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L'EXPLORATION GÉOLOGIQUE
ET MINÉRALE

MOUNT JACQUES-CARTIER-LAKE MADELEINE AREA

H.S. de Römer

GEOLOGICAL REPORT

ON THE

MT. JACQUES CARTIER-LAKE MADELEINE AREA

by

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FRONTISPIECE

Stereogram of the Mont Jacques Cartier (4,160 feet a.s.l.) area showing the typical morphology of the plateau. Extensive blockfields of hybrid granitoid rocks characteristically cover the hill tops. Note the prominent joints, and also the patterned ground (striations) on the slopes of Mont Jacques Cartier. (Q-63112-36 and 37, by courtesy of the Dept. des Terres et Forêts, 1963).

ABSTRACT

The Mt. Jacques Cartier-Lake Madeleine area (150 sqm) is situated in the Gaspé segment of the north-central Appalachian belt. It may be subdivided physiographically into the Mts. McGerrigle highlands and a gently rolling upland. Geologically, the area comprises four major units, each distinctive in lithology and structure: the Shickshock and Quebec Groups of the Quebec Supergroup, both of Cambro-Ordovician age, the Siluro-Devonian belt, and the Mts. McGerrigle Devonian pluton. In the map-area the Shickshock rocks consist of metasedimentary rocks intercalated with minor metabasalts, whereas the Quebec Group comprises chiefly a flyschoid assemblage of pelites, calcareous arenites and a conformable basalt sheet. Both groups show the effects of multiple deformation. The NE dominant tectonic grain is believed to be a product of the Taconic orogeny. It is characterized by northwesterly overturned folds plunging gently SW and NE. Separated from it by a regional strike fault, the Siluro-Devonian belt comprises platform arenites, silstones and impure limestones gently folded about NE-trending axes during the Acadian orogeny. The Mts. McGerrigle pluton is a discordant multiple intrusion surrounded by a striking 1 1/2-mile wide aureole of hornfels and skarn reaching a prevalent hornblende-hornfels facies near the contact. A quartz-poor, possibly contaminated, acidic magma invaded an early gabbroic phase resulting in hybrid rocks laden with xenoliths. Subsequently, the mass was intruded by coarse red granite and granite porphyry. Five K/Ar determinations indicate that in late Devonian time, that is during the last pulses of the Acadian orogeny, the Mts. McGerrigle pluton forcefully invaded Cambro-Ordovician rocks while adjacent porphyries (Hog's Back and Mt. Vallières-de-St. Réal) rose to higher levels to be emplaced as semi-concordant hypabyssal sheets in Siluro-Devonian formations. In the vicinity of those porphyries zones of hydrothermally

altered rocks are locally seen.

Every important copper deposit in the region has been found either in one of those alteration zones or in the Mts. McGerrigle granitic pluton aureole.

MONT JACQUES CARTIER-LAKE MADELEINE AREA

COUNTY GASPE-NORTH

by

H.S. de R  mer

CHAPTER I

INTRODUCTION

General Statement

This report reviews the geology of a 150 square-mile area mapped in detail during the summers of 1966 to 1970. The area is situated in north-central Gasp   and is part of the former Gasp  -North electoral district. Most of it lies within the limits of the Gasp   Provincial Park.

To improve the economic status of the Gasp   Peninsula the Quebec Department of Natural Resources decided to open, on November 1st 1963, the Gasp   Provincial Park to exploration and to launch a vast programme of detailed geological mapping particularly in the favorable belt around the Mt. McGerrigle granitic pluton. This programme which was to include the present work was aimed at localizing new orebodies in the Peninsula. As a consequence, a copper mine (Les Mines Madeleine) and a promising copper prospect have already been found in the Park.

The present area is part of the northern segment of the Appalachian orogenic belt. The regional structure is EW to SW-NE, following roughly the St. Lawrence River south shore (Map 1, in pocket).

Geologically, the map-area straddles the boundary between two major EW-trending zones. To the north are the Cambro-Ordovician metasediments and metavolcanics of the Quebec and Shickshock Groups, respectively. These are intruded by the Mts. McGerrigle pluton, a 50-square-mile body of leucocratic granitic and hybrid rocks surrounded by a 2 miles wide contact-metamorphic aureole. In which the Madeleine Copper Mine occurs. To the south, the area is underlain by gently folded Siluro-Devonian clastics and limestones. In that belts some copper mineralization (v.g. Sullipek deposit) has been found in association with hydrothermally altered limestone formation.

Location and Access

The area described in this report is situated in the north-central part of Gaspé Péninsula, some 25 miles ESE of Ste. Anne-des-Monts. It lies within the county of Gaspé-North and is defined by latitudes $48^{\circ}48'$ and $49^{\circ}03'$ and longitudes $65^{\circ}50'$ and $66^{\circ}01'30''$. Except for the extreme NE portion, the area is entirely within the Gaspé National Park. To the south, it embraces parts of Lesseps and Deville townships. The northern section lies within the townships of Deslandes and Boisbuisson.

The southern third of the area is readily accessible from the west by the Transgaspesian Highway, via the Pekan road that follows the stream

of the same name or via the southwest segment of the new (1972) road circling Mts McGerrigle. Another easy access is provided from the south by way of the Park road, which is the main artery joining Murdochville and Ste. Anne-des-Monts. A good gravel road following Lesseps creek and several smaller roads farther east provide access to Madeleine Nord river and to most ^{lakes} in the map-area.

Access to the central and northern parts is by the new and excellent circle road referred to previously. This road which is a 50 mile double lane road has been built by the Quebec Department of Natural Resources to give access to the Madeleine Mines Copper orebodies and to attract more prospectors to that rugged part of the Gaspé Péninsula.

The northern limit of the area may also be reached by well-maintained gravel roads from Marsoui, Rivière-à-Claude, and Mont St-Pierre, three settlements on the Gulf.

Only one road actually reaches the plateau of the Monts McGerrigle. This is the Mont St-Pierre jeep road which intersects the circle road at Ruisseau à Galène at an altitude of 1800 pieds. From here the road can be travelled by jeep only to Mont Jacques Cartier (4160 feet) via the broad valley of the Ruisseau à Galène.

Except for one small neglected cabin of the Quebec Department of Tourism, Game and Fisheries, the observation tower and surrounding quarters at Mont Jacques Cartier are completely abandoned and fallen into ruins. There is no doubt that Mont Jacques Cartier with its

beautiful scenery in the centre of caribou country has the potential of a tourist attraction comparable to Percé. (Plate I)

Access to any other part of the Monts McGerrigle is only possible on foot. One sizable river (Madeleine river) penetrated^s the mountaneous area from the south. However, because of its rapids, this river is unsuitable for navigation even during periods of high water.

Some of the lakes on the high plateau, such as Lac Côté, could well be used by sea-planes. Another efficient means of access would be by helicopter; many flat and barren areas could provide good natural landing strips.

Settlement and Resources

Most of the area is within the Gaspé National Park. It is generally densely wooded ^{has} with few roads and no permanent settlements. There is only a transient population of lumberman^s, prospectors, hunters and occasional tourists.

The principal natural resource is wood, cut for pulp and lumber. Since the official opening of the Park to exploration in late 1963, however, the area has known a tremendous surge in prospecting activity. This has resulted in increased traffic, the construction of new roads, and employment in the nearby villages.

There is no farming even in the flat southern portion of the area partly because of a general lack of good soil cover. As to the mountaneous region it is strewn with angular rocky débris which render it totally unsuitable for cultivation.

The forest is made up generally of balsam fir, white and black spruce with some white and yellow birch. Occasional stands of cedar and poplar are found along river courses. At places, such as in Madeleine Nord river, zones of fallen trees in young underbrush makes traversing slow and frustrating.

Above an elevation of 2,200 feet the timber is predominantly spruce. The general tree line is around 3,300 feet; above it, vegetation consists of scant growths of dwarf spruce and birch, moss and lichen.

Big game includes bear, moose, deer and caribou. Bear, deer and moose are found in the lowlands and the lower slopes; the caribou roam the higher parts of the Mts. McGerrigle.

Lakes in the lowlands, such as Lac Madeleine, are well stocked with trout; Madeleine river, on the other hand, is excellent for salmon fishing. Fish is particularly plentiful in the small lakes that dot the Mts. McGerrigle, such as Lac Côté (Frontispiece).

Field Work

The field work upon which this report is based was carried out during the 5 consecutive summer seasons from 1966 to 1970.

The writer used contoured base maps at a scale of 1000 feet to one inch prepared by the Cartography Branch of the Quebec Department of Natural Resources from aerial photographs issued by the Department of Lands and Forests.

Traversing was done by two-man teams using the pace and compass method. Throughout the field work, air photos were used in conjunction with topographic maps for accurate location.

Whenever possible, such as in the belt east of the Mts. McGerrigle, traverses were run along already existing cut lines to assure complete coverage of the area. In many parts, however, traversing was done at irregular intervals in order to concentrate on outcrop areas, previously located from air photos and ground observations.

Barren tops of the Monts McGerrigle are generally covered by extensive fields of fractured bedrock easily pin-pointed on air photos. Outcrops are plentiful on the steep slopes and stream courses.

The gently sloping ground east and south of Mts. McGerrigle is characterized by a thick mantle of residual soil covered by a dense growth of vegetation where exposures are rare. All streams and rivers as well as lumber roads and trails were traversed. Interstream areas, in particular crests of hills, were crossed wherever air photos and base maps suggested possibility of outcrops. Many unsurveyed bulldozed roads and trails were chained. Along these many significant exposures were found.

A several-square-mile area south of Lac Long is completely devoid of outcrop. Here, mapping was carried out using available rock debris in the soil cover. Of particular significance were angular rock fragments found at the base of up-rooted trees. This mapping method proved highly reliable in this part of Gaspé.

Acknowledgements

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The writer wishes to thank the personnel of the Mineral Deposits Service of the Quebec Department of Natural Resources for their cooperation and the facilities rendered, and in particular Dr. R. Assad, former head of the Service, for supplying numerous thin sections and chemical analyses.

Special thanks are due to Dr. A.F. Laurin, Director of Geological Services, for authorizing the writer to have 5 radiometric K/Ar analyses done. His interest and continuous encouragement in the progress of the work is hereby gratefully remembered.

The writer benefited greatly from stimulating discussions with K. Schrijver (McGill University); visits to the Mines Madeleine with P. Girard, chief geologist, proved also very interesting.

Previous Work

Geologic investigations in central Gaspé Peninsula can be divided into three successive periods: 1) the first stage which consisted of broad

reconnaissance surveys and explorations, both geological and geographical, by the Geological Survey of Canada, began some 130 years ago. 2) in the period 1930 - mid 1950's a program of reconnaissance mapping (1 mile - 1 inch) emphasizing the economic potential was carried out by the Quebec Department of Mines. 3) since the mid - 1950's, development and production at Gaspé Copper Mines Ltd. triggered a continuous program of detailed mapping (1000 feet to 1 inch) which is still in progress.

The first geologic work in Gaspé was done in 1844 by Sir William E. Logan who summarized his results first in a Report of Progress (1846), then in his "Geology of Canada" (1863) and finally on the Geological Map of Canada (1865). In 1857, J. Richardson and R. Bell made a geologic and biologic survey of the Rivière Madeleine, and in 1858, Richardson ascended the Mts. McGerrigle (formerly known as Tabletop Mountains) from the north and published a short account of its lithology. Subsequent visits to the mountainous areas were made by A.P. Low (1882-83-84). R.W. Ellis produced 2 reconnaissance maps at 4 miles to 1 inch that included the present area (1882-83-84).

Physiographic and glacial studies of the Mts. McGerrigle were begun by R. Chalmers (1904), followed by A.P. Coleman (1918-1922), who spent three weeks in the northern part of the area.

The second stage of geologic mapping was started by I.W. Jones for the Quebec Department of Mines (Map I, in pocket). His "Lesseps area, Gaspé Peninsula", published in 1931, covers the southern half of the writer's area.

It represents the first systematic mapping done at a scale of 1 mile to 1 inch in Gaspé. In 1931, I.W. Jones mapped at the same scale, the area (Bonnecamp) next to the east. His report of 1932 on the "Tabletop Map-area" which is immediately north of the Lesseps area, includes the northern 2/3 of the writer's area. Most of his succinct statements and accurate descriptions are still relevant today.

Broad reviews and summaries of the Gaspé geology are given by W.A. Parks (1931), and by Dresser and Denis in Vol. II of "Geology of Quebec" (1944).

Another invaluable contribution to the Gaspé geology is that of H.W. McGerrigle whose geologic compilation map No. 1000 (1953) is still the backbone of all mapping projects. The updated (1967) version of that map (No 1642) by H.W. McGerrigle and W.B. Skidmore broadly outlines the geology of the present area at a scale of 4 miles to 1 inch. McGerrigle's report on the glacial history (1952) and his synthesis on the geology of Gaspé as a whole (1954) relate indirectly to the writer's area. His "Madeleine River Area" (1959) lies immediately east of the present area.

Mapping projects undertaken by the Quebec Department of Mines in the northern and central belts, some 20 - 100 miles to the west, are included here for correlation purposes. Beginning in 1947, mapping (1" = 1 mile) of adjacent areas was carried out in the Schickshock region by H.W. McGerrigle (1954), J. Béland (1957, 1969), C.R. Mattinson (1964), C.W. Stears (1965) and N.C. Ollerenshaw (1967) (Map I, in pocket).

Detail mapping (1" = 1000') in the Gaspé peninsula was initiated in 1953 by J.J. Brummer (1966) who studied during three summer seasons, the Gaspé Copper Mines deposits at Murdochville. A similar work was begun in 1963 by J.L. Robert in the Mount Hog's Back (1966,a) area to study promising copper showings south of the Mts McGerrigle granitic pluton in the Gaspé Provincial Park. During the two following summer seasons Robert mapped farther east that is the Mont Vallières de Saint Réal (1966,b) and the Lesseps Creek (1967) areas.

Because of the sustained interest then shown by the mining companies in that general area the Quebec Department of Natural Resources decided to extend its mapping programme to the north in order to cover in full the Mts McGerrigle granitic Pluton and its aureole.

Thus, in 1965, Girard mapped the Mont Richardson area and from 1967 to 1970 the author covered successively the Lac Madeleine (1969), Rivière Madeleine Nord (1970), Mont Auclair (1972,a) and Mont Jacques Cartier (1972,b) areas. More recently Serge Lachance studied the Mines Madeleine and Candego (197¹⁻²₄) and the Lac-a-Claude (1973) regions. While mapping these areas the geologists collected stream sediments samples and had them assayed for their metal content.

CHAPTER II
PHYSIOGRAPHY

Topography and Drainage

Although the area described in this report is too small for a comprehensive physiographic study, the author feels justified to divide it into two main physiographic regions: 1) the Mts. McGerrigle highlands, and 2) the eastern upland.

The Mts. McGerrigle highlands constitute the most prominent physiographic feature of the area. Lying immediately east of the Shickshock mountains range these highlands are intersected by the 49° latitude and 66° longitude. It is a north-trending mountainous region giving rise to a plateau averaging 3,550 feet above sea-level. At the 2,250-foot level, the range is about 6 miles wide and 12 miles long.

The range is characterized by steeply rising, somewhat sinuous flanks deeply incised by torrential stream valleys. Although escarpments 50 feet high are common, the average slope is 35°. The highlands can be easily reached on foot by way of the numerous valleys leading to the plateau

from all sides.

Ascent from the north or south is more gradual and the grade of the valleys gentler. A rugged jeep road winds up to Mt. Jacques Cartier from the eastern foothills.



Plate I. Road leading to Mont Jacques Cartier. Note blockfield of frost heaved rock debris characteristic of the plateau. In the background are the abandoned cabins and observation tower at the top of the hill.

The top of the range itself forms a rolling plateau consisting of broad dome-like hills and gentle irregular depressions. Mechanical weathering being the dominant process at such elevations, the hill tops are bare of soil and hence of vegetation. They are strewn with rock fragments evidently derived from underlying bedrock. In the depressions one finds occasionally caribou trails winding across moss-covered open areas, reminiscent of park lands.

The highest elevation is Mont Jacques Cartier (4,160 feet), followed

by Mt. Table (3850 feet), Les Cônes (3850 feet), Mt. Richardson (3850 feet) Petit Mont Ste-Anne (3750 feet) Mt. Auclair (3600 feet), Mt. Ste-Anne (3450 feet), Mt. McWhirter (3400 feet) and Mt. Vieillard (3300 feet). Whereas the central part of the range may be described as a plateau with slight differences in elevation, the southern and northern segments are deeply dissected by steep-sided valleys resulting in relief differences of over 1,500 feet. Some of the steep wooded slopes bear several hundred-foot wide scars caused by mantle creep and mud flows. (Plate II).

Plate II Mantle creep and mud flows show up as scars on steep, wooded slopes 1.5 miles NE of Mont Jacques Cartier.

The eastern upland is a gently rolling plain underlying the eastern part of the area. A continuation of the Gaspé Upland, described by McGerrigle (1959, p. 11), it gradually descends southwardly from approximately 2,250 feet at the northern periphery of the area to 1,500 feet near

the Rivière Madeleine, a distance of about 10 miles.

In the northern part of the area, the undulating plain is interrupted by an easterly trending range, about one mile wide, of heavily wooded hills. Rising abruptly from the plain at 1,750 feet to a maximum height of 3,250 feet, the range forms a conspicuous landmark, an obvious product of differential erosion.

South of Rivière Madeleine, the upland consists of NS and NE-oriented, flat-topped ridges and broad interstream areas. There is a pronounced accordance of summits at the 2000 foot level rising gradually above flat, drift-covered valleys bottomed at approximately 1,500 feet.

Although a faint NS alignment of tops is noticeable in the lake area to the south, a NE trend of ridges is preponderant.

The major part of the area is drained northward toward the St. Lawrence river. Waters in the southernmost sector only flow to the Bay de Chaleurs. The principal divide between the south and north flowing streams follows the structural trend from the height of land south of the Pekan Brook to Lac Long and northeast beyond Lac Madeleine.

All the waters of the Mts. McGerrigle highlands are discharged through the Ste. Anne and Madeleine river drainage systems. The divide separating the systems follows a winding line through broad saddles from Mt. Jacques Cartier northward to Mt. Auclair. The area west of Mt. Ste. Anne is drained by several small streams cascading into the deep, spectacular gorge of the Ruisseau aux Cascades, the waters of which empty into the Ste. Anne Nord - Est.

South of Mont Jacques Cartier drainage is by way of Rivière Madeleine

and its chief tributary, the Rivière Madeleine-Nord. Nearly all the streams draining the eastern flank of the highlands, such as Ruisseau Auclair, Pierre-Jean and Vieillard, begin at an elevation of 2800-3000 feet joining Rivière Madeleine-Nord a mile farther east at an average elevation of 1600 feet. (Plate III).

The southern third of the highlands is deeply incised by the boulder-strewn, turbulent Rivière Madeleine and its tributary, the Rivière aux Orignaux, the headwaters of which penetrate far into the heart of the highlands.

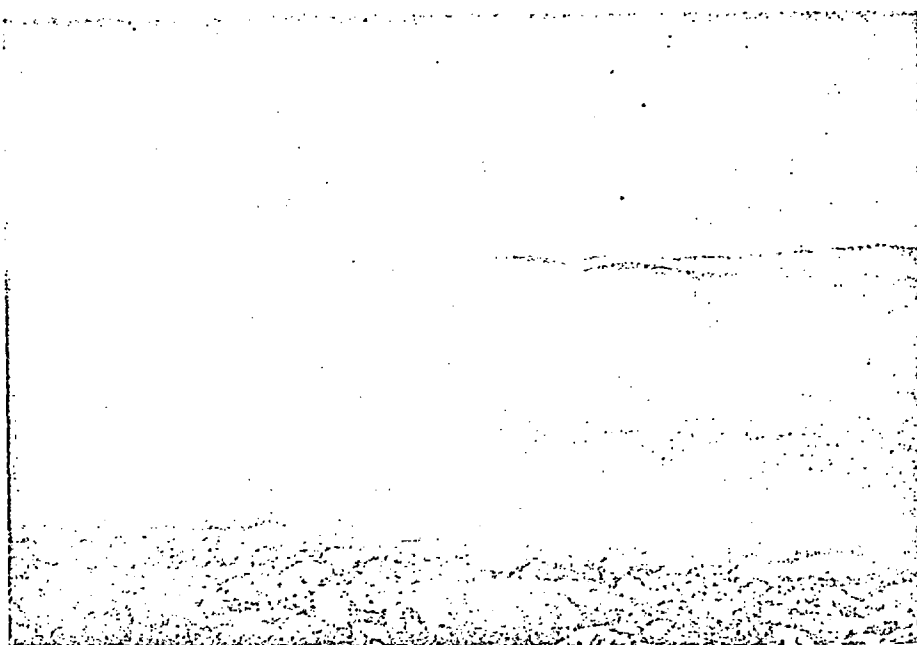


Plate III. View toward the south and the deep valley of the Rivière Madeleine. The western slopes of Mt. McWhirther are seen on the left. Blockfields form the foreground.

The drainage of the plateau itself is poorly developed and is of the deranged type, typical of glacially modified areas. This is clearly shown

by the irregular distribution of numerous, small lakes varying in elevation, choked streams resulting in swampy patches and stream reversals, and other evidence (Frontispiece).

Most of the lakes are located in the southern third of the area and in the interior of the mountainous region. By far the largest is lac Madeleine, 1.5 miles long and 0.5 miles wide, occupying a broad U-shaped, drift-covered valley. The lakes, west of it, comprising lac Long, lac Vert, lac Martin and lac Crochet, are structurally controlled by a set of NNW trending fractures.

Picturesque lac Vieillard at the foot of the abrupt 3300 foot Mt. Vieillard, occupies a hanging valley 500 feet above the Ruisseau à Galène. Many small lakes, either on the rim or at the foot of the plateau, such as lac de la Botte, are tarns forming the sources of torrential streams. The lakes farther inland, from 50 feet to 3/4 mile in diameter generally occupy shallow depressions in jointed bedrock, rimmed by marshes.

Climate and Geomorphic Analysis

Although the eastern upland area enjoys a temperate humid climate, the mountainous area has climatic conditions corresponding to those found ordinarily above 50° latitude. The average annual temperature in the eastern upland is approximately 35°F with abundant snow in wooded areas normally until June.

The highlands, on the other hand, because of their altitude, have a typical tundra climate with average annual temperatures of roughly 25°F. Temperature differences between day and night are minor. The flora and the presence of caribou are typical of cold climatic zones. Precipitation is

very high with an average of 18 feet of snow per year. Some of the deep gullies have patches of snow all year round, while lashing hail storms can occur in mid-summer.

A quick glance at the map shows the direct relationship between the physiographic divisions mentioned above and their lithology and structure. The strong influence of bedrock on topography is particularly well shown in the case of the Mts. McGerrigle highlands representing resistant plutonic, volcanic and hard metamorphic rocks. The undulating eastern upland 1,500 - 2,000 feet below is underlain by soft, metasedimentary and volcanic rocks.

Within the humid temperate climatic zone, topography is the result of constant adjustment between bedrock and structure on one hand and climate on the other. Climate is the chief factor controlling the processes of denudation. In the highlands mechanical weathering in the form felsenmeer, as well as headward river erosion appear to be predominant. In the eastern upland, on the other hand, down wasting and chemical weathering are the chief gradation processes resulting in top soil and rock fragments that are largely derived from underlying rocks.

There is no evidence to support the Davisian theory of peneplanation in the area despite the generally flat-topped character of the Mts. McGerrigle plateau. Simple statistical analysis of summit accordance corroborates the empirical observation above, namely that topographic levels are directly related to underlying lithologies.

Glaciation

Numerous papers have been written since 1857 (Richardson, 1858,

Coleman, 1922) and in particular since the '30's (Alcock, 1935; McGerrigle, 1952) on the extent and influence of Pleistocene glaciation in Gaspé. The present area is too small and information too scant to offer a valuable contribution to the problem of whether the region was glaciated on continental proportions and to what extent.

No particular pattern of distribution of erratics was observed in the area. There is no widespread evidence of glacial erosion and the general rule is that the surface debris are identical to subjacent bed-rock suggesting limited transport. The writer has not enough data to support McGerrigle's conclusions of complete glaciation of the Peninsula but agrees with the part played by valley glaciers radiating out from local highlands (McGerrigle, 1952, p. 40).

Features characteristic of the latter stage are plentiful in the area and in particular in the Mts. McGerrigle region. Well-preserved glacial striae are observed on the walls of the spectacular U-shaped valleys of Rivière Madelaine and Rivière-aux-Cascades. Tarns set at the foot of crescent-shaped cirques, such as 3,000 feet S. of lac de la Botte, further attest the effects of valley glaciation.

It is well accepted today that a periglacial environment reflects sub-glacial climates without necessarily implying permanently frozen ground (Embleton and King, 1971, p. 448). Undoubtedly the most important process in the periglacial zone is the alternating freeze-thaw action resulting from rapid temperature changes at high altitudes. In the present area, such features and processes as frost-heaving, blockfields (Felsenmeer), patterned ground and stone streams characteristically reflect such periglacial conditions.

The tops of the dome-like hills in the highland are covered by coarse, angular detritus termed blockfields or Felsenmeer. Such accumulations are derived from the subjacent bedrock by freeze-thaw action (Frontispiece).

Patterned ground, in the form of nets and stripes, is another conspicuous feature indicative of periglacial environment. Nets were observed in the immediate vicinity of Mt. Jacques Cartier and in particular on the plateau on both sides of the road leading to the top. The nets (or possibly circles) consist of polygonal accumulations of hybrid, angular granitic rocks and finer sand and gravel in the grass-covered level ground in the centre. (Plate IV). At places, the inner area is depressed with a few boulders occupying the centre. The polygons measure about 15 to 20 feet across and are apparently restricted to flat surfaces only. cursory examination shows them to be of the "sorted net" variety.



Plate IV. Polygonal accumulation of angular blocks NE of Mont Jacques Cartier. Such nets merge into stripes as the gradient of the slope increases.

The stripes consist of loose, angular fragments a few inches in diameter arranged in bands a few feet wide and approximately 6" high. Separated from each other by grassy strips about 10 feet wide, they can be traced for a few hundred or even thousand feet or so, and are best observed on the sloping ground (5 - 10) SW. of Mt. Jacques Cartier. In fact, they seem to have developed directly from polygonal ground as the gradient of the slope increased (Frontispiece).

Stone streams were observed in the wide valley S and SE of lake Vicillard. They consist of accumulations of rock debris extending down-slope in form of tapering tongues. They were formed either as a result of direct glacial transport or by solifluction.

No attempt was made by the writer to study the polygonal ground and stripes in depth to arrive at their mode of formation. Many suggestions as to their origin have been put forward, most of them based on processes related to rapid changes in temperature.

Although some snow patches in deep ravines remain throughout the summer, the writer is reasonably sure that there are no large areas of perennially frozen ground. McGerrigle, however, mentions a sporadic occurrence of frozen ground in the valley of the Salmon Branch of the Grand Cascapedia River (1952, p. 49), some 25 miles SSW of the area.

In any case, the structures described above are not relics of past climates, but probably developed in response to recent climatic conditions. They are thus not considered to be in the fossil state, but are actively forming at present.

CHAPTER III

REGIONAL GEOLOGY

Gaspé Peninsula has been commonly subdivided, both geologically and tectonically, into three parallel roughly EW-trending belts. According to McGerrigle (1959, p. 20), these are the northern, central and southern belts. The present area comprises parts of both the northern and central belts. Their lithology consists of sedimentary and volcanic rocks ranging in age from Cambrian to Upper Devonian and intruded by stocks of varying age and composition. Structurally, both belts have been affected by the Taconic and Acadian orogenies.

The Northern Belt

The northern belt extends from the St. Lawrence River southward for 25 miles to within one mile ^{south} S. of the Mts. McGerrigle pluton. It is in fault contact with the central belt, which adjoins it to the south.

The lithology of the northern belt consists of 3 principal units: The Quebec Group, the Shickshock Group (together forming the Quebec Supergroup) and various intrusive rocks.

The Quebec Group of Cambro-Ordovician age comprises a monotonous sequence of repeatedly folded shales, silstones and slates with intercalated sandstones and limestones. A conspicuous band of massive and amygdaloidal basalt and associated tuff, ^{to} 1-2 miles wide and 18 miles long lies conformable within the series.

Adjoining the Quebec Group to the south and partly lying within it, is the Shickshock Group, a ^{to} 4-10 mile wide zone of mafic volcanic ~~rocks~~ and pyroclastics ^{rocks} interstratified with metasedimentaries ^{rocks} in its southern part.

It is probable that pyroclastic and sedimentary members extend beyond the Mts. McGerrigle pluton. Although structural and age relationships between the Quebec and Schickshock Groups are by no means clear; faulted contacts between the two groups are locally indicated. Rocks of both groups have been intensely and repeatedly deformed. The last episode appears to have produced predominantly north-northwesterly overturned and gently plunging folds. Various trending lineations attest to other pulses or periods of deformation.

The rocks of the northern belt show all the features typically found in flysch terrains. Both, rock assemblage and associated structures indicate an eugeosynclinal environment of formation.

The third unit of the northern belt includes the Mont Albert peridotite and the Mts. McGerrigle granitic pluton. The former is an intrusive body associated with the Shickshock Group of metavolcanics^{rocks} and the latter a much younger intrusion.

The Mts. McGerrigle pluton underlies the highlands of the same name. It is a northerly elongated discordant body of leucocratic rocks covering approximately 50 square miles in area. It intrudes rocks of both the Quebec and Shickshock groups and has produced a 1 to 2 mile wide contact aureole in which the K-feldspar-cordierite hornfels facies has locally been reached. The pluton represents a multiple intrusion of Upper Devonian age. It consists of hybrid and granitic rocks complexly invading an earlier coarse-grained basic phase. Inclusions of metasediments and ^sbas~~is~~ites in all stages of assimilation characterize the hybrid rocks.

The Central Belt

The central belt forms a 40-mile wide zone of gently folded Silurian and Devonian sedimentary rocks which lie south, and in fault contact with, rocks of the northern belt. Only the northernmost 7-mile wide section of the central belt lies within the map-area.

Resting unconformably on Ordovician rocks, the Silurian consists of well-sorted marine sandstones at the base followed by reef-bearing limestones and calcareous siltstones at the top. These are conformably overlain by Devonian argillaceous and siliceous limestones topped by sandstones and conglomerates reflecting a terrestrial environment of deposition. Both the Silurian and Devonian sequences are locally intruded by felsic and mafic dykes and sills and show some interbedding with flows of mafic to intermediate composition.

In contrast to the Cambro-Ordovician rocks of the northern belt, folds in the central belt are open and simple with no evidence of multiple folding. Longitudinal faults and fractures transverse to the NE-regional trend characterize this belts. Such transcurrent faults have slightly displaced formation contacts and caused warping of the fold axes. The rock assemblage is indicative of a miogeosynclinal environment of deposition.

Two large felsic stocks are found in the Siluro-Devonian sequence immediately west of the area. These are the Hog's Back and Mont Vallières-de-St. Réal (Robert, 1966a; 1966b). Both stocks are reddish, porphyritic syenites surrounded by an alteration aureole of hornfels. In relation to the Mts. McGerrigle pluton, they possibly represent shallow offshoots ~~for~~.

Mineralization, chiefly ^{Copper} ~~Cu~~ sulphides, is generally associated with thermally altered rocks. The copper deposit presently exploited by Les Mines Madeleine in Boisbuisson township lies in the contact zones of the Mts. McGerrigle pluton, $\frac{1}{2}$ mile west of the present area and 2 miles south of Petite Lac Ste-Anne. It comprises two pipe - like discordant orebodies in which fracture-filling bornite and chalcopyrite are the dominant ore minerals (Girard, 1969, p. 845).

Cu-mineralization of interest in the region occurs also south of the pluton. Special reference should be made here to the Sullipek copper prospect in central Lesseps township where several million tons of a low grade copper material has been outlined in a hydrothermally altered limestone.

CHAPTER IV

THE SHICKSHOCK GROUP

General Remarks

Rocks of the Shickshock Group are exposed in a 1.5 - 2.5 mile wide belt in the southern third of the area. The belt is almost entirely transected by the Mts. McGerrigle pluton, with a narrow sliver of Shickshock rocks remaining immediately ^{south} S. of the pluton. Representing the eastern extension of the Shickshock Group as mapped west of the area (Girard, 1967, Robert, 1966a, 1966b), the belt is parallel to the EW or WSW-ENE regional trend of the

region. It is flanked by flysch units of the Quebec Group. Structural and lithological evidence suggests that the northern limit of the belt is a fault contact. The southern contact with the Quebec Group appears to be conformable. A more detailed account of age and structural relationships with rocks of the Quebec Group is given below.

The Shickshock Group consists of two principal units grading into each other along and across strike: a metavolcanic series and various types of hornfels and metasedimentaries. ^{y units} Although contacts are largely gradational each unit was subdivided into several distinct members. Considerable effort was made to trace the individual subunits through the thermal aureole of the pluton. In spite of drastic changes in texture and mineral assemblage within the alteration zone, effective correlation between units west and east of the pluton was partly established.

In view of the intimate association existing between the volcanic and metasedimentary rocks, it seems artificial to describe them separately. On the other hand, it is practical to distinguish the units genetically and speculate on the parent rocks involved.

Shickshock Volcanic rocks

The Shickshock volcanic rocks west of the pluton are represented by massive and uniform metabasalt (lbm), which east of Lacs des Castors forms tongue-like protrusions several 100 feet wide (lbm); these are flanked by spotted and massive hornfels (la₄M). There is no doubt that the metabasalt extends to, and is cut off by, the pluton. Angular débris of unmistakable volcanic rock, found 600 feet south of the SW corner of the pluton, indicate

that a tongue of metabasalt may also be present south of the pluton. East of the pluton, the Shickshock rocks of volcanic parentage are only represented by laminate chlorite schists, quartz-hornblende amphibolites and various types of hornfels. Outside of the aureole, green and red slates are in strike with the above-mentioned rocks and possibly correspond to tuff beds.

The metabasalt near Lacs des Castors (1bm) is a massive, dark-green hornblende - plagioclase rock with variable amounts of chlorite, epidote and calcite, and accessory magnetite and sphene. About 0.5 mile from the contact with the pluton, hornblende increases over plagioclase (An_{25-40}) and the rock becomes an amphibolite (Table 1, No. 5). Generally, the rock is spotty, the faint ovoid patches being made up of chloritized hornblende nests. At places, the metabasalt contains discontinuous amygdaloidal zones with calcite filling the vesicles. There are isolated areas of finely laminated schist of interlayered hornblende and quartz-feldspar. Immediately in the vicinity of the pluton, the hornblende-rich rock is largely chloritized.

Field evidence and microscope work indicate that the Shickshock metabasalt gradually peters out eastwardly and that individual pyroclastic zones are the sole representatives of the volcanic series east of the pluton.

Metasedimentary and Pyroclastic Rocks

In the aureole, east of the pluton, the predominant rock types of the Shickshock Group are: spotted and massive pelitic hornfels ($1a_4M$);

TABLE I.

*

CHEMICAL ANALYSES OF SHICKSHOCK AND QUEBEC GROUP ROCKS

Present No.	1	2	3	4	5	6	7	8	9	10
Sample No.	68f-5972 71-9577	68f-5975 71-9530	68f-5946 71-9551	68f-5963 71-9568	70f-9993 71-9624	68f-5964 71-9569	68f-5961 71-9566	68f-5965 71-9570	68f-5976 71-9581	68f-5953 71-9558
SiO ₂	65.09	96.14	62.76	37.53	44.00	47.42	50.39	44.64	46.82	44.61
TiO ₂	0.55	0.06	0.56	0.28	1.70	0.61	0.63	0.54	0.69	0.61
Al ₂ O ₃ ...	13.03	0.62	16.13	12.18	15.50	15.26	15.34	15.13	17.80	16.59
Fe ₂ O ₃ ...	1.45	0.44	1.84	8.54	6.94	1.23	0.60	5.38	0.51	0.49
FeO.....	3.84	0.32	9.93	8.06	7.86	8.13	5.37	4.57	4.86	4.24
MnO.....					0.12					
MgO.....	3.19	0.38	2.35	0.96	6.00	5.00	2.70	4.15	4.15	3.42
CaO.....	2.39	0.41	0.62	21.75	20.04	20.54	14.33	22.69	17.46	17.06
Na ₂ O....	0.85	0.03	4.92	0.53	0.79	0.76	5.30	0.76	2.16	1.68
K ₂ O.....	2.90	0.20	1.14	1.62	0.14	0.15	0.53	0.26	0.79	3.70
P ₂ O ₅	0.18	0.01	0.16	0.12	0.15	0.09	0.09	0.11	0.08	0.06
V ₂ O ₅										
CO ₂	0.39	0.03	1.13	2.84	0.09	0.45	0.30	0.15	1.06	5.04
Total	93.86	98.64	101.54	94.41	103.33	99.64	95.58	98.38	96.38	97.50
Minor Elements	Cu	51	40	57	52	21	68	67	27	53
	Zn	30	12	115	25	78	57	30	65	55
	Pb	18	8	33	22	36	25	17	27	27
	Ni	84	10	51	59	148	82	47	48	43
	Cr	130	110	180	60	180	220	260	170	250
	V	60	50	80	100	728	110	90	120	110
	W	2	2	2	8	0	4	2	4	24
	Sn	5	10	10	15	0	5	5	10	20
	Mo	n.d.	n.d.	n.d.	n.d.	0	n.d.	n.d.	n.d.	n.d.
	U	2	n.d.	1	1	0	n.d.	n.d.	2	2
	Au	n.d.	n.d.	n.d.	n.d.	0	n.d.	n.d.	n.d.	n.d.
	Ag	0.5	0.3	0.4	1.2	2.2	1.2	0.7	1.2	1.2
	Pt	<0.02	<0.02	<0.02	<0.02	0.02	<0.02	<0.02	<0.02	<0.02

Shickshock Group

1. Black slate (1a)
2. Pink quartzitic sandstone (1a₁)
3. Laminated diopside-quartz-scapolite (actinolite-tremolite) hornfels (1a₂M)
4. Dark-green hornblende-calcite-diopside-quartz hornfels (1a₂M)
5. Massive, chloritized metabasalt (1bM)
6. Calc-silicate hornfels, locally garnetiferous (1a₃M)
7. Calc-silicate hornfels (1a₃!)
8. Garnetiferous calc-silicate hornfels (skarn) (1a₃M)

Quebec Group

9. Skarn (2a₁M)
10. Skarn (2a₁M)

* Analyses by the Quebec Dept. of Natural Resources Laboratories; for location, see Index Map III.

a locally garnetiferous calcsilicate hornfels (laM); laminated diopside-scapolite hornfels (la₂M); and ~~g~~ garnetiferous calc-silicate hornfels and skarn (la₃M). These rocks have also been found interbedded with metabasalt west of the pluton.

The spotted pelitic hornfels is characteristically a light brown rock randomly peppered with dark-brown circular spots 1mm or less in diameter. At places, it is fissile and is then a spotted schist. In thin section, the spots consist of minute quartz, micas and iron minerals set in laminated trains of microcrystalline matrix curving around the aggregates.

Interbedded with the hornfels are several beds, a few feet wide, of white to purplish quartzitic sandstone (la₄q). It is probable that the rock corresponds to the quartz sandstone and quartzites exposed in the Shickshock belt east of the aureole (la₁). There, the rock is pink, purplish or buff, consisting largely of medium-grained quartz with rare biotite and calcite (Table 1, No. 2). The recrystallized and interlocking quartz grains are angular with iron oxide forming a thin interstitial film between them.

The massive pelitic hornfels is a tough dark grey to brown variety consisting of fine-grained quartz, biotite and some feldspar (K-feldspar?) with accessory iron minerals. In one thin section, unoriented and euhedral cordierite porphyroblasts were observed set in a fine matrix of recrystallized biotite and quartz.

The calc-silicate hornfels (laM) is exposed in the aureole zone on both flanks of the pluton. The rock is typically microcrystalline and

extremely hard, characterized by alternating apple-green and beige layers averaging 0.5 inches in width. At places, mauvish bands replace the greenish layers resulting in a reddish-brown attractively striped rock. Occasionally, the regularly banded hornfels grades into a rock showing diffuse and vague interfingering of variously hued streaks. In fact, such zones of streaked calc-silicate hornfels are quite common. At places, zones several tens of feet wide, of massive pelitic hornfels are also encountered.

Under the microscope, the laminae are almost monomineralic; diopside and clinozoisite with chlorite make up the greenish bands, while the beige bands consist of quartz and some scapolite. The mauve and reddish-brown layers contain mostly garnet. In some laminae, diopside is intimately intergrown with calcite, with muscovite being occasionally present. The massive hornfels typically interfingers with the calc-silicate variety. (Plate X).

It is fairly certain that both, the pelitic hornfels and the calc-silicate hornfels (Table 1, No.s 6 and 7) the aureole zone are the contact-metamorphic equivalents of the black slate and shale belt (1a) farther east (Table 1, No. 1). It is probable that the pelitic hornfels corresponds to argillaceous rocks, whereas the calc-silicate hornfels represents originally calcareous interbeds within the shale and slate belt.

The laminated diopside-scapolite hornfels (1a₂^M) occurs in form of large 1000 - 3000 foot wide zones interfingering with calc-silicate and pelitic hornfels. It is confined to the aureole and is found both east and west of the pluton. Excellent outcrops are exposed on the south flank

of Mt. Richardson and 2 miles NE of Mt. McWhirter.

The rock consists typically of alternating dark-green, mauve and greyish bands averaging 2 mm in width. The layers are surprisingly continuous in width and length and are generally folded (Plates V and VI).

In thin section, the rock consists almost exclusively of fine-to-medium grained, granoblastic diopside (green bands), scapolite (grey), and biotite and quartz (mauve). Some thin sections from the latter locality show an interbanding of diopside-tremolite-actinolite, with scapolite and occasional garnet of the grossularite-andradite series. At some places, pegmatitic pockets of hornblende, calcite and euhedral vesuvianite are present.

Calc-silicate hornfels of the type described above is generally considered to be a derivative of argillaceous carbonate rocks. Chemical analyses of two samples gave a strikingly different CaO-content, although their mineralogical composition appeared similar in the field (Table I, Nos 3 and 4). This is not surprising, since calc-silicate hornfels may vary in composition from sample to sample. The presence of tremolite-actinolite and the high percentage of total iron (Table 1, No 4) suggest that the hornfels may represent argillaceous carbonate rocks interbedded with tuff beds.

The black shale-slate zone (1a) east of the sphere of influence of the pluton contains several bands of green and red slates (1a₃). They vary in width from 100 to 500 feet and are here confined to the Shickshock belts. West of the pluton red slates are observed in both the Shickshock and Quebec groups. Such slates, as suggested by Girard (1967, p. 4), could well be hematitic tuffs.

