GEOLOGICAL SURVEY OF CANADA
BULLETIN 419

CARBONATE-HOSTED LEAD-ZINC DEPOSITS OF WESTERN NEWFOUNDLAND

Cynthia M. Saunders, D.F. Strong, and D.F. Sangster

1992

Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

Canada

DEPARTMENT OF MINES AND ENERGY
GOVERNMENT OF NEWFOUNDLAND AND LABRADOR

Contribution to Canada-Newfoundland Mineral Development Agreement 1984-89, a subsidiary agreement under the Economic and Regional Development Agreement. Project funded by the Geological Survey of Canada.

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Available in Canada through authorized
bookstore agents and other bookstores

or by mail from

Canada Communication Group — Publishing
Ottawa, Canada K1A 0S9

and from

Geological Survey of Canada offices:

601 Booth Street
Ottawa, Canada K1A 0E8

3303-33rd Street N.W.,
Calgary, Alberta T2L 2A7

A deposit copy of this publication is also available for
reference in public libraries across Canada

Cat. No. M42-419E
ISBN 0-660-14423-9

Price subject to change without notice

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Original manuscript submitted: 1990 - 08
Final version approved for publication: 1991 - 08

Cover description

See page 34.

Preface

The western Newfoundland carbonate platform has been the site of lead-zinc exploration for several decades. This activity has resulted in the discovery of several dozen occurrences and one commercial producer. Geological information on these occurrences, collected by industry, government, and university geologists over the years, is scattered among government assessment files, company reports, and university theses. Most of this available information consists of field observations; very little laboratory research was performed.

The aim of this study was to merge this previous information, on more than 40 of these occurrences, with new on-site observations and follow-up laboratory investigations. As a result, the occurrences have been grouped into three main types, each with distinct mineralogical and textural characteristics, with host rocks ranging in age from Middle Cambrian to Early Carboniferous. Fluid inclusion research has indicated that at least two brines with different temperatures and salinities were responsible for mineralization.

Consolidation of these data into a single publication creates a timely and useful basis for further research of, and exploration for, carbonate-hosted lead-zinc deposits not only in western Newfoundland but elsewhere in the Appalachian-Caledonian orogen.

Elkanah A. Babcock
Assistant Deputy Minister
Geological Survey of Canada

Préface

Pendant plusieurs décennies, la plate-forme carbonatée de l'ouest de Terre-Neuve a fait l'objet d'une exploration de gisements plombo-zincifères. Ces travaux ont permis la découverte de plusieurs douzaines d'occurrences et d'un gisement de valeur économique. Les données géologiques liées à ces occurrences, recueillies au cours des ans par l'industrie, le gouvernement et certaines universités sont disséminées dans des dossiers d'évaluation du gouvernement, des rapports de sociétés et des thèses universitaires. Très peu de travaux de laboratoire ayant été effectués, la plupart de ces données découlent d'observations faites sur le terrain.

La présente étude avait pour objet de fusionner les données portant sur plus de 40 de ces occurrences avec de nouvelles observations directes et des données de laboratoire complémentaires. Par la suite, les occurrences ont été regroupées en trois principaux types, chacun caractérisé par une minéralogie et une texture distinctes et l'âge des roches encaissantes variant du Cambrien moyen au Carbonifère précoce. Des recherches sur les inclusions fluides ont révélé qu'au moins deux saumures à température et salinité différentes ont été à l'origine de la minéralisation.

Le regroupement de ces données en une seule publication tombe à un moment opportun pour les futurs travaux de recherche et d'exploration de gisements de plomb-zinc logés dans des roches carbonatées, non seulement dans l'ouest de Terre-Neuve mais également dans d'autres zones de l'orogène appalachien-calédonien.

Elkanah A. Babcock
Sous-ministre adjoint
Commission géologique du Canada

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CARBONATE-HOSTED LEAD-ZINC DEPOSITS OF WESTERN NEWFOUNDLAND

Abstract

The more than 40 lead-zinc occurrences included in this study can be grouped into three basic types:

I. "Great Northern Peninsula Type" open-space filling/replacement mineralization associated with secondary white dolomite spar;

II. "Port au Port Type" vein/open-space filling/replacement mineralization associated with calcite with or without barite;

III. "Turners Ridge Type" replacing the matrix in intensely brecciated Silurian dolostone.

Type I contains three sub-types: Ia - found in open spaces and in the matrix to dolomite pseudobreccias, epigenetic dolomite bodies, and angular spar breccias in predominantly Ordovician strata; Ib - restricted to fractures, veinlets, small clots, and disseminations in Cambrian dolostones; Ic - occurrences with characteristics intermediate between the other two.

Type II can also be subdivided: IIa - vein/open-space filling/replacement in Mississippian rocks; IIb - veins in Cambro-Ordovician rocks; and IIc - veins of unknown age or affinity.

Type III mineralization occurs in brecciated dolostone in a Silurian volcano-sedimentary belt.

Fluid inclusion data show that Type Ia mineralization formed from low temperature generally highly saline fluids (mode 24-26 equivalent weight % NaCl). Two occurrences of Type Ib mineralization formed from relatively high temperature intermediate salinity fluids (18-22 equivalent weight % NaCl). Inclusions in Type Ic mineralization indicate mixing of cool moderately to highly saline brines (14-28 equivalent weight % NaCl) with one or possibly two hot low salinity brines. Thus, Type Ic mineralization, which has field characteristics intermediate between IIa and IIb, also has intermediate homogenization temperatures and a range of salinities equal to the other two types.

Résumé

La quarantaine d'occurrences de plomb-zinc traitées dans la présente étude peuvent être divisées en trois types de base :

I. Minéralisation de remplissage d'espaces ouverts ou de substitution du «type de la Grande péninsule du Nord» associée à de la dolomite spathique;

II. Minéralisation de remplissage d'espaces ouverts, de substitution ou de filons du «type Port au Port» associée à de la calcite accompagnée ou non de barytine;

III. Minéralisation du «type de la dorsale Turners» remplaçant la matrice dans la dolomie silurienne intensément bréchifiée.

Le type I comporte trois sous-types : Ia - présent dans des espaces ouverts et dans la matrice de pseudobrèches dolomitiques, de massifs dolomitiques épigénétiques et de brèche spathique anguleuse dans des couches principalement ordoviciennes; Ib - limité aux fractures, filonnets, petits grumeaux et disséminations dans des dolomies cambriennes; Ic - occurrences dont les caractéristiques sont intermédiaires relativement aux deux types précédents.

Le type II peut également être subdivisé : IIa - minéralisation de remplissage d'espaces ouverts, de substitution ou de filons dans des roches mississippiennes; IIb - filons dans des roches cambro-ordoviciennes; et IIc - filons d'âge ou d'affinité non déterminé.

Le type III correspond aux minéralisations présentes dans une dolomie bréchifiée dans une zone volcano-sédimentaire silurienne.

Les données sur les inclusions fluides révèlent que la minéralisation du type Ia s'est formée à partir de fluides généralement très salins (poids équivalent de 24 à 26 % en NaCl) à faible température. Deux occurrences du type Ib se sont formées à partir de fluides à température relativement élevée et à degré de salinité intermédiaire (poids équivalent de 18 à 22 % en NaCl). Les inclusions dans la minéralisation de type Ic indiquent un mélange de saumures froides à degré de salinité moyen à élevé (poids équivalent de 14 à 28 % en NaCl) avec une ou deux saumures à température plus élevée et à faible degré de salinité. Par conséquent, la minéralisation du type Ic dont les caractéristiques se situent entre IIa et IIb, présentent également des températures d'homogénéisation intermédiaires et un intervalle de salinité égaux à ceux des deux autres types.

SUMMARY

The occurrences studied can be grouped into three basic types:

(I) "Great Northern Peninsula Type" open-space filling/ replacement mineralization associated with secondary white dolomite spar.

(II) "Port au Port Type" vein/open-space filling/replacement mineralization associated with calcite plus or minus barite.

(III) "Turners Ridge Type" replacing the matrix in intensely brecciated Silurian dolostone.

Within Type I there exists a gradation between two end-members: (a) mineralization found in open spaces and in the matrix to dolomite pseudobreccias, epigenetic dolomite bodies, and angular spar breccias developed in predominantly Ordovician strata; and (b) mineralization restricted to fractures, veinlets, small clots, and disseminations in low porosity/permeability dolostones predominantly of Cambrian age.

Many occurrences (Type Ic) do not fit neatly into one of the end-members because they contain characteristics intermediate between the two, e.g. Salmon River #3 and Watts Point. Other occurrences are quite different from the end-members but still fit the general characteristics of Type I, e.g. Chambers Island and Round Head Island. These showings contain abundant pyrite which occurs in the fine-rock matrix of breccias. Mineralization is in part open-space filling and has associated minor dolomite spar.

Type II can be further subdivided into three categories: (a) vein/open-space filling/replacement mineralization hosted by Mississippian rocks of the Codroy Group, which are characterized by high porosity and permeability; (b) vein mineralization hosted by relatively impermeable Cambro-Ordovician rocks of the Port au Port, St. George, or Table Head groups, but of the same age and type as IIa and part of the same overall mineralizing system; (c) vein mineralization of unknown age or affinity. All mineralization studied on the Port au

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Les occurrences à l'étude peuvent être subdivisées en trois types de base :

I. Minéralisation de remplissage d'espaces ouverts ou de substitution du «type de la Grande péninsule du Nord» associée à de la dolomite spathique;

II. Minéralisation de remplissage d'espaces ouverts, de substitution ou de filons du «type Port au Port» associée à de la calcite accompagnée ou non de barytine;

III. Minéralisation du «type de la dorsale Turners» remplaçant la matrice dans la dolomie silurienne largement bréchifiée.

Au sein du type I, il existe une transformation entre deux membres d'extrémité : a) minéralisation présente dans des espaces ouverts et dans la matrice de pseudobrèches dolomitiques, de massifs dolomitiques épigénétiques et de brèche spathique anguleuse dans des couches principalement ordoviciennes; et b) minéralisation limitée aux fractures, filonnets, petits grumeaux et disséminations dans des dolomies à faible porosité et perméabilité d'âge surtout cambrien.

Plusieurs occurrences (type Ic) ne correspondent pas exactement à l'un des membres d'extrémité parce que leurs caractéristiques se situent entre les deux, par ex. Salmon River n° 3 et Watts Point. Même si elles sont très différentes des membres d'extrémité, d'autres occurrences possèdent les caractéristiques générales du type I, par ex. Cambers Island et Round Head Island. Ces indices contiennent de la pyrite en abondance dans la matrice fine des brèches. Il s'agit en partie d'une minéralisation de remplissage d'espaces ouverts comportant un peu de dolomite spathique.

On peut subdiviser le type II en trois catégories : a) minéralisation de filon/de remplissage d'espaces ouverts/de substitution logée dans des roches mississippiennes du Groupe de Codroy caractérisées par une porosité et une perméabilité élevées; b) minéralisation filonienne logée dans des roches cambro-ordoviciennes relativement imperméables des groupes de Port au Port, de St. George ou de Table Head, mais d'âge et de caractère équivalents au type IIa et faisant partie du même système de minéralisation global; c) minéralisation filonienne d'âge ou d'affinité non déterminé. Toutes les

Port Peninsula is Type IIa or IIb. Where the host is porous and brecciated sedimentary rocks (i.e. Codroy Group limestones) mineralization is randomly oriented open-space filling. Where the host rocks were nonporous, i.e. pre-Carboniferous carbonate, mineralization is confined to veins whose orientation is commonly controlled by pre-existing faults and fractures.

minéralisations étudiées dans la péninsule de Port au Port font partie du type IIa ou IIb. Lorsque la roche encaissante est une roche sédimentaire bréchifiée poreuse (telle que les calcaires du Groupe de Codroy), la minéralisation est un remplissage d'espaces ouverts orientés au hasard. Lorsque la roche encaissante n'est pas poreuse, comme les roches carbonatées antérieures au Carbonifère, la minéralisation est confinée aux filons dont l'orientation suit en général celle des failles et fractures existantes.

Type III mineralization occurs in the Sops Arm Group, a Silurian volcano-sedimentary belt. Very fine grained galena, pyrite, and subordinate sphalerite mineralization forms the matrix to intensely brecciated dolostone. The showings occur near a major fault zone and brecciation is likely of tectonic origin.

La minéralisation du type III est présente dans le Groupe de Sops Arm, une zone volcano-sédimentaire silurienne. La matrice de la dolomie largement bréchifiée est formée de galène, de pyrite et de sphalérite subordonnée à grain très fin. Les indices sont situés près d'une importante zone de failles et la bréchification est probablement d'origine tectonique.

Type Ia mineralization

This type is associated with abundant white saddle dolomite, which forms pseudobreccia, or pseudo-breccia-like texture, or cements angular spar breccia (Saunders and Strong, 1986). Pseudobreccia texture has resulted from overprinting of dolomite-mottled limestone such that the mottles are preserved as rounded "fragments" surrounded by saddle dolomite (Haywick, 1984). The saddle dolomite in part replaces original dolostone or limestone and in part fills open spaces formed by in situ dissolution of the original rock (Crossley and Lane, 1984).

The saddle dolomite tends to luminesce uniform medium to bright red and may have late thin zones of varying luminosity. Dolomite "fragments" in the clasts luminesce uniform medium to dark red or bluish red.

Sphalerite most commonly precedes the bulk of the saddle dolomite and is observed rimming "fragments" in the pseudobreccia. However in some occurrences sphalerite postdates at least some of the dolomite (e.g. Shorts Harbour and St. John Island). Fine grained hydrothermal quartz is intergrown with sphalerite from Salmon River #6 and St. John Island. At the latter occurrence geopetal cavities are filled with bedded sphalerite, quartz, and euhedral dolomite.

Replacement of sulphides by dolomite is not very common but is locally important. At Twin Ponds Quarry galena is extensively replaced by dolomite and ankerite, but sphalerite is not. Sphalerite rims angular fragments in spar breccia and appears to be later than the galena. Galena is fragmented and may predate brecciation. At Fish Point, sphalerite is corroded and replaced by fine grained dolomite which forms the fine-rock matrix to angular dolostone fragments.

