# ON THE IGNEOUS INTRUSION AT GUYSBORO N. S.

M.SC. THESIS

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BY

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Accompanied by
One box of microscope slides
Photographs
One blueprint of map.

# SOME NOTES ON THE IGNEOUS INTRUSION AT GUYSBORO

# GUYSBORO COUNTY ,NOVA SCOTIA

## PART 1.

## INTRODUCTION AND GENERAL DESCRIPTION.

The area studied in the following notes comprises some 4 square miles, and lies immediately to the southwest of the town of Guysboro proper.

The first reference to the geology of the district occurs in Dawsons Acadian Geology (Edinburgh 1855) but details are not described.

In part F. of the Annual Report of the Canadian Geological Survey for 1879-80 Messrs. Fletcher and Faribault give a preliminary report upon the geology of Nova Scotia which they supplemented by a more extensive publication forming part P. of the Annual Report of the same Survey for 1886. Topographical Maps were also prepared by the same authors on a scale of 1 inch to one mile, on which the geology was indicated, but the geological work was of necessity of a reconnaisance type, and while accurate in the larger features, did not represent the area in any great detail.

Use has been made in the present paper both of the publications and the map above mentioned, and an enlargement has been drawn from the latter, in which certain topographical details have been altered and the geological features added in accordance with the results of detailed study in the district.

### Location.

The town of Guysboro is situated at the eastern end of Chedabucto bay and would have possibilities of being a good port, being situated on a land-locked harbour, but for the fact that the entrance to the harbour is difficult.

on account of the very strong tide running in and out through a narrow and crooked channel. The area, geologically studied, lies about one mile west of the town itself, and covers an area of some four square miles, being reached at either end by roads but having none traversing the central part. On a clear day a fine view of the town and bay may be obtained from the top of the higher ledges of rock as can readily be seen from the photo No. 1.

GENERAL PHYSIOGRAPHY.

The region consists of low lands near the sea shore, rising rapidly as the shore line is left to an average elevation of say 300 ft, with some higher knobs and ridges, the whole being intersected by valleys of small size. All the hills show a sympathetic elevation, though varying in shape, the granite hills south of Salmon river having a more rounded outline than the igneous intrusives to the north of this line. (See photos 18.21) The soil is nowhere very good, and the land while suitable for pasture in many places, is not fertile for agriculture. Blueberries and wild raspberries grow, in considerable quantities, both in the lower and higher uncultivated lands, and the poorer people of the district earn a scanty livelihood, during the season, by gathering and selling these fruits.

The two most distinctive features of the county are the high ridge of rocks, which forms the eastern side of the area mapped, rising quite abruptly to the height of about 150-200 ft. above the level of the slates which lie between it and the shore, and, south of Salmon river, the granite outcrops which are covered with very sparse vegetation and to which the name "barrens" has been applied.

These "barrens" are scantily covered with vegetation consisting chiefly of low bush blueberries, dwarf laurels and azaleas.

The roads over these hills are rough and steep in places, but are serviceable for farm teams, and not too rough for use with a light buggy, and in all places on the more important roads there is space for two vehicles to pass. Many of the roads have been altered since the map was made, and these changes have been made in the enlargement.

The lower lands where they have not been burned or cleared for farming purposes are densely covered with spruce and fir timber of good growth and of considerable value, but the higher ridges have far less timber, and to a large extent are covered with boulders between which lie fallen logs and second growth scrub, making walking and obscuring outcrops very difficult.

LOCAL PHYSIOGRAPHY.

The area mapped and studied in detail consists of a ridge of high land, running in a direction roughly parallel to the coast, (see map) with an intervening area of low land between it and the actual shore line. Further to the north the ridge appears to widen but the area studied is itself bounded by a small stream which flows into Ingersoll's cove. On the western side the area is bounded by Godfrey's or Tovey's brook which falls into Salmon river at the "Second Bridge", mentioned in Mr. Fletcher's report, now commonly known as Spanks' Bridge. From here on, Salmon River practically forms the boundary of the tract which was studied in detail, although a hasty examination was made on one or two lines for an additional half mile to the south, and this territory is included in the map.

The eastern boundary is the shore of Chedabucto Bay. The portion of the area, however, lying between the shore line and the igneous mass, was not studied in such detail as the igneous mass itself, and the surrounding strip of contact metamorphic sediments. Into the bay projects Bigby's Head, a point lying just northward of Salmon river entrance, and composed of igneous rocks and sandstones together with shales. On this point occur pits, which were originally opened up for the exploitation of specular hematite, but they have fallen into decay, and no trace of ore can now be found on the outcrops. In general the valleys in the area studied are steepsided and show the V form from water erosion rather than the U form produced by glaciation. In places where the streams cut through the slates the sides are comparatively high and steep, although the slates themselves are of soft material. These facts point to the post glacial character of the streams and valleys, and this assumption would be borne out by the fact that the streams are all of small size, and swift flowing.

LOCAL GEOLOGY OF THE DISTRICT.

The district map is divided into two distinct sections by Salmon river which flows in an almost due easterly direction, and marks the line of fault between the lower Cambrian gold bearing series on the south, and the Devonian strata on the north. The gold series is intruded by granites, while the intrusive in the Devonian rocks is a diorite-dolerite, according to the Report P. 1886, Can.G.S. The area has been eroded to a peneplain after the intrusions of the later period, as the granite and more basic rock have much the same elevations.

Owing to the glaciation to which Nova Scotia has been subjected, and on account of their comparatively slow rate of weathering, the outcrops of igneous rock are not covered with soil to any great depth, and only sparsely with vegetation, and stand out as hills and ridges, the lower land being formed by the sediments. The resulting appearance of the county is barren stony ridges covered in places by trees, with more fertile land in the valleys. The sediments however, being more easily acted upon by the forces of weathering, have enough soil to enable a certain amount of farming to be carried on, though the soil is not rich and the farmers can only extract a scanty living by dint of much hard work.

