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VEIN MINERAL ZONING IN THE MINES GASPE, ORE SYSTEM, GASPE, QUEBEC

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Kirk Stevens

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Kirk Stevens

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ABSTRACT

This report describes regional zoning of major vein minerals in the Mines Gaspé, Quebec, ore system. Vein mineral assemblages were mapped over an approximately 100 km^2 area centred on the Copper and Needle Mountain Cu-Mo deposits, and over a 1 to 2 km vertical interval within and adjacent to these deposits.

Vein mineral zoning relations indicate that Mines Gaspé-related fluid flow occurred within a northwest-trending fracture zone at least 20 km long and at least 12 km wide at its widest point. Veining extends well beyond portions of the system which contain rock alteration detectable either visibly or by illite crystallinity methods. Peripheral veining is therefore a potentially valuable exploration guide for Mines Gaspe'-type ore deposits.

Some Mines Gaspe' zoning trends also occur in hydrothermal systems responsible for deposition of other Gaspesian granite-associated ore-deposits such as the Federal, Candego, and Madeleine mines. These observations suggest that vein mineral zoning could form the basis of a metallogenic model for Gaspesian hydrothermal ore systems.

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CHAPTER 1

INTRODUCTION

Aims of this report

The Les Mines Gaspé Ltée property at Murdochville, Quebec (Fig. 1) contains the most important known Cu-Mo deposits in the Gaspé peninsula. Stockwork and stratiform limestone replacement deposits occur within the 11 km^2 Copper Brook metamorphic aureole. The stockwork and replacement orebodies are estimated to have contained 249 million tonnes grading 0.4% Cu and 0.03% Mo, and 56 million tonnes of 1.2% Cu and 0.03% Mo, respectively.

This report is an investigation of vein mineral assemblages within the Mines Gaspé ore system. Vein mineral zoning data are used to define the major conduits used by the ore-depositing hydrothermal solutions, and thus help to indicate where future exploration efforts might best be directed. Discovery of zoning in peripheral veins beyond the area of visible rock alteration could result in field criteria useful in exploration for buried Mines Gaspé-type ore systems.

The results of this project will also be of use in a longer-term study of vein-mineral zoning in Gaspesian ore-bearing hydrothermal systems, which has been in progress for the past five years. Vein mineral zoning patterns are similar in systems which produced the Federal, Candego, and Madeleine deposits, situated about 50 km west or southwest

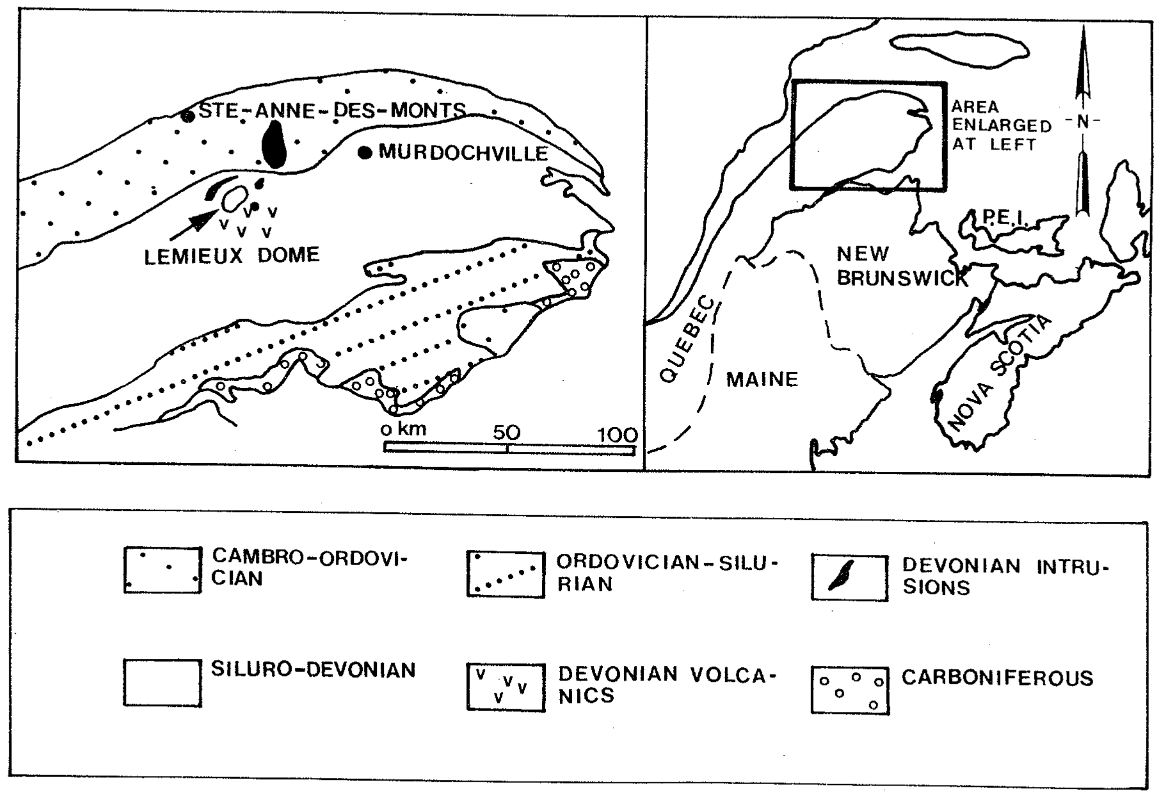

FIGURE 1: Location of Murdochville, Quebec.

of the Mines Gaspé area (Stevens 1986, 1987). Mines Gaspé vein mineral data could therefore contribute to development of a metallogenic model for Gaspesian granite-associated ore deposits, based on regional vein mineral zoning patterns.

The vein mineral data presented in this report were obtained from outcrop or drillcore, examined by the writer or described in publicly available sources such as company assessment work files, government reports, or articles in scientific journals.

Geology of the Mines Gaspé area

The Mines Gaspé area (Fig. 2) is underlain by shallow marine Siluro-Devonian siltstones, silty limestones, limy siltstones, and sandstones. These units were deformed into broad, open, gently-plunging folds with northeast-trending axes, in the late Devonian Acadian orogeny, and subsequently intruded by small Devonian granitic stocks, sills, and dykes. The 10.6 km^2 Copper Brook metamorphic aureole developed in calcareous units on the south limb of the Champou syncline, the most prominent structural feature of the Mines Gaspé area. The aureole is developed asymmetrically about a small granitic stock (0.2 km^2) known as the Copper Mountain plug. Metamorphic isograds delimit phlogopite, tremolite, diopside, and grossularite zones, towards the centre of the aureole. The aureole is easily recognized in the field because removal of carbonaceous matter early during the metamorphism resulted in bleaching

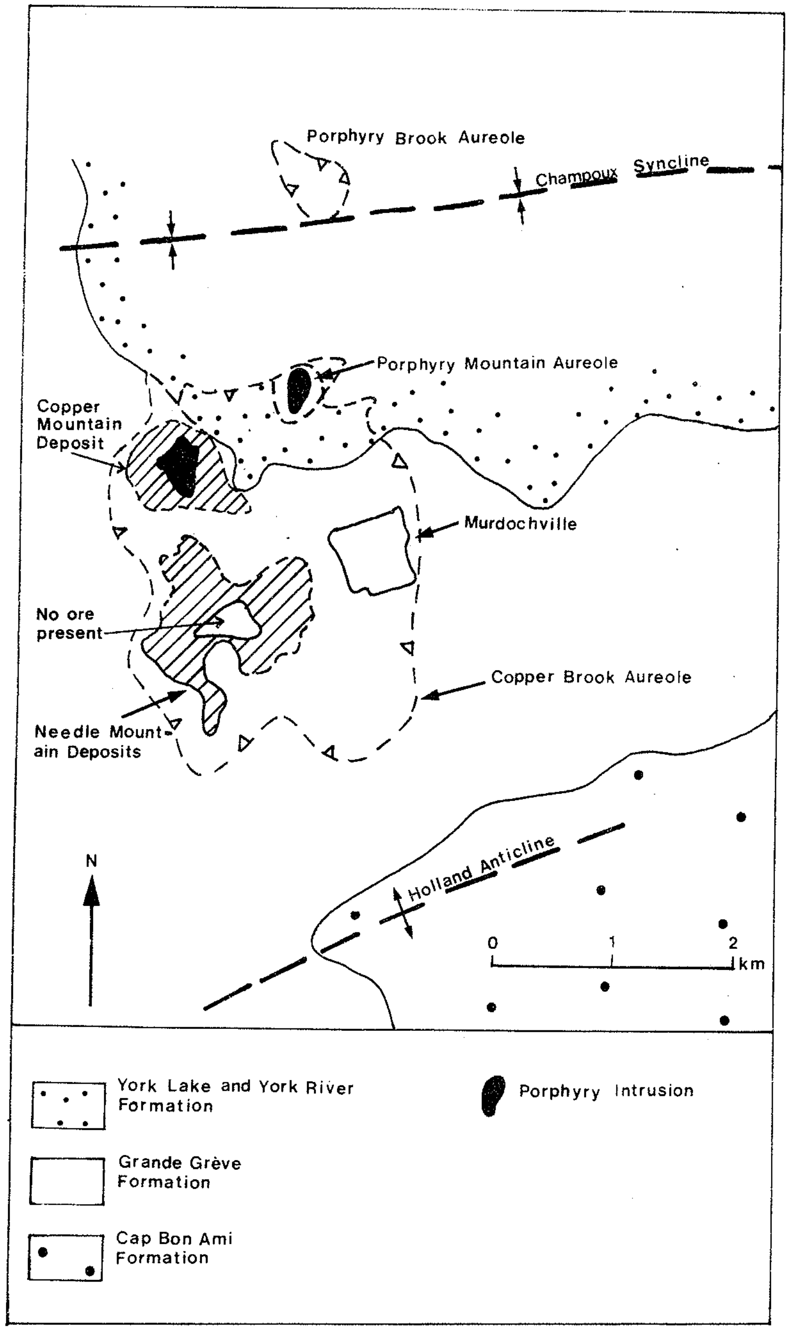

FIGURE 2: Generalized geology of the Mines Gaspé region, after Allcock (1982).

of the affected strata.