Sphalerite may be nonluminescent (e.g. the occurrences on St. John Island) or may have late, brightly luminescing zones or rims (e.g. Round Pond or

Minéralisation du type Ia

Ce type est associé à une abondante dolomite blanche à cristaux voûtés qui forme une pseudobrèche ou une texture de pseudobrèche, ou cimente une brèche spathique anguleuse (Saunders et Strong, 1986). La texture de la pseudobrèche est due à la surimpression d'un calcaire à nodules de dolomite de sorte que les nodules sont conservés sous forme de «fragments» arrondis baignant dans de la dolomite à cristaux voûtés (Haywick, 1984). La dolomite à cristaux voûtés remplace en partie la dolomie ou le calcaire originel et remplit en partie les espaces ouverts formés par la dissolution in situ de la roche originelle (Crossley et Lane, 1984).

La dolomite à cristaux voûtés a tendance à produire une luminescence uniforme de rouge moyen à brillant et peut parfois comporter de minces zones tardives de luminosité variable. Les «fragments» dolomitiques dans les clastes produisent une luminescence uniforme de rouge moyen à rouge foncé ou bleuâtre.

Le plus souvent, la sphalérite précède l'ensemble de la dolomite à cristaux voûtés et constitue des «fragments» de bordure dans les pseudobrèches. Cependant, dans certaines occurrences, la sphalérite est postérieure à une certaine partie de la dolomite (par ex. Shorts Harbour et St. John Island). Du quartz hydrothermal à grain fin est enchevêtré avec de la sphalérite aux occurrences Salmon River n° 6 et St. John Island. Dans la dernière occurrence, les cavités géopétales sont remplies de sphalérite, de quartz et de dolomite euédrique rubanés.

La substitution des sulfures par de la dolomite n'est pas généralisée mais elle est importante par endroits. À la carrière Twin Ponds, la galène a été largement remplacée par la dolomite et l'ankérite, mais non la sphalérite. La sphalérite borde les fragments anguleux dans la brèche spathique et semble être postérieure à la galène. La galène est fragmentée et pourrait être antérieure à la bréchification. À Fish Point, la sphalérite est corrodée et a été remplacée par de la dolomite à grain fin qui forme la matrice fine des fragments dolomitiques anguleux.

La sphalérite peut ne pas être luminescente (par ex. les occurrences de l'île St. John) ou produire des zones ou bordures tardives à luminescence brillante (par ex. Round Pond

Salmon River #6). Sphalerite in a sample from Salmon River #6 has brightly luminescent rims that are depleted in iron.

Sphalerite from Fish Point occurrence luminesces spectacularly. This was not analyzed but the light colours in transmitted light suggest that the brightly luminescent sphalerite, which is pale yellow, is lower in iron than the late, nonluminescent sphalerite, which is dark rust. Sphalerite luminescence in a Round Pond sample could not be related to concentration of any particular element.

In places saddle dolomite is followed by light brown luminescing calcite spar, or fine grained nonluminescent quartz.

Type Ib mineralization

Type Ib occurs in Cambrian dolostones of the March Point and Petit Jardin formations. It consists of sporadic sphalerite and galena occurring as disseminations and fracture coatings and in white dolomite spar veinlets and clots. Host rocks are typically massive dolostones with no development of pseudobreccia or angular spar breccia.

The fine grained dolomite of the Petit Jardin Formation tends to have early medium red luminescent cores, typical of all early synsedimentary dolostones of Cambrian to mid-Ordovician age (I. Knight, pers. comm., 1990), which are overgrown by one or two zones of varying luminosity where porosity was sufficient to allow penetration of fluids. Larger pore spaces and vugs allowed deposition of additional zones to form spar. Zoning is sharply defined; the latest zones are commonly nonluminescent (e.g. Eddies Cove, Pikes Feeder Pond). Electron microprobe analyses show that nonluminescent zones are iron-rich.

Dolostone from the March Point Formation tends to luminesce a uniform red, although in places it is overgrown by later zoned dolomite. Zoning is not as well developed as in the Petit Jardin Formation.

Most mineralization predates spar formation. A sample from Rocky Pond West contains cavities lined by fine grained sphalerite and pyrite, followed by quartz and dolomite. Sphalerite and galena commonly show evidence of replacement by dolomite spar, or less commonly by fine grained dolomite. Dolomite that replaces sphalerite in a sample from Contact Brook is Zn-rich.

In samples from Goose Arm Narrows, sphalerite zones are truncated by dolomite crystals, but in places galena fills fractures along dolomite spar grain boundaries, suggesting it is later. Sphalerite has been replaced by galena where cut by a late calcite vein.

ou Salmon River n° 6). La sphalérite dans un échantillon de Salmon River n° 6 comporte des bordures à luminescence brillante dont la teneur en fer est appauvrie.

La sphalérite de l'occurrence Fish Point produit une luminescence spectaculaire mais n'a pas été analysée; cependant, la présence de couleurs claires en lumière transmise indique que la sphalérite à luminescence brillante de couleur jaune pâle a une teneur en fer plus faible que la sphalérite non luminescente tardive qui est de couleur rouille foncée. La luminescence de la sphalérite dans un échantillon de Round Pond pourrait ne pas être reliée à la concentration d'un élément donné.

Par endroits, la dolomite à cristaux voûtés est suivie d'une calcite spathique à luminescence brun clair ou d'un quartz non luminescent à grain fin.

Minéralisation du type Ib

Le type Ib se retrouve dans les dolomies cambriennes des formations de March Point et de Petit Jardin. Il est composé de sphalérite et de galène sporadiques disséminées ou revêtant des parois de fractures et dans des veinules et des grumeaux de dolomite spathique. Les roches encaissantes caractéristiques sont des roches dolomitiques massives sans pseudobrèches ou brèches spathiques anguleuses.

La dolomite à grain fin de la Formation de Petit Jardin a tendance à comporter des noyaux luminescents rouge moyen précoces, caractéristiques de toutes les roches dolomitiques synsédimentaires précoces d'âge allant du Cambrien à l'Ordovicien moyen (I. Knight, comm. pers., 1990), qui sont auréolés par une ou deux zones de luminosité variable lorsque la porosité était suffisante pour permettre la pénétration de fluides. La présence de vides et de vacuoles interstitiels plus grands ont permis le dépôt de zones supplémentaires qui ont formé des spaths. Les zones sont nettement définies; les zones tardives sont en général non luminescentes (par ex. Eddies Cove, Pikes Feeder Pond). Les analyses par microsonde électronique révèlent que les zones non luminescentes sont riches en fer.

La dolomite de la Formation de March Point a tendance à produire une luminescence uniforme rouge même si, par endroits, elle est envahie par une dolomite zonée tardive. Les zones ne sont pas aussi bien définies que dans la Formation de Petit Jardin.

La grande partie de la minéralisation est antérieure à la formation de spath. Un échantillon de Rocky Pond West contient des cavités revêtues de sphalérite et de pyrite à grain fin, suivies de quartz et de dolomite. La sphalérite et la galène indiquent habituellement une substitution par de la dolomite spathique ou, moins souvent, par de la dolomite à grain fin. La dolomite qui remplace la sphalérite dans un échantillon de Contact Brook est riche en Zn.

Dans des échantillons provenant de Goose Arm Narrows, les zones de sphalérite sont tronquées par des cristaux de dolomite, mais par endroits la galène remplit des fractures longeant les limites des cristaux de dolomite spathique, indiquant qu'elle est d'origine postérieure. La sphalérite a été remplacée par de la galène là où elle est recoupée par un filon de calcite tardif.

Type IIa mineralization

This type is found as open-space fillings and replacements in fossiliferous, commonly brecciated Carboniferous Big Cove Formation limestones which unconformably overlie the Table Head Formation in north-trending paleokarst valleys. Marcasite, pyrite, galena, sphalerite, calcite spar, and barite fill voids and surround limestone fragments and fossils, replacing a micritic matrix. Mineralization also occurs in 1 to 10 cm wide, vuggy, randomly oriented veins.

Marcasite is abundant and generally forms radiating sheaves. Pyrite is abundant on one side of Bellmans Cove and elsewhere forms minor primary intergrowths with marcasite (e.g. at Piccadilly Brook). Galena is locally important, especially at Lead Cove, yet is extremely rare at Bellmans Cove, less than 1 km from Lead Cove. Sphalerite is minor and may occur as rare euhedral crystals in vugs or as rounded inclusions in pyrite or marcasite. Barite is minor except at Aguathuna Road, where it is very abundant. Zoning is generally marcasite (calcite)-galena (sphalerite)-marcasite-calcite -barite, although one or more zones (shown in parenthesis) may be absent.

The abundance of a mineral at one site (e.g. galena at Lead Cove, barite at Aguathuna Road) and its rarity at other sites suggests that zoning is also present on a regional scale.

The fluid inclusion data of von Bitter et al. (1990), combined with Type IIb data from the present study, suggests that Type IIa mineralization was deposited from relatively low to moderate temperature highly saline fluids (see below).

Type IIb mineralization

Mineralization of this type is confined to vertical to subvertical calcite veins which cut through carbonates of the Port au Port, St. George, and Table Head groups.

The Type IIb vertically oriented calcite veins on the Port au Port Peninsula can be divided into two types. Those from the northern part of the peninsula, i.e. the Goodyear Prospect and Piccadilly Harbour, are heavily mineralized and contain abundant galena, sphalerite, and marcasite as well as orange to yellow luminescent calcite gangue. Those along the southern shore at Fiods Cove, Felix Cove, and Abrahams Cove are characterized by thinly banded speleothem calcite (Dix, 1982) that locally surrounds collapsed fragments of the wall rock. The speleothem calcite ranges from nonluminescent to orange to yellow. It is followed by a zone of coarse orange to yellow luminescent calcite spar with minor sulphides and

Minéralisation du type IIa

Ce type se présente sous la forme de minéralisation de remplissage d'espaces ouverts et de substitution dans les calcaires fossilifères généralement bréchifiées de la Formation de Big Cove du Carbonifère, qui repose en discordance sur la Formation de Table Head dans des vallées paléokarstiques orientées vers le nord. Les vides sont remplis de marcasite, de pyrite, de galène, de sphalérite, de calcite spathique et de barytine; ces minéraux entourent les fragments de calcaire ainsi que les fossiles et remplacent la matrice micritique. Cette minéralisation loge également dans des filons vacuolaires orientés au hasard, dont l'épaisseur varie entre 1 et 10 cm.

La marcasite est abondante et forme généralement des faisceaux rayonnants. La pyrite est abondante dans une partie de l'occurrence Bellmans Cove et, ailleurs, elle forme des enchevêtrements primaires peu importants avec la marcasite (par ex. Piccadilly Brook). La galène est importante par endroits, en particulier à Lead Cove, mais elle est très rare à Bellmans Cove, à moins de 1 km de Lead Cove. La sphalérite est peu abondante et se présente parfois sous forme de rares cristaux euédriques dans des vacuoles ou des inclusions arrondies dans la pyrite ou la marcasite. La barytine est peu abondante sauf à Aguathuna Road où elle est très abondante. La zonation est définie en général par la marcasite (calcite)-galène (sphalérite)-marcasite-calcite-barytine, même si une ou plusieurs zones (indiquées entre parenthèses) peuvent être absentes.

L'abondance d'un minéral à un certain endroit (par ex. la galène à Lead Cove, la barytine à Aguathuna Road) et sa rareté à d'autres endroits révèlent que la zonation se manifeste également à une échelle régionale.

Les données sur les inclusions fluides tirées de von Bitter et al. (1990), combinées aux données sur le type IIb de la présente étude, révèlent que la minéralisation du type IIa s'est déposée à partir de fluides très salins de température faible à moyenne (voir ci-dessous).

Minéralisation du type IIb

La minéralisation de ce type se limite aux filons verticaux et quasi verticaux de calcite qui recoupent les roches carbonatées des groupes de Port au Port, de St. George et de Table Head.

Les filons verticaux de calcite du type IIb dans la péninsule de Port au Port peuvent être subdivisés en deux types. Ceux que l'on trouve dans le nord de la péninsule, comme la zone d'intérêt Goodyear et l'occurrence Piccadilly Harbour, sont fortement minéralisés et contiennent de la galène, de la sphalérite et de la marcasite en abondance ainsi qu'une gangue de calcite à luminescence orange ou jaune. Les filons le long de la rive méridionale à Fiods Cove, Felix Cove et Abrahams Cove sont caractérisés par la présence de calcite spéléothème finement rubanée (Dix, 1982) qui entoure par endroits des fragments tombés de l'éponte. La calcite spéléothème est non luminescente ou produit une luminescence variant d'orange à jaune. Elle est suivie par une zone de calcite spathique barite that is likely of the same age as the more significant mineralization in the Goodyear and Piccadilly veins. Pratt (1979) describes a heavily mineralized calcite vein from the area northwest of the peninsula (Fig. 1) that combines the features of both vein styles. This vein is bordered by banded, radial, columnar calcite interpreted by Pratt (1979) to be a speleothem deposit. This is followed by green sediment and then by colloform sphalerite intergrown with galena cubes — a texture similar to that in veins from the Goodyear Prospect and Piccadilly Harbour. The sphalerite is followed by a thin layer of marcasite, calcite spar, and green sediment. This suggests that mineralization at the Goodyear Prospect and Piccadilly Harbour also postdates deposition of speleothem calcite and is of relatively young age.

Other Type IIb occurrences also show evidence of a young age for these veins. For instance, at Fiods Cove, limestone conglomerate of the Upper Mississippian(?) Lower Cove Formation (Dix and James, 1989) is cut by a Type IIb calcite vein (Saunders and Strong, 1986) and at Gillams Cove (about 1 km east of Miners Brook), a mineralized calcite vein cuts fossiliferous Carboniferous sedimentary rocks localized along fractures in Ordovician carbonate (von Bitter et al., 1990).

