

GEOMORPHOLOGY AND SHALLOW OVERBURDEN ELEMENTAL AND
HEAVY MINERAL STUDIES IN SOUTHWESTERN GASPÉ-SIE,
QUEBEC - POSSIBLE AIDS TO GOLD EXPLORATION

By

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SHORT TITLE:

GEOMORPHOLOGY AND SHALLOW OVERBURDEN STUDIES IN SOUTHWESTERN GASPÉSIE, QUEBEC

ABSTRACT

A survey of geomorphology and shallow overburden geochemistry was conducted to ascertain factors which control the distribution of gold in overburden from an area of 2400 km² in southwestern Gaspésie, Quebec. The area is a dissected upland underlain by faulted and gently folded Siluro-Devonian strata. Complex geomorphic and glacial histories are reflected in the mainly non-glacial character of the landscape, the preservation of ancient erosional landforms and the large variation in the distribution and composition of overburden. The overburden consists of glacial drift, colluvium, rubble and alluvium. Three broad zones are recognized where overburden distribution and composition are the result of a combination of physical factors and geomorphic processes. Geochemical and heavy mineral characteristics of overburden also define three broad zones which correspond to the geomorphic zones. Gold analyses of non-magnetic heavy mineral concentrates (NM HMC), corrected to compensate for dilution by Shield-derived material, provide an estimate of gold variations in overburden and bedrock in the three zones. Heavy mineral studies are essential to the interpretation of the patterns of gold variation in NM HMC of overburden.

RESUME

Une étude de la géomorphologie et un leve géochimique des sols ont été effectués afin d'évaluer les facteurs qui contrôlent la répartition de l'or dans les dépôts meubles qui recouvrent une région de 2400 km² dans le sud-ouest de la Gaspésie. La région est un plateau fortement disséqué qui tronçonne une séquence de sédiments plissés et faillés d'âge Siluro-Devonien. L'aspect largement non-glaciaire du paysage, la préservation de formes d'érosion ancienne et la répartition des types de dépôts meubles témoignent d'une histoire géomorphologique et glaciaire complexe. Les dépôts de surface consistent en des diamictons glaciaires, des colluvions, des dépôts anguleux d'origine locale, et des alluvions. La région est découpée en trois zones dans lesquelles la composition et la répartition des dépôts meubles sont le produit d'une association de facteurs physiques et de processus géomorphologiques. La géochimie des sols et l'étude des minéraux lourds définissent trois zones qui correspondent aux zones géomorphologiques. Le traitement des teneurs en or de la fraction non-magnétique des concentrés de minéraux lourds (CML-NM) au moyen d'une correction qui neutralise l'effet de dilution causé par l'addition de débris provenant du Bouclier, permet d'estimer la répartition de l'or dans la couverture de dépôts meubles ainsi que la roche sous-jacente. L'analyse minéralogique des concentrés est essentielle à l'interprétation des données sur l'or dans la fraction CML-NM des sols.

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PREFACE

This thesis is the result of a research contract awarded by the Geological Survey of Canada to J.A. Elson and G.R. Webber of the Mineral Exploration Research Institute (GSC Contract Serial Nos. OSQ 85-00052 (1985) and 23233-6-0407/01-SZ (1986); IREM-MERI Project No. P85-15). The project is a contribution by the Geological Survey of Canada to the Economic Development Plan for the Gaspé and Lower St-Lawrence Mineral Program (1983-1988). The research project was carried out by the author. The contract work was supervised by J.A. Elson and G.R. Webber, in accordance with specifications by Y.T. Maurice of the Geological Survey of Canada, the scientific authority for the project. The results of the research project are presented in an open-file report (Bernier et al., 1987) and are the basis of a paper recently accepted for publication (Bernier and Webber, in press). The material presented in the paper forms the second part of this thesis (pages 57 - 93). The first part, on the geomorphology of the area, has not appeared previously. The author is responsible for the originality of all the material presented in this thesis with the exception of some observations on the geomorphic features of the area by J.A. Elson. The format of the thesis conforms with the new guidelines of the Department of Geological Sciences. The style used is that acceptable to the Journal of Geochemical Exploration.

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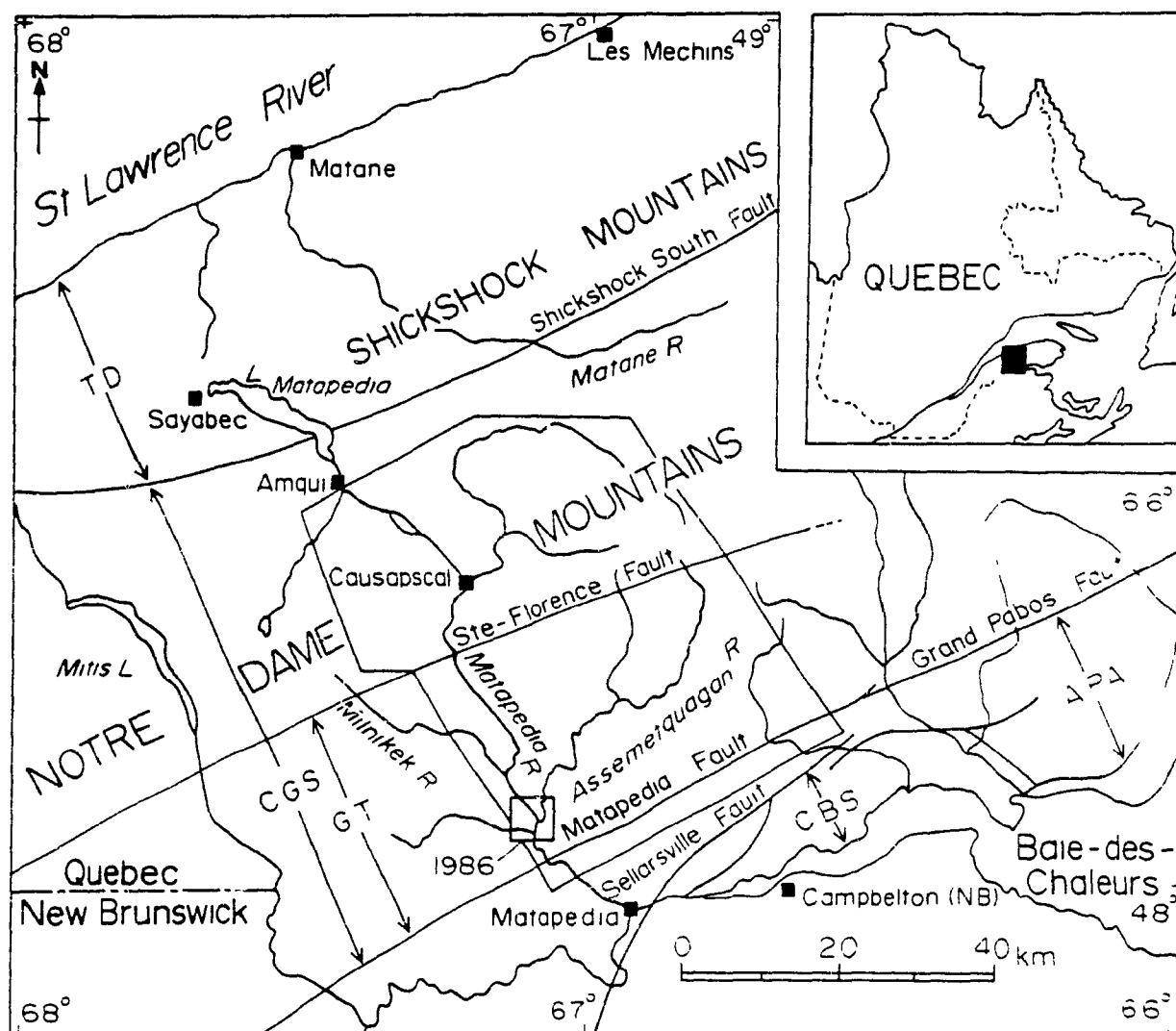
INTRODUCTION

In the summers of 1985 and 1986 a survey of surficial geology, geomorphology and shallow overburden geochemistry was conducted in an area of 2400 km² in southwestern Gaspésie, Quebec (Fig. 1). The two main objectives of the survey were (1) to evaluate the role of glacial and non-glacial processes in producing gold and other heavy mineral anomalies in stream sediments of the Assemetquagan River basin (Maurice, 1986), and (2) to suggest areas of possible gold mineralization in bedrock through mineralogical and geochemical analysis of shallow overburden. Two geochemical surveys were carried out, a regional survey including major, trace element and heavy mineral concentrate (HMC) analyses, and a local HMC survey in a 36 km² area surrounding the principal alluvial gold occurrence in southwestern Gaspésie, at the mouth of the Assemetquagan River. Geochemical data from these surveys together with preliminary interpretations have been reported (Bernier et al., 1987). This thesis examines parameters which control the distribution of gold in overburden across the area in an attempt to determine factors that should be considered in the design and interpretation of shallow overburden surveys as an aid to gold exploration in the region.

Parameters examined in the interpretation of the geochemical and mineralogical data can be grouped into two sets: (1) lithological parameters - compositional and

Figure 1. Location of the thesis area and tectono-stratigraphy of western Gaspésie (after Poole and Rodgers, 1972; Kirkwood and St-Julien, 1987; Malo, 1987).

T.D. = Taconic Domain
C.G.S. = Connecticut Valley - Gaspé Synclinorium
G.T. = Gaspé Trough
A.P.A. = Aroostook - Percé Anticlinorium
C.B.S. = Chaleur Bay Synclinorium



structural features of bedrock units and (2) overburden parameters - compositional characteristics and distribution patterns of overburden types. The extent to which overburden parameters reflect underlying lithological parameters is determined by the processes that have formed or modified the overburden. In the project area, such processes include pre-glacial weathering and erosion, glacial erosion, transport and deposition, and post-glacial slope, fluvial and groundwater action. An understanding of how these geomorphic processes influence the composition of overburden is required for the interpretation of the geochemical and mineralogical patterns, and is essential to the design and interpretation of all overburden surveys.

The thesis area is characterized by faulted sequences of gently folded and recrystallized Siluro-Devonian sedimentary rocks, complex geomorphic and glacial histories and relatively discontinuous and thin glacial drift cover. These characteristics are recorded in various degrees by heavy minerals in the overburden. Heavy minerals are examined in the interpretation of the geochemical data and are used to evaluate shallow overburden surveys as an aid to gold exploration in the region.

LOCATION OF THE THESIS AREA

Gaspésie Peninsula comprises that part of the Province of Quebec between the St-Lawrence River to the north and Baie-des-Chaleurs to the south, and extends from the

Matapédia valley in the west to the Gulf of St-Lawrence in the east. The thesis area (Fig. 1) is in the southwestern half of the peninsula. It is bounded by Latitudes $66^{\circ} 30'$ and $67^{\circ} 30'$, and Longitudes $48^{\circ} 00'$ and $48^{\circ} 30'$. The area covers parts of National Topographic Series maps 22-B2, B3, B6, and B7, at a scale of 1:50 000, and includes the following topographic regions: the Matapédia valley south of Amqui, The Causapscal and Assemetquagan River basins, parts of the Milnikek, Moulin and Escuminac River basins, and the upper section of the Baie-des-Chaleurs drainage basin east of the Matapédia River and west of the Escuminac North River.

PREVIOUS INVESTIGATIONS OF SURFICIAL GEOLOGY, GEOMORPHOLOGY AND GEOCHEMISTRY

There have been numerous investigations of surficial geology in Gaspésie Peninsula over the past 100 years but these have largely been conducted along the easily accessible perimeters, especially along the north coast and in the Shickshock Mountains. With the exception of a few reconnaissance traverses along the Matapédia valley (Alcock, 1935; McGerrigle, 1950) the first detailed studies of the surficial geology of southwestern Gaspésie began in the early 1970's at the same time as large-scale surveys of stream sediment geochemistry were being initiated. Early information on the physiography and geomorphic history of the peninsula is largely the result of work done by F.J. Alcock, although discussions of physiography are included in many

geological reports. The following is a chronological summary of previous investigations. Emphasis is placed on the studies which have dealt with the glacial geology, geomorphology and surficial geochemistry of southwestern Gaspésie. Previous investigations concerning the local survey area are reported on pages 87-89.

The earliest studies of surficial geology were conducted along the coasts of the peninsula (Bell, 1863; Chalmers, 1881, 1882, 1886, 1887a, b, 1905; Goldthwait, 1911, 1912). The contribution of R. Chalmers, who investigated the glacial geology of the Appalachian region of Canada in the period 1874-1904, is of historical importance. His classic studies of ice flow indicators and drift transport across southeastern Quebec and the maritime provinces were synthesized in the first model of glaciation of the northern Appalachians (Chalmers, 1890) and later led to the development of the first theory of glaciation of the Gaspésie peninsula (Chalmers, 1906). The surficial deposits of the region bordering Baie-des-Chaleurs were first examined by R. Chalmers between 1874 and 1886 and later by F.J. Alcock in the period 1928-1931. Alcock's comprehensive (1935) report contains a detailed treatment of the physiography and geomorphic evolution of the Gaspésie, including a discussion on the development of the Matapédia drainage system (Alcock, 1935; p.116-118). On the basis of detailed observations of topography and drainage, and following Davis' (1909) popular

penepplain theory, Alcock (1935) proposed a polyphase geomorphic history for the Gaspésie peninsula. He attributed the development of the upper plateau of the Gaspésie (Shickshock Peneplain; Alcock, 1944) to a first cycle of erosion which ended in late Cretaceous or early Tertiary times. Uplift of about 500 m inaugurated a new cycle of erosion. The lower plateau of the Gaspésie represents the development of a second peneplain (Gaspé Peneplain; Alcock, 1944) on the sedimentary rocks surrounding the Shickshock Mountains. Further uplift resulted in the inauguration of a new cycle of erosion and the development of the present valley system. Alcock (1935) suggested that the steep lower cross-profiles of several valleys was the result of a relatively recent uplift episode in late Pliocene times.

The surficial geology of the interior of the peninsula was first examined in the region of the Shickshock Mountains. The summit plateaus of Mounts McGerrigle and Albert were visited by A. Mailhot and A. Coleman in 1918. Their opposing views regarding the glaciation of the highest summits of the peninsula (Mailhot, 1919; Coleman, 1922) initiated a controversy. From 1918 to 1952, the Shickshock Mountains were the centre of numerous investigations and debate aimed at resolving whether or not the summit plateaus were glaciated (Fernald, 1925; Alcock, 1922, 1924, 1926, 1935; Jones, 1933, 1939; Aubert de la Rüe, 1941; Flint et al., 1942; Carbonneau, 1949; McGerrigle, 1950). McGerrigle

(1952) summarized the work of his predecessors and the results of his own investigations, and described the surficial geology and glacial history of the peninsula. These investigations brought a wealth of new information regarding the extent of glaciation of the Shickshock Mountains as well as their preglacial and post-glacial histories. This information still forms the basis for geomorphic and glacial research in the area (Gray and Brown, 1979; Allard and Tremblay, 1981; Hétu and Gray, 1980, 1981, 1985; Chauvin, 1982, 1983, 1984; David and Lebuis, 1985; Prichonnet and Desmarais, 1985; Chauvin et al., 1985).

The gradual loss of popularity of the Davisian concepts of erosion cycles and peneplains prompted some researchers to examine in more detail the relation between topography and underlying bedrock characteristics. Mattinson (1958) constructed projected profiles across the Shickshock Mountains in the region Mount Logan and made comparative cumulative counts of summit altitudes. He found only moderate accordance of summits at 550-670 m and 700-880 m above sea level (a.s.l.). Ollerenshaw (1963, 1967) made comparative cumulative counts of summit altitudes and obtained accordances at several levels which he attributed to lithological control. Lespérance (1960) conducted slope analyses and constructed a series of 12 projected profiles across the Lake Temiscouata region, to the west of the Matapédia valley. He found a correspondence between the

altitude of the area's surface and the order of resistance to erosion of the bedrock. Raudsepp (1969) conducted frequency distribution measurements of summit altitudes from 20 rock types in western Gaspésie. He found that frequency distribution of altitude parameters were related to base level and that arithmetic mean altitude was an index of relative bedrock erodibility.

In 1967 and 1968 the Société Québécoise d'Exploration Minière (SOQUEM) conducted detailed stream sediment surveys to outline possible zones of mineralization in the west half of Bonaventure county (Dionne, 1968, 1969; Kelly and Tremblay, 1971). In 1972 the Government of Quebec decided to extend the stream sediment sampling to obtain a geochemical inventory of the entire Gaspésie peninsula (Tremblay et al., 1975; Tremblay and Choinière, 1978a, b; Tremblay and Wilhelm, 1978; Choinière, 1982). The results of the 75 000 sample survey were published in 7 geochemical atlases and later compiled in a set of 1:50 000 scale maps (Choinière, 1984). One of the main findings of the massive survey was that the concentration of trace elements in the stream sediments varies characteristically across the peninsula with changes in underlying rock types. Choinière concluded that Pleistocene glaciations had little influence in shaping the observed geochemical patterns except in the north-central part of the peninsula where north-northeastward geochemical dispersion could be associated with northeastward

glacial transport of drift as documented by Chauvin (1982). Tremblay and Wilhelm (1978) analyzed heavy mineral concentrates from 800 stream sediment samples collected in northwestern Gaspésie. They divided the region extending from Ste-Florence to the St-Lawrence River into five zones based on heavy mineral associations. The upper half of the thesis area falls within Tremblay and Wilhelm's (1978) zone of high garnet, Ti-mineral and zircon in heavy mineral concentrates of stream sediments.

To coincide with the program of stream sediment surveys, the Government of Quebec initiated in the early 1970's a project of systematic mapping of surficial deposits in the western half of the peninsula (Lebuis and David, 1972; Lebuis, 1973a, 1973b). A set of 1:50 000 scale surficial geology maps was presented by Lebuis (1975) (revised by Gaucher, 1984) and later formed the basis for the development of a stratigraphic framework for the glacial deposits of western Gaspésie (Lebuis and David, 1977). Follow up work, mainly by Lebuis, led to publication of a revised theory of glaciation (David and Lebuis, 1985). According to the authors, western Gaspésie can be divided into four zones on the basis of the areal distribution of glacial erosion and deposition features, and erratics. They attribute the zonal distribution of glacial features to variations in basal ice conditions beneath an ice sheet derived from the fusion of southeast flowing Laurentide ice and a local ice cap. Breakup

of ice in the St-Lawrence river during the deglaciation stage of the area would have caused an inversion of the surface slope of the ice mass which provided the necessary conditions for late glacial reversal of flow and transport of material from south to north as documented by Lebuis (1973). The stratigraphic framework and the various concepts proposed by David and Lebuis (1985) have provided background for recent compositional and dispersion studies in the western half of the peninsula (Prichonnet and Desmarais, 1985; Maurice, 1986; Chauvin and David, 1987; Bernier et al., 1987) and in eastern Gaspésie (Cloutier and Corbeil, 1986; Veillette, 1987, 1988). The data collected by the various authors is the focus of a 1:250 000 scale regional compilation of the surficial deposits of the peninsula by the Geological Survey of Canada (Veillette, 1988).

GEOLOGICAL SETTING

Regional Setting

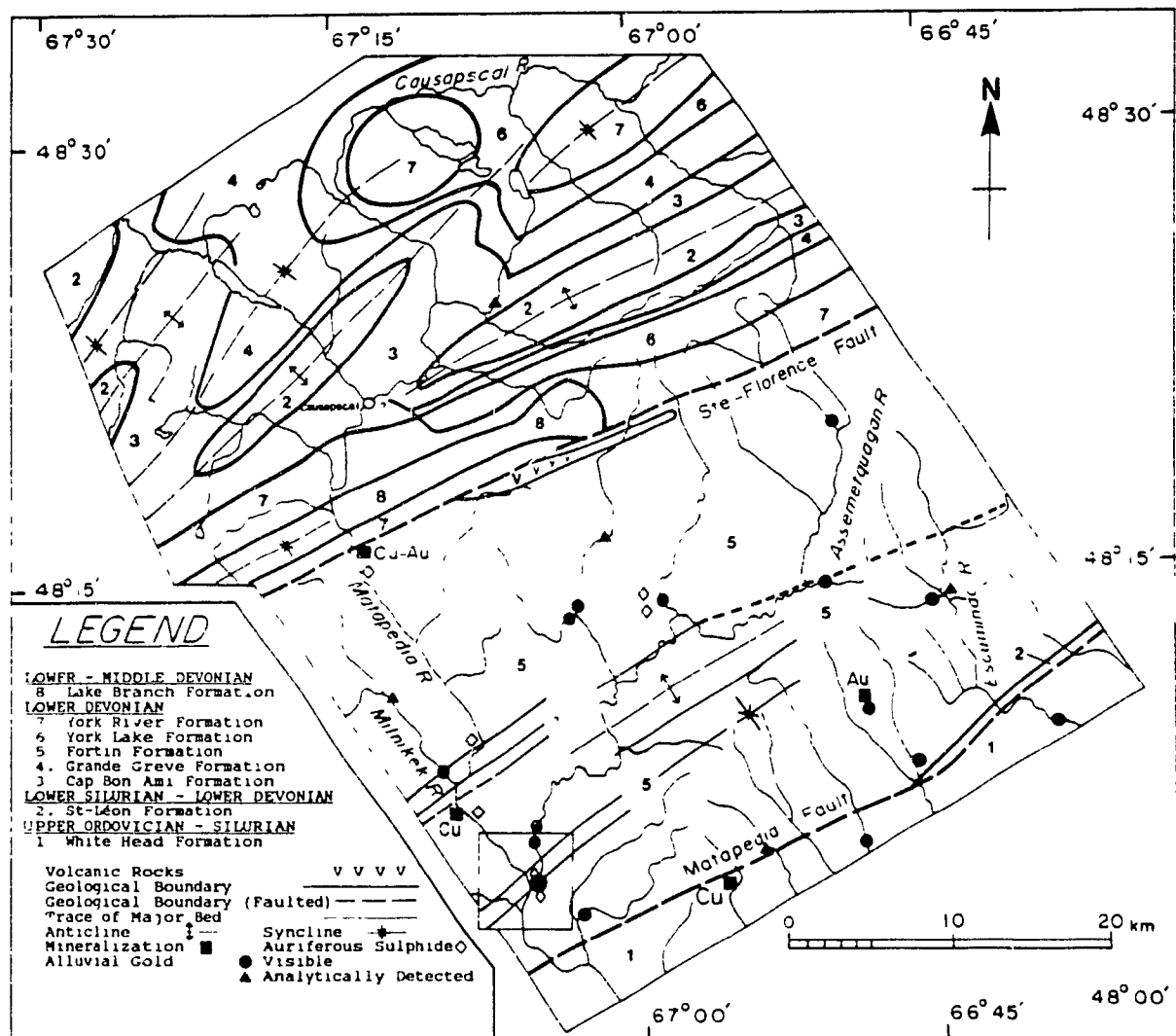
Gaspésie peninsula lies at the northwest margin of the Appalachian orogenic belt on the continental mainland (Poole, 1976). It consists of Paleozoic assemblages of sedimentary, metamorphic and volcanic rocks deformed into broad, northeast trending, fault-controlled belts. Four tectono-stratigraphic divisions are defined in western Gaspésie (McGerrigle, 1954; Neale et al., 1961; Poole and Rodgers, 1972) (Fig. 1; Table 1): The Taconic Domain in the

TECTONO-STRATIGRAPHIC DOMAIN						
AGE	Taconic Domain	Connecticut Valley - Gaspé Synclinorium		Aroostook - Percé Anticlinorium	Chaleur Bay Synclinorium	
		Gaspé Folded Belt	Gaspé Trough		Sellersville Splay	Restigouche Syncline
Middle Devonian		1 Lake Branch Fm.				
Lower Devonian		1 York River Fm.				
		York Lake Fm.				
		Gr. Grève Fm.	Fortin Fm.			
		2 Cap Bon Ami Fm.				
Silurian		St.-Léon Fm.	St.-Léon Fm.			
		Sayabec Fm.			Indian Pt. Fm.	
		3			3 West Point Fm.	
		Val Brilliant Fm.				Dalhousie Fm.
						New Mills Fm.
Late Ordovician						3 Laviche Fm.
						Anse à P. Fm.
						Mann Fm.
Late Ordovician				White Head Fm.		
				4	Pabos Fm.	
				4	Garin Fm.	
Cambrian to Middle Ordovician	Shickshock Québec Gps.					
		5	6	7	8	

- | | |
|-------------------|---|
| 1 Gaspé Sandstone | 5 Shickshock South fault |
| 2 Gaspé Limestone | 6 Ste-Florence fault |
| 3 Chaleur Group | 7 Matapédia (Restigouche) - Grand Pabos fault |
| 4 Matapédia Group | 8 Sellersville fault |

Table 1. Lithostratigraphy of western Gaspésie, (after Stearn, 1965; Lachance, 1974, 1977, 1979; Bourque and Lachambre, 1980; Kirkwood and St-Julien, 1987; Malo, 1987)

Figure 2. Geological map of the thesis area (modified after Skidmore, 1977, 1980) showing mineral occurrences (after Maurice, 1986; Bergeron et al., 1986; Bellemare and Germain, 1987).



north is a belt of highly contorted Cambro-Ordovician flysch, metasediments and metavolcanics (Québec Super Group), deformed and uplifted during the Taconic Orogeny (Middle-Late Ordovician), and later intruded by Upper Devonian ultramafic and felsic igneous rocks (Mounts McGerrigle and Albert complexes). To the south are the Connecticut Valley - Gaspé Synclinorium, the Aroostook - Percé Anticlinorium and the Chaleur Bay Synclinorium, structures formed during the Acadian Orogeny (Middle-Late Devonian) which consist of gently folded and faulted Upper Silurian to Lower Devonian strata locally intruded by, or interbedded with intermediate and felsic volcanic rocks. The Carboniferous sands of the Bonaventure Formation, exposed along the southern margin of the Chaleur Bay Synclinorium, unconformably overlie the rocks affected by Acadian tectonic deformation and display minor deformation features attributed to the Alleghenian Orogeny (Carboniferous-Permian) (Malo, 1987).

The four tectono-stratigraphic belts are separated by major southwest to northeast trending faults (Table 1, Fig. 1). The Shickshock South fault in the north is an east trending and south dipping fault displaced by a system of secondary north to south trending strike-slip faults (Ollerenshaw, 1963; Lachambre, 1987) and it separates the Taconic Domain from the Siluro-Devonian strata of the Connecticut Valley - Gaspé synclinorium to the south. The southern boundary of the Connecticut Valley - Gaspé

Synclinorium is the Matapédia (Restigouche) fault (Lachance, 1977, 1979). The Matapédia fault merges with the Grand Pabos fault in the east, forming a strike-slip fault system with a dextral displacement estimated to be close to 250 km (Malo, 1987). The Sellarsville fault, which separates the Aroostook - Percé Anticlinorium from the Chaleur Bay Synclinorium to the south, is a northwest dipping reverse fault (Kirkwood and St-Julien, 1987). It merges in the southwest with the Rafting Ground fault of northern New Brunswick.

Bedrock Geology

The numerous bedrock geology maps of Gaspésie peninsula (Alcock, 1926, 1935; Parks, 1931; Jones, 1933; McGerrigle, 1950, 1953; Carbonneau, 1953; Bélan, 1957, 1958, 1960; Ollerenshaw, 1961, 1963, 1967; Stearn, 1959, 1965; MacGregor, 1961, 1964) were compiled by McGerrigle and Skidmore (1967) and Skidmore (1977, 1980), to provide a framework for the region under study. Details of the lithostratigraphy and structure were obtained from Bélan (1960), Stearn (1965), Lachance (1974, 1977, 1979), Hubert and Bélan, (1978); Bourque and Lachambre (1980), Malo (1987), Kirkwood and St-Julien (1987), and Dalton (1987).

The northern 90% of the project area lies in the Connecticut Valley - Gaspé Synclinorium (Figs. 1, 2). Second order divisions in the synclinorium are separated by the Ste-Florence fault, a south dipping reverse fault (Kirkwood

and St-Julien, 1987)). The portion of the synclinorium north of the fault consists of a succession of Siluro-Devonian strata gently deformed into broad northeast trending anticlines and synclines. The oldest outcropping member of this succession is the St-Léon Formation (Fig. 2, Unit 2), a lower Silurian calcareous siltstone exposed in the crests of anticlines on the east and west sides of the Matapédia River (Crickmay, 1932), and in a narrow belt along the Matapédia fault in the southeast corner of the thesis area. The St-Léon Formation is conformably overlain by lower Devonian argillaceous limestones of the Cap Bon Ami Formation (Unit 3) and silty limestones of the Grande-Grève Formation (Unit 4). In fault contact with the Cap Bon Ami limestones to the north is a broad syncline in which are exposed the youngest rocks in the area, the red arkosic sandstones of the Lake Branch Formation (Unit 8) and the underlying argillaceous sandstones of the York River Formation (Unit 7). The York River and Lake Branch Formations belong to a sequence of Lower to Middle Devonian terrigenous clastic sediments referred to as the Gaspé Sandstones (Lachambre, 1987). Included in the sequence are the arkosic sandstones and calcareous siltstones of the York Lake Formation (Unit 6) which outcrop in the northeast corner of the area. The York Lake Formation grades downward into the Grande-Grève limestone and upward into the York River sandstone. The weakly metamorphosed, Lower Devonian siltstones and slates of

the Fortin Formation (Unit 5) outcrop in a 25 km wide trough south of the Ste-Florence fault (Dalton, 1987). The siltstones and slates along the northern faulted boundary are interbedded with intermediate volcanic and pyroclastic rocks known as the Ste-Marguerite volcanics (Stearn, 1965). The southern limit of the Fortin Formation, the Matapédia fault, marks the boundary between the Connecticut Valley - Gaspé Synclinorium and the Aroostook - Percé Anticlinorium to the south. The part of the anticlinorium in the lower fringes of the thesis area exposes the Lower Silurian banded argillaceous and silty limestones of the White Head Formation (Unit 1), the youngest of two formations in the Matapédia Group (Malo, 1987)(Table 1).

Mineral Occurrences

Known mineral occurrences in southwestern Gaspésie (Fig. 2) are found south of the Ste-Florence fault. Most are south of the Matapédia fault in bedrock of the Matapédia and Chaleur Groups (Bellemare and Germain, 1987). The occurrences are small base metal and gold showings close to major faults or in their shear zones. A description of mineral occurrences in the study area is given in Appendix 1.

The more important base metal occurrences are in the Matapédia group, a few kilometres south of the Matapédia fault. The Matapédia fault is the western extremity of the Grand Pabos fault, a major Acadian structure and mineral exploration target (Savard, 1985) which extends across the

southern margin of the peninsula. The mineralizations are in limestone skarns intruded by felsic dykes and sills. The hydrothermally altered rocks are host to a suite of sulphide minerals, mainly pyrite, pyrrhotite, arsenopyrite and bornite, with minor malachite, sphalerite, galena and molybdenite (Lachance, 1974, 1977, 1979). Several of the large copper ore deposits in the northeast part of the peninsula are of this type (Maurice, 1986).

Three small mineral occurrences, two of which are auriferous, are in large quartz veins which transect siltstone and slate beds of the Fortin Formation (Fig. 2). The Fortin Formation is cut by a complex system of massive quartz veins, with widths of up to 2 m. Bergeron et al. (1986) surveyed the gold potential of Fortin quartz veins in the Assemetquagan River basin. They found that Au was correlated with As and Sb and that the highest concentrations of these elements were associated with pyrite and arsenopyrite in both quartz vein and wall rock host.

Bedrock formations south of the Ste-Florence fault (Fig. 2) are also sources of a number of alluvial gold occurrences. The most important of these is in the lower 2 km segment of the Assemetquagan River. The occurrence has been the focus of several investigations (Girard, 1985; Maurice, 1986; Bergeron et al., 1986), but no obvious bedrock source for the gold has been found.

Surficial Deposits and Glacial History

Surficial deposits in southwestern Gaspésie include glacial drift (mainly till but some stratified deposits), alluvium of mixed fluvioglacial and non-glacial origin, colluvium, rubble, organic deposits and diamict materials of uncertain origin (Leblais, 1973, 1975; Leblais and David, 1977). In the northern half of the project area, till thicknesses average as much as 2 m, and eskers and other ice-contact stratified drift and outwash are common (Fig. 3; Plates 1, 2). The till on the upland areas and in valley bottoms has a low matrix-to-clast ratio, a silty to sandy matrix, varies from light brown to dark gray in color, and contains a large component of locally derived bedrock fragments with a smaller component of coarse far-travelled material. Colluvium on valley slopes is not extensive and is commonly derived from the till.

In the southern half of the study area (south of Ste-Florence), glacial deposits are limited to a few occurrences of ice-contact stratified drift in the Matapédia valley (Fig. 3; Plate 3). The valley contains much sand and gravel on the floor and in terraces. Some of this is outwash, much of which has been reworked by the present river. Alluvial fans deposited by tributary streams are numerous and are still active. The upland areas are mostly covered by a thin veneer of rubble in which occasional erratic clasts are found. The upper horizon of the overburden in certain places consists of

Figure 3. Generalized map of surficial deposits with ice flow indicators shown (modified after Lebuvis, 1973, 1975). The 0.1 wt.% heavy mineral abundance line defines the approximate southern boundary of thick glacial drift on the upland surface.

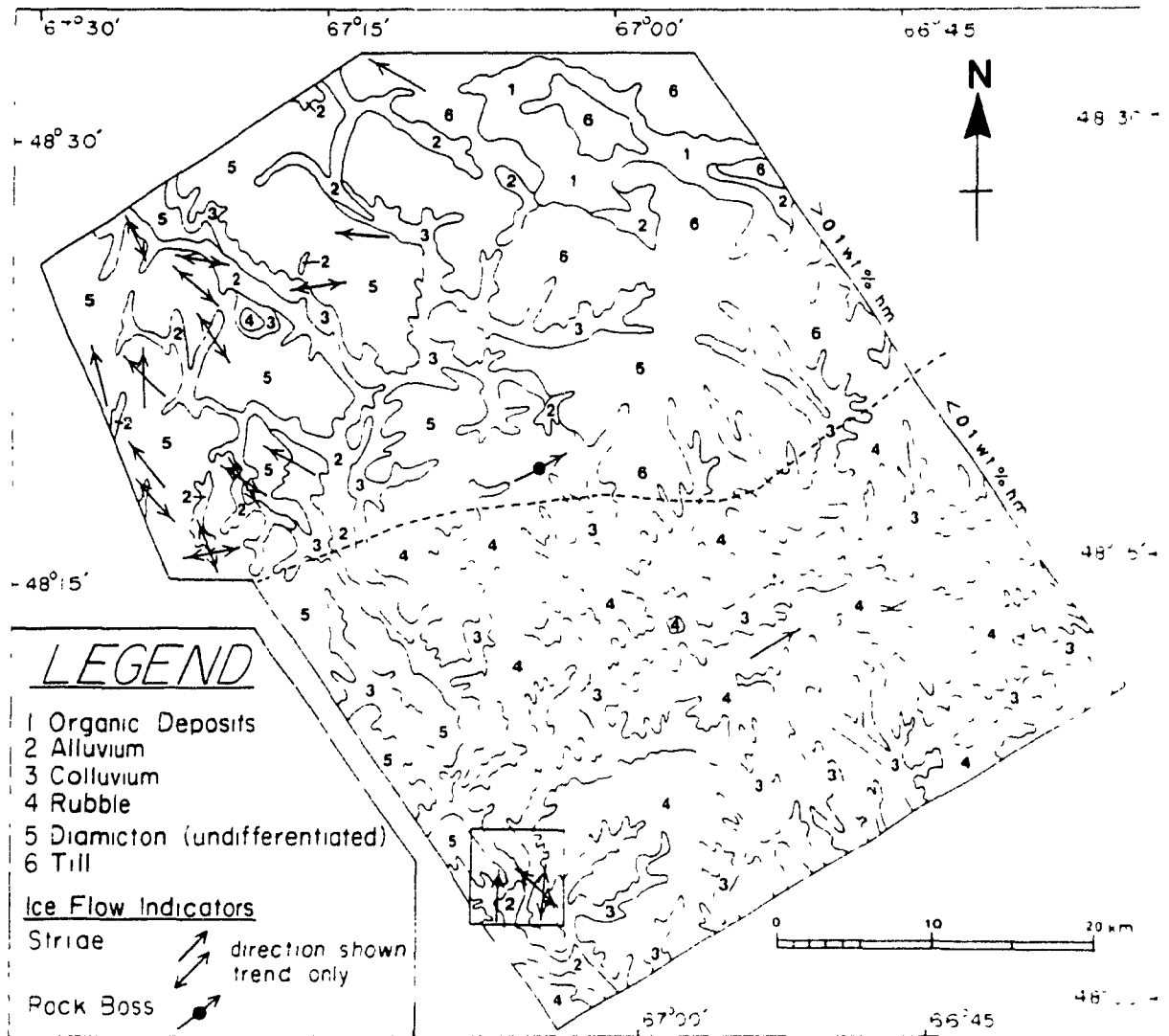


Plate 1. Southern panorama across a segment of the upper Matapédia valley. View toward the southwest.

