GEOLOGICAL SURVEY OF CANADA

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FLUID FLOW AND MINERAL DEPOSITION NORTHWEST OF THE McGERRIGLE GRANITIC PLUTON, CENTRAL GASPÉ REGION, QUEBEC

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Canada

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Contribution to the "Plan de development économique
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ABSTRACT

The Candego and Madeleine mines are the richest portions of an 80 km^2 vein system hosted by sedimentary rocks immediately northwest of the McGerrigle Mountains granitic complex. The principal aim of this investigation was to delineate the most important fluid conduits utilized by vein-depositing fluids by mapping regional zoning patterns of the vein mineral assemblages, and regional zoning patterns of vein quartz fluid inclusion homogenization and melting temperatures. To test whether quartz-depositing fluids also deposited other minerals, fluid inclusion data were compared from quartz and either sphalerite or calcite from selected sites.

The most important conclusions of this investigation are: 1) regional heat sources in or below the McGerrigle Mountains area caused flow of vein depositing fluids to be localized along major fracture zones oriented approximately perpendicular to the strike of the McGerrigle Mountains, 2) vein-deposition was accomplished in two major episodes characterized by the flow of $CO_2 \pm CH_4$-rich and H_2O-rich fluids respectively, 3) regional fluid conduits, identified through the use of mineral and fluid inclusion mapping techniques, were important loci of ore-deposition in the present study area, and in the nearby Lemieux Dome and Mines Gaspé region, 4) fluid conduit shape-definition should be included in exploration strategies of companies searching for hydrothermal vein-type mineralization in the Gaspésie region and 5) quartz-depositing fluids did not necessarily deposit ore minerals in the Candego and Madeleine mines area. The coincidence in this region between ore zones and thermal centres defined using quartz fluid inclusion geothermometry probably reflects the fact that quartz is a volumetrically-abundant ore-associated vein mineral.

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CHAPTER 1

INTRODUCTION

The Candego and Madeleine mines are the richest portions of an 80 km^2 system of quartz-carbonate veins hosted by sedimentary rocks immediately northwest of the McGerrigle Mountains granitic complex. East MacDonald Mines Ltd. produced 68,497 tonnes of Pb-Zn-Ag ore between 1948 and 1954 from the Candego mine, situated 6 km from the McGerrigle Mountains. Copper deposits at the McGerrigle Mountains periphery were mined by Madeleine Mines Ltd., who produced 8,655,000 tonnes of ore between 1969-1982.

This is the final report of a two-year investigation into regional zoning of 1) vein mineral assemblages and 2) vein crystal fluid inclusion compositions and homogenization temperatures in the Candego and Madeleine mines area. A previous report, (Stevens 1987), described the local geology, regional horizontal and vertical mineral zoning patterns, and preliminary data concerning regional zoning of vein quartz fluid inclusion melting and homogenization temperatures. The present report completes the quartz fluid inclusion studies, presents fluid inclusion data from sphalerite and calcite crytals, and discusses the data of the entire two year project with regard to the following subjects:

1) regional heat sources and fluid conduits
2) vein-depositing fluid sources

3) sequence of flow of different fluid types
4) temperatures and compositions of fluids responsible for quartz, sphalerite, and calcite deposition
5) comparison of thermal and vein mineral zoning in the Candego and Madeleine mines area with thermal and vein mineral zoning reported in studies of other Gaspesian felsic intrusion-associated mineralized regions
6) application of fluid inclusion and vein mineral mapping techniques in exploration for hydrothermal ore deposits.

CHAPTER 2

FLUID INCLUSION STUDIES

AIMS

The principal aim of this fluid inclusion study is to determine whether vein crystal fluid inclusion homogenization temperatures and compositions are zoned on a regional scale. Of the light-transmitting minerals contained in these veins, quartz has a spatial distribution which makes it the most useful mineral for fluid inclusion mapping studies. Calcite and sphalerite are restricted to certain zones in the study area. Fluid inclusion data from these minerals will be compared with quartz fluid inclusion data from selected areas to attempt to determine possible differences in the temperature and composition of fluids responsible for the deposition of different minerals. The extent to which thermal or compositional zoning maps, using quartz fluid inclusion data, are useful in predicting the thermal or compositional conditions of deposition of other minerals will also be discussed.

The sections of this chapter dealing with quartz fluid inclusion data regroup data presented in Open File 1407 and new data obtained since submission of Open File 1407.

Analytical techniques followed in heating/freezing experiments are as described in Stevens (1987).

In the entire two year project heating and freezing data were obtained from 680 fluid inclusions in 63 samples. Relative abundances of different fluid inclusion types were determined by petrographic examination of inclusions in 56 quartz samples. About half the heating/freezing data were collected during year one. The other half of the heating/freezing work and the mapping of different fluid inclusion types was carried out in year two.

FLUID INCLUSION DATA FROM QUARTZ CRYSTALS

Fluid Inclusion Petrography

Four types of fluid inclusions occur in veins of the Candego and Madeleine mines area. These inclusion types, their interpreted compositions, and phase changes observable at different temperatures in each type of inclusion are summarized in Table 1. Detailed descriptions of these four inclusion types are given in Section 4.3.1 of Stevens (1987). The bases for interpretation of the compositions reported in Table 1 are explained in Section 4.4 of Stevens (1987).

Fluid inclusions are extremely abundant in most quartz samples with Type 1 and Type 3 inclusions being by far the most common types. Inclusion shapes vary from regular (negative crystals, spheres, cylinders) to irregular. Inclusion diameters or lengths are from 10 to 100 microns and average 30 to 40 microns.

All samples contain a myriad of differently oriented trails and planes of fluid inclusions. It is probable that most of these inclusions are secondary or pseudosecondary; some planes or trails may indicate crystal growth planes, in which cases the inclusions in question would be primary. Trails of Type 1 and Type 3 inclusions, respectively, commonly crosscut each other, occur as closely-spaced parallel sets, or are almost superimposed on each other. In such instances the Type 1 inclusions invariably have relatively small apparent vapour:liquid ratios indicative of

INCLUSION TYPE	INTERPRETED COMPOSITION	OBSERVABLE PHASE CHANGES
1 (common)	H_2O-salts	1) ice melting -14° to -20°C 2) clathrate melting (rare) up to +7°C 3) homogenization 110° to 550°C
2 (rare)	CO_2	1) CO_2 melting -55° to -56°C 2) homogenization <26°C
3 (common)	H_2O-CO_2±CH_4 -salts	1) CO_2±CH_4 melting <-70° to -55° 2) clathrate melting 3° to 12°C 3) CO_2±CH_4 homogenization -74°C to +31°C 4) total homogenization 160° to 500°C
4 (rare)	H_2O-salts-unidentified components	1) ice melting <0°C 2) vapour phase disappearance 187° to 338°C 3) dissolution of solid phase(s) 159° to 338°C

Table 1: Interpreted compositions and obsevable phase changes of fluid inclusion types found in vein quartz.

relatively low homogenization temperatures, whereas the Type 3 inclusions typically have relatively high apparent $CO_2:H_2O$ ratios, indicative of relatively high homogenization temperatures. In trails containing one type of inclusion, apparent phase ratios are generally constant, but in some cases are variable. Inclusions of the same type but in different trails in some cases have different phase ratios.

Fields of randomly-distributed inclusions are fairly common. These inclusion fields typically contain mixtures of low homogenization temperature Type 1 inclusions and high homogenization temperature Type 3 inclusions. In some cases inclusions of the same type form clusters within the larger field; in other cases the mixing is more or less complete. The temperature-composition characteristics of these two trapped fluid types are such that they could not have had a boiling or condensing relationship. It would therefore seem that they were trapped at different times. However it is generally not possible to deduce relative ages of inclusion formation. Even where fields of randomly-distributed inclusions are mainly of one type, the very high abundance of fluid inclusions severely impedes attempts to isolate unambiguously primary inclusions. On prolonged examination of many of these fields, linear trails in a variety of orientations become discernable. It is not clear whether these trails indicate healed fractures or simply appear to be present as a result of having many inclusions in a relatively small crystal volume.

It is clear from the preceding description that primary inclusion recognition is not easy and in most cases probably impossible. Difficulties in primary inclusion recognition were also encountered by Williams-Jones et al. (1986) in their study of fluid inclusions in the Madeleine mine veins.

Presentation of heating/freezing data

Homogenization temperature and freezing point histograms for fluid inclusions in vein quartz are shown in Figs. 1 to 4. Data obtained from individual samples are tabulated in Appendix I. Homogenization temperatures of Type 1 inclusions (Fig. 1) range from 110° to 550°C; 97% of these temperatures are <400°C. There is a peak at about 195°C and a possible secondary peak at about 255°C. The highest values (450°-550°C) were obtained from vapour-rich inclusions. 98% of all Type 1 inclusions homogenized in the liquid phase. Most final melting points range from -14° to -2°C, which corresponds to a salinity range of 18 to 3.4 eq. wt.% NaCl (Fig. 3). Among these sub-0°C final melting points, values of -10° to -2°C (14 to 3.4 eq. wt. % NaCl) predominate, and there is a possible peak at about -4°C (7 eq. wt. % NaCl). Final melting temperatures of +6°C were observed in three Type 1 inclusions and +7°C in a fourth. For reasons discussed below, above-0°C final melting temperatures in Type 1 inclusions cannot be related to eq. wt. % NaCl salinity values.

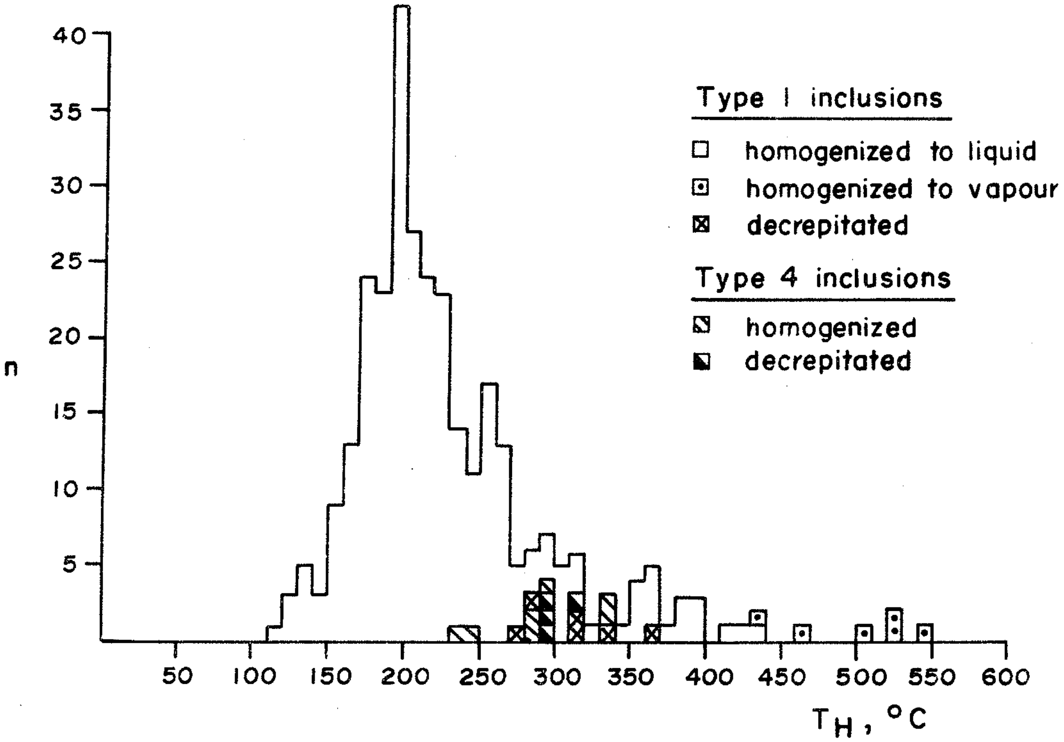

FIGURE 1: Homogenization or decrepitation temperature of Type 1 and Type 4 inclusions.

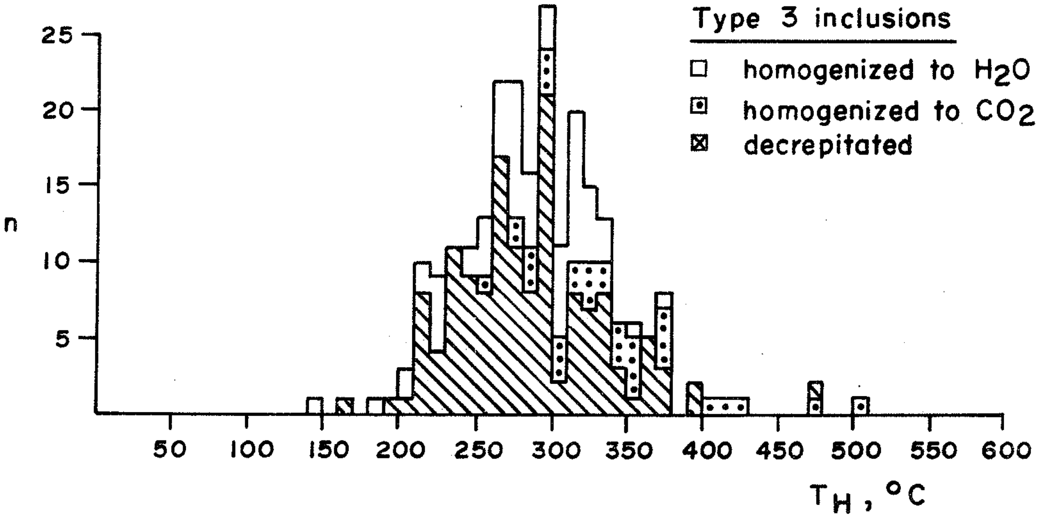

FIGURE 2: Homogenization or decrepitation temperature of Type 3 inclusions.

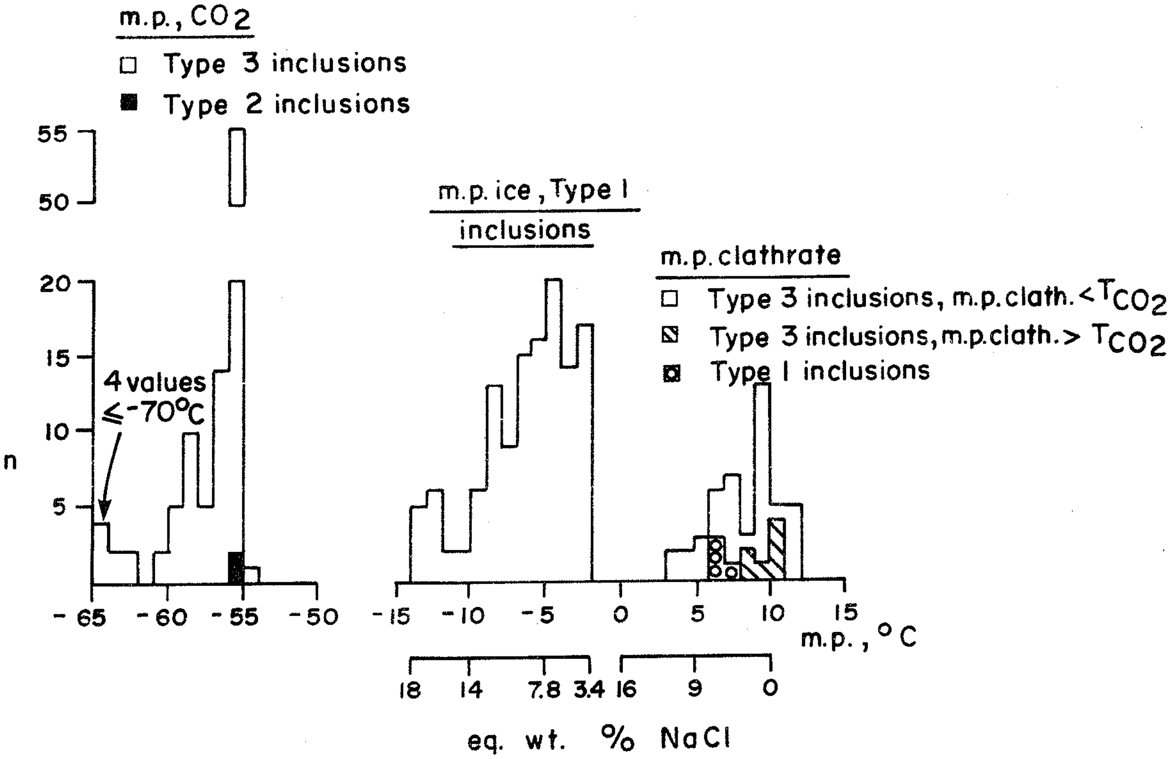

FIGURE 3: Temperature of final melting of CO_2 in Type 2 and 3 inclusions, of ice in Type 1 inclusions, and of clathrate hydrates in Type 1 and 3 inclusions.

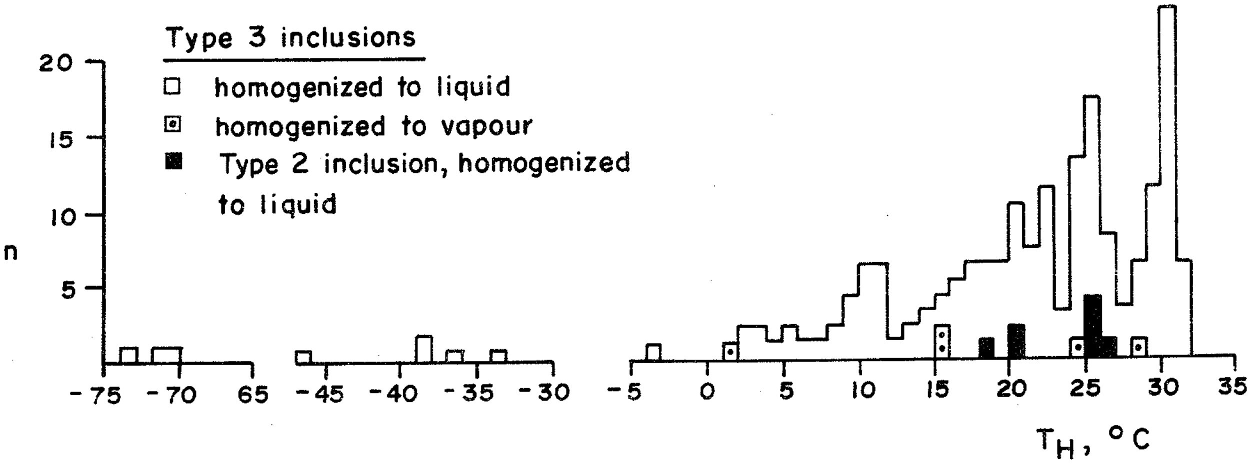

FIGURE 4: Homogenization temperatures of Type 2 inclusions and of the vapour and inner liquid portion of Type 3 inclusions.

Eight Type 2 inclusions were homogenized; they did so in the liquid phase at temperatures from 180° to 27°C (Fig. 4). Final melting in two Type 2 inclusions occurred at -55.6° and -55.8°C respectively (Fig.3).

18°

Homogenization of the CO_2+CH_4-rich portion of Type 3 inclusions occurred at temperatures of -74° to +31°C; the great majority of these temperatures are >10°C (Fig. 4). There are peaks at 30° and 25°C. In 97% of these inclusions homogenization took place in the liquid phase. Type 3 inclusions homogenize completely or more commonly decrepitate at temperatures from 140° to 510°C. 95% of these values are between 200° and 380°C and there is a peak in the data at about 295°C. Homogenization temperatures of inclusions which homogenize in the CO_2+CH_4 phase are on average higher than those of inclusions which homogenize in the H_2O phase. Homogenization temperatures >350°C were obtained mainly from inclusions which homogenized in the CO_2+CH_4 phase.

Clathrate hydrate final melting temperatures in Type 3 inclusions range from 3° to 12°C (Fig.3). For CH_4-free Type 3 inclusions in which clathrate melting occurred in the presence of CO_2 vapour, CO_2 liquid, and H_2O liquid, the final clathrate melting point can be related to salinity in terms of eq. wt. % NaCl (Collins, 1979). In CO_2-H_2O-NaCl fluids, clathrate melting in the presence of CO_2 vapour, CO_2 liquid, and H_2O liquid occurs at a maximum temperature of 10°C, which corresponds to 0 eq. wt. % NaCl. CH_4-free Type

3 inclusion salinities thus range from 0 to 12 eq. wt. % NaCl (Fig. 3). In Type 1 inclusions in which clathrate melting was observed this melting occurred in the presence of CO_2 vapour and H_2O liquid; in these cases the number of phases present at the moment of disappearance of the last clathrate crystal is insufficient for salinity determinations. Final melting of CO_2+CH_4 in Type 3 inclusions occurred at temperatures of -55° to <-70°C with values of -55° to -56°C being the most common (Fig. 3). Values increasingly less than -56°C indicate increasing amounts of dissolved CH_4.

