THE SILURIAN OF PICTOU COUNTY, NOVA SCOTIA

by

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ABSTRACT

In eastern Pictou County, Nova Scotia, a sequence of at least 15,000 feet of lower Devonian, Silurian, and pre-Silurian sedimentary and volcanic rocks are overlain unconformably by rocks of the Mississippian Windsor Group. The older Paleozoic succession is exposed in a broad anticlinal structure plunging to the west. The predominantly volcanic pre-Silurian Browns Mountain Group is at least 10,000 feet thick and displays two areas of flows surrounded by water laid tuffs and tuffaceous sandstones. In the northern part of the area studied, the Silurian is represented by a succession similar to the Arisaig Series of Antigonish County to the east. This sequence is composed of mudstones and argillaceous sandstones of a marine shelly facies. To the south, quartzites and black shales are present, marking a lithologic transition to the quartzites and black slates of a graptolitic facies observed in the Annapolis Valley to the southwest. The facies distribution indicates an east-west linear basin of deposition, with the shallow water beds of the marine shelly facies to the north. Ripple marks and small scale cross bedding reveal that currents flowed from the northwest, and the distribution of some ash and tuff beds suggests a source to the northeast. The lower Devonian is represented by a red-bed sequence in eastern Pictou County, and by a marine shelly facies in the Annapolis Valley, indicating widespread shallowing and emergence of the sedimentary basin. The fine-grained sedimentary rocks have developed cleavage in places, and compositionally are treated as low grade metamorphics. The major minerals present are quartz, muscovite, chlorite, albite, and orthoclase or kaolinite.

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PURPOSE

One of the chief problems associated with the Appalachian Geosyncline is the nature of its southeast margin. Throughout eastern United States, the rocks representing this portion of the geosyncline are buried beneath the sediments of the coastal plain and the continental shelf. Nova Scotia exhibits the easternmost outcrops of the older Paleozoic rocks in Continental North America and, hence, is the best area in which to study the southeastern side of the geosyncline.

With the exception of the Silurian at Arisaig, the older Paleozoic of northern Nova Scotia had not been previously studied in detail. The present investigation was undertaken to extend knowledge of the Silurian into neighboring eastern Pictou County. In addition, the stratigraphic relations of the Silurian to the underlying and overlying rocks, unclear in the Arisaig area, were to be studied.

During the time that the present investigation was underway, Charles Hickox (1958, unpubl.) completed a study which included the older Paleozoic of the Annapolis Valley. During this time, Boucot, Gross, and Hickox began a detailed study of the Silurian and Devonian rocks at Lockaber Lake, in Antigonish County. In the same county, Boucot, Griffin, and Fletcher (1959) investigated the older Paleozoic rocks at Cormorant Cliff Cove and School Brook Cove, on Cape George. In addition, Boucot, Zeigler, and Hickox have begun a more detailed study of the Silurian at Arisaig. With the exception of the volcanics (Zeigler, 1958, unpubl.), this work is still incomplete.

These related investigations, together with the present study, provide a basis for determining the regional pattern of deposition in the Silurian and Devonian sedimentary rocks.

LOCATION

Fig. 1 shows the location of Pictou County in northern Nova Scotia and the position of this province with respect to North America. Outcrop areas of Silurian and Devonian rocks, on which considerable work has been done recently, are shown.

PREVIOUS WORK

The earliest published geological work on the older Paleozoic of Pictou County was by Jackson and Alger (Jackson and Alger, 1829), which made mention of the iron ore on the East River of Pictou. This iron ore of the East River of Pictou was also described by R. Brown in Haliburton's History of Nova Scotia, in 1829. The rocks of this area were reported as Silurian in 1845 by Dawson, who also noted similarities to the Arisaig section (Dawson, 1845). A number of references are available, representing work done in this area in the nineteenth century. The only extensive investigation was the reconnaissance geology done by Fletcher during the last quarter of that century (Fletcher, 1886, 1892).

Following this, no further work was reported until Hayes (1914) reported on a single outcrop and Bell (1940) examined a few outcrops of the older Paleozoic rocks bordering the Carboniferous Pictou basin that he was studying (Bell, 1940).

In addition, some of the more detailed work done at Arisaig in Antigonish County (Twenhofel, 1909, Williams, 1914, McLearn, 1924) is relevant to the problems in Pictou County. Finally, the Nova Scotia Department of Mines (Messervey, 1943, Weeks, 1948) published descriptions of the long-closed Bridgeville iron mines and the geology of the immediate area.

The earliest workers (Jackson and Alger, 1829, 1832, Gesner, 1836) reported only that slates and graywackes of considerable age were present. Gesner (1836, p 59) and Honeyman (1860) reported some of the common fossils, and considerable mention was made in the literature of the iron occurrences.

Of the numerous references available[1] only Gesner (1836) and Gilpin (1879) gave information of geologic use.

No structural information was reported, other than occasional attitudes of beds. No stratigraphic subdivision was attempted, although Honeyman (1860) recognized that the outcrops along Route 4 correspond to some of the lowest beds at Arisaig (now middle Ross Brook Formation). Dawson (1875,p 129) noted that slates overlie quartzites in the East River of Pictou area, and later (Dawson, 1881) wrote of two stratigraphically distinct horizons of iron ore, and listed fossils collected. Gilpin (1880) had also mentioned two horizons of iron ore.

Fletcher (1886) provided a map of the distribution of rock systems with no further subdivisions in the older Paleozoic, with the exception of his "Lower Helderberg". This did correctly suggest that the youngest beds are mostly at the western end of the outcrop of the older Paleozoic, although incorrect as to age and detailed distribution. His work on the whole is reliable, although he never recognized the presence of the Devonian Knoydart Formation in Pictou County. He also reported some of the good fossil localities. In view of the large area covered, it is not surprising that the map is faulty in some details of the distribution of rock types or units.

In the course of mapping the Pictou Basin, Bell (1940) examined a few outcrops of older Paleozoic rocks. Fossils collected from some of these outcrops were sent to F. H. McLearn. Their identification indicated the presence of rocks of the Beechhill Cove and Ross Brook formations.

Weeks (1948) suggested that the Bridgeville iron deposits represent an ancient laterite, formed on the surface of the Silurian sedimentary rocks prior to the deposition of the upper Windsor limestone.

1. Brown (1829), Dawson (1860, 1881), Gesner (1836), Gilpin (1880) Harrington (1874), Hartley (1869), Honeyman (1870, 1872, 1880), Jackson and Alger (1829), Poole (1872, 1874, 1875, 1876, 1877).

GENERAL GEOLOGY

Rocks of two general ages are present in eastern Pictou County. Devonian, Silurian, and older non-fossiliferous rocks are found in the central part of this area. To the north, west, and south are rocks of Carboniferous age.

The older Paleozoic rocks are present in a sequence at least 15,000 feet thick. This sequence extends from the lower Devonian to the lower Silurian, plus a thick non-fossiliferous section below. No angular break is present in this sequence. With the exception of the non-marine Devonian sedimentary rocks, this succession is composed of volcanic and marine sedimentary rocks.

To the north, the two major stratigraphic divisions are separated by an extensive normal fault. To the southwest, the older Paleozoic rocks are overlain unconformably by the upper part of the Mississippian Windsor Group. To the west, this same unconformity has been the locus of relatively minor normal faulting.

To the south is present part of an east-west trending belt of quartzites and argillites. This belt extends from Guysborough County on the east, through Pictou County to Colchester County on the west. A few fossils found near the eastern end indicate that these rocks are of the same age as the Mississipian Horton Group, although of different lithology.

The contact between this belt and the older Paleozoic rocks is hidden beneath swampy ground in the upper reaches of the valley of the East River of Pictou and lies under rocks of the Windsor Group farther downstream in this valley.

The Carboniferous rocks to the southwest, west, and north are predominantly non-marine clastics, but include limestone and gypsum in the Mississippian Windsor Group and coal in the Pennsylvanian Stellarton Series.

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Many persons contributed to the field work. Chief among these was the author's wife, Joan, who accompanied him furing three field seasons. In the summer of 1957 the following persons also aided in the field work: C. Frye, D. Harris, M. McCollum, R. Simons, L. Sykes, and D. Wilson. In the summer of 1958 I. Adams, D. Bragan, J. A. Doucet, J. Galbraith, M. Hatch, and T. Wilcox gave assistance. In the summer of 1959 W. Bisson, R. Cohen, T. Cook, E. Essene, U. Janssons, K. Kenyon, and H. Lahman did field work in this area.

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METHODS

GENERAL

Large scale mapping was done by compass and tape traverses, using topographic sheets at a scale of 1:50,000 as base maps and utilizing aerial photographs. Detailed mapping was done partly by plane table methods (telescopic alidade and stadia), but mostly by use of tape and compass. The usual field descriptions of rock type, and data on attitudes, primary features, and structural features were recorded. In addition, orientations of current-derived primary features were recorded, and, where necessary, oriented specimens collected. Extensive lithologic and paleontologic sampling was carried out, and, at choice localities, large fossil collections were made.

Fossils were separated, cleaned, and treated with hydrochloric acid. Identifications, principally of the brachiopods, were made by Dr. Arthur J. Boucot, and of the ostracods by Dr. Murray Copeland of the Geological Survey of Canada.

Oriented specimens of small scale cross bedding were examined, and the original current directions calculated. Similar calculations were made from data on the orientation of ripple marks.

PETROGRAPHY

Optical

Polished surfaces were examined under the binocular microscope. Petrographic thin sections were examined and mineral percentages estimated. These data are presented under the respective formation descriptions in the chapter on Stratigraphy. These optical methods were used to determine grain size, shape, and sorting.

Differential Thermal Analysis

In all, 42 samples were subject to differential thermal anaylsis. These data were used qualitatively, and, in the case of calcite and pyrite, semi-quantitatively. The results may be found under the respective formation descriptions in the chapter on Stratigraphy.

The height of the thermogram peak, corresponding to the β-α inversion of quartz on the cooling curve, relative to all the samples investigated, is indicated by an s for small, m for medium, and l for large. The relative areas of the large endothermic peak centered at $600^{\circ}C \pm 20^{\circ}$ (representing chlorite, kaolinite, or both) are indicated in the same manner.

X-Ray Diffraction

One sample (DF 63, middle Ross Brook Formation) was analyzed by powder photograph. Eight other samples (AM, BRdl, Sunnybrae Formation; PF 1, lower Browns Mountain Group; ML 101, Kerrowgare Formation; DF 65a, middle Ross Brook Formation; GB 101, Glencoe Brook Formation; HA 2 lower McAdam Formation; and DT 35, Moydart Formation) were analyzed by x-ray diffractometer at the National Geophysical Laboratory, Washington, D. C.

The d-spacings were calculated for the measured values of 2θ, and A.S.T.M. cards used to determine the minerals present. The results may be found under the respective formation descriptions in the section on Stratigraphy. Peak heights, relative to all the samples analyzed, are indicated by an s for small, m for medium, and l for large.

Chemical Analysis

Major element chemical analyses were made, using a modification of the rapid silicate analysis procedure of Shapiro and Brannock (1956). In all, 14 samples were analyzed for SiO_2, Al_2O_3, Fe_2O_3, FeO, K_2O, Na_2O, CaO, MgO, MnO, TiO_2, and P_2O_5. In addition, 9 of these were analyzed for H_2O. Two of the 14 samples were run in duplicate to test the precision of the analyses, and a standard, the granite G-1 (Fairbairn, et al, 1951), was analyzed as a test of the accuracy.

Silica, SiO_2, was determined by measuring the transmission of light at 650 mμ in solutions of the yellow silico-molybdate complex, reduced to molybdenum blue (Bunting, 1944). The measurements of transmission of light in this and the following analyses were made on a spectrophotometer (Beckman, Model B).

In order to determine Alumina, Al_2O_3, the transmission of light at 475 mμ was measured in solutions containing the complex of alizarin red-S, aluminum, and calcium (Parker and Goddard, 1950). Empirically determined corrections were applied for the presence of TiO_2 and Fe_2O_3.

For the SiO_2 and Al_2O_3 determinations, the samples were dissolved by fusing with NaOH in a nickel crucible.

Ferrous oxide, FeO, was determined by titration with a standard dichromate solution (Sarver, 1927). Diphenylamine sulfonic acid was used as the indicator. The sample was put into solution, for this titration, by boiling with sulfuric and hydrofluoric acids.

Water, H_2O, was determined by absorption in filter paper of the water driven off on heating the sample. This was a modification of the Penfield method (Shapiro and Brannock, 1955). The samples were not dried immediately before the analysis, hence, some of the H_2O measured had been present as absorbed H_2O.

For the remainder of the determinations, the samples were put into solution by digesting overnight, on a steam bath, in a mixture of sulfuric and hydrofluoric acids. Nitric acid was added to dissolve any organic matter.

Total iron was determined as ferric oxide, Fe_2O_3, by measurement of light at 560 mμ in solutions with the orange colored ferrous orthophenanthroline complex present (Bandemer and Schaible, 1944). The percent Fe_2O_3 was calculated by subtracting the Fe_2O_3 equivalent of the FeO percentage from this total iron determination.

Titania, TiO_2, was determined by measurement of the transmission of light at 430 mμ in solutions containing a yellow colored complex resulting from the reaction of tiron (4,5-Dihydroxy-m-benzenedisulfonic Acid Disodium Salt) with the titanium (Yoe and Armstrong, 1947).

Phosphorous as the pentoxide, P_2O_5, was determined by measurement of the transmission of light at 430 mμ in solutions with the yellow molybdivanado-phosphoric acid complex (Kitson and Mellon, 1944).

Manganese oxide, MnO, was determined by oxidizing the manganese to permanganate with potassium metaperiodate (Willard and Greathouse, 1917) and measuring the transmission of light at 525 mμ.

Lime, CaO, was determined by automatic titration with Versene (disodium ethylenediamene tetraacetate) using a spectrophotometer at 590 mμ with a continuous strip recorder as the photometric titrator. Murexide (ammonium pupurate) is the indicator (Betz and Noll, 1950).

Magnesia, MgO, was determined by subtracting the MgO equivalent of the CaO percentage from the total of MgO and CaO determined as MgO. This combined determination was made by automatic titration with Versene, using Eriochrome Black-T as the indicator (Betz and Noll, 1950) and passing light at 650 mμ.

The results of the chemical analyses may be found in the respective formation descriptions under Stratigraphy and in Appendix 1. In Appendix 1, also, are the results for the standard G-1, compared with the arithmetic mean and the consensus mean of Fairbairn, et al (1951), and the conventional method values given by Shapiro and Brannock (1956) and obtained from five analysts in another laboratory of the U. S. Geological Survey, to indicate the accuracy attainable by the author with a granitic rock. Most of the sedimentary rocks analyzed were not radically different in chemical composition from G-1. The only consistent differences were less CaO, Na_2O, and K_2O, and more H_2O, FeO, Fe_2O_3, and TiO_2. A few of the samples, however, did differ enough in composition from G-1 to make uncertain an estrapolation of the degree of accuracy achieved with that standard. Shapiro and Brannock (1956) reported two analyses of N.B.S. samples of clays. These two analyses compared less favorably with the N.B.S. values than did their values of analyses of G-1 with the conventional results.

That sample, ML 101, of the first group which differend most in chemical composition from G-1 was analyzed again in the second group, as was another sample, PF 1, whose chemical composition was approximately the average of the group. A comparison of the two analyses for each of these two samples indicates the precision attained by the author. Inasmuch as this precision is poor in some elements (Al_2O_3, Fe_2O, Na_2O, and MgO), it suggests that the accuracy attained with the sample of G-1 cannot be extended to all the samples. The poor agreement of the Fe_2O_3 results on the ML 101 samples is partly a result of the method of determining Fe_2O_3 by subtracting equivalent FeO from total Fe as Fe_2O_3. In sample ML 101 a large percentage of iron is present, mostly in the reduced state. As a result, the percent Fe_2O_3 is a small number obtained by the subtraction of one large number from another. The limit of accuracy on the Fe_2O_3 value is the sum of the limits of accuracy of the FeO and total Fe values. The results of the two analyses are compatible within these limits if the FeO and total Fe (as Fe_2O_3) results are assigned accuracies of $\pm$ 1%.

Calculations

The results of the major element chemical analyses were utilized in calculating percentage mineral compositions. This was done by the use of standard compositions for the various minerals found to be present, in a manner somewhat analogous to the normative calculations of Cross, Iddings, Pirsson, and Washington (1903) for igneous rocks.

Inasmuch as adsorbed water was present in the samples, the results of the analysis will be low, for use in normative calculations, by a factor equal to the percent adsorbed water.

In the calculation, the mineral assemblage constituting the rock may be treated as a detrital sediment or as a metamorphic rock. In the former case, a non-equilibrium assemblage is assumed. In the latter case, it is assumed that the original, detrital minerals have reached chemical equilibrium through reaction. Several lines of evidence suggest that the latter assumption is valid. First, the severe alteration of the detrital grains, other than quartz, suggests reaction with the surrounding material. Second, the development of cleavage transverse to the bedding suggests recrystallization within the rock. Third, the small size of the grains, resulting in relatively larger surface area, would favor such reaction. Finally, the work of Zen (1960) in rocks of seemingly similar appearance indicate that the attainment of chemical equilibrium in such rocks is possible.

If chemical equilibrium has been attained, the possible mineral assemblages are greatly simplified. Instead of a mixture of various intermediate members of solid solution series, such as the feldspars and chlorites, all the chlorite will be of a single composition, and relatively pure potassium feldspar and albite will be the feldspars present, if any. Furthermore, three phases colinear in composition should not be found in coexistence. Thus, kaolinite, muscovite, and potassium feldspar should not

PETROGRAPHY(Cont'd.)

be found in the same assemblage.

These conditions, based on the assumption of chemical equilibrium, were then made use of in calculating the mineralogy.

In all the samples analyzed, there is an excess of SiO_2, hence, quartz can be assumed present. Its presence was confirmed by x-ray diffraction and differential thermal analyses. No evidence of paragonite is present, so all the Na_2O is assigned to albite, and the percent albite calculated on this basis. In all those samples for which x-ray diffraction data are available, chlorite is present. Accordingly, all the MgO and FeO content was attributed to chlorite, except for those samples in which pyrite was detected, in which cases the equivalent amount of FeO was first subtracted. The composition of the chlorites is unknown. An assumed composition, for purposes of calculation, was based on the formula, $(Fe,Mg)_5Al_2Si_3O_{10}(OH)_8$. No substitution of Fe^{+++} for Al^{+++} was assumed, and no substitution for Al^{+++} for Fe^{++} and Mg^{++}. The Fe^{++}/Mg^{++} ratio was determined by the results of the FeO and MgO analyses, corrected for pyrite, if present.

Muscovite is present in all the samples. The presence of a potassium feldspar is uncertain, and the detection of kaolinite in the presence of chlorite is also difficult. In the calculations, all the K_2O was first assigned to muscovite. Then the Al_2O_3 content of the calculated chlorite, albite, and muscovite was calculated and compared with the analyzed value. If Al_2O_3 was in excess over that accounted for by the mineral calculations, the remainder was assigned to kaolinite. If the Al_2O_3 determined by analysis was deficient, enough of the K_2O was reassigned to potassium feldspar to account for this. The silica content of the four calculated mineral phases (chlorite, albite, muscovite, and kaolinite or potassium feldspar) was then determined and subtracted from the analyzed value to obtain the amount of quartz present.

A check on the results of these calculations is afforded by the H_2O analyses. Chlorite, muscovite, and sometimes kaolinite, are the hydrous phases calculated. The sum of their water contents may be compared with that obtained by analysis. The H_2O analyzed includes some adsorbed water and possibly some from hydrous ferric oxide ("limonite"). The appreciable amount of Fe_2O_3 found by analysis in these samples and evident in the brown staining of the matrix as observed in thin sections, suggests the presence of such a hydrous ferric mineral. Hence, the calculated H_2O content should be less than the analyzed value. In those samples for which no H_2O analyses are available, subtraction of the remaining oxides from 100.00% provides a useful approximation if the deviations from 100.00% of the complete analyses are considered. The average deviation from 100.00% of the complete analyses is ± 0.64% and the maximum deviations are + 0.9% and - 2.4%, the latter possibly resulting from the presence of some component (s) not analyzed for.

Such a check indicated that one sample (DT 27) has more water in its calculated mineralogy than was determined by analysis. This sample is atypical, in that it is of a large, calcareous nodule, taken from the upper McAdam Formation. This nodule is composed of about 30% calcite. Some of the MgO determined by analysis might be present in solid solution in the calcite. If this were so, the amount of chlorite present would be lower and the equivalent Al_2O_3 in the calculations would be assigned to kaolinite. Since kaolinite has a lower H_2O/ Al_2O_3 mole ratio than chlorite, this would lower the calculated amount of H_2O. One difficulty with this possibility is that more carbonate must be present to account for the Mg, and this would result in a high total for the analysis. The answer to the difficulty with this sample may lie in an inaccurate value for MgO content. MgO was determined by subtraction of equivalent CaO from MgO plus CaO determined as MgO. In this sample a high CaO value was subtracted from a slightly higher total value. If an accuracy of ± 1% is assumed for the CaO and the CaO plus MgO analyses, the MgO value of this sample has an uncertainty of about ± 15% associated with it.

With the possible exception of sample DT 27, the method seems satisfactory for calculating the present mineral composition of these rocks. By the initial assumption, however, the original, detrital mineral composition is no longer present.

STRATIGRAPHY

INTRODUCTION

The lithologic differences which form the basis for the stratigraphic subdivisions are relatively slight, particularly within the Arisaig Series. All these sedimentary rocks have an abundant argillaceous matrix. Grain sizes range from fine sand down to clay sizes, and sorting is poor. In fact, the first impression given by these rocks is one of great monotony in rock type. In this series of rocks, such differences as the appearance of the bedding, and minor distinctions in color which reflect relatively minor grain size and compositional changes, became important features in formational mapping. Despite the lack of major differences, the rocks can be successfully divided and mapped.

The older Paleozoic rocks in eastern Pictou County are present in two distinct sequences. In the north is present a stratigraphy almost identical to that at Arisaig, to the east, in Antigonish County. The differences are related in the detailed descriptions below. To the south a distinctly different stratigraphy is present, and this is treated separately in the detailed descriptions. For each area, the formations are presented in order of decreasing age.

The two stratigraphic sequences are shown in Table 1. The various stratigraphic units may be characterized briefly as follows:

	NORTHEAST PICTOU COUNTY
Knoydart Fm.	red and green sandstone nodular red siltstone
Stonehouse Fm.	green sandstone and sandy mudstone, blue gray, limy mudstone and fragmental limestone
Moydart Fm.	
upper member	algal (?) nodules in red siltstone
lower member	green and blue gray sandstone and mudstone

McAdam Fm.	
upper member	dark gray nodular sandstone and mudstone
lower member	alternating blue gray mudstone and resistant sandstone
French River Fm.	blue and purple gray, micaceous sandstone
Ross Brook Fm.	
upper member	alternating blue gray mudstone and resistent sandstone
middle member	massive blue gray mudstone
lower member	light gray, well bedded mudstone
Beechhill Cove Fm.	massive, green gray sandstone and gray mudstone
Bears Brook Fm.	andesite and rhyolite flows, tuffs, tuffaceous sandstones and conglomerates
undifferentiated Browns Mountain Group	banded, gray and green shale, slate, and argillite, and minor quartzite

SOUTHEAST PICTOU COUNTY

Knoydart Fm.	red sandstone and siltstone
Stonehouse Fm.	green sandstone and siltstone
Kerrowgare Fm.	dark gray shale, slate, and minor sandstone
Glencoe Brook Fm.	varicolored quartzites and minor blue gray mudstone
Sunnybrae Fm.	banded, gray and green shale, slate, and argillite and minor tuff
Charcoal Fm.	green and purple tuff and conglomerate and minor trap rock.

TABLE 1

STRATIGRAPHY

	Northeast Pictou County		Southeast Pictou County
DEVONIAN	Knoydart Fm.		Knoydart Fm.
	Stonehouse Fm.	ARISAIG SERIES	Stonehouse Fm.
SILURIAN	Moydart Fm.	ARISAIG SERIES	
	McAdam Fm.	ARISAIG SERIES	
	French River Fm.	ARISAIG SERIES	Kerrowgare Fm.
	Ross Brook Fm.	ARISAIG SERIES	
	Beechhill Cove Fm.	ARISAIG SERIES	Glencoe Brook Fm.
	Bears Brook Fm.	BROWNS MOUNTAIN GROUP	Sunnybrae Fm.
	undifferentiated	BROWNS MOUNTAIN GROUP	Charcoal Fm.

UNITS

Introduction

In the descriptions below, the gross features are based on field observations and are presented first. Grain size, shape, and sorting, as well as small scale primary features, were determined under binocular or petrographic microscope. The composition is presented last, and classified according to petrographic or analytic technique. Finally, where possible, a quantitative mineral composition is given, based on a combination of differential thermal analysis, x-ray diffraction and major element chemical analyses, in addition to microscopic examination. The method of calculation is described under PETROGRAPHY. These detailed studies were necessarily carried out on only a small number of representative samples.

In the descriptions of the rock types given below, the terms sandy, sandstone, silty, and siltstone refer to grain size as given by the Wentworth Grade Scale. The author uses an adjective before these terms to indicate the type of matrix, i.e., argillaceous, ferruginous, etc. Many of the rocks of this area are of mixed grain size, from fine sand down to clay size. These same rocks lack well defined bedding. Both of these properties have been used as the definition of the term mudstone. The name mudstone is, therefore, quite appropriate for this widespread rock type. The term shale has been used only for rocks with greater than 80% clay size material, that have a fissility parallel to the bedding.

The grain size frequency distribution of the argillaceous sandstones, siltstones, and the mudstones has a bimodal character. The coarser particles, which consist of quartz, altered feldspar, and lithic fragments, and, in some, muscovite, fall within one or two grades on the Wentworth scale. These grains are predominantly angular, but range to sub-rounded. The remainder of the grains fall in the clay sizes.

It will be noted in the thin section descriptions that a major component of most of these rocks is listed only as altered feldspar. The grains referred to, under petrographic microscope, are seen to be largely altered to clay minerals and, in fact, are difficult to distinguish from the argillaceous matrix. Those grains which are not completely altered show low birefringence, low relief, and are uncolored. By these properties they resemble feldspars, although evidence of twinning is lacking. Interference figures are impossible to obtain. The presence of feldspar was detected in all the x-ray diffraction analyses. The estimates of percentages in petrographic thin section of these grains is not accurate, owing to the difficulty in distinguishing them from matrix material. Nevertheless, it is clear that in many rocks they are at least twice as common as quartz grains. Sedimentary rocks with this ratio of feldspar to quartz are rare and, of course, are extreme examples of arkoses. From the point of view of composition, these grains could be of shale or mudstone, being made up of clay minerals. However, the grains observed are approximately equidimensional, whereas fragments of shale and mudstone are generally elongated in one or two dimensions.

Feldspar rich, aphanitic rocks could alter to grains similar to those in question. If such were the origin of an appreciable number of these grains, the containing rock would fall under the category of graywacke in most systems of classification of sedimentary rocks (or a "high rank graywacke", referring to the presence of a significant amount of feldspar as well). In their induration, color, and abundant argillaceous matrix, these rocks certainly resemble graywackes rather than any arkoses known to the author. Thus, it is suspected, though in no way proved, that an important component of the sand and silt size grains of these rocks is altered lithic fragments.

Northeast Pictou County

Browns Mountain Group

NAME AND DEFINITION

The Browns Mountain Group was first recognized and described by Fletcher (1886, p 18) during his reconnaissance mapping of Antigonish and Pictou Counties. No further work was published on these rocks in Pictou County until Hayes (1816) described an occurrence of a ferruginous bed, and Bell (1940) described some rocks of this group on the margin of the Pictou Basin. In the past decade, a number of brief unpublished investigations have been undertaken in Antigonish County by students at the Nova Scotia Centre for Geological Sciences. Summaries of this work can be found in the annual reports of the Centre.