- a: Undulating upland surface and gently sloping west wall.
- b: Flat valley bottom underlain by floodplain alluvium.
- c: Ice-contact stratified drift deposits (kames) restricted to the east side of the valley.

Photographs taken at site 262, 2.5 km north of Ste-Florence (d). The Matapédia River meanders across the floodplain in an overfit fashion. At point (e) the river flows against the west wall of the valley, from right to left across the photographs.

a

d



Plate 2. An example of the thick fluvioglacial sediments which cover the upland west of Causapscal. Photograph taken at site 129 (Appendix 6). Crossbeds give a north-northwest melt water flow direction.



Plate 3. View north of the main ice-contact stratified drift deposits in the southern, narrow segment of the Matapédia valley. Photograph taken at site 265, 2.8 km south of Ste-Florence. The deposit occurs on the east wall of the valley.

Plate 4.

Thick layered colluvial deposits at the foot of the southeast wall of the lower 1 km segment of the Assemetquagan valley. The colluvial deposit is composed entirely of Fortin bedrock and may predate the last glaciation of the area.

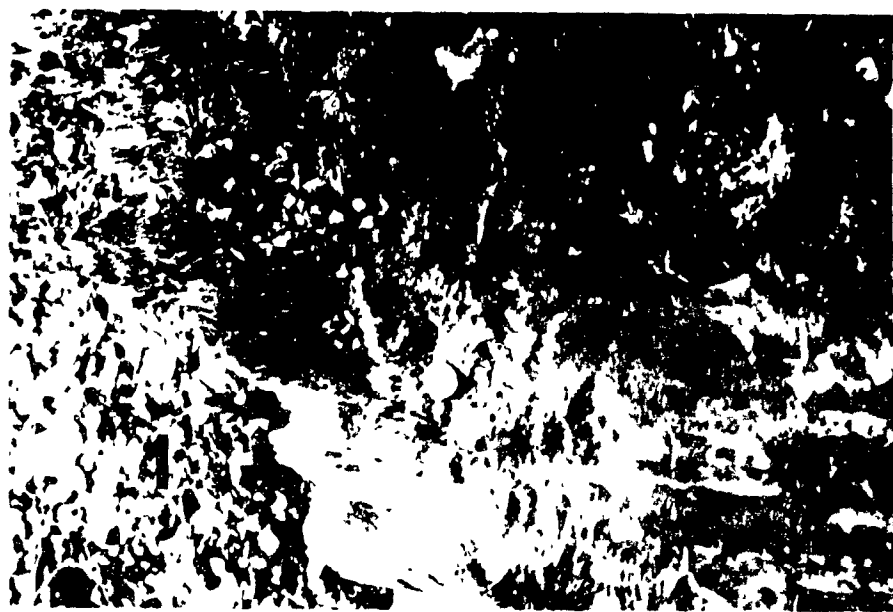


Plate 5. Formation of rubble (1) from active physical weathering of fissile Fortin slates (2). Glacial abrasion and polishing (3) protects the rock from weathering. Photograph of an outcrop on the east wall of the Matapédia valley, 500 m south of the mouth of the Moulin River.

well sorted silt and may be windblown. David and Lebuis (1985) noted that in places the upper horizon of the rubble showed evidence of remobilization. They suggested that the upper horizon was a monolithological till formed during the final stage of deglaciation of the area.

Valleys eroded into the fissile slates and siltstones of the Fortin Formation are lined with extensive and commonly thick sheets of colluvium (Plates 4, 5). Some of the colluvial deposits examined along the lower 2 km segment of the Assemetquagan valley are monolithologic, consisting entirely of Fortin rock, and possibly predate the last glaciation of the area.

Erratics are found throughout the area, in stream beds, on valley slopes and sparsely scattered over the upland surface. The most abundant erratics are derived from resistant formations within or adjacent to the area. The most common indicators of short-range transport are sandstone and siltstone cobbles and boulders of the York Lake, York River and Lake Branch Formations, and white orthoquartzite erratics of the Val Brillant Formation which outcrops north of the Shickshock South fault in the vicinity of Lake Matapédia (Ollerenshaw, 1967; Lachambre, 1987). Rare anorthosite, gneiss and granite erratics irregularly dispersed over the area are evidence of long-range transport from Precambrian sources on the north side of the St-Lawrence River and suggest that the main transport direction was

toward the southeast. Evidence for ice transport and deposition of Shield debris across western Gaspésie is well documented (Alcock, 1935; McGerrigle, 1952; Leblais, 1973; Leblais and David, 1977; Prichonnet and Desmarais, 1985; Lortie and Martineau, 1987) and assigned a Middle to Late Wisconsinan age (David and Leblais, 1985, Dredge and Thorleifson, 1987). Much uncertainty exists however, as to the exact timing, limits and patterns of Laurentide ice flow and deposition, especially in southwestern Gaspésie. Grant (in press) has suggested that some of the glacial deposits of western Gaspésie are derived from an Early Wisconsinan Laurentide ice flow episode.

The few glacial striations observed (Fig. 3) mostly record ice movement directions during the deglaciation stage of the area (14000-12000 years b.p.), as residual Laurentide ice flowed outward from a divide running along the south-central part of the peninsula (David and Leblais, 1985). Residual Appalachian ice in Baie-des-Chaleurs during this time temporarily blocked drainage of the Matapédia River, resulting in thick accumulations of outwash in the lower reaches of the Matapédia valley (Fig. 3). Rare east-to-northeast trending striations reflect an older ice flow episode from the west. A small number of erosional and depositional features in northern New Brunswick record pre-late Wisconsinan glacial movements from the west southwest (Rampton et al., 1984) and support the tenuous evidence in

the study area for an early glacial flow episode from the west.

GEOMORPHOLOGY

Physiographic Setting

Gaspésie Peninsula forms the northeastern extremity of the Appalachian Physiographic Region in the Province of Quebec (Bostock, 1970). The Shickshock range at the northeast end of the Notre Dame Mountains is the dominant topographic feature, rising 600-1200 m above sea level (a.s.l.) in a narrow southwest-to-northeast trending belt, 25-40 km inland from the northern coast (Fig. 4). The mountains are flanked by a series of flat to gently undulating plateau-like uplands with altitudes of 400-600 m a.s.l., which have been interpreted as remnants of erosional surfaces, or peneplains developed at the end of the Mesozoic or at the beginning of the Cenozoic (Goldthwait, 1924; Alcock, 1926, 1935; Blanchard, 1935; McGerrigle, 1959; Mattinson, 1964; Skidmore, 1965; Stearn, 1965; Birot, 1970). The plateau-like uplands rise steeply from the north coast and gently from the east and south coasts and are dissected by a well developed network of rivers and streams. The main valleys have floors ranging in altitude from 50 to 300 m a.s.l. and contain rivers which flow transverse to the structure with smaller subsequent tributaries developed along the direction of structure. The highest summits in the peninsula are the table-top plateaus of Mounts McGerrigle and

Figure 4. Physiography of western Gaspésie.
(Landsat image E-1760-14440, 22 Aug. 1974)

1. Shickshock Mountains (alt.: 600-1200 m a.s.l.)
2. Mount McGerrigle Plateau (alt.: 1000-1200 m a.s.l.)
3. Mount Albert Plateau (alt.: 1000-1100 m a.s.l.)
4. Notre Dame Mountains (alt.: 200-1200 m a.s.l.)
5. North-facing Upland (alt.: 200-600 m a.s.l.)
6. Lake Matapédia (alt.: 157 m a.s.l.)
7. Lac-au-Saumon (alt.: 148 m a.s.l.)
8. Lac Mitis (alt.: 270 m a.s.l.)
9. South-facing Upland (alt.: 400-600 m a.s.l.)
10. Baie-des-Chaleurs Lowland (alt.: 200-400 m a.s.l.)
11. Baie-des-Chaleurs
12. Restigouche River
13. Matapédia River

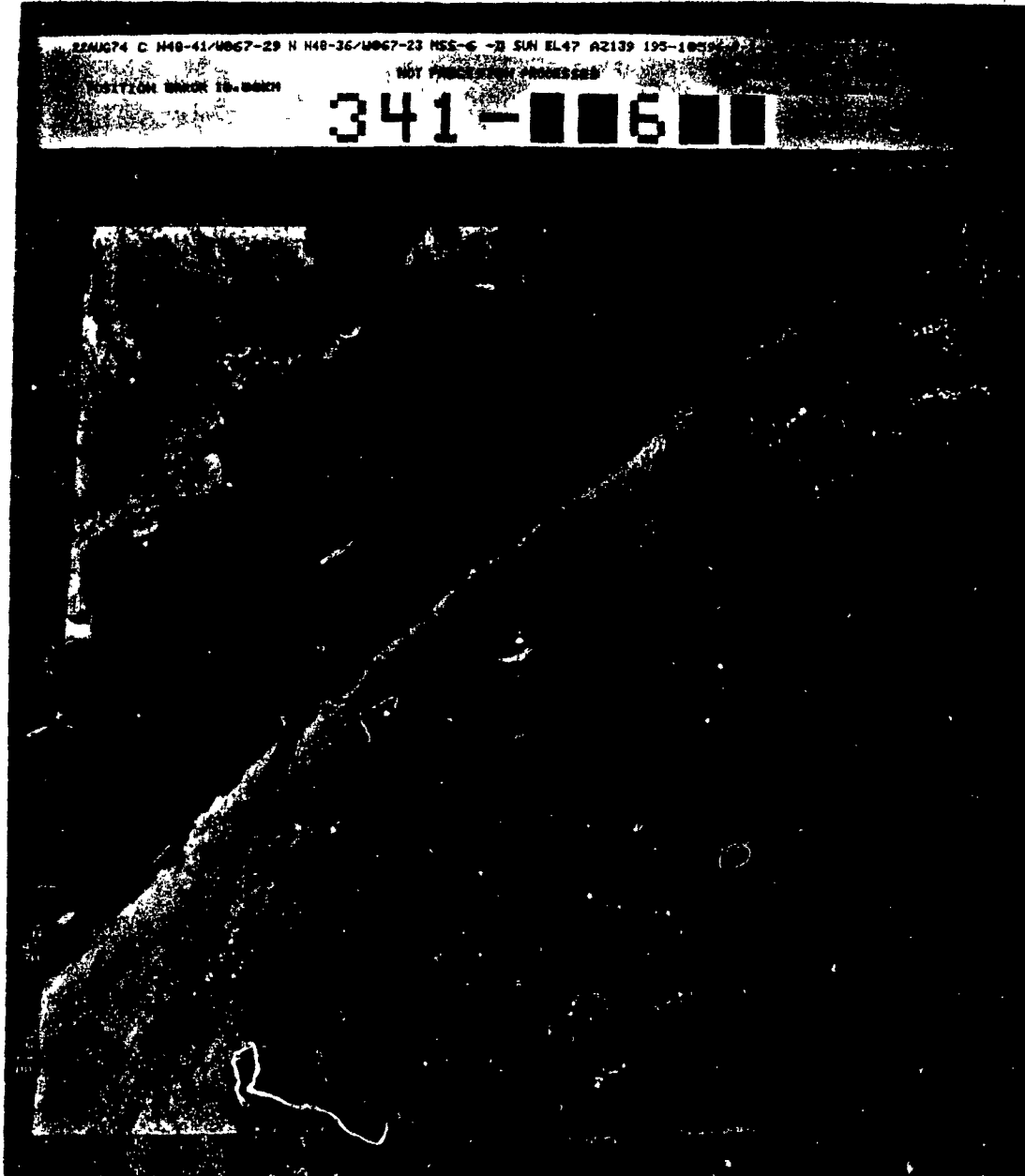
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Albert at the east end of the Shickshock mountains. Several peaks are over 1000 m a.s.l., including the highest peak of the Canadian Appalachians, Mount Jacques Cartier (1267 m a.s.l.), which is in the Mount McGerrigle plateau.

Geomorphology of the Thesis Area

The thesis area extends south-southeast from the southern flank of the Shickshock Mountains to a few kilometres south of the divide between waters flowing into the Matapédia River to the west and Baie-des-Chaleurs to the south (Fig. 1). The area is described as a plateau (Alcock, 1928, 1935; Stearn, 1965; Raudssep, 1969; Lachance, 1979; Girard, 1985) and the term is apt as far as the upland surface is concerned. The topography is an upland with altitude of 250-600 m a.s.l. (Fig. 5), crossed by subparallel chains of low, rounded asymmetric ridges and elongated hills oriented in the direction of structure. Projected profiles (Appendix 3) show the hills on this upland to be relatively low relief features with gentle to moderate slopes and rounded summits. The summits are between 30 and 90 m above the surrounding upland which has 30 to 50 m of relief. The upland surface is dissected by a well developed system of southeast trending valleys and southwest trending subsequent tributary valleys (Fig 6). The alternation of hills and ridges, flat interfluvial areas and steep-sided incised valleys forms a rugged topography (100-450 m) below a gently rolling to undulating, relatively low relief (30-50 m) upland

surface (Plate 6.).

The upland surface rises gently from the north and south and steeply from the west toward an east-central highland underlain in part by resistant York River sandstones, but mostly by weak Fortin slates and siltstones (Fig. 5). Summit altitudes are between 260 and 640 m a.s.l., and floors of the major river valleys range from 46 to 229 m a.s.l. The highest point (640 m a.s.l.) is a ridge top on a north-facing fault-line scarp which separates the York River sandstone from the weaker Grande-Grève limestone to the north, and the Causapscaal River basin from the Assemetquagan River basin to the south. Two other summits have elevations greater than 600 m a.s.l. The first (603 m a.s.l.) is the top of a southwest dipping bed of York River sandstone in the upper Assemetquagan River basin, and the second (602 m a.s.l.) a hilltop developed on Fortin slates where they are drained by an east flowing tributary of the Escuminac River at the east-central margin of the area. The lowest point, at the south end of the Matapédia River, has an altitude of 30 m a.s.l. Thus the maximum relief in the area is 610 m.

Projected profiles (Appendix 3) show upland surfaces at various levels. In the north half of the area (north of the Ste-Florence fault) two upland levels are identified (305-420 and 260-305 m a.s.l.), corresponding to areas east and west of the Matapédia valley (Fig.5). These low level upland areas show evidence of glacial erosion (Lebuis, 1973) and

are important sites of accumulation of thick drift and fluvioglacial sediments (Fig. 3). Several upland levels are identified in the south half of the area. The ridges and hills developed in bedrock of the Fortin Formation on the east side of the Matapédia valley are separated by gently rounded and inclined uplands with levels at 366-427 m a.s.l., 427-503 m a.s.l., and 503-533 m a.s.l. The upland between the Milnikek, Matapédia and lower Assemetquagan Rivers forms the floor of a broad southeast trending depression which transects geological structure at an altitude of 244-290 m a.s.l. In the southern quarter of the thesis area, south of the southern divide of the Assemetquagan River, the ridge and depression topography of the upland is less pronounced. The upland is underlain by weak Fortin slates and White Head Formation limestones which are truncated by surfaces at the 290-375 and 411-457 m a.s.l. levels. The upland surfaces slope south toward Baie-des-Chaleurs.

Drainage

The thesis area drains southeast to Baie-des-Chaleurs (Figs. 1, 5). The northern two-thirds of the area is drained by the Matapédia River and its tributaries. Four tributaries, the Assemetquagan, Causapscal, Milnikek and Matalik Rivers (Fig. 6; Appendix 2) have drainage basins which cover more than 80% of this area. The area south of the southern divide of the Assemetquagan River basin drains directly into Baie-des-Chaleurs via a system of subparallel rivers and streams.

Figure 5. Color contoured relief map of the thesis area, southwestern Gaspésie. Sketched and reduced from National Topographic Series, 1:50 000 maps 22-B2, B3, B6, B7, B10 and B11.

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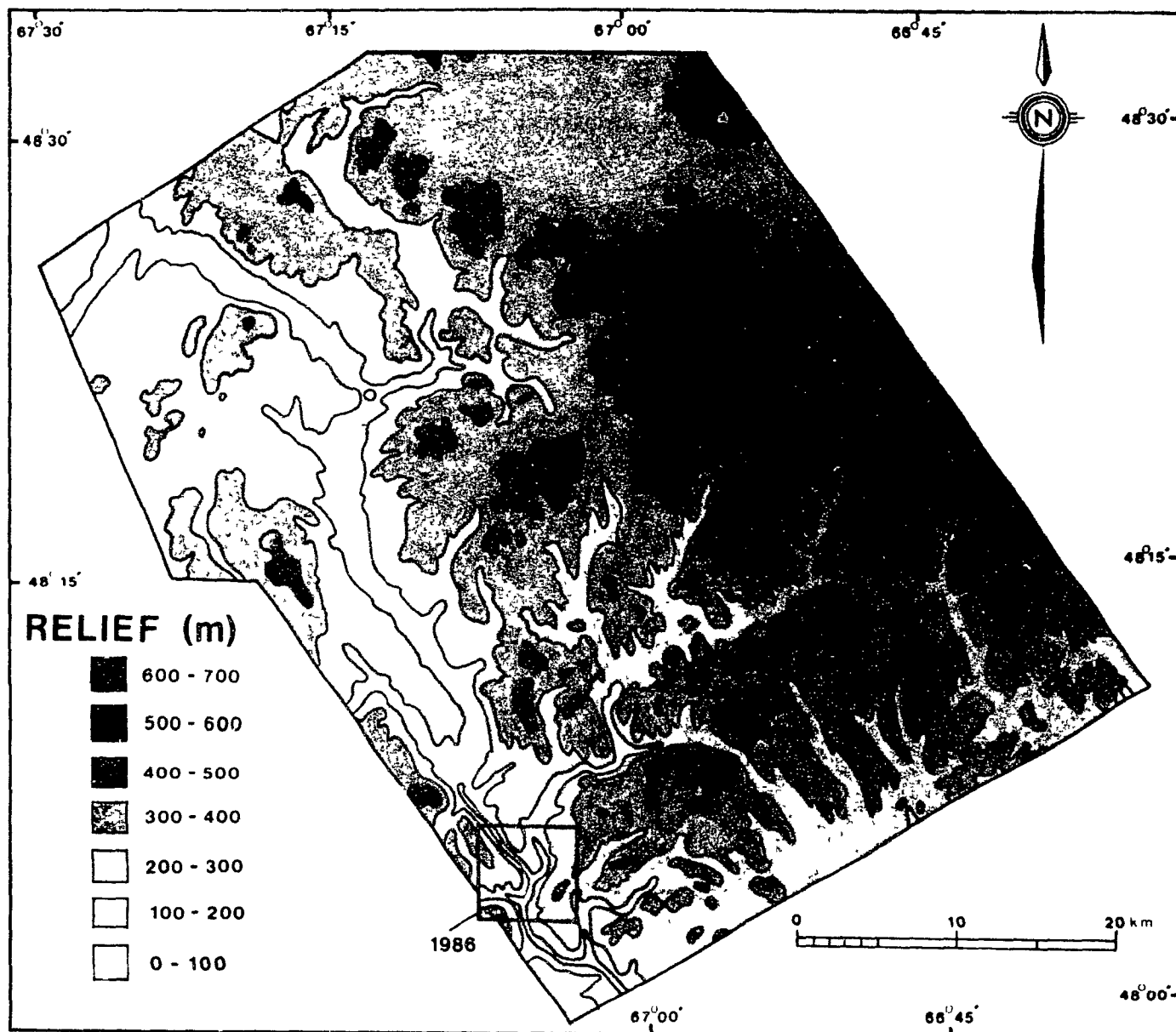


Figure 6. Drainage map of the thesis area, southwestern Gaspésie. Sketched and reduced from National Topographic Series, 1:50 000 scale maps 22-B2, B3, B6, B7, B10 and B11.

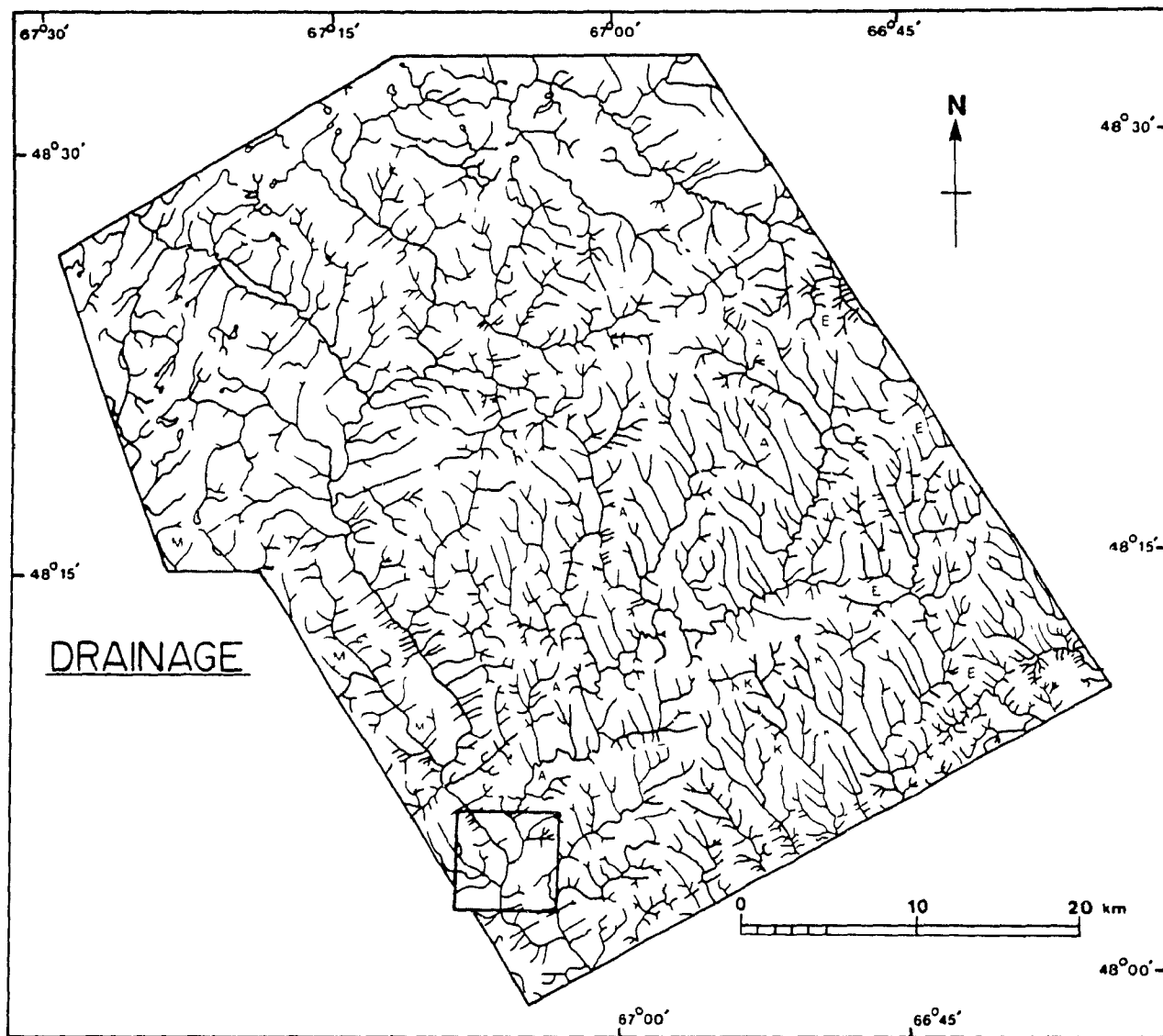




Plate 6. North-northeast view from the top of Mount Angus (UTM 624000E 5161750N) showing the undulating upland surface drained by the Causapscah River basin. The upland rises gently to the north to form the southern margin of the Shickshock Mountains (Background).

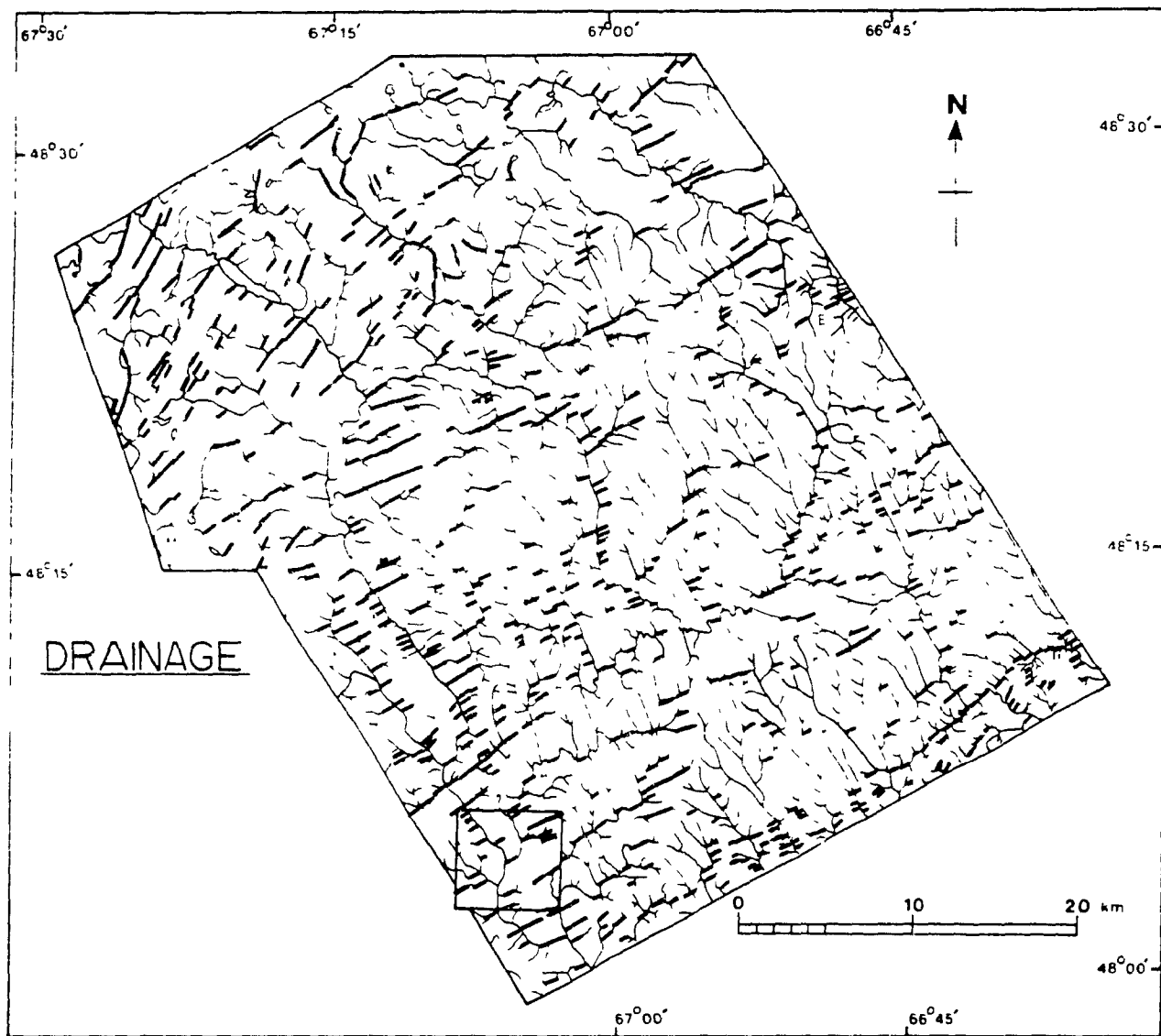


Plate 7 View north showing the lower Matapédia valley. The ancient valley floor forming the upland between the Matapédia and lower Assemetquagan Rivers is seen on the east (right) side of the river.

These include Flatland, Fraser and Moulin Brooks in the west, The Kempt River and its tributaries in the central part, and western tributaries of the Escuminac River in the east (Fig. 6; Appendix 2). All but one of the lakes in the study area are in more resistant bedrock north of the Ste-Florence fault. The highest concentration of lakes, including the two largest lakes in the area, Lac-au-Saumon and Lac Casault, occurs in sandstones of the York Lake and York River Formations and silty limestones of the Grande-Grève Formation. Ollerenshaw (1967) noted that 70% of the lakes in the Cuoq-Langis region to the north were in bedrock of these formations. Lac Casault, Lac-au-Saumon and Lac-des-Huit-Milles are in the cores of two of the broad synclines in the area (Fig. 2).

Drainage lineaments (Fig. 7) indicate that the drainage pattern, especially that of the first and second order streams, is strongly controlled by lithology and structure. Drainage lines follow two main orientations, either parallel to the northeast trending structural grain of the rocks or perpendicular to it. Structure and lithology have imparted a general weakness to the rocks which is reflected in the tendency of low order streams oriented parallel to the direction of structure to be much longer than those crossing structure. Low order streams combine to form higher order drainage lines with segments following one of the two main orientations. The Assemetquagan and the Causapsca Rivers

Figure 7. Map of drainage lineaments, southwestern
Gaspésie thesis area.



have arcuate reaches resulting from combinations of channel segments with these two main orientations.

Streams in the northwestern third of the area trend southeast across broad anticlinal and synclinal structures with smaller subsequent tributaries flowing in valleys between resistant beds. On the west side of the Matapédia River, drainage has an irregular, partly deranged pattern which is the result of glacial erosion and later deposition of drift and fluvioglacial sediments. The Causapscaal basin has a modified dendritic pattern. The large arcuate pattern of the main channel which gives the system an element of radial drainage reflects an adjustment to structure. Structural control is reflected in (1) the parallel-to-bedding course of the river along the north margin of the area and (2) the change of flow direction from west to southeast, as the river flows on weak York Lake sandstone beds which are folded around the core of a large northeast plunging syncline where the York River sandstone is exposed, (3) the shift of flow from southeast to southwest around the nose of an anticline where the siltstones and limestones of the Cap Bon Ami Formation are exposed, and (4) the return to westward flow parallel to bedding along the lower 3 km segment of the river (Figs 6, 7)

Low order streams in the Causapscaal River basin trend northeast in the direction of structure and have junctions with higher order streams varying from acute to right angles

The drainage in the west half of the basin has a higher degree of integration than in the east half where glacial activity has resulted in a local modification of drainage density and pattern. The Causapscal South River drains the flat low-lying area east of Lac-des-Huit-Milles and west of the main Causapscal River channel (Appendix 2). The thick accumulations of organic deposits which underlie this area are characterized by a very low drainage density ($< 0.5 \text{ km/km}^2$), and they give the Causapscal South River a very sinuous and irregular pattern with very few tributaries.

In the central part of the area, between the Ste-Florence fault and the southern divide of the Assemetquagan watershed, streams have a modified dendritic pattern with first and second order streams forming sharply rectangular patterns. Southeast trends tend to be to be closely spaced while northeast trends are farther apart. In several places the asymmetric, coarsely pinnate pattern of low order streams is a response to the dip direction of the rocks. All but two of the main tributaries of the Assemetquagan River trend southeast across the lithology and structure. A second tendency is for higher order cross-structure streams to be much longer than those parallel to structure. The greater dissection perpendicular to the main direction of weakness of the rocks suggests that factors other than the structure have influenced the larger drainage features of this area.

In the southern quarter of the area (south of the

southern boundary of the Assemetquagan basin), the streams have a subparallel pattern trending southeast. Tributaries of the Kempt and Escuminac Rivers in the southeast corner of this area form sharp rectangular patterns in response to structure and lithology. Drainage over the White Head Formation has the highest density in the thesis area (1.5-3.5 km/km²).

Valley forms

Valleys transect the upland surface in a trellis-like pattern following two main orientations, one northeast, parallel to structure and lithology, and the other southwest, at right angles to the structure. Length and size of valleys depends partly on orientation. The principal valleys or major tributaries have axes perpendicular to the direction of structure. Major cross-structure valleys include those of the Matapédia, Milniké, Moulin, Escuminac, Kempt, Creux, Castor, McDavid, Assemetquagan East, Assemetquagan West and Causapscal Rivers (Appendix 2).

A striking feature of the area is the deep (100-450 m) incision of major valleys into the gently rolling upland surface (plate 8). Projected profiles transverse to the valleys show that several of the main valleys tributary to the Matapédia (Assemetquagan, Creux, Castor, Assemetquagan East and West, Causapscal, Causapscal East, Huit-Milles) have narrow, steep lower cross-profiles and broad gentle upper cross-profiles indicating inner valleys 30-150 m below



Plate 8. Steep incision of Clark Brook, a tributary of the Matapédia River, into fissile Fortin slates. Photograph taken at site 328 (Appendix 7). View upstream.

broad older valleys with floors which are now at 250-305 m a.s.l. In the upper halves of the Assemetquagan and Causapscal River basins, rejuvenated streams occupy shallow but steep V-shaped notches in broad (500-2500 m), shallow valleys eroded into the sandstones and the slates. These broad and shallow ancient valleys are some of the oldest landforms in the area. They are now partly filled by alluvium and organic matter in their lower parts, and glacial drift on the upper slopes and interfluvies.