Total homogenization or decrepitation temperatures of ten Type 4 inclusions range from 235° to 335°C (Fig. 2). Fig. 1? Temperatures of halite dissolution and the equation of Potter et al. (1977) were used to calculate salinities of Type 4 inclusions; these salinities range from 30 to 39 eq. wt. % NaCl. Some Type 4 inclusions contain daughter crystals of unknown composition, in addition to halite. The salinity value calculated from the halite disappearance temperature for such inclusions may thus be a minimum value.

For the balance of this report, the following abbreviations will be used to identify homogenization and melting temperatures observable in Candego/Madeleine mines area fluid inclusions:

T_{H2O}	homogenization temperature of Type 1 inclusions

T_{CO2}	homogenization temperature of Type 2 inclusions or the CO2-rich portion of Type 3 inclusions
$T_{H2O+CO2}$	decreptitation or total homogenization temperature of Type 3 inclusions.
T_4	total homogenization temperature of Type 4 inclusions
T_{134}	average homogenization temperature of all Type 1, 3 and 4 inclusions homogenized in a sample
m.p.ice	final ice melting point of Type 1 inclusions
m.p.clathrate	final clathrate melting point in Type 1 or Type 3 inclusions
m.p.CO_2	final CO2 liquid phase melting point in Type 3 inclusions

Spatial distribution of average sample-site fluid inclusion homogenization and melting temperatures

The spatial distribution of average sample-site temperatures of homogenization and melting, for the homegenization/melting phenomena listed on the previous page, and corresponding sample-site locations are shown in Figs. 5, 6, 7, 8, 9, 10, 11 and 12.

Data for the point representing the Madeleine mine are from Williams-Jones et al.(1986). Vein-type zoning

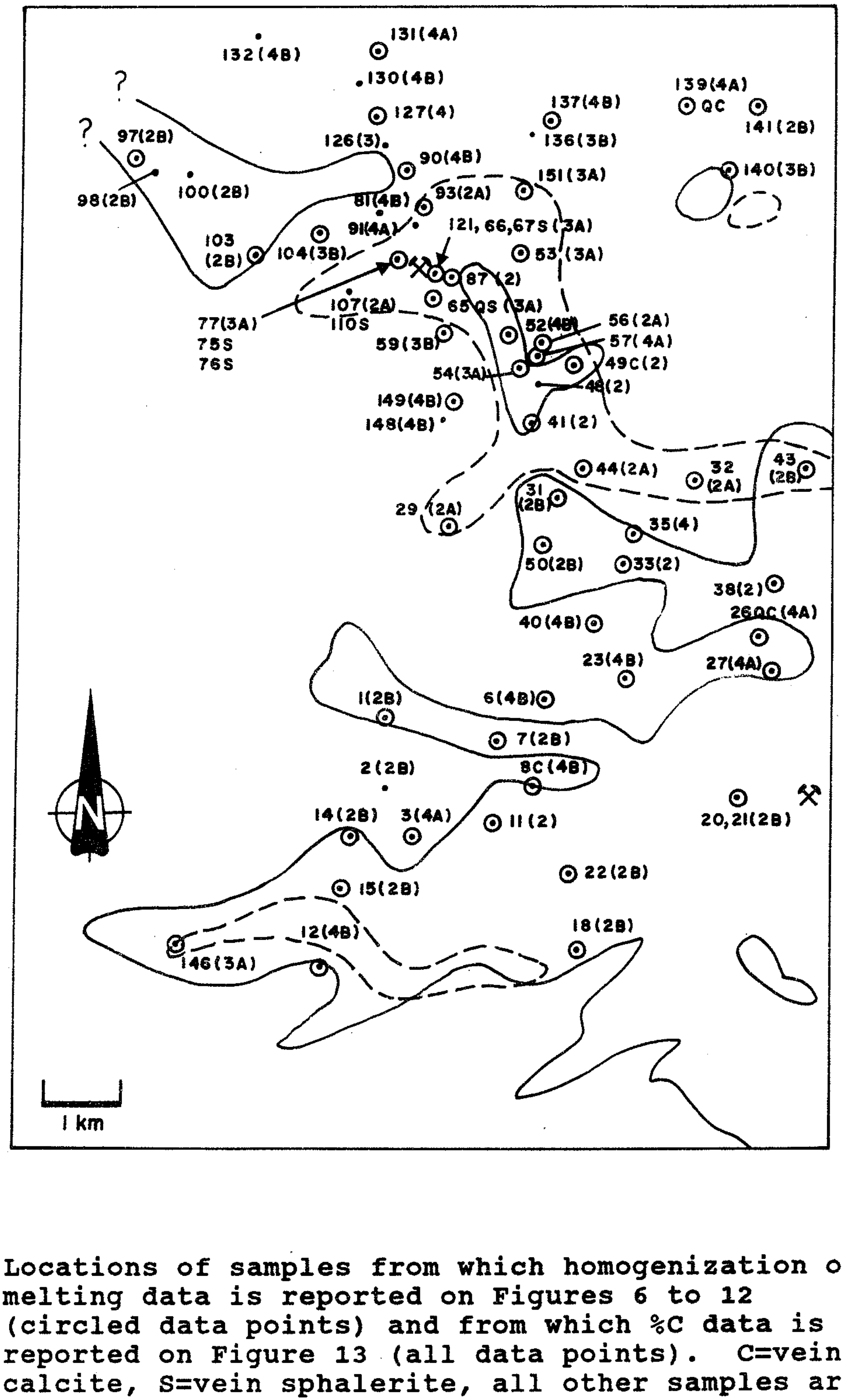

FIGURE 5: Locations of samples from which homogenization or melting data is reported on Figures 6 to 12 (circled data points) and from which %C data is reported on Figure 13 (all data points). C=vein calcite, S=vein sphalerite, all other samples are of vein quartz. Vein-type zones from Figure 8 of Open File 1407 included for reference.

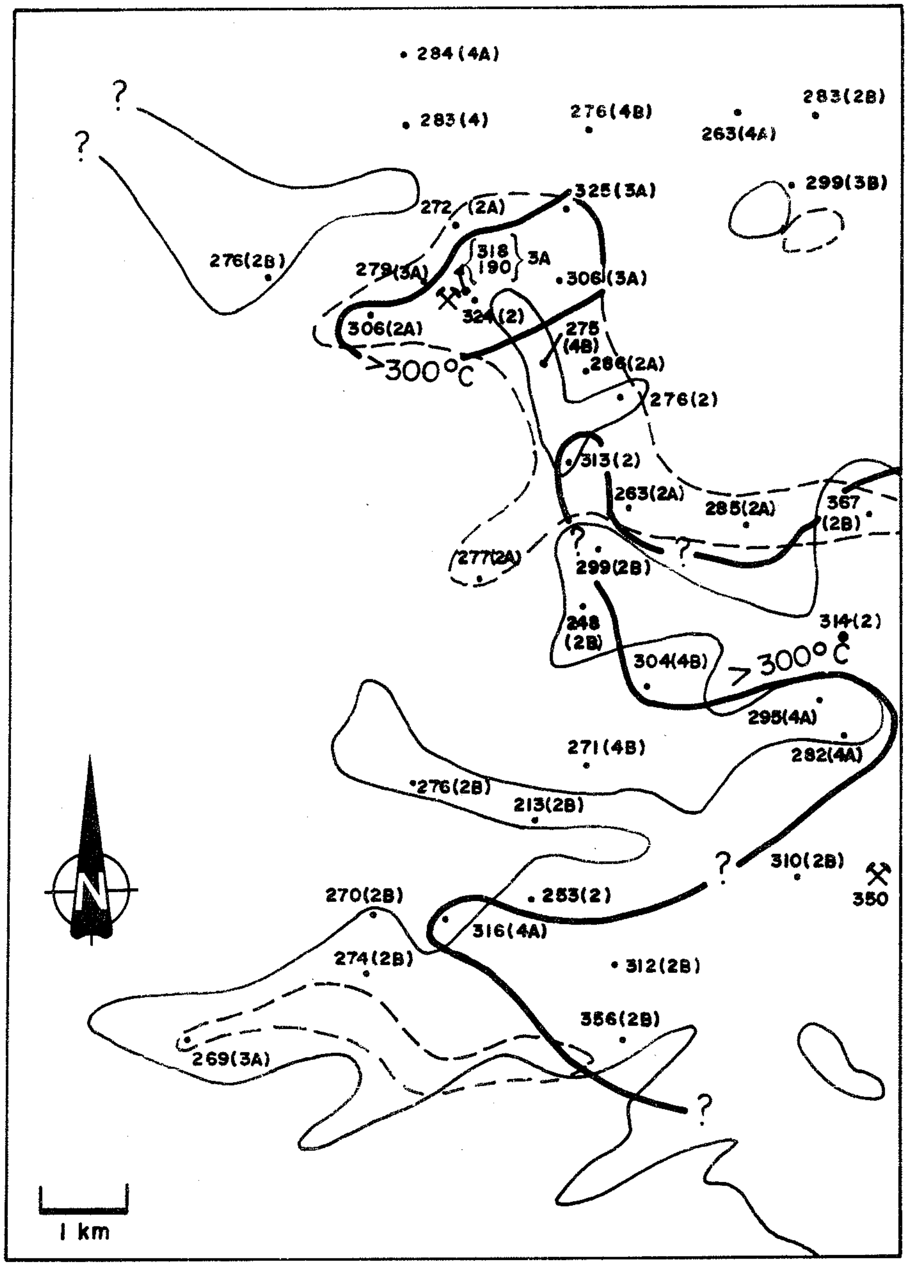

FIGURE 6: Average sample-site total homogenization or decrepitation temperatures in °C of Type 3 inclusions in vein quartz. Vein types from which samples were given in parentheses. Vein-type zones from Figure 8 of Open File 1407 included for reference.

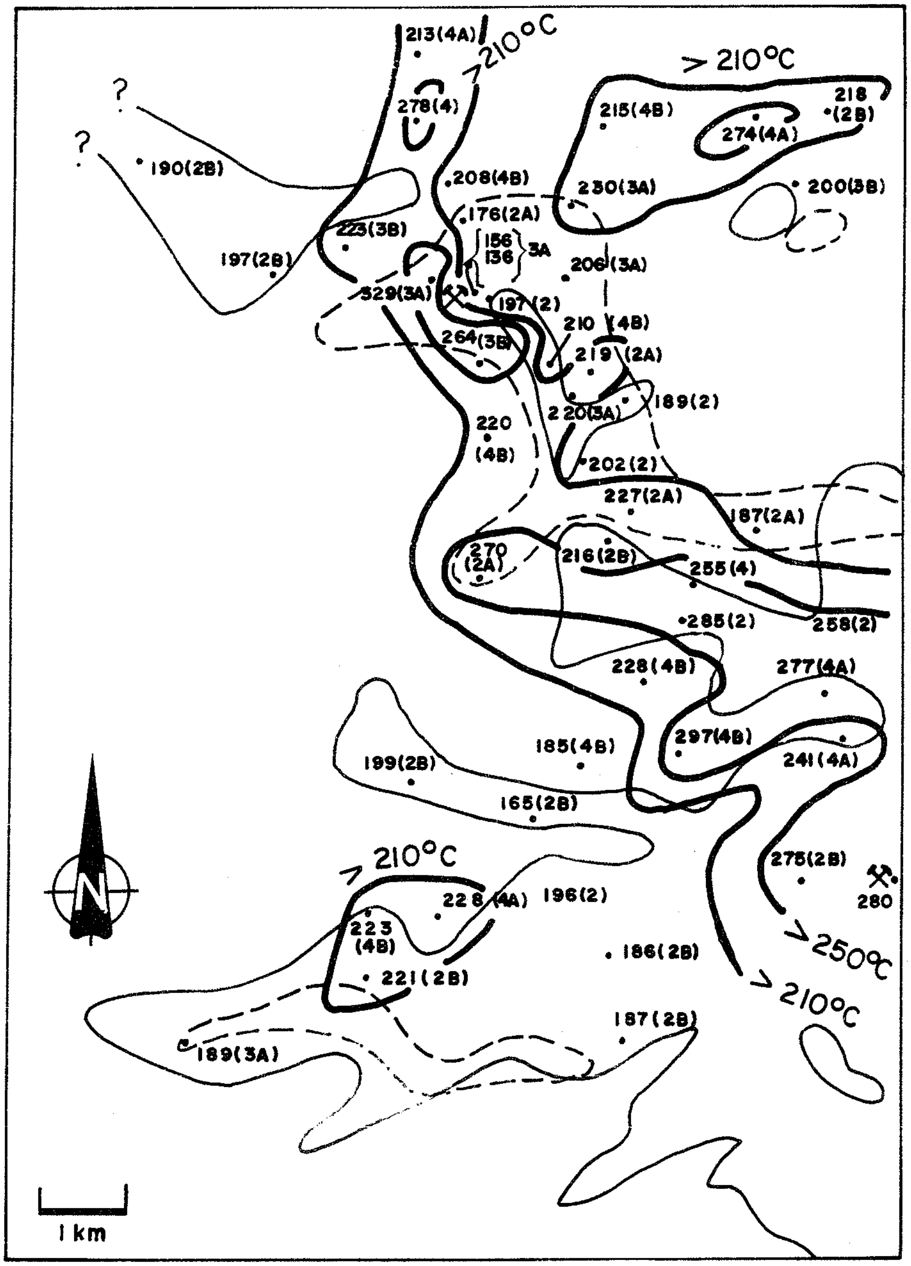

FIGURE 7: Average sample-site homogenization temperatures in °C for Type 1 inclusions in vein quartz. Vein types from which samples were taken given in parentheses. Vein-type zones from Figure 8 of Open File 1407 included for reference.

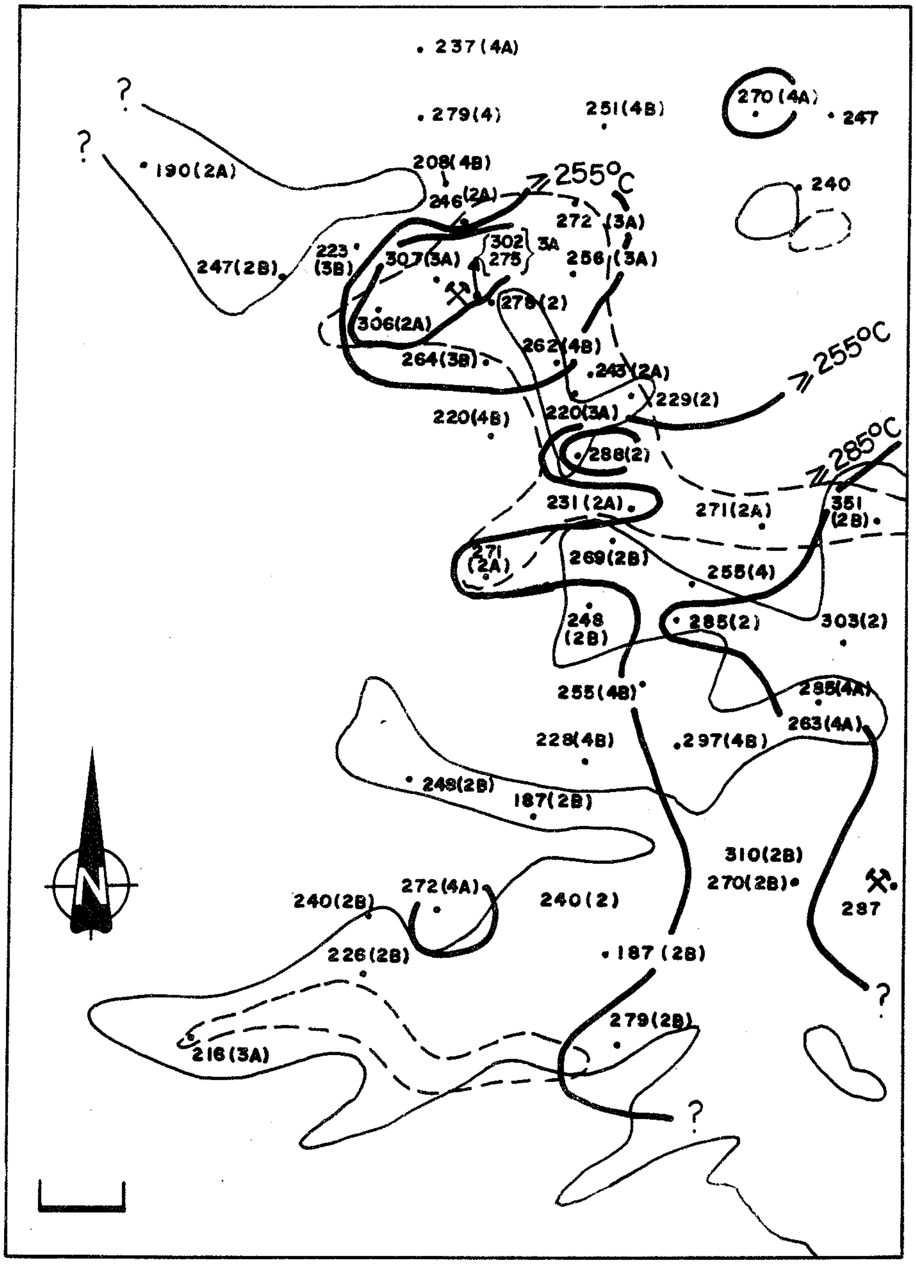

FIGURE 8: Average sample-site temperatures of homogenization or decrepitation of inclusion Types 1, 3, and 4 in vein quartz. Vein types from which samples were taken given in parenthesis. Vein-type zones from Figure 8 of Open File 1407 included for reference.

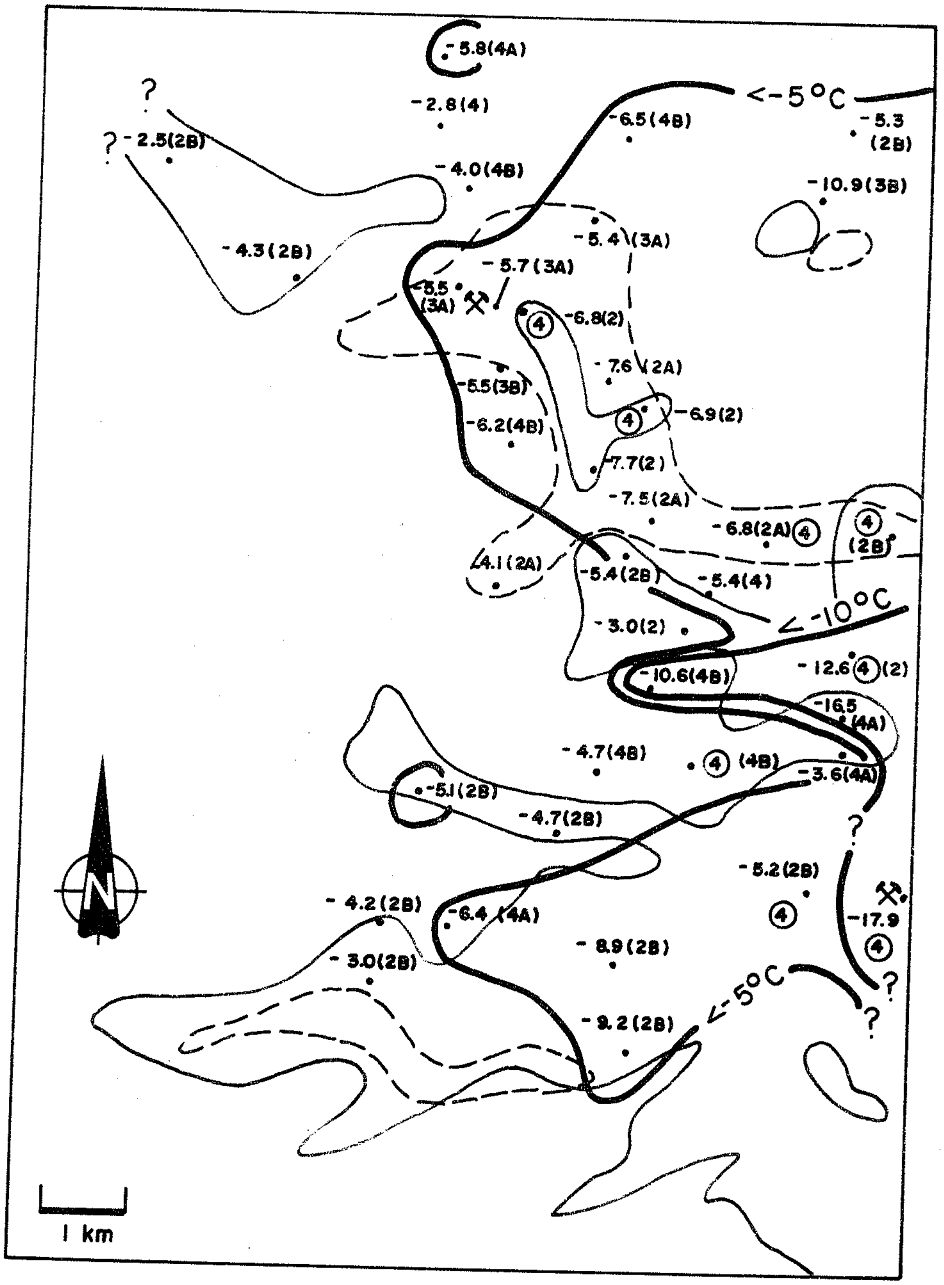

FIGURE 9: Average sample-site final ice melting temperatures in °C in Type 1 inclusions in vein quartz. Circled numeral 4 indicates a site at which Type 4 (daughter crystal-bearing) inclusions occur. Vein type from which samples were taken given in parentheses. Vein-type zones from Figure 8 of Open File 1407 included for reference.

