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MINERALOGICAL AND THERMAL ZONING ASSOCIATED WITH GRANITIC INTRUSIONS IN SOUTHWESTERN CANADIAN APPALACHIANS

VEIN MINERAL ZONING AND FLUID INCLUSION INVESTIGATION OF THE WOODSTOCK MINERAL DISTRICT, NEW BRUNSWICK

FINAL REPORT
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K. Stevens

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ABSTRACT

This Open File report describes vein mineral zoning trends, and vein quartz fluid inclusion homogenization and melting point zoning patterns, in a 24 km long by 6 km wide belt of granite-associated vein deposits centred on Woodstock, New Brunswick. In addition, fluid inclusion homogenization and melting point data are compared for quartz from different vein types, and phenocrystic and groundmass quartz in non-veined, hydrothermally altered and mineralized intrusive rocks.

The principal conclusions are 1) hydrothermal systems in the Woodstock district are composed of central zones of abundant veins containing quartz and Cu-Fe-sulphides, and peripheral zones characterized by the presence of quartz-galena-sphalerite-bearing veins and/or abundant quartz-carbonate-sulphides veins, 2) flow of relatively high temperature and high salinity fluids was localized mainly in the quartz-Cu-Fe-sulphides vein zones, whereas fluids with lower temperatures and salinities flowed inside and outside the latter zones, 3) exploration prospect features which indicate high ore potential are: a) quartz-rich, carbonate-poor vein mineralogy, b) phyllic alteration, c) vein quartz average fluid inclusion homogenization temperatures greater than 210°C, and d) vein quartz average fluid inclusion melting points less than -3.0°C.

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CHAPTER 1 INTRODUCTION

The Woodstock mineral district contains about 35 hydrothermal base/precious metal prospects within a 150 km2 north-trending belt (Fig. 1). The prospects are subeconomic at modern market conditions; the New Brunswick Mining Company mined copper from one locality for four years in the mid-1800's. Production figures for this operation are not available. In the Woodstock district showings, copper is the most common economic commodity, lead and zinc are common locally, and a few prospects contain up to 1 g/T Au.

It is generally recognized that deposits in the northern half of the district, which are the richest prospects in the district, constitute a porphyry copper-type mineralization system (Thomas and Gleeson, 1988). The system is centred on the Connell Mountain porphyry copper deposit which comprises 21 million tons of phyllically-altered rocks containing 0.18% Cu disseminated and in vein stockworks. Disseminated and stockwork-hosted copper mineralization and phyllic alteration are characteristic of the core zone of the porphyry system; peripheral showings are Cu+Pb-Zn+Au-bearing veins in propylitically altered wallrocks.

Economic sulphides are rare or have low abundances in showings in the south half of the district. Relations of these southern occurrences to the northern porphyry copper system or to each other are not clear.

The principal aim of this investigation is to define regional variations in vein mineral assemblages, and fluid inclusion homogenization and melting temperatures in vein quartz. These data could permit determination of the number and extent of hydrothermal systems associated with vein formation in the Woodstock district. In addition, it is possible that genetic relations between zones of particular systems will be clarified. Relating known mineral occurrences to regional hydrothermal systems may result in the refinement of exploration guidelines on both district and local scales.

This report also compares fluid inclusion data from quartz from veins with different mineral assemblages, and phenocryst and groundmass quartz in hydrothermally altered intrusive rocks. The aims of this part of the investigation are 1) to examine the possible influence of fluid temperature and compositions on vein mineral assemblages, and 2) to examine selected relations between intrusive rock emplacement, deposition of disseminated mineralization, and vein formation.

Samples required for the fluid inclusion studies, and field data, were collected under a previous M.D.A. contract: Metallogeny of the Woodstock Area, New Brunswick (Thomas and Gleeson, 1988).

The geology and exploration history of the Woodstock district are described by Thomas and Gleeson (1988). The following synopsis of the geological setting of the Woodstock vein occurrences was prepared from these authors' 1987 and 1988 reports.

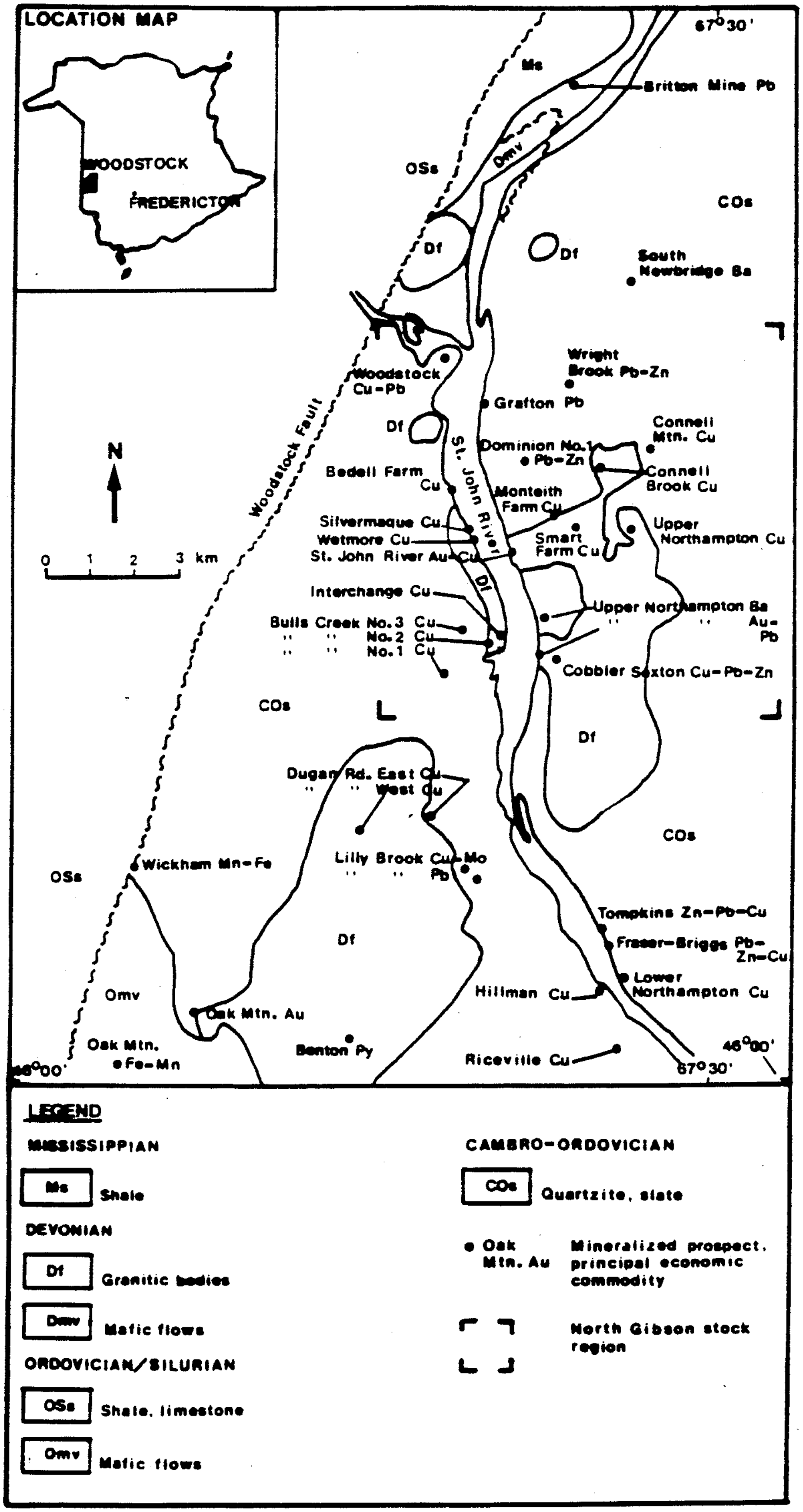


Figure 1: Location and generalized geology of the Woodstock mineral district, after Thomas and Gleeson (1988).

The project area occurs at the southwest end of the Miramichi Anticlinorium, a tectonostratigraphic zone composed of Cambro-Ordovician sedimentary rocks, Ordovician mafic volcanic rocks, Devonian felsic intrusions and minor areas of Devonian mafic volcanic and Mississippian sedimentary rocks. Most of the project area is underlain by Cambro-Ordovician metasedimentary units: mainly metaquartzites and slates. These sedimentary rocks are intruded by two large Devonian granitic bodies: the Benton stock in the south, which is mainly granite porphyry with lesser granodiorite porphyry, and the Gibson stock in the central part of the area, which is mainly tonalite with lesser granodiorite and trondhjemite; textures of the Gibson stock range from porphyritic to subophitic. Several small Devonian intrusions of generally intermediate composition occur in the north part of the area. Northwest- to northeast-trending mafic dykes are common throughout the area. Felsic dykes are common in the vicinity of the Gibson stock. Ordovician mafic flows occur in the southwest corner of the area near Oak Mountain. Lower Devonian volcanic units occur in the northern part of the region. Mississippian conglomerates, sandstones, and shales are also present in the north.

The dominant structural feature of the project area is a steeply-dipping, north- to northeast-trending fold, whose axial plane lies in the eastern part of the region. This fold is bounded to the west by the Woodstock fault, which is also the western limit of the project area. The Woodstock fault is a regional structural-stratigraphic break separating Cambro-Ordovician strata to the east from Siluro-Devonian sedimentary rocks to the west.

Hydrothermal base/precious metal mineralization occurs in quartz/carbonate veins, or as disseminations, in about 35 distinct localities. These occurrences form a north-trending belt 24 km long and an average of 6 km wide. Chalcopyrite is the most common economic mineral, galena and sphalerite are common locally, and up to 1 gm/T Au occurs in some prospects; at least some gold is in the elemental state.

Base/precious metal mineralization is the most abundant in showings of the north Gibson stock area (Fig. 1). This region hosts a porphyry copper type mineralization system which comprises a phyllically-altered core zone of disseminated and stockwork-hosted copper mineralization, and peripheral Cu+Pb-Zn+Au vein deposits in propylitically altered host rocks. The north Gibson stock area occurrence with the most economic significance by modern standards is the Connell Mountain porphyry copper deposit, where exploration drilling has outlined 21 million tons of 0.18% Cu.

Economic sulphides are present in minor amounts and/or are rare in the southern half of the project area.

A few occurrences of iron-formation, classified as Algoma-type by Gross (1984), are known in the project area. Data from veins which cut these occurrences are used in the present investigation, on the assumption that the veins are related to porphyry-type mineralization systems and not to the deposition of the iron-formation units.

CHAPTER 2 VEIN MINERAL ZONING

Vein mineral assemblage data reported below were obtained from the 1986 field notes of R. Thomas and from literature data summarized by Thomas and Gleeson (1988). Thomas visited 26 of the 36 sites shown an Fig. 1. Outcrops are present at most localities; in some cases debris from ore dumps or exploration trenches is also available or is the only source of field data. Some occurrences are known only from the literature: these include some of the older prospects and others which were flooded due to building of the Mactaquac dam.