It will be seen from the map of Messrs. Fletcher and Faribault, that in their opinion a reversal of the normal order of sequence has taken place, the Middle Devonian lying between the Cambrian (faulted) on one side, and the lower Devonian which in turn is overlain unconformably by the Carboniferous. No mention however is apparently made of this reversal in the report P. 1886, and perhaps this conclusion may be open to doubt, as the apparent dip of the slates is probably a slaty cleavage developed by strain, rather than the original normal bedding. The observations leading to this opinion will be taken up under the local geology in Tovey's Brook.

The igneous rock has evidently intruded the sediments as can be seen from the fragments of sedimentary material mixed with the igneous mass at outcrop No.9 (photo No.12) and must therefore be post Devonian, and, since it has been reduced to the uniform level of the peneplain, pre tertiary. Apart from these two facts it would be hard to establish the exact time of the intrusion from field observation alone. Reference however will be made later to the time of extrusion as indicated by petrographic observations.

LOCAL GEOLOGY: NORTHERN SIDE.

One important feature of the area, which would not at first be noticed, but which is important both geologically and for every day use, is a line of springs as shown on the map. These springs are small hollows in the ground which remain full of water but which are not gushing springs. The water itself is good for drinking purposes, and according to local information remains unfrozen all winter. These springs are situated on the side of a hill, where the road descends from the top of the intrusive mass, towards the town of Guysboro and are all, except two, located within one small area. The first of these two exceptions is situated on another road as shown and the second is marked with a ? mark to show that its exact location is doubtful. The hill on the side of which the springs occur, is evidently composed of intrusive rock, while on the other side of the valley, through which the road runs, occur sandstones. These facts point to the conclusion that the springs occur on a line of contact.

THE LOCAL GEOLOGY OF TOVEY'S BROOK, WESTERN SIDE.

The brook, which will in future be called Tovey's brook, rises to the northwest of the area studied and falls steeply from the intrusive mass into a valley. Here it enters a small lake or pond at the head of which the "old Salmon river road" crosses the brook. The stream continues its course passing through a wood of small deciduous trees, (among which a small outcrop occurs (No 36)) till it reaches the junction of a second small brook. Below the junction Tovey's brook, which is considerably increased in size falls into another small lake, and here again another outcrop occurs. (No 37). These two outcrops are mentioned, as being the only two discovered in this part of the area. After passing the third lake the brook passes under the bridge carrying the new Salmon river road. The brook ~~up~~ down to this point has exhibited no outcrops, but from here to its junction with Salmon river it flows over ledges of slate which all strike approximately N. 82 E. and dip steeply south and are apparently parallel in their line of strikes to the Salmon river.

On going up the brook however to the point marked outcrop 4 we find a sharply folded anticline of which the limbs are sandstone with a core of highly graphitic slate. The strike of the anticline (photo 7) is parallel to the strike of the slates and sandstones, with a dip approximately equal to the steepness, and according to Pumpelly's law that the larger features of the county are like the smaller, this fact would lead towards the conclusion that the dip of the rocks is not the true dip, but is that of the cleavage developed on the limbs of the folds by compression of the strata. Another reason for this assumption is the fact that these strikes run almost (if not quite) parallel to the direction of the fault along which Salmon river runs, and if the folding and the faulting took place at approximately the same time, which is most probable, cleavage would be developed by these forces in a direction parallel to the fault which could quite well obscure the original traces of bedding.

Thus the relative positions of the rocks of the Middle and Lower Devonian as marked on the map, still remain in doubt, and perhaps the line of demarcation should be removed until the area has been worked out in greater detail.

From the bridge carrying the Salmon river road to within about 100 yards from the point where it falls into Salmon River, the brook flows through a channel bounded by comparatively high walls of slate, but at the last it traverses a flat area and no outcrops are visible; but Near Spanks' Bridge and only a short distance below the mouth of the brook there are three pits which were formerly opened up for graphite but which have fallen into decay on account of the lack of value of the material. The pits are numbered 1,2,3, .

No. 1 which may really have been dug for some other purpose is on the south side of Salmon river at the point close to the abutment of Spanks' Bridge, but, as it occurs in the whin series, no graphite would be found here, and most of the evidence that a pit once existed, has disappeared. The slates at pit No. 2 and at outcrop 4 are bituminous, and graphite has been developed by metamorphism though not in large enough quantities to render it economically valuable. These characteristics are more pronounced at 4 than at 2. A careful search failed to disclose any trace of pit number 3.

The local inhabitants maintain that this so called graphite found in the pits is coal, as they can burn it in their stoves, and are much surprised that no company will undertake the mining of the material.

## SALMON RIVER. SOUTHERN BOUNDRY.

Salmon river, as has been said before, flows along the line of fault between the lower Cambrian "whin" series and the Devonian slates. The so called "whin" series outcrops at several points on the northern side of the river and an especially good exposure occurs about hafl a mile above Spanks' Bridge where the river flows between steep banks of the whin rock. The bridge itself spans the river at a point where the whin series forms both banks, and a photograph no. 17 shows the type of outcrop of this series. Between the bridge and the sea the river affords no good outcrops of rock, the left hand bank in particular being low with numerous embayments, but near the mouth of the river ~~where~~ the land gradually becomes higher, and, to the north of the mouth, forms Bigby's Head which will be dealt with in the next section. On the south side of the river the rocks belong to the whin series, and are intruded by a granite mass which forms a high ridge not far back from the bank. The road along the south bank of the river below Spanks' Bridge ascends the hill and continues along the edge of the granite mass at some distance above the water's edge, as the ground falls too steeply to the river to allow the passage of a road on level ground. Reference will be made to these rocks later.

## EASTERN BOUNDRY.

Bigby's Head, at the southeastern corner of the area, is formed by a strip of land jutting out into the sea between Salmon river and Cook's cove. The head is composed in part of igneous rocks through which run calcite veins, and in part of sandstones, and at the eastern end of the head the rock is weathered away to a reddish earth.