The Copper Mountain Cu-Mo deposit formed in the northwest corner of the Copper Brook aureole, and was centred on the Copper Mountain plug. This orebody occurred in a stockwork made up of four distinct vein sets, characterized by quartz-chalcopyrite-anhydrite, quartz-chalcopyrite-molybdenite-pyrite, calcite-quartz-pyrite-chalcopyrite-sphalerite, and calcite-quartz-zeolites-minor sulphides mineralization, respectively. Stratiform bodies of disseminated Cu-Mo mineralization formed in calc-silicate hornfels units near Needle Mountain, 1 to 2 km south of Copper Mountain. Quartz-chalcopyrite-pyrrhotite veins are associated with the stratiform ore deposits.

Two other smaller metamorphic aureoles are known in the Mines Gaspé area: the Porphyry Mountain aureole which completely overlaps a portion of the northern periphery of the Copper Brook aureole, and the Porphyry Brook aureole which occurs 1.5 km north of the Copper Brook aureole. These latter two aureoles contain subeconomic amounts of copper mineralization. For a more detailed account of the Mines Gaspé region geology the reader is referred to Brummer (1966) and Allcock (1982).

CHAPTER 2

VEIN MINERAL ZONING

Introduction

The vein mineral zoning data presented in this section were obtained from 110 cores of holes drilled mainly in or near the Copper Brook and Porphyry Brook aureoles, and 79 outcrop sites situated mainly outside areas of visible rock alteration. Thirty-nine cores and most of the outcrops were examined by the writer; the remaining data were taken from company assessment work files, government reports, or articles in scientific journals. Vein mineral data were collected over a surface area of about 103 km^2 and over a 2000 m vertical elevation interval: from about -1000m to about +1000 m relative to sea level. The surface area surveyed, compared to the Copper Brook aureole area is shown in Fig. 3 and drill hole locations are plotted in Fig. 4. Surface data are shown on Fig. 5; literature data sources are given in the Appendix. Because most literature-described cores are no longer available, the contents of these cores were checked in several localities by logging cores from nearby sites; no major discrepancies were revealed by this verification procedure.

General remarks

Veins in the Mines Gaspé region generally range from a few millimetres to a few centimetres in width; these widths

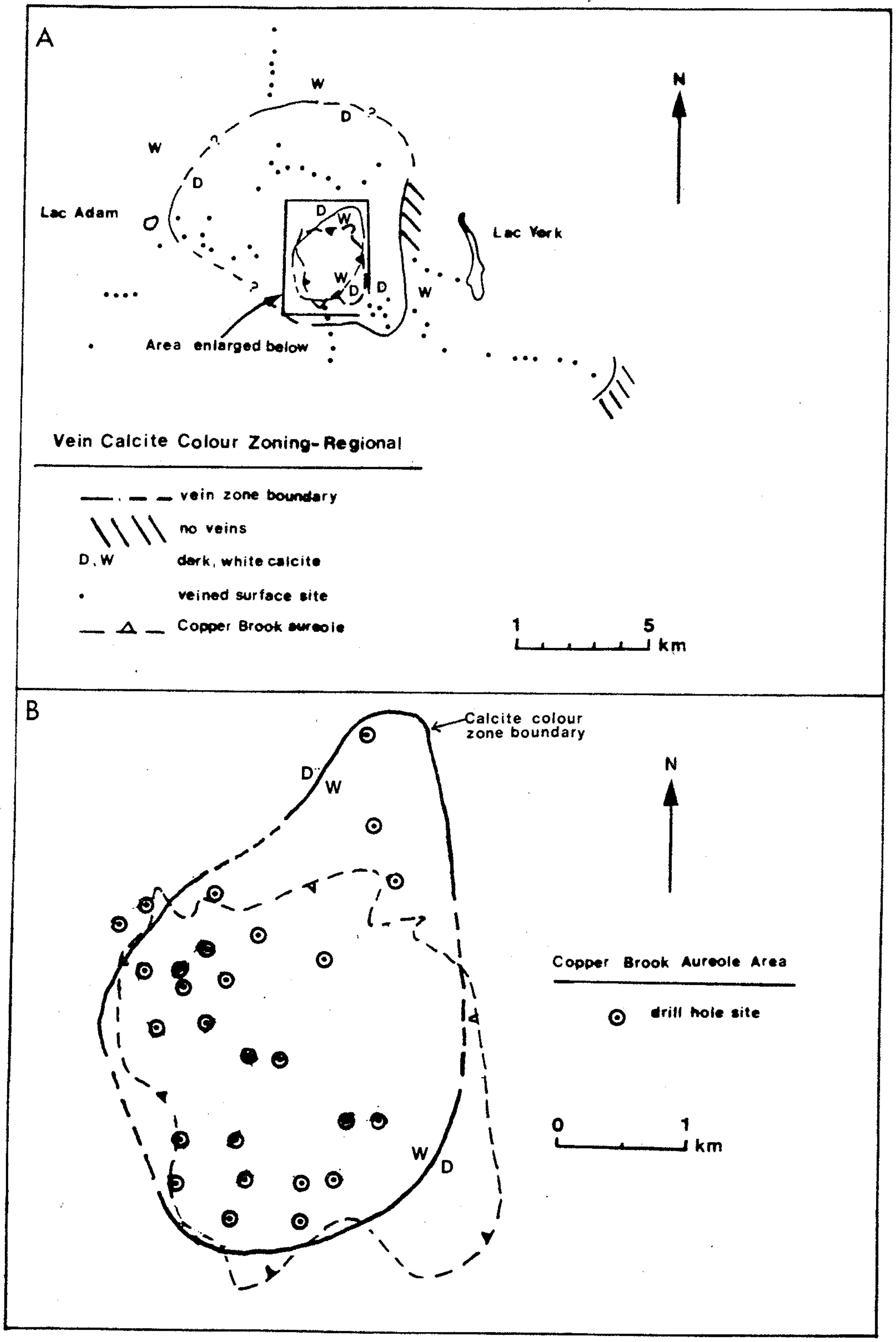

FIGURE 3: 3A: Locations of surface vein data sites outside the Copper Brook aureole area (see also Fig. 5). Surface boundaries between dark and white calcite zones also shown. 3B: Locations of Copper Brook aureole area drill holes for which vein calcite colour data are available. Near-surface vein calcite is white in cores within the W zone, and is mainly dark or a mixture of dark and white in cores from outside this zone.