Williams (1914, p 26) also briefly treated the rocks of this group in Antigonish County.

This group is named for Browns Mountain in western Antigonish County, 11 E/9 East Half, as shown on the National Topographic Series sheet located between Rte. 4 and the Northumberland Strait.

The Browns Mountain Group was subdivided by Fletcher (1886, p 18) into the James River Formation, Baxter Brook Formation, and Bear Brook Formation, in ascending order.

The James River Formation is characterized by quartzites and banded slates and argillites. The latter two, particularly, are widespread in both Antigonish and Pictou Counties.

The Baxter Brook Formation, on the basis of its stratigraphic position and description, seems to represent the transition zone between the underlying James River Formation and the overlying Bear Brook Formation.

Inasmuch as no detailed study of these rocks was made, and rocks of similar aspect are present in southeast Pictou County in a different stratigraphic position, wherever they were encountered in northeast Pictou County they were mapped only as Browns Mountain Group, undifferentiated. This term was used in northeast Pictou County to designate rocks older than the upper volcanic unit of the Browns Mountain Group, the Bear Brook Formation. As such, it includes some phyllites, and flows, as well as various quartzites not associated with the banded slates.

A ferruginous bed, seven feet thick, containing "oolitic hemetite and chamosite" was reported (Hayes, 1920) near the northern edge of the area of Browns Mountain Group outcrops, between Barneys River and French River north of Rte. 4. It is similar in description to the "iron ores" of Doctors Brook and Browns Mountain in Antigonish County (Williams 1914, p 57). It is similar, also, in containing shell fragments and in that the surrounding sedimentary rocks contain brachiopod shells. At the Doctors Brook location, the iron rich beds are placed near the top of the James River Formation (Williams 1914, p 57).

THICKNESS

The base of the Browns Mountain Group has not been observed. Furthermore, the lower Browns Mountain Group rocks were not mapped for their own sake, but only to determine the nature of the contact with the overlying Bear Brook Formation. For these reasons, only a minimum figure can be given which has been estimated from the incomplete data available.

Fig. 2 shows that most of the lower Browns Mountain Group exposures are present in the center of a major anticline trending about east-west. The East French River crosses the north flank of this anticline. For about

½ mile upstream of the contact with the overlying Bear Brook Formation, numerous outcrops of the lower Browns Mountain Group are present, displaying similar attitudes and representing about 1800 feet of section. Located 1½ miles farther upstream are abundant outcrops with attitudes similar to those downstream. Another 2000 feet of section are represented by these exposures. If this northern flank of the anticline is uninterrupted in the interval between these two exposed sections, about 10,000 feet of the lower Browns Mountain Group are present. If the anticline is a single fold without the development of a series of folds near its crest, at least another 5000 feet of these lower Browns Mountain Group rocks must be present.

In summary, it is estimated that the thickness of the lower Browns Mountain Group is at least 10,000 feet, and possibly more than 15,000 feet, in eastern Pictou County.

This figure may be compared with one of 5000 ± feet (Williams 1914 p 52) for the lower two formations of the Browns Mountain Group in Antigonish County. This latter figure is also only an estimate and a minimum figure.

DESCRIPTION

In northeast Pictou County these older Browns Mountain Group rocks consist predominantly of banded, gray and green slates, shales, and argillites with minor quartzites. At one locality (East French River, 1½ miles south of Rte. 4) diabasic dikes and sills have intruded this unit.

The finer grained rocks are gray and green on a fresh surface, but sometimes weather to white, purple, or orange colors. The green and gray colored beds frequently alternate, often in layers of about 1/16 inch each but as large as 1½ feet. The subsequent banded appearance is a distinctive feature of this unit and is present both in the massive argillites and in the fissile shales and slates.

Quartzites make up less than ten percent of these rocks in Pictou County. They are extremely fine grained and hard, almost flinty. They are green, gray green or blue gray on a fresh surface, and on a weathered surface appear dirty or a darker gray.

TABLE 2

BROWNS MOUNTAIN GROUP (below Bears Brook Formation)

No petrographic thin sections of samples from the lower part of the Browns Mountain Group were examined.

DIFFERENTIAL THERMAL ANALYSIS

SAMPLE	ROCK TYPE	Quartz	Chlorite and/or Kaolinite	Iron Oxides	Pyrite
RR 5A	argillite	s.	s.		trace
RR 5B	argillite	s.	s.	present	
PF 1	argillite	s.	m.		trace

X-RAY DIFFRACTION

SAMPLE	ROCK TYPE	Quartz	Feldspar	Kaolinite	Muscovite	Chlorite
PF 1	argillite	s.-m.	one v.l., one s.	?	m.	m.

CHEMICAL ANALYSIS

PF 1 (argillite)

av. of two analyses

SiO_2	64.4%
Al_2O_3	17.4
Fe_2O_3	2.11
FeO	3.65
MnO	0.13
TiO_2	0.82
P_2O_5	0.16
K_2O	3.77
Na_2O	2.46
CaO	0.22
MgO	2.43
H_2O	
TOTAL	97.5 plus H_2O

CALCULATED MINERALOGIC COMPOSITION

Sample PF 1 (argillite)

Quartz	Orthoclase	Albite	Muscovite	Chlorite
32.5-32.7%	1.1-1.4%	20.1%	29.6%	14.0%

The quantitative mineral compositions above were calculated by the method described under PETROGRAPHY.

Sample PF 1 is a typical argillite of the Browns Mountain Group. A small amount of pyrite was detected by D.T.A., accordingly, the calculations cover the range 0-½% pyrite. If the assumption of attainment of chemical equilibrium is correct, the present composition of this rock is as shown above.

AGE

The age of these rocks is uncertain. The only fossil evidence in Pictou County is a single species of brachiopod found near the ferruginous bed, mentioned above. It was identified as Lingulella bella, Walcott (Hayes 1916). No fossils are found lower in the section; therefore, no maximum age other than Cambrian can be given these rocks. They are older than the lower Llandovery age assigned to the Beechhill Cove Formation.

The age of the Browns Mountain Group was given as lower Ordovician, by Williams (1914, p 55). This age is based on the correlation of the James River Formation iron beds with those of Wabana in Newfoundland. This correlation is based on Obulus (Lingulobus) spissa, determined by Schuchert (Williams 1914, p 55). This fossil is also present in the Newfoundland beds which are of lower Ordovician age. The attempt at correlation was doubtless influenced by the similar lithologies.

The only other evidence bearing on the age of the Browns Mountain Group is the presence of fossiliferous rocks of Ordovician age at the end of Cape George, in Antigonish County (Boucot, Fletcher, and Griffin, 1959). The rock type is unlike any seen or described in the Browns Mountain Group. Nevertheless, the existence of sedimentary rocks of Ordovician age, in this area, is definitely established.

UPPER CONTACT

The banded argillities, shales, and slates of the lower Browns Mountain Group conformably underlie the Bear Brook Formation. In the single observed exposure of the contact, it is seen to be transitional as well as conformable. At the contact, beds of banded argillite alternate with medium grained, tuffaceous sandstone. These beds vary from about 3 inches to 3 feet in thickness, and the zone of alternation is at least 100 feet thick.

This upper contact exposure is on the East French River about 1.5 miles south of Rte. 4.

Areal mapping throughout this area south of Rte. 4, particularly between French River and Barneys River, gave additional evidence of the conformable nature of the contact.

Bear Brook Formation

NAME AND DEFINITION

The Bear Brook Formation of Fletcher (1886, p 18) is a mappable unit throughout northeast Pictou County, and is lithologically similar to the Stewart Brook Formation of Bell (1940, p 6) and the Malignant Cove Formation of Williams (1914, p 27) in Antigonish County.

The Bear Brook Formation was named for the tributary of Barneys River in eastern Pictou County, 600 yards east of Barneys River Station.

The Stewart Brook Formation was named for Stewart Brook in Pictou County, 4 miles southeast of New Glasgow. The type section is located on a tributary of Marsh Brook, about 1.4 miles east of McLellan Brook settlement. These rocks are exposed here for only about 400 feet along the brook. Bell (1940, p 6) noted its lithologic similarity to the sedimentary rocks of the Malignant Cove Formation.

The Malignant Cove Formation was named for Malignant Cove in Antigonish County on the Northumberland Strait. The only section is located on Malignant Cove Brook where it flows into the cove.

Rocks of the Bear Brook Formation are not found in Bear Brook, and no satisfactory type section was defined. In addition, this formation name has not gained usage. The name Malignant Cove Formation has been used only by geologists working in Antigonish County for the same rocks that originally were tentatively placed in the Bear Brook Formation. The name Stewart Brook

Formation has not been used outside of its original small area of definition. For these reasons, it is proposed to more clearly define this important rock unit. The name Bear Brook Formation is retained, and it is suggested that the names Malignant Cove Formation and Stewart Brook Formation be abandoned as they are synonymous with the Bear Brook Formation. The latter name has precedence over the others. The formation was named for the tributary which flows southwestward into Barneys River and joins the latter stream 600 yards due east of Barneys River Station.

The Bear Brook Formation is that series of flows, tuffs, and derived sediments that underlies the fossiliferous Silurian Beechhill Cove Formation and overlies the banded slates and quartzites of the older Browns Mountain Group in Antigonish and northeastern Pictou Counties.

TYPE SECTION

The type section for the Bear Brook Formation is on Wallace Brook about 3/4 mile east of Meiklefield Schoolhouse, and on a tributary of Wallace Brook which flows northwest and joins Wallace Brook less than ½ mile upstream from the junction of the latter stream with the French River. Meiklefield Schoolhouse is shown on National Topographic Series Sheet 11 E/9 West Half.

The type section begins at the base of the Beechhill Cove Formation sandstones on Wallace Brook, 750 feet upstream from the junction of Wallace Brook and the French River. It extends upstream and up the tributary, referred to above, to the limit of outcrop. The lower contact is not exposed at the type section.

The upper contact, with the Beechhill Cove Formation, and part of the section, are repeated through the action of a fold that carries this contact back into Wallace Brook 1900 feet upstream of the point where the above mentioned tributary enters Wallace Brook.

The Bear Brook Formation is characterized by rapid and significant lateral changes in lithology. Wallace Brook and its tributary provide the longest, nearly continuous, section of this unit, and display most of the rock types that represent this formation.

THICKNESS

The total thickness of these rocks at the type section is 2750 feet, with no lower contact present. At the western end of this area on the Sutherland River 1000 feet of these rocks are present, and again no lower contact is present.

On the East French River a thickness of the full section can be calculated. Here the lower contact is present, and the upper contact can be estimated closely. Outcrops of the Bear Brook Formation are not continuous on the East French River, but no evidence of loss or repetition of section was observed. A thickness of 2400 feet was calculated.

At Arisaig, to the east, in Antigonish County, a maximum of 910 feet of volcanics are exposed (Zeigler 1958, unpubl.) representing the Bear Brook Formation. Again, no lower contact was observed, and this figure is only a minimum for the formation thickness.

DESCRIPTION

In two areas the Bear Brook Formation is represented by flows and tuffs. Between these two areas, and in the regions beyond them, the formation is represented by tuffaceous sandstones, arkosic sandstones, and conglomerates.

Arisaig, in Antigonish County, is one of these two areas in which the Bear Brook Formation is present in the form of flows and tuffs. The volcanics that underlie the Silurian sedimentary rocks at this locality have never been adequately described or interpreted in the literature. Twenhofel (1909, p 159) established the volcanic origin of the rhyolitic, upper portion of these rocks. The lower, andesitic portion of the volcanics was still referred to as an intrusive of Mississippian age by Williams (1914, p 35). Zeigler (1958, unpubl.) made a detailed study of the volcanics at Arisaig, and the following description is based primarily on his work.

The uppermost unit at Arisaig is a welded rhyolitic tuff of a maximum thickness of 275 feet. Below this is a red ash bed 10 to 12 feet thick and fairly persistent. Below this is a rhyolite, displaying flow structures and including some tuffs. The maximum thickness of this unit is 225 feet. Below this lies a series of at least 10 andesite flows ranging from 7 or 8 feet to 100 feet in thickness and usually separated by ash beds that vary from 1 foot to 4 or 5 feet in thickness. This series has been measured as thick as 400 feet, but no lower contact is observed.

The second area in which the Bear Brook Formation is represented by blows and tuffs is the area from Parks Falls on the west, to a tributary of the French River near the French River Meiklefield Road on the east. This area includes the type section at Wallace Brook near its eastern limit. In this area an upper series of andesitic flows is present. The total thickness of these varies. At MacPhersons Mills, on the Sutherland River, the thickness is at least 25 feet, but no more than 100 feet. Only one half-mile downstream at Parks Falls the andesitic rocks are at least 100 feet, but no more than 250 feet thick. At the type section there are 170 feet exposed. These andesitic flows are sometimes porphyritic with feldspar phenocrysts about 1/16 inch in size, and occasionally are amygdaloidal with calcite amygdules.

At the top of the formation in Wallace Brook, in contact with the overlying Beechhill Cove Formation, there are 6 feet of cream colored felsites and ash beds. These are presumably of rhyolitic composition. These light colored igneous rocks are not seen farther upstream in Wallace Brook, where the Bear Brook Formation is almost in contact with the Beechhill Cove Formation again, nor are they present at MacPhersons Mills or Parks Falls.

Below the andesites lies a thick series of rhyolites, rhyolitic tuffs, tuffaceous sandstones, and conglomerates. Some of the rhyolites are also porphyritic with 1/16 inch phenocrysts of quartz and feldspar. The conglomerates range to very coarse with boulders 3 feet in diameter. The sandstones are often coarse grained and both they and the conglomerates show some graded bedding. These various rock types are repeated in a seemingly random order and are, in places, intruded by dikes of andesite porphyry.

In the remaining areas of northeast Pictou County, sedimentary rocks are present in the same stratigraphic position. These are tuffaceous sandstones and conglomerates, with occasional andesitic flows.

TABLE 3

BEAR BROOK FORMATION

THIN SECTIONS

SAMPLE NO.	ROCK TYPE	SAND AND SILT SIZE GRAINS						MATRIX
		Quartz	Altered Feldspar	Lithic Fragments	Hematite	Magnetite	Leucoxene	
ST 4	sandstone	15%	15% incl. andesine	45%(feldspar laths in hematite groundmass)	2%	2%	1%	20% incl. hematite
PF 17	sandstone	10-20%	20-30%	30-40% (same as above)	2	1	trace	20 incl. abundant hematite
RD 1	sandstone	15	40	20(same as above plus rhyolite and quartzite)	trace	10-20 in some layers	1	20 incl. hematite

No differential thermal analyses were made of samples from the Bear Brook Formation.

No x-ray diffraction studies were made of samples from the Bear Brook Formation.

No chemical analyses were made of samples from the Bear Brook Formation, hence, no calculations of quantitative mineralogic composition were made.

The samples in Table 3 above are typical of the tuffaceous sandstones of the Bear Brook Formation.

The dominant clastic particles are fragments of flow rocks, both felsites and trap rocks. These comprise about 50% the clastic grains. Weathered feldspar grains make up about 35% of the rock, with orthoclase and andesine having been identified. Only about 15% of the rock consists of quartz or quartzite grains. The matrix is rich in hematite, imparting to these rocks their characteristic red colors. Mica is rare or absent, but minor calcite may be present. These rocks are characterized by red and purple color, but may weather to a nearly white color. There is occasional regrowth of the quartz.

The grains are generally very angular, but range in shape to sub-rounded. Occasional grains of devitrified glass with perlitic structure were observed and some of the feldspar were euhedral crystals.

AGE

The age of the Bear Brook Formation is uncertain. It lies conformably above the older Browns Mountain Group and disconformably below the Silurian Beechhill Cove Formation. No fossils have been found in the Bear Brook Formation. This is not surprising in view of its volcanic and coarse clastic nature. The overlying Beechhill Cove Formation is of lower Llandovery age. The underlying rocks may be as old as Cambrian.

UPPER CONTACT

The Beechhill Cove Formation overlies the Bear Brook Formation disconformably. In Pictou County the contact is exposed only in the Wallace Brook section where sandstones rest on a series of ash beds and felsites.

Here the two formations are seen to be parallel, but the contact is not extensive. At Arisaig, the uneven nature of the contact can be observed, and a 1 foot bed of conglomerate, containing transported rhyolite pebbles, is locally developed in Doctors Brook. (Williams 1914, p 63). Mapping in the area between French River and Barneys River south of Rte. 4, and in the Parks Falls-MacPhersons Mills area, gave further indication of the lack of an angular break between these two formations in Pictou County. Mapping by the author, and by Zeigler (1958, unpubl.) between the pier at Arisaig and Doctors Brook, on the Northumberland Strait, indicated the same relationship in Antigonish County.

Arisaig Series

The Arisaig Series was defined by Williams (1910). He described the section along the shore of Northumberland Strait in the vicinity of the village from which the series takes its name. It includes the Beechhill Cove Formation[1], Ross Brook Formation, McAdam Formation, Moydart Formation, and the Stonehouse Formation. To this, the present author proposes to add the French River Formation, present only in Pictou County, where it is found immediately above the upper Ross Brook Formation. It has been faulted out of the shore section and the Arisaig Brook section in the Arisaig area. At both these places a fault is seen between the upper Ross Brook Formation and the overlying McAdam Formation. It is believed to exist in this area because a characteristic fossil of the French River Formation was found on the beach as a pebble.

1. McLearn (1924, p 7) in reporting on Williams(1914) stratigraphy erroneously referred to the Division I Beechhill Cove Formation as the Beechhill Formation, and then used the latter term throughout his report.

This is Eospirifer stonehousensis of McLearn (1924, p 84) which, as the specific name implies, was incorrectly assigned to the Stonehouse Formation. This error was made because the single specimen had been found at the base of a cliff of rocks of the Stonehouse Formation.

It should be noted, also, that the highest beds of the Stonehouse Formation, immediately underlying the Devonian Knoydart Formation, are not exposed in the Arisaig area, and, hence, have not previously been described.

Published studies of the Silurian rocks at Arisaig have presented different subdivisions. A comparison of these divisions with one another, and with that used by the present author, is presented in Table 4. The boundaries of the stratigraphic units described by Dawson (1868, 1891) and Ami (1900) were not clearly defined and have been so shown in the table.

The units of Fletcher's stratigraphic sequence are described by thickness. Since the section at Arisaig is cut by many faults, whose displacements are difficult or impossible to determine, there exists some doubt about the position of Fletcher's boundaries with respect to the stratigraphic successions of the other authors. The detailed subdivision established by Twenhofel (1909, p 148) is based on faunal zones. Nevertheless, the division boundaries (formation boundaries), except for that between his Divisions III and IVa (McAdam and Moydart formations), are also distinct lithologic boundaries. Twenhofel (1909, p 151-156) gave thicknesses and a general description of each of his zones. No mention was made of the abundance of faults and difficulty of determining thickness, hence, the correlation shown in Table 4 is based on descriptions. Accordingly, the boundary between the middle and upper members of the Ross Brook Formation lies somewhere within Twenhofel's zones 7 and 8, but cannot be more closely correlated. Williams (1914, p 62) adopted Twenhofel's division boundaries exactly, having accompanied Twenhofel on a traverse of the section. The zones of Williams are merely combinations of the more numerous zones of Twenhofel. McLearn (1924, p 8) followed the divisions established by Twenhofel with the possible exception of the McAdam-Moydart Formation boundary. The thickness of 380 feet for the McAdam Formation given by McLearn (1924, p 12) agrees with that of Twenhofel (1909, p 155), whereas the description by McLearn (1924, p 11) omits the greenish gray argillaceous sandstones of zone 26 and 27 of Twenhofel (1909, p 155). The boundary of the McAdam and Moydart Formations of McLearn, as shown in Table 4, is based on his rock descriptions. Hence, this boundary correlates with that used by the present author. McLearn (1924, p 8-15) presented still another set of faunal zones. The correlations shown in Table 4 are based primarily on the rock descriptions of McLearn's subdivisions.

TABLE 4 - ARISAIG SERIES

MAEHL 1960	McLEARN 1924	WILLIAMS 1914	TWENHOFEL 1909	AMI 1900	FLETCHER 1886	DAWSON 1868, 1891	HONEYMAN 1864
		Uppermost beds are not exposed at Arisaig					
STONEHOUSE FM.	STONEHOUSE FM. zone a,b,c	STONEHOUSE FM. DIV. V zone 11,12	STONEHOUSE FM. DIV. IVb zone 33-40	STONEHOUSE FM.	LOWER HELDERBERG E 6	UPPER	D
upper member	zone b	zone 10	zone 32	MOYDART FM.	RED STRATUM	ARISAIG	RED STRATUM
MOYDART FM. lower member	MOYDART FM. zone a	DIV. IV MOYDART FM. zone 9	DIV. IVa MOYDART FM. zone 28-31				
			Zone 26,27				
upper member	zone c	zone 8	zone 22-25	McADAM FM.	NIAGARA	LOWER	
McADAM FM.	McADAM FM.	DIV. III McADAM FM.	DIV. III McADAM FM.				
lower member	zone a,b	zone 5,6	zone 13-21				
FRENCH RIVER FM.		not observed at Arisaig			not observed at Arisaig		
upper member	zone e	zone 4	zone 9-12	ARISAIG FM.	UPPER CLINTON	ARISAIG	B^1
	zone d	zone 3	zone 7,8				
ROSS BROOK FM. middle member	ROSS BROOK FM. zone b,c	DIV. II ROSS BROOK	DIV. II ARISAIG FM. zone 3-6				
		zone 2					
lower member	zone a		zone 2		LOWER CLINTON		B
BEECHHILL COVE FM.	BEECHILL COVE FM.	DIV. I BEECHILL COVE FM. zone 1	DIV. I zone 1		MEDINA E_1		A (incl. rhyolites below)

Beechhill Cove Formation

NAME AND DEFINITION

The Beechhill Cove Formation was defined by Williams (1914, p 63) and named for the Beechhill Cove on the Northumberland Strait between Arisaig and Malignant Cove.

TYPE SECTION

The type section is at the eastern end of this cove. The lower contact is not exposed here; it lies under water to the north. The upper contact lies above water on the shore and is marked by the abrupt end of the hard, argillaceous quartz sandstones of this formation and the beginning of the black shale and mudstone of the lower Ross Brook Formation.

THICKNESS

The thickness at the type section is given as a minimum of 160 feet (Twenhofel, 1909, p 149), and 200 feet are present in a complete section a short distance to the east at Doctors Brook (Williams, 1914, p 63).

This formation is relatively well exposed in northeast Pictou County. Its thickness is seen to vary from a minimum of 50 feet in the area between Parks Falls and MacPhersons Mills to a maximum of 240 feet on Wallace Brook. The best section in Pictou County is in Wallace Brook, a tributary of the French River 2 miles south of Rte. 4.

DESCRIPTION

The Beechhill Cove Formation in Pictou County consists of hard, mostly well-bedded, greenish and bluish gray, argillaceous sandstones and siltstones, and of more massive bluish gray indurated mudstones.

The sandstones and siltstones are present in resistant beds from 1 inch to more than 1 foot thick, and in massive strata several feet thick.

These rocks are greenish or bluish gray on a fresh surface, but weather to a light greenish gray near the weathering surface, and to a tan gray at the surface.

The mudstones of this formation are only slightly less resistant, but lack the well-defined bedding of the sandstones and siltstones. Most are bluish gray, weathering to a medium gray at the surface.

A few fossiliferous living sandstones are present. These weather to a friable red-brown sandstone.

On the East French River south of Rte. 4, a 1 foot bed of quartz pebble conglomerate is present near the base of the Beechhill Cove Formation.

The lowest beds are resistant sandstones or siltstones.

With the exception of the quartz pebble conglomerate, described above, the size of the grains is not greater than fine sand. In the sandstones and siltstones the grains fall into two general size ranges. A histogram of the grain size frequency distribution would be bimodal with the coarser grains, falling into one or two grades on the Wentworth scale in the fine-sand-fine-silt range, and the remainder falling into the clay sizes. Most of the coarser particles are angular, but the range includes sub-angular and sub-rounded.

No studies by x-ray diffraction were made of samples from the Beechhill Cove Formation.

TABLE 5

BEECHHILL COVE FORMATION

THIN SECTIONS

SAMPLE NO.	ROCK TYPE	SAND AND SILT SIZE GRAINS						MATRIX
		Quarts	Weathered Feldspar	Muscovite	Biotite	Chlorite	Leucoxene	
DW 2	mudstone	15%	30%	1%		1%	1%	50% incl. abundant chlorite
DW 6	sandstone	30	35	2	trace			30% incl. muscovite and chlorite
Z 1	sandstone	70	15	1	trace			15
O 49	sandstone	35	30	1	trace			35 incl. chlorite

DIFFERENTIAL THERMAL ANALYSIS

SAMPLE	ROCK TYPE	Chlorite and/or Kaolinite	Quartz	Iron Oxides	Pyrite	Calcite
DW 2	mudstone	l.	m.			
Basal*	sandstone	s.	l.	present		
C 1,2*	sandstone	s.	l.	present		
PF 20	sandstone	s.	l.		trace	
PF 21A	sandstone	s.	l.	present		
FB 4	sandstone	v.s.	l.			
WB 136	sandstone	m.	l.			

(E)

* Samples from Arisaig, Antigonish County.

CHEMICAL ANALYSIS

PF 21 a

SiO_2	80.9
Al_2O_3	9.02
Fe_2O_3	1.56
FeO	1.89
MnO	0.01
TiO_2	0.48
P_2O_5	0.06
K_2O	1.67
Na_2O	1.17
CaO	0.00
MgO	0.61
H_2O	2.01
TOTAL	99.4

CALCULATED MINERALOGIC COMPOSITION

	Quartz	Albite	Muscovite	Kaolinite	Chlorite
PF 21a	65.2%	10.0%	14.2%	2.0%	5.4%

The calculated mineral percentages for sample PF 21a were arrived at by the method presented under PETROGRAPHY. Sample PF 21a is one of the more quartzose of the Beechhill Cove Formation sandstones, as determined by hand specimen and binocular microscope.

It may be concluded that the sandstones and siltstones of the Beechhill Cove Formation are composed of up to 85% sand and silt size grains, including 30%-70% quartz. The remainder of these coarser grains are predominantly altered feldspar, muscovite, which, in this form, make up 1 or 2% of the total rock, and trace amounts of biotite. As much as 35% of the rock consists of argillaceous matrix containing kaolinite, muscovite, and chlorite. The presence of almost 0.5% TiO_2 suggests the presence of leucoxene, such as was detected in larger amounts in most of the thin sections of rocks of the Arisaig Series.

The mudstones differ in composition in having less sand and silt size grains of quartz, and more clay matrix. The clay makes up about 50% of the mudstones.

FAUNA

The following fossils were identified from the Beechhill Cove Formation. A list of fossils by locality is included in Appendix 2.

Cornulites sp.
Eostropheodonta sp.
large dalmanellid
dalmanellid
linguloid
rostrospiroid, *Meristina* (?)
rhynchonellid
strophomenoid
horn coral
crinoid
orthoceroid
snail
pelecypod

AGE

The age of the Beechhill Cove Formation is lower Llandovery (lower Silurian) as indicated by the presence of the brachiopod, *Eostropheodonta* sp.

UPPER CONTACT

At Arisaig, the contact of the sandstones of the Beechhill Cove Formation, with the black shales of the lower member of the Ross Brook Formation, is sharp. The difference in age from lower Llandovery (Beechhill Cove Formation) to upper Llandovery (lower Ross Brook Formation) indicates the presence of a disconformity.

In Pictou County, the only exposure of the contact is on the East French River 3 miles above the confluence of this stream with the French River, and 3/4 mile north of Rte. 4. Here the Beechhill Cove sandstones are overlain by the lower member of the Ross Brook Formation. At this locality the lower member is different in lithology from the type section, being composed of a series of well-bedded mudstones. The contact is sharp, but the lithologic change is not as striking as at Arisaig. The overlying mudstones differ from the Beechhill Cove Formation in being slightly less resistant, less sandy, and in weathering to a lighter color.

