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MOUNT LOGAN AREA, MATANE AND GASPE-NORTH COUNTIES

QUEBEC DEPARTMENT OF NATURAL RESOURCES

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GEOLOGICAL EXPLORATION SERVICE
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GEOLOGICAL REPORT 118

MOUNT LOGAN AREA

Matane and Gaspe-North Counties

by

C. R. Mattinson

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ERRATUM

P. 15, 1st par., lines 3 and 10, read "crest line" instead of "height of land".

FOREWORD

This report records the results of the first of two detailed studies centering on the geology of the western half of the Shickshock range of mountains. Each study formed the basis for a doctorate thesis.

Field work for the present report was done in 1955 and 1956. Laboratory and office studies were done at McGill University and the University of Glasgow, and the thesis was presented at McGill in 1958. The second report, in press, was prepared by N.C. Ollerenshaw. Field research was done during the period 1960-62 and covered the western end of the Shickshocks as well as much adjacent territory. Both office and laboratory research were carried out at the University of Toronto, and the thesis was presented there in 1963.

The reports are shortened versions of the original theses.

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INTRODUCTION

General Statement

The area described covers some 220 square miles of the Appalachian Mountain system.

A northern upland of Cambro-Ordovician shales and meta-arkoses gives way abruptly on the south to the rugged Shickshock range which is developed on the Shickshock Group of metamorphosed lavas and minor meta-sedimentary rocks. Silurian and Devonian fine clastic rocks and limestones underlie a plateau south of the mountains. The Shickshocks were affected by local and continental glaciation and parts of the southern Shickshocks were overridden by a northward-moving ice-mass.

Regional metamorphism increases southward in intensity and has converted the lavas to albite-epidote-amphibole schists, and the sedimentary rocks to greenschists. Apparent greater metamorphism of the Shickshock Group has suggested to some that it is Precambrian in age. Actually, a Cambro-Ordovician age is indicated for the Group because it apparently overlies Cambro-Ordovician sedimentaries with interlayering at the contact.

Taconic folding and metamorphism largely obliterated primary flow layering and bedding in the Shickshock Group and developed a pervasive foliation generally parallel to the original layering. Acadian(?) folding threw the foliation into a tight ENE.-trending syncline with a more open anticline on the south. The Silurian and Devonian to the south were lowered into place adjacent to the Shickshocks by a major fault along which are found a small serpentine body and, at places, strong hydrothermal effects.

Copper mineralization is scattered through the area but deposits of economic interest are unknown.

Location and Area

The area treated in this report was mapped during the field seasons of 1955 and 1956. It is in northwestern Gaspé peninsula some 40 miles southeast of the town of Matane and is very largely in Matane county, only a few square miles in the extreme northeast being in Gaspé-North county. Most of the area is in Leclercq, Joffre and Faribault townships; smaller parts are in the townships of Cuoq, Dunière, Richard and Courcelette.

The accompanying map is bounded on the west and east, respectively, by longitudes 66°30' and 67°00', and on the south and north by latitudes 48°41' and 48°55'. Within these boundaries the mapped area forms an ENE.-trending band, 26 miles long and 5-12 miles wide. The total mapped area includes about 220 square miles and covers parts of three 15-minute quadrangles: about two-thirds and one-quarter respectively of the east and west halves of the Mount Logan quadrangle and about one-fifth of the west half of Boutet quadrangle. For convenience in discussion the whole area is here referred to as the Mount Logan area. The name is derived from Mount Logan, the highest peak of the included portion of the Shickshock range.

Access

The rugged topography of the Shickshock mountains limits access to, and travel within, the area. A private road, maintained by the Hammermill Paper Company, traverses the mountain belt from north to south near the west edge of the area. This road connects, via the village of Saint-Jean-de-Cherbourg, with Highway 6 along the coast to the north. Just beyond the extreme northeast edge of the area a truck road crosses the northern edge of the Shickshock mountains and penetrates a limited distance to the south. This road also connects with Highway 6 via the village of Saint-Octave-de-l'Avenir. A number of other roads, mainly constructed by lumber companies, lead up to and along, but do not go south of, the high scarp which marks the north edge of the Shickshocks. A dozen passes along streams descending this northern escarpment are negotiable on foot. At times these passes, used in conjunction with the nearest truck roads, provided the only practicable means of access and supply for field work in the northern part of the area, and, in general, the only practical means of travel within the Shickshocks is on foot.

The area south of the Shickshocks is accessible along a road which branches from the previously mentioned Hammermill Paper Company road and trends northeastward parallel to the south boundary of the Shickshocks. From this road a network of Company roads covers the country for several miles to the south. Other lumber operators have built roads which cross the southeast and southwest corners of the area, and connect respectively with Causapscal and Matane.

There is little prospect of air or water access to or within the area. Cap-Chat river, the largest stream, is negotiable only by small canoes at periods of high water. Lakes Matane, Joffre (Cap-Chat) and possibly Beaulieu and Côté are the only lakes on which pontoon aircraft might land, -and these are all near existing roads. Pontoon equipped helicopters probably would not be highly efficient because clear landing sites, apart from a few small lakes, are rare.

Climate

The interior of Gaspé peninsula suffers a somewhat more severe climate than is typical of maritime temperate zones of equivalent latitude. This is owing both to the influence of cold currents in the Gulf of St. Lawrence and to comparatively high altitudes. The Climatalogical Atlas of Canada (Thomas, 1953) shows a mean annual isotherm of 35° passing through the peninsula. In the Shickshocks the mean annual temperature is probably at least 5° lower.

The annual precipitation is about 21 inches of rain and 12 feet of snow. Snow, in deep shaded gulleys in the Shickshocks, was observed at the end of July, 1955. First snowfalls in the mountains may be expected around the middle of September. McGerrigle (1954a, p. 16) noted permafrost at one place and, on the basis of stream temperatures, suspected its existence elsewhere in valley bottoms.

Settlement and Resources

The only settlements in the area are the supply depots and semi-permanent work camps established by lumber companies. About half the area lies within the Shickshock Fish and Game reserve. In much of the remaining half, fish and game rights are included with the timber concessions. The major concession is that of Hammermill Paper Company of Erie, Pennsylvania, which holds pulp rights on some 65 square miles within the mapped area. The James Richardson Lumber Company of Cap-Chat, Gaspé-North county, has the principal long-term lumber concession.

McGerrigle (1954a, p. 6) has considered the agricultural possibilities of the Courcelette area to the east and suggests that the belt of land lying south of the Shickshocks should be suitable for this purpose. If so, the similar lowland belt which exists south of the Shickshocks in the Mount Logan area should be even more amenable to farming, being at a generally low altitude. Within the Shickshocks high elevations, precipitous slopes, and poor soil cover render farming prospects nil.

Big game in the area includes bear, moose, deer and caribou. The last appear to be scarce and none were seen by us. Beaver, mink, muskrat, otter, marten, skunk and weasel are found locally but very little trapping now is done here.

Trout are plentiful in lakes and streams in the lower parts of the area. All lakes in the higher parts of the Shickshocks are devoid of fish and none are to be seen in the mountain streams above the lowest major waterfall.

Timber is the main commercial asset of the region. Spruce and fir are the dominant types; poplar is common in the lowlands; and there are also pine, cedar, maple and birch. A high percentage of the birch has been killed by disease or some climatic factor but this tendency seems to be subsiding. Outside the Shickshocks, the land is everywhere wooded; within, some of the higher parts are barren or clothed only with small, stunted spruce (Plate I).

Field Methods and Personnel

A preliminary topographic map (22B/15, Mount Logan) at a scale of one inch to one-half mile, with a 50-foot contour interval, published by the Department of Mines and Technical Surveys, Ottawa, was used as a base map and, with a small part of map 22B/10, Boutet, forms the basis of the geological maps included with this report.

Traverses were made, normally by two-man teams, along most of the streams and lake shores, across some interstream areas, and along all the roads. Locations were controlled by pace and compass methods, by use of Royal Canadian Air Force air photos on a scale of approximately 3,300 feet to one inch, and, particularly in the Shickshock range, by aneroid altimeters.

Field party personnel during the 1955 field season included J. Béland of the Quebec Department of Mines as party chief, the writer as senior assistant, and M. Watson and R. Legault, first-year students at the Universities of New Brunswick and Montreal, respectively, as junior assistants. O. Soucy, P. Roy, C. Sergerie and M. Paquet of Cap-Chat served as packers and J. Paquet of Cap-Chat was cook. During the 1956 field season the writer acted as party chief, G. Ross, student at Acadia University, as senior assistant and A. Philpotts and J. Beauregard, students at McGill University and the University of Montreal, respectively, as junior assistants. O. Soucy, C. Sergerie, J. Sergerie and L. Dumont of Cap-Chat were packers and J. Paquet again served as cook.

Acknowledgements

The laboratory and office study of the field data on which this report is based were carried on at McGill University, Montreal, Quebec, and the University of Glasgow, Scotland. Both universities made available various facilities, and much assistance, particularly with problems of petrology, was had from the respective teaching staffs.

Fossil identifications in this report were kindly made by L.M. Cumming of the Geological Survey of Canada. C.H. Smith and J. Tanner of the Geological Survey of Canada and the Dominion Observatory, respectively, informed the writer on certain aspects of the geology and geophysics of the area.

Mr. L. Lister of the Hammermill Paper Company very kindly provided a map of his company's pulp concessions and allowed the field parties to use company roads and cabins. Officials of the James Richardson Lumber Company permitted use of roads on their concession.

Previous Work

Sir William Logan (1844) traversed Gaspé peninsula by way of Cap-Chat river (which bisects the present area), thence across the height of land to the headwaters of Miner brook, and down this brook and the Cascapédia river to the village of Cascapédia on Chaleurs bay. On this journey the peak now known as Mount Logan was climbed, as were some other nearby peaks.

The following year Logan's assistant, A. Murray (1847) observed the country along the Sainte-Anne, Matane, and Saint-Jean rivers, and in 1858 Richardson (1859) traversed the east end of the Shickshocks from the forks of the Sainte-Anne river to La Grange (Barn-shaped) mountain.

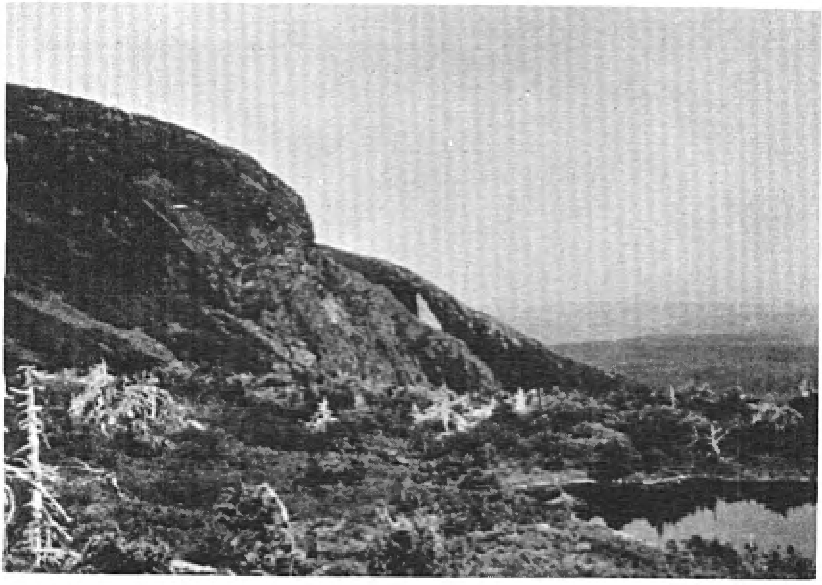
The information from these surveys is contained in Logan's Geology of Canada (1863). This volume gives a succinct statement of the lithology and structure of the Shickshock range as then conceived.

Low (1883) and Ells (1883) explored portions of interior Gaspé to the south and east of the Mount Logan area. Both dwell briefly on the relation of the rocks of the Shickshock range to surrounding formations.

Study of the glacial geology of the north-central portion of Gaspé was initiated by Chalmers (1904). His nearest approach to the Mount Logan area was along Sainte-Anne river 15 miles to the east and along the coast some 12 miles north. Mailhiot (1911) comments on the Shickshock rocks along the Sainte-Anne and mentions their relation to the 'Cambrian' rocks to the north. Coleman (1922), who made a study of the physiography and glacial geology of the peninsula, penetrated the area mapped by the writer via Cap-Chat river. His report mentions the geology and physiography of some of the peaks on either side of the river. Collins and Fernald (1925), with others, spent some time during the summer of 1921 and 1922 on an investigation of the geography of the Shickshocks between Cap-Chat river and Des Iles lake. No geological observations were made but a number of mountains which had been named by Logan were re-identified and a contour map (the elevations of which seem to be some 350 feet too high) of the vicinity was drawn.

Alcock (1925) mapped the Shickshocks between Mount Logan and Matane river. Geological data on his map are confined to lines representing the boundaries of the Shickshocks. The accompanying report gives a brief description of the rock types, their structure and possible age and a summary of the physiography. Some few comments relating to the area mapped by the author are to be found in a number of more recent papers which treat the geology of Gaspé as a whole, viz. Alcock (1941), Dresser and Denis (1944), and McGerrigle (1952, 1954b). Reconnaissance traverses of a number of streams in the Mount Logan area were made by McGerrigle. Information from these traverses was used in the preparation of his geological map of Gaspé which appeared in 1953. McGerrigle (1954a), mapped an area which adjoins the Mount Logan area on the east and northeast. Béland (1957) mapped the area to the northwest, and Ollerenshaw (1963) mapped the area immediately to the west.

PLATE I



A

B

Stunded spruce growth and barren stretches in high Shickshocks.

PLATE II

Looking south toward north escarpment of Shickshock mountains from road near Saint-Octave-de-l'Avenir.

PHYSIOGRAPHY

Topography

Three main physiographic divisions are recognized in the area, namely, a northern upland, a central mountain belt and a southern plain. These divisions are clearly related to lithology. The northern upland is underlain by mildly metamorphosed slaty shales and sandstones and the southern plain by limestones, limy shales and fine clastic rocks. Between these divisions lies the Shickshock range, developed on resistant metavolcanic and metasedimentary rocks. The three divisions trend about N.30°E., in harmony with the gross structural trends of the region.

The northern upland is a rolling, wooded country of gentle ENE.-trending ridges at an average altitude of 1,800 feet. Near the Shickshocks, the upland slopes southward so that a shallow piedmont trench, one to four miles wide, is formed between it and the mountain scarp. The average altitude of this trench is about 1,000 feet, but its lowest point, attained along an ENE.-trending portion of Cap-Chat river just north of the map-area, is less than 300 feet. The present mapping nowhere goes more than two miles north of the Shickshocks. The accompanying map thus illustrates only the south part of the trench which appears as a north sloping plain furrowed by small NNW.-flowing transverse streams. The topography of the extreme northwestern part of the area is anomalous. Here the trench is carved in the metavolcanic rocks normally associated with the mountain belt. To the north, broad, rounded hills are developed on a mile-wide band of resistant meta-arkoses flanked by a 1,500-foot-wide metavolcanic outlier.

At about 1,600 feet there is an abrupt break in the gently sloping south wall of the trench. Above the 'break' the terrain rises steeply in a pronounced escarpment that forms the north wall of the Shickshock range. The scarp is 2,000-1,500 feet high in the eastern half of the area; in the western half it is lower and less regular but is still generally more than 1,000 feet high. The slope of the scarp averages 20°-40°; vertical cliffs 200-300 feet high occur here and there. Impressive views of the scarp are possible from many points along the coast, whence it has the appearance of a high and forbidding wall (Plate II).

Another, less abrupt but nevertheless impressive, scarp bounds the Shickshocks on the south. This scarp ranges from 600-1,000 feet in height in a lateral distance from top to base of about one-half mile.

Between the two escarpments, the Shickshock mountains are 4 miles wide at the west edge of the area and 7 at the east edge. Two deep, canyon-like depressions trend N.25°W. across the mountains, one at the centre of the area and one at the extreme west edge. In the centre, the Cap-Chat valley has an average altitude of about 600 feet and, on the west, the Matane Lakes chain lies at about 750 feet. The floors of both these depressions are less than half a mile across and both are bounded by high hills forming escarpments only slightly less bold than the Shickshock 'Front' itself.

In the lower Shickshocks the main landscape elements are south sloping ridges separated by deep stream valleys. Slope reversals are common along the ridge tops, giving rise to small rounded hills which stud the divides in mammillary fashion. In the higher Shickshocks, steeply sloping ground is less common, stream gradients are more gentle and the depth of stream incision is much less. Thus, the long profile of many streams is broadly convex upward. The higher hills of the Shickshocks commonly are rounded in plan and conical in outline; many of these too are slightly convex upward. Some of the highest hills, near the north escarpment, have broad, gently undulating tops which may be remnants of an old erosion surface.

Altitudes in the mountains are up to the height of Mount Logan, 3,710 feet. Mount Logan is the highest of a line of lofty hills, the Logan range, which stretches across the area. The Logan range is about a mile wide and stands a mile or less south from the crest of the Shickshock Front.

South of the Shickshock mountains there is a broad plain on which stand a few low ridges. From the extreme southwestern corner of the area to a point about three-quarters of the way to the eastern boundary the southern plain is separated from the Shickshocks by a deep trench in which flow Bonjour, Alphonse and Wilson brooks. About 35 square miles of the southern plain, all in the east half of the area, were mapped. Near the Shickshocks the mapped part is at an elevation of about 1,400 feet. Southward there is a gentle rise which culminates in a N.60°E. trending group of very broad, rounded hills with a maximum elevation of 1,800 feet. Beyond these hills a second flat area, about 1 1/2 miles across, lies at an altitude of 1,300 feet. Still farther south, just in the corner of the area, the land begins a second rise to 1,800 feet, the general level of the great interior plateau of Gaspé peninsula.

The Shickshocks have previously (Alcock, 1944) been characterized as a youthfully dissected peneplain or peneplains with deep valleys separated by large areas of flat-topped upland surface. In his

1944 paper, Alcock relates the Shickshock summits between 3,000 and 4,200 feet to a peneplain of late Cretaceous or early Tertiary date. This was termed the Shickshock peneplain. The upland surface surrounding the Shickshocks was designated the Gaspé peneplain and assigned a probable late Tertiary age. McGerrigle (1954a, p. 12), in the Courcelette area immediately east saw 3,000 feet as one of the most important summit levels and noted another pronounced "levelling off or terracing" at 2,700-2,800 feet.

The present writer admits the strong visual impression of an accordance of summits and generally flat-topped character of the hills as viewed from within the Shickshocks (Plate III). Detailed study of the available topographic maps and topographic profiles drawn by the writer tends to show, however, that these features are more apparent than real. A cumulative plot of the frequency of summit altitudes (to the nearest 50 feet) is shown in Figure 1. On this graph long straight stretches are thought to represent surfaces of summit accordance and probably are related to significant erosion surfaces. The graph viewed in the light of the topographic map suggests a major surface of summit accordance (ES1) sloping from about 2,900-2,300 feet. A second and lower surface of summit accordance (ES2) appears between 2,200 and 1,800 feet. The direction of slope of these horizons of summit accordance was investigated by making elevation frequency graphs for various subdivisions of the area. Both surfaces slope southward and slightly to the west.

The considerable amount of upland surface which still exists above 2,900 feet suggests that the surfaces of summit accordance are not actual peneplain remnants. More probably they are surfaces inherited from, and parallel to, former peneplains which stood at somewhat higher levels. Flat-topped surfaces between 3,400 and 3,000 feet in the Logan range may be actual remnants of the uppermost of the old peneplains. Mass wasting in the area appears to be dominated by the backwasting of slopes rather than by downwasting. The high peneplain remnants are situated between the heads of streams draining northward and streams draining southward. They appear to owe their preservation to the fact that headward stream erosion has not been going on long enough to bring them under vigourous attack. The main mass wasting agency is a type of mudflow discussed below.

Mudflows and Slope Retreat

The latitude and elevation of the Shickshock mountains are such as to provide a long period of freezing and thawing each spring and fall. The foliated and fractured nature of the rock is favourable to water penetration and rock spalling under frost action. Mechanical weathering, therefore, is dominant. The flatter portions of many of the higher hills are covered with a mechanically produced felsenmeer (Plate III). Slopes are mantled with a few feet of soil and rock fragments largely derived from weathering of the underlying rocks.

In the spring, the slope mantle is thawed and soaked in melt-water and at places becomes so fluid that gravity is able to overcome the low coefficient of friction between mantle and probably ice-covered bedrock. When this happens, rock debris, mud and vegetation suddenly slide down the slope along channels up to 100 feet wide and with lengths ranging up to 1,500 feet, leaving great, conspicuous stripes of bare rock. The mudflow stripes thus formed are conspicuous features of the local landscape (Plates IV and V). They are present in all stages of evolution - from freshly formed stripes of bare rock to old scars now almost entirely reclothed in new vegetation. It is of interest that the mudflow gash is roughly the same depth (a few feet) at all points along its length. Evidently this erosional agent is carving the slopes back evenly so that each new edge parallels the previous one. Such parallel slope retreat is generally considered typical of semi-arid rather than humid climates.

Drainage

The line dividing the Chaleurs and St. Lawrence watersheds of Gaspé peninsula lies much nearer the northern coast than the southern, and about three-quarters of the peninsula drains into Chaleurs bay. Part of the divide lies in the Mount Logan area, the eastern quarter being drained by Des Iles and Go-Ashore brooks to Cascapédia river and eventually to Chaleurs bay.

The major drainage systems in the St.Lawrence part of the watershed are the Cap-Chat and Matane rivers. The northern part of the mountain belt sheds its waters into short streams which flow precipitously over the north escarpment and into various tributaries of the Cap-Chat and Petite Matane rivers. Because the height of land is near the north edge of the Shickshocks, the south-flowing streams in general are larger and have more deeply incised the south scarp. The waters of the south-flowing streams are collected in the trench which skirts the south edge of the Shickshocks over most of the area. They are then carried by Alphonse and Wilson brooks to Cap-Chat river or by the Bonjour to Matane river. A few subsequent streams flow N.60°E. or S.60°W. down the slopes leading into the Joffre (Cap-Chat) and Matane Lakes trenches.

Thus, a roughly trellised drainage pattern has developed. The Cap-Chat river and the Matane Lakes - Petite Matane (Upper Matane) chain are parallel and flow, respectively, N.25°W. and S.20°E. Their

PLATE III

A- Flat-topped hills and apparent accordance of summits; looking W.S.W. from Mount Logan. Felsenmeer in foreground.

B- Flat-topped hills and apparent accordance of summits seen looking N.E. from Mount Logan. Felsenmeer in foreground.

PLATE IV

A- Mudflow scars on mountain north of mouth of Bascan brook.

B- Mudflow scars on north escarpment of Shickshocks.

major tributaries, such second order streams as Isabelle river and Beaulieu and Wilson brooks, join at right angles and in turn are served by third order streams whose trends are subparallel to Cap-Chat and Matane rivers.