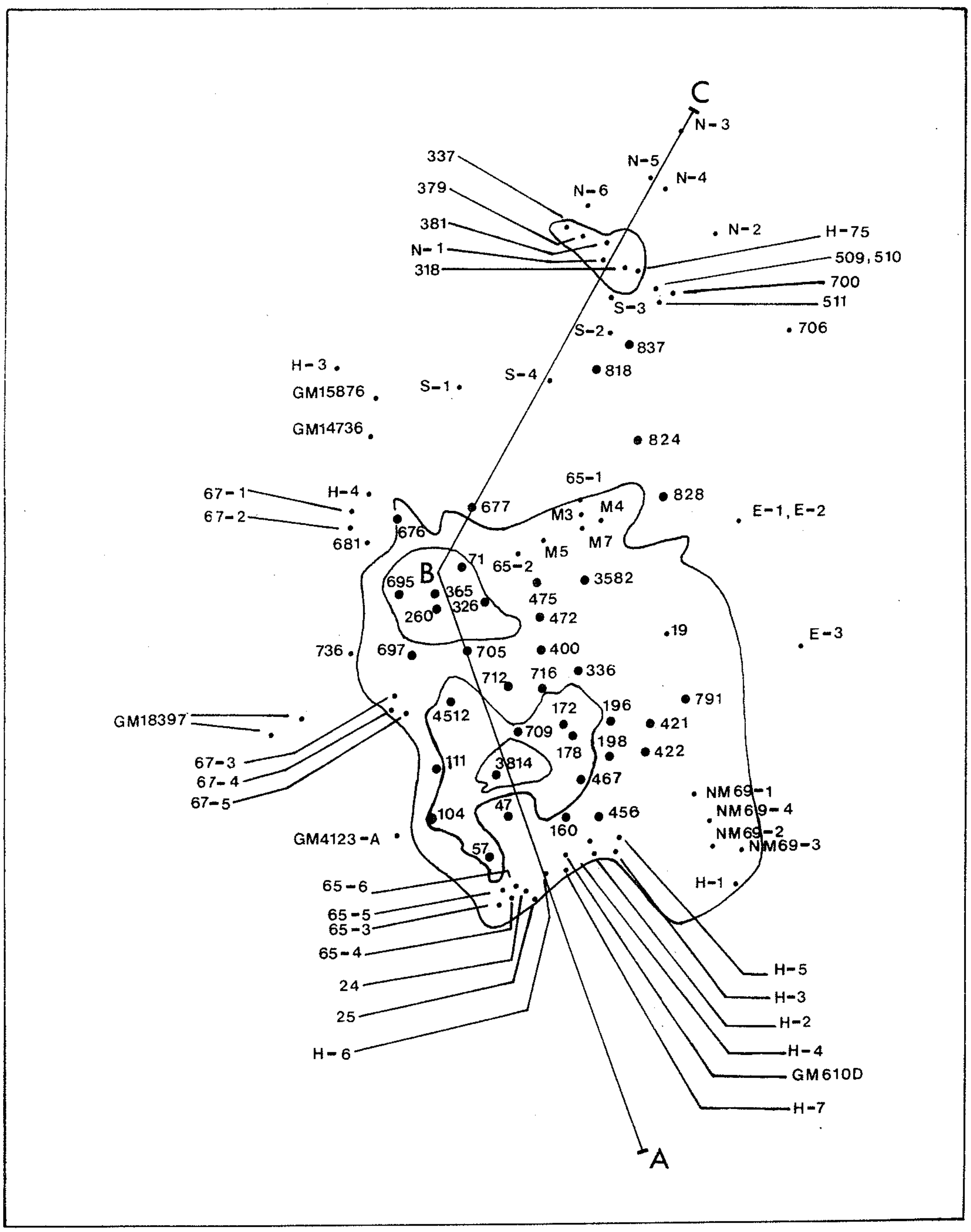

FIGURE 4: Locations of drill holes from which vein mineral information was obtained. Large and small points indicate cores examined by the writer, and described in the literature, respectively. Literature sources are given in the Appendix. ABC is a line along which vertical sections shown in Figs. 6 and 9 were prepared. Copper Brook aureole surface outline included for reference.

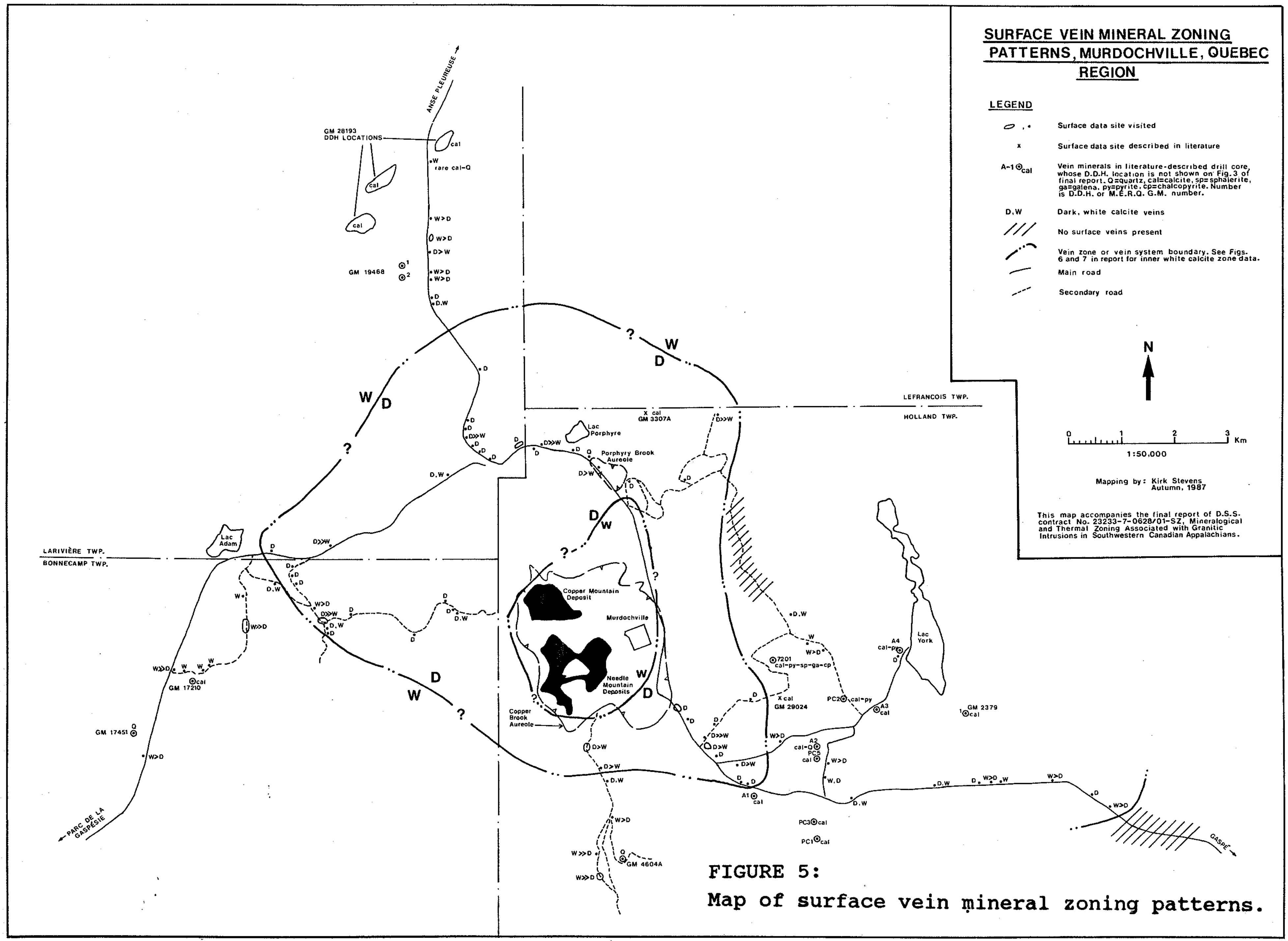

FIGURE 5:
Map of surface vein mineral zoning patterns.

are, on average, greater inside than outside the Copper Brook aureole. Vein abundance is highest within the Copper Brook aureole and decreases away from it, although at different rates in different directions. Vein-filled fractures range from regular to irregular; there is no regional zonation of vein-fracture shapes.

Vein calcite colour zoning

Extent of peripheral calcite veins

Calcite veins are common within and without the Copper Brook aureole; within and near the latter these veins are commonly sulphide-bearing. Outside the Copper Brook aureole calcite veining occurs over relatively long distances in all directions tested except to the east-northeast (Fig. 3,5). To the southwest calcite veining is traceable for 9 km, but is absent from outcrops from 9 to 11 km from the bleached aureole, and from an outcrop selected at random 13 km from the bleached aureole. The preceding observations suggest that the edge of the calcite vein system on the present surface occurs at about 9 km and about 1.5 km from the edge of the bleached aureole to the southeast and east-northeast respectively. To the south the pinching in of the dark calcite zone of the calcite vein system (described below) against the bleached aureole suggests that the southern edge of the calcite vein system on the present surface may lie relatively close to the bleached aureole.

At no other places were possible outer limits of the calcite vein system discovered or inferable. To the north, 8 km of continuous veining is followed by 2 km over which there are no outcrops or debris of local origin. To the west calcite veining is common for about 7.5 km.

Colour zoning

Vein calcite colours are zoned regionally in the horizontal and vertical planes. On or near the surface, white calcite predominates in the Copper Brook aureole area; outside the latter aureole there is a proximal dark calcite and a distal white calcite zone (Fig. 3, 5). In the vertical plane white and dark calcite are most abundant at relatively high and low elevations, respectively (Fig. 6). The colour zoning is described in detail below and commences with the following definitions:

Calcite vein: inside the bleached aureole, a vein in which calcite makes up 15-100% and typically 50-100% of the gangue. Outside the bleached aureole a vein in which the gangue is typically 100% calcite.

Dark calcite vein: contains 50% and typically 80-100% of a variety of dark calcite.

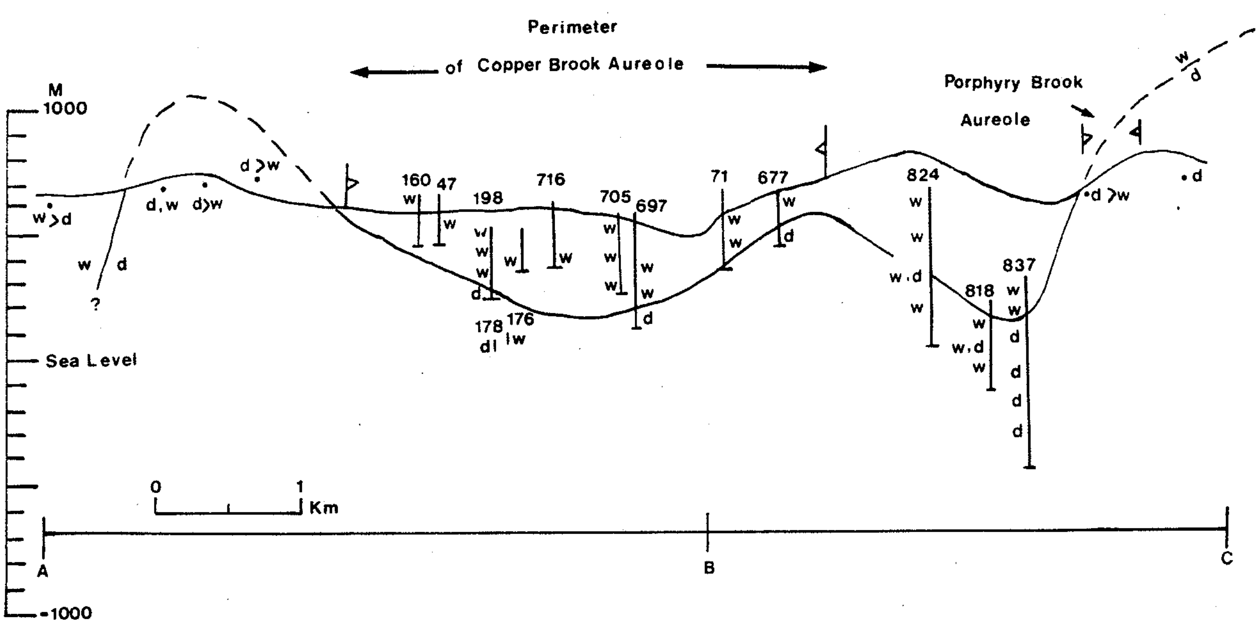

FIGURE 6: Vertical-plane dark/white calcite zoning relations. D, W = dark, white calcite vein occurrences. Numbers are drill hole numbers. See Fig. 3 for location of the line of vertical section ABC on the present surface.