Ross Brook Formation

NAME AND DEFINITION

The Ross Brook Formation, defined by Williams (1914, p 64) and named for the brook just west of the village of Arisaig, is exposed along the shore of the Northumberland Strait between the mouth of Ross Brook and a fault zone 300 yards west of the mouth of Smith Brook, and on Arisaig Brook from the shore south to a fault 100 feet downstream from the prospecting tunnels in the hematite bed. It can be subdivided lithologically into three mappable units, referred to, hereinafter, as the lower, middle, and upper members.

THICKNESS

A thickness of 833 feet was given by Twenhofel (1909, p 148), who recognized that some of the section was missing, due to faulting. In Pictou County a nearly complete section totaling 1200 feet is present along the French River.

The lower member at Beechhill Cove is about 100 feet thick at only one locality, on the East French River, where it is 84 feet thick. The lithology is different from that at the type section, and is described below.

On the French River, 330 feet of the middle member are exposed, and another 120 feet of covered section are present below this. This member corresponds approximately to zones 3-7 of Twenhofel (1909, p 150) reported to be 205-305 feet thick.

The upper member, in Pictou County is 750 feet thick in the French River. The upper contact is faulted out at Arisaig. Hence, the remaining 500-600 feet of Twenhofel's measured section is a minimum figure.

DESCRIPTION

Lower Member

The lower member of the Ross Brook Formation in the Arisaig area is composed of black mudstones and shales. At least 13 thin ash and tuff beds are present in the lowest 60 feet at Beechhill Cove.[1] Some of the shales are paper thin and contain graptolites.

This lithology is not observed in Pictou County. At one locality, on the East French River north of Rte. 4 about 3 miles upstream from the confluence of this stream with the French River, 84 feet of greenish gray,

1. F. Zeigler, personal communication, May 9, 1960.

slightly calcareous mudstones, well-bedded in layers of 1 to 6 inches, lies immediately above typical Beechhill Cove Formation rocks, and immediately below typical rocks of the middle member of the Ross Brook Formation. This series of mudstones contains two tuff beds about 1½ inches thick and thus may be correlated with the lower member of the Ross Brook Formation at Beechhill Cove. The Beechhill Cove Formation present below this anomalous series of mudstones is as thick as any found in the area, hence, there is no reason to place the mudstones in that formation.

On the French River, just downstream of the point where Wallace Brook enters, a 1/8 inch layer of ash is found in typical rocks of the middle member of the Ross Brook Formation, near the base of this unit. If this ash bed is correlated with those of the lower Ross Brook Formation, then the lower member is seen to have been wedged out by the middle member at this location. The lower member is exposed in Pictou County only at the East French River locality.

Middle Member

The middle member of the Ross Brook Formation is characterized by massive, cleaved, bluish gray mudstones, which weather subaerially to an orange or reddish brown, and underwater to grayish yellow or black.

Interbedded with these are some beds of resistant sandstone and siltstone, usually 1½-2 inches in thickness, but ranging up to 6 inches, which often furnish the only evidence of the bedding. These beds are bluish gray, argillaceous, fine grained, sandstones and siltstones. A few of the sandstones are a purplish color and contain abundant muscovite parallel to the bedding. The lower parts of some of these sandstone and siltstone beds are the sites of layers or lenses of fossils. These resistant beds locally comprise 10-15% of the thickness, but usually much less. They generally increase in frequency and thickness going upsection.

TABLE 6

ROSS BROOK FORMATION
MIDDLE MEMBER

THIN SECTIONS

SAMPLE NO.	ROCK TYPE	SAND AND SILT SIZE GRAINS					MATRIX
		Quartz	Altered Feldspar	Muscovite	Leucoxene	Pyrite	
DF 55	mudstone	10%	20%	7-8%	2-3%	trace	60% incl.Chlorite

DIFFERENTIAL THERMAL ANALYSIS

SAMPLE	ROCK TYPE	Chlorite and/or Kaolinite	Quartz	Iron oxides	Pyrite	Calcite
CB	sandstone	l.	l.	present		
DF 63	mudstone	l.	m.			
ES 3	mudstone	m.	m.		trace	
MI 7	mudstone	l.	m.			
DF 65a	ash bed	l.	s.			

X-RAY DIFFRACTION

SAMPLE	ROCK TYPE	Quartz	Feldspar	Muscovite	Chlorite
DF 65a	ash	v.s.	two(?)both s.	m.	m.
DF 63	mudstone	*	*	*	s.?

*Powder photograph not comparable with intensities obtained from diffractometer.

CHEMICAL ANALYSES

	DF 65a (ash)	DF 63 (mudstone)
SiO_2	49.2	58.7
Al_2O_3	25.2	20.6
Fe_2O	2.79	1.86
FeO	3.73	4.61
MnO	0.04	0.02
TiO_2	1.90	1.09
P_2O_5	0.69	0.17
K_2O	3.81	3.75
Na_2O	0.97	0.98
CaO	0.83	0.17
MgO	1.60	1.32
H_2O	6.80	5.48
TOTAL	97.6	98.8

CALCULATED MINERALOGIC COMPOSITION

	Quartz	Albite	Muscovite	Kaolinite	Chlorite
DF 63 (mudstone)	29.5%	8.3%	31.8%	12.2%	12.8%
DF 65a (ash)	14.7	8.2	32.3	23.5	11.8

The low total of the analyses for sample DF 65a indicates either that other components are present (possibly CO_2, S, SO_4) or the accuracy of one or more of the analyses is poor.

The rather low value (98.8%) for the total of the analyses of sample DF 63 again suggests either the presence of some other component or inaccuracy in the analysis.

From all available evidence, the mudstones of the middle member may be described as being composed of about 35% silt size grains and 65% argillaceous matrix. The silt size grains consist of quartz, altered feldspar, and muscovite, plus minor leucoxene, and, in some cases, pyrite. As in all the samples analyzed, for which thin sections are available, the SiO_2 content is greater than that of observed grains of quartz. The excess of silica is probably due, in part, to clay size detrital grains of quartz and, in part, to some form of silica resulting from the alteration of the feldspars. The matrix includes, in addition to some form of SiO_2, chlorite, muscovite, and kaolinite.

A sample of the interbedded sandstones is included in the D.T.A. data above. These sandstones are similar to those of the upper member. Detailed descriptions may be found under that unit, which apply as well to the sandstones and siltstones of the lower member.

Upper Member

The upper member is characterized by interbedding of sandstones and mudstones. This is distinctive because the sandstones (sometimes siltstones), like those of the middle member, are hard, resistant, and well-bedded, while the interbedded mudstones are less resistant and massive. Cleavage is developed in many of the mudstones.

The base of the upper member is arbitrarily defined as the first resistant bed greater than 6 inches in thickness. From this point upward the resistant beds everywhere comprise more than 10% of the total thickness. The proportion of resistant beds is about 15-20% of the total, just above the contact with the middle member. Upsection, this percentage increases to 50%, and then varies irregularly in the top half of the member from 15-80%, locally, but averages about 50% of the total.

The resistant beds are bluish gray, weathering to tan gray, argillaceous, quartz sandstones and siltstones. Some display fine bedding and some show small scale cross bedding as well. Some of the bedding surfaces are very micaceous. The beds range in thickness from 1 inch to $1\frac{1}{2}$ feet; however, most are from 2 to 8 inches thick.

The mudstones are bluish gray, weathering to a medium gray. The majority are relatively soft and lack bedding. Many display cleavage generally transverse to the bedding. A smaller proportion consists of a more quartzitic, sandy mudstone. This rock type is intermediate between the two major types described above.

A few of the resistant sandstones contain abundant fossils, predominantly brachiopods. These beds contain calcite in their matrix in addition to that in the remaining original shell material.

TABLE 7

ROSS BROOK FORMATION

UPPER MEMBER

THIN SECTIONS

SAMPLE NO.	ROCK TYPE	SAND AND SILT SIZE GRAINS					MATRIX
		Quartz	Altered Feldspar	Muscovite	Leucoxene	Limonite	
DF 32	sandstone	45%	30%	2%	1%	2-3%	20% incl.chlorite
DF 3	mudstone	15%	35%	5%	1%		45%

DIFFERENTIAL THERMAL ANALYSIS

SAMPLE	ROCK TYPE	Chlorite and/or Kaolinite	Quartz	Iron oxides	Pyrite	Calcite
DF 1	sandstone	v.s.	m.		trace	
ES 1Ac	sandstone	m.	l.			
DF 39c	sandstone	s.	m.			
ES 1Af	mudstone	m.	m.	present		
DF 39f	mudstone	l.	s.			
DF 3	sandstone	s.	m.			

No X-ray diffraction studies were made of samples from the upper member of the Ross Brook Formation.

CHEMICAL ANALYSES

	ES1Ac (sandstone)	ES1Af (mudstone)
SiO_2	67.5%	62.3%
Al_2O_3	15.8	18.7
Fe_2O	2.54	2.85
FeO	3.85	3.37
MnO	0.03	0.03
TiO_2	1.00	1.08
P_2O_5	0.10	0.13
K_2O	2.98	3.76
Na_2O	0.91	1.07
CaO	0.14	0.01
MgO	1.16	1.35
H_2O	4.03	4.72
TOTAL	100.0	99.4

CALCULATED MINERALOGIC COMPOSITION

SAMPLE	ROCK TYPE	Quartz	Albite	Muscovite	Kaolinite	Chlorite
ES 1Ac	sandstone	44.3%	7.7%	25.3%	7.6%	10.7%
ES 1Af	mudstone	35.2	9.1	31.9	7.8	10.4

The above values were calculated by the method described under PETROGRAPHY.

From all the data above, it may be seen that the resistant beds are composed of about 75% sand or silt size grains, and 25% clay matrix. Quartz grains account for about 40-45% of the rock, and altered feldspar grains for another 20-30% of the rock. In addition, about 2% of the rock is composed of muscovite grains of this size and 1% of leucoxene. Kaolinite, chlorite, limonite, and muscovite are present in the matrix.

The mudstones vary in composition. Sample ES 1Af is from one of the more silty mudstones. From the calculations above, it would appear that only about 50% of the rock is clay matrix, the remainder being composed of quartz and altered grains of feldspar. The more argillaceous mudstones, such as Sample DF 39f, contain less quartz and more clay minerals.

FAUNA

The following fossils were identified from the middle member of the Ross Brook Formation. A list of fossils by locality is included in Appendix 2.

Cornulites sp.
Calymene sp.
Atrypa reticularis
Brachyprion sp.
Chonetes sp.
Coelospira hemisphaerica
Pholidostrophia sp.
Plagiorhyncha cf. *P. glassi*
Resserella elegantula
Stropheodonta sp.
dalmanellid
linguloid
inarticulate
fine ribbed rhynchonellid
small rhynchonellid
Favosites sp.
conularid
crinoid

graptolite

Tentaculites sp.

Platyceras sp.

gastropod other than *Platyceras*

The following fossils were identified from the upper member of the Ross Brook Formation. A list of fossils by locality is included in Appendix 2.

trilobite

"*Camarotoechia llandoveriana* var. *rossonia*" McLearn

Chonetes sp.

Leptaena rhomboidalis

Plagiorhyncha glassi

Protomegastrophia (?) sp.

Resserella sp.

dalmanellid

small rhynchonellid

rostrospiroid

crinoid

Tentaculites sp.

Pterinea sp.

orthoceroid

AGE

The age of the lower member is lowest upper Llandovery (upper lower Silurian). O. T. Jones (1926, p 123) correlated these beds with the *Monographtus sedgwicki* zone of the upper Llandovery on the basis of the graptolites *M. tenuis*, *M. nuclus*, *M. jaculum*, *Glyptograptus serratus*, and *Climactograptus scalaris*.

The age of the middle and upper members is upper Llandovery (upper lower Silurian) on the basis of the brachiopod Coelospira hemisphaerica, found throughout both members.

UPPER CONTACT

The upper contact of the Ross Brook Formation is exposed on the French River, about 1050 feet south of Route 4. The overlying French River Formation is present on the axis of a syncline cut transversely by the French River. To the north of the synclinal axis, the French River Formation is conformably in contact with the upper member of the Ross Brook Formation.

French River Formation

NAME

The author proposes the name French River Formation for those beds conformably overlying the upper Ross Brook Formation on the French River south of Route 4. The French River crosses Route 4, 10 miles east of New Glasgow.

TYPE SECTION

The type section for the French River Formation is located on the river of that name beginning 1050 feet south of the Route 4 bridge, and continuing another 2050 feet to the south.

THICKNESS

At the type section and only exposure of the French River Formation, a thickness of 175 feet is present. No upper contact is present, hence, this is a minimum figure for the formation.

DESCRIPTION

The French River Formation consists of a series of blue gray and purplish gray, argillaceous, fine grained sandstones, and blue gray and green gray sandy mudstones. These rocks weather to gray and green gray. They are gradational in composition from very argillaceous sandstone to sandy mudstone. They display irregular bedding planes 1 to 4 inches apart and, in many beds, irregular fractures perpendicular to the bedding. The sandstones and some of the mudstones are micaceous.

Concretions are present in sandy mudstones near the base of the formation and in a zone 4 feet thick, about 20 feet below the highest exposed bed. In the former horizon, the concretions are black, non-limy, and in the shape of prolate spheroids, up to 2 inches in greatest dimension. The concretions in the upper horizon are of gray sandy mudstone, similar to the surrounding rock, and are in the shape of flat ellipsoids lying parallel to the bedding planes. They are as large as 6 inches long by 2½ inches wide by 1 inch thick.

A conspicuous feature of this formation is the abundant and distinctive fauna, present particularly in the upper half of the formation. Important elements of this fauna include Striaespirifer stonehousensis, Eatonioides sp., linguloids in vertical position, and relatively abundant large homalonotid fragments.

No x-ray diffraction studies or chemical analyses were made of samples from the French River Formation. The sandstones appear similar to the more micaceous and argillaceous horizons of the Ross Brook Formation, and are assumed to be nearly identical in composition.

TABLE 8

FRENCH RIVER FORMATION

THIN SECTIONS

SAMPLE NO.	ROCK TYPE	SAND AND SILT SIZE GRAINS					MATRIX
		Quartz	Altered Feldspar	Muscovite	Leucoxene	Pyrite	
DF 13	siltstone	25%	40%	2%	1%	1%	30%

DIFFERENTIAL THERMAL ANALYSIS

SAMPLE	ROCK TYPE	Chlorite and/or Kaolinite	Quartz	Iron oxides	Pyrite	Calcite
FR 22	sandstone	v.s.	m.		½-1%	

Neither X-ray diffraction nor chemical analyses were made of samples from the French River Formation.

AGE

The French River Formation is of highest Llandovery or of Wenlock age on the basis of stratigraphic position. Diagnostic faunal elements are not present.

FAUNA

The following fossils were identified from the French River Formation. A list of fossils by locality is included in Appendix 2.

Cornulites sp.

homalonotid

Brachyprion (?) sp.

Eatonioides sp.

Leptaena rhomboidalis

Meristina sp.

Orbiculoidea sp.

Resserella sp.

Striaespirifer stonehousensis

two dalmanellids

dalmenitid

linguloid

Pterinea sp.

orthoceroid

bellerophontid

UPPER CONTACT

The contact with the overlying McAdam Formation was not observed in northeast Pictou County. That the McAdam Formation in this area is parallel in attitude to the strata of the French River Formation was indicated by geologic mapping in the area of Telford Brook, south of Route 4, at the village of Telford 8 miles east of New Glasgow, and the brook flowing parallel to Telford Brook ½ mile to the east.

McAdam Formation

NAME

The McAdam Formation was named by Ami (1900, p 203) for the brook of that name which flows into the Northumberland Strait 1½ miles west of Arisaig pier. Williams (1914, p 66) defined the limits of the formation. The formation is present at Arisaig in a section along the shore of the Northumberland Strait from the fault zone west of Smith Brook to the contact with the green beds of the Moydart Formation. This contact is west of the mouth of McAdam Brook. Williams included some of these green beds in his McAdam Formation which was defined on a faunal basis. The present author has chosen the distinct and extensive lithologic change as the formation boundary. The lowest part of the McAdam Formation is not present along the shore due to faulting. It is present in Arisaig Brook, about 1 mile southeast of the shore, however, and includes the "iron ore" bed.

An upper and lower member can be distinguished on a lithologic basis and have been so mapped in Pictou County.

THICKNESS

A figure of 1100 feet for the thickness in the Arisaig area is given by Williams (1914, p 67). The lower contact was recognized to be a fault, making this a minimum thickness. The thickness of this formation in Pictou County is at least 660 feet. A minimum figure is given because the lower contact is not exposed. The complete upper member is present in two sections measuring 150 feet and 120 feet, compared to a figure of 375 feet at Arisaig based on Williams (1914, p 69) descriptions.

DESCRIPTION

Lower Member

The lower member of the McAdam Formation is characterized by interbedding of more resistant well-bedded strata, with less resistant massive strata. Within the lowest 100 feet on Arisaig Brook, a 2½ foot fossiliferous bed of oolitic hematite is present. Reports of earlier workers (Dawson 1881), Lindeman and Bolton (1917) indicate the presence of this bed in northeast Pictou County. Nevertheless, it is not present at either of the two good sections presumably lying below the exposed beds.

At the type section, on the short near Arisaig, the beds of the lower member are massive, gray mudstones up to 1 foot thick, alternating with resistant, well bedded, bluish gray, argillaceous quartz sandstones and siltstones that frequently display fine bedding or cross bedding, and calcareous beds up to 6 inches thick that are sandy, resistant, and well-bedded. The latter may be calcareous, argillaceous sandstones or arenaceous, argillaceous limestones.

In northeast Pictou County, the resistant beds are not calcareous, being bluish gray, argillaceous quartz sandstones and siltstones, which weather to a tan gray. They are $\frac{1}{2}$ inch to 8 inches thick. Thus, the lower member of the McAdam Formation, in this area, closely resembles the upper member of the Ross Brook Formation. The two are distinct in that the percentage of resistant beds in the lower McAdam Formation decreases upsection from as great as 90% of the total near the lowest exposure, to as little as 10% at the contact with the upper member of the McAdam Formation, whereas the percentage of resistant well-bedded strata in the upper member of the Ross Brook Formation increases upsection, as described above.

As in the upper Ross Brook Formation, an intermediate rock type is present at some horizons, but makes up less than 10% of the total thickness of the member.

The fine bedding within the resistant beds is a reflection of grain size differences. Some of the fine grained layers contain up to 10% muscovite. Swirled structures are also present in these laminae.

TABLE 9

McADAM FORMATION

LOWER MEMBER

THIN SECTIONS

SAMPLE NO.	ROCK TYPE	SAND AND SILT SIZE GRAINS						MATRIX
		Quartz	Altered Feldspar	Muscovite	Leucoxene	Hematite	Calcite	
HA 2	sandstone lamina	40%	30%	1%	2%	trace		25% incl. chlorite
HA 2	mudstone lamina	15	20	2	2	trace		60% incl. chlorite
HA 10	sandstone	20	40	2	2		veinlets	35% incl. chlorite
DT 24	sandstone	35	35	1 (locally 5%)	2	trace		30% incl. chlorite

DIFFERENTIAL THERMAL ANALYSIS

SAMPLE	ROCK TYPE	Chlorite and/or Kaolinite	Quartz	Iron oxides	Pyrite	Calcite
HA 5	sandstone	m.	m.			
HA 2	sandstone	s.	m.	present		
DT 26	mudstone	s.	m.			
DT 11	mudstone	m.	m.	present		

X-RAY DIFFRACTION

SAMPLE	ROCK TYPE	Quartz	Feldspar	Muscovite	Kaolinite	Chlorite
HA 2	sandstone	l.	one m. one(?)s.	s.	?	m.

No chemical analyses were made of samples from the lower member of the McAdam Formation.

No chemical analyses were made of samples from the lower member of the McAdam Formation. As a result, no calculations of mineral percentages were made.

The alternating mudstones and sandstones or siltstones of the lower member of the McAdam Formation are seen to be similar to their respective counterparts in the upper member of the Ross Brook Formation. The sandstones and siltstones are composed of 65% to 75% sand or silt size grains, and the remainder of clay matrix. The sand and silt size grains are of quartz, which comprises 20-40% of the total of the rock; altered grains, which appear to have been feldspar, account for 30-40% of the total; and 1 or 2% each of muscovite and leucoxene, and trace amounts of hematite. The matrix consists of chlorite and, probably, kaolinite and muscovite.

The mudstones are composed of almost 66% clay matrix. The remainder is larger grains of quartz and altered feldspar, in approximately equal amounts, plus about 2% each of muscovite and leucoxene, and trace amounts of hematite.

Upper Member

The upper member of the McAdam Formation is characterized by dark gray, almost black, weathered color and the presence of large, septarian, calcareous nodules.

The rocks of the upper member consist of less than 10% of well-bedded blue gray, hard, argillaceous quartz sandstones in beds up to 4 inches thick. Many of these sandstones are micaceous.

The remainder are irregularly bedded, finer grained and less quartzose. These are in ½ inch to 2 inch beds or cleaved into ¼ inch to 1 inch layers. They are gray, weathering to almost black, in color.

Nodules are present throughout this section in Pictou County. The largest observed was 2 feet in diameter by 5 inches thick, and dark gray. Some were light gray, weathering to a buff color. The composition of the largest nodule was determined (#DT 27, pg. 65).

TABLE 10

McADAM FORMATION

UPPER MEMBER

No petrographic thin sections were examined of samples from the upper member of the McAdam Formation.

DIFFERENTIAL THERMAL ANALYSIS

SAMPLE NO.	ROCK TYPE	Chlorite and/or Kaolinite	Quartz	Iron oxides	Pyrite	Calcite
HA 13	mudstone	m.	m.			
DT 27	nodule	s.	m.		1-2%	30% *

X-ray diffraction studies were not made of samples from the upper member of the McAdam Formation.

* Percentage determined by chemical analysis.

CHEMICAL ANALYSIS

DT 27 (nodule)

SiO_2	51.7	
Al_2O_3	6.74	
Fe_2O	0.90	
FeO	4.36	
MnO	0.54	
TiO_2	0.57	
P_2O_5	0.10	
K_2O	0.81	
Na_2O	0.05	
CaO	17.3	30.85 as $CaCO_3$
MgO	1.48	
H_2O	2.11	
TOTAL	86.7	plus CO and S or 100.62 plus S

CALCULATED MINERALOGIC COMPOSITION

SAMPLE NO.	ROCK TYPE	Quartz	Calcite	Albite	Kaolinite	Chlorite	Muscovite
DT 27	nodule	42.6-42.7%	30.4%	0.4%	6.0%	10.4-11.6%	6.8%

The above quantitative mineral composition is of a sample from one of the large nodules and was calculated by the method presented under PETROGRAPHY.

In summary, the large black, limy, septarian nodules are composed of about 40% quartz, 30% calcite, about 11% chlorite, 7% muscovite, 6% kaolinite, 1% to 2% pyrite, and negligible feldspar.

FAUNA

The following fossils were identified from the lower member of the McAdam Formation. A list of fossils by locality is included in Appendix 2.

Cornulites sp.

trilobite

Atrypa reticularis

Amphistrophia funiculata

Chonetes sp.

Chilidiopsis sp.

Isorthis sp.

Leptaena rhomboidalis

Meristina sp.

Resserella elegantula

dalmanellid other than *R. elegantula*

rhynchonellid

schuchertellid

crinoid

Tentaculites sp.

AGE

On the basis of stratigraphic position, the lower member of the McAdam Formation is possibly of Wenlock (middle Silurian) age. It is believed that graptolites from the upper member (collected at Arisaig) indicate a lower Ludlow (lower upper Silurian) age, (Boucot, unpubl. correlation table). Specimens have been sent to Dr. Berry of the U. S. National Museum for positive identification.

UPPER CONTACT

In Pictou County, the Moydart Formation is observed lying on the upper member of the McAdam Formation in Telford Brook, ½ mile south of Route 4, and ½ mile south of Route 4 in the small brook ½ mile to the east of Telford Brook and flowing parallel to it.

No angular difference in the attitudes of the strata of these two formations is present, nor are there any signs of an erosional surface. Nevertheless, a very sharp change in lithology takes place, and this change may indicate a disconformity. The same sharp contact is observed in the Arisaig district.

At Arisaig, a knife edge contact is present between the lower and upper members of the McAdam Formation, which may indicate a disconformity. The contact between the two members is not exposed in Pictou County.

Moydart Formation

NAME

The Moydart Formation, named by Ami (1900, p 203), and defined by Twenhofel (1909, p 155), was named after Moydart Point on the short of Northumberland Strait, two miles west of Arisaig pier. The present author uses the lowest green sandstones and mudstones, above the dark beds of the upper McAdam formation, as the lowest beds of the Moydart Formation. Twenhofel apparently included some of the lowermost green beds in the McAdam Formation. The Arisaig section is along the shore from a point about 300 yards west of McAdam Brook westward to the top of the distinctive "Red Stratum".

THICKNESS

According to Twenhofel (1909, p 155), 379 feet of section are present, the top 32 feet of which comprise the "Red Stratum". In northeast Pictou County, approximately 450 feet of Moydart Formation are present. The "Red Stratum" is exposed in one locality, and is 28.5 feet thick.

DESCRIPTION

With the exception of the "Red Stratum", the Moydart Formation in Pictou County is composed of mudstones, fragmental limestones, sandstones, and siltstones, many of which are calcareous.

The limestones are rare, and some are lenses.

The sandstones are green, hard, fine grained, and quartzose. Many show fine bedding or small scale cross bedding. They vary from well-bedded in ½ inch beds to massive strata several feet thick. Most are micaceous, and in many there has been regrowth of the quartz. Weathered surfaces are green gray, gray, or even bluish gray.

There is a gradation in rock type from these distinctive green sandstones and quartzites through similar siltstones, and less well-bedded green gray and blue gray siltstones to massive bluish soft mudstones.

The hard green sandstones and siltstones predominate, except near the top of the formation, where both mudstones and limestones become more common.

The limestones of this formation are impure and most of them are shell beds or lenses with a calcareous, argillaceous siltstone or sandstone matrix.

Where badly fractured by a nearby fault, as in McLellan Brook, many of the calcareous siltstones have developed veins and irregular areas of finely to coarsely crystalline calcite.

TABLE 11

MOYDART FORMATION

THIN SECTIONS

SAMPLE NO.	ROCK TYPE	SAND AND SILT SIZE GRAINS						MATRIX
		Quartz	Altered Feldspar	Muscovite	Chlorite	Leucoxene	Calcite	
DS 32	sandstone	35%	35%	5%				25% incl. chlorite and abundant calcite
DS 46	siltstone	40	30	4	4%	2%		20 incl. chlorite
DT 30	siltstone	35	35	5				25 incl. chlorite and abundant calcite
DT 32	siltstone	35	25	5		2	veinlets	35 incl. abundant chlorite
HA 14	sandstone	50	25			1-2		20 incl. chlorite

DIFFERENTIAL THERMAL ANALYSIS

SAMPLE NO.	ROCK TYPE	Chlorite and/or Kaolinite	Quartz	Iron oxides	Pyrite	Calcite
HA 20	sandstone	s.	m.			
DT 35	sandstone	s.	m.			
DT 30	sandstone	s.	m.		1%	
R 2	siltstone "Red Stratum"	m.	m.	present		
RS *	nodule "Red Stratum"	m.	m.	present		45-50%

X-RAY DIFFRACTION

SAMPLE NO.	ROCK TYPE	Quartz	Feldspar	Kaolinite	Muscovite	Chlorite
DT 35	sandstone	l.	one v.l., one s.	?	m.	m.