Bailey (1889, p. 401) and Laverdière and Morin (1941, p. 221) have called attention to the several streams in Gaspé which rise south of the height of land but drain northward across it to the St. Lawrence. Both the Matane and Cap-Chat rivers are prominent examples. Cap-Chat river has its source in Joffre lake about two miles south of the Shickshocks. From here it first flows south, then west and finally N.25°W. through the Shickshocks. The Matane rises north of the Shickshocks, traverses the Shickshocks in a S.20°E. direction, and then flows southwestward. Gradually it describes a great clockwise curve, recrosses the height of land at the west edge of the Shickshocks, and discharges into the St. Lawrence at the town of Matane. Both the Matane and Cap-Chat rivers are probably superimposed streams which incised their canyons across the Shickshocks during a period of uplift.

Study of contour maps suggests that flowage through the Matane Lakes trench originally was northward. The river and lake chain lie in a depression which leads northwestward to the headwaters of Petite Matane river. It is thought that originally the waters of Bonjour brook flowed into the south end of the present Matane lake, crossed the Shickshocks via the Matane Lakes gorge and were conducted by the above-mentioned depression to Petite Matane river and thence to the St.Lawrence. Drainage reversal may have been brought about by glacial damming of the former drainage lines or by southward tilting movements believed to have affected the peninsula as a whole. Study of contoured topographic maps and aerial photographs of the depression between the present Matane and Petite Matane drainage systems does not reveal any features suggestive of morainal dams, and the tilt hypothesis appears to be the more plausible explanation.

Lakes and ponds in the area mostly are small and shallow. The largest, Matane lake, was formed by glacial erosion which overdeepened the Matane River trench. Lake Beaulieu in the high Shickshocks occupies a semicircular depression at the head of Beaulieu brook and is probably a tarn.

Physiographic Evolution

The progression of events in the evolution of the physiography of the map-area may be summarized as follows:

In late Cretaceous or early Tertiary time the area was reduced to a peneplain, probably equivalent to the Schooley peneplain of the Appalachians of the United States. The ancestral Matane and Cap-Chat rivers were probably already in existence with a northward direction of flow. Uplift with slight southward tilt initiated a series of streams flowing southward across what is now the Shickshock mountains. As the softer rocks north of the Shickshocks were reduced the north escarpment began to form and small streams flowing northward down the scarp came into being. Between the heads of the north and south flowing streams peneplain remnants were preserved in a narrow strip of highland - the present Logan range.

Continuing erosion of the area eventually produced a second peneplain, probably equivalent to the Harrisburg peneplain recognized elsewhere in the Appalachians, on the rocks bordering the Shickshocks. The more resistant rocks of the Shickshocks were not reduced to base level, but the second peneplain is probably represented there by the lowermost of the two surfaces of summit accordance in Figure 1. The area was then rejuvenated and further southward tilt probably reversed the direction of drainage through the Matane Lakes trench. Erosion of the Shickshocks continued and the new peneplain endured rapid dissection by streams that now are entrenched some hundreds of feet below the general upland surface. The effect of glaciation, slight as far as topography is concerned, is discussed below.

Glacial Geology

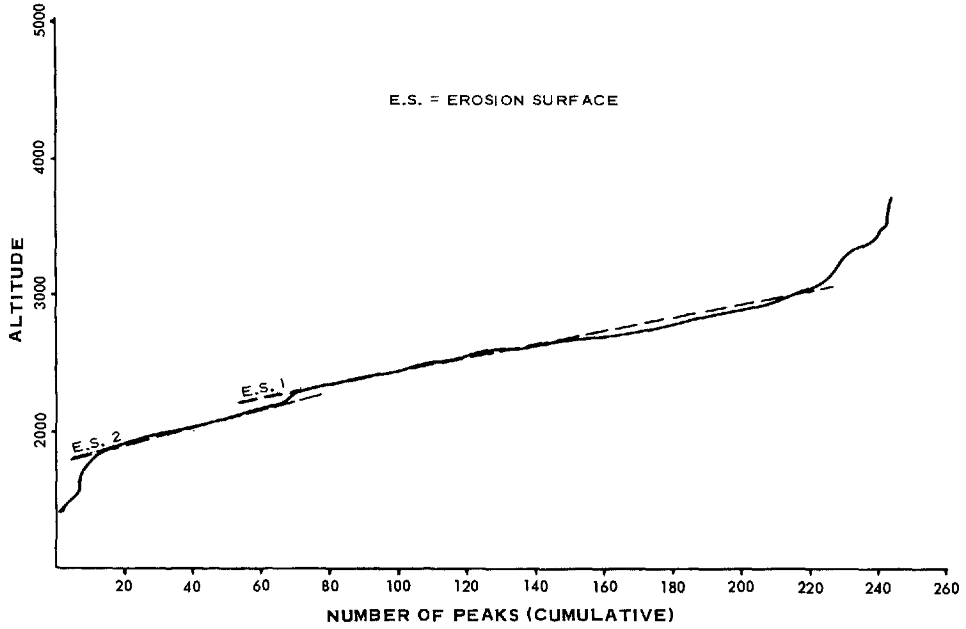
McGerrigle (1952) has carefully summarized the literature on Pleistocene glaciation in Gaspé peninsula. His paper points out the shift in the weight of opinion which, over the 85 years preceding, has changed from a view of local glaciation only, in Gaspé, to a theory of complete Laurentide (continental) glaciation. On theoretical grounds, supplemented by his own observations and those of previous workers, McGerrigle postulates a five-stage glacial history as follows:

1. Cirque or valley glaciation.
2. Local ice cap.
3. Laurentide ice sheet.
4. Local ice cap.
5. Cirque or valley glaciation.

In the present work three classes of glacial phenomena were noted, namely, cirques and cirque-like forms, erratics, and drift.

The northern rim of the Shickshocks appears to have been a locus of sites of small glaciers from which ice moved both north and

FIGURE 1



PLOT OF CUMULATIVE TOTALS OF PEAKS AGAINST
ALTITUDES – SHICKSHOCK MOUNTAINS

MOUNT LOGAN AREA, GASPÉ, P.Q. C.R. MATTINSON

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south. Northward moving ice created cirque and cirque-like forms (Plate VIa) at places along the northern escarpment and southward-moving ice gouged out a number of south-facing valley head depressions now occupied by lakes (Lake Beaulieu, e.g.). Former points of ice divide are now marked by the low cols which exist at intervals along the northern Shickshock rim (Plate VIb). At Côté lake the col was cut so low that the lake drainage was able to breach it after the original southward drainage was blocked by glacial damming.

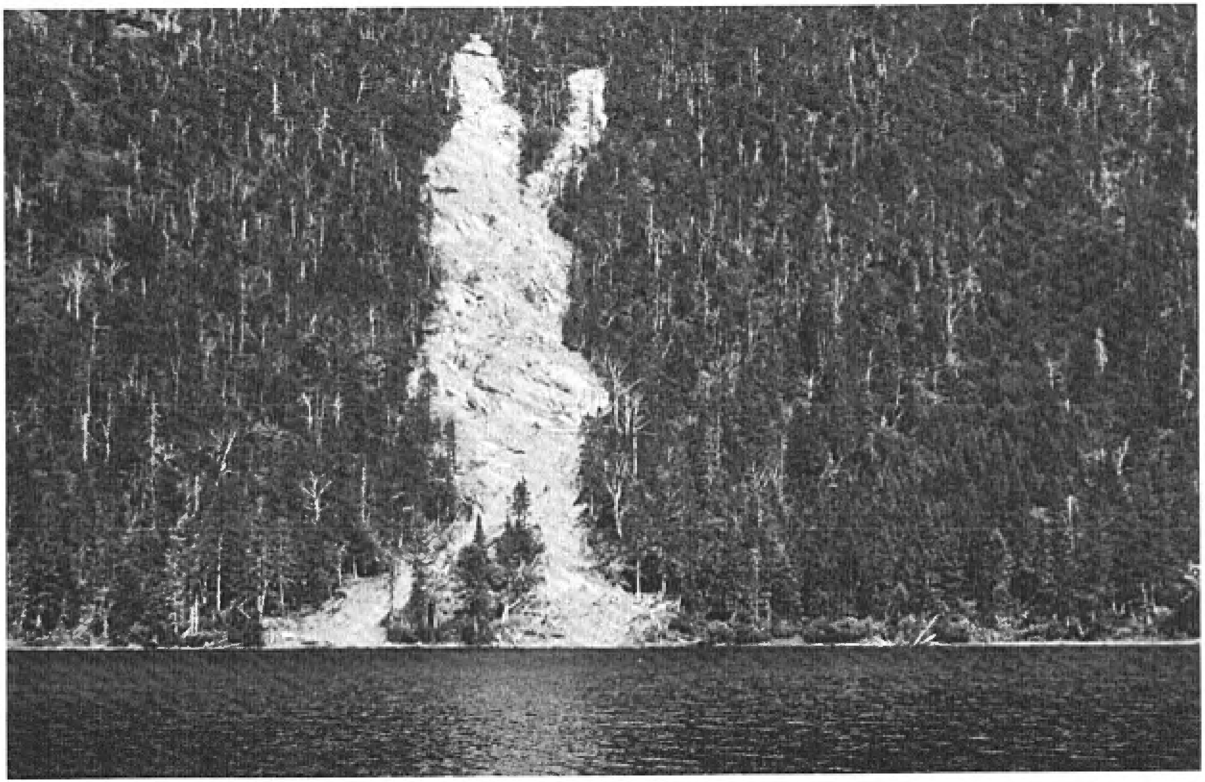
Erratics found in the Shickshocks include a boulder of limestone and boulders of fine limy clastics and quartzite. No Laurentian boulders were seen. Just south of the Shickshocks in the Cap-Chat valley, however, there is a boulder of anorthosite presumably derived from anorthosite bodies north of the St. Lawrence. A granite boulder just south of the Shickshocks and east of Joffre lake may be either of Laurentian type or from granite masses farther east. Other boulders of probable Laurentian derivation are known south of the map-area (McGerrigle, 1952).

Drift is exposed in a number of stream cuts in the Shickshocks. Most exposures have the unsorted and unstratified nature of till. In some, there is a conspicuous horizontal arrangement of the long axes of platy boulders (Plate VII). Holmes (1941, p. 1350), who studied the fabrics of tills in New York state, relates this phenomenon to subglacial deposition of boulders which have been carried along with their flat sides parallel to the laminar flow planes in the ice mass. Till is common around the shores of Matane lake, and along the northwest side of the lake there is well bedded and sorted glaciofluvial material.

South of the Shickshocks local hummocky topography and occasional stream and road cuts indicate the presence of local sheet moraine. One kame terrace was noted along Wilson brook 2 1/2 miles east of Cap-Chat river, and another 1 1/2 miles northeast of Joffre lake.

The material comprising the drift deposits in the Shickshocks is dominantly mud and metavolcanic boulders and fragments. Some drift banks, however, contain fine limy and clastic fragments identical in appearance to Silurian rocks south of the Shickshocks. Such material is most abundant near the south edge of the Shickshocks but has been recognized as far north as a point on Cap-Chat-Est (Epidote) river one mile south of Mount Logan at an elevation of 2,500 feet. These deposits, charged with material of southward derivation, and scattered isolated erratics from the same source, imply that ice moved from the southern plain northward and upward into the Shickshocks. Similarly, McGerrigle (1954a, p. 15) found erratics lying in the Shickshocks between Mount

PLATE V



Fresh mudflow into Chic lake.

PLATE VI

A- Northwest facing cirque at east side of embayment at head of Ouellette brook. Looking N.E. from Mount Logan. Note that the threshold or sill of normal cirques is not present in this example.

B- Looking northward across Des Iles lake. Low col in north rim of the Shickshocks.

Albert and Cascapedia lake from sources south of the Shickshocks. There is thus scattered evidence of ice movement northward along a 40-mile front and, as shown by the till bank a mile south of Mount Logan, evidence that this ice moved at least 5 miles into the Shickshocks and uphill at least 1,000 feet.

It is difficult to see how this ice could be related to the continental ice sheet. Laurentian ice from the north or north-northwest is known (McGerrigle, 1952, p. 43) to have crossed Mount Albert but there seems to be no reason for a lobe of this ice to have reversed its direction to move northward in the adjacent Mount Logan area. The same objection can be applied to any theory involving a lobe of continental ice which might be postulated to have moved down the St. Lawrence valley, swung south of the Shickshocks along the Matapedia valley then swung north into the Shickshocks. It seems more likely that the evidence of northward ice movement is related to a local ice centre, possibly somewhere in the region of Dunière township, south of the Shickshocks. The fact that deposits attesting to its former existence were found mainly along the larger stream valleys might imply that this ice tended to push into the Shickshocks along such easier avenues of approach. However, Silurian erratics at 2,500 feet on Cap-Chat-Est river imply that the top of the ice mass was, at least at this altitude, sufficiently high to blanket practically all the southern Shickshocks. This ice cap probably was active at a late stage in the glacial history of the region. Had it come before the stage of cirque and valley glaciation the stream bank deposits now attesting to its former existence probably would have been removed. The ice cap itself appears to have destroyed any terminal moraines which valley glaciers moving out of the mountains might be expected to have left.

In his 1952 paper, McGerrigle expresses doubt that any part of the Shickshocks escaped being covered by a continental ice sheet from the north. Laurentian ice crossed the summit of Mount Albert (3,775 feet) 20 miles east of the Mount Logan area and reached at least 3,700 feet in the Tabletop mountains at the east end of the Shickshock range. These conclusions were based on the distribution of erratics which appear to have been derived from the Laurentian terrain north of the St. Lawrence river. Laurentian erratics are unknown in the Shickshocks of the present area but their presence farther south implies that the Laurentide ice sheet crossed the height of land here as well. Quartzite boulders, probably from quartzite bands in the Ordovician farther north, were found at an elevation of 1,300 feet 2 miles north of Des Iles lake. A boulder of biotite gneiss is known (McGerrigle 1954a, p. 14) at 1,700 feet just east of the present area near Côté lake.

There is nonetheless some indication that the higher peaks of the Shickshocks in the Mount Logan area may have stood as nunataks above the continental ice sheet. Our failure to find any Laurentian or Ordovician type erratics on the higher summits such as Mounts Logan and Blanc seems fair negative evidence, because the barrenness of these higher peaks abets the chances of finding such erratics if any are present there. On the east shoulder of Mount Logan at about 3,425 feet, there is a rock needle some tens of feet high on which a great slab of rock is delicately perched, and two rock pinnacles exist at 2,700 feet on a spur north of Mount Logan. These features were examined only at a distance through binoculars but seemed to be products of normal mass wasting and of such size as to preclude their development during post-Pleistocene time. It seems probable that, if a continental ice sheet had been active here, such delicate features would have been destroyed provided, of course, that they are pre-glacial. Finally, on the higher summits of the Logan range no glacial groovings, roches moutonnées, stoss and lee structures, pavements, or faceted or striated boulders were seen. The statement is equally true of all parts of the Mount Logan area but again, while such features might easily be overlooked in the heavily wooded lower areas, some at least, if present, should have come to our notice in the comparatively barren higher areas. Thus, the writer accepts the proposition that Laurentian ice crossed the Shickshocks but suggests that it may have failed to cover many of the higher summits.

GENERAL GEOLOGY

The Appalachian Mountain System may be subdivided into an inner, folded and thrust faulted zone extending from Alabama to New York, and an outer, folded, faulted, metamorphosed and intruded zone extending from Alabama to Newfoundland. The inner belt suffered mainly Appalachian (Late Paleozoic) disturbance. The outer belt, through Newfoundland, the Maritimes and Quebec, south to New York, and probably in Pennsylvania and Maryland, endured both the Taconic (Late Ordovician) and Acadian (Middle to Late Devonian) disturbances. The eastern part of the outer belt appears to have been affected by Appalachian folding and faulting, accompanied by the uplift of Precambrian masses in Newfoundland, Nova Scotia, eastern New Brunswick and New England south to the Carolinas.

Gaspé peninsula lies wholly within the northern portion of the outer Appalachian belt. Most of the peninsula is underlain by sedimentary rocks of Cambrian to Pennsylvanian age believed to have been derived from a provenance to the east and southeast. There is also an important content of lavas of Cambrian to Devonian age. Granitic, granitoid, and ultrabasic rocks were intruded in Ordovician to Devonian time.

Table of Formations

ERA	PERIOD		FORMATION		DESCRIPTION
CENOZOIC	Pleistocene				Drift; ground moraine
PALEOZOIC	IGNEOUS ROCKS	Post-Lower Devonian			Basic dykes
		Ordovician? Devonian?			Serpentinite
	Lower Devonian		Grande Grève		Grey limestones
			Cape Bon Ami		Grey limestones; minor fine limy clastics
	Middle (and Upper) Silurian				Fine, limy and dolomitic clastics; limestones, minor dolomites and shales
	Middle Ordovician				Hard black shale
	Cambro-Ordovician		Shickshock Group		Blue-green amphibole schists; lesser meta-arkoses and fine, white mica schists
			NORTHERN ZONE	Sandstones	Mildly metamorphosed arkoses
				Shales	Mildly metamorphosed, fissile, black shales (slates)

In essence, the Shickshocks are carved from a prism of metavolcanic, metasedimentary and intrusive rocks some 65 miles long, and averaging 6 miles wide. They rise as much as 2,500 feet above their surroundings, and are of unknown depth. The Shickshock prism trends N.30°E. and is, on the whole, slightly arcuate with convexity to the north.

The Mount Logan area lies across the central part of the Shickshock zone and includes three major structural and lithological elements. Most of the map-area is in the highly deformed Shickshock terrain. Here, original layering and bedding have been obliterated and structural data are limited to readings of foliation, fractures, and lineations. The general arrangement of the foliation outlines a tight syncline north of a broader anticline. Both trend ENE.; plunges are ENE. except for one locality.

North of the metavolcanic belt, shales and sandstones dip generally south, although steep north dips are common. Limited sequence data suggest that tops face south, that is, that the succession is younger toward the Shickshocks. The metavolcanic and metasedimentary rocks of the Shickshocks are thought to be in part interlayered with, and, in part above, the northern sequence. South of the Shickshocks, and separated from them by a major fault, folded and faulted limy clastics and limestones dip generally southward.

Cambro-Ordovician

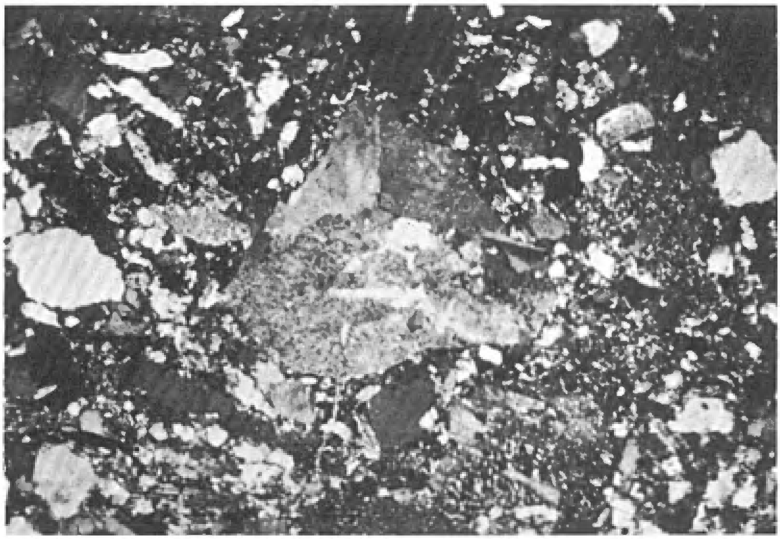
Sedimentary Rocks North of the Shickshocks

All the rocks of the area, apart from those in the 35 square miles of Silurian and Devonian terrain south of the Shickshocks, are Cambro-Ordovician in age. By far the greater part of this sequence is made up of the metamorphosed lavas and sedimentary rocks of the Shickshock range. North of the range, and structurally below the Shickshock Group, mildly metamorphosed sedimentary rocks are found. Only a thin fringe of these rocks immediately north of the Shickshock range, comprising some 10 square miles, was mapped by the writer. They may be divided into two main types, both mildly metamorphosed, namely, arkosic sandstones and dark shales. In general, the sandstones occur immediately north of the Shickshocks and the shales lie several hundred feet to as much as a mile farther north. Here and there, however, shales are found immediately north of the Shickshocks and, in some instances, only one or two outcrops of sandstone intervene between the metavolcanic and shale sequences.

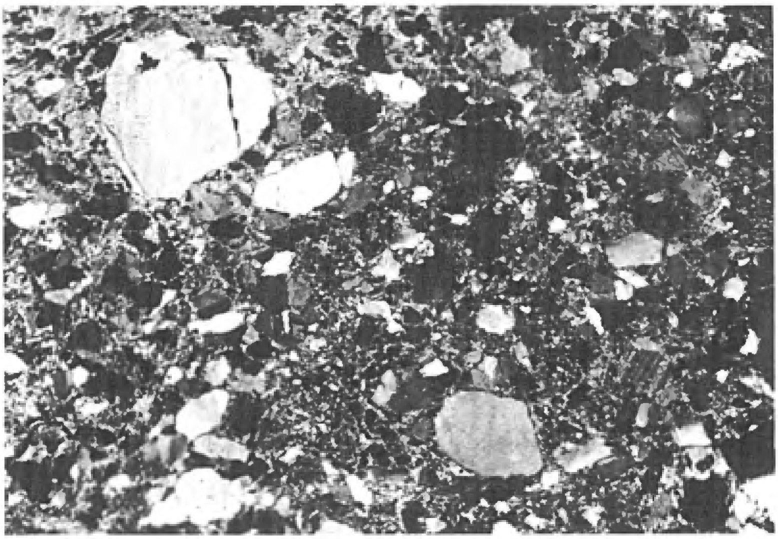
PLATE VII

Till exposed in cut bank on Cap-Chat-Est river, 3 miles north of south boundary of Shickshocks. Note horizontal arrangement of tabular boulders.

PLATE VIII



A- Poorly sorted, comparatively undeformed meta-arkose from north of Shickshocks. Note rock fragment at centre of photo.
Crossed nicols. x12



B- Poorly sorted meta-arkose from sandstone group north of Shickshocks. Note crack in large feldspar clast, and strain shadows in quartz grains.
Crossed nicols. x 18

From work done by McGerrigle (1954a) in the Courcelette-Tourelle area to the east and from unpublished observations by McGerrigle (personal communication) it is known that the sedimentary terrain of shales, sandstones, quartzites, limestones and conglomerates is continuous northward to the coast. Within the limits of the present mapping, however, rocks other than arkosic sandstones and shales are not present in significant amounts.