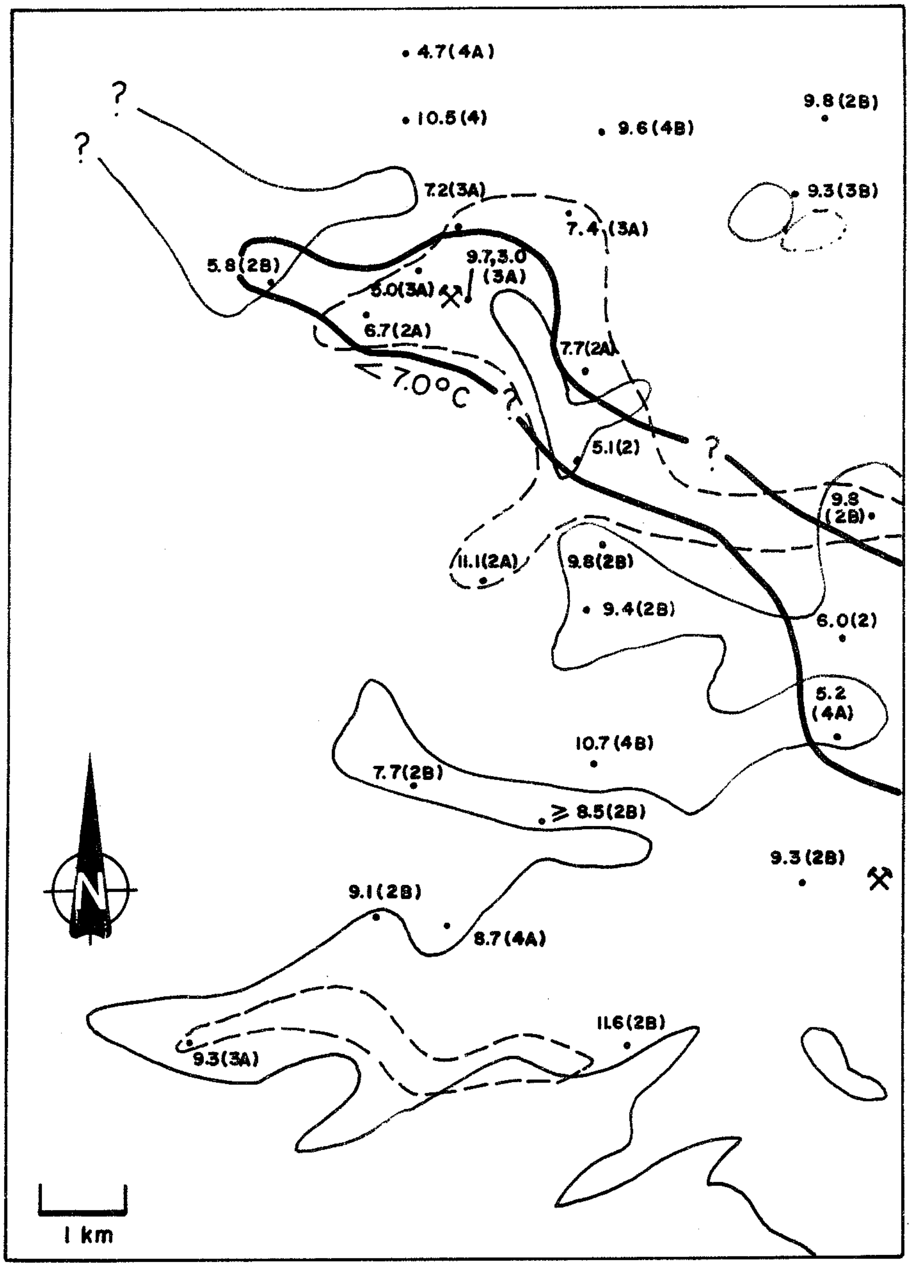

FIGURE 10: Average sample-site clathrate hydrate melting temperatures in °C in Type 3 and Type 1 inclusions in vein quartz. Vein types from which samples were taken given in parentheses. Vein-type zones from Figure 8 of Open File 1407 included for reference.

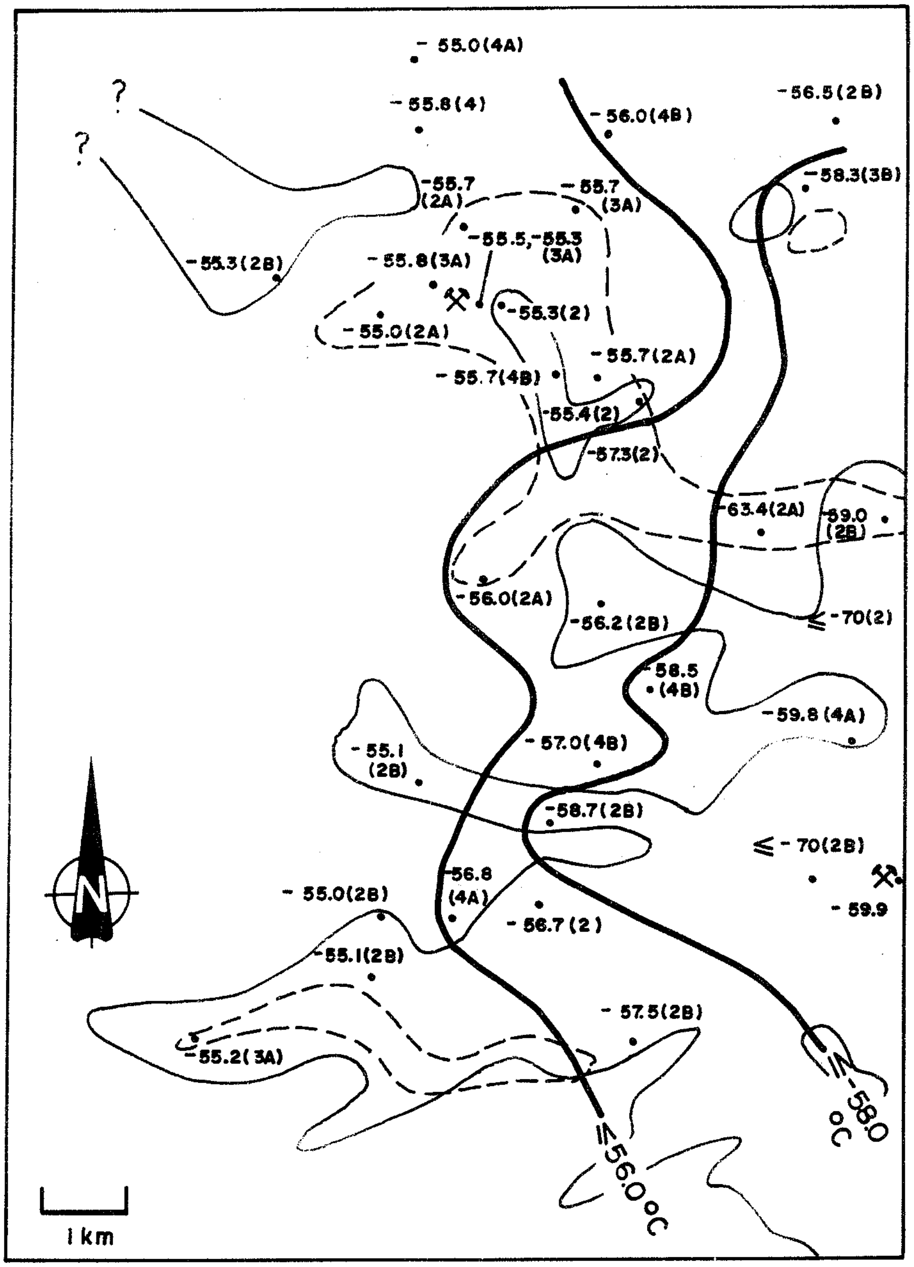

FIGURE 11: Average sample-site CO_2 melting temperatures in °C in Type 2 and Type 3 inclusions in vein quartz. Vein types from which samples were taken given in parentheses. Vein-types zones from Figure 8 of Open File 1407 included for reference.

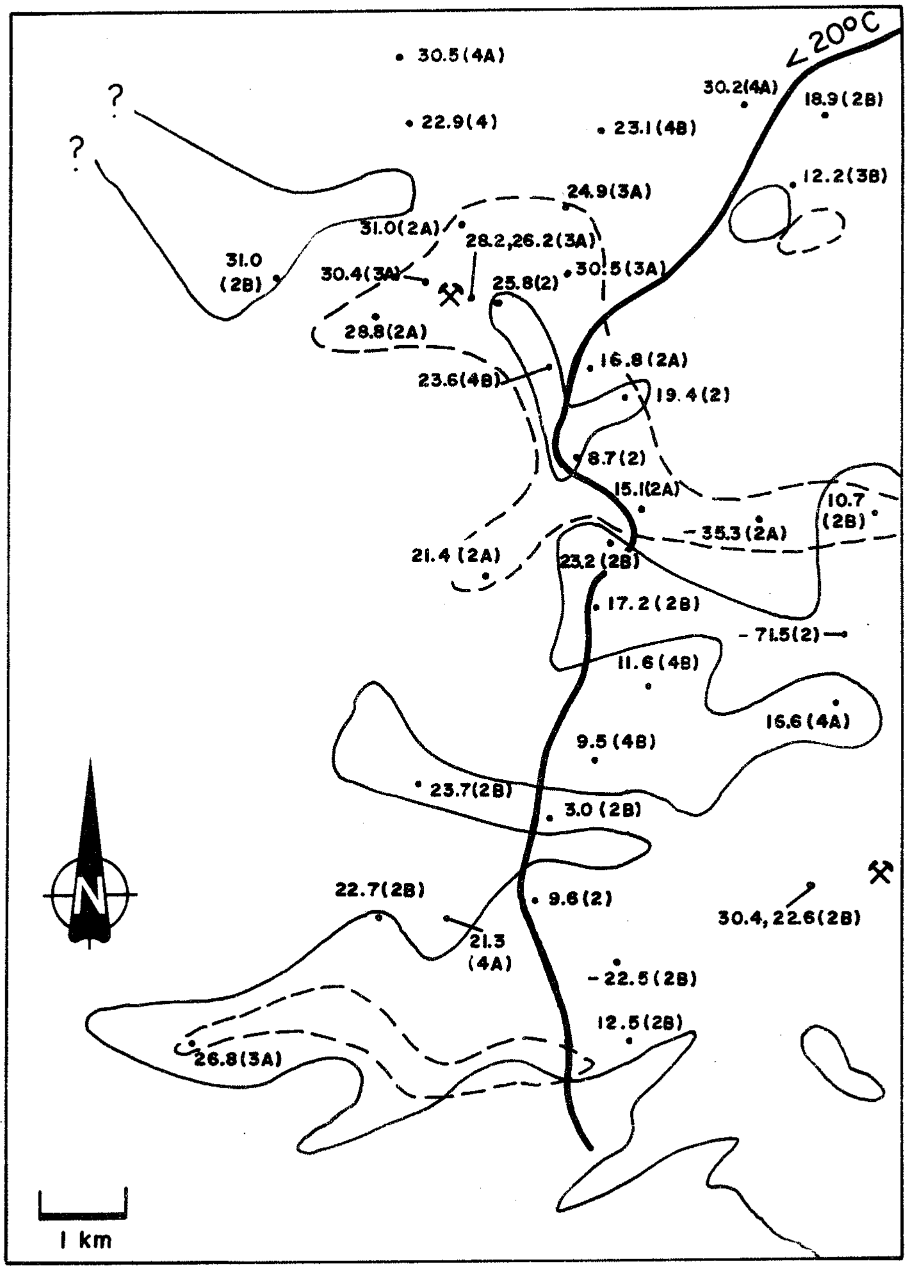

FIGURE 12: Average sample-site CO_2 homogenization temperatures in °C in Type 2 and Type 3 inclusions in vein quartz. Vein types from which samples were taken given in parentheses. Vein-type zones from Figure 8 of Open File 1407 included for reference.

boundaries from Fig. 8 of the interim report are included for reference purposes in each of Figs. 6 to 12. Lack of a value at a particular sample site on a particular figure (for Figs. 6-12) reflects in some cases absence of the appropriate fluid inclusion type(s) at that sample site and in other cases experimental difficulties encountered in observation of homogenization/freezing phenomena.

Average Type 3 inclusion temperatures of total homogenization or decrepitation ($T_{H2O+CO2}$) for each Type 3 inclusion bearing sample are shown on Fig. 6. The average values presented here were calculated from an average of 5.8 measurements per sample site. There are two zones in which average $T_{H2O+CO2}$ values are >300°C and range as high as 367°C. Outside these zones average $T_{H2O+CO2}$ values vary from 213° to 295°C. The southern $T_{H2O+CO2}>300°C$ zone parallels the part of the central portion of the southern quartz-rich vein zone which is nearest to the McGerrigle Mountains. The northern $T_{H2O+CO2}>300°C$ zone comprises several non-contiguous regions in which $T_{H2O+CO2}>300°C$. The zone formed by these non-contiguous $T_{H2O+CO2}>300°C$ regions parallels fairly closely the strike of the northern quartz-rich vein zone. The northwesternmost segment of the northern $T_{H2O+CO2}>300°C$ zone is centred on the Candego mine. The Madeleine mine occurs within the southern $T_{H2O+CO2}>300°C$ zone.

Average sample-site homogenization or decrepitation temperatures of Type 1 inclusions (T_{H2O}) are shown in Fig.

7; an average of 6.7 measurements per site were used to obtain the average values shown. Most average T_{H2O} values >210°C occur in a corridor which extends from the Madeleine mine area to north of the Candego mine; the trend of this corridor is northwest from the Madeleine mine area to the centre of the map area, north-northwest from the centre of the map area to the Candego mine, and north from the Candego mine to the northern edge of the map area. Within this major T_{H2O}>210°C zone average T_{H2O} values rise locally to >250°C. An average T_{H20} value >300°C was obtained from only one sample; this sample is of vein debris from outside one of the Candego mine adits. A small T_{H2O}>210°C zone strikes west from the Mineral Creek area in the northeast corner of the map area. It may join up with the northernmost part of the major T_{H2O}>210°C zone. A small oval-shaped T_{H2O}>210°C zone occurs towards the western end of the southern quartz-rich vein zone. There is no preferred spatial association between the T_{H2O}>210°C zones and a particular vein-type zone.

The average temperature of homogenization or decrepitation of inclusion Types 1, 3 and 4 (T134) at each sample site is shown on Fig. 8. The average T134 values shown are based on the TH values of an average of 10.9 inclusions per sample. Type 2 inclusion TH values are so low as to be of little use as estimates of the minimum temperatures of vein-deposition. The patterns of Fig. 8 are essentially a mixture of the distribution patterns of average $T_{H2O+CO2}$ and T_{H2O} values (Figs. 6 and 7, respectively) because Type 1 and Type 3 inclusions are the most abundant fluid inclusion types in the veins of this region. Flow of the Type 1 and Type 3 inclusion fluids were probably distinct events. Fig. 8 is presented to show the loss of detail in the shapes of regional fluid conduits that results when the effects of different generations of fluid inclusions are not separated (compare Figs. 6, 7, and 8).

Average sample-site final melting points of ice in Type 1 inclusions are shown in Fig. 9; the plotted averages are based on an average of 3.6 ice melting temperatures per site. The reader will recall that increasing amounts of depression of fluid inclusion melting points relative to 0°C corresponds to increasing salinity of the trapped fluid. There are two main zones in which m.p.ice values are >-5°C and as low as -17.9°C. Outside these zones most m.p.ice values are from -2.5° to -4.7°C. One m.p.ice<-5°C zone strikes southeast within the portion of the central part of the southern quartz-rich vein zone which is most proximal to the McGerrigle Mountains. The other m.p.ice<-5°c zone occupies almost the entire northeast quarter of the map area. There is a small east-trending zone in which m.p.ice values are <-10°C, in the east-central part of the map area.

Fig. 9 also shows sites at which Type 4 (daughter crystal-bearing) fluid inclusions occur. Seven of the eight samples represented come from quartz-rich veins in the central portions of the quartz-rich vein zones, relatively near to the McGerrigle Monuntains. The eighth Type 4 inclusion-bearing sample is from a non-opaque mineral-bearing carbonate-rich vein (Type 4B vein). Average sample-site clathrate final melting temperatures (m.p.clathrate) are shown on Fig. 10. The great majority of the data of Fig. 10 were obtained from Type 3 inclusions; m.p.clathrate values of a few Type 1 inclusions were also used. The average values of Fig. 10 were calculated from an average of 1.8 m.p.clathrate values per sample. Most m.p.clathrate values <7.0°C occur in a poorly-defined zone stretching from south of Petit Lac Ste-Anne to the Candego mine. Outside of this zone most average m.p.clathrate values range from 7.7° to 11.6°C. It is difficult to comment on regional fluid composition trends signified by m.p.clathrate zoning because many of the inclusions from which data on Fig. 10 were obtained contain both NaCl and CH_4. These two substances have opposing effects on the temperature of pure CO_2-clathrate melting. It is not possible to determine the respective contributions of NaCl and CH_4 to an observed fluid inclusion clathrate melting point without chemical analysis of the trapped fluid.

Average sample-site CO_2 melting temperatures measured in Type 3 and Type 2 inclusions are shown on Fig. 11; these average values were determined from an average of 3.2 m.p.CO_2 values per sample site. Average m.p.CO_2 values are -55° to -56°C relatively far from the McGerrigle Mountains, and decrease to as low as <-70°C with decreasing distance from the pluton-sedimentary rock contact. The zone of m.p.CO_2<-56°C values has the form of an aureole about the northwestern contact of the McGerrigle Mountains. The reader is reminded that increasing depression of the m.p.CO_2 values below about -56°C is caused by increasing amounts of methane dissolved in the CO_2 of Type 3 inclusions.

Average sample-site CO_2 homogenization temperatures (that is, the homogenization temperature of Type 2 inclusions and of the vapour + inner liquid portion of Type 3 inclusions) are shown in Fig. 12. An average of 5.1 T_{CO2} values per site were used to obtain the average values plotted on Fig. 12. Average T_{CO2} values <20°C occur inside a 3 km-wide aureole about the McGerrigle Mountains pluton; within and without this aureole average T_{CO2} values range from 19.6° to -71.4°C, and 21.4° to 30.5°C, respectively. The T_{CO2}<20°C aureole coincides spatially with the m.p.CO_2<-56°C aureole of Fig. 11; lowering of average T_{CO2} values in the vicinity of the McGerrigle Mountains is another effect of the high CH_4 content of Type 3 inclusions in this region.