CHEMICAL ANALYSIS

DT 35 (sandstone)

SiO_2	74.0
Al_2O_3	11.9
Fe_2O_3	1.91
FeO	2.42
MnO	0.03
TiO_2	1.07
P_2O_5	0.16
K_2O	2.16
Na_2O	2.44
CaO	0.26
MgO	1.43
H_2O	2.12
TOTAL	99.9

CALCULATED MINERALOGIC COMPOSITION

SAMPLE NO.	ROCK TYPE	Quartz	Orthoclase	Albite	Muscovite	Chlorite
DT 35	sandstone	48.3%	1.5%	20.7%	16.2%	8.5%

The above quantitative mineralogic composition was calculated by the method presented under PETROGRAPHY.

The sandstones and siltstones contain 35-50% quartz, plus 25-35% altered feldspar and up to 5% muscovite in sand or silt size grains. The matrix comprises 20-35% of the rock, and is composed of chlorite, muscovite, and, in some, calcite. Leucoxene is present in amounts up to 2%. Fine laminae are present in many of these beds. The alternating laminae may differ in amount of muscovite, some layers containing 10% of the mica as silt size grains. In other beds, the alternating laminae differ in having, alternately, a calcitic or an argillaceous matrix.

FAUNA

The following fossils were identified from the lower member of the Moydart Formation. A list of fossils by locality is included in Appendix 2.

Cornulites sp.

trilobite

Amphistrophia sp.

Howellella sp.

Isorthis sp.

Leptaena sp.

Meristina sp.

Pholidops sp.

Rhynchospira sp.

chonetid

dalmanellid

rhynchonellid

strophomenoid

bryozoan

crinoid

orthoceroid

Pterinea sp.

gastropod

AGE

The Moydart Formation is assigned a Ludlow (upper Silurian) age on the basis of its stratigraphic position above the lower Ludlow portion of the McAdam Formation and below the Stonehouse Formation whose uppermost beds are Gedinnian (lower Devonian) in age.

UPPER CONTACT

The contact of the overlying Stonehouse Formation with the "Red Stratum" is exposed at one locality in Pictou County. This is on McLellan Brook, 1 mile northwest of Brookville schoolhouse. The two units show no angular discordance, but the "Red Stratum" is overlain by, and pinches out into, a conglomeratic green mudstone.

Elsewhere in Pictou County, mapping shows that the two formations are parallel.

Stonehouse Formation

NAME

The name Stonehouse Formation was first used by Ami (1900, p 203), but was defined by Twenhofel (1909, p 156) to include all the beds above the "Red Stratum" and below the Devonian Knoydart Formation. The term is used in this sense by the present author.

The Arisaig section of the Stonehouse Formation, measured and described by Twenhofel (1909, p 156), is on the short of Northumberland Strait, from the top of the distinctive "Red Stratum" westward to the trap rocks at the mouth of McAras Brook.

THICKNESS

The thickness of the Stonehouse Formation at Arisaig was measured as 1075 feet by Twenhofel (1909, p 156). This figure is only a minimum, because the top of the section is not exposed in the Arisaig area.

In Pictou County, no complete section of this formation is present. Strata, higher than any exposed on the shore at Arisaig, are present in contact with the Knoydart Formation. At the western end of the area under study, scattered outcrops of Stonehouse beds, displaying similar attitudes, indicate a thickness of at least 2000 feet. No lower contact is exposed in this area. In McLellan Brook, the section has been disturbed, as a result of its proximity to the Irish Mountain Fault. Nevertheless, a minimum of about 1250 feet, and a maximum of about 2000 feet, are present. The lower contact is exposed in this section, and the upper contact can be estimated, inasmuch as the overlying Knoydart Formation is present.

DESCRIPTION

The beds of the Stonehouse Formation immediately above the "Red Stratum" are similar to those of the Moydart Formation immediately below. Farther up in the section, slightly calcareous, argillaceous sandstones and siltstones predominate. These are mostly blue gray on a fresh surface, though some are green gray resembling the Moydart sandstones. They weather to gray or tan gray. A few are micaceous. Most show fine bedding or small scale cross bedding. These sandstones and siltstones are well bedded in strata, 1 inch to $1\frac{1}{2}$ feet thick. A few calcareous shell beds, 1 inch to 4 inches thick, and some bluish gray mudstones, up to 6 inches thick, complete the section.

The uppermost 50 feet (approximately) are apparently higher than any rocks exposed on the Arisaig shore. These Stonehouse rocks are more massive argillaceous sandstones. The beds are slightly calcareous and predominantly green gray in color, with some blue gray. They weather to olive green, very light gray, or red. At one locality (on road on east side of Forbes Lake), these uppermost beds yielded a distinctive brachiopod fauna (see AGE, below), and another locality (Telford Brook) yielded a distinctive ostracod fauna (see FAUNA, below).

Within 25 feet of the top of the formation is a mottled red and green sandstone, with finer grained silt size, laminae interbedded.

TABLE 12

STONEHOUSE FORMATION

THIN SECTIONS

SAMPLE NO.	ROCK TYPE	SAND AND SILT SIZE GRAINS						MATRIX
		Quartz	Altered Feldspar	Muscovite	Leucoxene	Ilmenite	Hematite	
DT 17	sandstone lamina	50%	25%	trace	trace	1%		25% incl. abundant calcite
DT 17	silty lamina	10	10	5-10%				75 incl. abundant hematite
DT 1	sandstone	20	30	5	2%		trace	40 incl. chlorite

No D.T.A. studies were made on samples from the Stonehouse Formation.

No x-ray diffraction studies were made on samples from the Stonehouse Formation.

No chemical analyses were made of samples from the Stonehouse Formation, and, hence, no calculations of quantitative mineral composition.

Sample DT 17 is from the mottled red and green sandstone horizon, about 25 feet below the Knoydart Formation. It differs from the usual Arisaig Series sandstone in its irregular, hematitic and calcitic laminae. In this way, it represents a temporary depositional environment similar to that of the Knoydart Formation.

FAUNA

The following fossils were identified from the Stonehouse Formation. A list of fossils by locality is included in Appendix 2.

Cornulites sp.

homalonatid

Atrypa reticularis

Chonetes sp.

Delthyris rugaecosta

Howellella (?) sp.

Orbiculoidea sp.

Pholidops sp.

Platyorthis (?) sp.

Podollela sp.

Proschizophoria sp.

Rhynchospira sp.

Salopina (?) sp.

dalmanellid

dalmenitid

linguloid

small rhynchonellid, "*Camarotoechia*" sp.

large rhynchonellid

rhynchonellid

trepostome bryozoan

coral

crinoid

Pterinea sp.

orthoceroid

In addition, the following ostracods were identified by M. J. Copeland of the Geological Survey of Canada:

Beyrichia (Nodibeyrichia) postulosa	Hall	1860
Beyrichia (Neobeyrichia) cf. B. salteriana	Jones	1855
Beyrichia (Neobeyrichia) maccoyiana (?)	Jones	1855
Beyrichia (Neobeyrichia) maccoyiana var. sulcata	Reuter	1885
Kloedenia wilckensiana	Jones	1855
Kloedenellid (?) ostracod		

AGE

The uppermost 50 feet of the Stonehouse Formation, observed only in Pictou County, contain a lower Gedinnian (lowest Devonian) brachiopod fauna, including Podolella sp. and Proschizophoria sp. Presumably, much of the great thickness of this formation below these upper beds is of upper Ludlow (highest Silurian) age.

UPPER CONTACT

The upper contact with the Knoydart Formation, now exposed at Arisaig, is nearly exposed at two locations in Pictou County. About 1 mile south of Route 4 on Telford Brook, 9 miles west of New Glasgow, a few feet of the

Knoydart Formation are exposed in the axis of a syncline with rocks of the Stonehouse Formation present within 50 feet on either flank. To the north, the Stonehouse Formation contains mottled red and green beds, at least 2 feet thick. This suggests the beginning of conditions under which the red beds of the Knoydart were formed and an almost transitional contact.

Both at this locality and along the road east of Forbes Lake, 6 miles south of New Glasgow, the Knoydart is parallel to the underlying Stonehouse Formation.

Knoydart Formation

NAME

The Knoydart Formation was defined by Ami (1900 b, p 30) to include the Devonian rocks of McAras Brook. The formation is named for Knoydart Brook about 4½ miles west of Arisaig pier on the Northumberland Strait.

This Arisaig section is located on McAras Brook, which flows into the Northumberland Strait 2½ miles west of Arisaig pier. The Knoydart Formation underlies the trap rocks present at the mouth of the Brook.

THICKNESS

Fletcher, in 1897, measured 683 feet for the thickness of the Knoydart Formation at Arisaig, but realized that this was an incomplete section (Ami, 1900 c, p 177). The maximum section exposed in Pictou County is only 250 feet thick. This exposure is on McLellan Brook, 1½ miles northwest of Brookville schoolhouse. No top or bottom is exposed, so that this is a minimum figure for the thickness actually present.

DESCRIPTION

The Knoydart Formation consists of green and red, fine grained sandstones and red mudstones. Some of the red sandstones are micaceous, and many show fine bedding or cross bedding. Some beds have abundant green, calcareous nodules, about 1 inch in diameter, that weather differentially with respect to the remainder of the rock. The nodules become yellow on weathering.

The green, fine grained sandstones are very resistant, well bedded, and show fine bedding of calcareous sandstone laminae alternating with darker, argillaceous laminae. These rocks are present in beds 1 inch to 5 inches thick.

The red and green strata alternate in zones of up to 3 feet of green and up to 20 feet of red. The red beds predominate.

TABLE 13

KNOYDART FORMATION

THIN SECTIONS

SAMPLE NO.	ROCK TYPE	SAND AND SILT SIZE GRAINS				MATRIX
		Quartz	Altered Feldspar	Muscovite	Hematite	
DT 15	siltstone	35%	30%	5-10%	5%	25% incl. minor chlorite and abundant calcite and hematite in areas

DIFFERENTIAL THERMAL ANALYSIS

SAMPLE NO.	ROCK TYPE	Kaolinite	Quartz	Iron oxides	Pyrite	Calcite
TB 18	siltstone	?	m.	present	trace	5-10%

No x-ray diffraction studies were made of samples from the Knoydart Formation.

No chemical analyses were made of samples from the Knoydart Formation.

A typical red siltstone of the Knoydart Formation contains about 25% of clay size matrix with minor chlorite that is calcitic in some areas and hematitic in others. The remainder of the rock is composed of quartz, which makes up about 35% of the rock, altered grains of feldspar, which comprise about 30%, over 5% muscovite, and about 5% hematite, in silt size grains. Pyrite may also be present in trace amounts. The rock, as a whole, contains 5-10% calcite.

AGE

Fossil fish remains, from the Knoydart at Arisaig, were identified by A. Smith Woodward and H. Woodward (Ami, 1900) and the beds correlated with the Lower Old Red Sandstone (lower Devonian).

UPPER CONTACT

The upper contact of the Knoydart Formation is not exposed in Pictou County. Both areas, where the Knoydart Formation is exposed, are along the axis of a syncline. The only contacts, other than with the underlying Stonehouse Formation, are large faults.

The Silurian-Devonian sedimentary rock sequence is separated from the overlying Mississippian sedimentary rocks by an unconformity. This is exposed on the north side of the East River of Pictou. The west limit of the area of Silurian-Devonian rocks in Pictou County is a fault; however, the lowest Mississippian bed is a conglomerate containing pebbles of the underlying rocks, indicating the existence of the unconformity.

Southeast Pictou County

In southeast Pictou County, a distinctly different stratigraphic sequence is present, representing the lower and middle parts of the section. At the top of this sequence, the Stonehouse and Knoydart Formations are recognized as in northeast Pictou County. It should be noted that beds this young were only observed at the western end of this southern area.

Charcoal Formation

NAME

The author proposes the name Charcoal Formation for a series of tuffs and flows, which comprise the oldest layered rocks in south Pictou County. The name is taken from a settlement on the East River of Pictou, 11 miles southeast of New Glasgow and 4½ miles west of Sunnybrae, as shown on National Topographic Series sheet 11 E/7 East Half.

No lower contact is observed, nor are any rocks in the area known to be older.

TYPE SECTION

No type section for this formation has been designated. No adequate sequence has been observed. Rocks typical of this formation are found in Glencoe Brook about 1¼ miles north of the point where this brook enters the East River of Picton, 12½ miles southeast of New Glasgow, and 2½ miles west of Sunnybrae.

THICKNESS

Less than 200 feet of this formation is present in Glencoe Brook. Formational mapping to the east of Glencoe Brook (fig. 2) indicates over 2000 feet of these rocks. The widespread distribution of this formation is added evidence of considerable thickness. The base of this formation is not seen, hence, only a minimum thickness can be reported.

DESCRIPTION

The Charcoal Formation is composed of green and purple crystal tuffs and lithic tuffs. The grain size varies from medium to very coarse sand, and many of the beds are pebbly. A few flows of trap rock, probably andesite, are also present.

The tuffs are composed predominantly of fragments of felsite and trap, crystals and angular fragments of feldspar, both plagioclase and orthoclase. Quartz is a minor constituent where present at all. The matrix includes much chlorite. Pyrite and hematite occur in amounts from a trace up to 2%. Some of the green tuffs are of such a color as to suggest the presence of epidote.

The pebbles in the conglomeratic layers are of red and yellow felsites and purple microporphyries, with feldspar phenocrysts, some of which are amygdabidal.

Petrographic work on samples from the Charcoal Formation was limited to examination of polished sections under binocular microscope.

AGE

The age of the Charcoal Formation is unknown. No fossils have been found in it. No older layered rocks are present in this area. All that can be said is that this formation is older than the overlying Sunnybrae Formation, which, in turn, is older than the lower Llandovery age of the Glencoe Brook Formation.

UPPER CONTACT

The upper contact of the Charcoal Formation is exposed in Glencoe Brook. The overlying Sunnybrae Formation is composed of banded shales and slates. Here the two formations are seen to pass transitionally into each other. The contact zone is a series of interbedded banded silty shales and tuffs. The top of the Charcoal Formation is defined as the bottom of the lowest banded shale or slate.

Sunnybrae Formation

NAME

The author proposes the name Sunnybrae Formation for the series of soft, gray green, banded shales and slates present in southeast Pictou County stratigraphically above the tuffs of the Charcoal Formation and beneath the quartzites of the Glencoe Brook Formation. This formation is named for the village of Sunnybrae on the East River of Pictou 15 miles southeast of New Glasgow, as shown on the National Topographic Series sheet 11 E/7 East Half.

TYPE SECTION

The type section for the Sunnybrae Formation is on Glencoe Brook ½ mile north of Glencoe schoolhouse. It extends from beneath the coarse conglomerate at the base of the quartzites, 3000 feet upstream to the tuffs of the Charcoal Formation.

This section is cut by a major fault, as indicated by a 20 feet wide, vein filled, fault zone. Nevertheless, this section exposes both upper and lower contacts, and all the major rock types.

The Charcoal Formation passes upward transitionally into the Sunnybrae Formation. The base of the Sunnybrae is defined as the lowest banded, gray or green, slate or shale. This horizon was chosen inasmuch as thin tuff beds are present throughout much of the Sunnybrae Formation. Below the transition zone, the Charcoal Formation is devoid of banded shales or slates.

THICKNESS

The Sunnybrae Formation is about 1200 feet thick. This figure is calculated from geological mapping in the area of Glencoe Brook and to the east. Only about 750 feet are present at the type section. The remainder of the sequence has been faulted out.

DESCRIPTION

The Sunnybrae Formation is composed principally of green, weathering to green and purplish brown, banded shales and slates. These rocks are very fine grained and can be easily scratched with a knife. The cleavage, in places, is well developed transverse to the bedding, hence, the use of the term slates for these relatively soft rocks.

Some silty beds are present, in which feldspar is the chief mineral in the larger grains. In a few places, thin beds of tuff are present.

These are characterized by a green and white color which readily distinguishes them from the tuffs of the Charcoal Formation. These intermittent tuffs shown grain size layering, and, in some samples, graded bedding.

The lowest part of the Sunnybrae Formation is composed of alternating strata of the typical Charcoal Formation tuffs and the banded rocks of the Sunnybrae Formation.

TABLE 14

SUNNYBRAE FORMATION

THIN SECTIONS

SAMPLE NO.	ROCK TYPE	SAND AND SILT SIZE GRAINS					MATRIX
		Quartz	Weathered Feldspar	Lithic Fragments	Muscovite	Leucoxene	
IB 5	tuff	0	35%	35% (fine grained igneous, chiefly feldspar)		1%	30% incl. abundant chlorite and calcite
BRd 1	tuff	2	40	15 (same as above)		2	40 no calcite
BRd 1	silty shale	20	25		1%	1-2	50 no calcite
GB 51-2	tuff	0	55(½ plag.)	20 (same as above, plus one grain of rhyolite)		1	25 incl. calcite, abundant near weathered surface and abundant chlorite

DIFFERENTIAL THERMAL ANALYSIS

SAMPLE NO.	ROCK TYPE	Chlorite and/or Kaolinite	Quartz	Pyrite	Calcite
AM	shale	m.	s.		
BRd 1	tuff and shale	s.	s.	trace	trace ?

X-RAY DIFFRACTION

SAMPLE NO.	ROCK TYPE	Quartz	Feldspar	Kaolinite	Muscovite	Chlorite
AM	shale	l.	two (?) s.	?	m.	m.
BRd 1	tuff and shale	m.	one v.l., one(?) s.	?	v.s.	m.

CHEMICAL ANALYSES

	AM (shale)	BRd 1 (tuff and shale)
SiO	67.1%	67.4%
Al O	17.3	15.3
Fe O	1.79	0.81
FeO	2.54	3.02
MnO	0.04	0.11
TiO	0.78	0.54
P O	p.13	0.13
K O	4.75	3.14
Na O	p.24	2.82
CaO	0.33	0.70
McO	2.29	2.08
H O	3.56	2.58
TOTAL	100.9	98.6

CALCULATED MINERALOGIC COMPOSITION

SAMPLE NO.	Quartz	Orthoclase	Albite	Anorthite	Muscovite	Chlorite
AM	44.2%	1.2%	2.0%	negl.	38.5%	11.4%
BRd 1	33.8	8.1	23.9	3.5%	15.0	13.0

The above calculations were made by the method described under PETROGRAPHY.

The typical banded shales apparently consist of about 44% quartz, 11% chlorite, 38.5% muscovite, and 2% albite.

The tuffs are typically composed of feldspar grains and euhedral crystals and lithic fragments of felsites and feldspathic fine grained rocks in an argillaceous matrix. Little or no quartz is present in the form of sand or silt size grains.

Some of the samples of tuffs contain abundant calcite in the matrix, whereas others contain none.

AGE

The exact age of the Sunnybrae Formation is uncertain, as no fossils have yet been found in the formation. It underlies, and therefore is older than the Glencoe Brook Formation of lower Llandovery (lower lower Silurian) age.

UPPER CONTACT

The upper contact is exposed at the type section in Glencoe Brook. The fine grained banded rocks of the Sunnybrae Formation at this locality are overlain by a coarse conglomerate containing pebbles and boulders of quartzite and of rocks similar to those of the Sunnybrae Formation. No angular difference in attitude of the beds is present, but the contact is partly obscured by the presence of a porphyry. This igneous rock appears to lie wholly below the conglomerate, but may be intrusive or extrusive. Mapping the area to the east bears out the parallel relationship of the attitudes of the two formations.

The presence of the igneous rock below the contact and the basal conglomerate strongly suggests a disconformity at this horizon.

Glencoe Brook Formation

NAME

The author proposes the name Glencoe Brook Formation for the series of quartzites, sandstones, and minor mudstones that overlie the banded shales and slates of the Sunnybrae Formation in this area. This formation includes the lowest fossiliferous rocks observed in southeast Pictou County.

This formation is named for a tributary of the East River of Pictou 12 miles southeast of New Glasgow and $2\frac{1}{2}$ miles west of Sunnybrae.

TYPE SECTION

The type section of the Glencoe Brook Formation is on Glencoe Brook, beginning at the first outcrop upstream from the Glencoe schoolhouse and continuing upstream for 2250 feet. The base of the formation is several feet of coarse conglomerate.

THICKNESS

The Glencoe Brook Formation is 910 feet thick at the type section. In this section, the lower contact is exposed, but the upper is not. Although the thickness is, therefore, a minimum, it is believed to represent almost a complete section, because the fossil bed near the top of the type section is similar to one found near the top of the formation at other localities where the upper contact is present.

The Glencoe Brook Formation can be subdivided into an upper and lower member. The lower member is 280 feet thick and the upper member is at least 630 feet thick at the type section.

DESCRIPTION

Lower Member

The base of the lower member, at the type section, is a series of conglomerates totaling 8 feet in thickness. The lowest bed is a coarse conglomerate with cobbles up to $1\frac{1}{2}$ feet in maximum dimension. The cobbles and smaller pebbles are composed of banded fine grained rocks similar to the Sunnybrae Formation, quartzites and quartz. The matrix is quartzitic and green, weathering to orange brown. Pyrite is present in minor amount. Above this is 2 feet of fine grained gray quartzite. Overlying this is a conglomerate and conglomeratic quartzite with pebbles up to 4 inches in maximum dimension. These are interbedded with sandy quartzitic mudstone. The pebbles are quartz, quartzite, and flat pebbles of fine grained rock that resemble rocks of the Sunnybrae Formation.

Above this lies a series of argillaceous quartz sandstones and quartzites. They are colored gray or dark gray. Near the top of the member, some display a distinctive speckled yellow and black appearance on weathered surfaces. The sandstones and quartzites are present in beds of 4 inches to 3 feet thick. Some of these weather to orange or purple.

Massive gray mudstones that weather to darker gray are present in minor amount.

TABLE 15

GLENCOE BROOK FORMATION

LOWER MEMBER

THIN SECTIONS

SAMPLE NO.	ROCK TYPE	SAND AND SILT SIZE GRAINS					MATRIX
		Quartz	Altered Feldspar	Lithic Fragments	Leucoxene	Pyrite	
GB 101	sandstone	50%	5-10%	5-10%	1-2%	trace	30%

DIFFERENTIAL THERMAL ANALYSIS

SAMPLE NO.	ROCK TYPE	Chlorite and/or Kaolinite	Quartz	Pyrite	Iron oxides
GB 101	sandstone	s.	l.	1%	
K 3	sandstone	m.	m.		present

X-RAY DIFFRACTION

SAMPLE NO.	ROCK TYPE	Quartz	Feldspar	Muscovite	Kaolinite	Chlorite
GB 101	sandstone	v.l.	v.s.	s.	?	s

CHEMICAL ANALYSES

GB 101 (sandstone)

SiO_2	81.0%
Al_2O_3	11.3
Fe_2O	0.91
FeO	0.42
MnO	0.01
TiO_2	1.27
P_2O_5	0.07
K_2O	3.30
Na_2O	0.19
CaO	0.11
MgO	0.19
H_2O	not determined
TOTAL	98.8 plus H_2O

CALCULATED MINERALOGIC COMPOSITION

SAMPLE NO.	Quartz	Muscovite	Albite	Kaolinite	Chlorite
GB 101	67%	28%	1.6%	trace	0.8-1.1%

Sample GB 101 is of an argillaceous quartz sandstone from near the top of the lower member. A small amount of pyrite was shown to be present by D.T.A., and the calculations are, accordingly, based on the presence of $\frac{1}{4}$-$\frac{1}{2}$% pyrite.

Upper Member

The base of the upper member, at the type section, is composed of $1\frac{1}{2}$ foot beds of white quartzite and quartz pebble conglomerates. These total 18 feet in thickness. Over this lies a series of about 60 feet of mudstones and quartzites, above which quartzites and ferruginous quartz sandstones predominate.

The mudstones are massive, resistant, and blue gray weathering gray.

The quartzites and quartz sandstones range from very fine grained to medium grained. Many have a ferruginous matrix, which causes them to weather yellow, red, or purple, or a mottling of these colors. They are found in well bedded layers from 2 inches to 2 feet, and in massive strata several feet thick.

Near the top of the section is a fossiliferous layer containing brachiopods in abundance.

TABLE 16

GLENCOE BROOK FORMATION

UPPER MEMBER

THIN SECTIONS

SAMPLE NO.	SAND AND SILT SIZE GRAINS					MATRIX
	Quartz	Altered Feldspar	Leucoxene	Pyrite	Hematite	
GB 5-3	70%	5-10%	1%	1%	5%	15% incl. hematite

Sample GB 5-3 is typical of the ferruginous quartz sandstones or quartzites of the upper member of the Glencoe Brook Formation. The abundant quartz grains are joined by regrowth in many cases, hence, the term quartzite is applied. These beds are rich in hematite; 5% of the rock is composed of grains of hematite and about an equal amount is disseminated throughout the matrix.

AGE

The upper part of the Glencoe Brook Formation is correlated with the Beechhill Cove Formation on the basis of the brachiopods *Eostropheodonta* sp. and a rostrospiroid (a primitive *Meristina*) common to these two formations. The former is indicative of a lower Llandovery (lower lower Silurian) age.

FAUNA

The following fossils were identified from the upper member of the Glencoe Brook Formation. A list of fossils by locality is included in Appendix 2.

- *Dolerorthis* sp.
- *Eostropheodonta* sp.
- ribbed atrypacean, not *Atrypa reticularis*
- two dalmanellids
- rostrospiroid, primitive *Meristina*
- strophomenoid
- horn coral
- crinoid
- snail

UPPER CONTACT

The upper contact of the Glencoe Brook Formation is exposed in the tributary of McLellan Brook that flows past the Brookville schoolhouse. The contact is about parallel with the stream 300 feet east of the schoolhouse. The Kerrowgare Formation is to the south, conformably over the Glencoe Brook Formation. At this location, the contact is relatively sharp, the transition taking place through changes in rock type from argillaceous sandstone through sandy, then silty, mudstone, to shale. This transition takes place within a stratigraphic interval of 10 feet.

Elsewhere the formations are seen to be parallel in attitude of bedding. A transitional zone up to 50 feet thick is encountered in these areas. This transition displays interbedded sandstones or quartzites, similar to those of the Glencoe Brook Formation, and highly cleaved mudstones of the overlying Kerrowgare Formation. This transition zone is arbitrarily assigned to the Kerrowgare Formation.

Kerrowgare Formation

NAME

The author proposes the name Kerrowgare Formation for the series of dark gray shales, slates, and minor sandstones that are widespread in the southeast Pictou County area. They overlie the quartzites of the Glencoe Brook Formation and underlie the Stonehouse Formation in the west of this area. Kerrowgare, as shown on National Topographic Series sheet 11 E/8 West Half, is the location of a postoffice in the valley of the East River of Pictou, about 4 miles east of Sunnybrae on the north side of the river.

TYPE SECTION

No one section is satisfactory as a type section for this formation. Fairly extensive sections are present on the upper reaches of Holmes Brook $1\frac{1}{2}$ miles east of Springville, and on McLellan Brook in the area just north of the Brookville schoolhouse.

THICKNESS

Much of the Kerrowgare Formation is composed of homogeneous, dark gray sedimentary rocks of predominantly clay size particles. Where interbedded sandstones or quartzites are not present, the bedding is usually undiscernible. Cleavage is always developed, and some of the cleavage faces have a phyllitic appearance. In some of the areas in which the bedding is evident, the cleavage is parallel to it, in others the cleavage is transverse to the bedding.

The difficulty in determining bedding, compounded by the numerous small folds and the lack of a single complete section, rendered it impossible to measure the thickness of this formation. Formational mapping indicates that the formation is on the order of hundreds of feet thick, rather than tens or thousands of feet thick. Formational mapping (fig. 2) in the area north of Bridgeville indicates the presence of about 600-700 feet of this formation between outcrops of the Glencoe Brook Formation and the Stonehouse Formation.