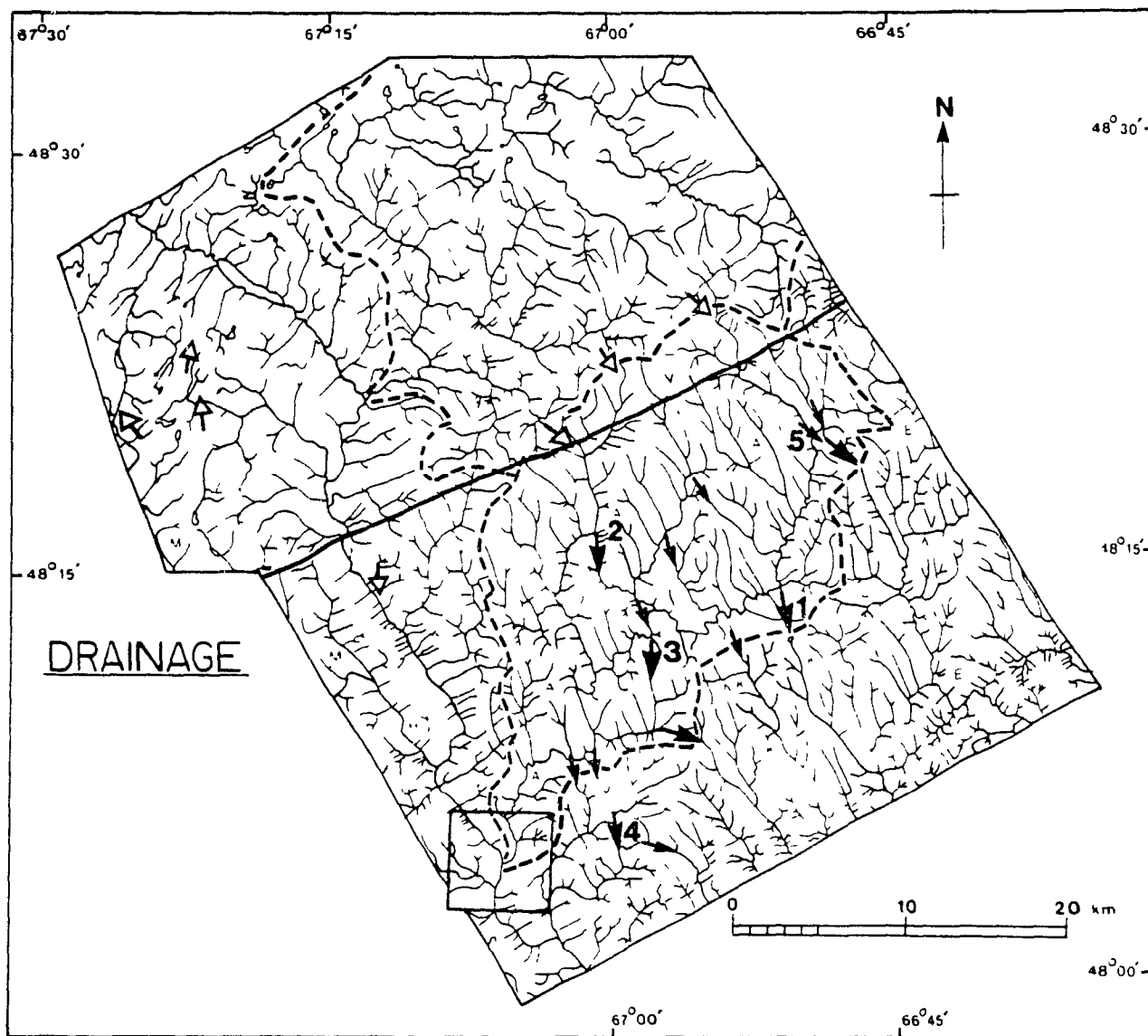
The Matapédia valley is the master valley, forming a broad, deep southeast trending depression in which is exposed a complete cross section of the lithology and structure of the thesis area. Transverse projected profiles across the Matapédia valley, between the Milniket valley in the north (Appendix 4) and the lower Assemetquagan valley in the south (Appendix 5), show a broad ancient valley floor at 244-290 m a.s.l. (Plate 7). A striking feature is the difference in cross-profile between the upper and lower halves of the valley. North of Latitude $48^{\circ} 15'$ the Matapédia River flows in a broad, 2.5 km wide flat-floored valley with a wide floodplain, except at the junction with the Causapscal River where the valley narrows to a few hundred metres for about 1.5 km. South of this latitude, the Matapédia River is confined in a narrow, locally sinuous canyon 1.5-2.5 km wide with little or no flood plain. Alcock (1928, 1935) suggested that the difference in valley form was the result of erosion

of the upper valley by a northward flowing river, to which the present Causapscal River was tributary. He attributed the diversion to capture, at Causapscal, of part the northward flowing river by a tributary of the original Matapédia River eroding headward from the south. Stearn (1965) proposed an alternative hypothesis, suggesting the change in valley form was related to a change in character of the bedrock over which the Matapédia river flowed, from resistant sandstones and siltstones in the upper part of the valley, to fissile slates in the lower part.

Some of the valleys in the south half of the area show anomalies that indicate that a major shift in the direction of drainage to the southwest has occurred (Fig. 7), and that the Assemetquagan River basin developed from the northeastward headward growth (in the direction of structure) of a tributary of the Matapédia River, and progressive capture of streams that originally flowed southeast to Baie-des-Chaleurs. An upper segment of the Assemetquagan River flows south-southwest for 10 km to a point where it shifts abruptly to the west to follow structure (Fig. 8, point 1). In line with the upper axis of the Assemetquagan River, and 3 km south of the abrupt bend, the Kempt River North follows a southerly course to join the Kempt River which discharges into Baie-des-Chaleurs. The presence of a lake at the divide and a large depression to the north

Figure 8. Former drainage routes, southwestern Gaspésie thesis area. Solid arrows indicate drainage modifications as a result of stream piracy. Open (triangular) arrows show former meltwater flow directions. The boundary between the fissile Fortin slates and the resistant York River sandstone (Ste-Florence fault) is shown by the solid line. The outlines of the Assemetquagan and Causapscal River basins are shown by dashed lines. Note the northward headward growth of Assemetquagan River tributaries across the lithological boundary resulting in capture of Causapscal River drainage and progressive northward shift of the divide. Numbers refer to drainage modifications discussed in the text. Refer to Appendix 2 for location of major rivers and streams.

- A: Assemetquagan River basin
- C: Causapscal River basin
- E: Escuminac River basin
- K: Kempt River basin
- M: Milnikek River basin



suggest a relict through valley, and a former southward drainage route for the upper Assemetquagan River. A large windgap at an altitude of 300 m a.s.l. separates the head of Gendron Brook from a sharp bend where the upper Creux River turns west to follow the structural trend (Fig. 8, point 2), suggesting that the upper Creux River once flowed south to Castor River through Gendron Brook. The floor of the Creux valley at the sharp bend is 80 m below the floor of the older through valley. A prominent windgap also separates the valley of the St-Etienne North Brook from a short south flowing segment of the Assemetquagan River, where the Castor River enters (Fig. 8, point 3), suggesting a former southward drainage route for the Castor River. An arcuate valley as wide and deep as the Matapédia joins the head of St-Etienne Brook to the Kempt West River (Fig. 5, Fig. 8, point 4) and may have been the outlet for the Castor - St-Etienne basin before headward growth of a southwest flowing tributary of the Assemetquagan River captured the system. Northeast growth of the Assemetquagan River would also have captured tributaries of the Escuminac River. A large depression north of the divide between the Assemetquagan East River and the Escuminac River (Fig. 8, point 5) suggests that the Assemetquagan East and West Rivers were tributary to the Escuminac River prior to capture. Further evidence for the rapid northeast growth of the Assemetquagan River and capture of southeast flowing drainage lies in the gradients

of tributary streams. Several of the small southeast flowing tributaries of the Assemetquagan River have gentle upper gradients which steepen abruptly a few hundred metres upstream from the confluence with the main southwest flowing channel of the river. The abrupt change in gradient of the southeast flowing tributary streams as they enter the main channel is a response to a change in base level caused by the rapid northeast headward growth of the Assemetquagan River and progressive capture of southeast flowing drainage.

Geomorphic Evolution

A close examination of the geomorphology of the area, through projected profiles, Landsat image, airphoto and drainage pattern analyses, reveals a highly developed landscape system in which topography, drainage, lithology and structure show evidence of a long history of subaerial erosion extending back possibly to late Paleozoic time, with relatively little modification by Pleistocene glacial events. The juxtaposition at the surface of bedrock formations with concordant positions in the stratigraphic column together the presence of relict landforms (broad ancient valleys, relict through valleys), the gentle ridge and depression topography of the upland, the presence of multiple upland levels and the low relief, undulating or "worn down" character of the upland are evidence of fluctuations in diastrophic activity over long periods of time. The present pattern and intensity of denudation, as shown by the steep incision of valleys into a

gently undulating surface, the active headward advance of the north divide of the Assemetquagan basin (Fig. 8), the abrupt change in profile of southeast-flowing tributaries joining the main channel of the Assemetquagan River, and the strong tendency of low order streams to adapt to the present structural arrangement of the rocks reflect a geomorphic response to a relatively recent tectonic uplift event and/or climatic variation.

The starting point in the geomorphic development of the area was the differential uplift of fault-bounded blocks of gently folded Upper Ordovician to Lower Devonian sedimentary rocks during the Acadian orogeny of Middle to Late Devonian age. In the study area the three main blocks of strata affected are (1) The Siluro-Devonian sediments of the Connecticut Valley - Gaspé Synclinorium north of the Ste-Florence fault, (2) The Siluro-Devonian sediments of the Gaspé Trough, and (3) the Upper Ordovician strata of the Aroostook - Percé Anticlinorium south of the Matapédia fault (Figs. 1, 2). At the time of the Acadian orogeny the area was entirely covered by the terrigenous Gaspé Sandstone, at least 4550 m of which is still preserved in the block of strata north of the Ste-Florence fault (Stearn, 1965). The Acadian compression resulted in faulting, uplift and thrusting of sediments in the Gaspé trough over the sequence of deeper water limestones formed at the north margin of the basin and overlying Gaspé sandstone (north of the Ste-

Florence fault), exposing the sandstones which filled the trough. Early consequent drainage lines would have developed flowing both north and south of a northeast trending divide which was somewhere above the present position of the Fortin Formation. Drainage discharged toward basins north and south of the divide. The upper Causapsal River basin drained north through the Tamagodi River to the Matane River during this time (Ollershaw, 1967). A basin at the site of the present Baie-des-Chaleurs has been a feature of the region since Upper Ordovician times when the Matapédia Group limestones were deposited. The sandstones of the Bonaventure Formation were deposited in this basin during the Carboniferous Period (Malo, 1987). Long continued uplift and subaerial erosion removed an estimated 11-12 km of sandstone which overlay the Fortin Formation and filled the Gaspé trough in western Gaspésie (Dalton, 1987). As much as 5-7 km of Gaspé sandstone north of the Ste-florence fault was also removed during this interval. Assuming a rate of weathering for sandstone of 0.3 mm per year (Chorley et al., 1984) the removal of 12 km of sandstone in the Gaspé trough could account for approximately 40 of the 360 million years since the initial Acadian uplift. The removal of the sandstone resulted in a superimposition of consequent drainage lines onto the Fortin Formation, causing the present anomalous southeast and elongated trends of the main tributaries. In south-central and eastern Gaspésie, Gaspé sandstones still

overlie the Fortin Formation. The absence of Gaspé sandstone over the Fortin Formation to the west may be the result of a higher rate of uplift in the western part of the Gaspé trough, assuming sandstone thicknesses were similar throughout the basin.

A renewal of uplift resulted in a increase in the rate of erosion and the northeastward growth of the Assemetquagan River which resulted in the diversion of a considerable proportion of the upper Baie-des-Chaleurs drainage to the Matapédia River. The capture of the Causapschal drainage by headward erosion of the Matapédia River, as envisaged by Alcock (1935), would have occurred during this more recent phase of uplift. The acceleration of erosion is expressed in the steep V-shaped incision below the floors of the ancient valleys, and the development of low order streams parallel to the structural trend.

Subsidence took place beneath the ice sheet and local glaciers in the Pleistocene. The Laurentide ice sheet covered most of the area, with little evidence of erosion and deposition except in parts of the north half of the area. There is little evidence outside of the Matapédia valley that it reached Baie-des-Chaleurs. This was followed by a local glaciation which saw ice spread north and south of a divide above the Fortin Formation (David and Leblais, 1985). Evidence of the glaciations are limited almost exclusively to the north half of the area. Topography may have influenced

the pattern of flow and deposition of the ice sheet. Drift deposits and fluvioglacial sediments occur mostly in the low lying areas west of Causapscal and north of the upper part of the Assemetquagan River basin.

The area has evolved, and is presently progressing under metastable equilibrium conditions. Relict landforms in the present landscape are evidence of recent fluctuations of tectonic uplift, and unequal rates of geomorphic response to the rate of fluctuation, indicating that the long term, decay-type equilibrium (Davis, 1909) which may have been achieved in the development of the upper relict topography, has been disturbed. Individual elements of the present landscape system are still adapting to the recent change in conditions. The high degree of integration of the drainage system, the strong correlation of low order streams with structure and the relation of upland topographic features with present lithology, rock competency and structure are indications of a geomorphic trend toward an equilibrium between form, lithology, structure, recent deformational forces and the present climatic regime.

GEOMORPHOLOGY AS AN AID TO GOLD EXPLORATION

The basic premise underlying the use of geomorphology in mineral exploration is that mineral deposits are in some way physically reflected in the configuration of the terrain, or genetically associated with geomorphic processes (Thornbury, 1969, Verstappen, 1983). The type and degree of

applicability of geomorphic approaches in the search for economic mineral resources varies according to (1) the type of mineral deposit and its mode of formation, (2) the physiographic setting, geomorphic history and climatic regime of the region of interest, and (3) the relation to other methods (geophysical or geochemical) employed in exploration. Geomorphology has a limited but direct application in the search for mineral deposits with strong surface expressions or associations with ancient relief forms (Mills and Eyrich, 1966; Smith, 1977; Rowan and Lathram, 1980), and in the search for surface or buried placer deposits (Biliban, 1955; Kuzvart and Bohmer, 1986; Sivadas, 1987). The use of geomorphology as a aid to mineral exploration rather than as a direct prospecting method is more common. The indirect applications of geomorphic approaches to mineral exploration are in (1) the mapping of lithology, structure and overburden types (Ray, 1960; Howard, 1967; Paarma et al., 1977), (2) the study of physical and geochemical alluvial dispersion (Slingerland, 1984; Bonham-Carter et al., 1987; Fletcher and Day, 1988), (3) the study of element mobility and migration in overburden (Webster and Mann, 1984), and (4) the study of mineralogical, geochemical and boulder dispersion in glaciated terrains (Chauvin and David, 1987; Stea et al., 1988).

The geomorphology of the southwestern Gaspésie study area was examined in the context of the first and last

categories of indirect applications. The principle application of geomorphology to gold exploration using shallow overburden surveys is in providing basic information on the various parameters (lithological and overburden) and processes that control the composition of overburden and the shape of mineralogical and geochemical patterns.

Geomorphology as an indication of lithology and structure

Structure and lithology are revealed in the morphology of individual landforms, in the arrangement of topographic features and low order streams, and in the density and pattern of drainage. Once the effects of cross-structural negative features (major southeast-trending depressions) are removed, alignments of hills and ridges become evident and they outline boundaries of resistant beds striking northeast and dipping either northwest or southeast as part of large anticlinal and synclinal structures. Dips of major resistant beds are indicated by smooth backslopes on asymmetric hills and ridges and by flat-iron forms, some of which are clearly visible on Landsat images. Boundaries between major beds are determined by the step-like arrangement of hills and depressions on the upland surface, the alignment of valleys containing low order streams, and the trellis-like pattern of drainage. The Fortin Formation, whose complex lithology and structure have yet to be mapped, appears on airphotos as a succession of thick beds of relatively uniform competency but varying lithology, folded into broad, gentle anticlines and

synclines, and faulted and fractured in several places.

Structural control is evident in the straight, parallel northeast trending arrangement of low order streams (Fig. 7), the northeast-trending straight segments of the main channel of the Assemetquagan River including the lower 1 km segment where there is an alluvial gold occurrence, and in the arcuate patterns of the Causapscal River. Fault-line structures are also responsible for the progressive shift to the west of the Matapédia River (Fig. 2), first along the fault-line scarp 2 km south of Causapscal, then along a set of faults separating two beds of the Fortin Formation at the mouth of, and 2 km above the Milnikek River, and farther south along a succession of bedding planes crossing the Matapédia River between the mouths of the Assemetquagan and Moulin Rivers.

Faults appear as alignments of steep, V-shaped valleys (fault-line valleys), as steep scarps on asymmetric ridges (fault-line scarps), or as narrow depressions on the upland surface. Fault-line valleys outline the position of (1) the Matapédia fault and a tributary fault which crosses the Matapédia River 1.25 km to the north, (2) the faulted geological boundary between the York River and Cap Bon Ami Formations which crosses the southern end of the Causapscal airport at Laville Brook, and (3) a set of faults which cross the Matapédia valley near the mouth of the Milnikek River, one of which crosses the entire Fortin Formation. This last

fault has an important bearing on the structural arrangement of the Fortin Formation and as such should be examined in future structural and bedrock investigations, and mineral exploration programs. Prominent fault-line scarps occur 2 km south of Causapscal and at the boundary between the York River and Grande-Grève Formation in the northeast corner of the area. The Ste-Florence fault, a major structure in southwestern Gaspésie has little topographic expression. Its approximate position can be determined by the change of topography, relief and drainage associated with the change in rock type from siltstones and sandstones in the north to fissile slates to the south. On airphotos the fault appears only as a narrow notch on a hill west of Ste-Florence, and less than 1 km north of a string of low rounded hills of volcanic rocks.

Geomorphology, Overburden Distribution and Composition and Overburden-Forming Processes

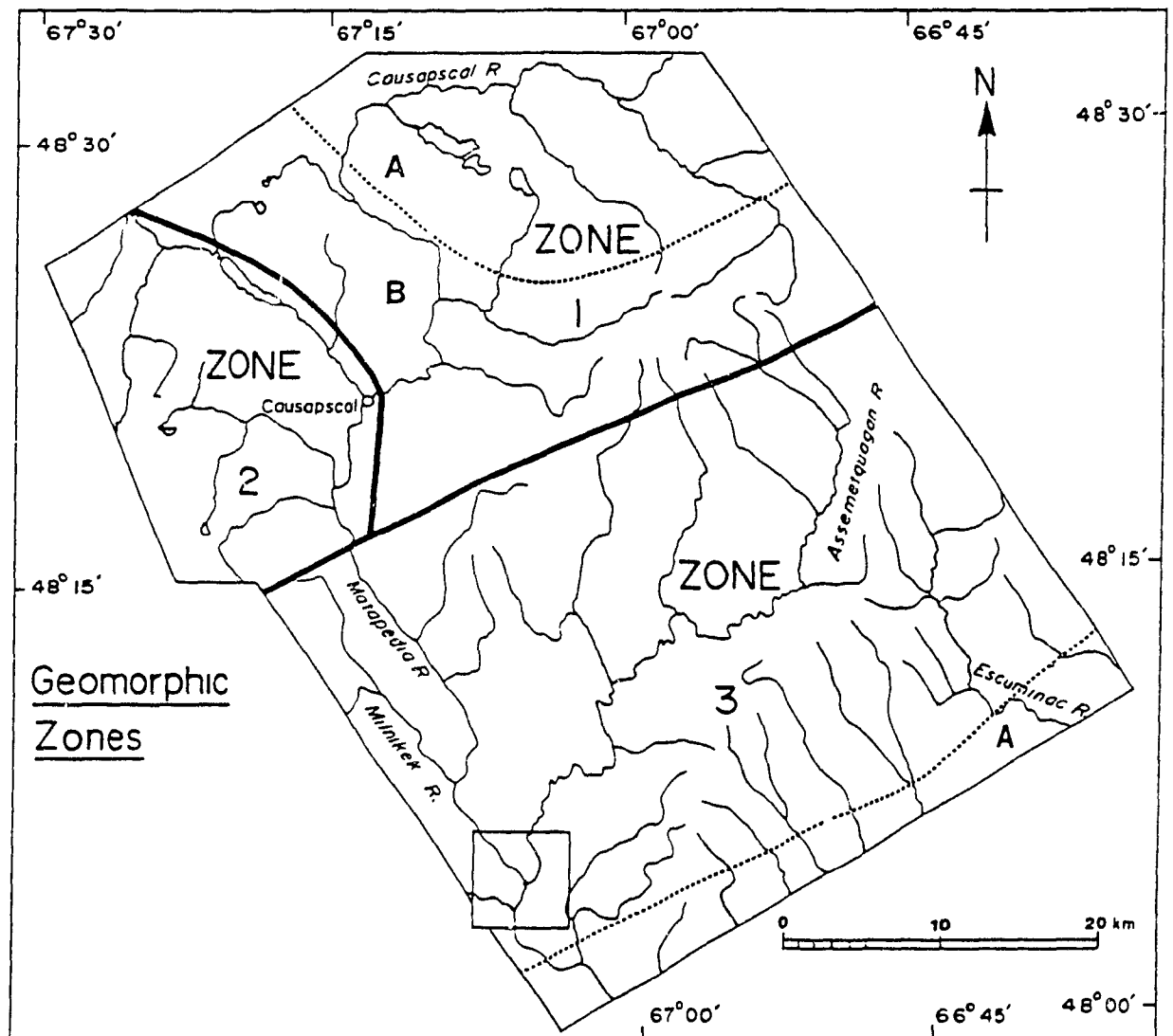
The thesis area can be divided into three broad geomorphic zones where overburden distribution and composition reflect particular combinations of geomorphic parameters (lithology, bedrock composition and competency, structure, drainage, topography, and relief) and processes (pre-glacial geomorphic activity, glacial erosion, transport and deposition, post-glacial weathering, fluvial erosion and deposition) (Fig. 9).

Zone 1.

Zone 1 corresponds roughly to the northeast third of

Figure 9 Broad geomorphic zones and their major characteristics, southwestern Gaspésie thesis area

	Zone 1	Zone 2	Zone 3
A. TOPOGRAPHY			
1 Upland levels	1 (305-420 m a s l)	1 (260-305 m a s l)	6 (244-290, 366-427, 411-457, 427-503, 503-533 m a s l) Zone 3A (290-375 m a s l) 30-450 m 650 m
2 Local Relief	10-300 m	5-70 m	
3 Max Relief	505 m	335 m	
4 Valley Form	Zone A Shallow and broad Zone B Broad with upper gentle slopes and steep lower cross profiles, large ancient valleys	Shallow and broad valleys filled with glacial drift	Steep and narrow, V shaped valleys, 1 main broad ancient valley along the west margin, tributaries with 2 step cross-profiles
5 Ridge and depression topography	Well developed in Zone 1A, ridges spaced between large and flat, low lying interfluvies in Zone 1B	Round ridges separating large and flat, low lying interfluvies. Topography masked by thick drift cover	Pronounced ridges and hills closely spaced and separated by narrow flat interfluvies and steep V shaped valleys
6 Pre glacial landforms	Well preserved, several landforms of lithology and structure, large ancient valleys are the oldest landforms in the area	Landforms of lithology and structure masked by thick drift cover, topography affected by glacial erosion, low relief upland surface	Well Preserved, little evidence of glacial modifications, many landforms of lithology and structure, pre glacial valley forms preserved. Several wind gaps and through valleys
7 Landforms of glacial erosion and deposition	Four scoring features in E trending valleys. Rare in lowland features. Some hummocky terrain underlain by glacial drift (till) and alluvium	Developed on alluvium and glacial drift (till), Kames and other ice contact stratified deposits in the Matapedia valley	Developed on alluvium and glacial drift (till). Major ice contact deposit in the Matapedia valley. No evidence of glacial activity on the upland surface
8 Landforms of post glacial weathering and erosion	Alluvial terraces along main rivers and tributaries, alluvial fans (active), steep lower cross profile of many streams, falls and rapids	Alluvial terraces and fans in the Matapedia valley, mostly landforms of glacial deposition on upland surface	Alluvial terraces along the Matapedia valley south of the Assomption River. Steep lower cross profile of several streams. Colluvial deposits at foot of slopes
B. DRAINAGE			
1 pattern	modified dendritic, partly dendritic (Zone 1A), dendritic (Zone 1B)	deranged trellis	subparallel dendritic, dendritic, strongly rectangular (Zone 3A)
2 Density	< 1 - 1.5 km/km ²	<< 1 - 1.2 km/km ²	1.2 km/km ² , 1.5-3.5 km/km ² (Zone 3A) 20-30%, 40-50% (Zone 3A)
3 Control	10-15%	15-20%	
4 Basins	Caussepeal and Matapedia River basins	Matapedia, Bonaparte, and Matapedia River basins	Assomption, Matapedia, Bonaparte, Clark, Fong, Fard, L'Anse-au-Loup and Matapedia River basins
C. BEDROCK			
1 Distribution	St 1, CBA, G Grey (55%) Yrk P, Yrk I, I Br (45%)	St 1, CBA, G Grey (80%) Yrk R, Yrk I (20%)	Fortin Formation (90%) Wheat Formation (Zone 3A) (10%) Fortin Formation (W, F)
2 Competency	St 1 (W), CBA (W) G Grey (R), Yrk R (R), Yrk I (W), I Br (R)	St 1 (W), CBA (W) G Grey (F), Yrk R (R) Yrk I (R)	Wheat Formation (Zone 3A) (w)
D. STRUCTURE			
1 Tectono-stratigraphy	Connecticut Valley - Gaspé Synclinalium	Connecticut Valley - Gaspé Synclinalium	Gaspé Trough (C.V. - Gaspé Syncl.) Arcostock Trench Axis (Zone 3A)
2 Folds	Narrow tight folds, broad gentle folds	Large open folds	Large open folds, several narrow and tight folds on a local scale
3 Faults	Faulted geol. boundaries	Faulted geol. boundaries	Faulted geol. lithol. boundaries
OVERBURDEN CHARACTERISTICS			
1 Main Overburden Types and Distribution	Discontinuous glacial drift (till), Alluvium of fluvioglacial and non glacial origins on upland and in valleys, organic deposits and outwash in low lying upland of Zone 1A (Fig. 3)	Fluvioglacial deposits (clays, kames, ice contact stratified drift), discontinuous glacial drift (till) on upland, alluvium in the Matapedia valley (Fig. 3)	Rubble on upland surface, colluvium on valley slopes, till near the north margin and on the upland bordering the Matapedia Valley, alluvium and colluvium in the Matapedia valley (Fig. 3)
2 Provenance	Local origin with a far-travelled component derived from the north	Local origin with a far-travelled component derived from the north	Local origin for the rubble and colluvium. Very small far-travelled component derived from the north. Possible dispersion from the west
3 Thickness	Glacial drift (till) < 2 m Fluvioglacial drift 1-20 m	Glacial drift (till) < 1 m Fluvioglacial drift 1-10 m	Rubble 1 m, colluvium 1-5 m, Alluvium 1-100 m, till < 1 m
4 Oxidation	Moderate (down to 1 m depth)	Moderate to strong (0-2 m)	Strong (below bedrock surface)
GEOMORPHIC PROCESSES (Effect on Overburden distribution (D) and composition (C))			
1 Pre glacial Weathering	(D) No important effect (C) No important effect	(D) No important effect (C) No important effect	(D) Important in valleys (C) Important
2 Glacial Erosion and deposition	(D) Important (C) Significant (far travelled component)	(D) Significant effect (C) Important (far travelled component)	(D) No important effect (C) Uncertain (far travelled component?)
a Laurentide Ice	(D) Local remobilization (C) local mixing of overburden	(D) Local remobilization (C) local mixing of	(D) No important effect (C) No important effect
b Local Glaciers	(D) Local remobilization on slopes (C) Local mixing on slopes	(D) No important effect (C) No important effect	(D) Major control distribution of colluvium (C) Very important
3 Post glacial	(D) Important in Zone 1A (C) Important in Zone 1A	(D) No important effect (C) No important effect	(D) Important in Matapedia valley (C) No important effect
a Slope processes	(D) No important effect (C) Important effect degree of oxidation degree of leaching	(D) No important effect (C) Important effect degree of oxidation degree of leaching	(D) No important effect (C) Very important effect Strongly oxidized overburden Strongly leached (Zone 3A)
b Fluvial action			
c Weathering (Groundwater)			



the area. It is characterized by an upland with low relief and intermediate altitude (305-420 m a.s.l.) developed on folded and faulted sandstones of the York Lake, York River and Lake Branch Formations, and siltstones and limestones of the St-Léon, Cap Bon Ami and Grande-Grève Formations. Landforms of glacial ice erosion are rare and limited to a few southeast-trending valleys which show evidence of scouring. The upland surface is covered by a thin (< 2 m) but almost continuous blanket of glacial drift (till) initially deposited by Laurentide ice and later remobilized by local ice movements. The more extensive cover of till occurs on the higher ground of Zone 1A. The large upland depression which forms the northeast part of the zone (Zone 2A) contains thick (> 2 m) glacial outwash and organic sediments. The Causapscal River and its tributaries drain this zone.

The boundary between Zone 1 and Zone 2 is defined by contrasting differences in the altitude of the uplands and in their lithology and structure, by the presence of glacial erosion features, and the distribution of the overburden.

Zone 2

Zone 2 (Fig. 9) is west of the Matapédia valley and north of the Ste-Florence fault. It is a large, low relief and low altitude (260-305 m a.s.l.) upland surface developed on folded and faulted limestones and siltstones of the St-Léon and Cap Bon Ami formations in the northern two-thirds

of the area, and resistant sand tones of the York Lake and York River Formations along its southern edge. Numerous landforms of glacial ice erosion (meltwater channels, southeast trending U-shaped valleys) and deposition (eskers, kames, outwash deposits, hummocky terrain) are evidence of extensive glacial activity on the upland surface and in valleys. The lithology of Zone 2 is masked by an extensive cover of overburden which includes thick (1-30 m) ice-contact stratified drift and fluvio-glacial sediments, thin (1-2 m) glacial drift (till) and undifferentiated diamictons. Zone 2 is drained by the upper Matapédia River and two main tributaries, the Humqui and Matalic Rivers.

The boundary that separates Zones 1 and 2 from Zone 3 is the Ste-Florence fault. The change from relatively competent sandstones, siltstones and limestones in Zones 1 and 2 to fissile slates and siltstones in Zone 3 is reflected in the topography. Most noticeable is the change in valley form from broad and shallow cross-profiles in Zones 1 and 2 to steep and narrow cross-profiles in Zone 3 (best seen in the Matapédia valley); the change to a more pronounced ridge and depression topography of the upland and the increase in density of structurally controlled depressions occupied by low order streams from Zones 1 and 2 to Zone 3; the north to south decrease of glacial erosion features and the absence of landforms of glacial deposition on the upland surface in Zone 3.

Zone 3.

Zone 3 extends from the Ste-Florence fault to the southern limit of the area. This zone is characterized by its multiple level upland surface, pronounced ridge and depression upland topography, steep dissection, high relief, absence of glacial erosion and depositional features on the upland and in valleys other than the Matapédia valley, and the preservation of the preglacial topography and drainage. The upland surface is formed by extremely fissile slates of the Fortin formation except along the southern margin of the zone (Zone 3A) where older limestones are exposed. Thin (1-2 m) glacial drift (till) is still preserved on the upland surface along the north margin of Zone 3, and on the upland between the Milniké and Matapédia Rivers. The upland surface is mostly covered by rubble derived from the physical breakdown of the underlying rock. Valley walls are lined by thick sheets of colluvium. The presence of extensive and thin rubble on the upland surface and thick colluvium on valley slopes reflects the rapid weathering and slope transport which characterize the particular combination of physical factors (steep dissection, high relief, fissile bedrock) under post glacial climatic conditions. The drainage pattern is modified dendritic with a trellis element. The boundary between the Fortin slates and the White Head Formation limestones to the south is marked by a distinct increase in drainage density and a change in tone from dark gray to light

gray on Landsat imagery (Fig. 4). The boundary between the two formations is marked by a distinct alignment of fault-line valleys (Matapédia fault).

The processes that are responsible for the distribution and composition of overburden in the thesis area are associated with past glacier ice dynamics and post-glacial weathering, erosion and deposition. Geomorphology provides an indication of the distribution of glacial sediments and the relative influence of glacial erosion and deposition on topography. However, it does not provide a sufficient basis for determining the complex patterns of ice movements across the area or predicting the effect of glaciation on the composition and provenance of the overburden. The absence of landforms of glacial erosion and deposition in Zone 3 complicates the problem of determining the pattern of flow of Laurentide ice and, more important to the problem of gold exploration in southwestern Gaspésie, the extent of deposition of far-travelled and foreign debris and the degree of mixing with local bedrock-derived material in the overburden.

The glacial and post-glacial processes that control the composition and distribution of overburden operate under topographic and climatic constraints. Climate is an independent variable. It influences the overburden primarily through its effects upon drainage, runoff and erosion, and to a lesser degree, vegetation cover. Topography, is a function

of lithology, bedrock composition, and structure. Raudsepp (1969) was able to express the relationship between the lithology, structure and topography of western Gaspésie in a quantitative manner using frequency distribution measurements of altitude as an index of the resistance of the various rock formations. The division of the thesis area into the three zones in which overburden composition and distribution reflects particular combinations of physical factors and processes (Fig. 9) is essentially based on the relation between topography and the other physical characteristics, with the assumption that the overburden-forming processes operate under these physical constraints. The mineralogical and geochemical patterns obtained from the overburden surveys should reflect the combinations of physical factors and processes that characterize each of the three broad zones.