Differences in individual mineral abundances between the north and south parts of the project area are 1) chalcopyrite, pyrrhotite, molybdenite, sphalerite, galena, and barite are much rarer in the south than in the north, and 2) tetrahedrite is present only at one southern prospect. Chalcopyrite, galena, or sphalerite occur in more than trace amounts at only four southern prospects: the Tompkins, Frazer-Briggs, and Lower Northampton showings in the southeast corner of the map area, and the Oak Mountain Au prospect in the southwest corner of the map area.

Veins in the project area can be divided into eleven types based on commonly-occurring assemblages of major vein minerals. These assemblages and their areal distributions are shown on Fig. 2. The large numeral beside some data-sites is a measure of the relative abundance of carbonate mineral-bearing veins among vein types present at the site. A value of 10 indicates that all veins at the site contain carbonate minerals whereas a value of 0 indicates that no carbonate mineral-bearing veins are present.

Veins containing abundant quartz and/or Cu-Fe-sulphides and/or Fe-sulphides (vein types 1, 2, and 3) are common throughout the project area. However there are two areas where these vein types are the dominant or only vein types present: a 6 km long x 3 km wide northeast-trending zone in the North Gibson stock area, and a much smaller Type 1-2-3 vein zone in the southeast corner of the project area. Type 1-2-3 vein zones are hereafter referred to as quartz-Cu-Fe (Q-Cu-Fe) vein zones.

To the north and south of the North Gibson stock Q-Cu-Fe vein zone, there are zones characterized by the presence of Type 4 veins: veins containing quartz, galena, and sphalerite. Another zone in which Type 4 veins are common occurs to the north of the Q-Cu-Fe vein zone in the southeast corner of the map area. Type 4 vein-bearing zones are hereafter called quartz-Pb-Zn (Q-Pb-Zn) vein zones.

The southern Q-Pb-Zn zone of the North Gibson stock area is bounded to the south by a zone in which Q-Pb-Zn are absent. It is not clear whether this same trend occurs to the north, due to uncertainty as to whether the northernmost prospect in the project area is a Q-Pb-Zn vein or a quartz-carbonate-Pb-Zn vein. Development work on this prospect was performed in the 1890's, records from this time indicate that the "ore" was hosted in vein quartz. However, vein material in the mine debris pile is rich in quartz and calcite.

The relative abundance of carbonate mineral-bearing veins per prospect site decreases away from the North Gibson stock Q-Cu-Fe zone. From north to south, carbonate vein abundances are on average zero in the Q-Cu-Fe vein zone, 2.25 in the Q-Pb-Zn zone, and 5 south of the Q-

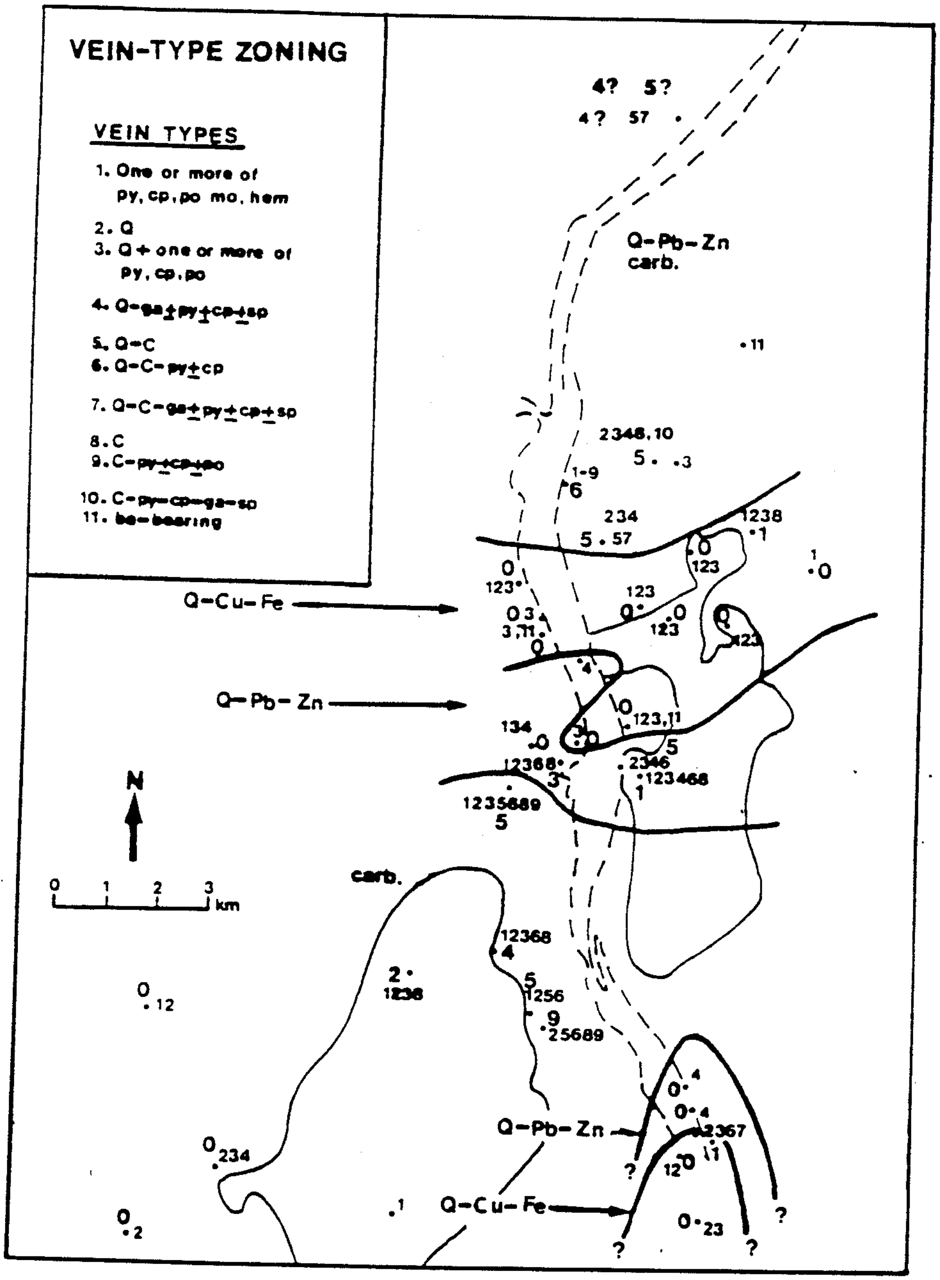


Figure 2: Vein type zoning trends. Small and large numerals at each data site indicate vein types present, and relative carbonate mineral-bearing vein abundance, respectively. The latter abundance scale goes from 0 (low) to 10 (high). Q-Cu-Fe, Q-Pb-Zn, and carb. are the names of zones characterized by the common occurrence of veins containing abundant quartz and Cu-Fe-sulphides, abundant quartz-galena-sphalerite, and quartz-carbonate-sulphides, respectively. Geographic and geologic features from Fig. 1 included for reference.

Pb-Zn vein zone. To the north of the north Gibson stock Q-Cu-Fe zone, relative carbonate mineral-bearing vein abundances average 5 to the northern limit of the project area.

Relative carbonate mineral-bearing vein abundances are low in the Q-Cu-Fe and Q-Pb-Zn zones of the southeast corner of the project area, as well as in prospects of the Oak Mountain area, in the southwest corner of the project area.

CHAPTER 3 FLUID INCLUSION STUDY

3.1 INTRODUCTION

The principal aims of this fluid inclusion study are to determine whether vein quartz fluid inclusion homogenization and melting temperatures are zoned on a regional scale, and to examine relations between this zoning, if present, and the vein mineral zoning patterns described in the previous chapter. Fluid inclusion heating and freezing data will also be compared for quartz from different vein types, and from phenocryst and groundmass quartz in non-veined intrusive rocks. The intrusive rock samples display pervasive hydrothermal alteration (phyllic and/or propylitic) and in some cases contain secondary disseminated sulphide mineralization. The aim of this part of the study is to attempt to determine whether the same or different fluids deposited veins with different mineral assemblages, or participated in wallrock alteration and mineralization processes in intrusive rocks.

Fluid inclusion sample locations are shown on Fig. 3.

3.2 EXPERIMENTAL PROCEDURES

Fluid inclusions were studied in 300 μm-thick slices of quartz polished on both sides. The microthermometric work was performed on a Chaixmeca Heating-Freezing Stage MTM-85 which has been calibrated between -56.6° and 398°C against the melting points of various pure standards. Differences between "true" and measured melting points are from -0.40° to +0.24°C over the range -56.6° to 100°C. From 100° to 398°C deviations of measured melting points from "true" values increase linearly from -0.32°C at 100°C to -15.74°C at 398°C. Temperature measurements 100°C in this study have been corrected for instrument error. Homogenization temperatures and freezing points were checked regularly for repeatability.

Homogenization temperatures for two-phase inclusions (liquid + vapour) were determined by gradually heating the inclusions and observing the temperature at which the vapour bubble in each inclusion shrank to disappearance or expanded to fill the inclusion cavity. Partial and total homogenization temperatures of three-phase inclusions (e.g. 2 immiscible liquids + a vapour phase or liquid + vapour + solid) were determined from the temperatures of disappearance of different phases during heating. Melting points of CO_2, ice and clathrate hydrate were determined by chilling inclusions until completely frozen and then, during gradual reheating, observing the temperature of disappearance of the last CO_2, ice, or clathrate crystal.