DESCRIPTION

The Kerrowgare Formation is composed of blue gray, weathering to dark gray, clastic sedimentary rocks. Shales and slates, some of them silty, are by far the most common. Less than 10% of the total thickness is composed of hard, resistant, similarly colored, argillaceous fine grained sandstones and siltstones, in beds ½ inch to 2 inches thick. Near the base of the formation, lighter colored, very hard, argillaceous sandstones or quartzites, up to 4 inches thick, are interbedded with the fine grained rocks in a transition from the Glencoe Brook Formation. These sandstones or Quartzites weather light gray or tan gray. In this zone, cleaved, silty, or even sandy, mudstones are present in place of shales.

TABLE 17

KERROGARE FORMATION

No petrographic thin section of Kerrowgare rocks were examined.

DIFFERENTIAL THERMAL ANALYSIS

SAMPLE NO.	ROCK TYPE	Chlorite and/or Kaolinite	Quartz	Pyrite	Iron oxides	Calcite
ML 101	shale	v.l.	s.	1%		
I 3	shale	m.	m.	trace	present	
I 6	siltstone	m.	m.-l.	2-5%		trace ?
BL 7	sandstone	m.	l.			

X-RAY DIFFRACTION

SAMPLE NO.	ROCK TYPE	Quartz	Feldspar	Kaolinite	Muscovite	Chlorite
ML 101	shale	s.	two(?) m.	?	l.	l.

CHEMICAL ANALYSIS

	I 6 (siltstone)	ML 101 (shale) av. of two analyses	ML 104 (mudstone)
SiO_2	70.3%	45.8%	61.0%
Al_2O_3	14.6	22.2	21.1
Fe_2O_3	1.74	0.31	1.19
FeO	4.76	12.07	5.74
MnO	0.02	0.07	0.04
TiO_2	0.74	1.02	1.15
P_2O_5	0.19	0.17	0.10
K_2O	2.41	3.10	3.60
Na_2O	0.85	0.81	0.61
CaO	0.26	0.22	0.26
MgO	1.50	3.55	1.01
H_2O			
TOTAL	97.4 plus H_2O and S	89.3 plus H_2O and S	95.8 plus H_2O and S (?)

CALCULATED MINERALOGIC COMPOSITION

SAMPLE NO.	Quartz	Muscovite	Albite	Kaolinite	Chlorite
I 6	48.7-48.9%	20.4%	7.2%	9.1-10.0%	8.8-11.2%
ML 101	13.4-13.5	26.3	6.9	14.5-15.0	31.4-32.6
ML 104	32.8-33.2	30.5	5.2	16.6-17.5	7.1-11.8

Sample I 6 is of an argillaceous siltstone from the lower transitional beds of the Kerrowgare Formation. It is dark gray on a weathered surface and displays an irregular cleavage, transverse to the bedding, thus resembling the mudstones and shales of this formation.

Differential Thermal Analysis indicated the presence of 2-4% pyrite. The variations in the calculations are based on this range of pyrite percentage.

Sample ML 101 is typical of the shales of the Kerrowgare Formation. As in the case of sample I 6 above, pyrite is known to be present from the D.T.A. results, and the calculations are based on the presence of 1-2% pyrite.

Sample ML 104 is typical of the dark mudstones of the Kerrowgare Formation. The high ferrous iron content, and the presence of pyrite in the other samples from this formation, suggest that pyrite is present in this sample as well. The calculations above are based on the presence of 2-6% pyrite.

AGE

The stratigraphic position of the Kerrowgare Formation limits it to the Silurian. Only in a fault block, 1 mile northwest of Sunnybrae, tentatively assigned to the Kerrowgare Formation, were abundant fossils found. These were in a 2½ feet thick bed of oolitic hematite, resembling the "iron ore" bed of the lower McAdam Formation in the Arisaig area. The Fauna was also the same, permitting correlation. These rocks would then be of possible Wenlock age as is the lower member of the McAdam Formation.

FAUNA

The following fossils were identified from the Kerrowgare Formation. A list of fossils by locality is included in Appendix 2.

Isorthis (?)

Resserella (?)

dalmanellid

rostrospiroid

rhynchonellid

strophomenoid

orthid

Tentaculites sp.

orthoceroid

ostracods

In addition, the following fossils were found in the oolitic hematite tentatively assigned to the Kerrowgare Formation:

Cornulites sp.

Atrypa *reticularis*

Chonetes sp.

Howellella sp.

Meristina sp.

dalmanellid, *Isorthis* (?)

rhynchonellid

Platyceras sp.

orthoceroid

UPPER CONTACT

The upper contact of the Kerrowgare Formation is not exposed. Formational mapping in the area north of Bridgeville indicates that the strata of this formation are parallel to those of the overlying Stonehouse Formation. The lowest beds of the Stonehouse Formation in this area are green, fine grained sandstones, similar to those described above found in the Stonehouse Formation in northeast Pictou County. This is a significant lithological change from the Kerrowgare Formation. Nevertheless, the covered area between the nearest outcrops of these two formations conceals the nature of the contact and the possibility of a transition.

STONEHOUSE FORMATION

The Stonehouse Formation overlies the Kerrowgare Formation in southeast Pictou County. Its thickness in this area is uncertain, since neither contact is exposed. A minimum of 500 feet must be present, and possibly several times this figure. This formation was described above, under the stratigraphy of northeast Pictou County. The upper contact is not exposed, but stratigraphically above the highest beds of the Stonehouse Formation in this area there is present abundant float of Knoydart Formation lithology. Only 3 miles to the north, the Stonehouse Formation is conformably overlain by the Knoydart Formation, as described under the stratigraphy of northeast Pictou County. It seems reasonable to assume that the same stratigraphic relationship exists in southeast Pictou County.

Knoydart Formation

The Knoydart Formation was not observed in outcrop in southeast

Pictou County. Nevertheless, its presence is suggested by an abundance of large, angular blocks lithologically similar to the Knoydart Formation. This was found in a small area $\frac{1}{4}$ mile east of Springville, in such a position as to overlie the Stonehouse Formation. Outcrops of the Knoydart Formation, associated with the stratigraphic sequence in northeast Pictou County, are present only 3 miles to the north.

The area of Knoydart Formation float is limited by Stonehouse Formation outcrops to the east, and by outcrops of the Mississippian Windsor Group to the west, permitting the presence of no more than 500 feet of the Knoydart Formation. A description of the Knoydart Formation was given above under the stratigraphy of northeast Pictou County.

The upper contact is not exposed, but is presumed to be an unconformity with the rocks of the Windsor Group of Mississippian age. The latter unit overlies all the older formations in southeast Pictou County unconformably.

Facies Changes

In addition to the lateral changes of lithology in the Bear Brook Formation described above, two other major facies changes were noted. The first of these is the presence of impure quartzites, with streaks of miniature lenses less than 1/16 inch thick of argillaceous material, in the stratigraphic position of the Glencoe Brook Formation. These rocks are found in the area between the areas of the typical sequences of northeast and southeast Pictou County. They represent the transition from the more argillaceous facies of the northern area, to the less argillaceous, quartz sandstones and quartzites of the southern area.

The second major facies change was noted in the southeast corner of the area under study. Quartzites, typical of the Glencoe Brook Formation, are interbedded with slates and mudstones typical of the Kerrowgare Formation. The alternating strata are on the order of several tens of feet thick. This is a much larger transition zone, both in terms of total thickness and in thickness of individual strata, than is present in the type area to the west.

Intrusive Rocks

Rocks of the Browns Mountain Group are intruded, in Antigonish County, by the James River Granite (Williams 1914, p 102). A determination of the age of this intrusive, based on the radioactive decay of Rb^{87} in potash feldspar, gave an age (370 m.y.) in excellent agreement with ages determined elsewhere in Nova Scotia for granites intruding Devonian sedimentary rocks (Fairbairn, Hurley, Pinson, and Cormier, 1960).

Numerous dikes, and at least one diabase sill, cut the Browns Mountain Group, including the Bear Brook Formation, in Pictou County. Most of these can be assigned to the volcanic activity that marked the deposition of the Bear Brook Formation.

A few scattered basic dikes cut the fossiliferous Silurian rocks. These have been found intruding the Beechhill Cove and Ross Brook Formations. In addition, a small irregularly shaped basic intrusive is present in a fault zone which brings the Ross Brook Formation in contact with the Moydart Formation. Inasmuch as the intrusives of the Devonian period, associated with the Acadian orogeny in Nova Scotia, are in the form of large bodies of granite, these small basic intrusives are assigned to the Mississippian. Basic volcanics, of Mississippian age, are present in Pictou County one mile west of the area under study (Bell 1940, p 10) and in Antigonish County near Arisaig on the Northumberland Strait, and at Ballantyne Cove on Cape George.

STRUCTURAL GEOLOGY

INTRODUCTION

The major structural feature of eastern Pictou County is the high angle fault which separates the older Paleozoic rocks from the Carboniferous rocks to the north. To the west and southwest, the Carboniferous rocks overlie the older Paleozoic rocks with great unconformity.

The structure within the older Paleozoic sequence consists of folds trending approximately east-west and cut transversely by high angle faults.

The structural geology is presented graphically in the geologic map, fig. 2, and the cross sections, fig. 3. The detail maps, fig. 4 through fig. 13, show smaller structural features.

Many of the important faults of this area are indicated by topographic features. The high angle fault, mentioned above, has a scarp of several hundred feet for much of its great length. Elsewhere, its topographic expression is less striking, but still present in such features as Parks Falls on the Sutherland River. In Antigonish County, the upper reaches of Arisaig Brook and Doctors Brook follow the foot of this scarp. The Marshy Hope Fault[1] is marked by the east-west valley, through which flows the upper part of Barneys River and through which pass Route 4 and the railroad. Farther west this same fault is followed by an unnamed stream

1. The Marshy Hope Fault is that east-west, high angle fault which extends beyond the Antigonish County line just north of Route 4. It is observed on a tributary from the north of the East French River, in West Barneys River north of Route 4, and in the railroad cut north of Route 4 and east of Barneys River Station, and must be present farther east, separating the Ross Brook Formation from the Browns Mountain Group. This has been named by the present author for the railroad station of that name near the Antigonish County line.

until it intersects the Hollow Fault. The steep northeast face of Irish Mountain is the scarp of an important fault. McLellan Brook flows along the base of this scarp. The upper segment of the French River follows what must be a fault contact between different rock units. Much of the lower portion of Sam Cameron Brook, in the southeast corner of this area, follows a fault, as do two segments of the unnamed brook 2 miles east of Sunnybrae. The numerous small faults and deformation observed in many other streams suggest that their courses also are following a fault or fault zone. Examples of this are Blanchard Brook at Sunnybrae, Sutherland River in the area mapped in detail, and Holmes Brook northeast of Springville. On the French River, and $1\frac{1}{2}$ miles to the west on Telford Brook, the presence of a fault is noted by, respectively, the repetition and the absence of strata. In each case, a stretch of flat topography, with no outcrop, is encountered.

These numerous examples indicate the extent to which geologic structure controls the topography. The control of elevation by rock type noted by Bell (1940, p 4), to the northwest, generally holds true in this area as well. With this in mind, the striking pattern of major streams oriented northwest-southeast was noted. Several such streams are among the above examples of fault-controlled stream orientations. These are the upper French River, McLellan Brook, and the unnamed brook 2 miles east of Sunnybrae. This dominant northwest-southeast pattern is taken as representing the major fault pattern. Where no contradiction arises, this pattern has been used to infer directions of faults and to suggest the connection of some faults.

FOLDS

Plunging Anticline

The outcrop pattern in eastern Pictou County indicates that the older Paleozoic rocks are present in an anticline plunging to the west. The older Browns Mountain Group is present in the east central area, with Silurian to the north, south, and west, and Devonian present to the west above the Silurian. This anticline is cut off on the north by the Hollow Fault, and plunges under the Mississippian unconformity to the southwest. The anticline is terminated on the west by the unconformity and relatively minor faults.

Superimposed on this anticline are two smaller but persistent folds, a syncline on the northern flank, and a syncline near the axis of the major anticline.

Northern Syncline

In the north, adjacent and sub-parallel to the Hollow Fault, is a syncline about 8 to 10 miles across. This syncline plunges to the west south west, gently at its eastern end and more steeply in the west. The lower part of the Browns Mountain Group is present on both flanks. Near its eastern end, the youngest rocks present are of the Ross Brook Formation, while toward the west the remainder of the formations of the northern stratigraphic sequence appear. At the western extreme, the base of the Devonian Knoydart Formation is exposed. At this end, the syncline is cut off by a major transcurrent fault which brings these youngest beds of the syncline in contact with rocks of the Browns Mountain Group.

The dips are shallow in the center of the syncline, but become increasingly steep in the older beds on the flanks. Several smaller folds are present near the axis of this syncline, as well as drag folds up to 50 feet wide on its limbs.

Central Syncline

In the center of the major plunging anticline, a second syncline is present, whose axis extends east-west. The transitional facies of the Glencoe Brook Formation and the Kerrowgare Formation are exposed in this structure, flanked on the north by volcanic rocks of the Bear Brook Formation. This syncline is a narrow structure, being only about 3 miles wide. To the east it is terminated by an inferred fault which has brought these beds down against undifferentiated Browns Mountain Group rocks. To the west it is also terminated by a fault. At this end it has been faulted against rocks of the Moydart Formation.

Small areas of Silurian sedimentary rocks are present at two localities, in line with the axis of this central syncline, 2 miles and 5 miles to the east respectively. These are presumably faulted down against the surrounding Browns Mountain Group. In both areas, the transitional facies of the Glencoe Brook and Kerrowgare Formations are exposed. Although no attempt was made to map the structure within the undifferentiated Browns Mountain Group, these younger beds, in line with the axis of the central syncline, may indicate its extension in this direction.

North-South Folds

On Cross Brook, and less than a mile to the west, north-south trending synclines are present. The Cross Brook syncline has its east limb overturned, and the more westerly syncline has a vertical east limb. These folds may be essentially drag folds on the steep nose of the anticlinal structure that makes up the older Paleozoic rocks of eastern Pictou County.

Small Scale Folds

Numerous parallel small folds are present at several localities in the Ross Brook Formation. This feature is best developed in Cameron Brook, 1 mile southwest of Parks Falls, and on the French River between Meiklefield and the mouth of Wallace Brook. Small scale folding is also present in the Kerrowgare Formation in the Central Syncline and in the Holmes Brook-Bridgeville-Springville area. However, in the Ross Brook Formation, with its interbedded sandstones, attitudes of the beds can be frequently determined and the small folds mapped, whereas, this is not always possible in the Kerrowgare Formation.

The best exposures of these structures are on the French River, as described above. Outcrops are abundant, and many extend from the stream channel up the bank and into the cliffs on one side of the river. In these excellent exposures, the axes of the small folds are the sites of many very small faults, some with rotational motion resulting in a generally fractured and almost crushed appearance to the mudstones. This fracturing usually destroys all traces of bedding, and the small folds must be recognized by the attitudes of the limbs. Here, in the distance of a mile, are 13 small anticlines and synclines with moderate plunges to the northwest.

On Cameron Brook, 12 small anticlines and synclines are present in a little more than a mile. They plunge gently to both the northwest and the southeast.

These small scale folds in the Ross Brook Formation are present throughout the northern syncline, particularly where this formation lies along the axis of the syncline.

In the Kerrowgare Formation on Holmes Brook, similar structures are observed. In a distance of half a mile, anticlines and synclines are observed plunging gently to the north.

Although these three examples display the same average width or spacing of folds, the individual folds vary from less than 250 feet between axes of consecutive anticlines to almost 2000 feet.

Three areas show complex folding, including the small-scale folds just described. These are the wedge-shaped area between the Hollow Fault and the Marshy Hope Fault, the area south of Parks Falls, which lies between the Parks Falls Fault and the fault zone along the Sutherland River, and the Holmes Brook area between the fault along Holmes Brook and the fault west of Sam Cameron Brook. All three of these area are wedge-shaped blocks between important faults, and the complex folding is a result of movement along these faults.

FAULTS

Hollow Fault

The major fault that marks the northern boundary of the Devonian, Silurian, and older rocks in eastern Pictou County, extends northeastward through Antigonish County, continuing along the northwest coast of Cape George, and thence out to sea. For most of its length, it is marked by a scarp several hundred feet in height. This was recognized by Fletcher (1887), and named The Hollow, after the valley at the foot of the scarp. This fault also extends southwestward. Beyond the region of exposed older Paleozoic rocks, it can be followed as one or more faults cutting through the Carboniferous rocks. These faults can be seen on the Geological Survey of Canada Map 616A (Bell, 1940), and include the important "South Fault" shown thereon. The topography continues to reflect this fault or fault zone, though not as strikingly as to the east. Another feature of the Hollow Fault is its straightness throughout its considerable length. With a few changes in direction, of no more than 10°, this fault system can be traced 44 miles from the tip of Cape George to the East River of Pictou. Throughout this length, the rocks on the southeast side are always older than those which they face across the fault. No evidence of strike slip movement was observed. Hence, it is concluded that this is a high angle fault, along which the southeast block has moved up with respect to the northwest block.

Vertical movement is suggested by the presence of small folds adjacent and parallel to the Hollow Fault. Anticlines are present on the south side of this fault at Parks Falls, Telford Brook, "Harri Brook", and the East French River. Synclines are present on the north side on Barneys River, and on the East French River. If these are the result of movement on the fault, they correctly indicate that the south side has moved upward relative to the north side.

In only one place is there any indication that considerable strike slip movement may have occurred. At School Brook Cove, on Cape George, (see fig. 1) Ordovician and lower Silurian rocks of a sandy facies are in fault contact with upper Silurian rocks similar to the Arisaig-northwest Pictou County sequence. The outcrops in this cove resemble a large scale fault breccia in their structural complexity (Boucot, Griffin, and Fletcher, 1959). Some or all of the faults present may be a zone representing the Hollow Fault. The presence of a different sedimentary facies could be the result of strike-slip movement along the Hollow Fault. However, Cape George is the site of several thrust faults in Mississippian rocks. Such a fault may have carried the rocks of the different facies to this locality. Since rocks of the same age are not represented by two different facies, it is also possible that the anomalous beds are the result of original differences in environment of deposition between this locality and Arisaig, 16 miles to the southwest, that existed during the Ordovician and early Silurian time, but which differences ceased to exist by later Silurian time. It should be noted that this is the situation which exists between the Northeast Pictou County and Southeast Pictou County areas. Here, considerable differences in the sediments existed, until the time of deposition of the Stonehouse Formation, after which the two sequences were similar.

Faults Branching from the Hollow Fault

Several large faults intersect the Hollow Fault at low angles. The clearest example is the fault above Parks Falls called the Parks Falls Fault by the present writer. This fault trends more southwesterly than the Hollow Fault, and forms the boundary between the older Browns Mountain Group rocks to the north, and the Bear Brook, Beechhill Cove, and Ross Brook Formations, respectively from east to west, to the south.

Folds in the rocks on both sides of the fault can be ascribed to a drag effect which agrees, in the sense of the relative movement, with vertical displacement along this fault.

The continuation of this fault is uncertain in the region of scarce outcrops to the southwest. It probably continues as the fault which brings the Browns Mountain Group up against the Knoydart Formation in McLellan Brook.

A second example is the Marshy Hope Fault. The nature of the movement along this fault is uncertain. The contact of the Ross Brook Formation and the older Browns Mountain Group across part of this fault indicates considerable displacement. The rocks to the north are in a wedge-shaped block between this and the Hollow Fault. The strata within this block are complexly folded. In addition, the valley of Barneys River and West Barneys River may be the site of one or more faults not observed in the outcrops.

In the northwestern corner of this area, some outcrops of the Bear Brook, Beechhill Cove and Stonehouse Formations suggest another wedge caught between the Hollow Fault and a fault branching from it. The juxtaposition of Silurian and Carboniferous rocks indicates considerable displacement on both faults.

Another example of this type of fault may exist in the area of Telford Brook and the next small brook to the east. On Telford Brook most of the Stonehouse Formation has clearly been faulted out, but only a swampy region, devoid of outcrop, marks the fault itself. On the next brook to the east, the stratigraphic units are offset and differ in attitude in such a manner as to indicate a fault between these two brooks. These two features can be explained by a fault, as shown in Fig. 2, with relative strike slip displacement of the northwest side to the southwest by about 2000 feet. This fault would intersect the Hollow Fault at an angle of about 35°.

Faults Transverse to the Folds

The Irish Mountain Fault and its extension to the southeast have a north northwest orientation that is paralleled by many of the main streams.

In view of the topographic expression of the structure, described above, these streams have been used to infer the orientation of faults otherwise only approximately known. These are high angle faults with vertical displacement. Several of them may prove to have extensions down some of the stream valleys to the southeast, such as the Kittle River and the Moose River.

In the southwest corner of the area under study are a number of high angle faults with varying orientations, all of which may have only vertical displacement, with the exception of that along Holmes Brook and that at the contact with the Carboniferous on Cross Brook. These last two are of a different age than the others, inasmuch as they displace Carboniferous beds as well, while the former are covered by the Mississippian unconformity. Displacement along the unconformity, for part of its distance north of Springville, probably occurred at the time of this later post-Mississippian faulting.

TECTONIC HISTORY

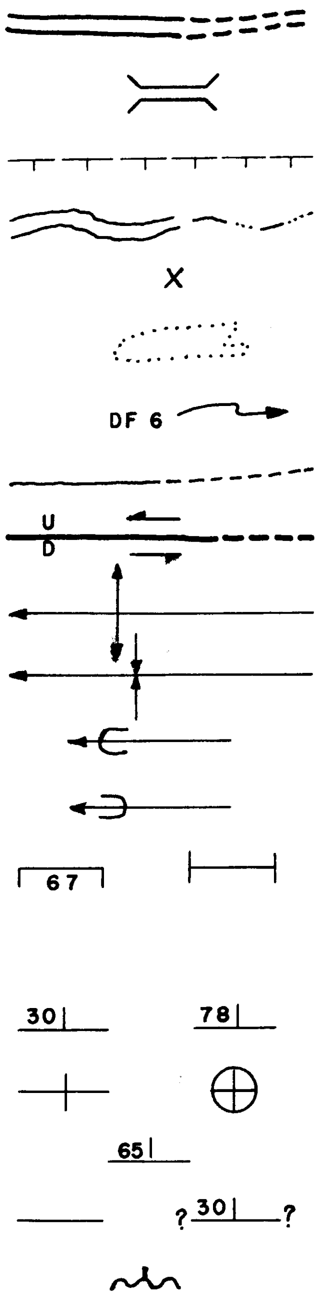
During the volcanism accompanying the deposition of the Bear Brook Formation, the underlying Browns Mountain Group sediments were intruded by dikes and sills, as were the Bear Brook sediments themselves. The first structural deformation that these, and the overlying Silurian and Devonian rocks, were subjected to was the compressional folding along approximately east-west axes. As is the case in the rest of the Appalachian Geosyncline, the compressional forces acted in directions perpendicular to the linear basin of deposition. The difference is that in Nova Scotia the axes of the basin of deposition, and the folds, trend east-west. This was accompanied by, or followed by, cross faulting trending north northwest-south southeast with vertical displacement. These faults are overlapped by the Mississippian unconformity in the southwest, and so predate the upper Windsor Group. The folding, and perhaps the cross faulting as well, can be assigned to the Acadian orogeny of Devonian age. After the deposition of the Windsor Group, the Hollow Fault and smaller faults at Cross Brook and Holmes Brook brought Carboniferous rocks down against the older strata. Earlier movements along these faults are suggested by Mississippian basal conglomerates in contact across these faults with Silurian rocks and containing angular pebbles of the same rocks. Movements along these faults, prior to the time of deposition of the Windsor Group, could be a result of the Acadian orogeny. Since the Hollow Fault is later than the folds and transverse faults, it is more likely that any pre-Windsor movement was contemporaneous with that which followed the deposition of the Horton Group of lower Mississippian age. The post-Windsor movement along these faults is of uncertain age. In view of the clastic nature of the post-Windsor Carboniferous sediments, some of these later movements may also have taken place within the Carboniferous. Still further movement may have accompanied the deformation of the Pennsylvanian strata.

DETAIL SECTIONS

Nine areas were chosen to be mapped in detail at a scale of 1 inch to 50 feet, and a tenth area at 1 inch to 200 feet. These detail maps are shown in figure 4 through figure 13. Only two of the nine areas were compact enough to present at the original scale. The other seven have been reduced to a scale of 1 inch to 500 feet. The tenth area is presented at the same scale as originally mapped. The locations of these areas are shown on figure 14.

