates are bare or thinly covered by a worthless soil; while farther south towards the granite country the surface is thickly strewn with granite boulders and wholly given over to forest growth.

The town of Wolfville lies at the foot of the northern slope of this elevated band of country, but the slate ridge to the south of the town, though essentially a part of the plain above described, is cut off from it by a river valley and narrow strip of fertile land which duplicates in every essential character the broader Cornwallis Valley to the north. The Gaspereau Valley is as essentially an outlying fragment of the Cornwallis Valley as the Wolfville ridge is an outlier and separated fragment of the broad southern tableland.

This ridge, some three hundred feet in height behind the town of Wolfville, gradually rises towards the southwest and within a few miles becomes level with and a part of the plain to the southeast. To the northeast it descends with long and convex sweeps, sinking beneath the marsh at Lower Horton. From its southern brow of slate the observer looks down upon a silvery stream winding through double lines of drooping willows, or through level intervales rising into broad low terraces, which sweep with many a curve up into the bounding hills, the whole presenting a scene of quiet and tranquil beauty that the broader valley cannot equal.

Opposite Wolfville the valley bottom is rather more than a mile in width. Eastwardly, as the enclosing northern ridge becomes less pronounced, drumlin-like hills of boulder-clay increasing in abundance encroach from both sides upon the valley and veneer the eastward extension of the table-land beyond. Westwardly this table-land curves gradually in around the head of the valley which, within a few miles, becomes a deep gorge within steep walls of slate.

These topographic features are in part dependant on the characters of the underlying geological formations ; in part they depend on structural features, subsequent to the deposition, and independent of the characteristics, of the rocks.

In the region under discussion these rocks present considerable variety in texture and composition. Passing over the newer and unconsolidated sediments, that form the marine marshes, the terrace gravels, and the hills and sheets of boulder-clay, to the foundation rocks of the district, we find uppermost and resting against the lower slopes of the ridge at Wolfville a dull red sandstone composed of a variable mixture of grains of different minerals. Rounded particles of white and colorless quartz appear to predominate, and minute gleaming flakes of both muscovite and biotite are scattered through the rock. Bright red specks are numerous, and according to their relative abundance the sandstone varies considerably in coloring between red and grey. The cementing matter is calcite, which is present in considerable quantity filling the interstices between the other minerals and effervescing briskly when the rock is touched with acid The size of the grains also varies considerably and rounded pebbles of white vein quartz are not uncommon. The stratification is uneven and the beds dip north at angles of from 10 to 12 degrees.

This sandstone, possessing the same general characters, but varying in texture and in the relative abundance of its constituents, underlies the whole Cornwallis Valley and extends westwardly for upwards of 90 miles. Eastwardly it forms a narrow interrupted band along the margin of the Basin of Minas, which appears to lie in a slight depression of its surface.

Near Wolfville this formation, which is regarded as of

Triassic age, is only found along the base of the hills. Deeply buried by heavy accumulations of boulder-clay it forms the first low rise or step, but is not known to ascend the slopes of the southern tableland. Its contact with the rocks that form these slopes is not visible here, but the inclination of the beds is such that their continuation would carry them up over, and thus indicate that they rest upon, the next appearing beds to the south.*

These older beds, dipping northeasterly at angles of from 12 to 20 degrees, first appear at or near the surface within a few hundred yards of the above mentioned Triassic sandstone. They are dark grey, drab, purplish and black shales, in thin layers, containing abundant plant remains. These shales become more sandy to the south, passing first into fine-grained sandstones which separate in weathering into remarkably uniform thin laminæ. These in turn are underlaid by coarser and coarser grey sandstones, with occasional interstratified beds of black mud-rock and occasional layers of conglomerate, in more and more variable uneven or lenticular strata, as the crest of the ridge and the base of the formation are approached. This whole series is inclined to the northeast at angles varying from 5 to 20 degrees. If the strata were continued, this inclination would carry them up over the slates which are the next appearing rocks to the south.

The contact of the sandstone and slate is concealed by surface material, but the above mentioned geographical and structural relations point to the sandstones as the newer rocks. The occurrence of pebbles and partially worn fragments of slate in the coarse sandstone beds, and the unmetamorphosed condition of the occasional black carbonaceous layers very near the contact with the slate, are convincing proofs of the subsequent deposition of the sandstone and shale series.