White calcite vein: contains 50% and typically 100% white calcite, inside and outside the bleached aureole respectively.

Dark calcite: calcite exhibiting one of the following colors: pale to dark grey, pale to dark grey-green, dark green, lavender, medium to dark purple, jet black. Overall, dark grey and dark purple varieties are commonest; other colours are common locally.

Drill core calcite colour zoning relations in the Copper Brook aureole area are shown on Figs. 3B and 6. No surface data were collected from this area. See Fig. 4 for the location of the vertical section of Fig. 6 in the horizontal plane.

Fig. 3B shows that near-surface calcite veins are white in most drill core from the Copper Brook aureole area. The only exceptions to this general observation occur at two drill hole locations just outside the northwest periphery of the bleached aureole: near-surface calcite veins in these two cores contain mainly dark, and a mixture of dark and white, calcite respectively. Fig. 6 shows that white calcite predominates at relatively high elevations and dark calcite at relatively low elevations, and that the white-to-dark surface-to-depth transition occurs at different elevations at different points in the horizontal plane. This vertical-plane zone boundary is at relatively low elevations under the central part of the Copper Brook aureole, and rises towards the edge of this aureole. At the south edge of the aureole it reaches the surface to expose the dark calcite zone. To the north the dark-white transition boundary grazes the present surface near the northern perimeter of the Copper Brook aureole. Between this latter point and a point south of the Porphyry Brook aureole, it plunges to approximately the same depth as under the central part of the Copper Brook aureole, before rising steeply to cut the surface at a point immediately south of the Porphyry Brook aureole.

The white-to-dark, surface-to-depth transition occurs gradually: with increasing depth dark calcite becomes increasingly abundant, as dark calcite veinlets or as increasing percentages of white calcite veinlets. White calcite veinlet widths vary from 1 to 10 mm and average 1 to 3 mm; dark calcite veinlets range from 1 to 40 mm wide with the widest veinlets occurring the furthest away from the overlying white calcite zone.

Starting from 0.5 to 1.0 km outside the bleached aureole, dark calcite predominates at veined surface sites relatively near to the bleached aureole whereas veined sites situated distal to the latter contain mainly white calcite (Fig. 3A, 5). The outer limit of the dark calcite zone of the calcite vein system occurs at about 4.5 km from the bleached aureole to the north, northwest, and west. To the south, southeast, and east this distance is 1, 2, and 1.5 km respectively. The location of the dark calcite-outer white calcite zone boundary remains hypothetical to the northeast and southwest. Bush roads are present over much of the unsurveyed region; the shape of the calcite vein system and its zones could be refined by additional fieldwork.

Within the dark calcite zone calcite veins contain only or mainly dark calcite; white-only calcite veins are very rare. Calcite vein thicknesses in this zone are 1 mm to 10 cm and average 1 to 10 mm. Dark calcite vein widths are greatest towards the bleached aureole and diminish away from it. Towards the outer edge of the dark calcite zone, dark calcite veins are typically 1 mm wide and remain so into the outer white calcite zone.

The beginning of the outer white calcite zone is marked by the appearance of white-only calcite veins which commonly attain widths of several centimetres and which increase in abundance away from the bleached aureole. In some directions the white calcite content of dark calcite veins increases away from the bleached aureole. North and southeast of the bleached aureole dark calcite veins are fairly common in the outer white calcite zone but are thinner and less numerous than white-only calcite veins. To the east and west dark calcite veins disappear relatively close to the bleached aureole; however small amounts of dark calcite are fairly common in white calcite veins of the outer white calcite aureole. Rare sites at which vein calcite is mainly or only dark do occur in the outer white calcite zone. To the north and southeast of the bleached aureole the widest white calcite veins are commonly localized along near-vertical joint planes at high angles to bedding, whereas to the east and west white calcite veins occupy irregularly-shaped fractures and are less obviously associated with joint or bedding planes.

Sulphides are common in white calcite veins in the Copper Brook aureole area, and are rare in dark calcite veins.

Calcite/quartz zoning

Horizontal-plane variations in drill core vein calcite/quartz proportions are shown in Fig. 7 for the area containing the Copper Brook and Porphyry Brook aureoles. The calcite/quartz proportion is reported as a percent calcite in the calcite-quartz portion of veins, based on the relative volumes of these minerals present at each drill hole site. Because quartz and calcite are the most abundant vein gangue minerals, Fig. 7 essentially shows vein gangue mineral zoning patterns.

The most prominent feature of Fig. 7 is a 5 km x 2 km, north-trending zone in which vein gangue calcite abundance is 0 to 89%. This 0-89% zone overlaps most of the Copper

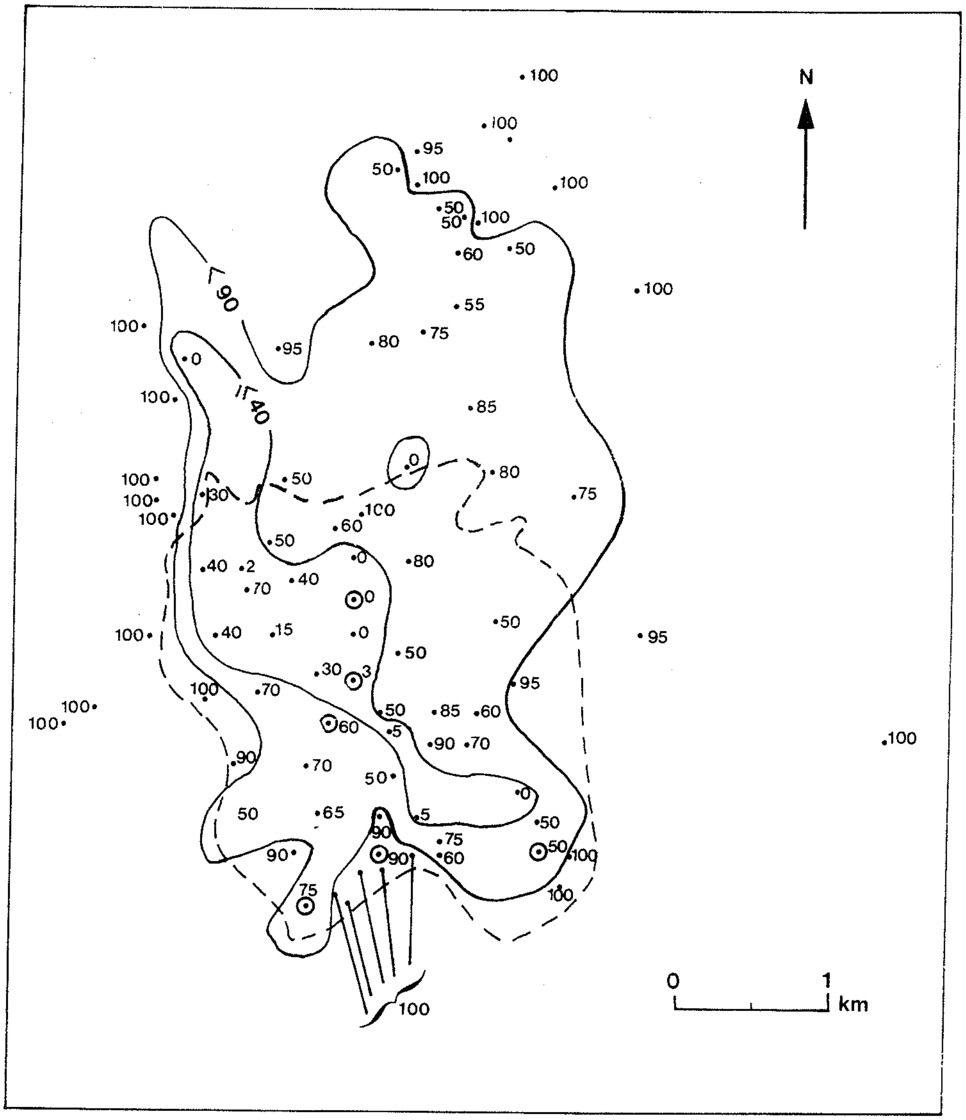

FIGURE 7: Horizontal-plane zoning of drill core vein calcite/ quartz proportions. Copper Brook aureole surface outline included for reference. Circled points indicate calc-silicate vein-bearing drill hole locations.