Regional variation in relative abundance of Type 1 and Type 3 inclusions

Regional variations in the relative abundances of Type 1 and Type 3 inclusions in vein samples are depicted in Fig. 13. The number associated with each sample site is the

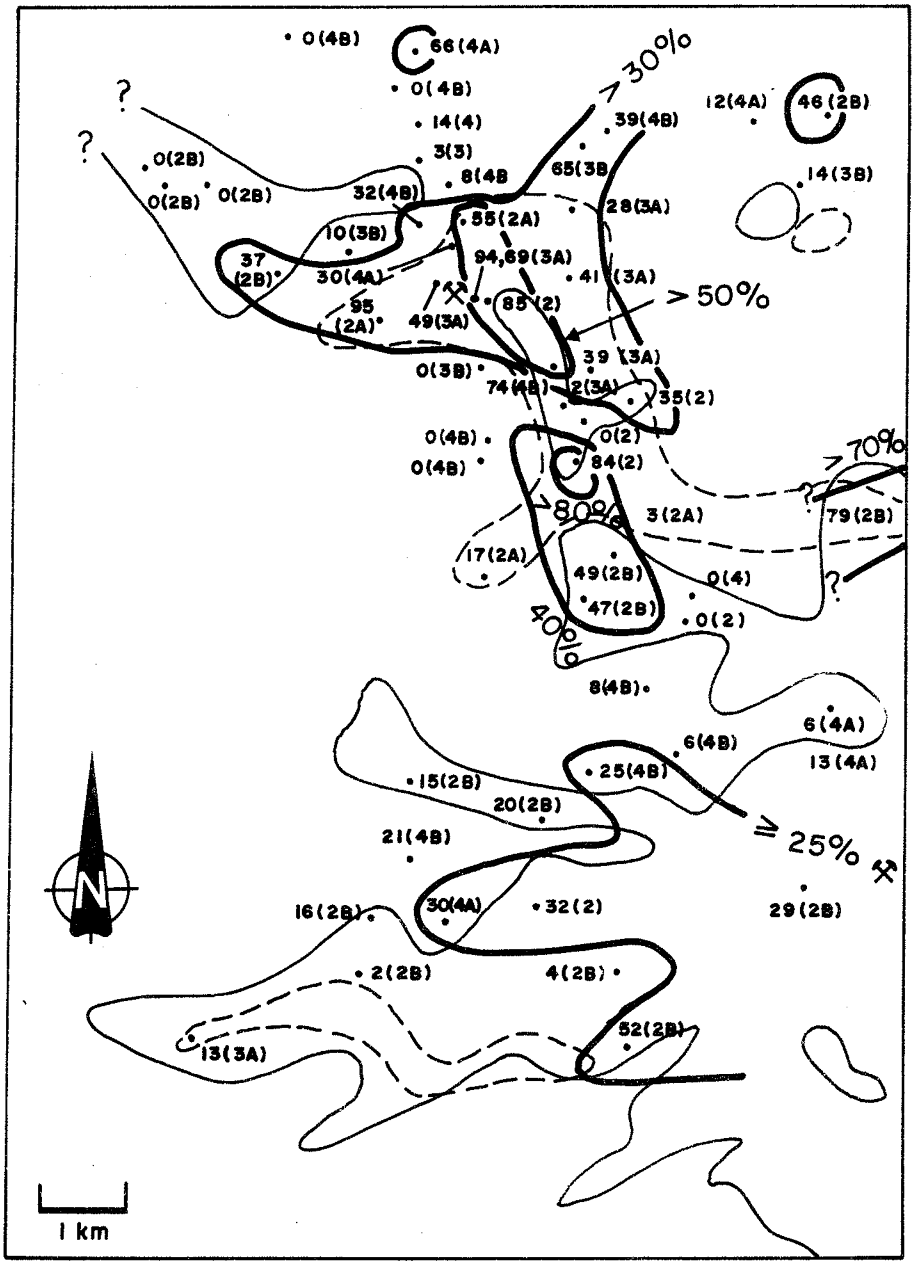

FIGURE 13: Map showing the percent of Type 3 inclusions in the (Type 1 + Type 3) inclusion population in vein quartz samples from the sample sites indicated. Vein types from which samples were taken given in parentheses. Vein-type zones from Figure 8 of Open File 1407 included for reference.

percent of Type 3 inclusions present in the (Type 1 + Type 3) inclusion population at each site and is referred to hereafter as a %C value (% CO_2-rich inclusions value). %C values could not be determined for very CH_4-rich Type 3 inclusion-bearing samples, such as those taken from veins at the southeast end of the northern quartz-rich vein corridor. T_{CO2} values are -35°C to -75°C in these samples and inclusions typically freeze before distinction between Type 1 and Type 3 inclusions becomes possible, even when using high cooling rates. Ice or clathrate crystals commonly inhibit clear viewing of the CO_2+CH_4-rich portions of Type 3 inclusions, especially in small inclusions.

High %C values (30-90%) were obtained most commonly from quartz-rich veins in the northern quartz-rich vein corridor. In this region high %C values occur in a 4 km-long, east-trending, Y-shaped zone centred on the old Candego mine site, in a smaller area to the south of this Y-shaped zone, and at the McGerrigle Mountains contact. There is a 4 km-long zone of moderately high %C values (25-50%) extending west from the Madeleine mine site. High %C values were also recorded at a site to the north of the Candego mine (60%) and at another in the Mineral Creek Vein area (46%). Outside the high to moderately high %C zones just described, %C values range from 0 to 21%, and are typically <15%.

T_{H2O}, $T_{H2O+CO2}$, and %C data from different vein types

Histograms of T_{H2O}, $T_{H2O+CO2}$, and %C values for quartz from different vein types are shown in Fig. 14. %C values are on average highest in Type 2, 2A, and 3A veins (40-50%). Of the quartz and/or carbonate-bearing vein types in the Candego and Madeleine mines area, Type 2, 2A and 3A veins are the main ore-bearing vein types. %C values average 7 to 26% in carbonate-rich veins (Types 4, 4A, 4B) and in non-opaque mineral-bearing quartz-rich veins (Types 2B, 3B, 3).

There are no significant differences in the range of homogenization temperatures observed in different vein types, for either Type 1 or Type 3 inclusions. Average $T_{H2O+CO2}$ values for different vein types vary from 283° to 300°C. Average T_{H2O} values for different vein types cover a somewhat wider range of 209° to 267°C.

Although the relative ages of the inclusions from which homogenization temperature data were obtained are not known, these T_{H2O} and $T_{H2O+CO2}$ histograms suggest strongly that the average temperature of quartz deposition was the same or very similar in all vein types, whether deposition occurred from Type 1 or Type 3 inclusion fluids. Note, however, that within a particular vein type, average T_{H2O} or $T_{H2O+CO2}$ values for different samples vary considerably (Figs. 6 and 7).

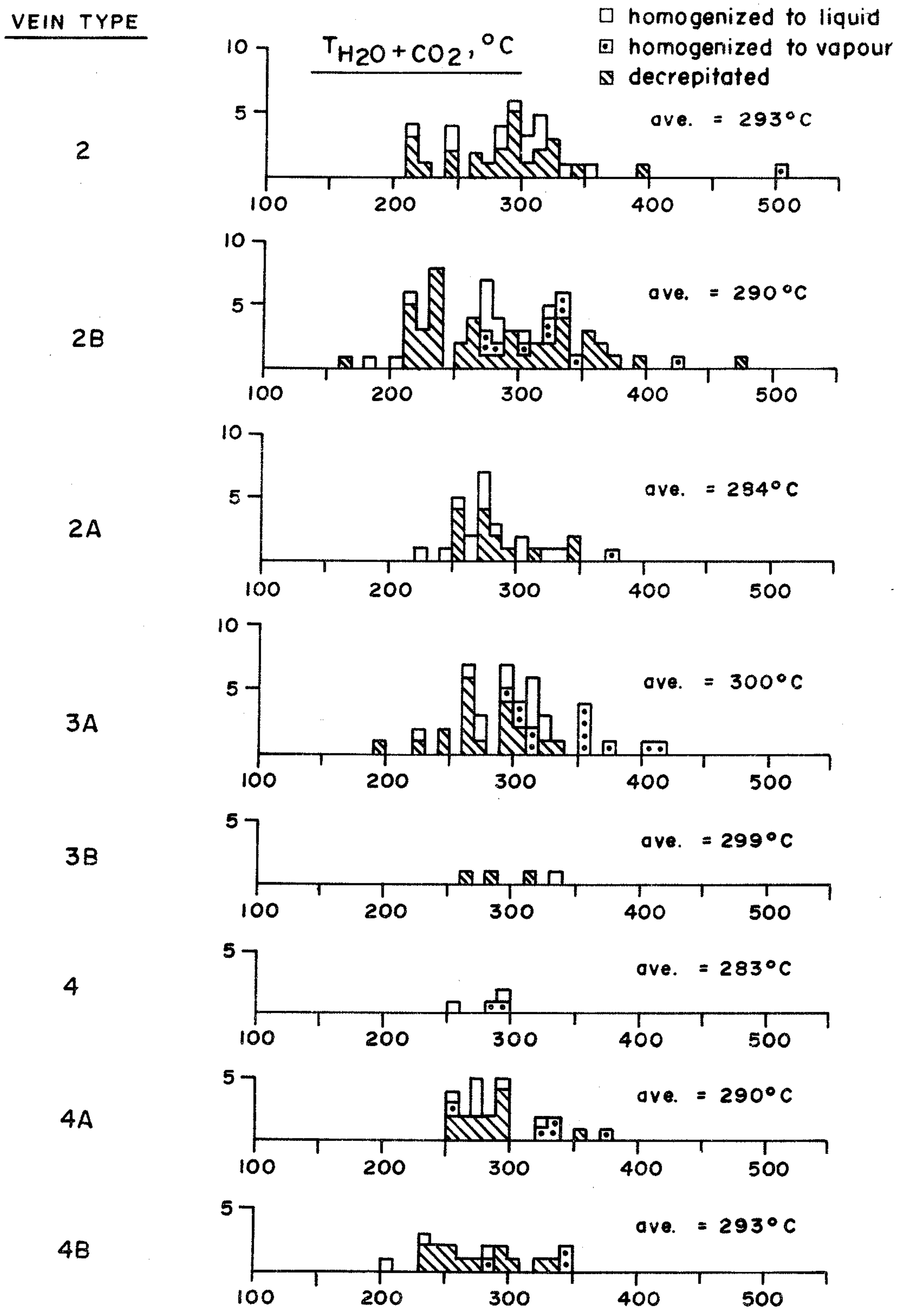

FIGURE 14: Histograms of $T_{H2O+CO2}$ values of fluid inclusions in vein quartz, and °C values of vein quartz samples, for quartz from different vein types. See Table 1 of Open File 1407 for mineral assemblages of each type.

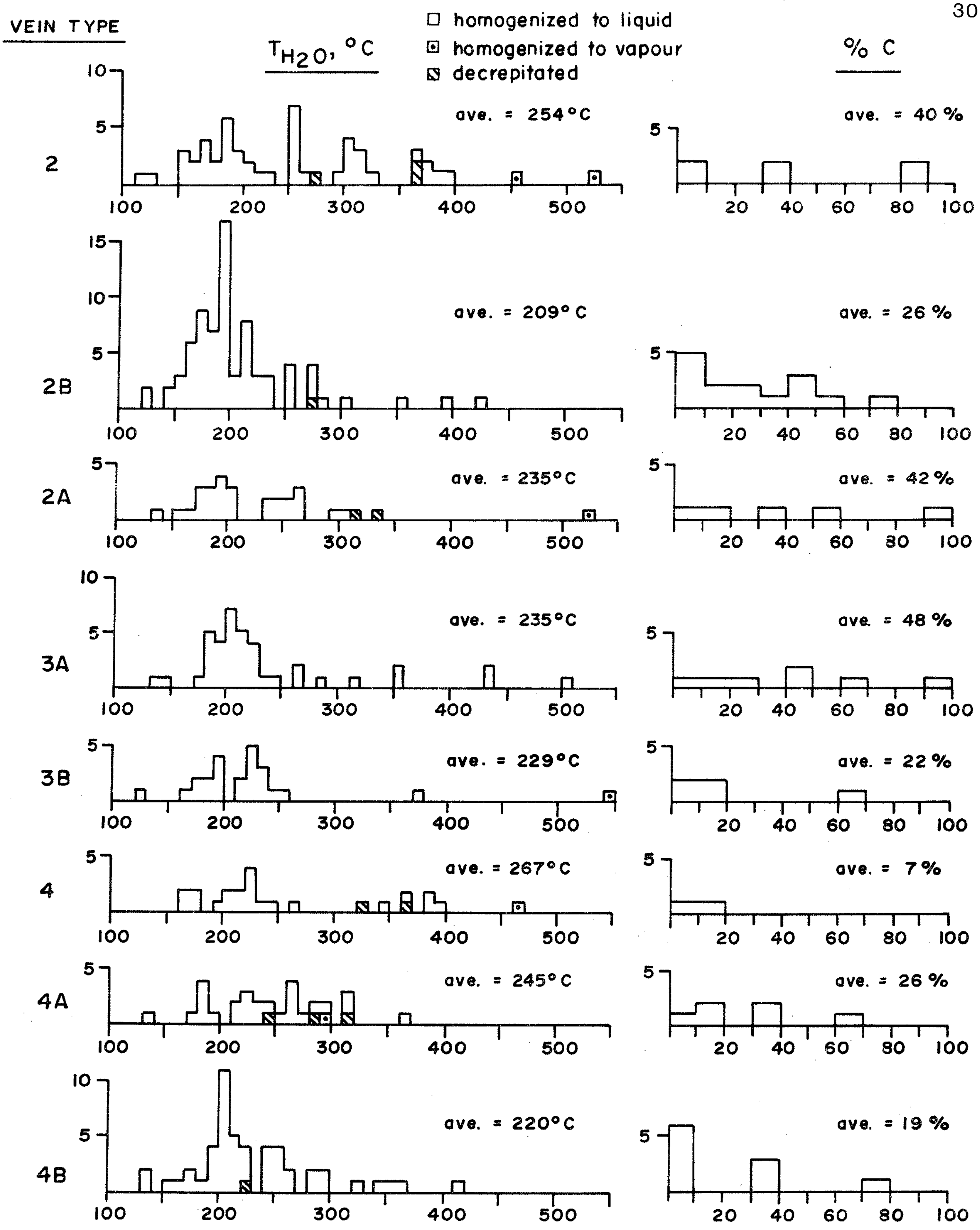

FIGURE 14 (cont.) See Table 1 of Open File 1407 for mineral assemblages of each vein type.

Temperature-salinity relations of Type 1 inclusions from different vein types

A TH-salinity plot for Type 1 inclusions in vein quartz is presented in Fig. 15. The vein types from which the host quartz crystals were taken are also indicated.

Most values occur between 150°C and 250°C and from 3 to 18 eq. wt. % NaCl; most points in this latter part of the diagram are clustered between 150°C and 250°C and 3 to 11 eq. wt. % NaCl. There is a curving line of points extending from 250°C to 400°C and from 6 to 10 eq. wt. % NaCl. Each vein type has a distinct TH-salinity profile. No broad generalizations can be made concerning associations between particular TH-salinity ranges and selected groups of veins such as quartz-rich veins, carbonate-rich veins, etc.

FLUID INCLUSIONS IN SPHALERITE AND CALCITE

General remarks

Sphalerite and calcite are much less widespread than quartz in this region, and not all sphalerite and calcite samples contain fluid inclusions usable in microthermometric studies. These minerals are thus unsuitable for large-scale mapping of fluid inclusion homogenization and melting temperatures. However, it is possible to compare fluid inclusion data obtained from different minerals from selected sites or areas. This information was used to evaluate the general usefulness of temperature-composition

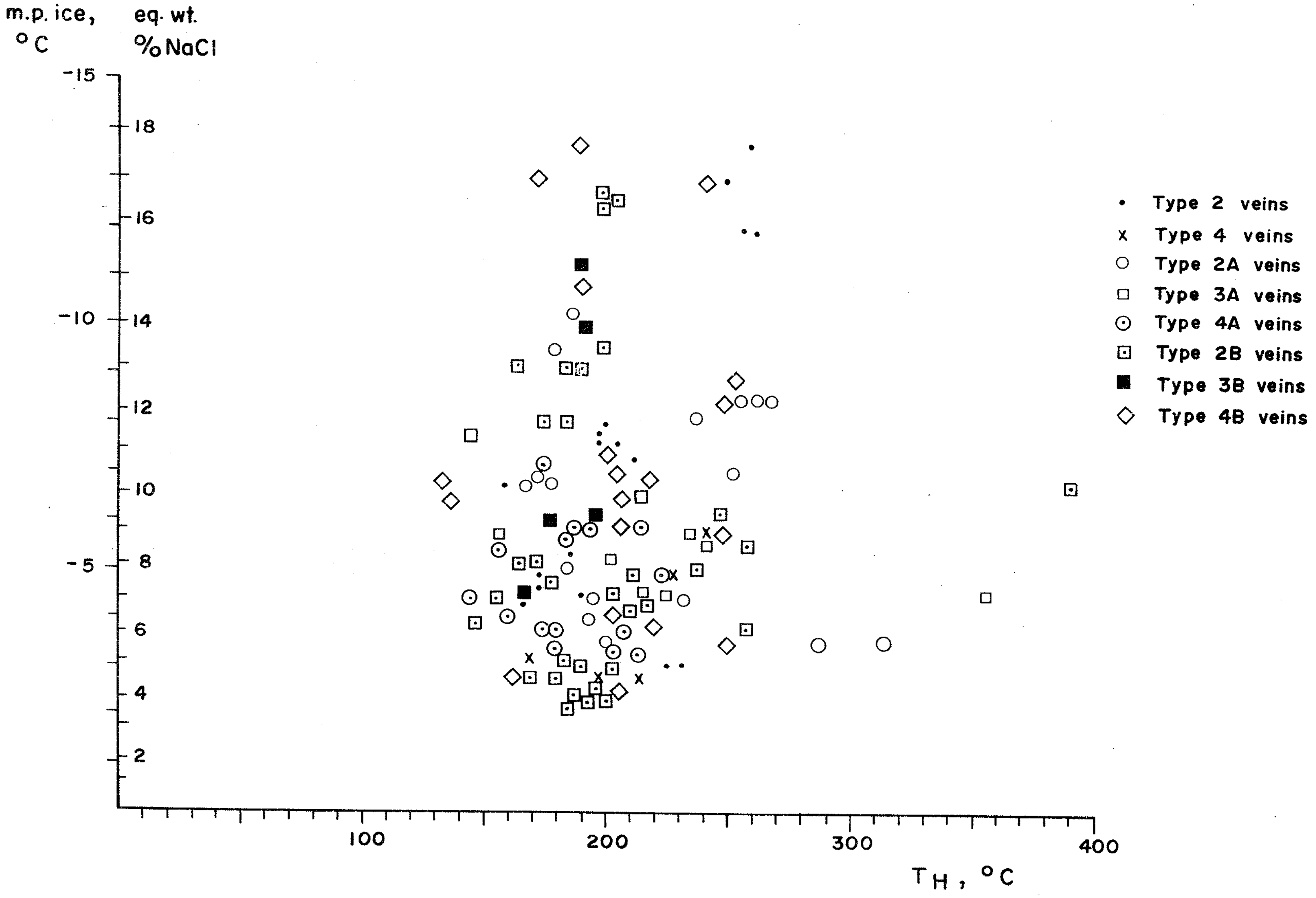

FIGURE 15: A plot of homogenization temperature versus salinity of Type 1 inclusions in vein quartz.

maps made using fluid inclusions in quartz in predicting the thermal/compositional characteristics of fluids trapped in other minerals.

Fluid inclusions in sphalerite

Study of fluid inclusions in sphalerite of this region is considerably more time-consuming than in the case of quartz. Sphalerite is a rare mineral compared to quartz or calcite and not all sphalerite is light-transmitting. Where sphalerite crystals are small or too widely scattered in a vein, it is difficult to obtain a large surface area of sphalerite in a thin section. Fluid inclusion abundance ranges from high to zero, so that some sphalerite crystals contain no fluid inclusions. Finally, most sphalerite inclusions are opaque or nearly so.

Sphalerite inclusions are mostly secondary or pseudosecondary; some are primary. Inclusion sizes and shapes are comparable to those of fluid inclusions in quartz. Inclusions which are not opaque comprise Types 1 and 3. A given crystal or crystal portion contains only one of these two inclusion types.

Inclusions suitable for heating and freezing work were found in five samples from the Candego ore veins and one sample from the Cromar Vein area. Inclusions in the Candego samples are almost all Type 3 inclusions; Type 1 inclusions were observed in one small crystal portion. Type 1 inclusions are contained in the Cromar Vein area sphalerite sample.

Presentation of heating/freezing data

Homogenization and melting temperatures measured in fluid inclusions in sphalerite crystals are shown in Fig. 16.

The Type 3 inclusion data of Fig. 16 are all from Candego samples. Type 3 inclusion temperatures of decrepitation or total homogenization range from 170° to 310°C and are most commonly 230°C to 260°C. Inclusions believed to be primary homogenized at about 235°C or about 255°C. Homogenization was in the H_2O phase in every case.

T_{CO2} values of Type 3 inclusions range from -3°C to +30°C with values of 22°C to 30°C being the most abundant. Homogenization took place in the liquid phase in each case.

Clathrate melting occurred from 0° to 8°C, corresponding to a salinity range of 4 to 16 eq. wt. % NaCl. CO_2 melting temperatures range from -61°C to -55°C, with values between -55°C and -57°C occurring the most frequently. A m.p.CO_2 value of about -55°C was obtained from a primary inclusion.

Type 1 inclusions represented in Fig. 16 are all primary inclusions.