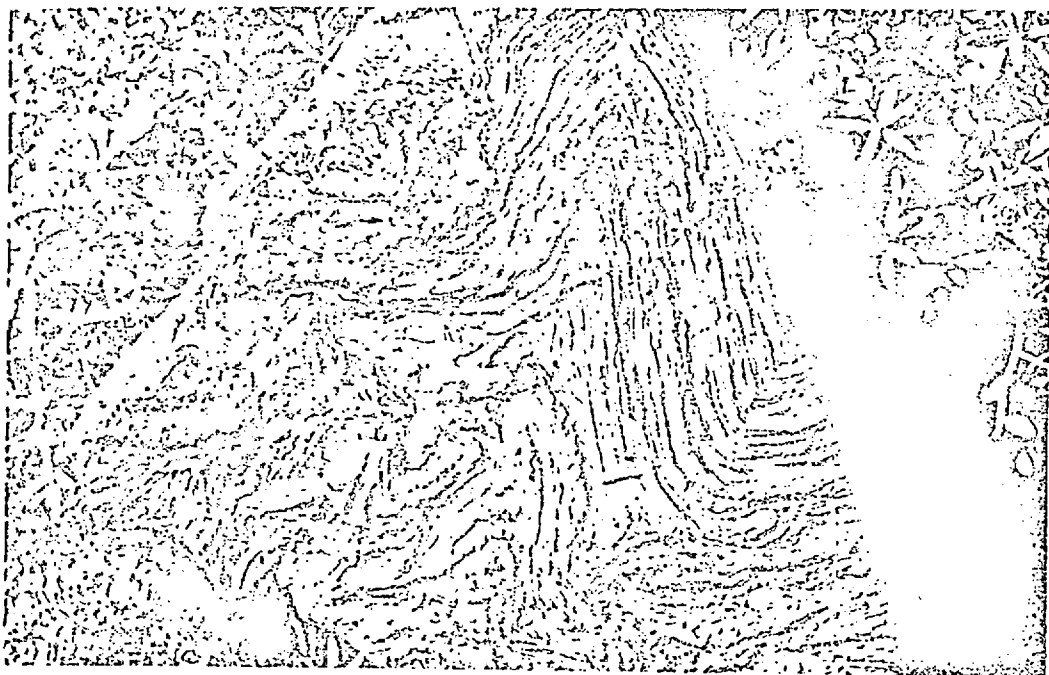


Plate V Intensely folded laminated diopside-quartz-scapolite (actinolite-tremolite) hornfels (la₂M) (2.5 miles E. of Mt. McWhirter)

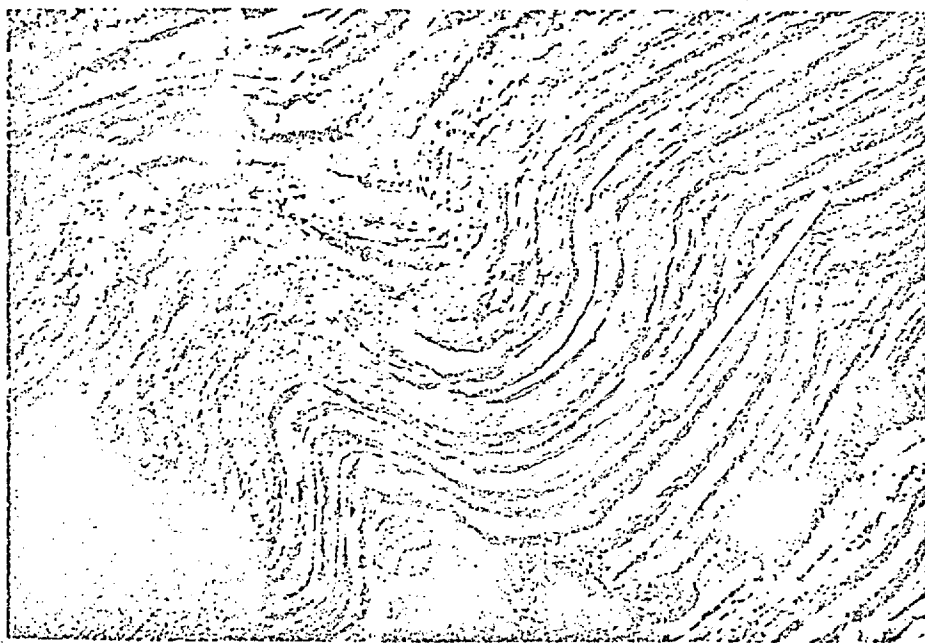


Plate VI Laminated calc-silicate hornfels consisting of alternating diopside (tremolite-actinolite) and scapolite-quartz layers (la₂M) (3.5 miles NE of Mt. McWhirter)

Another mappable calc-silicate hornfels of the Schickshock Group is a garnetiferous variety (la_3^M) exposed within the inner zone of the aureole, east and west of Mt. McWhirter. The belt is 1000-2000 feet wide and consists of laminated green and purplish rocks. Reddish bands, 0.5 inches wide, of vesuvianite stand out in relief and alternate with greenish and buff diopside and scapolite. At places, thin sections show an intimate association of intergrown calcite and diopside accompanied by zoned garnet. The rock could appropriately be termed a skarn (Plates VII, VIII and IX).

The belt is in gradational contact with green calc-silicates to the north (la_2^M) and merges southward into streaked mauve-greenish hornfels (la^M) (Plate X).

The distinctive mineralogy and structure of the garnetiferous hornfels are lost in the outer zone of the aureole, where the rock along with other hornfels is represented by massive to foliated argillite and calcareous argillite (la^m). Farther northeast and outside of the aureole, mapping clearly shows the garnetiferous hornfels (la_3^M) to be the contact-metamorphic equivalent of calcareous slates and limestone interbeds (la_3). This correspondence is strikingly evidenced by the similar trend and width of both belts. The high CaO-content of the hornfels further supports this view.

Age and Structural Relations

As mentioned above, the Shickshock Group, west of the pluton,

consists of metabasalts interbedded with pyroclastic rocks, and metasedimentary rocks largely converted to hornfels. South and east of the pluton, the Shickshock rocks are made up of hornfels, partly derivatives of pyroclastic rocks. Farther east and beyond the thermal aureole the Shickshock Group of rocks gradually merge along strike with those of the Quebec Group.

The age and contact relations of the Shickshock Group have been a subject of controversy for over 100 years. The writer has no first hand information on the contacts and therefore on the age of Shickshock rocks outside the present area and relies therefore on results of previous reconnaissance work. In fact, not much can be added here to Ollerenshaw's excellent review of opinions expressed on that problem (1967, p. 12-18). Only data from the immediate vicinity having a direct bearing on the Shickshock Group in the present area are therefore presented here.

The nature of the southern limit of the Shickshock Group west of the area appears certain. Although partly masked by overburden in the Hog's Back and Mont Vallières-de-Saint-Réal regions, Robert (1966a, p.5; 1966b, pp. 7 and 16) confirmed the presence of a fault separating ^{the} Silurian from the Shickshock rocks to the north. (Ollerenshaw, 1967, p. 13). The writer believes that the EW-trending shear zone in the map-area, south of the pluton, probably represents the eastern extension of that fault (de Romer, 1969, p. 30). It is suggested that it is an imbricate zone of thrusting affecting mainly Quebec Group rocks south of the Shickshock belt. Despite scarcity of outcrops, there is no real evidence to indicate that the southern limit of the Shickshock Group east of the pluton is a

fault contact. Compositional gradation across strike between Shickshock black slates and shales (1a) and calcareous shales, slates and phyllites of the Quebec Group (2a) rather suggests a conformable contact between the two groups.

The nature of the northern limit of the Shickshock Group has not been definitely established as yet. Reconnaissance mapping in the Courcellette region, 15 miles west of the area, lead McGerrigle to conclude that the Shickshock rocks, Cambrian or ^R Precambrian in age, are probably thrust northward over the Ordovician Quebec Group (1954, p. 23). However, more recent work in the Mt. Logan (Mattinson, 1964, p. 59-63) and Cuoq-Langis regions (Ollerenshaw, 1967, p. 12-18; 56-60), 40 and 60 miles WSW of the area, indicates the contact between the two groups to be a conformable one. In those areas Shickshock and Quebec rocks interfinger at the contact.

In the Mt. Richardson region, immediately west of the present area, Girard shows a local fault separating both groups, but no eastward continuation. In fact, Girard mentions that there is no sharp demarcation between the Quebec and Shickshock Groups (1967, p. 3).

From what was observed on Mt. Richardson, on the western edge of the pluton, the writer agrees that the contact between these two groups appears indeed conformable, although the zone of contact is, here, largely masked by the aureole effects.

East of the pluton, a different situation would prevail. Detailed mapping of the eastern flank of the pluton revealed the nose of a tight fold in sharp contact with Shickshock rocks to the south (de Romer, 1970, p. 3).

Several quartzite beds (2b₁^q), acting as excellent marker horizons, were meticulously walked out and found to be part of a west-plunging synform. There is no evidence of an eastward extension of this fold. Another closed fold apparently truncated by the Shickshock belt was located near the Auclair-Pierre-Jean Ruisseaux intersection. The core of this fold is made up of argillaceous limestone and interbedded shales (2b₂). These can be traced eastward across the outer (2b_m) and into the inner zone of alteration, where they are represented by calc-silicate hornfels and skarn (2b₂^M). Although there is a marked scarcity of outcrop in the critical zone, the writer suggests, in view of the considerations above, that the northern contact of the Shickshock belt east of the pluton, is, at least locally, unconformable.

As regards the age of the Shickshock Group, the writer agrees in principle with the facts and interpretation as given by Ollerenshaw (1967, p. 16-18). K-Ar age determinations of Shickshock rocks indicate a possible Middle Cambrian to Lower Ordovician age (Lowdon et al, 1963, p. 106-108). Although future studies may prove the rocks to be mainly Cambrian, a Cambro-Ordovician age is here adopted.

In brief, the following criteria suggest the continuation of the Shickshock belt east of the pluton and its eventual merger with the metasedimentaries of the Quebec Group farther east:

- 1) Corresponding units of the Quebec Group have been located east and west of the pluton in identical stratigraphic positions. The writer has field evidence that the Shickshock belt abuts against, and is truncated by the pluton. It is therefore logical to conclude that the Shickshock belt also extends beyond the pluton.
- 2) The northern limit of the Shickshock belt

east of the pluton is exactly collinear with the contact of the belt west of it.

3) Lenses of laminated dioside-scapolite hornfels (la_2^M) and hornblende-rich pockets south and east of the pluton are in part derivatives of pyroclastic rocks. They are confined to a belt in strike with the Schiskshock belt west of the pluton. 4) Green and red slates (la_2) east of the pluton are of possible tuffaceous origin. They are restricted to a well-defined belt in strike with the Shickshock rocks. 5) the quartz-sandstone beds (la_4q), clearly interbedded with pelitic hornfels west of the pluton have their counterparts east of the pluton (la_1).

The writer is well aware that his conclusions do not agree with those of previous workers. Field evidence, however, would support the above interpretation.

CHAPTER V

QUEBEC GROUP

General Statement

The northern two thirds of the map-area belong to the northern belt of the Gaspé Peninsula (Map 1). In this belt most rock units belong to the Quebec Group which is an assemblage of NE-striking, complexly folded metasedimentary rocks and minor metavolcanic rocks. Lithology and structure indicate a typical flysch terrane. Its southern contact with the central belt is a fault, possibly an overthrust by Siluro-Devonian rocks.

In the map-area, the Quebec Group belt is 12.5 miles wide extending from the northern boundary of the area southward to the wide Madeleine River valley. In its southern part the belt is believed to be interrupted by a

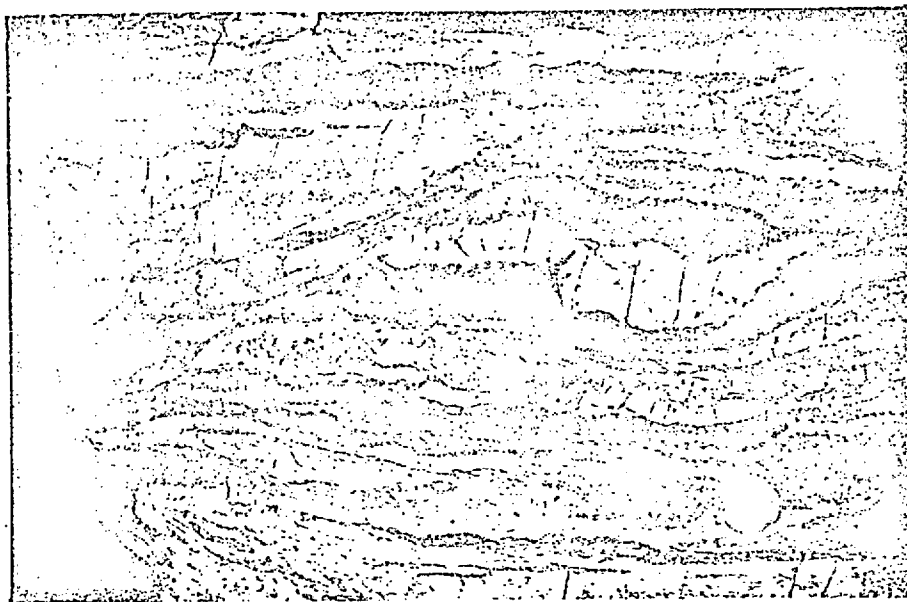


Plate VII: Banded diopside-scapolite-garnet-(calc silicate) hornfels (la_3M) (1.5 miles ESE of Mt. McWhirter).

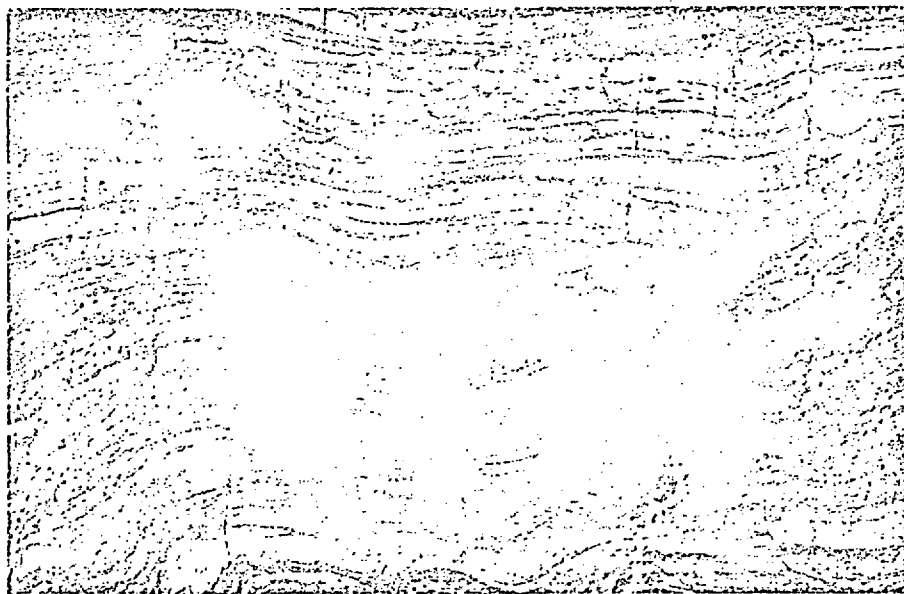


Plate VIII: Finely layered, greenish-red, streaked garnetiferous calc silicate hornfels (la_3M) (1.5 miles ESE of Mt. McWhirter).

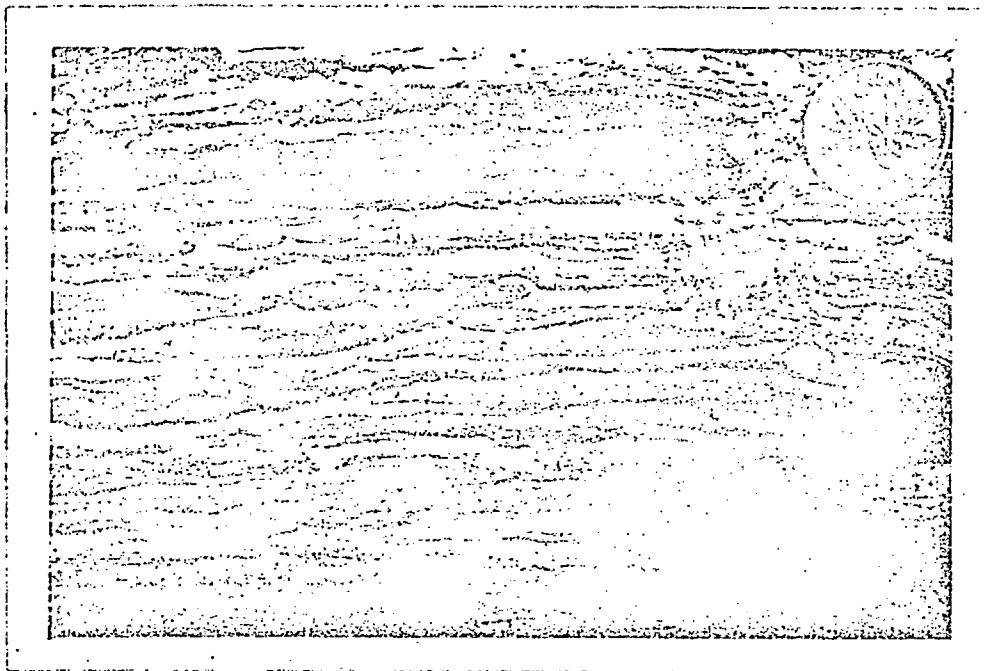


Plate IX: Alternating bands of garnet, diopside and scapolite in garnetiferous calc-silicate hornfels (la3M) (11 miles ESE of Mt. McWhirter).

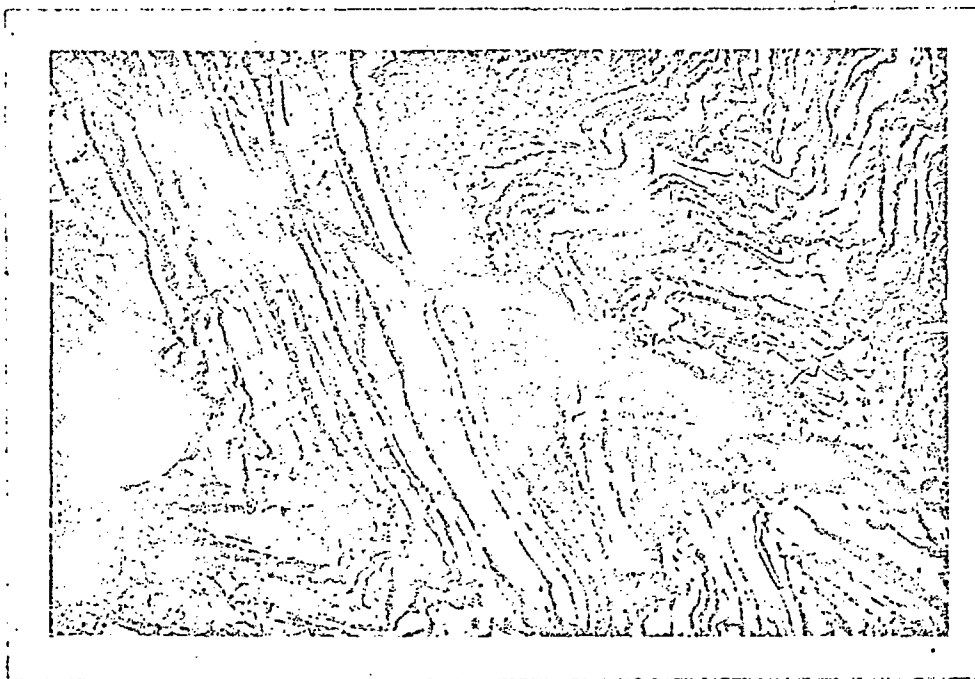


Plate X: Folded, laminated mauve-green hornfels made up of diopside-calcite-clinozoisite and quartz-scapolite bands (la4M) (4.9 miles ESE of Mt. McWhirter).

^{to}
1-2 mile wide zone of Shickshock rocks wedged in between units of the Quebec Group.

The Quebec Group is intruded by the Mts. McGerrigle granitic pluton around which a conspicuous, 1-2 mile wide contact-metamorphic aureole has developed.

The regional layering in the Quebec Group rocks is EW to ENE. Near the pluton the strike of the units on both flanks of the intrusive swings northward. Dragging, cross-cutting, xenoliths and contaminated contact rocks indicate that the injection is discordant and therefore post-Quebec Group in age.

The writer has subdivided the Quebec Group into 8 principal units. With the exception of the basalt, contacts between them are gradational; their contact trace on the map is therefore approximate. Although a southward dip of the layering and bedding is clearly prevalent the whole assemblage cannot be seen as a simple homoclin^{cl}al sequence. Due to multiple folding and great lithological similarities between several units the overall stratigraphy is extr^emely difficult to establish. Within the inner zone of the aureole because here recrystallization, metamorphic segregation and other contact-metamorphic effects have accentuated the compositional differences between some of the sedimentary units they are more easily distinguishable.

Particular attention was paid in the field to trace the various units of the belt across the alteration zone and identify corresponding units on both flanks of the pluton. The following account describes from south to north and this inside as well as outside the aureole, the lithology of the 8 units (2a to 2h) and subunits of the Quebec Group. It must be remembered that the true stratigraphic succession is not known.

First Unit (2a)

A 1-1.5 mile wide belt of grey and black calcareous shales, slates and phyllites is exposed north and south of Rivière Madeleine. In thin section, the shales consist of tiny carbonate grains and mica flakes set in a carbonate-clay matrix. Fissility is prominently displayed by the parallelism of the mica flakes. Outcrops of calcarenite, dolomitic limestone and conglomerate are particularly well exposed on the cliffs along the sinuous Rivière Madeleine at the extreme eastern margin of the area. The calcarenites are characteristically grey and coarsely bedded or laminated consisting of calcite grains cemented by carbonate. White calcite veins cut irregularly across the bedding. At places, the rock contains recrystallized unidentified fragments of organic origin, probably derived from reefs. Interbeds of brown weathering dolomitic limestone with local pockets of ankerite and siderite are occasionally present. At some places, beds of limestone conglomerate are interbedded with the calcarenites; the pebbles and cobbles consist of grey-bluish limestone embedded in a carbonate-argillaceous to arenaceous matrix. They are probably intraformational conglomerates. In summary, the above carbonate interbeds are mostly clastic limestones made up of recrystallized organic remains and other fragments chemically cemented by carbonates.

North of Barter Lake, outcrops of a brecciated limestone conglomerate are found here and there for about 1,000 feet along the south bank of Rivière Madeleine. Some of these outcrops show zones of dark-grey calcareous shale and slate containing pebble- to cobble- sized limestone and calcareous siltstone and calcareous siltstone fragments. Phyllitic slates containing boulders

of pebbles to oolitic limestone are also seen. Except for a slight parallelism of the phenoclast-bearing zones, there is little evidence of bedding. Recrystallized calcite veins cut irregularly across the fragments or follow thin partings between the contorted beds. Loose, angular fragments of a fossiliferous limestone (mainly brachiopoda) appearing to be in place, were noted alongside the outcrops.

The quartz sandstone interbeds (2a₁) are best exposed south of Rivière Madeleine. They are several hundred feet wide and have been traced for $\frac{1}{2}$ mile or so. The rock is massive, medium-grained and usually grey, made up of subangular quartz with occasional interstitial quartz, calcite and feldspar. Many grains are strained. At places, they are true quartzites consisting of interlocking quartz. Small, rounded inclusions of shale are present locally. Several small outcrops of Quebec Group quartzite were also observed 1,500 feet northwest of the main elbow of Rivière Madeleine, 2 miles S of Mt. McWhirther. In thin section, the rock is made up of a tight mosaic of subangular quartz with occasional patches of recrystallized calcite. Where carbonates abound, the rock becomes a calcarenite.

The above grey and black calcareous shales and slates merge westward along strike into argillite and calcareous schists (2a_m). These constitute the outer zone of the alteration zone, but are scantily exposed because of low ground north of Rivière Madeleine. The argillites are dark, massive, slightly indurated and recrystallized pelites. Some excellent outcrops of interlayered argillite-limestone are found on the north bank of Rivière Madeleine and along the south-flowing creeks 2.5 miles SE of Mt.

McWhirter. The rock consists of dove-weathering limestone layers $\frac{1}{4}$ to $\frac{1}{2}$ inch thick, alternating with light-brown, laminated and calcareous siltstone layers one inch or so thick. In general, the outcrop has a ribbed appearance due to preferential weathering of the limestone layers. The bedding, very regular, strikes northeast and dips steeply to the southeast. Some of the argillite layers display a faint, but discernible cross-bedding, indicating top to the south.

The calcareous schists are particularly well exposed on the straight course of the Rivière Madeleine, 1,500 feet N of the main elbow of the river. In thin section, the grey, well-foliated rock consists of calcite-tremolite layers, a fraction of an inch thick, alternating with seams of muscovite and phlogopite. At places, 2-inch wide lensoid crystalline beds consisting of granulated and strained carbonate are interbedded with streaks of mica and recrystallized calcite.

The rocks of the inner alteration zone exposed immediately south of the pluton comprise 3 subunits: calcareous schists, crystalline, limestone, minor pelitic hornfels and skarn ($2a_m$); massive pelitic hornfels ($2a_2m$); and garnetiferous schist and calc-silicate hornfels ($2a_3m$). They constitute the contact-metamorphic equivalents of the subunits described above.

The calcareous schists consist of $1/16$ to $\frac{1}{4}$ inch wide beds of recrystallized tremolite-calcite-scapolite alternating with thin seams of brownish weathering siltstone and dark-grey or greenish shale partings. Scapolite replaces calcite with accompanying muscovite forming distinct laths of random orientation. Where the original SiO_2 and clay content was more abundant, pelitic hornfels developed; such pelitic interbeds, which are relatively

rare, consist of an extremely fine-grained mosaic of unoriented quartz and feldspar with vague aggregates of sericite. At places, the calcareous beds contain tiny, unoriented amphibole needles embedded in a matrix of recrystallized calcite and scapolite. Occasionally, the recrystallized calcareous material has penetrated minute fractures which cut across the argillaceous and silty layers. Where the effects of metamorphism were more pronounced, discontinuous 1/32 to 1/16 inch thick greenish seams of a hornfelsic material alternate with bands consisting of up to 3/16-inch long, green tremolite-actinolite prisms. At places, the rock is a grey-brownish impure limestone in which bedding is manifested by disrupted, but readily discernable shreds of dark indurated material. Where observed, such remnants of original stratification strike east and dip vertically or steeply to the south. Some of these streaked rocks, however, have all the characteristics of mylonites.

Beds of grey, crystalline limestone are occasionally present. The rock consists chiefly of a mosaic of interlocking calcite grains; at places, muscovite is concentrated in thin layers producing a striking foliation trending EW and dipping steeply south.

Irregular patches of skarn have been observed in the eastern part of the inner alteration zone. The rock is light-green and consists of intergrown coarse calcite and diopside; scapolite and andradite are also present. In one section, wollastonite and diopside are found in large crystals side by side. (Table 1, No. 9 and 10). At places, the skarn consists of a fine-grained mosaic of diopside and tremolite penetrated by garnet-rich veinlets.

Massive pelitic hornfels ($2a_2M$) constitutes the southern limit of

the inner alteration zone south of the pluton. The brown to mauve rock consists characteristically of a microcrystalline mosaic of recrystallized quartz and biotite. Tiny circular knots (probably altered cordierite porphyroblasts) filled with quartz and opaque minerals are occasionally present. At places, the massive hornfels contains irregular zones of oriented tiny muscovite and biotite giving the rock a distinctly foliated appearance.

Outcrops of garnetiferous schist and calc-silicate hornfels ($2a_3M$) are particularly well exposed in a south-flowing creek, 2.5 miles S of Mt. McWhirter north of Rivière Madeleine. The rock varies considerably in color and fabric. Some of the reddish-green varieties show even laminations or bands of hornblende and garnet-diopside-rich material. In the well-foliated zones, muscovite and biotite flakes are warped by garnet porphyroblasts. (Plate XI). In other parts discontinuous lenses of scapolite and quartz, a fraction of an inch long, alternate irregularly with garnet-or chlorite-rich pockets or layers. At places, the rock is extremely tough consisting of intertonguing lenses of green (quartz and diopside) and light-grey (scapolite and quartz) flinty material. Some of the lenses contain ovoid knots or elongate aggregates of brown-weathering andradite $\frac{1}{4}$ inches across. Here again, the light grey-greenish and purplish coloration of the intertonguing lenses gives the rock the appearance of a streaked mylonite.

Second Unit (2b)

The second unit of Quebec Group metasedimentary rocks is exposed in a 0.5 to 2 miles wide belt in unconformable contact with Shickshock rocks to the south. It is stratigraphically and structurally significant that correspond-



Plate XI. Euhedral, zoned andradite-grossularite porphyroblasts in a matrix of calcite ($2a_3M$) (2 miles SE. of Mt. Whirter) (Natural light, X45).



Plate XII. Calcite-filled amygdules set in a matrix of plagioclase microlites ($2e$) (2 miles SE. of lac St. Pierre) (natural light, X45).

ing members composing the unit have been located both east and west of the pluton.

Outside the contact aureole the rock assemblage consists of grey, arenaceous and oolitic limestones (2b); black shale and phyllitic slate (2b₁); and dark-grey argillaceous limestone with shaly interbeds (2b₂). The outer zone of the aureole is underlain by calcareous argillite and argillite (2bm). Within the inner zone, the prevalent rocks comprise crystalline limestone (2bM); spotted, pelitic hornfels with minor calc-silicate hornfels and spotted pelitic schist (2b₁M); this member includes several quartzite horizons (2b₁q); a calc-silicate hornfels with skarn (2b₂M); and finally, another band of calc-silicate hornfels (2b₃M).

The arenaceous and oolitic limestone probably forms the oldest member of the above sequence. Commonly, the rock is dark when fresh, weathering to light grey. It consists of irregular ill-defined, partly recrystallized calcic fragments cemented by calcite. Zones of tiny oolites embedded in a calcitic mudstone matrix often characterize the rock. The grain size and its nature suggest that the limestone is a typical calcarenite.

Within the inner alteration zone this calcarenite alters to a slightly recrystallized limestone (2bM) still preserving its arenaceous nature. Interbedded with the crystalline limestone are occasional dark-brown, banded and tough hornfels. In thin section, they consist of a tight mosaic of quartz and biotite interlayered with thin diopside-scapolite seams. They are probably derived from originally calcareous siltstone interbeds (Table II, No. 16).

In contact with the above calcarenite is a belt of black shale and phyllitic slate (2b₁) (Table II, No. 15). Outcrop distribution and structure indicate that it forms part of a large westwardly-plunging fold transected by the Mts. McGerrigle pluton.

In the outer zone of the thermal aureole black shales and slates are represented by commonly calcareous argillites (2bm). Typically, the argillites are dark-grey, fairly hard and fine-grained rocks, showing conchoidal fracture. In hand specimen, they are generally massive and devoid of foliation. In thin section, however, a slight planar orientation of tiny muscovite and biotite flakes is observed. These are embedded in a very fine-grained mass of equigranular recrystallized quartz.

In the inner part of the zone the argillites grade into spotted, pelitic hornfels with minor interbeds of calc-silicate hornfels and spotted pelitic schist (2b₁M). They are well exposed on the steep western (S of Lac des Américains) and eastern (S of Lac de la Botte) flanks of the pluton. The spotted, pelitic hornfels is characteristically a grey to brown, fine-grained rock peppered with dark-grey or reddish spots. Generally 1 mm in diameter, the knots are roundish, ill-defined patches consisting chiefly of aggregates of muscovite, biotite, chlorite, quartz and carbonaceous matter (Table II, Nos. 19 and 20). Because of the vague outline and make-up of the spots, thin section studies regarding their origin remained inconclusive. No single porphyroblast could be identified, although simultaneous extinction within large parts of the inclusion-riddled knots suggests the presence of altered metacrysts. North of lac de la Botte, however, similar spotted, pelitic hornfels are characterized by large cordierite and andalusite metacrysts.

Generally, the spots show an irregular random distribution. At places, however, they are concentrated in bands and are probably mimetic after bedding. Locally, the knots are ellipsoidal with definite orientation of their long axes clearly at an angle to the banding. At places, the rock is distinctly foliated and then becomes a spotted, pelitic schist. Interbeds of massive, quartz-biotite hornfels, and mauve and green calc-silicate hornfels are occasionally present.

Scattered outcrops of black shale and argillite were observed 1.5 miles east of Lac Fortin. Although it lies within the high-grade zone of thermal metamorphism, some 1,500 feet east of the contact with the pluton, the rock is, surprisingly, only slightly altered (Table II, No. 17).

Because of good outcrop density, correlation between black shales and slates (2b₁), argillites (2bm) and spotted, pelitic hornfels (2b₁M) was easily established. Clearly, variation in fabric and mineral assemblage in the above rocks evidently reflects increasing thermal metamorphism of pelitic rocks. Change in composition was probably slight.

Several horizons of white to creamy quartzite (2b₁q) are interbedded with spotted pelitic hornfels SE of Lac Fortin. The rock consists mostly of medium-grained, interlocking, subangular quartz, with occasional hornblende and biotite filling the interstices. In the vicinity of the pluton, the quartzite beds merge into a single 500-foot wide band that is dragged northward and cut off by the intrusive. Close-spaced traverses, a few 100 feet apart, undertaken in search of this excellent marker horizon revealed a tight fold opening westward. Although based chiefly on the distribution pattern of rock debris, the writer feels confident that such a structure is

present here. There is definitely no eastward continuation of the quartzite beyond the alteration aureole. Special attention to this striking marker horizon was also paid in the area west of the pluton. Quartzite debris in place were located on the northern slopes of Mt. Richardson. Similarly, outcrops of quartzite interbedded with spotted, pelitic hornfels (2b₁M) were observed on the jeep road 1 mile SSW of lac des Américains. Both locations are exactly in line with exposures of quartzite on the eastern contact of the pluton. In addition, débris of quartzite xenoliths were located in the centre of the pluton, 1 mile NNW of lac Côté. It is probable that the latter represents the apex of a cusped fold-like structure opening southward brought about by dragging action of the pluton.

The dark grey argillaceous limestone (2b₂) forms a 500-foot wide tongue, outcrops of which are well exposed along an EW lumber road, S. of ruisseau Auclair. It is characterized, at places, by silty and shaly interbeds and forms the core of a light NNW-overtured fold in the low area east of the pluton.

The identity of this calcareous belt was lost in the 1-mile wide argillite zone (2b_m) east of the pluton. This is mainly because low-grade thermo-metamorphic effects in the outer part of the aureole have masked and obliterated characteristic pre-existing features, both in terms of structure and composition. In other words, argillites in the area have been derived from considerably different parent rocks.

In the inner zone of alteration, both east and west of the pluton, the calcareous belt is represented by calc silicate hornfels and skarn (2b₂M), respectively. East of the pluton, S. of lac de la Botte, the pre-

TABLE II
CHEMICAL ANALYSES OF QUEBEC GROUP ROCKS *

Present No.	11	12	13	14	15	16	17	18	19	20
Sample No.	68f-5952	68f-5970 71-9575	68f-5954 71-9559	68f-5977 71-9582	68f-5968 71-9573	68f-5947 71-9552	68f-5949 71-9554	68f-5969 71-9574	68f-5955 71-9560	68f-5943 71-9548
SiO ₂	30.36	53.04	59.28	54.00	57.71	64.44	53.58	54.10	59.45	57.70
TiO ₂	0.25	0.90	0.83	0.54	0.57	0.55	0.63	0.57	0.99	0.94
Al ₂ O ₃ ...	7.25	14.30	16.53	12.63	12.74	11.07	14.16	11.86	19.72	20.12
Fe ₂ O ₃ ...		2.22	1.76	0.51	1.93	1.15	0.98	0.44	1.38	1.62
FeO.....		5.43	5.62	3.58	3.27	8.52	5.89	4.75	6.38	3.76
MnO.....										
MgO.....	2.21	3.30	4.83	6.33	0.79	4.31	4.88	5.08	1.89	2.09
CaO.....	29.40	6.85	1.32	14.86	10.19	5.51	12.18	14.61	1.87	1.23
Na ₂ O.....	0.60	1.64	0.99	1.52	0.74	0.48	1.29	1.40	1.88	2.10
K ₂ O.....	1.48	2.80	4.90	2.80	2.80	1.64	3.20	4.56	4.95	4.68
P ₂ O ₅		0.14	0.15	0.12	0.15	0.18	0.16	0.13	0.08	0.11
V ₂ O ₅										
CO ₂		4.13	0.11	0.12	2.83	0.19	0.02	0.35	0.08	0.12
Fe t....	2.61									
Total	74.16	94.75	96.32	97.01	93.72	94.04	96.97	97.85	98.67	94.47
Minor Elements										
Cu	58	30	63	91	48	59	70	61	86	41
Zn	17	111	72	63	67	79	34	62	90	190
Pb	25	15	18	17	22	30	33	17	33	17
Ni	18	41	72	48	79	48	98	86	92	35
Cr	80	70	160	130	160	260	310	290	90	120
V	100	60	110	120	40	100	100	90	140	80
W	2	4	4	2	2	2	4	4	8	4
Sn	5	5	5	10	5	10	10	5	5	10
Mo	n.d.	n.d.	n.d.	3	n.d.	n.d.	n.d.	7	n.d.	n.d.
U	1	2	2	1	7	2	2	5	2	2
Au	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Ag	2.2	0.8	0.9	0.8	0.9	0.9	0.8	0.7	0.8	0.5
Pt	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02

11. Calcareous, finely laminated shale (2c₁)
12. Green slate (2c₁)
13. Dark, fine-grained, spotted hornfels (2c₁M)
14. Banded, brown and beige hornfels (2c₁M)
15. Black shale (2b₁)
16. Dark, banded hornfels (2b₁M)
17. Dark, massive argillite (2b₁M)
18. Porcellanite (2b₁M)
19. Dark, massive, pelitic hornfels (2b₁M)
20. Dark, spotted pelitic hornfels (2b₁M)

* Analyses by the Quebec Dept. of Natural Resources Laboratories; for location see Index Map III.

valent hornfels is a light-grey or beige, very fine-grained and massive, flint-like rock. It has, characteristically, the dull luster of unglazed porcelain. In thin section, it appears to consist of a microcrystalline mesh of quartz and calcite (Table II, No. 18). In many respects the rock resembles the porcellanite found in altered Cap Bon Ami formation beneath Needle Mountain at Murdochville.

West of the pluton, a coarse-grained skarn takes the place of the above hornfels. It is irregularly banded and consists of calcite, diopside, scapolite and, locally, garnet.

There is little doubt that the calc silicate hornfels and skarn are intertonguing and that both have been derived from argillaceous and siliceous carbonate parent rocks, (2b₂), exposed 2.5 miles east of the pluton.

The last member of the second unit is exposed both east and west of the pluton, at 1 mile SE of lac Fortin and NNW of Mt. Richardson, respectively. It consists of calc silicate hornfels occasionally interlayered with bands of purplish-brown pelitic hornfels. As shown 1000 and 6000 feet NNW of Mt. Richardson, calc-silicate hornfels appears to be part of a tight fold as evidenced by outcrop and debris distribution of the quartzite marker horizon.

The rock is extremely hard and fine-grained consisting of regular mauve, beige and apple-green $\frac{1}{4}$ - $\frac{1}{2}$ inch wide bands. At places, intertonguing of the layers produces hazy contacts and gives the rock a steaked appearance. Its mineralogical composition is very similar to the calc silicate hornfels described from S of Mt. McWhirter (p. 42).

Third Unit (2c)

The third unit of the Quebec Group is exposed in a 2-mile-wide belt both east and west of the pluton. Similarly to the other units, this belt also swings northwardly as the contact with the pluton is approached.

Outside the aureole, east of the pluton, two subunits could be distinguished: finely laminated, black, green and grey slates, siltstones and shales (2c); and calcareous siltstone and silty and arenaceous limestone (2c₁). The sub-units merge westward into occasionally banded and, at places, calcareous argillites (2cm). Pronounced metamorphic reconstitution in the inner alteration zone has brought out and accentuated original compositional differences, which are not readily apparent in the argillites. They gradually merge along strike into the following sub-units: spotted, pelitic hornfels (2cm); cordierite hornfels and spotted, pelitic hornfels with minor calc-silicate hornfels interbeds (2cm_c); and a calc-silicate hornfels and spotted, pelitic hornfels (2c₁m).

The argillites, occurring in the outer zone of alteration (2cm), are mauve, massive and occasionally banded. Generally, they have a dull luster, are hard and show conchoidal fracturing. Under the microscope, the rock consists of slightly oriented muscovite and biotite metacrysts embedded in a very fine-grained and equigranular matrix of recrystallized quartz. At places, small pockets of iron sulphides are important accessories.

The spotted, pelitic hornfels (2cm) crop out west of lac Vieillard and at the same latitude at the western contact of the pluton. The mauve tough rock is generally massive and peppered with 0.5-1 mm large spots.

Occasionally, the rock is distinctly fissile. The spots are rounded aggregates of muscovite and biotite set in a finer-grained, quartz-rich matrix of similar composition. At places, such as on and near the road from Mines Madeleine to the plateau NE of the mine, the typical rock is a massive, spotless variety. It is generally hard, mauve or rusty and frequently interbanded with light-grey calc silicate layers a fraction of an inch in width. In thin section, the rock consists mostly of a fine-grained mesh of quartz and biotite. Some fine-grained and streaked purplish interbeds contain angular rock fragments and shreds typical of tuffaceous rocks (Table IV, No. 39).

At places, such as near the 2,720-foot adit of the Mines Madeleine, the quartz-biotite hornfels contains lenses of evenly banded garnetiferous calc-silicate hornfels. Two varieties are present: a diopside-scapolite-rich type consisting of dark-green (diopside and actinolite) and buff (quartz and scapolite) bands; the other variety is a flinty and purplish rock containing biotite-quartz bands interlayered with garnetiferous layers. Both varieties are similar in appearance and composition to hornfels found in the Shickshock group (la_2M and laM , respectively). It is probable that the former variety is of pyroclastic origin (Table IV, No. 40). whereas the composition of the latter suggests an impure carbonate parent rock (Table IV, No. 41).

In immediate contact, both east and west, with the pluton is a band of cordierite hornfels ($2cMc$), which is in many respects similar to the spotted, pelitic hornfels described above. The most prevalent rock is a brownish to grey, fine-grained, variety characterized by dark-grey, reddish

TABLE III

CHEMICAL ANALYSES OF QUEBEC GROUP ROCKS AND DIKE *

Present No.	21	22	23	24	25	26	27	28	29
Sample No.	68f-5973 71-9578	68f-5962 71-9567	68f-5957 71-9562	68f-5945 71-9550	68f-5966 71-9571	68f-5944 71-9549	68f-5959 71-9564	69f-4021 71-9613	70i-10004 71-9635
SiO ₂	66.26	56.87	67.14	52.60	49.50	51.23	66.97	73.41	49.50
TiO ₂	0.89	1.19	0.79	0.86	0.66	0.63	0.84	0.71	1.70
Al ₂ O ₃	15.32	20.61	15.57	12.02	15.36	13.06	15.83	9.08	15.00
Fe ₂ O ₃	0.88	7.32	1.37	2.71	0.72	0.61	1.07	1.70	4.93
FeO.....	3.53	3.19	2.37	2.43	4.36	3.61	2.82	3.98	4.78
MnO.....									0.15
MgO.....	2.18	1.24	1.86	4.15	5.94	8.05	1.94	3.23	5.26
CaO.....	1.71	1.06	0.44	10.58	12.90	17.26	0.92	0.79	7.90
Na ₂ O.....	2.00	1.88	0.94	2.20	0.85	1.32	1.86	1.94	4.10
K ₂ O.....	3.60	4.26	5.28	3.60	4.84	1.98	4.20	0.55	5.58
P ₂ O ₅	0.11	0.19	0.04	0.14	0.09	0.10	0.10	0.12	0.47
V ₂ O ₅								0.009	
CO ₂	0.11	0.07	0.20	0.06	0.14	0.00	0.06	0.13	0.04
Total	96.59	97.88	95.96	91.35	95.36	97.85	96.61	95.64	100.41
Minor Elements									
Cu	58	24	58	88	112	108	22	21	32
Zn	33	98	31	57	72	34	26	60	83
Pb	13	37	12	32	22	38	10	19	34
Ni	26	51	48	35	61	59	22	110	79
Cr	160	70	150	160	150	210	80	330	57
V	210	100	100	100	120	100	110		336
W	4	2	4	2	2	1	8	n.d.	0
Sn	5	10	5	10	5	10	10	5	10
Mo	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0
U	5	1	10	1	5	1	5	5	1
Au	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0
Ag	0.7	0.5	0.5	0.5	0.9	0.9	0.4	n.d.	0.6
Pt	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.02

21. Black shale (2c)

22. Spotted, cordierite hornfels (2cMc)

23. Spotted, cordierite hornfels (2cMc)

24. Mauve and grey, laminated calc silicate hornfels (2cMc)

25. Mauve and grey, laminated calc silicate hornfels (2cMc)

26. Mauve and grey, laminated calc silicate hornfels (2cMc)

27. Spotted, finely laminated pelitic hornfels (2cMc)

28. Impure quartz-feldspar sandstone (2g)

29. Basic dike (15)

* Analyses by the Quebec Dept. of Natural Resources; for location, consult Index Map III.

or greenish, oval spots. These range from 1-5 mm in size and are randomly distributed throughout the rock. Biotite is the only mineral that can be positively identified in hand specimen. In thin section, the spots consist largely of vaguely defined aggregates of biotite, quartz and opaques (Plates XIII and XIV).