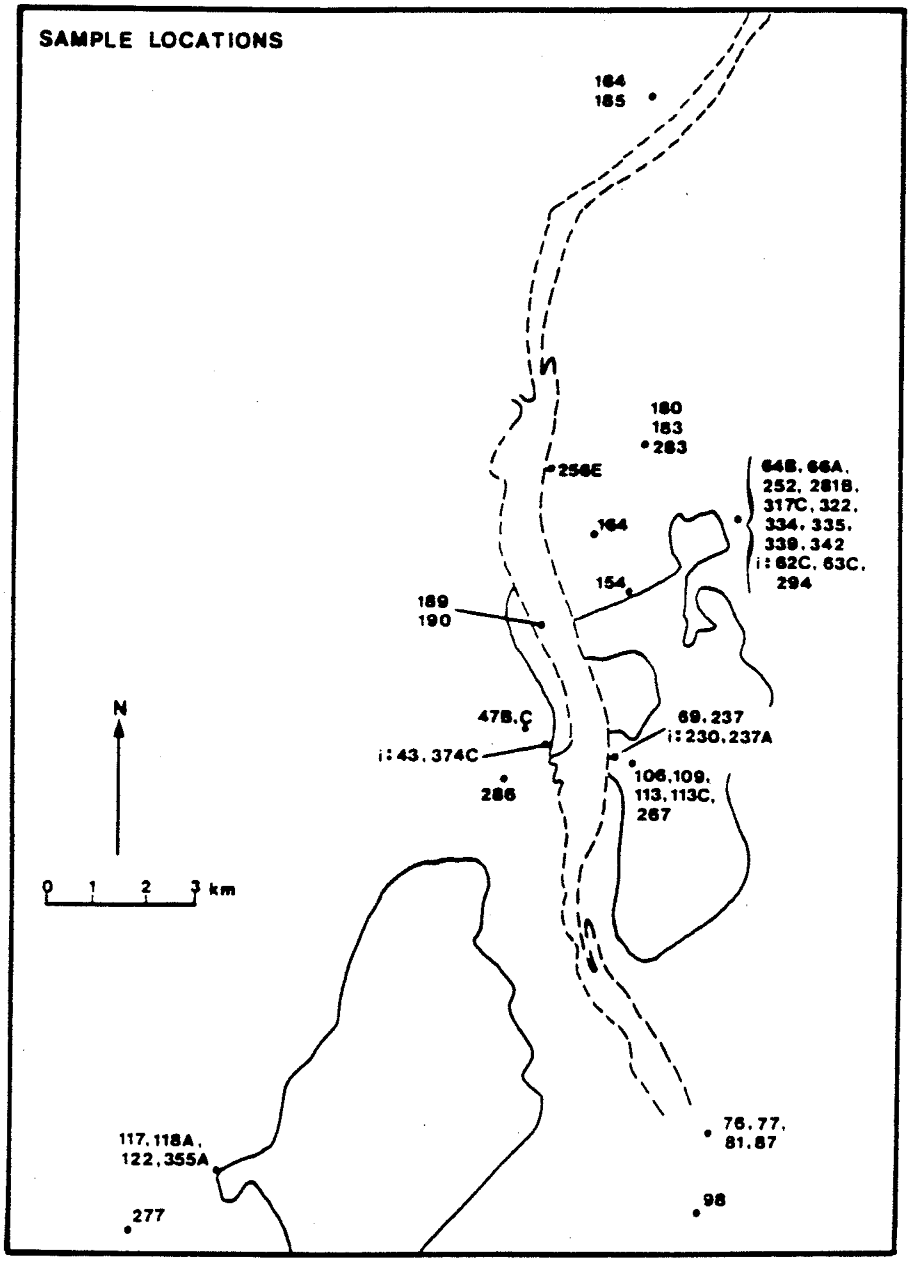


Figure 3: Locations of vein quartz and intrusive rock (i) fluid inclusion samples.

3.3 FLUID INCLUSION TYPES, PETROGRAPHY

Four types of fluid inclusions are found in the Woodstock area samples. Type 1 inclusions contain liquid, and a vapour bubble which occupies from 5 to 95% of the inclusion volume at room temperature. Type 1 inclusions comprise 99% of all Woodstock district inclusions, and occur in veins and intrusive rocks. In vein samples, vapour bubbles typically occupy 10 to 20%, and fairly commonly 20 to 50%, of inclusion volumes. Inclusions containing 20 to 50% vapour are more abundant in intrusive rock than in vein quartz samples, however 10 to 20%- vapour inclusions are much more common that 20 to 50%-vapour inclusions, in intrusive rocks. Inclusions with vapour percentages of less than 5% or greater than 50% are very rare in vein and intrusive rocks.

Type 2 inclusions contain two immiscible liquids and a vapour bubble. At room temperature, one liquid floats as a globule inside the other which wets the inclusion walls. The vapour phase, which either is present at room temperature or appears on cooling the inclusion to a minimum temperature of about 0°C, occurs within the inner liquid globule. The inner liquid occupies from 20 to 80%, but most commonly 30 to 50%, of the inclusion volume. Type 2 inclusions were observed in only two vein quartz samples, both from the southeast corner of the study area (samples 81 and 98, from the Lower Northampton and Riceville prospects, respectively). Abundance of these inclusions with respect to Type 1 inclusions which are also present in these two samples, range from fairly common to the main inclusion type present.

Only one Type 3 inclusion was encountered; it occurs in one of the Type 2 inclusion-bearing samples. This inclusion contains only liquid at room temperature but evolves a vapour bubble on cooling below about 7°C.

Type 4 inclusions comprise liquid, a vapour bubble which occupies about 10% of the inclusion volume, and a cubic solid phase which takes up 15 to 20% of the inclusion volume. One Type 4 inclusion was seen in vein sample 47C (Bulls Creek No. 3 prospect) and a few were noted in intrusive rock sample 237A (Upper Northampton Au showing).

The remarks of the following paragraph apply to vein and intrusive rock samples. Inclusion long dimensions vary from approximately 5 to approximately 25 microns, with the average lying close to the low end of this range. Most inclusion cavities are irregularly shaped; some are negative crystals. Inclusions occur typically in planes or trails which are extremely numerous in most samples and display diverse orientations. Most planes and trails are evidence of healed fractures; relatively few may represent growth banding. The vast bulk of inclusions are thus secondary or pseudosecondary. Undeniably primary inclusions are extremely rare.

In vein samples, Type 1 inclusions with <20% vapour are common throughout the survey area; those with >20% vapour are common only at some sites. At sites where <20% and >20% vapour-bearing inclusions occur, a particular vein sample may contain either or both these inclusion types; however <20% vapour-bearing inclusions generally greatly predominate in samples containing both types. >20% vapour-bearing Type 1 inclusions are present at all four sites from which intrusive rock samples were examined; individual intrusive rock samples contain either both <20% and >20% vapour-bearing inclusions, or only <20% vapour-bearing inclusions. In intrusive rock or vein samples where both these inclusion types are observed, different trails or planes may contain inclusions with different vapour percentages.

In the two samples containing Type 1 and Type 2 inclusions, Type 1 inclusions typically contain <20% vapour, whereas the inner liquid of the Type 2 inclusions generally occupies 30 to 50% of the inclusion volume.

3.4 PRESENTATION AND INTERPRETATION OF HEATING AND FREEZING DATA

Homogenization and melting point data for all samples studied are shown in Fig. 4. Data from individual samples is tabulated in the Appendix. Almost all Type 1 inclusions in vein quartz homogenize from 100° to 350°C; one value of 395°C was recorded. The most commonly observed vein quartz Type 1 inclusion homogenization temperature (Th) values are 140°-220°C; there is a strong peak at 150°-170°C. Homogenization occurred in the liquid phase for all but the inclusion which homogenized at 395°C, which homogenized in the vapour phase.

Type 1 inclusions in intrusive rocks homogenize between 130° and 380°C; values between 150° and 220°C occur the most often. Inclusions homogenized to liquid in all cases. Type 1 inclusions in vein quartz have final melting points between -7° and +4°C. Most values lie between -5° and 0°C, and there is a peak at -4° to -1°C. Intrusive rock Type 1 inclusion melting points range from -6° to 0°C, with values in the -5° to 0°C range occurring the most frequently.

The homogenization and freezing behaviour of Type 1 inclusions indicates that they are composed mainly of an aqueous salt solution and a H_2O-rich vapour phase. Rare melting points >0°C indicate the presence of between 3.7 and 9.0 wt.% CO_2 dissolved in the liquid phase (Hedenquist and Henley, 1985). The substance which melts above 0°C is not ice but a clathrate hydrate compound of formula $CO_2(5.75H_2O)$. The final melting points of same Type 1 inclusions in intrusive rock or vein samples are impossible to detect, even where inclusions are large and well-exposed. This latter phenomenon may reflect the presence of small amounts of CO_2 in these inclusions. The phenomenon would result from the fact that CO_2 clathrate hydrates have indices of refraction equal or close to that of the solution from which they grow, and thus may escape detection.

Up to 3.7 wt.% CO_2 can be dissolved in aqueous inclusions without clathrates forming during cooling (Hedenquist and Henley, 1985). At these low concentrations CO_2 acts to lower the melting point of the aqueous solution in much the same manner as do salts. In view of the evidence for CO_2 dissolved in some Type 1 inclusions, it is reasonable to suspect the presence CO_2 in other Type 1 inclusions whose freezing behaviour gives no indication of its presence. If this possibility is true, then the Type 1 inclusion salinities given on Fig. 4 and on subsequent figures in this report are in fact overestimated by an unknown amount.

The inner liquid portion of Type 2 inclusions melts at temperatures between -55° and -60°C; final melting of the outer liquid occurs at 5° to 11°C. Homogenization of the (inner liquid + vapour) portion of these inclusions occurs at 7° to 28°C, and takes place in the liquid or vapour phase. Total homogenization or decrepitation of

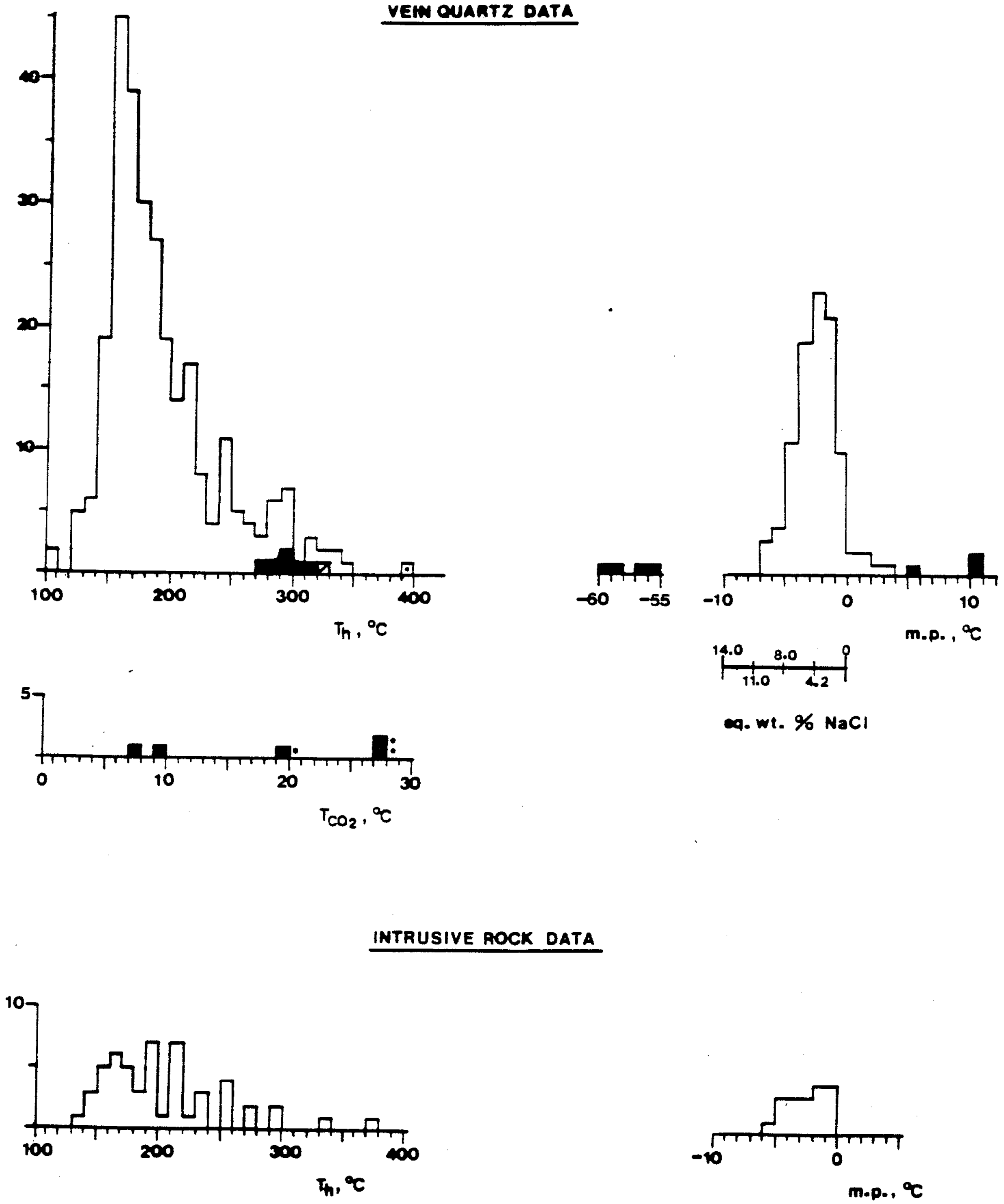


Figure 4 : Homogenization and melting temperature histograms for fluid inclusions in vein quartz and intrusive rock samples. White areas = data from Type 1 inclusions, dark areas = data from Type 2 or 3 inclusions, slanting line = Type 4 inclusion data. A dot inside a white or beside a dark data point indicates vapour-phase homogenization of Type 1, 2, or 3 inclusion; homogenization of these inclusions was to liquid for all other data points. T_{CO2} = homogenization temperature of Type 3 inclusion or the CO_2-rich portion of Type 2 inclusions.