Shales

The shales or slates typically are thinly bedded, highly fissile, and black or grey; many weather reddish. Greyish green and rare green and maroon argillites were observed at a few places very near the mountain front. At a few places the shale sequence is interrupted by zones, a few feet or tens of feet thick, of medium-grained, white, quartz sandstone. Commonly these are limy or closely associated with limestone beds.

Phyllite zones are common, especially near the mountain front. They are characterized by a mildly warped and undulating bedding fissility with a marked silvery luster, abundant milky quartz veins, and numerous inconsistent fractures. These zones may be several hundreds of feet long but are usually only a few tens of feet wide. They are transitional to normal slates although the transition is, in some instances, abrupt. They probably were generated by shearing stress and mark fault zones.

Veins - Irregular lensoid veins of quartz or calcite, some with both minerals in combination, are found in many exposures. Quartz veins are by far the most common. Vein widths range up to 2 inches and lengths, up to 3 feet. The veins have a preferential orientation in the bedding direction but numerous vein protrusions and stringers transect bedding.

Metamorphism - None of the shales observed are entirely free from the effects of metamorphism, and there is a regional increase in the degree of metamorphism toward the mountain front. Nearly all the shales are highly fissile. As the mountain front is approached the fissility becomes finer, the shales become harder, the surfaces of fissility assume a glazed and slickensided look and the silky luster of finely divided white mica becomes apparent. The most highly metamorphosed shales, encountered in stream cuts just north of the mountain front, contain minute crushed and flayed-out quartz grains and are pervaded by dimensionally oriented mica and chlorite grains.

At an indefinite point near the mountain front, where the shales develop an appreciable quantity of directionally oriented flaky minerals, schistosity or flow cleavage becomes recognizable. In all but one of the exposures where both bedding and schistosity could be recognized the two features are parallel. The one contrary exposure showed a strike divergence of about 20° between bedding and schistosity. This and a few other discordancies in other rock types suggest that the schistosity is of the axial plane type, and that the rocks involved lie in isoclinal folds.

Sandstones

The sandstones are composed of poorly sorted and rounded clastic particles of various minerals. Most beds are medium to coarse grained but beds of fine to silt grade are present. Thin zones of shale occur sporadically, and there are a few thin conglomerate beds in the eastern part of the area.

The sandstones are mostly dark and weather grey, greenish grey, and brown. Those at Montagne pond and at the head of Ouellette brook weather purplish. Beds a few inches thick are quite apparent in many outcrops, especially where purplish or brown weathering. Granularity ranges up to 1 cm. but averages around 1 mm.

In the eastern part of the area, a conglomerate zone 3-20 feet thick occurs on three adjacent streams. The pebbles are dominantly feldspar, less commonly quartz and feldspar, quartz, and rare dark green chloritic material. Most of the pebbles are augen shaped, being about twice as long as broad (maximum 1" x 1/2"), and are oriented with long axes parallel to bedding. Their appearance, plus the common close association of small pegmatite stringers and vein-like feldspar masses, suggests that the pebbles are actually augen of secretion origin. However, the pegmatites contain potassium feldspar and the pebbles are of albite, about An_4. Thus, the association is probably fortuitous and the apparent augen doubtless are true pebbles, their shape being due to deformation after deposition.

In the field it is difficult to recognize the more deformed and metamorphosed sandstones for what they are. Under the microscope, however, their originally clastic nature usually is apparent (Plate VIII). Feldspar, quartz and rock fragments are the largest grains; the matrix is of chlorite, white mica and a variety of fine mineral grains. In general, the cement content is low, being highest in the finer-grained rocks. The average mineral composition of 35 thin-sections of these rocks is given below:

Mineral		Percentage
Plagioclase		42
Quartz		24
Muscovite		12
Chlorite		7.4
Aphrosiderite-diabantite	3.0	
Prochlorite	2.4	
Penninite	Trace	
Undetermined	2.0	
Epidote		4.4
Perthite		2.9
Orthoclase		2
Black oxides (ilmenite and magnetite)		1.8
Microcline		1
Titanite		1
Green biotite		0.5
Carbonate (mainly or entirely calcite)		0.4
Apatite		Minor
Zircon		Minor
Monazite		Minor
Leucoxene		Minor
Tourmaline		Minor
Brown biotite		Minor
Pyrite		Minor
Red iron oxide		Minor
Actinolite		abundant in one section.

A few rock fragments are present in thin-sections of the more mildly sheared rocks. These are intergrowths of various combinations of quartz, plagioclase, orthoclase, microcline, perthite and, rarely, black oxides and titanite. The rock fragments have crystalloblastic textures and appear to have been derived from granitic gneiss. All plagioclase grains for which a good determination of the anorthite content was obtained are more albitic than An_{15} and most are close to An_5. Alteration of the plagioclase is not strong in general; secondary white mica is the most common alteration product followed by epidote, carbonate, clay, chlorite and zoisite. Some slides contain both highly altered and comparatively fresh plagioclase. An unequivocal determination of the anorthite content of the highly altered plagioclase is difficult but it appears to be around 30%. Chlorite and white mica are associated in the more fine-grained rock. The main varieties of chlorite are diabantite-aphrosiderite and prochlorite. The magnesium content of these chlorites is about the same but prochlorite has considerably less iron and more aluminum than diabantite-aphrosiderite. The two varieties do not occur in the same thin-section unless one is present as a vein mineral. Most of the rocks contain 6% to 7% epidote, mainly as clouds of very fine grains. The epidote is thought to be of metamorphic origin, and probably results from the early reaction of free calcite, kaolin and iron oxide deposited with the original sediments. Rocks containing as much as 25% epidote occur sparingly near metavolcanic outcrops, and an influx of volcanic ash may have provided the elements necessary for epidote generation at those localities.

Patch, blade and bleb ex-solution perthites occur in a third of the sections studied. Microcline or orthoclase is the normal host mineral but there are some antiperthites. A little late orthoclase or adularia occurs in minute veins, and where these cross plagioclase grains a narrow band of plagioclase on each side of the vein is replaced by orthoclase.

Ilmenite and magnetite in these rocks are largely or wholly of detrital origin. They occur in shapeless grains in thin bands representing depositional laminae rich in heavy minerals. Much of the ilmenite is altered to titanite and/or leucoxene. Practically all the rocks contain titanite in amounts ranging from traces to 4%. Most is in extremely fine grains strung out in ropy masses parallel to the schistosity. Larger titanites have a dark, murky appearance and commonly are in part composed of leucoxene. A common relationship shows a kernel of ilmenite surrounded by titanite, the whole irregularly touched with leucoxene. Thick rods of titanite are intergrown along the cleavages of some plagioclase grains, and rarely the plagioclase is almost completely converted to a titanite pseudomorph (Plate IX A). This titanization of plagioclase appears to be a rare event in metamorphism.

The green biotite has properties and composition intermediate between those of chlorite and normal biotite. About a quarter of the sandstones examined contain green biotite; these are all from localities west of Cap-Chat river and within 1/4 mile of the mountain front. Green biotite is a secondary mineral formed as a consequence of metamorphism and its appearance is considered to mark a level of metamorphism higher than that shown by the chlorite-bearing rocks.

Veins - Much of the sandstone is cut by small irregular veins of quartz and pink or white feldspar. The proportion of quartz to feldspar is variable but the tendency is toward a vein composition high in one or the other. Fine veins seen in thin-section are mainly quartz, with a little chlorite or carbonate. Minute potassium feldspar veins of both replacement and fracture-filling types are present.

Metamorphism - Few of the sandstones are free of the effects of deformation. This may be evident only in the strain shadows in quartz and in a weak tendency toward alignment of the long axes of inequidimensional grains. In more strongly sheared rocks, crushing of quartz and feldspar clasts and dimensional orientation of newly formed scaly minerals appear. Strongest strain effects are seen in rocks which, in hand specimen, show long, streaky lenses alternately light and dark in tone. These result from the segregation of quartz and feldspar in thin layers alternating with layers rich in chlorite, mica and epidote. In general the intensity of deformation increases toward the Shickshocks. The increase is not uniform, however, and local zones of only mildly sheared rocks exist near the mountains whereas more strongly sheared rocks occur farther away.

Schistosity in the sandstones shows up as a parallel arrangement of the flaky minerals. In hand specimen, this is best observed on schistosity or bedding surfaces but, under the microscope, the effect is seen throughout. Some of the sandstones show only schistosity, but many show both schistosity and bedding. At all but three localities, the two structures are parallel.

The mineral transformations which resulted in the generation of white mica, chlorite and green biotite, and the association of those minerals with albite, mark these rocks as members of the greenschist facies. The albite, for much the greater part, was part of the original sediment. Being chemically stable under the physical condition of the greenschist facies it underwent only mechanical changes, such as crushing, granulation and lattice alteration.

The intensity of metamorphism increases southward. In terms of mineral zones, most of the sandstones are in the chlorite zone although a narrow strip along the south, in the western part of the area, is in the higher green biotite sub-zone. Turner (1938, p. 163) presents a scheme of sub-zones for the chlorite zone which is based on fabric differences. Most of the rocks under consideration would fall into his two zones of lowest intensity. Locally, there are rocks equivalent to his Chlorite-B sub-zone of second highest intensity.

Correlation, Age, and Provenance

The shale group of the above-described sequence, on the basis of similar lithology and direct on-strike continuation, is correlated with the belt of "Lower Ordovician or older" rocks described by McGerrigle (1954a, p. 30) in the adjoining Courcelette quadrangle.

Sandstones along the north front of the Shickshocks, apparently identical with sandstones of the present area, were placed by McGerrigle in the Shickshock Group. The present writer differs in preferring to include the sandstones with the other sedimentary rocks. There is no evident structural break between the shale and arkose sequences, and the contrast between shale and arkose lithologies seems less impressive than between the arkoses and a dominantly metavolcanic sequence.

The upper age limit is deduced from the apparent structural position of these rocks as the lower part of the south limb of a large syncline. Middle Ordovician (Normanskill) strata at the centre of the syncline crop out 8 miles north of the Shickshocks in the Tourelle area. The north limb of the syncline is well defined by the existence of rocks dated as Lévis (Lower Ordovician) in age, north of and structurally below the Normanskill beds. Between the area of Normanskill outcrop and the Shickshocks, however, no fossils have been found. Thus, the presence of the band of Lévis rocks which should make up part of the south limb of the syncline cannot positively be demonstrated. Indeed, south of the Normanskill zone the dips are largely southward, which would imply that the rocks present actually lie upon the Normanskill. McGerrigle, however, points out that the section may be overturned.

Editor's note: The writer's Cambro-Ordovician sequence is in strike continuation with Ollerenshaw's Matane River Group of the area immediately to the west and which Ollerenshaw dates as Cambro-Ordovician (with a lean towards Middle Cambrian) (Ollerenshaw, 1963, MS.).

The character of the sandstones provides some clue as to their provenance although their exact source cannot be determined. Dapples, Krumbein and Sloss (1953) claim that rocks in which the ratio of content of alkali feldspars to the aggregate content of clay, chlorite, mica and rock fragments is greater than three are arkoses. These derive from cratons of plutonic rock or highly feldspathic metamorphic complexes. The comparable ratio for greywackes is less than 3/4 and such rocks derive from areas which are likely to have had a complex tectonic history of depression, filling with sedimentary and effusive rocks, metamorphism, and finally uplift to become a source area. From the table of composition given above, the ratio for the rocks in question is found to be 2 1/2, suggesting that they should be considered arkosic types. From the texture of the contained rock fragments and the nature of the component grains, particularly the remarkable perthites, it can be inferred that the source rock was a highly metamorphosed granitic gneiss probably of the granulite facies. The nearest exposures of rocks of this type are north of the St. Lawrence, where they underlie vast areas. However, most of the descriptions of rocks of the North Shore refer to gneisses with more anorthitic plagioclase than occurs in the arkoses. Furthermore correlative sedimentary rocks, elsewhere in the Appalachians, are composed of sediments derived from sources to the south and east. The arkoses in the Mount Logan area show no internal evidence of the direction from which the component sediments were derived. If their source was to the southeast it probably comprised uplifted basement blocks in what is now southern Gaspé peninsula or in the St. Lawrence Gulf. The basement rocks were presumably similar in character to, but somewhat more alkalic than, the bulk of the Laurentian gneisses of the North Shore.

Shickshock Group

Distribution and Subdivisions

The area of outcrop of rocks of the Shickshock Group coincides closely with the Shickshock range. In the Mount Logan area this is an expanse of about 175 square miles, some 85% of which is underlain by metavolcanics, and 15% by metasedimentaries of various compositions. Despite their great genetic difference, distinction of metasedimentary and metavolcanic rocks is difficult in some cases and impossible in others. The difficulty stems from the effects of metamorphism which have in large part obliterated primary structures and imposed upon both rock types a similar dark, schistose appearance. Combined field and thin-section study have allowed the delimitation of five distinct zones, comprising some 20 square miles in all, within which metasedimentary rocks are dominant. It is thought that these zones mark former sites of sediment deposition during temporary lulls in volcanism. The beds in these zones dip steeply and, as the zones cross areas of high and low topography, they extend to depths of 2,000 feet or more. That is to say the zones, as seen on the geological map, are edge-on views of tabular bodies rather than plan views of shallow troughs. Each is named, for descriptive purposes, for some local topographic feature which it crosses.

The Bivé (Tag) Brook zone is 1 1/2 miles wide and can be traced from the north end of Matane lake to a point about 4 miles east of Mount Blanc. There the belt appears to 'nose' around an anticlinal axis and apparently wedges out.

East of Cap-Chat river, the narrow Bardey (Man) Lake zone extends from the headwaters of Bascon (Mem) brook to Voligny (west branch of Epidote) brook. Beyond that point, there is a 2 1/2-mile gap in outcrop control and then two metasedimentary belts appear, either of which could be the continuation of the Bardey Lake zone. The most northerly of these, the Vignon (Windsor) Lake zone, has about the same width as, and is roughly in line with, the Bardey Lake zone but, owing to a bend in the local structural trends between the two, the Vignon Lake zone structurally is offset to the north. Moreover, the Vignon Lake zone carries phyllites not found in the Bardey Lake zone. For these reasons, the Bardey Lake zone is represented as connecting to the east with a zone of similar lithology and on the same structural trend. The correlation is not entirely satisfactory in that the eastern part of the Bardey Lake zone is thus made two or three times as wide as the western part. However, in the eugeosynclinal environment of sediment dumping and intermittent volcanism, rapid lateral variation in the thicknesses of sedimentary accumulations may be expected.

The narrow Bascon Brook zone lies parallel to, and 1/2 mile south of, the Bardey Lake zone. It can be traced from the junction of Bascon brook and Cap-Chat river to the east branch of Cap-Chat-Est river, about a mile south of Mount Logan.

Near the south boundary of the Shickshocks, between Bieil (Fox) and Bauvas (Behrend) brooks, variously altered sedimentary and intrusive rocks make up the 11-mile-long Weir Brook zone. At its widest part this zone is one mile across. Its south boundary is everywhere coincident with or very near the south boundary of the Shickshocks.

Outside the main metasedimentary belts, small patches and single outcrops of metasedimentary rocks are scattered through the schistose metavolcanics terrain. Similarly, small intercalations of metavolcanic rocks appear at places in the metasedimentary zones.

In the succeeding pages the petrography of each metasedimentary belt and that of the metavolcanic rocks is considered separately. A subsequent section considers the structural relations of the Shickshocks as a whole.

Bivé (Tag) Brook Zone

These rocks are typically grey to black on fresh surface. The weathered surface, owing to kaolinization of the contained feldspar, usually is some shade of brown. Granularity ranges from medium to aphanitic. Apart from a very few outcrops all these rocks show one dominant S-plane here called foliation. The foliation results from the coincident orientation of one or more of the planar elements, including fissility, platy mineral alignment (schistosity), colour layering, and fine lamination apparently due to metamorphic segregation. Bedding is revealed at a few places by coarse colour layering, grain gradation, interlayering of fine and coarse layers and interlayering of different lithologies. In all cases where bedding was observed it was parallel to the foliation. Hence, the schistosity symbol on the accompanying map probably also represents the attitude of now obliterated bedding.

Scattered, small, quartz and pegmatite veins, similar to those in the Cambro-Ordovician sandstones, are generally parallel to foliation, but some fill cross-cutting gash joints.

Under the microscope, these rocks are largely recrystallized to lepidoblastic aggregates. Relict clastic grains make up 10-15% of the rock. Dimensional orientation is shown not only by flaky mineral grains but also by quartz and feldspar which, on recrystallization, have assumed lensoid shapes. These grains range from 0.02-0.1 mm., the average being nearer the larger figure.

The average mineral content of 25 thin-sections is given below:

Mineral		Percentage
Plagioclase		50.1
Quartz		22
Green-brown biotite		7.4
Epidote		4.7
Chlorite		4.3
Prochlorite	1.5	
Diabantite-aphrosiderite	1.5	
Unclassified	1.3	
Muscovite and sericite		4.2
Orthoclase		2.5
Biotite		2.2
Titanite		1
Opaque oxides		<1
Apatite		<1
Zircon		Trace
Perthite		Trace
Monazite		Trace
Microcline		Trace
Tourmaline		Trace
Garnet	appears in one section.	

The appearance and composition of many of these minerals are closely akin to those of the minerals in Cambro-Ordovician sandstones north of the Shickshocks.

Most clastic plagioclase grains are albite although in two thin-sections grains with compositions of An_{23} and An_{40} were found. Recrystallized plagioclase occurs in lensy, untwinned grains, normally completely fresh and unaltered. The anorthite content of most plagioclases is less than 10%; in several it was fixed at 2-5%. Plagioclase in rocks bearing brown biotite, however, contains 10-16% anorthite.

Nearly all the green biotite has a more brownish colour and biotite-like habit than the specimens from the Cambro-Ordovician sandstones. Textural relations suggest that it has formed at the expense of chlorite. Four thin-sections contain normal brown biotite; the appearance of this mineral and associated more calcic plagioclase marks an increase in grade of metamorphism over that shown by green biotite.

Epidote occurs in small clear grains about 0.05 mm. in diameter scattered between the grains of recrystallized quartz and plagioclase. It presumably records the disposition of calcium rejected during the recrystallization of plagioclase more calcic than the newly formed plagioclase. The more calcic plagioclase in the biotite-bearing sections probably retained the calcium of pre-existing plagioclase or gathered calcium by the destruction of any early-formed epidote. Epidote is noticeably less abundant in those sections. At the east end of the zone, near the edge of the zone, epidote is unusually abundant. An influx of volcanic ash probably provided the constituents necessary for the formation of this epidote.

Potassium feldspar in this zone was derived both from the recrystallization of feldspars in the original rocks and from potash-bearing solutions which appear to have circulated in the rocks during metamorphism. Some potash feldspar is present in micrographitic intergrowths. These are ill-formed to augen-shaped albite grains up to 4 mm. across containing fine, rounded quartz blebs and, in some examples, a ramifying orthoclase or microcline intergrowth. These are possibly secretion features but their textures and appearance suggest that they developed by the attack of silica and potash-bearing solutions on large albite clasts.

Metamorphism - In the writer's conception of the geology of the area the Cambro-Ordovician sandstones north of the Shickshocks and the metasedimentaries of the Bivé Brook zone are near in time as well as space. They are thought to have been derived from the same, or a similar, provenance and their character before metamorphism probably was essentially the same. The similarity of the clastic particles and heavy mineral suites of each supports this contention.

The widespread recrystallization and the common presence of brown and brownish green biotite indicate that the Bivé Brook rocks endured higher metamorphism than the arkosic sandstones north of the Shickshocks. In Turner's (1938, p. 94) classification, these rocks are in the chlorite-biotite subfacies of the greenschist facies. Chlorite, muscovite and biotite should not coexist in this facies because one or the other of the two first-named constituents should be completely consumed in the biotite-forming reaction. However, in some specimens a little muscovite is present with chlorite and biotite or a little chlorite with muscovite and biotite. The amount of the inferior component, however, is always very minute and its failure to react probably is owing to its dispersion in small flakes, isolated from grains of the other reactant. At the east end of the zone, where metamorphism is less intense, larger amounts of chlorite and muscovite coexist with greenish biotite.

Associated Metavolcanic Rocks - The existence of a few intercalations of metavolcanic rocks provides an opportunity for comparing the mineral assemblages characterizing a metamorphosed basic lava with that of arkoses at the equivalent grade of metamorphism. The metavolcanic rocks in question are albite-epidote-amphibole schists. The constituent amphibole is a bluish green mineral with pleochroism X - faint yellowish green to colourless, Y - pale to medium grass green, Z - pale to medium bluish green. There is considerable variation in colour tone from individual to individual and even within a single grain. Index measurements on a specimen from a locality with generally paler amphiboles show $X = 1.644$, $Y = 1.656$, $Z = 1.666$. The maximum extinction angle $Z \wedge C$ is about 19^0. These amphiboles closely resemble actinolite but some evidence (given below) suggests that they are hornblendes. In the opinion of most authorities the host rocks would be considered to be in the albite-epidote-amphibolite facies and constitute a higher-grade assemblage than the biotite-bearing greenschists with which they are interlayered. This raises the question as to how this intimate association of rocks of different metamorphic facies can be maintained and why the albite-epidote-amphibolites have not reverted to a lower-grade assemblage involving biotite, or iron-rich actinolite or chlorite-calcite. Two explanations can be put forward. The first is that there may have been too little water in the volcanic rocks to permit them to change from amphibolites to the more water-rich greenschists. Yoder (1952) has pointed out the importance of water in metamorphism and has shown how mineral assemblages indicating widely different facies may coexist under the same PT conditions provided that there is some variation in the bulk water content of each assemblage. However, the probability is that the volcanic rocks of this area suffered no lack of water. They probably were extruded under water and certainly were soon blanketed by water-rich sediments. A second, and more probable, explanation of the facies discrepancy is found in a consideration of the difference in the metamorphic history of the two rock types. The sedimentary rocks reached their present state by being raised from lower to higher metamorphic rank. The volcanic rocks, on the other hand, were extruded at the high temperature and low pressure characteristic of the sanidinite facies; their metamorphism involved a descent to a lower temperature facies. It is well known that metamorphic transitions occur more easily under conditions of rising metamorphism and that under falling temperatures the theoretical reactions may be delayed or completely inhibited. The albite-epidote-amphibolite metavolcanic intercalations under discussion are considered to be an unstable assemblage which failed to descend completely to the metamorphic level appropriate to the PT conditions indicated by the associated metasedimentaries.

Bardey (Man) Lake Zone

Rocks of this zone are similar to those of Bivé Brook except that they are generally finer grained. Colour banding is rare; this and the fineness of grain makes bedding particularly difficult to distinguish. In the one outcrop in which bedding was recognized with certainty it is parallel to schistosity.

The relatively rare quartz veins are generally less than one inch thick and one foot long, and they habitually parallel the foliation. Scattered small veins of feldspar or pegmatitic feldspar and quartz also occur. Locally, these are abundant, notably where the belt is crossed by Voligny (west branch of Epidote) brook.