In several cases, cordierite porphyroblasts set in a granoblastic matrix of quartz, brown, pleochroic biotite, and plagioclase could be identified. Their borders are commonly altered to penninite. The presence of cordierite was also confirmed by X-ray diffraction (R. Ledoux, written communication, 1969).

Interbeds of spotted, pelitic hornfels were observed at places. Chemically and mineralogically, they are similar to the cordierite hornfels described above. (Table III, Nos. 22, 23, 27). It was generally noted that the spots increased in size toward the contact with the pluton. It is therefore, probable that both, the spotted and cordierite hornfels, are derivatives of similar parent rocks and that the size of the crystals was largely determined by the heat available.

Minor, laminated, mauve and grey calc-silicate hornfels are also present. Their chemical composition indicates that they were probably derived from calcareous interbeds in a predominantly argillaceous series (Table III, Nos. 24, 25, 26).

Occasionally, some thin sections show andalusite porphyroblasts embedded in a fine-grained matrix of quartz, muscovite, biotite, graphite and iron minerals. Generally, however, clusters of sericite arranged in a prismatic or rhombic shape are the only evidence left of former andalusite.

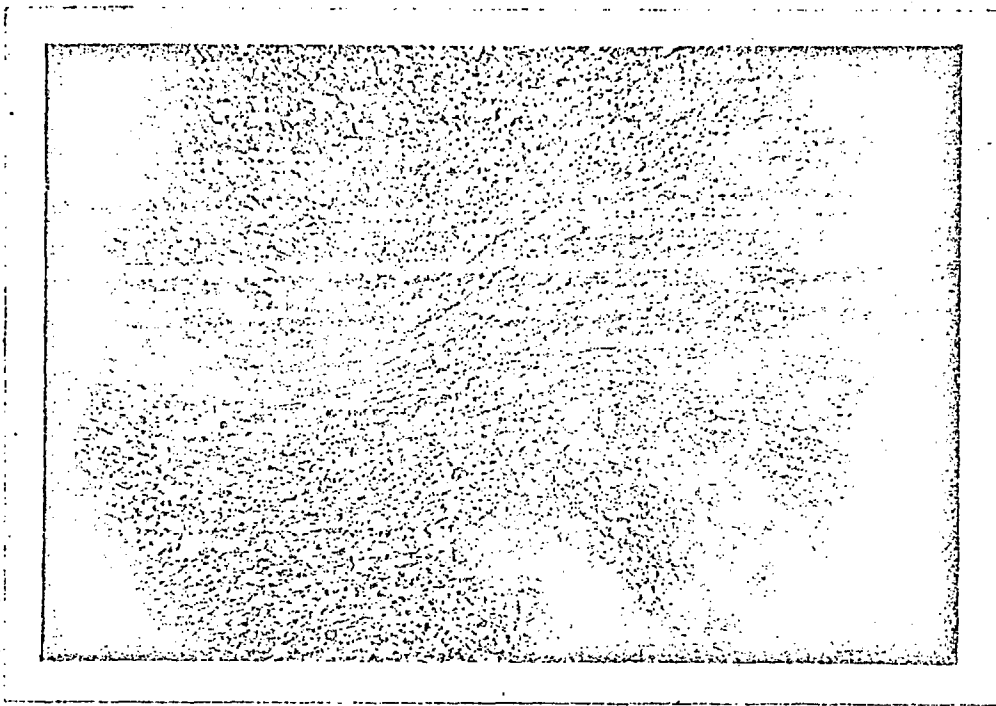


Plate XIII: Coarsely-spotted, pelitic hornfels showing trains of muscovite and biotite surrounding aggregates of quartz, biotite and opaques (2cm) (0.8 miles NE of lac de la Botte) (natural light, X45).

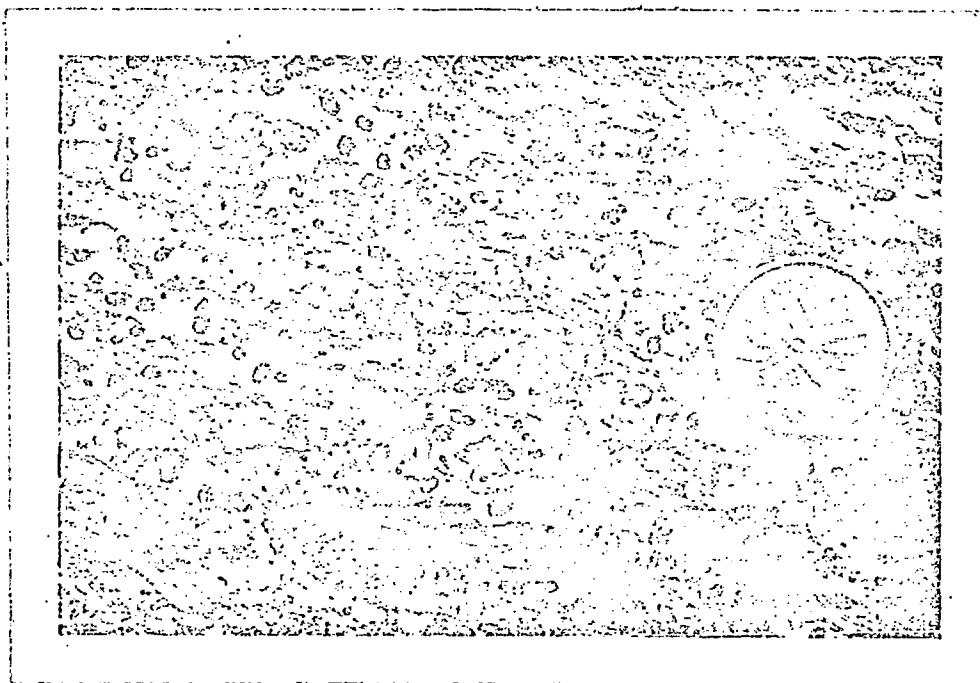


Plate XIV: Partly weathered-out cordierite porphyroblasts in a cordierite hornfels (2cm) (1 mile NE of lac de la Botte).

Excellent sections with cross-shaped patterns characteristics of chiastolite were obtained from samples of spotted, garnetiferous, pelitic hornfels located on the west side of the Couturier road, 4 miles due east of Mt. Jacques Cartier. The presence of hornfels is unexpected here, because the contact with the Mt. McGerrigle pluton is over 2 miles away and there is no evidence of other igneous rock exposure nearby. It is probable that this isolated occurrence of contact-metamorphic rocks amid only slightly altered sedimentaries reflects the proximity of a buried protuberance of the pluton. In any case the anomalous location of the hornfels and its significance should be further investigated.

In short, mapping as well as mineralogical and chemical composition indicate that the pelitic and calc-silicate hornfels (2cM and 2cMc) described above are the thermally metamorphosed equivalents of slates, shales (Table III, No. 21) and calcareous siltstone encountered outside the contact aureole (2c).

The other member of the third unit lying within the inner zone of alteration is banded calc-silicate hornfels and spotted, pelitic hornfels (2c1M). It is exposed both east (S of lac de la Botte) and west (N of lac des Américains) of the pluton. The banded rock consists of alternating 0.5 - 1 inch-wide dark brown (quartz-biotite-garnet) and beige (scapolite and diopside) layers (Table II, No. 14). The calc-silicate and spotted pelitic hornfels (Table II, No. 13) can be traced through the argillite zone into calcareous siltstones and silty and arenaceous limestone (2c1) exposed 1.5 miles E of pluton.

TABLE IV

CHEMICAL ANALYSES OF QUEBEC GROUP ROCKS *

Cont No.	30	31	32	33	34	35	36	37	38	39	40	41
Sample No.	69f-4020 71-9612	69f-3999 71-9617	69f-4006 71-9599	69f-4005 71-9598	68f-5967 71-9572	69f-4004 71-9597	68f-5948 71-9553	69f-4009 71-9593	68f-5960 71-9565	68f-5950 71-9555	70i-9994 71-9625	70i-9990 71-9622
SiO ₂	63.04	52.06	47.22	46.15	40.16	39.40	37.63	71.00	60.61	53.72	49.50	48.75
TiO ₂	0.61	0.70	2.68	3.03	5.11	4.06	5.18	0.50	1.44	1.23	0.11	0.34
Al ₂ O ₃	15.89	15.05	11.98	12.55	12.79	15.43	18.50	8.81	16.58	21.83	3.50	11.75
Fe ₂ O ₃	2.87	3.08	5.29	4.06	18.44	12.38	2.29	0.97		7.33	3.04	2.87
FeO.....	2.50	4.01	8.08	11.40	4.57	10.29	21.95	7.17		2.43	12.30	3.66
MnO.....											0.57	0.57
MgO.....	3.65	7.38	6.76	7.52	6.10	3.48	0.91	2.68	1.78	1.55	6.54	4.90
CaO.....	0.29	12.78	8.47	9.15	4.83	2.90	0.96	2.50	1.24	1.46	21.08	22.88
Na ₂ O.....	1.70	1.28	3.94	3.84	4.55	2.30	0.85	0.37	3.32	2.25	1.10	0.86
K ₂ O.....	3.38	3.32	0.68	0.51	0.09	6.60	6.10	1.60	3.30	4.65	0.18	0.24
P ₂ O ₅	0.05	0.14	0.26	0.31	0.42	0.29	0.16	0.05		0.13	0.06	0.17
V ₂ O ₅	0.009	0.028	0.070		0.042		0.008					
CO ₂	0.06	0.43	0.03	0.07	0.02	0.55	0.01	0.38		0.05	0.00	0.33
Fe t.....									5.75			
	94.04	100.25	95.46	98.59	97.12	97.68	94.54	96.03	94.02	96.63	97.98	97.32
Cu	24	32	25	14	24	3	161	96	24	144	11	47
Zn	70	85	120	120	143	80	102	70	120	68	181	156
Pb	24	30	21	24	17	26	22	14	23	18	36	38
Ni	46	50	85	85	61	77	84	20	37	113	37	56
Cr	90	120	210	150	24	120	230	70	70	70	35	70
V					400		460		100	110	112	168
W	n.d.	n.d.	n.d.	n.d.	2	n.d.	2	n.d.	4	4	0	0
Sn	5	10	10	5	10	20	20	5	10	10	0	0
Mo	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0
U	1	3	3	5	1	8	1	n.d.	2	2	2	0
Au	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0
Ag	n.d.	1.0	0.7	0.6	0.9	0.8	1.3	0.5	0.4	0.3	0	1.2
Pt	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.02	0.02

1. Black, laminated shale (2f₁)
2. Banded cherty and pelitic hornfels (2f₂M)
3. Andesitic basalt (2e)
4. Andesitic basalt (2e)
5. Andesitic basalt (2e)
6. Quartz-biotite-rich rock (2dM)
7. Biotite-rich rock (2e₁M)
8. Quartz-biotite schist (2dM)
9. Purple tuff (2dM)
10. Purple tuff (2cM)
11. Banded, diopside-scapolite hornfels (2cM)
12. Banded, biotite-quartz-garnet hornfels (2cM)

* Analyses by the Quebec Dept. of Natural Resources Laboratories; for location see Index Map III.

Fourth Unit (2d)

The fourth unit is a 1000-foot to 1-mile-wide belt of clastic rocks exposed east and west of the pluton. It conformably overlies a basalt adjoining it to the north. The unit comprises 2 members: a quartz-feldspar conglomerate with interbeds of black shale and tuff (2d); and a dark grey siltstone (2d₁). In the outer zone of alteration, the above rocks merge into slightly altered siltstone and argillite (2d_m); the corresponding assemblage in the inner zone consists of quartz-conglomerate and cherty hornfels (2d_M); and a massive pelitic hornfels (2d_{1M}).

The quartz-feldspar conglomerate (2d) is typically grey-brownish consisting of rounded fragments making up to 40% of the rock. Excellent outcrops are exposed along a path 1.5 miles east of Lac Vieillard. At places, it is a quartz-pebble conglomerate; generally, however, the clasts consist of rounded to subangular quartz, feldspar and rock fragments 1-4 mm in size embedded in a sandy matrix of similar composition. At some places, both quartz and feldspar are clearly angular with muscovite, calcite and opaques being important accessories. Occasionally, pebbles of silty shale are present. At places, particularly west of the pluton, the rock is distinctly banded consisting of interbedded quartz-conglomerate and biotite-rich layers. Some of the purple beds containing angular rock fragments are probably lithic tuffs of acid composition (Table IV, No. 38). They are particularly common in the lower part of the unit immediately overlying the basalt. Association side by side of mature and poorly-sorted types and their important textural discrepancies suggest a varied provenance of

the components. The conglomerate is evidently polymictic made up of recycled sediments.

In the outer alteration zone east of the pluton, the prevalent rocks are slightly recrystallized silty shales, siltstones, sandstones and argillites (2dm). These grade along strike into quartz conglomerate and cherty hornfels interbeds of the inner zone (2dM). The quartz pebbles are mostly round and set in a groundmass of interlocking, evidently recrystallized and granulated quartz. Most of the feldspar is altered to sericite and epidote. Interbeds of streaked cherty hornfels are derived from silty parent rocks. Thin extremely biotite-rich layers are conspicuous. They probably are of tuffaceous origin and are common near the band of overlying volcanics (Table IV, No. 35). Occasional quartz-biotite schist interbeds are probably derived from silty shales encountered in the outer alteration zone (Table IV, No. 37).

The dark grey siltstone (2d₁) is exposed in a 2000-4000 foot wide belt east of the pluton adjoining the above conglomerate to the south. It is a finely-laminated rock containing minor argillaceous interbeds. In thin section the siltstone is heterogeneous in grain size and composition and is poorly sorted. At some places, coarser layers contain transparent quartz and kaolinized feldspar and altered rock fragments, suggesting reworked sediments. Certain beds have elongated and discontinuous shreds of ill-defined inclusions such as are typical of tuffaceous rocks.

The siltstone of the outer alteration zone (2dm) is slightly recrystallized and indurated; it grades westward into a massive, pelitic

hornfels (2d1M) in the vicinity of the pluton. It becomes then a generally dark, very hard and massive, purplish rock composed essentially of micro-crystalline quartz and biotite. It is equivalent to the quartz-biotite hornfels ("main hornfels") described by Girard in the Mines Madeleine deposit, west of the pluton (1969, p. 840-843). Characteristically, the biotite occurs in slender and unoriented, brown flakes embedded in a mesh of recrystallized quartz.

Fifth Unit (2e)

The unit next to the north is composed of massive and amygdaloidal basalt with minor tuff interbeds (2e) and their metamorphic equivalents in the thermal aureole of the pluton. The latter include metabasalt (2em), spotted actinolite schist with metabasalt (2em) and a biotite-rich rock (2e1M).

The unit is part of a 1-2 mile wide and 15-mile long belt of conformable volcanic rocks belonging to the Quebec Group. In the present area, they underlie a prominent NE-trending ridge rising steeply from an average 1,750 feet to 2,950 feet above sea-level. The unit is 3,000-4,000 feet thick at the eastern border of the area, but then gradually decreases to about 1,100 feet near the contact with the pluton. Complete truncation of the belt by the Mts. McGerrigle pluton is accompanied by dragging, shearing and superimposed thermo-metamorphic effects. While the western contact is clear-cut, contact relations at the eastern edge of the pluton are complex. Here, detached patches of volcanic rock several thousand feet long are separated by apophyses and irregular bodies of granitic rocks. Relations

are further complicated by the presence of a gabbroid phase which intrudes the volcanic series.

The volcanic rocks outside of the aureole, east of the pluton (2e), are typically dark green, massive flows with amygdaloidal layers here and there probably representing different flows. At places, distorted pillows were observed. Amygdaloidal zones are particularly conspicuous near the southern, i.e. probably upper, contact of the series. The amygdules, either round or oval and reaching up to $\frac{1}{2}$ inch in diameter, consist of penninite and/or pink calcite surrounded by a felt of plagioclase microlites (Plate XII). Single tubules filled with calcite were also observed. The massive rock is entirely holocrystalline, rarely porphyritic and typically of di-basic texture. It consists of intermediate feldspar, augite, epidote, clacite and chlorite with accessory opaques. The feldspars, averaging An_{45} , form either euhedral, well-twinned laths associated with interstitial augite or occur as microlites. Chlorite is generally after pyroxene, while some of the calcite, epidote and sericite is an alteration product of the feldspars. Epidote occurs either as isolated grains or forming irregular veins in which it is associated with calcite in well-defined bands.

The basalt becomes more chloritic in the outer alteration zone (2em) and then grades westward into a spotted actinolite schist and metabasalt close to the pluton (2eM). Calcite-bearing amygdules are surrounded by rims of hornblende, some epidote and sphene. Most of the groundmass of metabasalt consists of plagioclase and brown or green hornblende. At places, anomalous blue penninite forms rounded aggregates in the rock. The plagio-

clase is altered to saussurite without apparent recrystallization nor addition of soda. In some thin sections, it forms a mass of equigranular xenoblastic grains forming the matrix between oval patches of recrystallized quartz, calcite and epidote. Magnetite, sphene and some apatite are typical accessories. Occasionally, the metabasalt contains thin zones of schistose rock varying in texture and composition. Such shredded rock is interpreted as pyroclastic in origin. A zone 200-300 feet thick of apparently massive biotite-rich rocks was observed near the southern contact of the basalt, both east and west of the pluton. In thin section, however, the dark grey to green rock is composed of oval sericite-filled spots surrounded by un-oriented biotite flakes. They probably also represent thermally altered tuffaceous beds (Table IV, No. 36).

Chemical analyses of three representative samples of unaltered basalt (Table IV, Nos. 32 and 34) and metabasalt (Table IV, No. 33) show a low SiO_2 content typical of basalts. The unusually high $\text{Na}_2\text{O}/\text{K}_2\text{O}$ ratio suggests Na - enrichment. Thin section study, however, shows the typical plagioclase to be more sodic than labradorite and indicates no apparent albitization. The low SiO_2 content on one hand and the presence of andesine, biotite and quartz on the other, indicate that the prevalent volcanic rock of this unit is an andesitic basalt.

Sixth Unit (2f)

The sixth unit of the Quebec Group is exposed in a 1.5 mile wide belt north of the volcanic series. Outside the aureole, east of the pluton, the members comprise dark-grey, occasionally calcareous, shales, siltstones

and slates (2f); grey limestone, shale and calcareous siltstone (2f₁); finally, dark-grey and black slates, and calcareous shales (2f₂). They grade westward into calcareous and silty argillites of the outer zone of alteration (2fm). The equivalent rocks in the inner zone are spotted, pelitic and cherty hornfels with minor skarn (2fM); spotted pelitic hornfels with calc-silicate hornfels, skarn and garnet-mica schist (2f₁M); and finally, a spotted, pelitic hornfels with minor calc-silicate hornfels (2f₂M).

As in previous cases, no effective separation of lithologies could be made within the outer zone of the aureole. Here, the main rock type is argillite, i.e. a dark-grey, firmly indurated and slightly recrystallized, massive, occasionally calcareous pelite (2fm). Bedding is, at places, evidenced by faint bands of silty material alternating with darker and finer-grained argillaceous matter. Uniform, although slight, reaction with diluted HCl in samples indicates homogeneously distributed carbonate. In thin section, the rock consists of a microcrystalline mesh of unoriented calcite, muscovite, biotite, feldspar and quartz.

As mentioned above, the eastern contact relations are complex in contrast to the clear-cut truncation of the country rocks at the western periphery of the pluton.

The various kinds of hornfels described below are either within the inner aureole or occur as xenoliths and large inclusions within the plutonic rocks. They range in size from hand specimens to large areas several thousand feet across. The writer was not always certain in establishing the equivalency of the lithologies, since some of the in-

clusions are widely separated from each other and from the truncated parent band. The similarity of the country rocks outside of the aureole made the matching even more hazardous.

Spotted pelitic and cherty hornfels with minor skarn (2fM) are the contact metamorphic derivatives of dark-grey shales, siltstones and shales (Table V, No. 46), east of the pluton (2f). The spotted hornfels is similar in hand specimen and thin section to the altered pelitic rocks described above. They are derived from argillaceous sediments (Table V, Nos. 48 and 49). The cherty hornfels is a grey, faintly banded, extremely hard and streaky rock consisting essentially of a granoblastic mosaic of quartz and some alkali feldspar and micas. It is probably equivalent to a thermally altered siltstone (Table V, No. 47). At places, the spotted hornfels contains mauve and green calc-silicate interbeds (Table V, No. 54).

A few locally derived, angular debris of a grey, porphyroblastic rock were observed near a jeep road, some 2,800 feet SSE of Mt. Auclair. A thin section revealed relatively unaltered andalusite prisms, $\frac{1}{4}$ inch long, embedded in an even-grained matrix of pale-brown biotite, sericite and quartz.

The limestone shale and calcareous siltstone member (2f₁) grade westward through the argillite zone into spotted, pelitic and calc-silicate hornfels skarn and garnet-mica schist (2f₁M). The grey limestone is inter-laminated with shaly interbeds and intensely folded; excellent outcrops are observed along Ruisseau à Galene, S. of lac St. Pierre. At places, the typical rock is a calcareous siltstone or a black, finely laminated silty

shale observed at the eastern periphery of the area (Table V, No. 30).

The limestone beds and the skarn derived from it proved to be an excellent marker horizon. Outstanding outcrops of skarn are observed in a 200-foot wide band extending from 4,000 feet SE of Mt. Auclair northward to 2,000 feet S of the above hill. The whitish-yellow-mauve rock is typically very coarse-grained and consists chiefly of calcite, scapolite, diopside, grossularite-andradite and quartz, with accessory epidote, spinel and occasionally tremolite (Table V, No. 51). The garnet is associated with diopside and is generally riddled with inclusions of quartz and calcite resulting in a poikiloblastic texture.

A conspicuous rock of limited extent is a garnet-mica schist composed of brown biotite and garnet porphyroblasts in a mesh of recrystallized and granulated quartz and sodic plagioclase. Evidently, such garnetiferous schists are derived from Al-rich interbeds (Table V, No. 50). At places, such as on the steep jeep road 2,000 feet SSW of Mt. Auclair, a pelitic garnetiferous rock (Table V, No. 52) is interlayered with greenish, cherty calc-silicate hornfels derived from silty carbonate interbeds (Table V, No. 53).

Dark-grey and black slates and calcareous shales (2f₂) are in immediate contact with the overlying belt of basalt, east of the pluton. Structures on the northward slope of the basalt sill indicate a moderate southward dip of the beds. Farther west, they are altered to undifferentiated argillites (2fm) and then, in the inner part of the aureole, they become an intimately interbedded series of alternating pelitic and calc-silicate hornfels

TABLE V

CHEMICAL ANALYSES OF QUEBEC GROUP ROCKS *

Present No.	42	43	44	45	46	47	48	49	50	51	52	53	54
Sample No.	69f-3995 71-9589	69f-4019 71-9606	69f-3997 71-9616	69f-3998 71-9591	69f-4023 71-9615	69f-3992 71-9586	69f-4008 71-9601	69f-4007 71-6900	69f-3993 71-9587	69f-4000 71-9592	69f-3996 71-9590	69f-4001 71-9594	69f-4003 71-9595
SiO ₂	63.01	39.00	60.21	56.13	68.76	53.05	58.02	56.40	58.28	26.43	38.03	49.65	49.92
TiO ₂	0.73	0.45	0.74	0.75	0.44	0.64	0.79	0.82	0.79	0.42	3.72	0.56	0.52
Al ₂ O ₃	13.26	10.00	14.69	17.06	11.25	14.22	17.73	17.63	21.23	7.80	22.55	10.06	9.40
Fe ₂ O ₃	2.78	0.44	2.01	0.89	3.95	0.72	1.22	0.10	0.98	2.06	3.70	0.71	0.64
FeO.....	3.07	3.22	4.11	6.40	1.86	3.53	3.78	7.34	3.85	1.39	20.58	8.77	4.17
MnO.....													
MgO.....	3.08	2.37	4.16	5.06	1.94	9.60	3.14	4.74	2.94	3.48	0.82	6.96	11.72
CaO.....	2.84	23.24	2.81	5.31	3.98	8.42	0.65	3.51	0.63	39.10	0.33	20.96	19.52
Na ₂ O.....	1.80	0.84	1.05	1.33	2.80	1.38	1.83	1.79	1.54	0.33	0.74	0.68	0.48
K ₂ O.....	2.60	1.74	4.20	3.34	1.37	4.88	4.00	3.94	6.22	0.68	4.72	0.07	0.34
P ₂ O ₅	0.12	0.50	0.07	0.10	0.12	0.04	0.15	0.08	0.04	0.05	0.35	0.11	0.09
V ₂ O ₅	0.017	0.017	0.024	0.028	0.006	0.021	0.023	0.027	0.023	0.023	0.080	0.023	0.028
CO ₂	0.38	14.71	3.59	0.12	1.66	0.99	0.07	0.07	0.05	20.17	0.00	0.24	0.24
Total	93.68	96.52	97.66	96.51	98.13	97.49	91.40	96.44	96.62	101.93	95.62	98.79	97.06
Minor Elements													
Cu	23	14	20	52	14	25	33	33	32	9	22	8	14
Zn	88	51	83	105	52	72	72	70	26	120	56	155	87
Pb	21	40	20	25	19	27	21	37	23	40	25	26	34
Ni	115	52	110	120	68	43	56	130	74	34	85	24	36
Cr	270	90	250	220	230	160	110	210	230	90	190	80	80
V													
W	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Sn	10	5	5	5	5	10	5	10	10	10	15	10	10
Mo	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
U	1	5	3	3	3	n.d.	13	3	3	1	n.d.	3	5
Au	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Ag	0.4	1.9	0.7	1.0	0.4	0.6	0.5	1.2	n.d.	3.5	0.9	1.0	0.7
Pt	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02

42. Dark-grey, silty shale (2h)

43. Black, calcareous argillite (2hm)

44. Black argillite with silty interbeds (2hm)

45. Black, firmly indurated and recrystallized argillite (2hm)

46. Laminated siltstone (2f)

47. Streaky, pelitic and cherty hornfels (2fM)

48. Spotted, pelitic hornfels (2fM)

49. Spotted, pelitic hornfels (2fM)

50. Streaky, quartz-garnet-biotite schist (2f₁M)51. Garnetiferous skarn (2f₁M)52. Pelitic, garnetiferous hornfels (2f₁M)53. Green, cherty, calc silicate hornfels (2f₁M)

54. Calc silicate hornfels (2fM)

* Analyses by the Quebec Dept. of Natural Resources; for location, consult Index Map III.

(2fM). Excellent exposures of the mauve-green-brown rock are observed between Ruisseau à Michaud and the steep hill 2,000 feet north of it. A chemical analysis of a representative sample of the banded calc-silicate-spotted hornfels showed a substantial amount of MgO and CaO (Table IV, No. 31). The band is lost farther north, because of lack of exposure and absence of features distinguishing it from the adjacent hornfels. It is possible, therefore, that some of the large inclusions of hornfels found within the basic and granitic facies of the pluton are part of the above hornfels (2f₂M) rather than of other similar hornfels bands as shown on the map (2f₁M or 2fM). A few outcrops and debris attest to the continuity of the 2f₂M-belt west of the pluton.

Seventh Unit (2g)

A small area in the NE corner of the region is underlain by an approximately 2,000 foot wide belt of clastic rocks exposed on a prominent hill. Only the lower 550-600 feet of the unit are exposed. Bedding and cleavage relationships indicate an open synclinal fold of gently dipping beds plunging ENE. The general aspect is that of an undulating, warped sequence dipping gently north and south.

The unit consists of grey-green, coarse-grained quartz-feldspar sandstone interbedded with siltstone and shale. The shale is green where fresh, but weathers to beige or white. At places, sedimentary structures, such as scour and fill showing distinct pockets of conglomerate in a green or dark-grey shaly matrix, are conspicuous. Irregular and discontinuous intra-formational conglomerate and zones of sedimentary breccia are also observed.

In thin section, the coarse facies is an impure quartz-feldspar sandstone or a quartz-greywacke. The poorly-sorted rock consists of subangular quartz, kaolinized sodic plagioclase, micas, chlorite, opaques and occasional rock fragments embedded in a similar matrix. The feldspars are generally clouded by alteration products, their margins fading into the ground-mass. In two thin sections, fragments of microlite-bearing and heavily chloritized basalt were recognized. Generally, however, the fragments of shale predominate. At places, the aspect is that of a microbreccia.

The above impure quartz-sandstone resembles in many respects the conglomerate-siltstone-shale series (2d) exposed south of the basalt. The presence of basalt fragments suggests that it may be part of a basal, largely eroded sheet (outlier) of clastic sediments overlying the volcanics. Although the contact with the underlying shales, siltstones and slates (2f) was nowhere observed, the possibility of an unconformity between the two belts should be considered. Additional work east of the present area is therefore warranted. Structural data indicate that the regional pattern is that of open, gently ENE plunging folds. The broadly undulating pattern is believed to be the product of the latest deformation.

Eight Unit (2h)

The last, exposed unit of the Quebec Group occupies the northernmost part of, and extends beyond, the area. It comprises calcareous sandstones and siltstones interbedded with grey and black shales and slates (2h). The equivalent rocks in the outer zone of alteration are calcareous and silty argillites (2hm). The corresponding country rocks in contact with the pluton

comprise cherty and pelitic hornfels and some skarn (2H4).

The sandstones are fine-to medium-grained rocks composed of feldspar, quartz and calcite with accessory biotite, and iron minerals. Although calcite is frequently the cementing material, the sandstones vary mineralogically between feldspathic arenite, quartz arenite and calcarenite. Generally, both the calcisiltstones and sandstones show a rusty weathering surface and react more or less vigorously to diluted HCl. Beds may vary in width from a fraction of an inch to 1 foot; generally, however, it is an uniformly stratified rock made up of interlayered sandy, silty and shaly beds (Table V, No. 42). Flow structures, load casts, scour and fill, flame structures and other contemporaneous structures normally associated with flysch terrains are typical features (Plate XV).

The calcareous argillites (2H4) are generally dark-grey rocks of dull luster made up of calcite, muscovite and some quartz and pyrite (Table V, No. 43). The slaty cleavage, common in argillaceous rocks outside of the aureole, is absent here and the rock appears massive. This is primarily due to the interlocking texture of recrystallized quartz. The silty argillites are coarser grained and shiny on the fresh surface as a result of neo-formation of muscovite and biotite. In thin section the rock is a uniformly textured mosaic of muscovite, biotite and recrystallized quartz accompanied by abundant pyrite (Table V, No. 44).

Commonly the silty argillites contain isolated, rusty blebs of partly recrystallized silty material $\frac{1}{4}$ to $\frac{1}{2}$ inch in diameter, enclosed in a darker and finer grained argillaceous groundmass. Those oval patches are remnants

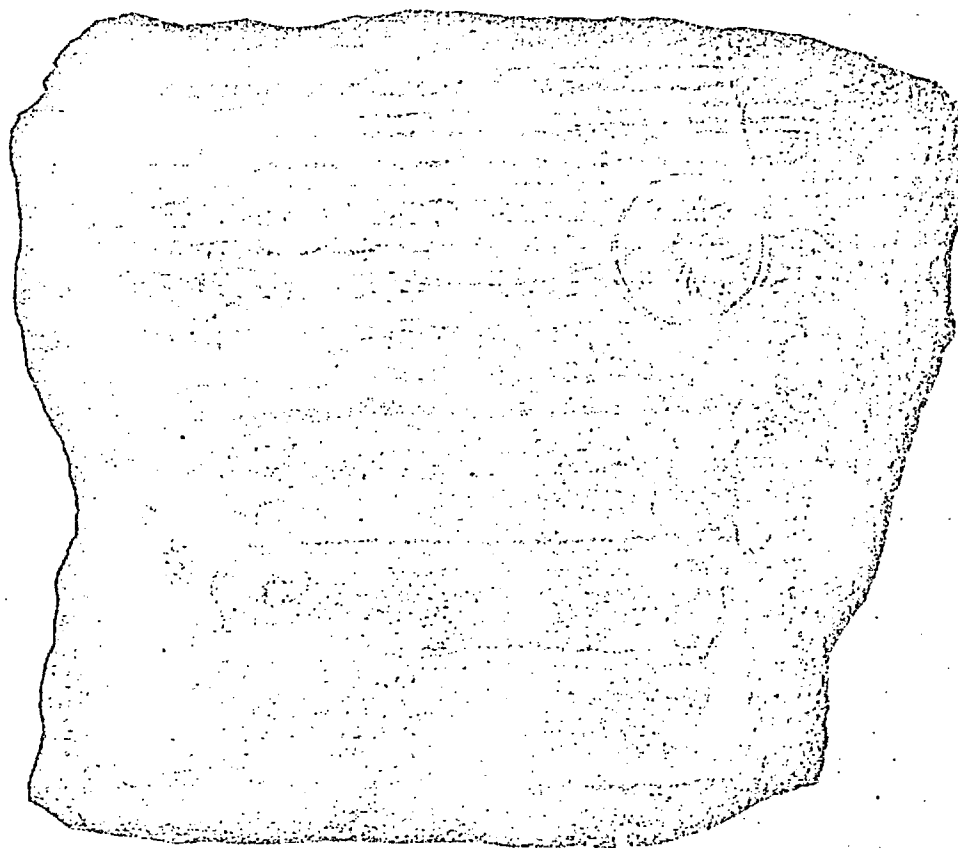


Plate XV. Flame structures at the base of a calcareous sandstone within flysch lithology (2h) (2 miles NE of Lac St. Pierre).

of load casts, the lobes of which became detached from their parent beds. In comparison with argillites of other units, bedding is easily identified here, because of interbedded sandy and argillaceous layers.

The argillites merge into cherty and pelitic hornfels, and minor skarn interbeds (2h1), as the grade of metamorphism increases toward the contact with the pluton. The pelitic hornfels has been described from other units. The cherty variety, however, is somewhat different in that it contains psammitic bands and blebs clearly differentiated from a pelitic groundmass. In thin

section, the protruding lobes of flame structures consist of a mosaic of interlocking quartz with accompanying feldspar, calcite, muscovite, light-brown biotite, pyrite and pyrrhotite (Table V, No. 45)

Skarn was observed at two locations at the northern periphery of the area. Probably part of the same 300-foot wide band, the light-grey skarn is well differentiated from the dark-grey and mauve, massive and spotted hornfels adjoining it. The coarse-grained skarn consists of diopside, scapolite, calcite and magnetite. Some layers contain, in addition, calcic plagioclase, quartz, some epidote and sphene, reflecting more argillaceous parent beds. The skarn above is probably derived from relatively pure calcareous rocks, whereas the massive and spotted hornfels are thermally altered limy argillites.

The southern contact of the 8th unit described above is believed to coincide with the boundary between the "Normanskill" to the north and the "Deepkill" or older to the south (McGerrible-Skidmore, 1967). The latter is likely in part correlative with the lower Ordovician Cap des Rosiers Formation (Kindle, 1938; Enos, 1969).

As mentioned above, rocks of the 7th and 8th-units of the present area show properties typical of the so-called flysch lithology. They are, both compositionally and structurally, quite different from other units but quite similar to the Normanskill flysch sequence lying next to the north to which they are believed, to belong.

First of all, the medium-to-coarse clastic facies is more important in rocks of the 7th-and 8th-units, than in those of other units, where the argillaceous and calcareous facies clearly predominate. The sequence within the last two described units is monotonous, consisting of alternating,

thinly bedded and generally laminated, more or less calcareous, siltstones, shales and sandstones. Although generally devoid of fossils, the rocks of the 7th and 8th units are characterized by a profusion of sedimentary structures, such as scour and fill, asymmetrical folds, convolute bedding, flutes, current ripple-bedding and others.

CHAPTER VI

SILURO-DEVONIAN ROCKS

General Statement

The southern part of the area, representing about 30 square miles, is part of the central belt of Gaspé Peninsula (Map I). It is underlain by a miogeosynclinal assemblage of clastic and carbonate rocks interbedded with volcanic rocks of intermediate composition. Part of the sequence is contact-metamorphosed to hornfels and skarn. Ranging from Lower Silurian to Lower Devonian in age, the assemblage is intruded at places by swarms of N- and NW-trending granophyre and lamprophyre dikes.

The sequence comprises a conformable series of well-sorted sandstones at the base (Val Brilliant Formation) successively overlain by reefy limestones

(Sayabec Fm.), calcareous siltstones (Saint-Leon Fm.), argillaceous limestones (Cap Bon Ami Fm.), silty limestone (Grande Grève Fm.) and finally feldspathic sandstones (York River Fm.). Most formations include interbedded pyroclastic rocks and felsites. This continuous sedimentation reflects a depositional environment that was gradually changing from marine to terrestrial.

A small portion of the Siluro-Devonian sequence is altered to meta-siltstone, hornfels and skarn. The well-defined alteration zone is believed to represent the contact aureole of a buried igneous offshoot of the Monts McGerrigle granitic pluton.

The above assemblage and the underlying Awantjish Formation (not exposed in the map area) overlies unconformably the Quebec Group. In contrast to the severely disturbed Cambro-Ordovician rocks, the Siluro-Devonian sequence is characterized by broad folds and simple structures. Their thickness in the present area is 5,750-7,700 feet, which roughly represents 1/3 of the total thickness estimate of the Siluro-Devonian pile in Central Gaspé. Finally, the assemblage would have been thrust northward over the northern belt along a regional E-W trending fault. North-and NW trending transcurrent faults with small horizontal displacement would be the most recent structures observed in the area.

Val Brilliant Formation

The Val Brilliant Formation is remarkably uniform in structure and composition throughout northern Gaspé. It extends from west of Matapédia Lake (Crickmay, 1932, p. 374) to the Dartmouth Valley in the Madeleine River area (McGerrigle, 1959, p. 26-28; Lajoie, 1962, p. 4), a total distance of over 180 miles. Stratigraphically, the Val Brilliant is conformably underlain by the Awantjish Formation and overlain by the Sayabec Formation.

The Val Brillant formation is 250 to 800 feet wide and is traceable by outcrop, debris and topography from north of Earter lake to the eastern boundary and beyond. Being composed of resistant rocks, it forms two elongated and narrow ridges the continuity of which is offset here and there by NW-trending cross-faults.

The Val Brillant is typically a medium-grained, white, creamy to purplish weathering quartz arenite or orthoquartzite. At the base of the formation, quartz-sandstone beds 10 inches thick are essentially composed of clear, rounded quartz grains tightly cemented by authigenic silica. At places, conglomeratic layers 3 to 5 inches thick are present. Toward the top the rock has a locally sugary appearance being composed of well-sorted and subrounded quartz grains embedded in a largely calcareous matrix. Near the contact with the overlying Sayabec Formation, the Val Brillant contains an increasingly larger proportion of calcareous matter. At places, unidentified organic fragments of about the same size and roundness as the quartz grains are present. Small pyrite cubes and limonite stains are common. Typically, certain beds have a purplish hue due to finely distributed hematite.

Bedding is well defined striking NNE to ENE and dipping 10° to 30° to the SE.

Although the contact with the underlying Awantjish is nowhere exposed, it is safe to assume that the northern ridge constitutes the base of the formation. No Awantjish rocks have been found, although they are recorded west of the area (Robert, 1966a, p. 5; 1966b, p. 5; Ollerenshaw 1967, p. 95). Actually, scattered, angular debris and structural considerations suggest that the Val Brillant overlies unconformably interbedded limestone-shale and quartzites

of the Quebec Group. The upper contact with the Sayabec Formation is gradational and conformable.

The thickness of the Val Brilliant in the area is estimated to be 250 to 300 feet, comparable with the values reported farther west (Béland, 1960, p. 4; Lajoie, 1962, p. 3; Ollerenshaw, 1967, p. 8). Reconnaissance traverses outside the area revealed thinning of the formation to the east (150 - 180 feet). McGerrigle reports an approximate thickness of 10 to 75 feet in the Madeleine River area (1959, p. 27).

The thoroughly clear and sorted character of the rock, at least in the upper part of the formation, suggests a very stable, probably marine environment of deposition. Furthermore, the well-rounded grains suggest that it is a product of several cycles of erosion and deposition in essentially well-oxidizing conditions.

Paleontological age determinations from outside the area place the Val Brilliant Formation into the Late Llandoveryan-Early Wenlockian stage (Burk, 1964, p. 440; Boucot, 1965, p. 2297).

Sayabec Formation

As in other parts of northern Gaspé, the Sayabec rests conformably on the Val Brilliant and is overlain conformably by the Saint-Léon Formation. It is exposed in the low ground along the Madeleine River valley, west of Barter Lake, then swings ENE to form two parallel-trending ridges, easily traceable on aerial photographs.

The rock is generally a buff to gray, fossiliferous (reefy), and common-

ly conglomeratic limestone. Although a complete section of the formation was nowhere seen, it appears to consist of quartz-rich and dolomitized limestones at the base, overlain by limestone pseudoconglomerates and reefy limestones, and succeeded by silty limestones and fossiliferous limestone conglomerates at the top.

The Sayabec Formation occupies the northern limb of the Lesseps syncline. Except where slightly disturbed by cross faults, the beds dip consistently 10° to 30° southeast.

The basal zone consists of cream-to-buff colored quartz-bearing limestone, which, in the western part of the area, is extensively silicified and dolomitized. In some outcrops exposed on the south bank of Madeleine river, 800 feet west of the area, the thick-bedded, well-sorted rocks consist of rounded quartz grains cemented by a calcareous matrix. Similar rocks occur in an E-W-trending fault zone at the south western boundary of the area. Here, the basal Sayabec rocks have been altered by intense silicification and dolomitization to buff, limy quartzites, in which partly replaced remnants of corals and algae can still be recognized.

There are good exposures of the middle part of the Sayabec succession on both banks of Madeleine river and east of Barter's camp. The rocks are in the eastward extension of the above-mentioned fault zone and consist of medium- to coarse-grained buff-weathering dolomite intruded by acidic sills and dikes. At the Lepage Road - Madeleine River intersection (Fig. 1), an E-W trending, 40-foot-wide acidic sill is flanked by 20 to 40 feet of gray, silicified and disturbed limy rocks containing here and there faint remains of

corals and algae (Table VI, No. 55). Abundant flow structures in the contact zone and the chaotic aspect of the material suggest that this is a remobilized and injected rock. A 90-foot-wide area of almost flat-lying, 6-inch-thick dolomitic beds adjoins it immediately to the south (Table VI, No. 56). The rock contains sporadic lenses and pockets of white, recrystallized limestone. At one place, an upward swelling, irregularly shaped inclusion of marble, approximately 25 feet long and 5 to 10 feet wide, displays faint, but definite concentric layers attributed to algae growth (Table VI, No. 57). Commonly, such reef pockets are partly or entirely surrounded by seams of evidently injected, dark green basic material (Table VI, No. 65). There is enough evidence here to suggest that iron- and magnesium-rich solutions have been introduced and that selective replacement of the Sayabec limestone has taken place. The reefy parts were not affected by the solutions, probably on account of their massiveness or superior degree of compaction, but simply recrystallized to medium-grained marble.