Type 2 inclusions occurs at temperatures of 270° to 320°C; this homogenization occurs by shrinkage of the inner liquid phase.

The homogenization and melting behaviour of Type 2 inclusions can be explained in terms of phase equilibria in the system H_2O-CO_2-CH_4-salts. Final melting of the inner liquid phase at about -55° to -56°C indicates that this liquid is pure CO_2; increasing depression of this final melting point below about -56°C reflects increased amounts of dissolved CH_4 (Hollister and Buruss, 1976). Addition of CH_4 to CO_2 also depresses the boundary of the liquid + vapour field in the CO_2-CH_4 system to lower temperatures than in the pure CO_2 system. This results in progressively lower homogenization temperatures for increasingly CH_4- rich fluids. Such a trend is present in the Woodstock Type 2 inclusions: the liquid CO_2 melting point values of -55° to -56°C, and -58° to -60°C, are associated with (inner liquid + vapour) homogenization temperatures of about 27°C, and below 10°C, respectively.

Clathrate hydrate melting in the presence of liquid CO_2, CO_2 vapour, and liquid H_2O can be used to determine the salinity of the outer liquid portion of Type 2 inclusions which are CH_4-free (as determined by liquid CO_2 melting points) (Collins, 1979). One such inclusion exhibits clathrate melting at 5.8°C, corresponding to a salt content of about 9 eq. wt.% NaCl. The presence of CH_4 in Type 2 inclusions raises the clathrate melting point above the value of 10°C for pure CO_2 clathrate; salts have the opposite effect of depressing clathrate melting point values below 10°C. For inclusions in which CO_2 melting points indicate the presence of dissolved CH_4, it is not possible to quantify the opposing effects of CH_4 and salts on the pure CO_2 clathrate melting point, and thereby determine a salinity.

The single Type 3 inclusion represented in Fig. 7 has a final melting point of -58.7°C and homogenizes at +7.6°C in the liquid phase. This inclusion contains mainly CO_2 with a small amount of dissolved CH_4.

In the sole Type 4 inclusion represented on Fig. 4, the vapour bubble vanished (by shrinkage) at 143°C; inclusion decrepitation occurred at 323°C prior to dissolution of the cubic daughter crystal. Type 4 inclusions are interpreted to contain NaCl-supersaturated aqueous solution. The above inclusion for which heating data are available has a salinity of at least 39.6 eq. wt.% NaCl, calculated using the equation of Potter et al. (1979).

3.5 ZONING OF AVERAGE SAMPLE HOMOGENIZATION TEMPERATURE VALUES

Average homogenization temperatures of Type 1 inclusions in vein quartz and intrusive rock samples from 15 prospects in different parts of the survey area are shown on Fig. 5, listed by sample material type (intrusive rock, vein type). Average homogenization temperatures of Type 2 (liquid CO_2-bearing) inclusions are indicated in parentheses following the average Type 1 inclusion homogenization temperature value, for two samples from the southeast corner of the map area, which contain Type 1 and Type 2 fluid inclusions. Average Type 1 inclusion intrusive rock sample homogenization temperatures are shown for three prospects in the north Gibson stock area.

Average vein quartz Type 1 inclusion Th values range from 150° to 252°C; 13 out of 40 values are above 200°C. Average intrusive rock

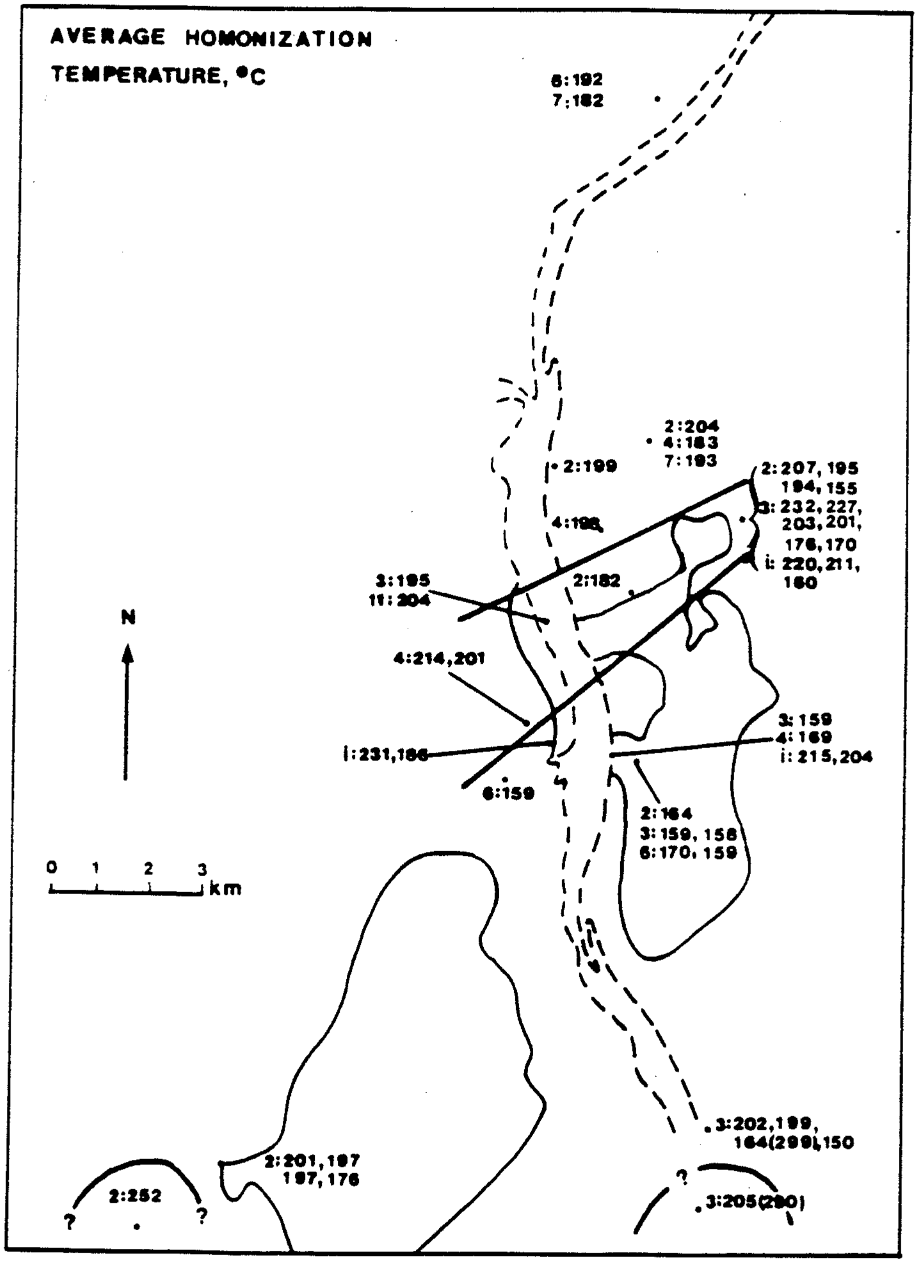


Figure 5: Average Type 1 or Type 2 (parenthesized values) inclusion homogenization temperatures, from vein quartz samples (grouped according to vein type numbers of Fig. 2) and intrusive rock samples (indicated by i). Heavy lines indicate zones in which vein quartz average Type 1 inclusion homogenization temperatures are commonly greater than 200°C.

Type 1 inclusion Th values vary from 160° to 231°C with 5 out of 7 values above 200°C.

Individual vein quartz samples with average Th >200°C are common in a northeast-trending zone extending from Connell Mountain to the Bulls Creek area, and possibly also at the Riceville and Oak Mountain Fe-Mn showings, in the southeast and southwest corners of the field area respectively. A prominent low-temperature area occurs in the southern part of the north Gibson stock area, where vein quartz Type 1 inclusion Th values are 170°C.

The highest vein quartz average Type 1 inclusion Th value obtained is 252°C, from a quartz vein which cuts the Oak Mountain Fe-Mn occurrence. The highest vein quartz average Type 1 inclusion Th values measured in the north Gibson stock area are 232° and 227°C; both samples come from the Connell Mountain porphyry copper deposit. Other 200°C Type 1 inclusion average Th values from the north Gibson stock area range from 201° to 214°C.

Average Type 2 inclusion Th values are 290° and 299°C respectively in the two samples which contain these inclusions.

3.6 ZONING OF AVERAGE SAMPLE MELTING POINT VALUES

Average Type 1 inclusion melting points are shown for vein quartz and/or intrusive rock samples from 14 prospects on Fig. 6. Prospect sites at which CO_2-bearing inclusions are present, as determined by melting points 0°C in Type 1 inclusions, or presence of liquid CO_2 in Type 2 inclusions, are circled.

Average vein quartz and intrusive rock melting points range from -6.8° to +0.1°C, and -4.8° to -1.1°C, respectively.

There are two areas in which vein quartz Type 1 inclusion average melting points are commonly below -3.0°C: 1) a northeast-trending zone in the north Gibson stock area which extends from Connell Mountain to the Upper Northampton Au and Cobbler Sexton showings, and 2) at the Riceville and Lower Northampton prospects in the southeast corner of the map area. Outside these two low-melting-point zones, average Type 1 inclusion melting points in vein quartz vary from -2.5° to +0.1°C.

CO_2-bearing inclusions occur at prospects inside and outside the m.p. <-3.0°C zone in the north Gibson stock area, and at prospects in the southeast corner of the map area.

3.7 COMPARISON OF HOMOGENIZATION AND MELTING POINT DATA FROM INTRUSIVE ROCKS AND DIFFERENT VEIN TYPES

Homogenization and melting temperature histograms for fluid inclusions in intrusive rocks, and quartz from different vein types are shown on Fig. 7. The vein types represented are quartz (Type 2) veins, veins with common quartz, and Cu-Fe- or Fe-sulphides (Type 3 veins), veins with common quartz, galena, and sphalerite (Type 4 veins), and quartz- carbonates-sulphides veins (Type 6, 7 veins).