The speleothem calcite ranges from Early to Late Mississippian age (Dix, 1982). The later calcite spar and associated sulphide mineralization in these veins may be related to Type IIa sulphide mineralization, which is hosted by the mid-Visean Big Cove Formation (Dix and James, 1989) in overlying paleokarst valleys. This is supported by the similar zonation shown by Type IIa occurrences and the two most heavily mineralized Type IIb veins as well as by the fluid inclusion data of von Bitter et al. (1990). Based mainly on diagenetic evidence, Dix (1982) suggested that Type IIa sulphide deposition occurred at a relatively late stage in the phreatic zone after the host carbonate had been buried by prograding fluvial and terrestrial sediments. However, von Bitter et al. (1990) interpreted this (IIa) mineralization to be syndepositional, i.e. mid-Visean, based on paleontological evidence that suggests a hydrothermal vent-associated faunal community. The occurrence of an apparently Type IIb calcite vein cutting Lower Cove Formation conglomerates at Fiods Cove indicates that deposition of these veins persisted into the Late Mississippian and thereby supports the conclusion of Dix (1982). However, Knight (pers. comm., 1990) suggests that such veins may have formed at different times throughout the evolution of the sedimentary sequence as the result of escaping groundwater.

Dix (1982) and Dix and James (1989) have determined that during the mid-Visean the Port au Port Peninsula was partly submerged with marine conditions existing in low-lying areas, including paleokarst valleys,

grossière à luminescence variant d'orange à jaune accompagnée d'un peu de sulfures et de barytine qui devraient être d'âge équivalent à la minéralisation logée dans les filons de Goodyear et de Piccadilly. Pratt (1979) la décrit un filon de calcite très minéralisé situé au nord-ouest de la péninsule (fig. 1) qui possède les caractéristiques des deux styles de filons. Ce filon bordé de calcite prismatique, radiale et rubanée est, selon Pratt (1979), un gisement spéléothème. Il est suivi de sédiments verts et d'une sphalérite colloforme enchevêtrée avec des cubes de galène, créant une texture semblable à celle observée dans les filons de la zone d'intérêt Goodyear et l'occurrence Piccadilly Harbour. La sphalérite est suivie d'une mince couche de marcasite, de calcite spathique et de sédiments verts, indiquant que la minéralisation à la zone d'intérêt Goodyear et à l'occurrence Piccadilly Harbour est également postérieure au dépôt de calcite spéléothème et qu'elle est relativement récente.

Les autres occurrences du type IIb contiennent également des indices que ces filons sont d'âge récent. Par exemple, à Fiods Cove, le conglomérat calcareux de la partie inférieure de la Formation de Cove du Mississippien supérieur (?) (Dix et James, 1989) est recoupé par un filon de calcite du type IIb (Saunders et Strong, 1986), et à Gillams Cove (1 km environ à l'est de Miners Brook), un filon de calcite minéralisé recoupe les roches sédimentaires fossilifères d'âge carbonifère longeant les fractures formées dans les roches carbonatées ordoviciennes (von Bitter et coll., 1990).

L'âge de la calcite spéléothème varie du Mississippien précoce à tardif (Dix, 1982). La calcite spathique tardive et la minéralisation sulfurée associée dans ces filons pourraient être liées à la minéralisation sulfurée du type IIa qui est contenue dans la Formation de Big Cove du Viséen moyen (Dix et James, 1989) dans des vallées paléokarstiques sus-jacentes. Cette hypothèse est confirmée par la similarité de la zonation des occurrences du type IIa et les deux filons du type IIb les plus fortement minéralisés ainsi que par les données sur les inclusions fluides de von Bitter et coll. (1990). En se basant principalement sur des données diagénétiques, Dix (1982) indique que le dépôt des sulfures du type IIa a eu lieu à une étape relativement tardive dans la zone phréatique après l'enfouissement des roches carbonatées encaissantes par les sédiments fluviatiles et terrestres de progradation. Toutefois, von Bitter et coll. (1990) en ont conclu que cette minéralisation (IIa) est synsédimentaire, c'est-à-dire datant du Viséen moyen, en fonction des données paléontologiques disponibles qui semblent indiquer la présence d'une communauté faunique associée à une cheminée hydrothermale. La présence d'un filon de calcite apparemment du type IIb recoupant les conglomérats de la partie inférieure de la Formation de Cove à Fiods Cove indique que le dépôt de ces filons s'est poursuivi jusque pendant le Mississippien tardif, appuyant de ce fait la conclusion de Dix (1982). Cependant, selon Knight (comm. pers., 1990), ces filons se seraient formés à différentes époques pendant l'évolution de la séquence sédimentaire par suite de l'expulsion d'eau souterraine.

Dix (1982) et Dix et James (1989) ont établi que durant le Viséen moyen, la péninsule de Port au Port était en partie submergée par la mer dans les zones basses, dont les vallées paléokarstiques, tandis que dans les hautes terres adjacentes les and fluvial/terrestrial conditions existing on adjacent highlands; re-emergence of the entire peninsula occurred by the Late Mississippian. The abundance of speleothem calcite in veins on the southern shore of the peninsula may be related to the longer period of emergence in the rocks of this area. The difference in sulphide content, i.e. abundant in veins along the northern part of the peninsula and minor in veins along the southern shore, may relate to the distribution of marine versus terrestrial conditions during the Mississippian. The metal rich veins may represent proximal deposition from relatively saline metal-rich mineralizing fluids that emanated from the offshore marine sedimentary basin. The metal-poor veins may be representative of more distal evolved (i.e. diluted) fluids. This would suggest the source of the fluids lay to the north of the Port au Port Peninsula rather than to the south.

Fluid inclusion data show that Type I mineralization in general may have formed from mixing of cool moderately to highly saline (14-28 equivalent wt. % NaCl) brines with one or maybe two hot low salinity brines. Two occurrences of Type Ib mineralization from the Great Northern Peninsula (Eddies Cove and Pikes Feeder Pond) formed from relatively high temperature intermediate salinity (18-22 equivalent wt. % NaCl) fluids. The Goose Arm Narrows occurrence (also Type Ib) has differing fluid inclusion characteristics which may be the result of secondary fluids or of differing conditions of formation. Differing conditions would perhaps not be unexpected as this deposit is situated at considerable distance from the others (150-250 km). Type Ia mineralization formed from lower temperature generally highly saline fluids (mode 24-26 equivalent wt. % NaCl). Type Ic mineralization which has field characteristics intermediate between the two end-members also has intermediate homogenization temperatures and varying salinities.

It is not known what the origin of the hot brine (or brines) was, but the low temperature, high salinity brine may be similar in composition (and age?) to the cool and highly saline brines which formed Type IIb (and IIa?) occurrences.

The Carboniferous Deer Lake Basin to the south is a possible source of the Turners Ridge (Type III) mineralization. The brecciated dolostone may have acted as a structural and chemical trap for up-welling, lead-rich basinal fluids. This is broadly similar to the situation on the Port au Port Peninsula where lead-rich mineralization is hosted by Carboniferous limestones (Type IIa). The gangue mineralogy (calcite and minor barite) is comparable at the Turners Ridge/Side Pond and Port au Port showings. The source of fluids for the latter may have been present day offshore Carboniferous sediments.

conditions étaient de type fluvial ou continental, ou les deux; l'émergence de toute la péninsule a eu lieu avant le Mississippien tardif. L'abondance de calcite spéléothème dans les filons de la rive sud de la péninsule pourrait être liée à une période d'émergence plus longue dans les roches de cette zone. Les différentes teneurs en sulfures, c'est-à-dire teneur élevée dans les filons le long de la partie nord de la péninsule et teneur faible dans les filons le long de la rive sud, pourraient être attribuables à la répartition des conditions de nature marine et de nature terrestre au cours du Mississippien. Les filons à haute teneur en métaux pourraient correspondre à un dépôt proximal à partir de fluides métallifères relativement salins ayant émanés du bassin sédimentaire situé au large des côtes. Les filons à faible teneur en métaux pourraient refléter des fluides évolués (ou dilués) plus distaux. La source des fluides pourrait donc être située au nord de la péninsule de Port au Port plutôt qu'au sud.

Les données sur les inclusions fluides indiquent que la minéralisation du type I aurait généralement été formée à partir du mélange de saumures froides de moyennement à très salines (poids équivalent de 14 à 28 % en NaCl) avec une ou peut-être deux saumures chaudes à faible degré de salinité. Deux occurrences de la minéralisation du type Ib dans la Grande péninsule du Nord (Eddies Cove et Pikes Feeder Pond) se sont formées à partir de fluides à température relativement élevée et à salinité intermédiaire (poids équivalent de 18 à 22 % en NaCl). Les inclusions fluides de l'occurrence Goose Arm Narrows (également du type Ib) présentent des caractéristiques différentes qui peuvent être dues à la présence de fluides secondaires ou à l'existence de conditions de formation différentes. Les conditions ont pu différer étant donné que ce gisement est situé à une distance considérable des autres (150 à 250 km). La minéralisation du type Ia s'est formée à partir de fluides à température plus basse et généralement très salins (poids équivalent de 24 à 26 % en NaCl). La minéralisation du type Ic, dont les caractéristiques sur le terrain se situent entre celles des deux membres d'extrémité, présente aussi des températures d'homogénéisation intermédiaires et des degrés de salinité variables.

On ne connaît pas l'origine de la saumure chaude (ou des saumures), mais la saumure de basse température et de forte salinité pourrait être de composition (et d'âge?) semblable aux saumures froides et très salines qui sont à l'origine des occurrences du type IIb (et IIa?).

Le bassin carbonifère de Deer Lake au sud pourrait être une source pour la minéralisation de la dorsale Turners (type III). La dolomie bréchique a pu servir de piège structural et chimique pour les fluides de bassin ascendants, riches en plomb. Cette situation est dans l'ensemble semblable à celle observée dans la péninsule de Port au Port où la minéralisation riche en plomb loge dans des calcaires carbonifères (type IIa). La minéralogie de la gangue (calcite et une peu de barytine) est comparable à celle des indices de la dorsale Turners/Side Pond et de Port au Port. La source des fluides, dans le dernier cas, pourrait être les sédiments carbonifères reposant actuellement au large des côtes.

INTRODUCTION

Carbonate rocks of the western Newfoundland carbonate platform (Fig. 1) ranging in age from Cambrian to Carboniferous, are host to many lead-zinc occurrences as well as one zinc producer (Newfoundland Zinc Mine). The occurrences have been examined by industry over a period of several years and information in the form of assessment files, company reports, drillcore, and logs, is available for most of them. The purpose of the present study was to consolidate this material, augmenting existing descriptions with on-site visits and follow-up laboratory studies. The latter consisted of petrographic studies of mineralization textures including cathodoluminescence, paragenesis, determinations of homogenization and freezing temperatures in fluid inclusions, as well as conodont biostratigraphy to establish the age of host rocks.

Acknowledgments

This study was funded by the Geological Survey of Canada under the Newfoundland-Canada Mineral Development Agreement (1984-89). The cooperation of several mining and exploration companies who permitted access to their properties is hereby gratefully acknowledged. Permission to examine and sample drill core at its Pasadena core library was graciously granted by the Newfoundland Department of Mines and Energy. The senior author takes this opportunity to thank C. Anstey for her assistance in the field. R. Knight and R. Bretzlaff drafted the diagrams; R. Knight was responsible for word processing of several early versions of the manuscript. The authors particularly wish to thank I. Knight (N.D.M.E.) for his thorough and perceptive review which considerably improved the manuscript in many ways.

GENERAL GEOLOGY

The rocks of western Newfoundland that host the lead-zinc deposits discussed in this report are readily divided into two geological time frames and tectonic settings. The oldest setting consists of carbonate rocks deposited on a passive margin and foreland shelf during the Cambrian to Middle Ordovician (James et al., 1989). The second setting comprises carbonates deposited along the edge of an extensive Carboniferous basin that evolved within a complex wrench fault system (Knight, 1983; Bradley, 1982).

In the western White Bay area, galena occurs within a dolostone unit within the Lower Volcanic formation of the Silurian Sops Arm Group.

Cambro-Ordovician sequence

The Cambro-Ordovician carbonate host rocks of western Newfoundland fall into an autochthonous to parautochthonous sequence that is mildly to locally strongly deformed. The generalized stratigraphy of the autochthonous carbonate platform of western Newfoundland is summarized in Table 1 which is based largely on sections of the Great Northern Peninsula (Knight, 1983). It comprises three groups: the Port au Port, St. George, and Table Head groups.

Port au Port Group

The March Point Formation, of late Middle Cambrian age, is the oldest unit of concern to this study. It consists of bioturbated, dolomitized micritic limestone, locally with a basal unit of grey shale and rusty-weathering sandstone. The burrows tend to be preferentially dolomitized, but near the top of the formation bioturbation is less evident and dolomitization is well developed throughout. Deposition took place in a predominantly low energy subtidal environment (Knight, 1977).

The Petit Jardin Formation of Late Cambrian age overlies the March Point Formation and, on the Great Northern Peninsula, was divided by Knight (1980) into four members: 1) Lower Dolostone Member, 2) Stromatolite Member, 3) Upper Dolostone Member, and 4) Cherty Dolomite Member, now referred to as the Berry Head Formation (Chow, 1986; Chow and James, 1987). Thinly-bedded dolostones, dolomitic shales, mottled dolostones, stromatolitic dolostones, and intraclastic and oolitic dolarenites occur throughout the formations. Shallow water features such as mudcracks, mudflake breccias, ripple marks, and crossbedding are common. The formation is probably the result of deposition on a shallow water carbonate flat environment during prolonged shelf progradation (Knight, 1980, pers. comm., 1990).

St. George Group

The Watts Bight Formation (Table 1) consists mainly of dark grey to black coarsely crystalline dolostone. It was originally a bioturbated lime mud with large crypt-microbial mounds (Knight, 1978, 1980) deposited in a dominantly subtidal environment during lowest Ordovician transgression. A bed of micritic and dolomitic limestone occurs in the middle of the formation. Coiled gastropods and orthocone cephalopods are abundant (Knight, 1977).