Type 1 inclusions homogenized between 270°C and 340°C in one Candego sample, and from 100°C to 170°C in the single Cromar Vein area sample. Ice melting in the Cromar Vein

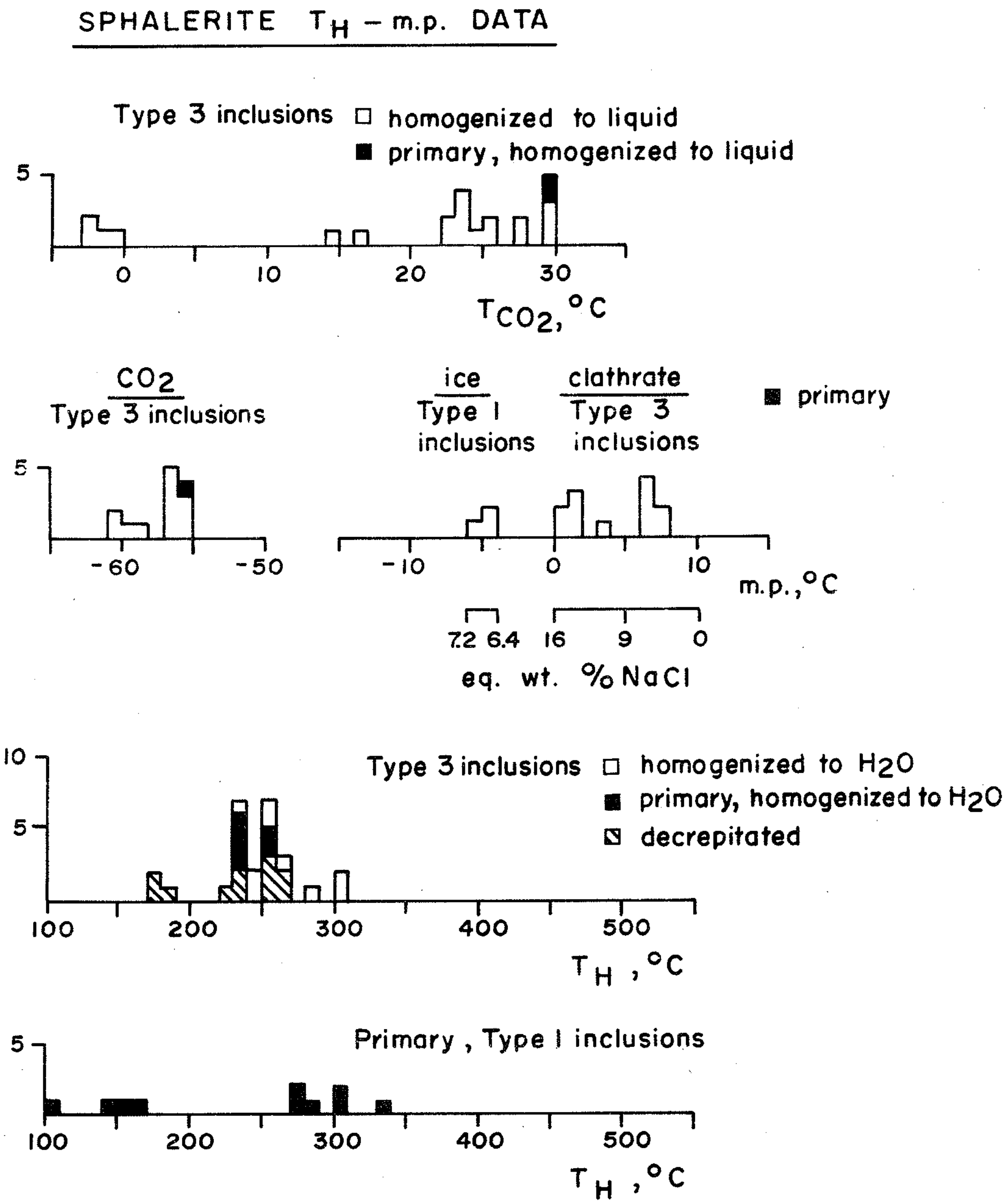

FIGURE 16: Homogenization and melting temperatures of fluid inclusions in vein sphalerite crystals.

area Type 1 inclusions took place at -4°C to -6°C, indicating salinities of 7 to 8 eq. wt. % NaCl.

Fluid inclusions in calcite

Fluid inclusion abundance in calcite varies from high to low. Secondary and pseudosecondary inclusions are more common than primary inclusions. Inclusion shapes vary from regular to irregular. Inclusions in calcite are much smaller than those in quartz or sphalerite; inclusions in which phase changes are easily observable during heating/freezing work are relatively rare.

Inclusion Types 1, 2 and 3 were observed in petrographic examination of eight thin sections. It is difficult to estimate the relative abundances of different inclusion types in a particular sample because most inclusions are too small to permit easy distinction between different types. However, in fields of large inclusions, inclusions tend to be of only one type, and have phase ratios which span narrower ranges than do the ranges observed in quartz crystals.

Fluid inclusions suitable for heating/freezing experiments were found in four samples: three from the periphery of the Madeleine mine hydrothermal centre and one from the Mineral Creek Vein area. The Mineral Creek Vein area sample contains only Type 1 inclusions. Inclusions whose type is identifiable are Type 1 inclusions in two of the Madeleine mine area samples; in the third sample from this area identifiable inclusions are of Type 3. In another Madeleine mine area sample Type 2 inclusions were observed; these are too small and too poorly exposed for the measurement of homogenization and melting points.

Presentation of heating/freezing data

Homogenization and melting temperatures measured in fluid inclusions in calcite are shown in Fig. 17.

The Type 3 inclusion data in Fig. 17 are all from sample K85-8 from the Madeleine mine area (see Fig. 5 for sample locations). CO_2 melting took place at -56°C to -57°C. Clathrate melting occurred at 5°C to 80°C, and indicates a salinity range of about 4 to about 9 eq. wt. % NaCl. CO_2 homogenization temperatures are 24°C to 27°C. Of the three inclusions from which total homogenization or decrepitation data were obtained, one decrepitated at about 285°C, the other two homogenized in the vapour and liquid phases at about 235°C and about 295°C, respectively.

Ice melting in Type 1 inclusions occurred at temperatures of about -7°C to -8°C (10 eq. wt. % NaCl). Type 1 inclusion homogenization temperatures range from 110°C to 280°C with a peak at 210°C to 230°C. Primary inclusions from sample K85-12 homogenized at temperatures of 210°C to 240°C.

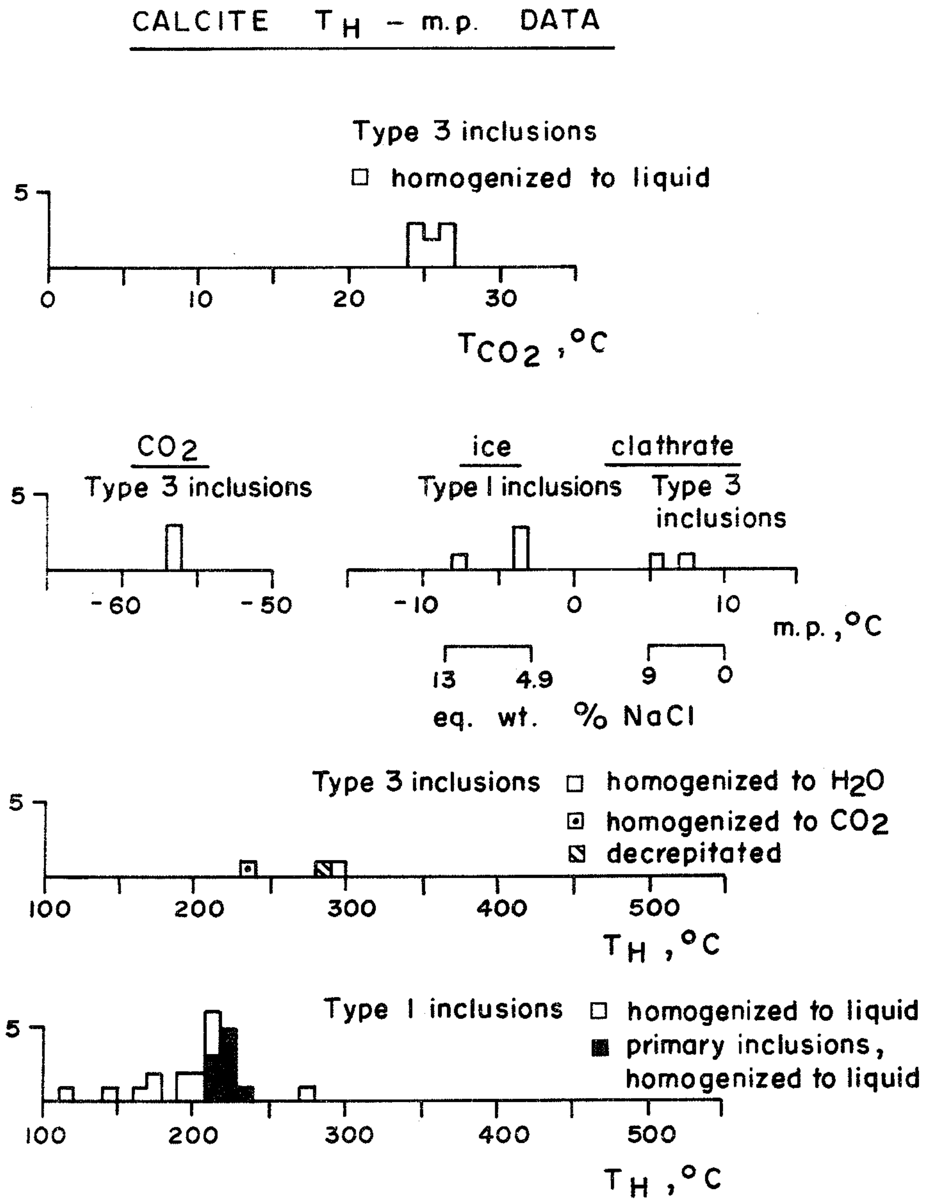

FIGURE 17: Homogenization and melting temperatures of fluid inclusions in vein calcite crystals.

COMPARISON OF FLUID INCLUSION DATA FROM DIFFERENT MINERALS AT PARTICULAR SITES

Quartz and sphalerite in the Candego ore veins

Fluid inclusions were examined in six quartz and five sphalerite samples from the Candego ore veins.

Fluid inclusions in quartz comprise Types 3 and 1, and very rare Type 4 inclusions. %C values range from 49% to 95% and average 78%. Fluid inclusions in sphalerite are almost all of the Type 3 variety. Type 1 inclusions were observed in one very small sphalerite crystal portion.

Fluid inclusion homogenization and melting temperatures from the six quartz and five sphalerite samples are displayed in Fig. 18.

Type 3 inclusions in quartz homogenize or decrepitate at temperatures between 200°C and 510°C, with an average value of 304°C; in sphalerite crystals this range and average are 170°C to 310°C and 238°C, respectively. T_{CO2} and m.p.CO_2 values range from 16°C to 30°C and -56°C to -55°C respectively in quartz, and from -3°C to +29°C and -60°C to -55°C respectively in sphalerite. CO_2 homogenization and melting temperatures are on average lower in sphalerite inclusions than in quartz inclusions, indicating a higher average methane content in sphalerite inclusions compared to the quartz inclusions. M.p. clathrate values vary from 3°C to 9°C in quartz and from 0°C to 8°C in sphalerite. Clathrate melting is on average lower in sphalerite than in quartz, indicating higher average salinity in the sphalerite

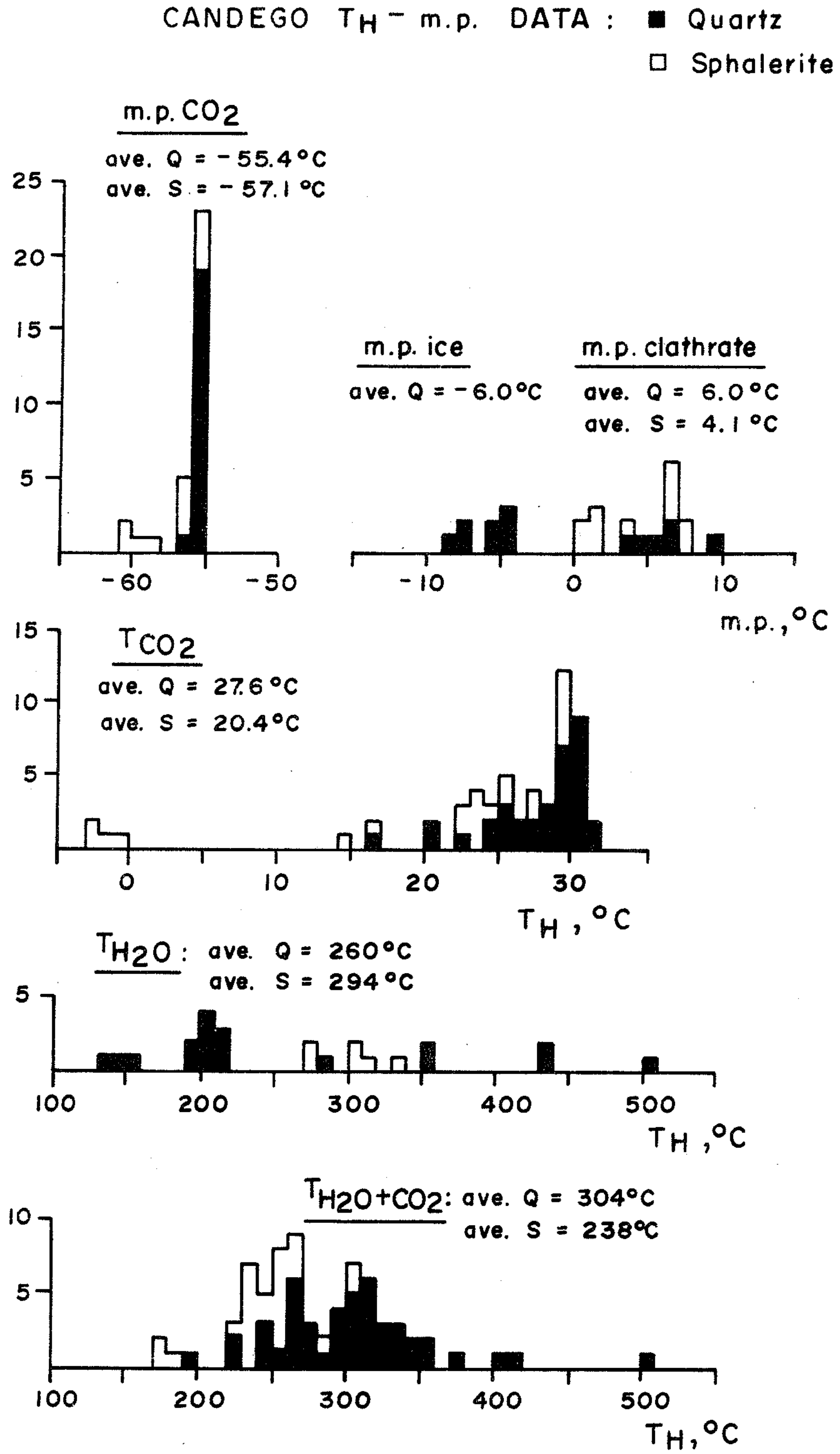

FIGURE 18: Histograms comparing homogenization and melting temperatures of fluid inclusions in quartz and sphalerite from the Candego ore veins.

inclusions than in the quartz inclusions.

Type 1 inclusions in quartz have homogenization temperatures of 170°C to 500°C, with an average value of 260°C. The range of Type 1 inclusion TH values recorded in sphalerite is 270°C to 330°C, and the average value is 294°C.

Average homogenization and melting temperatures obtained from fluid inclusions in a quartz and a sphalerite grain in the same thin section (sample K85-65) are compared in the following table. The data in this table are included in the histograms of Fig. 18.

SAMPLE NO.	MINERAL	AVE. m.p. CO_2, °C	AVE. T_{CO2}, °C	AVE. T_{H2O}, °C	AVE. $T_{H2O+CO2}$, °C
K85-65	Qtz.	-55.9	23.0	213	307
K85-65	sph.	-58.7	15.4	294	231

To summarize, Type 3 inclusions in quartz are characterized by higher average $T_{H2O+CO2}$, T_{CO2}, m.p.clathrate, and m.p.CO_2 values than are Type 3 inclusions in sphalerite. Type 1 inclusions are extremely scarce in sphalerite, but those present have higher average homogenization temperatures than do Type 1 inclusions in quartz.

Quartz and sphalerite in the Cromar vein area

Fluid inclusion data from quartz sample K85-56 and sphalerite sample K85-57, taken from veins 50 m apart in the Cromar Vein area, are presented in the following table.

SAMPLE NO.	MINERAL	VEIN TYPE	INCL. TYPES	%C	AVE. m.p.ice, °C	AVE. T_{H2O}, °C	AVE. $T_{H2O+CO2}$, °C
K85-56	Qtz.	2A	1,3	39	-7.6	219	286
K85-56	Sph.	4A	1	0	-4.6	144	

Thus, the quartz sample contains inclusion Types 1 and 3 whereas only Type 1 inclusions occur in the sphalerite sample. Type 1 inclusions in quartz have higher average homogenization temperatures and lower average melting points than Type 1 inclusions in sphalerite.

Quartz and calcite from selected sites

Fluid inclusion data from quartz and calcite crystals contained in the same thin section, from samples K85-26 and K85-139, are presented in the table below. Sample K85-26 was collected at about 2 km NNW of the Madeleine mine; sample K85-139 is from the Mineral Creek Vein area.

In the sample from each site, the quartz contains inclusion Types 1 and 3 whereas the identifiable inclusions in calcite are Type 1 inclusions. In each case Type 1 inclusions in quartz have average homogenization temperatures significantly higher than those of Type 1 inclusions in calcite. In sample K85-26 average m.p.ice values are significantly lower in quartz Type 1 inclusions than in calcite Type 1 inclusions.

SAMPLE NO., VEIN TYPE	MINERAL	INCL. TYPES	%C	AVE. m.p.ice, °C	AVE. T_{H2O}, °C	AVE. $T_{H2O+CO2}$, °C
K85-26 4A	Qtz. Cal.	1,3 1	6	-16.5 - 7.1	277 150	295
K85-139 4A	Qtz. Cal.	1,3 1	12		274 210	263

Temperatures and compositions of fluids which deposited quartz, sphalerite, and calcite

Primary inclusion data are not available from quartz and are scarce from other minerals. However it is reasonable to assume that samples containing mainly one kind of inclusion were deposited by the fluids contained in this inclusion type. Thus quartz samples with very low or very high %C values can be presumed to have been deposited by H_2O-rich (Type 1 inclusion) and CO_2-rich (Type 3 inclusion) fluids respectively. By the same reasoning sphalerite at Candego was deposited by CO_2-rich fluids whereas at least some sphalerite in the Cromar area was deposited by H_2O-rich fluids. The small size of calcite inclusions prevents reliable estimates of relative abundances of inclusion types in most calcite thin sections. However the available data suggests that calcite crystals were deposited in some cases by H_2O-rich fluids and in other cases by CO_2-rich fluids.

In the previous section it was shown that fluid inclusions in different minerals from a particular site typically record markedly different fluid flow histories. This suggests strongly that different minerals were deposited under different temperature-composition conditions. We can speculate that one region-wide trend was for quartz to be deposited at higher temperature than in the case of sphalerite and calcite, at particular localities.

CHAPTER 3

DISCUSSION

REGIONAL HEAT SOURCES

The McGerrigle Mountains contain the largest body of intrusive rocks in the Gaspé peninsula. Islam et al., (1982) showed that diagenesis of clay minerals occurred at temperatures of about 300°C in a 16 km-wide aureole around the 3 km-wide metamorphic aureole which surrounds this granitic body. The McGerrigle pluton is clearly a heat source of regional importance; it is therefore probable that it and/or its deeper-seated parent magmas provided the heat necessary for fluid flow in the Candego and Madeleine mines area.

REGIONAL FLUID CONDUITS

The west- to northwest-striking vein mineral and thermal zones discovered in this investigation (Fig. 8 of interim report for mineral zones; Figs. 6, 7 of this report for thermal zones) indicate that the fractures most permeable to flow of mineralizing fluids were oriented approximately perpendicular to the strike of the McGerrigle Mountains. Further support for regional east-west-striking fluid conduits is available from the geological map of de Romer (1977). De Romer's (1977) map indicates an east-trending belt of Cu-Fe mineralization-bearing sites on the east side of the McGerrigle Mountains, immediately east of the Madeleine mine (Fig. 19). Among these Cu-Fe mineralization-bearing sites is discernable an east-trending bornite-rich zone stretching from 1 to 4 km away from the McGerrigle Mountains. Mineralized sites surrounding this bornite-rich zone contain chiefly chalcopyrite, pyrite, and pyrrhotite. De Romer does not distinguish between vein and disseminated mineralization at each site, but his Cu-Fe belt could be an eastward continuation of the Madeleine mine zone of veins rich in quartz and/or Cu- and/or Fe-sulfides and/or Fe-oxides.

DISTINCT FLUID FLOW EVENTS

The history of fluid flow in this region is essentially that of the Type 1 and Type 3 inclusion fluids, because these are by far the most abundant inclusion types present. There is considerable evidence that flow of Type 1 and Type 3 inclusion fluids were distinct events. Most thin sections contain Type 1 and Type 3 inclusions both of which could not have formed from the same boiling or condensing fluid, and hence must have formed at different times. On a macroscopic scale Type 1 inclusions are abundant over a much wider area than are Type 3 inclusions (Fig. 13). The zones of maximum average T_{H2O} and $T_{H2O+CO2}$ values approximately overlap but the high-T_{H2O} zones are much more extensive than are the high-$T_{H2O+CO2}$ zones (Fig. 6,7).