This sandstone is largely made up of sub-angular, grey, translucent, quartz grains. Muscovite is common, and the presence of small ironstained cavities points to the former presence

*At Avonport, this unconformable superposition is revealed by a fault which brings up the base of these red beds to the surface of the beach.

of some iron-containing mineral, now decomposed and in part removed. Soft slate-colored specks and pieces, which are doubtless fragments of the slate formation beneath, are also present. The cementing matter of the rock is a light grey powdery substance, probably decomposed feldspar, which appears to be quite easily removed by the mechanical action of rain. There is no effervescence with acids, showing the absence of carbonates.

Because of its constituent minerals the rock is light grey in color, although the joint surfaces are frequently stained a dark red by iron oxide. This is a further indication of removal of iron oxide; and the absence of carbon from these coarse and somewhat porous sandstones when compared with its abundance in the accompanying fine-grained argillaceous beds, is suggestive of the mutual decomposition of the organic substances and iron-containing minerals, and their subsequent removal in solution by the underground water.

The prevalent red color of the overlying Triassic red sandstones, which, without doubt, were derived in large part from these older sandstones, is probably due to the subsequent oxidation and precipitation of these same dissolved iron compounds.

Because of their relations to adjacent formations, and their fossil contents, this series of beds has been regarded as of Lower Carboniferous and even of Devonian age.*

A short distance south of the last outcrop of sandstone, greenish-grey compact slates with clean-cut joint planes come to the surface in many places along the summit of the ridge, and generally underlie the country to the south and west. At this locality the cleavage is nearly vertical and the beds dip northwesterly at angles of from 20 to 70 degrees. Several almost vertical veins of quartz, from one to two feet in thickness, lie in the slate along the southern brow of the ridge approximately parallel with the cleavage planes of the rock.

Just below the southern brow, a narrow band of sandstone, exactly similar to the coarser beds of Carboniferous sandstone above described, crops out at the top of the slope. Its elevation

*See H. M. Ami, Summary Report of the Geol. Surv. Dept. for 1898. Pp. 180-182.

above the Gaspereau Valley is about 200 feet, and, like the similar beds on the northern slope, it dips to the northeast or directly into the hill, and seemingly must pass beneath the slate. That it does not is proved by the presence of fragments of the slate and vein quartz in the sandstone itself, and some other explanation of this relation must be sought.

Along the lower slopes to the south, and in the bottom of the Gaspereau Valley, the underlying rock is concealed by surface material; but along its south side the brooks from the southern tableland have plowed deep urrows at right angles to the valley in t surface material and rock formations beneath, and have revealed the whole structure from the top of the terraces which flank e river to the level of the high land beyond. The first rocks t appear from beneath the terraces in the Angus brook are grey or brown sandy shales in rather thin layers. Their surfaces are abundantly ripple-marked, the ridges of the ripples running generally north 70° west. Worm trails are common; and the surfaces frequently bear the imprints of stems of Lepidodendra. These beds dip to the north at an angle of about 20 degrees, and the brooks flow directly across them at right angles to the strike and in the direction of the dip, so that in stepping from bed to bed as they successively come out from beneath each other, one is passing to older and older strata while ascending the brook and the slope. There is a good deal of local variation in the direction of the strike and in the amount of inclination from the horizontal. An average strike, however, would be a little north of west; an average dip about 15 degrees in a general direction a little east of north.

The beds vary in composition from sandy to argillaceous and carbonaceous shales, and in coloring from grey or brown to black according to the abundance of organic matter and the degree to which they have been open to the passage of underground water. Here, as in the series of strata lying on the north slope of the Wolfville ridge, the finer sediments are succeeded by coarser and coarser materials with occasional interstratified layers of black mud-rock as we pass down into the series and up the slope of the hill, until we come to massive beds of coarse irregularly bedded sandstone with sub-angular quartz grains powdery cementing matter and all the conspicuous features of the sandstones forming the basal members of the Horton series before described.

In the Duncan Brook the sandstones finally change, rather abruptly, in character, a soft reddish-brown substance appearing and making up a larger and larger portion of the rock, until it passes at a well-defined boundary, into a soft argillaceous rock with bright ribbon-like bands of coloring where the edges of highly inclined green, brown and drab layers have been smoothed and rounded by the stream. This rock is evidently the source of the soft brown constituent of the immediately over-lying sandstones, and furnishes certain proof that they are newer than and laid down upon these argillaceous beds.