The overlying Boat Harbour Formation represents a return to shallower water conditions. The formation consists of shallowing-upwards sequences containing bioturbated lime mudstone, abundant stromatolites, and thinly laminated dolostone (Knight, 1980). The lowest part of the Boat Harbour Formation is extensively silicified, dolomitized, and brecciated. Lithologies include dolomite pseudobreccia and collapse breccias, the latter forming small to large bodies that can affect tens of metres of strata including, locally, the underlying Watts Bight Formation. Dolomite pseudobreccia replaces bioturbated limestone. A pebble bed near the top of the formation represents a widespread sedimentological and faunal break (Knight, 1978; Knight and James, 1987; Boyce, 1989).

The Catoche Formation consists predominantly of extensively bioturbated, well-bedded, blue-grey micritic limestone. Fossils are abundant and include trilobites, brachiopods, ostracods, gastropods, cephalopods, and

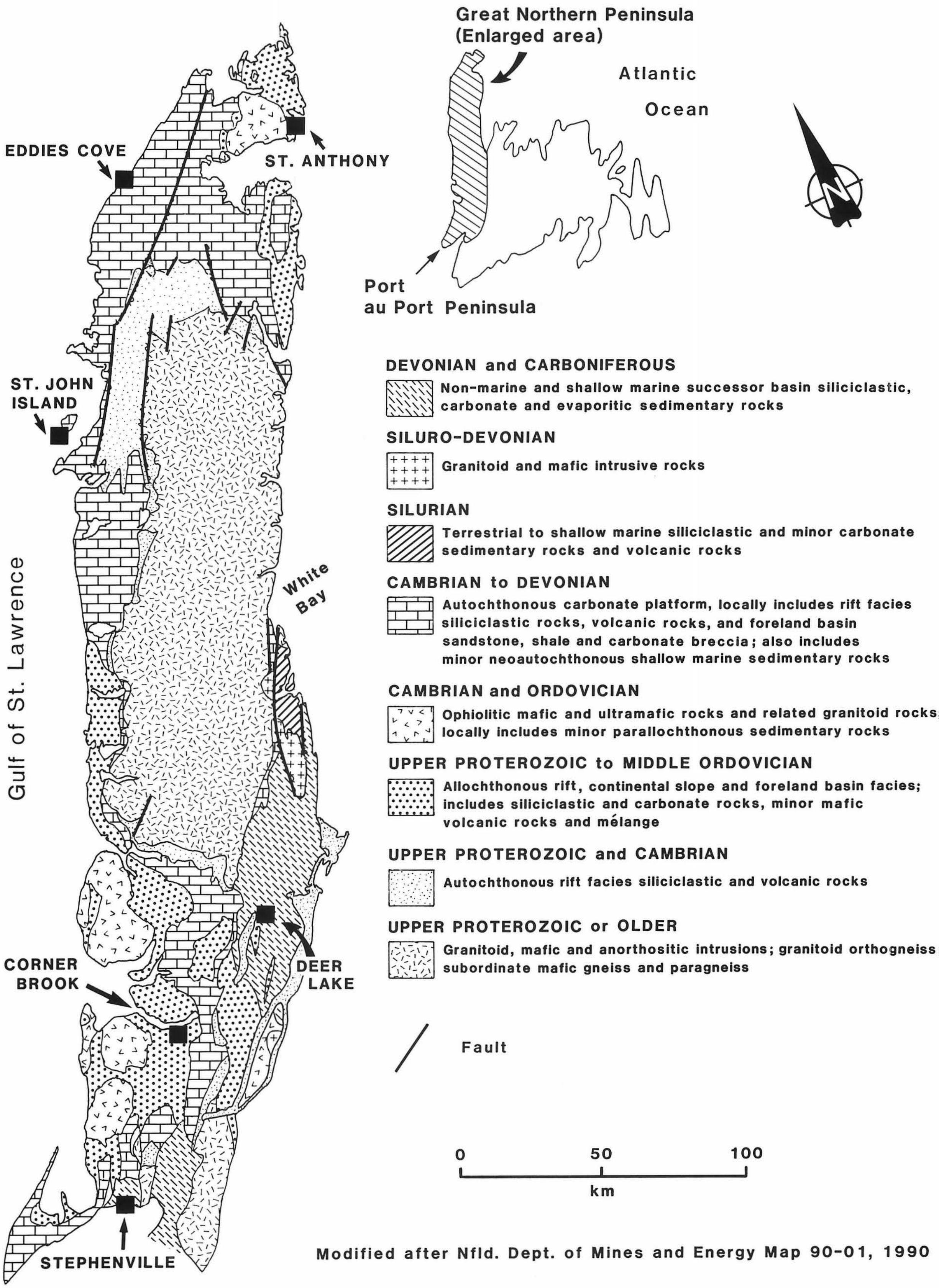

Figure 1. Geological map of study area, Great Northern Peninsula, Newfoundland.

Table 1. Generalized stratigraphy of western Newfoundland (after Knight, 1977, 1978, 1980; Klappa et al., 1980; James and Stevens, 1982; Knight and James, 1987; Dix and James, 1989; and Stouge, 1982). Stratigraphic positions of mineral occurrences discussed in this report are indicated by an asterisk.

AGE	GROUP	FORMATIONS	MINERALIZATION
Mississippian	Codroy Group	Lower Cove Fm.	
		Big Cove Fm.	*
		Codroy Road Fm.	
		Ship Cove Fm.	
	unconformity		
Middle Ordovician	Table Head Group	Cape Cormorant Fm.	
		Black Cove Fm.	
		Table Cove Fm.	
		Table Point Fm.	*
Early Ordovician	St. George Group	Aguathuna Fm.	
		Catoche Fm.	*
		Boat Harbour Fm.	*
		Watts Bight Fm.	*
Late Cambrian	Port au Port Group	Petit Jardin Fm.= Hughes Brook Fm.	*
Middle Cambrian		March Point Fm.	*
Early Cambrian	Labrador Group	Hawke Bay Fm.	
		Forteau Fm.	
		Bradore Fm.	

sponges. Locally, thrombolite-sponge mounds are developed (Knight, 1977, 1980). In parautochthonous rocks of the Canada Bay, Hare Bay, and Pistolet Bay areas, these mounds form a thick member in the middle of the Catoche Formation (Knight, 1986, 1987). The formation is probably the result of deposition in a subtidal shelf environment during (marine) transgression. The upper part of the Catoche Formation is intensively dolomitized; white dolomite spar pseudobreccia and dolomite collapse breccia zones are common, and host the Newfoundland Zinc (Daniels Harbour) deposit.

The overlying Aguathuna Formation consists of thinly laminated siliceous dolostones and shales which, according to Knight (1980), formed in a restricted carbonate flat environment. Macrofossils are absent but conodonts date the formation as Early Ordovician (Stouge, 1982).

Table Head Group

The Middle Ordovician Table Head Group, generally unconformably overlying the St. George Group, has been divided by Klappa et al. (1980) into the Table Point, Table Cove, Black Cove, and Cape Cormorant formations. The Table Point formation, in which most mineralization in the Table Head Group occurs, consists of bioturbated, rubbly weathered, massive grey limestones and zones of interbedded limestone-dolostone (Klappa et al., 1980). Fossils include ostracods, gastropods, orthocone cephalopods, trilobites, bryozoa, sponges, and brachiopods (Klappa et al., 1980; James and Stevens, 1982).

Carboniferous

Codroy Group

On the Port au Port Peninsula, Carboniferous carbonate, sulphate, and clastic rocks of the lower Codroy Group locally unconformably overly carbonates of the St. George and Table Head groups. The lower Codroy Group rocks were deposited upon an Upper Devonian to Lower Mississippian paleokarst terrain (Dix, 1982; Dix and James, 1989) and represent erosional outliers of the Carboniferous Bay St. George Subbasin to the south (Knight, 1983). The Codroy Group is preserved in a narrow belt extending from Piccadilly to Boswarlos, but elsewhere is restricted to narrow paleokarst valleys that generally are localized along north- to northeast-trending faults (Dix, 1982; Knight, 1984; Dix and James, 1989).

Codroy Group rocks on the Port au Port Peninsula have been divided into four formations (Dix and James, 1989) two of which, the Ship Cove and Codroy Road formations, are the lowermost units within the Bay St. George Subbasin (Knight, 1983). The oldest unit, the Ship Cove Formation, consists of basal conglomerate to breccia, composed of clasts of the underlying Ordovician carbonate, overlain by limestone and terrigenous plant-bearing sandstone. The Codroy Road Formation consists of gypsum characterized by thin seams of green sands. The Visean Big Cove Formation, which is host to sulphide mineralization at Lead Cove, Bellmans Cove, and elsewhere, consists of bryozoan-microbial carbonate mounds, green plant-bearing sandstones, and limestone conglomerates and breccias made up of Ordovician carbonate clasts. The carbonate mounds contain an abundant fossil assemblage dominated by brachiopods, bryozoans, and worm tubes; intermound calcarenites are dominated by bivalves and gastropods (Dix, 1982). Von Bitter et al. (1990) considered the mound assemblage to be representative of hydrothermal vent-associated fauna. The youngest unit, the Lower Cove Formation, consists of red beds of probable Late Mississippian age (Dix and James, 1989). These are made up of arenites, thickly bedded conglomerates, and chaotic breccias. The conglomerates and breccias contain boulder to cobble sized clasts of Ordovician limestone. Dix (1982) and Dix and James (1989) give a more complete description of these formations and their fossil assemblages.

Silurian

Sops Arm Group

The Silurian volcano-sedimentary Sops Arm Group outcrops in the western White Bay area and is divided into several formations. The basal Lower Volcanic formation consists of felsic tuffs, rhyolite flows, mafic volcanics, and minor interflow conglomeratic sandstone and dolostone (Smyth and Schillereff, 1982). The last is host to the Turners Ridge and Side Pond galena occurrences.

MINERAL OCCURRENCES

Locations of mineral occurrences examined in this study are shown in Figure 2. Some of the inaccessible occurrences or those that did not outcrop were sampled from drill core. In some instances the sampled core does not represent the precise location of the occurrence concerned but is from the immediately surrounding area.

The occurrences studied can be grouped into three main types:

(I) "Great Northern Peninsula Type" open-space filling/replacement mineralization associated with secondary white dolomite spar, with or without veins.

(II) "Port au Port Type" vein/open-space filling/replacement mineralization associated with calcite, with or without barite.

(III) "Turners Ridge Type" sulphide mineralization replacing the matrix in intensely brecciated Silurian dolostone.

Within Type I there exists a gradation between two end-members: (a) mineralization occurring in veins, open spaces, and in the matrix to dolomite pseudobreccias and collapse breccias developed in predominantly Ordovician strata and, (b) mineralization restricted to fractures, veinlets, small clots, and disseminations in low porosity, low permeability dolostones of predominantly Cambrian age.

Type II can be subdivided into three categories: (a) vein/open-space filling/replacement mineralization hosted by Mississippian rocks of the Codroy Group, which are characterized by high porosity and permeability; (b) vein mineralization hosted by relatively impermeable Cambro-Ordovician rocks of the Port au Port, St. George, or Table Head groups, but otherwise of the same type as IIa and presumably part of the same overall mineralizing system; and (c) vein mineralization of unknown age or affinity.

Type III mineralization occurs in the Sops Arm Group, a Silurian volcano-sedimentary belt. Very fine grained galena, pyrite, and subordinate sphalerite form the matrix to intensely brecciated dolostone.

All mineral occurrences examined on Port au Port Peninsula are of Type IIa or IIb whereas those on the Great Northern Peninsula are Type I. Occurrences in the Goose Arm area are of Type Ib and Type IIc. Type III mineralization is restricted to the White Bay area.

TYPE DESCRIPTIONS

Type Ia

Type Ia occurrences are those that are associated with significant amounts of secondary white dolomite spar that forms pseudobreccia or forms the matrix to angular spar breccias. These occurrences are found within Ordovician strata of the St. George Group.

"Pseudobreccia" is a term for a distinctive rock, developed by dolomitization of burrowed lime mudstone, and containing 5 to 80% white dolomite spar (Lane, 1984; Knight, 1980; Cumming, 1968). The dolomite spar replaces secondary dolostone or original limestone and fills open spaces formed by in situ dissolution of the original rock (Crossley and Lane, 1984). The relict, rounded domains of secondary dolostone resemble breccia fragments, (hence the term "pseudobreccia"), and are rimmed by the dolospar (Fig. 3a, b).

Some occurrences are also associated with variable amounts of true spar breccia, characterized by slightly rotated angular fragments set in a white dolomite spar matrix. These breccias are formed by disruption of strata due to faulting or collapse, the latter as a result of dissolution (Lane, 1984). They are collectively referred to as angular spar breccias, angular breccias, and/or collapse breccias elsewhere in this report.