The dominant fabric characteristics of these rocks were inherited from the original sediments. Detrital grains make up more than half the rock volume, and have not been greatly sheared or crushed. Grain size sorting is poor. The size range is from 0.75 mm. downward, the average being 0.1 mm. The well developed megascopic schistosity is due to the parallel alignment of newly formed flaky minerals and the alignment of inequidimensional clastic grains. There is also some segregation of minerals. White mica, where it makes up more than 1/5 of the rock volume, tends to occur in fine layers. This may be partly an effect of metamorphic segregation but probably is also a depositional effect. Some specimens show fine streaky quartzo-feldspathic layers. The average composition of 15 thin-sections is as follows:

Mineral		Percentage
Plagioclase		47.3
Recrystallized quartz-plagioclase mosaic		13.0
Epidote		10.2
White mica		7.7
Quartz		6.8
Chlorite		6.3
Prochlorite	1.2	
Diabantite-aphrosiderite	4.2	
Unsclassified	0.9	
Greenish-brown biotite		2.9
Carbonate		2.4
Orthoclase		1.1

Mineral (Cont'd)	Percentage
Titanite	0.75
Magnetite	0.5
Ilmenite	0.4
Apatite	<1.0
Monazite	Minor
Zircon	Minor
Tourmaline	Rare
Rock fragments	occur in three sections

About 1/6 of the plagioclase is albite which, with quartz, forms fine-grained mosaics. It is mainly derived from recrystallized, fine, detrital plagioclase. Most of the rest of the plagioclase is in larger detrital grains which range from An_5 to An_{20}. Patches of free calcite were found in three thin-sections and several others show a little calcite as an alteration product of the plagioclase grains. Green biotite occurs in nine thin-sections and, in two of these, has a fairly prominent brownish tint. Orthoclase, noted in six thin-sections, is secondary. It appears as minute veins or as replacement patches along fine cracks in or around plagioclase grains.

The grade of metamorphism shown by these rocks is about equivalent to that shown by rocks in the green biotite zone of the Cambro-Ordovician arkosic sandstones north of the Shickshocks.

Vignon (Windsor) Lake Zone

Most of the rocks of this zone are visually similar to those of Bardey (Man) Lake. They are medium grained to aphanitic, dark grey on fresh surface and weather brownish grey. Bedding is apparent in an outcrop southwest of Côté lake. Foliation like that of the Bardey Lake zone is everywhere present and presumably is generally parallel to the now obliterated bedding.

A thin zone of fine, white mica schists, probably less than 100 feet across, is continuously exposed along strike for 3,000 feet in a small brook flowing N.80°E. into the stream draining Chic and Choc lakes. A thin band of similar schists extends westward from the west end of Gagnon lake, 2 1/2 miles farther west, for 1,000 feet. These rocks are silvery grey, highly fissile, and have rolls and undulations in the schistosity. They closely resemble the phyllites of the more highly sheared parts of the Cambro-Ordovician shales. They are thought to represent argillaceous layers in the sedimentary sequence along which, because of structural weakness, shearing occurred. Quartz veins, rarely with a little pink feldspar, are common. They are very irregular, and pinch and swell remarkably along their lengths. They are dominantly parallel to schistosity but in part transect it.

In thin-section, the coarser rocks are comprised dominantly of subrounded to subangular, poorly sorted, detrital quartz and feldspar grains in a matrix of finer quartz, feldspar, epidote, mica and chlorite. Shearing effects vary from apparently nil to an intensity sufficient to crush all the quartz and feldspar. Ten thin-sections indicate the following average composition for the rocks of the zone, excluding the white mica schists:

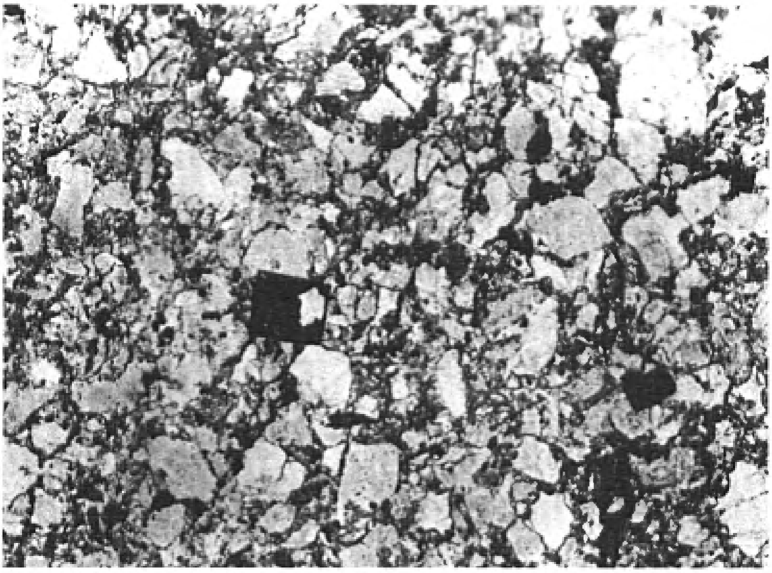
Mineral		Percentage
Albite		37
Quartz		15.4
Fine quartz-albite mosaics, dominantly albite		14.7
Epidote		13.7
White mica		4.9
Chlorite		8.4
Prochlorite	2	
Diabantite-aphrosiderite	2.5	
Unclassified	3.9	
Green biotite		1.8
Titanite		0.9
Ilmenite		0.4
Orthoclase		0.3
Magnetite		0.2
Zircon		Minor
Apatite		Minor
Monazite		Minor
Pyrite		Minor
Red iron oxides (goethite, hematite?)		Minor
Perthite		Minor
Garnet		Rare
Calcite		abundant in one section

Three thin-sections of the white mica schists give the following average mineral composition:

Mineral	Percentage
Quartz	37.5
Albite	31
White mica	22.5
Chlorite	5
Pyrite and magnetite	2
Titanite	1
Epidote	1

PLATE IX

A- Idiomorphic plagioclase clast. (Centre of photo) partly converted to dark titanite. Plane light. x 48



B- Authigenic pyrite in arkoses of Vignon Lake zone.
Plane light. x 16

PLATE X

A- Sub-ophitic texture. Lath-like plagioclase grains project into masses of amphibole which represents an alteration of the original pyroxene.
Crossed nicols, x 21.5

B- Ditto. Crossed nicols x 34

Most of the detrital plagioclase grains are albitic but are near An_{10}. They are mildly altered to clay and secondary white mica. Streaks of clear, unaltered albite appear along cracks in the clasts and around the edges of some grains. One thin-section showed clastic grains of orthoclase; in five sections, orthoclase appears in fine veins, and as minor replacement patches along plagioclase grain edges. Pyrite occurs both in the white mica schists and in the coarser rocks. Sharp, idiomorphic outlines of pyrite grains in contact with feldspar, epidote, and quartz testify to the authigenic origin of at least some pyrite (Plate IX B).

Metamorphism - In their original state these rocks must have been very similar to the Cambro-Ordovician sandstones to the north. The important metamorphic reactions are those which led to the formation of white mica, chlorite and green biotite. The chlorite and white mica presumably formed by recrystallization of fine detrital shreds of those minerals and perhaps by neomineralization from clays. Green biotite presumably formed at the expense of chlorite and white mica although it is always pseudomorphous after chlorite. The rocks are considered to be in the chlorite-muscovite subfacies of the greenschists and just above the green biotite isograd. An isolated metasedimentary outcrop 1/2 mile north of the zone shows no green biotite nor is there any in the Cambro-Ordovician sandstones one mile to the north.

Associated Metavolcanic Rocks - Metavolcanic rocks immediately adjacent to, or interlayered with, the Vignon Lake rocks are composed dominantly of pale, bluish-green amphibole, epidote, and albite, with lesser quartz and chlorite. The amphibole is a very pale type with fibrous habit and maximum extinction $Z \wedge C$ of 16°. It is probably a true actinolite or hornblende so low in aluminum as to be practically equivalent to actinolite. According to Harker (1939, p. 280) such a metamorphic assemblage indicates a rock equivalent to the biotite zone of pelitic rocks. Inasmuch as the associated metasedimentary rocks are barely at the green biotite isograd it appears that here, as in the Bivé (Tag) Brook zone, the metavolcanic rocks are at an unstably high level of metamorphism. One highly sheared example contains some calcite which may have resulted from the conversion of a little amphibole to calcite and chlorite. It has been shown by Wiseman (1934, p. 40) that a certain intensity of shear stress permits a more complete adjustment of metamorphic rocks from higher to lower grade assemblages.

Bascon (Mem) Brook Zone

Rocks of this zone are mainly white mica schists but some limestones are exposed at places along Bascon brook. The principal minerals of the schists are white mica, quartz, and albite; lesser ones are chlorite, epidote, titanite, magnetite and pyrite. In some of the schists, quartz and feldspar are arranged in minute segregation layers parallel to the schistosity. Many such layers trace out complex recumbent crumples and folds with dimensions of the order of 1-2 cm. The axial planes and long limbs of these minute folds are parallel to the schistosity of the rock as a whole.

Veins of milky or, less commonly, vitreous quartz make up 15-20% of the rock at most exposures in the eastern part of the zone. Calcite is also a common vein mineral, and there are a few feldspar veins. The western part of the zone has great amounts of calcite vein material intimately permeating the schists and limestones. Quartz veins are less common there than elsewhere but are nevertheless plentiful. Locally, the rocks are invaded by much pegmatitic and feldspathic material.

The rocks of this zone represent beds of silty shales and limestones recrystallized under strong shearing stress. They are in the chlorite-muscovite subzone of the greenschist facies. The writer considered the possibility that the mica schists had been formed in tuff zones or even in zones of normal lavas along which shearing stress was unusually high. The idea is scarcely tenable, however, because the bulk chemical composition of the schists, as estimated from the mineral composition, is so different from what the bulk composition of the parent volcanic rocks could have been.

Near the eastern termination of the Bascon Brook zone and along its southern edge the mica schists grade into darker green schists whose mineralogy and field appearance suggest that they are metamorphosed tuffs. Under the microscope, they contain pale bluish green amphibole, albite, prochlorite, iron-rich epidote, calcite and a little titanite and magnetite. The content of mafic minerals diminishes toward the zone of normal schists. It is postulated that these rocks are a reconstituted shale and tuff mixture. High shearing stress was imposed on the tuffs in common with the adjacent shales. This promoted the dissociation of the blue-green amphibole to the calcite-chlorite-*et al*. assemblage stable at lowest grades of metamorphism.

Weir Brook Zone

The Weir Brook zone extends east-northeastward from Bieil brook some 11 miles to Bauvas (Behrend) brook. Its maximum width is about one mile. It appears to wedge out to the east, and it probably terminates to the west against the fault bounding the south side of the Shickshocks.

The rocks are dominantly metasedimentary, but there is considerable metavolcanic material as well as sills of sodic diorite and sodic quartz diorite. At places, they have been variously carbonatized, silicified, feldspathized and hematized. Locally, over zones several feet wide, so much quartz and feldspar invaded these rocks that they were converted to a granitic substance and the alteration assumes the character of granitization. Shearing and brecciation accompanied the alteration widely.

A fairly complete section across the zone occurs along Weir brook. There the metasedimentary rocks are typically quartz-sodic plagioclase arkoses with minor amounts of the usual accessory minerals. One outcrop of finely crystalline, dove-grey limestone containing a little tremolite, quartz, muscovite and biotite was noted.

In the northern part of the zone, over a width of 1,900 feet along Weir brook, only scattered metavolcanic outcrops are present. Elsewhere in the belt, metavolcanics are intercalated in zones some tens of feet wide up to a maximum width of 150 feet. These, in general, are highly schistose, dark green to black rocks composed dominantly of plagioclase (An_{10}) and dark, well formed, deep blue-green amphibole. Both the metasedimentary and metavolcanic zones are invaded by sills of sodic diorite, sodic quartz diorite and granodiorite.

There is abundant evidence of the movement of mobile constituents through all the rock types represented. Transportation may have been by hydrothermal liquids or by some diffusion process associated with metamorphism, or both in combination. Veins of quartz and feldspar are present here and there, but the main evidence of the transfer and redeposition of elements comes from thin-section study. Under the microscope the mobile minerals are seen to be localized now in four main habitats:

(i) long, irregular masses trending with the schistosity;

(ii) cross-cutting veins and breccia fractures;

(iii) replacement nodes and patches along veins and grain edges;

(iv) zones of tight, parallel fractures at some angle to the schistosity. These are thought to be fracture cleavage developed after schistosity became the dominant S-surface in the rock.

The mobile minerals, in approximate order of abundance, are quartz, orthoclase, calcite, plagioclase, epidote, chlorite, muscovite, two unidentified minerals (probably hydrous iron silicates), zeolite, and pyrite.

Much of the Weir Brook zone has suffered strong shearing and brecciation. The metavolcanic rocks display a highly developed schistosity and high degree of dimensional orientation of the elongate amphibole grains. In the metasedimentary and intrusive rocks, shear deformation is expressed in the development of long, ribbon-like bands of lensoid grains. Shearing is so intense locally as to create rocks with a milled and flayed-out mylonitic texture. However, there are also zones where shearing effects are negligible. In general, shearing and deformational effects are strong in the east end of the band but become much less pronounced west of Paris brook.

Both the metasedimentary and intrusive rocks of the zone had original compositions similar to those of the metasedimentaries discussed above. The molecular percentage of anorthite in the common recrystallized plagioclase is 5-20%, most being more calcic than An_{10}. Plagioclase in clastic grains that escaped recrystallization ranges from nearly pure albite to An_{35}. In the rocks which appear to be sills of sodic diorite or trondhjemite,the plagioclase is no more basic than An_{20}. The typical assemblage, biotite - sodic oligoclase, to which the original rocks have been converted places them in the chlorite-biotite subfacies of the greenschists. The lower epidote and higher biotite contents and the presence of slightly more basic plagioclase suggest that we are dealing with rocks somewhat nearer the upper boundary of the subfacies than in the Bivé Brook zone.

Near the mouths of Vyette and Paris brooks, at the south edge of the central part of the zone, there is a small area of garnet-bearing metasedimentary rocks. This delimits a garnet isograd and also marks the transition of the metasedimentary rocks to the albite-epidote-amphibolite facies, the highest degree of metamorphism reached anywhere in the area.

Altered Zone of the Southern Boundary

East of Cap-Chat river, the junction of the Shickshocks with the younger sedimentary sequence to the south is marked, at places, by a zone of intense brecciation, silicification, and carbonatization. The zone was not seen at the one place west of the river where rocks near the contact are known. The best exposures are along Wilson brook.

Rocks from this zone are hard, reddish weathering, green, white, and red mottled siliceous carbonates. In thin-sections, they are seen to comprise dolomite, siderite and coarse to chalcedonic quartz. Some sections are suggestive of an earlier period of silica and dolomite deposition followed by brecciation and siderite veining.

The alteration is considered to be owing to the action of quartz- and carbonate-bearing hydrothermal fluids which replaced and veined the material adjacent to the fault separating the Silurian and Shickshock groups. The hydrothermal activity may be related to the period of ultrabasic intrusion that gave rise to serpentine bodies in the region. This is suggested by the areal association of the quartz-carbonate alteration and a small serpentine mass 3 miles northeast of Joffre lake. Furthermore, the serpentine carries chromite, and chromiferous serpentine (mineral) is found in the altered zone at the mouth of Weir brook.

Most of the effect of the alteration is found in Shickshock rocks, and only those rocks could satisfactorily be shown to be replaced by the carbonate. Patches of sedimentary rocks are included in the altered zone along Wilson brook, but these probably have been faulted in. It is probable that much of the hydrothermal activity was completed before the Silurian rocks were faulted down against the Shickshock Group.

Metavolcanic Rocks

The metavolcanic rocks, which make up 85-90% of the Shickshock Group can, on the basis of field appearance, be divided into four main classes. One class comprises the less-altered flows found mainly near the north edge of the Shickshocks in the zone of less intense regional metamorphism. The three remaining classes, lying generally to the south, are characterized by a fabric and mineral suite imposed by a rising metamorphic gradient.

Metavolcanics of the Northern Shickshocks

This class includes rather massive, medium- to fine-grained green rocks. In detail, the fresh surface shows clots of dark green amphibole liberally interspersed in a white plagioclase groundmass. Locally, the feldspar shows sub-idiomorphic outlines and the texture approaches ophitic. In the west half of the area, rocks of this type are found very near the north edge of the Shickshocks and within a 1,500-foot wide metavolcanic outlier north of the sandstones around Montagne pond. This latter feature, although sampled at two or three places, lies outside the map-area proper and is not shown on the geological map. Air photo study suggests that it is a large tongue which wedges out about 1 1/2 miles east of Pérot lake and probably merges with the main mass of the Shickshock metavolcanics about 5 miles west of the area. East of Cap-Chat river, rocks of this type appear here and there in a zone extending 2 or 3 miles south of the Shickshock front, and as intercalations in the sedimentary rocks north of the Shickshocks.

Under the microscope, textures range from sub-ophitic to completely disorganized. The sub-ophitic rocks are medium grained and show laths of plagioclase projecting into square or rounded pigeonites or lumps of blue-green amphibole (Plate X). A few show laths of plagioclase aligned in a mass of amphibole, chlorite and epidote (Plate XI). These latter probably represent relict fluidal textures from edge facies of flows.

Seven thin-sections of these rocks contained pigeonite, the maximum amount in any one being 44%. The pigeonite grains are surrounded by a reaction rim of bluish green amphibole in turn surrounded or partly surrounded by a reaction rim of diabantite. Epidote and albite occur in tenors of 5-20%. Titanite is ubiquitous and averages 3%. Quartz ranges from nil to 5% and there is up to 2% of magnetite and pyrite. In most of the rocks of this group, however, the pigeonite is completely reconstituted to blue-green amphibole and chlorite. The average mineral content of 23 thin-sections free from pigeonite is as follows:

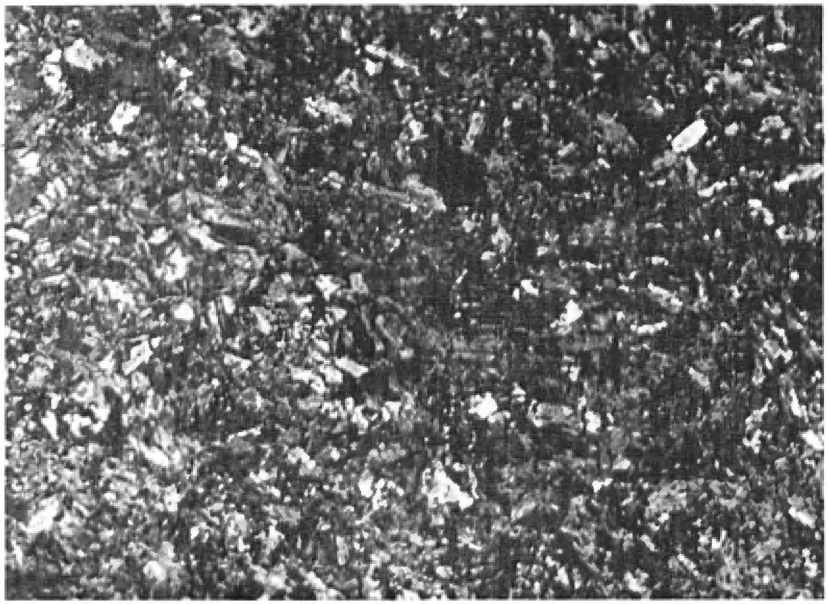
Mineral	Percentage
Blue-green amphibole	44.5
Plagioclase	26
Epidote	17
Chlorite	8.7
Titanite	2.5
Quartz	0.5
Ilmenite	less than 0.5
Magnetite	less than 0.5
Pyrite	less than 0.5
Carbonate	occurs in four thin-sections

Metavolcanics of the Central and Southern Shickshocks

Field Appearance and Distribution - The most widespread type comprises aphanitic to very finely granular schists with medium to bright green fresh surface and greyish green weathered surface. Foliation is emphasized by layers with slight colour variation. Greenish amphibole, feldspar, epidote and chlorite are the main constituents. Similar to, and closely associated with, the foregoing types are hard, dark green to greyish, generally bluish green weathering, aphanitic, schistose rocks which may or may not be easily fissile.

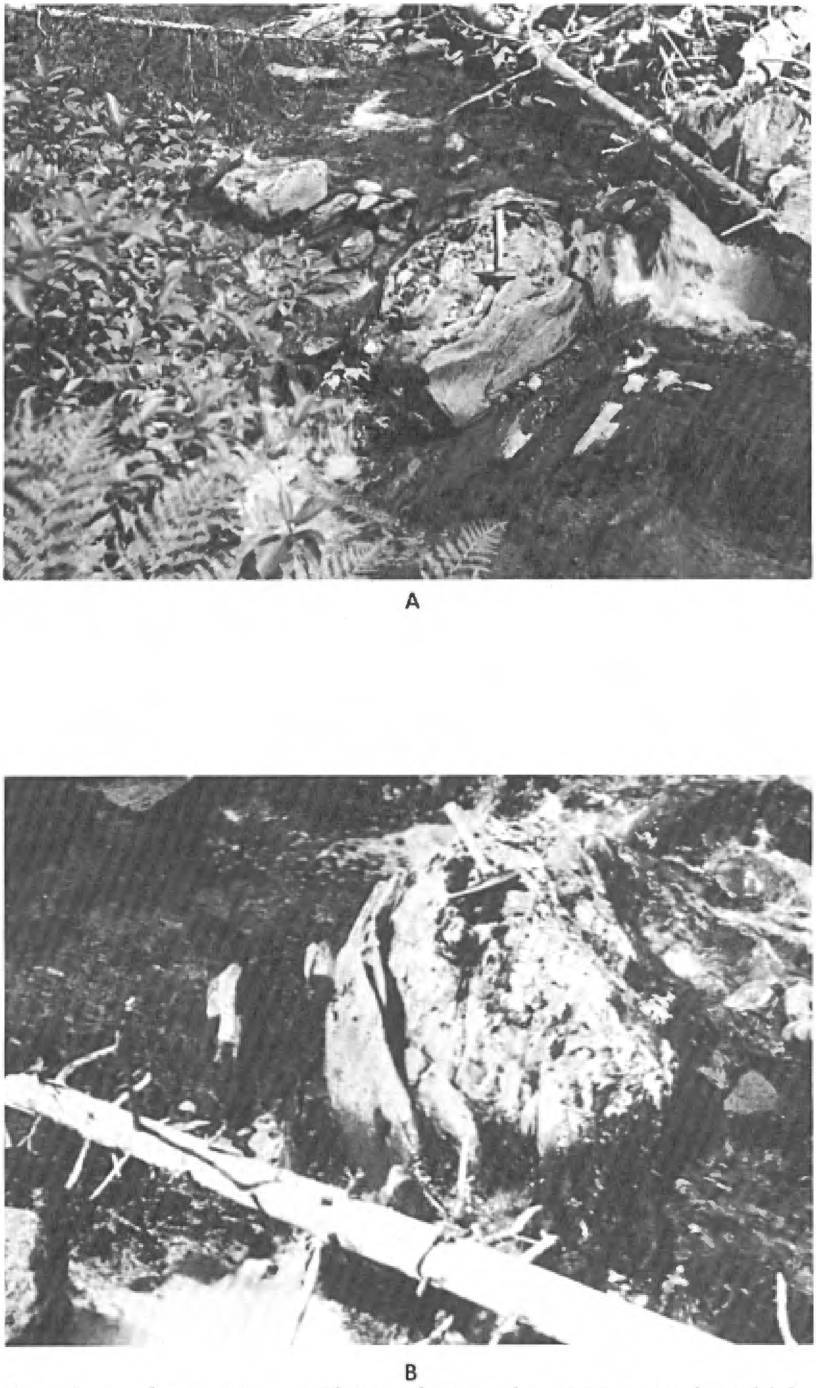
Two features commonly met with in both of the above varieties are described below:- The first consists in the occurrence here and there of small (1-3 mm.), rounded inclusions containing one or more of epidote, quartz, chlorite, calcite and albite. Where present at all they are

PLATE XI



Relict fluidal texture. Lath like character of some feldspar still evident but the mafic mineral grains have completely disintegrated to a confused aggregate of chlorite and amphibole. Crossed nicols. x 19

PLATE XII


A

B

Two views of a quartz - epidote node, Des Iles river. Note sheet (right hand side of node in XIIIB) of schistose chlorite and amphibole wrapping around the feature.

usually abundant. At first glance they resemble relict amygdules. However, as they do not occur in the very mildly metamorphosed lavas of the northern Shickshocks, and as they do not possess the pipe-like third dimension commonly seen in amygdules, they are considered to be segregation knots formed during metamorphism.