Head

Boulders of conglomerate are scattered over the head but the rock was not observed in place, either there or at any other locality within the area mapped except at outcrop 6 near Spank's Bridge. The specular hematite pits referred to in the Annual Report of the Canadian Geological Survey, in 1886, part P. were visited, but the pits had fallen in from disuse and no outcrops of iron ore were visible.

Between Bigsby's Head and Guysboro itself the sediments occur as the chief county rock and the land is mostly low lying. The area was not studied in detail, but a few specimens were collected for petrographic work.

## PART 11.

## MICROSCOPICAL AND PETROLOGICAL DETERMINATIONS.

On account of the small area covered and the proximity of many of the outcrops, it has been deemed wiser to indicate upon the map the position of each outcrop. The rocks have been divided by means of thin sections into several series, and each series into types, each type being in turn described, and mention being made of the special features of all specimens which do not exactly conform to the type to which they belong. The outcrops will be assigned to whatever type they may be pertain to, and the conclusions, if any, which may be drawn from the examination will follow.

### SERIES. 1. METAMORPHOSED SEDIMENTS.

The first series to be discussed consists of the following various members.

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|---|---|---|---|
| Type | A, | - | Sandstones, |
| " | B, | | Graywackes, |
| " | C, | | Slates, |
| " | D, | | Phyllites, |
| " | E, | | Chlorite schists. |

The rocks have all undergone regional metamorphism due to the folding of the strata, but in some types the schistosity so developed is brought out more strongly than in others. Near the mouth of Tovey's Brook and not far from outcrop No. 6 occurs a conglomerate bed, tilted at the same angle as the other beds, and made up of pebbles about 1 inch to 2 inch in diameter, set in a matrix of red clay; the pebbles being drawn out by pressure and the whole rock having the appearance of a continental deposit.

Type A - SANDSTONES.- Nos. 4, 4a, 11, 22, 23, 36, 37, 38, 40, 42.

This type consists of micaceous sandstones, which perhaps may be called quartzites, on account of the metamorphism to which they have been subjected. These sandstones, with slight variations, are found in some ten thin sections and are of the following general composition. Quartz grains, of an average diameter of .2 mm., either rounded, sub-angular, or angular, are distributed in varying amount but fairly uniformly through the whole slide. The grains themselves show strain shadows. Feldspars occur in small amounts, showing the twinning striae of plagioclase, but not in sufficient quantity for the rock to be named an arkose. The matrix is to a great extent sericitic, containing at the same time some chlorite and some other grains, probably chiefly derived from original feldspathic grains. Small crystals of tourmaline appear rarely, scattered through the slide, sometimes as few as one crystal in a slide, and small quantities of magnetite which is altering to hematite and limonite.
A number of fragments which have the appearance either of an indurated clay, or of tuffaceous material, but are of indeterminable character appear also in the section. Dark segregations, with feldspar phenocrysts, occur which are evidently derived from the igneous rock.

No. 23. Typical sandstone. (See photo ). Angular and sub-angular quartz grains .3 mm. diameter are bound together by a sericitic and chloritic matrix. Crystals of muscovite can be distinguished, and grains composed of aggregated secondary minerals derived originally from grains of feldspar and rock material other than quartz. Tourmaline occurs in the slide. The hand specimen is a light colored fine grained rock breaking with a hackly fracture.

Outcrop No. 4 is of peculiar variety and the parts which differ have been labeled in the photo 4, 4a, and 4b; Nos. 4 and 4a being similar, but 4b is a black graphitic shale. In 4 bright specks of muscovite have been developed which appear in the hand specimen.

In the thin section crystals of muscovite become prominent in the slide, and show much straining and twisting, with decomposition rims in part. Sericite is more abundant as a secondary product than in the type, and is the chief component of the matrix.

No. 11. The rock is very like the type slide but plagioclase feldspar appears. The matrix is chiefly secondary chlorite and sericite with a quantity of magnetite grains scattered through the slide, and fragments of fine texture igneous rock are abundant.

No. 22. This differs from the type in the fact that it contains little cement. Magnetite occurs showing a dendritic structure, and occasional small crystals of zircon and titanite.

No. 36. is again like the type but the matrix is stained red from hematite which is altered from magnetite scattered through the slide, the same tuffaceous material appears as in the type section, and all the grains show shadows due to strain

No. 37 is like No. 4 in the hand specimen and like No. 36 in the thin section. Feldspar grains occur and tourmaline, and also small quantities of a minute aggregate which appears like epidote.

No. 40. The quartz grains are in great amount and the strain has produced striations which resemble those in a grain of feldspar. Tourmaline also appears and limonite in noticeable quantities.

No. 42. This specimen is taken from Bigsby's Head Quartz composes 70% of the slide, the grains being sub-angular and of the average diameter, together with a few grains of feldspar, and some small flakes of muscovite; a few fragments of the secondary aggregate derived from feldspathic grains, appear together with magnetite, hematite, and some fragments of the same tuffaceous material mentioned previously, In the hand specimen the rock is like No. 11 but redder in color.

No. 38. In the hand specimen this rock is almost indistinguishable from No. 37...No slide, however, was made.

No. 39. No slide was made of this rock but the hand specimen shows a very coarse sandstone or fine-grained conglomerate. The rock is reddish in color and hard and compact in texture. The grains of quartz, which are clear and greyish in color, vary from about 1/16th to 1/4th of an inch in diameter, and inclusions of substances not determinable in the hand specimen are scattered through the rock.

Type B. GRAYWACKES. Nos. 10, 12, 25, 26.

No. 10. Typical Graywackes shows a matrix composed chiefly of chlorite or sericite or both, through which are distributed small angular and sub-angular grains of quartz of a uniform size .05 mm. making up perhaps 30% of the slide, together with small grains of magnetite which are altering to hematite, and in some cases to limonite. Fragments of tuffaceous material again occur with those of the indeterminable substance already mentioned under type A, No. probably some decomposition product such as kaolin. All the grains and fragments show alignment.

No. 12. This differs from No. 10 which is taken as the type in the fact that more chlorite appears in the matrix, the grains of quartz are more angular and limonite occurs in greater amount. Fresh crystals of plagioclase feldspar occur, with greater amounts of the indeterminable substance before mentioned, and calcite occurs in small quantities in the groundmass.