Brook aureole and continues for about 2 km northward. Within the 0-89% zone vein calcite abundances with respect to quartz are 0 to 40% in a 3.5 km x 0.5 km, northwest-trending zone, extending from the southeast corner, to about a kilometre beyond the northwest edge, of the bleached aureole. This 0-40% zone is widest in the vicinity of the Copper Mountain orebody. Zones in which calcite/quartz proportions are about 50% occur adjacent to the 0-40% zone, and in the Porphyry Brook aureole area. Outside the 0-89% zone calcite is essentially the only major vein gangue mineral; calcite/quartz proportions in this region are 90%, and typically 100%. Calcite-quartz proportions are not zoned vertically in the elevation interval tested.

Sites at which calc-silicate mineral veins were encountered are also shown on Fig. 7; these sites only occur within the Copper Brook aureole.

Pyrite/pyrrhotite zoning

Zoning of pyrite and pyrrhotite abundances in the horizontal plane for drill core veins in the Copper Brook and Porphyry Brook aureole region, is shown on Fig. 8.

There are two zones in which pyrrhotite has an abundance equal to or greater than that of pyrite: one zone overlaps the southern half of the Copper Brook aureole; the other extends from the northern edge of the Copper Brook aureole to the Porphyry Brook aureole area. The southern zone

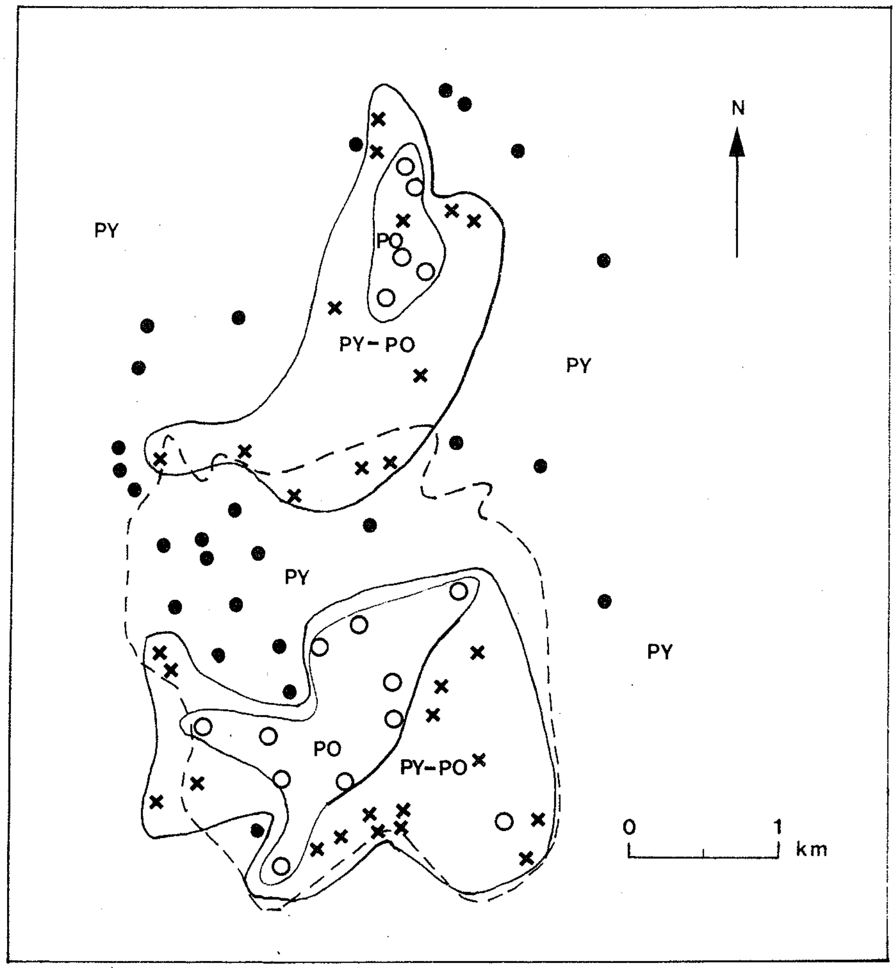

FIGURE 8: Distribution of vein pyrite and vein pyrrhotite in the horizontal plane. Symbol locations are drill hole locations. Open circles indicate that pyrrhotite is the dominant Fe-sulphide present, crosses that pyrite and pyrrhotite have approximately equal abundances, and solid circles that pyrite is the dominant Fe-sulphide present. Copper Brook aureole surface outline included for reference.

comprises a core subzone in which pyrrhotite is almost the only vein Fe-sulphide present, and a peripheral subzone in which pyrrhotite and pyrite abundances are approximately equal. The northern pyrrhotite-bearing vein zone has a pyrrhotite-dominant subzone near the Porphyry Brook aureole. Outside these two pyrrhotite-bearing vein zones pyrite is the main Fe-sulphide mineral present in veins.

The two pyrrhotite-bearing vein zones probably merge at depth at a point below the Copper Mountain orebody (Fig. 9). Vertical-plane data also indicate the existence of a pyrite-rich lens within the northern pyrrhotite-bearing vein zone, immediately north of the Copper Brook aureole.

Distribution of chalcopyrite, sphalerite, galena, and molybdenite

Zones of common occurrence of chalcopyrite, and sphalerite and/or galena, in drill core veins in the horizontal plane in the Copper Brook and Porphyry Brook aureole area, are shown on Fig. 10. Holes in which vein molybdenite occurs are also indicated.

Chalcopyrite is the most abundant ore sulphide in a circular area whose outer limit lies just within the boundary of the Copper Brook aureole. Outside of this chalcopyrite zone, sphalerite and/or galena are as common as chalcopyrite, or occur without chalcopyrite, in holes drilled near the perimeter of the Copper Brook aureole; an exception to this pattern occurs at the southwest perimeter

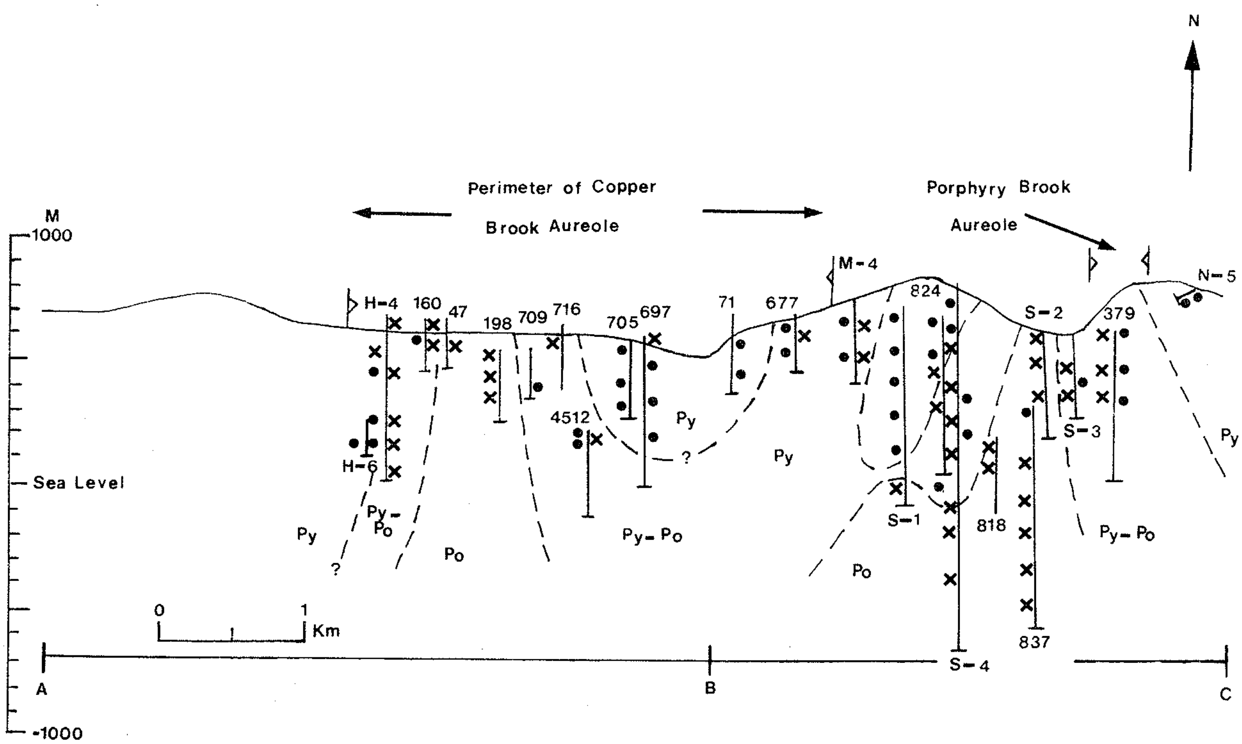

FIGURE 9: Distribution of vein pyrite (solid circles) and vein pyrrhotite(X) in the vertical plane along cross-section line ABC, whose location in the horizontal plane is shown on Fig. 4. Numbers are drill hole numbers.