The second feature is quartz-epidote nodes. These are oval-shaped masses containing white vein quartz in an epidote-rich groundmass, the whole generally surrounded by a dark green sheath (Plate XII A-B). They range from the size of a football to ovoids several feet long. The long dimension lies parallel to the foliation but the foliation wraps around the nodes. These objects were at first considered to be relict pillows but are probably, in fact, metasomatic features. Booth (1950, p. 1139), describing a like feature from the Tibbit Hill metavolcanic schists of Vermont, suggested that they may have been due to the residual liquors of the magma working their way through the vesicles and fissures of the lava. In the writer's opinion, they probably are large-scale segregation features. Quartz and epidote were concentrated in the central part, whereas the dark outer sheath developed as a metasomatic halo containing the displaced chlorite and amphibole.

Rocks of the fourth metavolcanic type are very hard, black to dark green schists found only near the south edge of the Shickshock range. They include the hard, black amphibolite-like rocks of the Weir Brook belt.

Microscopic Appearance - The most northerly and least metamorphosed of these rocks show an immature fabric characterized by small grain size (around 0.05 mm.), allotriomorphic, often ragged grain outlines, confused intermingling of minerals and, at places, poor to negligible dimensional orientation of the constituents (Plate XIII). Farther south, more mature fabrics are characterized by increased grain size, more pronounced elongation of amphibole and chlorite grains and better dimensional orientation of those grains. Albite begins to appear in little lens-shaped grains whose long dimensions trend with the general schistosity. Commonly it shows preferred optical orientation. Segregation of constituents occurs in some of these rocks although others remain homogeneous. The most highly organized fabrics appear in the black and dark green schists of the southern Shickshocks, in which amphibole grains are very well formed and have almost perfect optical and dimensional orientation. The other minerals are well aligned, the chlorite, albite, epidote and, in some places, even iron oxides being in grains elongated parallel to the schistosity. Strong segregation of components is featured by some of these latter rocks and, characteristically, albite-epidote layers or layers of pure albite alternate with layers of amphibole, amphibole-magnetite or amphibole-epidote. The grain size of these rocks is about 0.5 mm.

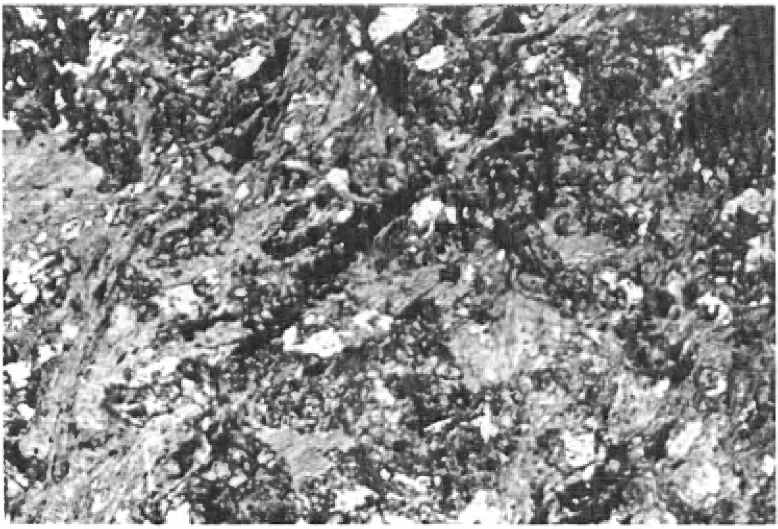
Mineral Composition - The average mineral composition of 72 thin-sections cut from rocks of the central and southern Shickshocks is as follows:

Mineral		Percentage
Blue-green amphibole		45
Albite		22.5
Epidote		17.3
Clinozoisite (up to 10% $H_2Ca_2Fe_3Si_3O_{13}$)	8.3	
Iron-rich epidote (10-30% $H_2Ca_2Fe_3Si_3O_{13}$)	9.0	
Chlorite		6.9
Prochlorite	4.7	
Diabantite-aphrosiderite	2.2	
Quartz		4
Titanite		1.6
Calcite		1
Magnetite		0.9
Ilmenite		0.4
Biotite		0.25
Pyrite		0.1

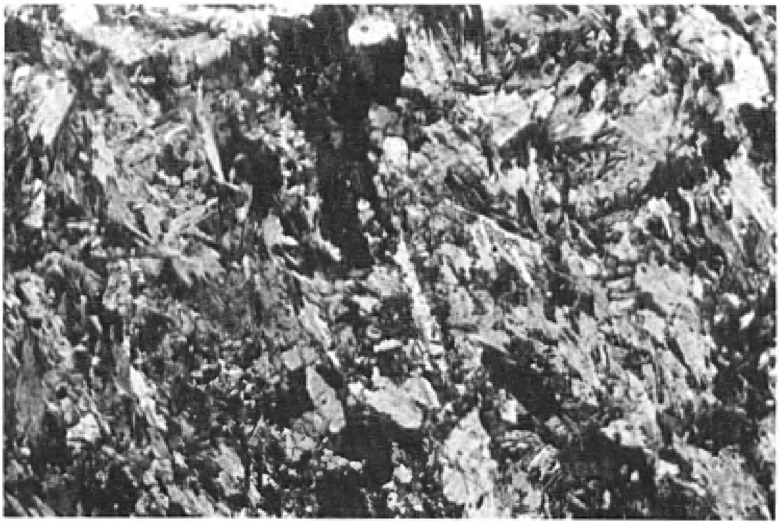
Plagioclase in the metavolcanics of the central and southern Shickshocks ranges from nearly pure albite to An_7, except in the dark amphibole schists of the southernmost Shickshocks, where the anorthite content is about 10%. This is true of the plagioclase in which the ophitic texture of the original rock is retained as well as recrystallized plagioclase.

Blue-green amphibole accounts for nearly half the rock volume of the Shickshocks. For this reason, and because its properties vary according to the degree of metamorphism, it is considered in some detail. The first appearance of this amphibole is as a reaction rim around pigeonites of the original lavas. As these rocks break down the amphibole encroaches inward to form a complete pseudomorph of the pyroxene. At about the time the pyroxene has been completely consumed the amphibole begins to replace plagioclase laths. At first, fine spicules of amphibole are projected into the plagioclase, these widen and coalesce until eventually no trace of plagioclase is left (Plate XIV). Meanwhile the amphibole itself is under attack by chlorite which tends to reduce the larger grains to smaller shreds and knots separated by chlorite. By this means, and by diffusion of the amphibole forming elements, the amphibole eventually is reduced to a mass of ragged grains dispersed throughout the rock. Concomitant shearing stress may impart some directional orientation to the dispersed amphibole grains but this is not common.

Under conditions of rising metamorphism, recrystallization and regrowth of the amphibole commences. The recrystallized amphibole is a blue-green mineral apparently identical to the amphibole which first replaces the pyroxene. The effect of rising metamorphism is manifest in

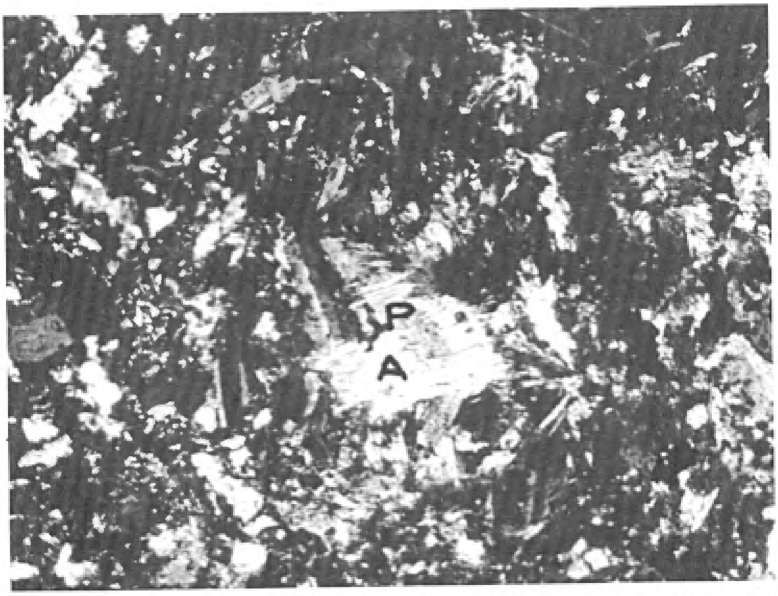


A- Confused mixture of chlorite, amphibole, plagioclase, epidote and titanite with the disorganized fabric characteristic of complete breakdown of Shickshock lavas without any metamorphic reconstitution. Note relict plagioclase lath near centre of XIIIB. Crossed nicols. x 30.



B- Ditto. Plane light. x 55.

PLATE XIV



A- Replacement of plagioclase laths (P) by blue-green amphibole (A) during breakdown of primary volcanic rocks. Crossed nicols. x 60.

B- Ditto. Crossed nicols. x 65.

a continuous variation in colour, texture, refractive indices and extinction angle of the amphibole. Essentially, the higher the grade of metamorphism the higher the refractive index, the greater the extinction angle and the more well defined and clean cut the grains. An amphibole from the zone of low grade metamorphism shows the following optical properties: Indices, $X = 1.644$, $Y = 1.656$, $Z = 1.666$. Its pleochroism is Z - pale bluish green, Y - pale green, X - pale yellow to nearly colourless. The extinction angle $Z \wedge C$ for amphiboles of this type is as low as 16°. In contrast an amphibole from the zone of highest metamorphism shows $X = 1.652$, $Y = 1.664$, $Z = 1.674$. Pleochroism is Z - deep blue-green, Y - emerald green, X - pale green to yellowish. The extinction angle $Z \wedge C$ for such high-grade amphiboles is between 21° and 24°. All the amphiboles of the area have negative sign and large 2V. Many also show a more or less well developed colour zoning with the peripheral portion always darker than the interior. An analysis of a sample of the amphibole from a higher-grade metamorphic zone, recalculated to allow for an estimated 2% of albite present as fine inclusions, is as follows:

Oxide	Percentage
SiO_2	46.42
Al_2O_3	12.50
Fe_2O_3	3.78
FeO	11.59
MnO	0.31
MgO	9.66
CaO	11.38
K_2O	0.65
Na_2O	1.58
H_2O	2.15

TiO_2 was not analysed for but probably makes up 0.5-0.8% of the oxide content.

Amphiboles of similar nature have been studied by Seitsaari (1953, 1956). The chemical composition of deep blue-green amphiboles given by him are very similar to the above. Amphiboles of paler hues have significantly less Fe_2O_3, FeO, Al_2O_3 and TiO_2 and are significantly higher in MgO and SiO_2. In the Tampere area, Finland, Seitsaari (op. cit.) relates the deeper colour rim of zoned amphiboles to a slight late rise of metamorphic temperature in the absence of shearing stress. In the Mount Logan area there is no suggestion of a distinct period of late temperature rise; rather it seems to have been continuous and gradual, producing amphiboles in which the zone of colour gradation is wide.

It seems curious that the late-forming amphiboles should be the deep blue-green, magnesium-poor variety. Normally magnesium-bearing mix-crystals show an enrichment in that element during the late metamorphic stages. The explanation appears to be that magnesium for the late-forming amphiboles is available only from chlorite and is relatively much less abundant than the other amphibole-forming elements.

The zoned amphiboles, as they now exist, are obviously in an unstable state and complete reaction of the central and outer parts would give rise to homogeneous individuals with intermediate properties. Some of the smaller grains in the higher-grade rocks are unzoned. This may be due to the reaching of an equilibrium condition in an originally zoned amphibole owing to the lesser diffusion distance in such smaller grains. Equally well, however, they may be grains which began to grow only in the late stages of amphibole formation.

Chemical Composition - In order to gain some idea of the bulk chemical composition of the Shickshock metavolcanics the average mineral percentages of 72 thin-sections (given above) were recalculated to oxide percentages. For the calculation the composition of the amphibole was based on the analysis of the sample from the high-grade zone. Some of the oxide percentages of that analysis were adjusted slightly in order to arrive at an average composition representative of the amphiboles of the area as a whole. An indication of the direction and amount of adjustment required was gained from a consideration of Seitsaari's (1953, 1956) analyses for both high- and low-grade blue-green amphiboles. During the writer's study the epidotes were divided into four classes representing epidotes with 0, 10, 20 and 30% of the $H_2Ca_2Fe_3Si_3O_{13}$ molecule. Chlorites were classified as prochlorite or as a mineral about at the border line of the diabantite and aphrosiderite groups. The chemical composition of these chlorites was obtained from Winchell's (1947, p. 280) graph and may be represented as:

Prochlorite $H_{40}Fe_{7.35}Al_{18}Mg_{14.6}Si_{10.7}O_{90}$
Diabantite-aphrosiderite $H_{40}Fe_{13.2}Al_{12}Mg_{15.2}Si_{11.8}O_{90}$

The average chemical composition arrived at is believed to be fairly valid, based as it is on 72 thin-sections from widespread localities in a rock body of fairly simple mineral composition. The content of TiO_2 as given probably is too low (by about 0.25%) because no TiO_2 was reported in the writer's amphibole analysis, and Seitsaari's (op. cit.) analyses indicate a TiO_2 content of the order of 0.5%. The Fe_2O_3 content should probably be adjusted slightly upward at the expense of FeO inasmuch as the improbable assumption was made that all the iron in the chlorite is in the ferrous state.

In the table below, column (1) gives the oxide percentages of the Shickshock metavolcanics as computed by the writer and column (2), included for comparison, is Daly's (1933, p. 17) average composition for 161 basalts.

Oxide	(1)	(2)
SiO_2	47.6	48.8
Al_2O_3	16.7	15.8
Fe_2O_3	4.1	5.4
FeO	7.0	6.3
MgO	5.7	6.0
CaO	11.34	8.9
Na_2O	2.9	3.2
K_2O	0.4	1.6
H_2O	2.4	1.8
TiO_2	1.1	1.4
P_2O_5	-	0.5
MnO	0.2	0.3
SO_2	0.1	-

Veins

Like the metasedimentary rocks the volcanics are permeated by quartz, epidote, and calcite veins. Epidote veins and quartz-epidote veins are larger and much more common than in the metasedimentary rocks. Pegmatite veins are comparatively rare. In general, the veins lie in lensoid sheets parallel to the schistosity. Swellings and constrictions of the vein walls are numerous and so marked that some 'veins' are, in surface view at least, strings of isolated knots of vein material. Vein protrusions may extend across the foliation and some veins lie in gash fractures at an angle to the foliation. Few veins are more than a few feet long and most are less than 2 inches wide.

Metamorphism

The early stage alteration of the volcanic rocks appears to involve autometamorphic processes that are hard to separate from the effects of regional metamorphism. These include the albitization of the plagioclase grains without destruction of the original sub-ophitic texture and the simultaneous replacement of pigeonite by amphibole and amphibole by chlorite.

The conversion of what in all probability was originally a calcic plagioclase to albite is the most puzzling of these reactions. Tyrrell (1926, p. 329) quotes authorities to the effect that such a transformation probably is accomplished by the action of a sodium-rich residual mother liquor on the lavas. It would seem that any such mother liquor, to work this process, would require continuous local enrichment in sodium. The picture of fresh supplies of liquor continuously emerging from the magma chamber and working their way through long sheets of rather poorly permeable lavas is an unlikely one. Impregnation of the lavas with sodium from sea water is an attractive possibility but the bulk composition of the rock is about that of a normal basalt (see analyses above) and does not point to any enrichment in sodium. This group of rocks then is not of the sodiumenriched spilitic suite, examples of which sometimes are found in this environment. The only remaining sodium source seems to be the plagioclase itself. Some of the original plagioclase (labradorite or calcic andesine) must have been disintegrating to provide fresh supplies of sodium to the mother liquor which was in the act of converting the remaining calcic plagioclase to albite pseudomorphs. We can only speculate about the conditions that determined which plagioclase would be destroyed and which preserved. Perhaps the grain size was a factor for only in the coarser rocks were such albite pseudomorphs observed.

Autometamorphic breakdown passed insensibly into regional metamorphism. Associated shearing was early felt by some lavas in which the amphibole and chlorite alteration products show some alignment; stronger shearing without significant temperature rise allowed continued retrogression of the amphibole to chlorite-actinolite or biotite.

In general terms, these rocks are in the albite-epidote-amphibolite facies and, except near the most southerly part of the Shickshocks, comprise a somewhat higher-grade assemblage than their metasedimentary associates. The difference is owing to the failure of the originally high-grade volcanic assemblage to adjust completely to the lower-grade conditions.

Metasomatism has had little place in the metamorphic evolution of the Shickshock volcanics. A comparison of their chemical composition with that of the average basalt suggests little gain or loss of rock-making elements. The comparatively low degree of veining of sizeable tracts suggests that the rocks acted essentially as a closed chemical system.

Structural Features

Original flow layers are nowhere seen in the Mount Logan area and the dominant structural element is foliation, which encompasses colour banding and schistosity. The primary foliation (S_1) generally strikes N.60°E., and is crossed at about right angles by a second foliation (S_2). The S_2 foliation is a series of minute superimposed bends in the S_1 schistosity. These bends are not folds, merely minute homoclinal warps where the schistosity bends at perhaps 30° and, after a millimeter or two, resumes its original direction. The feature shows up as a series of fine light and dark shadings or minute striations, best viewed on the weathered surface, and so faint as often to be perceptible only by viewing the rock at certain angles in the sun. The widespread existence of this S_2 foliation was not recognized during the work in the eastern part of the area, although it was later observed in hand specimens from there, and its attitude was measured only in the western part of the area. Typically it is parallel to the cross joints, and was in fact observed to pass into cross joints at one or two places.

Presumably it developed under the influence of the same forces that caused the cross joints but represents yield by flexure rather than rupture. It may have been generated while the rocks were still at high temperature and under some pressure.

The cross joints are sets of clean-cut, smooth-walled fractures spaced at distances of fractions of an inch to a few feet. Most are tight; some contain a film of calcite or hematite. They strike about at right angles to the foliation and stand about perpendicular to the b-lineation. In a few outcrops, a second and less well-developed fracture set parallels, but dips at right angles to, the foliation. These latter are probably tension joints developed in the stretched outer portion of a major fold arc.

The features commonly measured as lineations were axes of small drag folds, rolls and crumples in the schistosity. Other linear features include the flutings of uncertain origin observed on some foliation surfaces and the intersections of foliation and fractures other than cross joints. These appear to be parallel to the minor fold axes and, with them, are considered indicators of the plunges of the major folds.

Faults in rocks of the Shickshock Group are not easily discerned owing to lack of distinctive horizon markers. Actual observation of the zone of rupture or zones of brecciation or intense shearing allowed recognition of 13 faults. The strikes of these faults fall mainly in the zones NNW.-NE. and E.-SE. Dips are steeply southward to vertical.

Two features observed only in thin-section are included here for the sake of completeness. The development of a new foliation by isoclinal folding of the old schistosity was seen in some thin-sections. In these, the elongation direction of the flaky minerals at the fold crests represents the old schistosity direction and the axial planes and long limbs of the folds represent the new. In some instances the folds are Z-shaped, and in these the long limbs are the primary schistosity and the new schistosity is sub-parallel to the short limbs or fold axes. Related to these is a strain-slip cleavage which cuts the primary schistosity at various angles. Where this cleavage crosses lines of flaky minerals they are bent out of alignment with the primary schistosity into parallelism with the cleavage direction.

Correlation and Age

The term "Shickshock series" was introduced by McGerrigle (1954a, p. 18) to cover all the rocks of the Shickshock range with the exception of intrusive serpentine and granite bodies toward the eastern end of the range. The writer has followed this usage with the exception that a fringe of arkosic sandstones along the north front of the range has been excluded and placed with the Cambro-Ordovician sedimentaries. Also, the term "group" is preferred to "series". In the writer's conception of the structural relations, there is no structural discontinuity between the Cambro-Ordovician sedimentary rocks and those of the Shickshock Group. In the absence of any paleontological data to the contrary the most marked lithological change, that between rocks of sedimentary and volcanic origin, is made to serve as the boundary. North of the boundary thus defined, the rocks are almost wholly of sedimentary origin and south of it dominantly volcanics, although minor intercalations of each type appear in the other.

The writer's boundary is as much as 1 1/4 miles south of that defined by McGerrigle. The discrepancy is greatest in the western part of the area where a band of sedimentaries and a 1,500-foot-wide band of mildly metamorphosed volcanics flanking them to the north are included as part of the Shickshock Group by McGerrigle's (1953) geological map of Gaspé peninsula. (Editor's note: In the area adjoining to the west, Ollerenshaw (1963, MS.) puts this arkosic sandstone band in the Shickshock Group.)

No paleontological information bearing on the age of the Shickshock Group has been obtained. No radioactive material by which a dating might be attempted has been found and dating by correlation with volcanic rocks of known age seems impossible. Recourse must then be had to an age determination based on structural considerations. The absence of metamorphism and the lower degree of deformation exhibited by the Middle Silurian rocks to the south leave little room for doubt concerning the pre-Silurian age of the more highly deformed and metamorphosed Shickshock Group. The critical factor becomes the nature of the relationship of the Group to the Cambro-Ordovician rocks to the north.