Cleavage is not well-marked in these underlying clay rocks at this point, but the bedding is plainly shown by the color banding and by the occurence of occasional gritty layers. The dip at the contact is to the southeast, but in passing up the brook the beds gradually become vertical and then dip to the northwest, suggesting an overturn. The rocks also change gradually to compact bluish slates with well-deffned cleavage.

The succession in the next brook to the east is the same, but the contact of the two formations is concealed by loose material in the bed of the brook. The argillaceous color-banded beds are well exposed, dipping to the southeast at an angle of 45 degrees. Dr. Ami has found *Dictyonema Websteri* in these beds and considers them as of Silurian age.* Farther south, these are succeeded by blue slates, as in the Duncan Brook.

The topographic features of the region have been stated to be due in part to the characteristics of the underlying geological formations, in part to structural phenomena subsequent to the deposition, and independent of the characteristics of these rocks.

Wolfville rests at the junction of the slate with the overlying sandstone. From the town this junction extends eastwardly, ascending the ridge obliquely to the crest, where it suddenly

*Summary Report of the Geol. Surv. of Canada for year 1898. Pp. 180-182 curves to the southwest and just below the brow of the hill continues along in that direction for about half a mile to the westernmost outcrop of the sandstone on the north side of the valley. The next outcrop of sandstone occurs on the opposite side of the Gaspereau Valley, about a mile and a half to the southwest, in a brook just west of Gaspereau Village. It is here about two hundred feet below its last mentioned occurrence on the brow of the ridge, and its contact with the slate lies within a few rods of this exposure, as the next watercourse to the west lies in compact bluish slates. The line of contact next ascends the slope, but curves eastwardly before reaching the edge of the southern tableland and extends in that direction for about three miles, when it again sweeps around southerly, and then southwesterly, up the valley of the Half-way River.

The slate is tough and resistant, and the country occupied by it to the southwest of this bounding line presents smooth level outlines gashed by sudden gorges. The sandstones and shales to the north and east of it are variable in hardness but relatively less resistant than the slates, and the country underlaid by these younger rocks lies, as a rule, at a lower level and presents broadly undulating outlines.

The Cornwallis Valley has a geological history which has already been traced out as far as the records have been available and intelligible to the writer up to the present time.* The Gaspereau outlier has been subject to the same general changes, but its separation from the main portion calls for additional explanation.

If we imagine a vertical plane cutting deep into the earth's crust and extending north and south from the borders of the Minas Basin at Wolfville to the edge of the elevated southern plain, and if the part on the west side were removed so that we could see the underlying structure of the whole district, the surface exposures lead us to believe that the rocks in the geological section thus laid bare are arranged as in the accom-

* "Records of Post-triassic Changes in Kings County, N. S." Transactions of Nova Scotian Institute of Science, Vol. X., Session 1899-1900. Pp. 287-302.

panying Plate VII, Fig. 1, in which the horizontal and vertical distances are represented on the same scale of two inches to one mile.

The most striking feature of this section is the repetition of geological formations. The red Triassic sandstone of the margin of the Basin is underlaid by the shales and sandstones of the Horton series, which are in turn underlaid at the summit of the ridge by slates. Upon the corresponding slope on the opposite side of the valley, shales and sandstones are again underlaid by slates. The red sandstone is not found in the Gaspereau Valley along the line of the section.

Several interpretations of the underlying structure are suggested by the surface indications. The beds are all water-formed, and all dip to the northern quadrant of the compass, so that the first and simplest explanation is that they form successively deposited series, as shown in Fig. 2, the southernmost slate older than and succeeded unconformably by the southern series of sandstone and shale, this dipping beneath and therefore older than the slates of the Wolfville ridge, and these again unconformably overlaid by the Wolfville sandstone and shale series, and these again by the calcareous red sandstones of the Cornwallis Valley.

A brief study of the rocks, however, reveals the fact that the sandstone and shale formations of both slopes are alike, not only in mineralogical composition but also in fossil contents, and that they are merely geographically separated parts of the same formation. If further reasons for rejecting this explanation were necessary, the slates also possess similar characteristics, and we know of no way in which the clay-slates of the Wolfville ridge could have been cleaved and altered while the sedimentary beds beneath, often as fine in texture, remained unchanged.

A second explanation is that the rocks appearing at the surface are the northern limbs respectively of two anticlines, as shown in Fig. 3, the joining limb being concealed by the thick surface deposits of the lower slopes of the north side and bottom of the Gaspereau Valley.

Fig. 1.