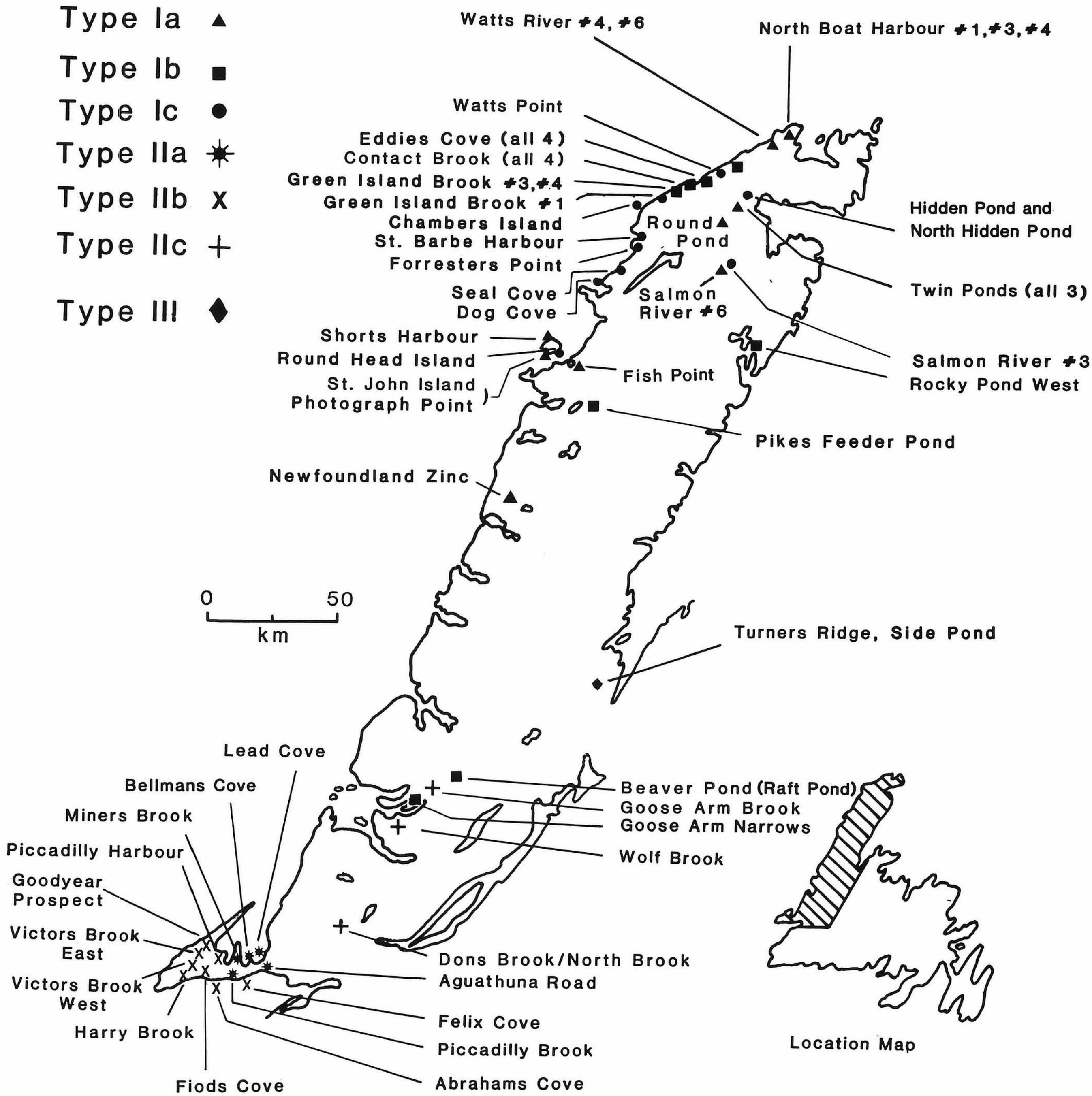

Figure 2. Location and classification of lead-zinc deposits and occurrences, western Newfoundland carbonate platform.

Characteristics of Type Ia occurrences are:

1. mineralization is hosted by dolomite pseudobreccia (or similar texture) with or without angular spar breccia;
2. sphalerite is the dominant sulphide and occurs with or without pyrite and galena;
3. pre-ore, pre-spar porosity was high;
4. sphalerite generally precedes the dolomite spar and tends to rim "fragments" in the pseudobreccia;
5. the host rock is Ordovician;
6. "fragments" in the pseudobreccia tend to be medium grained dark brown to black dolostone, regardless of the country rock which may be limestone or fine grained, lighter coloured dolostone.

These pseudobreccia zones are locally well developed in the Boat Harbour and Catoche formations, where they preferentially replace bioturbated and/or thrombolitic limestones that are interbedded with fractured, dolomite veined beds of syngenetic finer grained dolostone. The

Figure 3. a) Outcrop of pseudobreccia developed in the Boat Harbour Formation near Fish Point. White dolomite spar (W) surrounds and isolates patches of medium grained dolostone (D). Note the high proportion of void in the rock. GSC 1991-563A b) Dolomite pseudobreccia, Boat Harbour Formation, Round Pond. White dolomite spar surrounds grey dolostone fragments and in part overprints intraformational breccia. GSC 1991-563B

pseudobreccia zones can be traced laterally into dolostones that can consist of fine grained or salt-and-pepper dolomite or irregular to massive clots of recrystallized sparry dolomite; these dolostones then abruptly pass across an alteration front into unaltered limestone (I. Knight, pers. comm., 1990).

There are, in addition, replacive dolomite fabrics that resemble the pseudobreccia fabrics of the St. George Group but are somewhat different. For example discordant to tabular concordant dolomite zones occur in limestones of the Table Point Formation on St. John Island. A sample from one of these dolomite zones (Fig. 4) shows evidence that white dolomite spar lines fragments and replaces a fine grained carbonate void sediment in previously brecciated and stylolitized rock.

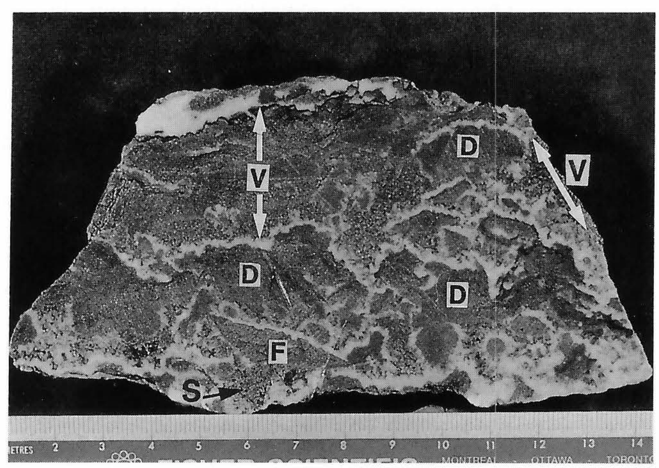

Figure 4. Dolomite pseudobreccia, Table Point Formation, Shorts Harbour. Medium grained, brown dolomitized limestone (D) is surrounded by white dolomite spar. S=sphalerite; V=void now filled with fine grained carbonate cement partially replaced by euhedral secondary white dolomite resulting in a "salt-and-pepper" texture; F=angular fragment surrounded by spar. GSC 1991-563C

Type Ia occurrences can be classified as "Mississippi Valley Type" mineralization. Occurrences of variable significance are found throughout the St. George Group on the Great Northern Peninsula. The most important deposit is the Newfoundland Zinc Mine at Daniels Harbour, where sphalerite associated with pseudobreccia zones is found in the upper 50 m of the Catoche Formation. Small-scale stratabound angular spar breccias are cogenetic with the pseudobreccia. Large (10-30 m by 100 m) linear spar breccias which cross the stratigraphy are generally later than the pseudobreccias (Lane, 1984). White dolomite spar in both types of breccia represents the latest phase of dolomitization in the diagenetic history of the rock (Haywick and James, 1984). Sphalerite generally precedes the white dolomite spar and tends to coat fragments in both the pseudobreccia and angular spar breccia. Botryoidal sphalerite also fills cavities in pseudobreccia (Crossley and Lane, 1984).

Type Ib

Type Ib mineralization occurs in Cambrian dolostones of the March Point and Petit Jardin formations. Mineralization consists of minor sphalerite and galena occurring as clots, disseminations, veinlets, and fracture fillings with associated white dolomite spar which tends to form 1-3 cm round clots. Minor amounts of quartz are associated with the dolomite especially in the Petit Jardin formation. Host rocks for Type Ib mineralization are typically massive dolostones generally lacking pseudobreccia or angular spar breccia. Type Ib deposits are generally characterized by the following:

(1) their occurrence in nonporous dolostone host rocks;
(2) mineralization and associated dolomite spar, is restricted to clots, small vugs, fractures, and minor disseminations;
(3) host rocks are Cambrian in age;
(4) galena tends to be more abundant than in Type Ia.

Type Ic

Some occurrences are gradational between the Type Ia and Type Ib end members. The gradation is effected by such features as local and/or poor development of pseudobreccia and angular spar breccia in Cambrian rocks, e.g. at Salmon River #3 and Watts Point. Occurrences that cannot easily be assigned to either end-member (i.e. that display features characteristic of both mineralization types or features different from both mineralization types) have been classified as Type Ic mineralization.

Type II

Type II occurrences are vein/open-space fillings associated with calcite, with or without barite, and can be divided into three subgroups. All Type IIa and IIb occurrences are located on the Port au Port Peninsula. Type IIc occurrences are found in the area between Stephenville and Corner Brook.

Type IIa

Mineralization at Lead Cove, Bellmans Cove, Aguathuna Road, Miners Brook, and in part at Piccadilly Brook occurs as open-space fillings and replacements in Codroy Group limestones in north-trending paleokarst valleys (Fig. 5). The Codroy Group unconformably overlies Table Head Group limestone at these localities. The former is locally brecciated, consisting of angular limestone fragments up to several centimetres long set in a micritic matrix that is commonly replaced by calcite spar. The limestones are very fossiliferous and contain brachiopods, gastropods, and oncolites. Marcasite, galena, sphalerite, pyrite, calcite, and barite replace the micritic matrix, fill voids, and surround limestone fragments and fossils. Mineralization also occurs in 1-10 cm wide, randomly oriented, generally vuggy, veins. Most are zoned, but the zoning varies for each occurrence.

Type IIa mineralization is characterized by:

(1) host rocks of fossiliferous limestone and limestone breccia of the Codroy Group;
(2) marcasite, and in places, pyrite, abundant to rare galena, and minor to rare sphalerite;
(3) calcite, barite, and in places, celestite.
(4) mineralization occurs as open-space fillings, replacements, and irregular veinlets.

From observations made at all Type IIa occurrences, a generalized paragenetic sequence can be constructed as follows (from first to last): marcasite, (calcite), galena, (sphalerite), (marcasite), calcite, barite. Minerals listed in brackets are minor or absent at the majority of occurrences. Figure 6 from Lead Cove illustrates typical Type IIa mineralization.

Type IIb

Type IIb mineralization occurs in vertical to subvertical calcite veins which cut limestones of the Port au Port, St. George, and Table Head groups. Veins, containing abundant

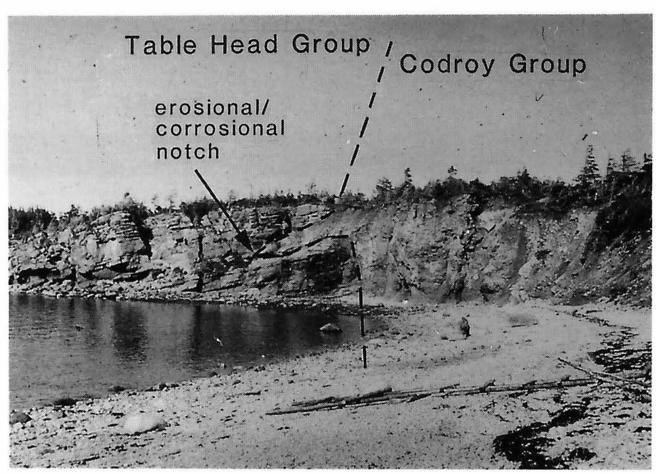

Figure 5. Unconformable contact between Codroy Group and Table Head Group, Lead Cove. GSC 1991-563D

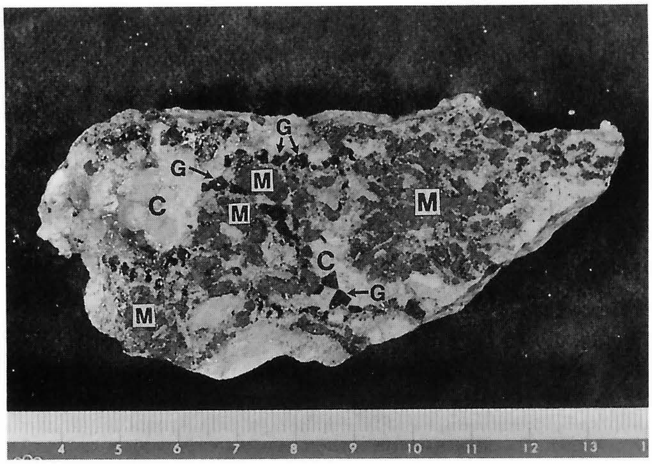

Figure 6. Galena (G), marcasite (M), and calcite spar (C) in Codroy Group limestone breccia, Lead Cove. GSC 1991-563E

galena, sphalerite, and marcasite, at Piccadilly Harbour and the Goodyear Prospect, cut the Table Head Group. Those veins which cut Port au Port and St. George Group limestone at Felix Cove, Abrahams Cove, and Fiods Cove along the southern shore of Port au Port Peninsula are barren or contain only minor sulphides. The veins are commonly cored by cavities lined with dogtooth calcite spar and, in places, minor barite; some are bordered by speleothem calcite. The veins appear to have been emplaced along pre-existing faults.

The overall mineralogy of the veins indicate a similar age and type as the mineralization hosted by Codroy Group rocks (Type IIa) and suggests that mineralization may have precipitated in open fractures beneath the Carboniferous unconformity. The features of Type IIb mineralization are:

(1) restriction to subvertical veins cutting nonporous flat-lying Cambro-Ordovician carbonates;
(2) mineralogy consists of marcasite, galena, sphalerite, calcite, and minor barite;
(3) mineralization may be sparse (e.g. Fiods Cove, Felix Cove) or abundant (e.g. Piccadilly Harbour, Goodyear Prospect).

Type IIc

Type IIc occurrences are those of a miscellaneous nature. These occur at Dons Brook, north of Stephenville, and at Wolf Brook and Goose Arm Brook of Goose Arm, in the Bay of Islands area. They are all different from each other, and no generalized description applies.

Type III

The Turners Ridge and Side Pond showings in Silurian carbonate breccias are significantly different from all other types and are described in a later section.

[1]Figures marked with an asterisk can be found in colour section, p. 31.