The range of Th values is similar in all five histograms: about 130°C to about 350°C. There are strong peaks at about 150° to 160° or 170°C in the Type 2, 3, and 6-7 vein histograms. In the histogram for Type 4 veins there is a small peak at about 215°C. Th values greater than 250°C are fairly common in quartz from intrusive rocks and vein types 2 and 3, and are rare in quartz from vein types 4, 6, and 7.

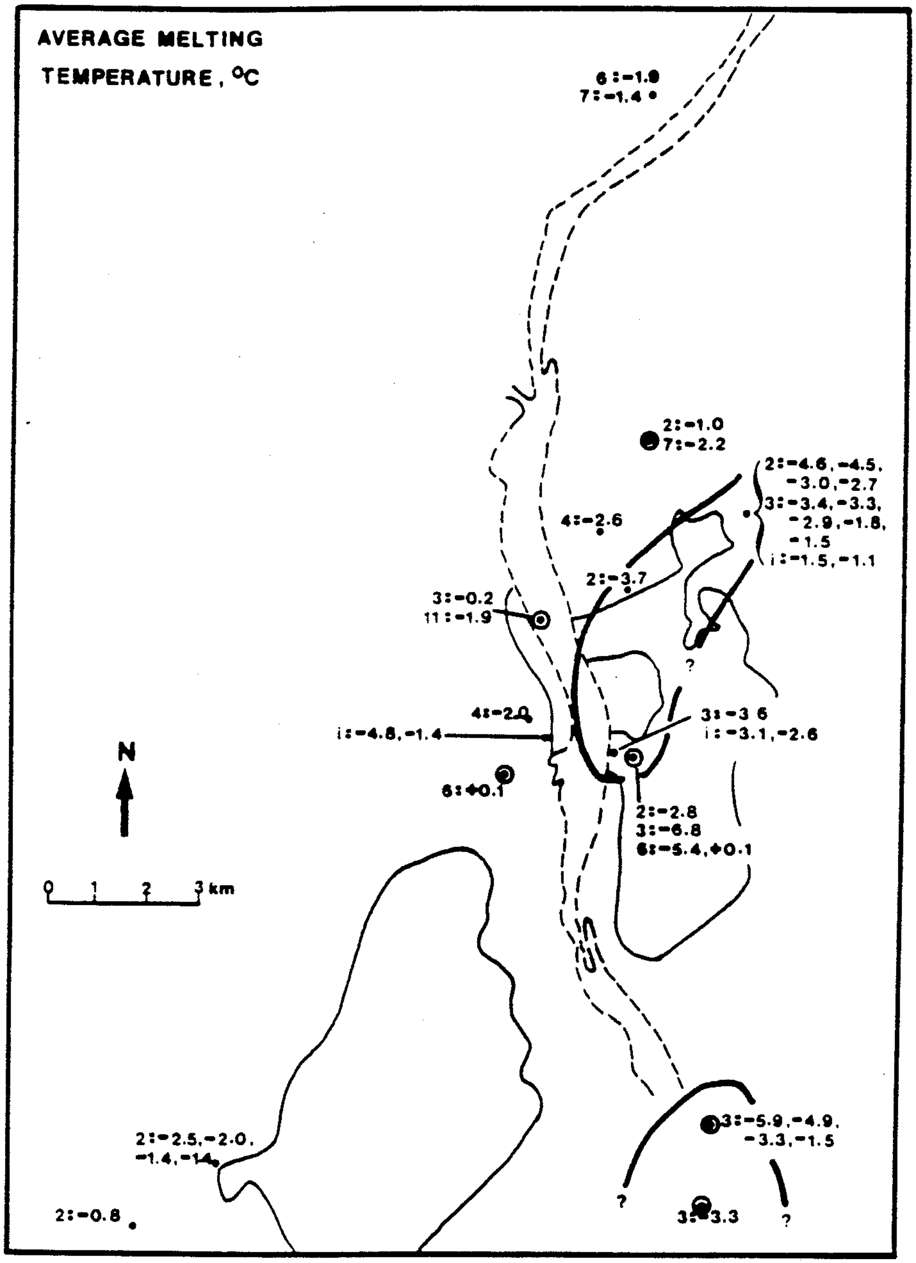


Figure 6: Average Type 1 inclusion melting temperatures, from vein quartz sample (grouped according to vein type numbers of Fig. 2) and intrusive rock samples (i)). Heavy lines indicate zones in which vein quartz average Type 1 inclusion melting temperatures are commonly less than -3.0°C. Circled data points represent sites at which CO_2-bearing Type 1 (four northern sites) or Type 2 (two southern sites) inclusions occur.

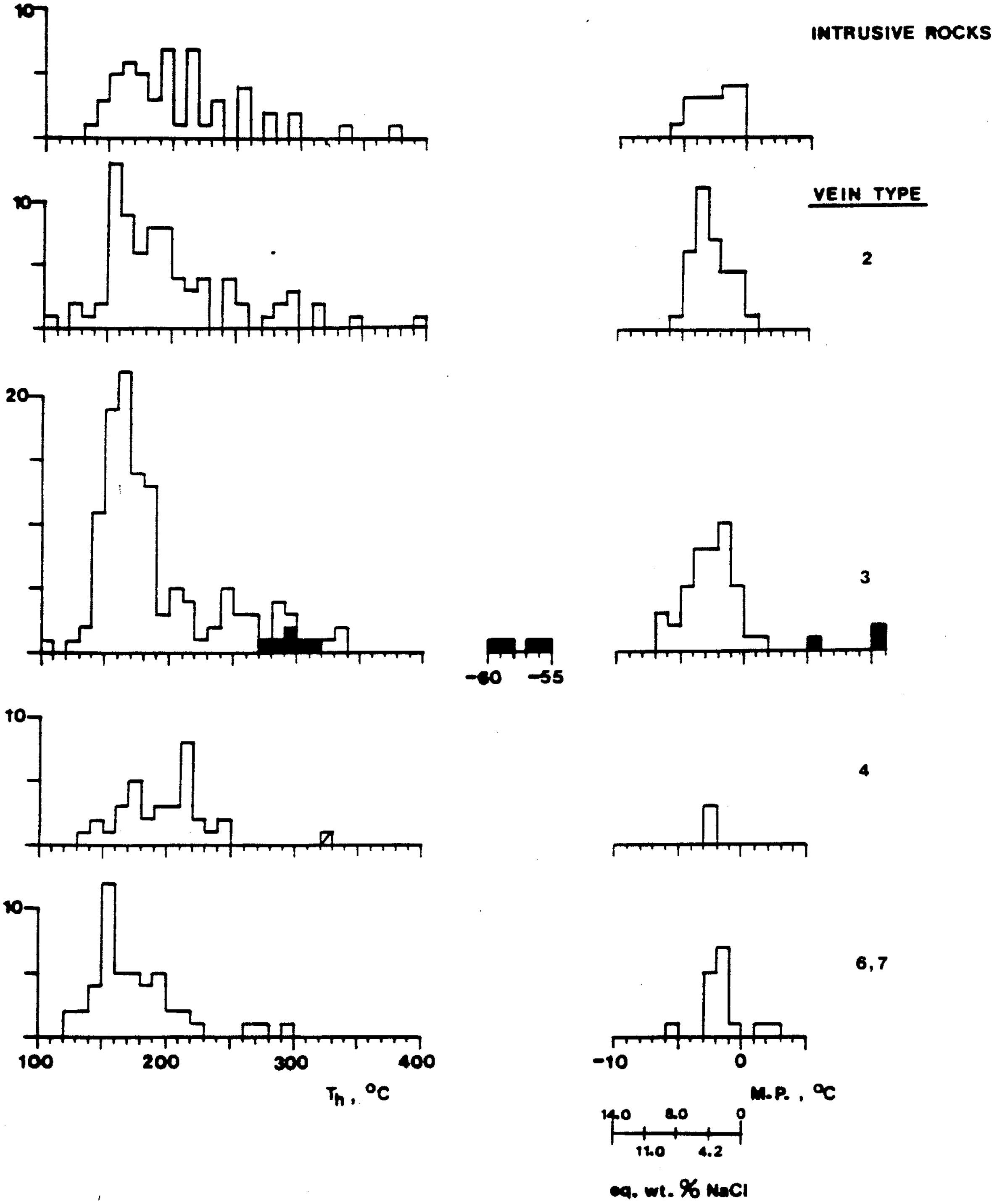


Figure 7 : Homogenization and melting temperature histograms for fluid inclusions in intrusive rocks, and Type 2, 3, 4, and (6, 7) veins, respectively. White areas = Type 1 inclusions, dark areas = Type 2, 3 inclusions, slanted line = Type 4 inclusion.

Type 1 inclusion melting points are most commonly between -5° and 0°C in all materials studied. Within this interval values <-3°C are common in quartz from intrusive rocks, and from vein types 2 and 3, and are rare in quartz from vein types 4,6, and 7. There are peaks at about -3.5°C for Type 2 veins, -4° to -2°C for Type 3 veins, and -3° to -2°C for Type 6 and 7 veins. Melting points >0°C are fairly rare in vein quartz inclusions and absent from intrusive rock inclusions. Melting points less than -6°C occur only in vein quartz inclusions.

Average Type 1 inclusion homogenization and melting points are compared for intrusive rocks, all vein quartz samples, and for different vein types, in the following table.

	Intrusive Rocks	Vein Quartz	Type 2 veins	Type 3 veins	Type 4 veins	Type 6,7 veins
Average Th °C	204	190	197	188	197	175
Average m.p. °C	-2.7	-2.5	-2.7	-2.8	-2.4	-1.5

Type 2 inclusions were only encountered in Type 3 veins. Type 2 inclusion homogenization and melting point ranges are described in Section 3.4.

Homogenization temperatures are plotted against melting points for Type 1 inclusions in quartz from Type 2, 3, 4, 6, and 7 veins in Fig. 8, and intrusive rock quartz in Fig. 9. Figs. 8 and 9 resemble each other in that 1) for Th >200°C, melting point values span a relatively narrow range of about -4° to about 0°C, and 2) for Th <200°C the range of melting points is greater than for Th >200°C. Differences in these two histograms are 1) for Th <200°C the range of melting point values is greater for vein samples than for intrusive rock samples, and 2) Th values are strongly clustered between 140° and 220°C for the vein samples, whereas they are much more evenly spread over the entire observed range in the case of the intrusive rock data. In the vein quartz Th-m.p. diagram it is seen that whereas m.p. values for veins with no carbonate minerals (vein types 2, 3) span most of the observed range, almost all m.p. values for carbonate mineral-bearing veins (Type 6, 7 veins) are above -3°C. This trend is especially clear at Th <220°C.

Note that Th values >300°C were measured in intrusive rock samples (Fig. 4) but are not represented on the intrusive rock Th-m.p. plot due to experimental difficulties encountered in measuring the melting points of these inclusions. For the same reason Th values >250°C from Type 2 and 3 veins are under-represented on the vein quartz Th-m.p. diagram (see Fig. 4).