OVERBURDEN SAMPLING, PROCESSING AND ANALYTICAL METHODS

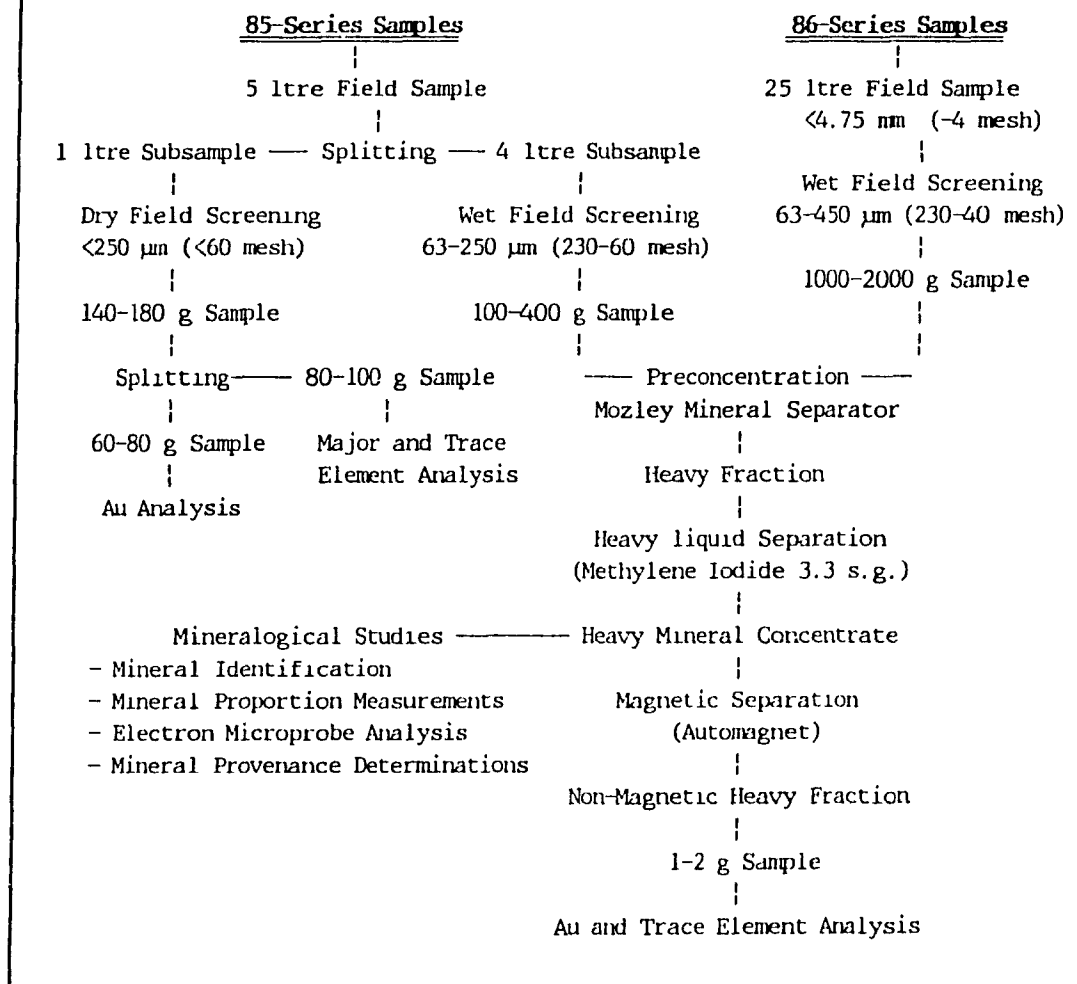
Field Methods

Shallow overburden sampling was carried out during the summers of 1985 and 1986. The 1985 sampling program was designed to provide a representative coverage of the project area and of the various overburden types. Samples were collected at 1.5 to 3 km intervals along roads accessible by two-wheel-drive vehicle. Limited access to most of the southern half of the project area resulted in uneven sample density. Approximately 10 litres of overburden were

collected from the C horizon of hand excavated pits at 295 sites (Appendix 6). Samples with a high matrix (sand size and finer)-to-clast ratio were collected where possible, but where the matrix fraction was small, larger samples of up to 20 litres were taken. In 1986 82 overburden samples were collected in a 36 km² area surrounding the auriferous lower segment of the Assemetquagan River (Appendix 7). The sampling procedure was modified to take into consideration the low content of heavy minerals in overburden samples collected in the surrounding area in 1985. Approximately 25 litres of <4.75 mm (-4 mesh) material were collected at every site. Samples were taken from the C horizon where possible. However, at most sites the overburden was thin and lacked distinct soil horizons. Sixty-nine samples were collected on the upland surface at a spacing of 500 to 700 m. A further 13 samples were collected on the valley slopes within the lower 2 km segment of the Assemetquagan River.

Sample treatment is illustrated in Figure 10. Approximately 1 litre of material was separated from 300 1985-series samples and then dry screened to <250 µm (-60 mesh) in preparation for geochemical analysis. The remaining portion of the 1985-series samples were then wet sieved to obtain the 63-250 µm (230-60 mesh) fraction for heavy mineral separation. The 1986-series samples were wet sieved to obtain the 63-450 µm (230-40 mesh) fraction for heavy mineral separation. The upper size limit of the 1986-series samples

Figure 10.
Sample Treatment Chart



was doubled to ensure maximum recovery of heavy minerals, a concern for geochemical methods.

Geochemical Methods and Heavy Mineral Studies

The 300 <250 μm (-60 mesh) samples from the 1985 survey were analyzed for gold content by a commercial laboratory using combined fire assay and plasma emission spectrometry (detection limit of 2 ppb). One hundred <250 μm (-60 mesh) samples were also analyzed for major and trace elements using a Philips PW 1400 X-ray spectrometer in the Department of Geological Sciences at McGill University. Heavy minerals were extracted from 185 1985-series samples and all of the 1986-series samples using a Mozely MK II mineral separating table and then concentrated by density-dependent settling in methylene iodide (3.3 s.g.). Magnetic minerals were removed from the concentrates using a Sepor automagnet. The resulting fractions were weighted to provide percentages of heavy minerals in the total sample and percentages of magnetic minerals in the heavy mineral fraction (Appendices 8, 9). The heavy mineral concentrates were examined under a stereoscopic microscope to determine (1) the characteristic mineral assemblages, (2) the approximate proportion of local and far-travelled components and (3) the mineralogical form(s) of gold. Two hundred and forty non-magnetic heavy mineral concentrates were then sent to a commercial laboratory and analyzed for gold and 25 other elements by neutron activation. Ninety-six of the samples were from the

1986 survey. The results of the analyses, including 19 duplicate sample analyses are listed in Bernier et al. (1987).

The chemical composition of various silicate, oxide and sulphide heavy minerals was obtained by electron microprobe analysis. Individual mineral grains were handpicked and mounted in Araldite epoxy resin onto standard 27x46 mm glass slides. Grinding and polishing of the individual grain mounts was performed by the thin section laboratory of Ecole Polytechnique. Chemical analyses were conducted at McGill University using a Cameca Microbeam MB1 electron microprobe equipped with four wavelength dispersion spectrometers (Appendix 10). Oxide and silicate analyses were recalculated into their molecular proportions using the Cameca STRGEO software file.

REGIONAL SURVEY RESULTS

Major Element, Trace Element and Gold Analyses (<250 μ m Samples)

Major and trace element averages and standard deviations for 100 <250 μ m samples of overburden are given as a function of underlying rock in Table 2. Major element averages show a general pattern of variation related to changes in bedrock composition from north to south across the area. Overburden samples collected over silica-rich lithologies north of the Ste-Florence fault show the highest contents of SiO_2 (75.45 - 78.1%) and the lowest contents of Al_2O_3

Table 2

Summary of major and trace element averages in overburden (<250 µm) as a function of underlying bedrock, regional survey, southwestern Gaspésie. Major element analyses are recalculated to exclude LOI in summation.

Major Elem (%)	Lake Branch Formation		York Lake York River Fms		Cap Bon Ami-Gr -Grève Fms		St -Léon Formation		Fortin Formation		White Head Formation	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
SiO ₂	78.1	4.56	75.5	3.76	77.1	3.57	76.9	1.73	71.6	4.14	65.5	6.76
TiO ₂	76	01	86	10	66	08	75	12	57	10	89	07
Al ₂ O ₃	11.5	2.85	12.8	1.64	11.8	1.83	12.0	72	15.7	2.55	16.9	1.28
Fe ₂ O ₃	5.12	2.23	5.56	1.89	5.11	1.14	4.26	10	6.56	1.66	7.58	94
MnO	04	00	05	03	06	04	04	02	04	02	08	03
MgO	99	02	134	31	139	52	140	09	162	35	226	101
CaO	25	06	28	09	35	20	55	45	20	12	270	690
Na ₂ O	1.32	20	1.48	23	1.07	24	1.56	35	1.37	26	1.50	29
K ₂ O	1.61	14	1.95	39	1.96	58	2.00	09	2.07	34	2.78	59
LOI	9.64	8.63	6.13	3.25	7.85	1.49	4.83	23	10.6	6.27	9.85	1.94
Trace Elem (ppm)	Lake Branch Formation		York Lake York River Fms		Cap Bon Ami-Gr -Grève Fms		St -Léon Formation		Fortin Formation		White Head Formation	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Ba	269	27	328	58	414	178	394	8	318	71	320	63
Co	7	5	13	8	8	5	5	0	17	9	26	7
Cu	31	4	32	12	40	22	29	2	32	12	26	7
Li	30	8	49	16	39	16	33	1	59	19	73	26
Zn	37	4	58	19	73	21	55	10	70	17	82	22
Pb	14	3	15	4	13	5	9	1	16	4	20	3
Zr	354	91	317	54	223	59	389	211	269	42	218	42
V	14	1	17	4	20	14	22	1	20	4	23	12
Sr	78	4	89	9	77	13	104	35	63	12	98	97
Rb	66	2	86	13	93	23	86	10	96	13	121	17
Pb	17	2	20	3	23	4	20	4	21	3	23	3
Th	11	1	12	1	11	2	12	2	13	1	14	2
U	13	2	11	2	11	2	10	1	10	2	9	2
No. of Samples												
		2			19			18			2	46
											13	

(11.54-12.84%), Fe_2O_3 (4.26-5.56%), MgO (0.99-1.4%) and K_2O (1.61-2.00%). Samples collected over clay mineral and mica rich Fortin slates and siltstones in the central part of the area, and calcareous and clay mineral rich siltstones and limestones of the White Head Formation to the south show the lowest contents of SiO_2 (65.48-71.55%) and the highest contents of Al_2O_3 (15.74-16.85%), Fe_2O_3 (6.56-7.58%), MgO (1.62-2.26%) and K_2O (2.07-2.78%). The calcareous nature of the White Head Formation is reflected in the two highest concentrations observed in overburden (7.85 and 24.57%) but is not evident from the average CaO content of the 13 samples analyzed. The high standard deviation of CaO (6.90) is attributed to compositional variations in the White Head Formation with possible loss of CaO in overburden through groundwater leaching.

The parallelism of major element variations in <250 μm overburden with that of the underlying rock confirms field observations that the overburden in general contains a strong component of the underlying bedrock. The north to south trend of decreasing SiO_2 and increasing Al_2O_3 , Fe_2O_3 , MgO and K_2O in <250 μm overburden reflects decreases in bedrock-supplied quartz with corresponding increases in clay minerals, clay-sized micas, feldspar, sulphide and carbonate minerals.

Specimens of the sedimentary formations in the thesis area were also collected and analyzed for major and trace

element analysis (Appendix 11). The few rock samples analyzed do not permit estimation of compositional ranges within bedrock formations or comparison of SiO_2 concentrations in overburden in relation to underlying bedrock. The bedrock samples roughly match their corresponding overburden equivalents. The principle exception is the rock specimen from the Grande-Grève Formation which is high in CaO and low in SiO_2 in contrast to till and colluvium samples which are high in SiO_2 and low in CaO . A second exception is the single Fortin Formation specimen with a CaO concentration (1.74%) well outside the range of the CaO (0.07-0.43%) in the corresponding overburden.

A comparative summary of trace element averages for the major overburden types and the stream sediment data of Choinière (1982) is shown in Appendix 12. Concentration differences among upland overburden, stream sediments and bedrock formations cannot be readily explained without taking into account variations associated with differing analytical procedures and detection limits, and the number of samples analyzed. Trace element concentrations in overburden (Table 2) show considerable overlap and no trends are observed. Overburden samples collected over the White Head Formation show the highest concentrations of Co, Ni, Nb and Rb.

The regional distribution of gold in $<250 \mu\text{m}$ overburden is shown in Figure 11. The $<250 \mu\text{m}$ results show that the overburden contains very low concentrations of gold, with

only 15 samples registering above the detection limit of 2 ppb. The highest concentrations, 30 ppb and 7 ppb, are in samples collected over White Head and Fortin Formations, the two formations hosting mineral and alluvial gold occurrences in the area.

Analyses of Non-Magnetic Heavy Mineral Concentrates (NM HMC)

Trace element data from the regional survey of non-magnetic heavy mineral concentrates (NM HMC) were subjected to factor analysis (Table 3), and geometric mean and standard deviations were calculated (Table 4). Selenium and Ag were excluded from all statistical treatment because of abundances below the detection limit in almost all cases. Because detection limits were highly variable for certain elements (a function of sample size and composition), analyses below the detection limit were considered as missing values and treated by pair-wise deletion in the factor analysis.

The distribution of trace elements can be summarized as follows: (1) NM HMC in overburden collected over Cap Bon Ami and Grande-Greve Formations show the lowest contents of rare earth elements (REE), Mo, Ni and Th; (2) overburden from the Fortin Formation shows the highest concentrations of REE, Hf, Sc, W, U and Ni, with intermediate concentrations of As, Co and Sb; (3) As, Co, Sb, Fe and Zn are highest in NM HMC of overburden collected over the White Head Formation; (4) overburden from the York Lake and York River Formations

Figure 11. Concentration of gold in 63-250 μm samples of overburden from the regional survey area, southwestern Gaspésie.

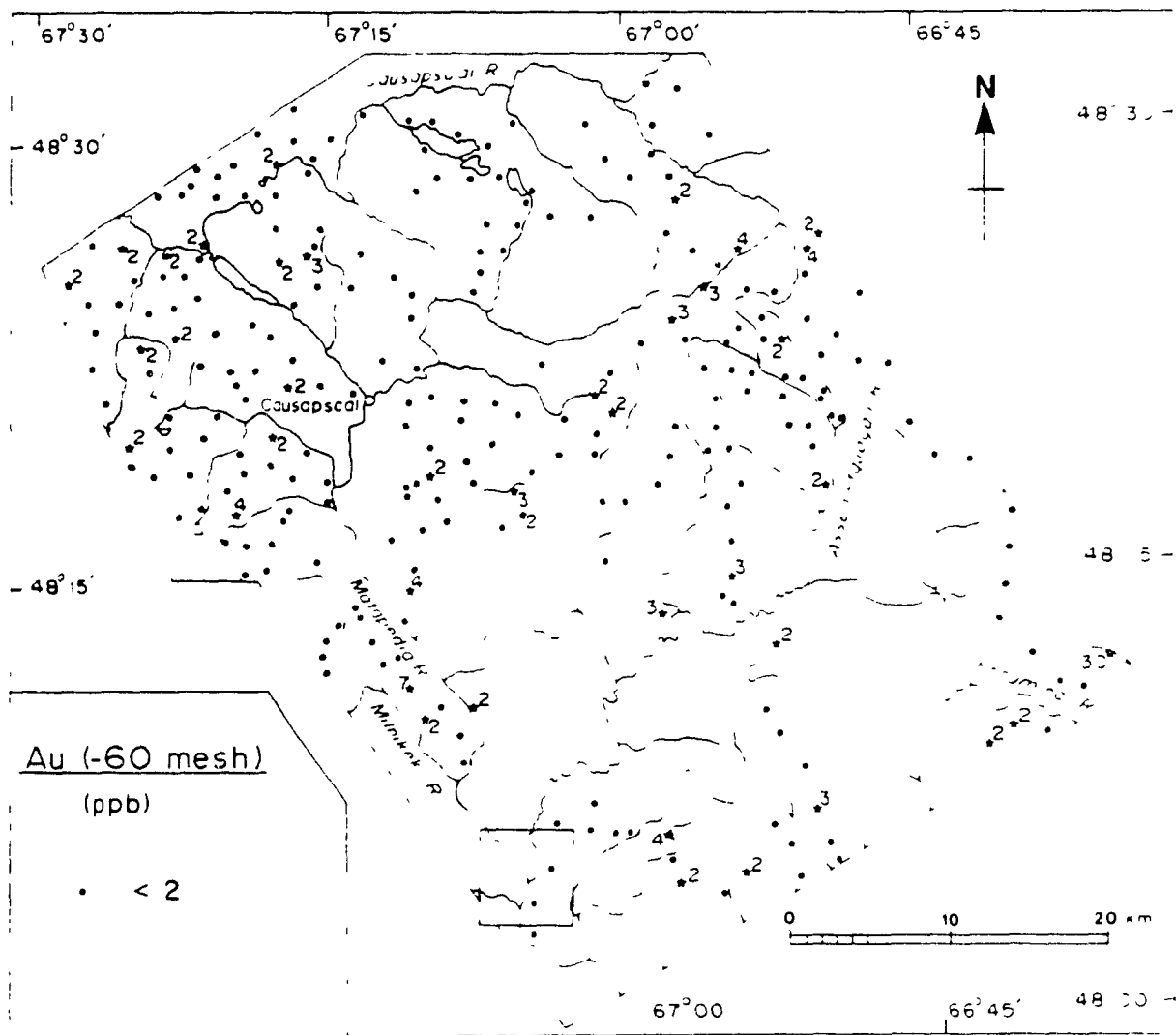


Table 3

Factor analysis, Varimax-rotated loadings on log transformed NM HMC data, regional survey, southwestern Gaspésie.

Element	Factors				
	1	2	3	4	5
Hf	0.95	-0.08	-0.01	-0.16	0.09
Lu	0.95	-0.13	-0.17	-0.08	0.12
Yb	0.95	-0.15	-0.15	-0.08	0.14
Th	0.92	-0.17	-0.22	-0.12	0.20
U	0.90	-0.16	-0.16	-0.23	0.18
Ce	0.89	-0.23	-0.22	-0.02	0.24
Sm	0.88	-0.27	-0.24	-0.05	0.25
La	0.86	-0.30	-0.24	-0.06	0.26
Eu	0.82	-0.31	-0.31	-0.05	0.24
Cr	0.76	0.03	0.18	-0.34	-0.09
Sc	0.74	-0.08	0.07	-0.30	-0.25
W	0.60	-0.23	-0.46	-0.26	0.08
As	0.20	-0.91	-0.05	0.05	0.12
Co	0.27	-0.85	-0.16	-0.16	-0.05
Sb	0.34	-0.78	-0.12	-0.12	0.07
Fe	-0.09	-0.59	0.05	0.08	-0.63
Ni	0.23	-0.40	-0.86	-0.33	-0.01
Na	0.24	0.03	-0.81	0.01	0.12
Ta	0.43	0.19	0.01	-0.76	-0.01
Zn	0.08	-0.44	-0.15	-0.76	0.08
Au	0.16	-0.10	-0.28	-0.63	0.70
Ba	0.14	-0.39	0.13	-0.23	0.70
Mo	0.33	0.06	-0.27	0.00	0.63

Variance explained by rotated components:

9.51	3.54	2.29	2.15	1.93
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Percent of total variance explained:

41.4	15.4	9.97	9.33	8.39
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Table 4

Characteristics of trace element concentrations in 63-250 μm R1 HX in relation to underlying bedrock, regional survey, southwestern Gaspésie

Elem	Fortin Formation				Cap Bon Ami Cradle Cove Formations				York Lake-York River Formations				White Head Formation				St. Leon Formation				Lake Branch Formation			
	n	Geom	Log	Std	n	Geom	Log	Std	n	Geom	Log	Std	n	Geom	Log	Std	n	Geom	Log	Std	n	Geom	Log	Std
		Mean	Dev			Mean	Dev			Mean	Dev			Mean	Dev			Mean	Dev			Mean	Dev	
As	122	116.95	2.42		38	64.42	2.90		27	37.24	2.32		9	242.66	2.37		8	36.98	2.88		4	33.45	1.45	
Au	48	368.13	13.09		13	389.94	37.15		7	66.67	1.74		2	174.62	60.81		3	23.39	1.29		0			
Ba	83	1157.61	2.12		20	1253.14	3.98		13	668.34	1.74		4	1737.80	2.01		3	190.83	10.45		2	289.75	1.33	
Ca	4	7.82	1.96		6	2.75	1.31		0				2	11.22	1.37		2	3.87	1.44		1	3.00	0.09	
Co	126	100.69	1.88		39	76.03	2.10		27	57.56	1.63		9	179.89	1.78		8	60.95	1.95		4	34.12	1.25	
Cr	124	724.36	1.56		38	5035.01	2.84		27	10351.42	1.92		9	3953.67	2.25		8	5069.91	2.04		4	7961.78	1.58	
Fe	124	20.83	1.53		39	22.23	1.70		27	20.97	1.55		9	35.24	1.32		8	21.33	1.67		4	22.44	1.64	
Hf	124	1073.99	1.86		38	401.79	2.39		27	674.53	1.75		9	344.35	2.49		8	528.45	1.77		4	694.31	1.61	
Mo	35	23.88	2.13		13	12.16	1.76		6	14.93	2.06		3	50.58	2.96		3	27.67	1.67		2	16.42	1.16	
Na	103	10	1.60		33	09	1.35		20	11	1.69		5	11	1.36		7	11	1.31		3	07	1.34	
Ni	16	1253.14	1.97		3	543.25	1.43		1	899.50	0.00		1	1300.17	0.00		0				0			
Sb	123	7.40	2.16		36	4.53	2.70		26	3.47	1.97		9	12.82	2.72		8	3.50	2.26		4	4.58	1.64	
Se	124	53.83	1.30		38	44.06	1.77		27	49.20	1.56		9	29.04	1.41		8	56.77	1.62		4	37.55	1.12	
Ti	117	14.00	1.69		37	14.16	2.08		27	16.83	1.65		6	11.09	2.07		8	12.19	2.10		4	13.87	1.40	
Th	124	128.82	2.19		38	37.76	2.43		27	68.71	1.73		9	55.34	1.92		8	42.56	1.98		4	66.56	1.56	
U	124	56.10	2.02		37	19.91	2.49		27	36.33	1.90		9	26.67	2.14		8	22.86	1.93		4	29.34	1.63	
W	73	43.95	2.00		13	20.99	2.34		8	27.23	1.37		2	15.43	1.59		1	26.00	0.00		3	18.11	1.65	
Zn	93	205.12	1.75		33	259.03	1.94		24	240.99	1.71		7	99.41	2.92		7	208.93	1.74		3	177.04	1.79	
La	124	597.04	2.32		38	150.31	2.30		27	200.62	1.76		9	341.74	1.59		8	166.46	1.85		4	141.79	1.61	
Ce	124	924.70	2.20		38	295.12	2.16		27	496.59	1.75		9	550.81	1.33		8	286.42	1.66		3	423.64	1.15	
Sm	124	63.24	2.25		38	20.42	2.07		27	30.90	1.71		9	35.89	1.52		8	23.01	1.61		4	21.38	1.50	
Eu	123	13.55	2.31		38	4.31	2.19		27	5.58	1.84		9	7.21	1.64		8	4.33	1.68		4	4.92	1.24	
Yb	124	78.16	1.84		38	27.86	2.11		27	40.66	1.69		9	25.64	2.15		8	34.04	1.64		4	28.18	1.61	
Lu	124	15.67	1.85		38	5.40	2.14		27	8.18	1.67		9	4.84	2.27		8	6.67	1.69		4	5.63	1.48	

Elem = Element

Geom = Geometric

n = Number of analysis

Log Std. Dev. = Antilog of the standard deviation of the Log data

ppm As, Ba, Co, Cr, Hf, Mo, Hf, Sb, Se, Sc, La, Th, U, W, Zn, La, Ce, Sm, Eu, Yb, Lu

% Ca, Fe, Na

ppb Au

shows the highest contents of Cr and Ta.

A striking feature of the trace element distribution is the high concentration of REE, Hf, Th, U, W and Ni in NM HMC of Fortin overburden. These elements also show a particularly strong loading on Factor 1 in the table of factor analysis (Table 3), the REE, Hf, Th and U displaying the highest correlation coefficients among each other (Appendix 13). The strong correlation among the REE, HF, Th, and U suggests an association with zircon. X-ray fluorescence analysis of one sample with a high Hf concentration (4700 ppm) showed a high Zr content and the presence of zircon was confirmed by X-ray diffraction analysis. The main source of the zircon carrying these elements in Fortin overburden appears to be the underlying bedrock. This is suggested because the Fortin Formation is a major uranium anomaly over Gaspésie Peninsula (Choinière, 1982, 1984) and zircon, the main U carrying mineral, is the dominant heavy mineral species in the rock (Dalton, 1987).

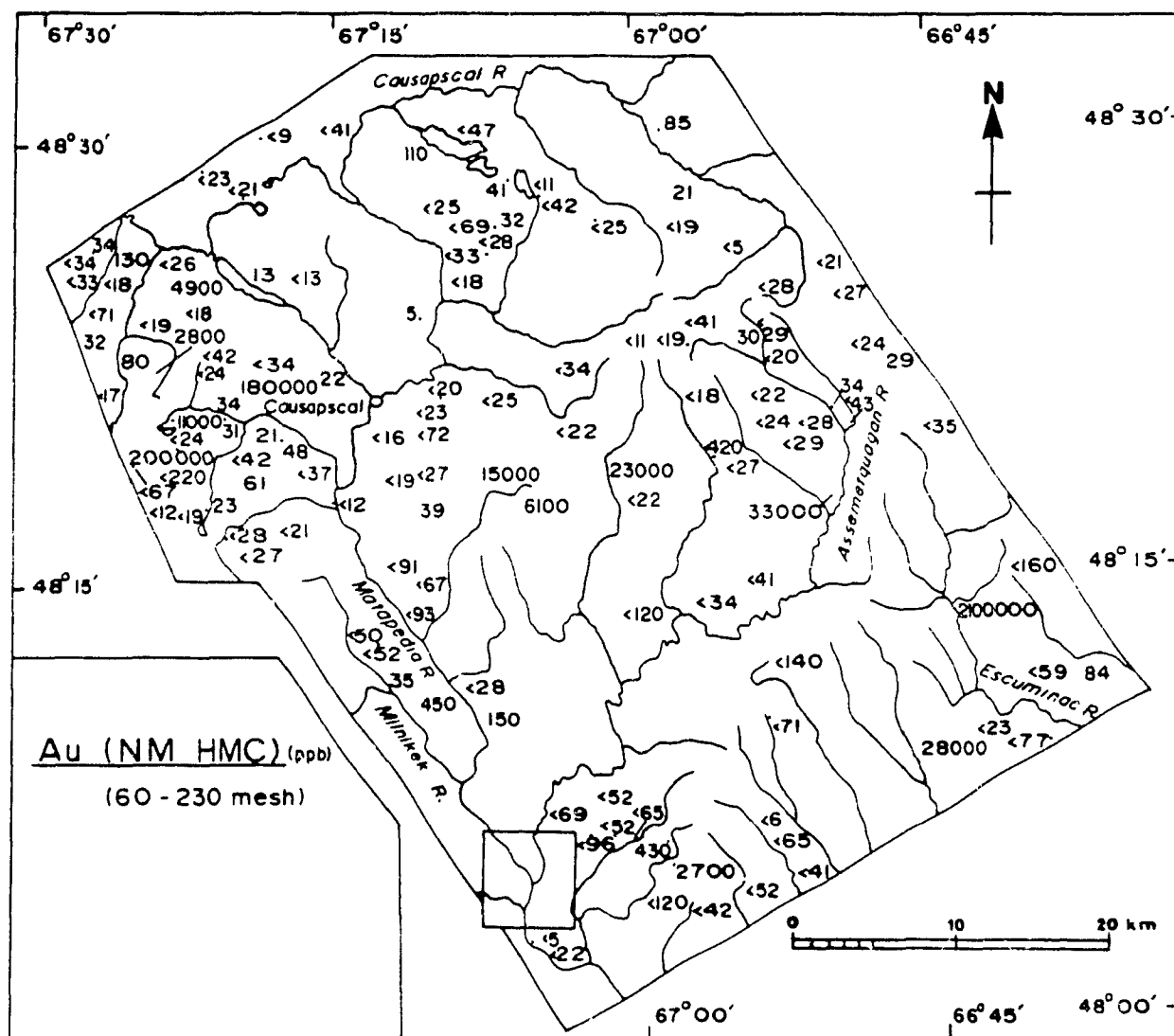
The other factors in Table 3 are less readily interpreted. Factor 2 (As, Co, Sb and Fe) is a possible indicator of sulphide minerals. The highest concentrations of Factor 2 elements are in NM HMC from overburden collected over the White Head Formation, where sulphide occurrences are common (Lachance, 1979) and strong As concentrations in stream sediments are reported (Choinière, 1987). The correlation of Au with Zn and Ta is accidental and reflects

the effect of a very high outlier value (2100 ppm Au) on the calculation of the factors.

The regional distribution of gold in NM HMC is shown in Fig. 12. In contrast to <250 μ m analyses, NM HMC data show considerable spread in gold concentrations and define several anomalies across the area. Anomalous gold concentrations are observed in four geological settings (1) in four overburden samples collected over Fortin bedrock (including the highest gold concentration, 2100 ppm), (2) in three samples collected along the section of the Ste-Florence fault where volcanic rocks are interbedded with Fortin slates, (3) in one overburden sample underlain by bedrock of the White Head Formation; and (4) in five samples collected over the Cap Bon Ami Formation on the west side of the Matapédia River. The Cap Bon Ami anomalies provide the first indication of possible gold mineralization in Siluro-Devonian strata north of the Ste-Florence fault.

The NM HMC data show erratic gold concentrations and considerable spread in values. The pattern produced is complex and reflects the effect of several variables on the heavy mineral chemistry of the overburden (1) the composition and distribution of overburden types; (2) the composition and distribution of bedrock types; (3) the nature of bedrock contributions to overburden; and (4) the degree of oxidation of the overburden. The combined effects of these variables on the gold chemistry of NM HMC are recorded in

Figure 12. Concentration of gold in 63-250 μm NM HMC of overburden from the regional survey area, southwestern Gaspésie.



the mineralogical characteristics of the samples. Information necessary to the interpretation of the complex pattern of gold variation in NM HMC can therefore be obtained through detailed mineralogical studies.

Heavy Mineral Studies

Heavy mineral abundance, assemblages and distribution patterns

The project area can be divided into three broad zones using heavy mineral assemblages, distribution patterns and total abundance in the 60-250 μ m fraction of overburden (Table 5). These zones correspond almost exactly with the zones defined on the basis of geomorphology (Fig. 9).

Zone 1: Zone 1 corresponds broadly to the northeastern third of the project area. In this zone magnetic minerals, ilmenite and garnet form between 80 and 95% of the heavy mineral fraction of overburden. The remaining 5 to 20% is epidote and clinopyroxene, with minor orthopyroxene, hematite, zircon, limonite, goethite, rutile, amphibole, chromite, kyanite and corroded sulphide minerals. The enrichment of magnetic minerals, ilmenite and garnet is also reflected in the total heavy mineral and magnetic mineral contents of the overburden (Figs. 13, 14). Zone 1 corresponds to the zone of highest abundance of heavy minerals (>0.5 wt.%) and magnetic minerals (10-30 wt.% of heavy minerals) in overburden. Maurice (1986) found similar heavy mineral concentrations in adjacent stream sediments and

Table 5
Heavy mineral abundances and assemblages, and proportions of far-travelled to locally derived components in the 63-250 μ m fraction of overburden, south-eastern Tasmania

	Zone 1	Zone 2	Zone 3
A Heavy Mineral (HM) Abundance	High (> 0.5 wt. %)	Intermediate (0.1 - 0.5 wt. %)	Low (< 0.1 wt. %)
B Magnetic Mineral Content *	High (> 10 wt. %)	Low (< 10 wt. %)	Intermediate (5 - 10 wt. %)
C. Heavy Fraction Mineralogy	Major magnetic minerals, ilmenite, garnet	Major ilmenite, limonite, goethite, zircon, barite	Major goethite, zircon, barite
and	Minor epidote, pyrite, zircon, pyroxene, rutile, hematite, barite, chromite, kyanite	Minor clinopyroxene, amphibole, pyroxene, epidote, pyrite, arsenopyrite, garnet	Minor zircon, barite, arsenopyrite, garnet
Chemical alteration	- leucoxene alteration of Fe-Ti oxide minerals	- extensive limonite replacement of sulphide minerals, alteration of Fe-Ti oxide minerals	- extensive goethite replacement of Fe-Ti oxide minerals
Features	- goethite alteration of euhedral pyrite - minor limonitic alteration of Fe-Ti oxide minerals	- goethite alteration of euhedral sulphide minerals	- extensive limonite replacement of sulphide minerals - limonite alteration of Fe-Ti oxide minerals
D Local (L) and Far-Travelled (F) HM Assemblages and % of Total HM Fraction	F (60-90%) hemo ilmenite, ilmeno magnetite, titanomagnetite, rutile, leucoxene, pyrope/grossularite almandine, kyanite, zircon L (10-40%) goethite, limonite, ferrian ilmenite, zircon, pyrite, titanomagnetite, epidote, barite, chromite, barite, arsenopyrite	L (50-100%) limonite, goethite, pyrite, barite, zircon, clinopyroxene, amphibole, arsenopyrite, Fe-Ti Oxide minerals F (0-50%) hemo ilmenite, ilmeno magnetite, titanomagnetite, rutile, pyrope/grossularite almandine, zircon	L (70-100%) goethite, zircon, limonite, pyrite, epidote, barite, arsenopyrite L (0-30%) hemo ilmenite, ilmeno magnetite, titanomagnetite, rutile, pyrope/grossularite almandine, zircon
E. Dilution by Far-Travelled Heavy Minerals	Extensive - Moderate F/L = 1 - 100 L/(L+F) = 0.5 - 0.01	Moderate - Neglectable F/L = 0.01 - 1 L/(L+F) = 0.5 - 0.9	Neglectable F/L < 0.01 L/(L+F) > 0.9

* Magnetic Mineral Content = (wt. Magnetic Minerals / wt. Total Heavy Minerals) * 100

also defines the area as a zone of high abundance of heavy minerals.

Zone 2 and 3. Heavy mineral concentrates from the northwestern (Zone 2) and southern (Zone 3) thirds of the area show differences in mineral assemblages, proportions and abundances. Overburden in Zone 2 displays intermediate heavy mineral abundances (0.1-0.5 wt.%) and low magnetic mineral contents (<5-10 wt.% of heavy minerals) (Figs. 13, 14). Ilmenite, limonite, goethite and magnetic minerals are the dominant heavy mineral species (60-80%). Subordinate minerals (10-40%) include barite, zircon, epidote, amphibole, clinopyroxene and strongly corroded pyrite and arsenopyrite. Overburden samples in Zone 3 have the lowest contents of heavy minerals (<0.1 wt.%) and low contents of magnetic minerals (<5-10 wt.% of heavy minerals) (Figs. 13, 14). Goethite, limonite, ilmenite, magnetic minerals, zircon and epidote are the major heavy minerals with minor barite, fluorescent minerals, corroded pyrite and arsenopyrite, garnet, orthopyroxene and clinopyroxene.

Degree of oxidation of HMC

Heavy mineral assemblages show moderate to strong degrees of oxidation across the area. Differences in oxidation are related to varying degrees of chemical alteration of sulphide and Fe-Ti oxide minerals. Fresh sulphide grains are found in all three zones but rarely in abundance of more than 1% of their oxidized equivalents.

Figure 13. Total abundance and zonal distribution of 63-250 μm heavy minerals in overburden from the regional survey area, southwestern Gaspésie.