OCCURRENCE DESCRIPTIONS

Type Ia

Round Pond

Of all the carbonate-hosted zinc deposits on Great Northern Peninsula, Round Pond (Newfoundland Department of Mines and Energy Mineral Occurrence Data System - 12P/8-Zn049) is second in importance only to the Newfoundland Zinc Mine. Drilling has outlined about 400 000 tons (406 400 tonnes) of 2% Zn (Born, 1983). The deposit was sampled from drill core only for this study and the following description relies heavily on Born (1983).

The Round Pond deposit is hosted by basal limestones and dolostones of the Lower Boat Harbour Formation and is underlain by dark grey, medium grained dolostone of the Watts Bight Formation. The area, which lies close to the northern extension of the Ten Mile Lake Fault, is gently folded by an S-shaped flexure (I. Knight, pers. comm., 1990). Most of the mineralization is found within pseudobreccia zones developed within dolomitic limestones ("middle limestone" unit of Born, 1983). Other rock types within this informal unit include fine rock matrix breccia, characterized by fragments of various lithologies set in a sandy clastic matrix, and crackle breccia (angular spar breccia). The pseudobreccia contains 10 to 60% secondary white dolomite spar and occurs as 3 to 15 m thick flat tabular masses that may extend a few hundred metres laterally. They pass laterally and vertically into collapse breccia, dolomitic limestone and limestone, and locally completely replace the middle limestone unit (Born, 1983). The middle limestone unit is overlain by grey fine grained, algal-laminated, bioturbated dolostone ("upper dolostone" unit of Born, 1983), also of the Boat Harbour Formation. Crackle breccia, consisting of angular grey dolomite fragments set in white dolomite spar, occurs within this dolostone unit at the contact with the underlying pseudobrecciated limestone; the crackle breccia is locally host to significant sphalerite mineralization (Born, 1983).

Sphalerite is disseminated over a thickness of 10 to 15 m in the pseudobreccia with a maximum local concentration of 5%. Sphalerite tends to be concentrated in the "crackle breccia" (locally up to 6%) but is less extensive overall. In both breccia types sphalerite is more abundant in bitumenrich zones (Born, 1983).

Samples for this study were obtained mainly from 1970-1971 Cominco drill core, for which no logs are available. The highest grade mineralization encountered by Cominco was in drill holes 66, 67, 68, and 77. Sphalerite concentration ranged from 3.30% to 6.40% over intervals of 2 to 3 m (Rhodes, 1971).

Straw-coloured to brown sphalerite occurs as 1 mm to 1 cm thick bands rimming "fragments" in the pseudobreccia or angular spar breccia. Most "fragments" contain very fine grained disseminated marcasite and pyrite. In places sphalerite contains zones which luminesce dull yellow and brilliant purple (Fig. 7*)[1]. Nonluminescent zones are commonly higher in iron than luminescent zones.

Sphalerite is followed by saddle dolomite, which forms curved crystals that surround pseudobreccia "fragments". Cathodoluminescence shows that in most samples the spar is zoned. Zoning consists of an initial thick dirty-red zone followed by an interval of sharply defined bands of varying luminosity (better developed in some samples than others), followed by a thick zone of very bright red dolomite. In places core areas are filled with calcite which luminesces brown.

Galena is rare in core but is widely disseminated in the general area (Knight, 1980). It occurs as inclusions in, or coats fractures in, sphalerite. In places minor smithsonite and calcite crosscut sphalerite and saddle dolomite.

Fragments in the pseudobreccia generally consist of fine grained grey dolostone replaced by up to 50% disseminated, medium grained, secondary white dolomite. The secondary white dolomite luminesces bright red and is contemporaneous with saddle dolomite. The fine grained dolomite luminesces dull, dirty red, and in places is surrounded by the later, bright red dolomite.

Salmon River #6

The Salmon River #6 showing, also known as the Shell IIb showing or the Frying Pan Pond showing (12P/1-Zn006), is located in trenched, stripped outcrop in a heavily wooded area. Many similarities exist between the Salmon River #6 showing and mineralization at Newfoundland Zinc Mine.

Sphalerite and galena occur as clots and disseminations in dolomite pseudobreccia zones in dark brown, thrombolitic, bioturbated, micritic limestone of the Catoche Formation. Burrows within the limestone contain fine grained diseminated calcite spar and, as a result, are lighter brown and slightly coarser grained than the surrounding rock. Contacts between limestone and pseudobreccia zones are abrupt and irregular. "Fragments" in the pseudobreccia consist of anomalously fine grained (0.1-0.2 mm) anhedral black dolostone containing up to 50% disseminated secondary white dolostone, producing a "salt-and-pepper" texture.

Sphalerite ranges from green to yellow to red and occurs in several modes. At one trench green sphalerite forms clots up to 4 cm and locally constitutes up to 20% of the rock. Sphalerite also forms well developed "snow on roof" texture recognized by its preferential occurrence on the tops of dolostone "fragments" in the pseudobreccia. Sphalerite is followed by white dolomite spar and then calcite. Dolomitic spar generally postdates the sphalerite and galena, but in places a thin zone of spar predates mineralization. Minor 1 to 3 mm cubes of galena are also associated with dolomite spar.

In a second trench, fine grained yellow sphalerite is disseminated in black dolostone while red to yellow sphalerite crystals up to 3 mm coat calcite-filled vugs. Locally, galena, in clots up to 3 cm, occurs on the rims of "fragments". The galena is followed by, and in places is also preceded by, dolomite spar.

Vugs in a third trench contain red to yellow sphalerite, intergrown with quartz and displaying well developed "snow on roof" texture (Fig. 8). The quartz, which appears black on slabbed surfaces, forms elongate crystals ranging from <0.05 to 0.4 mm and is commonly intergrown with euhedral (up to 1 mm) dolomite crystals. Quartz, sphalerite, and dolomite spar also occur to a lesser extent along the "hanging walls" of these cavities, which are later filled with calcite spar. For comparison, at Newfoundland Zinc Mine, red sphalerite, calcite, and galena generally occur late in the paragenesis (T. Lane, pers. comm., 1985).

Sphalerite luminesces preferentially where it is in contact with calcite (Fig. 9*), suggesting that relatively late fluids, which accompanied or immediately preceded the calcite, were responsible for altering the sphalerite. Analysis of this sphalerite by electron microprobe (Appendix B) indicates that the luminescent sphalerite is depleted in iron relative to the nonluminescent sphalerite (0.01% FeO vs. 0.40%). Minor smithsonite occurs in late formed vugs and veinlets and luminesces bright blue (Fig. 10*).

Fine grained dolomite in the pseudobreccia "fragments" luminesces dark red to bluish red and commonly has diffuse red cores and bluish red rims. In many intances grain boundaries of the fine grained dolomite luminesce bright red (Fig. 11). The coarse euhedral dolomite luminesces dull red, but in places has an irregular, brighter red outer zone. The spar luminesces a similar dull red and in places has a thin

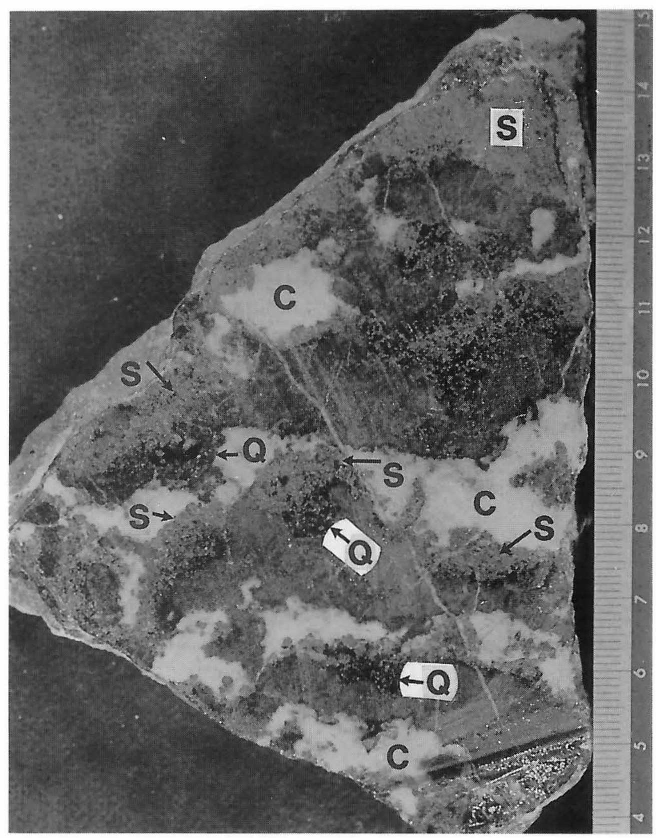

Figure 8. Sample illustrating "snow on roof" texture. Red to yellow sphalerite (S) and quartz (Q) occur preferentially on the floors of cavities in fine grained, dark grey dolostone. Cavities were subsequently filled by calcite spar (C). Specimen is right way up. Salmon River #6. GSC 1991-563F

outer bright red or yellow, followed by bright red zone (Fig. 9*, 10*, 11*). Calcite spar luminesces medium brown.

Sulphides in the Salmon River/Main Brook drill core consist of minor sphalerite, pyrite, and galena. Sphalerite and galena line fractures and vugs cored by white sparry dolomite. In one drill core sample galena was observed in a white sparry dolomite vein.

St. John Island

Table Point Formation limestones on St. John Island host three base metal showings in local bodies of epigenetic dolomite. Along the south shore of the island, showings occur in the southward-facing cliff, east of and at Photographic Point. A third showing occurs at Shorts Harbour on the north shore of the island. At each of these occurrences, mineralization is associated with discordant to tabular concordant dolomite bodies that superficially resemble pseudobreccia (Fig. 4; I. Knight, pers. comm., 1990).

St. John Island South Cliff

This occurrence (12I/14-Zn004) consists of vertical pillars of white dolomite spar replacing limestone of the Middle Ordovician Table Point Formation. The limestone is thick-bedded, grey, micritic, and nodular weathered. The contact between the limestone and the dolomite spar is characterized by a 10-20 cm border of brown porous dolostone consisting of about 50% hydrothermal quartz and 50% microcrystalline calcite. Coarse white saddle dolomite forms most of the material in the vertical pillars. In places the vertical pillars are narrow (20 to 30 cm) and the white dolospar zone is missing. The result is a pillar, cored by calcite spar, and bordered by brown porous dolostone. The orientation of the individual pillars varies but the zone as a whole strikes 60° with vertical dip.

The white dolomite spar surrounds small, round "fragments" of dark brown dolostone. Intercrystalline areas and irregular patches in these fragments are filled with <0.025 to 0.1 mm dolomite and brown organic or clayey material. The "fragments" themselves are composed of euhedral, loosely packed dolomite that luminesces medium red, followed by an irregular zone of brighter red. The saddle dolomite follows the same zonation but in places has later thin zones of varying luminosity. In other places the early, medium red dolomite is brecciated and cemented by the later, bright red dolomite. Calcite spar, which locally fills voids within the epigenetic dolomite, luminesces light brown.

Within the dolomite pillars, sphalerite occurs as 1-4 cm botryoidal clots surrounded and corroded by dolomite spar although it appears to postdate some of the dolomite spar. Rare galena occurs as 1 mm cubes. The sphalerite is zoned — yellow in the centre and red on the rims.

Finer grained sphalerite also is disseminated in, and rims, the dark brown dolostone "fragments". It is followed by coarse grained saddle dolomite, then calcite, or fine grained quartz or dolomite. Fine grained, bedded geopetal sphalerite fills cavities in the coarse dolomite spar. Zoning is similar to that in the botryoidal sphalerite (pale yellow at the base of the cavities to dark orange at the tops). Near the bottoms of the cavities sphalerite is accompanied by fine grained quartz and minor dolomite which range from small (0.1 mm) crystals to large curved saddle crystals surrounded by the quartz gangue. Sphalerite is intergrown with the quartz and, as a result, forms irregular ragged clots. Quartz, which appears black in hand specimen, forms elongate crystals and looks very similar to that observed in cavities from Salmon River #6. Towards the top of the cavities sphalerite is coarser (0.2 mm), forms round grains, and is accompanied by 0.1 to 0.6 mm subhedral to euhedral dolomite. Since the geopetal cavities are developed in dolomite spar, the bedded sphalerite must be preceded by at least one stage of saddle dolomite. The latest dark orange to red sphalerite is accompanied by coarse dolomite. In one sample, red sphalerite clearly precedes saddle dolomite and, in another, geopetal cavities are cut by veinlets of dolomite. Local tilting and brecciation of the geopetal layers have been observed (I. Knight, pers. comm., 1990). Thus, several stages of dolomitization have obviously affected these samples.

Fluid inclusions were observed in the botryoidal sphalerite but those in the geopetal sphalerite were too small for microthermometric study.

Photograph Point

The showing at Photograph Point (12I/14-Zn001) lies approximately 1.5 km west-northwest of the St. John Island South Cliff showing. Mineralization occurs in epigenetic dolomite zones that are in sharp contact with surrounding Table Point Formation limestone. The showing is located just above the high tide level between a sea stack and the shore. The dark brown, micritic limestone contains numerous shaley partings which result in a nodular weathered appearance. The dolostone unit is at least 2 m thick and is brown with disseminations of fine grained, secondary white dolomite which results in a salt-and-pepper texture. White dolomite spar lines vugs and, in places, tends to form a texture similar to pseudobreccia. "Fragments" in the rock are internally thinly banded and consist of very fine grained dolomite rhombs accompanied by intercrystalline quartz. The dolomite rhombs are locally overgrown by later dolomite, but both rhombs and overgrowths luminesce uniform dull red.

"Fragments" are rimmed by a thin zone of dolomite spar, followed by coarse grained crystals of sphalerite, followed by saddle dolomite. Sphalerite also occurs as clots in vugs and as smaller crystals disseminated in the host rock. Sphalerite grains tend to be black in the centre and become reddish-orange at the rims. Black growth-zones are visible in thin section (Fig. 12). Cores of spar crystals luminesce uniform dull red, similar to the fine grained dolomite in the "fragments", followed by a dark red-brown and then a bright red zone. In places additional thin zones exhibit variable intensity of cathodoluminescence. Figure 13* shows thin zones of spar draping over sphalerite crystals, indicative of the earlier precipitation of the sphalerite. Rare galena occurs as 1 to 2 mm cubes.