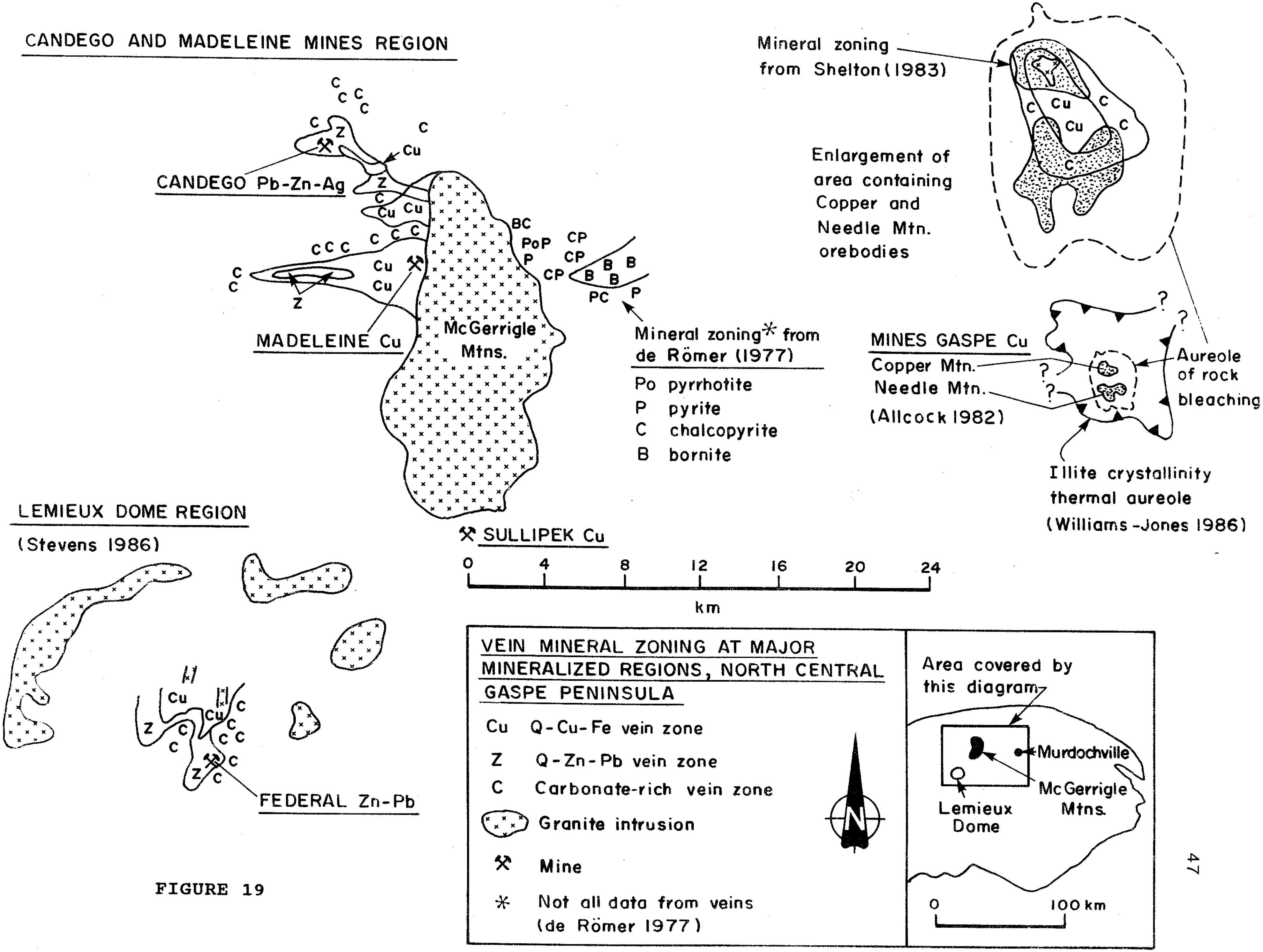
CANDEGO AND MADELEINE MINES REGION
CANDEGO Pb-Zn-Ag
MADELEINE Cu
McGerrigle Mtns.
BC
PoP
P
CP
PC
B
SULLIPEK Cu
Mineral zoning* from de Römer (1977)
Po pyrrhotite
P pyrite
C chalcopyrite
B bornite
Mineral zoning from Shelton (1983)
Enlargement of area containing Copper and Needle Mtn. orebodies
MINES GASPE Cu
Copper Mtn.
Needle Mtn.
(Allcock 1982)
Aureole of rock bleaching
Illite crystallinity thermal aureole
(Williams-Jones 1986)
LEMIEUX DOME REGION
(Stevens 1986)
FEDERAL Zn-Pb
Cu
Z
C
?
0
4
8
12
16
20
24
km
VEIN MINERAL ZONING AT MAJOR MINERALIZED REGIONS, NORTH CENTRAL GASPE PENINSULA
Cu Q-Cu-Fe vein zone
Z Q-Zn-Pb vein zone
C Carbonate-rich vein zone
Granite intrusion
Mine
* Not all data from veins (de Römer 1977)
N
Area covered by this diagram
Murdochville
McGerrigle Mtns.
Lemieux Dome
0
100 km

FIGURE 19

The order of occurrence of the Type 1 and Type 3 inclusion fluid flow events cannot be established beyond doubt with the available data. However, two lines of reasoning suggest that the Type 3 inclusion fluid event preceded the Type 1 inclusion fluid event. First, average temperatures of the Type 3 inclusion fluids were significantly higher than those of the Type 1 inclusion fluids. Decreasing temperatures of progressively later mineralization/alteration events is reported extremely commonly in hydrothermal ore deposit studies (eg. Kamilli and Ohmoto, 1977; Casadevall and Ohmoto, 1977; Rye and Sawkins, 1974). Second, the %C, average T_{H2O}, and average $T_{H2O+CO2}$ distribution patterns suggest that the fracture system available to the Type 3 inclusion fluids was much less extensive than the fracture system employed by the Type 1 inclusion fluids. Multiple intrusive events, flow of high-pressure fluids, and tectonic activity in the McGerrigle Mountains region would have acted to increase fracture permeability over time.

SPECULATION CONCERNING FLUID SOURCES

Plausible origins of the Type 2 and Type 3 inclusion fluids are 1) separation of CO_2+CH_4-rich solutions from a cooling magma and 2) diagenesis/metamorphism of black shales followed by heating of these diagenetic/metamorphic fluids in the vicinity of a magma body. Black shales are common in the local sedimentary formations. Higher hydrocarbons which may have been generated during diagenesis would have cracked during subsequent heating.

The Type 4 inclusion fluids could represent magmatic fluids which evolved under P-T conditions in the two-phase region of water-salt systems. These two phases comprise a dense highly saline liquid and a light low-salinity vapour (e.g. Sourirajan and Kennedy, 1962). The dense highly saline liquid could have been trapped as Type 4 fluid inclusions in veins outside the magma body. Type 4 inclusion fluids could also represent meteoric, formation, or metamorphic fluids which had their salinities increased by extensive boiling. Such ebullition would have to have occurred below the present surface because there is no evidence that Type 4 inclusions in surface samples were trapped from a two-phase fluid.

Speculation on the origin of the Type 1 inclusion fluids is difficult because fluids from diverse sources can have Type 1 inclusion TH-salinity characteristics and can participate in ore-forming processes: e.g. magmatic fluids (So et al. 1983); formation/metamorphic brines (Kamilli and Ohmoto, 1977; Landis and Rye, 1974); meteoric fluids (Smith et al., 1982).

SPECULATION ON THE ORIGIN OF THE METHANE AUREOLE AROUND THE MCGERRIGLE MOUNTAINS

Increasing XCH_4 in Type 3 inclusions with decreasing distance from the McGerrigle Mountains is most easily explained by one or a mixture of the following two processes.

In the first scenario, CH_4-generating metamorphic reactions occur in rock volumes near the McGerrigle Mountains and above a deeper-seated CO_2-rich fluid source situated in or near the McGerrigle Mountains. Vertically-or near-vertically-rising CO_2-rich fluids would traverse the zone of CH_4-production and absorb CH_4. CO_2-rich fluid flow paths which pass below the zone of CH_4-production and lead away from the McGerrigle Mountains would not be contaminated by CH_4.

Increasing XCH_4 in Type 3 inclusions towards the McGerrigle Mountains could also reflect an increasingly reduced state of vein-depositing fluids in this direction. Eugster and Skippen (1967) showed that at a particular temperature and pressure the oxidation state of a C-H-O-fluid in the presence of graphite determines whether CH_4, CO_2 or H_2O is the dominant species present. Graphite is present in at least the Candego ore veins (E. Procyshyn, personal communication; subsequent confirmation by present author). At high fluid oxidation levels CO_2 predominates, whereas CH_4 is the major species under relatively reducing conditions.

A reducing environment could have existed within the granite magma and/or within the metamorphic aureole. If reducing chemical conditions were restricted to within the McGerrigle Mountains, then the occurrence of CH_4-bearing Type 3 inclusions in veins up to 3 km from the granite contact could be explained by high fluid flow rates and high fluid:rock ratios in the fluid conduits leading away from the granite.

It is also possible that a mixture of the above two situations prevailed. Reducing chemical conditions caused by metamorphic reations could have occurred only within a relatively small stratigraphic interval above a source of oxidised fluid. Depending on whether or not the oxidized fluids passed through the reduced zone, they could arrive at the present erosion level in reduced or oxidized state.

Within the methane aureole, Type 3 inclusions have average T_{CO2} values of 22°C and 30°C, indicative of little or no methane contamination, in samples from a site about one kilometer west of the Madeleine mine (Fig. 12). This observation may reflect local perturbation of a regional CH_4-production or redox pattern, perhaps due to local changes in fracture permeability or in the types of metamorphic or metasomatic reactions taking place.

Type 3 inclusions are typically methane-bearing in Candego sphalerite crystals (Fig. 16) whereas they are generally methane-free in quartz from the Candego mine and neighbouring regions (Fig. 11). Were these sphalerite crystals deposited by anomolously CH_4-rich fluid pulses arriving at the Candego mine site, or were CH_4-rich fluids common distal to the McGerrigle Mountains and depositing minerals other than quartz? The fact that CH_4-rich Type 3 inclusions are common in quartz near the McGerrigle Mountains suggests that at least some quartz was deposited by CH_4-rich fluids. It is therefore unreasonable to postulate widespread CH_4-bearing fluids in the Candego mine area which deposit sphalerite but not quartz. It is more likely that these Candego sphalerite crystals were deposited by anomalously CH_4-rich or anomalously reduced pulses of Type 3 inclusion fluids. In terms of the models outlined above anomalously CH_4-rich pulses could have arrived from the McGerrigle Mountains region via fluid flow paths which curved through the CH_4-generation zone and then outward away from the McGerrigle Mountains. Anomalously reduced fluid pulses could have had higher than usual flow velocities in order to reach the Candego mine site without undergoing oxidation.

RELATION BETWEEN VEIN MINERAL ZONES, THERMAL ZONES, AND OREBODIES IN THE CANDEGO/MADELEINE MINES AREA, THE LEMIEUX DOME REGION, AND THE MINES GASPE PORPHYRY COPPER SYSTEM

Regional vein mineral zoning data is available from the Lemieux Dome and Mines Gaspé regions, 30 km south and 50 km east of the present study area respectively (Stevens (1986) for Lemieux Dome; Allcock (1982) and Shelton (1983) for

Mines Gaspé). Mineral zoning at the Lemieux Dome, the Mines Gaspé porphyry Cu system and the Candego/Madeleine mines area is depicted on Fig. 19.

Vein mineral zoning in these three areas can be described in terms of quartz-Cu-Fe (Q-Cu-Fe), quartz-Zn-Pb (Q-Zn-Pb), and carbonate-rich vein zones. In the Candego and Madeleine mines area the Q-Cu-Fe zone contains Type 1 and 2 veins, the Q-Zn-Pb zone Type 2A and 3A veins, and the carbonate-rich zone Type 4 and 4A veins. Note that the non-ore mineral-bearing veins have been omitted in drawing the vein mineral zoning patterns for the present study area, on Fig. 19.

Q-Cu-Fe veins on the Lemieux Dome contain quartz, hematite, pyrite and chalcopyrite. In the Mines Gaspé porphyry copper system these veins contain quartz, chalcopyrite, pyrite, molybdenite, anhydrite, and K-feldspar. Of the Q-Cu-Fe veins in the three areas compared in this section, Q-Cu-Fe veins in the Candego and Madeleine mines area contain the greatest number of Cu- and/or Fe-sulfides and Fe-oxides: chalcopyrite, bornite, pyrite, pyrrhotite, magnetite, and hematite.

The main difference between Q-Zn-Pb zone vein mineral assemblages on the Lemieux Dome and in the present study area is that pyrrhotite occurs in some Candego and Madeleine mines area veins but in none of the Lemieux Dome veins. Q-Zn-Pb veins have not been reported from the Murdochville area. However the major studies of the economic geology of the Murdochville region have focussed on the orebodies within the bleached aureole (Fig. 19) (Brummer, 1966: Allcock, 1982; Shelton, 1983). Veins occur at a number of localities outside the bleached aureole (see Québec MER Fiche de Gîte Nos. 22 A/14-2,-3, 22 A/13-7, -8). Illite crystallinity studies around Murdochville revealed that clay mineral metamorphism caused by the Mines Gaspé hydrothermal system is detectable over a region about five times the size of the area covered by the bleached aureole (Williams-Jones, 1986). It is therefore possible that vein mineral assemblages have been mapped over only a relatively small portion of the Mines Gaspé vein system. Mapping of vein mineral assemblages outside the bleached aureole may reveal the presence of Q-Zn-Pb veins. Note that Q-Zn-Pb veins are relatively rare in the Madeleine mine area and are most abundant several kilometres away from the Madeleine mine.

Carbonate-rich veins invariably contain sphalerite and galena on the Lemieux Dome. In the other two areas these two minerals are commonly absent from these veins. The carbonate phase in carbonate-rich veins is mainly calcite in the Candego and Madeleine mines area, mainly dolomite on the Lemieux Dome, and is calcite + dolomite at Mines Gaspé.

In all three areas sphalerite-galena-bearing vein zones overlie zones of veins containing Cu- and/or Fe-sulfides with or without Fe-oxides. At the Lemieux Dome and Candego and Madeleine mines regions, zones of veins containing Cu- and/or Fe-sulfides +Fe-oxides overlie zones of Fe-sulfideand Fe-oxide-bearing veins. Carbonate-rich vein zones overlie quartz-rich vein zones in all three regions.

In all three areas felsic intrusions intrude or occur in close proximity to the Q-Cu-Fe zones. These intrusions are porphyritic at the Lemieux Dome and Mines Gaspé. The McGerrigle Mountains are equigranular in the Candego and Madeleine mines area but contain porphyritic phases elsewhere. Felsic intrusion compositions are dacite to rhyodacite, rhyolite, and granite at Mines Gaspé, the Lemieux Dome, and in the Candego and Madeleine mines area, respectively. There is no relation between intrusion sizes and areal extents of hydrothermal mineralization or alteration among the three regions. In each region granitic magmas are proposed as hydrothermal system heat sources, and significant vein deposition is interpreted to have occurred up to several or many kilometres away from these heat sources. In the Candego and Madeleine mines area and in the Lemieux Dome region Q-Zn-Pb vein zones are best-developed distal to felsic intrusions in the strike direction of quartz-rich vein zones. Carbonate-rich veins occur adjacent to or surround Q-Cu-Fe or Q-Zn-Pb vein zones at all three areas.

Thermal centres occur mainly within the Q-Cu-Fe and Q-Zn-Pb vein zones on the Lemieux Dome. Average homogenization temperatures within the Lemieux Dome thermal centres are about 260°C.

The thermal centre of the Mines Gaspé porphyry copper system occurs within the Q-Cu-Fe vein zone; average homogenization temperatures within this centre are about 350°C.

Orebodies exploited presently or in the past in these three regions occur within thermal centres and within quartz-rich vein zones. Economic copper deposits such as those at the Mines Gaspé porphyry copper or Madeleine mine sites occur in Q-Cu-Fe vein zones. Zinc-lead+silver mines such as the Candego and Federal mines occur in Q-Zn-Pb vein zones.

COMPARISON OF FLUID INCLUSION TH AND COMPOSITION DATA FROM THE CANDEGO/ MADELEINE MINES AREA, THE LEMIEUX DOME REGION, AND THE MINES GASPE PORPHYRY COPPER SYSTEM

Fluid inclusion homogenization temperature and composition data from veins in the Candego and Madeleine mines area, the Lemieux dome region, and the Mines Gaspé porphyry copper system are compared in Table 2.

Table 2 shows that fluid inclusion TH-composition characteristics are for the most part quite different in the three areas. Inclusions bearing visible CO_2 are common in the Candego and Madeleine mines area, fairly rare in the Mines Gaspé porphyry copper system and absent in the Lemieux Dome region. Daughter crystal-bearing inclusions are common in the Mines Gaspé porphyry copper system, fairly rare in the Candego and Madeleine mines area, and extremely rare at

Lemieux Dome. Salinities of Type 1 or Type 4 inclusions are mainly 3 to 11 eq. wt. % NaCl at the Candego and Madeleine mines area, mainly 0 to 25 eg. wt. % NaCl at Lemieux Dome, and mainly either 10-24 or 28-44 eq. wt. % NaCl in the Mines Gaspé porphyry copper system. Homogenization temperatures span a similar range at all three areas; the most commonly obtained values are in the 150°C to 380°C range in the Candego and Madeleine mines area and in the Mines Gaspé porphyry copper system, whereas they are 100°C to 250°C at Lemieux Dome.

		Candego/ Madeleine mines area	Lemieux Dome*	Mines Gaspé** porphyry Cu system
Fluid inclusion types, relative abundances		1=3>>>4>2	1>>>4	1=4>>3
TH, °C	range	100-550	50-450	80-480
	most common values	150-380	100-250	140-380
Salinity of Type 1, 4 incls., eq. wt. % NaCl	range	3-18, 30-39	0-40	3-44
	most common values	3-11	0-25	10-24, 28-44

* Data from Stevens (1986).
** Data from Shelton (1983).

TABLE 2: Fluid inclusion TH and composition data from vein quartz in Candego and Madeleine mine area, Lemieux Dome region, and Mines Gaspé porphyry copper system. Fluid inclusions in Lemieux Dome and Mines Gaspé regions have been classified according to the Type 1 to 4 scheme used for the Candego and Madeleine mines area.

The data presented in this and the preceding two sections demonstrate that vein crystal fluid inclusion homogenization temperatures and compositions can be quite different in hydrothermally-mineralized regions with very similar regional vein mineral and thermal zoning patterns.

USE OF VEIN MINERAL AND THERMAL ZONING TECHNIQUES IN MINERAL EXPLORATION

Economic mineral deposits in the Candego and Madeleine mines area, the Lemieux Dome region, and in the Mines Gaspé porphyry copper system occur within thermal centres characterized by high vein-quartz fluid inclusion homogenization temperatures, and within quartz-rich vein zones. If these vein mineral and thermal zones are interpreted as indicating major fluid conduits then it would seem that such conduits were important loci of ore-deposition.

Fluid conduits of considerable length between heat sources and sites of mineral deposition have been inferred not only at the three areas mentioned above but in the Sullipek (Wares, 1982) and Patapedia (Williams-Jones, 1982) areas. These five areas contain the richest hydrothermal mineralization known in the Gaspésie. Fluid conduit shape-definition should therefore be included in the exploration strategies of companies searching for hydrothermal vein-type mineralization in the Gaspésie. Fluid conduit shape-definition can be accomplished not only with vein mineral or fluid inclusion mapping techniques, but with lithogeochemical (Stevens, in press) and illite crystallinity (Williams-Jones, 1986) methods.

The data presented here suggest strongly that fluids which deposited quartz did not necessarily deposit ore minerals, in the Candego and Madeleine mines area. A similar conclusion is suggested by a comparison of fluid inclusion data from Lemieux Dome quartz and sphalerite crystals (Stevens, 1986). How can these conclusions be reconciled with the observed coincidence in these two areas of mines and thermal centres delineated using quartz fluid inclusion geothermometry? A plausible explanation of this spatial association is based upon two observations. First, quartz is the major vein mineral in both these areas. This suggests that thermal maps made from fluid inclusions in quartz crystals reveal the largest fluid conduits. Second, quartz is common in the ores of both regions. This suggests that fluids with any temperature or composition were preferentially channelled toward the most permeable fracture zones. It is thus reasonable that ore deposits should occur in thermal centres delineated using vein quartz fluid inclusion geothermometry, in hydrothermally-mineralized regions where quartz is a volumetrically important ore-associated mineral.