LEGEND

USE WITH DETAIL MAPS, FIG. 4 THROUGH FIG. 13



PAVED ROAD; UNPAVED ROAD

BRIDGE

POWER LINE

STREAM; INTERMITTENT

OUTCROP

EXTENT OF OUTCROP

FOSSIL LOCALITY

CONTACT; APPROXIMATE

FAULT (SHOWING RELATIVE MOVEMENT); APPROXIMATE

ANTICLINE

SYNCLINE

MINOR ANTICLINE

MINOR SYNCLINE

STRIKE AND DIP OF CLEAVAGE; VERTICAL

BEDDING

STRIKE AND DIP; OVERTURNED

VERTICAL; HORIZONTAL

STRIKE AND DIP (TOP UNCERTAIN, NEAR OVERTURNED BEDS)

STRIKE; QUESTIONABLE STRIKE AND DIP

GENERALIZED STRIKE AND DIP OF CLOSELY FOLDED BEDS

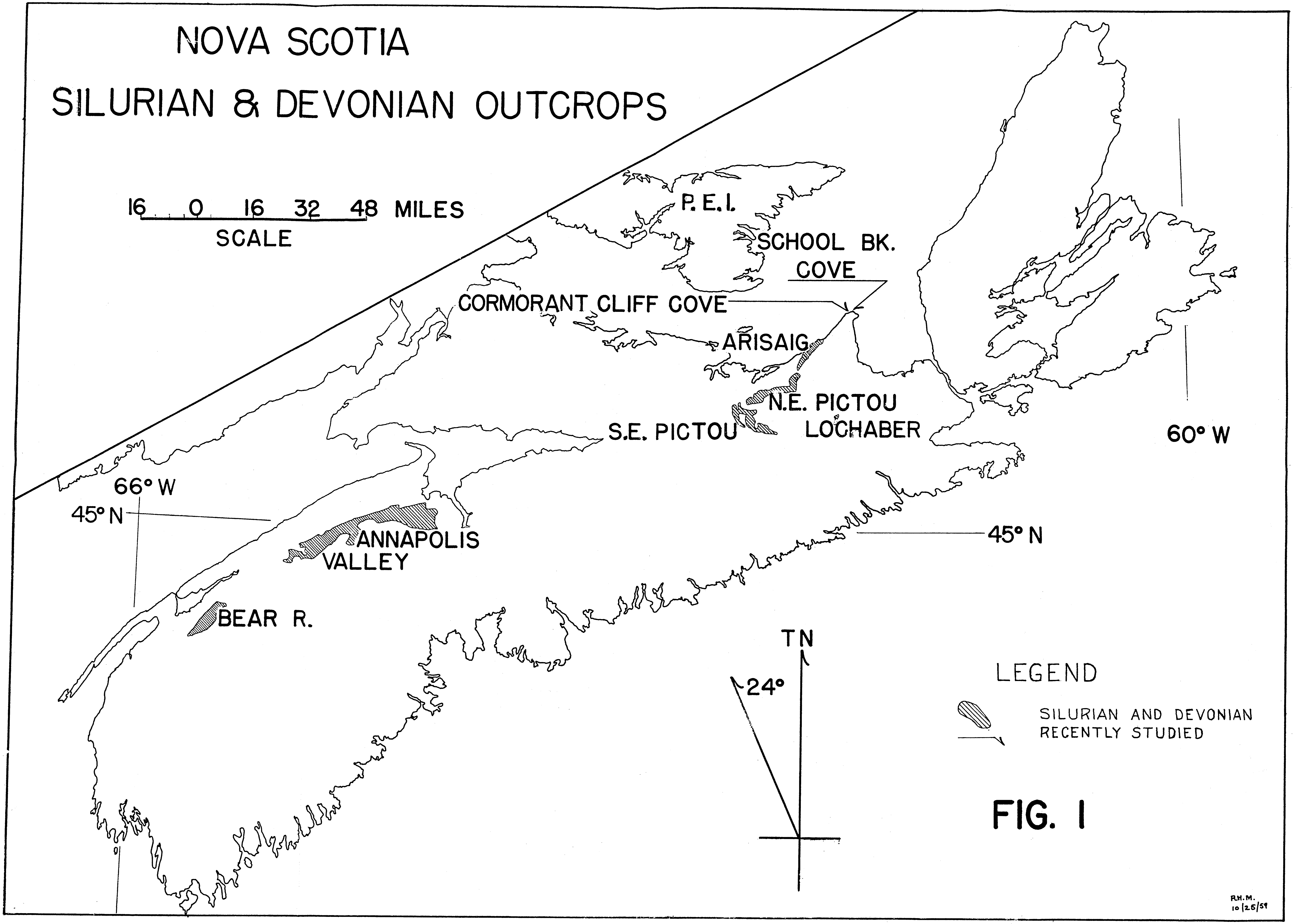

NOVA SCOTIA
SILURIAN & DEVONIAN OUTCROPS
16 0 16 32 48 MILES
SCALE
P. E. I.
SCHOOL BK.
COVE
CORMORANT CLIFF COVE
ARISAIG
N.E. PICTOU
S.E. PICTOU
LOCHABER
60° W
66° W
45° N
45° N
ANNAPOLIS
VALLEY
BEAR R.
TN
24°
LEGEND
SILURIAN AND DEVONIAN
RECENTLY STUDIED
R.H.M.
10/25/59

FIG. I

FIG. 2


EASTERN PICTOU COUNTY
NOVA SCOTIA
TN
1000 0 1000 2000 3000 4000 5000 YARDS
1 0 1 2 3 MILES
SCALE 1:50,000
BARNEYS RIVER
EAST FRENCH RIVER
FRENCH RIVER
PICTOU COUNTY
ANTIGONISH COUNTY
BEAR BROOK
HOLLOW FAULT
MARSHY HOPE FAULT
BAXTER BROOK
SUTHERLAND RIVER
TELFORD BROOK
MCLELLAN BROOK
PARKS FALLS
WEST BARNEYS RIVER
WALLACE BROOK
MEIKLEFIELD
CROSS BROOK
IRISH MOUNTAIN FAULT
FRENCH RIVER
GARDEN RIVER
MOOSE RIVER
HOLMES BROOK
SPRINGVILLE
EAST RIVER OF PICTOU
MCPHERSON LAKE
SUTHERLAND RIVER
BLANCHARD BROOK
SAM CAMERON BROOK
GLENCOE BROOK
BRIDGEVILLE
KITTLE RIVER
SUNNYBRAE
EAST RIVER OF PICTOU
EDEN LAKE
62° 15'
62° 30'
45° 30'
LEGEND
HIGHWAY
COUNTY BOUNDARY LINE
STREAM; INTERMITTENT
FAULT; INFERRED; POSSIBLE
CONTACT; INFERRED
ANTICLINE
SYNCLINE
MINOR ANTICLINE
MINOR SYNCLINE
GENERALIZED STRIKE AND DIP OF CLOSELY FOLDED BEDS
STRIKE AND DIP OF BEDS; OVERTURNED; VERTICAL
OUTCROP
STRATIGRAPHY
CARBONIFEROUS
Cu UNDIFFERENTIATED
DEVONIAN
Dk KNOYDART FM.
N.E. PICTOU CO.
S.E. PICTOU CO.
SILURIAN
Ss STONEHOUSE FM.
Smo MOYDART FM.
Smu Sml McADAM FM.
Sf FRENCH RIVER FM.
Sru Srm ROSS BROOK FM.
Sb BEECHHILL COVE FM.
ARISAIG SERIES
Ss STONEHOUSE FM.
Sk KERROWGARE FM.
Sg GLENCOE BROOK FM.
PRE-SILURIAN
pSb BEARS BROOK FM.
pSu UNDIFFERENTIATED
pSs SUNNYBRAE FM.
Ch CHARCOAL FM.

FIG. 3

CROSS SECTIONS

FIG. 4

EAST FRENCH RIVER

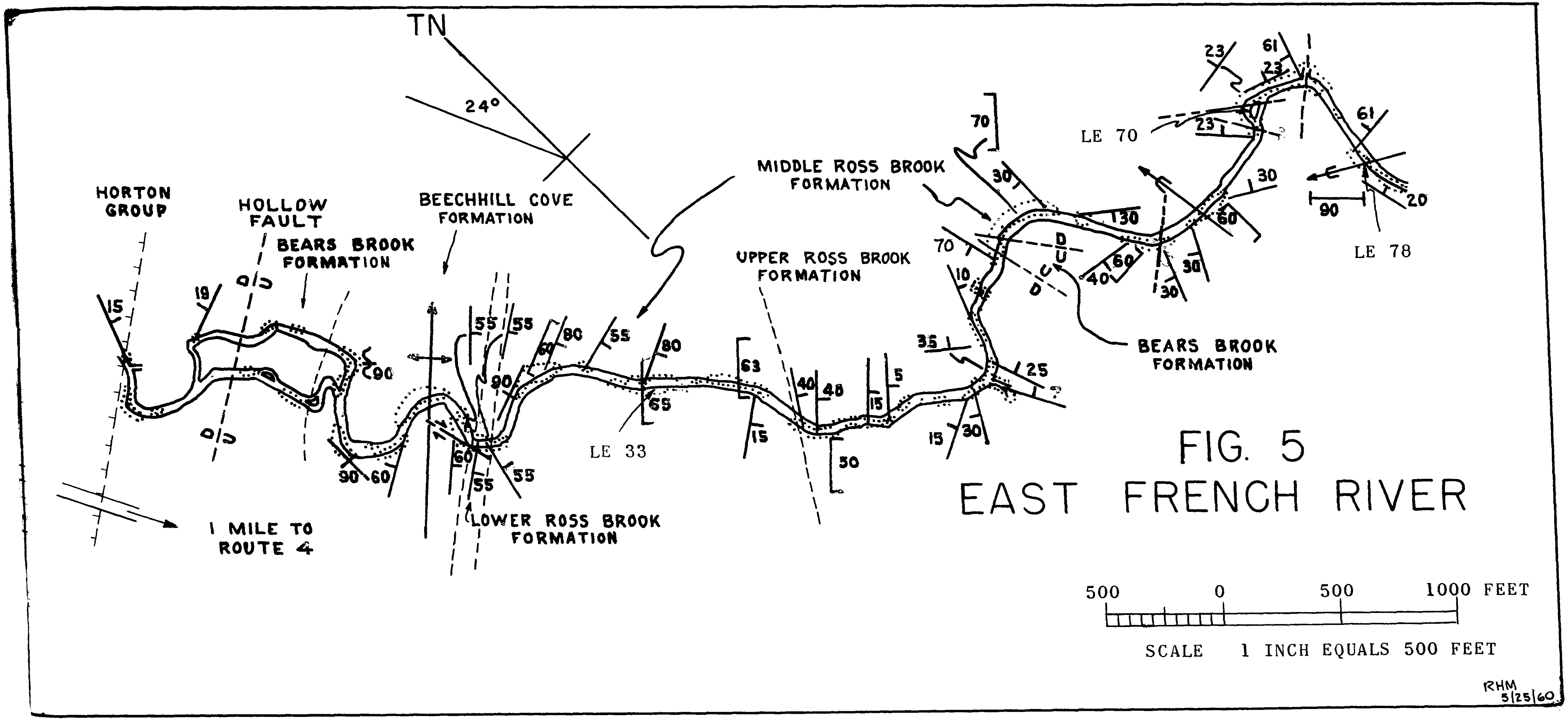


FIG. 5
EAST FRENCH RIVER

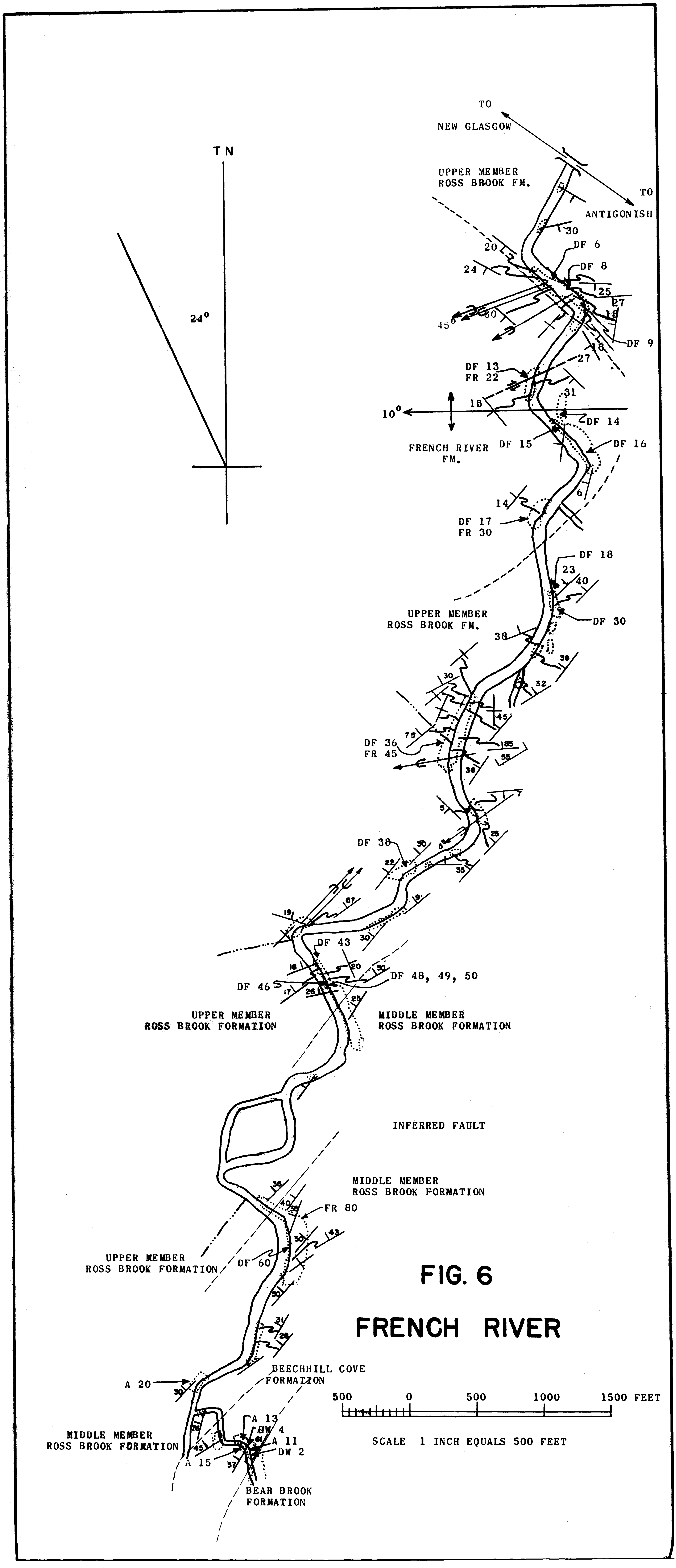


FIG. 6

FRENCH RIVER

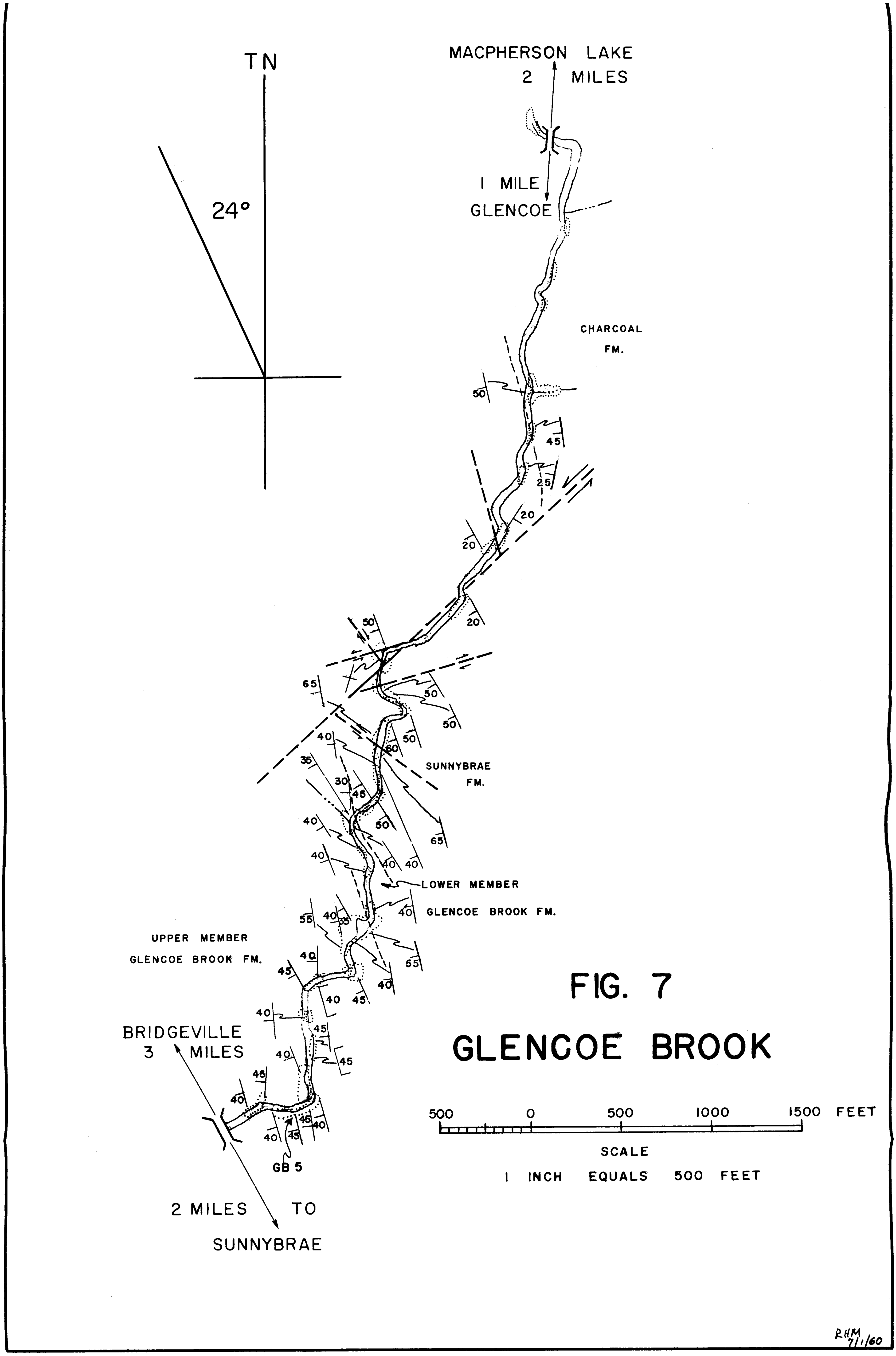
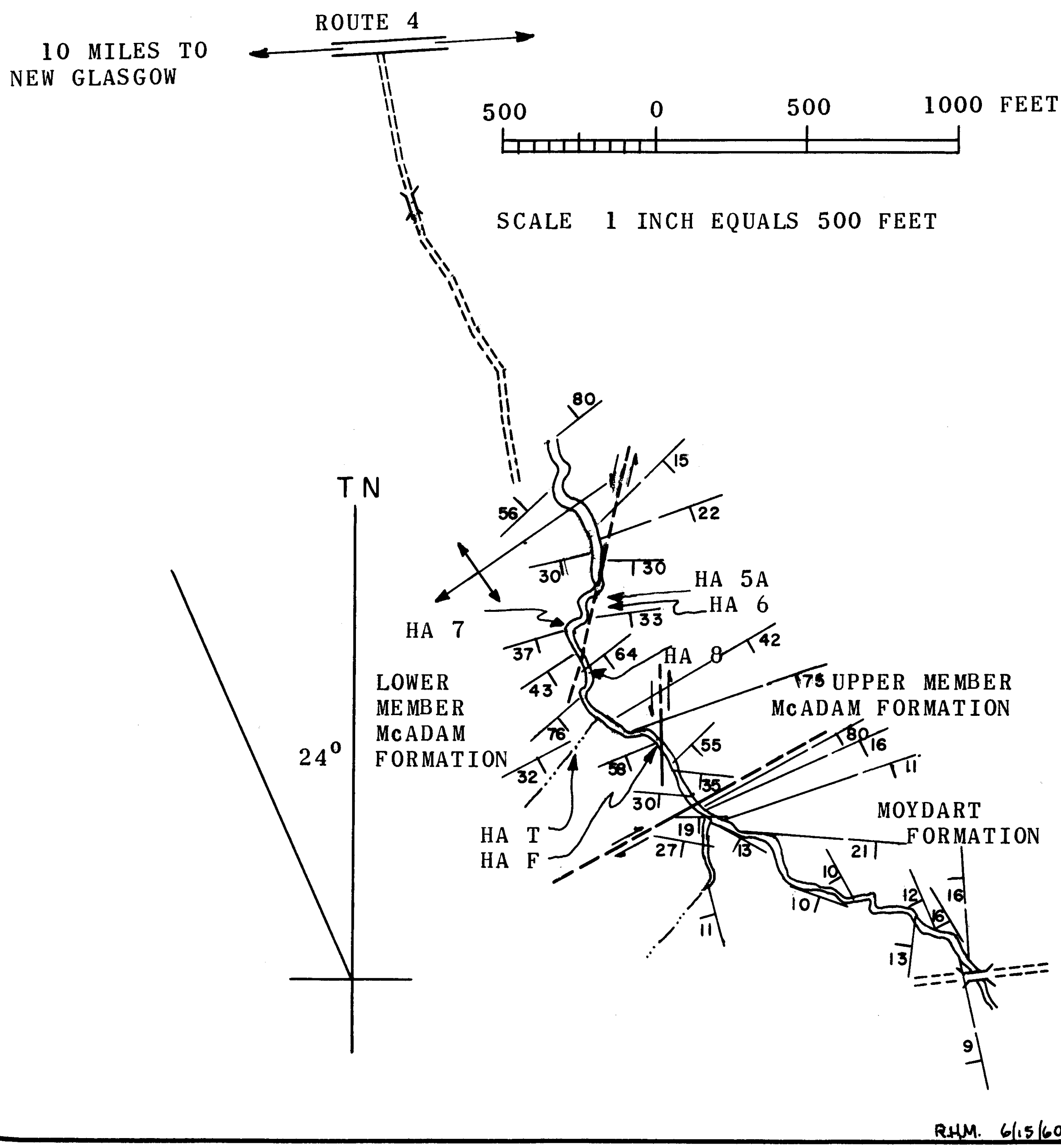