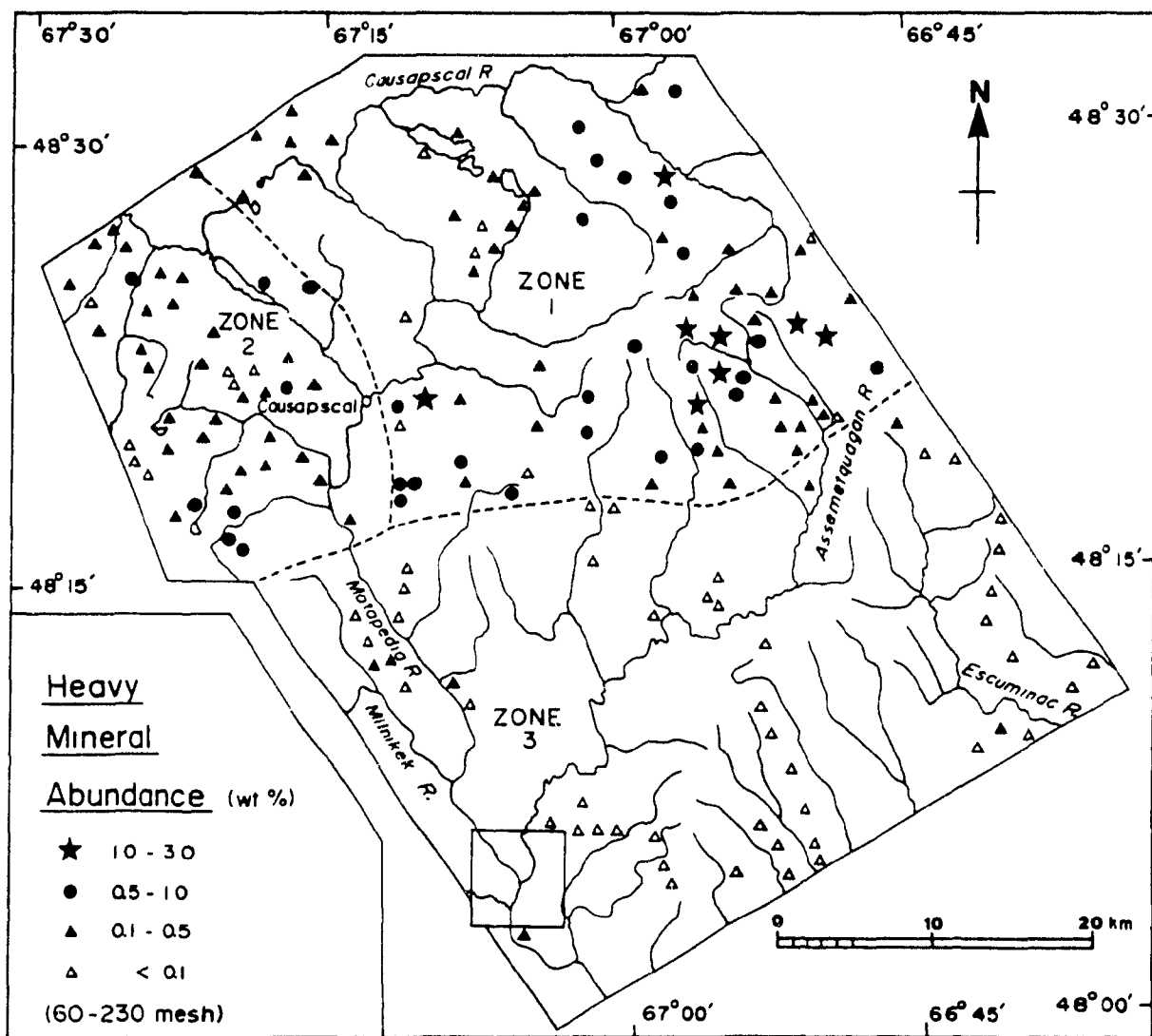
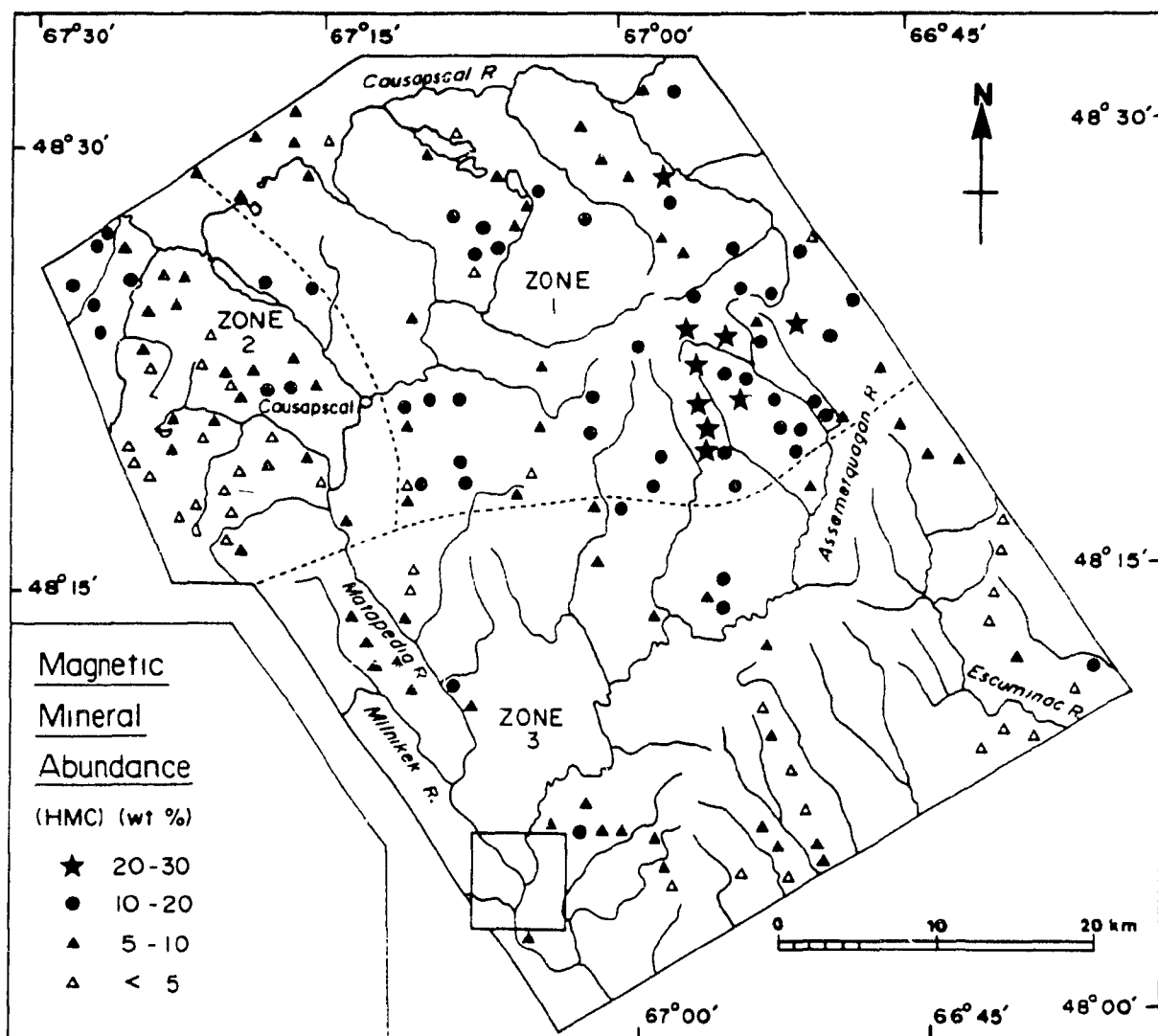


Figure 14. Abundance and zonal distribution of 63-250 μm magnetic minerals in the heavy mineral fraction of overburden samples from the regional survey area, southwestern Gaspésie.



Zone 1: Heavy mineral assemblages in this zone are predominantly composed of angular and fresh looking particles. Limonite and goethite replacements of rare (< 1%) sulphide minerals and leucoxene alteration of Fe-Ti oxide minerals provide evidence of oxidation of HMC below the depth of the C horizon.

Zones 2 and 3: Heavy mineral assemblages in these zones show moderate to strong oxidation. Heavy minerals in Zone 2 show extensive limonite alteration of sulphide and Fe-Ti oxide minerals and goethite replacements of euhedral pyrite and arsenopyrite grains. In Zone 3, over 90% of original sulphide minerals are either replaced by goethite pseudomorphs or completely weathered to anhedral goethite and limonite. The remaining 10% of original sulphide minerals show surficial goethite-hematite alteration.

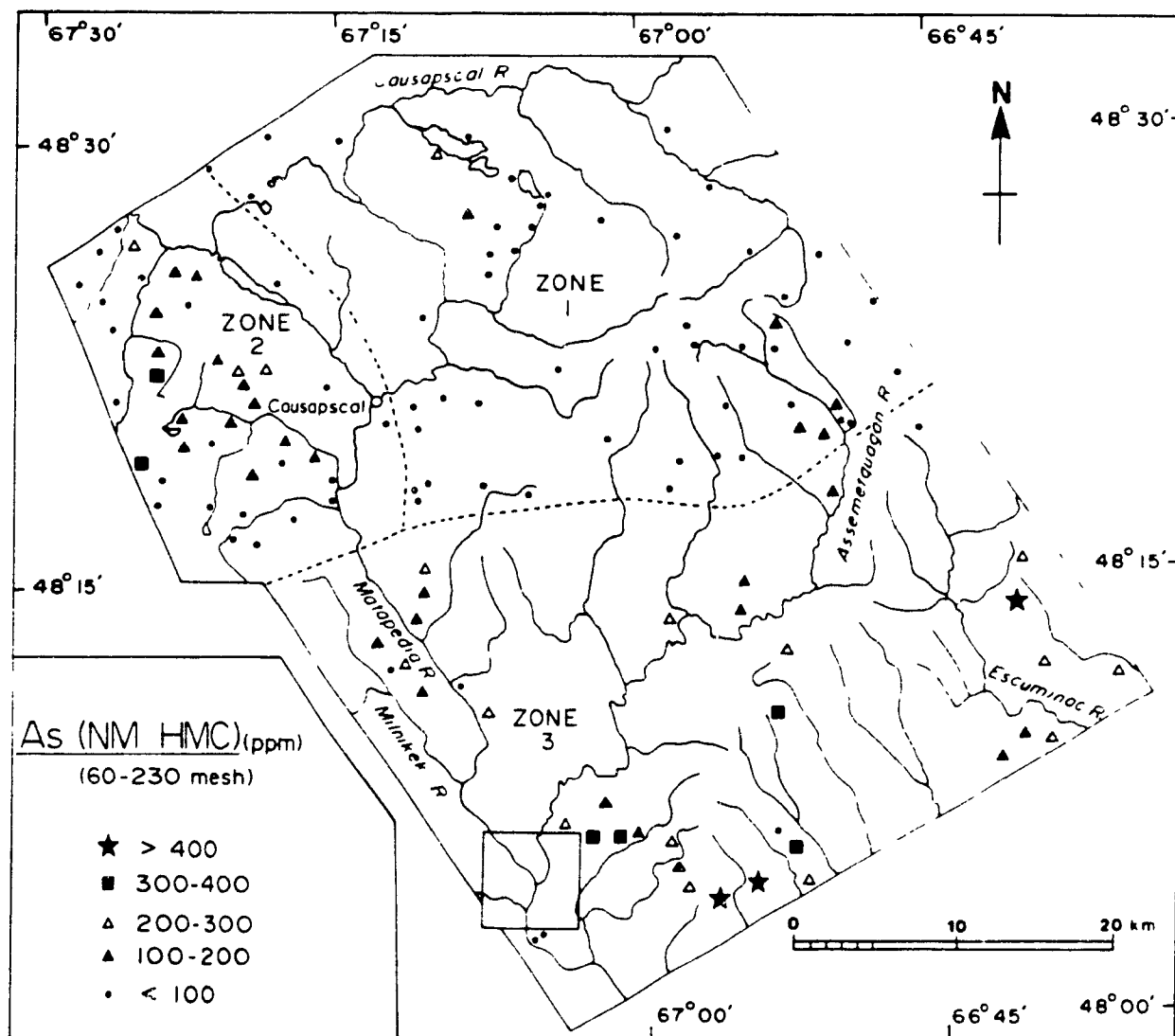
Relation of gold to mineralogy

Particulate gold was not observed in any of the NM HMC. Studies of mineral associations with high gold concentrations suggest that gold is present in locally derived corroded sulphide or hydrous iron oxide minerals. Possible carriers include anhedral limonite and goethite pseudomorphs after sulphide minerals in highly oxidized NM HMC of Zone 2, and in moderately oxidized samples along the Ste-Florence fault in Zone 1, and goethite and limonite replacements of original pyrite grains in highly oxidized NM HMC of Zone 3. Corroded arsenopyrite grains may be carriers of gold in anomalous

samples with high As contents (Fig. 15). Free gold may have been present in sample 181 (Zone 2) which contains 180 ppm Au and less than 1% secondary oxide and sulphide minerals. Using a diameter-to-thickness ratio of 10 (Clifton et al., 1969), minimum and maximum numbers of gold flakes which can account for the 180 ppm Au concentration are 2 flakes with diameters of 230 μm and 95 flakes with a diameter of 64 μm . The absence of gold grains and the low abundance of possible carriers in the split sample examined suggests that the anomaly reflects the presence of a few gold grains in the portion of the sample analyzed.

The presence of gold in limonite, goethite and other secondary oxide minerals in alteration zones of mineral deposits and overlying soil is well documented (Boyle, 1979). DiLabio (1985) reported high concentrations of gold in oxidized fractions of till in which no particulate gold was observed. He attributed the gold to secondary oxide minerals and suggested that it had been concentrated in oxidized fractions of till by groundwater movements. The presence of high gold concentrations in strongly oxidized overburden across the project area along with the distinct association with secondary oxide minerals replacing primary, locally derived sulphide grains indicates that gold is at least partially retained in the fine sand fraction of overburden during oxidation. Some of the gold removed from the fine sand fraction of overburden during oxidation may be

Figure 15. Concentration of arsenic in 63-250 μm , NM HMC of overburden from the regional survey area, southwestern Gaspésie.



concentrated in finer fractions. Shilts (1975, 1984) advocates the use of the clay fraction of oxidized overburden in geochemical exploration because of the capacity of clay minerals to scavenge elements lost to coarser fractions during oxidation.

Proportion of locally derived and far-travelled components

Dilution of locally derived heavy minerals by far-travelled, glacially transported Fe-Ti oxide minerals, garnet, and other associated high grade metamorphic minerals is the most important cause of regional variations in mineral proportions (Table 5). Dilution is greatest in Zone 1, where far-travelled magnetic minerals, ilmenite and garnet show the highest abundances. Electron microprobe analyses of oxide and garnet minerals (Appendix 10) define specific high grade metamorphic assemblages characteristic of Canadian Shield rocks north of the St-Lawrence River. The most common association is that of titanomagnetite, ilmenomagnetite, hemo-ilmenite, and rutile. This mineral assemblage is diagnostic of Fe-Ti-rich anorthositic complexes in the Shield terrain north of the St-Lawrence River (Rose, 1969). The anorthositic bodies are in a highly metamorphosed basement consisting predominantly of granitic gneisses, with local occurrences of pyroxenites, amphibolites, quartzites and crystalline limestones. These lithologies are likely sources for the remaining high grade metamorphic minerals pyrope/grossularite-rich almandine, kyanite and various types of

zircon. Possible secondary sources of high grade metamorphic minerals are garnet and Fe-Ti mineral rich beach sands that form extensive deposits along the north shore of the St-Lawrence River, as suggested by Maurice (1986).

Iron-titanium oxide and garnet contributions from bedrock within or adjacent to the project area are minor. Multiple phase Fe-Ti oxides along with garnet, chromite and hematite are detrital minerals in various arenaceous formations in western Gaspésie (Carbonneau, 1953, Thérioux, 1975). Estimated abundances of these minerals in the local bedrock are far too low, however, to account for their high contents in the overburden of Zone 1.

Locally derived heavy minerals are easily identified in Zones 2 and 3 where dilution by Shield-derived heavy minerals is weaker. These include single phase Fe-Ti oxide minerals, physically unstable and highly altered sulphide grains, low grade metamorphic epidotes, barite, pyroxene and zircon grains.

Effect of dilution on Au concentration in HMC

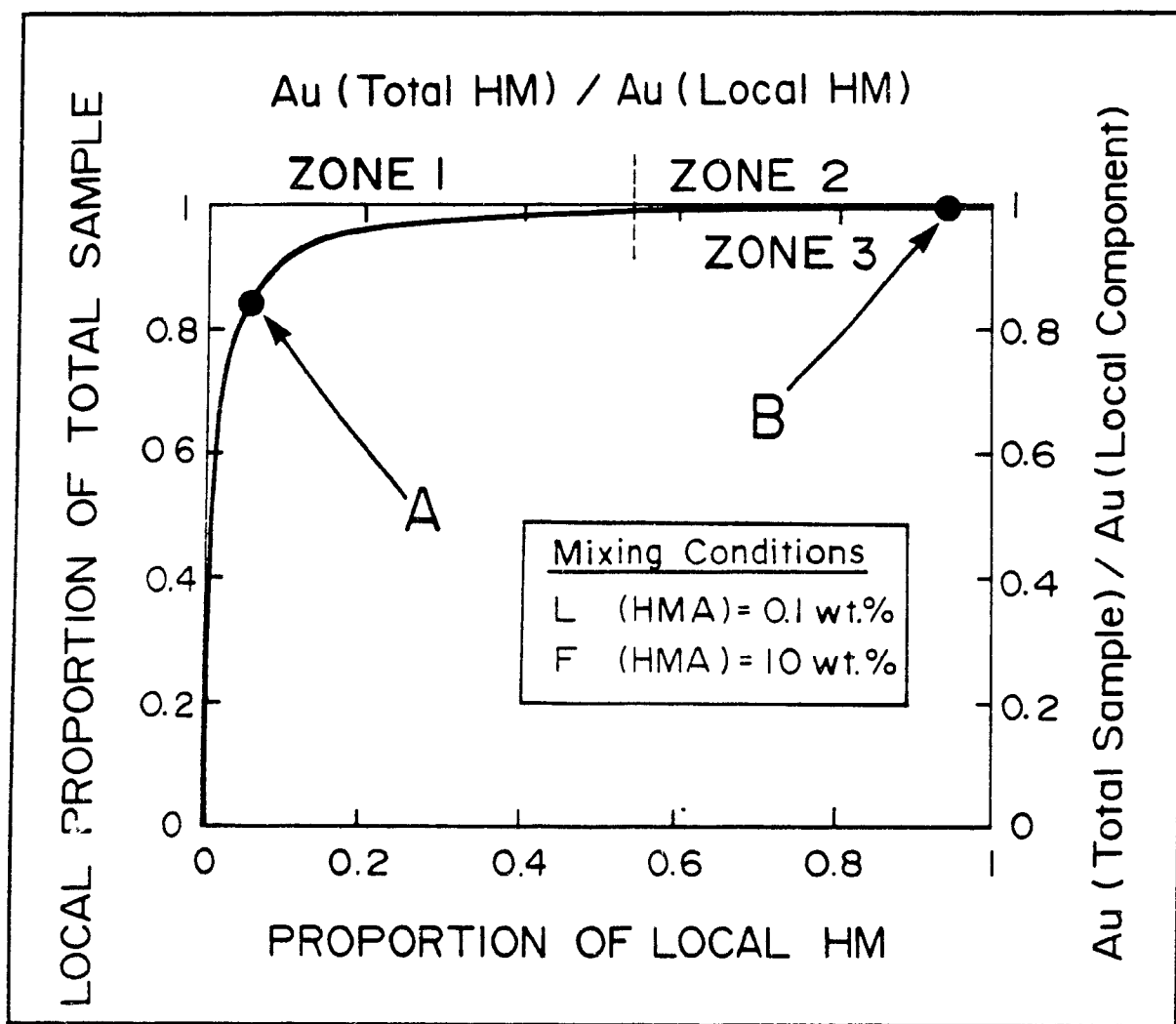
Calculations of heavy mineral abundances indicate that the concentration of 63-250 μm heavy minerals in the far-travelled component of overburden is two to three orders of magnitude greater than in the component derived from the local bedrock (Table 5). Even in small amounts, the presence of far-travelled material in overburden causes important variations in heavy mineral abundance across the area.

(Fig.12). Mineralogical studies also suggest that the far-travelled component contains little gold. If it did, high gold values in NM HMC would be expected in Zone 1 where the abundance of far-travelled material is highest. Zone 1, however, is the zone of lowest gold abundance.

Some of the erratic behaviour of gold concentrations in NM HMC relates to the variation of heavy mineral abundances across the area and can be corrected by converting gold concentrations in NM HMC to gold concentrations in total size fraction. Shelp and Nichol (1987) suggested a similar correction involving the recalculation of gold concentrations to weight contents in the sample. Like the total size fraction conversion, their correction fails to differentiate variations in heavy mineral abundances associated with dilution by far-travelled material from that associated with changes in local bedrock contributions. Variations in abundance of heavy minerals caused by incorporation of far-travelled material are most important because they result in significant dilution of the mineralogical and geochemical contributions of underlying bedrock.

Figure 16 models the effect of progressive dilution by far-travelled material on gold in HMC and total size fraction under conditions estimated for the project area. A simplifying assumption is that all gold in the diluted sample occurs in the heavy mineral fraction of the local component. Because of the nature of the conversion, the

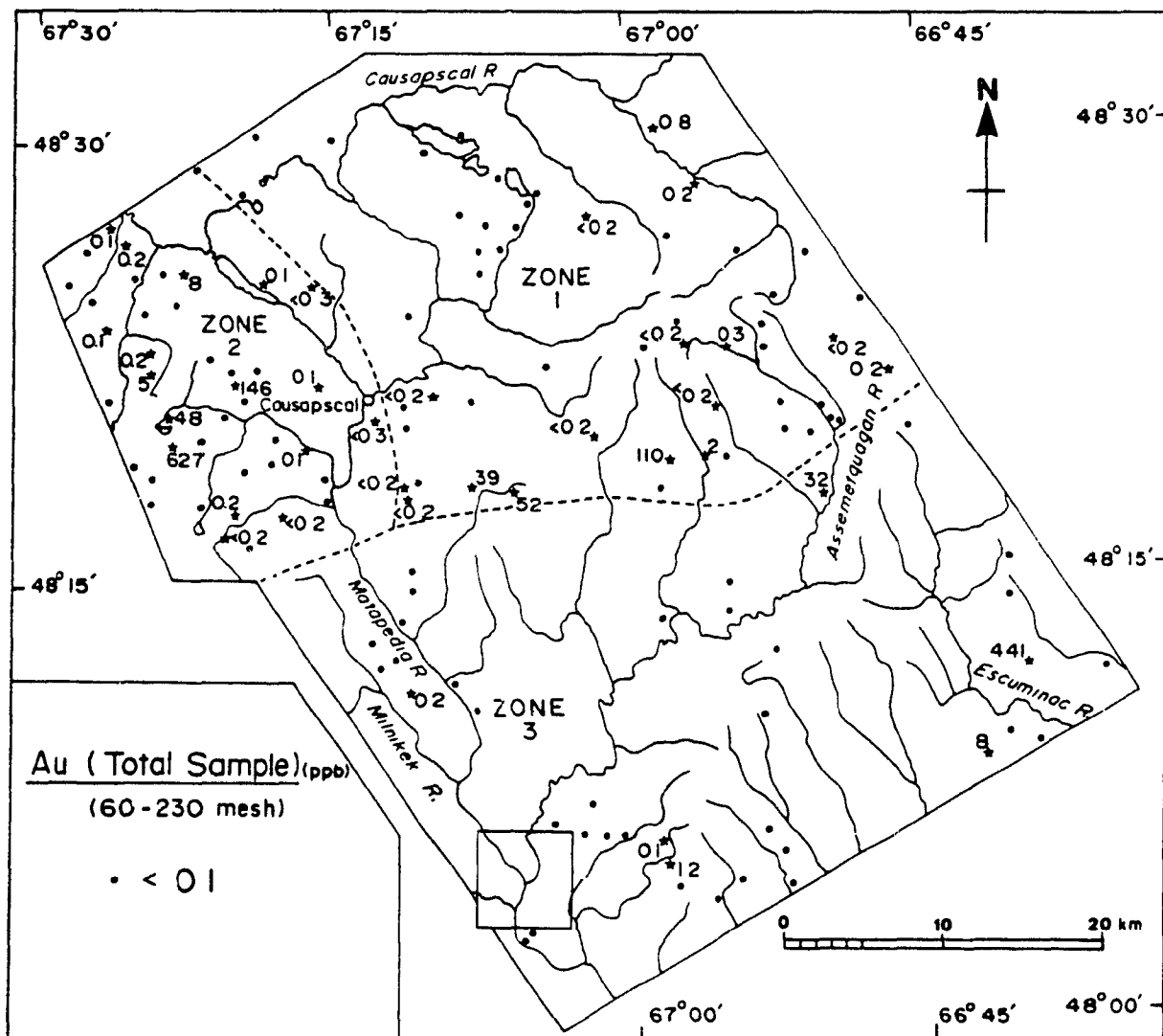
Figure 16. Effects of dilution by far-travelled material (under conditions estimated for the project area) on the gold concentration in heavy minerals (HM) and Total Size Fraction (Total Sample). Points A and B simulate strong dilution conditions in Zone 3 and weak dilution conditions in Zone 1 respectively. L = local component, F = far-travelled component, HMA = heavy mineral abundance.



proportionate variations of gold concentrations in HMC and sand fraction of overburden during oxidation may be total size fraction. However since dilution is much greater in HMC than in total size fraction, gold concentrations in HMC decrease drastically with slight dilution while decreases in total size fraction only become apparent at stronger dilutions. For a typical sample in Zone 1 (point A) the concentration of gold in HMC is 5% of that in the local component, and the concentration of gold in the total size fraction is 84% of that in the local component. For a typical sample in Zone 3 where dilution is weak (point B) the concentration of gold in HMC is 95% of that in the local component and the concentration of gold in the total size fraction is 99.5% of that in the local component. Conversion of gold concentrations in NM HMC to total size fraction thus corrects for incorporation of far-travelled material when it causes strong dilution such as in Zone 1. Where the diluting component is local, such as in Zones 2 and 3, conversion to total size fraction will tend to correct variations in heavy mineral abundances related to differences in bedrock contributions.

The corrected NM HMC gold concentrations are plotted in Figure 17. Anomalous gold concentrations in Zones 2 and 3 remain anomalous after conversion, reflecting the lower dilution conditions in these zones. Conversion of NM HMC gold concentrations in Zone 1 reinforces some lower level

Figure 17. NM HMC gold concentrations corrected to total size fraction (63-250 μm), regional survey area, southwestern Gaspésie.



concentrations, but does not produce new anomalous values, indicating that the local component contains very low concentrations of gold or is extremely diluted by Shield-derived heavy minerals. The median value of corrected gold concentrations suggests a contribution from NM HMC of 0.07 ppb to the background in the 63-250 μm fraction of overburden.

Although gold concentrations in NM HMC remain anomalous after conversion to total size fraction and no new anomalies are produced, the conversion removes some of the erratic behaviour of NM HMC data caused by varying heavy mineral abundances and corrects for incorporation of far-travelled material. the conversion provides a better estimate of gold variations in individual zones and allows for a clearer identification of anomalous areas. Where the diluting component is local, the conversion simply removes the effect of varying heavy mineral abundances caused by differences in bedrock contributions and does not necessarily provide a better estimate of gold variations in underlying bedrock. A comparison of both patterns in all cases will provide information regarding the nature of some of the parameters which control the distribution of gold in overburden and underlying bedrock.

LOCAL SURVEY RESULTS

The local HMC survey was carried out in the 36 Km^2 area surrounding the mouth of the Assemetquagan River (Figs. 1,

18; Appendix 7). The purpose of the survey was to evaluate the overburden, mainly colluvium, rubble and alluvium, as a carrier of gold and other alluvial heavy minerals found in the lower 2 km segment of the river (Plate 9).

Previous Investigations

The occurrence of alluvial gold at the mouth of the Assemetquagan River is known since the 1950's (Maurice, 1986). The first documented study is by Girard (1985) who investigated gold and associated minerals in heavy mineral and fine fraction samples of stream sediment collected near the mouth of the river. He proposed, on the basis of physical appearance, that garnet and magnetite have a long transport history and that pyrite, hematite, ilmenite and gold are of local origin. The possible association of the alluvial gold with quartz veins in the Fortin Formation, as suggested by the presence of quartz gang on one gold grain (Girard, 1985) and the local occurrence of quartz veins with auriferous snowings (Dumont, 1961, 1963; Appendix 2), led Bergeron et al. (1986) to systematically sample quartz veins and their enclosing lithology throughout the Assemetquagan River basin. They found that gold was correlated with As and Sb, and that the highest abundances of these (Fig. 2) were associated with the presence of sulphide minerals (pyrite, arsenopyrite) independent of host lithology, whether quartz vein or country rock.

Maurice (1986) made regional and detailed stream

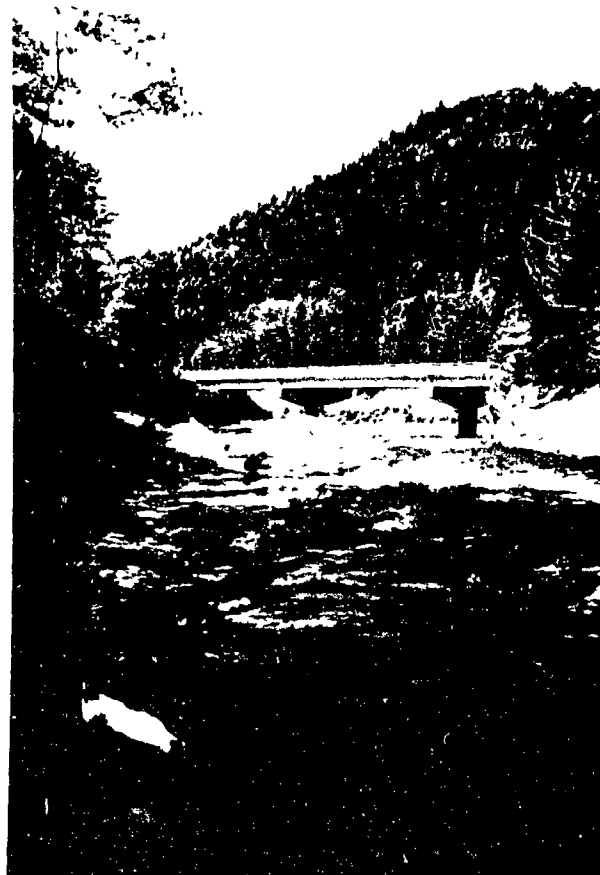


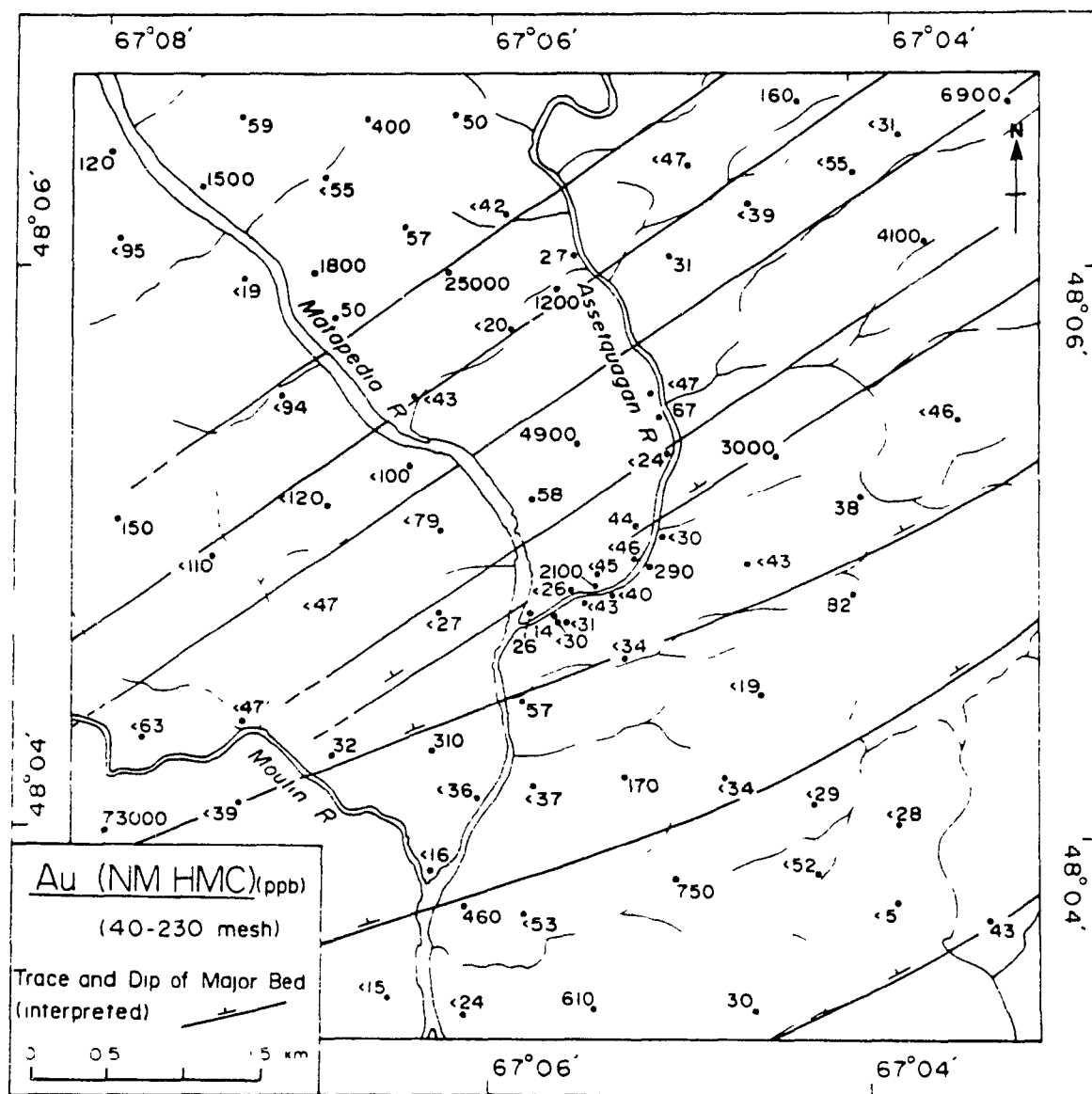
Plate 9. Downstream view of the lower 300 m section of the auriferous segment of the Assemetquagan River. Alluvial gold is preferentially found in northwest dipping cleavage fractures in Fortin slates seen at the front and left side of the photograph, and in moss on outcrop surfaces in the floodplain. The Assemetquagan River joins the Matapédia River behind the bridge.

sediment surveys for gold in southwest Gaspésie. From an orientation survey in the auriferous lower segment of the Assemetquagan River, he found that alluvial gold is concentrated in crevices and cleavage openings of fissile bedrock and also in moss on surfaces of boulders and bedrock. He suggested that gold may have been eroded from Fortin lithologies by the Laurentide ice sheet during its southeastern movement across western Gaspésie. Deposition of gold and Shield-derived heavy minerals in the Assemetquagan valley would have been promoted by the retardation or obstruction of the debris-rich basal part of the ice sheet by the northwest-facing wall of the valley, which is 40-60 m higher than the opposite wall.

Geological Setting

The local area is underlain by Fortin Formation slates, siltstones and sandstones. Lithology and structure are obscured by a prominent cleavage nearly parallel to the strike of bedding. Airphoto studies indicate an alternating sequence of resistant and non-resistant beds striking northeast (Fig. 18). Curved drainage lines, asymmetric ridges and a prominent flat-iron landform show that beds in the southern half of the area dip steeply toward the northwest. The axis of a broad syncline to the northeast (Fig. 2) when extrapolated, crosses the local area between 1 and 1.5 km north of the mouth of the Assemetquagan River. Structural control is evident in a segment of the Moulin

Figure 18. Concentration of gold in 63-450 μm NM HMC of overburden from the local survey area, southwestern Gaspésie. Projected bedding traces and dips of major beds were obtained from airphoto studies.



River and is also expressed in the straight channel of the lower 1 km segment of the Assemetquagan River.