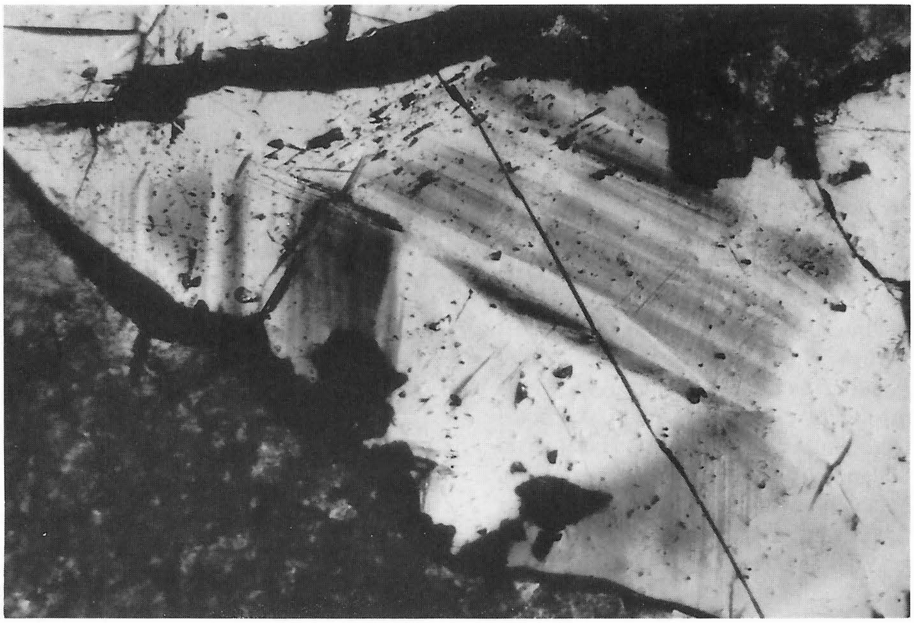

Figure 12. Photomicrograph of zoned black and yellow sphalerite. Photograph Point. Field of view 3 mm.

Shorts Harbour

At Shorts Harbour (12/14-Zn005) on St. John Island two areas of mineralized epigenetic dolostone are developed in thrombolitic limestone of the Table Point Formation. The contact between limestone and dolostone is sharp and occurs just below the high water mark. The latter rock consists of medium grained, brown dolostone in which thin zones of white dolomite spar are irregularly developed. Although this texture superficially resembles pseudobreccia, it is somewhat different in that the rock has been previously brecciated and subjected to development of open spaces that were later filled by fine grained geopetal sediment (I. Knight, pers. comm., 1990). The spar rims angular fragments and rounded patches of dolomitized limestone. The fragments consist of 0.05 to 0.1 mm dolomite and are surrounded by curved crystals of saddle dolomite. In places they show evidence of previous stylolitization. The geopetal sediment has been replaced by secondary greyish-white sugary euhedral dolomite that forms salt-and-pepper texture. Intercrystalline areas in this salt-and-pepper dolomite are occupied by elongated quartz crystals and tiny euhedral dolomite. All stages of dolomite luminesce uniform bright red. Stylolites appear to both predate and postdate the formation of the white dolomite spar.

Yellow-brown to black sphalerite forms clots up to 3 cm across which overprint the white dolomite spar. Sphalerite truncates stylolites and contacts between the different types of dolomite. The sphalerite may be contemporaneous with the late salt-and-pepper dolomite, although the rims of the sphalerite are locally replaced by dolomite spar.

Further north in the cove, a similar epigenetic dolomite zone with sphalerite and galena mineralization is developed within thrombolite mounds in the limestone. This dolomite zone may be continuous with the first exposure, although this could not be confirmed as the intervening area is covered by mud flats and water.

Fish Point

The Fish Point (12I/14 Zn-002) occurrence is hosted in brecciated dolostone from the lowest beds of the Boat Harbour Formation. Mineralization is very limited in extent; most of it occurs in two large boulders. The host rock consists of fine grained, dark grey dolostone in which angular spar breccias are well developed, although fragments have generally undergone little rotation. An early white dolomite spar forms a thin coating around the fragments, followed by later and more abundant pink dolomite spar. Locally, dolomite has corroded and rounded the fragments to form a pseudobreccia-like texture.

Mineralization in outcrop consists of minor vug-filling pyrite; heavier mineralization of a similar type was noted in the two large boulders. Minor amounts of black sphalerite coat round clots of pyrite. One boulder contains abundant pyrite which is generally surrounded by dolomite spar. Pyrite without associated dolomite spar is also disseminated in the rock. Thin section studies of samples from the boulders reveal that fragments of dolostone rock, pyrite, and zoned sphalerite "float" in a matrix of fine grained dolomite. Sphalerite forms botryoidal masses which are strongly zoned under cathodoluminescence; early zones luminesce brightly and are rimmed by nonluminescent sphalerite and, in places, the fine grained dolomite has corroded and replaced sphalerite (Fig. 14*, 15*). Locally, later white dolomite spar has replaced much of the matrix and has corroded fragments. The fine grained dolomite luminesces uniform dull red, but in places has an outer brighter red rim. The spar is uniform bright red, with a thin brighter red zone near the rims. In places pyrite crystals

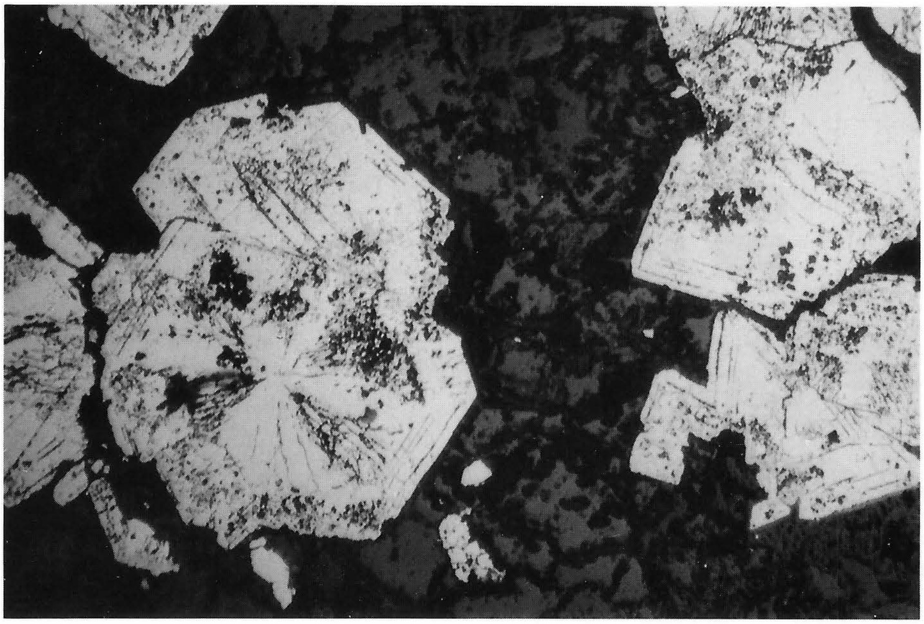

Figure 16. Reflected light photomicrograph of sector-zoned pyrite. Fish Point. Field of view 1.4 mm.

have hexagonal outlines. Pyrite also occurs as elongate, originally void-lining, masses possessing a chaotic internal structure which may represent an original pyrite-marcasite intergrowth similar to that seen in some samples from Round Head Island and Forresters Point. At least two stages of pyrite are present; fragments of pyrite are surrounded by massive pyrite to form a breccia. Some pyrite is also sector-zoned (Fig. 16).

Twin Ponds

The Twin Ponds #5 or Wade Showing (12P/8-Zn040) is the most important showing in the Twin Ponds area. The host rock consists of fine- to medium-grained grey to cream dolostone of the Watts Bight Formation. The unit strikes northeast and dips gently southeast. Nonrotated angular spar breccias occur locally; white dolomite spar is irregularly distributed in the rock in stringers, clots, and as cement to angular fragments. Locally the spar surrounds and corrodes patches of rock to form pseudobreccia. Minor quartz occurs in vugs lined by white to pink dolomite spar. Medium grained, secondary white dolomite is disseminated throughout the rock replacing earlier fine grained dolomite. The early dolomite luminesces medium-red, whereas the secondary dolomite is slightly brighter red. In places, this dolomite is void-filling and has alternating zones of bright red and dull red luminosity. Late saddle dolomite luminesces uniform bright red.

A small outcrop of fossiliferous, micritic limestone is in contact with the mineralized dolostone and is cut extensively by a network of pinkish-white dolomite spar-veinlets. Microspar occurs in irregular patches and fills fossil molds in the limestone. Curved crystals of pink-brown dolomite, intergrown with calcite, occur as replacements and void-fillings. The dolomite is zoned bright red under cathodoluminescence whereas calcite is nonluminescent except for late bright to dull yellow zones.

Honey-brown to black sphalerite and minor pyrite form regular coatings around angular to round dolostone fragments and line voids occluded by later white dolomite spar. Disseminated sulphides occur locally. Zoning is honeybrown sphalerite — black sphalerite — white to pink dolomite spar — quartz. Sphalerite is followed by a 2 to 4 mm wide zone of white saddle dolomite. In places sphalerite — dolomite zones are truncated by other sphalerite — dolomite zones or by geopetal cavities filled with fine- to coarse-grained dolomite commonly accompanied by sphalerite. Rare chert clasts rimmed by sphalerite also contain clots of sphalerite and abundant fine grained pyrite. Figure 17 illustrates a large cavity containing geopetal dolomite, dolomite, fine grained sphalerite, and stacked layers of sphalerite topped by dolomite spar which may have grown in place or may be fragments. However, if they are fragments one would expect some of them to be upside-down, i.e. to have dolomite topped by sphalerite. If they have grown in place they provide evidence for alternating precipitation of sphalerite and saddle dolomite.

Late wispy stringers of white to grey, fine grained material cut the host rock, the mineralization, and the geopetal cavities. In places the stringers brecciate the rock on a scale too fine to be seen in hand specimen.

The Twin Ponds #2 (12P/8-Zn042) showing, also hosted by the Watts Bight Formation, outcrops a few hundred metres from the Wade Showing. Mineralization is similar to that of the Wade Showing in that honey-yellow sphalerite and minor pyrite rim round "fragments" of finely crystalline, grey dolostone in dolomite pseudobreccia.

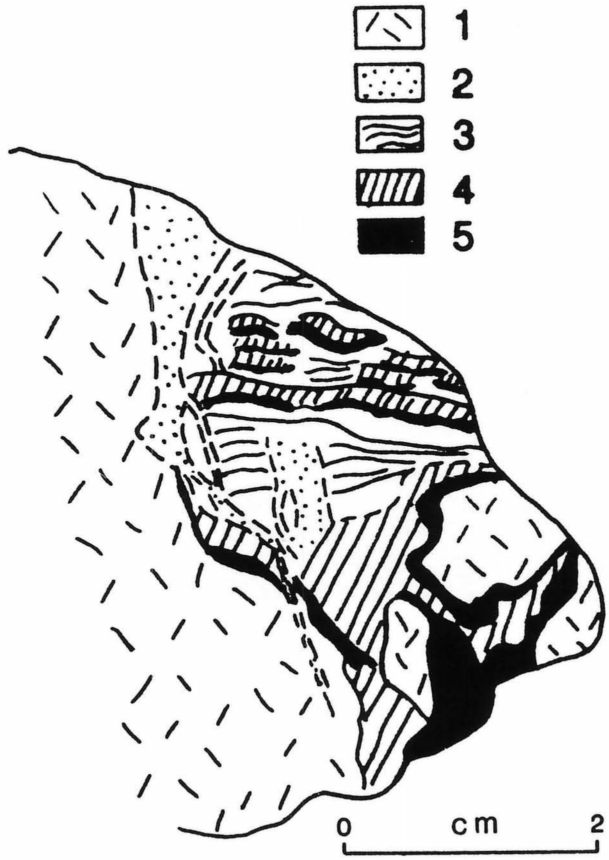

Figure 17. Tracing of a slab from Twin Ponds #5. (1) fine grained dolostone with disseminated, medium grained, secondary white dolomite; (2) fine grained late dolomite; (3) geopetal fine grained dolomite; (4) saddle dolomite; (5) sphalerite.

The Twin Ponds Quarry (12P/8-Zn043) occurrence is located on the edge of a low water-filled quarry on the south side of the Viking Highway. The area is underlain by northeast-striking rocks of the Boat Harbour Formation. Sphalerite and galena occur in oligomictic fine-rock matrix breccia. Breccia fragments are thinly-laminated, fine grained, dark grey dolostone and range in size from less than one centimetre to several centimetres. The fragments have been dropped and rotated and, in places, the matrix has been completely replaced by white dolomite spar. Some fragments consist of tightly-packed dolomite with a minor amount of intercrystalline brown material. Most consist of brown (organic?) laminated material which contains variable amounts of euhedral to subhedral fine grained dolomite. Many of these dolomite crystals have been flattened in the plane of the laminations indicating a precompaction origin for the crystals. They luminesce uniform medium red.

Interfragment areas are filled with fine grained, anhedral dolomite which also replaces fragments in places. This dolomite, which luminesces slightly brighter red than that in the fragments, is replaced to varying degrees by white sparry dolomite. White dolomite spar-filled fractures cut both fragments and fine-rock matrix. Minor disseminated sphalerite and galena occur predominantly in the fine-rock matrix. Abundant yellow- to red-brown sphalerite rims fragments where the matrix has been replaced by white dolomite spar. Galena occurs in the fine grained breccia matrix as broken skeletal grains which have been replaced to varying degrees by inclusion-free carbonate. This carbonate has thin dolomite rims which luminesce bright red. The nonluminescent cores are ankerite with up to 13% iron (Appendix C). Minor sphalerite is also disseminated in the matrix but it preferentially lines spar veinlets. It post-dates intraformational brecciation and is not replaced by carbonate, unlike galena which predates intraformational brecciation. In places true angular spar breccias are developed.