CHAPTER 4

CONCLUSIONS

The most important copnclusions of this report are:

1) Vein-depositing fluids were driven by heat sources in or below the McGerrigle Mountains region,
2) Principal fluid conduits were at least 10 km in length and were oriented approximately perpendicular to the strike of the McGerrigle Mountains,
3) CH_4-rich vein depositing fluids were localized in a 3 km-wide aureole about the McGerrigle Mountains,
4) Of the quartz-carbonate-bearing vein types of this region, $CO_2 \pm CH_4$-rich fluids inclusions are commonest in quartz from the main ore-bearing vein types (Types 2, 2A, 3A),
5) Quartz, sphalerite, and calcite were deposited in some cases by $CO_2 \pm CH_4$-rich fluids and in other cases by H_2O-rich fluids,
6) Average T_{H2O} or $T_{H2O}+T_{CO2}$ values vary considerably for different quartz samples from the same vein type. Average $T_{H2O+CO2}$ values for all quartz samples from a particular vein type are similar for all vein types,
7) Type 1 fluid inclusions have a different TH-salinity profile in each vein type,
8) Fluids with different temperature-composition characteristics deposited different minerals,

9) Vein mineral and thermal zoning patterns similar to those described in this investigation were reported from the nearby Lemieux Dome and Gaspé regions; however fluid inclusion homogenization temperatures and compositions are for the most part markedly different in quartz from these three regions,

10) Regional fluid conduits delimitable using vein mineral and fluid inclusion mapping techiques were important loci of ore-deposition in the Candego and Madeleine mines area, the Lemieux Dome region, and the Mines Gaspé porphyry copper system,

11) Fluid conduit shape-definition should be included in exploration strategies of companies searching for hydrothermal vein-type mineralization in the Gaspé.

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APPENDIX I

FLUID INCLUSION HEATING AND FREEZING DATA

EXPLANATION OF SYMBOLS

Note: Type 1 and Type 3 inclusions homogenized to liquid and H_2O phases respectively unless otherwise indicated.

Incl. Group no.	Distinct group of spatially associated inclusions within a thin section.
P.R.	Visually estimated room temperature vapour:liquid or CO_2: H_2O ratio for Type 1, 3 inclusions respectively.
m.p.CO_2	CO_2 melting point.
m.p.ice.	Ice melting point.
m.p.clath.	Clathrate melting point.
T_{H2O}	Homogenization temperature of Type 1 inclusion.
T_{CO2}	Homogenization temperature of Type 2 inclusion or CO_2-rich portion of Type 3 inclusion.
$T_{H2O-CO2}$	Temperature of decrepitation or total homogenization of Type 3 inclusion.
T_4	Temperature of decrepitation or total homogenization of Type 4 inclusion.
d	Decrepitation temperature.
c.p.	Critical phenomena displayed.
v	Homogenized to vapour phase.
CO_2	Homogenized to CO_2 phase.
Ts	Dissolution temperature of solid phase in Type 4 inclusion.
Tv	Temperature of disappearance of vapour bubble in Type 4 inclusion.

TYPE 2 VEINS

Sample-Site No., Sample No., Mineral,%C	FLUID INCLUSION DATA								
	Incl. Group No.	Incl. Type, P.R.	m.p., CO_2 ^oC	m.p., ice ^oC	m.p. clath. ^oC	T_{H2O}, ^oC	T_{CO2} ^oC	$T_{H2O-CO2}$ ^oC	T_4 ^oC
K85-11 Quartz	1	1,1:7				159			
	1	1,1:5				193			
	1	1,1:2				293			
	1	1,1:4				127			
	1	3,1:5					26.4		
	1	3,1:1.5					18.7	305	
	1	3,1:3					26.0	281	
	2	3,1:1.5					22.7		
	2	3,6:1					16.3		
	2	3,1.5:1					22.7		
	2	3,3:1					21.3		
	3	1,1:1				364			
	3	1,1:5				210			
	3	2					20.0		
	3	2					20.2		
	3	3,10:1	-56.7				8.3	312d	
	3	3,6:1	-56.7				3.2	218d	
	3	3,1.75:1	-56.7		11.0		3.6	218d	
	3	3,1:1.5					-46.0	218d	
	3	3,4:1					-38.2	218d	
	3	3					-38.2		
K85-33 Quartz	1	1,1:6				251			
	1	1,1:6				251			
	1	1,1:6		-3.0		231			
	1	1,1:12				255			
	1	1,15:1				385cp			
	1	1,1:7		-3.0		225			
	1	1,1:1			8-14	362d			
	1	1,1:5				209			
	1	1,1.5:1				398			
K85-38 Quartz	1	1,20:1				528v			
	1	1,1:20				159			
	1	1,1:5				270d			
	1	1,1:20				117			
	1	1,1:2				305			
	1	1,1:3				321			
	1	1,1:2				301			
	1	1,1:1				367			
	1	1,1:5				301			
	1	4					Ts=253,		291d
	1	4							291d
	1	4							294d
	1	4						Ts=Tv=Td=289	

TYPE 2 VEINS (CONT.)

Sample-Site No., Sample No., Mineral,%C	FLUID INCLUSION DATA								
	Incl. Group No.	Incl. Type, P.R.	m.p., CO_2 °C	m.p., ice °C	m.p. clath. °C	T_{H2O}, °C	T_{CO2} °C	$T_{H2O-CO2}$ °C	T_4 °C
K85-38 Quartz (cont.)	2	1,1.5:1				375			
	2	1,1:1				363d			
	2	1,1:3			6.0	316			
	2	1,1:9		-12.0		258			
	2	1,1:7		-12.0		258			
	2	1,1:7		-13.7		258			
	2	1,1:2.5				313			
	2	1,1:4			6.0	319			
	2	1,1:1.5			6.0	301			
	2	3,5:1					-73.3v	<329d	
	2	3,8:1					-71.2v		
	2	3,8:1					-71.0v	<329d	
	2	1:1						<329d	
K85-41 Quartz	1A	3,1:2						246	
	1A	3,1:3	-60.9		3.7		6.3	301	
	1A	3,1:4					- 3.7	310	
	1A	3,1:2					4.2		
	1A	3,1:3					3.5	348d	
	1A	3,1:5					5.0	248d	
	1A	3						355	
	1B	1,1:6				268			
	1B	1,1:1		- 8.6					
	1B	3,1:8						268d	
	1B	3,1:3.5	-60.5				1.8v	310d	
	2	1,1:9		- 6.8		158			
	2	1,1:25				184			
	2	1,1:18				197			
	2	1,4:1				456v			
	2	3,2:1	-55.2		6.4		13.2	<281d	
	2	3	-55.2				19.1	<281d	
	2	3,3:1	-55.2				13.2	397d	
	2	3,1:5					24.6	262d	
	2	3,4:1						313d	
K85-49C Quartz	1A	1,1:9				176			
	1A	1,1:12		- 4.3		166			
	1A	1,1:9				169			
	1A	1,1:12		- 4.9		173			
	1A	1,1:11		- 4.7		173			
	1B	1,1:20		- 7.1		178			
	1B	1,1:8		-13.0		250d			
	1B	1,1:8		- 7.6		197			
	1B	1,1:8		- 7.6		197			
	2	1,1:10		- 5.3		186			

TYPE 2 VEINS (CONT.)

	FLUID INCLUSION DATA								
Sample-Site No., Sample No., Mineral,%C	Incl. Group No.	Incl. Type, P.R.	m.p., CO_2 °C	m.p., ice °C	m.p. clath. °C	T_{H2O}, °C	T_{CO2} °C	T_{H2O} CO2 °C	T_4 °C
K85-49C Quartz (cont.)	2	1,1:7		-7.2		212			
	2	2	-55.6				18.3		
	2	3,20:1	-55.8				15.9	291d	
	2	4						Tv=187,	Ts=243
	3	3,6:1	-55.0					<291d	
	3	3,8:1	-55.0					<291d	
	3	3,1:3.5					17.7	273d	
	3	3,1:3					20.0	291	
	3	3,1:1					17.2	<291d	
	3	3,1:6					25.1	245	
	3	3,1:10					24.8	<222d	
K85-85 Quartz	1	3,1:26					26.3	142	
	1	3,1:17					28.9	227	
	1	3,1:8					25.9	243d	
K85-87 Quartz	1A	1,1:8				194			
	1A	1,1:5		-4.5		190			
	1A	1,1:6		-7.6		206			
	1A	1,1:8		-8.3		200			
	1B	3,1:1	-55.3				27.5	<247d	
	1B	3,4:1	-55.4				16.2	<300d	
	1B	3,2:1					26.4	338	
	1B	3						310	
	1B	3,1:2	-55.3				30.3	286	
	1B	3,1:5	-55.1				28.7	291d	
	1B	3,1:1						507CO_2	

TYPE 4 VEINS

Sample-Site No., Sample No., Mineral,%C	FLUID INCLUSION DATA								
	Incl. Group No.	Incl. Type, P.R.	m.p., CO_2 °C	m.p., ice °C	m.p. clath. °C	T_{H2O}, °C	T_{CO2} °C	$T_{H2O-CO2}$ °C	T_4 °C
K85-127	1A	2					25.6		
Quartz	1A	2					25.6		
	1A	2					26.0		
	1A	2					25.6		
	1A	2	-55.8				25.5		
	1A	3,15:1					21.8	297	
	1A	3,8:1	-55.8		10.5		18.3	293CO_2	
	1A	3,5:1	-55.8				14.9	289CO_2	
	1A	3,1:3					22.5	252	
	1B	1,1:5				232			
	1B	1,1:21		-3.1		169			
	1B	1,1:9				177			
	1B	1,1:8				163			
	2	1,1:1.5				362d			
	2	1,1:2				366			
	2	1,20:1				460v			
	2	1,1:1				398			
	2	1,1:3				332d			
	2	1,1:7				269			
	2	1,1:5		-2.7		197			
	2	1,1:7		-2.7		214			
K85-35	1	1,3:1				384			
Quartz	1	1,1:1.5				388			
	1	1,1:7				201			
	1	1,1:8				208			
	1	1,1:7				227			
	1	1,1:4				211			
	1	1,1:7				170			
	1	1				344			
	1	1,1:2.5				227			
	1	1,1:3.5		-5.8		241			
	1	1,1:3		-4.9		228			
	1	1,1:3							
K85-8	1	3,8:1					26.8		
Calcite	1	3,8:1	-56.6		5.8		26.2		
	1	3	-56.8				24.0		
	1	3,4:1			7.8		26.9	239CO_2	
	1	3	-56.6						
	1	3,12:1					25.1		
	2	3,2:1					24.4	>291	
	2	3,1.5:1					24.7	<282d	
	2	3,2:1					25.6		

TYPE 2A VEINS

Sample-Site No., Sample No., Mineral,%C	FLUID INCLUSION DATA								
	Incl. Group No.	Incl. Type, P.R.	m.p., CO_2 °C	m.p., ice °C	m.p. clath. °C	T_{H_2O}, °C	T_{CO_2} °C	$T_{H_2O-CO_2}$ °C	T_4
K85-29 Quartz	1	1,1:1				332d			
	1	1,1:8		-3.5		201			
	1	1,2:1				522v			
	1	1,1:11				197			
	1	1,1:12		-4.4		195			
	1	1,1:8		-4-4		233			
	1	1,1:10				188			
	1	3,1:5					23.6	272	
	1	3,5:1	-56.0		11.1		19.2	281d	
K85-32 Quartz	1A	1,1:8		-9.5		179			
	1A	1,1:11		-4.0		194			
	1A	3,1:7						277d	
	1A	3,7:1	<-62.0				-33.4	253d	
	1A	3,8:1	-63.4				-38.4	253d	
	1A	3,8:1	<-62.0				-32.6	253d	
	1A	3,10:1	-63.4				-36.9	<272	
	1A	4							
	1B	1,1:2				313d			Tv=238
	1B	3,1:1						376CO_2	
	1B	4					Tv=249,	T_{S1}<277	T_{S2}=338
K85-44 Quartz	1A	1,1:8		-6.9		172			
	1A	1		-6.9					
	1A	1,1:10		-6.9		176			
	1A	1,1:15		-6.9		152			
	1A	1,1:6				292			
	1B	1,1:5		-8.5		264			
	1B	1,1:4		-8.5		264			
	1B	1,1:3.5				262			
	2	1,1:5				248			
	2	1,1:2.5				209			
	2	3,1:2.5					15.1v	263	
K85-56 Quartz	1A	1,1:7		-6.7		168			
	1A	1,1:8		-5.0		186			
	1A	3,1:1	-55.5				18.5	286d	
	1A	3,4:1	-55.5				21.3	272	
	1A	3,3:1	-55.8		7.7		11.4	274d	
	1A	3,1:1	-55.8				15.9	311d	
	1B	1,1:12		-10.2		187			
	1B	1,1:8		-7.0		253			
	1B	1,1:10		-8.5		255			
	1B	1,1:6				243			

TYPE 2A VEINS (CONT.)

Sample-Site No., Sample No., Mineral,%C	FLUID INCLUSION DATA								
	Incl. Group No.	Incl. Type, P.R.	m.p., CO_2 °C	m.p., ice °C	m.p. clath. °C	T_{H_2O}, °C	T_{CO2} °C	$T_{H2O-CO2}$ °C	T_4 °C
K85-56 (cont.)	1B	1,1:15		-8.1		238			
K85-93 Quartz	1	1,1:7				139			
	1	1,1:7				200			
	1	1,1:6				190			
	1	3,1:5.5					31.0v	243	
	1	3,1:6					31.1v	223	
	1	3,1:3.5	-55.9		7.2		31.6	250d	
	1	3,1:2.5						272	
	2	1,1:1				300			
	2	3,1:2					30.8	302	
	2	3,1:1	-55.4				30.8	302	
	2	3,1:2					30.8	286	
K85-107 Quartz	1	3,1:6	-55.0		6.8		30.6cp	261	
	1	3,1:3			6.6			255	
	1	3,1:1						291d	
	1	3,1.5:1	-55.0				28.5	347d	
	1	3,1:1.5	-55.0					336	
	1	3,2:1					29.3	278d	
	1	3,4:1					25.9	<348d	
	1	3,1:2					29.6	322	

TYPE 3A VEINS

Sample-Site No., Sample No., Mineral,%C	FLUID INCLUSION DATA								
	Incl Group No.	Incl. Type, P.R.	m.p., CO_2 °C	m.p., ice °C	m.p. clath. °C	T_{H2O}, °C	T_{CO2} °C	$T_{H2O-CO2}$ °C	T_4 °C
K85-53	1	1,1:10				197			
Quartz	1	1,1:6				221			
	1	1,1:8				208			
	1	1,1:8				210			
	1	1,1:6				196			
	1	3,1:1					31.0	298d	
	1	3,1:3					30.2	298d	
	1	3,2:1					30.1	320	
	1	3,1:1					30.7	316	
	1	3,1:2					30.7	298	
K85-54	1	1,1:4				185			
Quartz	1	1,1:2.5				284			
	1	1,1:6.5				197			
	1	1,1:7				185			
	1	1,1:7				200			
	1	1,1:5				204			
	1	1,1:4				209			
	1	1,1:2				265			
	1	1,1:3				268			
	1	1,1:10				202			
K85-66	1A	1,1:13		-5.7		156			
Quartz	1A	3,1:3	-55.7				29.6	<195d	
	1A	3,1:3	-55.1		3.0		30.7	320d	
	1A	3,1:4	-55.1				30.6	309d	
	1A	3,1:3					29.8	277d	
	1A	3,8:1	-55.9				24.2	350CO_2	
	1B	3,7:1					26.0	376CO_2	
	1B	3,5:1					24.9	315CO_2	
	1B	3,1:4					30.0	315	
	1B	3						414CO_2	
K85-72	1	3,1:7					30.3	201	
Quartz	1	3,1:10					30.3	226	
	1	3,1:11					28.7	277d	
K85-77	1A	1,1:7		-5.3		201			
Quartz	1A	1,1:5		-4.5		215			
	1A	1,1:11		-7.7		145			
	1A	3,1:4					30.5	<267d	
	1A	3,1:7					30.5	<267d	
	1A	3,5:1	-55.8		5.3		29.6	<267d	
	1A	3,1:1.5	-55.8				29.3	<267d	
	1A	3,1:1					31.1	262d	

TYPE 3A VEINS (CONT.)

Sample-Site No., Sample No., Mineral,%C	FLUID INCLUSION DATA								
	Incl. Group No.	Incl. Type, P.R.	m.p., CO_2 °C	m.p., ice °C	m.p. clath. °C	T_{H2O}, °C	T_{CO2} °C	$T_{H2O-CO2}$ °C	T_4 °C
K85-77	1A	3,1:3.5					31.2	310	
Quartz	1B	1,1:3.5				318			
(cont.)	1B	1,1:1				352d			
	1B	1,1:1		-4.5		354			
	1B	1,1:4				437			
	1B	1,1.5:1				507v			
	1B	1,8:1				432v			
	1B	3,1:2			4.9		30.4	314	
K85-121	1	1,1:15				136			
Quartz	1	3,1:3.5					30.4	246d	
	1	3,1:1.5	-55.3				28.2	309d	
	1	3,5:1	-55.3		9.1		22.9	243d	
	1	3,1:10					29.2	229	
	1	3,1:6					27.8	224d	
	1	3,4:1	-55.3				25.1		
	1	3,10:1					20.2	291d	
	1	3						312CO_2	
	1	3						350CO_2	
	1	3						408CO_2	
K85-146	1	1,1:12				188			
Quartz	1	1,1:15				180			
	1	1,1:6				194			
	1	1,1:11				186			
	1	1,1:10				176			
	1	3,1:2	-55.2				26.8	264d	
	1	3,1:2	-55.2		9.4		26.8	264d	
	1	1,1:8				211			
	1	3,1:1			9.1			279	
K85-151									
Quartz	1	3,10:1	-55.5				22.7		
	1	3,12:1	-55.5				25.5		
	1	3,10:1	-55.5				24.9		
	2	1,1:4.5				223			
	2	1,1:3				223			
	2	1,1:7		-5.7		235			
	2	1,1:9		-4.5		226			
	2	1,1;9		-5.7		241			
	2	3,5:1	-56.1		7.4		21.7	359CO_2	
	2	3,1.5:1						359CO_2	
	2	3,7:1	-56.1		7.3		24	292CO_2	
	2	3,1:3					30.7	<291d	

TYPE 3A VEINS (CONT.)

Sample-Site No., Sample No., Mineral	FLUID INCLUSION DATA								
	Incl. Group No.	Incl. Type, P.R.	m.p., CO_2 °C	m.p., ice °C	m.p. Clath. °C	T_{H2O}, °C	T_{CO2} °C	$T_{H2O-CO2}$ °C	T_4 °C
K85-65	1	1,1:5				216			
Quartz	1	1,1:4.5				218			
	1	1,1:5				205			
	1	3	-56.1						
	1	3,1:2	-55.8					292d	
	1	3,1:1.5						329	
	1	3,4:1						304CO_2	
	1	3,7:1	-55.8					304CO_2	
	1	3,5:1	-55.8					333d	
	1	3,1:1.5						277	
K85-65	1	3,1:2.5						286	
Sphalerite	1	3,1:4	-59.2		6.2		16.1	260d	
	1	3,1:4						269	
	1	3,1:4						170d	
	1	3,1:6	-58.1				14.7	170d	
	2	1,1:5				330			
	2	1,1:3.5				303			
	2	1,1:6				270			
	2	1,1:4.5				302			
	2	1,1:3.5				282			
	2	1,1:1.5				276			
K85-110	1	3,1:6			3.8				
Sphalerite	1	3,1:4					23.5	251	
	1	3,1:3	-56.8		1.7		22.0	249	
	1	3,1:3	-56.8		1.7		22.9	249	
	1	3,1:5					25.1	251	
	1	3,1:3	-56.6				24.6	262d	
	2	3,1:3.5	-56.6		2.2		27.1	<257d	
	2	3,1:3	-56.6		2.2		25.5	<257d	
	2	3,1:3					27.8	257	
	2	3,1:4					23.8	224d	
	2	3,1:3					23.8	238d	
	2	3,1:2.5					23.4	238d	
K85-75	1	3,1:4	-60.0				- 2.9	<196d	
Sphalerite	1	3,1:2					- 1.0	<196d	
	1	3,1:3	-60.2		1.1		2.9	<196d	
	1	3,1:2					- 0.4	209d	
K85-76	1	3,1:1	-55.3		7.4		29.4	300	
Sphalerite	1	3,1:1	-55.3		7.4		29.3	300	
	1	3,1:1	-55.3				29.3	181d	
	1	3,1:2.5			5.4			234	
	1	3,1:2.5			5.4				
	1	3,1:1			5.4				

TYPE 3A VEINS (CONT.)