There appear to be four main possibilities:

(i) The Cambro-Ordovician sedimentaries unconformably overlie the Shickshock Group;

(ii) The Shickshock Group unconformably overlies the Cambro-Ordovician sedimentaries;

(iii) The contact is a fault;

(iv) The contact is along a zone of interlayered sedimentary and volcanic rocks with the Shickshock Group either (a) older or (b) younger than the Cambro-Ordovician.

Some variety of opinion is met with in the literature. The opinions of the various investigators may be summarized by saying that possibility (iv) seems to have been favoured by Low (1883, p. 16F), Murray (1846, reported by Low, op. cit.) and Béland (1957, p. 2);

possibility (ivb) by Logan (1863, p. 265) and Alcock (1926, p. 132); possibility (iva) by Ells (1883, p. 31) and possibilities (i) and (iii) by McGerrigle (1954a, p. 23).

Actually, evidence can be brought forward to support any of these views.

The most compelling feature has been the apparent higher degree of metamorphism of the volcanic rocks. However, the present writer's study has shown that the Shickshock Group is more metamorphosed than the rocks farther north because it lies in a zone of higher regional metamorphism, and that age is not a factor.

Support for the unconformity theory can be had from a close study of bedding and foliation strikes near the boundary. These are, at places, somewhat oblique to the trend of the boundary. The alternation of shales and sandstones in contact with volcanic rocks could suggest disconformity, with the volcanic rocks resting on a sandstone layer, at places eroded through to the underlying shale. Another possibility is that the sandstones filled erosional lows on the shale. In the Courcelette area (McGerrigle, 1954a) a band of sedimentary rocks and some structural trends in the metavolcanics are truncated by the Cambro-Ordovician sedimentaries to the north, suggesting that the sedimentaries rest unconformably on the metavolcanics.

None of these pieces of evidence really carries much weight. Formation strikes at many places in the area show considerable local variation. Statistically there does not seem to be enough difference in the strike directions of the Cambro-Ordivician sedimentaries and the nearby volcanics to suggest an angular unconformity. The alternation of shales and sandstones in contact with the volcanic rocks can be explained as owing to the local nature of the extrusion which may have commenced earlier at some places than at others. At certain localities the flows were poured directly onto a shale floor, whereas elsewhere later extrusion may have allowed time for the shales to be covered with arkose before any lavas were deposited. Even if emergence and erosion are involved there is no evident structural discordance and no necessary implication of an important time discontinuity. The apparent truncation of the Cascapédia Lake sedimentary trough (Courcelette area) by Cambro-Ordovician sedimentaries also can be discounted. The Shickshock lavas probably were fissure extrusions and in their unfolded state existed as a thick prism elongated east-west. Unless folding forces were directed exactly at right angles to the long dimension of this body, folding would cause both structural trends and trends of bodies of intercalated sedimentaries to be oblique to the outline of the lava body as a whole.

The writer attempted to solve the boundary problem by a careful examination of the contact wherever possible. To this end, 19 traverses were made along streams crossing the contact in the Mount Logan area. A lumber haulage road which crosses the contact just east of the area was traversed, and the contact was observed where crossed by the Gaspé National Park road, 20 miles east of the Mount Logan area.

These observations indicate that the transition from the volcanic to the sedimentary suite takes place along a zone of interfingered sedimentaries and lavas. As the observer moves southward from the Cambro-Ordovician sedimentary terrain, outcrops of Shickshock-type metavolcanic rocks begin to appear and, within a short distance, the main body of volcanics is encountered. Metavolcanic rocks now become the dominant lithology but scattered outcrops of metasedimentary rocks of exactly the same type as the Cambro-Ordovician sandstones show how loads of sediment continued to be dumped in the area when extrusion was temporarily lulled. The larger metasedimentary bands mark longer periods of effusive inactivity although minor volcanic intercalations show that the volcanoes or fissures were not entirely quiescent.

No important indications of faulting were seen anywhere by the writer although shearing in outcrops near the transition on the road to Gaspé National Park may suggest faulting there. Faults are shown at places along the contact by McGerrigle's (1954a) Courcelette map. These probably are not of great extent. It seems likely that local faulting might develop at this zone of lithological contrast during the intense folding movements that later affected the region.

The foregoing statements lead to the conclusion that the Shickshock Group is about of the same age as the sedimentaries to the north. The writer considers it probable that the rocks for some distance north of the Shickshocks become generally younger to the south. Hence, the Shickshock Group would be younger than these. To explain the northward progression north of the Shickshocks to the younger Normanskill and Lévis rocks, despite the generally southward dips, one must assume either an isoclinal overfold or a fault. In the case of the overfold the Shickshock Group should reappear north of the fold axis. It does not, and we are left to choose the fault theory or assume that the Shickshock Group has wedged out before the north limb of the fold is attained. The evidence for one or the other lies beyond the map-area and further discussion of the question beyond the scope of this report.

No correlation of the Shickshock Group with rocks elsewhere is made here as it is felt that the only supporting data would be a vague similarity of lithologies and general structural setting. The nearest volcanic rocks are patches intercalated in the Lower Ordovician in Saint-Denis and Tessier townships, Matane county (Béland, 1957). Six thin-sections of these rocks examined by the writer showed little similarity even with the least metamorphosed phases of the Shickshock volcanics. One important difference is in the pyroxene. In the Shickshocks the pyroxene is normal pigeonite but in the Saint-Denis - Tessier volcanics there is an abnormal pyroxene with low 2V, negative optic sign and nearly parallel extinction. Ordovician basalts are known (Jones, 1933) near the northern part of the Tabletop granite mass some 8 miles northeast of the east end of the Shickshock metavolcanics. The volcanic rocks at this locality are much fresher and less metamorphosed than those of the Shickshock Group. However, this is not necessarily evidence of an age difference, as the more metamorphosed condition of the Shickshock lavas may be due to the accident of regional metamorphism rather than greater antiquity.

Structural Geology

Field and thin-section observations overwhelmingly indicate that rock foliation is generally parallel to the flow layering and stratification of the primary lavas and sedimentaries. Confirmatory evidence is found in the regional parallelism of foliation strikes with the trends of the meta-sedimentary belts. McGerrigle (1954a, p. 21) reached the same conclusion from his work in the Courcelette area.

A few observations of discordant bedding and schistosity, and perhaps the regional obliquity of the east end of the Vignon Lake zone to foliation trends there, show that the parallelism is not absolute. This is taken to indicate that the foliation is not of the bedding plane type caused by heat and static load but is a dynamic effect consequent on strong folding allied with metamorphism and recrystallization. Foliation of the latter type shows general parallelism with bedding but local discordance can be expected.

The writer believes that the foliation of the Shickshock Group, and of the Cambro-Ordovician sedimentaries nearby, was created by strong folding during Taconic orogeny. At that time the rocks probably were cast into a series of tight, recumbent folds with sub-horizontal long limbs, short crests, and more steeply dipping short limbs. Flow layering was obliterated and bedding partly so, leaving a tract of metamorphosed rocks in which the dominant S-surface was sub-horizontal foliation. The present fold structures resulted from later folding of this foliation.

The main structural features at present are a tight northern syncline paralleled by a more open anticline 2-4 miles to the south.

South of the anticlinal axis the Shickshock block is in fault contact with Silurian sedimentaries and has been elevated relatively to the Silurian block. There is no information about the attitude of this fault. The writer suspects that it is steep and, from its association with ultrabasic rocks, that it may go to great depths.

The synclinal axis can first be identified near Mount Blanc. From there it runs in a direction about N.60°E. and persists to Côté lake at the northeast corner of the area. Beyond the limits of the area it is continuous with the axis of a syncline mapped by McGerrigle in the Courcelette area. The average southward dip of the north limb of the syncline is 65°-70°. The south limb also is steeply dipping near the axis. Farther south it dips less steeply and eventually flattens out to form the anticlinal crest. The anticlinal axis persists throughout the area from the southern part of Matane lake, east-northeastward to the bend in Cascapédia (Des Iles brook) river. Like the syncline, the anticline continues eastward into the Courcelette area. It is difficult to set an average figure for the dip of the south limb as it varies considerably. At places near the contact with the Silurian sequence there is a marked steepening of the dip. This is probably a drag induced during uplift of the Shickshock Group along the boundary fault.

The fold structures indicated by the foliation are not well borne out by the trends of the metasedimentary zones. The syncline is so tight that the limbs may go to great depths. Thus, the failure of the thin metasedimentary zones to reappear on the opposite side of the synclinal axis may be due to wedge-outs.

In the case of the more open anticline one might expect the thick Bivé Brook zone to reappear on the south side of the axis. The belt does seem to run up to and perhaps 'nose' around the anticlinal axis, about 2 miles east of Tallard (Moose) pond. The northeasterly trending portion of the Weir Brook band, between Bieil (Fox) and Saugon (Alder) brooks, may join with the Bivé Brook band at the nose of the fold. There is no surface connection, however, for the intervening outcrops on Bernier and Bouynot (Little North Branch) brooks are of volcanic rocks. However, the two belts may join in the sub-surface. If this is so, then that part of the Weir Brook zone between Bieil and Saugon brooks becomes the upright portion of a Y which at Saugon brook splits into two arms. One of these is seen on surface as the eastward prolongation of the Weir Brook zone; the other does not emerge on surface until it merges with the Bivé Brook zone at the nose of the fold. Between the two arms is a wedge of volcanic material. The whole feature presumably represents a large-scale interfingering of volcanic and sedimentary material.

Through the western half of the area the fold structures plunge ENE. at 5^0-25^0, averaging about 15^0. The plunge was determined from the lineation features and the ac jointing and foliation previously described. East of Cap-Chat river there is a zone of reverse plunge of 20^0-40^0. This persists for 2-4 miles before reverting to the general ENE. plunge.

The map shows that the trend of the anticlinal axis is slightly oblique to the outline of the Shickshock Group as a whole. At its extreme east end in the Courcelette area (McGerrigle, 1954a), the anticlinal axis is only about 2 miles south of the north boundary of the Shickshocks. By contrast, in the southwest corner of the Mount Logan area it is only about a mile north of the south boundary. The amount of warp is greatest near the east end of the axis. Other structural elements in the east part of the Courcelette area show a more pronounced warp, the average trend of one anticlinal axis being about N.30^0E. This obliquity of Shickshockian structural elements to the boundary between the Shickshock Group and the Cambro-Ordovician sedimentaries does not indicate an unconformable cutting off of structural trends by overlying sedimentaries. It merely records approach of structural elements to the wedge-edge of the volcanic pile, and the strike trends in the sedimentaries to the north are parallel with those in the metavolcanics to the south. It is evident that the eastern part of the Shickshocks was subjected to folding by forces directed about N.60^0W. rather than the more nearly north direction which is normal for the peninsula as a whole. A zone of these skewed structural elements can be seen on the Geological Map of Gaspé (McGerrigle, 1953), sweeping in a north-northeasterly direction through the central part of the peninsula. Around the east end of the Shickshocks they are related, arealy at least, to the Table Mountain - Hogsback - Mount Valliers granitic intrusions and the Mount Albert serpentinite mass. The skewed structures affect rocks as young as Lower to Middle Devonian. Presumably they are older than the relatively undisturbed Carboniferous sedimentary rocks in the southern part of the peninsula. To that extent this folding period is dated. Because this folding created structures some of which are continuous with structures in the Mount Logan area, the folding there is inferred to be of the same age. It might be argued that the main structural trends were formed during an earlier period of folding and that the twist of their east ends was caused by cross folding perhaps at a much later date. However, the cross folding theory cannot explain the obliquity of the structural trends of the Shickshock Group as a whole. Later cross folding could not have caused the east ends of the structural elements to migrate northward across the metavolcanic belt but would have warped the whole volcanic belt in harmony with the warping of the structures.

The minor phenomena associated with the Shickshock structures are of some interest. The Z-shaped folds observed in the field, and the fracture cleavage, strain-slip and minute folds seen in thin-section all represent adjustment to folding by this rock whose dominant S-planes during the folding were schistosity rather than flow layering or bedding. Had the folding been longer continued or of greater intensity the present schistosity would have been obliterated and a new schistosity formed parallel to the short limbs of the Z-shaped folds, and the strain-slip and fracture cleavage directions.

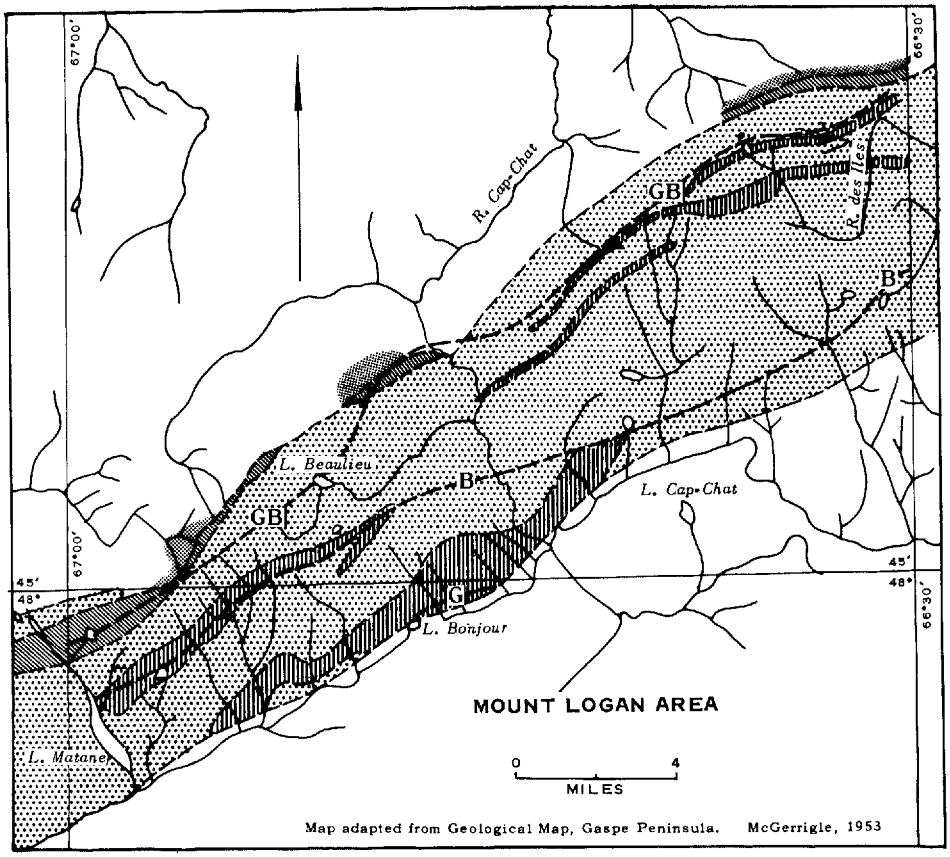
The date of the later folding of the Shickshocks already has been established as post-Lower to Middle Devonian and pre-Carboniferous. Tentatively, these movements can by related to an Acadian orogeny during the later part of Devonian time.

The earlier fold movements that created the main foliation in the rocks of the Shickshock Group are considered to be pre-Middle Silurian because rocks of this age to the south show no evidence of such intense folding. Middle Ordovician (Normanskill) rocks to the north show an intensity of folding compatible with the folding that may be inferred to have created the foliation of the Shickshocks. They failed to become schistose only because they were out of the zone of regional metamorphism. Thus the earlier stage of folding is dated as pre-Middle Silurian, and post-Middle Ordovician and may be attributed to Taconic orogeny.

Regional Metamorphism

J. Béland (personal communication) has informed the writer that in the Grosses Roches - Sainte-Félicité map-area (Béland, 1957) slight metamorphic effects are perceptible as far as 10 miles north of the Shickshocks and that metamorphism appears to increase in intensity southward. The writer has shown above that, at the limit of his mapping 2 miles north of the Shickshocks, such metamorphic phenomena as the development of slatiness and a micaceous lustre appear in the Cambro-Ordovician shales and sandstones. At a certain point the appearance of chlorite marks a superior level of metamorphism. The writer's information is too scanty to allow a delimitation of the chlorite isograd. Over the west part of the area it probably is north of the limits of mapping. A little farther southward green biotite comes in. West of the headwaters of the Matane river the green biotite isograd lies in the Cambro-Ordovician rocks shortly north of the Shickshocks. The trend of the isograd is more easterly than that of the Shickshock Front. East of Cap-Chat river the isograd cuts southward enough to bring it into the outcrop area of the Shickshock Group (see Fig. 2). Moving southward in a direction perpendicular to the green biotite isograd, changes in the mineralogy and fabric of the rock testify to the continued increase in grade of metamorphism and, eventually, the biotite isograd is

FIGURE 2



Map adapted from Geological Map, Gaspe Peninsula. McGerrigle, 1953

METAMORPHIC ISOGRADS

--GB--Green biotite isograd

--B-- Biotite isograd

--G-- Garnet isograd

▩ Slaty shales

▨ Meta-arkoses

░ Metavolcanics

▥ Metasedimentaries

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reached. The biotite isograd is only about a mile south of the green biotite isograd in the extreme western part of the area. The two isograds diverge to the east, however, and are more than 4 miles apart at the east edge of the area. Metamorphism continues to rise southward beyond the biotite isograd and reaches its zenith in a small zone of garnet-bearing rocks at one place along the south edge of the Shickshocks.

Thus, the overall picture is of a broad region of progressive metamorphism extending southward from the St. Lawrence shore and reaching its exposed culmination some 15 miles to the south at the southern edge of the Shickshocks. The isograds of equal metamorphic intensity are not quite parallel to the regional structural trends, being bent to a more nearly eastward direction.

Recognition of the regional and progressive nature of this metamorphism is of fundamental importance to a consideration of the age of the Shickshock Group. The knowledge that there is no sudden transition between the metamorphic grade of the Cambro-Ordovician sedimentaries and the Shickshock rocks removes a major previous stumbling block, namely, the implication of greater age for the Shickshock rocks because of their greater metamorphism.

At least two possibilities to account for the southward increase in metamorphism may be postulated. The first is that the higher grade of metamorphism to the south is a manifestation of deeper burial, or depression of the southerly rocks to a higher temperature zone. However, the structural geology does not support this suggestion. A conservative estimate, based on the generally eastward plunge and taking into consideration the limited area of westward plunges east of Cap-Chat river, is that the rocks around Matane lake at the west edge of the area may be from a depth zone at least 5 miles below those at the east edge. Therefore, metamorphic isograds, if related to depth of burial, should run approximately north-south, perpendicular to the direction of maximum depth difference.

A more probable reason for a higher temperature toward the south is an invasion of the upper levels there by material from the deeper, granitic zone of the earth. The main body did not rise to the level represented by the present erosion surface but its presence below is signaled by the acid sill-like bodies in the Weir Brook zone and by the strong hydrothermal influences there. The areal association of these phenomena with granites is known throughout the world.

Supporting evidence is at hand in a gravity map of Gaspé peninsula recently prepared by J. Tanner (see, Tanner, 1960) of the Dominion Observatory, Ottawa. The map shows a very extensive, pronounced, oval-shaped, positive gravity anomaly in interior Gaspé. In the western part of the Mount Logan area the long axis of the anomaly lies about along the southern contact of the Shickshock Group. Farther east, the anomaly transgresses northward becoming first weaker, then rising to a new high over the Mount Albert serpentinite mass. Beyond Mount Albert the anomaly continues strongly in an east-northeast direction to the coast.

A part of this feature can be related to the dense metavolcanic rocks of the Shickshock Group but its off-centre position with respect to their main area of outcrop implies that it is not due to them alone. Its association with Mount Albert indicates that the serpentine mass there, and other serpentine bodies along the south part of the Shickshocks also contribute to the anomaly. However, in its great regional extent and continuation far beyond the known area of volcanic and serpentine outcrop it also has the appearance of an actual basement upwarp. Thus, the whole zone may represent a line of long continued crustal weakness. Its earliest manifestation may have been the series of fissures or pipes from which, in Cambrian or Early Ordovician time, the Shickshock lavas were extruded. Later, probably during Taconic orogeny, came the granitic upwelling. Still later the zone served to localize the great fault which now separates the Shickshock mountains from the Silurian rocks to the south. This fault may have pierced downward to the basic crustal substratum providing a path for the ascent of ultrabasic material which now appears as Mount Albert and the other serpentinite bodies of the region.

MIDDLE ORDOVICIAN

Fossil collections fixing the age of the containing rocks as Middle Ordovician (Normanskill) were made in the Mount Logan area during 1957 by C.H. Smith (personal communication) of the Geological Survey of Canada. The localities are indicated as F14 and F15 on the accompanying geological map. These collections are of great interest in that they are from the first Middle Ordovician rocks described from the south side of the Shickshocks.

The F15 locality is only 100-200 yards north of the writer's F1 locality (Silurian) along a section of road constructed by the Hammermill Paper Company after the present writer had worked in the area. The F14 locality is on Wilson brook about 3/4 mile above its junction with the Cap-Chat.

Fossils collected include: F15 locality-*Climacograptus* sp., cf. *C. schlarenbergi* Lapworth; F14 locality-*Dicranograptus nicholsoni* Hopkinson var. *minor* Bulman, and *Climacograptus bicornis* var. *tridentatus*

Lapworth (identifications by L.M. Cumming of the Geological Survey of Canada). The lithology and fossil content of these rocks suggest a correlation with the lower part of the Middle Ordovician as mapped by McGerrigle (1954, p. 24) in the Tourelle area. The wider correlation of those beds has been given by that author.

Specimens examined by the writer are hard, black shales notably more indurated and metamorphosed than the nearby Silurian rocks. The extent of these rocks is not well defined as their presence is known only from the two outcrops. Hard grey shales along Alphonse brook about one mile to the west possibly are part of the same zone but limestones of Silurian type appear 1/2 mile farther upstream on that brook. Other Silurian exposures and fossil collections in the vicinity serve to limit further the Normanskill area and its probable maximum extension has been indicated on the accompanying geological map. The nature of the contact of these rocks with the Shickshock Group is unknown.

SILURIAN

Distribution and General Character

Other than along the small area of Normanskill rocks just described, Silurian strata bound the south edge of the Shickshocks in the east half of the area. The sedimentaries south of the Shickshocks in the west half of the area also are believed to be of Silurian age although only a few observations were made there.

Silurian strata in the east half of the area make up an ENE.-trending band about 3 miles wide. The band is in fault contact with the Shickshock Group to the north and probably passes conformably up into the Devonian to the south.