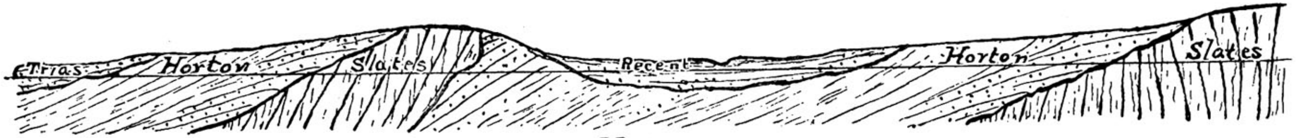

Fig. 2.

Fig. 3.

Fig. 4.

SECTION OF GASPEREAU VALLEY, N. S.

(TO ILLUSTRATE PAPER BY PROF. HAYCOCK.)

Face p. 370.

An objection to this view is, that the bit of north-dipping sandstone on the southern brow of the Wolfville ridge lies where the south-dipping limb of the northern anticline should be found; and this explanation must also be rejected.

Still a third explanation remains. The repeated outcrop of the same set of beds can be accounted for by a theory that is not in opposition to known facts and even has some special evidence in its favor. If a fault, concealed by the heavy accummulations of surface material, is supposed to extend east and west along the north side of the valley, and the rocks on the north to have moved upwards relatively to those on the south side of the fault, as in Fig. 4, the same strata that dip northerly from the southern side of the valley would be cut off, a mile or more to the north, along with the formation on which they rest. Erosion would act more effectively along the elevated surface, and the soft overlying shales would be quickly removed down to the coarse and more resistant sandstones, and these even worn through to the underlying slates.

On the south side of the fault, the relatively lower position would be less favorable to removal and the softer shales would remain to furnish evidence of the amount of material that had been worn away to lay bare the sandstones and slates of the Wolfville ridge. The northerly dips in the south-sloping surface of this ridge are what we would expect on this theory.

Some additional facts in support of this explanation exist. A line of springs lies along the north side of the valley well up on the slopes of the ridge, and quartz veins a foot or more in thickness, extend along in the same direction, very near the line of springs. If these springs rise in the line of fracture caused by the fault, as appears probable, their occurrence is explicable. The water for these can scarcely be supplied from the almost bare rock surface of the part of the ridge, or escarpment, above, but its source must be rather in the more distant and higher lands to the southwest. A somewhat long underground journey for the water is thus required, and this is favorable to the removal of silica from the rocks along the path and its deposition along the sides of the fissure as the waters approach the surface, giving rise to the mineral veins that have been mentioned.

If this be the correct explanation, the amount of displacement that has taken place along the fault can be approximately estimated from the average dip, and the present position and elevation of corresponding portions of the same formation. This dip is about 15 degrees, and the horizontal distance between the outcrop of the coarse carboniferous sandstones on the south side of the valley, and the outcrop of the same set of beds on the ridge on the north side, is about two miles; so that a displacement of about 2,500 feet would be necessary to bring the coarse basal sandstones that dip beneath the surface on the south side of the valley to the same elevation on the Wolfville ridge.

The scenic effects of this displacement upon the surface of this portion of the county, are more conspicuous than those described as due to the characteristics of the underlying rocks. By it the harder, more resistant sandstones and compact undering slates are again brought to the surface and produce the Wolfville ridge. By it a long tongue of the Cornwallis Valley, with its fertile farms and apple orchards, has been cut off to form the Gaspereau Valley. If this fault had not occurred, the broader valley would have swept without a break up to the base of the main southern table-land beyond, and the most charming bit of scenery of this portion of Nova Scotia would have no existence.

There are indications that the movement taking place along this line of fracture has been exceedingly slow; that the Gaspereau Valley is even more ancient than the Carboniferous sandstones that rest in it; that it bordered a loftier land to the south which, even in that remote time, supported upon its sheltered slopes and bottom-lands a luxuriant forest of Lepidodendra and magnificent ferns whose remains have been partially preserved in the muddy sediments of an ancient river flowing from this southern land.

Reasons have been advanced for believing that the quartz veins of the slate of the Wolfville ridge have been deposited by the action of underground water while finding its way to the surface through the fissures of the fractured zone of the Gaspereau fault. These veins, though newer than the slate in which they occur, are still older than the Carboniferous sandstones that overlie them and contain abundant fragments of the white quartz of which they are composed. If the interpretation of their origin be correct, it follows that the fault along which they were formed had its beginnings before the Carboniferous period. The outlining of the Wolfville ridge was contemporaneous with the formation of the fault, and its Pre-Carboniferous origin is thus indicated.