FIG. 7

GLENCOE BROOK

FIG. 8
HARRI BROOK



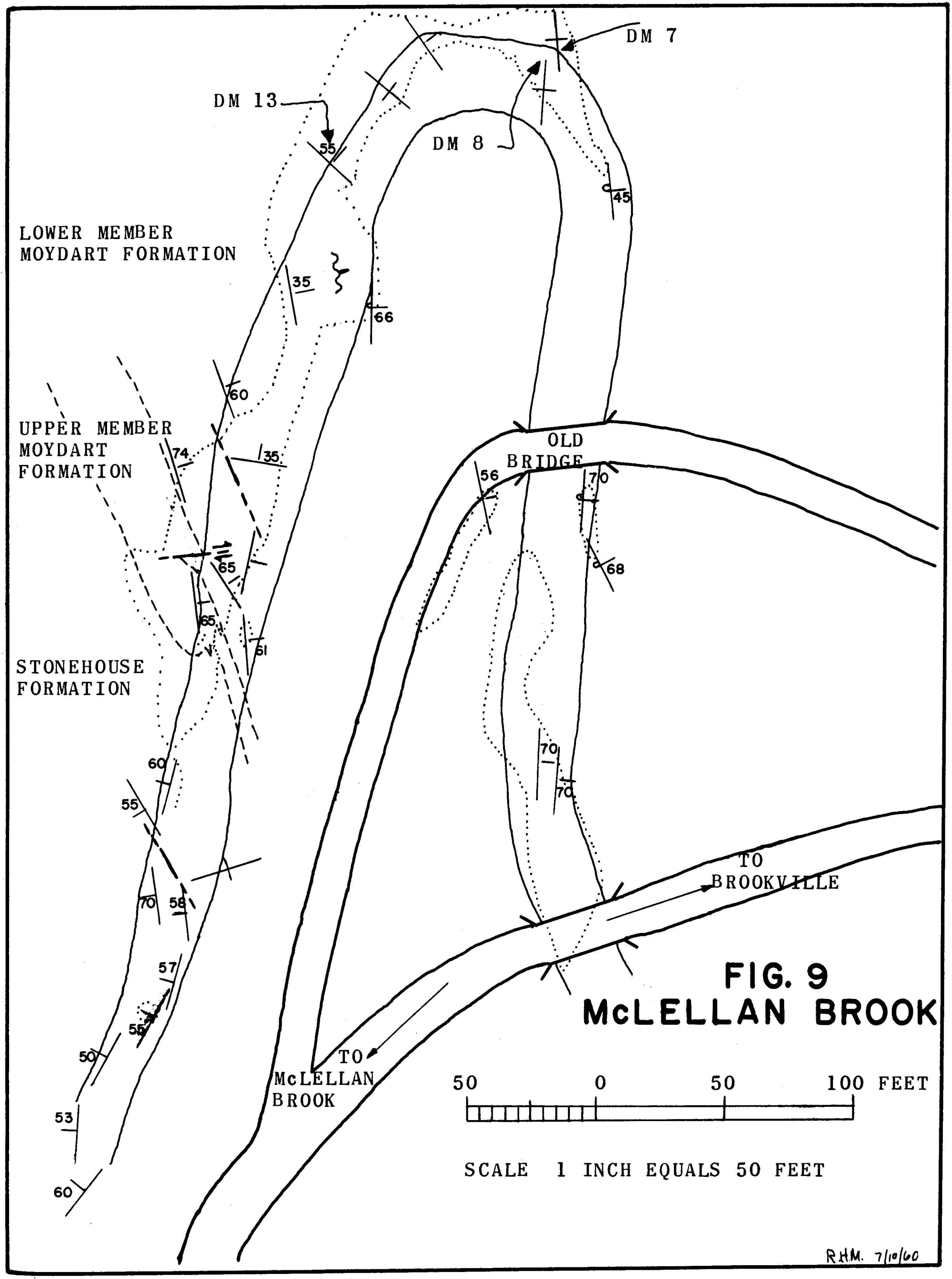


FIG. 9
McLELLAN BROOK

SCALE 1 INCH EQUALS 50 FEET

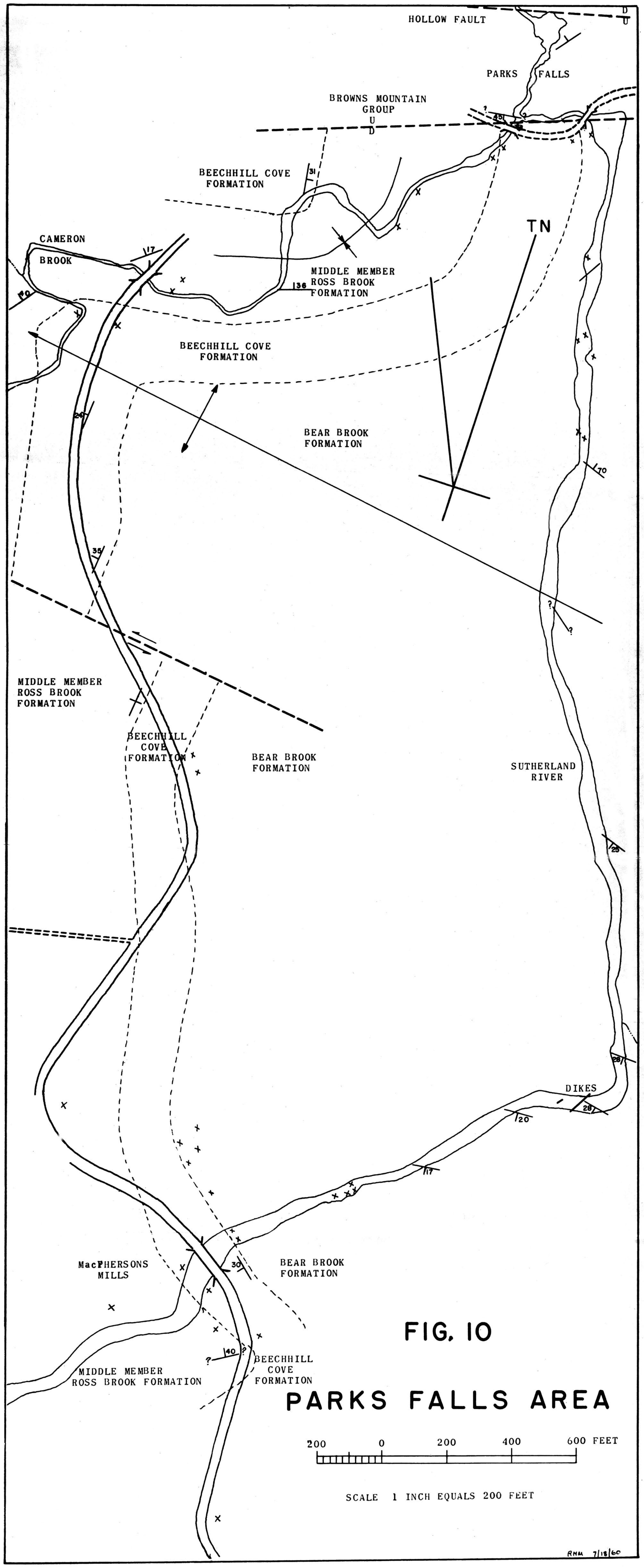


FIG. 10

PARKS FALLS AREA

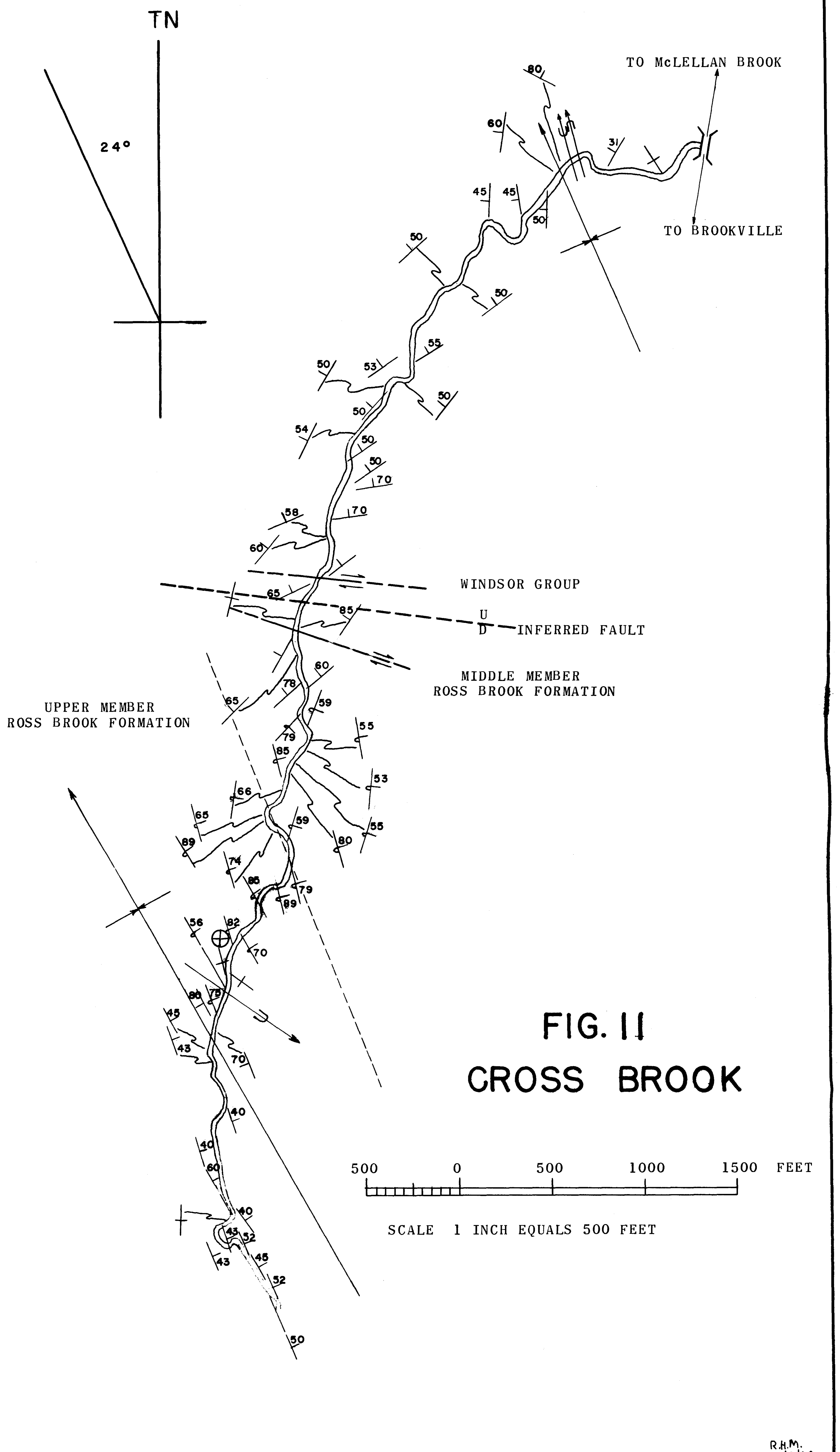


FIG. 11
CROSS BROOK

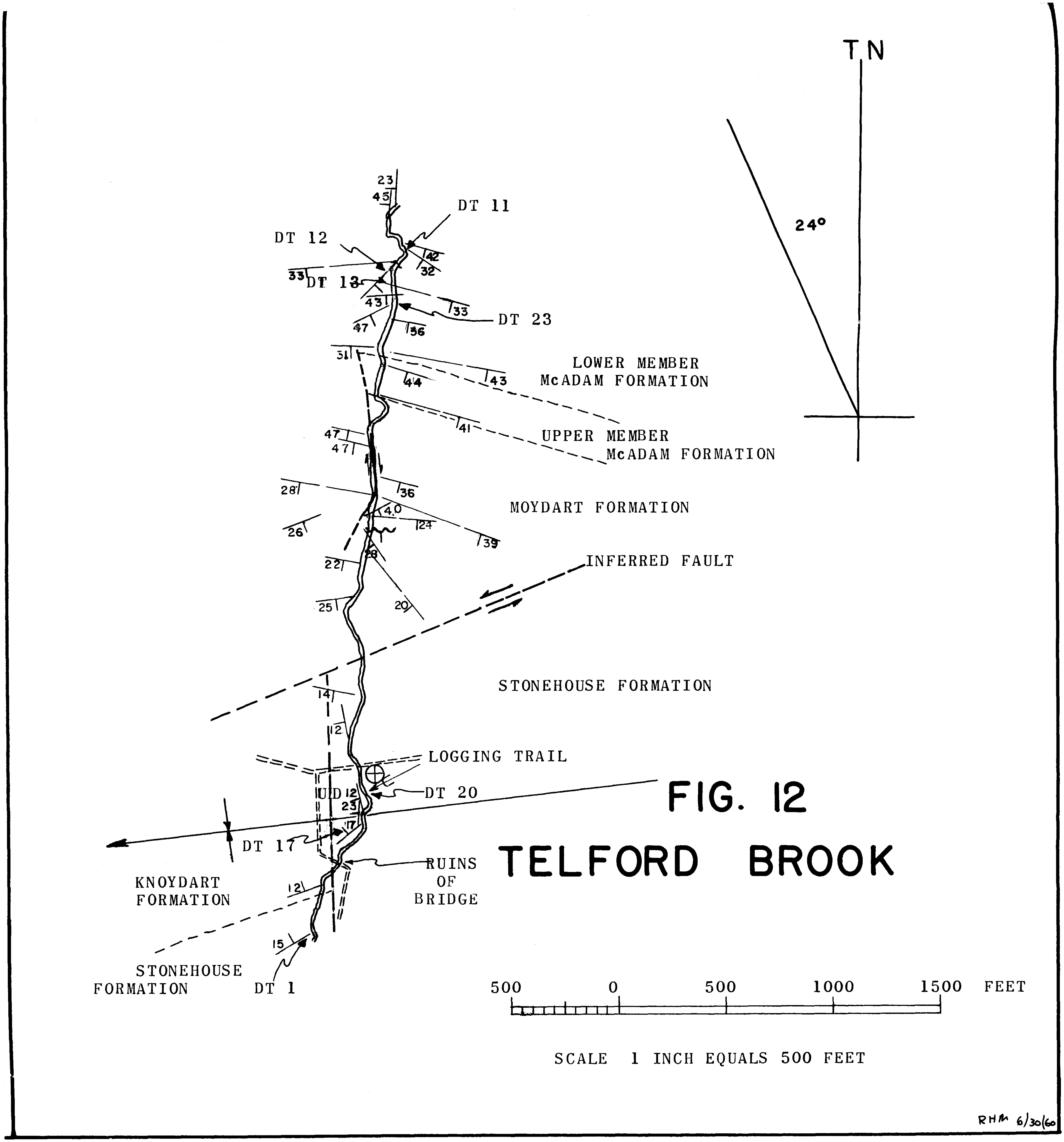


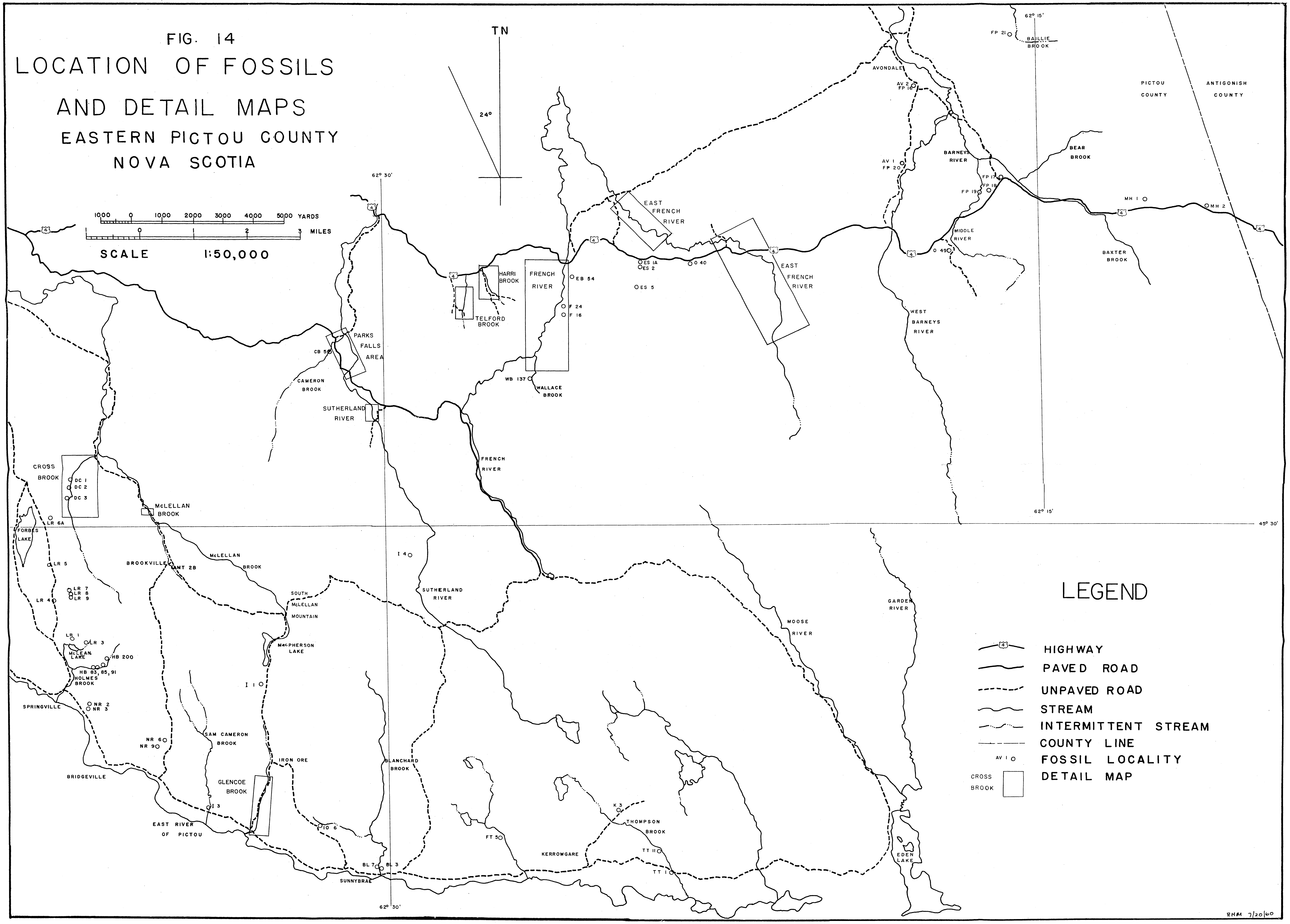
FIG. 12

TELFORD BROOK

FIG. 13

SUTHERLAND RIVER

FIG. 14
LOCATION OF FOSSILS AND DETAIL MAPS
EASTERN PICTOU COUNTY
NOVA SCOTIA



ECONOMIC GEOLOGY

IRON

The only mineral deposit in this area of economic importance, to date, was the iron ore at Bridgeville. This deposit has been known since 1828 which the General Mining Association removed some ore. In 1891, the Pictou Charcoal and Iron Company began mining, and erected a blast furnace. The Nova Scotia Steel Company, about this time, also mined iron from this area for a blast furnace at Ferrona. In 1903, the Bridgeville Mining Company started a new shaft. During the period from 1892 through 1903, approximately 188,000 tons of this ore were mined from seven different workings, and used in blast furnaces in Pictou County (Messervey, 1943).

The ore was mostly limonite, and located in discontinuous bodies along the Silurian-Mississippian unconformity. None of the workings is now accessible and even their locations are becoming lost. The distribution of the ore with respect to the unconformity, however, suggests a weathering origin on the pre-Windsor surface. This origin was also proposed by Weeks (1948).

Numerous other iron prospects were explored, mostly in the 19th century, within the lower Paleozoic rocks of Pictou County. The only deposits of any appreciable extent thus investigated were two sedimentary, hematite rich beds in the Silurian rocks. One of these is the same bed that is present in Arisaig Brook and its vicinity, in Antigonish County, where prospecting tunnels can still be seen. In the Arisaig area, it is present in the lowermost McAdam Formation. In both areas, it is an oolitic hematite bed about 2½ feet thick, with numerous calcitic shells of brachiopods and gastropods, and fragments of crinoids.

The other extensive iron bed is found near the top of the iron rich quartzites of the Glencoe Brook Formation. Outcrops of this bed were not seen by the author, but large blocks present at two of the former prospecting sites were examined. These consist of medium and coarse grained quartz sandstones, some of which contain pebbles up to ½ inch in greatest dimension. Some of the blocks are also rich in hematite, including the specular variety which is present along fracture surfaces.

A ferruginous bed is also present in the Browns Mountain Group rocks on the scarp of the Hollow Fault, north of Route 4. This occurrence was described by Hayes (1920) as containing oolitic hematite and chamosite. The thickness was reported as seven feet, and brachiopod fragments were observed. This bed was correlated with the "iron ores" of the Browns Mountain Group at Doctors Brook and Browns Mountain, in Antigonish County.

In this day of 100 million ton deposits, these latter three beds are of no commercial value. The once important Bridgeville deposits are discontinuous, and though of a good manganese rich grade, are too small to be commercially competitive. This is unfortunate, inasmuch as coal and limestone are abundant in the nearby Carboniferous rocks.

QUARTZITE

The Glencoe Brook Formation is primarily composed of quartzites and quartz sandstones, and is over 900 feet thick. A few of these quartzites are quite pure. A large volume of the remainder appears to have iron as its chief impurity. A chemical analysis of one of the most argillaceous of the quartz sandstones is reported (#GB 101). Approximately 1½ square miles of the area north of the East River of Pictou between Sunnybrae and St. Paul have rocks of this unit as bedrock.

Quartzites of the Glencoe Brook Formation are also present east of

Sunnybrae as far as the Thompsons Brook shown on the National Topographic Series sheet number 11 E/8 West Half. In this area, the quartzites are present in massive strata, several tens of feet thick, alternating with strata of mudstones and slates of the same order of magnitude of thickness. Distribution of rock types and formations is not well enough known in this area to present a useful approximation to the area underlain by quartzites.

BARITE

Veins of barite and calcite are present, filling a fault zone 20 feet wide on Glencoe Brook 3000 feet north of Glencoe schoolhouse. Formational mapping indicates that this fault extends 4000 feet to the southwest, and an indefinite distance to the northeast. The possibility of barite in veins throughout a considerable portion of this fault zone seems well worth investigating.

SEDIMENTOLOGY

PALEOCURRENT STRUCTURES

In an attempt to determine the direction, or at least the orientation of the currents which transported these Silurian sediments, small scale cross bedding and ripple marks were examined.

The orientation of the ripple marks, and the attitudes of the containing beds, were recorded. Through use of stereographic projection, the beds were graphically rotated into the horizontal to determine the original orientations of the ripples.

Oriented samples of small scale cross bedding were collected, and the attitudes of the containing beds recorded. The samples were typically about 3 inches by 3 inches by 1 inch in size. Two saw cuts were made at right angles, and the apparent dips measured on these cut surfaces. The true dip of the plane passing through these two apparent dips was calculated graphically. This plane approximates the slightly curved surface of the cross bed. The portion of the cross bed sampled, and the approximate attitude calculated, are of a random segment of the primary feature. If the cross beds are the foreset beds of a distinctly lobate structure, the possible attitudes found from a single such structure may vary by almost 180°. Since the individual structures will vary in direction about the mean current direction, the result to be expected from this study would be a wide scatter of dip directions approximately centered about the direction of the current.

The results of these studies are shown in figures 15 and 16. The directions of the dips of the cross beds, fig. 15, are widely scattered,

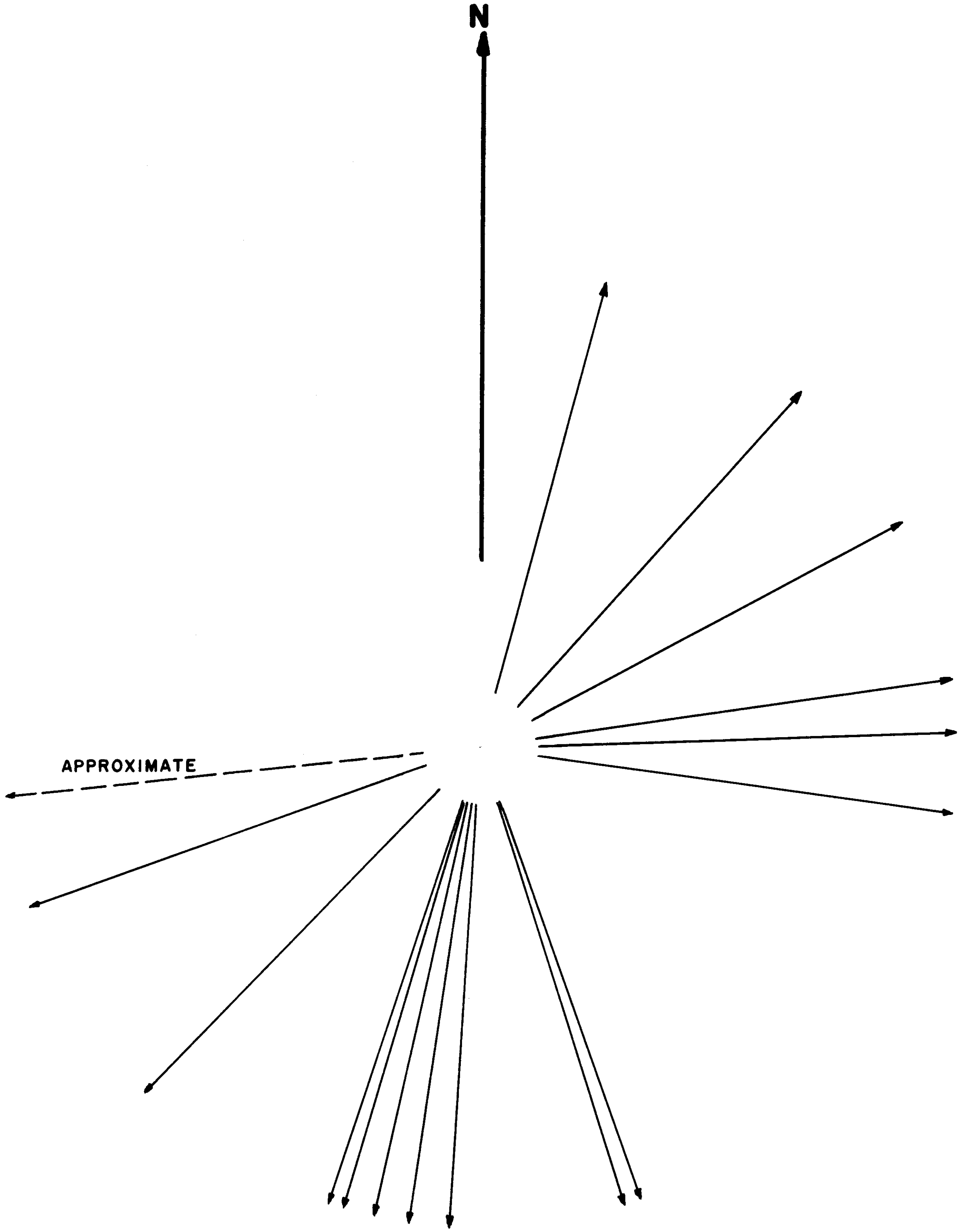


FIG. 15
SMALL SCALE CROSS BEDDING
DOWN DIP DIRECTIONS

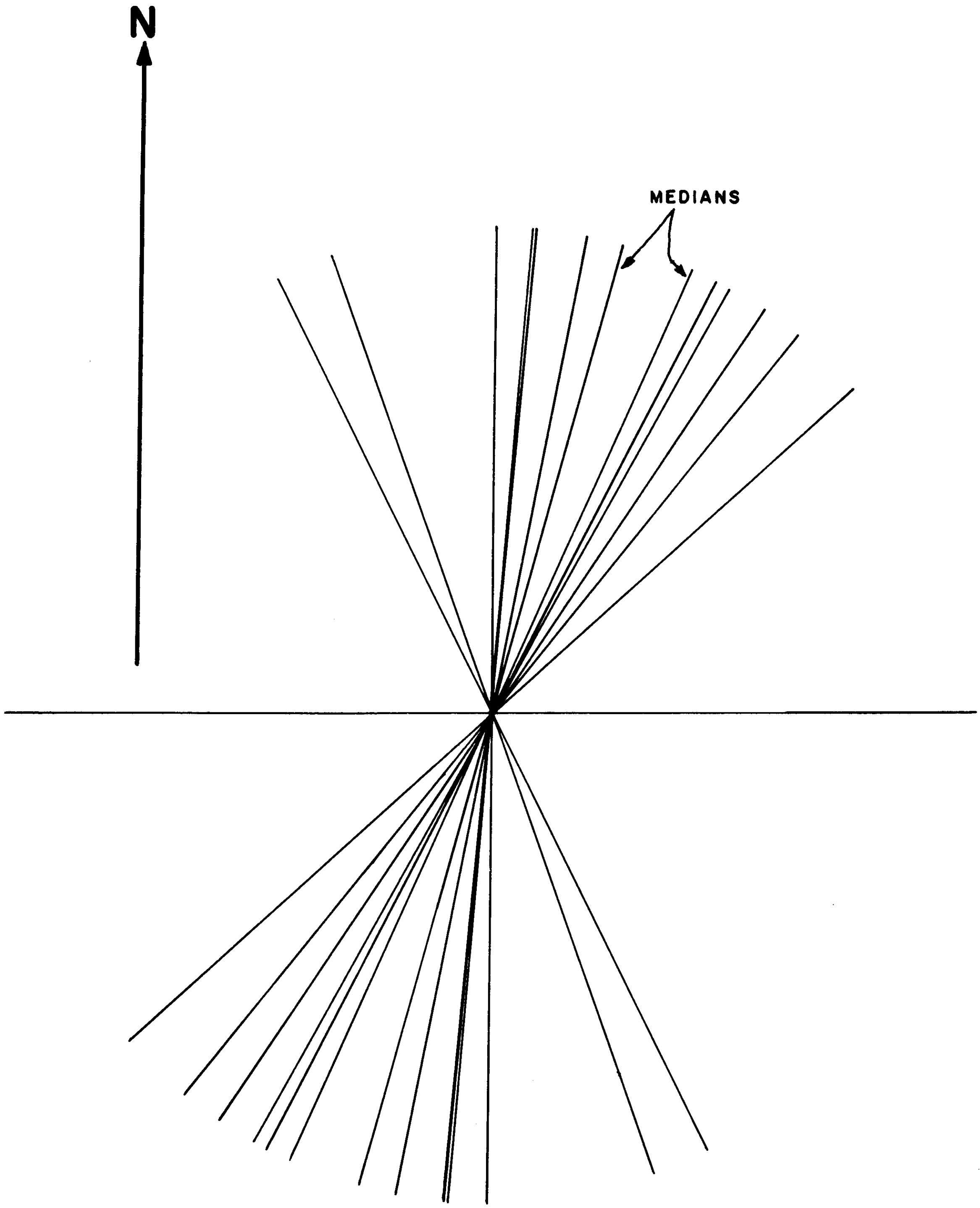


FIG. 16
RIPPLE MARK ORIENTATIONS

as was expected. The complete absence of dips into the northwest quadrant, and the presence of only one relatively inaccurate direction of dip within 15° to either side of the northwest quadrant, indicates no current flow to the northwest. The distribution of dip directions is bimodal and may be indicative of two directions of current flow, one about south southwest and the other about east northeast. In view of the small sample, however, the distribution may represent the scatter about a single current direction. The paucity of dip directions in the southeast quadrant must then be attributed to change in the sampling. The direction of this single current system would have been to the southeast. The total lack of dip directions in the opposite quadrant lends credence to this hypothesis.

The ripple marks examined in Pictou County are all symmetrical, though not all have the sharp crests of oscillation ripples. Their orientations, as shown in fig. 16, suggest a normal, rather than a bimodal, distribution. Current ripples are oriented perpendicular to the current direction. The orientation pattern of symmetrical ripples is less well understood, but has been observed to parallel that of a symmetrical current ripples and to be perpendicular to the current direction, as indicated by cross bedding (Pettijohn 1957, p 187). If this is the case in Pictou County the orientations would indicate a single current system to the east southeast or west northwest. The cross bed data rule out the latter.

In summary, the orientations of the ripple marks, and the directions of dip of the cross beds, taken together, indicate a current system in which flow was to the southwest.

SEDIMENTARY HISTORY

Pictou County and Vicinity

The same stratigraphic sequence is present throughout northeast Pictou County, and in Antigonish County at Arisaig. The oldest of these rocks are predominantly banded slates and argillites. These represent fine grained sediments deposited in generally quiet water. Several sedimentary iron beds are present, and in the adjacent beds are inarticulate brachiopods, indicating a marine origin for at least part of these beds. The age of these rocks is probably Ordovician.

Following this, came a period of volcanism, represented by the Bear Brook Formation. During this time, flows and tuffs were deposited at Arisaig in Antigonish County, and in the area from Parks Falls to the French River in Pictou County. Elsewhere in these two counties, tuffaceous sandstones and conglomerates represent this period of volcanism. The presence of tuffs indicates that volcanoes existed above sea level at this time, whereas the tuffaceous sandstones exhibit cross bedding indicative of deposition in water. Two volcanic islands can thus be located; one at Arisaig, the other in the Parks Falls-French River area.

A space of time elapsed during which an uneven erosional surface was developed on the flows. Sedimentation began again, with the deposition of the Beechhill Cove Formation. This formation is similar to the remainder of the Arisaig Series.

The sediments that form the Arisaig Series were deposited as a succession of muds and muddy, fine grained sands, alternating in irregular and relatively thin strata. Many of these strata contain small, irregular patches and lenses of different grain size. These resemble features shown in samples taken from relatively shallow, near-shore locations in several studies of recent sediments. Small scale cross bedding and ripple marks (predominantly oscillation ripples) are common primary features at some horizons. Graded bedding, flow casts, and various groovings associated with turbidity current deposits are not present; however, slump rolls over 2 feet in diameter and many feet long, are present in at least one bed near the base of the Moydart Formation, both in Pictou County and at Arisaig. These record an instance of extensive slumping of the uncompacted sediments.

The upper member of the Moydart Formation is composed of red siltstones, some of which contain limy algal (?) nodules. Near the top of the Stonehouse Formation is a mottled red and green sandstone. The color of these red beds is the result of ferric iron present in hematite. They are believed to represent sediments periodically exposed to the air.

These features of the Arisaig Series, together with its shelly fauna (predominantly brachiopods, but including crinoids, pelecypods, gastropods, trilobites, corals, and only rarely, graptolites) imply a relatively shallow water and near-shore environment of deposition.

One exception to the shelly fauna exists. The lower member of the Ross Brook Formation at Arisaig is a sequence of thin black shales with an abundance of graptolites. To the west, at its only exposure in Pictou County, it is composed of light gray mudstones in beds several inches thick. The graptolitic black shales are overlain and underlain by beds of shallow water origin, and are limited in lateral extent. Their origin, therefore, is attributed to a local reducing environment rather than to the deep water environment hypothesized for more extensive graptolitic black shale deposits.

At least 13 tuff beds are present in the lower member of the Ross Brook Formation at Arisaig. Only 2 are present in the same member 20 miles to the southwest, and only 1 thin ash bed is seen near the base of the middle member another 3 miles to the southwest. This distribution suggests a source to the northeast, possibly at or related to the thick sequence of volcanics underlying fossiliferous Silurian rocks at the Mabou Highlands on Cape Breton Island (Phinney 1956, unpubl. S.M. thesis).

The Knoydart Formation was deposited as alternating red and green, fine grained sediments. The former are considered indicative of at least intermittent subaerial exposure. Fish fossils have been found in these red beds at Arisaig (Ami, 1900). The fact that the Arisaig Series passes quickly and transitionally into these red beds further indicates its shallow water origin.

Regional

The facies distribution of the Silurian and Devonian rocks in Nova Scotia is shown in figure 17.

In the Arisaig-Northeast Pictou County area are the shallow water beds, discussed above. To the south, these pass through a narrow transitional zone into the sequence present in southeast Pictou County, described above under STRATIGRAPHY. To the southwest, in the Annapolis Valley Bear River areas, the Silurian is represented by a thick succession of graptolitic black shales and minor quartzites. A deeper water origin is usually ascribed to such a graptolite facies. The southeast Pictou County sequence of sandstones, shales, and slates is intermediate between the Arisaig lithology and that of the Annapolis Valley.