Sample-Site No., Sample No., Mineral	FLUID INCLUSION DATA								
	Incl. Group No.	Incl. Type, P.R.	m.p., CO_2 °C	m.p., ice °C	m.p. Clath. °C	T_{H2O}, °C	T_{CO2} °C	$T_{H2O-CO2}$ °C	T_4 °C
K85-67	1	3,1:6	-55.1				30.5v	253	
Sphalerite	1	3,1:6					30.3v	253	
	1	3,1:3						232	
	1	3,1:3						239	
	1	3,1:3.5						238	
	1	3,1:4						239	

TYPE 4A VEINS

Sample-Site No., Sample No., Mineral,%C	FLUID INCLUSION DATA								
	Incl. Group No.	Incl. Type, P.R.	m.p., CO_2 °C	m.p., ice °C	m.p. clath. °C	T_{H2O}, °C	T_{CO2} °C	$T_{H2O-CO2}$ °C	T_4 °C
K85-3 Quartz	1	1,1:10				131			
	1	1,1:1				280			
	1	1,1:4				235			
	1	3,1:2.5					21.5	258	
	1	3,1:1	-56.7		8.7		21.5	371CO$_2$	
	1	3,2:1					21.9	298	
	2	1,1:3.5				267			
	2	1,1:4.5				227			
	2	3,1:1					22.0	323cp	
	2	3,3:1					18.8	330CO$_2$	
K85-27 Quartz	1	1,1:1		-3.5		314			
	1	1,1:1		-3.5		288d			
	1	1,1:10		-3.8		180			
	1	1,1:7		-3.4		179			
	1	1,1:4				243d			
	1	3,19:1	-59.8				5.2	<251d	
	1	3,5:1	-59.9					251d	
	1	3,9:1	-59.8					<281d	
	1	3,4:1						<288d	
	1	3,2:1						350d	
	1	3,1:1						268d	
K85-131 Quartz	1	1,1:2				263			
	1	1,1:6		-5.9		216			
	1	1,1:4				213			
	1	1,1:9		-5.9		187			
	1	1,1:6				187			
	1	1,1:6		-5.6		185			
	1	1,1:11		-5.9		193			
	1	1,1:4				263			
	1	3,2:1	-55.0				30.4	<291d	
	1	3,1:1	-55.0				30.4	<291d	
	1	3,3:1			4.7				
	1	3,1:1						262d	
	1	3,1:1.5	-55.0				30.6	<291d	
K85-139 Quartz	1	1,1:6				235			
	1	1,1:1.5				295			
	1	1,1:2				318			
	1	1,1:6				266			
	1	1,1:2.5				258			
	1	3,1:4					30.5	262	
	1	3,1:5						262	
	1	3,1:4.5					29.8	266	

TYPE 4A VEINS (CONT.)

Sample-Site No., Sample No., Mineral,%C	FLUID INCLUSION DATA								
	Incl. Group No.	Incl. Type, P.R.	m.p., CO2 °C	m.p., ice °C	m.p. clath. °C	T_{H2O}, °C	T_{CO2} °C	$T_{H2O-CO2}$ °C	T_4 °C
K85-139 Calcite	1	1,1:2				272			
	1	1,1:4				196			
	1	1,1:4				196			
	1	1,1:5		-3.3		202			
	1	1,1:5		-3.3		212			
	1	1,1:6				218			
	1	1,1:5				218			
	1	1,1:7.5		-3.7		209			
	1	1,1:7.5		-3.7		175			
K85-26 Quartz	1	1,1:4		-4.8		224			
	1	1,1:5				224			
	1	3,1:1						326CO_2	
	1	3,5:1					19.1	259CO_2	
	1	3,2:5:1					19.1	337dCO_2	
	1	3,3:1					17.8	275d	
	1	3,1:1					17.4	275d	
	1	3,2:5:1					10.5	295d	
	2	1,1:1				365			
	2	1,1:1				315d			
	2	1,6:1				297v			
	2	1,1:2.5				245			
	2	1,1:6				270			
K85-26 Calcite	1	1,1:6				110			
	1	1,1:14				166			
	1	1,1:16				147			
	1	1,1:8		-7.1		175			
K85-57 Sphalerite	1	1,1:13		-5.5		158			
	1	1,1:10		-4.2		146			
	1	1,1:8		-4.0		163			
	1	1,1:7				108			

TYPE 2B VEINS

Sample-Site No., Sample No., Mineral,%C	FLUID INCLUSION DATA								
	Incl. Group No.	Incl. Type, P.R.	m.p., CO_2 °C	m.p., ice °C	m.p. clath. °C	T_{H2O}, °C	T_{CO2} °C	$T_{H2O-CO2}$ °C	T_4 °C
K85-1	1A	3,1:1.5	-55.1		7.7		23.0	265d	
Quartz	1A	3,1:1.5	-55.1				23.0	297d	
	1A	3,1:3.5					23.9	279	
	1A	3,1:4					23.9	265d	
	1A	3,1:1.5					24.0	279	
	1A	3,1:5	-55.1				23.7v	265d	
	1A	3,1:2	-55.1		7.7		24.1	265d	
	1B	1,1:6				223			
	1B	1,1:15		-5.1		172			
	1B	1,1:9				232			
	1B	1,1:13		-5.1		167			
K85-7	1	1,1:23				120			
Quartz	1	1,1:5				214			
	1	1,1:8		-4.8		177			
	1	1,1:6		-4.9		179			
	1	1,1:4				168			
	1	1,1:13		-4.3		155			
	1	1,1:9				141			
	2	3,1:6					6.7	226d	
	2	3	-58.7				0.8		
	2	3,1:14					8.0	168d	
	2	3,1:2			≥8.5		4.7		
	2	3,2.5:1	-58.7				- 6.9	234d	
	2	3,1:1			≥8.5		- 3.0	226d	
	2	3,1:7					6.9	211d	
	2	3,1:9					8.2	211d	
K85-14	1	1,1:2			7.4	282			
Quartz	1	1,1:27		-4.2		156			
	1	1,1:7				212			
	1	1,1:5				231			
	1	1,1:1.5				255			
	1	1,1:1.5				274d			
	1	1,1:15				154			
	1	3,9:1	-55.1				20.7	318dCO_2	
	1	3,5:1	-55.1		10.7		17.9	299dCO_2	
	1	3,1:7					25.6	231d	
	1	3,1:1	-54.8				20.9	231d	
	1	3,1:3					25.9v		
	1	3,1:1					25.1v		
K85-15	1	1,1:6				196			
Quartz	1	1,1:2				277			
	1	1,1:11		-3.1		182			
	1	1,1:1.5				302			

TYPE 2B VEINS (CONT.)

Sample-Site No., Sample No., Mineral,%C	FLUID INCLUSION DATA								
	Incl. Group No.	Incl. Type, P.R.	m.p., CO_2 °C	m.p., ice °C	m.p. clath. °C	T_{H2O}, °C	T_{CO2} °C	$T_{H2O-CO2}$ °C	T_4 °C
K85-15	1	1,1:5				218			
Quartz	1	1,1:8		-3.0		191			
(cont.)	1	1,1:5		-3.1		202			
	1	1,1:10		-2.6		196			
	1	3,1:2	-55.1			274			
K85-20	1	3,5:1					30.8cp	322v	
Quartz	1	3,6:1					30.8 c	334v	
	1	3,12:1						275v	
	1	3,8:1					31.0v	286v	
	1	3,2.5:1					30-31		
	1	3,1:2					28.7	334d	
K85-21	1	1,1:7				175			
Quartz	1	1,1:4		-3.7		257			
	1	1,1:10				161			
	1	1,1:2				353			
	1	1,1:15		-6.7		393			
	1	1,2:1				422			
	1	1,1:13				165			
	2	3,1:1			9.3		22.6		
	2	4						Ts=178,	Tv=236
K85-22	1	1,1:10		-2.0					
Quartz	1	1,1:12		-8.0		173			
	1	1,1:12		-3.8		148			
	1	1,1:15		-8.0		186			
	1	1,1:9		-8.0		176			
	2	1,1:11		-12.7		199			
	2	1,1:12				179			
	2	1,1:20				197			
	2	1,1:14		-12.6		205			
	2	1,1:17		-12.7		199			
	2	1,1:9		-12.6		198			
K85-31	1	1,1:2				256			
Quartz	1	1,1:3				271			
	1	1,1:6.5		-6.5		214			
	1	1,1:5		-6.1		223			
	1	1,1:6				217			
	1	1,1:8		-4.2		217			
	1	1,1:5.5		-4.9		211			
	1	3,1:1.5					25.6	310d	
	1	3,1:2.5						285	
	1	3,1:2						282	
	1	3,1:1			9.8		22.5	337dCO_2	

TYPE 2B VEINS (CONT.)

Sample-Site No., Sample No., Mineral,%C	FLUID INCLUSION DATA								
	Incl. Group No.	Incl. Type, P.R.	m.p., CO2 °C	m.p., ice °C	m.p. clath. °C	T_{H2O}, °C	T_{CO2} °C	$T_{H2O-CO2}$ °C	T_4 °C
K85-31	1	3,7:1					20.5	348CO_2	
Quartz	1	3,1:2.5					24.1v	272	
(cont.)	1	3,2:1			9.8		23.3	326dCO_2	
K85-18	1	1,1:7		-9.1		185			
Quartz	1	1,1:8		-9.1		190			
	1	1,1;12		-9.1		190			
	1	1,1:7		-9.5		199			
	1	1,1:15		-9.1		169			
	1	3,2:1						370dCO_2	
	1	3,1:1	-58.0		11.7		10.1	333d	
	1	3,1:1					9.0	360dCO_2	
	1	3,1.5:1	-57.3		11.4		14.3	<357d	
	1	3,4:1	-58.1					<357d	
	1	3,1:1	-56.5				16.5	<357d	
K85-50	1	3,1:9						233d	
Quartz	1	3,1:7					21.8	233d	
	1	3,1:8					18.6	<215d	
	1	3,1:12						233d	
	1	3,2:1	-56.1				18.9	338CO_2	
	1	3,1:10						215	
	1	3,1:16					24.4	187	
	1	3,9:1	-56.2		9.7		8.5	320CO_2	
	1	3,1:7					25.0	215d	
	1	3,5:1	-56.2				5.2	271d	
	1	3,2:1	-56.2		9.1		15.1	299d	
	1	3,1:10						233d	
	1	3,1:7						233d	
	2	3,1:9					24.3	209d	
	2	3,1:6					20.9	256d	
K85-97	1A	1,1:8		-2.4		189			
Quartz	1A	1,1:7		-2.4		199			
	1A	1,1:12		-2.1		189			
	1A	1,1:6		-2.4		199			
	1A	1,1:11		-2.4		194			
	1B	1,1;14		-2.7		169			
	1B	1,1:11		-2.7		197			
	1B	1,1:7		-2.3		195			
	1B	1,1:6		-2.3		198			
	1B	1,1:14		-2.7		184			
	1B	1,1;14		-2.7		180			

TYPE 2B VEINS (CONT.)

Sample-Site No., Sample No., Mineral,%C	FLUID INCLUSION DATA								
	Incl. Group No.	Incl. Type, P.R.	m.p., CO2 °C	m.p., ice °C	m.p. clath. °C	T_{H2O}, °C	T_{CO2} °C	$T_{H2O-CO2}$ °C	T_4 °C
K85-103	1	1,1:9		-4.1		210			
Quartz	1	1,1:7		-4.5		203			
	1	1,1:12				179			
	1	3,1:2.5						285d	
	1	3,1:2					31.0	303d	
	1	3	-55.2				31.7v		
	1	3,1:4					31.6	271	
	1	3,1:1						303	
	1	3	-55.3		5.8		30.2		
	1	3	-55.3		5.8		30.7		
	1	3,1:6						210d	
	1	3,2:1					30.6v		
K85-141	1	1,1:6				178			
Quartz	1	1,1:7				195			
	1	1,1:4				222			
	1	1,1;3		-5.0		238			
	1	1,1;3		-5.5		258			
	1	3,1:1	-56.5		9.5		19.9	254d	
	1	3,2:1	-56.5		9.5		19.5	<222d	
	1	3,3:1	-56.5		10.3		17.2	328CO_2	
	1	3,1.5:1						327cp	
K85-143	1	3	-59.2						
Quartz	1	3,11:1					11.4	472dCO_2	
	1	3,6:1	-59.2				11.4	333dCO_2	
	1	3,1:2						397d	
	1	3,1:3						361d	
	1	3,1.5:1						424CO_2	
	1	3,9:1	-58.7		9.8		9.9	303CO_2	
	1	3,18:1	-58.7		9.8		10.0	276CO_2	
	1	4						Ts1=Ts2<159,318d	
	1	4						Ts=316, Tv=338	
	1	4						Ts1<167, 285d	

TYPE 3B VEINS

Sample-Site No., Sample No., Mineral,%C	FLUID INCLUSION DATA								
	Incl. Group No.	Incl. Type, P.R.	m.p., CO_2 °C	m.p., ice °C	m.p. clath. °C	T_{H2O}, °C	T_{CO2} °C	$T_{H2O-CO2}$ °C	T_4 °C
K85-59 Quartz	1	1,4:1				545v			
	1	1,1:6		- 6.0		178			
	1	1,1:25				125			
	1	1,1:7		- 6.0		195			
	1	1,1:9		- 4.4		168			
	1	1,1:2				378			
	1	1,1:1.5				256			
K85-104 Quartz	1	1,1:6				196			
	1	1,1:5				228			
	1	1,1:4				223			
	1	1,1:15				178			
	1	1,1:5				228			
	1	1,1:1.5				228			
	1	1,1:5				235			
	1	1,1:2.5				235			
	1	1,1:2				238			
	1	1,3.5				216			
	1	1				246			
K85-140 Quartz	1	1,1:4		-12.6 to -8.4		194			
	1	1,1:6				224			
	1	1,1:9				184			
	1	1,1:8				194			
	1	1,1:8				216			
	1	1,1:5.5		-11.3		189			
	1	3,2:1	-58.3		11.1		10.9	314d	
	1	3,1:1.5	-58.3		8.0		10.1	331cp	
	1	3,1:1	-58.3		8.7		10.5	264d	
	1	3,1:1					17.3	286d	

TYPE 4B VEINS

Sample-Site No., Sample No., Mineral,%C	FLUID INCLUSION DATA								
	Incl. Group No.	Incl. Type, P.R.	m.p., CO_2 °C	m.p., ice °C	m.p. clath. °C	T_{H2O}, °C	T_{CO2} °C	$T_{H2O-CO2}$ °C	T_4 °C
K85-6 Quartz	1	1,1:6		- 7.0		205			
	1	1,1:14				155			
	1	1,1:8		- 4.2		203			
	1	1,1:9		- 2.8		165			
	1	1,1:7				202			
	1	3,3:1	-57.2		11.4		11.3	238d	
	1	3,10:1					8.7	281CO_2	
	1	3,1:1	-57.0				12.2	238d	
	1	3,1:2	-57.0		10.0		14.4	323d	
	1	3,1:1	-57.0				7.1		
	1	3,2:1					3.4	276d	
K85-40 Quartz	1	1,1:6		- 8.5		250			
	1	1,1:9				258			
	1	1,1:12		-13.8		190			
	1	1,1:3.5		- 8.4		248			
	1	1,1:6		- 8.5		251			
	1	1,1:3		- 8.5		248			
	1	1,1:9		-11.0		190			
	1	1,1:14		-13.1		241			
	1	1,1:21		-13.1		172			
	2	3,3:1	-58.3				11.8	346CO_2	
	2	3,4:1	-58.6				9.5	346CO_2	
	2	3,1:2	-58.6				15.9v	288	
	2	3,1.5:1					9.1	330d	
	2	3,1:3.5						208	
K85-52 Quartz	1	3,1:10					27.8	<248d	
	1	3,1:8					22.4	247d	
	1	3,1:7					25.4	234	
	2	1,1:8				191			
	2	1,1:4.5				228			
	2	3	-55.8						
	2	3	-55.6						
	2	3	-55.6				20.9	297d	
	2	3,1:1.5					25.4		
	2	3,1:1					20.2	267d	
	2	3,1:3					23.8	292d	
	2	3,1.5:1						363d	
	2	3,1:5.5					22.5v	256	
K85-90 Quartz	1	1,1:5				210			
	1	1,1:8		- 2.5		206			
	1	1,1:1		- 3.6		<224d			
	1	1,1:6		- 6.0		208			
	1	1,1:7				222			
	1	1,1:10				212			

TYPE 4B VEINS (CONT.)

Sample-Site No., Sample No., Mineral,%C	FLUID INCLUSION DATA								
	Incl. Group No.	Incl. Type, P.R.	m.p., CO_2 °C	m.p., ice °C	m.p. clath °C	T_{H2O}, °C	T_{CO2} °C	$T_{H2O-CO2}$ °C	T_4 °C
K85-90 Quartz (cont.)	1	1,1:12				200			
	1	1,1:15				178			
K85-137 Quartz	1	1,1:5.5		-6.3		213			
	1	1,1:6.5				223			
	1	1,1:7				218			
	1	1,1:8		-6.7		206			
	1	3,1:3					22.3	291d	
	1	3,1:3					22.3	253d	
	1	3,1:4.5					28.0v	291d	
	1	3,3:1	-56.0		9.6		23.0	301d	
	1	3,2:1	-56.0		9.6		21.8	256d	
	1	3,3:1	-56.0		9.6		21.2	262d	
K85-149 Quartz	1	1,1:28		-6.8		133			
	1	1,1:8				208			
	1	1,1:7				208			
	1	1,1:9		-7.6		204			
	1	1,1:13				201			
	1	1,1:25		-6.8		133			
	1	1,1:5				264			
	1	1,1:5		-5.6		246			
	1	1,1:6		-4.0		218			
	1	1,1:18				190			
	1	1,1:1				413			
K85-12 Calcite	1	1,1:5				225			
	1	1,1:12				210			
	1	1,1:3.5				225			
	1	1,1:6				225			
	1	1,1:1.5				227			
	1	1,1:6				216			
	1	1,1:4				223			
	1	1,1:1				233			
	1	1,1:2.5				217			
K85-23 Quartz	1	1,1:2.5				285			
	1	1,1:3				285			
	1	1,1:1				322			
	1	1,1:1.5				344			
	1	1,1:1				358			
	1	1,1:12				185			
	1	3					14.7		
	1	3					23.1		
	1	3					23.1		

APPENDIX II

DIAMOND DRILL HOLES FROM WHICH VEIN MINERAL ZONING DATA WERE OBTAINED

M.E.R. G.M. NO.	HOLE NO. (THIS REPORT)	HOLE NO. (PUBLIC ARCHIVES)
49133	1	Bérubé - 1
	2	Bérubé - 2
21098	3	Mt. Ste-Anne Mines Ltd. -1
	4	" " " -2
	5	" " " -3
	6	" " " -4
	7	" " " -5
	22	" " " -6
19057	8	Twin Mountain Uranium Mines Ltd. -1
	9	" " " -2
	10	" " " -3
21838	11	Credo Mining Ltd. H-3
	12	" " " H-8
	13	" " " H-2
	15	" " " H-1
	16	" " " H-7
	17	" " " H-6
	41	" " " H-5
	72	" " " H-4
23458	14	McIntyre Porcupine Mines Ltd. 68-3
	18	" " " 68-1
	19	" " " 68-4
	20	" " " 68-5
	21	" " " 68-6
	73	" " " 68-2
11488	23	Pelletier and Landry Claims -3
	24	" " " -5
	42	" " " -1
	43	" " " -3
19475	25	Western Beaver Lodge Mines Ltd. -3
	44	" " " -2
	45	" " " -1
23349	26	Keevill Mining Group Ltd. -2
	27	" " " -1
	28	" " " -3
	29	" " " -5

M.E.R. G.M. NO.	HOLE NO. (THIS REPORT)	HOLE NO. (PUBLIC ARCHIVES)	
24620	30	Keevill Mining Group Ltd.	-6
	31	" " "	-4
24429	32	MacGregor	-1
24057	33	Lowlands Exploration Ltd.	-3
	34	" " "	-2
	35	" " "	-1
3356	36	Claude Lake Mines Ltd.	-1
	37	" " "	-2
	38	" " "	-3
	40	" " "	-9
28387	61	Madeleine Mines Ltd.	S-109
	62	" " "	S-98
	63	" " "	S-95
	64	" " "	S-100
	65	" " "	S-107
	66	" " "	S-110
	67	" " "	S-101
	68	" " "	S-111
	69	" " "	S-113
	70	" " "	S-112
	71	" " "	S-114
G.M. No. unknown. Surface Holes, Madeleine Mine area	46	Wexford Mines Ltd.	S-10
	47		S-9
	48		S-13
	49		S-7
	50		S-6
	51		S-29
	52		S-33
	53		S-8
	54		S-35
	55		S-89
	56		S-82
	57		S-30
	58		S-37
	59		S-103
	60		S-104
	74		S-34
	75		S-106