No. 25. The hand specimen is almost identically the same as No. 10. The matrix is sericitic and fresh plagioclase feldspar appears. The material mentioned before as indeterminable, can in this case be determined as grains of orthoclase altering to kaolin. One or two grains of epidote and tourmaline occur with magnetite, some hematite and chlorite. Fragments occur also of the igneous rock which, however, are not well defined nor in large amounts as in the rock of the contact type.

No. 26. The matrix is more chloritic than No. 25, the grains of quartz are smaller, and of more uniform character and fresh grains of muscovite appear in long needle shaped forms. Magnetite also appears in the same needle-like forms and a little hematite. One or two grains of epidote appear and a piece of the glassy igneous rock as in No. 17.

Type C. SLATES. - No. 13 and 16.

No. 13 shows an argillaceous matrix composing almost the entire slide and very strongly impregnated with iron. Through this matrix are scattered minute quartz grains which are very evenly distributed. Grains of unaltered magnetite also occur scattered through the slide in moderate amounts.

No. 16, differs from No. 13 in that the quartz grains are larger, the iron stain is not so prominent, and crystals of muscovite can be distinguished. The hand specimen is a dark reddish rock of fine texture with veins of a dark green chlorite with quartz and specular iron running through it.

Type D. PHYLLITES.- Nos. 1, 4b, and 5.

These rocks have been differentiated from the slates on account of having the matrix composed of chlorite, rather than of argillaceous material. The thin section shows a matrix consisting of chlorite, and containing small angular grains of quartz which show strain shadows and make up about 20% of the slide. Magnetite also occurs altering to hematite, and in some instances the ~~hematite~~ hematite may have been formed directly as a secondary alteration product of the ferromagnesium minerals. Tourmaline crystals occur and some pyrite. The schistose structure of these rocks is well developed.

No. 5. TYPICAL PHYLLITE. (photo) Outcrop No. 5 occurs in Tovey's Brook and is shown in photograph No. 8, while a microphotograph of the phyllite is also given. Two kinds of rock appear in this outcrop. Firstly, a sandstone the same as No. 4b, and second, a phyllite which in the hand specimen appears rather like a slate. The thin section shows a sericitic and partially argillaceous matrix through which are scattered small quartz grains which compose about 20% of the slide, together with small grains of magnetite and a little muscovite. The schistosity of the rock is apparent.

No. 1. In the outcrop this rock is penetrated in various directions by veins and veinlets of pegmatite. The section is much like the type but some crystals of muscovite very much strained and partially altered to sericite occur, together with Tourmaline crystals in moderate quantities and some pyrite.

No. 4b. This rock forms the centre part of the anticlinal fold at outcrop No. 4. The shales in this outcrop are highly graphitic, due to the metamorphic effects upon the bituminous constituents. The thin section is very much like No. 5, except that the matrix is almost entirely composed of graphite and is penetrated by small veinlets of granular quartz and sericite.

Type E. CHLORITE SCHISTS: No. 2 and 6.

No. 2, (Photo;) This in the hand specimen shows a dark green soft rock with well marked cleavage. The thin section shows a matrix almost entirely composed of chlorite and sericite, occuring as an intimate mixture of fragments which are drawn out, strained and twisted. In this matrix occur small grains of quartz of an angular character, together with grains of magnetite altering to hematite, epidote grains, small tourmaline crystals, and finally some fragments of indeterminable material, probably a decomposition product such as kaolin. The schistose structure is so well developed that it can be seen in the slide without the aid of a microscope.

No. 6. The thin section shows a matrix of sericite and chlorite forming almost the entire slide in which crystals of muscovite very much strained can be distinguished. The rock is very much like No. 2 but the schistosity is not so plainly developed. The grains of quartz vary in size from about .025 to .1 mm. and comprise some 20% or less of the slide.

This is much the same proportion which is found in No. 2. Grains made up of decomposition products of the feldspar occur with grains of magnetite, fragments of tuffaceous material and others which are indeterminable.

## SERIES II. IGNEOUS ROCKS

The igneous rock, though showing some slight variations in different slides, is all of much the same general composition, but shows differentiation in various directions, the small differences in each slide being noted.

Type IGNEOUS. Nos. 8, 28, 7, 14, 15, 19, 26a, 29, 30, 32, 33, 35, 41.

The rock is volcanic of basic composition having both feldspars:- plagioclase (labradorite) as its chief mineral, with some orthoclase. The ferromagnesium minerals are either entirely altered to iron and other secondary products, as in No. 15, or are altered to a bastite-like material while still retaining their crystal outline, as in No. 14, or again remain fairly fresh, as in No. 28. Areas of secondary products suggesting olivine appear, which can only be so described because of their shape and associations, as the actual material has been altered to a secondary aggregate of chlorite, calcite, etc. No serpentine, however, apparently has been formed. Vesicles occur through the rock which are filled sometimes with chlorite, sometimes with epidote, or again with secondary calcite and quartz. The diabasic structure of the rock is well shown especially in the coarse sections, and in many slides the trachytic structure is also well developed. The feldspars all show good crystalline boundries indicating their development before the ferromagnesium minerals, probably due to a supersaturation of a magma of almost eutectic composition, by feldspathic material, followed by a state of surfusion and sudden consolidation. The iron in the slides may be either magnetite or specular hematite, the probability being that both occur to a certain extent. However, the abundance of hematite in the groundmass, and the fact that some of the altered ferro-magnesiun minerals are changed to red hematite in the centre, rather point to the conclusion that the iron is hematite rather than magnetite, and this view is strengthened by the fact that none of the grains show the crystal shape of the original magnetite, The specular hematite pits opened up on Bigsby's Head in conjuction with the same rock, also support this idea. Therefore, in default of better proof, the iron will be considered in this paper as specularite and red hematite. The rock would be called on olivine basalt on its purely mineralogical composition, but all the minerals are so much altered that a name based more upon the structure, such as a porphyrite, will be surer though not so definite. The rock is of intermediate composition between the olivine pyroxene andesites, and the basalts, and might be named in either group, the large proportion of feldspar tending to place it with the andesites. On the other hand, the diabasic structure, and the basicity of the feldspar, together with the fact that the fresh ferromagnesium minerals which do appear are pyroxene, would place the rock in the basalt group. The name which seems best to apply to and describe the rock, taking into consideration the structure the mineral composition, and the proportions of the constituents, is a porphyritic olivine basalt.