Figure 8 : Plot of homogenization temperature vs. melting point for Type 1 fluid inclusions in different vein types. Numerals are vein type numbers from which each T_h-m.p. pair was obtained. See Fig. 2 for mineral assemblage of each vein type.

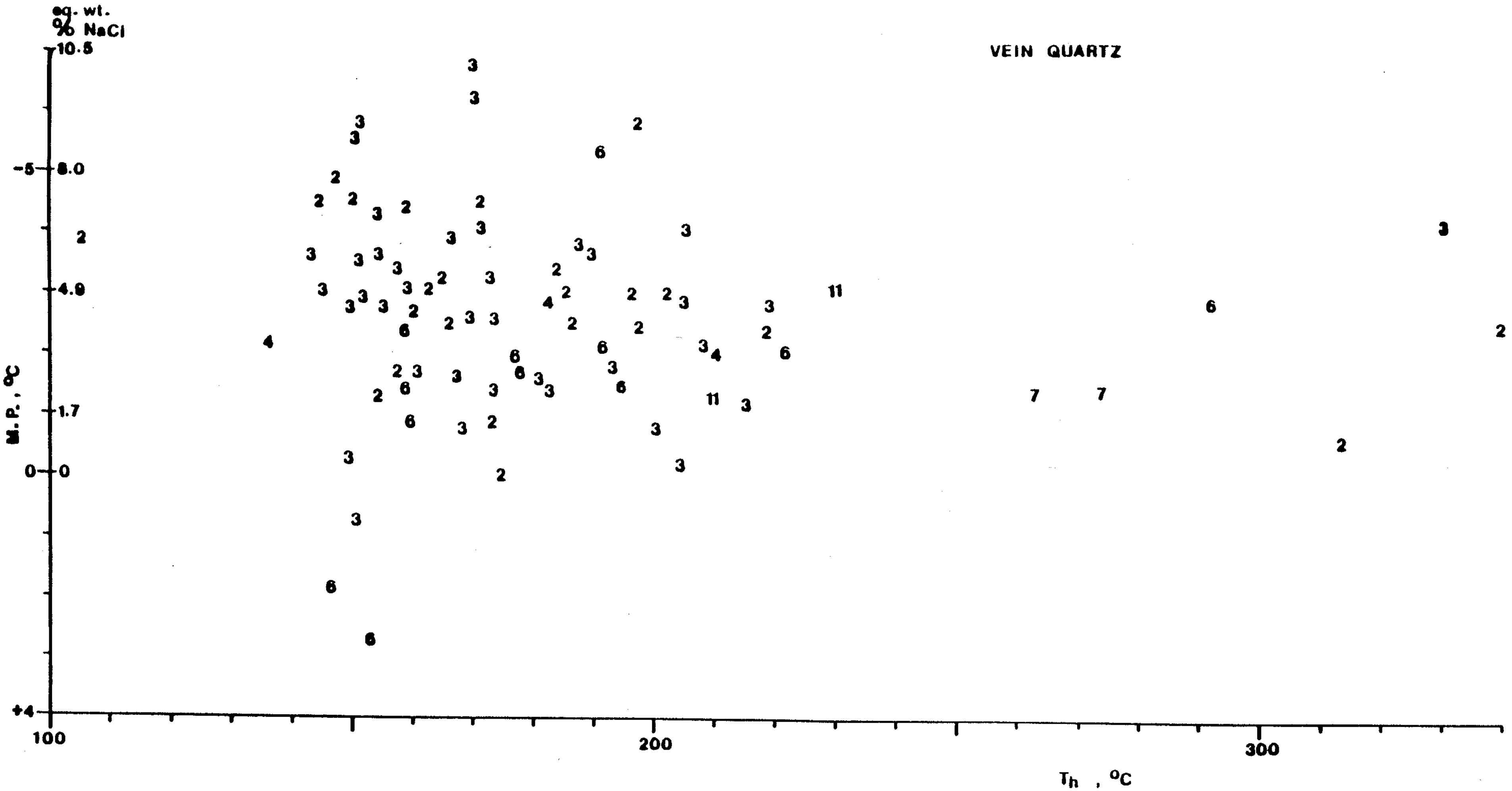
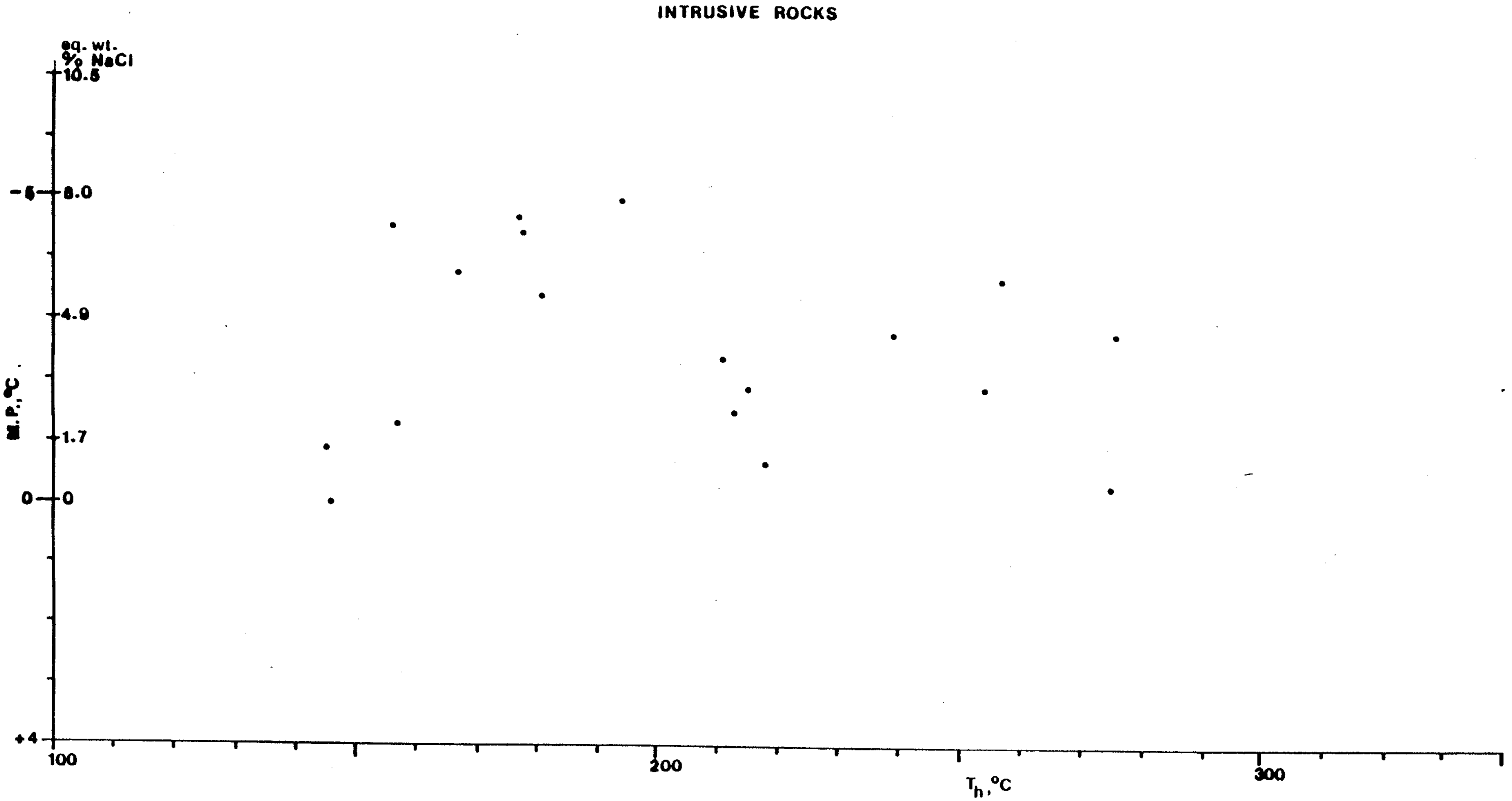


Figure 9: Plot of homogenization temperature vs. melting point for Type 1 fluid inclusions in intrusive rock phenocrystic or groundmass quartz.



CHAPTER 4 DISCUSSION

4.1 HYDROTHERMAL CENTRES IN THE WOODSTOCK DISTRICT

Vein mineral zoning trends of Fig. 2 converge on the area occupied by the northern end of the Gibson stock. These data suggest that this area was a local centre of hydrothermal activity, and that the hydrothermal system as a whole comprised a central Q-Cu-Fe vein zone, and peripheral Q-Pb-Zn, and carbonate mineral-bearing, vein zones. Vein mineral zoning trends in the southeast corner of the map area display a north to south Q-Pb-Zn to Q-Cu-Fe vein zoning trend, which suggests the presence in this region of a small hydrothermal centre or the tip of a large one which lies mainly outside the present survey area. The hypothesis that Q-Cu-Fe vein zones are hydrothermal centres is supported by the commonness with which vein quartz Type 1 fluid inclusions with high average homogenization temperatures and salinities occur in these zones: 8 of 11 vein samples with average Type 1 inclusion Th >200°C, and 10 of 14 vein samples with average Type 1 inclusion m.p. <-3.0°C, were taken from Q-Cu-Fe vein zones (Figs. 5, 6).

The Oak Mountain area veins in the southwest corner of the map area may be part of a hydrothermal centre: the veins are quartz-rich with no carbonate minerals, and a very high average Type 1 inclusion homogenization temperature (252°C) was obtained from a quartz vein which cuts the Oak Mountain Fe-Mn prospect. On the other hand, vein fluid inclusion salinities are low in this region (average m.p. >-2.5°C). More work is needed in order to confirm the possible existence of a hydrothermal centre in this locality.

4.2 HYDROTHERMAL SYSTEM HEAT SOURCES

Individual inclusion homogenization temperatures are generally well below 300°C in intrusive rock and vein samples. Average Type 1 inclusion homogenization temperatures in intrusive rock or vein samples are most commonly about 200°C throughout the survey area; this observation applies to veined sites situated relatively near to or far from intrusive bodies. These observations indicate that the exposed intrusive stocks were not the principal heat sources of the Woodstock hydrothermal system. It is more probable that heat from a deep-seated, areally extensive igneous body, which could have been the parent magma of the Gibson and Benton stocks, was responsible for fluid flow. The distance between the surface of this deep magma chamber and the present erosion surface, and fracture permeability between the heat sources and the present surface, were probably respectively similar throughout the survey area.

4.3 TEMPORAL RELATIONS BETWEEN INTRUSION EMPLACEMENT AND FLUID FLOW

Type 1 inclusion homogenization and melting temperature ranges are similar in intrusive rock and vein samples. This fact and the observations that 1) homogenization temperatures are generally less than 300°C in intrusive rock and vein samples, and 2) homogenization temperatures are on average slightly higher in intrusive rocks than in veins, indicates that the bulk of hydrothermal fluid flow through intrusions and vein fissures occurred after solidification of the igneous bodies, but before they had cooled to the temperature of the surrounding sedimentary rocks.