The area is part of Zone 3 (Figs. 9, 13). Surficial deposits consist of a thin mantle of rubble on the upland surface, extensive colluvium on valley slopes, reworked outwash sands in the Matapédia valley, and younger flood plain alluvium (Fig. 19). Glacial striations (Fig. 3) record Laurentide ice flow along the axis of the Matapédia valley and localized ice flow to the north within the valley.

Distribution and Origin of Alluvial Gold and Shield-Derived Heavy Minerals

The lower 900 m section of the Assemetquagan River contains the highest concentrations of detrital gold in southwestern Gaspésie (Maurice, 1986). Strong hydraulic activity (past and present) in this narrow, rapid and turbulent section of the river appears to have controlled the distribution and mode of occurrence of the gold. Detrital Gold is found, along with high concentrations of Shield-derived heavy minerals, in cleavage fractures in the fissile slates and in moss on outcrop surfaces subjected to seasonal flooding. Panned concentrates of material in these settings yield coarse detrital gold (>500 μm diam.). Geochemical analyses of the same material show high gold concentrations in the >106 μm fraction (Maurice, 1986) and indicate that gold grains are present in the 63-450 μm size range selected for overburden HMC analyses. The <106 μm fraction of the sediment trapped in these settings contains low gold

Figure 19. Map of surficial deposits, local survey area,
southwestern Gaspésie.

concentrations and does not reflect the presence of the coarse gold. Panned concentrates of loose sediment collected in the river or in gravel bars on its banks yield large volumes of Shield-derived heavy minerals but no detrital gold. Gold is also geochemically undetected in the loose sediment (Maurice, 1986).

Inclusions of arsenopyrite, gersdorffite and quartz in the detrital gold grains along with the correlation of Au with As and Sb in the local rock suggest a source in Fortin bedrock for the alluvial gold (Girard, 1985, Maurice, 1986, Bergeron et al., 1986). The presence of high concentrations of Shield-derived heavy minerals with the gold in the lower 2 km segment of the Assemetquagan River, along with the failure to detect gold in moss and outcrop fissures upstream from the auriferous segment led Maurice (1986) to suggest that the gold was eroded from Fortin bedrock to the north or northwest by Laurentide ice and transported along with large quantities of Shield-derived heavy minerals to the lower Assemetquagan valley. In such a model, the heavy mineral and geochemical composition of overburden to the north or northwest of the lower 2 km segment of the Assemetquagan River would reflect the high concentrations of gold and Shield-derived heavy minerals in the stream sediments.

Results of Overburden HMC Analyses

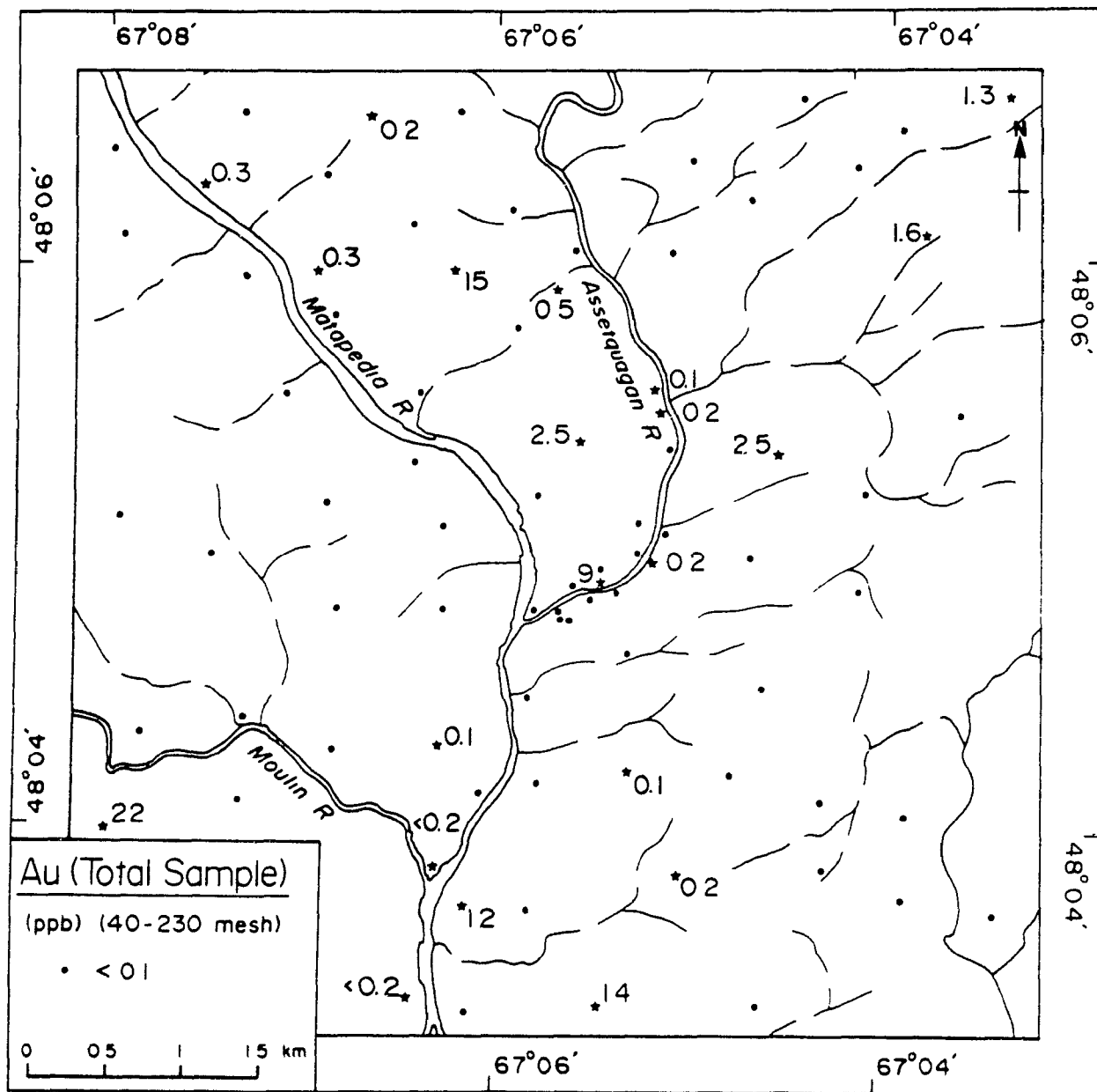
Gold concentrations in NM HMC and heavy mineral abundances in 63-450 μm overburden from the 36 km^2 area

surrounding the mouth of the Assemetquagan River are shown in Figures 18 and 20. Heavy mineral abundances (Fig. 20) reflect the distribution of overburden types and show that alluvium contains five to ten times more heavy minerals than rubble and colluvium. Analyses of NM HMC (Fig. 18) show several anomalous gold concentrations, with the single highest concentration (73 ppm) in a sample collected on a small plateau south of the Moulin River. Corrected NM HMC concentrations (Fig. 21) show that the majority of anomalous concentrations, however, are in rubble and colluvium from an area bounded on the south by the lower reach of the Assemetquagan River and on the west by the Matapédia River. High gold concentrations in the Matapédia valley south of the Assemetquagan River are all in alluvium. Free gold was not observed in any of the NM HMC examined. In anomalous samples gold is associated with hydrous iron oxide replacements of locally derived pyrite grains.

Maurice's model suggests that gold and Shield-derived heavy minerals in the lower 2 km segment of the Assemetquagan River have the same local overburden source. The overburden in the lower Assemetquagan basin, however, contains very little far-travelled material, so that a local overburden source for the Shield-derived heavy minerals is improbable. Although gold and Shield-derived heavy minerals show anomalous concentrations in the lower segment of the river, two lines of evidence suggest that these have different

Figure 20. Abundance (wt.%) of heavy minerals in the 63-450 μm fraction of overburden in the local survey area, southwestern Gaspésie.

Figure 21. NM HMC gold concentrations corrected to total sample (63-450 μm), local survey area southwestern Gaspésie.



provenance: (1) high concentrations of detrital gold are confined to the lower 900 m section of the Assemetquagan River, while Shield-derived heavy minerals are dispersed throughout the drainage basin; (2) panned concentrates of sediment in favorable settings in other parts of the river yield appreciable concentrations of Shield derived heavy minerals but no detrital gold. The high concentrations of Shield-derived heavy minerals in the auriferous segment of the Assemetquagan River appear to be the result of repeated reworking of outwash material transported by the river earlier. The Assemetquagan basin drains an extensive area and contains important sources of Shield-derived heavy minerals in its upper reaches so that it must have carried appreciable outwash as the Laurentide ice-front retreated to the northwest. The important accumulations of outwash sands plastering the sides of the Matapédia valley below the mouth of the Assemetquagan River indicate that the Matapédia, Moulin and Assemetquagan Rivers transported appreciable fluvioglacial sediment.

Although evidence to support Maurice's model of Laurentide ice transport was not found, and visible gold was not detected in any of the overburden samples, a local source for the alluvial gold to the north or northwest of the lower reach of the Assemetquagan River is not precluded. Most high gold concentrations in overburden occur north of the auriferous segment of the river. The high gold concentrations

are expected to reflect similar highs in underlying rocks since the overburden there consists essentially of rubble and colluvium, and gold occurs in iron-oxide alteration products of locally derived sulphide minerals. Future gold exploration in the local area should involve detailed bedrock and structural mapping with geochemical studies being directed at the bedrock on the upland surface between the Matapédia and Assemetquagan Rivers and the lower north wall of the Assemetquagan valley.

SUMMARY AND CONCLUSIONS

1. The southwestern Gaspésie thesis area is a dissected upland underlain by gently folded and faulted Siluro-Devonian sedimentary rocks of the Connecticut Valley - Gaspé Synclinorium in the northern 90% of the area, and the Aroostook - Percé Anticlinorium along the southern edge. Known mineral and alluvial gold occurrences are found south of the Ste-Florence fault. Surficial deposits consist of thin and discontinuous glacial drift (till), alluvium of fluvioglacial and non-glacial origin, colluvium, rubble, organic deposits and diamict material of uncertain origin. The overburden is composed largely of locally derived bedrock fragments with a smaller component of far-travelled material. Sparse to rare granite and gneiss erratics irregularly dispersed over the area provide evidence of long range glacial transport from Precambrian sources on the north side of the St-Lawrence River, and along with local indicators and

rare striations, indicate that the main glacial transport direction was toward the southeast.

2. Investigations on the geomorphology of the area show that Pleistocene events had little influence in shaping the topography and drainage features of the area. The topography is an upland crossed by subparallel chains of low rounded asymmetric hills and ridges oriented in the direction of structure. The upland is cut by a well developed system of southeast trending valleys and southwest trending subsequent tributaries. Summit altitudes are between 305 and 360 m above sea level (a.s.l.) and floors of the main valleys range from 46 to 229 m a.s.l. Projected profiles indicate two main levels of upland in the north half of the area (305-420 and 260-305 m a.s.l.), corresponding to areas east and west of the Matapédia valley. Several upland levels are identified in the south half of the area (244-290, 366-427, 427-503 and 503-533 m a.s.l.). The alternation of hills and ridges, flat interfluves, and steep-sided valleys forms a rugged topography below a gently rolling to undulating upland surface with 30-50 m of relief. Drainage lineaments show that the drainage pattern, especially the low order streams, is strongly controlled by lithology and structure. Streams in the north half of the area trend southwest across broad anticlinal and synclinal structures with smaller subsequent tributaries flowing in valleys between resistant beds. Streams in the central part of the area have a modified

dendritic pattern with first and second order streams forming sharply rectangular patterns. Streams in the southern quarter of the area have a subparallel pattern trending toward Baie-des-Chaleurs and display the highest drainage density in the thesis area ($1.5-3.5 \text{ km/km}^2$).

3. Transverse projected profiles show that the main valleys are incised 30-150 m below broad older valleys with floors now at 250-305 m a.s.l. The Matapédia River is incised 100-300 m below the floor of a large ancient valley, cross-axial to the present structure. North of Ste-Florence the Matapédia valley is broad and typical of glaciated valleys. South of Ste-Florence the Matapédia River is confined in a narrow, locally sinuous canyon. Drainage anomalies (windgaps, through valleys, drainage alignments and changes in the gradient of stream profiles) indicate former southerly drainage routes for the main tributaries of the Assemetquagan River and suggest that the Assemetquagan basin developed from the rapid northeast growth of a tributary of the Matapédia River capturing the headwaters of southeast flowing streams.

4. The major geomorphic features of the area are the product of differential uplift and long-continued erosion of fault-bounded blocks of Siluro-devonian strata. The Acadian compression resulted in uplift of the Gaspé trough relative to the block of strata to the north, and the development of an early divide somewhere over the Fortin Formation. Long-

continued subaerial erosion removed an estimated 11-12 km of Gaspé sandstone which overlay the Fortin Formation and filled the Gaspé trough in western Gaspésie. The removal of the sandstone resulted in the superimposition of southeast trending consequent drainage lines onto the Fortin Formation. A relatively recent renewal of uplift resulted in northeast growth of the Assemetquagan River and diversion of a considerable proportion of the upper Baie des-Chaleurs drainage to the Matapédia River. Pleistocene glacial events had little influence in shaping the observed topography and drainage. Topography may have influenced the pattern of flow and deposition of the Laurentide ice sheet and local glaciers. Glacial drift deposits and fluvioglacial sediments occur mostly in the low lying upland areas to the north of the Ste-Florence fault.

5. The principle application of geomorphology to gold exploration using shallow overburden surveys is in providing information on the physical factors and processes that control the distribution and composition of overburden, and thus the shape of mineralogical and geochemical patterns. Structure and lithology are revealed in the morphology of landforms, in the arrangement of topographic features and low order streams, and in the density and pattern of drainage. Broad northeast trending anticlinal and synclinal structures are identified south of a fault which crosses the Fortin Formation in its middle. The thesis area is divided into

three geomorphic zones on the basis of the relation of topography with other physical factors (lithology, structure, bedrock composition) and geomorphic processes (pre-glacial geomorphic weathering and erosion, glacial erosion, transport and deposition, and post-glacial weathering, slope and fluvial action). The geochemical and mineralogical features of the overburden should reflect the combination of physical factors and geomorphic processes that characterize the three zones identified.

6. Analyses of $<250\text{ }\mu\text{m}$ (-60 mesh) overburden samples along with mineralogical studies and multi-element analyses of non-magnetic heavy mineral concentrates (NM HMC) show changing overburden composition across the project area in approximate correspondence with changes in underlying bedrock and indicate three broad zones which correspond to the geomorphic zones identified. Gold analysis of the $<250\text{ }\mu\text{m}$ fraction of overburden generally shows very low concentrations of gold and is insensitive to variations on a regional scale. A better estimate of gold variation is obtained from chemical analysis of non-magnetic heavy mineral concentrates (NM HMC). The NM HMC data show variable distribution of gold and are not readily contoured. However clusters of anomalous values can be used to define zones of higher elemental abundance. Individual anomalous values are potentially significant if they can be related to locally derived components in the NM HMC. Although sample density is

uneven, and the spread of values is erratic, NM HMC data point to four types of anomalies which can be related to particular bedrock and structural settings. Particulate gold was not observed in any of the samples. Mineralogical studies suggest that gold in NM HMC occurs in locally derived hydrous iron oxide or sulphide minerals. Anomalous gold concentrations in overburden in the local (1986) area are related to locally derived sulphide phases. The high concentrations of gold in overburden within reach of the lower Assemetquagan valley support the hypothesis of a local bedrock source to the north or northwest for the alluvial gold in the lower 2 km segment of the river.

7. Heavy mineral studies also show that dilution of locally derived heavy minerals by far-travelled, Shield-derived minerals is the most important cause of regional variation in heavy mineral proportions. The far-travelled component of overburden contains at least two orders of magnitude more heavy minerals than the local component. Conversion of gold concentrations in NM HMC to concentrations in total size fraction eliminates the effect of varying heavy mineral abundance and corrects for the effect of dilution where the proportion of heavy minerals in the far-travelled component of overburden is much greater than in the local component. Where the diluting component is local, conversion of NM HMC data will eliminate variations in heavy mineral abundances related to differences in bedrock

contributions. Where dilution by far-travelled components is excessive, analyses of NM HMC of overburden are inadequate to reflect compositional characteristics of underlying bedrock.

8. Results of this study indicate that shallow multiple-type overburden NM HMC surveys integrating lithologic, geomorphic and glacial data, and controlled by detailed mineralogical studies, can be effectively used to measure gold variations in overburden as an aid to the evaluation of the gold potential of the Siluro-Devonian sedimentary rocks of western Gaspésie.

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Appendix 1. Summary of mineral and alluvial gold occurrences in the thesis area.

A. Mineral Occurrences

1. Fauvel No. 1

- A. Location: Map 22 B-2; Kempt River basin.
UTM: 6631000 E - 5338700 N
- B. Mineralization: Au (trace)
- C. Host Lithology: 0.6-2.4 m wide quartz veins crosscutting Fortin Formation slates and siltstones.
- D. Structural Setting: Veins oriented N60°E, parallel to shear zones associated with the Matapédia fault to the south.
- E. Mineral Assemblage: Pyrite - Carbonate - Quartz
- F. Note: Alluvial gold anomaly in stream adjacent main showing.
- G. References: McGerrigle, 1949a; Dumont 1961,63; Duquette, 1981 (Mineral Occurrence File 22B/2-1).

2. Milnikek No. 1

- A. Location: Map 22 B-3; Matapédia River basin.
UTM: 638700 E - 5330500 N
- B. Mineralization: Cu (trace)
- C. Host Lithology: 1.6 m wide quartz vein crosscutting Fortin Formation siltstones.
- D. Structural Setting: Mineral occurrence adjacent to northeast trending fault
- E. Mineral Assemblage: Malachite - Quartz - Pyrite
- F. References: Denis, 1922; Savard, 1985.

3. Causapscal No. 1

- A. Location: Map 22 B-6; Matapédia River basin
UTM: 631250 E - 5347400 N
- B. Mineralization: Au-Cu (trace)
- C. Host Lithology: 1.0 m wide quartz vein crosscutting Fortin Formation slates.
- D. Structural Setting: Occurrence 300 m south of the Ste-Florence fault. Possibly associated with andesitic volcanics 200 m to the north.
- E. Mineral Assemblage: Chalcopyrite - Quartz - Pyrite
- F. References: McGerrigle, 1950; Girard, 1985.

4. Ristigouche No. 1

- A. Location: Map 22 B-2; Flatland Brook
UTM: 655200 E - 5326250 N
- B. Mineralization: Cu (trace Zn)
- C. Host Lithology: Felsic dykes and sills and enclosing limestone skarns, White Head Formation.

Appendix 1. (Cont.)

Alteration zone is 800 m long, approx.
100 m wide.

- D. Structural Setting: Alteration zone oriented N55°E, 3 km south of Matapedia fault.
- E. Mineral Assemblage: Pyrite - Chalcopyrite - malachite - carbonate
- F. References: Lachance, 1979; Duquette, 1982 (Mineral Occurrence File 22B/2-3); Savard, 1985.

B. Alluvial Gold Occurrences

1. Assemetquagan River Basin

1.1 Major

Assemetquagan No. 1

- A. Location: Map 22 B-3; Lower 1 km segment of Assemetquagan River.
- B. No. of Gold Grains detected: 1-25 grains per 3 l of trapped sediment (mosses, outcrop fissures); in panned concentrate.
- C. Geological Setting: Fortin Formation slates. Lower 1 km segment of the river is structurally controlled.
- D. Note: Sulphide-bound gold detected in quartz veins and slates near the alluvial gold occurrence. Strong geochemical anomaly in >106 μ m fraction of stream sediments. Low Au conc. in <106 μ m fraction.
- E. References: Girard, 1985; Bergeron *et al.*, 1986; Maurice, 1986; Bernier *et al.*, 1987; Bernier and Webber (in press).

1.2 Minor

Assemetquagan No. 2,3,4

- A. Location: Map 22 B-3, 22 B-3, 22 B-2: 2.9, 3.5, 20 km from mouth of the Assemetquagan River.
- B. No. of Gold Grains Detected: 1, 1, 1; from panned concentrate
- C. Geological Setting: Fortin Formation slates, siltstones and sandstones.
- D. Reference: Maurice, 1986

Creux River No. 1,2

Castor River No. 1

Assemetquagan No. 5

- A. Location: Map 22 B-3, 22 B-3, 22 B-3, 22 B-7. Creux River, Castor River, Assemetquagan River West.
- B. No. of Gold Grains Detected 2, 1, 1, 1; from

Appendix 1. (Cont.)

- panned concentrate.
C. Geological Setting: Fortin Formation slates,
siltstones and sandstones.
D. Reference: Maurice, 1986.

2. Clark and Milnikek River Basins

Clark River No. 1

Milnikek River No. 1

- A. Location: Map 22 B-3, 22 B-3: Clark River South;
Milnikek River, lower 1.5 km.
B. No. of Gold Grains Detected: 1, 1; from panned
concentrate.
C. Geological Setting: Fortin Formation slates,
siltstones and sandstones.
D. Reference: Maurice, 1986.

3. Kempt and Escuminac River Basins

Kempt River No. 1, 2

Fauvel No. 1

- A. Location: Map 22 B-2, 22 B-2, 22 B-2: Kempt River;
Kempt River East; Kempt River North.
B. No. of Gold Grains Detected: 1, 1, several; from
panned concentrate.
C. Geological Setting: White Head Formation limestones;
Fortin Formation slates,
siltstones and sandstones.
D. References: Kempt River No. 1, 2; Maurice, 1986.
Fauvel No. 1; McGerrigle, 1949b;
Dumont, 1961, 1963.

Escuminac River No. 1, 2

- A. Location: Map 22 B-2; 22 B-2: Upper Escuminac River;
Lower Escuminac River.
B. No. of Gold Grains Detected: 2, 1; from panned
concentrate.
C. Geological Setting: Fortin Formation slates,
siltstones; White Head
Formation limestones.
D. Reference: Maurice, 1986.

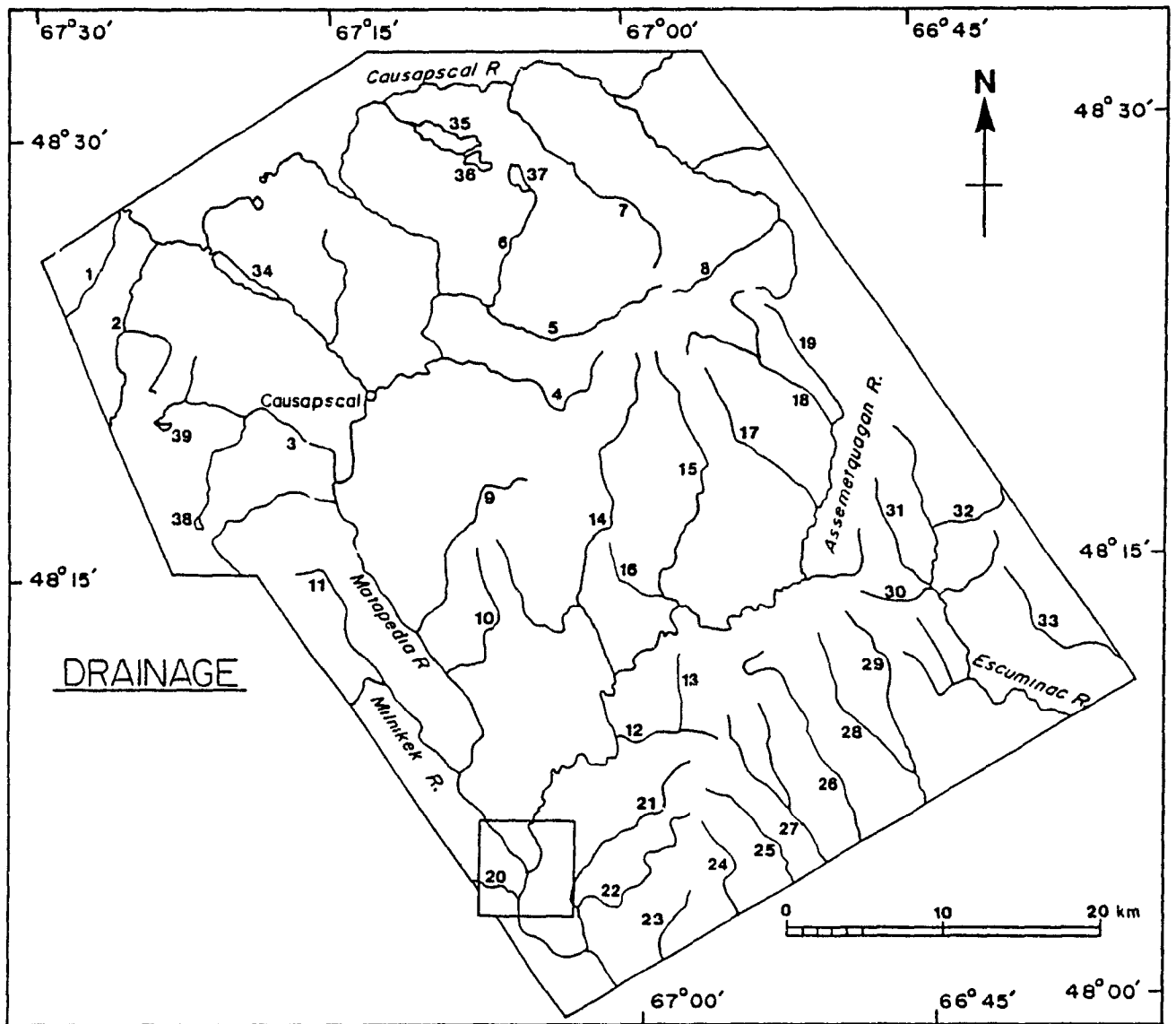
**Appendix 2. Drainage hierarchy and location of rivers,
major tributaries and major lakes,
southwestern Gaspésie thesis area.**

Baie-des-Chaleurs Drainage

Lakes

Map Reference No.

I. Restigouche River (south of map)	(34)	Lac-au-Saumon
A. Matapédia River	(35)	Lac Casault
1. Humqui River (1)	(36)	Lac Causapscal
2. Sauvages River (2)	(37)	L.-Huit-Milles
3. Matalic River (3)	(38)	Lac Matalic
4. Causapscal River	(39)	Lac Indien
4.1 Quatre Milles Brook (4)		
4.2 Laverendrye Brook (5)		
4.2.1 Huit Milles Brook (6)		
4.3 Causapscal South River (7)		
4.4 Levesque Brook (8)		
5. Fraser Brook (9)		
6. McCormick Brook (10)		
7. Milnikek River		
7.1 Cinq Milles Brook (11)		
8. Assemetquagan River		
8.1 St.-Etienne Brook (12)		
8.1.1 St. Etienne N. Br. (13)		
8.2 Creux Brook (14)		
8.3 Castor Brook (15)		
8.3.1 Albert Gendron Br. (16)		
8.4 McDavid Brook (17)		
8.5 Assemetquagan West R. (18)		
8.6 Assemetquagan East R. (19)		
9. Moulin River (20)		
10. Clark Brook (21)		
10.1 Clark East Brook (22)		
11. Gilmour Brook (23)		
II. Flatland Brook (24)		
III. Moulin Brook (25)		
IV. Kempt River (26)		
A. Kempt West River (27)		
B. Kempt North River (28)		
C. Kempt East River (29)		
V. Escuminac River		
A. Rivière du Loup Brook (30)		
B. Patricia Brook (31)		
C. Rachel Brook (32)		
D. Daudin Brook (33)		



Appendix 3. Selected projected profiles, southwestern Gaspésie thesis area.

Profile 1. NW-SE, 1 km-wide projected profile showing the ridge and depression topography and the major structural features of the Fortin Formation between UTM coordinates 641E5147N (left) and 651E5124N (Right).
A: Assemetquagan River valley
F. Fault

Profile 2. NW-SE, 5 km-wide projected profile across the eastern half of the thesis area (Zone 1 - Zone 3) between UTM coordinates 638E5178N (left) and 670E5133N (right).
A: Assemetquagan River Valley
C: Causapscal River Valley
1: 305-420 m a.s.l. upland level (Zone 1a)
2: 366-427 m a.s.l. upland level (Zone 1b)
3: 427-503 m a.s.l. upland level (Zone 3)
4: 503-533 m a.s.l. upland level (Zone 3)
5: 290-375 m a.s.l. upland level (Zone 3a)

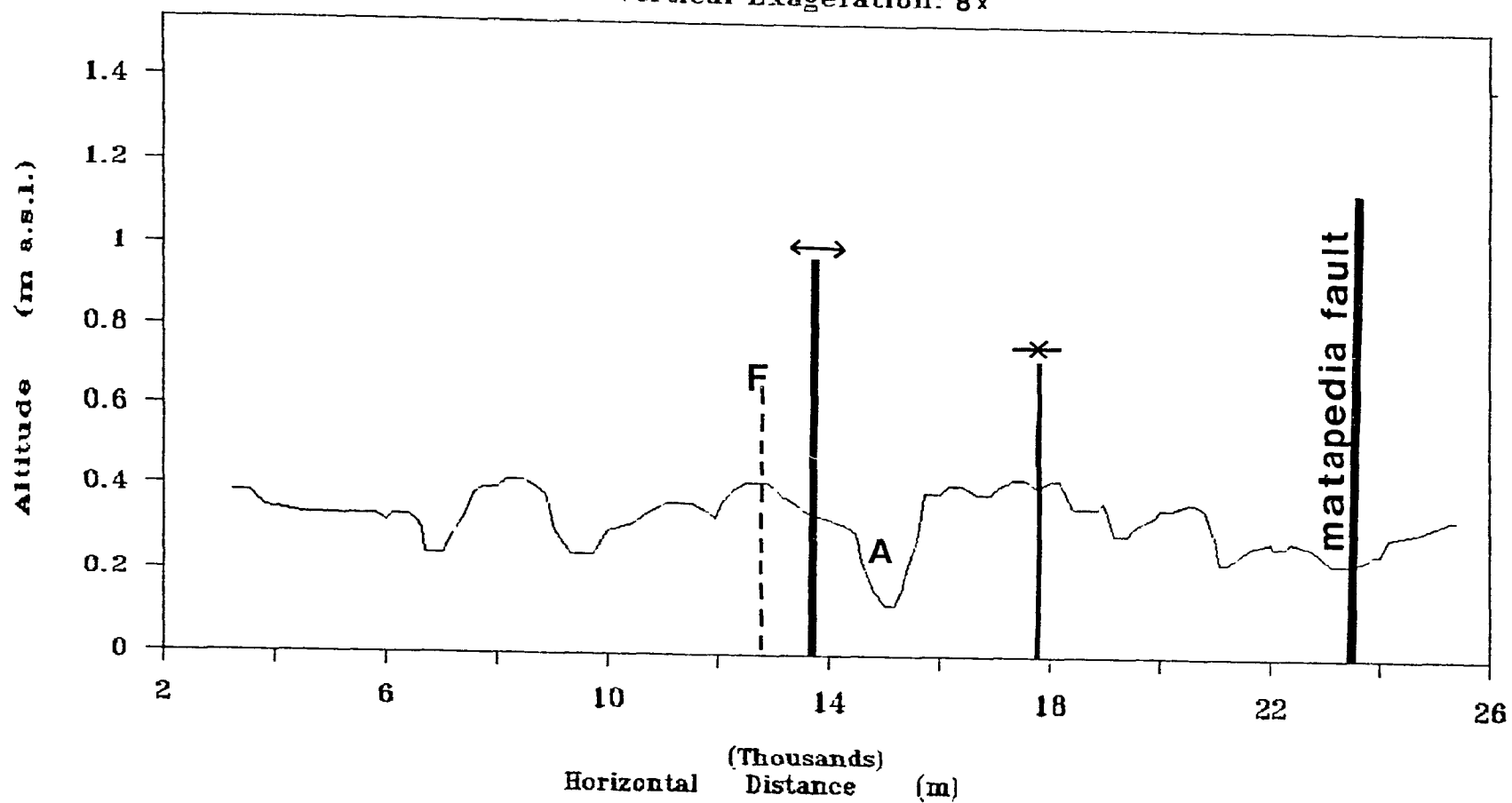
Profile 3 SW-NE, 2 km-wide projected profile across the northern half of the thesis area (Zone 2 - Zone 1) between UTM coordinates 611E5155N (left) and 646E5180N (right).
m: Matapédia River valley
c: Causapscal River valley
6: 260-305 m a.s.l. upland level (Zone 2)

Profile 4 SW-NE, 1 km-wide projected profile across Lavendrye Brook between UTM coordinates 645E5163N (left) and 649E5160N (right).
Lavendrye Brook (L) (Appendix 2) is incised below the floor of broad ancient valley.
L: Laverendrye Brook valley
F: Fault separating the York River Sandstones (right) from the Grande-Grève silty limestone to north (left)

Profile 5 E-W, 1 km-wide projected profile across the Matapédia valley at Ste-Florence. The Matapédia valley (m) is incised 100-150 m below the floor of an ancient valley (o) Profile modified from an original by J A Elson

NW-SE Profile, Fortin Formation

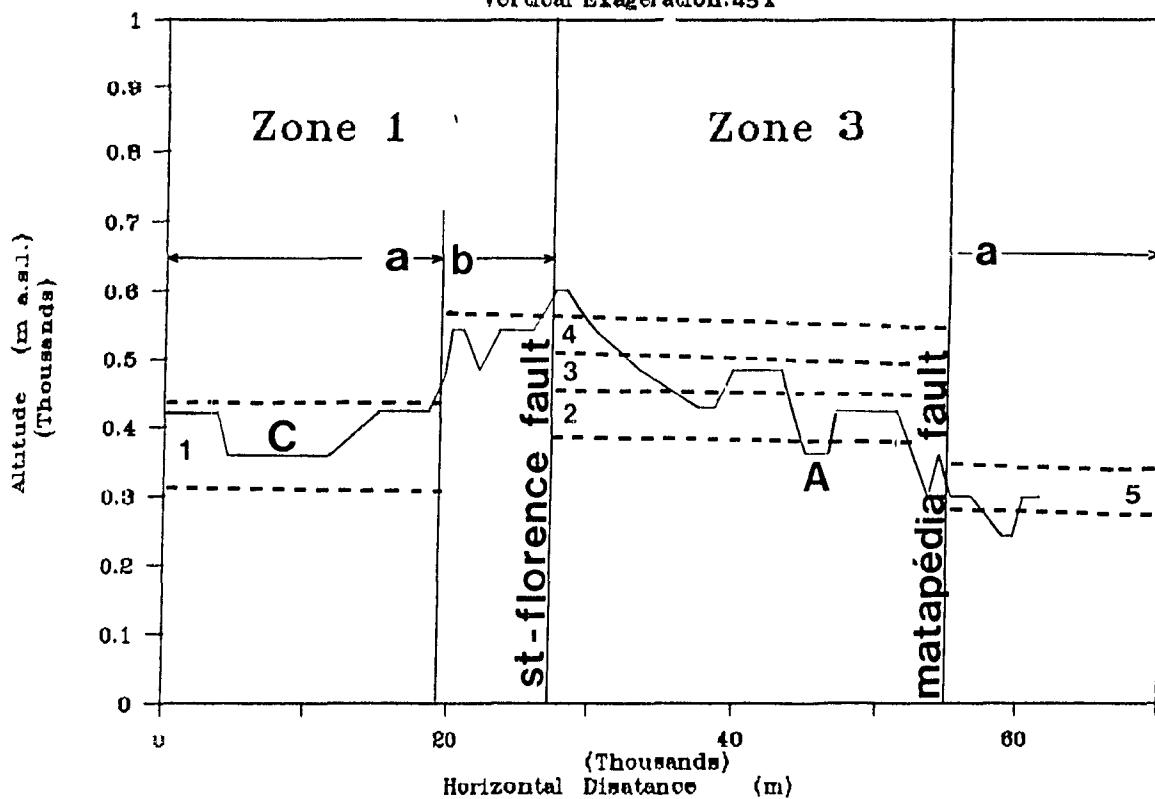
Vertical Exaggeration: 8x



Appendix 3. (cont.)