No. 8. (Photo.) The section shows firstly the igneous rock, second, a line of iron, epidote and calcite, about .6 mm. wide; third, the epidote and calcite filling. The igneous rock consists of larger phenocrysts of feldspar (labradorite) lying in a groundmass composed of smaller feldspar, augite, and iron. The augite still shows high interference colors, but is beginning to alter over to aggregates of secondary products, and this slide together with 28 are the only two in which original crystals give any evidence of the origin of these products. Large areas also occur quite different in appearance from the augite, and these appear to be derived from olivine. The iron shows beautiful dendritic growth, and cavities occur filled sometimes with calcite alone, sometimes by calcite, epidote and secondary quartz.

No. 28. This section shows coarser structure than the greater number of the specimens. The rock is of very much the typical composition, but the phenocrysts of augite are fresh and can be definitely identified. The iron occurs as specular hematite altering to the red oxide and to limonite. One or two fragments of tuffaceous material appear.

No. 7. This rock contains both feldspar lying in a groundmass of smaller crystals of feldspar, and a mass of iron oxide. Amygdules occur filled with secondary chlorite and epidote. This rock shows differentiation toward an olivine free basalt or andesite; as no olivine is seen in the slide. A fragment of sandstone like No. 23 is included in igneous rock.

No. 14. (Photo.) The rock which is fairly typical appears in the hand specimen as a fine grained compact rock of a darkish purple color with small phenocrysts of feldspar which can be distinguished with the unaided eye. In the slide, phenocrysts occur which show the bastite-like material probably to be a secondary alteration of the ferro-magnesium minerals in which a mica-like substance predominates, possibly a species of hydro-mica, somewhat, though not exactly, like sericite. The mineral although displaying characteristics most nearly allied to those of bastite, shows interference colors which are too high for true bastite.

No. 15. This is almost the same as No. 14 but the groundmass is very heavily charged with iron, making the slide appear almost black under one nicol. Some of the phenocrysts appear as before to be altered to the bastite-like material, while others are altered to chlorite. In the bastite-like phenocrysts calcite often predominates over the mica content, and points to the derivation from ferro-magnesium mineral rather than from the olivine.

No. 19. The thin section differs from the type, in that the bastite-like aggregates are wanting, but the small grains of the aggregate derived from olivine are present.

No. 26a. This rock is almost exactly the same as No. 14. The feldspars occur as usual in two generations and can be determined as labradorite. In the bastite-like phenocrysts, calcite is more predominant in the secondary alteration product.

No. 29. This shows feldspar crystals altered to sericite lying in a matrix of chlorite. The whole section shows parallel alignment and is different from any of the other sections. All the other minerals seem wanting except a few crystals of epidote together with some specular hematite altering to the red oxide. In the hand specimen, the rock is very like No. 2, having the same green color and cleavage, but microscopic sections show this rock to be of igneous origin, whilst No. 2 is a sedimentary rock.

No. 30. (Photo) This section shows feldspar small in size but not decomposed to any great extent. The large phenocrysts are apparently lacking. Large grains of iron ore occur, showing red stains in the centre surrounded by a blue black color given by the massive ore, but again altering on the edges to red hematite and thus giving very good proof that the iron is specular hematite. Vesicles appear in this slide showing beautiful chloritic filling, some being filled partially by secondary quartz as well as ~~the~~ chlorite. The trachytic structure is well developed.

No. 32 is the same as No. 14. Some phenocrysts of orthoclase appear, with plagioclase in two generations altered with the development of sericite. Grains of a bastite-like aggregate are present, but the areas derived from the olivine are wanting. Vesicles like those in No. 30 can also be seen.

No. 33. The slide shows a coarse texture like No. 28 and the diabasic structure is especially well developed. A considerable amount of calcite and epidote has been developed as a secondary product. Some of the pyroxene crystals have altered to calcite. Aggregates of epidote and calcite appear, and chlorite in the interstitial spaces shows beautiful markings.

No. 35. The thin section shows coarse structure. No large phenocrysts of feldspar occur, but the size of the smaller crystals is larger than usual. The alteration products of the olivine are present but not those from the pyroxene. Grains of iron appear in considerable amount giving red oxide and limonite as alteration products, and some chlorite is found in the groundmass.

No. 41. BH. This rock comes from Bigsby's Head, and in the hand specimen is like No. 14, though in this case penetrated by veins of calcite. The slide also shows a rock something like No. 14. Large phenocrysts of feldspar are, however, wanting, and the rock is made for the most part of an aggregate of small feldspar crystals. The same secondary aggregate occurs in this rock also, the grains having the appearance of those derived from the pyroxene rather than those derived from the olivine. The veins which can be seen in the rock, are reproduced as veinlets on a small scale in the slide, and are filled with secondary calcite, and quartz, while some calcite is present and iron is scattered through the slide in small grains.

## SERIES 111. CONTACTS.

These contacts, as will be seen from the slides, show no sharp line of definition in the microscopic examination, the rocks occuring mixed together without any definite boundaries. In the field, however, the igneous mass stands out in bold relief from the sediments, and the contact can easily be seen. Very little contact effects are to be noted in these slides, and this is probably due to the fact that the igneous mass was of volanic type, cooling quickly before contact phenomena had time to develop.

The contact specimens may be divided into two types A. & B. of which type A consists of contact between sediments and rock and of a porphyritic and tuffaceous composition, while in type B. the contact occurs between sediments and a rock of glassy character.

Type A. PORPHYRITIC & TUFFACEOUS CONTACTS.

Nos. 9, 16a, 21, 24, 27, 31, 31a.