In the Courcelette area to the east, the base of the exposed Silurian section is marked by a reddish weathering dolomite* . In the present area, this zone probably is represented by outcrops of dolomite near the base of the section on Go-Ashore brook. Slightly lower in the section of the same brook, and at other places near the exposed base of

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* Editor's note: This dolomite is regarded by some (e.g. MacGregor, 1962) to have been formed by the hydrothermal alteration of schisted serpentinites, and some of it evidently had such an origin. However, dolomite has been seen by McGerrigle in various places along the Shickshock-Silurian contact zone between Mount Albert and Cap-Chat river, and, in many places (as with Mattinson's locality on Go-Ashore brook) a close relationship with serpentinites is not apparent.

the Silurian there are outcrops of a hard, white, fine-grained orthoquartzite (Val Brillant?) characterized by minute rusty flecks on the weathered surface. The thickest section of this rock exposed at any place is 50 feet.

Conglomerate is rare in the section. A few feet of conglomerate is exposed on Go-Ashore brook some 200 feet below the orthoquartzite zone. This rock consists of sub-rounded pebbles and cobbles of shale, shaly limestone, and limestone in a dark, shaly matrix.

In general, the lower part of the section comprises brownish weathering limy and argillaceous siltstones giving place upward to grey silty and shaly limestones, purer limestones and minor dolomites and shales. Ripple mark and grain gradation are seen in some silty beds. In thin-section, the clastic rocks show subangular to subrounded grains and a moderate degree of grain-size sorting. Quartz and a smaller amount of feldspar are the main fragmental components, and are cemented by calcite and argillaceous material. Nearer the base of the section the composition of the detrital fragments becomes more complex and the proportion of feldspar to quartz rises. Grains of shale and siltstone become quite common, rising in some instances to 20% of the rock. There are also some fragments of trachyte, granite, vein quartz and phyllite. These rocks are more poorly sorted and the grains are more angular. In the upper part of the section, quartz, argillaceous material, and a small quantity of plagioclase make up only impurities in the dolomites and limestones.

Horizon markers are scarce in the section. However, the white orthoquartzite near the base is a good marker and its position everywhere near the Shickshocks shows that the boundary fault is quite closely parallel to bedding strikes. Beds of coarse, bioclastic calcarenite, which give off a fetid odour when broken, are present in the upper part of the section. The various beds are not distinctive enough to be positively correlated from place to place but the zone can be followed in a general way and is of assistance in determining the general strike trend.

Section and Thickness

The section given below comes mainly from outcrops along Cap-Chat river and the bordering Company road. Parts of it were measured but it is based mainly on calculations from plotted outcrops. The thickness arrived at is 7,263 feet, but this should be increased by 100-500 feet to include rocks at the base and top which are obscured by cover and faulting. This compares favourably with McGerrigle's (1954a, p. 34) estimate of 7,000 feet in the Courcelette area, although the writer's upper boundary is some 1,500 feet below that used by McGerrigle. No allowance was made for faults. One known fault interrupts the section and another fault is probable; these may not be of great magnitude as there is no obvious repetition. If other faults occur it is likely that they are thrusts and their net effect would doubtless be to render the section somewhat too thick.

	Thickness in feet	Cumulative thickness
Devonian Cape Bon Ami Formation		
Covered interval	250	
Soft, dark grey, silty, argillaceous limestone	4	4
Thin bedded, fawn, argillaceous, limy siltstone	3	7
Covered interval	25	32
Thin bedded to flaggy, brown weathering limy, argillaceous siltstone; grey, silty, shale	200	232
Thin bedded, flaggy, fawn weathering, limy and dolomitic siltstone	5	237
Thin bedded to flaggy, brown weathering, limy, argillaceous siltstone; grey silty shale	170	407
Covered interval	10	417
Thin bedded, light greyish-green, argillaceous, dolomitic siltstone	5	422
Covered interval	385	807
Thin bedded, brown, argillaceous siltstone	5	812
Covered interval	250	1062
Silty, argillaceous limestone with considerable limy shale	400	1462
Poorly sorted sandstone with fossil fragments	5	1467
Brownish weathering, silty, grey shale with lesser amounts of siltstone	305	1772
Brownish weathering, slightly limy siltstone with fossil fragments, weathering to a pitted surface; silty, limy shale	175	1947
Gritty calcarenite	1 1/2	1948
Silty, argillaceous limestone	55	2003

	Thickness in feet		Cumulative thickness
Brown weathering, light grey, dolomitic siltstone	75	....	2078
Silty, argillaceous limestone and limy shale	200	....	2278
Covered interval	70	....	2348
Silty and shaly limestone; calcareous shale	180	....	2528
Silty and argillaceous limestone; pure grey limestone	100	....	2628
Silty and argillaceous limestone; minor calcareous shale	865	....	3993
Covered interval with blocks of silty, argillaceous limestone	800	....	4293
Silty, argillaceous limestone	160	....	4453
Grey, shaly and thin bedded, silty limestone; calcareous shale; a few pure limestone beds	300	....	4753
Covered interval	100	....	4853
Grey, shaly and silty limestone	5	....	4858
Covered interval	100	....	4958
Fault?			
Grey, silty and shaly limestone	5	....	4963
Covered interval	190	....	5153
Covered interval; abundant blocks of thickly bedded limestone with thin calcareous shale interbeds	50	....	5203
Thickly bedded limestone with shale interbeds	25	....	5228
Dark grey, silty, shaly limestone; calcareous shale	10	....	5238
Calcareous shale	5	....	5243
Covered interval	5	....	5248
Shaly limestone	5	....	5253
Covered interval	20	....	5273
Shaly limestone and calcareous shale	5	....	5278
Covered interval	40	....	5318

	Thickness in feet	Cumulative thickness
Flaggy siltstone	5	5323
Covered interval	80	5403
Limestone	5	5408
Covered interval	40	5448
Grey argillaceous limestone	5	5453
Covered interval	35	5488
Limestone with thin shaly interbeds	5	5493
Covered interval	20	5513
Limestone	5	5518
Covered interval	25	5543
Limestone	5	5548
Covered interval with limestone blocks	20	5568
Limestone with shaly interbeds	5	5573
Covered interval	80	5653
Covered interval with blocks of grey limestone	60	5713
Shaly limestone; thin bedded, silty limestone with worm burrows; Fossil locality (F5)	10	5723
Shaly limestone	10	5733
Covered interval	10	5743
Shaly and silty grey limestone	5	5748
Covered interval	10	5758
Thinly bedded calcareous and argillaceous siltstones; Fossil locality (F4)	10	5768
Covered interval	140	5908
Grey argillaceous limestone	5	5913
Covered interval with blocks of grey argillaceous limestone	130	6043
Grey argillaceous limestone	10	6053
Covered interval with large blocks of grey limestone and calcareous shale	35	6088
Grey limestone and calcareous shales	45	6133
Covered interval	75	6208

	Thickness in feet	Cumulative thickness
Well bedded, flaggy, argillaceous, limy siltstone	320	6528
Reddish weathering, silty, argillaceous dolomite	10	6538
Smooth, flaggy, greenish-grey, argillaceous limy siltstone varying to silty argillaceous limestone	85	6623
Greyish-green, silty limestone to calcareous siltstone	105	6728
Argillite with limy layers	5	6733
Greyish-green silty limestone	100	6833
Covered interval	35	6868
Dolomitic siltstone	5	6873
Covered interval	15	6888
Grey limestone	8	6896
Covered interval	10	6906
Blotchy and striped limestone and dolomitic limestone; Fossil locality (F3)	25	6931
Thickly bedded, grey limestone with thin shale partings	7	6938
Covered interval	275	7213
Very fine-grained orthoquartzite	50	7263
Short covered interval including horizon of Fossil locality (F2)		
Fault		
Grey shaly limestone and limy grey-brown argillite; Fossil locality (F1)		
Short covered interval to Middle Ordovician beds		

Paleontology and Age

Fossil collections were made from six new localities in the Silurian. These appear on the map as F1, F2, F3, F4, F5, and F9. A brachiopod was observed at locality F6. Collections of *Monograptus* sp. had previously been made by McGerrigle (personal communication) at localities F7 and F8 near the base of the exposed section.

Fauna identified from the new collections and the indicated time ranges are given below (identifications by L.M. Cumming, Geological Survey of Canada).

Locality F9, near the base of the exposed section and shortly above the conglomerate on Go-Ashore brook, yielded *Atrypa reticularis* (Linnaeus) and *Favosites* sp. Cumming states that the brachiopod is of Silurian type, that is with nearly equal valve convexity and well developed reticulate ornamentation.

Locality F1 is 9 miles WSW. of locality F9 and probably is near the same stratigraphic level. The identified fauna comprises a *Calymene* pygidium possibly belonging to *C. celebra* (Raymond), *Nucleospira* sp., cf. *N. pisiformis* Hall, *Atrypa reticularis* (Linnaeus) and *Loxonema* sp., cf. *L. subangulatum* (Opik). Of these, the two first mentioned are indicative of a Middle Silurian age.

Locality F2 is only some 300 feet south of locality F1 but the two probably are separated by a fault. The collection includes *Atrypa* sp., *Tentaculites* sp., *Schuchertella* sp., *Trematospira* sp., and *Pentamerus* sp. cf. *P. laevis* Sowerby. The last named is restricted to the Middle Silurian. The other forms are not diagnostic.

Locality F3, about 350 feet stratigraphically above locality F2, yielded the non-diagnostic brachiopod *Nucleospira* sp.

Localities F4 and F5, respectively some 1,165 and 1,200 feet above locality F3, yielded (F4) *Monograptus tumescens* (Wood), *Monograptus ultimus* (Perner), and (F5) *Monograptus ultimus* (Perner). Both of these indicate a Lower Ludlow age.

These collections suffice to indicate the Middle Silurian age of the lowermost 1,500 feet of the section. In the Courcelette area McGerrigle (1954a, p. 37), in the absence of fossils, assigned the lowermost 1,500 feet of the section to the Silurian on the basis of lithology and comparison with other areas. The present work bears out the correctness of that assignment. No diagnostic fossils were found in the uppermost

6,000 feet of Silurian strata in the Mount Logan area. McGerrigle (op. cit.) found Middle Silurian fossils throughout the middle part of the section but notes that the uppermost 1,500 feet yielded no fossils. Because of this absence of fossils in the uppermost strata and the apparent transitional passage to the Devonian, the presence of Upper Silurian beds in the section is a possibility.

The collection is scarcely large enough to permit a good correlation with other areas. The most diagnostic species do not appear in McGerrigle's fossil list for the adjacent Courcelette area, and there is little similarity with the faunal content of the Silurian section at Lake Matapédia (Dresser and Denis 1944, p. 319). Nucleospira sp., cf. pisiformis in the type Silurian section of Gaspé at Port-Daniel has been found only in the Bouleaux formation in the upper part of the Chaleurs series. However, McGerrigle's Courcelette area collections, from higher in the section, are more suggestive of a correlation with the lower part (Clemville to Gascons) of the Chaleurs series. On the basis of similar lithology and position low in the sequence the white orthoquartzite band may tentatively be correlated with the Val Brillant sandstone of the Matapédia Lake Silurian section. At Matapédia lake the Val Brillant sandstone is about 200 feet thick; here the maximum exposed thickness is 50 feet.

No fossils were found in the remainder of the Silurian section and it is difficult to fix the upper boundary accurately. The main control comes from localities on Cap-Chat river just south of the map-area. Near the junction of Cap-Chat river and Truite brook, McGerrigle (personal communication) found Monograptus sp. and, a short distance higher in the section, plant fragments allied to those known to occur in the Devonian. The Silurian-Devonian contact is thus defined there, and from that point the writer projected the contact northeastward as suggested by the local strike trends. Correlation based on scattered outcrops of a zone of bioclastic calcarenite and a band of nodular maroon shale serve to reinforce the validity of the strike trends. The boundary thus arrived at is not entirely satisfactory because it requires classing as Devonian silty and dolomitic limestones that are lithologically more closely allied to Silurian types. This boundary falls about 1,500 feet lower in the section than McGerrigle's lithologically controlled boundary in the Courcelette area. However, it does reduce the thickness of Silurian strata and increase that of the Devonian Cape Bon Ami Formation to values more compatible with thicknesses of these formations elsewhere in the region.

Structural Geology

The Silurian rocks strike about N.65°E. and dip generally southward. The angle of dip tends to become less steep toward the south.

Northeast of Joffre (Cap Chat) lake the Silurian strata are thrown into a sharp, narrow syncline whose axis can be traced about 4 miles. A complementary anticline parallels the syncline to the north. Exposures bordering the Shickshocks show marked crumpling and abundant shear and rupture zones. Dips there are, for the most part, southward at 60^0 or greater.

Well developed planar joints spaced 1 inch to 2 feet apart are exhibited by most of the Silurian rocks. Almost all strike normal to the bedding strike. Of some 45 cross joint sets whose attitudes were measured, 25 dip vertically and the rest dip steeply ENE. or WSW. Of 13 lineations (drag fold axes), two plunge ENE., seven plunge WSW., and four are in random directions. Another indication of a general westward plunge of fold structures is the record, at scattered localities, of beds striking NW. and dipping shallowly SW.

The attitudes of only four faults were measured; all strike between north and east and dip steeply. The one fault whose sense of movement could be ascertained strikes east, dips vertically, and shows the north block down with respect to the south block. Other faults or very sharp flexures are suggested by the abrupt dip differences of adjacent outcrops and local overturned zones.

The Silurian block was brought into position adjacent to the Shickshocks by being lowered along a major fault. The zone of steep dips near the fault is considered to be a large-scale drag effect and the increased structural complexity near the Shickshocks also is related to the fault. However, it is suggested that most of the deformation of the Shickshock Group was achieved before the Silurian block was brought into fault contact with the Shickshocks because:

(i) The Silurian strata do not appear competent to have transmitted the considerable force which would have been required to create the present structures in the hard and competent Shickshock Group.

(ii) The tendency of folded structures in the Silurian to a westward plunge contrasts with the eastward plunges shown by structures in the Shickshock Group.

The period of folding and faulting in the Silurian is tentatively related to Acadian orogenic movements of the later Devonian. The major boundary fault may be related to a period of normal faulting that has affected other areas in the peninsula. This can be dated no more closely than post-Malbaie, the youngest Devonian sedimentaries of the peninsula.

DEVONIAN

Cape Bon Ami Formation

Distribution and General Character

Rocks of the Cape Bon Ami Formation appear in a band about 1 1/2 miles wide, lying south of, and parallel to, the wider band of Silurian outcrops. The formation is not well exposed in the area. Some outcrops appear along the Company road in the southwest corner of the outcrop area and there are a few along Go-Ashore brook in the east.

The lower part comprises mainly soft, dark grey, argillaceous limestones but has an important content of silty limestones, dolomitic and limy siltstones, fine-grained sandstones, and silty dolomites. About 35 feet of nodular maroon shale, with thin greenish shale interbeds, occurs some 700 feet above the base of the section. In the upper part of the section, scarce outcrops indicate a transition to purer, thicker bedded, dove to creamy weathering, finely crystalline, grey limestones.

At its base the formation grades into the Silurian along a somewhat indefinite boundary. The relationship to the overlying Grande Grève is similarly conformable. The boundary as drawn by McGerrigle in the Courcelette area depended on the passage from softer and more shaly rocks to harder, well bedded calcareous siltstones and arenaceous limestones. In the present area outcrop control is too poor to allow positioning to the contact on this basis. An upper limit is suggested by the discovery of the brachiopod Meristella champlaini Clarke at a locality (F12) west of Go-Ashore brook. This fossil is reported from the Grande Grève but not from the Cape Bon Ami of eastern Gaspé. Hence, the boundary was selected so as to pass just below this locality and was extended from there to the limits of the area on the basis of regional trends. At the eastern edge of the Mount Logan area the boundary thus defined falls more than a mile north of the Cape Bon Ami - Grande Grève boundary as fixed by McGerrigle (1954a) in the adjoining Courcelette area. However, the faunal evidence used here is admittedly weak and lithology may well provide a better basis for separation. From a consideration of the width of outcrop and average dips the thickness of the formation would be about 2,500 feet. The comparable figure in the Courcelette and Matapédia areas is about 3,000 feet. The average for eastern Gaspé more nearly approaches 4,000 feet.

Paleontology and Age

No fossils were discovered by the 1955 or 1956 field parties. McGerrigle (personal communication) found the brachiopod Leptocoelia flabellites at localities along Go-Ashore brook (marked F10 and F11 on the geological map) and on Lucy brook 200 yards south of the area. The range of this species is too wide to permit its use in achieving a correlation with other areas. The upper part of the formation as defined by the writer is directly continuous with the Cape Bon Ami of the Courcelette area. McGerrigle (1954a, p. 42) points out that his modest fossil collections there do not permit zoning but in general bear more resemblance to the Grande Grève than to the Cape Bon Ami of the type area of eastern Gaspé. It is possible that if the Cape Bon Ami - Grande Grève boundary assumed by the writer were to be applied to the Courcelette area a part of this discrepancy might be removed. However, this does violence to the lithologies involved.

Structure

The Cape Bon Ami Formation rests conformably on Silurian beds and, like them, strikes N.65°E. and dips south at moderate angles. Dips are steeper in the western part of the outcrop area so that the outcrop width is constricted there. Folds or faults have not been recognized.

Grande Grève Formation

Only five outcrops of this formation were seen. These are well bedded, light brown weathering, grey limestones and, at one locality, dark shales. Fossils were found near the mouth of the west branch of Go-Ashore brook and others were found about 1/2 mile upstream on the same watercourse. The last-mentioned locality (F12) yielded the non-diagnostic brachiopods Schuchertella sp., and Meristella champlaini Clarke. According to Cumming (personal communication) the last-named fossil is found in the lower part of the Grande Grève formation in eastern Gaspé. It has not been reported from the Cape Bon Ami (see lists provided by McGerrigle, 1950). In the absence of other information, the boundary was drawn so as to pass slightly north of this fossil locality. As so drawn it is about 1/2 mile north of its position on McGerrigle's (1953) geological map of Gaspé peninsula.

The Grande Grève rocks conformably overlie those of the Cape Bon Ami formation and dip at low angles to the SSE.

PLEISTOCENE AND RECENT

The surficial deposits of the area include soil and rock mantle, mudflow deposits, stream valley fillings, glacial drift and fluvioglacial material.

The distribution of the glacial deposits has already been indicated in the section on glacial geology. These, as seen, were mainly stream cut and lake bank exposures of drift. Most show the unstratified and unsorted character of till. Less commonly, as around the west side of the north end of Matane lake, sorting and stratification provide evidence of fluvioglacial origin. Road and stream cuts show, and the hummocky nature of the topography implies, the presence of ground moraine in the southern plain in the east half of the area. This material, however, does not extend over the whole plain and is not very deep.

Most of the slopes in the Shickshocks are mantled with a few feet of soil and rock fragments. Felsenmeers occur on the higher peaks. The lower part of the soil, as exposed in mudflow cuts, appears to contain a higher proportion of fragments of the underlying rock. The bulk of these are angular and less than a few inches in maximum dimension. They probably result from freeze-and-thaw and frost wedging processes operating on the underlying rocks.

Minor Chemical Elements of the Stream Sediments

Procedures

During the second summer's field work the writer carried on a program of stream sediment sampling. The purpose was, by analysis of the samples, to indicate areas of anomalously high concentrations of certain elements which might be of interest from the geochemical or economic view points.

At about 1/2-mile intervals along the streams traversed, a sample of 25-50 grams of sediment was collected from the stream bed, and an equivalent amount from the stream bank. The bank samples were collected on the flat part of the valley bottom 2-3 feet from the lip of the stream channel. The samples were stored in small aluminum boxes of 50cc. capacity and were later analysed by the Quebec Department of Mines' laboratories.

In order to obtain fine material it was necessary to collect from places of lesser stream gradient. For this reason sample spacings are more or less than 1/2 mile at many places. Only the -80 mesh part of the samples was analysed for copper, lead, and zinc and it was found that many of the samples collected, particularly those from stream bottoms, contained too little fine material for this analysis. In order to ensure that the chemical environment, particularly acidity, would be as constant as possible we attempted to collect all the bank samples from the same part of the soil profile. The horizon selected was the top of the B soil horizon. This is easily recognized because it occurs immediately below a white leached zone and usually at a depth of 8 inches or less. The white leached zone was found at about 3/5 of the places where bank samples were collected.

The samples were treated for analysis as follows:

The sample was dried at 105°C. then crushed lightly to break up aggregates. It was then split into two parts. One part was sieved and the -35 mesh portion subjected to semi-quantitative spectrographic analysis. The elements found were reported as falling into one or the other of the abundance classes 0.001%-0.01%, 0.01%-0.1%, 0.1%-1%, 1%-10% and 10% or greater. The second portion of the sample was sieved and the -80 mesh portion further split. Both parts were analysed by wet chemical colourimetric methods for copper, lead and zinc. The metals were extracted from one part by the ammonium citrate leach described by Bloom (1955, p. 553) and from the second part by a hot nitric acid leach (Bloom and Crowe, 1953). The purpose of the ammonium citrate leach is to extract heavy metal which has been transported in solution and adsorbed on or into clay or silt minerals. The metal content indicated by analysis of this extract normally is derived from chemical weathering of sulphide or carbonate concentrations. The hot nitric acid leach is able to extract both the metal adsorbed on silt and soil minerals and that transported as actual fragments of sulphides or carbonates. The spectrographic analysis is capable of detecting elements contained in silicate and oxide minerals as well as those in sulphides, carbonates, silts, or clays.

Results

The results of the analyses are reported in Figures 3-14. On the figures, each symbol represents the location of an analysed sample and, in the case of bank sediment samples, is located on the right or left of the stream as an indication of the side from which a sample was collected. Also indicated are the boundaries of the Shickshock Group and approximate boundaries of the Bivé Brook and Weir Brook metasedimentary zones.

For the spectrographic analyses the results are reported in the semi-quantitative terms as received from the laboratory. Copper, lead and zinc results from the wet chemical analyses are reported as a function of background rather than absolute values. Background is the tenor of an element in most of the samples from an area, and it is the departures from background that are of greatest interest. To obtain the background for a particular metal one proceeds as follows:

Copper, Lead and Zinc - The ammonium citrate leach gave negative results for nearly all the samples analysed. This may in part be due to the scarcity of clay and very fine material in most samples. A number of the bank samples and some bed samples, however, contain clay and silts so that this explanation is not entirely satisfactory. A more general reason probably is the very low degree of chemical weathering.

Larger amounts of copper, lead and zinc are shown by the analyses of the hot nitric acid extract.

Figure 3 showing copper distribution in stream bed samples, fails to show any areas of great interest. Most of the samples are in the zero to twice background range. Six show a copper content of two to four times background. Three of these are concentrated near the head of Bernier brook and may indicate a copper concentration in the hills at the head of the brook. It might be noted that the background of 90ppm is rather high. Riddell (1954, p. 9) reports background quantities of only about 25ppm for copper in soils in Lemieux township, Gaspé-North county. The higher background here probably reflects the general affinity to copper for basaltic flows; minute amounts of copper, some perhaps in the native state, may be widespread in the metavolcanics. Basalts with native copper are known 20 miles west of Mount Blanc.