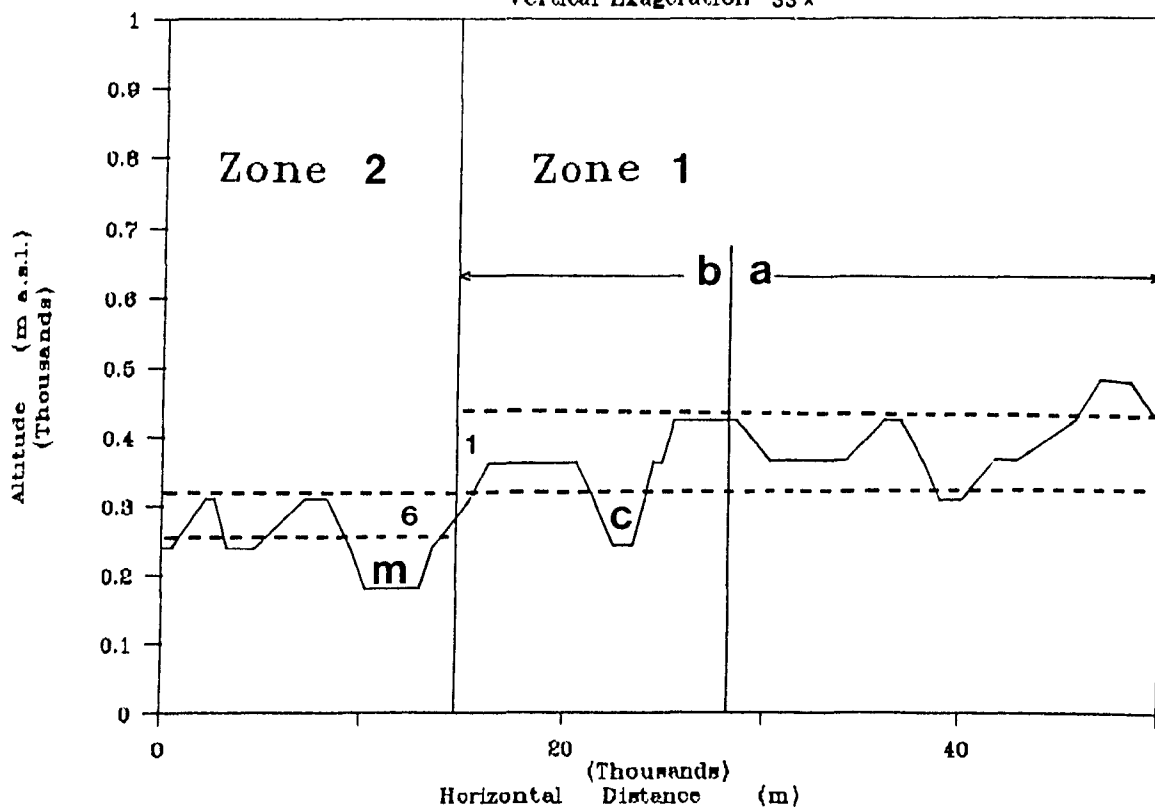
Zone 1 - Zone 3 Profile

Vertical Exaggeration: 45x



Zone 1 - Zone 2 Profile

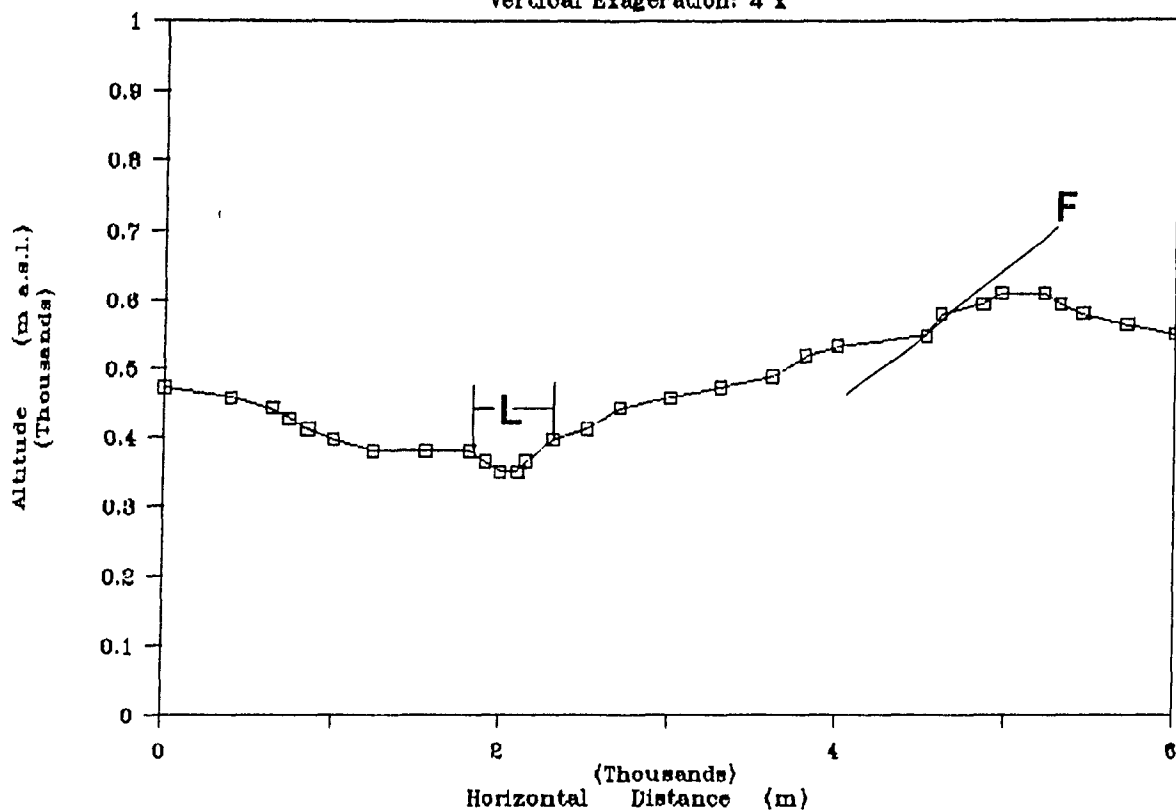
Vertical Exaggeration 33x



Appendix 3. (cont.)

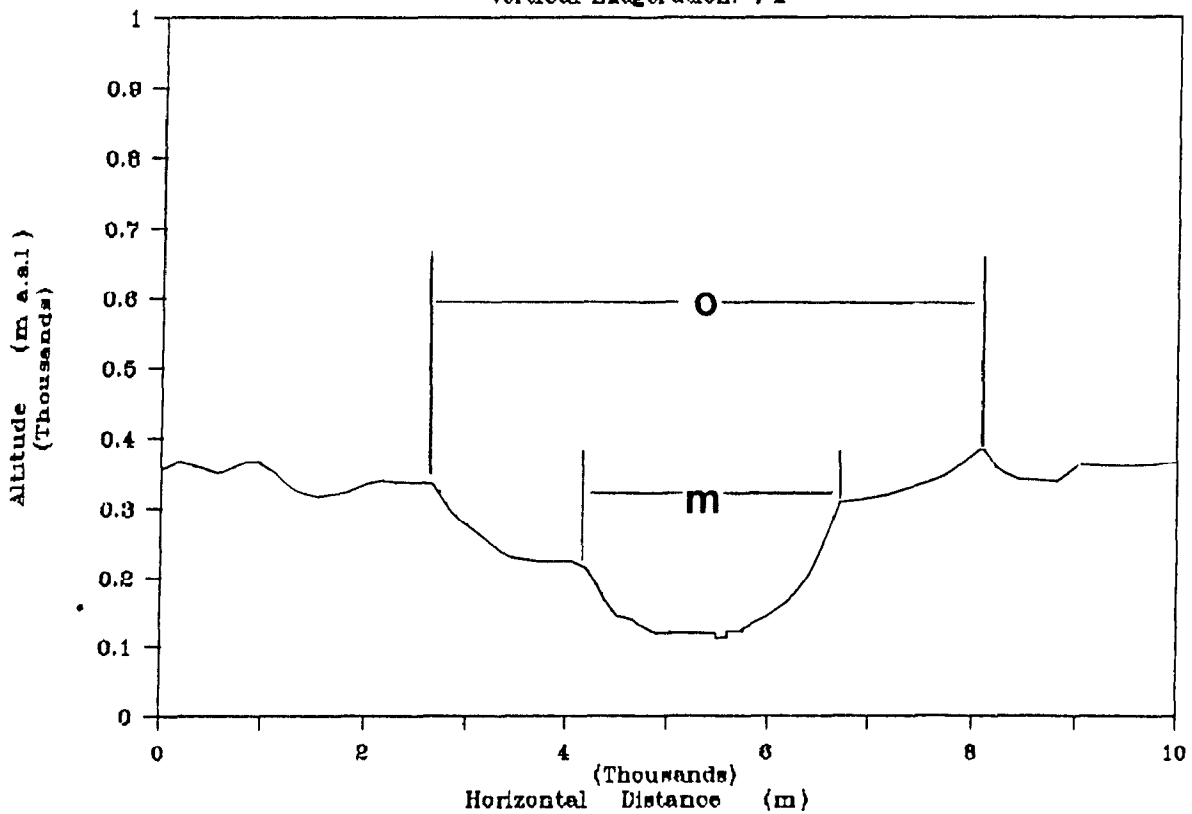
Laverendrye Brook Profile

Vertical Exaggeration: 4 x



Ste-Florence Profile

Vertical Exaggeration: 7 x



Appendix 4. Transverse projected profile, 2 km-wide, across the Milnikek (mil) and Matapédia (mat) River valleys between UTM coordinates 632E5135N and 638E5144N.

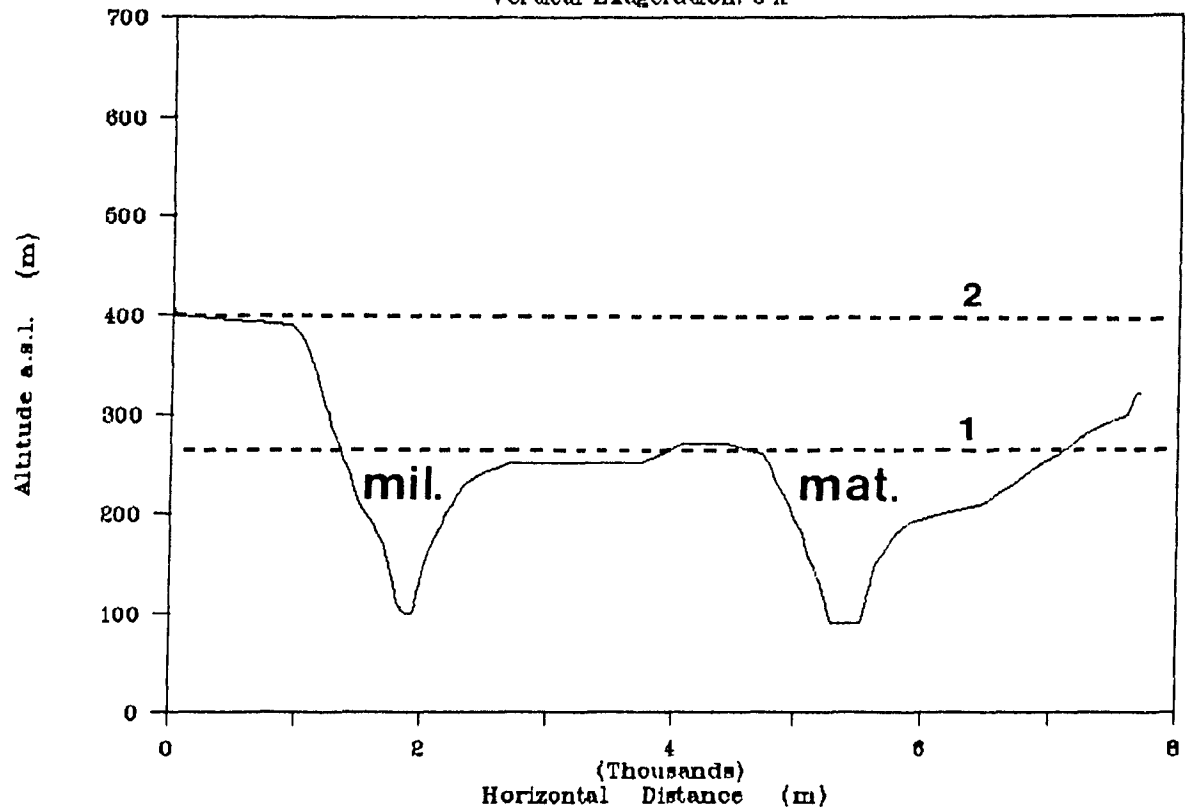
1. 244-290 m a.s.l. upland level
2. 366-427 m a.s.l. upland level

Appendix 5. Transverse projected profile, 2 km-wide, across the Matapédia (mat) and lower Assemetquagan (A) River valleys, between UTM coordinates 638E5129N and 642E5134N.

1. 244-290 upland level
2. 366-427 upland level

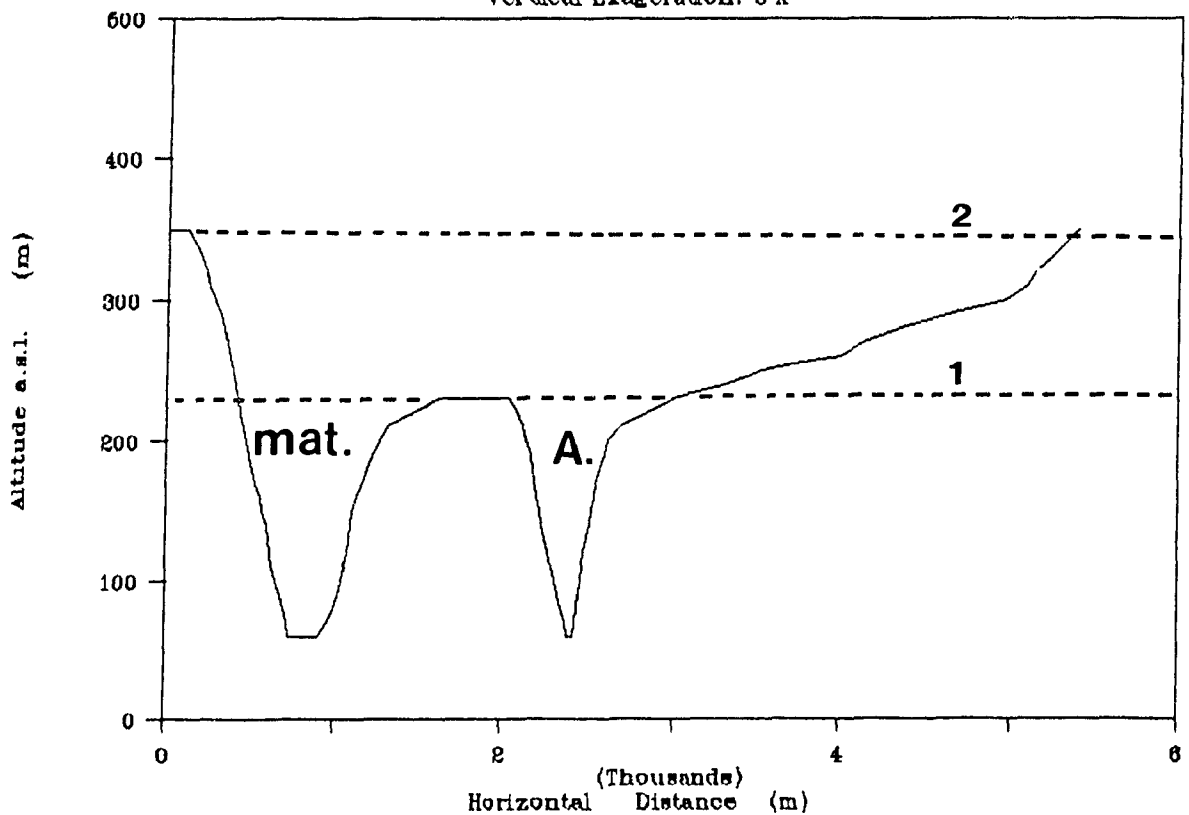
MILNIKEK - MATAPEDIA PROFILE

Vertical Exaggeration: 8 X

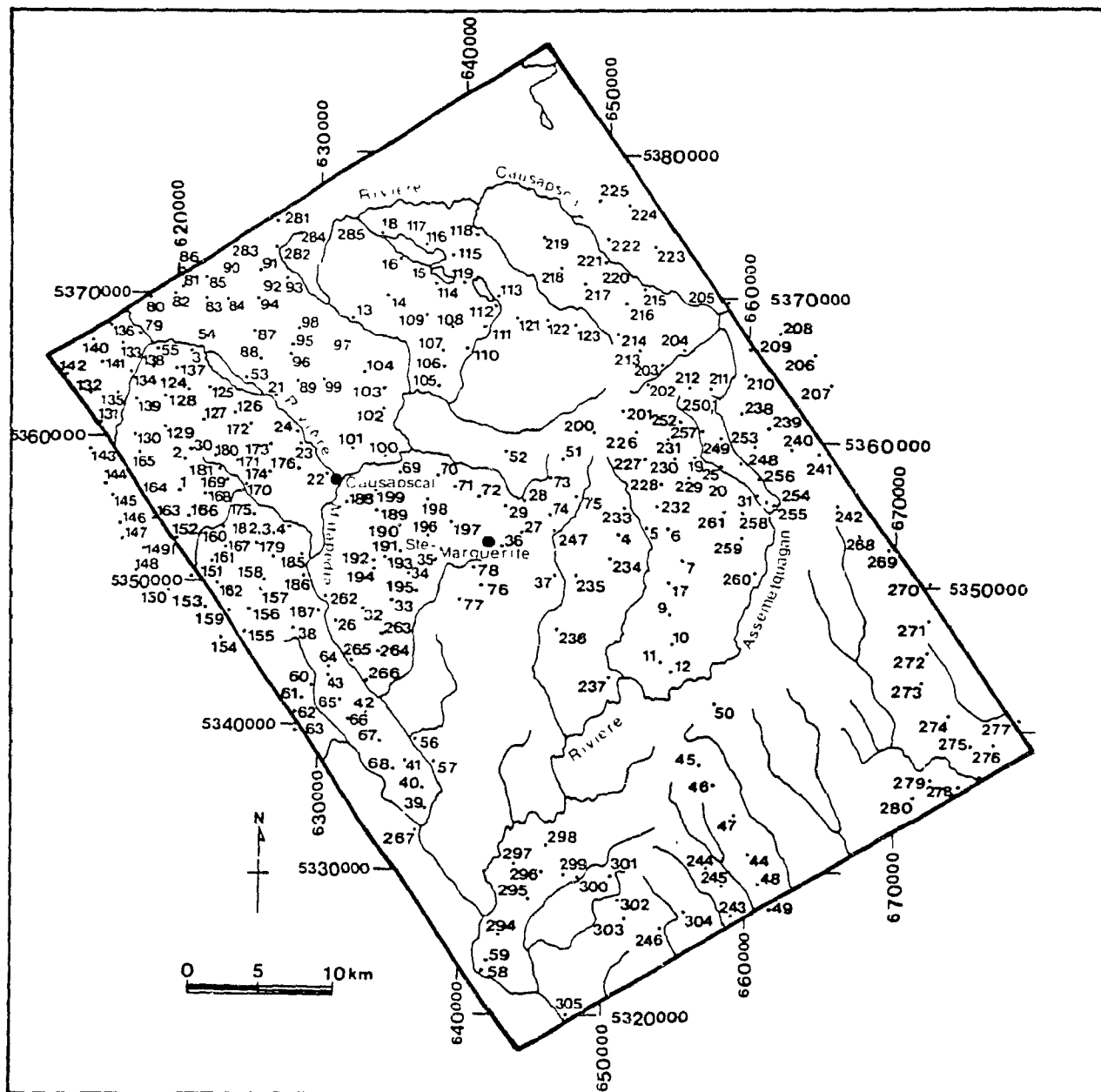


MATAPEDIA - LOWER ASSEMETQUAGAN PROFILE

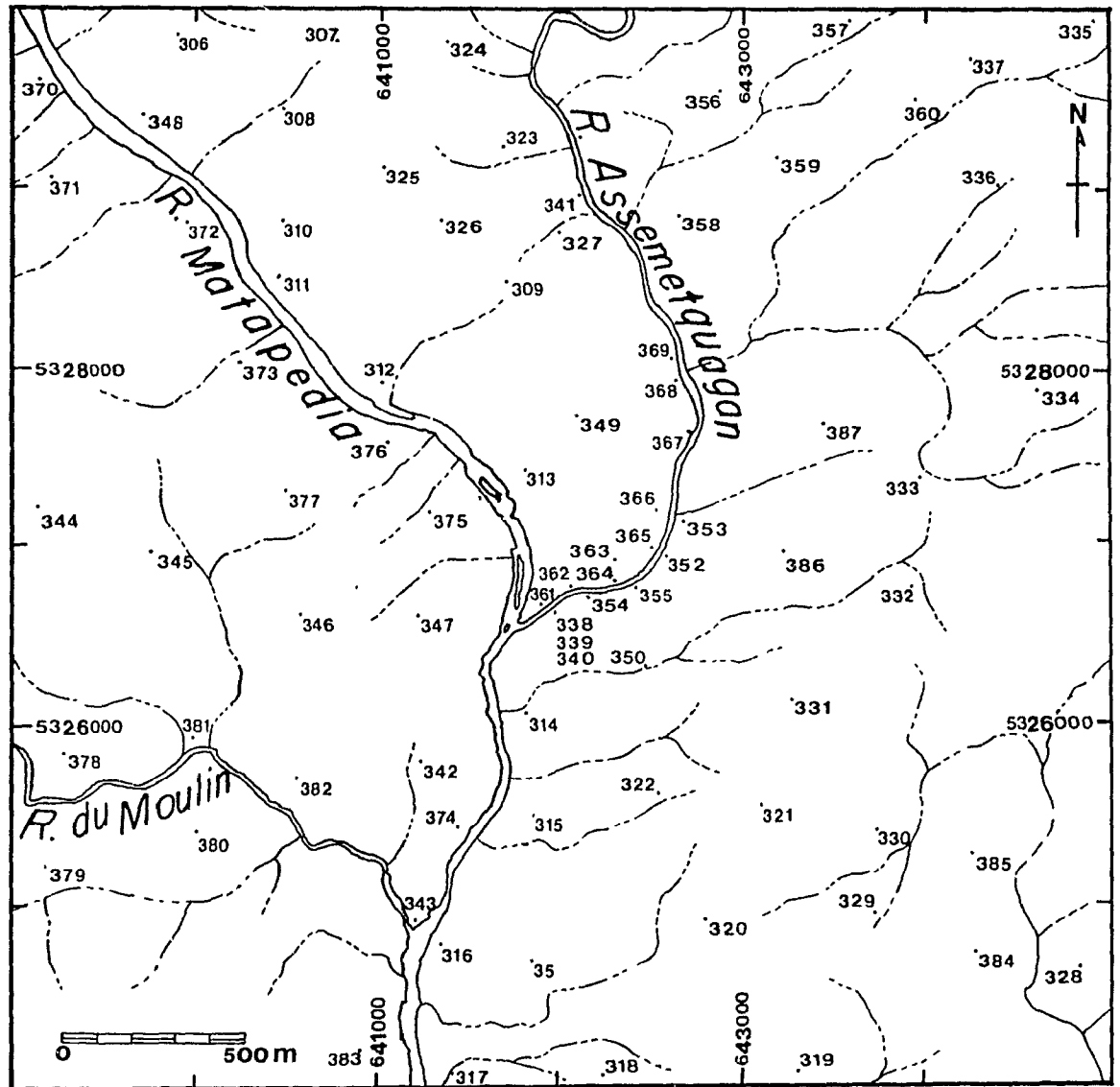
Vertical Exaggeration: 8 X



Appendix 6. Sample location map, regional (1985) survey area,
southwestern Gaspésie.



Appendix 7. Sample location map, local (1986) survey area,
southwestern Gaspésie.



Appendix 8. Heavy mineral separation data (85-series samples).

Sample No.	Wt. (g)	Wt. H.M. (g)	Wt. M.M. (g)	%H.M. X 100	%M.M.	Sample No.	Wt. (g)	Wt. H.M. (g)	Wt. M.M. (g)	%H.M. X 100	%M.M.
4	237.66	1.39	.2599	.59	18.64	131	250.99	1.02	.1188	.41	11.61
5	611.67	3.58	.7873	.58	22.02	132	129.21	.05	.0051	.04	10.85
6	401.32	1.01	.1270	.25	12.52	133	143.81	.20	.0140	.14	7.04
10	321.27	.20	.0257	.06	12.85	134	279.01	1.61	.1640	.58	10.17
12	293.69	.29	.0435	.10	15.00	136	217.74	.85	.1040	.39	12.31
16	64.73	.02	.0017	.03	8.02	137	310.69	.56	.0419	.18	7.47
20	258.56	.61	.0611	.24	9.97	138	179.33	.25	.0185	.14	7.52
30	166.98	.18	.0082	.11	4.56	139	357.54	.61	.0390	.17	6.35
31	272.96	.59	.0714	.22	12.14	140	262.63	.78	.0812	.30	10.45
35	435.88	1.36	.2396	.31	17.59	142	61.86	.18	.0216	.29	11.87
42	288.60	.39	.0280	.14	7.11	144	303.85	1.62	.1944	.53	11.99
45	317.05	.09	.0043	.03	4.83	147	405.97	.71	.0277	.17	3.93
50	89.34	.03	.0018	.03	7.20	148	87.74	.76	.1603	.87	20.98
52	386.80	1.18	.0950	.30	8.07	149	97.98	.01	.0002	.01	1.57
53	202.89	1.97	.2190	.97	11.12	151	300.87	1.93	.0658	.64	3.42
56	509.08	1.36	.1756	.27	12.88	153	459.77	3.58	.1220	.78	3.41
57	318.87	.02	.0019	.01	8.26	157	516.87	4.19	.1850	.81	4.42
58	593.17	2.93	.2766	.49	9.44	159	648.67	3.82	.3560	.59	9.32
59	415.77	.87	.0431	.21	4.97	162	417.27	2.81	.1173	.67	4.17
65	190.43	.17	.0100	.09	5.85	163	291.66	.99	.0747	.34	7.55
66	233.04	.34	.0315	.15	9.32	164	458.97	2.14	.1505	.47	7.02
67	405.75	.20	.0137	.05	6.75	165	252.21	.46	.0226	.18	4.90
69	106.90	1.44	.1934	1.35	13.43	166	362.52	1.80	.0426	.50	2.37
70	212.35	.37	.0470	.17	12.81	167	310.19	.70	.0291	.22	4.18
74	621.17	6.02	1.1030	.97	18.32	168	212.82	.47	.0271	.22	5.75
78	493.67	4.63	.4064	.94	8.77	169	214.06	.24	.0164	.11	6.83
84	181.91	.43	.0405	.24	9.35	170	205.63	.27	.0273	.13	10.15
86	179.87	.40	.0232	.22	5.87	171	379.45	.34	.0250	.09	7.29
89	276.51	7.96	1.2331	2.88	15.49	174	132.34	.88	.1031	.66	11.76
93	321.80	.37	.0184	.11	4.97	175	346.53	.52	.0226	.15	4.39
102	98.36	.08	.0068	.08	8.35	179	286.79	.57	.0335	.20	5.92
106	262.30	1.21	.0419	.46	3.46	180	449.27	.34	.0270	.08	7.94
107	228.39	.14	.0261	.06	18.51	181	254.15	.21	.0029	.08	1.39
108	50.10	.05	.0067	.10	13.40	182	430.50	1.09	.0683	.25	6.25
109	175.03	.25	.0243	.14	9.60	184	359.53	.74	.0472	.20	6.42
110	180.31	.55	.0941	.31	17.08	185	350.91	.72	.0229	.20	3.19
111	324.06	1.47	.1268	.45	8.64	186	207.84	2.41	.3141	1.16	13.05
112	63.54	.13	.0107	.20	8.56	188	138.86	2.55	.2916	1.83	11.45
113	148.03	.45	.0620	.31	13.66	189	89.25	.07	.0044	.08	6.20
116	168.35	.36	.0011	.21	30	192	326.82	2.88	.0811	.88	2.82
119	387.25	.83	.0454	.22	5.45	193	239.30	1.24	.2141	.52	17.32
122	116.83	1.12	.1876	.96	16.75	194	370.43	2.06	.1050	.55	5.11
128	296.88	.58	.0361	.19	6.26	199	189.06	1.50	.1580	.79	10.55
130	295.59	.75	.0388	.25	5.18	200	509.67	4.34	.7477	.85	17.22

Appendix 8. (Cont.)

Sample No	Wt. (g)	Wt. H M (g)	Wt. M.M. (g)	%H M. X 100	%M M	Sample No	Wt. (g)	Wt. H M (g)	Wt. M.M. (g)	%H.M. X 100	%M.M.
201	191.39	.19	.0267	10	14.13	280	234.95	.07	.0005	.03	.71
204	252.80	.48	.0496	.19	10.25	283	358.15	1.28	.0685	.36	5.33
207	378.78	1.23	.1906	.33	15.50	284	369.07	.64	.0303	.17	4.70
209	306.80	.82	.1276	.27	15.64	293	414.37	.98	.0892	.24	9.10
211	375.91	1.32	.2058	.35	15.54	295	320.52	.17	.0166	.05	9.82
214	627.97	2.88	.1932	.46	6.71	296	155.80	.08	.0076	.05	10.13
215	185.13	2.76	.6197	1.49	22.49	297	302.97	.11	.0057	.04	5.00
222	474.07	5.43	.7707	1.14	14.20	298	356.39	.31	.0165	.09	5.32
226	331.78	4.70	.9606	1.42	20.44	299	323.92	.23	.0024	.07	9.78
228	202.88	2.50	.5038	1.23	20.19	300	552.57	.46	.0205	.08	4.47
231	424.52	6.23	1.4760	1.47	23.68	301	115.21	.03	.0020	.03	6.90
234	201.02	.51	.0967	.25	18.90	302	326.98	.15	.0077	.04	5.24
237	233.35	.06	.0036	.02	6.55	303	339.91	.03	.0016	.01	4.71
239	453.55	4.77	.5913	1.05	12.39	304	309.65	.11	.0031	.03	2.95
241	299.39	1.94	.1800	.65	9.27						
242	172.97	.19	.0171	.11	9.24						
243	310.70	.12	.0023	.04	1.98						
244	485.88	6.11	1.2828	1.26	20.99						
245	254.83	.09	.0058	.04	6.30						
246	335.49	.19	.0079	.06	4.07						
250	213.83	.28	.0237	.13	8.53						
251	187.67	.28	.0152	.15	5.53						
254	208.89	.47	.0654	.22	13.94						
255	217.45	.15	.0140	.07	9.52						
257	359.18	2.04	.3683	.57	18.07						
258	232.52	.33	.0494	.14	15.11						
260	334.11	.35	.0227	.10	6.54						
261	225.13	.34	.0496	.15	14.42						
263	286.57	.07	.0031	.02	4.49						
264	345.19	.19	.0096	.06	4.97						
266	180.81	.06	.0035	.03	6.25						
271	235.22	.04	.0014	.02	3.18						
272	246.53	.05	.0012	.02	2.26						
274	345.94	.30	.0180	.09	6.06						
277	198.27	.26	.0500	.13	19.53						
278	215.59	.04	.0016	.02	3.64						
279	207.99	.40	.0057	.19	1.44						

Wt . Weight

H M . Heavy Mineral Fraction

M M . Magnetic Mineral Fraction

%H M. : Heavy Mineral Abundance = (H.M. / Wt. of Sample)*100

%M.M. : Magnetic Mineral Abundance = (M.M. / H.M.)*100

Appendix 9

Heavy mineral separation data (86 series sample) sorted by decreasing heavy mineral abundance

Samp No	Comp	Wt (g)	Wt H M (g)	Wt M M (g)	Wt H M % 100	Samp No	Comp	Wt (g)	Wt H M (g)	Wt M M (g)	Wt H M % 100	Samp No	Comp	Wt (g)	Wt H M (g)	Wt M M (g)	Wt H M % 100
343	A	618.40	9.012	8010	145.73	889						330	R	1000	643	0655	6.43
383	A	1000	12.238	144.21	122.38	11.78						326	R	1007.20	636	0287	6.31
341	A	569.80	3.683	645.9	64.64	17.62						370	C	1000	628	0915	6.28
364	C	1151.97	5.712	7206	49.58	12.77						384	R	1091.50	610	0109	5.50
372	A	1177.80	5.393	6311	45.79	11.70						349	D	1660.84	909	0647	5.47
317	A	1000	3.703	4653	37.03	12.57						357	D	1000.50	506	0346	5.06
338	A	1092.60	3.694	5408	33.82	14.64						325	R	1000	504	0372	5.04
369	A	824.90	2.686	4232	32.56	15.76						324	C	861.80	521	0381	4.89
316	A	1175.40	3.469	4325	29.50	12.47						340	C	1010.20	487	0401	4.82
318	D	816	2.121	2586	25.99	12.20						349	C	982.60	445	0424	4.53
361	A	1001.70	2.523	1457	25.19	5.78						392	C	1000	434	0039	4.34
362	C	1000	2.510	4490	25.10	17.89						385	R	1081.30	567	0320	4.32
353	A	1000	2.123	3760	21.23	17.71						327	C	1006.60	527	0563	4.24
367	A	1861.62	3.890	6264	20.90	16.10						358	C	1101.50	459	0411	4.17
321	R	1000	1.611	0839	16.11	5.21						366	C	1000	415	0541	4.15
354	C	1000	1.381	1229	13.81	8.60						336	R	1005.60	408	0136	4.06
355	A	1000	1.110	1205	11.10	10.86						337	R	1319.29	518	0417	3.93
312	C	1071	1.161	1196	10.84	10.30						344	R	1079.30	474	0202	3.94
363	C	1000	1.072	1068	10.72	9.96						311	C	1000	368	0300	3.68
350	C	2079.79	2.167	1552	10.56	7.16						323	R	1000	368	0301	3.68
315	C	1151.90	1.204	0640	10.45	4.2						333	D	1000	366	0171	3.66
386	R	1000	1.038	0671	10.38	6.56						345	R	1000	362	0262	3.62
374	A	1060	1.035	1591	10.35	15.37						342	A	649.40	222	0161	3.42
369	A	1145.57	1.131	0344	9.87	8.44						336	R	1000	325	0317	3.25
365	C	1040.50	1.020	1346	9.80	13.29						325	C	1000	325	0250	3.25
313	C	977.20	854	0895	8.74	10.48						344	D	1024.40	328	0320	3.20
352	C	1000	865	0685	8.65	7.92						376	C	1000	303	0202	3.03
387	R	1161.72	1.002	0296	8.61	2.95						379	R	728.80	270	0007	3.02
329	C	1057.60	906	0617	8.57	6.81						309	R	1000	306	0438	2.96
331	R	1017.50	850	0735	8.35	8.65						359	R	1000	242	0284	2.42
308	C	1000	830	0950	8.30	11.45						320	R	1261.83	329	0269	2.61
351	C	1047.10	799	0678	7.63	8.49						351	C	1083.90	380	0243	2.59
319	C	1000	752	0695	7.52	8.05						373	C	1000	241	0216	2.41
314	A	1249.22	903	0944	7.23	10.56						360	R	1000	219	0145	2.19
332	R	1000	706	0531	7.06	7.52						350	R	1000	219	0251	2.19
322	R	1000	700	0335	7.00	4.79						345	R	1002.10	207	0133	2.03
307	R	1031.20	707	0853	6.86	12.07						378	R	927	184	0350	1.84
328	D	1000	679	0545	6.79	8.03						310	C	1084	190	0154	1.90
347	C	1000	670	0551	6.70	8.22						348	C	1034.16	195	0058	1.78
346	R	1931.77	1.293	0460	6.69	7.58						371	C	1011.40	179	0035	1.79
306	R	1269.33	816	1041	6.43	12.76						377	R	1000	057	0035	.57

A Alluvium C Collicium D Diametron R Rubble Samp Sample Comp Composition
H M Heavy Mineral Fraction M M Magnetic Mineral Fraction
Wt H M Heavy Mineral Abundance - (H M / Wt of Sample) 100 Wt M M Magnetic Mineral Abundance - (M M / H

Appendix 10.