No. 9. The slide shows a contact between the igneous rock and a fine-grained rock of the phyllitic type (like No.5). The igneous rock is porphyritic and has a groundmass of iron like No. 15 in part, while other parts show a glassy devitrified mass almost like No. 17. Small fragments derived from olivine appear in the matrix, but are not large in size, and are decomposed. Along the contact iron has separated out which is weathering to hematite, and other areas have apparently segregated out enclosing some quartz grains. Small vesicles occur which have been filled by secondary chlorite, and particles of tuff are scattered through the whole section. The whole slide shows great differences in the various constituents composing it.

No. 21. This section shows a rock, evidently a sandstone, with fragments of igneous matter like that seen in No. 17 mixed with it. The section, however, does not show much igneous rock, and forms a connecting link in a series between the sediments, those containing tuffaceous material, and the igneous mass.

No. 24. This is on the contact between the igneous rock and the sandstone. The igneous rock is composed of feldspar, partially decomposed, but in places showing well-defined boundaries, baveno twinning and zonal growth around the edges. (Photo). Secondary products occur in small amounts, and the groundmass itself is composed of feldspar and secondary

secondary iron for the most part, with some chlorite and calcite. The sedimentary portion of the slide is composed of sub-angular fragments of quartz and feldspar grains, in a matrix containing sericite, chlorite, tourmaline crystals, secondary quartz, epidote and calcite. The boundaries between the igneous and the sedimentary rocks are fairly sharply defined, but in some cases the quartz grains seem to indent the feldspars and the igneous rocks, which points to the fact that the sandstone was mixed with the igenous material while the latter was still soft. The various fragments of igneous material show great differentiation.

No. 27 This section shows a type of contact in which the igneous part predominates, this portion being on the whole like No. 14, but again showing variation in the amount of iron in the groundmass. The sedimentary portion is of the composition shown in No. 1. The actual contact shows slight evidences of contact action in that sericite is more prominently developed, but this effect only extends over a band from .2 to .3 mm. wide. Veinlets of secondary quartz traverse the sedimentary portion of the slide.

No. 31. The thin section seems to be divided into three distinct parts. Firstly, the igneous portion which shows up in fragments of porphyritic texture exhibiting considerable differentiation. Next appears a fine grained sedimentary rock like No. 1 apparently free from igneous fragments. Thirdly, occurs a mixture of quartz grains, feldspar phenocrysts, olivine, specularite, hematite, and chlorite fragments, all mixed together.

No. 31a. The igneous rock in this specimen is in great preponderance, and the sediment only shows in small amounts. The igneous portion again exhibits great differentiation both in the coarseness of the crystals and in the amount of iron in the groundmass. It is porphyritic in texture and is like the rock shown in photo No. 24, while the sedimentary is like No. 2. The contact is of the usual type, the two rocks being mixed one with the other in small fragments. Chlorite and secondary quartz appear, and some fragments which seem to be an aggregate of secondary mineral. The iron shows beautiful dendritic growth.

Type B. GLASSY CONTACTS Nos. 17 and 20.

These two sections are very much like each other, but differ from the ordinary type of contact specimen in that they show a glassy, igneous phase instead of a porphyritic.

No. 17 shows a devitrified glass which has apparently undergone the same action by vapours and gases with the development of sericite, as have the porphyry specimens. This glass occurs in close contact with a sedimentary rock almost identical with No. 13, and the whole slide is similarly highly impregnated with red oxide of iron, with faint traces of limonite appearing in places. The flow structure is well shown in the rock, and the sediment occurs in long drawn out pieces giving the appearance of ~~being~~ having been enclosed while the rock was in motion.

No. 20: This rock, though like No. 17, is not so highly charged with iron. The slide shows the same devitrified glass, carrying numerous grains of quartz, and having fragments of tuffaceous material lying enclosed in it. The same development of sericite appears as shown in No. 17 and the same flow structure. Fragments occur composed of secondary aggregates of sericite, and large areas of specular hematite appear to have segregated out, and are altering to the red oxide.

The contacts though of one general type, viz., an intimate mixture of sedimentary and igneous matter, form a series which ranges from sediments containing very little igneous material to types of rock in which the igneous material predominates to a large extent. The differentiation of the various igneous fragments in a single slide indicates their tuffaceous origin, and the admixture of these fragments with the sediments points to contemporaneous deposition.

## SERIES IV. GRANITES (WHIN SERIES)

Slides B, C, D, E, F, G, H, K,

These specimens were taken from the granite intrusive south of Salmon River, and show a regular sequence in the granulation of the rock as the contact is approached. Slide B. shows an acid granite of rather coarse texture. The composition is quartz, orthoclase-feldspar, a little plagioclase, and muscovite, together with accessory ~~tourmaline~~ and zircon, secondary chloritic aggregates, sericite and limonite having been formed in the interstices of the grains. The rock has been subjected to great strain, and the minerals all show strain shadows, although granulation has not taken place in the specimen to any large extent.

Slides C and H exhibit a transition stage where the granite is still recognizable, but parts of the slide are so granulated that it would be impossible to identifly the rock from slides made up only of such material. Slide H shows beautiful little tetrahedra and octahedra of original magnetite which is altering at the edges to red hematite. The same slide shows most beautiful microscopic folding and faulting in the feldspar crystals as seen in the photo.

The hand specimen H was taken from an outcrop on the northern side of Salmon River close to the contact, but does not show the maximum effect of granulation; the explanation probably being that this portion of the mass was in some way protected from the most intense stresses.

Slides D, E, and F, show a further stage in the process, where the grains which are left are smaller in size, and the ~~portion of the slide~~ areas which are completely granulated form a large proportion of the slide.

Slides G and K taken from the edge of Salmon River on the north side, exhibit the last stage in the process, where the rock has been entirely granulated. The specimens are taken from the fault contact and are so granulated as to be indeterminable by themselves, but studied in conjunction with the other slides they can be clearly traced back to the granite shown in B.

The discussion of the contact will be taken up in Part 111.

PART 111.