The simplest interpretation of the strip of sandstone dipping into the southern brow of this ridge is that it was deposited along the southern shore when the ridge projected eastwards, as a low point, into the Carboniferous sea. Contemporaneous beds of similar material were deposited on the north side of the point of land. The whole area gradually subsiding, the coarse sandstones that lined the coast in shallow water crept farther and farther up the slopes, covering the low point of slate as the water level rose upon the land. Subsequently, as farther movement along the fault plane took place, these newer beds were broken and their ends pushed upward along its northern side until elevated above the sea and laid bare by ages of erosion, we now see them apparently dipping into the hill of slate along which they were deposited as approximately horizontal beds when the hill itself was a low point of land on the coast of a Carboniferous bay.

The Triassic sandstones have not yet been observed in the Gaspereau Valley along the line of section, although there seems to be no good reason for there not being found if they exist there. A reasonable interpretation of their absence is that when the Triassic sandstones that occur at corresponding levels on the north side of the ridge in the Cornwallis Valley were being laid down as a shallow water formation, along a slowly subsiding coast, the displacement along this fault plane had not taken place to its present extent and the land surface south of the fault was relatively higher and thus above sea-level. If subsequently submerged and buried by deposits, as seems not unlikely, the beds have been removed along with those that have disappeared from above the present surface of the Triassic beds to the north.

From the above we have reason to believe that displacement along this fault began in Pre-Carboniferous times, continued after the deposition of the Horton series of beds, and had not reached its present proportions when the Triassic rocks of the valley were being laid down. There has probably been no perceptible displacement within recent times, but the slow movement of elevation or subsidence that separated the broken ends of the same beds one half a mile in the lapse of time between the earliest Carboniferous and the Glacial Periods, may still be proceeding at the same rate and the movement since the Glacial Period remain unnoticed.

We can scarcely leave the subject without attempting to decipher some of the faint records of that Palæozoic valley land and bay, the traces of which lie, for the most part, beneath the surface accummulations of more recent geological periods. The slate was then, as now, a surface rock, along the coast at least, as its unconformable contact with the sandstones and the presence of its fragments among their constituents plainly indicate. The region was also subsiding, as the passage of coarse shallow-water sediments up into fine muddy beds, characteristic of deeper, quieter water as plainly proves. The land lay to the south as the derivation of the sediments testifies. As the sea advanced, the coast line must have retreated and its changing outline, for any particular time, is very difficult to fix. It would seem, however, that for the time represented by the basal Wolfville sandstones the coast line must have followed approximately their present line of contact with the slates, outlined earlier in the paper, which was then more nearly horizontal; its present departure from that level being readily explainable by the subsequent displacement along the Gaspereau fault plane.

The early existence of the Wolfville ridge and its undoubted westwardly continuation, would form a barrier then as now to the direct northward flow of the drainage from that ancient land ; and this little indentation of the coast line was doubtless the estuary of a small river. The absence of coarse conglomerates from the basal sandstones, indicates quiet sheltered waters along the shores. With the exception of ice-transported material, the shore deposits of the Minas Basin average about the same in coarseness as these Lower Carboniferous or Devonian deposits. This would lead to the inference that the ancient Bay was but little more extensive than the Minas Basin of to-day, and that the shores were not exposed to more violent wave action than the more exposed portions of the borders of the present Basin.

This absence of conglomerates also indicates gentle slopes of the land, but we can scarcely do more than speculate as to the character of the interior. The lowest sandstones are evidently made up of the more or less decomposed constituents of a granitic rock. The present boundary of the granite country is to the south, not nearer than from seven to ten miles, and because of the lowering of the surface of the land by erosion in subsequent geological times, this boundary must be nearer now than when these beds were laid down. In what manner all this material could have been transported from the inland areas whence it evidently was derived, is a most perplexing problem.

The land was clothed with a luxuriant vegetation, as the abundant plant remains testify, but the picture of the life that inhabited it must be sketched by the palæontologist. The Geological Record is not one of living forms alone, but geographical and scenic features have a history that forms a too-often overlooked part of that record. This history of the Gaspereau Valley is but a single instance in the evolution of the topographic features of the Nova Scotia of to-day. Whether the facts have been rightly arranged and interpreted, must be left to the judgment of those who follow ; but the great age of this valley, and its checkered history, the latest stages of which have not been looked into, are reminders of the wealth of material about us for study, and of the exceedingly slow and labored process by which the landscape has come to be as it to-day.