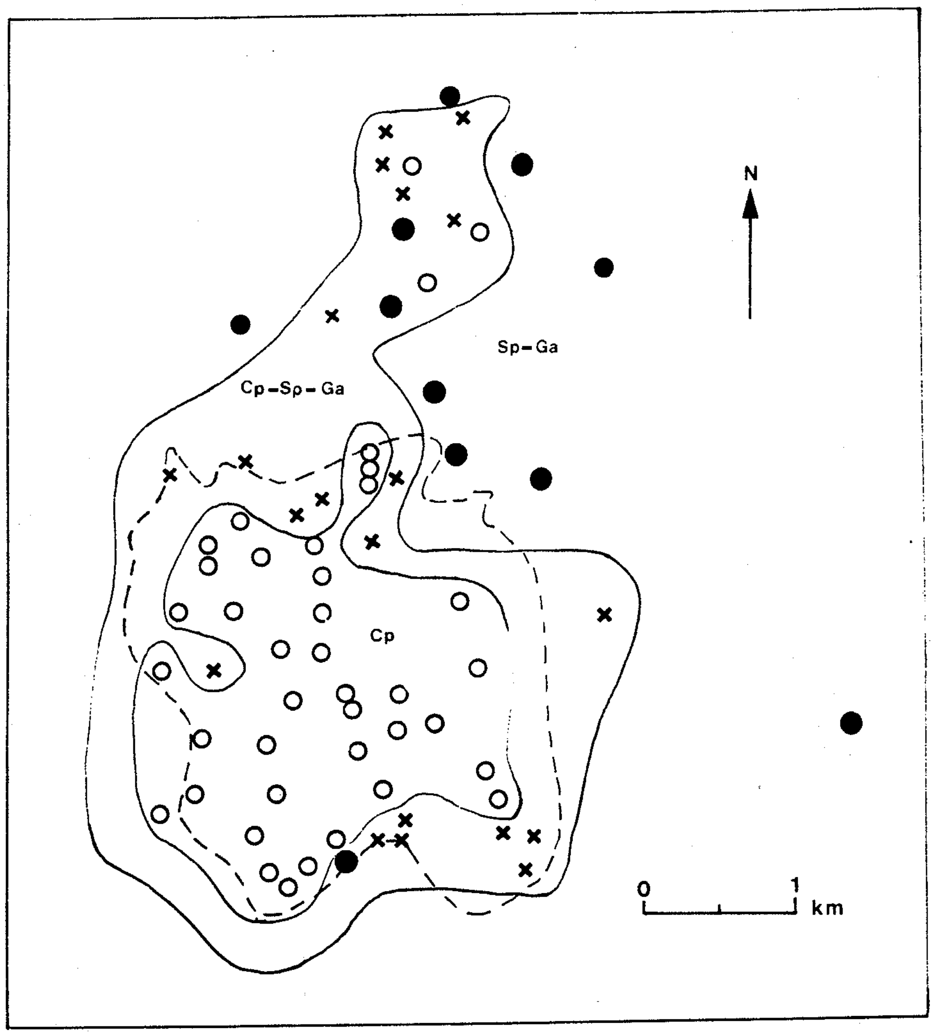

FIGURE 10: Distribution of common chalcopyrite, sphalerite, galena, and molybdenite in drill core veins, in the horizontal plane. Symbol locations indicate drill hole locations. Open circles indicate holes in which chalcopyrite is the dominant vein ore-sulphide. Crosses indicate holes in which chalcopyrite, and sphalerite and/or galena, have approximately equal abundances in veins. Solid circles indicate holes in which sphalerite and/or galena are the main vein ore-sulphides. M indicates holes in which vein molybdenite occurs. Cp = chalcopyrite zone, cp-sp-ga = chalcopyrite-sphalerite-galena zone, sphalerite-galena zone. Copper Brook aureole surface outline shown for reference.

of the Copper Brook aureole, where sphalerite and galena are absent and chalcopyrite is common.

Chalcopyrite, sphalerite, and galena have approximately equal abundances in the Porphyry Brook aureole area; this latter area may constitute a northward extension of the Copper Brook aureole chalcopyrite-sphalerite-galena zone. There is a poorly-defined chalcopyrite-rich subzone within the Porphyry Brook chalcopyrite-sphalerite-galena zone.

Sphalerite and/or galena are the main ore sulphides present in many holes drilled north of the Copper Brook aureole and in one hole situated east of the Copper Brook aureole. This sphalerite-galena zone partly overlaps the Porphyry Brook chalcopyrite-sphalerite-galena zone.

Occurrences of vein molybdenite are restricted to within and adjacent to the Copper Mountain orebody, and at Porphyry Mountain in the northeast corner of the Copper Brook aureole.

No vertical zoning relations are present among the minerals chalcopyrite, sphalerite, galena, and molybdenite, or between these minerals and pyrite and pyrrhotite, in the elevation interval examined in this investigation.

Vein type zoning

Veins of the Mines Gaspé ore system can be divided into three groups: Cu-Fe±quartz (Cu-Fe±Q), Zn-Pb±quartz (Zn-Pb±Q), and carbonate±sulphide veins; these vein-types form zones shown in Fig. 11. Cu-Fe±Q veins are

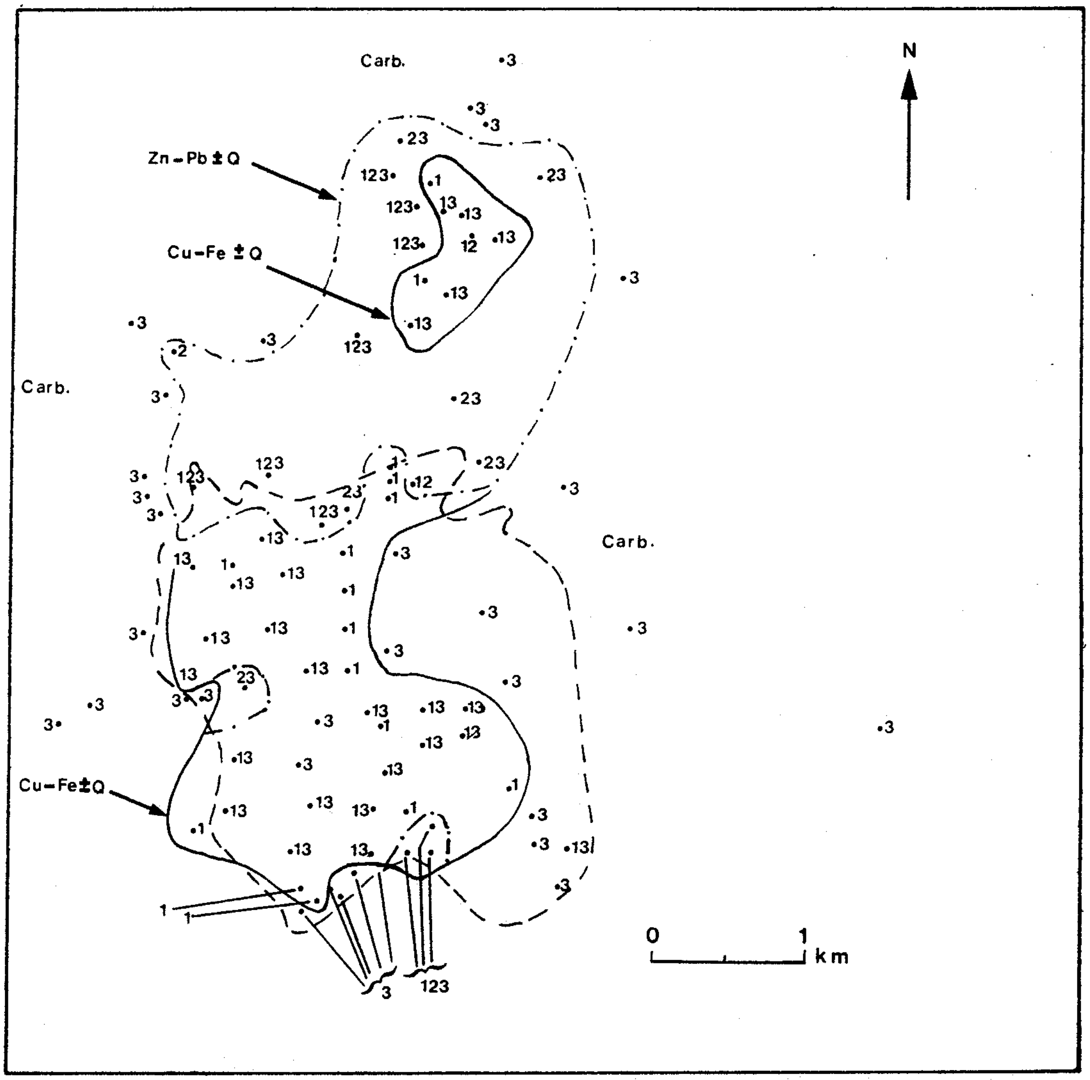

FIGURE 11: Distribution in horizontal plane of Cu-Fe+Q (1), Zn-Pb+Q (2), and carbonates+sulphides (3) veins in drill core. See text for definitions of these vein types. Copper Brook aureole surface outline included for reference.

characterized by common Cu-Fe- and/or Fe-sulphides with or without quartz; Mo is present locally. Up to 15% carbonate minerals can be present in the (quartz±carbonate) portion of a Cu-Fe±Q vein. Zn-Pb±Q veins contain sphalerite and/or galena, with or without quartz; Cu-Fe and/or Fe-sulphides are also common. Up to 15% carbonate minerals can be present in the (quartz+carbonates) portion of a Zn-Pb±Q vein. Carbonate±sulphide veins contain carbonate minerals, 0 to 84% quartz in the (carbonate+quartz) portion of the vein, and may contain various sulphide minerals.

Cu-Fe±Q, Zn-Pb±Q, and carbonate±sulphide vein zones occur in vein systems which host other Gaspesian granite-associated deposits such as the Federal, Candego, and Madeleine deposits (Stevens, 1986, 1987).