## DISCUSSION AND CONCLUSIONS

A consideration of the field relationship of the igneous rock to the adjacent sediment taken in conjunction with the petrographic character of the slides leads to two alternative theories of the origin of the igneous rock.

Firstly the mass may be a flow of lava from a volcano which has poured out its stream over the adjacent sediments while in course of deposition, so that the igneous rock has been interbedded with them.

This theory is supported by the following facts. In the field the mass has a long tongue like shape in the area in question forming the south ward extrusion of a mass which is in all some 6 miles long and one mile wide in its widest part. The rock in the hand specimens is of a very fine grained texture. The slides show the trachytic structures and vesicular texture of an effusive flow, while the glassy groundmass seen in some of the slides, and the drawing out of the various constituents also indicates a surface flow.

The second view of the case is that the mass is of a stock like character and has intruded the sediments. Under certain conditions the trachytic structure and vesicular texture would still be possible, and the lack of evidence of any contact with the overlying or underlying sediments upholds this theory rather than that of an effusive flow. It is of course possible that an actual contact between the igneous mass and the underlying sediments may occur but at no place in the field could evidence of such a contact be found. The differentiation of the magma shown in the various slides might mean that several outflows of varying composition had been extruded, or again might merely indicate differentiation of the same magma either in an outflow or in a volcanic neck.

The lack of evidence of any variations of the magma ~~resulting~~ in the field, resulting in different outflows of lava rather indicates that the miscroscope sections merely show local variations in the same magma, as the igneous mass is apparently of a perfectly uniform character in its field occurance and no indications of any different streams of lava occur. Again, on the edge of the igneous mass at outcrop No. 9 appear inclusions of sediment in the igneous rock as shown in the photo. No. 12, and the line of springs along the contact indicates eruptive action and could be more easily explained by the theory of an eruptive mass than an effusive flow. The more coarsely crystalline structure exhibited in Nos. 28 and 33, taken from the portion of the mass more remote from the contact might be explained as easily by one theory as the other, on the ground that the interior part of the mass would naturally cool more slowly than the edges and thus enable the crystals to form more completely; or again the sections might exhibit merely local differentiation of the same magma. The glassy ground mass exhibited in some of the slides could be easily explained if the mass was a stock, as the specimens were taken from the contact of the igneous rock and the sediment, where the former would have been quickly chilled.

The decomposition of the feldspars, olivine, and ferro-magnesium minerals point to the action of hot vapours and gases rather than of cold circulating waters, as the product resulting from the action of cold waters upon the orthoclase would be kaolin rather than sericite, and that from olivine would be serpentine rather than chlorite. The large amount of decomposition which has taken place would favour the idea of prolonged action by the vapours and gases which would be more likely to occur in a stock than in an effusive flow which would cool quickly. Again if the mass was an effusive flow interbedded with the sediment, some indications would be expected that the mass had been subjected to the same processes of folding as the adjacent sediment. The mass under these circumstances should show evidences of faulting or folding, none of which however appear. If on the other hand the mass is a stock, it would form a large body of solid and resistant material relatively to which the softer sediments might well have been folded and distorted without any material effect upon the igneous rock itself.

The great similarity which the slide taken from Bigsby's Head bears to the other sections taken from the igneous mass, brings forward the possibility, or rather probability, that the igneous material found in Bigsby's Head was once connected in some way with the mass studied. The igneous rock on Bigsby's Head might either have formed part of the same outflow and have been separated by erosion, or it may have been ~~separated by~~ another eruptive stock from the same parent magma. or again it might have been a continuation of the same stock without any point of separation. This third view seems from the field relations to be the most probable. The ground, as will be seen from the panoramic photograph, slopes uniformly to Bigsby's Head, and if the head itself had been composed of another stock like mass it would most probable have appeared as a separate small hill. If however, it was merely an outlying part of the same mass as that studied, the apparently uniform slope from the centre to the edges would be easily accounted for.

Whether the mass was an effusive flow or an eruptive stock, the time of extrusion or intrusion was apparently the same as that of the deposition of the sediments. The contact slides show an intimate mixture of tuffaceous and sedimentary material with that of sediments, and the only explanation for this is that the tuffaceous material was blown out at a time when the sediments were in course of formation. The area was later probably overlain by carboniferous strata which are still found in parts of the area, and possible by even later strata than these. The tuffaceous material itself is so like that shown in the slides of the igneous mass that there can be little doubt that it was derived from part of the same magma.

The most likely solution seems to be that an igneous eruption occurred in Devonian times while the sediments were in course of deposition, accompanied by a large amount of tuffaceous material. The upper parts of the mass were then removed by the peneplain which culminated in tertiary times, and the glacial action of the pleistocene, any overlying sediments being also removed by these same agencies.

The result now apparent is either the remains of the effusive flow accompanying such action, or is more probably a lower portion of the actual stock of the mass itself.

The sediments themselves are accepted as of Devonian age, as Messrs. Fletcher & Faribault in the Report 1886 state that fossil plants were found together with some Psilophyton.

A search in Tovey's Brook where these plants were described as having been found, failed to bring to light any fossils, and the statement of the Devonian age of the sediments in these notes is based upon the Report quoted above.

From a study of the outcrops and relative positions of the sediments in this small area, it is almost impossible to form any idea of the original relationship in which the sediments were deposited. However, from the highly micaceous matrix together with the occurrence of unaltered feldspar, and the angular appearance of the quartz, the sediments probably had their origin at a point not very distant from the point of their present position. The origin of the sands which have been transformed into sandstones or quartisto may well have been from the weathering of the granite intrusions southward, and this view is strengthened by the appearance of tourmaline in the sediments, which can also be found in the slides taken from the granite. These facts are by no means conclusive, but favor this view of the case. On the other hand, the present granite masses may not have been laid bare in Devonian times, but from the shattering effects shown in the slides they were presumably intruded before the period of folding which involved the Devonian sediments. Whether they were, however, intruded long enough before that to have been laid bare and have furnished the material for the sediments themselves, it seems impossible to say.