Immediately overlying the dolomite is a series of limestone pseudoconglomerate beds forming structures typical of biohermal limestone.

A few hundred feet east of Barter's camp, the beds are made up of finely comminuted, possibly autochthonous organic debris, characteristic of reef talus. Excellent specimens of well-preserved halysitids, a foot or so in diameter, and stromatolites have been observed here and there. The contacts between the 1- to 2-inch-thick beds are largely gradational and wavy. On Madeleine river, south of the main fault zone, the beds strike east and dip consistently 15° to 25° degrees south. A striking feature of the Sayabec

fragmental limestones in this particular area are the abundant, rectilinear, N-to NW-trending fractures. They are 1/16 to 1/8 inch wide and are generally filled with limonite-rich dolomitic or ankeritic material.

Northwest of Petit Lac Madeleine, the Sayabec Formation comprises mainly limestone pseudoconglomerates and fragmental limestone made up almost entirely of recrystallized crinoid stems and stromatolites.

Although the actual boundary between the Sayabec and the overlying Saint-Léon is concealed, the contact is almost certainly a conformable one. In fact, it appears that there is a 100- to 15-foot-wide contact zone of slightly silty and more evenly bedded limestones between the two formations.

The thickness of the formation in the area is estimated to be between 600 and 900 feet. Thicknesses reported in the literature vary considerably, but, general speaking, they decrease eastward. The formation is 1,000 to 2,000 feet thick in the Matapédia-Témiscouata region (Stearn and Hubert, 1966, p.33) and only 200 feet thick in the Madeleine River area (McGerrigle, 1959, p. 27).

The age of the Sayabec appears to extend from Wenlock to Lower Ludlow (Naylor and Boucot, 1965, p. 159; Ollerenshaw, 1967, p. 111).

Saint-Léon Formation

Two northeasterly trending belts of Saint-Léon rocks are exposed in the southern part of the area. The northern one, approximately 3,000 to 4,500 feet wide, is located on the northern limb of the Lesseps syncline; the other, 2 to 3 miles wide, forms the core of a complementary, northeasterly plunging anticline, some 3 miles to the southeast. Apart from a few exposures along

Lesseps creek and the Park road, the southern belt is virtually devoid of outcrops.

The formation comprises limestones and siltstones inter-tonguing with zones of pyroclastic material and felsites. The unit has been subdivided into a lower (mostly calcareous rocks) and an upper section (mostly calcareous siltstones). Both sections contain felsites and pyroclastic zones. Part of the northern belt comprises metasiltstones and cherty hornfels, which are exposed in a well-defined $\frac{1}{2}$ mile wide zone trending E-W. They represent contact-metamorphosed siltstones, felsites and pyroclastics. A characteristic of all sedimentary Saint-Léon rocks is the continuous and even stratification marked either by delicate laminations or by alternating siltstone-limestone beds.

Sedimentary Rocks

Lower Section

The lower part of the formation consists of dark-gray, finely laminated limestone beds, interbedded limestone-siltstone, and limestone pseudoconglomerates. Several zones of pyroclastic rocks of acid to intermediate composition are also present. Estimated to be 500 to 800 feet thick, this part of the formation represents a facies gradational with the underlying Sayabec Formation.

Some of the best exposures of the laminated limestones occur along Madeleine river, west of Barter lake, where they rest conformably on Sayabec rocks. The beds strike east and dip slightly south; some of the more massive beds contain abundant crinoid stems. A few outcrops of the same type of limestone occur about 2,000 feet SW of the Bélanger Road - Deslandes-Lesseps Town-

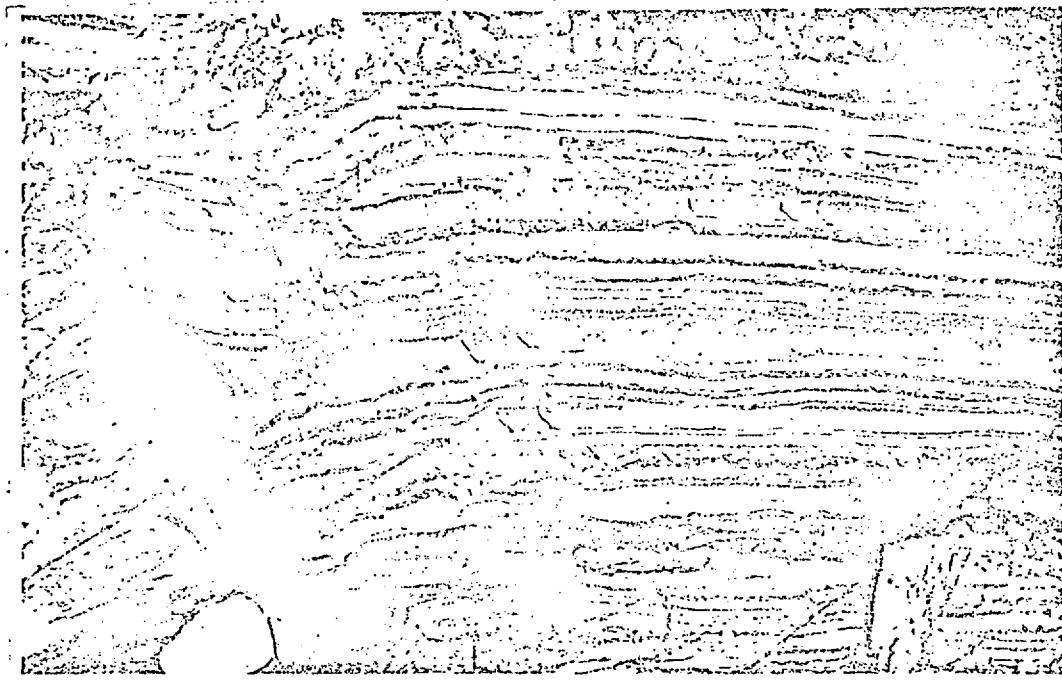


Plate XVI. Banded limestone-siltstone sequence in the lower part of the Saint-Leon Formation (1.5 miles WSW of Barter lake)

ship intersection, east of the area. The lithology of these outcrops and the fact that they are located near the axial part of an anticline suggest that they also belong to the basal part of the Saint-Léon Formation.

Stratigraphically above the limestone beds is a conspicuously banded limestone-siltstone sequence, outcrops and debris of which are particularly well shown in a cut on the Lepage road, immediately west of the area. The sequence is made up of 1- to 2-inch thick, slightly wavy, grey to blue limestone beds alternating with $1/8$ to $1/2$ inch-thick laminated argillite beds. At places, the outcrops have a ribbed appearance owing to preferential weathering of the limestone layers (Plate XVI). The sequence contains a lens, about 100

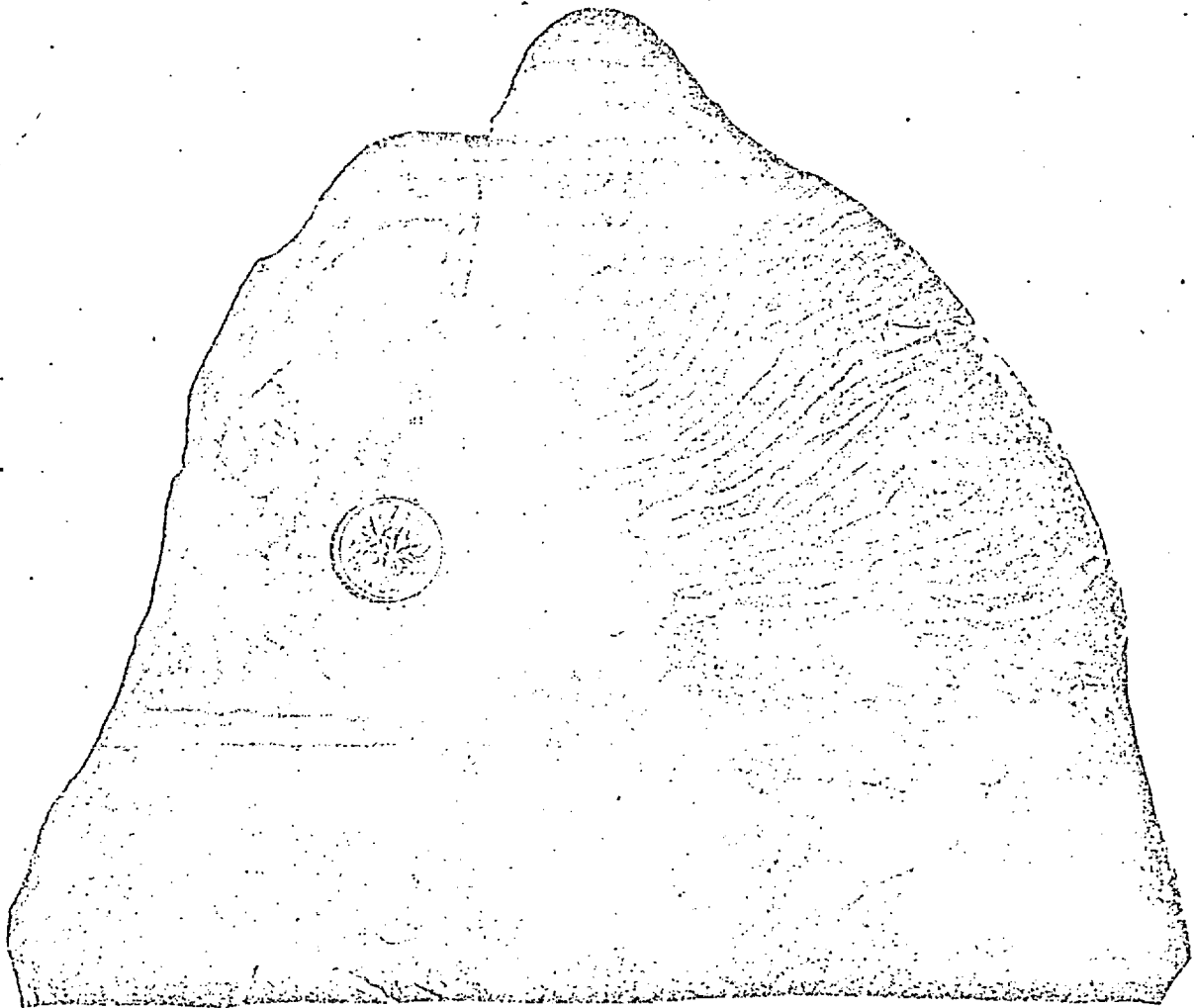


Plate XVII: A crinoid stem and cup from the fossiliferous "Lesseps Brook" locality. (Road cut at the Lesseps Creek - Park Road intersection, Lesseps Twp.).

feet long, of highly fossiliferous beds, containing mainly crinoid and favositid fragments. Débris, almost in place, of a similar sequence occur 2,000 to 3,000 feet NE and NNE of Barter lake.

Limestone pseudoconglomerate overlies the limestone-siltstone sequence. At certain places, as near a trail 2,500 feet NNW of Petit Madeleine lake, the rock is made up of disconnected limestone lenses, 1 inch thick and 2 to 3 inches long, surrounded by silty calcareous material. In a series of outcrops making up a section several tens of feet thick 1 mile N of Petit Lac Madeleine, these lenses may be traced laterally and vertically into a succession of ribbed limestone-argillite beds.

Upper Section

The upper part of the Saint-Léon succession, estimated to be 1,000 to 1,700 feet thick in the northern belt, but presumably much thicker in the southern one, comprises, in decreasing order of importance, the following rocks: grey to greenish calcareous siltstone; dark grey silty limestone, pyroclastic rocks and minor felsites; and finally, red, silty shales. As the overlying Cap Bon Ami Formation is approached, the silty limestones become gradually darker and more argillaceous.

The calcareous silstones are particularly well exposed near the intersection of Lesseps creek and the Park road. They are brown weathering and evenly laminated. Muscovite flakes are common on the separation planes and the rock breaks into large flat flagstones. Sedimentary structures include small-scale crossbedding and convolute bedding suggesting penecontemporaneous slumping. Several measurements of current laminations indicate that the probable source of sediments was to the SE. The rock is fossiliferous at places, containing monograptids and well-preserved crinoids (Plate XVII). Excellent exposures of the upper Saint-Léon occur also along the segment of road parallel

to Lesseps creek. The grey, silty limestone is twisted and contorted by primary slumping and sliding, and the strike and dips of the beds are extremely irregular. A short description of the fossiliferous rocks at the "Lesseps Brook" locality is given by Cumming (1959, p. 31-32).

An outcrop of silty and argillaceous limestone, which the writer believes to belong to the Saint-Léon Formation, was found 3,000 feet NW of the northern tip of Madeleine lake. The attitude of the beds, which strike NE and dip 30° SE, and the relation of cleavage to bedding indicate that the outcrop is part of the northern limb of the Lesseps syncline.

Pyroclastic Rocks and Felsites

With the exception of a few felsite sheets of rhyo-dacitic composition most of the volcanic rocks of the Saint-Léon consist of pyroclastic deposits. The middle and upper part of the formation contain the most significant bodies of pyroclastics, although some are also interbedded with siltstone-limestone and limestone pseudoconglomerates of the basal part of the formation.

The best outcrops of pyroclastics forming part of the basal Saint-Léon are observed along Madeleine river, west of Barter lake, and north and south of Lepage road, immediately west of the area. On the fresh surface, the rock is greenish to grey and hard; upon weathering, it becomes very porous and characteristically white or creamy, as a result of kaolinization.

Although they have not been separated on the map, two main types of pyroclastic material, based essentially on composition and texture, are present. Particularly well-exposed immediately west of Petit Lac Madeleine and

SE of Barter lake they are well-layered rocks interstratified with silty limestones and calcareous siltstones.

The first type, which is of common occurrence, is a tuff made up of small, dark, rectangular crystals or angular crystal fragments embedded in a glassy, aphanitic matrix. Unoriented and 1/16 to 3/16 inch in diameter, these particles are invariably surrounded by a thin, white alteration film, a feature commonly found in rocks affected by deuteric alteration. Small, brilliant and apparently unaltered quartz crystals or glass shreds are usually present. The rock generally exhibits a notable streaky lamination or fluidal banding and is identified as welded tuff.

The other type of pyroclastic material is a green, white-weathering pisolitic tuff made up entirely of concentrically laminated pellets which may reach 3/16 inch across. Some of the pellets are altered to clay minerals or surrounded by films of this material (Table VI, No. 61).

Another east-striking band of pyroclastic rocks is exposed south of the Bélanger road, NW of Crochet lake.

The above described pyroclastic deposits, which range from 20 to 250 feet in thickness, are undeniably an integral part of the Saint-Léon Formation. Owing to insufficient continuity of outcrops, determination of lateral or vertical facies variations within the deposits was not possible. This lack of outcrops may also explain their apparent absence on the southern flank of the Lesseps syncline.

Sheets of grey to beige, layered felsites are interstratified with basal Saint-Léon 2,000 and 3,000 feet west of Barter lake. The upper and lower con-

ECOLOGY OF THE BARKER SHOWING AND VICINITY ALONG RIVIÈRE MADELEINE

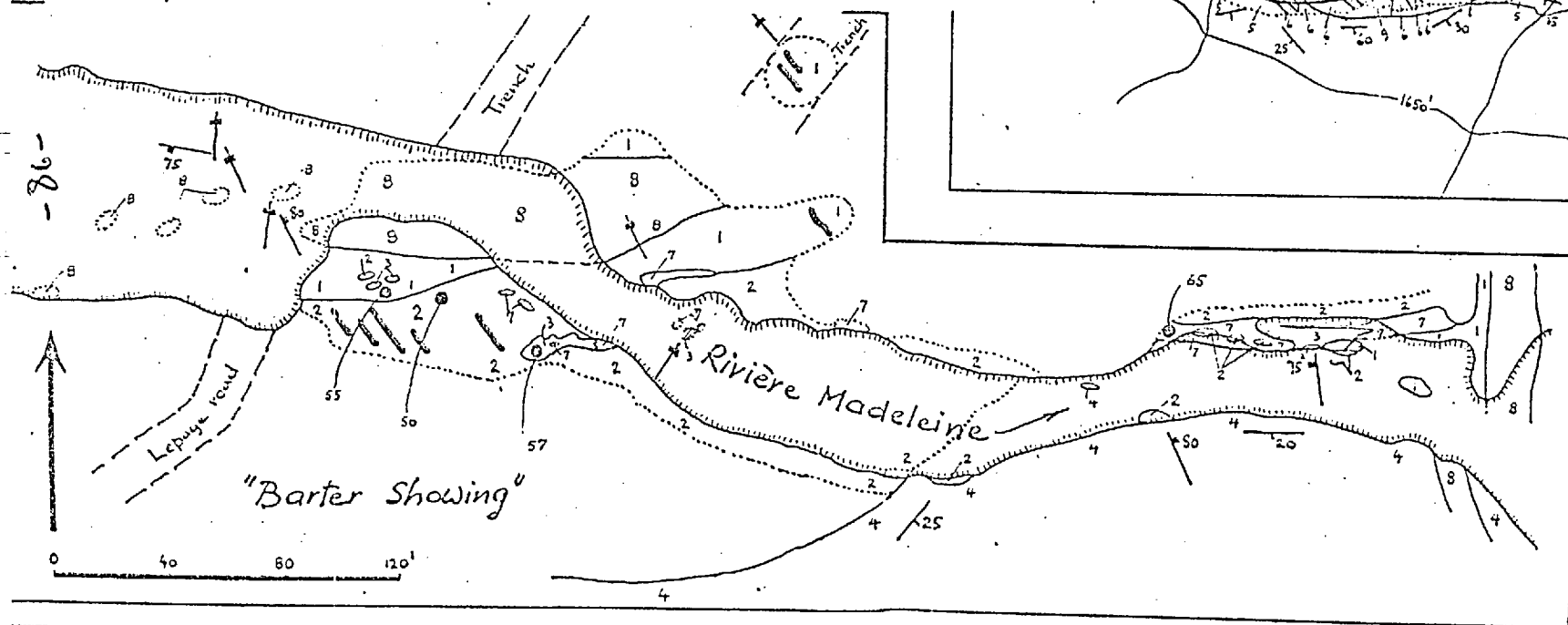
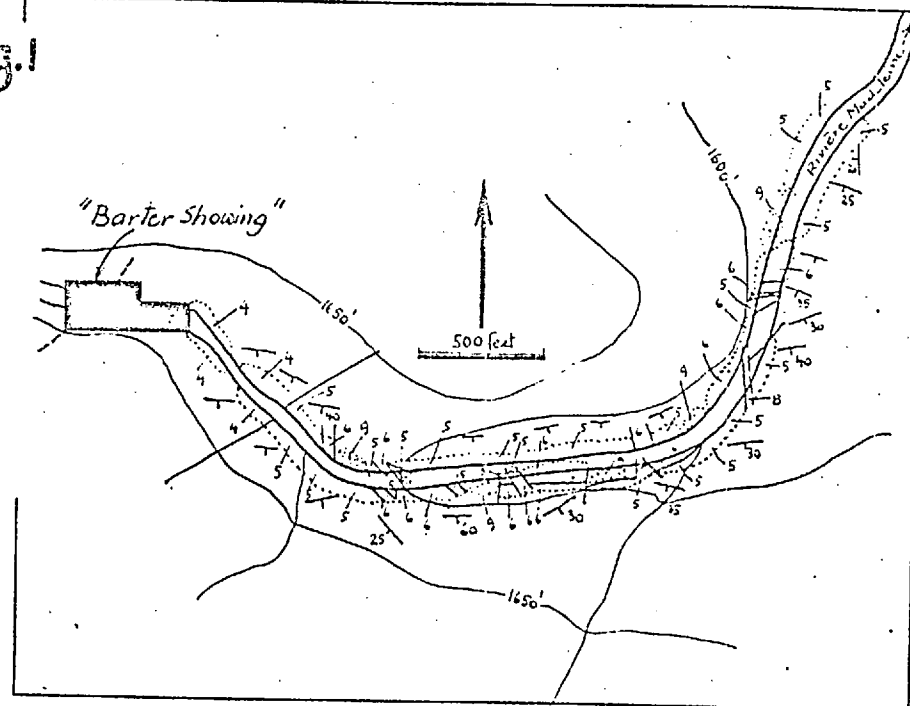
- 9 alluvium
8 quartz-feldspar porphyry
7 f. grained basic injections
ST. LEON FORMATION
6 pyroclastic beds and felsite
5 laminated limestone

SAYABEC FORMATION

- SAYABEC FORMATION**
- 4 reefy limestone & limestone congl.
 - 3 limestone and marble
 - 2 dolomite-ankerite-bearing rock
 - 1 silicified carbonate rock
-  jointing
 sulfide-bearing quartz veins
 chemical analysis
 river bank

-  outcrop outline
-  geologic contact
-  bedding
-  jointing
-  sulfide-bearing quartz veins
-  chemical analysis
-  river bank

Fig. 1



H.S. de Zeeuw, 1972

tacts are marked by a slight alteration zone in the adjacent silty limestone. In hand specimen, the rock consists of tightly packed subrounded vitreous phenocrysts up to 1 mm in size, surrounded by thin concentric layers of dull white material (Table VI, No. 62).

Embedded in a cryptocrystalline groundmass, they give the rock a perlitic structure reminiscent, in places, of pisolitic sedimentary rocks. Another lithologically similar rock cuts the Grande Grève in the immediate vicinity of Parent camp.

With few exceptions, the felsite bodies are generally concordant and have evidently undergone the same type of metamorphic alteration as the enclosing sediments.

Alteration

The belt of metasiltstones and hornfels of the Saint-Léon Formation, some 2,500 feet wide, is the eastern extension of a much wider zone reported from west of the area (Robert, 1966a; 1966b, 1967). Owing to their superior hardness, they underlie an EW-trending ridge, which rises sharply southward from the low areas of the Madeleine River valley to the north. An E-facing scarp, 500-800 feet west of the Bélanger road, represents the abrupt eastern boundary of the ridge and alteration zone.

The transition from siltstone to metasiltstone to hornfels can be well observed over a distance of 2,000 feet from the Bélanger road southward, immediately west of the area. A few 100 feet south of Bélanger road, the Saint-Léon consists of an indurated, dark-grey, limy metasiltstone in which

the characteristic fine and regular laminations are perfectly preserved (Table VI, No. 58). Farther south, the laminations give place to alternating, light-green and whitish irregular streaks and bands of recrystallized quartz and feldspar with calcite and tremolite. With advanced metamorphic segregation the bands desintegrate into interconnected bands varying from microscopic to 1/8 inch in diameter (Table VI, No. 59). At places, the hard, spotty rock is entirely made up of such small, ovoid knots of calcite and tremolite embedded in a light-grey or greenish, aphanitic matrix of quartz, feldspar, calcite and biotite (Table V, No. 60). The greater part of the altered Saint-Léon rocks are white to beige, massive and cryptocrystalline hornfels with a conchoidal fracture. Some hornfels have a considerable amount of diopside and granoblastic quartz. At places, the rock is cryptocrystalline and flint-like with the dull early luster typical of porcellanites. In thin section, such massive rocks are made up of microgranular quartz-calcite and opaque minerals with occasional diopside, scapolite and biotite.

The alteration pattern is complex. While it is generally true that the grade of metamorphism is less pronounced at the periphery of the alteration zone than in the center, it is common to find pockets of unaltered material side by side with completely reconstituted rocks. Although original composition is an important factor in determining the degree of alteration reached, the patchy distribution of altered rocks is indicative of a complex injection pattern. No large igneous masses capable of such extensive alteration are exposed in that particular area.

Another difficulty is to determine the parentage of the hornfels.

- 67 -
49-
TABLE VI

CHEMICAL ANALYSES OF SAYABEC, ST. LEON AND
CAP BON AMI ROCKS AND THEIR METAMORPHIC EQUIVALENTS

Present No.	55	56	57	58	59	60	61	62	63	64	65	66
Sample No.	67g-13019	67g-13015	67g-13016	67g-13029	67g-13022	67g-13028	67g-13027	67g-13030	67g-13026	67g-13025	67g-13018	67g-13024
SiO ₂	62.00	0.54	- -	64.00	58.90	60.59	77.73	74.34	60.60	45.35	39.44	74.35
Al ₂ O ₃	10.50	- -	- -	13.79	10.19	10.18	12.15	13.22	13.79	7.12	18.41	13.96
FeO	0.95	4.38	0.20	4.46	2.12	2.25	0.22	0.15	2.13	4.84	6.83	0.56
Fe ₂ O ₃	0.36	- -	- -	0.64	0.40	0.87	0.52	1.48	0.47	0.55	0.90	0.95
CaO	10.50	29.47	53.80	3.87	8.16	9.41	1.59	0.65	7.60	24.55	13.71	0.10
MgO	1.86	17.78	0.50	4.25	7.21	7.21	0.81	0.49	5.09	3.85	6.28	0.71
Na ₂ O	0.32	- -	- -	2.04	2.76	1.77	3.20	1.32	2.38	1.97	0.61	2.84
K ₂ O	3.50	- -	- -	2.96	4.08	4.68	2.14	4.88	4.06	0.30	3.50	4.20
CO ₂	- -	0.49	0.084	- -	- -	- -	- -	- -	- -	- -	- -	- -
EL	- -	0.002	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
CO ₂	- -	46.15	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

5. Sayabec silicified limestone ("Barter Showing")
6. Dolomite-ankerite-bearing rock (Sayabec) ("Barter Showing")
7. Coarse Sayabec marble ("Barter Showing")
8. Laminated metasiltstone (Saint-Léon) (SSW of "Barter Showing")
9. Spotted metasiltstone (Saint-Léon) (Near Terra Nova adit entrance)
10. Spotted, altered Saint Léon siltstone (SSW of "Barter Showing")
1. Layered pisolitic pyroclastic rock (Saint-Léon) (SW of Barter Lake)
2. Layered pyroclastic rock or felsite (Saint-Léon) (WSW of Barter Lake)
3. Altered green cherty hornfels (originally metasiltstone, Saint-Léon) (SSW of Barter Lake).
4. Garnetiferous calc-silicate hornfels or skarn (Cap Bon Ami) SSW of Barter Lake
5. Fine-grained basic injection into Sayabec ("Barter Showing")
6. Felsite (rhyo-dacite or pyroclastic rock) (Saint-Léon) (SE of Barter Lake)

Pyroclastic rocks form a considerable part of the Saint-Léon formation, particularly west of the area. Both, siltstones, felsites and pyroclastics, alter to an identical light-grey, greenish hornfels indistinguishable in hand specimen. The occasional relics of recrystallized quartz and feldspar in some sections suggest a faint felsophyric texture indicative of volcanic parentage. The widespread kaolinization observed on the weathered surface of such hornfels is another supporting evidence of volcanic derivation. Chemical analyses indicate that in comparison to metasiltstones, the pyroclastic rocks and felsites are richer in silica and alumina, and are relatively impoverished in CaO, MgO and iron (Table VI, Nos. 61, 62, 63 and 66).

Thickness and Age

The total thickness of the Saint-Léon ranges from 1,500 to 2,500 feet in the northern limb of the Lesseps syncline, but it may be greater in the broad anticlinal fold to the south. Robert (1967, p. 6) estimated a maximum thickness of 4,050 feet in the Lesseps Creek area, immediately to the west, and McGerrigle (1959, pp. 26-27) gives an approximate thickness of 1,000 feet for Saint-Léon-like rocks, some 10 miles NE of the area.

The age of the Saint-Léon Formation is controversial. A recent re-study of graptolite fauna of the "Lesseps Brook" locality disclosed that it may range from Late Llandoveryan to post-Ludlovian (Boucot, 1965, p. 2297; Berry, 1965, p. 2304). In other words, part of the Saint-Léon may reach up to Lower Devonian.

Cap Bon Ami Formation

Rocks of the Cap Bon Ami Formation are exposed in the southern part of the area south of Madeleine river. Gently folded about northeasterly trending synclinal and anticlinal axes, the formation consists of three bands. The exact upper and lower contacts of the Cap Bon Ami were not located in the area. It is fairly certain, however, that the contacts with the underlying Saint-Léon and overlying Grande Grève Formations are conformable and transitional, as shown by débris and the structural attitude of enclosing rocks. Owing to fault displacements and low dips, the width of the bands may reach 2,000 to 2,500 feet, as can be observed north of Crochet lake and at Lesseps creek.

The formation comprises essentially sedimentary rocks, interbedded at places with volcanic material. Being less resistant than the adjacent Grande Grève or Saint-Léon, it occupies valleys and swampy areas and is consequently very poorly exposed, except where it is altered to hornfels.

Except for narrow, argillaceous or silty facies bordering Grande Grève or Saint-Léon, the typical Cap Bon Ami is a fairly massive, soft, argillaceous and carbonaceous limestone. The rock is typically dark-grey to black on fresh surface, but weathers to a faint greyish or brownish cast. Bedding is not conspicuous, except where the rock is altered, presumably as a result of metamorphic segregation and recrystallization. Where disturbed, the rock is commonly graphitic or brecciated and veined by calcite.

Northwest of Madeleine lake, the middle of the Cap Bon Ami section contains a 300-foot-thick sheet of heterogeneous acidic volcanic rocks. At some places, the fine-grained, grey, pink or greenish rock is massive and

feldspar- and quartz-rich, suggesting a dacitic or rhyo-dacitic composition. Commonly, however, the porous rock contains tiny, spheroidal and concentric structures exhibiting a discontinuous lamination. Small, vitreous aggregates are embedded in a fluidal aphanitic groundmass and are commonly surrounded by a thin, dull white alteration rim. At one place, faint but distinct columnar joints were noted.

Although contacts with the sedimentaries were nowhere observed, the attitude of the banding indicates that the sheet is conformable. The textural and structural variations observed in it may be the result of gravity sorting of the fragmental material or may represent idfferent parts of a thick ash deposit. In many aspects, the above-described volcanic rocks are identical to the pyroclastics and felsites encountered in the underlying Saint-Léon.

Apart from the volcanic fragmental rocks just described, the Cap Bon Ami comprises several thin horizons of unquestionable lithic or crystal tuff, mostly in the upper part of the section.

Surface widths and regional dip suggest a thickness of 400 to 500 feet for the formation. This is in agreement with the values recorded to the west (Robert, 1967, p. 6). The formation appears to thicken in the Madeleine River area to the east, where McGerrigle reports an estimated thickness of about 2,000 feet (1959, p. 31).

Recent paleontological studies seem to confirm the view that the Cap Bon Ami is of Lower Devonian age, more precisely, equivalent to the Gedinian (Boucot et al., 1967, p. 11).

Alteration

The southern boundary of the alteration zone cuts diagonally across the Cap Bon Ami, NW of Crochet lake. Some excellent outcrops of black, soft, argillaceous limestone are seen on an exploration roadcut, immediately south of the alteration zone, near the western limit of the area. As the rock débris is traced eastward into the alteration zone, the Cap Bon Ami becomes a slightly indurated and bleached massive argillite, which grades over a few feet into hornfels. Commonly, the hornfels consist of light-grey or purplish bands or ill-defined streaks or hues intertonguing with dark cryptocrystalline layers. In thin section, the latter consists chiefly of quartz, K-feldspar and minute unoriented, brown biotite flakes, an assemblage typical of altered pelitic rocks. The lighter streaks contain diopside and clinozoisite, beside quartz, occasional garnet, chlorite and iron minerals. It is a calc-silicate hornfels evidently derived from argillaceous and calcareous beds within the Cap Bon Ami Formation.

The typical altered equivalent of the Cap Bon Ami impure limestone is found farther inside the aureole. It is a grey-green, porous, yellow-brown weathering rock readily reacting to diluted HCl. It contains irregularly shaped knots of coarse calcite and small, greenish and reddish euhedral garnet of the grossularite-andradite series. At places, the calcite is leached out leaving a vuggy rock with a deeply weathered, earthy surface. Under the microscope some large crystals of idocrase were also observed, enclosing subhedral clinozoisite. In some sections, diopside, scapolite and calcite are associated with accessory sphene, iron minerals and sulphides.

Where the parent rock was more pelitic, a lighter colored, occasionally garnetiferous, and much harder and massive rock developed. It is a calc-silicate hornfels that does not react to acid and that is evidently a derivative of Al-rich calcareous rocks.

Grande Grève Formation

The Grande Grève Formation occupies in the southern part of the area a 1.5- to 2.0-mile-wide, northeasterly trending axial belt of the Lesseps syncline. Traverses outside the area revealed that another band of Grande Grève, located on the southern limb of an anticline, crosses the extreme SE corner of the area. The Grande Grève overlies the Cap Bon Ami rocks and is itself conformably succeeded by the York River Formation.

The Grande Grève Formation is characterized by an interfingering lithology comprising chiefly limestones. The base is made up of silty or argillaceous limestone with minor quartz arenite and conglomerate or coquina; siliceous and silty limestones form its upper part. The Grande Grève also includes several discontinuous sheets of pyroclastic rocks and felsite, exposed on the northern flank of the Lesseps syncline and concentrated in the basal part of the formation.

The basal limestone is commonly a thinly to coarsely laminated rock, dark gray to bluish when fresh. Owing to leaching of the carbonate, the exposed surface is usually brown, porous, and gritty to the touch. Weathering penetrates deeply into the rock, leaving irregular grey-bluish patches or lenses of unaltered material. An outstanding feature distinguishing Grande

Grève limestone from Cap Bon Ami or Saint-Léon lithology is their irregularly undulating planes. Commonly, the rock consists of slightly pinching and swelling limestone beds, $\frac{1}{2}$ to 6 inches thick, alternating with thinner silty or argillaceous layers.

The basal Grande Grève rocks on the northern limb of the Lesseps syncline are lithologically somewhat different from those on the southern limb. On the northern flank, the lower part of the Grande Grève is a grey quartz arenite, 50 to 100 feet thick and 100 to 200 feet stratigraphically above the base of the formation. This arenite is exposed 6,000 feet due west of Crochet lake and its débris can be traced eastward almost to Madeleine lake. The fine- to medium-grained rock is well-sorted and pure, consisting of tightly packed, subangular quartz grains and very little matrix. At places it is peppered with small limonite stains.

Overlying the quartz arenite is a zone, perhaps 100 feet thick, of lithic tuff. This is evidenced by the abundant float encountered 2,000 feet WNW of Crochet lake and 2,500 feet NW of Madeleine lake. The grey, fresh-looking rock is finely laminated and, locally crossbedded. It forms tapering lenses, $\frac{1}{2}$ to 1 inch thick, intertonguing with irregular pockets of breccia. At places, slightly oriented spindle-shaped fragments and subangular quartz aggregates produce a faint primary layering.

Other thin, conformable tuff horizons are exposed west of Madeleine lake, approximately 500 feet above the base of the formation. At one locality, about 1,000 feet west of the lake, the lithic tuff is associated with roughly layered pisolitic tuff, consisting of ash pellets in a siliceous flow matrix.

The large surface expression on the map of the pyroclastic zone NW of Madeleine lake is mainly the result of structure and topography; in fact, this conformable zone is less than 100 feet thick and dips 20° - 30° SE.

The basal beds of Grande Grève on the southern limb of the Lesseps syncline occupy an approximately 500-foot-wide band extending from Lesseps brook northeastward to the southern tip of Madeleine lake. Outcrops occur on the road leading to Parent camp, 3,000 feet SW of Long lake, at Gagnon camp, and at the road fork SE of Madeleine lake camp.

The rock is dark grey on the fresh surface and consists mainly of angular fossil fragments embedded in a fine-grained argillaceous or silty matrix. The weathered surface is a characteristic limonite-brown and generally coarsely porous owing to leaching of the carbonate. The rock commonly contains angular fragments of black shale varying in size from microscopic to 1 inch across. On the road to Parent camp, 2-inch-long lenses made up of comminuted rock debris are embedded in a matrix of siliceous composition. A few small coal particles have been noted. The outcrop near Gagnon camp shows undulating and contorted bedding planes. At places, the rock has the appearance of a typical coquina.

The continuity of this horizon marker and its fixed stratigraphic position indicate that the above-described fragmental rock is not a fault breccia. Furthermore, the angularity and variety of its components, as well as its association with slumped beds, suggest that it is a sedimentary breccia, formed as a result of possibly repeated submarine slumping and gliding. Lithologically similar and stratigraphically equivalent "key beds"

have been reported by Robert in the Mount Hog's Back region (1966a, pp. 7-8), some 10 miles west of the present area.

A large part of the middle and upper Grande Grève Formation is made up of hard, dark grey to bluish, siliceous limestones. Some of the best exposures are along the N-S lumber road and in the hills east of Madeleine lake. The rock is finely bedded and shows laminae curving around gently swelling and pinching silty interbeds.

In the axial zone of the Lesseps syncline, the rock is massive, thick-bedded and strongly cleaved. At places, bedding in the siliceous limestone is marked by lenticular depressions formerly occupied by carbonate material.

In the upper part of the section, the siliceous limestone passes to a softer, argillaceous or silty limestone. Gradually, perhaps through a stratigraphic distance of 300 to 500 feet, the silty partings become more evident; the rock is irregularly layered with alternating silty and dark calcareous beds. Still higher in the section, small, interconnected pockets of brown-weathering clastic material, comprising chiefly fine-grained feldspar and quartz, are embedded in a Grande Grève-type lithology. This succession represents the transitional facies between the Grande Grève and York River Formations, referred to by some geologists as the York series or facies.

Typical outcrops of the transitional facies are well exposed south of Parent camp and on the slopes of the hill west of Madeleine lake. At the latter locality, load casts and other sole marks are common. Usually, such structures consist of bulbous protrusions of silty and arenaceous

material extending into the underlying, argillaceous limestone of the Grande Grève type.

It has been generally accepted that the Grand Grève - York River contact is characterized by alternating zones of both lithologies. Following other geologists, the writer has drawn the upper boundary of the Grande Grève rather arbitrarily at the first appearance of typical York River lithology.

The thickness of the Grande Grève Formation is estimated to be 1,500-2,000 feet, a figure in agreement with the values recorded east and west of the area. The age is universally accepted as being Lower Devonian.

York River Formation

The York River Formation is incompletely exposed in that only the basal 1,500 feet of the section is preserved in the area. It is exposed in the southern part of the area, forming the core of the Lesseps syncline west of Long lake; it also appears as an outlier west of Madeleine lake. As mentioned above, the contact of the York River with the underlying Grande Grève is both conformable and gradational.

Some of the best outcrops occur SSW of Parent camp and 4,500 feet west of Madeleine Lake camp. At the latter locality, the grey-greenish rock is a thick-bedded, medium-grained quartz-feldspathic wacke or argillaceous sandstone. On weathered surface, it is characteristically peppered with tiny whitish feldspar grains and limonite stains.

The rock contains abundant black, disc-shaped, argillaceous inclusions of Cap Bon Ami lithology suggesting sedimentary boudinage structures.

At places, these flat inclusions, $\frac{1}{4}$ inch to 2 inches long, are completely isolated and embedded in an unsorted matrix made up of a largely unstable mineral assemblage. Where the inclusions are laterally continuous, the beds exhibit excellent sole marks; the load and current structures consist of siltstone and sandstone filling depressions in the underlying mudstone.

In outcrops and débris near Parent camp and along the road paralleling Lesseps creek west of the area, the rather fresh-looking sandstone is made up of weakly cemented, subangular quartz and rectangular feldspar grains, and carries occasional acidic tuff (?) fragments.

Reconnaissance traverses south of the area disclosed a 1.5-mile-wide band of York River rocks in the core of a northeasterly trending syncline, some 3 miles south of the Park road. The base of the section comprises 1,000 to 2,000 feet thick volcanic flows and tuffs of intermediate composition overlain by grey, medium-grained feldspathic sandstones or arkoses with conglomeratic interbeds at the base. At places, the hematite-stained rock contains abundant tube-like structures attributed to boring organisms.

The York River Formation in the area is correlated on general lithologic grounds with similar rocks recorded in areas to the west (Robert, 1966b, 1967) and to the east (McGerrigle 1959). Its age is generally accepted to be Lower Devonian.

CHAPTER VII

THE MTS MCGERRIGLE PLUTON

General Statement

The Mts. McGerrigle pluton is the largest complex of intrusive and hybrid rocks of the Gaspé Peninsula. Covering an area of about 40 square miles, the pluton forms a rugged mountaneous area rising abruptly above the surrounding upland. Torrential streams cut deeply into the highland forming amphitheater-like embayments. While tarns and U-shaped valleys are typical of the marginal areas, the rounded tops of the plateau are covered by frost-heaved blocks arranged in stripes and nets or characterized by extensive block fields.

The pluton is in intrusive contact with ^{prevalently} southward dipping Cambro-Ordovician rocks which completely surround it. The country rocks are contact-metamorphosed to various types of hornfels, skarn and meta-volcanic rocks forming a 1-2 mile wide thermal aureole. While several lines of evidence indicate a forceful injection, the pluton is conspicuously lacking in internal structures normally associated with deep-seated intrusions. The exposed part probably represents the roof portion of the pluton.

A product of multiple intrusion, the Mts. McGerrigle pluton lithology is very varied and complex, both in texture and composition. It comprises mainly granites and hybrid rocks of chiefly syenitic composition. The latter incorporate abundant xenoliths of metabasite and hornfels in all stages of alteration.

Petrography

Introduction:

Due to the great variety in texture and composition characterizing the rocks of the Mts. McGerrigle pluton, a terminology had to be devised that would be both simple and comprehensive. While mapping, it was considered practical to base the field classification mainly on the estimated amount of quartz present in the rock.

A division based on distinction and proportions of the feldspars proved unreliable. Thin section work and chemical analyses broadly confirmed the field classification. Slight discrepancies between field estimates and microscopic analysis arose in the case of fine-grained hybrid rocks in which quartz occurs intimately intergrown with feldspars and could therefore not be made out with the hand lens.

Although the mineralogical variations within the pluton seemed at first very involved, microscope work disclosed the presence of only a few basic rock types. In Moorhouse's classification of igneous rocks silicic feldspars include potash feldspar, albite and sodic oligoclase, whereas varieties more calcic than An_{20} belong to the plagioclase group (1959, p. 151). Since the average anorthite percentage of feldspar present in the southern half of the pluton is less than 20 and rarely exceeds 30, all the rocks there would necessarily be grouped as granites or sodic granites. This is not supported by chemical and mineralogical evidence from this area.

The writer adopted here the system of classification as used by Williams, Turner and Gilbert (1954, p. 34-35), because it fitted best the

mineral assemblage and fabric present. Both, the alkali feldspar -plagioclase ratio and the presence or absence of quartz, are used as norms. Because of the intimate association of K-feldspar and albite, the latter is included with the alkali feldspars. The critical volume of quartz chosen to differentiate quartz-poor from quartz - rich rocks is 10%.

Six principal texturally and compositionally different rock types constitute the Mts. McGerrigle pluton. In order of decreasing surface area, they are: 1) granite and granitic rocks; 2) hybrid rocks; 3) inclusions of rocks;
a) nepheline syenite; b) hornfels and meta-volcanic $\wedge$ c) fine- and coarse-grained metabasites; and 4) aplite-lamprophyre-pegmatite and granophyre-dikes.

Granite and Granitic Rocks

Leucocratic granite, quartz-monzonite porphyry, granodiorites and monzonite are the preponderant rocks of the southern half of the pluton. They also occur in irregular patches within and marginal to the hybrid rocks. Contact relations between granite and hybrid granitoid rocks and inclusions in the northeast corner of the area indicate beyond doubt that the former are the youngest plutonic rocks of the region.

The granite, which is prevalent, is typically red and of coarse hypidiomorphic-granular texture. The rock is massive and remarkably fresh. The dominant feldspar is perthitic alkali feldspar showing parallel stringers of albite in the orthoclase host (Plate XVIII). K-feldspar occurs either in large, euhedral grains, or quite commonly, it mantles and replaces plagioclase. It is often found together with quartz interstitial to larger plagioclase crystals. The typical grid twinning of microcline is very rare.