Vein-type zoning provides a basis for comparing different ore-forming hydrothermal systems, as do the other vein mineral zoning relations presented in this report. There are two main concentrations of Cu-Fe±Q veins in the Mines Gaspé system: in the western three-fourths of the Copper Brook aureole, and in the Porphyry Brook aureole area. Zn-Pb±Q veins are widespread between the northern perimeter of the Copper Brook aureole, and the Porphyry Brook aureole area. Isolated holes in which Zn-Pb±Q veins are common were drilled just inside the western and southern periphery of the Copper Brook aureole. Carbonate±sulphide veins are common within and outside the Cu-Fe±Q and Zn-Pb±Q vein zones; sulphide-bearing carbonate±sulphide veins are restricted to within and relatively short distances outside the Cu-Fe±Q and Zn-Pb±Q vein zones.

There is no vertical-plane zoning displayed by these vein types in the elevation interval surveyed.

CHAPTER 3

DISCUSSION

Structural control on fluid flow

The area over which calcite veins occur, the known boundaries of the calcite vein system on the present surface, and calcite colour zoning relations indicate that Mines Gaspé-related hydrothermal fluid flow occurred within a northwest-trending fracture zone at least 20 km long and with a maximum width of at least 12 km (Fig. 3). The northwest orientation of the fracture system is also indicated by the shape of the dark calcite zone on the present surface (Fig. 3) and is strongly suggested by the shape of the illite crystallinity thermal aureole mapped by Williams-Jones (1986). The areas occupied by the dark calcite zone on the present surface and the illite crystallinity aureole are compared in Fig. 12; the significance of the illite crystallinity data with respect to the vein mapping results is discussed later in this report.

Calcite/quartz, pyrite/pyrrhotite, chalcopyrite-sphalerite-galena, and vein type zoning patterns in the area containing the Copper Brook and Porphyry Brook aureoles indicate that north- to north-northeast-trending fractures guided fluid flow in this part of the hydrothermal system (Figs. 7, 8, 9, 10, 11). These vein mineral zoning patterns

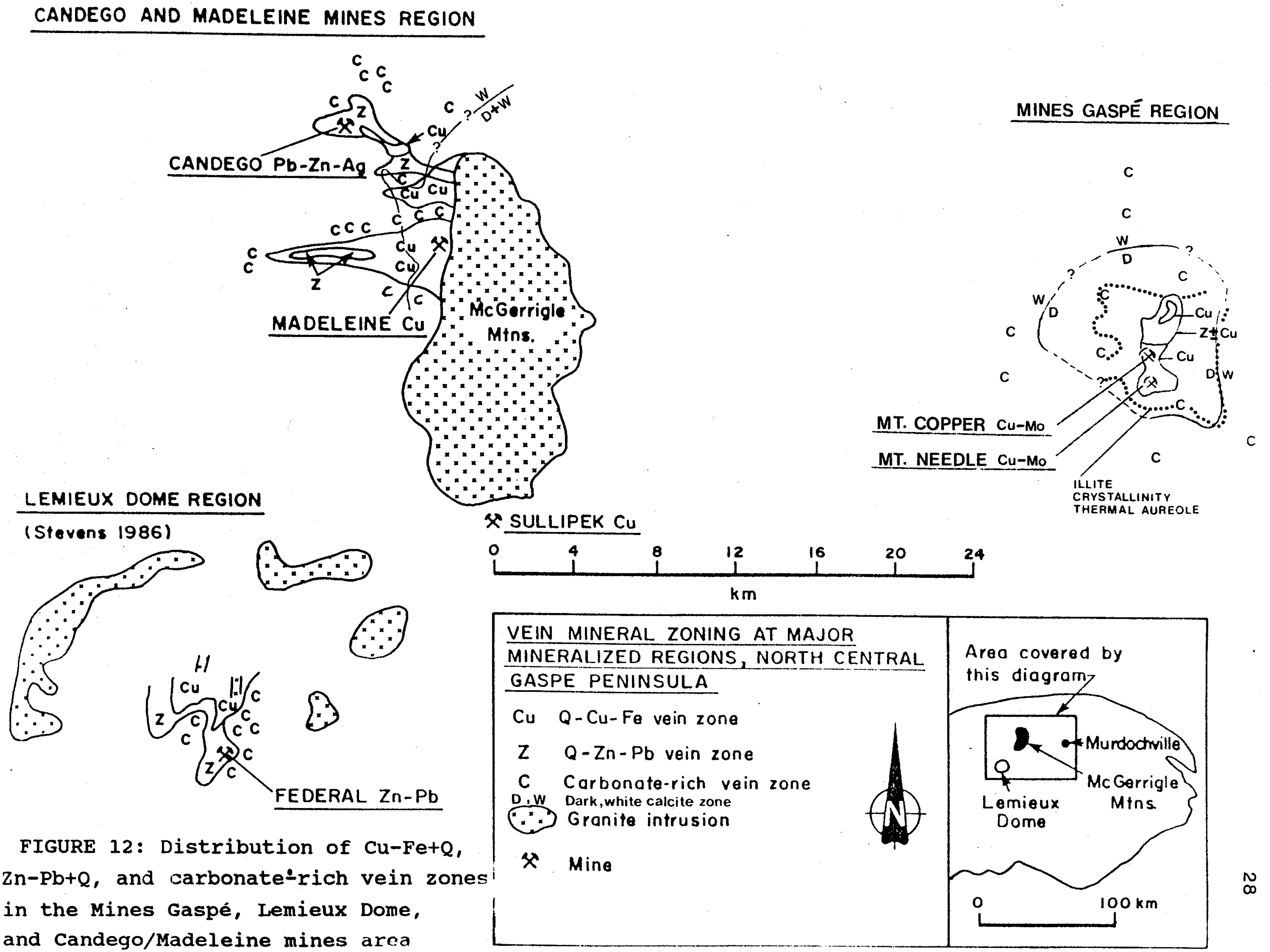

FIGURE 12: Distribution of Cu-Fe+Q, Zn-Pb+Q, and carbonate-rich vein zones in the Mines Gaspé, Lemieux Dome, and Candego/Madeleine mines area hydrothermal systems.

converge on local centres, which occur within the Copper Brook aureole, and within or near the Porphyry Brook aureole, respectively. The shapes of these local centres are different on different figures. For example, on the calcite/quartz diagram (Fig. 7) we see northwest-trending quartz-rich vein zones centred on the Copper Mountain orebody and the Porphyry Brook aureole, whereas on the chalcopyrite-sphalerite-galena diagram (Fig. 10) there is a circular convergence pattern on the Copper Brook aureole and, to a lesser extent, on the Porphyry Brook aureole. The preceding observations suggest that the north- to north-northeast-trending fractures at the centre of the Mines Gaspé ore system comprised permeable chimneys separated by intervals of relatively tight fractures. The observation that different mineral zoning patterns converge on different geographic localities or have different shapes may reflect different fracture geometry during different mineral-depositing episodes.

Comparison of areal extents of veining and wallrock alteration on the present surface

The vein calcite colour zoning pattern centred on the Copper Brook aureole and the gradational boundaries between dark and white calcite zones would seem to indicate that deposition of these veins was genetically related to ore-forming events within the aureole of visible rock bleaching. The 103 km^2 over which calcite veins occur could well be increased by fifty percent upon completion of vein mapping in the outer portions of the vein system. The calcite vein system therefore has a surface plan at least ten times greater than that occupied by the Copper Brook aureole - 10.6 km^2. The Williams-Jones (1986) illite crystallinity aureole, whose outline is shown on Fig. 12, delimits a zone of low-grade clay mineral alteration invisible to the naked eye, and can be considered the outer limit of detectable wallrock alteration caused by the Mines Gaspé hydrothermal system. Even this thermal front falls well within the known veined area. The large area of veining compared to the relatively small region containing altered wallrocks could be explained if near the periphery of the vein system, fluid temperatures and/or fluid:rock ratios eventually decreased to the point where essentially no heat exchange or chemical reaction occurred between solutions and host rocks; under these conditions vein deposition could continue with no accompanying wallrock alteration.

The results of this investigation suggest that peripheral vein mapping is potentially of great value in exploration for Mines Gaspé-type deposits, especially deeply-buried ones. Chemical and fluid inclusion studies of peripheral veins may increase the usefulness of this promising technique.

Comparison of vein mineral zoning in different Gaspesian granite-associated hydrothermal systems

Cu-Fe±Q, Zn-Pb±Q, and carbonate-rich vein zones in the Mines Gaspé, Lemieux Dome, and Candego and Madeleine mines regions are shown on Fig. 12. Vein type zoning data of Fig. 12 from the Lemieux Dome and Candego and Madeleine mines areas are taken from Stevens (1986) and (1987), respectively.

Fig. 12 also shows vein calcite colour zoning data from the Mines Gaspé, and Candego and Madeleine mines areas. The dark/white calcite zoning in the latter areas is reported for the first time in this report. Its presence was revealed by a review of vein mineral zoning data collected from the Candego and Madeleine mines area, in the light of the calcite colour zoning results of the present investigation. Vein calcite colour zoning has not been mapped in as much detail at the Candego and Madeleine mines area as at Mines Gaspé; however zones in which vein calcite is dark or white, and mainly white, respectively, are recognized.

Cu-Fe±Q, Zn-Pb±Q, and carbonate-rich vein zones are present and have similar relative positions at all three of the areas of Fig. 12. Calcite colour zoning is present in the Mines Gaspé, and Candego and Madeleine mines area vein systems; it has not been searched for at the Lemieux Dome. Calcite/quartz proportion zoning, not shown on Fig. 12, is present in all three areas, although developed to different degrees at different areas. Zoning patterns of individual minerals other than quartz and calcite are different in different regions.