4.4 DISTINCT FLUID FLOW EVENTS

In section 3.3 it was mentioned that Type 1 fluid inclusions in particular vein samples can contain mainly <20% vapour, mainly >20% vapour, or a mixture of both these inclusion types when viewed at room temperature. Where both inclusion types occur in the same sample, inclusions with different vapour percentages can occur in different trails, planes, or groups. Statements analogous or similar to the preceding two can be made concerning the intrusive rock samples. Generally, the <20% vapour are much more abundant and geographically widespread than the >20% vapour inclusions.

These observations are evidence of at least two fluid flow events in the Woodstock district: a high temperature event represented by the >20% vapour inclusions, and a lower temperature event during which the <20% vapour inclusions were trapped. The relative rarity of the >20% inclusions and the fact that they do not occur at every sample site suggests that the high temperature fluid event was volumetrically smaller than the lower temperature event, and was of relatively local extent.

Homogenization temperature data of Fig. 4 corroborate and quantify the conclusions deduced from fluid petrography. High temperature fluid flow (recorded by fluid inclusions with Th >200°C) occurred mainly in the area occupied by the north part of the Gibson stock, and in the Riceville and Oak Mountain Fe-Mn areas. Flow of lower temperature fluids, represented by fluid inclusions which homogenize below 200°C) occurred in most parts of the map area.

Homogenization temperatures and compositions of coexisting aqueous (Type 1) and carbonic (Type 2) inclusions in samples from the Riceville and Lower Northampton prospects, are such that these two inclusion types could not have formed from the same boiling or condensing fluid. A third, CO_2-rich, very high temperature (>300°C) fluid therefore flowed in this part of the survey area, in addition to the two described above.

Local episodes of higher-than-average temperature fluid flow probably occurred in response to periods of increased fracture permeability below the present surface. Factors affecting fracture permeability would have been faulting or tectonic activity, cementing of fluid conduits by excessive mineral deposition, and explosive rupturing of fluid conduits due to fluid overpressures.

4.5 FLUID TEMPERATURE AND COMPOSITION VARIATIONS IN HYDROTHERMAL PROCESSES IN VEINS AND INTRUSIVE ROCKS

Homogenization temperatures less than 250°C are common in quartz from intrusive rocks and all vein types tested, but Th values greater than 250°C are conspicuously scarce in quartz from veins containing sphalerite, galena, or carbonate minerals (Fig. 7). The homogenization temperature histograms of Fig. 7, along with average-Th data from Fig. 5, suggest strongly that mineral deposition in quartz veins, and quartz with Cu-Fe- or Fe-sulphides veins, occurred at relatively high and low temperatures. Flow of Type 1 inclusion fluids through the Gibson stock was probably at least partly responsible for pervasive alteration and disseminated mineral deposition; these processes would likewise seem to have occurred over a wide temperature interval. In contrast, mineral deposition in sphalerite-, galena-, and carbonate mineral-bearing veins occurred mainly at relatively low temperatures.

The melting point histograms of Fig. 7 suggest that fluid salinities were on average higher during disseminated mineralization or alteration events in intrusive rocks, and during mineral deposition in quartz veins and quartz with Cu-Fe- or Fe-sulphides veins, than during mineral deposition in sphalerite-, galena-, or carbonate mineral-bearing veins. Fluid CO_2 contents were higher during vein deposition than during inclusion entrapment in intrusive rocks.

4.6 SPECULATION CONCERNING FLUID SOURCES

The relatively uniform salinity range of Type 1 fluid inclusions which homogenize at temperatures greater than 200°C and the restricted areal distribution of these inclusions suggest that the trapped fluids came from a unique source, such as a cooling magma chamber. Type 1 fluids inclusions which homogenize below 200°C and melt at temperatures above -2.0°C have a wide areal distribution, and could contain meteoric water. High salinity inclusions with low homogenization temperatures (m.p.=-4° to -6°C, Th <200°C) occur mainly within the hydrothermal centres defined by vein mineral zoning patterns; it is possible that such fluids were generated as a result of boiling of lower salinity fluids, such as might arise during temperature/pressure drops in the heat/fluid sources.

The high abundances of the liquid CO_2-bearing Type 2 inclusions in the Riceville-Lower Northampton area suggest that these inclusions may be widespread in veins outside the present survey area. It is therefore suggested that mapping of the areal distribution, and homogenization and melting point zoning trends, of these inclusions might provide clues as to the origin of these fluids.

It is difficult to even speculate on the origin of other Woodstock area fluids, such as the CO_2-bearing Type 1 inclusions or the Type 4 inclusions, with the available data.

4.7 IMPLICATIONS OF THE PRESENT SURVEY FOR MINERAL EXPLORATION

The aim of this section is to examine and comment on trends in the correlation of vein mineral, alteration, and fluid inclusion zoning patterns, with economic mineral abundances.

The Connell Mountain porphyry copper deposit is the Woodstock district prospect with the most economic significance at modern market conditions. This deposit is characterized by veins rich in Cu-Fe-sulphides, quartz, very low carbonate mineral-bearing vein abundances, quartz samples with the highest average Type 1 inclusion homogenization temperatures in the north Gibson stock area, and vein quartz fluid inclusion salinities among the highest recorded for the north Gibson stock area. Thomas and Gleeson (1988) noted that the Connell Mountain area lies at the centre of a regional propylitic to phyllic alteration zoning pattern.

Quartz-Cu-Fe-sulphide vein mineralogy, low carbonate mineral-bearing vein abundances, and high average homogenization temperatures and salinities of Type 1 and Type 2 inclusions in vein samples, also occur in the Riceville and Lower Northampton showings. Mineralization in the Lower Northampton and nearby Tompkins and Frazer-Briggs prospects is not rich, but is more abundant than in showings to the northwest which contain abundant carbonate mineral-bearing veins (Lilly Brook, Dugan Road East).

The Bulls Creek No. 2 showing is the only one in this district that was ever mined: this operation lasted several years in the mid-1800's; no production figures are available. Carbonate mineral-bearing veins are fairly rare at the Bulls Creek No. 2 showing, quartz-Cu-Fe-sulphide veins are fairly common; this showing occurs in a small zone of phyllic alteration (Thomas and Gleeson 1988). Unfortunately, no vein samples were available for fluid inclusion measurements from the Bulls Creek No. 2 showing. Vein quartz average Type 1 inclusion homogenization temperatures are relatively high (about 210°C) and low (about 160°C) at the nearby Bulls Creek No. 3 and 1 showings, respectively. Type 1 inclusion salinities are low at both these latter prospects.

The observations of the preceding three paragraphs suggest that the following features indicate a high ore potential of a particular showing:

1) quartz-rich, carbonate-poor vein mineralogy,
2) phyllic alteration,
3) vein quartz average Type 1 inclusion homogenization temperatures greater than 210°C,
4) vein quartz average Type 1 inclusion melting points less than -3.0°C,
5) possibly, vein quartz average Type 2 inclusion homogenization temperatures greater than about 300°C.

Coincidence of all these features on an exploration property would be favourable evidence for the presence of a Connell Mountain-type porphyry copper deposit. A property exhibiting several of these parameters would have good potential for vein-style Cu-Pb-Zn ± precious metal-bearing deposits.

The particular attractiveness of the survey methods employed in this investigation, i.e. vein mineral and fluid inclusion mapping, are:

1) vein mineral mapping can be carried out using no equipment other than the naked eye, and
2) both methods permit useful information to be obtained from veins containing little or no economic sulphides and displaying no wallrock alteration. Use of these methods could also provide a rational basis for distinguishing potentially ore-related from potentially non-ore-related geochemical or geophysical anomalies.

The observed coincidence of anomalous amounts of economic sulphides, and vein mineral, alteration, and fluid inclusion zoning centres, can be rationalized in the following way. In view of the probable deep-seated heat sources for Woodstock district hydrothermal systems, centres defined by the afore-mentioned zoning parameters probably indicate zones of maximum fracture permeability between the heat sources and the present surface. Availability of high fracture permeability is a prerequisite for the formation of economic-sized mineral deposits; these hydrothermal centres are therefore good places in which to look for ore.

CHAPTER 5 CONCLUSIONS

The principal conclusions of this investigation are:

1) Hydrothermal systems in the Woodstock district are composed of central zones of abundant veins containing common quartz-Cu-Fe-sulphides, and peripheral zones characterized by the presence of veins containing common quartz-galena-sphalerite, and/or abundant quartz-carbonates-sulphides veins.

2) The heat source responsible for hydrothermal fluid flow was probably a deep-seated, areally extensive magma body.

3) Hydrothermal activity commenced after intrusion and solidification of the Gibson and Benton granitic stocks, but before they had cooled to the temperature of the surrounding sedimentary rocks.

4) Flow of relatively high temperature fluids was localized mainly in the quartz-Cu-Fe-sulphides vein zones, whereas lower-temperature fluid flow occurred inside and outside these zones.

5) Fluid temperatures and salinities probably ranged from relatively high to relatively low values during deposition of quartz-Cu-Fe-sulphides veins, and perhaps also during pervasive alteration and disseminated mineral deposition in intrusive rocks. Fluid temperatures and salinities were relatively low during deposition of quartz-galena-sphalerite-bearing, and quartz-carbonate-sulphides veins.

6) Exploration prospect features which indicate high ore potential are:

1) quartz-rich, carbonate-poor vein mineralogy
2) phyllic alteration
3) vein quartz average Type 1 inclusion homogenization temperatures greater than 210°C
4) vein quartz average Type 1 inclusion melting points less than -3.0 °C.

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APPENDIX - FLUID INCLUSION MICROTHERMOMETRIC DATA

SYMBOLS USED IN DATA TABLES

Th	Homogenization temperature, Type 1 inclusion.
m.p.	Final melting point, Type 1 inclusion.
$v:1_A$	Apparent room temperature vapour:liquid ratio, Type 1 inclusion.
v	Homogenized to vapour, Type 1 inclusion.
m.p.CO_2	Final melting point of liquid CO_2.
m.p.clath	Final clathrate melting point.
TCO_2 ;v	Homogenization temperature of Type 3 inclusion, or CO_2-portion of Type 2 inclusion; v indicates that homogenization took place in the vapour phase.
TH_2O+CO_2	Total homogenization of Type 2 inclusion.
T_v	Temperature of vapour disappearance in Type 4 inclusion.
d	Decrepitation temperature.
$CO_2:H_2O$	Room temperature $CO_2:H_2O$ ratio in Type 2 inclusion.
I	Intrusive rock sample.
2, 3, etc.	Vein type for which vein quartz data is reported.
Incl. Gp.	Group of spatially associated fluid inclusions from which data is reported. Where no inclusion group number is indicated, inclusions all belong to same group.

A: Type 1 Inclusion Data

All Type 1 inclusions homogenized to liquid unless indicated otherwise.