Plagioclase occurs generally in subhedral forms with borders corroded by quartz and K-feldspar. Those grains which show prismatic outlines exhibit carlsbad-albite twinning. Zoning is rare and normal with the rim rarely exceeding An_{25} . Commonly, both alkali and plagioclase feldspars are sericitised.

Quartz is generally plentiful forming 10-30% of the rock, and averaging 20% of the 25 thin sections examined. It occurs typically in anhedral interstitial grains or intimately with alkali feldspar. It is then cuneiform resulting in graphic texture (Plate XIX). Myrmekite is rare except in portions richer in plagioclase and mafic minerals. The origin of such micrographic intergrowth is generally considered to be primary.

Mafic minerals are rare and where present consist of biotite and, less typically, hornblende. The former is brown and occurs in euhedral laths forming, on the average, 2% of the rock. Hornblende, invariably green and prismatic, is rare increasing in size and volume in those fractions richer in plagioclase and where the rock is evidently contaminated by inclusions.

Muscovite and augite are seldom observed; the latter is associated with hornblende. Magnetite, apatite, zircon and sphene are minor accessory minerals. Sphene again increases in proportion with plagioclase and hornblende being particularly conspicuous in the marginal parts of the pluton. Black tourmaline up to $\frac{1}{4}$ " long are common SW. of lac Vièillard. Chemical analyses indicate a typical granitic composition (Table VII, Nos. 67, 68, 69, 70 and 74).

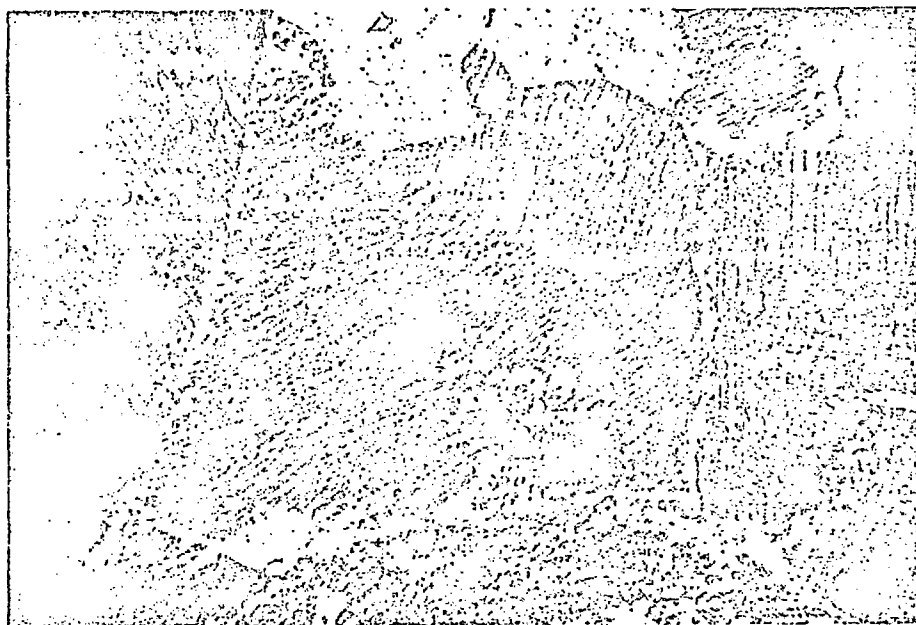


Plate XVIII. Perthitic intergrowth in large phenocrysts of a biotite-hornblende granite (Natural light, X45) (1.5 miles ENE. of Mt. McWhirter).

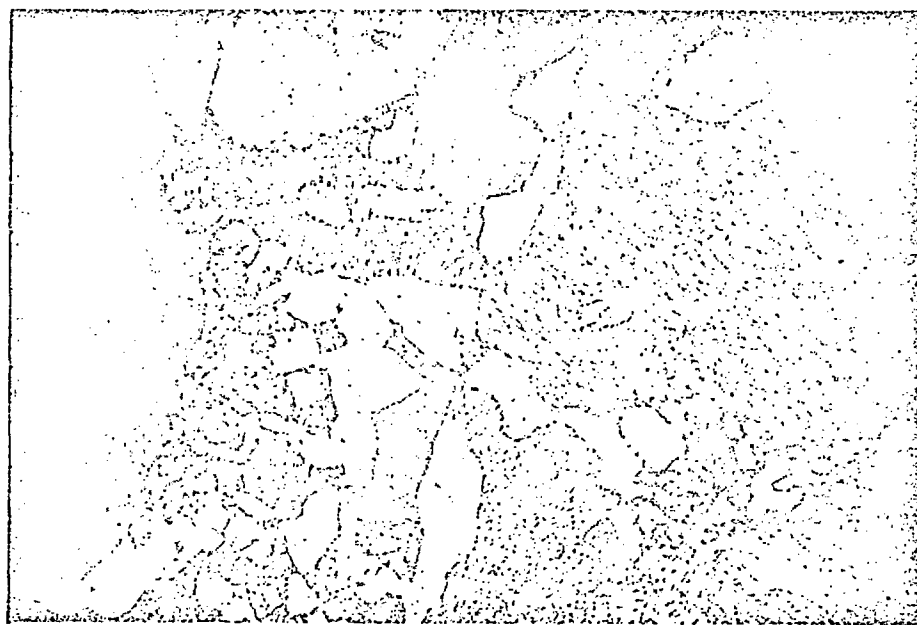


Plate XIX. Granophyre texture in quartz monzonite (Natural light, X45) (2 miles NE. of Mt. McWhirter).

Two important textural varieties of the coarse granite are a reddish, fine-to medium-grained facies and a grey granodiorite porphyry. Both occur in large patches covering half to 2 square miles. They grade into the main granite and do not constitute separate intrusions.

The fine-to medium-grained phase of the granite occupies the extreme SW-corner of the pluton. Representative outcrops are exposed all along the steep upper part of the Ruisseau des Orignaux. At places, the rock is a true granite porphyry and is mineralogically and chemically undistinguishable from the coarse granite; in fact, it differs then only in texture (Table VII, No. 73).

The grey granodiorite porphyry is well-defined, because of its distinctive textural characteristics, although here too the contacts with the main granite are somewhat vague. Large areas of porphyry are found SW of lac Côté and NE of Mont Jacques Cartier. Excellent exposures are observed in the gorge of the Rivière Madeleine headwaters, some 1.5 miles SW of lac Côté. Here, the outcrops are part of a well-delineated oval belt 3 miles long and approximately $3/4$ mile wide.

The greyish rock consists of euhedral, frequently zoned phenocrysts of sodic to calcic oligoclase set in a medium-grained groundmass of quartz and alkali feldspar. Some of the prisms reach $3/4$ " in length, although on the average they are $\frac{1}{4}$ - $\frac{1}{2}$ inch long. The quartz content varies between 10 and 30% and is generally 15%. Brown biotite laths amount to 2% and small quantities of hornblende are invariably present. Occasionally, the prismatic grains are kaolinized perthites. Iron minerals, epidote, sphene and apatite are accessory.

CHEMICAL ANALYSES OF UNCONTAMINATED
GRANITES, GRANITE PORPHYRY, QUARTZ-MONZONITE AND GRANODIORITES
OF THE MTS. MCGERRIGLE PLUTON *

Precent No.	67	68	69	70	71	72	73	74	75	76	77	78
Sample No.	701-9988 71-9620	701-9989 71-9621	701-9995 71-9626	701-9997 71-9628	701-10005 71-9627	69f-3991 71-9563	69f-4017 71-9633	69f-4013 71-9605	68f-5951 71-9556	68f-5956 71-9651	68f-5971 71-9576	68f-5974 71-9570
SiO ₂	73.50	64.00	73.60	73.60	65.50	57.47	68.10	72.47	72.14	73.23	72.70	73.34
TiO ₂	0.11	0.53	0.11	0.11	0.53	1.20	0.35	0.18	0.25	0.23	0.28	0.32
Al ₂ O ₃	12.50	16.00	11.45	13.00	15.15	18.58	15.69	13.92	13.49	12.98	12.97	13.34
Fe ₂ O ₃	0.55	2.68	1.52	1.41	1.32	1.38	1.37	0.76	0.67	0.96	0.94	1.15
FeO.....	0.26	1.42	0.64	0.77	0.70	1.09	0.64	0.51	0.70	0.58	0.77	0.64
MnO.....	0.03	0.10	0.06	0.04	0.10							
MgO.....	0.13	0.76	0.32	0.32	0.60	1.43	0.63	0.13	0.40	0.50	0.49	0.34
CaO.....	0.81	1.61	0.97	0.88	1.27	2.97	1.19	0.46	1.67	1.59	1.24	1.14
Na O.....	4.42	6.20	4.54	4.10	5.64	6.80	4.85	4.41	4.13	3.93	3.90	4.00
K ₂ O.....	5.83	5.98	4.95	4.63	6.13	0.93	4.96	4.60	5.05	4.65	4.36	4.80
P ₂ O ₅	0.04	0.15	0.04	0.04	0.04	0.12	0.07	0.05	0.04	0.02	0.04	0.04
V ₂ O ₅					0.009	0.003	0.001					
CO ₂	0.13	0.15	0.03	0.11	0.03	0.00	0.05	0.07	0.05	1.09	0.24	0.08
Total	98.31	99.48	98.20	99.01	97.01	91.97	97.86	97.49	98.59	99.76	97.93	99.19
Cu	10	14	9.0	14	8	8	4	8	13	41	48	48
Zn	49	63	49	36	60	61	38	12	90	30	24	30
Pb	24	28	27	25	30	24	34	26	28	17	17	15
Ni	27	29	27	26	26	16	17	11	48	17	18	17
Cr	34	36	37	33	28	20	30	30	50	90	60	50
V	0	56	112	0	0				50	50	100	50
W	0	0	0	0	0	n.d.	n.d.	n.d.	4	8	4	4
Sn	0	0	10	0	0	10	10	5	10	5	5	5
Mo	0	0	0	0	0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
U	5	5	5	5	5	3	5	1	5	5	10	2
Au	0	0	0	0	0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Ag	0	0	0	0	0	n.d.	n.d.	n.d.	0.3	n.d.	0.3	n.d.
Pt	.02	.02	.02	.02	.02	<.02	<.02	<.02	<0.02	<0.02	<0.02	<0.02

67. Typical coarse, red granite
 68. Red, hornblende-biotite monzonite
 69. Typical coarse, red granite
 70. Coarse, red granite
 71. Typical quartz-monzonite porphyry
 72. Soda-rich monzonite porphyry
 73. Fine-to-medium-grained granodiorite
 74. Fresh, coarse-grained granite (outcropping on Mt. Jacques Cartier road)
 75. Biotite granite
 76. Biotite granite
 77. Biotite granite
 78. Porphyritic granite

Analyses by the Quebec Dept. of Natural Resources Laboratories for location see Index Map III.



Plate XX. Myrmekitic intergrowths showing worm-like quartz enclosed in oligoclase. Quartz-monzonite contact-rock, (2 miles NE. of Mt. McWhirter) (Natural light, X45).

Patchy distribution and the gradational contacts with the main granite indicate that the granodiorite porphyry represents texturally and mineralogically slightly different facies of the red granite (Table VII, Nos. 71, 72 and 78).

A third facies of the red granite is a quartz monzonite containing considerable hornblende. Only occasional outcrops have been observed, as for example 0.5 and 1.5 miles E and S, respectively, of lac Fortin. Their sporadic occurrence and isolated nature does not warrant separation on the map. The reddish to greyish quartz monzonite is massive and medium-to-coarse-grained or slightly porphyritic. In thin section it consists of subhedral oligoclase-andesine set in a granular matrix of quartz and alkalic feldspar. Fresh

green hornblende occurs in distinctive laths. Commonly, the plagioclase is marginally replaced by alkali feldspar forming myrmekite (Plate XX). The quartz content varies considerably, but is generally between 10 and 15%; it is about 5% in the hornblende-rich varieties and the rock should then be classed as a syenite or monzonite (Table VII, Nos. 75, 76 and 77). Thin sections show that the red to grey quartz monzonite may be the dominant rock type at the eastern margin of the pluton. This is probably due to contamination with country rocks.

Hybrid Rocks

The hybrid rocks occupy the smaller, northern half of the pluton extending from a roughly EW line connecting Lac de la Botte and lac Côté northwestward to the 49° latitude. Except for 2 or 3 small areas and a large oval patch 2 miles long and 1 mile across, hybrid rocks are practically absent south of lac Côté. On the other hand, several large patches of granite and quartz-monzonite porphyry lie within, or at the periphery of, the hybrid mass.

The hybrid rocks comprise chiefly syenite, granodiorite and monzonites, all different facies of a large, single intrusion. Mafic inclusions of all shapes and sizes are the most characteristic single feature of the hybrid rocks. Chemical and mineralogical compositions, as well as the color index, vary from place to place depending on the degree of contamination of the originally acid magma.

In hand specimen, the hybrid rocks are characteristically light-to dark-grey, occasionally reddish, fine-to medium-grained and contain erra-

tically distributed, more or less nebulous clusters of mafic minerals. These are derived from partly digested mafic xenoliths described under a separate heading below. One of the most important properties distinguishing the hybrid rocks from the granite to the south is the low content of quartz. With few exceptions microscopic examination corroborated field observation that quartz is consistently below 10% in hybrid rocks.

Because of the extreme heterogeneity of the hybrid rocks, it would be impossible to describe in detail the mineralogy and textures in all the thin sections observed. Only the most important and recurrent features are therefore described here.

The fabric is generally hypidiomorphic granular, although porphyritic and blastoporphyratic textures, the latter indicating an igneous origin, are also of common occurrence. The color index varies greatly with mafic minerals reaching, at places, 30%.

The alkali-feldspar is distinctly perthitic and rarely euhedral. Generally, it is subhedral and associated with plagioclase, which it frequently replaces at the margins. Carlsbad twinning is present in some of the coarser-grained facies of syenitic composition, in which alkali feldspar is the preponderant mineral. Good outcrops of pink, coarse-grained, leucocratic syenite are well exposed in a 1 square mile area centered 1.5 miles S. of Mt. Auclair. Microcline has been observed only once.

Plagioclase are generally euhedral and largely sericitized. Some of the porphyritic varieties observed NE of Mt. Jacques Cartier display perfect zoning well-visible in prismatic crystals up to 3/4" long. In thin

CHEMICAL ANALYSES OF HYBRID ROCKS
OF THE MTS. MCGERRIGLE PLUTON AND NEIGHBOURING STOCKS

Pt No.	79	80	81	82	83	84	85	86	87	88	89	90
Sample No.	70i-10005 71-9636	69f-3991 71-9585	69f-4017 71-9610	70i-9998 71-9629	70i-1003 71-9634	70i-10006 71-9637	69f-3990 71-9584	69f-4014 71-9607	69f-4018 71-9611	70i-9992 71-9623	70i-9999 71-9630	70i-10001 71-9630
SiO ₂	65.50	57.47	68.10	59.00	55.00	53.40	61.53	69.42	63.84	70.50	70.10	66.
Al ₂ O ₃	0.53	1.20	0.35	1.30	2.00	2.40	0.50	0.32	0.71	0.11	0.14	0.
Fe ₂ O ₃	15.15	18.58	15.69	15.50	16.00	15.05	18.0	14.70	17.07	15.00	14.25	14.
FeO.....	2.58	2.15	1.39	3.23	3.96	3.95	2.54	1.49	1.79	1.47	0.75	1.
MnO.....	1.84	3.21	1.86	3.78	4.21	4.82	1.15	0.90	1.74	1.21	1.53	0.
MgO.....	0.10			0.13	0.20	0.19				0.04	0.07	0.
CaO.....	0.60	1.43	0.63	2.33	2.73	3.20	0.57	0.41	0.77	0.63	0.91	1.
Na ₂ O.....	1.27	2.97	1.19	5.13	5.20	5.94	1.14	0.94	1.43	0.60	0.67	1.
K ₂ O.....	5.64	6.80	4.85	5.32	5.32	5.22	6.96	4.85	6.28	6.32	6.45	4.
P ₂ O ₅	6.13	0.93	4.96	3.50	3.55	3.40	4.64	4.88	4.98	2.61	2.95	5.
V ₂ O ₅	0.33	0.37	0.10	0.45	0.83	0.95	0.16	0.02	0.19	0.06	0.08	0.
CO ₂	0.009	0.003	0.001				0.005	0.003	0.005			
	0.00	0.04	0.06	0.05	0.03	0.08	0.09	2.84	0.00	0.04	0.04	0.
Total	99.67	95.15	99.18	99.59	99.03	98.60	97.28	100.77	98.80	98.59	97.94	99.
Minor Elements												
Cu	8	8	4	14	15	15	11	5	4	11	25	
Zn	60	61	38	66	94	56	30	19	28	37	57	
Pb	30	24	34	29	30	28	25	26	35	18	18	
Ni	26	16	17	39	29	28	16	12	16	33	33	
Cr	28	20	30	40	34	31	40	30	10	37	37	
V	0			224	220	330				56	0	1.
W	0	n.d.	n.d.	0	0	0	n.d.	n.d.	n.d.	0	0	
Sn	0	10	10	0	0	10	10	5	10	0	0	
Mo	0	n.d.	n.d.	1	0	0	n.d.	n.d.	n.d.	0	0	
U	5	3	5	2	2	2	5	n.d.	3	0	0	
Au	0	n.d.	n.d.	0	0	0	n.d.	n.d.	n.d.	0	0	
Ag	0	n.d.	n.d.	0	.4	0	n.d.	n.d.	n.d.	0	.4	
Pt	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.0

79. Hornblende-quartz monzonite
 80. Soda-rich monzonite
 81. Biotite granodiorite
 82. Hornblende-biotite, Na-rich monzonite
 83. Pyroxene-hornblende-biotite diorite
 84. Diorite
 85. Soda-rich syenite
 86. Biotite, quartz-diorite
 87. Peralkaline syenite
 88. Quartz-albite porphyry (Mont Chauve)
 89. Quartz-albite porphyry (Hog's Back)
 90. Quartz-albite porphyry (Mont Vallières-de-St. Réal)

* Analyses by the Quebec Dept. of Natural Resources Laboratories; for location, see Index Map III and Map I.

section, the zoning is normal with an albite-rich rim. In only two sections have plagioclase been observed to mantle alkali feldspar phenocrysts resulting in reverse zoning similar to the rapakivi texture.

Rarely exceeding 10%, quartz is almost always present, although it hardly shows in hand specimen. This is largely due to its small anhedral grain size and to its habit of growing interstitially with plagioclase. Its cuneiform shape filling the angular interstices between feldspars is typical and a clear indication of late crystallization. Quartz may be of course the product of deuteritic alteration, but in this case some of it is probably introduced material derived from the younger granitic mass to the south. In some thin sections, interstitial quartz reaches 20%. It is then clearly related to granophyre veinlets observed in hand specimen consisting of fresh, intergrown feldspar and quartz. At some places, such as 4,000 feet SSW of Mt. Jacques Cartier, granophyre veinlets merge into larger masses of red, coarse granite described in the previous section.

The content of mafic minerals is very variable and may reach 30% depending on the degree of contamination and assimilation of xenoliths. Their concentration is very irregular and difficult to assess. The most prevalent dark mineral is hornblende. It almost always occurs as euhedral, green porphyroblasts, either single or in nebulous clusters. At places, such as on Mt. Jacques Cartier, débris in place show hornblende metacrysts vaguely oriented and shrung out in subparallel bands resulting in a quasi gneissic foliation. At other places, for example, on the jeep road to Mt. Jacques Cartier, 15% of the reddish and greyish melasyenite is made up of unoriented hornblende needles set in a coarse-grained alkali feldspar and oligoclase matrix (Fig. 2).

Where amphiboles are abundant, they are clearly after diopsidic augite, relicts of which are rimmed by hornblende. Metacrysts of green to green-brown biotite are generally euhedral and occur either as independent laths or replacing hornblende. Together with hornblende, biotite is an essential mineral of the hybrid rocks. In the marginal parts of the pluton, N. of lac de la Botte, hornblende and biotite are particularly abundant. Together with oligoclase-andesine, some quartz and considerable alkali feldspar, the rock is a typical quartz monzonite. At places, such as on the Mt. Jacques Cartier road and in débris immediately N. of lac Vieillard, thin biotite porphyroblasts up to 1.5 inches long stand out conspicuously in a coarse largely alkali feldspar, pegmatitic facies (Plate XXI). Muscovite is very rare and was observed only in one section,

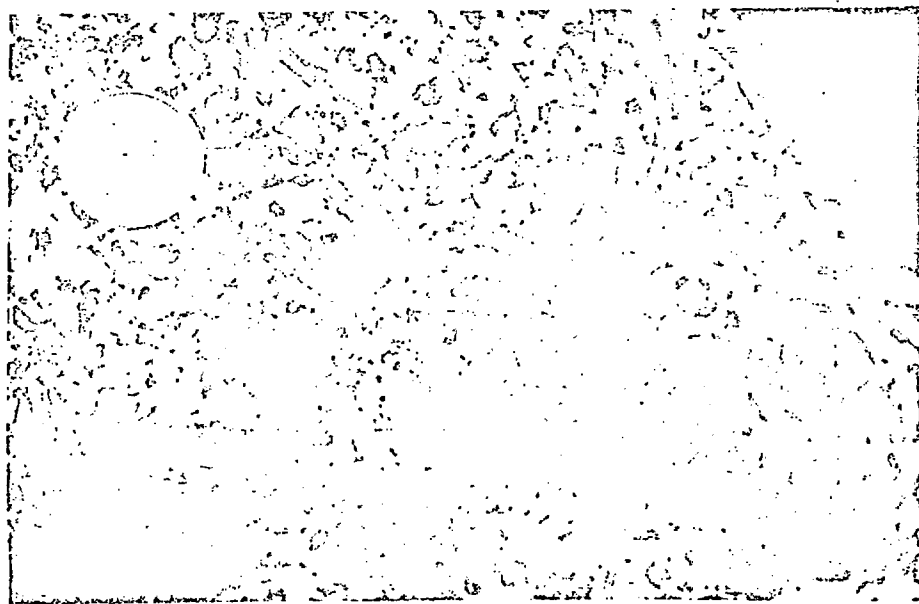


Plate XXI. Pegmatitic facies of the hybrid rock showing biotite metacrysts in a coarse matrix of alkali feldspar. (1500' NW. of lac Vieillard).

where it is associated with tourmaline and alkali feldspar in granophyre
viens. Chlorite is not abundant and is clearly an alteration product of
hornblende and biotite. It is common wherever the hybrid rocks contain
abundant mafic metacrysts.

Iron minerals, zircon, sphene and apatite are the common accessory
minerals, of which the latter two are by far the most important and charac-
teristic ones. Apatite occurs in tiny, slender needles and is particularly
abundant in those parts rich in mafic aggregates. Sphene is also concen-
trated in the heavily contaminated hybrid rocks and is associated with
pyroxene and hornblende. Their significance in terms of magma composi-
tion is discussed in a section below.

Inclusions:

Large inclusions (xenoliths) and small mafic aggregates (xenocrysts)
are characteristic of the northern part of the pluton underlain by hybrid
rocks. Except for isolated patches of hybrid rocks (e.g. SE. of lac aux
Américains and lac Côté) the southern half, comprising chiefly younger
granite, contains practically no inclusions. Presence of biotite and horn-
blende at the periphery of the normally leucocratic granite is the only in-
dication of contamination in the southern half of the pluton.

Compositionally, the inclusions are of three types. In order of
abundance, they are: 1) nepheline syenite, 2) Quebec Group xenoliths, and
3) metabasite xenoliths subdivided into a) fine-, and b) coarse-grained.

As mentioned above, the hybrid rocks of the area are contaminated
acid plutonic rocks characterized by inclusions. Only those xenoliths

measuring over several hundred feet and only those particularly mafic hybrid rocks are mappable units and are indicated as inclusions on the map.

Nepheline Syenite:

Small outcrops of nepheline syenite are exposed 1.5 miles SSE of lac Côté, immediately east of Les Cônes. Débris and outcrops form a bulbous, 3000-foot long area about 1000 feet wide at its southern end and tapering to 100 feet at its northwestern extremity.

The uniformly grey rock is tough, massive and medium-grained; it is also fresh-looking and of equigranular texture. In thin section, it is made up of a felt of small tabular anorthoclase showing a faintly trachytic habit, together with nepheline, sodalite, aegirine-augite, amphibole and considerable sphene and apatite. The nepheline is generally anhedral and interstitial between feldspars. In one section, it forms large phenocrysts. Aegirine-augite occurs in stumpy grains generally associated with amphibole. The latter is deep-green, strongly pleochroic and shows parallel extinction. It is probably riebeckite and is associated with calcite; both seem to be an alteration product of the pyroxene. The deep-brown biotite is of the lepidomelane variety.

Abundant débris of a similar rock are observed a few thousand feet NNW and NW of lac Côté. Here, thin sections show considerably more riebeckite, a typically felty texture and conspicuous laths of lepidomelane. Quartz has not been observed anywhere.

The nepheline syenite seems to lie within an area of hybrid rocks, themselves enclosed in the granite mass SSE of lac Côté. It is, however,

also possible that the patch of biotite-hornblende granite and red syenite, rich in basic inclusions, actually represents a quartz-poor and contaminated facies of the main granite, similar in lithology to rocks exposed 4,000 feet ESE of lac Côté. Contact relations and the northwestern trend of the outcrop area indicate that the nepheline syenite is a recent hypabyssal intrusion cutting across hybrid rocks and granite alike. This is supported by K. Schrijver's opinion that the rock appears to be petrographically fresh (oral communication, 1971). Contradictory evidence was obtained at one point on the western contact, where nepheline syenite fragments are chilled and enclosed by red, hornblende-syenite. There is also the possibility that the nepheline syenite is genetically related to the feldspar pegmatitic veins observed nearby. The latter trend NW and NE paralleling the main joint directions of the pluton. The restricted distribution of cébris NW and NNW of lac Côté seems also to be joint-controlled. Although usually unimportant as compared to other inclusions, the nepheline syenite is noteworthy, because of its distinctive mineralogy and its conspicuously Na-rich composition.

Quebec Group Hornfels and Metavolcanic rocks:

No xenoliths of Quebec Group rocks are present in the granite part of the pluton, south of lac Côté. In the hybrid rocks, such xenoliths are present and vary in size from 100 square feet to oval patches 2000 feet long and 100 feet wide. They are largely composed of various types of hornfels and minor metavolcanics and occur either in well-exposed outcrops or as inclusions of angular cébris within the blockfields. Because of their

darker colour, such patches can be readily spotted on aerial photographs, although the tone is similar to that of metabasite inclusions. In fact, some of the metabasite and metasedimentary rock inclusions may be practically undistinguishable in the field. At first, the writer assumed the abundant, finely layered and laminated inclusions within the hybrid mass to be reconstituted Quebec Group rocks. However, some inclusions well within the pluton were found to be identical in every respect to the hornfels of the wall-rocks. Subsequently, careful rechecking revealed that the mineralogy and grade of metamorphism reached by both, hornfels xenoliths and hornfels wall-rocks, are practically identical. It is important to note here that the contacts between the granitic rocks and the xenoliths are sharp, and that little reaction had taken place between them.

The Quebec Group xenoliths are chiefly concentrated in three separate areas: on the western contact of the pluton, NW. of lac Paré; in the vicinity of Mt. Auclair; and in the area around Mt. Jacques Cartier. In the first-named locality, most outcrops consist of tough, banded or streaked green and mauve calc-silicate hornfels and brown, pelitic hornfels. The latter consists chiefly of quartz and biotite and is, at places, spotted with altered cordierite xenoblasts.

In the Mt. Auclair area, the Quebec Group xenoliths consist of metabasalt, skarn and hornfels the mineralogy of which was described in a previous section. Of particular interest is a small patch of metabasalt, 1.7 miles SSE of Mt. Auclair. Together with coarse metabasite it is located well within the hybrid mass and over $\frac{1}{2}$ mile away from the contact with the

nearest metabasalt wall-rock. The basic wall rocks and the metabasalt inclusion are identical in appearance, mineralogy and texture and are certainly part of the same body. In thin section, the massive, dark rock consists of a granoblastic mosaic of calcic feldspar hornblende and diopside with accessory apatite and sphene. The mauve slightly schistose hornfels xenoliths within the hybrid mass SSW. of Mt. Auclair are made up of very fine and uniformly textured quartz, alkali feldspar, oligoclase and biotite. Except for its low K_2O/Na_2O ratio, the hornfels is almost undistinguishable, both in hand specimen and thin section, from finely laminated tuff described below under metabasite.

Small *débris* fields of faintly spotted pelitic hornfels occur NNW and SW of Mt. Jacques Cartier. The writer assumes that they represent xenoliths in place, since the areas have sharply defined boundaries. Of particular significance here are *débris* of mauve to pinkish quartzite, a little over $\frac{1}{2}$ mile SW of Mt. Jacques Cartier. Quartzite being an excellent marker horizon in this area, it is fairly certain that it forms part of the transected and dragged quartzite band exposed east and west of the pluton.

Metabasite:

"Metabasite" is a convenient, descriptive term adopted from K. Schrijver (pers. comm., 1971) for altered basic igneous rocks, irrespective of their mode of emplacement. Xenoliths and xenocrysts of metabasites are characteristic of the hybrid rocks, but are extremely rare in the southern half of the pluton. Chemically very similar, they have been subdivided into

two texturally different types: fine-grained and coarse-grained metabasites. Both have the following properties in common: 1) they form conspicuous patches enclosed within a light-grey or reddish mass; 2) although they are everywhere associated with hybrid rocks, they are also found incorporated in granite; 3) the xenoliths are very heterogeneous in their size, texture and color index, which change from place to place; 4) they show various stages of reaction with the surrounding medium, ranging from angular xenoliths with clear-cut boundaries to mineral clusters, schlieren and greyish hues; metabasite xenoliths are incorporated and assimilated in the hybrid rocks, whereas reaction between xenolith and granite is only slight; 5) quartz, if present, is introduced.

Fine-grained metabasites:

The fine-grained metabasites occur in three varieties: even-grained of felty texture, amygdaloidal and laminated. Although they were differentiated as such during field work, their separation on the final map proved unpractical, because of their erratic distribution and close spacial and genetic association. They all have similar mineralogy and chemical composition, and are derived from similar parent volcanic and pyroclastic rocks.

The felty metabasites are by far the most common variety (Plates XXII and XXV). They are particularly abundant in a large patch of hybrid rocks south and southeast of lac aux Américains. In thin section, the calcic plagioclase occurs in a felt of zoned microlites. Stubby remnants of clinopyroxenes are altered to porphyroblastic hornblende that can make up to 20% of the rock. In the contact zone with the leucocratic rock,

biotite, some quartz and newly formed oligoclase metacrysts, up to $\frac{1}{4}$ " in length, also show up.

Contacts in hybrid rocks between acid and basic fractions are largely gradational. At some places, however, small sized xenoliths are surrounded by a reaction rim of hornblende and minor biotite. Commonly, it is difficult to tell whether the fine-grained diorite is a contaminated acid rock or whether it represents largely converted and absorbed xenoliths. The percentage and distribution pattern of hornblende needles is then an indication of the degree of assimilation and mutual reaction that had taken place. Among the accessory minerals, sphene and particularly apatite are the most abundant ones. The latter occurs characteristically in tiny, colorless needles.

The only sizable concentration of felty metabasites in granite occurs SE. of lac Côté. In contrast to the relationships described above, contacts between metabasite and granite are knife-sharp, indicating little mutual reaction. Here, the granite has incorporated already altered xenoliths.

Xenoliths of amygdaloidal metabasite are common, but are particularly abundant SE. of Petit lac Ste. Anne, on the flanks of the plateau SSW. of Mt. Auclair and in the upper section of the Mt. Jacques Cartier road (Fig. 2). They grade, at places into felty varieties and are probably of the same age. The most conspicuous feature are the dark, circular spots, $\frac{1}{2}$ " in diameter set irregularly in a grey, felty matrix (Plate XXIV). Wherever the metabasite is associated with younger, red granite, such as on the Mt. Jacques Cartier road, the spots consist of hornblende and

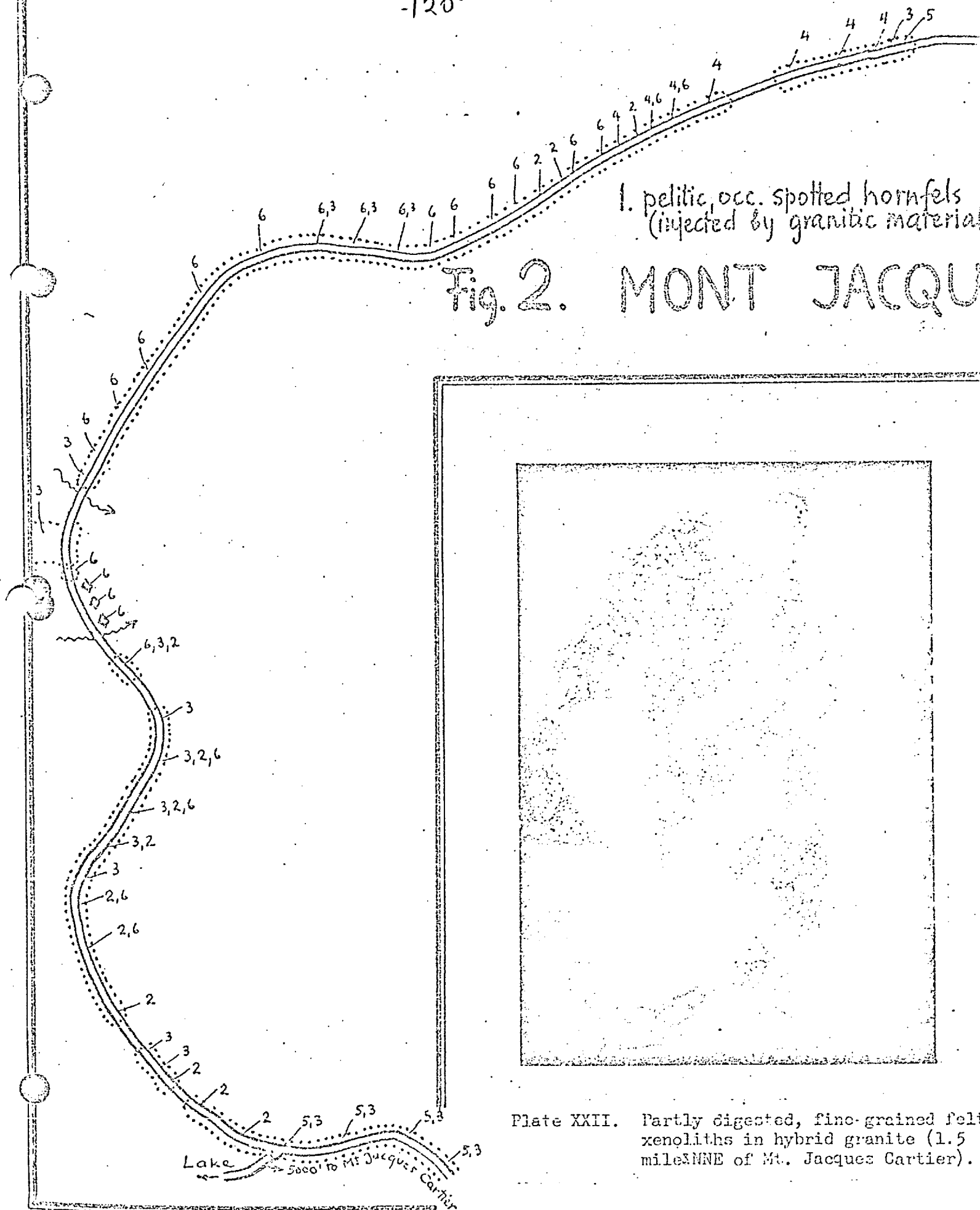


Fig. 2. MONT JACQU

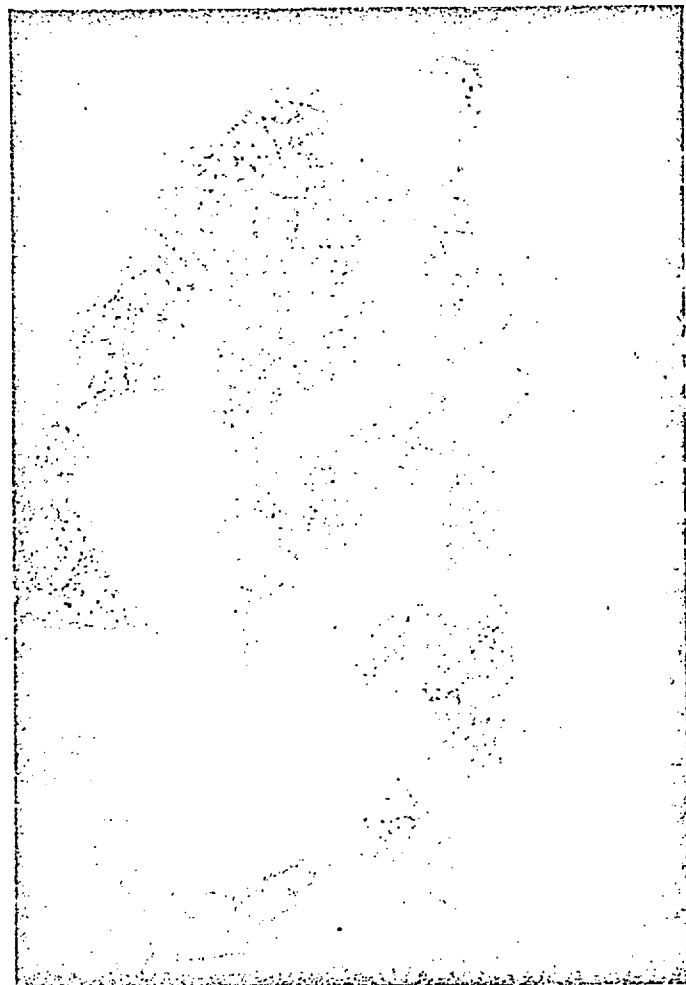
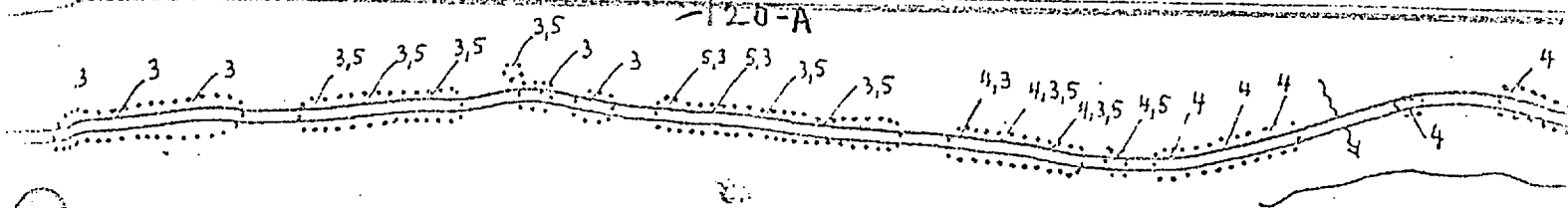


Plate XXII. Partly digested, fine-grained felsic xenoliths in hybrid granite (1.5 mile NNE of Mt. Jacques Cartier).



- 1) 2. fine, amygdaloidal metabasite 3. fine, felty metabasite

JACQUES CARTIER ROAD GEOLOGY ACROSS

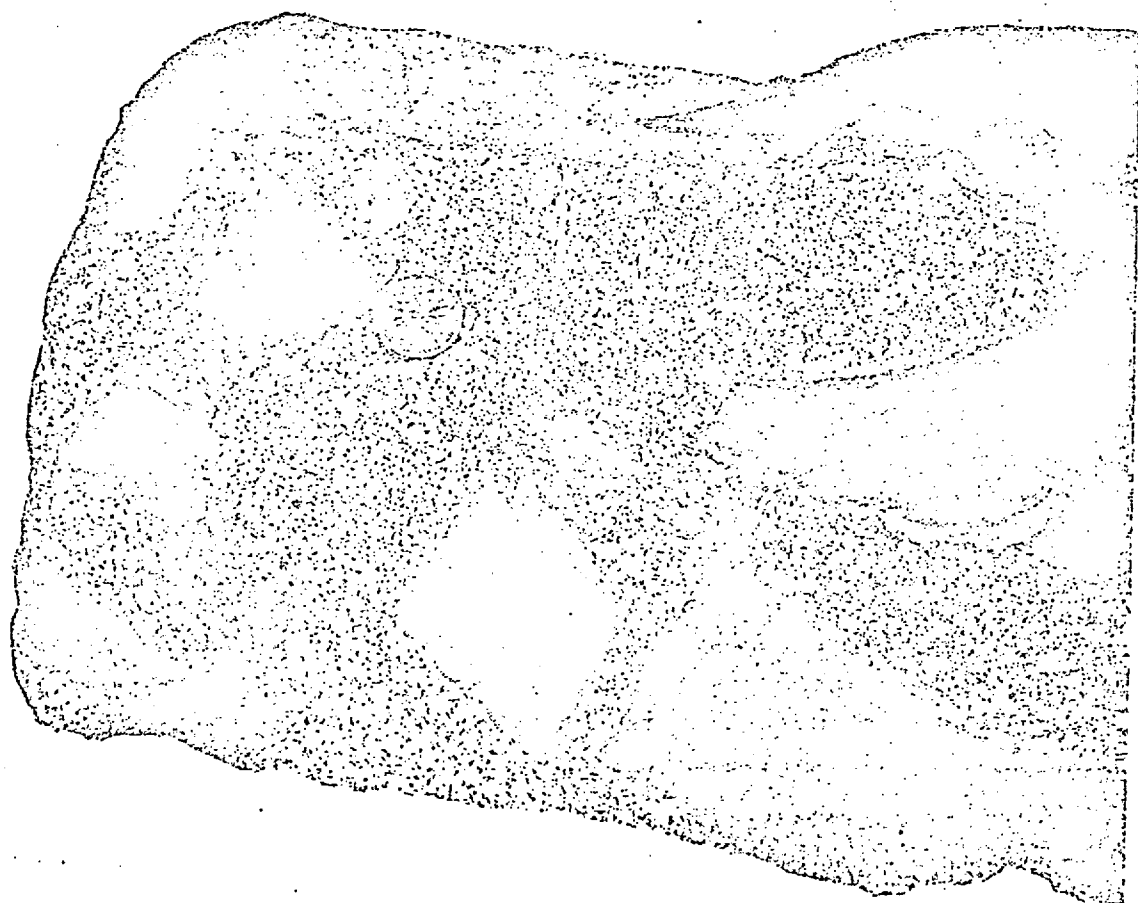
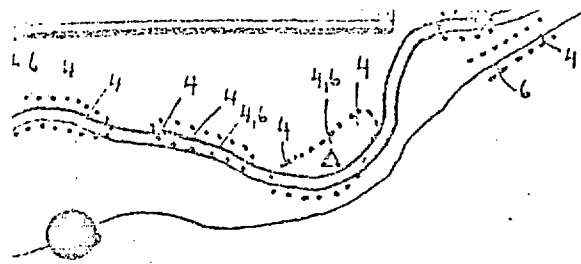


Plate XXIII. Laminated fine-grained metabasite inclusions in hybrid granite (1.1 mile WNE of Mt. Jacques Cartier).