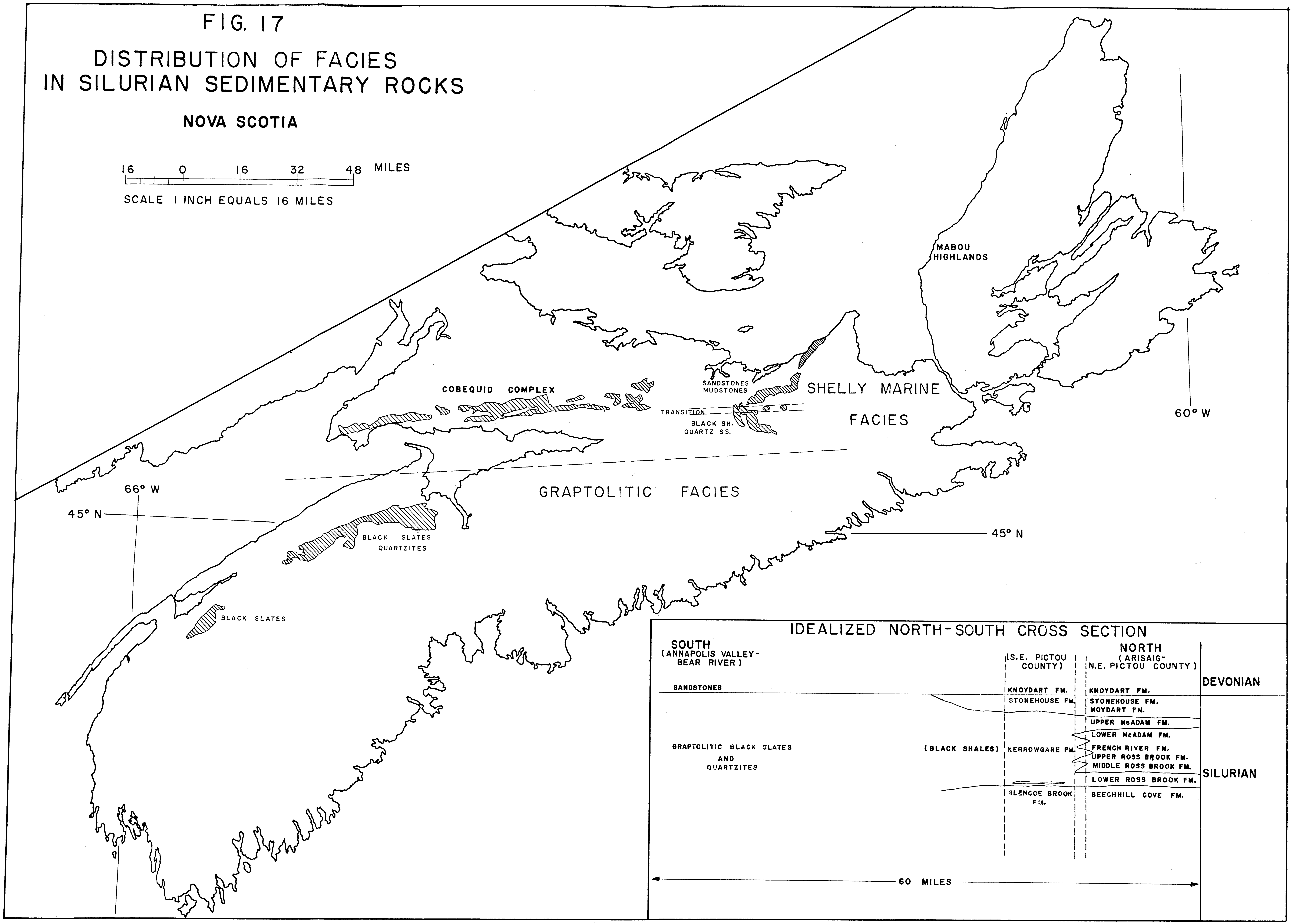


FIG. 17
DISTRIBUTION OF FACIES IN SILURIAN SEDIMENTARY ROCKS
NOVA SCOTIA

Fletcher (1892, p 15) describes a section in the Silurian rocks of the Cobequids as igneous rocks overlain by Medina sandstone, overlain by Clinton black shale, in turn overlain by green sandstones. In his terminology, this could represent either of the stratigraphic sequences observed in Pictou County, but differs from that of the Annapolis Valley.

The various facies are distributed in belts running about east-west, with shallow water beds of a marine shelly facies to the north and deeper water beds of a graptolitic facies to the south. In the Devonian period, the Antigonish and Pictou County areas were the sight of intermittently exposed sediments, possibly non-marine, while in the Annapolis Valley a marine shelly facies was being deposited. Thus, the sea retreated to the south at the beginning of the Devonian.

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APPENDIX I

RESULTS OF CHEMICAL ANALYSES

The results of the rapid silicate analyses of the 14 samples and the one standard are tabulated below, including the individual and average results for the two samples run in duplicate. In addition, some conventional values of the standard, G-1, are included for comparison.

Samples ML 101, ML 104, and I 6 are from the Kerrowgare Formation. The first two of these are of a black shale and a black mudstone, respectively, from near the middle of the formation. Sample I 6 is of a black quartzitic siltstone, near the base of the formation.

Sample PF 1 is of an argillite, from the lower part of the Browns Mountain Group. Samples AM and BRd 1 are from the Sunnybrae Formation. The former is a shale and the latter a tuff lamina within shale.

Sample PF 21A is of an argillaceous, quartzos, fine grained sandstone, from the base of the Beechhill Cove Formation.

Samples DF 63 and DF 65a are from the middle member of the Ross Brook Formation. The former is a typical mudstone of this formation, and the latter is a 1/8 inch ash lamina found near its base.

Samples ES 1Ac and ES 1Af are of, respectively, a well bedded argillaceous, fine grained sandstone and an adjacent mudstone. These samples were collected near the base of the upper member of the Ross Brook Formation.

Sample DT 27 is of a black, limy, septarian nodule from the upper member of the McAdam Formation.

Sample DT 35 is of a typical green, argillaceous sandstone from high in the Moydart Formation.

Sample GB 101 is of an argillaceous quartz sandstone from the top of the lower member of the Glencoe Brook Formation.

SAMPLE	G-1	Consensus mean * for G-1	Arithmetic mean * for G-1	Conventional value ** for G-1	ML 101	ML 101	av.	PF 1	PF 1	av.
SiO_2	72.9	72.45	72.22	72.5	45.7	45.9	45.8	64.3	64.5	64.4
Al_2O_3	14.4	14.30	14.44	14.3	22.3	22.2	22.2	17.0	17.7	17.4
Fe_2O	0.82	0.85	0.94	0.84	0.58	0.04	0.31	2.15	2.06	2.11
FeO	0.88	1.00	1.00	0.95	12.1	12.1	12.07	3.65	3.65	3.65
MnO	0.01	0.025	0.03	0.03	0.06	0.07	0.07	0.12	0.13	0.13
TiO_2	0.26	0.25	0.26	0.25	1.05	0.98	1.02	0.82	0.82	0.82
P_2O_5	0.08	0.10	0.10	0.09	0.18	0.15	0.17	0.14	0.17	0.16
K_2O	5.37	5.45	5.57	5.5	3.12	3.08	3.10	3.88	3.65	3.77
Na_2O	3.33	3.35	3.26	3.3	0.93	0.68	0.81	2.55	2.37	2.46
CaO	1.34	1.35	1.42	1.3	0.21	0.23	0.22	0.21	0.23	0.22
MgO	0.40	0.45	0.39	0.36	3.73	3.36	3.55	2.45	2.41	2.43
H_2O(total)	0.42	0.40	0.37 +	0.34 +						
TOTAL	100.2				90.0 plus H_2O	88.8	89.3	97.3 plus H_2O	97.7	97.5

* Fairbairn, et al, 1951

** Shapiro and Brannock, 1956 (obtained by 5 analysts in another laboratory of the U. S. Geological Survey).

SAMPLE	BRd 1	DF 63	DT 35	ES 1Af	ES 1Ac	PF 21A	I 6	GB 101	DF 65a	AM	ML 104	DT 27
SiO_2	67.4	58.7	74.0	62.3	67.5	80.9	70.3	81.0	49.2	67.1	61.0	51.7
Al_2O_3	15.3	20.6	11.9	18.7	15.8	9.02	14.6	11.3	25.2	17.3	21.1	6.74
Fe_2O	0.81	1.86	1.91	2.85	2.54	1.56	1.74	0.91	2.79	1.79	1.19	0.90
FeO	3.02	4.61	2.42	3.37	3.85	1.89	4.76	0.42	3.73	2.54	5.74	4.36
MnO	0.11	0.02	0.03	0.03	0.03	0.01	0.02	0.01	0.04	0.04	0.04	0.54
TiO_2	0.54	1.09	1.07	1.08	1.00	0.48	0.74	1.27	1.90	0.78	1.15	0.57
P_2O_5	0.13	0.17	0.16	0.13	0.10	0.06	0.19	0.07	0.69	0.13	0.10	0.10
K_2O	3.14	3.75	2.16	3.76	2.98	1.67	2.41	3.3	3.81	4.75	3.60	0.81
Na_2O	2.82	0.98	2.44	1.07	0.91	1.17	0.85	0.19	0.97	0.24	0.61	0.05
CaO	0.70	0.17	0.26	0.01	0.14	0.00	0.26	0.11	0.83	0.33	0.26	30.9(as $CaCO_3$)
MgO	2.08	1.32	1.43	1.35	1.16	0.61	1.50	0.19	1.60	2.29	1.01	1.48
H_2O (total)	2.58	5.48	2.12	4.72	4.03	2.01			6.80	3.56		2.11
TOTAL	98.6	98.8	99.9	99.4	100.0	99.4	97.4 plus H_2O	98.8 plus H_2O	97.6	100.9	95.8 plus H_2O	100.3

APPENDIX 2

LIST OF FOSSILS BY LOCALITY

The following is a list of identifiable fossils found at each location sampled. The fossil locality map, fig. , and where appropriate, the detail maps, fig. to fig. , indicate the locations of sampling points.

BEECHHILL COVE FORMATION

A 11 Wallace Brook (fig. 6)

strophomenoid
rostrospiroid

A 13 Wallace Brook (fig. 6)

Cornulites sp.

A 15 Wallace Brook (fig. 6)

linguloid

AV 1 Road between Route 4 and Avondale west of Barneys River

Cornulites sp.
dalmanellid
linguloid

AV 2 Road between Route 4 and Avondale west of Barneys River

Cornulites sp.
dalmanellid
rhynchonellid
horn coral
gastropod

DW 2 Wallace Brook (fig. 6)

dalmanellid
horn coral
crinoid
gastropod
pelecypod

DW 4 Wallace Brook (fig. 6)

dalmanellid

FP 16 Road between Route 4 and Avondale west of Barneys River

Eostropheodonta sp.

dalmanellid

horn coral

crinoid

FP 17 Junction of Route 4 and road to Avondale east of Barneys River

rostrospiroid, *Meristina* (?)

snail

FP 20 Road between Route 4 and Avondale west of Barneys River

dalmanellid

orthoceroid

FP 21 Baillie Brook

orthoid (?)

MH 2 Route 4 near Antigonish County line

Cornulites sp.

Eostropheodonta sp.

rhynchonellid

O 49 Road south of Route 4 between Barneys River and Barneys River Station

large dalmanellid

crinoid

UE 22 East French River (fig. 4)

dalmanellid

strophomenoid

crinoid

WB 137 Wallace Brook

dalmanellid

ROSS BROOK FORMATION, MIDDLE MEMBER

A 20 French River (fig. 6)
Coelospira hemisphaerica
Plagiorhyncha cf. *glassi*

BR 6 West Barneys River near junction with Barneys River
Favosites sp.

DC 1 Cross Brook
conularid

DC 2 Cross Brook
Chonetes sp.
Coelospira hemisphaerica

CB 5 Cameron Brook (fig.14)
Coelospira hemisphaerica
Resserella sp.
crinoid

DF 60 French River (fig. 6)
Coelospira hemisphaerica
Resserella sp.
Platyceras sp.

ES 5 Tributary of East French River south of Route 4
Coelospira hemisphaerica
crinoid

FP 18 Route 4 southwest of Barneys River Station
Coelospira hemisphaerica

FP 19 Middle River north of Route 4
Coelospira hemisphaerica

FR 80 French River (fig. 6)
Coelospira hemisphaerica

FR 114 French River (fig. 6)
Coelospira hemisphaerica

FR 127 French River (fig. 6)
Coelospira hemisphaerica

FR 130 French River (fig. 6)
Coelospira hemisphaerica
linguloid

LE 33 East French River(fig. 5)
Coelospira hemisphaerica

LE 78 East French River(fig. 5)
Coelospira hemisphaerica

LE 80 East French River(fig. 5)
Coelospira hemisphaerica
Resserella sp.

ME 7 East French River(fig. 4)
inarticulate brachiopod

ME 14 East French River(fig. 4)
trilobite
Coelospira hemisphaerica
Resserella sp.

ME 20 East French River(fig. 4)
trilobite
Coelospira hemisphaerica

ME 21 East French River(fig. 4)
Coelospira hemisphaerica
Stropheodonta sp.
dalmanellid
crinoid

ME 26 East French River(fig. 4)
trilobite
Coelospira hemisphaerica (?)

ME 28 East French River(fig. 4)
Calymene sp.
Coelospira hemisphaerica
crinoid

ME 29 East French River(fig. 4)

Cornulites sp.

Calymene sp.

Atrypa reticularis

Brachyprion (?) sp.

Coelospira hemisphaerica

Pholidostrophia sp.

Resserella elegantula

small rhynchonellid

Platyceras sp.

Tentaculites sp.

ME 38 East French River(fig. 4)

Coelospira hemisphaerica

ME 50 East French River(fig. 4)

Coelospira hemisphaerica

ME 57 East French River(fig. 4)

Priodon (?) sp.

ME 60 East French River(fig. 4)

Chonetes sp.

Coelospira hemisphaerica

fine ribbed rhynchonellid

ME 62 East French River(fig. 4)

Coelospira hemisphaerica

ME 63 East French River(fig. 4)

trilobite

Coelospira hemisphaerica

ME 64 East French River(fig. 4)

Calymene sp.

Coelospira hemisphaerica

ME 65 East French River(fig. 4)

Coelospira hemisphaerica

ME 66 East French River(fig. 4)

Coelospira hemisphaerica

crinoid

ME 67 East French River(fig. 4)

trilobite

Coelospira hemisphaerica

ME 68 East French River(fig. 4)

trilobite

Coelospira hemisphaerica

linguloid

crinoid

gastropod

ME 69 East French River(fig. 4)

trilobite

Coelospira hemisphaerica

MH 1 Route 4 near Antigonish County line

Coelospira hemisphaerica

O 40 Route 4 between East French River and French River

Coelospira hemisphaerica

dalmanellid

UE 5 East French River(fig. 4)

Coelospira hemisphaerica

ROSS BROOK FORMATION, UPPER MEMBER

DC 3	Cross Brook	(fig. 14)
		Coelospira hemisphaerica
DF 6	French River	(fig. 6)
		Coelospira hemisphaerica
		pelecypod
DF 8	French River	(fig. 6)
		Chonetes sp.
		Coelospira hemisphaerica
		orthoceroid
DF 9	French River	(fig. 6)
		Chonetes sp.
		Coelospira hemisphaerica
		dalmanellid
DF 18	French River	(fig. 6)
		Coelospira hemisphaerica
DF 30	French River	(fig. 6)
		Coelospira hemisphaerica
DF 36	French River	(fig. 6)
		Chonetes sp.
		Coelospira hemisphaerica
		Leptaena rhomboidalis
		rhynchonellid
DF 38	French River	(fig. 6)
		"Camarotoechia llandoveriana var. rossonia" McLearn
		Chonetes sp.
		Coelospira hemisphaerica
		Plagiorhyncha glassi
		dalmanellid

DF 43 French River (fig. 6)

trilobite

Plagiorhyncha glassi

Resserella sp.

rostrospiroid

Pterinea sp.

Tentaculites sp.

DF 46 French River (fig. 6)

Plagiorhyncha glassi

Resserella sp.

pelecypod

DF 48 French River (fig. 6)

Plagiorhyncha glassi

Resserella sp.

DF 49 French River (fig. 6)

Plagiorhyncha glassi

Resserella sp.

fine ribbed rhynchonellid

DF 50 French River (fig. 6)

Plagiorhyncha glassi

Resserella sp.

EB 54 East Branch French River

Coelospira hemisphaerica

Meristina sp.

ES 1A Tributary of East French River at Route 4

Coelospira hemisphaerica

Plagiorhyncha glassi

Resserella sp.

ES 2 Tributary of East French River south of Route 4

Resserella sp.

F 16 Tributary of French River

Coelospira hemisphaerica

Resserella sp.

F 24 Tributary of French River

Coelospira hemisphaerica

FR 45 French River (fig. 6)

Coelospira hemisphaerica

Protomegastrophia (?) sp.

LE 70 East French River (fig. 5)

Coelospira hemisphaerica

UE A Tributary of East French River (fig. 4)

Coelospira hemisphaerica

UE A4 Tributary of East French River (fig. 4)

Coelospira hemisphaerica

UE A12 Tributary of East French River (fig. 4)

Coelospira hemisphaerica

crinoid

Tentaculites sp.

FRENCH RIVER FORMATION

DF 13	French River	(fig. 6)
		homalonotid
		Brachyprion (?) sp.
		Eatonioides sp.
		Leptaena rhomboidalis
		Striaespirifer stonehousensis
		dalmanellid
		orthoceroid
		pelecypod
DF 14	French River	(fig. 6)
		Cornulites sp.
		Eatonioides sp.
		Pterinea sp.
DF 15	French River	(fig. 6)
		trilobite
		Eatonioides sp.
		Striaespirifer stonehousensis
		dalmanellid
		Pterinea sp.
		orthoceroid
DF 16	French River	(fig. 6)
		Eatonioides sp.
		Leptaena rhomboidalis
		dalmanellid
		orbiduloid
		Pterinea sp.

DF 17	French River	(fig. 6)
		Cornulites sp.
		trilobite
		Eatonioides sp.
		Meristina sp.
		Striaespirifer stonehousensis
		dalmanellid (different than DF 16)
		dalmenitid
		linguloid
		Pterinea sp.
FR 22	French River	(fig. 6)
		Cornulites sp.
		Eatonioides sp.
		Striaespirifer stonehousensis
		dalmanellid
		bellerophontid
		pelecypod
FR 30	French River	(fig. 6)
		homalonotid

McADAM FORMATION, LOWER MEMBER

DT 11	Telford Brook	(fig. 12)
		Tentaculites sp.
DT 12	Telford Brook	(fig. 12)
		Cornulites sp.
		Amphistrophia _funiculata_
		Chilidiopsis sp.
		Leptaena _rhomboidalis_
DT 13	Telford Brook	(fig. 12)
		Cornulites sp.
		Chilidiopsis sp.
DT 23	Telford Brook	(fig. 12)
		Amphistrophia _funiculata_
		dalmanellid
		rhynchonellid
HA 5A	Harri Brook	(fig. 8)
		Cornulites sp.
		Atrypa _reticularis_
		Resserella _elegantula_
		dalmanellid other than _R._ _elegantula_
		rhynchonellid
HA 6	Harri Brook	(fig. 8)
		Cornulites sp.
		trilobite
		Meristina sp.
		dalmanellid
		schuchertellid

HA 7	Harri Brook	(fig. 8)
		<u>Cornulites</u> sp.
		<u>Isorthis</u> sp.
		<u>Meristina</u> sp.
HA 8	Harri Brook	(fig. 8)
		<u>Cornulites</u> sp.
		<u>Leptaena</u> <u>rhomboidalis</u>
		<u>Meristina</u> sp.
		crinoid
HA F	Harri Brook	(fig. 8)
		<u>Amphistrophia</u> <u>funiculata</u>
		<u>Chonetes</u> sp.
		dalmanellid
		rhynchonellid
		crinoid
HA T	Harri Brook tributary	(fig. 8)
		<u>Cornulites</u> sp.
		<u>Amphistrophia</u> <u>funiculata</u>
		<u>Chilidiopsis</u> sp.
		<u>Leptaena</u> <u>rhomboidalis</u>
		rhynchonellid

MOYDART FORMATION, LOWER MEMBER

DM 7 McLellan Brook (fig. 9)
Cornulites sp.
Isorthis sp.
Meristina sp.
rhynchonellid

DM 8 McLellan Brook (fig. 9)
Cornulites sp.
Amphistrophia sp.
Isorthis sp.
Leptaena sp.
Meristina sp.
rhynchonellid

DM 13 McLellan Brook (fig. 9)
rhynchonellid
strophomenoid
crinoid

DS 4 Sutherland River (fig. 13)
bryozoan
rhynchonellid
crinoid
Pterinea sp.

DS 45 Sutherland River (fig. 13)
trilobite
Howellela sp.
Pholidops sp.
chonetid
rhynchonellid
gastropod

DS 53 Sutherland River (fig. 13)
dalmanellid
rhynchonellid
orthoceroid

SR 101 Sutherland River (fig. 13)
rhynchospira

STONEHOUSE FORMATION

DT 1 Telford Brook (fig. 12)

- Beyrichia cf. B. salteriana
- Chonetes sp.
- Salopina (?) sp.
- dalmanellid
- linguloid
- large rhynchonellid
- small rhynchonellid
- crinoid
- orthoceroid
- pelecypod

DT 17 Telford Brook (fig. 12)

- Beyrichia of the B. maccoyiana sulcata type
- Kloedenellid (?) ostracod
- Chonetes sp.
- dalmanellid
- rhynchonellid
- crinoid

DT 20 Telford Brook (fig. 12)

- trilobite
- Kloedenellid (?) ostracod
- Chonetes sp.
- large rhynchonellid
- small rhynchonellid
- trepostome bryozoan
- Pterinea sp.

HB 200 (Stonehouse ?) Holmes Brook

- spirifer Delthyris (?) sp.
- trepostome bryozoan
- crinoid

LR 1 Ridge east of McLean Lake

Cornulites sp.

homalonotid

Beyrichia (*Nodibeyrichia*) *pustulosa*

Beyrichia (*Neobeyrichia*) cf. *salteriana*

Beyrichia (*Neobeyrichia*) *maccoyiana* ?

Beyrichia (*Neobeyrichia*) *maccoyiana* var. *sulcata*

Kloedenia *wilkensiana*

Chonetes sp.

Delthyris *rugaecosta*

Pholidops sp.

dalmanellid

dalmenitid

orbiculoid

small rhynchonellid "*Camarotoechia*"

coral

crinoid

gastropod

Pterinea sp.

LR 3 Brook feeding McLean Lake

Cornulites sp.

Kloedenia *wilkensiana*

Beyrichia cf. *B.* *pustulosa*

Beyrichia sp.

Chonetes sp.

Delthyris *rugaecosta*

Pholidops sp.

dalmanellid

rhynchonellid

crinoid

orthoceroid

Pterinea sp.

LR 4 Road east of Forbes Lake

Podollela sp.

Proschizopheria sp.

orbiculoid

trepostome bryozoan

Pterinea sp.

LR 5 Road east of Forbes Lake

Chonetes (?) sp.

LR 6A Road east of Forbes Lake

rhynchonellid

crinoid

LR 7 Road east of Forbes Lake

pelecypod

LR 8 Road east of Forbes Lake

Atrypa reticularis

Platyorthis (?) sp.

rhynchonellid *Rhynchospira* (?) sp.

Pterinea sp.

LR 9 Road east of Forbes Lake

Chonetes sp.

Delthyris rugaecosta

Platyorthis (?) sp.

Rhynchospira sp.

Shaleria sp.

dalmanellid

rhynchonellid "*Camarotoechia*" sp.

coral

Pterinea sp.

NR 2 Ridge north of road between Bridgeville and Springville

Chonetes (?) sp.

linguloid

rhynchonellid

crinoid

NR 3 Ridge north of road between Bridgeville and Springville

Chonetes sp.

Howellela sp. (?)

Pholidops sp.

dalmanellid *Salopina* (?) sp.

rhynchonellid

GLENCOE BROOK FORMATION

FT 5 Brook 2 miles east of Sunnybrae

Dolerorthis sp.

dalmanellid

rostrospiroid, primitive *Meristina*

horn coral

GB 5 Glencoe Brook (fig. 7)

ribbed *Atrypa* sp., not A. *reticularis*

strophomenoid

I 1 Road south of MacPherson Lake

primitive *Atrypa* sp.

K 3 Road northeast of Kerrowgare

two dalmanellids

snail

MT 2B Tributary of McLellan Brook east of Brookville schoolhouse

Atrypa sp.

dalmanellid

NR 6 Road west of Sam Cameron Brook

Atrypa sp. not *A*. *reticularis*

NR 6A Road west of Sam Cameron Brook

Atrypa sp.

strophomenoid

NR 9 West of Road west of Sam Cameron Brook

Eostropheodonta sp.

dalmanellid

strophomenoid

TT 1 Thompson Brook

dalmanellid

TT 11 Thompson Brook

Atrypa sp. same as GB 5

KERROWGARE FORMATION

BL 3 Blanchard Brook

rostrospiroid

BL 7 Blanchard Brook

rostrospiroid

strophomenoid

HB 83 Holmes Brook

Isorthis (?) sp.

dalmanellid

rhynchonellid

HB 83A Holmes Brook

Resserella sp. (?)

rhynchonellid

HB 83B Holmes Brook

brachiopods

HB 85 Holmes Brook

dalmanellid, *Isorthis* (?) sp.

rhynchonellid

HB 91 Holmes Brook

ostracods

dalmanellid, *Isorthis* (?) sp.

rhynchonellid

Tentaculites sp.

orthoceroid

I 3 Sam Cameron Brook

brachiopods

I 4 Sutherland River near South McLellan Mountain Road

dalmanellid

orthid

IO 6 Road from Sunnybrae to Iron Ore

Cornulites sp.

Atrypa reticularis

Chonetes sp.

Howellela (?) sp.

Isorthis (?) sp.

Meristina sp.

rhynchonellid

Platyceras sp.

orthoceroid

Autobiography of the Author

The author was born in Clifton, New Jersey on July 1, 1934, the second child of Mr. and Mrs. Henry Maehl. He began his schooling in the public schools of Clifton in September 1939. He moved with his family to Cincinnati, Ohio in 1941 residing there and attending the public schools until the end of World War II at which time he returned to Clifton, New Jersey and continued in the public school system there, graduating from Clifton High School in June 1951. He ranked third in a class of 250 and was awarded the Baush and Lomb Award in Science. He matriculated to the Massachusetts Institute of Technology in September 1951, majoring first in geophysics but transferring to geology in which field he received his S.B. in June 1955. Following his freshman year he worked as a drafts - man at the Acme Tool and Machine Company in Kearney, New Jersey.

The following two summers were spent at the Nova Scotia Centre for Geological Sciences, in 1953 as a student and in 1954 as an instructor while engaged in field work for his S.B. thesis undertaken jointly with David B. Brooks.

The summer of 1955 was spent in the Four Corners area of the United States Southwest doing structural mapping and reconnaissance geology for the Rocky Mountain Division of Sun Oil Company.

In Spptember 1955 graduate work was begun at the M.I.T., as a teaching assistant in the Department of Geology and Geophysics. The summer of 1956 was spent engaged in structural geology research at the Gulf Research and Developement Corporation in Harmarville, Pennsylvania.

In September 1956 the author was married to the former Joan Benson of Mattapan, Massachusetts, then a biology student at Simmons College.

The academic year 1956-57 was again spent in graduate school at the M.I.T. as a teaching assistant. In May, 1957 general exams were completed in theoretical geology and sedimentology. During the summer of 1957 field work on the PhD thesis was begun in Nova Scotia while again an instructor at the Nova Scotia Centre for Geological Sciences. The academic year 1957-58, 58-59, and 59-60 as well as the summers of 1958 and 1959 were spent primarily in the completion of this thesis research. In the academic year 1957-58 he was awarded a full tuition scholarship and the following year was the recipient of the Standard Oil Company of California Fellowship.

The author was appointed part-time instructor in chemistry and mathematics at Suffolk University for the year 1959-60. He was then offered and accepted a post of assistent professor and head of the chemistry department for the year 1960-61.