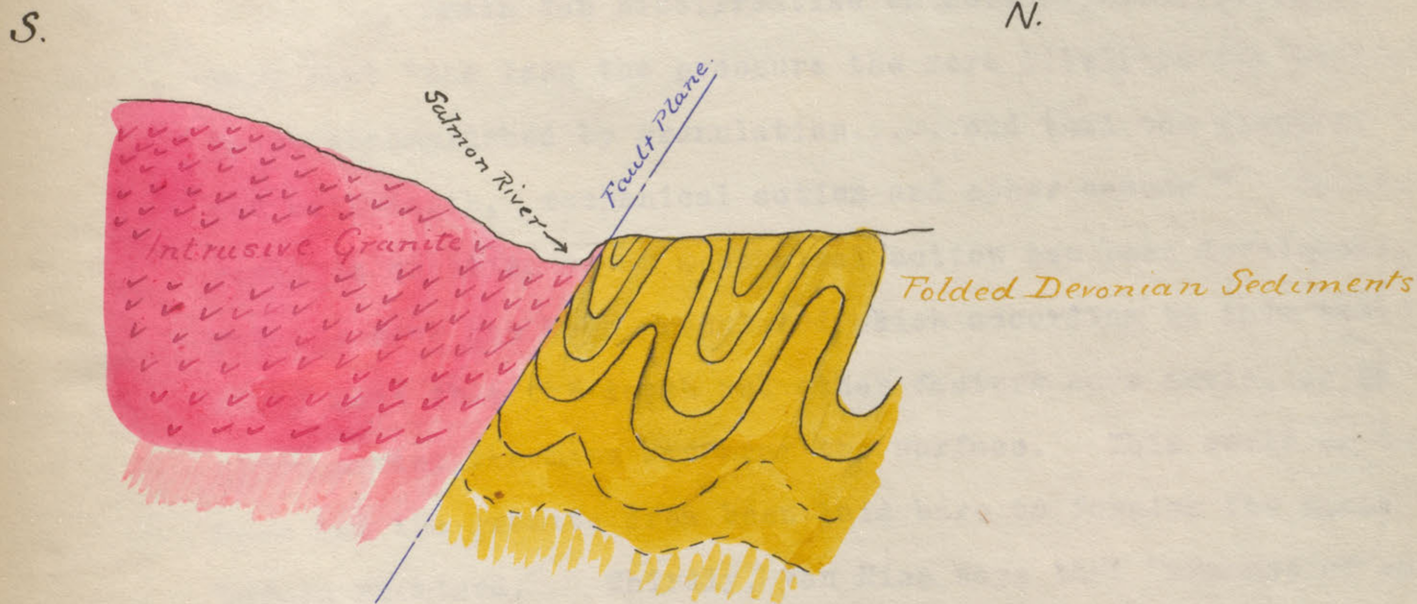
The tuffaceous material contained in the sediments must have been ejected at the time that the sediments were forming and have been incorporated with them as they were deposited.

The sediments themselves have the appearance of Continental deposits, as no marine fossils have been found in them and in some beds plant remains have been found.

The formation in this district may be possibly the same as the Knoydart Formation mentioned by Dr. Ami in Vol. Xll of the Geological Society of America. For this correlation there is no proof and the proposition is only put forward tentatively.

The granite slides show a series in which the amount of granulation is increased as the line of Salmon River is approached. The course of the river seems to follow the trace of the fault though not absolutely exactly, and on the northern side of the river the Devonian sediments appear. The sediments themselves are steeply titled and No. 4 outcrop shows a very tightly folded anticline with a fault crack in the centre. All the outcrops in Tovey's Brook appear to have to same dip, and the geological structure seems to be a series of tight anticlines and synclines, folded so tightly as to become isoclinal, and developed by a thrust fault from the south which has involved the more brittle granite and granulated it. A diagram will best illustrate the conditions of the structure though this diagram is not intended to show the structure to scale.

# Theoretical Section at Spanks Bridge



According to Van Hise("Treatise on Metamorphism, p 740) low temperatures favor granulation and high temperatures recrystallization. If this is so, the granite mass would have to have been intruded a long enough period of time before the deformation movement began for the igneous mass to have become cold, for otherwise we would have redrystallization appearing instead of granulation.

Again Van Hise(Treatise on Metamorphism, p. 739.) says that "the less the pressure the more likely is the deformation to be accomplished by granulation......and that the pressure increases with depth, mechanical action and other causes." In the fault in question great mechanical action has been developed and yet the rock has been granulated, which according to this theory would mean that the depth and other factors were small, or in other words, the mass was near the surface. This would be the case had the granite area been laid bare to furnish the sands as before surmised. Thirdly, Van Hise says that "absence of water is favorable to granulation; presence of water is favorable to recrystallization". Now, if the igneous mass had remained heated and was given off vapour and waters, the rock in the region of the fault would be recrystallized rather than granulated.
These views all favor the assumption that the granite had been intruded long before Devonian times and had in fact furnished the Devonian sediments themselves.

Conclusion.

A summary of the notes presents the following features. An igneous mass of volanic type and basic composition has appeared either as an effusive flow poured out upon sediments of Devonian age, or as an eruptive stock breaking through these sediments. The igneous activity was accompanied by volcanic ash and tuff of the same composition as the mass itself. This tuff upon being blown out fell back upon the sediments while they were in course of deposition and was incorporated with them, thus indicating that the extrusion occurred contemporaneously with the deposition of the sediments and is therefore of Devonian age. The field relationships and sections are more in accordance with the view that the mass is a stock rather than an effusive flow, though the second explanation is possible.

After the eruption of the igneous mass the strata underwent folding from forces acting from approximately W. 80°S. and were folded into a series of anticlines and synclines which have their axes striking approximately N. 80°E. and which have since been folded so tightly as to become isoclinal.

Finally it should be noted that a fault occurs along the line of Salmon River, and the granite mass forming the area directly south of this river is very much granulated the granite itself outcropping on both sides of the river at Spanks' Bridge, and no rocks of the whin series proper being present.