120-e

rock débris

banding

Δ K/Ar age determination

granite, melasyenite and granitic rocks with occasional
 dikes of coarse, fine and amygdaloidal metabasite

EDER ZONE OF THE PLUTON

H.S. de Römer, 1972

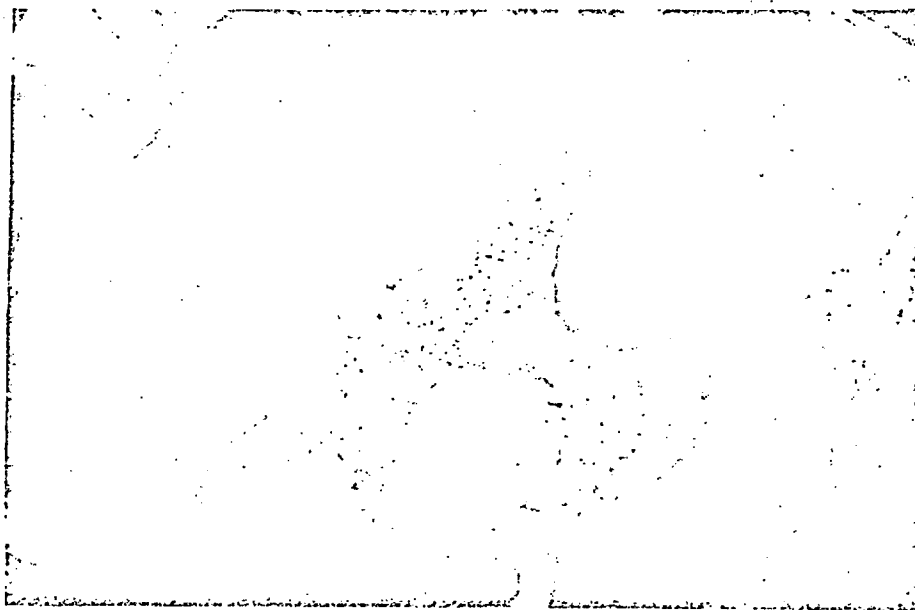
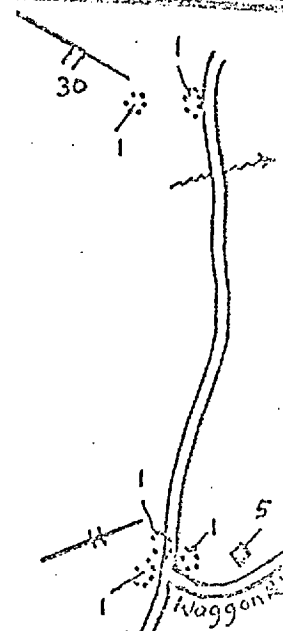
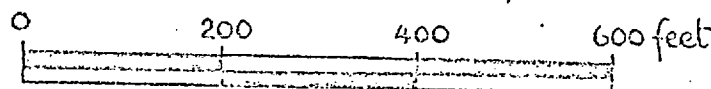


Plate XXV. Fine-grained felty metabasite inclusions within
 late granite (1.4 miles NNE of Mt. Jacques
 Cartier).

120 d



- outcrop
- ◇ rock debris
- / banding
- △ K/Ar age determination

granite, melanophyre and granitic rocks with occasional
 thin layers of fine and amygdaloidal metabasite

commonly pink K-feldspar in the centre (Plate XXIV), surrounded by a rim of brown biotite, sphene, epidote and also calcite and quartz. Such metabasites occurring within hybrid rocks contain occasional augite remnants, but generally only vague spots of chloritized hornblende and calcite in a felty matrix, which is dotted here and there by oligoclase metacrysts. Here again, as in all basic inclusions, apatite needles are common.

The amigdaloidal metabasites xenoliths should not be confused with spotted actinolite schists (2eM) derived from the Quebec Group metabasalt (2e), described in a previous section (p. 61-63). Both rock types can be observed in the same area, some 3,500 feet S. of Mt. Auclair. The actinolite schist is deep green and contains abundant actinolite aggregates that are largely altered to penninite and calcite. Its texture is largely granoblastic. In the amygdaloidal metabasite, on the other hand, the spots are made up of black hornblende, pink K-feldspar, sphene, epidote and occasionally quartz. Its groundmass is felty. Although both may have had a similar origin, the metabasite reflects a higher grade of metamorphism.

Field appearance, chemical composition and petrographic evidence indicate that the metabasites are altered massive and amygdaloidal basalts. As compared to normal basalts, however, the fine-grained metabasites are relatively rich in Na_2O and K_2O , and impoverished in CaO . This is also evidenced in thin section by the presence of K-feldspar, biotite and oligoclase xenoblasts.

The laminated metabasites, such as occur along the eastern slope of the prominent valley east of Mt. Ste. Anne, can easily be mistaken for

xenoliths of sedimentary origin. The layers or mere shreds consist of hornblende-biotite-rich aggregates and granoblastic bands of quartz and feldspar fading into the enveloping acid rock. They were at first identified as partially digested sedimentary inclusions. In some outcrops, however, layers are grading across strike into the familiar, oligoclase-spotted felty xenoliths. They are also strikingly similar in chemical composition to definite felty metabasites (Table IX, Nos. 101, 102, 103). Their low K_2O/Na_2O ratio is further evidence that the laminated xenoliths are probably altered rocks of pyroclastic origin (Plate XXIII).

Coarse metabasite:

Coarse-grained metabasite xenoliths occur only in the northern part of the pluton underlain by hybrid rocks. Forming large irregular bodies several thousand feet in length, they are concentrated mainly in two areas: NE of Petit lac Ste. Anne and in the area between Mt. Auclair and Mt. Jacques Cartier.

In hand specimen, the coarse-grained rock has the appearance of a typical, massive gabbro. Generally, it is unusually mafic with a color index of over 60. In thin section, the holocrystalline rock has a blastophitic or relict sub-ophitic texture indicative of its igneous parentage. It is composed chiefly of long, andesine laths and green hornblende after diopside. In one thin section, remnants of hypersthene were observed (Table IX, No. 94). Some altered, largely saussuritized feldspars are also present. Calcite, biotite, chlorite and quartz occur in minor amounts; the latter is interstitial and appears introduced. Apatite, some epidote

CHEMICAL ANALYSES OF XENOLITHS IN THE
MTS. MCGERRIGLE PLUTON *

Percent No.	91	92	93	94	95	96	97	98	99	100	101	102	103
Sample No.	70i-1000 71-9631	69f-4010 71-9602	69f-4012 71-9604	69f-4016 71-9609	69f-4024 71-9618	69f-4011 71-9603	68f-5958 71-9563	70i-9987 71-9619	70i-9991 71-9638	69f-4002 71-9595	69f-3994 71-9588	69f-4015 71-9608	69f-4022 71-9614
SiO ₂	47.00	44.95	49.74	53.73	47.08	46.81	46.48	58.00	53.60	46.95	47.67	53.99	51.6
TiO ₂	2.25	2.46	2.20	1.95	2.07	2.74	2.47	0.14	3.45	2.40	2.67	1.66	1.9
Al ₂ O ₃	16.90	17.07	17.27	16.78	15.59	15.89	15.73	18.50	15.10	16.67	15.54	16.88	17.1
Fe ₂ O ₃	4.35	3.37	4.53	4.48	5.60	4.75	4.53	3.13	1.11	3.65	3.96	4.45	3.3
FeO.....	6.12	7.14	4.99	4.95	5.07	8.28	7.21	1.02	1.42	6.39	7.73	4.68	3.2
MnO.....	0.21							0.26	0.07				
MgO.....	5.28	5.20	3.28	3.11	5.96	5.06	5.38	0.45	4.10	3.63	4.66	2.93	3.0
CaO.....	8.95	8.05	5.85	5.01	10.18	6.89	9.13	0.78	13.92	6.43	7.73	4.47	4.9
Na ₂ O.....	3.97	4.28	5.76	5.16	4.27	4.41	3.75	9.25	5.24	5.02	4.58	6.80	6.4
K ₂ O.....	1.43	2.32	2.56	3.32	1.16	2.04	1.48	5.98	0.22	2.36	2.06	1.62	2.4
P ₂ O ₅	0.52	0.67	1.17	0.53	0.35	0.71	0.39	0.05	1.25	1.18	0.95	0.78	0.5
V ₂ O ₅		0.035	0.032	0.034	0.060					0.044	0.060	0.028	0.02
CO ₂	0.35	0.00	0.07	0.15	0.14	0.04	0.06	0.06	0.00	0.12	0.02	0.18	0.0
Total	97.33	95.54	97.45	99.20	97.53	97.62	96.61	97.62	99.48	94.84	100.63	98.46	94.7
Minor Elements													
Cu	52	33	16	20	53	34	63	13	7.2	28	6	12	1
Zn	90	80	96	48	75	86	85	121	22	78	120	56	7
Pb	33	26	28	28	28	26	18	51	33	24	22	21	2
Ni	71	50	18	29	57	38	59	30	25	19	32	23	1
Cr	60	50	10	20	100	10	50	33	31	10	20	10	1
V	504						180	0	336				
W	0	n.d.	n.d.	n.d.	n.d.	n.d.	2	0	0	5	n.d.	n.d.	n.d.
Sn	0	10	10	10	10	10	10	5	10	10	15	10	1
Mo	0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0	n.d.	n.d.	n.d.	n.d.
U	0	n.d.	1	n.d.	n.d.	n.d.	1	1	2	5	1	n.d.	
Au	0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0	n.d.	n.d.	n.d.	n.d.
Ag	1.0	0.6	n.d.	n.d.	0.6	n.d.	0.8	0	.4	0.9	0.5	n.d.	0.
Pt	.02	0.02	0.02	0.10	0.02	0.02	0.02	.02	.02	0.02	0.02	0.02	0.0

91. Hornblende-biotite diorite	coarse metabasite
92. Hornblende-diorite	
93. Hornblende-biotite diorite	
94. Pyroxene-hornblende-biotite diorite	
95. Hornblende diorite	
96. Diorite	fine metabasite
97. Alkali diorite	
98. Nepheline syenite	
99. Nepheline syenite	
100. Fine-grained, felty metabasite	
101. Amygdaloidal metabasite	
102. Fine metabasite remnants	
103. Finely laminated pyroclastic rock.	

* Analyses by the Dept. of Natural Resources Laboratories, for location, consult Index Map III.

and sphene, the latter replacing iron minerals, are the common accessory minerals.

Small blocks of coarse metabasite are rare. They are found to be in a very advanced state of reconstitution, such as can be seen at the western periphery of the pluton, along the 49° parallel. Here, the coarse-grained, dark-grey rock consists largely of oligoclase-andesine, long, green hornblende needles after diopside-augite and some biotite. It merges imperceptibly into the enclosing contaminated acid rock, which consists essentially of the same minerals although in different proportions. The feldspar is largely oligoclase and alkali-feldspar. The larger xenoliths have been altered substantially by the enclosing acid rock only in their marginal parts. Advanced stages of alteration and contamination can be observed in the large inclusions N. of Petit lac Ste. Anne and 1.8 miles N. of Mt. Jacques Cartier. At the latter locality, the mottled metabasite contains small aggregates of red, K-feldspar and hornblende metacrysts and abundant biotite after the latter, suggesting advanced stages of reaction and transfusion of material from enclosing magma to xenolith.

The degree of alteration is very variable indeed, depending to a large extent on the enclosing medium. The presence of metabasite xenoliths in hybrid rocks that became contaminated by them suggests that mutual reactions had taken place. Except for the superimposed K-feldspar addition, metabasite inclusions within the red granite, on the other hand, are sharp-edged. As shown in the vicinity of Mt. Auclair, granite apophyses inject and incorporate already altered basic rocks with relatively slight mutual

reaction taking place. This is also evidenced by the fresh and uncontaminated nature of the granite bodies.

The metabasite is in intrusive contact with Quebec Group rocks. Both, metabasalt and folded hornfels, are cut across by coarse metabasite producing a thin chill zone in the latter, as observed 1.2 miles SE. and 2,400 feet SSW of Mt. Auclair, respectively. Blocks of metabasalt were found enclosed within metabasite in the former area.

Relations with fine-grained metabasite are not as clear. Although some outcrops in the Mt. Auclair region show felty rocks incorporated in coarse metabasites, it is fairly certain that the origin of fine-grained metabasites is twofold: 1) most are of volcanic derivation, as proposed in the previous section; 2) some of the xenoliths associated with the coarse metabasites in the northern part of the pluton are a product of interaction between basic rocks and acid magma; they are, therefore, metasomatic in origin (Williams, Turner and Gilbert, 1954, p. 141). At various places along the Mt. Jacques Cartier road, for example, felty and coarse metabasites are very intimately associated suggesting a genetic relationship (Fig. 3). In fact, transition between felty or amygdaloidal metabasites and coarse varieties 2,500 feet SSW of Mt. Auclair suggests that a metasomatic origin for at least some of the finer metabasites is also possible.

Inherited igneous textures, the mineral composition and field occurrence indicate that most coarse metabasites in the area must have been gabbroic rocks originally. Reaction with the magma particularly in the border zones converted them to rocks of dioritic composition.

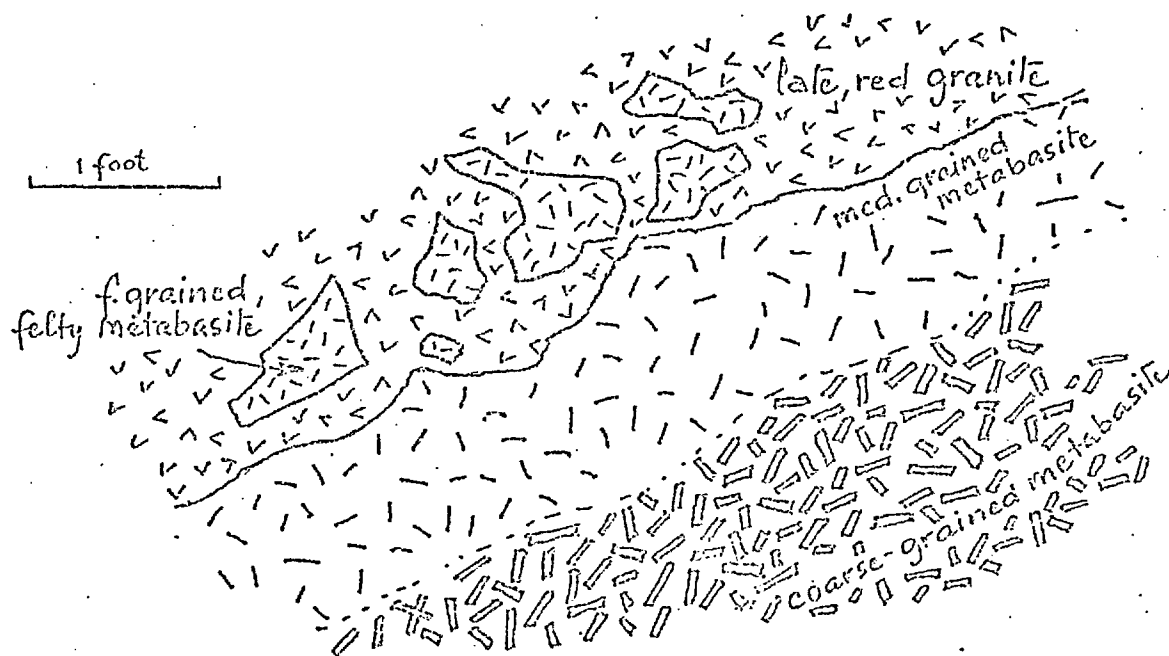


Fig. 3. Transition between fine and coarse metabasite, 2,500 feet SSW of Mt. Auclair.

Minor Intrusive Rocks

The youngest intrusive facies of the pluton are acid and basic dikes, comprising diabase, lamprophyres, aplites and granophyre; pegmatite- and quartz-veins are few and have restricted distribution. All have 2 important properties in common: 1) their trend is controlled by the prevalent joint system of the area; most of the fractures strike NW and NE (Fig. 4). 2) they are almost entirely confined to the granitic; i.e. southern, part of the pluton.

The diabase dikes occur in swarms and are concentrated principally in 2 areas: NE of Mt. McWhirter, and SE of lac Côté. They are characteristically dark, fine-to medium-grained rocks, generally less than 12 feet wide and of vertical to subvertical dip. They are composed of randomly oriented, largely andesine-labradorite crystals enclosed in larger, euhedral

augite grains. Augite also occurs interstitially between plagioclase or as relics enclosed by urallite, which in turn alters to chlorite with anomalous blue and purple colors. Other secondary minerals include prehnite, characterized by its "bow-tie" structure, and calcite. The principal opaques are pyrrhotite and pyrite. Alkali-feldspar metacrysts or xenocrysts were occasionally observed in thin section; this may explain the unusually high K₂O content (Table III, No. 29).

Outside the pluton, basic dikes occur abundantly along ruisseau Pierre-Jean, ESE of lac de la Botte. Here, lamprophyre is preponderant. The dike is distinctly porphyritic with aggregates of purplish augite largely altered to calcite, epidote and purplish or bluish chlorite in a fine-grained, even textured matrix of hornblende and calcic plagioclase. Slender needles of apatite are abundant. Reddish alkali feldspar is occasionally associated with the aggregates.

A large concentration of basic dikes outside the pluton are found between lac Madeleine and lac Long. Mapping was largely based on debris distributed and no consistent altitudes were obtained. Their attitude, which is believed to be N-S, does not correspond to that of the basic dikes in the pluton.

Among the acidic dikes, aplites and granophyres are the most common ones. Their attitude is identical to that of the basic dikes both, in the pluton and country rocks. Most are concentrated in the Mt. McWhirter region, where they reach a few hundred feet in length, and also in the wall rocks east of the pluton. Typical aplitic dikes cutting across red, coarse-

grained granite, are observed east of lac aux Américains. The majority of the leucocratic dikes, however, are granophyres. They are porphyritic rocks with hexagonal or angular quartz phenocrysts, up to $\frac{3}{4}$ " in diameter, set in a medium-grained matrix of quartz and feldspar. Commonly, the quartz and large, rectangular alkali feldspar are intimately intergrown producing a typical graphic texture.

Outside of the pluton, acid granophyres are particularly common in the area underlain by Siluro-Devonian rocks, west of ruisseau Barter. They strike N-S, similar in trend to that of basic dikes. The granophyres of the area in general are similar in appearance, texture and mineralogical composition to the quartz-feldspar porphyry dikes of the Murdochville (Brummer, 1966) and the Lesseps Creek areas (Robert 1967).

Regarding the origin of the diabase dikes, there is some evidence that they are genetically related to metabasite. This is supported by the fact that the dikes are localized in areas where fine-grained metabasite xenoliths are most abundant. These areas are NE of McWhirter and SE of lac Côté. Here, field specimens of metabasite and dike are difficult to tell apart. Furthermore, their mineralogical and chemical compositions are almost identical. The higher K_2O -content in the dikes is due to K-metasomatism during or after injection, and is corroborated by evidence in thin section. (Table III, No. 29 and Table IX, Nos. 100, 101 and 102).

As stated above, intimate association of basic rocks and acid magma resulted in contaminated and mixed rocks in the northern half of the pluton. Remobilization and subsequent injection of basic material into

fractures was more likely to take place in rocks that are homogeneous in texture and composition, such as the granite. This possibly explains why the basic dikes are virtually confined to the southern, granite, part of the pluton.

Several pegmatitic veins near Les Cônes consist exclusively of coarse interlocking alkali feldspar showing a protoclastic texture. Quartz veins from one to several feet in width are concentrated in a 1-square mile area, 1.5 miles NW of Mt. McWhirter. The majority follow joint directions.

Chemical and Age Relations

It has been inferred all along in the above description that the Mts. McGerrigle pluton consists of three separate intrusive phases that bear definite age relations to each other. From older to younger, they are: coarse metabasite, hybrid rocks and red granite. They can be distinguished by their contact relations, color index, their mineralogical and chemical compositions and in terms of aerial concentration.

The coarse metabasite occurs in large patches that may be either severed remnants or the uneven top part of a larger basic intrusion in depth. At two localities, 1.5 miles SSW and 2 miles SSE of Mt. Auclair, elongate bodies of coarse metabasite, shrung out along flanks of hills, seem to be part of large sheets dipping slightly southward. The patches are confined to the northern part of the pluton.

The dark rock is characterized by a high color index and a coarse, holocrystalline texture in which hornblende and oligoclase are the principal minerals. Relict minerals indicate that both are secondary, derived

from pyroxene and probably labradorite. Reaction between the gabbroid rock and enclosing acid magma resulted in the formation of hornblende and plagioclase, i.e. minerals in equilibrium with the liquid at that time. Compositionally, the rock is now a diorite. Contamination of the acid magma with development of abundant amphiboles was an accompanying process. It resulted in hybrid rocks described below.

Contact relations with the other units of the pluton are reasonably clear. Coarse metabasite contains inclusions of fine-grained metabasites, pelitic and calc-silicate hornfels. Its protrusions cut across Quebec Group metavolcanic ^{rocks} and folded hornfels in the Mt. Auclair area. They postdate the folding of the wall rock, but may have caused its alteration. At places, fine and coarse metabasites seem to grade into each other and are practically undistinguishable in the field (Fig. 3). Their mineralogical and chemical compositions are also very similar, suggesting that some of the coarser varieties are of metasomatic origin.

The hybrid rocks are granites contaminated by mostly fine-grained xenoliths of basic composition. Generally, the hybrid rocks are medium-grained, grey and quartz poor. They are extremely heterogeneous in color index, texture and composition depending on the degree of contamination reached. The effects of assimilation are everywhere apparent in the field and in thin section, resulting in rocks more basic in composition than the original granitic magma. Chemical analyses indicate a relative enrichment in Al_2O_3 , CaO, MgO and TiO_2 and a lower K_2O/Na_2O ratio.

It is important to note here that: 1) most of the xenoliths are of probable volcanic origin, and that 2) contamination by wall rocks and

sedimentary xenoliths is negligible and restricted to a narrow marginal zone. The only wall rocks of basic composition in the northern part of the area are the Quebec Group basalt. It forms large distinct patches within the younger granite (described in the section below) and is genetically unrelated to the basic xenoliths in hybrid rocks. A particularly anomalous situation arises south of the lac aux Américains on the western flank of the pluton. Here, a 2 square-mile area of hybrid rocks and fine-grained metabasites in all stages of assimilation is in contact with pelitic country rocks. Evidently, the hybrid rocks represent an intrusion of a xenolith-laden magma. It is in intrusive contact with coarse metabasite inclusions, resulting in reciprocal reaction.

The red granite of the southern half of the pluton is, in contrast to the hybrid variety, a coarse, fresh rock of remarkably uniform texture and composition. With the exception of some fine-grained and porphyritic facies, it is a monotonous area of slightly Na₂O- and CaO-rich granite, typically poor in mafics. A prototype of the rock can be seen on the road, 2.5 miles NE of Mt. Jacques Cartier. Slight contamination with the wall rocks resulted in a narrow marginal zone enriched with biotite and hornblende, particularly well observed all along the eastern contact, south of lac de la Botte.

Contact relations with the other members of the pluton are reasonably clear. The red granite cuts sharply across hybrid rocks and basic xenoliths alike with little reciprocal reaction having taken place (Plates XXV and XXVI). This is in marked contrast to the gradational contacts

observed within the hybrid rocks. Large lobes of granite, such as east of lac aux Américains, penetrate deeply into the hybrid area. It is probable that the xenolith laden area near lac Fortin and Les Cônes are large remnants of hybrid rocks engulfed by the younger granite.

Contacts with the Quebec Group rocks are particularly well observed in the complexly injected area SE of Mt. Auclair. Offshoots of a large patch of young, unaltered granite clearly intrude the metabasalt - hornfels assemblage, as well as the coarse metabasite. There is some K-metasomatism, but contacts are generally sharp, suggesting that little mutual reaction had taken place. In fact, granite encloses and cuts across previously contact metamorphosed xenoliths and wall rocks, which were in equilibrium

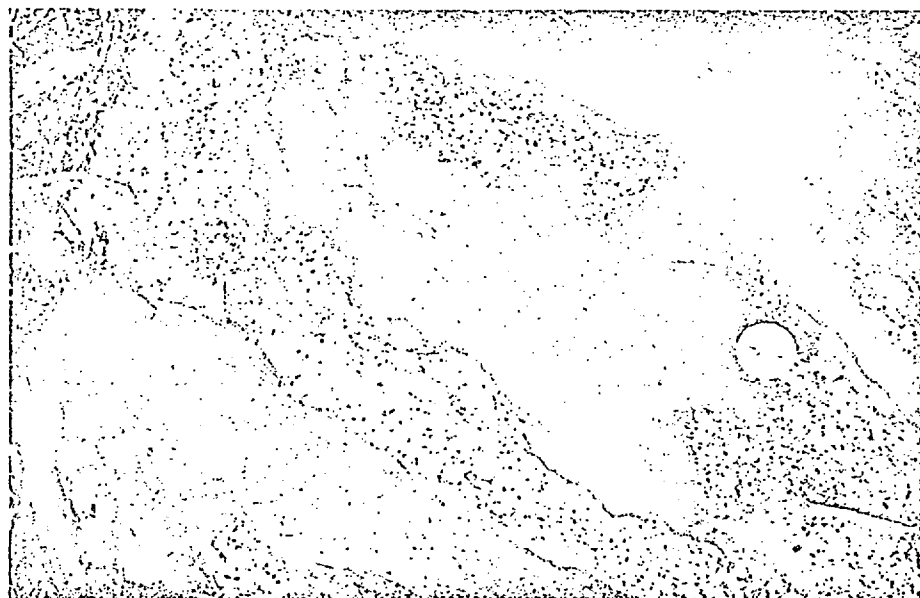


Plate XXVI. Xenolith of fine-grained metabasite in late, red granite. Although some reciprocal reaction has taken place, the contacts are sharp - (2.5 miles SW of Mt. Auclair).

with the invading magma at that time. Granite injections filling small fractures within hybrid rocks further attest its relatively recent age. With the exception of leucocratic and basic dikes, the red granite is certainly the youngest igneous rock of the area.

In view of the evidence presented above, it is probable that the aureole around the northern part of the pluton is related to the hybrid rock intrusion. The alteration belt in the southern half, on the other hand, is probably associated with the red granite.

Structural Features

External Structures

Information about the geometry and subsurface configuration of the Mts. McGerrigle pluton is provided by the attitude of its contact, the trace of the aureole boundary and the patchy distribution of contact-metamorphic rocks south of the pluton.

It is well established that the regional trend of the Cambro-Ordovician rocks completely surrounding the Mts. McGerrigle Pluton is NE. The predominant axis of the pluton being NS, it is evident that the contact between it and the border rocks is discordant. A 1-2 mile wide contact-metamorphic aureole, as well as dragging effects and intrusive breccias at the margin furthermore indicate that the body is a discordant intrusive stock. The contact of the pluton, as here defined, is based on the first appearance of a granitic or hybrid facies that is attached to the main mass. At some places, such as along the Mt. Jacques Cartier road, the contact was drawn at the first outcrops of leucocratic apophyses and stringers cross-

cutting or enclosing country rocks.

The southern and northern traces of the pluton appear to be smooth in contrast to the eastern and western edges, where deep embayments and bulky protrusions of the pluton into the country rocks are typical. Detailed structural information about the southern contact is lacking because of scarcity of outcrops in this area.

Within the 1-to 2-mile wide aureole flanking the pluton, the normally NE trend of the country rocks swings to a N and NW direction. This brings about, at places, an apparent parallelism between the structure of the border rocks and the contact. Normally, however, the contact cuts clearly across the layering; it is sharp and is easily traceable in the field.

Occasionally, the contact is ill-defined being marked by irregular veins and thin apophyses of leucocratic rocks penetrating and engulfing country rocks. This is well observed along 1000 feet of the Mt. Jacques Cartier road and also 3 miles SSE of lac Côté. At the latter locality, offshoots a few inches thick parallel the banding of the hornfels. At other places, such as 1.5 miles SSE of Petit lac Ste. Anne and east of lacs des Castors apophyses obviously associated with the pluton intrude the country rocks. Similar relations exist 1.5 miles SE of lac Côté. Here, protuberances of the pluton have forcibly pushed and displaced the country rocks resulting in chaotic folding.

The grain size of the plutonic rocks does not change appreciably at the contact. The offshoots paralleling the structure of the country rocks, however, have a pronounced chill zone.

The dip of the pluton was observed at several places. About 2 miles S. of Petit lac Ste. Anne, the contact is subvertical or dipping steeply west. On the eastern flank, some 3 miles SE of lac Côté, the contact can be clearly traced across a steep valley; it dips steeply east.

Information on the attitude of the pluton can also be obtained indirectly by considering the shape of the pluton and the extent of the thermal aureole surrounding it, the irregular outline of the pluton suggests that its contact in cross-section is also not uniform. On the other hand, the fact that the trace of the aureole matches almost exactly that of the eastern contact infers an uniformly steep dip of the pluton. At its northern extremity, the inner zone of the aureole, at least, is surprisingly narrow, suggesting a steep contact. A small, apparently isolated, area of skarn east of the pluton and just south of the 49° parallel probably indicates a near-surface satellitic stock.

The subsurface attitude of the pluton to the south is somewhat difficult to deduce, mainly because of scarcity of outcrop. The pattern of alteration is complex, because of the patchy distribution of altered and unaltered rocks lying side by side. It is probable that, here again, the islands of thermally altered rock indicate the near-surface presence of subvertical offshoots of the Mts. McGerrigle pluton. The writer is of the opinion, backed by results of radiometric dating (Table X), that the Mts. McGerrigle pluton and the smaller stocks to the south are essentially part of the same intrusive mass, although they may be different as to their level of emplacement.

An alternative hypothesis may consider the Mts. McGerrigle pluton and the other leucocratic stocks to represent separate intrusions resulting in superimposed aureoles.

In summary, there is circumstantial evidence to believe that the subsurface profile of the Mts. McGerrigle pluton to the south is highly irregular with some steep offshoots and protuberances lying within a few thousand feet below the present surface.

Internal Structures:

Planar and linear fabric, concentric zoning, xenoliths and joints are common internal structures found in plutons. It is noteworthy that there is no preferred orientation of fabric elements in the Mts. McGerrigle pluton. Normally, planar and linear structures, both primary features induced by rising magma, are particularly conspicuous in the marginal zone. Since their orientation generally follows the outline of the pluton, their attitude provides invaluable information as to its sub-surface configuration. By contrast, the Mts. McGerrigle pluton is conspicuously lacking in preferred orientation of its fabric elements.

There is, however, a gross concentration of mafic minerals in the eastern marginal zone, due to contamination with country rocks. In the southern half of the pluton, the zone varies in width from a few hundred to two thousand feet grading into granites and granodiorites. In the other half, roughly north of lac de la Botte the contaminated zone merges imperceptibly into the xenolith-laden hybrid rocks of the pluton. In general, however, the pluton does not show obvious concentric zoning, either induced

by normal differentiation processes operative in acid magmas or brought about by contamination with wall rocks.

Apart from the xenoliths concentrated in its northern part the pluton is also characterized by 2 sets of NW-and NE-striking, vertical and subvertical joints (Fig. 4). They occur largely in the area of homogeneous red granite and are occupied by basic dikes and leucocratic granophyres and aplites.

Contact Metamorphism

General Statement

While mapping, the writer traced the complete outline of the Mts. McGerrigle pluton in order to determine among other things its exact boundary and establish the equivalency of the lithologic units east and west of the pluton. It was noted that an extensive thermal aureole completely envelops the pluton.

The writer is familiar with the eastern and northern segments of the aureole (de Romer, 1969, 1970), but has mapped in detail only the innermost part of its southern and western segments, marginal to the intrusion. The full extent of the alteration aureole west and south of the pluton was outlined by Girard (1966) and Robert (1966b, 1967), respectively.

Contact Aureole

The aureole is on the average 1.5 miles wide varying from 1 mile to a rare maximum of 2 miles in width. It can be subdivided into two separate units distinguishable by their varied grade of metamorphism: an outer zone

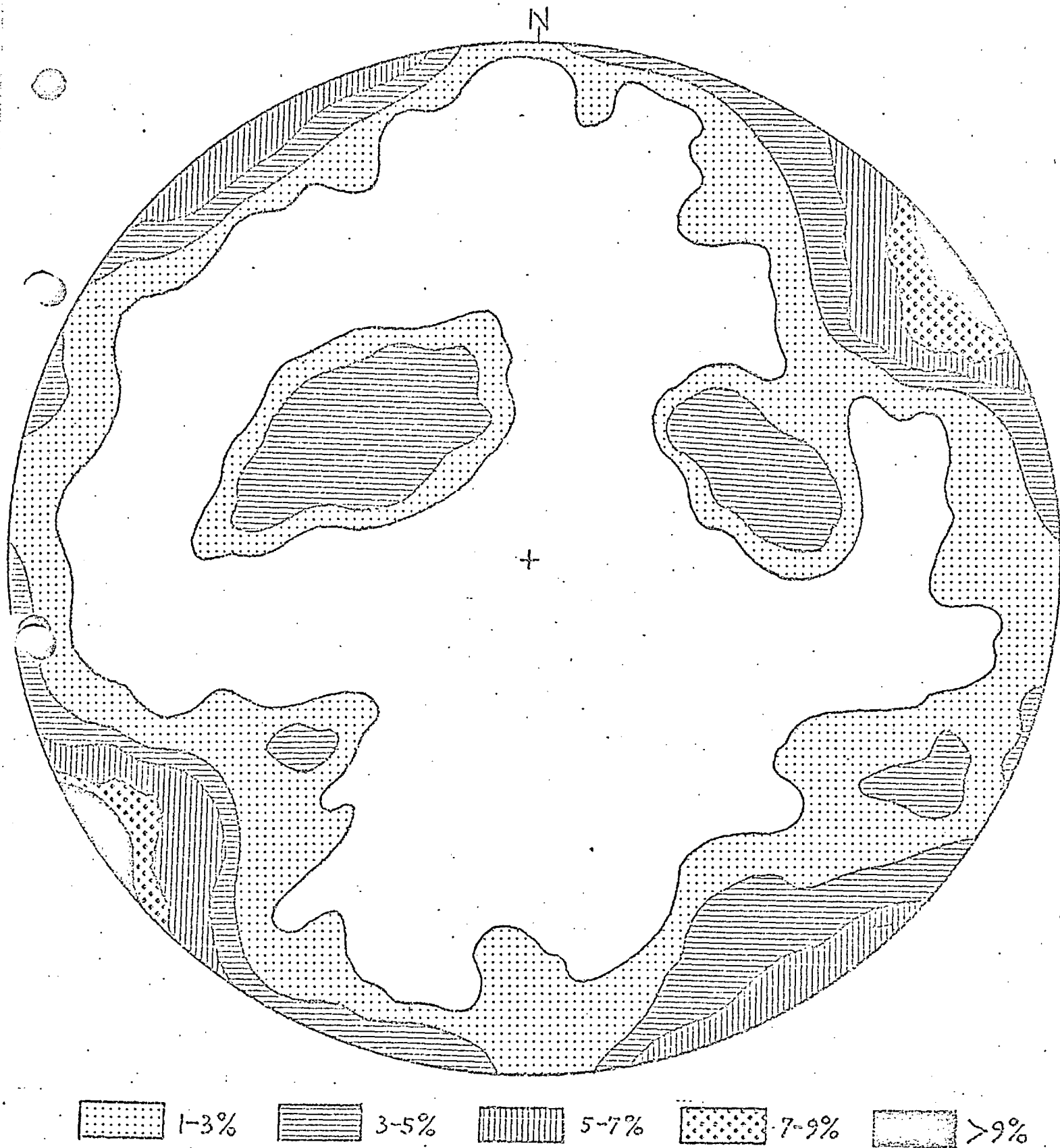


Fig. 4. Equal area contour diagram of 429 joints in the Mts. McGerrigle pluton (contours per 1% area).

and an inner zone marginal to the pluton. Both are of approximately equal width and generally follow very closely the surface trace of the intrusive contact, both east and west of the pluton. No striking irregularities in the outline of the western aureole are reported (Girard, 1967).

Relations between the contact trace and aureole outline are not as regular north and south of the pluton. In the Mt. Auclair area, the injection pattern is extremely involved as shown by the patchy distribution of intrusives and xenoliths on the map. Here, early metabasites intruding Quebec Group rocks are in turn complexly injected by satellitic stocks of younger granite. As a result of multiple injection, a superimposition of alteration zones can thus be expected NE of the pluton.

In contrast to a surprisingly narrow strip N. of the pluton, the extent of the thermal aureole S. of it is irregular and patchy. This anomalous distribution is directly related to the uneven configuration of subsurface cupolas.

The Mts. McGerrigle aureole extends southward and merges into the contact rocks of the smaller stocks such as Hog's Back, Mont Chauve and Mont Vallières. Each of these leucocratic intrusives is surrounded by a thermal aureole averaging 0.5 miles in width (Robert, 1966a, 1966b).

Traverses into the Mt. Vallières-de-St. Réal area confirmed a patchy and apparently random distribution of high-grade and unaltered rocks. At places, irregular zones a few thousand feet in diameter of unaltered rocks are engulfed by high-grade metamorphism. One of these patches covering approximately 1 square mile lies immediately south of the main bent of Rivière Madeleine (Robert 1967).

On the other hand, irregular zones of thermally altered rocks can also be found isolated within vast areas of regionally unaltered sedimentaries. The unexpected discovery, for example, of a chiasolite-bearing, garnetiferous skarn 1.5 miles NW of the ruisseau Vièillard-rivière Madeleine-Nord junction, sheds more light on the probable subsurface profile of the pluton. The high metamorphic grade reached by shales and siltstones (2cMc) in this small area suggests that an offshoot is buried here at a short distance below surface.

The effects of thermal metamorphism extend to as far as 2 miles from the intrusive contact. They are superimposed on regionally metamorphosed rocks of the lower greenschist facies, comprising limestones, siltstones, shales and slates; their impure equivalents; and metabasalts.

The writer has shown in a previous section the age equivalency and derivation of each individual lithologic unit, as it was traced across the thermal aureole. Correlation between altered and unaltered rocks is also established in tabular form in the legend of the map accompanying this report. Only a very brief account of the mineral assemblages in both, inner and outer, zones of alteration is therefore given here.

Outer Zone:

The thermal effects observed depend largely on the original composition of the rock. The first indications in hand specimen, of thermal alteration in argillaceous rocks are readily observed: 1) a slight induration and 2) a change in structure from slaty to massive with conchoidal fracture. In thin section, a very fine granoblastic textures and

tiny muscovite flakes are characteristic. A faint orientation, not visible in hand specimen, is probably mimetic after cleavage. These rocks are argillites and calcareous argillites, depending on the composition of the parent rocks. Abundant development of muscovite, some of it also undoubtedly relict, in silty argillites north of the pluton produces a characteristic low-luster appearance. The detached, coarser lobes of flow casts characteristic of silty beds consist largely of recrystallized quartz and feldspar.

The appearance of tremolite in association with quartz, calcite and phlogopite is typical of leached impure calcareous schists, south of the pluton. Some excellent outcrops (2am) exhibiting the above assemblage are exposed on a steep bulldozed road 1 mile N15E of the Barter showing on rivière Madeleine.

The normal mineral association of metabasalt in the outer zone comprises chiefly actinolite, albite and epidote along with some chlorite.

The above mineral assemblages, of which tremolite and muscovite (pyrophyllite?) are the most diagnostic representatives, are typical of the albite-epidote hornfels facies. The lower stability limit for the kaolinite + quartz $\rightleftharpoons$ pyrophyllite reaction has been established at about 400°C (Winkler, 1967, p. 70).

Inner Zone:

The inner zone of the aureole reflects faithfully the surface outline of the eastern contact of the pluton, forming a band averaging 3,000-4,000 feet wide. Its behaviour is erratic north of the pluton, where

it varies from a few hundred feet to 1 mile across. As stated above, this is an indication of superimposed effects of multiple injections and of an uneven subsurface profile, resulting in a patchy distribution of altered rocks.

For pelitic rocks, the demarcation line between the inner and outer zones was put at the first appearance of macroscopically visible spots. Spotted schists and spotted, massive quartz-biotite hornfels are practically coexistent. The spots, which at first consist of aggregates of quartz, chlorite, feldspar, organic matter etc. rapidly change to vague patches of cordierite and andalusite, indicating a steep thermal gradient. The formation of cordierite is concomitant with a gradual decrease in muscovite and chlorite and an increased development of light brown biotite. Xenoliths of spotted schists (not hornfels sensu stricto) and mauve and massive quartz-biotite hornfels side by side indicates original compositional differences with relatively little addition of material. In general, however, the massive, slightly spotty, quartz-biotite hornfels reflects a higher grade of alteration. Although quartz is completely recrystallized, remnants of flow casts are still recognizable in cherty hornfels (2h4).

Massive development of diopside, scapolite, grossularite-andradite, along with the usual quartz, tremolite-actinolite and calcite in calc-silicate hornfels marks the beginning of the inner zone in calcareous rocks. The mineralogical banding, so typical of the hornfels, probably reflects original bedding.

The most significant mineral to develop in metabasalt is hornblende, which together with plagioclase, forms the typical mineral assemblage in

this zone.

In brief, the appearance of diopside, scapolite, hornblende, garnet, cordierite and minor andalusite on one hand, and the gradual disappearance of both, chlorite and muscovite, (mainly leading to the formation of cordierite, andalusite and hornblende) on the other, characterizes the inner zone of the aureole. Quartz, calcite, brown biotite, calcic plagioclase, tremolite and phlogopite are also stable common minerals. The above mineral assemblage corresponds to that of the hornblende-hornfels facies, the lower limit of which is marked at a temperature of slightly above 500°C. This is the highest grade of metamorphism reached by wall rocks and xenoliths in the area, whether they be of sedimentary or igneous origin.

In his recent dissertation on the "Madeleine Copper Mine", Girard (1971, p. 56) mentions a 5-10 foot wide zone immediately adjacent to the pluton, as well as xenoliths, bearing a mineral assemblage indicative of the K-feldspar-cordierite hornfels facies. It is plausible that this facies was produced by the basic magma that gave rise to the gabbroid metabasite bodies in the northern part of the pluton. The K-feldspar-cordierite hornfels facies is associated with basic intrusives, which are considerably hotter, whereas the hornblende-hornfels facies generally represents the highest grade of contact metamorphism found around granitic plugs (Winkler, 1967, p. 63).

It is possible that patches within the inner zone have reached the lower-temperature grade of the above facies. The orthoamphibole sub-facies

implies coexistence, at a temperature of about 630°C, of hornblende-cordierite-biotite-orthoclase (Winkler, 1967, p. 75). Be it as it may, there is no sillimanite, hypersthene nor enstatite, and virtually no wollastonite, to suggest that the higher-temperature orthopyroxene subfacies is represented here. Furthermore, xenoliths of spotted pelitic schists well within metabasites or hybrid rocks, suggest that the temperature was not high enough for the orthopyroxene subfacies to be stable. Absence of the K-feldspar-cordierite facies may also, however, be attributed to unusually high water pressure.

Other Considerations:

Secondary effects, whether due to retrograde metamorphism or to hydrothermal alteration are widespread and were described in the section dealing with petrography. Suffice it to say that uralitization of pyroxene, chloritization of garnet, hornblende, biotite, diopside and tremolite-actinolite, replacement of diopside by calcite and prehnite, and the diagnostic yellow sericite alteration of cordierite porphyroblasts are the most common secondary reactions encountered.

There is no real evidence of massive transfusion of material from magma to wall rocks. Thermal alteration of pelitic rocks to hornfels is generally accompanied by loss of H₂O and CO₂ and there has been some K as well as Na- and Cl-metasomatism, as shown by the presence of scapolite, for example. Numerous cases in the literature refer to the abundance of apatite needles in acid magmas contaminated by basic xenoliths (Nockolos 1932, p. 442; 1933, p. 563). In the map area apatite is one of the most

consistently occurring accessory minerals in xenoliths and hybrid rocks. Its presence is attributed to action of volatiles and entry of lime into the magma from the xenoliths. On the other hand, preservation of sedimentary structures and the side by side occurrence of pelitic and calc-silicate hornfels deep within the pluton suggest that no significant addition of material has taken place.

Temperature-Pressure Conditions:

It is well-known that in most cases, 1) contact-metamorphic effects are associated with shallow intrusions of 2 to 8 km, corresponding to load pressures of 500-2100 bars; 2) most of the plutons are of granitic composition; 3) the width of the aureole and the metamorphic facies reached are primarily dependent on the size of the intrusion.