The fact that several large-scale vein mineral zoning trends are common to these areas suggests strongly that the same type of hydrothermal system operated at each region. Differences in the shapes or sizes of zones found in all three regions can be ascribed to factors such as different erosion levels, orientations in space, metal or mineral abundances, or degrees of telescoping of zones, of hydrothermal systems in different localities. For example, comparison of vein type and calcite colour zone shapes in the Mines Gaspé, and Candego and Madeleine mines areas, suggests that zoning developed vertically to a much greater extent in the former than in the latter area. Zn-Pb±Q veins are small and relatively rare in the Mines Gaspé and Madeleine mines areas, whereas these veins are large and abundant in the Lemieux Dome and Candego areas. These observations may reflect, at least in part, lower Zn-Pb abundances in the former two than in the latter two systems. It is clear that vein mineral zoning can be used as a basis for comparing features of different mineralized regions, and thus as the basis for a metallogenic model for Gaspesian granite-associated ore deposits. The idea of describing Gaspesian hydrothermal ore systems in terms of Cu-Fe±Q, Zn-Pb±Q, and carbonate-rich vein zones is analogous to Lowell and Guilbert's (1970) division of porphyry copper ore systems into potassic, phyllic, and propylitic zones. In each case hydrothermal systems are broken down into domains or facies which are associated with or which may help to point the way to specific ore deposit types. In the Lowell and Guilbert porphyry copper model Cu±Mo and Zn-Pb±precious metal deposits occur in the potassic and propylitic alteration zones, respectively; in the Gaspesian hydrothermal ore system model Cu±Mo and Zn±Pb+precious metal deposits occur in Cu-Fe±Q and Zn-Pb±Q vein zones, respectively. In some porphyry copper systems a particular alteration zone may be weakly developed, however its mere presence helps to identify the system as belonging to the porphyry copper family of deposits. An analogous statement can be made concerning the degree of development of a particular vein mineral zone in a given Gaspesian mineralized region.

Given the Cu±Fe to Zn±Pb core to periphery metal zoning reported in many porphyry copper system studies, and the association of these systems with granitic intrusions, it seems probable that these systems are closely related to Gaspesian granite-associated ore systems. Vein mineral studies of some porphyry copper districts would be a relatively easy way to investigate this hypothesis.

CHAPTER 4

CONCLUSIONS

The conclusions of this report are:

1) Vein mineral zoning relations indicate that Mines Gaspé-related fluid flow occurred within a northwest-trending fracture zone at least 20 km long and at least 12 km wide at its widest point.

2) Veining extends well beyond portions of the system which contain rock alteration detectable visibly or by illite crystallinity methods. Veins on the extreme periphery of ore systems therefore have considerable potential as guides to undiscovered ore deposits.

3) Certain vein mineral zoning trends at the Mines Gaspé region also occur in hydrothermal systems responsible for deposition of other Gaspesian granite-associated ore deposits such as the Federal, Candego, and Madeleine mines. These observations suggest that vein mineral zoning could form the basis of a metallogenic model for Gaspesian hydrothermal ore systems.

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REFERENCES

Allcock, J.B., 1982, Skarn and porphyry copper mineralization at Mines Gaspé, Murdochville, Quebec: Econ. Geol., v. 77, p. 971-999.

Brummer, J.J., 1966, Northwest quarter of Holland township, Gaspé-North county, Quebec: Dept. of Natural Resources Geol. Rept. 125, 95 p.

Lowell, J.D. and Guilbert, J.M., 1970, Lateral and vertical alteration-mineralization zoning in porphyry ore deposits: Econ. Geol., v. 65, p. 373-408.

Stevens, K., 1986, Fluid inclusion and geological studies on the Zn-Pb-Cu vein system at Lemieux Dome, Gaspé, Québec: unpub. M.Sc. thesis, McGill University, 150 p.

Stevens, K., 1987, Mineral zoning and fluid inclusion studies in the Candego/Madeleine mines area, Gaspé, Quebec: Geol. Surv. Can. Open File Rept. 1407, 73 p.

Williams-Jones, A.E., 1986, Low-temperature metamorphism of the rocks surrounding Les Mines Gaspé, Quebec: implications for mineral exploration: Econ. Geol., v. 81, p. 466-470.

APPENDIX

LITERATURE-DESCRIBED

VEIN MINERAL DATA SOURCES

The following table identifies M.E.R.Q. G.M. documents from which drill hole vein mineral data were obtained for this report. Holes indicated by a parenthesized M are located on Fig. 5 accompanying this report; all others are located on Fig. 4.

Hole No.	M.E.R.Q. G.M. No.
337	13166
379,381	15910
318	11064
N1 to N6	1759D
H-75-1	31726
509,510,511	25884
700	33691
51,52,53	3501B
54	27949
61-1	17567
65-3,-4,-5,-6	18792,17915
M3,M4,M5,M7	648
E1 to E3	1759E
19	19422,25407
69-1,-2,-3,-4	25407
H1,H2,H3	1611B
H4 to H7	5145A
24,25	5145B

Hole No.	M.E.R.Q. G.M. No.
67-3,-4,-5	20630
736	31483
61-1,-2	21309
2,H-3*,H-4*	15876
A1 to A4(M)	1603B
PC-1(M)	758, 4029A,B,C,D
PC-2(M)	23991
PC-3(M)	24010
PC-5(M)	19169
7201(M)	29024

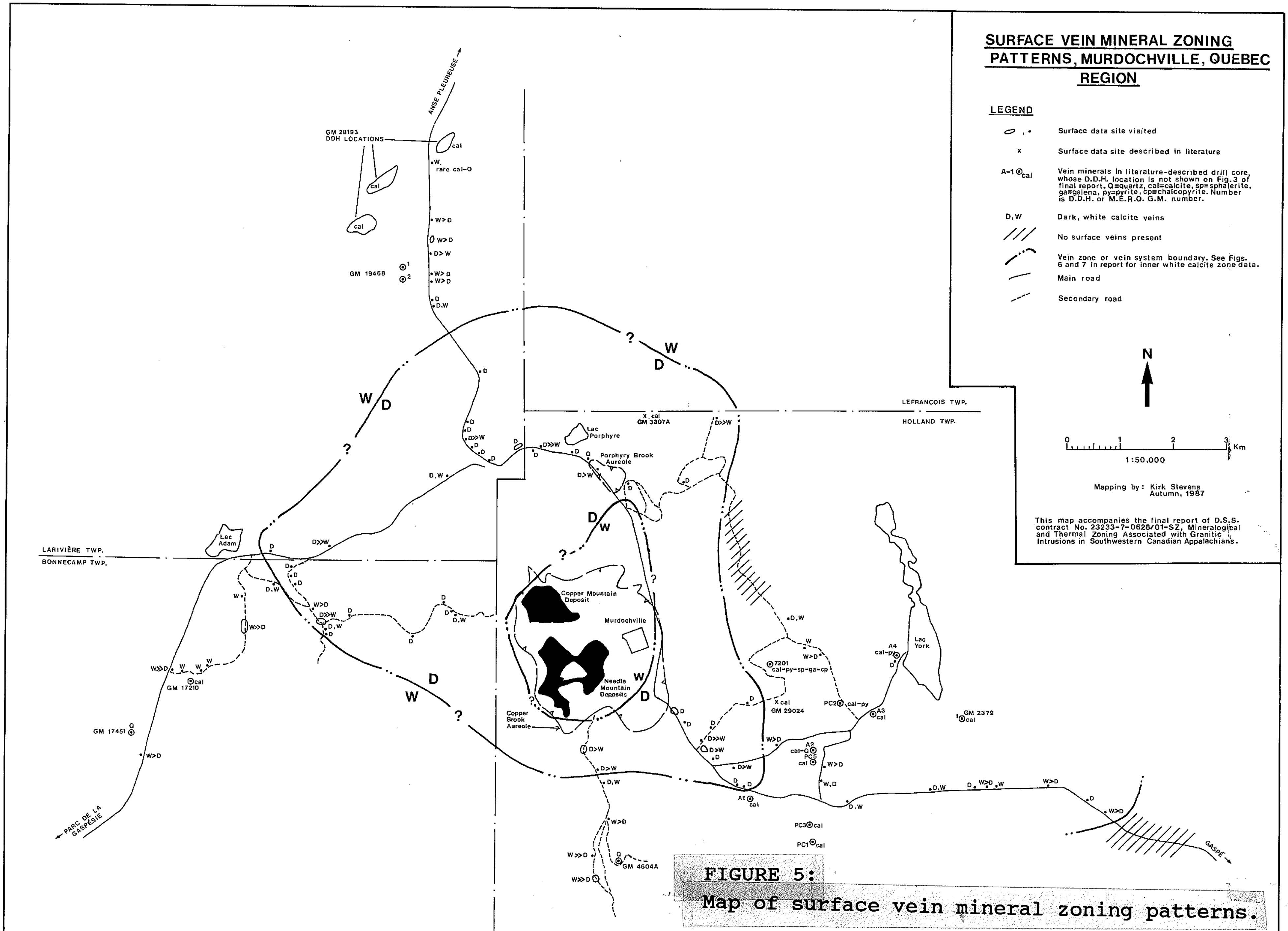

FIGURE 5:
Map of surface vein mineral zoning patterns.