The stream bank samples (Figure 4) indicate two areas of anomalously high copper content, one around Matane lake and one at Bouynot (Little North Branch) and Bernier brooks. The latter may represent two separate highs because three samples on the intervening Plinguet (Emerson) brook are low. Chalcopyrite in a quartz-epidote vein was discovered near the head of Bouynot brook. It is unlikely that the downstream highs are related to this occurrence because the intensity of copper increases downstream. No adequate explanation of why these areas of anomalously high copper content are not revealed by the stream bed samples is at hand. It may be due in part to the lower background of the stream bank samples which makes them more sensitive to differences in copper concentration.

Lead, like copper, has a higher background for stream bed samples (55ppm) than for bank samples (30ppm). Neither group of samples indicates any sizable lead anomaly (Figures 5 and 6). The stream bank samples do show some scattered occurrences of values of two to four times background. Three on Desjarlais (Gros) brook, not far south of the lake could indicate an upstream lead deposit. There also is some indication of lead concentration around Matane lake including an analysis result in the four to eight times background range.

The analyst reported no lead in many of the samples. The next lowest figure reported is 10ppm; thus, it is probable that up to 10ppm lead may have existed in some of the samples for which negative results were shown. The distribution of these samples shows that the east half of the sampled area generally is lead deficient.

The zinc background for both bed and bank samples is 115ppm. Little variation is shown by the stream bed samples (Figure 7), most of which are in the range 10ppm to twice background. Two stream bank samples (Figure 8) show high values which may record local lode concentrations. About half the stream bank samples are in the 0-10ppm range. These are scattered through the area but are concentrated around Matane lake to cover the same general area where analyses of the bank samples show a copper high. They are also present in above-normal abundance in the Cambro-Ordovician sedimentaries to the north, which may imply that zinc in the area is syngenetic with the lavas rather than introduced from an external source.

Graphs made by the writer show that only in a very crude way is there an association of high concentrations of copper, lead and zinc in bank samples and the corresponding bed samples. Bank samples are generally lower in metal than are the corresponding bed samples, except in the case of lead. Nevertheless the figures have shown that the bank samples are capable of indicating areas of metal concentration more reliably than are the bed samples. One reason for this may be the steep stream gradients and the rapidity with which the stream load is transported. Sulphides and carbonates of the metals in question probably are removed with erosion from their source, and metal-bearing material rapidly becomes diluted in the downstream direction. The proportion of these metals in the fine fraction, however, increases downstream owing to more rapid disintegration of the friable ores during erosion. These fines stand the best chance of being washed over the edge of the stream channel onto the bank during floods. The bank samples thus show a longer dispersion train and this has more chance of being picked up by reconnaissance work of the type done by the author.

The foregoing considerations suggest some principles of importance to geochemical prospecting for copper, lead and zinc in regions of steep stream gradients and dominantly mechanical weathering such as the Mount Logan area. These are:

(i) Analyses of ammonium citrate extracts are useless.

(ii) For reconnaissance geochemical prospecting, bank samples are likely to be more widespread indicators of areas of anomalous metal content than are stream bed samples.

(iii) For detailed prospecting, stream bed samples may be useful as they should show high-value anomalies very near the metal source.

Chromium, Boron and Zirconium - These are among the elements analysed by spectrographic means. Their average content in a number of rock types has been given by Rankama and Sahama (1950). This provides a guide for estimating which of these metals should be associated with the metavolcanic rocks and which with the metasedimentaries. Chromium is more definitely associated with basalts than it is with granites, the figures being 340ppm and 2ppm respectively. Boron, although comparatively abundant in volcanic emanations, is in low concentration in basalts and tends to be concentrated in many sediments. Rankama and Sahama give the average zirconium content of basalts as 140ppm.

In general, the sediment sample maps bear out the conclusion which could have been reached from a knowledge of these figures. Chromium is richer in samples collected in streams flowing in metavolcanic rocks, and zirconium and boron are richer in samples collected where the stream courses are in metasedimentary zones. The correlation is highly imperfect, however.

Chromium concentration both in stream bank and stream bed samples generally is between 0.001% and 0.1% (Figures 9 and 10). In the stream bank samples chromium leaves a longer downstream dispersion trail than it does in the stream bed samples.

Zirconium in all but one sample is present in amounts of 0.001-0.1% (Figures 11 and 12). The zirconium content of the bank samples is appreciably higher than that of the bed samples. This seems curious in view of the fact that zircon is the only zirconium-bearing mineral of much importance and, being very resistant to both chemical and mechanical weathering, should be more at home in the bed samples.

Most of the samples, both from stream banks and beds, contain less than 0.001% boron (Figures 13 and 14). Three or four samples collected from streams flowing in the metavolcanic terrain have 0.001-0.01% boron. Some 45 samples from streams in the sedimentary terrains contain 0.001-0.01% boron. The most probable boron source is tourmaline, which was seen in some thin-sections of sedimentary rocks.

Other Metals - The spectrographic analyses revealed the presence of a number of other trace elements in the samples. Most of these so commonly fall into one range of concentrations that it was considered not worth while to make maps of their concentration variation. Among them are manganese which was found in all samples either in the 0.01-0.1% or 0.1-1% ranges, generally the higher. Vanadium and gallium were reported in all samples in the ranges respectively 0.01-0.1% and 0.001-0.01%. Most samples contained 0.001-0.01% nickel and most have 0.1-1% titanium. Cobalt was found in about three-quarters of the samples, generally in amounts of 0.001-0.01% and rarely in the 0.01-0.1% class.

INTRUSIVE ROCKS

Devonian or Later Basic Dykes and Sills

A few sills and dykes, up to 6 inches thick, occur in the mica schists of the Vignon Lake band, 2 miles east of the north end of Des Iles lake. These are fine-grained, dark reddish rocks in which a faint alignment of feldspar laths can be seen in hand specimen. Under the microscope, they are composed of basic plagioclase, chlorite, impalpably fine-grained material, and a little olivine, largely altered to antigorite. The reddish colour is due to iron oxide, mainly goethite, which permeates the rock.

Nine basic dykes were found in the sedimentary terrain south of the Shickshocks. Six occur far south on Go-Ashore brook, two on the Company road about 4 miles due east of Joffre lake and one on the road about 2 miles southeast of the lake. The largest noted was 160 feet thick and the smallest, 3 feet thick. Most stand nearly vertical and strike SE.

Megascopically these are brownish weathering, dark grey rocks. The edge facies is very finely granular; the interior portions are coarser, in some cases porphyritic with phenocrysts up to 1 cm. Ophitic texture is common; more rarely the feldspar laths are aligned. The rock is commonly amygdaloidal, the amygdules being composed of chlorite or calcite.

Thin-sections show these rocks to consist dominantly of lath-like plagioclase in a mass of chlorite and carbonate, with minor titanite, magnetite, ilmenite and pyrite. Small amounts of augite were observed in the coarser, central parts of some dykes. The former presence of larger amounts of pyroxene is revealed by numerous box-work structures composed of iron oxide rods which meet at approximately 93° and 87°, the characteristic angles of pyroxene cleavages. This iron oxide is thought to record the disposition of excess iron liberated during the transformation of pyroxene to chlorite and carbonate. Most of the plagioclase is labradorite; however, in the thickest dyke, the plagioclase is albite or sodic oligoclase. Ophitic textures and the presence of augite in this rock imply that the plagioclase originally was much more basic. The transformation to more sodic plagioclase without destruction of textures must be owing to an early autometamorphic change, as in the basic volcanics at the north edge of the Shickshocks. The titanite, in part at least, formed by alteration of ilmenite-magnetite intergrowths. Titanite intergrown with opaque oxide grains is quite common. Removal of the titanite from some of these intergrowths has given rise to remarkable skeletal crystals of magnetite. These appear to develop by replacement of the ilmenite portion of ilmenite-magnetite intergrowths by titanite which is subsequently removed.

Only very minor contact effects are shown by the limestones and shales intruded by these dykes. Within a few inches of the contact the wall rock is hardened and may change to a lighter or darker colour.

Serpentinite

Outcrops of serpentinite were found at two places, some 3 miles northeast of Joffre lake. The two groups of outcrops are 1/2 mile apart, both near the Silurian-Shickshock boundary. On the map they have been represented as a continuous body although the surface connection is uncertain.

The rock is black to bronzy and has the usual serpentine lustre and sheared and slickensided appearance. In thin-section, the main constituents appear as a mixture of antigorite, serpophite and magnesite. Veins of chrysotile, some with a medial line of magnetite and magnesite, cut the groundmass. In a thin-section from one of the groups of outcrops the antigorite is mainly of the bastite variety, and there are rare grain outlines suggestive of the former presence of olivine. Relict textures in a thin-section from the other outcrop group suggest that the component materials are largely secondary after olivine. Opaque minerals are not abundant. The tenor of magnetite is about 5%. About 3% of one thin-section is composed of larger spinels with brownish translucent edges, probably picotite. No rocks were observed in actual contact with the serpentinite and it is uncertain whether it is intrusive into the Silurian sequence or is emplaced along the altered contact zone between the Silurian rocks and the Shickshock Group. One outcrop of the rusty, carbonate contact material was found north of the body. Outcrops of unaltered Silurian rocks appear less than 200 feet south of the most southerly serpentine exposure. Thus, in the present area, evidence for the age of the serpentinite is lacking.

In the Courcelette area the presence of serpentinite pebbles in a conglomerate of Lower or Middle Devonian age provides an indication of its upper age limits. Jones (1934, p. 34) found serpentinite cutting

Lower Devonian limestones in the Mount Serpentine area, 90 miles to the east. On the assumption that all the serpentinites of this part of the Appalachian belt are of the same age, the writer tentatively dates the serpentinite of the present area as Lower to Middle Devonian. However, cutting relations as an indication of the lower age of serpentinites are not very satisfactory criteria. Neale (1957, p. 105) has suggested that the serpentinite bodies in Gaspé which cut post-Ordovician rocks actually may have been intruded in Ordovician time, the penetration into younger rocks being achieved by later tectonic squeezing of the consolidated serpentinite. MacGregor (1962) accepts an Ordovician age for the Mount Albert and associated serpentinite masses.

ECONOMIC GEOLOGY

Copper - Traces of copper were found at seven localities in the area, as indicated on the accompanying geological map.

A few grains of chalcopyrite were found in a quartz-epidote vein 1 1/2 miles north of Matane lake. An assay of 6 ounces of this material showed 0.06% copper. A boulder of yellowish green, epidote-rich metavolcanics with common malachite stains was found in the bed of Bouynot brook, about 1 1/2 miles south of Tallard pond. The stains came from chalcopyrite along fine fractures in a quartz vein. The boulder resembles the country rock at that locality but its source was not found. Flecks of chalcopyrite also were seen in an outcrop of metavolcanic rock on Cap-Chat-Est river (Volcanic brook) about 6,500 feet north of its junction with Cap-Chat river. Thin carbonate veins cutting Silurian shales on the Company road about a mile east of the junction with the road to Joffre lake contain a little pyrite and traces of malachite. Assay of a sample gave 0.43% copper and traces of nickel and cobalt.

Malachite stain was noted at three places in the Shickshocks. An outcrop between the forks of Bascon brook about 3 miles north of Behrend lake shows a few malachite stains, and a little malachite is associated with quartz veins on the northeast side of Côté lake. On the east side of Bauvas (Behrend) brook malachite persists for a few inches along a foliation layer one inch thick. Assay of a sample indicated 0.43% copper and a trace of zinc.

The two areas in which anomalously high copper values were found in the stream bank samples are worthy of further investigation. Sampling at closer intervals, perhaps 200 feet, should localize the sources of the copper.

Lead and Zinc - No lead or zinc mineralization was noted in the area, and the sediment sample analyses failed to indicate any significant lead or zinc anomalies.

Pyrite - Pyrite, in grains up to 2 mm. and, more commonly, as fine plates parallel to the schistosity, is widely disseminated in the country rock in amounts of less than 1%. A higher tenor of pyrite occurs in the white mica schists of the Vignon Lake and Bascon Brook zones and in the quartz veins in these rocks. Large vugs in carbonate masses of the Bascon Brook zone are filled with pyrite and coarse calcite. A sample from one of these assayed 0.01% copper.

Talc - Along a fault in the massive carbonate alteration zone near the mouth of Weir brook a line of pods of a greenish, talc-like substance is exposed for about 20 feet. Analysis showed this to be a mixture of talc and chromiferous serpentine, with some finely divided quartz.

Asbestos - No asbestos veins above microscopic size were found in the serpentinite. A little picrolite appears along some shear planes. Slip fibers of asbestos up to 1/2 inch long occur in shears in outcrops of metavolcanics north of Côté lake. A locality at the north edge of the Shickshocks, 2 miles east of Mount Blanc, contains a little cross fiber in a gash vein in metavolcanic rocks.

Marl - Grey to white marl associated with thick, black organic muck is found over most of the bottom of Joffre lake. A thickness of at least 4 feet was measured at one place. Where the black muck is absent and, at places, below a blanket of muck the marl is as much as 90% $CaCO_3$. The lime seems to be derived in part from the calcareous tests of fresh water invertebrates and in part by a diagenetic change of the muck. A probable mechanism for the process, involving the action of CO_2-producing bacteria and lime-precipitating bacteria, has been suggested by Twenhofel (1937, p. 67).

This material should be suitable for neutralizing acid soils. However, most of the soils of the area are developed on a calcareous terrain and even if the area were opened to settlement they probably would not require lime treatment.

Oil and Gas - Limestone and limestone conglomerate beds associated with dark carbonaceous shales on Cap-Chat-Est river give off a petroliferous odour when freshly broken. Some calcarenite beds in the upper part of the Silurian section react similarly. The calcarenites form a thick enough zone and appear sufficiently porous to serve as suitable reservoir beds. The porosity, however, may be only the effect of surface weathering.

BIBLIOGRAPHY

ALCOCK, F.J. (1926) Shickshock Mountains, Central Gaspé, Quebec: Geol. Surv. Can. Rept. 1924, Part C, pp. 127-133.

ALCOCK, F.J. (1941) Around Gaspé: Can. Geog. Jour. v. 23, No. 2, pp.80-103.

ALCOCK, F.J. (1944) Further Information on Glaciation in Gaspé: Trans. Roy. Soc. Can., ser. 3, v. 38, Sec. 4, pp. 15-21.

AUBERT de la RÜE, E. (1941) Matapédia Lake Area: Que. Bur. Mines, Geol. Rept. 9.

BAILEY, L.W. (1889) Acadian and St. Lawrence Watersheds: Can. Record of Science, v. 3; pp. 398-413.

BÉLAND, Jacques (1957) Ste-Félicité - Grosses Roches Area: Que. Dept. Mines, P.R. No. 339.

BLOOM, H. and Crowe, H.E. (1953) Determination of Readily Soluble Copper, Zinc and Lead in Soils: Nitric Acid Digestion; U.S.G.S. open-file release, Sept. 16, 1953.

BLOOM, H. (1955) A Field Method for the Determination of Ammonium Citrate-Soluble Heavy Metals in Soils and Alluvium: Econ. Geol. v. 50, No. 5, p. 533.

BOOTH, V.H. (1950) Stratigraphy and Structure of the Oak Hill Succession in Vermont: Bull. G.S.A., v. 61, No. 10, pp. 1131-1168.

CHALMERS, R.D. (1904) Surface Geology of Eastern Quebec: Geol. Surv. Can. Ann. Rept. v. 16, pp. 250-263.

CLARKE, J.M. (1908) Early Devonic History of New York and Eastern North America: N.Y. State Museum, Mem. 9, v. 1.

COLEMAN, A.P. (1922) Physiography and Glacial Geology of Gaspé Peninsula, Quebec: Geol. Survey Canada, Nat. Mus., Bull. No. 34.

COLLINS, J.F. and FERNALD, M.L. (1925) The Region of Mount Logan, Gaspé Peninsula: Geographical Review, v. 15.

CRICKMAY, G.W. (1932) Evidence of Taconic Orogeny in Matapédia Valley, Quebec: Am. Jour. Sci., v. 24, pp. 368-386.

DALY, R.A. (1933) Igneous Rocks and the Depths of the Earth: McGraw-Hill Co., N.Y. and London.

DAPPLES, E.C., KRUMBEIN, W.C. and SLOSS, L.L. (1953) Petrographic and Lithographic Attributes of Sandstones: Jour. of Geology, v. 61, pp. 291-317.

DRESSER, J.A. and Denis, T.C. (1944) Geology of Quebec, v. 2: Quebec Dept. Mines Geol. Rept. 20.

ELLS, R.W. (1883) Report on Explorations and Surveys in the Interior of the Gaspé Peninsula, Quebec: Geol. Surv. Canada. Rept. of Progress 1882-84, Pt. E, pp. 1-34.

ENGEL, A.E.J. (1949) Studies of Cleavage in the Metasedimentary Rocks of the Northwest Adirondack Mountains, New York: Amer. Geophys. Union Trans., v. 30, No. 5, pp. 767-784.

HARKER, A. (1939) Metamorphism: Methuen and Co. Ltd., London, p. 362.

HOLMES, C.D. (1941) Till Fabric: Bull. G.S.A., v. 52, No. 9, pp.1299-1354.

HUTCHINSON, R.D. (1952) Middle Cambrian of the Atlantic Realm in Eastern Gaspé: Amer. Jour. Sci., v. 250, pp. 275-280.

JONES, I.W. (1933) Summary Report on North-Central Gaspé: Que. Bur. Mines Ann. Rept. 1933, Part D, pp. 41-54.

JONES, I.W. (1934) Dartmouth River Map-Area, Gaspé Peninsula: Que. Bur. Mines, Ann. Rept. 1934, Pt. D, p. 34.

LAVERDIERE, J.W. and MORIN, L.G. (1941) Géologie des Apalaches Canadiennes: Le Naturaliste Canadien, v. 68, pp. 216-260.

LOGAN, Sir W.E. (1844) On the Geology of the Chatte and Cascapedia Rivers, Gaspé, and Parts of Chaleurs Bay: Geol. Surv. Canada, Rept. of Progress 1844.

LOW, A.P. (1883) Report on Explorations and Surveys in the Interior of the Gaspé Peninsula (1883): Geol. Surv. Canada Rept. of Progress 1882-84.

MAILHIOT, A. (1911) Geological Reconnaissances in the Gaspé District: Que. Dept. Col., Mines and Fisheries, Rept. on Mining Operations in the Province of Quebec during 1910.

MacGREGOR, D.I. (1962) Geology, Petrology and Geochemistry of the Mount Albert and Associated Ultramafic Bodies of Central Gaspé, Quebec: M.Sc. Thesis, Queen's University, 1962, MS.

MEAD, W.J. (1940) Folding, Rock Flowage and Foliate Structures: Jour. of Geol. v. 48, pp. 1007-1021.

MURRAY, A. (1847) On the Topography and Geology of the Matane, Ste-Anne and St. John Rivers, Gaspé: Geol. Surv. Canada Rept. of Progress for 1845-46, pp. 99-118.

McGERRIGLE, H.W. (1950) The Geology of Eastern Gaspé: Que. Dept. Mines, Geological Report 35.

McGERRIGLE, H.W. (1952) Pleistocene Glaciation of Gaspé Peninsula: Roy. Soc. Canada Trans., v. 48, sec. 4, pp. 37-51.

McGERRIGLE, H.W. (1953) Geological Map of Gaspé Peninsula: Que. Dept. Mines, Map No. 1000.

McGERRIGLE, H.W. (1954a) The Tourelle and Courcelette Areas: Que. Dept. Mines, Geol. Rept. 62.

McGERRIGLE, H.W. (1954b) An Outline of the Geology of Gaspé Peninsula: Can. Min. Jour., v. 75, No. 8, pp. 57-63.

NEALE, E.R.W. (1957) Ambiguous Intrusive Relationship of the Betts Cove-Tilt Cove Serpentinite Belt, Newfoundland: Geol. Assoc. Can. Proc., v. 9, pp. 95-107.

OLLERENSHAW, N.C. (MS.) Stratigraphic Problems of the Western Shickshock Mountains in the Gaspé Peninsula: Ph.D. thesis, University of Toronto, 1963. (To be published as "Cuoq-Langis Area, G.R. 121" by Que. Dept. Nat. Res.)

PARKS, W.A. (1931) Geology of the Gaspé Peninsula, Quebec: Geol. Soc. Am. Bull. 42, pp. 785-799.

RANKAMA, K. and SAHAMA, T. (1950) Geochemistry: Univ. of Chicago Press, Chicago, Ill., U.S.A., p. 912.

RASETTI, Franco (1946) Cambrian and Early Ordovician Stratigraphy of the Lower St. Lawrence Valley: Geol. Soc. Am. Bull. 57, pp. 687-706.

REJHON, George (1957, MS.) A Study of the Ordovician Conglomerates Near Matane, Quebec: Unpublished M.Sc. thesis, McGill University, p. 67.

RICHARDSON, J. (1859) On a portion of Gaspé Peninsula Including an Examination of the Coast from Marsouin River to Rivière du Loup: Geol. Surv. Canada, Rept. of Progress for 1858, pp. 105-169.

RIDDELL, J.E. (1954) Geochemical Soil and Water Surveys in Lemieux Township, Gaspé-North County: Que. Dept. Mines, P.R. No. 302, p. 22.

SEITSAARI, J. (1953) A Blue-green Hornblende and its Genesis from the Tampere Schist Belt, Finland: Bull. Comm. Geol. Finlande 159, p. 83.

SEITSAARI, J. (1956) Some New Data on the Blue-green Hornblende from the Tampere Schist Belt: Soc. Geol. de Finlande Comptes Rendus No. 29, pp. 41-46.

TANNER, J.G. and UFFEN, R.J. (1960) Gravity Anomalies in the Gaspé Peninsula, Quebec: Canada, Dom. Observatory Pub. v. XXI, No. 5.

THOMAS, M.K. (1953) Climatological Atlas of Canada: Can. Nat. Research Council No. 3151, 254 pp.

TURNER, F.J. (1938) Progressive Regional Metamorphism of Southern New Zealand: Geol. Mag. v. 78, pp. 160-174.

TWENHOFEL, W.H. (1937) The Bottom Sediments of Lake Monona, A Fresh-water Lake of Southern Wisconsin: Jour. of Sed. Pet., v. 7, No. 2, pp. 67-77.

TYRRELL, G.W. (1926) The Principles of Petrology: Methuen and Co. Ltd., London, 349 pp.

WINCHELL, A.N. (1947) Elements of Optical Mineralogy, Part II. John Wiley and Sons.

WISEMAN, J.D.H. (1934) The Central and Southwest Highland Epidiorites: Geol. Soc. Lon., Quarterly Journal v. 90, pp.354-417.

YODER, H.S. (1952) The MgO - Al_2O_3 - SiO_2 - H_2O System and the Related Metamorphic Facies: Am. Jour. Sci., Bowen Volume, Part II, pp. 569-627.

ALPHABETICAL INDEX