It has been shown experimentally that the upper stability of muscovite is approximately 2.5 kb and that its decomposition temperature in the presence of quartz to K-feldspar, alumino-silicate and water lies between 630°C and 650°C (Evans, 1965, p. 660; Velde, 1966, p. 929).

Absence of sillimanite (stable above 2.5 kb) and the fact that cordierite and andalusite are very common minerals in the inner zone, suggest that the true total pressure (assuming total pressure = load pressure = water pressure) is more likely to be 2 kb or less, corresponding to a maximum load pressure of 7-8 km.

Regarding the temperatures of wall rocks during intrusion, some interesting data have been obtained by Jaeger (1967). Using sheets or vertical dikes and their temperature of intrusion, (700°-800° for granite

magmas) he was able to determine the temperature of wall rocks at various distances from the contact. The calculation is based, however, on the following assumptions: 1) that the intrusion be a single body without outstanding apophyses that would dissipate the heat, and 2) that the country rocks are heated entirely by conductivity.

The northern part of the Mts. McGerrigle pluton with its multiple intrusions and offshoots certainly does not qualify for the requirements specified above. The southern half, however, is a very steeply outwardly dipping, fairly homogeneous single body of granite. There are indications that the present level of exposure represents the roof portion of the pluton. At a depth of 7-8 km, the temperature of the country rocks prior to intrusion is taken to be approximately 180°C. The temperature of the wall rocks at the immediate contact would be somewhat greater than 60% of the intrusion temperature (Winkler, 1967, p. 81). Taking into account the correction for load pressure this would amount to a temperature of 600-660°C. The average thickness of the homogeneous pluton being about 7 km, the temperature at about 700 m away from the contact would be in the order of 530°C, and dropping to about 410-450°C at 3,500 m. These values are in reasonable agreement with the temperatures given above for the alteration zones.

Origin and Emplacement of the Pluton

The reader can deduce from the petrographic and field descriptions presented above that the rocks of the Mts. McGerrigle pluton solidified from a melt and did not originate by metasomatic alteration of preexisting

rocks. That the pluton was indeed injected is supported by the following considerations: 1) the contact of the plutonic mass with the wall rocks is sharp; 2) apophyses of red granite emanating from the pluton penetrate and cut sharply across the wall rocks; 3) the wall rocks are dragged and intensely folded at the contact, indicating a forceful penetration of the pluton; 4) a well-defined zoned contact aureole in the country rocks points to a centrally located source of heat; 5) few of the xenoliths in the hybrid granite are derived from the presently exposed wall rocks; the majority of xenoliths are of basic composition, probably of volcanic parentage.

The fact that large areas of early granite, not just its marginal parts, are contaminated indicates large-scale incorporation and assimilation of xenoliths. This necessitates a high water pressure to enhance mutual reciprocal reaction and introduction of considerable Ca, Fe and Mg into the granite. This would lead to the formation of hydrous mafic minerals in the granite, but also convert pyroxenes to amphibole, as observed in coarse metabasites. Eventually, parts of the originally basic xenolith will be composed of the same minerals as the granite itself, only in different proportions.

Absence of flow fabric in the hybrid granite and of protoclastic texture in its margins indicates that the hybridization process may have taken place in situ, and that little post-contamination movement has occurred. On the other hand, there are no basic wall rocks in contact with the hybrid mass at the present level of exposure that could account for the xenoliths. Moreover, dragging effects in the country rocks definitely suggest movement.

The writer believes that a granite melt, considerably cooled by contamination with fine-grained xenoliths (possibly picked up from the Shickshock Group) inched and stoped its way into a weakness zone already occupied by a gabbroic body. The abundance of xenoliths, both fine- and coarse-grained some of which are merely incorporated, as well as the lack of linear and planar orientation in the hybrid granite suggest that the presently exposed surface is the roof portion of the mass. Isolated patches of coarse metabasite are remnants and possibly protrusions of a larger basic intrusion in depth.

It has been taken for granted all along that the contact aureole is genetically associated with the granitic intrusions. In view of a multiple intrusion hypothesis, it would be more realistic to assume several thermal effects superimposed upon each other. In fact, some evidence has been presented from the Mt. Auclair area that little reciprocal reaction had taken place between the late, red granite and xenoliths suggesting equilibrium conditions.

The homogeneous composition and isotropic fabric of the late granite indicate a slow and uniform cooling of a post-kinematic mass. Petrographic study suggests that siliceous liquids impregnated the acid and basic facies of the pluton during the last stages of crystallization. Interstitial quartz introduction and K-metasomatism is widespread. Abundant water may also have been available from previous alteration processes connected with hornfels formation.

The mechanism of emplacement of the late granite was probably by forceful intrusion rather than by stoping. This is suggested by the abund-

ant cross-cutting apophyses and the general lack of xenoliths.

The gross structural features of the pluton indicate a northerly trending, steep-sided body cutting across previously folded Cambro-Ordovician rocks. Some authors (Dugas et al, 1969, p. 852) attribute the N-S elongation of the pluton to prominent transverse structures as reflected by magnetic linear trends. Most leucocratic and basic dikes south (de Römer, 1969) and SW (Robert, 1966, 1967) of the pluton trend in a northerly direction. There is no field evidence, however, of N-S fractures along contacts of the pluton or in the general area underlain by Cambro-Ordovician rocks for that matter.

From his study of the western flank of the pluton, Girard (1967; 1971, p. 25) concludes that the intrusion was emplaced along the axial plane of a south-plunging Acadian cross-fold. A similar hypothesis involving a granitic body in the core of a regional anticline was recently put forward in the case of the Opemiska pluton (Wolhuter, 1971).

The writer has found no field evidence of the reported axial plane cleavage east of the pluton. A S_2 -cleavage is present here, but it is pre-granite and likely Taconic in origin. All evidence points to the fact that the northward converging Cambro-Ordovician units are the result of dragging action by the pluton. However, deep-seated N-S fractures, regional in scope, may have controlled its emplacement.

The depth of intrusion was probably shallow. This is suggested by the absence of primary muscovite in the granite. The intersection point of the minimum melting curve of the system $\text{NaAlSi}_3\text{O}_8\text{-KAlSi}_3\text{O}_8\text{-SiO}_2\text{-}$

H₂O, corresponding to that of the late granite, (Luth et al., 1964, p. 760) with the muscovite stability curve (Velde, 1966, p. 928) lies at a total pressure of slightly less than 2 kb and a temperature of $\pm 680^{\circ}\text{C}$. This corresponds to a depth of roughly 7-8 km, corresponding to the figure suggested for the depth of hornfels formation in the contact aureole (p. 146)

Relating deposition to erosion and orogeny may also give a very rough approximation of the depth of emplacement of the pluton. At the present level of exposure, the pluton is in contact with Cambro-Ordovician rocks. As mentioned above (p. 73), it is probable that its northern tip intrudes into Middle Ordovician strata.

After post-Taconic erosion presumably removed part of Upper Ordovician and possibly part of Middle Ordovician pelites, there followed deposition of at least 6,500 feet of Siluro-Devonian platform sediments (Béland, 1969, p. 815). As is pointed out in the next section (p.) the main part of the pluton was emplaced during the last pulses of the Acadian orogeny. At that time, the depth of cover must have been the total thickness of the Siluro-Devonian series and an unknown thickness of Upper and Middle Ordovician strata.

It may therefore be safely assumed that the minimum depth of cover at the time of emplacement was in the order of 6,500 m, but the real figure was probably significantly greater. This depth corresponds to a total pressure of over 1.6 kb. It was probably closer to 2 kb, as suggested earlier.

Radiometric Dating

Introduction

Some 10 years ago, the age of granitic plutons in north-central Gaspé had been universally accepted as Devonian, as it was for the past 100 years. Mapping by Quebec Dept. of Mines geological parties firmly established the association between leucocratic intrusives and the Acadian orogeny.

Then, in 1963, a Geological Survey of Canada paper on radiometric age determinations (Leech et al. 1963) startled all concerned with unexpected results obtained by K/Ar dating methods. Analyses of 2 samples from the contact-aureole of Mt. Albert and one from the western edge of the Mts. McGerrigle pluton (Tabletop) yielded 495 m.y. in each case for the former and 420 m.y. for the latter. It consequently placed the Mts. McGerrigle pluton into the Silurian, a surprisingly old age. Veteran Gaspé geologists tacitly questioned the results, although they were accepted and partly incorporated in the literature.

Mapping in the critical area of Gaspé enabled the writer to re-examine the contacts and the age problem in the light of new field data. Five K/Ar age determinations were obtained with the view to 1) strengthen the hypothesis of a Devonian age for the Mts. McGerrigle pluton, 2) establish a genetic relation between the pluton and the leucocratic stocks a few miles to the southwest, and 3) hopefully corroborate field evidence that the pluton is a multiple intrusion.

Sample Description

Three samples were collected from various parts of the pluton, one

from Hog's Back and one from Mt. Vallières-de-St. Réal (Map I, in pocket). The exact location, age, chemical analyses and other pertinent data are given in Table X. Following is a brief description of the samples:

Sample 1: The rock is typically a red, coarse, slightly porphyritic granite forming a large area within the contaminated rocks. It is almost identical in texture, mineral and chemical composition to the rocks underlying the northern part of the pluton (Table VII, Nos. 67, 69, 70 and 78). The dominant feldspar is perthitic alkali feldspar; quartz is interstitial forming 25% of the rock. Biotite is an alteration product of green hornblende, together amounting to less than 3% of the rock. Magnetite, apatite, zircon and sphene are minor accessory minerals. The analyses in duplicate gave isotopic ages of 358.9 and 353.8 m.y., averaging 356.4 ± 4 m.y., indicating an Upper Devonian age.

Sample 2: Collected from the NW corner of the pluton it also has a hypidiomorphic-granular texture. The rock is coarse-grained, but contains considerably more plagioclase than alkali feldspar; 15% quartz and 8-10% of mafic minerals, mostly biotite and green hornblende. Although the sample lies within a granite patch, it contains less alkali feldspar and quartz and more mafic minerals than the normal, red granite of the south. Clusters or streaks of mafic minerals suggest contamination by fine-grained metabasite xenoliths. The rock is probably intermediate in composition between granite and hybrid rocks (Table VIII, No. 81). Two whole-rock analyses yielded 352.4 and 339.9 m.y. averaging 346.2 ± 7 m.y., again indicating an Upper Devonian age.

K/Ar WHOLE-ROCK AGE DETERMINATIONS OF THE
MTS. MCGERRIGLE PLUTON AND ITS NEIGHBOURING STOCKS (1)

Rock Name	Sample No.	Geograph. Coordinates	Sample weight (lbs)	Age (m.y.)	%K	Ar ⁴⁰ /K ⁴⁰	% A ⁴⁰ rad.	Chemical analysis no. in this rept	Location
Porphyritic granite	1(R357-8)	49°00'01"N 65°55'55"W	20	358.9 353.8 av. 356.4±4	3.70 3.70	0.0235	98	78	Mts. McGerrigle
Biotite grano-diorite	2(R527-9)	49°01'53"N 65°59'39"W	25	352.4 339.9 av. 346.2±7	4.21 4.20	0.0227	98	81	Mts. McGerrigle
Hornblende-biotite metabasite	3(Rd163B-0)	49°00'23"N 65°55'36"W	20	323±10 315±10 av. 319±10	1.30 1.31	0.0210	87.0 86.0	91	Mts. McGerrigle
Coarse, red granite (2)	4	48°57'24"N 65°59'36"W	-	420	7.24	0.0276	100	70	Mts. McGerrigle
Quartz-sodic feldspar porphyry	5(Rd164B-0)	48°51'33"N 66°06'38"W	20	339±10 333±10 av. 336±10	2.18 2.14	0.0221	88.0 88.5	89	Hog's Back
Quartz-sodic feldspar porphyry	6(Rd165B-0)	48°49'00"N 66°02'25"W	20	363±11 365±11 av. 364±11	3.30 3.285	0.0241	97.0 97.0	90	Mt. Vallières-de-St. Réal

1) All samples, with the exception of No. 4 were collected by the writer and dated by Teledyne Isotopes Inc., New Jersey.
See Map I, II and III for sample location.

2) Sample dated by the G.S.C. (G.B. Leech et al., Geol. Surv. Canada Paper 62-17, p. 81, 1963).

Sample 3: The sampled rock is a holocrystalline, massive, coarse-grained metabasite of high color index situated at the eastern edge of the pluton and intersected by the Mt. Jacques Cartier jeep road. The subophitic texture is indicative of its igneous, probably gabbroic origin. It is composed of andesine and green, chloritized hornblende after diopsidic augite. Minor, apparently older and very saussuritized feldspars are also present; calcite, biotite and quartz occur in minor amounts; the latter about 1-2%, is interstitial and is introduced. Apatite, sphene and iron minerals are accessory minerals. Duplicate analyses of the coarse metabasite gave 323 ± 10 m.y. and 315 ± 10 m.y., averaging 319 ± 10 m.y., suggesting a surprisingly young Mississippian age.

Sample 4: This is the G.S.C. sample that yielded a biotite K/Ar age of 420 m.y. (Paper 62-17, p. 81). The writer resampled the rocks for petrographic study and chemical analysis, and on request for the Geological Survey of Canada. The rock is a holocrystalline, coarse-grained, red granite as found typically in the southern part of the pluton. It is very similar in every aspect to the No. 1 sample. Biotite is very scarce (Table VII, No. 70).

Sample 5: It was collected from Hog's Back, a sloping, barren and debris-covered ridge some 12 miles SW of Mt. Jacques Cartier. About 3 square miles in surface, it extends west (Hog's Back) and east (Mt. Chauve) of the Park road. Deeply weathered and extensively fractured the red, fine-grained rock is massive and distinctly porphyritic. In thin section, euhedral,

sericitized albite-oligoclase phenocrysts and also deeply corroded and fractured quartz are characteristically embedded in a fine matrix of quartz, alkali feldspar, plagioclase and minor chloritized biotite and hornblende. The rock is typically a quartz-feldspar porphyry. Duplicate analyses gave 339 ± 10 m.y. and 333 ± 10 m.y., averaging 336 ± 10 m.y. or a Mississippian age.

Sample 6: The sample was taken from the southern part of Mt. Vallières-de-St. Réal, a 3.5 square-mile stock 12 miles SSW of Mt. Jacques Cartier. As in the case of Hog's Back, it is a talus-covered, gently to moderately dipping sill or semi-concordant body intruded into Siluro-Devonian rocks. These are contact metamorphosed, forming an irregular thermal aureole of hornfels, averaging $\frac{1}{4}$ mile in width. The lithology is also very similar to that of Hog's Back. The pink rock is fine-grained, massive and porphyritic. Here again, idiomorphic, zoned phenocrysts of albite-rich plagioclase and some corroded quartz are embedded in a fine-grained matrix of quartz, sodic plagioclase and minor K-feldspar. Chloritized biotite and hornblende are more abundant than in Hog's Back accounting for its slightly less acid composition (Table VIII, No. 90). Opaques are very minor accessories. The Mt. Vallières-de-St. Réal stock is like Hog's Back, a quartz-sodic feldspar porphyry. Both are considered to be hypabyssal intrusions.

Analyses of the 20 lbs sample performed in duplicate yielded 363 ± 11 m.y. and 365 ± 11 m.y., averaging to 364 ± 11 m.y., which places the age in the Upper Devonian.

Analytical Data

All the sample except No. 4, were collected in 20-25 lb lots during the 1968-70 field seasons. Particular care was paid to fine representative, homogeneous and fresh specimens. Some difficulty was experienced when sampling the deeply weathered and fractured porphyries of Hog's Back and Mt. Vallières-de-St. Réal.

The analyses were performed by Teledyne Isotopes, Inc., New Jersey. All were done in duplicate by dividing first the submitted sample into 2 equal halves, each of which was then analyzed for K and Ar^{40} . The K-analyses represent the total K in the whole-rock sample and were performed by flame photometry using a Na-buffer technique. This involves addition of a large excess of Na to both standard and unknown solutions in equal amounts. This is done in particular, when rocks with low-potassium minerals (such as pyroxenes) are analyzed (Cooper, 1963, p. 538).

The error indicated for the ages consists of a summation of all analytical errors, generally amounting to 1-3%. The upper limit was used to calculate the analytical error in the isotope ages.

Background Information

One of the fundamental assumptions made in K/Ar age calculations is that the age value obtained corresponds to the time since the diffusion of argon from the sample ceased, i.e. the time (t_0) and temperature (diffusion threshold) since the mineral became a closed system. Whether the sample remains a closed system will depend essentially on two factors: 1) the capacity of the sample to retain Ar^{40} as it decays from K^{40} , and 2) on the

disturbance, thermal or mechanical that may affect the physical or chemical state of the sample. Since most minerals will lose argon when heated to several hundred degrees, probably the most decisive single factor in reopening the system is a rise in temperature. Diffusion of argon will result in an age which is too young.

Argon accumulates as soon as the sample solidifies. Unless subsequently disturbed, dating of rapidly cooling bodies, such as lavas, will therefore give the approximate time of solidification. In case of deep-seated intrusives, however, where cooling may extend over millions of years, the K/Ar value may postdate the time of crystallization, because argon diffuses easily at temperatures well below those of igneous intrusions or those associated with high-grade metamorphism. In other words, the age value obtained from a plutonic rock does not represent its time of crystallization. It is known that plutons remain at elevated temperatures long after the minerals had formed. Therefore, the interval between the time of crystallization and the time when a mineral has reached its threshold temperature may be considerable and will depend primarily on the rate of cooling of the igneous mass, and on the threshold diffusion temperature of the sample analyzed. In other words, the age value obtained will represent the time elapsed since the threshold temperature was reached. Reheating or any disruption of the mineral lattice will cause diffusion and loss of argon resulting in a younger age value. On the other hand, xenoliths and xenocrysts can contribute significant amounts of A^{40} to the sample. The age obtained is then too old.

Discussion and Interpretation

The granite sample No. 1 is homogeneous and fresh. Field evidence suggests that the red granite is the youngest plutonic intrusion of the area and that it has not been disturbed or reheated since its emplacement. It is possible that the 356 ± 4 m.y. records the time of final cooling of the granitic melt, not too long after crystallization had taken place. As shown in the preceding section, temperature-pressure conditions around the pluton suggest a forceful, rather shallow type intrusion, conducive to a relatively rapid loss of heat. On the other hand, the coarse and homogeneous texture of the red granite suggests a slowly and uniformly cooling mass. It is probable that the age reported actually represents the time of uplift of the cooling pluton in the last post-kinematic phase of the Acadian orogeny.

Sample No. 2 of granodiorite is intermediate in composition between hybrid rocks and red granite. In fact, a few 1000 feet north of the sample location, hybrid rocks are laden with fine-grained metabasite inclusions. Aggregates of mafic minerals in the sample may represent remnants of xenoliths. Its 346.2 ± 7 m.y. is lower than the reported age of the granite, although field evidence unequivocally indicates that hybrid rocks are pre-granite. It is possible that reheating of the hybrid rocks by the granite resulted in a partial resetting of the K/Ar clock and a younger age value. On the other hand, xenocrysts and xenoliths can add "inherited" argon to the sample thereby increasing its age (Dalrymple, 1964, p. 182). It is more likely, however, that in this case, the calculated value is too low. In

any event, the sample indicates again an Upper Devonian age for the acid phase of the pluton.

The relatively low age of 319 ± 10 m.y. for the No. 3 metabasite sample is disappointing because field evidence indicates that a basic intrusion precedes all other phases of the pluton. The writer assumes that the analytical results are reliable; the difference between the duplicate values lies, at least, within the permissible error. The past history of the sample suggests that its low age is due to loss of argon. Field relations show that coarse metabasites were affected by two granite injections, each pulse partly or completely resetting the time clock. Thin sections also indicate K-metasomatism and introduction of quartz into the largely uralitized rock. Possibly, the age value records the time when the regional temperatures, induced by the late post orogenic granite, had decreased to a point where the sample could retain its radiogenic argon. Evidently, the originally gabbroic rock did not remain a closed system to argon diffusion, because of multiple heating.

The G.S.C. sample No. 4 falls in the area of the late, red granite. Originally dated as 420 m.y. old, it was recently reanalyzed and the new age obtained is very similar to those of samples No. 1 and No. 2 of this report (Poole, written communication, 1971). Different samples yielding similar results obtained by different analytical methods is powerful evidence that the age of the late granite is reliable.

Samples from Hog's Back and Mt. Vallières-de-St. Réal, yielding 336 ± 10 m.y. and 364 ± 11 m.y., respectively, are lithologically very similar,

although the latter has more mafic minerals, as reflected in its chemical analysis (Table VIII, Nos. 89 and 90). Unfortunately, only few fresh samples were available, thus probably accounting for some argon loss. They average 350 m.y., surprisingly close to 351 m.y. which is the average age value of No. 1 and No. 2 samples.

Conclusions

It was first pointed out by Jones (1953) that the "Tabletop Mass" is nowhere in contact with Siluro-Devonian rocks. Hog's Back and Mt. Vallières-de-St. Réal, on the other hand, are clearly intrusive into Siluro-Devonian formations.

The writer believes that the marked concordance in age between the Mts. McGerrigle granite, Hog's Back and Mt. Vallières is not fortuitous. Field evidence, backed by results from radiometric dating, indicate that the above leucocratic bodies may be part of the same igneous mass in depth which invaded post-kinematically the country rocks in late Devonian or Early Mississippian time. While the granite intruded Cambro-Ordovician rocks, satellitic porphyries such as Hog's Back and Mt. Vallières rose to higher levels to be emplaced in form of semi-concordant hypabyssal sheets in Lower Devonian formations. Some protuberances of the igneous mass are not far below the present surface, as shown by the patchy distribution of thermally altered rocks south of the Mts. McGerrigle pluton.

CHAPTER VIII
STRUCTURAL GEOLOGY

Introduction

Although beneficial in general geological studies, group work is seldom conducive to carry out detailed structural analyses unless structure is the main objective and the party members have the necessary qualifications and interest. In addition, working with a new team each year in a complexly folded belt makes evaluation of the structural inventory hazardous.

This report covers a heavily wooded and partly mountainous area of 150 square miles. Mapped at a scale of 1000 feet to 1 inch during five summer seasons, the area provided sufficient information to obtain a reasonably clear picture of the structural set up of the region.

In contrast to the continuous and spectacular exposures on the coast, Cambro-Ordovician outcrops inland are scarce and of erratic distribution. The rocks are complexly folded and data must be pieced together from widely isolated outcrops, making a detailed structural profile difficult to establish. The best exposures are found along short stretches of the Rivière Madeleine and along Rivière Madeleine Nord, a few thousand feet east of the area studied.

In the southern part of the region underlain by Siluro-Devonian formations, the structural pattern is easier to trace, due to slight deformation and because structure is firmly supported by stratigraphic evidence, although distribution of outcrops here too is very irregular.

General Structural Setting

The most important structural feature of Gaspé Peninsula is the Gaspé-Connecticut Valley synclinorium. Forming the eastern part of the Appalachian fold system, it extends for over 1,000 miles from New England to Gaspé and beyond. It consists of three parallel belts, each with its own particular lithology, structure and age. The boundary between the northern and central belts cuts obliquely across the area under study.

Intensely and repeatedly folded pelites and intercalated basalts (Quebec Group) and metabasalts (Shickshock Group) of Cambro-Ordovician age characterize the northern part of the area. The latter probably extend eastward beneath a cover of younger rocks. The rock assemblage reflects an eugeosynclinal and mobile environment. An acidic plug, Acadian in age, (Mts. McGerrigle pluton) cuts across the Lower Paleozoic rocks, resulting in a 1-2 mile wide thermal aureole. The southern third of the area, which lies within the central belt, comprises on the other hand, gently folded limestones, clastics and volcanics of Siluro-Devonian age, reflecting a miogeosynclinal or platform-type deposition. A thrust fault of regional importance separates the two belts.

Northern Belt (Quebec and Shickshock Groups)

Introduction

At first glance, the belt east of the pluton seems to represent a thick homoclinal assemblage of pelites and calcosiltites striking NE and dipping moderately SE. Examination of minor structural features in detail shows,

however, the unmistakable imprint of multiple deformation. Few actual closures of large scale second-order folds are apparent in the field. The structural pattern was mainly deduced by careful examination of minor features in outcrop and thin section. The structural analysis in this lithologically monotonous area was also hampered by lack of stratigraphic control and absence of horizon markers of any kind.

The following fold elements constitute the structural inventory of the northern belt: S_0 (bedding), S_1 (foliation), and S_2 (crenulation cleavage), lineations L_1 and L_2 , and folds F_1 and F_2 . They suggest several generations of superimposed structures, and are therefore grouped below genetically from oldest to youngest.

Fold Elements:

S_0 (bedding, conveniently included here) is a common feature well observed in the silty and calcareous rocks of the central and northern units of the Quebec Group. It becomes obscure in the argillites of the outer contact zone, but shows up well in the inner zone. It corresponds here to the compositional banding encountered in pelitic and calc-silicate hornfels (Fig. 8e, f, and Plate XXVII). Due to advanced recrystallization, S_0 is not visible in skarn. Within the aureole, the strike of the banding swings NW due to drag action of the pluton. As mentioned above (p. 130) coarse metabasite cuts across folded calc-silicate hornfels xenoliths, suggesting a pre-basite deformation.

S_1 (foliation) is in most cases parallel to S_0 , although in a few cases it is observed to intersect it at a very small angle (Fig. 8c). Some

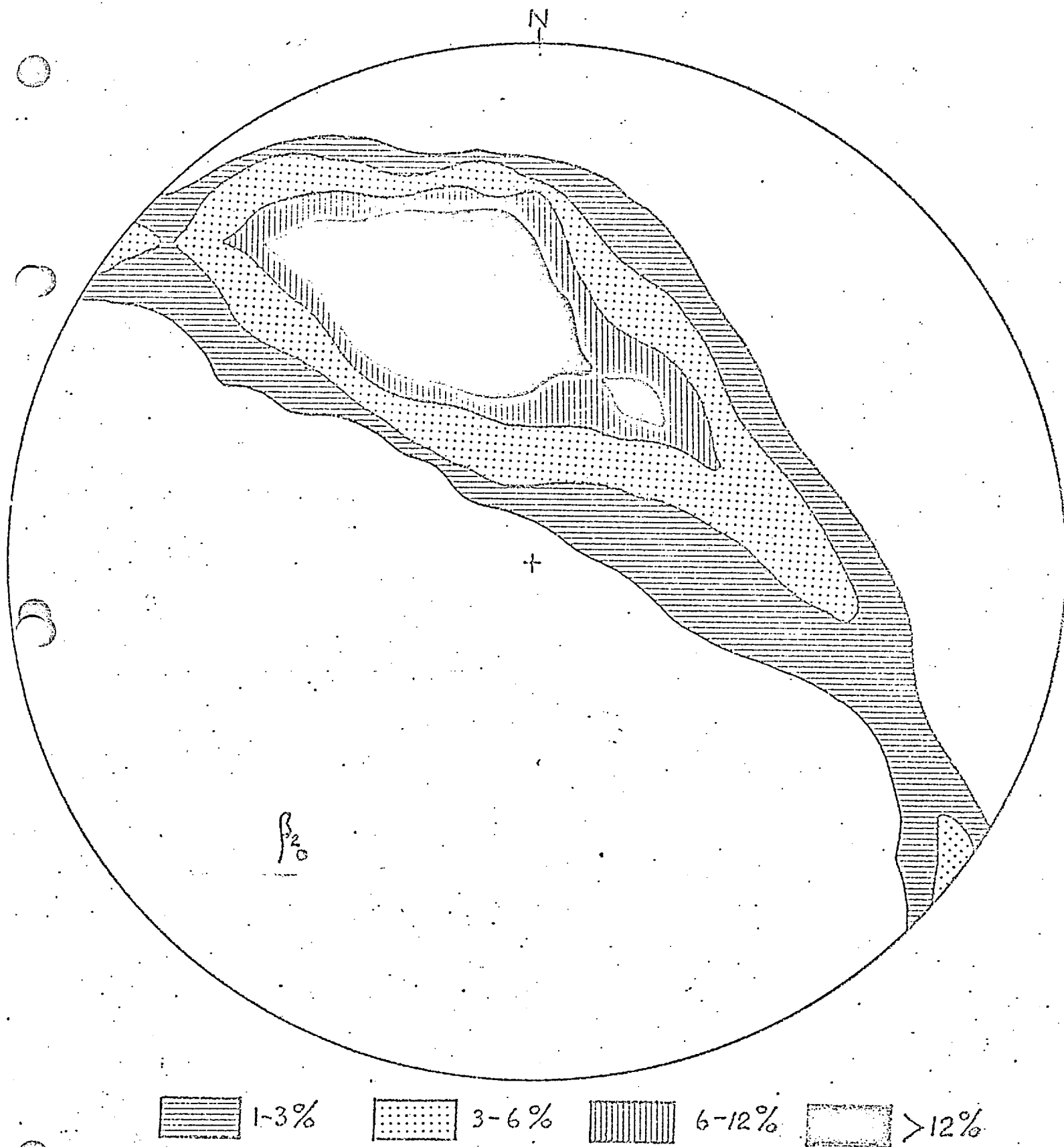


Fig. 5. S-girdle of 105 poles to S_0 and S_1 in a 1 mile-diameter area, centered between ruisseau Pierre-Jean and ruisseau Auclair, 1 mile W. of rivière Madeleine-Nord (contours per 1% area).

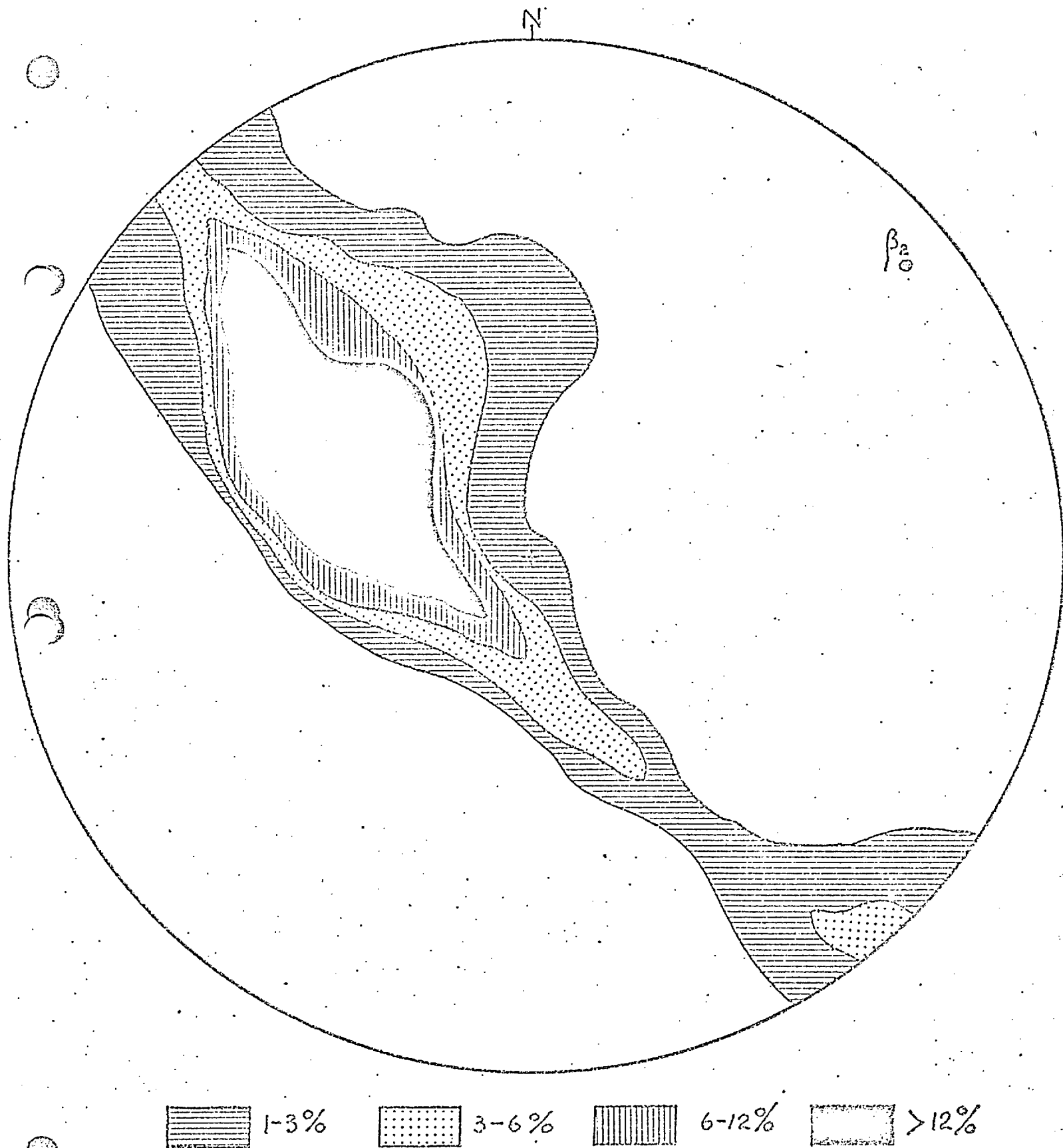


Fig. 6. S-girdle of 128 poles to S_0 and S_1 in a $\frac{1}{2}$ mile-diameter area, centered 3 miles ENE of lac de la Botte, E. of rivière Madeleine-Nord (contours per 1% area).

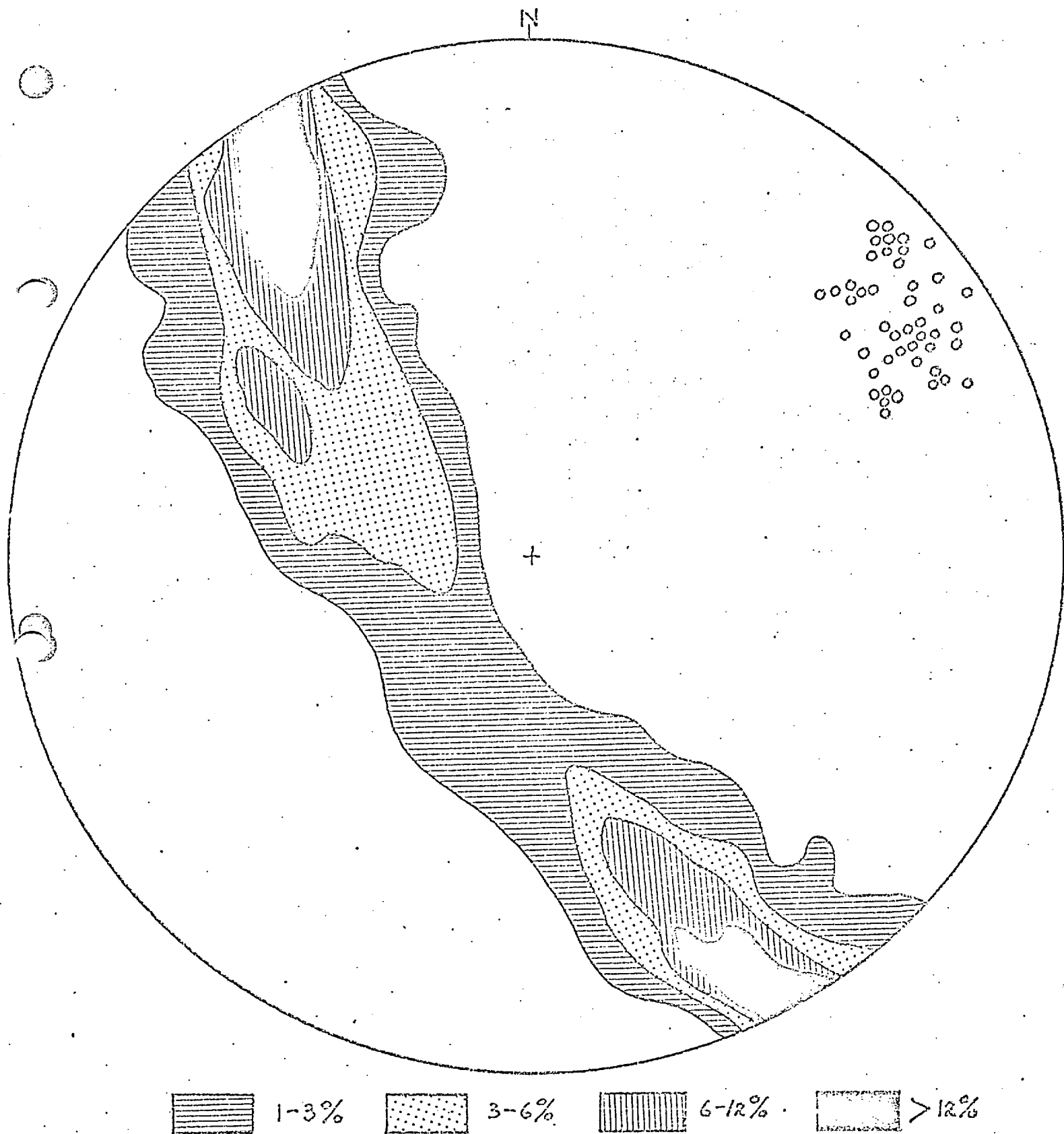


Fig. 7. S-girdle of 128 poles to S_0 and S_1 and distribution of L_2 in a 1 mile-diameter area, centered $\frac{1}{2}$ mile N. of the rivière Madeleine-Madeleine-Nord junction (4,500 feet E. of the area) (contours per 1% area).

of the slaty cleavage may be primary foliation and should then be called bedding fissility or bedding cleavage. In general, thin sections show a strong preferred orientation of slaty minerals imparting a distinctly tectonic fabric. S_1 is axial plane to early, probably isoclinal folds F_1 .

F_1 (early folds) are the earliest evidence of deformation in the Quebec and Shickshock rocks. Only small-scale folds were observed in thin section (Fig. 8a, b). Large-amplitude, isoclinal and possibly recumbent F_1 folds may be present, but are not detectable.

L_1 (early lineation) refers to F_1 fold axes and S_0 - S_1 intersections. Very rare, they appear to be of very erratic orientation. Strike readings as disparate as 10° , 35° , 85° and 140° have been recorded (Fig. 8c). On a series of small road outcrops, 3,000 feet SW of the NE corner of the area, a faint lineation folded about later fold axes plunges gently toward 240° (Plate XVIII). What is also believed to be an S_0 - S_1 intersection is observed in some outcrops 1,500 feet SW of the above location. Here, L_1 plunges gently southeasterly. A consistent southerly plunge of an anomalous lineation is observed in river outcrops of Ruisseau Porc-Epic and Ruisseau Galène, SSW and S. of lac St. Pierre. At the former locality the S_0 trace on what appears an S_1 cleavage plane results in L_1 plunging gently south. The southward plunge of minor fold axes in limestones at the latter locality is unexplained and needs further checking.

The fact that L_1 is so rare suggests that the first generation folds are insignificant, unless, of course, they were completely over-printed by effects of a later deformation. If isoclinal (as suggested by S_0 - S_1 parallel-

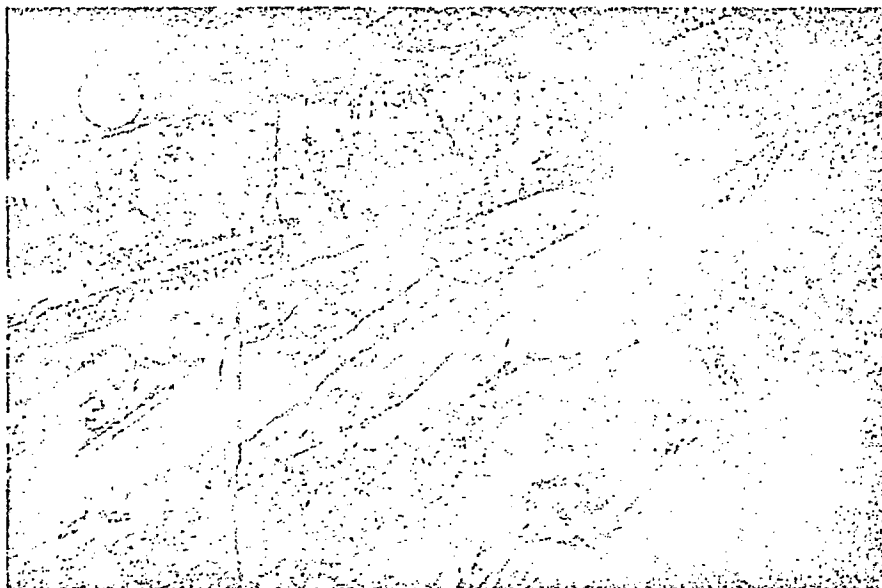


Plate XXVII. S_2 -cleavage cutting diagonally across compositional banding in pelitic hornfels (1,500 feet ESE of the southern tip of lac Vièillard).



Plate XXVIII. L_1 -lineation ($5^\circ/240^\circ$, match) being refolded by F_2 folds (pencil, $5^\circ/80^\circ$). S_2 (crenulation cleavage) is not visible here. (3,000 feet SW of NE corner of the area).

lism) and coaxial with later generation folds, F_1 folds may remain difficult to identify. Their axial trend is actually unknown.

S_2 (late cleavage). Together with S_0 and S_1 , this cleavage is the most widespread and penetrative S-plane of the northern belt. In fact, S_1 and S_2 are at many places difficult to distinguish, because both often occur as fine slaty or fracture cleavage depending chiefly on the type of lithology affected. It may be generalized at this point that most of the slaty cleavage, such as observed along the main road north of lac St. Pierre (1000 feet outside the map-area) should be identified as S_2 (Plate XXIX and Fig. 8c). Where it is a crenulation cleavage, S_2 is unmistakably a late feature and evidence of repeated deformation (Fig. 8a, d). Crenulation cleavage is well shown in a number of locations. Perhaps the most representative outcrops occur a few thousand feet east of the area along the Rivière Madeleine Branche Nord, 1,500 and 5,000 feet north of its junction with the main Rivière Madeleine (Fig. 8h). S_2 serves as axial plane cleavage to F_2 folds and frequently cuts across S_0 and S_1 at a considerable angle (Plate XXIX).

Particular attention was paid to trace S_2 across the aureole and into hornfels. At several locations, S_2 was identified transecting the compositional layering (Fig. 8e, f). On the back of a prominent ridge, 3 miles SSE of lac de la Botte and approximately 6,000 feet east of the pluton, S_2 distinctly cuts across a green and grey banded calc-silicate hornfels (1a2M, p. 30). Again, some 1,500 feet ESE of the southern tip of lac Villard (Plate XXVII), S_2 clearly cuts S_0 S_1 , made evident by bands of cordierite metacrysts (2cM, p. 52).

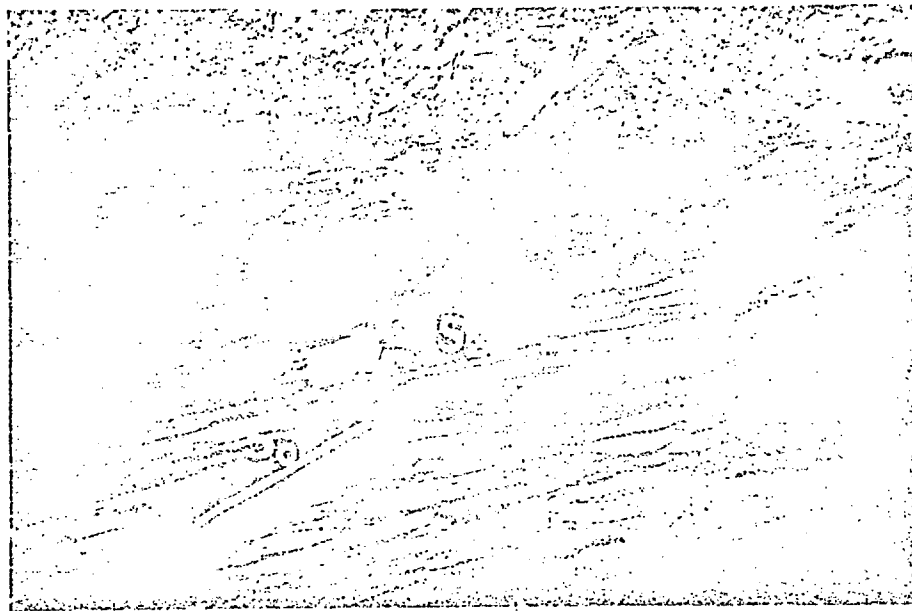


Plate XXIX. Bedding (S_0) and slaty cleavage (S_2) relationship in silty shales (along road, N. of lac St. Pierre, 1000 feet outside the area).