Prospect	Sample No.	Sample Mat'l.	Incl. Gp., $v:l_A$	Th, °C	m.p., °C
Connell Mountain	281B	2	1:10	171	-4.5
			1:6	148	-4.9
				164	
			1:5	125	
			1:6	145	-4.5
			1:5	156	
			1:5	186	
			1:7	150	-4.5
				152	
	339	2	1:2	218	-2.4
				197	
			1:4	175	
			1:4	197	
			1:3		-3.3
			1:2	186	-2.5
	64B	2	1:6	196	-3.0
			1:10	185	-3.0
			1:2	253	
			1:5	178	
			1:6	202	-3.0
			1:3	152	
	322	2	1:3	189	
			1:3	195	
			1:1	257	
			1:4	105	-3.9
			1:3.5	189	-3.7
			1:1	291	
			1:6	175	
			1:4	197	-5.8
			1:1.5	224	
			1:1	243	
	317C	3	1,1:8	152	
			1,1:6	155	-2.8
			1,1:7	163	
			1,1:6.5	171	-4.0
			2,1:3	257	
			2,1:1	296	
			2,1:1	334	
			2,1:1	288	

Prospect	Sample No.	Sample Mat'l.	Incl. Gp., v:1$_A$	Th, °C	m.p., °C
Connell Mountain (cont'd)	66A	3	1:3	257	
			1:4	175	
			1:5	205	-4.1
			1:6	230	
			1:4	161	
			1:3		-4.1
			1:3	208	-2.2
			1:6	211	
			1:4	173	-2.6
	252	3	1,1:4	161	
			1,1:11	182	-1.4
			1,1:4		-2.4
			1,1:7	171	
			1,1:8	160	-1.7
			2,1:4	171	
			2	232	
			2,1:7	135	
			3	162	
			3	162	
			3	214	
	342	3	1:4	185	
			1:4	171	
			1:1	286	
			1:6	162	
	335	3	1:2.5	205	-2.9
			2:1	286	
			1:2	175	
			1:4	250	
			1:2	266	
			1:3	266	
			1:1	266	
			1:1	240	
			1:3	180	
			1:4	187	
	334	3	1:6	204	-0.2
			1:4	196	
			1:9	149	
			1:5	175	
				124	
			1:4	161	
			1:4.5	184	
	294	I	1,1:3.5	194	
			1,1:13	167	
			2,1:5.5	204	

Prospect	Sample No.	Sample Mat'l.	Incl. Gp., $v{:}1_A$	Th, °C	m.p., °C
Connell Mountain (cont'd)	294 (cont'd)	I	2	189	
			2,1:11	152	
			2,1:4.5	177	
			2,1:3	295	
			2,1:2.5	295	
			2,1:2	223	
	62C	I	1:6	177	
			1:10	157	-1.3
			1:5	177	
			1:10	145	
			1:10	145	-0.9
	63C	I	1:3	213	-1.5
			1:5	251	
			1:3	195	
Dominion No.1	164	4	1,1:7	183	-2.9
			1,1:4	136	-2.2
			2,1:9	221	
			2,1:12	206	
			2,1:4	243	
Monteith Farm	154	2	1:7	163	-3.1
			1:7	157	
			1:6	159	-3.1
			1:7	159	-4.4
			1:1	212	
			1:3.5	205	
			1:2.5	196	
			1:2	207	
			1:7		-4.0
Wetmore	189	3	1,1:5.5	157	
			1,1:1	330	-4.2
			1,1:5	201	-0.8
			1,1:6	161	
			1,1:2	215	-1.2
			2,1:10	149	-0.3
			2,1:11		+1.7
			2,1:11	150	+0.7
			2,1:10		+3.0
	190	11	1.5:1	230	-3.1
			1:6	172	-1.3
			1:4	210	-1.3

Prospect	Sample No.	Sample Mat'l.	Incl. Gp., v:1$_A$	Th, °C	m.p., °C
Upper Northampton Au	237	3	1:10	161	
			1:10	143	-3.7
			1:5	162	
			1:4.5	181	
			1:7		-3.7
			1:6.5	184	
			1:10	157	-3.4
			1:16	145	
			1:15	146	
			1:8	154	-3.7
	69	I	1,1:11	156	
			1,1:5	145	
			1,1:7	145	
			1,1:12	165	
			2	173	
			2	179	
			2	219	
	230	I	1:4	190	
			1:5	181	-3.3
			1:5	210	
			1:4	185	
			1:3	254	-1.9
			1:8	194	
				219	
			1:4	190	
				213	
	237A	I	1,1:7	215	-1.9
			1,1:5	217	-0.7
			1,1:1	276	-2.8
			1,1:2	250	-3.7
			1,1:2.5	236	
			1,1:3	211	-2.4
			1,1:3.5	239	-2.8
			2,1:8	168	
			2,1:7	178	-4.5
			2,1:15	156	
Cobbler Sexton	267	2	1:9	165	
			1:6	173	-3.3
			1:6	154	-1.3
				163	
			1:6	186	
			1:12	180	-3.4
			1:8	165	-3.3

Prospect	Sample No.	Sample Mat'l.	Incl. Gp., v:1_A	Th, °C	m.p., °C
Cobbler Sexton (cont'd)	113	3	1,1:6.5	182	
			1,1:10	156	
			1	163	
			1,1:2.5	163	
			1	157	
			1,1:5	156	
			2,1:10	135	
			2,1:5		-6.8
			2,1:3.5	169	-6.8
			2,1:9	147	
	113C	3	1,1:6	150	
			1,1:8	153	
			2,1:10	172	-4.0
	106	6	1:5	178	-1.7
				178	
				146	+1.9
				166	
				181	
				171	
	109	6	1,1:8	152	
			1,1:4	150	
			1,1:12	128	
			2	191	-5.4
			2,1:9	159	
			2	151	
			2	182	
Bulls Creek No.1	286	6	1,1:8	165	
			1,1:7.5	159	-0.9
			1	152	
			1,1:9.5	153	+2.7
			1,1:8	194	-1.5
			2	164	
			2,1:6	143	
			2,1:8	147	
			2,1:6	160	
			2	148	
Bulls Creek No.2	374C	I	1:4	157	
			1:4	167	
			1:5.5	146	0.0
			1:3	275	-0.3
			2:1	334	
			1:1	372	
			1:5	167	-3.8

Prospect	Sample No.	Sample Mat'l.	Incl. Gp., v:1_A	Th, °C	m.p., °C
Bulls Creek No.2 (cont'd)	43C	I	1:2.5	194	-5.0
			1:3.5	232	
			1:6	166	
			1:3	177	-4.7
				160	
			1:1	258	
			1:7	135	
			1:7	198	
			1:3.5	156	-4.6
Bulls Creek No.3	47C	4	1:5	200	
			1:7	175	
			1:2.5	213	
				165	
			1:5.5	179	
			1:8	208	
				218	
			1:2.5	241	
			1:4	233	
			1:6	199	
	47B	4	1:5	229	
			1:5	210	-2.0
				210	
				210	
				210	
				210	
				160	
				178	
				192	
				197	
Grafton Pb	256E	2	1:3	218	
				179	
Wright Brook	283	2	1,1:7	229	
			1,1:3.5	248	
			1,1:9		+0.7
			1,1:6	208	
			1,1:7	192	
			2,1:4.5	160	-2.7
			2,1:7	186	
	183	4	1:10	180	

Prospect	Sample No.	Sample Mat'l.	Incl. Gp., $v:1_A$	Th, °C	m.p., °C
Wright Brook (cont'd)	180	7	1,1:3.5	221	-2.1
			1,1:6	191	-2.1
			1,1:4	199	
			1,1:6	158	-2.4
			1,1:5	158	-2.4
			1,1:5.5	136	
			1,1:1.5	292	-2.9
			1,1:3.5	211	
			1	215	
			1,1:5	205	
			2,1:9	159	-1.4
			2,1:8	171	
Lower Northampton	76	3	1,1:4	167	-3.9
			1,1:4	170	-6.2
			1,1:4	244	
			1,1:8	188	
			1,1:6	176	
			1,1:6	170	
			1,1:6	150	-4.6
			1,1:4	170	
			1:1	353	
	77	3	1,1:30	140	
			1,1:4	167	-1.7
			1,1:12	181	-1.7
			1,1:8	167	-1.7
			1	329	
			1,1:14	167	-0.8
			1	183	
			1,1:3	243	
			2,1:3	244	
	81	3	1,1:5	145	-3.1
			2,1:6	150	-2.9
			2,1:5	219	-2.9
			2,1:10	162	
			2,1:7	154	-4.3
			2,1:10	154	
	87	3	1:7	151	-5.8
			1:3	147	
			1:11	150	-5.9
			1:8	162	
			1:10	175	
			1:7	162	
			1:6	149	
			1:5	103	

Prospect	Sample No.	Sample Mat'l.	Incl. Gp., $v:1_A$	Th, °C	m.p., °C
Oak Mountain Au	355	2	1:5	197	-2.5
	177	2	1:7	149	
			1:2.25		-1.1
			1:12	173	-1.4
			1:11	185	
			1:6	193	-1.8
			1:15	160	
			1:6	196	
	118A	2	1,1:5	158	-1.7
			1,1:4	158	-1.7
			1,1:10	134	
			1,1:1	315	
			1,1:6	173	-0.9
			1,1:4	224	
			2,1:10	161	
			2,1:1.5	285	
	122	2	1:3		-0.6
			1:1.25	340	-2.5
			1:4	167	-2.5
			1:5	161	
			1:8	159	
			1:4	159	-2.5
Oak Mountain Fe-Mn	277	2	1,10:1	394_v	
			1,1:13	174	0.0
			1,1:2.25	1313	-0.7
			1,1:1	297	
			1,1:1	282	
			1,1:6	242	
			1,1:5		-1.8
			1,1:3	242	
			1,1:4	299	
			1,1:2	271	
			2,1:17	157	
			2,1:7	228	
			2,1:6	128	
Riceville	98	3	1:1	229	
			1:3.5	243	
			1:8	188	-3.8
			1:9	169	-2.6
			1:4	216	
			1:5	151	-3.5
			1:4	232	

Prospect	Sample No.	Sample Mat'l.	Incl. Gp., $v:1_A$	Th, °C	m.p., °C
Britton Mine	184	7	1,1:2	275	-1.4
			1,1:4	263	-1.4
			1,1:4	151	
			1,1:13	165	
			1,1:6	156	
			2,1:4	182	-1.5
			2,1:10	132	
			2,1:8	122	
			2,1:8	191	
	185	6	1:5	206	
			1:5	177	-1.9

B: Data from Type 2,3, and 4 inclusions

Total homogenization of Type 2 inclusions occurred in H_2O phase. CO_2 (liquid + vapour) homogenization is in liquid phase unless indicated otherwise.

Prospect	Sample No., Vein Type	Incl. Type, $CO_2:H_2O$	m.p. CO_2 °C	m.p. clath., °C	T_{CO_2} °C	$T_{H_2O+CO_2}$ °C
Lower Northampton	81,3	2,1:1			19.0_V	307
			-56.6	5.8	27.0_V	314
				10.1	27.5_V	277
Riceville	98,3	2,1:1	-59.0	10.4	9.3	291d
		2,2:1				291d
		2,1:3				288
		3	-58.7		7.6	
Bulls Creek No. 3	47C,4	4; T_V = 141, 323d				