Electron microprobe analyses of selected heavy mineral grains.

Wt. %	1	2	3	4	5	6	7	8	9	10	11	12
FeO *	.56	.80	15.39	15.32	31.06	31.73	31.92	31.81	33.54	33.34	27.12	27.51
Fe2O3 *	2.23	2.05	.40	.12	0.00	0.00	0.00	0.00	0.00	0.00	.11	0.00
Al2O3	20.62	20.79	22.91	23.03	22.00	22.17	21.80	21.74	21.59	21.37	21.12	21.36
SiO2	38.62	38.57	40.30	40.33	38.03	38.06	37.89	38.01	37.70	36.99	36.93	37.18
CaO	35.74	35.70	5.61	5.68	.96	1.05	1.05	1.13	.76	.98	1.76	1.70
Cr2O3	.04	.04	0.00	0.00	.01	0.00	.02	.03	.08	.09	.01	.04
MgO	.42	.48	15.09	14.91	7.92	7.81	7.29	7.16	5.86	2.71	4.49	4.38
MnO	.06	.01	.30	.31	.47	.45	.54	.53	1.14	4.81	7.98	7.98

Total 98.29 98.43 100.00 99.70 100.45 101.27 100.51 100.40 100.67 100.29 99.51 100.15

* Recalculated

No. of ions on the basis of 24 O

Fe	.07	.10	1.89	1.89	4.04	4.11	4.17	4.16	4.42	4.49	3.64	3.67
Fe	.26	.24	.04	.01	0.00	0.00	0.00	0.00	0.00	0.00	.01	0.00
Al	3.75	3.77	3.97	4.00	4.04	4.05	4.02	4.01	4.01	4.06	4.00	4.02
Si	5.95	5.94	5.93	5.94	5.92	5.89	5.92	5.95	5.94	5.96	5.93	5.94
Ca	5.90	5.88	.88	.90	.16	.17	.18	.19	.13	.17	.30	.29
Cr	.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.01	.01	0.00	.01
Mg	.10	.11	3.31	3.28	1.84	1.80	1.70	1.67	1.38	.65	1.08	1.04
Mn	.01	0.00	.04	.04	.06	.06	.07	.07	.15	.66	1.09	1.08

Total 16.04 16.05 16.06 16.05 16.06 16.08 16.06 16.05 16.04 16.00 16.06 16.05

Proportions (%)

Alm	1.19	1.69	30.92	30.95	66.26	66.85	68.20	68.33	72.73	75.28	59.65	60.37
Pyr	1.59	1.80	54.05	53.71	30.10	29.35	27.76	27.41	22.65	10.90	17.59	17.12
Spe	.14	.02	.60	.64	1.02	.97	1.16	1.15	2.51	11.01	17.79	17.73
Gro	90.58	90.55	13.35	14.37	2.59	2.83	2.81	3.00	1.88	2.52	4.63	4.64
And	6.38	5.83	1.09	.33	0.00	0.00	0.00	.01	0.00	0.00	.31	0.00
Uva	.13	.10	0.00	0.00	.03	0.00	.07	.09	.23	.30	.03	.14

FM Ratio 46 49 37 37 69 .70 .71 72 77 89 82 82

Analysis	Grain no	Description **	Analysis	Grain no	Description **
1, 2	2.5	Colorless garnet	9	2.23	light pink garnet
3, 4	3.19	Very light pink garnet	10	2.10	light orange-pink garnet
5, 6	3.18	light pink garnet	11, 12	3.27	light orange-pink garnet
7, 8	3.21	light pink garnet			

* Binocular stereoscopic microscope, air mount

Appendix 10. (cont.)

Wt. %	13	14	15	16	17	18	19	20	21	22	23	24
FeO *	31.24	31.35	24.42	23.99	26.04	24.79	22.72	22.73	21.76	22.08	30.15	30.11
Fe2O3 *	.09	.07	.05	0.00	.01	0.00	.15	.42	.40	.07	.23	.45
Al2O3	21.18	21.13	21.65	21.75	21.65	21.69	21.54	21.36	22.31	22.45	21.45	21.34
SiO2	37.22	37.03	37.78	37.73	37.79	37.96	37.80	37.73	39.15	39.47	37.41	37.59
CaO	3.99	3.99	10.39	10.45	9.61	10.41	12.53	12.67	5.52	4.80	2.97	2.92
Cr2O3	.02	.01	.01	0.00	.02	.03	.01	0.00	0.00	.04	0.00	.01
MgO	2.96	2.72	3.52	3.48	3.72	3.32	3.57	3.52	10.97	10.95	6.26	6.40
MnO	3.69	3.90	2.47	2.52	1.35	2.04	1.14	1.05	.23	.26	1.42	1.37
Total	100.39	100.19	100.29	99.91	100.17	100.23	99.47	99.48	100.34	100.10	99.89	100.24
* Recalculated												
No. of ions on the basis of 24 O												
Fe	4.18	4.21	3.21	3.16	3.42	3.25	2.99	2.99	2.75	2.79	3.98	3.96
Fe	.01	.01	.01	0.00	0.00	0.00	.02	.05	.05	.01	.03	.06
Al	4.00	4.00	4.01	4.03	4.01	4.01	3.99	3.96	3.97	4.00	3.99	3.96
Si	5.96	5.95	5.93	5.94	5.94	5.96	5.95	5.94	5.92	5.96	5.91	5.92
Ca	.69	.69	1.75	1.76	1.62	1.75	2.11	2.14	.89	.78	.50	.49
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mg	.71	.65	.82	.82	.87	.78	.84	.83	2.47	2.46	1.47	1.50
Mn	.50	.53	.33	.34	.18	.27	.15	.14	.03	.03	.19	.18
Total	16.04	16.04	16.06	16.04	16.05	16.03	16.05	16.05	16.07	16.03	16.08	16.07
Proportions (%)												
Alm	68.88	69.28	52.52	52.00	56.20	53.78	49.07	49.09	44.77	46.00	64.77	64.55
Pyr	11.62	10.72	13.48	13.43	14.30	12.82	13.75	13.55	40.21	40.64	23.97	24.46
Spe	8.23	8.72	5.38	5.54	2.94	4.47	2.49	2.30	.48	.55	3.09	2.98
Gro	10.93	11.05	28.45	29.03	26.46	28.84	34.20	33.54	13.43	12.50	7.51	6.56
Al	.27	.21	.14	0.00	.04	0.00	.45	1.22	1.11	.21	.66	1.42
Uva	.08	.02	.04	0.00	.06	.09	.03	0.00	0.00	.10	0.00	.04
FM Ratio	87	88	81	81	81	82	79	79	53	53	74	73
Analysis	Grain no.	Description					Analysis	Grain no.	Description			
	13, 14	3.25	light orange pink garnet					19, 20	3.23	orange pink garnet		
	15, 16	3.20	light orange pink garnet					21, 22	3.24	orange garnet		
	17, 18	3.22	light orange pink garnet					23, 24	3.26	orange garnet		
* Binocular stereoscopic microscope, air mount												

Appendix 10. (Cont.)

Wt. %	25	26	27	28	29	30	31	32	33	34	35	36
FeO *	24.59	24.58	28.33	24.28	24.39	25.60	25.62	27.36	28.46	27.14	27.00	31.61
Fe ₂ O ₃ *	.88	1.22	.86	.50	.48	.76	.60	.81	.68	.60	.88	.82
Al ₂ O ₃	21.21	20.89	21.21	21.93	21.78	21.24	21.42	20.77	21.11	20.93	20.98	20.60
SiO ₂	38.43	38.26	38.05	38.86	38.43	38.07	38.42	37.45	37.43	37.45	37.76	36.80
CaO	7.44	7.20	6.57	6.26	6.14	6.73	6.76	6.64	6.44	9.01	9.36	8.11
Cr ₂ O ₃	0.00	0.00	.06	.11	.10	0.00	0.00	.04	0.00	.01	0.00	0.00
MgO	5.71	5.68	5.03	8.16	8.11	6.00	5.97	4.68	4.79	3.02	3.20	1.42
MnO	1.78	1.90	.95	1.05	.99	1.36	1.30	1.12	1.04	1.30	1.20	.76

Total 100.04 99.73 101.05 101.17 100.42 99.76 100.09 98.87 99.95 99.47 100.38 100.12

* Recalculated

No. of ions on the basis of 24 O

Fe	3.21	3.22	3.70	3.10	3.14	3.35	3.34	3.65	3.77	3.62	3.56	4.26
Fe	.10	.14	.10	.06	.06	.09	.07	.10	.08	.07	.10	.10
Al	3.90	3.86	3.90	3.94	3.95	3.92	3.93	3.90	3.94	3.93	3.90	3.91
Si	5.99	5.99	5.94	5.93	5.92	5.96	5.99	5.97	5.92	5.97	5.96	5.93
Ca	1.24	1.21	1.10	1.02	1.02	1.13	1.13	1.13	1.09	1.54	1.58	1.40
Cr	0.00	0.00	.01	.01	.01	0.00	0.00	.01	0.00	0.00	0.00	0.00
Mg	1.33	1.33	1.17	1.86	1.86	1.40	1.39	1.11	1.13	.72	.75	.34
Mn	.23	.25	.13	.14	.13	.18	.17	.15	.14	.18	.16	.10

Total 16.01 16.00 16.05 16.06 16.07 16.03 16.01 16.02 16.06 16.03 16.03 16.06

Proportions (%)

Alm	53.34	53.59	60.71	50.67	51.13	55.30	55.40	60.34	61.45	59.79	58.79	69.78
Pyr	22.08	22.08	19.20	30.36	30.29	23.11	23.02	18.38	18.45	11.86	12.43	5.58
Spe	3.90	4.21	2.05	2.23	2.10	2.98	2.85	2.51	2.28	2.91	2.65	1.70
Gro	18.10	16.53	15.36	15.00	14.83	16.41	16.98	16.24	15.84	23.59	23.55	20.48
And	2.57	3.59	2.50	1.40	1.36	2.21	1.75	2.41	1.97	1.80	2.57	2.46
Uva	0.00	0.00	.18	.34	.30	0.00	0.00	.12	0.00	.04	0.00	0.00

FM Ratio .72 .72 .77 .64 .64 .72 .72 .77 .78 .84 .83 .93

Analysis	Grain no.	Description **	Analysis	Grain no.	Description **
25, 26	2.18	orange garnet with multiple oxide inclusions	30, 31	3.30	dark orange garnet
			32, 33	3.31	dark orange garnet
27	2.12	orange garnet with oxide inclusion	34, 35	3.28	dark orange garnet
			36	3.32	dark orange garnet
28, 29	3.29	orange garnet			

** Binocular stereoscopic microscope, air mount

Appendix 10. (cont.)

Wt. %	37	38	39	40	41	42	43	44	45	46
FeO	31.77	30.02	29.69	31.65	24.52	25.08	35.31	35.11	15.19	15.60
Fe2O3	92	1.61	1.72	1.12	1.23	1.68	56	0.00	3.34	2.87
Al2O3	20.69	19.92	19.66	20.25	20.10	20.05	20.08	20.35	17.84	18.09
SiO2	36.94	36.74	36.54	36.74	36.91	36.88	35.93	35.55	35.52	35.47
CaO	8.19	9.08	8.86	7.59	8.80	8.71	2.32	2.31	6.25	6.20
Cr2O3	0.00	06	02	03	0.00	0.00	0.00	01	0.00	02
MgO	1.39	46	46	75	1.36	1.47	21	20	30	29
MnO	77	2.31	2.24	2.04	6.00	5.74	4.75	4.86	15.02	17.60

Total 100.57 100.19 99.20 100.17 98.82 99.42 99.16 98.39 96.47 96.14

* Recalculated

No. of ions on the basis of 24 O

Fe	4.27	4.07	4.06	4.29	3.33	3.40	4.91	4.92	2.15	2.22
Fe	10	20	21	14	15	18	07	0.00	13	17
Al	3.92	3.81	3.79	3.87	3.85	3.83	3.94	4.02	3.57	3.62
Si	5.93	5.96	5.98	5.96	5.99	5.97	5.97	5.95	6.03	6.03
Ca	1.41	1.58	1.55	1.32	1.53	1.51	.41	.41	1.14	1.13
Cr	0.00	01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mg	33	11	11	18	33	36	05	05	08	07
Mn	10	32	31	28	83	79	67	69	2.59	2.53

Total 16.06 16.04 16.02 16.04 16.01 16.02 16.02 16.04 15.98 15.97

Analysis	Grain no	Description	Analysis	Grain no	Description
37	3.32	dark orange garnet	41, 42	2.9	dark orange-red garnet
38, 39	3.34	dark orange-red garnet	43, 44	3.33	dark orange-red garnet
40	2.8	dark orange-red garnet	45, 46	3.35	dark red garnet

Wt. %	47	48	49	50	51	52	53	54	55	56	57	58
FeO	10.46	14.95	8.61	40.36	41.69	43.52	44.05	44.33	40.99	41.59	3.68	3.40
Fe2O3	76.72	66.26	79.73	9.82	7.08	5.55	0.00	73	9.38	8.14	89.66	91.90
Cr2O3	01	0.00	05	0.00	0.00	06	05	01	03	0.00	05	07
Al2O3	10	10	24	02	03	05	01	04	08	06	09	18
MgO	28	39	06	1.23	1.23	22	17	14	1.04	2.04	13	11
SiO2	0.00	03	05	0.00	0.00	0.00	0.00	01	01	0.00	02	0.00
TiO2	12.24	17.43	9.58	47.54	49.03	49.46	52.25	51.79	48.15	48.74	4.95	4.06
MnO	13	10	08	20	22	62	2.15	2.00	52	42	61	21

Total 99.94 99.26 98.40 99.18 99.27 99.49 98.67 99.06 100.19 100.00 99.16 99.92

* Recalculated

* Binocular stereoscopic microscope, air mount

Appendix 10. (cont.)

No of ions on the basis of 6 0

Fe	46	66	39	1 71	1 76	1 85	1 88	1 89	1 72	1 75	.16	15
Fe	3 03	2 62	3 20	37	27	.21	0 00	03	.36	31	3.59	3 66
Cr	0 00	0.00	0 00	0 00	0 00	0 00	0.00	0 00	0 00	0 00	0 00	0.00
Al	01	01	02	0.00	0 00	0 00	0 00	0 00	01	0 00	.01	01
Mg	02	.03	01	09	09	.02	01	01	08	08	.01	.01
Si	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0.00	0 00	0 00	0 00	0 00
Ti	.48	69	39	1 81	1 86	1 89	2 01	1 98	1 82	1 84	20	16
Mn	.01	.01	0.00	01	01	03	09	.09	.02	.02	.03	.01

Total	4 00	4 00	4 00	4.00	4 00	4.00	3 99	4.00	4 00	4 00	4 00	4 00
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FM Ratio	.96	96	99	.95	.95	99	99	99	96	96	95	.95
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Wt. %	59	60	61	62	63	64	65	66	67	68	69	70
FeO *	1 81	1 79	3.54	1 79	3 54	2 85	40 32	37 56	42.58	11 18	8.63	39.63
Fe2O3 *	97 19	0 00	0.00	0.00	0 00	94 67	11.42	18.85	8 83	75 21	81 89	7.64
Cr2O3	0 00	04	26	04	26	21	59	13	06	36	.04	02
Al2O3	06	03	02	.03	.02	0.00	.02	07	03	15	01	0 00
MgO	02	0 00	02	0 00	02	03	04	.07	13	02	0 00	22
SiO2	0 00	01	0 00	01	0 00	04	02	.01	01	01	0 00	0 00
TiO2	2.06	97 40	95 09	97 40	95 09	3 16	45 05	41.93	47 78	12 26	9 75	48 46
MnO	03	01	0.00	.01	0.00	.04	.40	12	.19	07	16	3.53

Total	101 17	99 29	98 94	99.29	98 94	101.01	97 85	98 74	99 62	99 27	100.47	99 49
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* Recalculated

No. of ions on the basis of 6 0 (except analyses 62, 63)

				(2 0)	(2 0)							
Fe	.08	06	12	02	04	.13	1 75	1 62	1.81	50	38	1 69
Fe	3.83	0 00	0 00	0.00	0.00	3 74	.45	73	.34	2.99	3.23	29
Cr	0.00	0 00	01	0 00	0 00	.01	02	01	0 00	02	0 00	0 00
Al	0 00	0 00	0 00	0 00	0 00	0 00	0.00	0 00	0 00	.01	0 00	0 00
Mg	0 00	0 00	0.00	0 00	0.00	0.00	0 00	.01	01	0 00	0.00	02
Si	0 00	0 00	0 00	0 00	0 00	0.00	0 00	0 00	0 00	0 00	0 00	0 00
Ti	.08	2.97	2 93	99	98	.13	1.76	1 63	1 83	49	38	1 85
Mn	0.00	0 00	0 00	0 00	0 00	0 00	02	.01	.01	0 00	.01	15

Total	4.00	3.03	3 06	1 01	1 02	4.00	4 00	4 00	4.00	4 00	4.00	4 00
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FM Ratio	98	1 00	.99	1 00	99	98	1 00	1 00	.99	1.00	1 00	.99
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Appendix 10. (cont.)

Analysis no.	Grain no.	Description
47, 48, 49	2 18	Hematite phase within a 2-phase hematite-ilmenite grain coexisting with pyrope-grossularite almandine (Analyses 25, 26)
50, 51	2.18	Ilmenite phase within a 2-phase hematite-ilmenite grain coexisting with pyrope-grossularite almandine (Analyses 25, 26)
52	2.13	1-phase ilmenite grain coexisting with epidote (Analyses 9, 10)
53, 54/55, 56	3 37/3.38	1-phase ilmenite grain
57, 58	3 39	1-phase hematite grain
59	3 49	Hematite phase within a multi-phase hematite-TiO ₂ -FeTiO ₃ grain
60, 61	3.49	TiO ₂ phase within a multi-phase hematite-TiO ₂ -FeTiO ₃ grain
62, 63	3 49	TiO ₂ phase within a multi-phase hematite-TiO ₂ -FeTiO ₃ grain
64	3 49	Hematite phase within a multi-phase hematite-TiO ₂ -FeTiO ₃ grain
65	3 49	Ilmenite phase within a multi-phase hematite-TiO ₂ -FeTiO ₃ grain
66, 67, 68	1.09	Ilmenite phase within a weakly magnetic 2-phase hematite-ilmenite grain
69	1.11	Hematite phase within a weakly magnetic 2-phase hematite-ilmenite grain
70	1 11	Ilmenite phase within a weakly magnetic 2-phase hematite-ilmenite grain

Wt. %	71	72	73	74	75	76	77	78	79	80	81	82
Co	.05	0 00	.04	0 00	0 00	.05	0 00	0 00	0 00	0 00	.02	0 00
Cu	0.00	.01	.01	0 00	.32	.27	.08	.02	0 00	0 00	0 00	.16
Ni	0 00	0 00	.09	0.00	.08	0 00	.04	0 00	0 00	0 00	0 00	0 00
Si	.04	.01	.04	.05	.06	.05	.03	.03	.02	.01	.05	.05
As	.02	0 00	.02	0 00	0 00	.02	0 00	0 00	0 00	0 00	0 00	0 00
Pt	0 00	0.00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Au	91.23	91.67	94.23	95.08	99.43	99.60	93.96	93.70	92.29	92.49	93.47	95.48
Ag	8.93	8.68	6.61	6.37	1.51	.99	6.47	6.08	7.27	7.13	5.87	5.82
Sb	.04	.02	0 00	0 00	.03	.08	.01	0 00	.02	0 00	0 00	.08
S	.05	.08	.06	.07	.11	.10	.03	.09	.06	.03	.08	.07
Ba	.06	.06	.04	0 00	0 00	0 00	.02	.07	.03	0 00	.08	0 00
Total	100.42	100.52	101.14	101.57	101.54	101.18	100.64	99.98	99.70	99.66	99.56	101.65

Wt. %	83	84	85	86	87	88	89	90	91	92	93	94
Co	.02	.08	0 00	0 00	.05	0 00	0 00	0 00	.01	.05	0 00	0 00
Cu	.12	0 00	0 00	.10	0 00	.01	.05	0 00	.02	0 00	0 00	.01
Ni	.01	0 00	.03	.04	0 00	.15	.03	.03	.04	.10	.12	0 00
Si	.03	.03	.03	.04	0 00	1.17	0 00	0 00	0.00	.01	0.00	1.18
As	.02	0 00	0 00	.01	0 00	.01	.08	0 00	.02	.02	0 00	0 00
Pt	0 00	0 00	0 00	0 00	0 00	0 00	.04	0 00	.03	0 00	0.00	0 00
Au	94.59	94.57	94.73	94.19	0 00	0.00	0 00	0 00	0 00	.03	.01	.03
Ag	6.38	6.36	6.02	6.41	0 00	.04	.06	0 00	0 00	0 00	.04	0 00
Sb	.03	0 00	0 00	0 00	0 00	.02	.04	0 00	0 00	0 00	.03	0 00
S	0 00	.04	.06	.07	54.03	.10	55.99	55.52	55.34	53.35	54.08	.02
Ba	0 00	.06	0 00	.04	0 00	0 00	0 00	0 00	.06	.06	.06	0 00
Total	101.24	101.32	100.87	100.90	54.08	1.49	56.29	55.55	55.52	53.62	54.34	1.24

Appendix 10. (cont.)

Analysis no.	Grain no	Description
71, 72	3 01*	Alluvial gold grain (anhedral, subrounded edges, long axis (l a.) = 800 μ m)
73, 74	3 02*	Alluvial gold grain (elongate, rounded edges, l a. = 1200 μ m)
75, 76	3 03*	Alluvial gold grain (ellipsoidal, rounded edges, l a. = 800 μ m)
77, 78	3 04*	Alluvial gold grain (anhedral, subrounded edges; l a. = 950 μ m)
79, 80	3 11*	Alluvial gold grain (anhedral, subrounded edges, l a. = 900 μ m)
81, 82	3 10*	Alluvial gold grain with quartz inclusions (ellipsoidal, rounded edges; l a. = 1000 μ m)
83, 84	3 08*	Alluvial gold grain (anhedral, angular edges, l a. = 800 μ m)
85, 86	3 06*	Alluvial gold grain (elongate, rounded edges, l a. = 1000 μ m)
87	3 12	Pyrite from Fortin bedrock (elongate, euhedral, unoxidized, l a. = 700 μ m)
88	3 13	Goethite pseudomorph after euhedral pyrite (cubic form; l a. = 500 μ m)
89, 91	3 14	Pyrite core of goethite pseudomorph (cubic form, l a. = 500 μ m)
90	3 17	Pyrite core of goethite pseudomorph (elongate, euhedral, l a. = 600 μ m)
92	2 35	Pyrite phase in limonite grain, 146-H (brown and black, anhedral)
93	2 34	Pyrite phase in limonite grain, 146-H (brown and black, anhedral)
94	2 48	Core of goethite pseudomorph after euhedral pyrite, 277-H (l a. = 300 μ m)

* Assenmetquagan River alluvial gold occurrence

l a = Long axis

Wt. %	95	96	97	98	99	100	101	102	103	104	105	106
Co	.01	0	.03	.04	0.00	0.00	.33	0.00	.02	0.00	0.00	.07
Cu	.01	.07	0.00	.02	.06	.03	.01	.03	.04	.05	.08	.07
Ni	0.00	0.00	0.00	0.00	.04	0.00	.03	.01	.02	0.00	.03	.13
Si	0.00	.01	0.00	.01	.06	0.00	0.00	.01	0.00	0.00	.02	.02
As	.01	.02	0.00	.04	.04	0.00	.05	.01	.03	.01	.04	.05
Pt	0.00	.04	.02	0.00	.04	0.00	0.00	.05	.05	0.00	0.00	0.00
Au	.02	.02	.06	0.00	.04	0.00	.05	0.00	0.00	0.00	0.00	0.00
Ag	0.00	.04	.01	.01	0.00	.05	.01	.07	0.00	.03	0.00	0.00
Sb	0.00	0.00	.01	.01	0.00	.02	0.00	0.00	0.00	.04	0.00	.04
S	8.80	8.62	8.79	9.32	8.83	52.71	53.98	52.77	53.02	54.27	53.07	52.80
Ba	58.97	60.68	59.14	60.09	57.04	.05	0.00	0.00	0.00	0.00	0.00	.08
Total	67.82	69.50	68.07	69.53	66.15	52.85	54.47	52.94	53.18	54.40	53.23	53.26

Analysis no	Grain no	Description
95, 97	2 37	Barite, 146-H (anhedral, cloudy, white-gray; l a. = 150 μ m)
96	2 38	Barite, 146-H (anhedral, cloudy, white-gray, l.a. = 200 μ m)
98	2 68	Barite, 267-H (anhedral, cloudy, white-gray; l a. = 250 μ m)
99	2 69	Barite, 267-H (anhedral, cloudy, gray, l a. = 200 μ m)
100	2 49	Pyrite core of goethite pseudomorph, 277-H (cubic form, l.a. = 200 μ m)
101	2 43	Euhedral unoxidized pyrite, 272-H
102	2 55	Pyrite phase in limonite grain, 146-H (brown-yellow-black, anhedral)
103	2 62	Pyrite phase in goethite pseudomorph, 276-H (euhedral grain, l.a. = 200 μ m)
104	2 96	Euhedral unoxidized pyrite, 277 H
105	2 102	Pyrite phase in limonite grain, 29-H (brown black, anhedral; l a. = 300 μ m)
106	2 104	Pyrite phase in limonite grain, 181-H (brown-black, anhedral; l a. = 250 μ m)

Appendix 10 (cont.)

Wt. %	107	108	109	110	111	112	113	114	Wt. %	115	116
FeO	7.53	8.83	7.31	16.15	16.20	9.52	12.72	12.64	FeO	10.56	10.20
Al ₂ O ₃	4.87	5.18	3.89	2.63	2.38	7.52	4.39	4.22	Al ₂ O ₃	24.28	24.47
SiO ₂	48.97	47.74	50.10	52.80	52.88	49.25	52.81	52.85	SiO ₂	37.91	37.79
CaO	22.18	20.54	21.75	.36	.28	5.34	.29	.32	CaO	23.27	22.69
Cr ₂ O ₃	.39	.43	.31	.10	.09	.49	.25	.25	Cr ₂ O ₃	.02	.02
MgO	12.96	13.95	13.80	26.73	27.13	20.55	28.88	28.84	MgO	0.00	.01
MnO	.19	.20	.20	.25	.31	.10	.21	.25	MnO	.12	.12
									OH	3.52	3.50
Total	97.10	96.86	97.35	99.02	99.27	92.77	99.54	99.38	Total	99.68	98.79

No. of ions on the basis of 6 O

No. ions on the basis 15 O

Fe	.24	.29	.23	.49	.49	.30	.38	.38	Fe	.75	.73
Al	.22	.24	.18	.11	.10	.34	.19	.18	Al	2.44	2.47
Si	1.88	1.84	1.91	1.93	1.93	1.89	1.89	1.89	Si	3.23	3.26
Ca	.91	.85	.89	.01	.01	.22	.01	.01	Ca	2.12	2.08
Cr	.01	.01	.01	0.00	0.00	.01	.01	.01	Cr	0.00	0.00
Mg	.74	.80	.78	1.46	1.47	1.17	1.54	1.54	Mg	0.00	0.00
Mn	.01	.01	.01	.01	.01	0.00	.01	.01	Mn	.01	.01
									OH	1.00	1.00
Total	4.01	4.03	4.00	4.01	4.02	3.94	4.02	4.01			

Proportions (%)

Total 9.55 9.53

Wo	47.97	43.70	46.47	.72	.55	12.88	.57	.63	FM Ratio	1.00	1.00
En	39.00	41.31	41.01	73.84	74.12	69.00	79.46	79.44			
Fs	13.03	14.99	12.52	25.44	25.33	18.12	19.97	19.93			
FM Ratio	.25	.27	.23	.26	.26	.21	.20	.20			

Analysis no.	Grain no.	Description
107, 108, 109	3.16	Brown pyroxene
110, 111	2.26	Brown orthopyroxene
112, 113, 114	2.27	Brown orthopyroxene
115, 116	2.13	Yellow frosted epidote coexisting with 1-phase ilmenite grain (Analysis no. 52)

Appendix 11.

Chemical analyses of bedrock samples collected from various formations in the southwestern Gaspésie thesis area.

Rock Type	St. Léon siltstone	Lake Branch sandstone	York River sandstone	Fortin shale	Ste.-Marguerite andesite	White Head siltstone	Grande Grève siltstone
Sample	85-7	85-2	85-3	85-4	85-1	85-5	85-6
Major Elements (%) recalculated to exclude LOI in summation							
SiO ₂	81.23	79.68	76.99	66.67	63.35	61.85	50.25
TiO ₂	.43	.55	.49	.87	1.25	.74	.19
Al ₂ O ₃	8.15	9.54	10.40	15.96	16.99	13.71	4.04
Fe ₂ O ₃	3.16	3.19	3.17	6.72	5.34	5.49	1.84
MgO	1.77	1.23	2.05	2.68	2.14	3.03	4.08
CaO	1.27	.42	1.14	1.74	1.74	9.74	36.97
Na ₂ O	.90	2.31	1.83	1.91	6.83	2.21	.34
K ₂ O	1.94	2.13	2.69	2.99	1.09	2.78	1.01
LOI	2.82	1.89	3.19	4.60	2.83	10.36	25.43
Trace Elements (ppm)							
Ba	124	192	228	248	537	192	226
S	n.d.	n.d.	40	n.d.	n.d.	n.d.	n.d.
Cr	196	111	102	94	n.d.	57	n.d.
Co	13	18	21	15	5	4	n.d.
Ni	31	27	202	78	n.d.	37	n.d.
Cu	124	45	106	78	6	n.d.	n.d.
Zn	60	37	33	84	111	72	23
Nb	12	15	14	18	29	17	10
Zr	386	230	184	221	417	185	63
Y	23	21	22	27	45	29	14
Sr	58	74	71	135	589	199	387
Rb	70	66	72	115	34	101	41
Pb	18	12	16	22	24	21	10
Th	<10	<10	<10	<10	13	11	<10
U	10	<10	<10	<10	16	10	16

Appendix 12

Comparison of trace element analyses of overburden from the regional survey with averages for alluvium (obtained from Choinière, 1982)

Sample Type	Formation or Group	No of Samples	Cu (ppm)		Zn (ppm)		Pb (ppm)		Ni (ppm)		Co (ppm)		U (ppm)	
			Arith Mean	Std Dev	Arith Mean	Std Dev	Arith Mean	Std Dev	Arith Mean	Std Dev	Arith Mean	Std Dev	Arith Mean	Std Dev
Coll	Fortin	27	33	12	69	17	21	3	58	18	19	10	10	1
Diam *	Fortin	10	31	9	73	19	21	1	65	23	11	5	10	2
Alluv	Fortin	1968	13	5	81	33	19	10	35	11	11	4	4	5
Diam *	Gr Grève	14	40	24	70	22	22	4	37	14	8	5	11	2
	Cap Bon Ami													
Alluv	Gr Grève	2730	31	30	100	42	22	8	39	15	20	10	2	2
	Cap Bon Ami													
Diam *	York River	13	33	12	56	17	21	3	49	17	12	9	11	2
	York Lake													
Alluv	York River	1102	9	5	76	32	10	7	40	12	14	5	3	4
	York Lake													
	Lake Branch													

* Diam = Glacial Diamicton

Appendix 13.

Correlation coefficients for log transformed data, NM .MC analyses.

	As	Au	Ba	Co	Cr	Fe	Zn	Hf	Mo	Na	Ni	Sb	Sc	Ta	Th	U	W	La	Ce	Sm	Eu	Yb	Lu
As	1 00																						
Au	201	1 00																					
Ba	361	425	1 00																				
Co	820	271	344	1 00																			
Cr	113	213	145	245	1 00																		
Fe	348-	252-	129	447-	043	1 00																	
Zn	374	437	397	513	294	113	1 00																
Hf	279	354	270	355	761-	130	254	1 00															
Mo	091	303	333	056	175-	291	121	352	1 00														
Na	088	148	150	223	145-	192	202	338	380	1 00													
Ni	408	647	141	522	078	247	525	437	225	720	1 00												
Sb	812	133	318	724	251	249	506	414	180	148	532	1 00											
Sc	130	221	180	338	588	206	269	709	128	232	169	265	1 00										
Ta	086	435	075	075	515-	224	485	485	242	068	279	197	502	1 00									
Th	380	383	317	425	675-	140	295	960	432	392	524	497	623	446	1 00								
U	348	435	315	433	745-	136	374	963	415	383	460	498	624	513	969	1 00							
W	347	355	247	437	481-	125	405	702	340	369	789	519	477	345	725	711	1 00						
La	477	405	356	517	573-	066	312	808	477	389	554	553	553	369	968	925	683	1 00					
Ce	413	360	357	456	582-	074	223	899	474	390	507	505	597	365	957	912	672	968	1 00				
Sm	452	368	354	493	571-	074	301	905	492	412	512	545	591	371	970	924	706	985	970	1 00			
Eu	479	373	375	524	519-	073	285	866	406	391	687	579	570	360	925	887	689	953	932	954	1 00		
Yb	344	332	295	403	644-	110	240	968	401	354	435	466	726	427	964	938	705	930	931	946	913	1 00	
Lu	334	326	281	387	655-	115	223	974	384	358	468	458	724	429	963	940	706	923	922	938	906	996	1 0