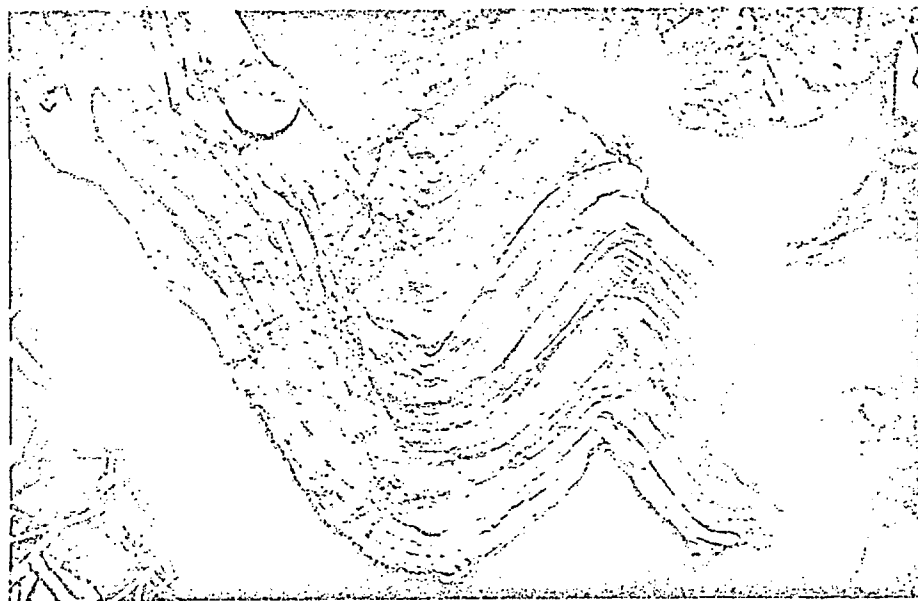


Plate XXX. Open, parallel F_2 -fold in argillaceous limestone (in rivière Madeleine, 0.9 miles W. of the eastern boundary of the area).

Evidence has been gathered at many places that S_2 cleavage, together with S_0 and S_1 , has been warped and dragged by the forceful injection of the pluton. This indicates a pre-pluton age for S_2 formation.

Slight warping of S_2 was observed in a few places, such as along ruisseau Pierre-Jean near camp Couturier. Here, dark calcareous shales show a monoclinaly folded S_2 crenulation cleavage. No consistent attitudes could be obtained, and the deformation responsible for this flexing is regionally unimportant. Recent creep in road cuts, N. of lac St. Pierre, has produced disharmonic folds of F_2 (Fig. 8d).

F_2 folds are very common in the rocks of the Quebec and Shickshock Groups. In fact, practically all the folds of the map-area are of the F_2 type and generation. The geometry varies from place to place, but all appear tectonic in origin. Their style in outcrop size varies from open to isoclinal, but generally they are either similar or parallel, depending on the competency of the affected strata, and frequently overturned to the northwest.

A number of larger NE-trending folds has been located using S_0 S_1 - S_2 relations in plan and section. A major F_2 fold occurs north of and parallel to, Rivière Madeleine. Recorded by Jones during his reconnaissance work of the "Tabletop Map-area" (1933, p. 27), it is a tight, upright synform in silty shales plunging 10° - 20° NE. Numerous, subordinate, small-scale folds in the core show a perfect development of S_2 .

Two major F_2 -folds were identified in the aureole SE of lac Côté. Both are flattened and dragged northwardly (in plan view) by a prominent bulge

of the pluton. The continuation of the southern fold west of the pluton is indicated by the distribution of quartzite bands. Another F_2 -fold occurs in the contact zone north of the pluton. Here, calc-silicate and pelitic hornfels show upward converging S_2 planes. At first interpreted as a F_3 structure of folded S_2 it was later established to be an almost symmetrical, open antiform of the F_2 type with upward converging cleavage.

The fact that the pluton warps and cuts across S_2 and F_2 -folds indicates that they are of pre-Acadian age.

L_2 (late lineation) refers to fold axes of microfolds and also corresponds to S_0S_1 - S_2 intersections. S-girdles of poles to S_0 and S_1 , clearly show a preferred concentration of L_2 in the NE and SW quadrants (Figs. 5 and 6). L_2 is the lineation associated with F_2 folds and is therefore the most obvious and dominant linear feature observed (Figs. 7 and 8c). In the field, rapid reversals of the dip direction are common, although the plunge never exceeds 35° . In the NE corner of the area, excellent examples of L_2 in calcareous siltstones and silty shales are common. Here, the prevalent attitude is $5-10^\circ$ toward $N80^\circ E-S80^\circ E$.

A widely spaced fracture cleavage (S_3 ?) has been observed locally in phyllites and calcareous slates and intercalated limestones along rivière Madeleine, slightly over one mile west from the eastern boundary of the area (Plate XXXI). The fractures, 3-4 inches apart, offset S_2 and are axial planes to open flexures trending NE. Development of S_3 (?) seems to be very restricted and is probably of little significance. It may, however, belong to the generation of folds that affected the Siluro-Devonian rocks to the south.



Plate XXXI. Wide-spaced fracture cleavage (S_3 ?) cutting across S_2 (in rivière Madeleine, 0.9 miles W. of eastern boundary of the area).

Fractures

Most fractures recorded in the northern belt are NW-trending joints occasionally occupied by dikes. While acid granophyres are found only in the vicinity of the pluton and within the aureole, basic dikes occur commonly farther out in the country rocks. A swarm of basic dikes is conspicuous in outcrops along Ruisseau Pierre-Jean. They appear to be of the same generation as the fractures observed within the pluton. Some of the basic dikes, however, are deeply altered and may be related to the basic pre-granite intrusion of the Mts. McGerrigle pluton.

There is some evidence to believe (p. 26) that the Shickshock metasediments and pyroclastic units extend beyond the pluton and gradually

wedge out northeastward into or possibly beneath, the Quebec Group rocks. It appears that the northern contact is discordant in that it truncates and eliminates the southern limbs of F_2 -folds north of it. The southern contact is believed to be conformable, but its location is largely inferred, because of total lack of exposure.

Traced from some 100 miles west of the present area, the Shickshock fault extends to south of the pluton and possibly a few thousand feet into the writer's area. Representing an important break, it has given rise to arguments regarding contact relations between Cambro-Ordovician and Siluro-Devonian rocks. Some workers imply a downthrow of the Silurian block along a normal fault (Jones, 1933, p. 19-20; Ollerenshaw, 1967, p. 149). From evidence east and west of the area, others regard the contact to be an angular unconformity (Cumming, 1959, p. 15-18; McGerrigle, 1959, p. 22; Béland, 1960, p. 2; Burk, 1963, p. 455).

There is little evidence that the Shickshock fault maintains its EW course beyond the present area. It is rather inferred that a recent set of vertical NNW fractures, west of Barter lake, rotated and displaced the fault zone northward to parallel the wide and straight valley of rivière Madeleine. Extensive outcrops of tectonic breccia, gouge and intensely twisted rocks on the flat river banks, north of Barter lake and northeast of it, suggest that the rivière Madeleine valley is the site of an important fault zone. The writer infers that a thin slice of Cambro-Ordovician rocks unconformably overlain by a Siluro-Devonian cover was thrust north or northwest along the rivière Madeleine fault zone. There is no evidence in the

area under study that the contact between Cambro-Ordovician and Silurian rocks is a fault.

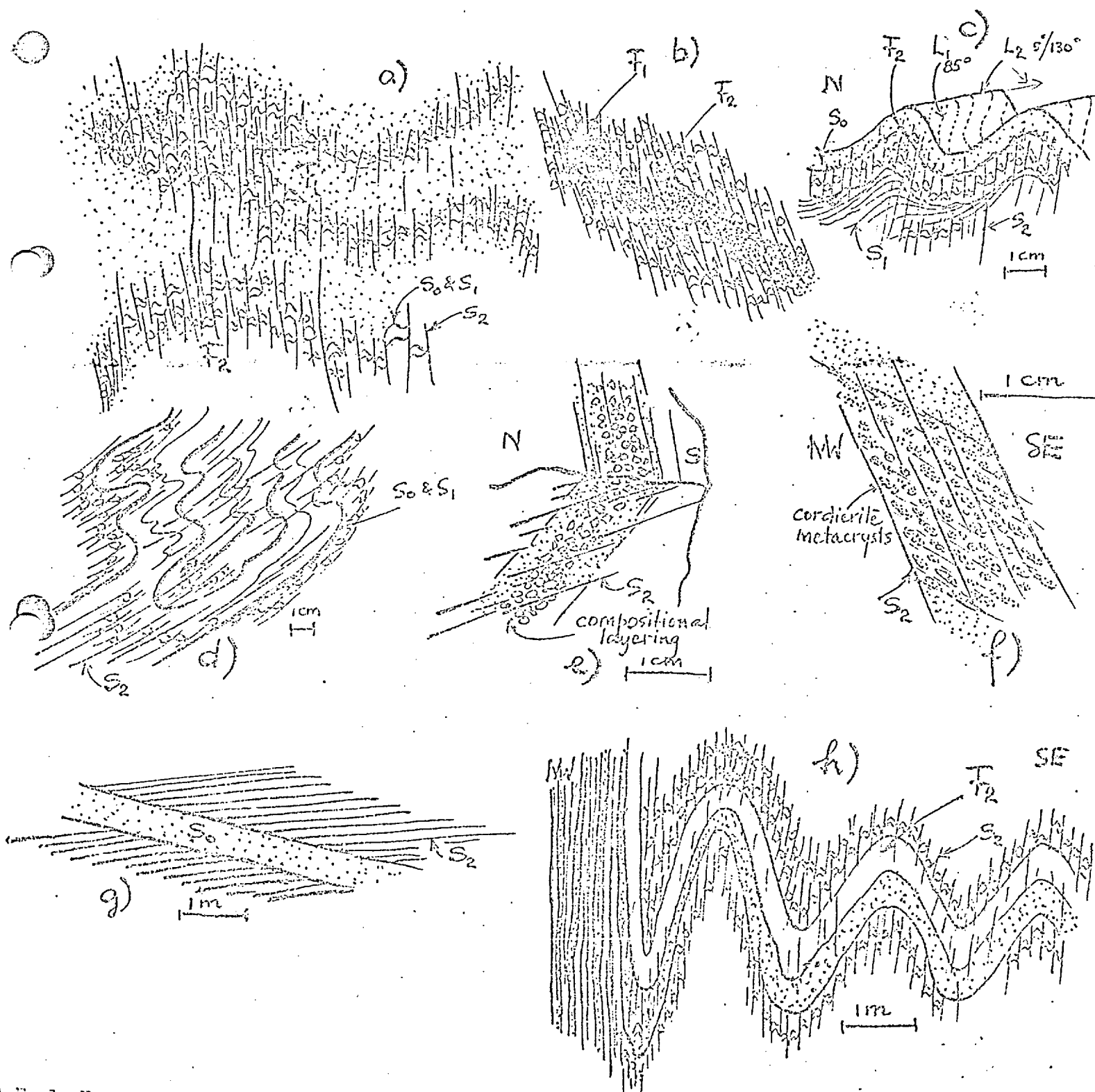
South of the pluton, the lithology from rivière Madeleine northward shows an undisturbed series of calcareous schists, crystalline limestone and garnetiferous hornfels, the compositional layering of which dips consistently south. Occasional dragfolds show a northward movement of the upper limb. The homoclinal attitude and dragfold pattern certainly do not suggest a disturbed unit. To the contrary, the attitude of the banding suggests an antiform to the north. As in the case west of the area, here too, the Shickshock fault is totally obscured and masked by heavy overburden in the rivières Pékan and Madeleine valleys.

Structural Synthesis

The above account suggests that three tectonic events have affected the northern belt of Quebec and Shickshock rocks. Whereas the early foliation was the product of the first pulse, most observed and inferred NE-trending folds (F_2) are the result of the second deformation. It was certainly the most penetrative and dominant event that determined the tectonic pattern of the Cambro-Ordovician rocks in the area. The effects of the third pulse were slight and were probably local producing broad flexures and fractures superimposed on the second generation structures.

The fact that S_1 - and S_2 -cleavages as well as F_2 folds in Cambro-Ordovician rocks are clearly truncated by the pluton indicates that at least the two first tectonic events are pre-Acadian in age. The effects of the second deformation are by far predominant and are probably associated

Fig. 8. Minor structures in rocks of the Quebec Group



- a) Early F₁-folds in thin section (3 miles ENE of lac de la Botte)
- b) Folded F₁-folds in thin section (1.7 miles S. of lac St. Pierre)
- c) Fold elements in calcareous siltstone (1 mile NNE of lac St. Pierre)
- d) Cusp-shaped F₂-fold in silty shale (1 mile NNE of lac St. Pierre)
- e) Cusp-shaped F₂-fold in silty shale (1 mile NNE of lac St. Pierre)
- f) Cordierite metacrysts in compositional layering (1.7 miles SE of Mt. Auclair)
- g) S₂ developed as slaty type cleavage (1 mile NNE of lac St. Pierre).
- h) Gneissation cleavage S₂ and F₂ folds in calcareous slate (0.5 mile NW of Riv. Madeleine-Madeleine Nord junction)

with the Taconic orogeny whereas the first pulse must therefore be of pre-Taconic age. The third tectonic event was not of far reaching significance in the area; it may belong to the last pulses of the Taconic orogeny or be related to the Acadian deformation.

Central Belt (Siluro-Devonian Formations)

Introduction

The southern third of the area under study lies within the upper part of the central belt of the Gaspé-Connecticut Valley synclinorium.

Most of the structural interpretation is based on stratigraphic data. Marker horizons and rigid stratigraphic control are sufficiently well established to arrive at a reasonable structural synthesis. Due to total lack of outcrops, a 10 square-mile area in the SE corner of the region was mapped entirely by *débris*. The lithology pattern and resulting structural picture fit well with information obtained from outside the area.

The structural inventory of the Siluro-Devonian rocks comprises sedimentary and penecontemporaneous structures, S_3 (slaty cleavage), L_3 (lineation), F_3 -folds and fractures. The "3" in the symbols refers to post 2nd-generation structures in the Cambro-Ordovician belt.

Sedimentary and Penecontemporaneous Structures

Bedding is well displayed everywhere. In addition, cross-bedding, sole markings and washouts are common, particularly in Silurian rocks. They all provide additional structural control to support stratigraphic data. Convolute bedding and penecontemporaneous slumping showing characteristic disharmonic folds and sedimentary boudinage are other features observed in

the Silurian calcosiltites.

Fold Elements

S₃ (slaty cleavage) is the only foliation observed in Siluro-Devonian rocks. It is axial plane cleavage to large, open folds. Usually vertical to subvertical, S₃ is well exhibited in the core of a NE plunging, synclinal F₃-fold, NE of lac Madeleine.

L₃ (lineation) invariably represents S₀-S₃ intersections and parallels F₃-fold axes.

F₃-folds: Only one generation of folds is present in Siluro-Devonian rocks. They consist largely of two large upright and parallel structures representing the youngest folds of the entire area. They cross the area SE of the pluton in an approximately northeasterly direction.

The northern fold is the eastern continuation of the Lesseps syncline recorded by Robert (1966b, 1967). It merges into the Bonnacamp syncline, east of the area (McGerrigle, 1959). The Lesseps syncline, which is a fold of the parallel type, plunges southward as it enters the area and then swings northward. The fold axis is rediscovered east of a prominent valley where it forms an easterly trending arcuate structure considerably displaced from its NS direction west of the valley. It gradually assumes its normal northeasterly course across lac Madeleine as it becomes again parallel to the tectonic grain of the region. East of the valley, the fold has reversed its plunge to NE. It is reasonable to conclude from the above that the Lesseps syncline has been displaced and dragged along a major fault or fault zone occupying the broad and conspicuous, NW-trending valley

of lacs Long, Vert, Martin, Crochet and Barter.

A complimentary anticline of normal NE strike and exposing older formations in its core is located 3 miles to the south. Its trace was established by débris and from evidence outside the area. It represents the southeastern continuation of the Béland anticline, recorded by McGerrigle in the Madeleine River area (1959).

Reconnaissance traverses have located a NE-striking syncline with Devonian sedimentary and volcanic rocks occupying its core, approximately three miles SE of the above anticline.

Fractures

Aerial photographs reveal that the Siluro-Devonian terrain is criss-crossed by various sets of fractures, some of which are of regional significance and possibly reflecting preexisting lineaments beneath younger cover rocks. This is probably so in the case of EW lineaments, which cut diagonally across the formations without offsetting or disturbing the general trend.

NW-trending fractures are prominent features south of the pluton, as shown by the attitude of granophyres and basic dikes. Numerous vertical joints and faults, some of them showing displacements several tens of feet long, are observed in the gorge of rivière Madeleine east of the Barter showing (Fig. 1). Of regional significance here is the $\frac{1}{2}$ mile wide Barter Lake-lac Long valley. The following criteria indicate a major zone of dislocation along this topographic low: 1) The EW-trending alteration zone ends abruptly at an E-facing scarp bounding the valley on the west, 2) The un-

usually large surface expression of the Cap Bon Ami Fm. suggests a decrease in dip of the beds brought about by tilting of the block, 3) Offsetting and abrupt change in trend of the Lesseps synclinal axis, 4) The presence of anomalous strikes and dips on the flanks of the fold east and west of the lakes. The above evidence suggests that the valley is the site of a fault-bound block, the northern part of which was depressed as a result of rotation about an EW hinge located farther south.

NW-trending fractures, particularly evident in the area N. of lac Madelaine, are probably the youngest structural features of the area. They are identical in attitude to the dike-filled joints observed within the pluton and in the country rocks east of it. They are typical cross-faults, probably of the normal type, involving little displacement and no overturning of beds.

Structural Synthesis

In contrast to the northern belt, the structural pattern in the southern part of the area is simple. While the Cambro-Ordovician rocks are tightly folded showing evidence of multiple deformation, the Siluro-Devonian sequence is deformed into broad upright and shallow plunging folds.

Minor tectonic structures are rare; they indicate that only one generation of folds (F_3) is present, a product of the Acadian orogeny.

Surprisingly, F_2 - (in the northern belt) and F_3 -fold axes (in the southern belt) show similar attitudes, although the geometry of the folds themselves is strikingly different. However, it was stated above (p.170) that F_2 -folds are truncated by the Mts. McGerrigle pluton and are therefore

pre-Acadian. The mid-Devonian Acadian orogeny probably did affect the northern belt, but deformation must have been very slight, since there is no record of it. In any case, the superposition of an additional NE fold fabric on Quebec and Shickshock rocks would probably go undetected.

CHAPTER IX
ECONOMIC GEOLOGY

Introduction

The primary objective of governmental mapping projects is the development of mineral resources. A detailed geological survey, such as the present work, provides the company geologist and prospector with the incentive and the preliminary tool to carry out exploration. At times, the mapped area includes patches of already staked ground. The emerging regional picture on published government maps will renew interest in the area and reopen possibilities unrealized before. This is particularly true in the case of the Gaspé Peninsula.

Recent Exploration Activity

Recently, north-central Gaspé and in particular the present area, became the focus of nationwide attention. The boom started upon the opening on Nov. 1st, 1963 of the Gaspé National Park to mineral exploration. An area of some 60 miles long and 30 miles wide, centred in the Gaspé National Park was staked almost overnight by geologists and prospectors from every part of the country. Exploration work was carried out in 14 townships, and particularly in Boisbuisson, Lesseps, La Potardière, Lemieux, Deslandes, Bonnacamp, Holland, Weir and Deville. The frantic activity reached its peak in 1965, when Terra Nova Explorations, Ltd. announced the discovery of a promising copper prospect (Sullipek) and Wexford Mines, Ltd. decided to explore in detail what was to become the Madeleine Copper Mine. The mine is in production since June 1969.

In the span of 4 years (1964-1967), more than 700 field exploration programmes have been carried out within the above area. The pace of exploration in 1966 is perhaps best illustrated in the case of Lesseps township. Of 45 companies holding properties in this approximately 200 square mile area, about 35 were actively engaged in geophysical, geochemical or geological work, spending a total of about 10 million dollars in exploration. In 1967 about 100,000 feet of drilling were reported to have been completed in central Gaspé (excluding Gaspé Copper).

The map area itself, comprising important parts of Lesseps, Deslandes, La Potardière and Boisbuisson townships, was the center of activity, with 50 companies engaged off and on in exploration work. The encouraging results from Terra Nova Explorations and Les Mines Madeleine kept the level of activity high until the end of 1967, when interest in the area gradually faded out. Difficult access, rough topography, dense and widespread vegetation and thick overburden were some of the conditions the prospector had to put up with. In addition, erratic mineralization and the presence of numerous intersecting dikes required a dense pattern of holes; on the other hand, the choice of drilling sites was restricted by low drainage density. A recently enlarged road system in the critical areas including a 55-mile circle road around the Mts McGerrigle pluton has significantly alleviated some of the difficulties mentioned above.

Operating Properties and Deposits

Metallic mineralization in the map-area is characterized by a copper mineral assemblage that is typically associated with acidic intrusions. It is therefore similar in type and origin to the deposits of the two producers in the region: Gaspé Copper Mines, Ltd., and Les Mines Madeleine, Ltd. It is also similar to the Sullipek (Pékan) copper deposit of Terra Nova Exploration Ltd. located 1.5 miles south of the Mts McGerrigle pluton. Another economically significant mineral occurrence in the region also associated with igneous activity is the former lead-zinc-silver Candego mine located 2.5 miles NW from the centre of the present area. From that deposit which consists of narrow, silver-bearing galena and sphalerite-quartz-carbonate veins following strike-slip faults in folded middle Ordovician shales, sandstones and slates of the Quebec Group (Wolofski, 1957, p. 479) 68,497 tons of ore would have been extracted during the 1948-52 period.

Gaspé Copper Mines, which is by far, the largest metal producer in the Gaspé Peninsula, operates since 1955. It has reached a production of 11,000 tons per day in 1968 and should extract, before the end of 1974, about 39,000 tons of ore per day. Located in Holland township, 15 miles east of the present area, the ⁴orebodies, totalling (Jan. 1973) close to 300,000,000 tons (0.5% Cu) are essentially made up of chalcopyrite-pyrrhotite-pyrite(+bornite-molybdenite) replacement and fracture-filling material in thermally altered calcareous siltstone and limestone (calc-silicate hornfels) of Devonian age. Thermal alteration and mineralization would be related to an unexposed granitic mass at depth (Mac Issac, 1969, p. 830).

The other producer in the Gaspé district, Les Mines Madeleine, extracts, since June 1969, copper ore in the aureole rocks of the Mts McGerrigle pluton at a daily rate of 2,400 tons. The mine with reserves (Jan. 1973) close to 4.5 million tons (1.17% Cu) is located just west of the region in northwest Boisbuisson township some 35 miles ^{south} S. of Ste-Anne des Monts. The main orebody, less than 700 feet west of the Mts McGerrigle pluton, has the shape of a flat ^{land} ~~land~~ (N-S) chimney that plunges 60° S. and transgresses slightly the layering of the local pelitic hornfels. (Map I in pocket). The plunge of the main zone and the rake of the smaller ones is roughly parallel to the line of intersection of the N 10° W striking fractures with the NE-trending beds. Mineralization largely corresponds to a stockwork of quartz and sulphide veinlets in slightly chloritized biotite hornfels. Mineral zoning is well developed in the main zone with bornite in the centre changing to chalcopyrite and then to pyrrhotite at the rim. The controlling factor in ore deposition appears to be the brittleness of the hornfelsic host rock. According to Girard (1969, p. 843) the Madeleine orebodies represent fracture-filling, hydrothermal deposits genetically related to the nearby Mts. McGerrigle granitic pluton.

The Sullipek (Pékan) deposit lies 1.5 miles S. of the southern limit of the Mts McGerrigle pluton and about 2 miles west of the southern portion of the present area (Map I, in pocket). Situated in the central part of Lesseps township, it is easily reached by car from Ste. Anne-des-Monts a distance of 35 miles. Mineralization occurs in thermally altered limestone and siltstone of the St-Léon Formation (Siluro-Devonian). These are highly interlayered and cut by felsitic bodies which are very similar, in hand specimen and in thin section, to the granophyres penetrating the

southern part of the pluton (p. 128).

In the mineralized zones pyrite and magnetite ^{the} are most abundant minerals. They are followed by specular hematite, chalcopyrite, bornite and traces of molybdenite and sphalerite. The chalcopyrite distribution is extremely erratic and unpredictable. It occurs both as disseminated grains and as irregular blebs in dark green tactite zones which cut across light-colored calc-silicate hornfels. These zones lie, most of them, along side vertical and northwest-striking quartz porphyry dykes. Fracture filling is present, although replacement appears to be prevalent. The patchy nature of the tactite (coarse-grained hydrothermal skarn) the erratic distribution of the copper mineralization and the abundance of porphyry dikes make it difficult to truly evaluate the property (Perusse, 1969, p. 826). And this is true inspite of the fact that during the 1965-1971 period more than 300 holes totalling approximately 150,000 feet and a 4662-foot adit have been made to explore that deposit.

Mineralization and Mineral Prospects

None of the mineral occurrences located in the area under study has reached the status beyond that of a mineral showing or prospect. Three broad generalizations can be made regarding metallic occurrences in the writer's area: 1) the interesting showings consist of copper sulphide mineralization, 2) most occurrences are found in thermally altered rocks and are therefore assumed to be related to the Mts McGerrigle pluton or some of its off shoots. They are thus similar in their mode of occurrence to three copper properties described above. 3) Some mineralization is also associated with the metabasaltic belt of the Quebec Group. All samples were collected by the writer and assays carried out by the Laboratories of the Quebec Department of Natural Resources.

Mineralization associated with metabasalt

The only worthwhile mineralization in unaltered rocks appears to be associated with the metabasaltic belt and its enclosing rocks. Three particularly noteworthy prospects within or close to basalt are described below. Two of them (Prospects 2 and 3) lie within the thermal aureole of the pluton the remaining one (Prospect 1), outside of it. They are all associated with quartz veins and are fracture controlled. In that respect they are remarkably similar in type to the Madeleine Mines deposit.

Prospect 1

Trenching and bulldozing uncovered a ^{to} 4+6 inch wide mineralized quartz vein near the contact of basalt and overlying quartz-feldspar conglomerate 1,000 feet west of Rivière Madeleine Nord. The vein traceable for about 100 feet, trends N25°E and dips steeply south. Mineralization consists of massive chalcopryrite, chalcocite, bornite and malachite in a gangue of quartz and minor carbonate. The vein material assayed 9.08% Cu. Similar, although much less impressive, mineralization occurs 1,500 feet NW in basalt, where a sample assayed 2.69% Cu. Here, quartz-filled fractures trend 20° and 120° and can be traced for a few tens of feet. Mineralized boulders were found along the upper contact of the basalt belt farther northeast.

Another minor showing associated with basalt occurs 1.5 miles due east of lac Vieillard. Pockets of quartz-feldspar conglomerate embedded in shale and siltstone are mineralized with pyrite and specks of chalcopryrite. The outcrops are spread over a width of 500 feet with bedding dipping 40° south. They lie 300-700 feet stratigraphically above the basalt. A sample taken at random assayed 0.23% Cu and nil for uranium. To explore these three showings 7 holes totalling 3095' were drilled by Osisko Mines in 1968.

A few tiny smears of native copper are observed in a fractured and baked shale flooring the basaltic belt 1 mile NNE of lac Vieillard. A sample analyzed 0.93 Cu.

Hematite-rich pockets in unaltered basalt occur east of rivière Madeleine-Nord. A magnetite-rich boulder found near the upper (south) contact of the basalt 0.5 mile west of the eastern boundary analyzed 36.63% Fe, 0.02% Cu, 0.08% As, 0.00% Sb and 0.000 oz Ag/t.

Prospect 2

Interesting showings occur in metabasalt 1 mile SE of Mt. Auclair. Blasting and drilling by New Calumet-Conwest in 1968-69 (6 holes) and, in 1972, by Les Mines d'Iberville (300'/6holes) and by Cumex next to the southeast disclosed the presence of small, fracture-controlled smears of bornite, chalcopyrite and malachite, with abundant pyrrhotite in a fractured and thermally altered basalt of the Quebec Group, characterized by $\frac{1}{4}$ to $\frac{1}{2}$ -inch long, oval spots of chlorite and actinolite. This area is structurally complex. Large bodies of coarse metabasite are in intrusive contact with metabasalt, hornfels and skarn. Subsequently, the area was injected by granite resulting in hybrid rocks. Finally, the youngest intrusive is the late, red granite. A grab sample of the mineralized rock assayed 0.91% Cu. This favorable area warrants further study and exploration.

Prospect 3

Another mineralized area worth noting lies in the inner alteration zone, 1,500 feet east of the pluton and 1,500 feet NNW of lac Vieillard. Here twelve drill sites were located along a steep bulldozed trail that branches off the Mt. Jacques Cartier road, crosses the ruisseau à Galène and continues to lac Vieillard. These 12 holes (totalling 6959 feet).

were drilled jointly by Labrador Mining and Gaspex during the 1968-69 period on a property then held by La Société Boisbuisson. Core inspection confirmed surface indications that mineralization follows essentially a spotty, micaceous metabasalt and consists of tiny seams of pyrite, pyrrhotite and minor chalcopyrite and bornite. Nearby outcrops of hornfels and metabasalt show clearly that mineralization is of the fracture-filling type.

Mineralization Associated with Thermally Altered Rocks

Except for a few specks of molybdenite in the vicinity of Mt. Jacques Cartier, the granitic rocks of the pluton appear to be completely barren of sulphides. The metabasite inclusions have a normal amount of pyrrhotite and pyrite. However hornfels xenoliths and the pluton wall rocks are often mineralized with pyrrhotite and pyrite producing rusty stains. Such areas, in which iron sulphides and specks of chalcopyrite are particularly evident, can be seen 1.6 miles N. of lac Vieillard, within xenoliths of hornfels 2,800 feet NNW of Mt. Jacques Cartier, 1 mile N. as well as 1.5 miles NNE of Mt. Ste-Anne where a group of 5 holes (1160') was completed by Asarco in 1967 and finally along the western boundary of the pluton from the steep hill ^{south} S_w of lac des Américains southward to past Mt. Richardson.

Extensive pyrite and pyrrhotite mineralization is also located within rocks of the Shickshock group, particularly within the diopside-actinolite-scapolite hornfels (1a₂M) and garnetiferous calc-silicate hornfels (1a₃M) NE and E of Mt. McWhirter, respectively. Small, scattered spots of chalcopyrite and bornite were observed within the Shickshock metabasalt, 1,500 feet east of the southern lac des Castors.

Prospect 4 ("Barter Showing")

A showing mentioned by Jones occurs near the Lepage Road-rivière Madeleine intersection (1931, p. 225-226; 1933, p. 30-31). Several quartz stringers and veinlets carrying galena, sphalerite, chalcopryite, pyrite and pyrrhotite are localized along vertical, NW-striking fractures on the south bank of the river. The host rock is the basal, dolomitized part of Sayabec limestone. On the north side of the river, a similar mineral assemblage in short fractures is confined to two parallel 20 to 60 feet wide belts of silicified and deformed Sayabec rocks. Squeezed between them is a 40-foot-wide, E-striking and vertical quartz-feldspar porphyry (Fig. 1). Fine lamination and banding in the wall rock immediately in contact with the veins indicates that the NW fractures served as channelways for the mineralizing solutions. A preliminary study indicates that, following partial dolomitization of the limestone, introduction of Mg, Fe and Si resulted in formation of talc and calcite, both of which marginally replace the dolomite. The sulphides and quartz have been introduced last. A specimen collected from lean vein material assayed as follows: Cu, 0.08%; Pb, 0.35%; Zn, 0.96% and Ag, 1.039⁶⁷₀₃/ton. One hole is reported to have been drilled by Newmont-Sullico in 1964 near the western extremity of the showing.

A very similar type of mineralization occurs in a 25 X 80 feet outcrop on the north bank and 1,750 feet up the river from Prospect 4. A series of pinching and swelling quartz veinlets contain galena, sphalerite, chalcopryite, pyrrhotite, and pyrite in NW-striking fractures. Similarly trending fractures in the area are occupied by granophyres and dikes cutting across the pluton. It suggests that Pb-Zn mineralization belongs to the last phases of hydrothermal activity. The host rock, which extends beneath rivière Madeleine, is an almost flat-lying, brown-weathering, pitted

and fractured limy quartzite in which grey, oval remains of favositid and algae are still preserved. It probably represents the basal silicified part of the Sayabec limestone. A sample of the vein material assayed Cu 0.08%; Pb, 2.27%; Zn 4.34% and Ag, 7.185 oz/ton. It is reported that three unsuccessful holes have been drilled by Sullico in 1965 some 1200 feet west of that showing.

Prospect 5

A 300-foot-wide rusty zone mentioned by Robert (1967, p. 12) is observed on the western bank of rivière Madeleine, some 3,000 feet south of the southern boundary of the pluton. Thin seams of pyrrhotite and chalcopyrite occur along EW-trending fractures and also parallel to the layering of the hornfels and skarn host rocks. The latter are generally garnetiferous and accompanied by crystalline limestone and pelitic hornfels interbeds. The banding strikes EW and dips consistently south. Abundant dragfolds are overturned to the north suggesting an anticlinal axis to the north. Stringers of pyrrhotite and traces of bornite are present along the banding and parallel to the cleavage in the host rock. Only a few specks of galena and sphalerite have been observed. Following up the river, that is approaching the pluton, the content of pyrrhotite in the laminated diopside-amphibole-scapolite rock (la_2M) and associated hornfels appears to increase. Recent (1966-70) drilling in that belt of metasediments of the Schickshock Group has shown that an extensive zone of disseminated iron sulphides is present south of the pluton. In fact 15 holes (6739') were drilled by Soquem east of the river and 21 holes (10,981') by Soquem-Sullivan and United Buffaddison west of it.

Prospect 6

Of considerable interest is the sulphide mineralization located in the alteration zone west of Barter brook. Geochemical quick tests for "total heavy metal" and for Cu carried out by the writer in the field season of 1966 gave a very strong copper anomaly localized in a small tributary of ruisseau Barter, 1,500 feet west of the Bélanger trail (de Romer, 1967). Subsequently, several samples rich in chalcopyrite and pyrite were collected in the area, analyzing up to 1% Cu. The mineralization occurs in a grey, rusty-weathering skarn, containing pockets of coarse, recrystallized calcite and small octahedra of andradite. It probably is the metamorphic equivalent of the Cap Bon Ami argillaceous and carbonaceous limestone. As mentioned above (p. 179) the alteration zone is abruptly cut off by a NNW trending late fracture. In 1966 and 1968 Terra Nova Explorations carried out in that area an extensive exploration program which ended with the drilling of 16 holes (11,163'). ^{Most of} these holes ~~ran, most of them,~~ ^{cut} through altered limestone and porphyry but failed to intersect ^{at} ore zones. Best result was a 35-foot section assaying 0.4% Cu. Less impressive results were obtained by Brandy Brook Mines ~~who drilled~~ ⁱⁿ in 1967 a series of 4 holes a little farther to the east. Still farther east, one thousand feet ^{north} of Madeleine lake, disseminated sulfides were drill-intersected by Terra Nova ^{Explorations Ltd} in 1967 and by Merland ⁱⁿ in 1970.

The mineralization at Barter brook ^{just} like the one at the Sullipek-Pékan deposit is very similar in type to that of Needle Mountain at Gaspé Copper. In both cases, thermally altered calcareous rocks are mineralized by hydrothermal solutions believed to be derived from a subsurface granitic pluton or offshoot. It seems that both replacement and fracture-filling took place, reflecting several pulses or phases of

mineralization. An early introduction of mineralizing solutions probably took place at the time of thermal alteration. Subsequent igneous activity as shown by criss-crossing, fresh porphyry dikes, brought about extensive fracturing of the previously silicified and brittle rock and remobilization of the sulphides. It appears that the NE-trending graphophyres and Pb-Zn strig^{er}s observed farther north are the last phases of igneous activity and mineralization in the area.

Geochemical Results

The field party collected over 1,270 stream sediment samples during the 1966-1970 summer seasons. They were taken concurrently with geological mapping and subsequently analyzed by the Laboratories of the Quebec Dept. of Natural Resources for Cu, Pb, Zn, Mo, Ni, U, Co, W, Mn, Sn, Au and Ag. The location of samples and the analytical results in ppm. are shown on the maps and reports, respectively (de Romer, 1969, 1970; subsequent reports in press).

Anomalous geochemical values reflect faithfully the areas of mineralization observed in the field. In addition, concentration of anomalous values clearly outline several areas in which mineralization was not evident. The distribution pattern of the elements clearly indicates that interesting mineralization is largely confined to two environments: the basalt belt and the inner alteration aureole.

Background values for Cu in the granitic rocks are in the order of 6-9 ppm., and considerably lower than those in the aureole around the pluton (10-20 ppm). High Cu-values within the pluton are confined to xenolith-laden areas. Thus, 600 ppm. Cu (more than 15 times the background) are recorded in the vicinity of Prospect 2, which carries visible Cu-mineralization. Another interesting anomaly with 320 ppm Cu is located near a band of skarn and calc-silicate hornfels (2h₁M), 4,000 feet north of Mt. Auclair. The highest Cu-values recorded in the area lie in the valley west of ruisseau Barter (Prospect 6), where a maximum of 10,000 ppm. was obtained. Anomalous Cu-values averaging 240 ppm. and reaching 300 ppm. (or 10 times the background) are found near the upper and lower contacts of the

basalt belt outside the aureole (Prospect 1). This suggests that, genetically, Cu-mineralization is primarily related to the basalt.

Zn has a background of 50-80 ppm. in the aureole rocks, slightly higher than in granite. Some interesting values of 200 ppm. and 348 ppm. were observed again near the 2hM band and in a deep valley 1 mile east of lac Fortin, respectively.

High values of 300 ppm. Pb and 120 ppm. (against a background of 10-50 ppm.) are observed near the 2hM band and at Prospect 2.

The distribution pattern of Mo-values is interesting in that Mo gradually increases from hornfels (12 ppm.) up the valleys to granite, where it reaches 35 ppm. Background in the granitic rocks is 6-10 ppm. High Mo-values of 180 ppm. and 120 ppm. in granitic rocks are found near the headwaters of the ruisseau aux Cascades and in the vicinity of the Mt. Jacques Cartier road. A highly anomalous 400 ppm. is obtained in the valley east of lac Fortin.

Ni-values higher than background in granite (6-8 ppm.) and in unaltered clastics (10-40 ppm.) are associated with diabase dikes (64 ppm., 6,000 feet ENE of Mt. Jacques Cartier).

The behaviour of U is erratic and puzzling. Although its background in the unaltered Siluro-Devonian rocks is 8-10 ppm., individual samples have analyzed up to 80 ppm. Abnormally high U-values are concentrated in the granite-hornfels contact area, 2 miles SE of lac Fortin. Here the maximum values of 304, 180, 72, 80 and 64 ppm. are obtained from granite underlain areas. Background in granite is 20-40 ppm.

Co has a background of 6-8 ppm. in granite. High values of 62 ppm. and 85 ppm. (or 5 times the background in Quebec Group rocks) are associated with high Ni-content. The latter value is recorded in the vicinity of diabase dikes, 0.7 miles south of the ruisseaux Pierre-Jean and Auclair junction. Some anomalous Co-values (220 ppm.) are obtained for unexplained reasons at the head of the ruisseau aux Cascades. Anomalous Co-values are also present within the granitic area east of lac Fortin (80 and 34 ppm.)

W shows a background of 1-8 ppm. in granitic rocks. The skarn and hornfels band north of Mt. Auclair recorded 24 ppm., one of the highest values in the area.

A surprisingly high Mn concentration was located in the area of high Co and Ni (max. 9,250 ppm.). Other anomalous values (12,480 and 24,000 ppm.) are recorded from 1 mile east of lac Fortin.

Sn has a background of 20-40 ppm. in granitic rocks and 2-8 ppm. in Quebec Group rocks. No particularly anomalous concentration are apparent

Ag does not show up anomalous values.

The brief account of geochemical distribution patterns presented above points to several areas that should be reexamined. The writer suggests the following locations in decreasing order of importance: 1) the complexly injected area 1 mile SE of Mt. Auclair (Prospect 2) with 600 ppm. Cu and visible mineralization. 2) the skarn and calc-silicate hornfels at 4,000 feet N. of Mt. Auclair, where 320 ppm. Cu, 200 ppm. Zn, 120 ppm. Pb and 24 ppm. W were recorded. Although limited in extent, the 500-foot wide band is worth further study. It may extend westward for over 1 mile. 3) the area 1 mile

east of lac Fortin lying within granite at approximately 1,000 feet west of the contact with pelitic hornfels. Here, anomalous values for Mo (400 ppm.), Co (80 ppm.), Mn (24,000 ppm.), Zn (348 ppm.) and U (70 ppm.) have been recorded. An area of abundant diabase dikes and fine-grained metabasite xenoliths NE of lac Fortin may explain the reason for this well-defined anomalous concentrations of maxima. 4) the valley 2 miles SE of lac Fortin also indicates unusual concentrations of U (304 ppm.), Mo (84 ppm.), Co (73 ppm.), Ni (50 ppm.), Pb (90 ppm.) and Ag (1.8 ppm). Here again, the waters drain a granite area densely injected by diabase dikes. The above data clearly show the suitability of the area for geochemical prospecting. This is confirmed by the fact that mineralization observed in the field is faithfully reflected by anomalous results in the laboratory.

Conclusions and Recommendations

It is today an accepted fact that in this part of Gaspé important Cu-sulphide mineralization is of the hydrothermal type, associated with acidic stocks or plutons. This is primarily indicated because of the spatial relationship between leucocratic intrusions and orebodies. Practically all known ore deposits and showings of the region occur within thermally altered rocks. There are indications, however, that mineralization associated with basalt in the northern part of the area is syngenetic and that it may have been remobilized and possibly collected by the heat of the pluton to form showings such as observed at Prospect 2. It is probable that several pulses of mineralization occurred in view of the complex history of the pluton.

In any case it appears that mineralization in the area was not confined to any particular lithology. Siliceous rocks are most favorable host rocks, because they fracture easily, thereby inducing fissure filling and dissemination as well.

Geological targets in the search for copper mineralization should therefore be acidic plutons and thermally altered rocks, but also possibly basalt. As is well known, leucocratic felsites and felsic welded tuffs can easily be mistaken for hornfels derived from pelitic or silty sedimentaries, unless contacts are seen. Excellent examples of hornfels formation across compositional banding are well displayed in the 2,720-foot adit of Les Mines Madeleine.

In order to identify the characteristic type of rock and habit of mineralization, perhaps the first step should be a visit to the operating mines. One of the most rewarding traverses, as regards outcrop density and rock variety, is the rough road leading up to Mt. Jacques Cartier. Apart from its scenic beauty, it is a continuous section from pelitic hornfels across a complex zone of injected metabasites to the hybrid granitic rocks at the top. Anyone working in north-central Gaspé would be well advised to examine that section. It is hoped that this report and maps will help understand some of the problems.

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