Minor sphalerite and fine grained pyrite were noted in the drill core from the Twin Ponds area. Pyrite is concentrated along fractures and around rims of fragments where it occurs with white sparry dolomite. Sphalerite was observed in only one drill core sample where it occurs as fine grained, straw-coloured crystals which tend to be concentrated in stringers.

A sample from the drill core contains a mineralized breccia consisting of angular chalcedony fragments set in a fine- to medium-grained dolomite matrix. Sphalerite replaces parts of the chalcedony fragments (Fig. 18*). The matrix dolomite luminesces uniform dull red but the rims of the sphalerite and chalcedony are replaced by zoned dolomite which luminesces in shades of red, orange, yellow, and red (i.e. two red zones).

Watts River

The Watts River #6 (12P/9-Zn004) occurrence is located in an area of widespread rubble outcrop, most of which is extensively pseudobrecciated. The occurrence is underlain by completely dolomitized Boat Harbour Formation. Three types of dolostone are irregularly distributed throughout the area and probably formed in the following order: (a) fine grained, thinly-laminated beige dolostone with little porosity (syngenetic dololaminites); (b) medium grained, vuggy brown dolostone showing traces of bioturbation; and (c) well developed dolomite spar pseudobreccia. Type (b) and (c) correspond to the epigenetic dolomite described by Haywick (1984). The pseudobreccia is similar to that at Watts River #4 (12P/9-Zn002), i.e. patches of fine- to medium-grained dark dolostone surrounded by dolomite spar. Pseudobreccia from Watts River is somewhat anomalous because the "fragments" are extremely fine grained (rather than the more typical medium grained), light grey dolostone and appear to be burrows. The domains of light grey dolostone are bordered by medium grained brown dolostone and white dolomite spar. The medium grained brown dolostone, which appears to precede pseudobreccia formation, is commonly the lithology of the "fragments" in other areas. Angular spar breccia occurs locally. The pseudobreccia may overprint pods of dolomite-mottled limestone as observed near Watts River #6.

Sphalerite, observed sporadically in the area, occurs as greenish-yellow grains rimming, or disseminated within clasts in the pseudobreccia. In places, sphalerite luminesces brightly in shades of green, blue, orange, or yellow on rims and along fractures. Electron microprobe analyses show that the luminescent areas are depleted in Cd relative to the nonluminescent areas (0.21% and 0.85% respectively).

Remnants of the original dolostone, preserved within the clasts, consist of euhedral dolomite crystals with brown organic intercrystalline material. Commonly the original dolostone is replaced by anhedral white dolomite which grades into saddle dolomite crystals. "Ghosts" of the original crystals can be seen within the epigenetic dolomite. All dolomite luminesces medium red with irregular brighter red areas.

Watts River #4 occurrence is located in angular boulders in a dry lake bed. Pseudobreccia is well developed and is characterized by rounded patches of medium grained, dark brown to black dolostone surrounded by white dolomite spar. In one of the boulders 1 to 2 mm grains of greenish-yellow sphalerite are disseminated within these patches.

North Boat Harbour

Locally developed dolomite pseudobreccia and disseminated fine grained, secondary white dolomite occur in vuggy brown dolostone of the Catoche Formation. At North Boat Harbour #1 and #3 the original bioturbated brown and micritic limestone is preserved; a small patch was also found at North Boat Harbour #4. Burrows have been preferentially dolomitized and are slightly coarser grained than the matrix; as a result, they tend to stand out on weathered surfaces.

At North Boat Harbour #1 (2M/12-Zn001) the rock consists of a medium grained, brown dolostone characterized by disseminated, fine grained, secondary, white dolomite and clots of dolomite spar. Dolomite pseudobreccia is locally developed. Both the brown dolostone and the pseudobreccia are the epigenetic dolostones of Haywick (1984). Medium grained white dolomite occurs as disseminations and clots in the brown dolostone. In places this grades into pseudobreccia texture — rounded patches of brown dolostone surrounded by saddle dolomite. Small crystals of sphalerite are disseminated in the rock. Locally, the rock contains clots of quartz cored by yellowish dolomite spar.

At North Boat Harbour #3 (2M/12-Zn003) pseudobreccia contains patches of medium grained, black dolostone in which secondary white fine grained dolomite is disseminated. Crystals of green, black, orange, and blue sphalerite, up to 5 mm in diameter, are disseminated within the dolostone patches as well as on the rims and are followed by white dolomite spar. Pseudobreccia "clasts" consist of reddish-brown, tightly packed, subhedral dolomite and, in places, the "clast" rims are replaced or overgrown by white dolomite. Interclast areas are filled with saddle dolomite. In places, voids are filled by chalcedony, most of which has inverted to quartz. All dolomite luminesces uniform red. Locally dolomite spar is followed by later calcite spar.

At North Boat Harbour #4 (2M/12-Zn004) pseudobreccia is locally developed in medium grained dark brown dolostone. Over a small area, sphalerite crystals are disseminated in the rock and associated with white dolomite spar.

In a sample from #4, sphalerite forms crystals which are partly replaced by an unidentified birefringent fibrous mineral and by an isotropic mineral (opal?). The sphalerite luminesces bright pink, orange, and yellow.

Type Ib

Eddies Cove

Numerous small lead and zinc showings are scattered throughout the neighbourhood of Eddies Cove. Mineralization straddles dolostones of the March Point Formation and lower dolostone member of the Petit Jardin Formation. The epigenetic dolostones of the March Point Formation are dark grey, finely crystalline, vuggy, and have replaced dark grey, thinly stratified, bioturbated limestones. They contrast with the microcrystalline massive dolostone of the lower dolostone member of the Petit Jardin Formation which mostly exhibits features of carbonate tidal flats, including stromatolite mounds and finely laminated dolostone (I. Knight, pers. comm., 1990). Several occurrences are described below.

The Eddies Cove Brook area is underlain by flat-lying, thinly-stratified black dolostone of the March Point Formation. The dolostone is fine- to medium-grained, subhedral to euhedral, luminesces a uniform medium-red, and contains intercrystalline brown organic material. The occurrences along the brook, Eddies Cove #11, #12, and #13 (12P/8Zn006, Zn005, and Zn004 respectively) contain sphalerite and/or galena. Sphalerite occurs intergrown with white dolomite in rounded clots. Galena occurs only at Eddies Cove #12 associated with white dolomite spar in veinlets and clots up to 3 mm.

Sulphides are replaced by dolomite spar and quartz, although only the latest nonluminescent spar replaces galena. Coarse grained quartz is commonly intergrown with the dolomite spar and the sulphides. The contact between the galena and the spar luminesces blue (Fig. 19*). Sphalerite has been replaced by dolomite spar which contains numerous sphalerite inclusions.

Locally, late orange-brown luminescent, fine grained calcite or calcite spar fills voids and postdates all other minerals.

The occurrences at Eddies Cove Trenches (12P/8Pb002) are hosted by bluish-grey, very fine grained, thinly-laminated dolostones of the Petit Jardin Formation. Sporadic galena mineralization occurs in two trenches as clots and in generally thin (<0.5 cm) veinlets with white dolomite spar. In places, clots of galena are up to 3 cm in diameter. Drill core from the area contains galena and straw-coloured sphalerite hosted by similar very fine grained dolostone. The sulphides occur in calcite and dolomite spar-filled vugs, 1 mm wide veinlets, and as isolated disseminations.

The very fine grained dolostone from Eddies Cove Trenches and drill core consists of subhedral to anhedral tightly packed dolomite with minor intercrystalline material.

Dolomite commonly displays medium-red luminescent cores overgrown by zones of varying luminosity. The latest zones, which form spar, are generally only present in areas of high original porosity. Fine grained dolomite is overgrown only by the earliest two or three zones. In most samples one or more sharp fiery-red zones are followed by late thick nonluminescent zones (Fig. 19*). Electron microprobe data from samples other than those at Eddies Cove, which were not analyzed, indicate that the degree of luminosity varies inversely with the iron content (see Appendix C).

Green Island Brook

The Green Island Brook occurrences (#3 and #4) (12P/7-Zn004 and 12P/7-Pb001) are similar to those at Eddies Cove and Contact Brook. They are hosted by black to brown, very fine grained dolostones of the March Point Formation.

The dolostone is mottled, laminated, and bioturbated with sparse, rounded, dolomite-quartz-minor calcite clots and minor amounts of sphalerite. Zoning is dolomitecalcite-quartz with sphalerite in the centre of clots, postdating the dolomite. Most of the dolostone is dark brown, consisting of very small, euhedral to subhedral grains and an abundance of brown organic material. Irregular patches and laminations of lighter brown rock consist of subhedral dolomite. Rare galena occurs as disseminated cubes and as fracture coatings. The galena is intergrown with dolomite spar, which contains numerous galena inclusions, suggesting replacement of galena by spar.

Contact Brook

The Contact Brook occurrences southwest of Eddies Cove (Contact Brook, Contact Brook #3, #4, and #5) are very similar to those at Eddies Cove. They are hosted by black, fine grained dolostones of the March Point Formation. At the Contact Brook occurrence (12P/8-Zn011) fine grained, laminated dolostone passes upwards into bioturbated dolostone. The dolostone consists of euhedral to subhedral grains with intercrystalline brown organic material, quartz, and pyrite. Local laminations are defined by varying amounts of intercrystalline organic material. Sporadic galena occurs along hairline fractures and in small clots with associated white dolomite spar. Rounded clots of white dolomite spar, flattened parallel to bedding, are cored by a void and/or galena. At this occurrence and at Contact Brook #3, #4, and #5, (12P/8-Zn009, Zn007, and Zn008) honey-brown sphalerite crystals are associated with white dolomite spar in rounded clots and along fractures. The sphalerite luminesces bright yellow where it is in contact with dolomite (Fig. 20*). Fine grained dolomite luminesces a uniform medium red that, in places, is overgrown by additional thin variably-luminescing zones. Euhedral zoned crystals of dolomite replace sphalerite and dark red luminescing dolomite spar. Fine grained dolomite also replaces sphalerite.

Electron microprobe analyses indicate that the dolomite replacing sphalerite is enriched in Zn (Appendix C). As at Eddies Cove there is little porosity and no development of pseudobreccia.

Pikes Feeder Pond

The Pikes Feeder Pond (12I/10-Pb001) occurrence was not visited due to inaccessibility; samples were, however, donated by I. Knight (Newfoundland Department of Mines and Energy). The showing is briefly described by Knight and Boyce (1984). Mineralization is hosted by grey, massive dolostone of the Petit Jardin Formation. Galena, sphalerite, and lesser amounts of chalcopyrite and pyrite occur in open spaces along an irregular fracture network. Mineralization also forms clots and disseminations filling intercrystalline porosity and is locally concentrated in layers parallel to bedding. Mineralization distribution may be partly controlled by the original depositional fabric of the rock. Mineralization is up to 60 cm thick but overall averages less than 2% galena with local higher concentrations (Beckett, 1966).

In samples examined for this study sphalerite and galena occur in white dolomite spar clots and veinlets. The rock is fine grained grey dolostone, locally brecciated on a fine scale. Fragments are angular, <1 cm in size, rotated, and consist of subhedral to anhedral fine grained dolomite. Fine grained quartz occurs in intercrystalline areas and is concentrated along stylolites. Anhedral dolomite is commonly replaced by subhedral slightly coarser grained turbid dolomite. This coarser grained dolomite also forms the matrix to the fragments. White dolomite spar, in places intergrown with quartz, sphalerite, and galena, cements the fragments.

The dolomite is zoned. Core areas are dull red, followed by zones of varying intensity from dark brown to bright red (Fig. 21*). As the grain size increases the number of zones present increases. Thus the fine grained dolomite may be uniform-red or have only one or two zones. Grain size and number of zones increase proportionally with increasing original void size. Voids are filled with spar. This zoning is similar to that at Eddies Cove Trenches except for the later thick bright red zone.

In places, the dolomite spar partially replaces sphalerite. Sphalerite rims appear black as a result of numerous chalcopyrite inclusions. Fluid inclusions in the sphalerite commonly contain small chalcopyrite grains.

Rocky Pond West

Mineralization at Rocky Pond West (12I/16-Zn001) occurs in bluish-grey, fine grained dolostones of the Petit Jardin Formation. The dolostone consists of subhedral to anhedral dolomite that luminesces a uniform faintly bluish-red. Coarser grained dolomite projects into voids. The cores of this dolomite also display a uniform faintly bluish-red luminescence followed by alternating bright red and brown zones. The calcite spar luminesces medium brown.

Minor sphalerite and pyrite are associated with dolomite spar, quartz, and calcite in irregular patches and stringers. The pyrite forms cubes while the sphalerite forms honey-coloured grains on the rims of gangue-filled clots, i.e. the sphalerite precipitated in vugs which were later filled with gangue. In one sample, sphalerite is followed by fine grained geopetal dolomite, quartz, and pyrite which, in turn, is followed by coarse anhedral quartz. Pyrite appears to be slightly earlier than the sphalerite and is embayed by dolomite and sphalerite.

Goose Arm Narrows

The Goose Arm Narrows occurrence (12H/4-Pb004) was only examined in drill core. Galena, sphalerite, and minor pyrite and chalcopyrite occur in grey fine- to medium-grained dolostone of the lower massive member of the Hughes Brook Formation (Wilkinson, 1983; McHale and McHale, 1984); mineralization occurs about 10 m below the contact with the overlying middle stromatolitic limestone member. Sulphides occur along stringers, coat fractures, and are disseminated throughout the rock. Minor fine- to medium-grained white dolomite spar is associated with the sulphides. Highest assay results are 4.7% Zn, 0.77% Pb, and 0.23 oz/ton (7.89 g/t) Ag over a 90 cm chip sample from a trench (Wilkinson, 1983), and 3.99% Zn and 0.28% Pb over a 2 m drill core interval (McHale and McHale, 1984).

Galena occurs in veinlets with sphalerite and dolomite and is especially prevalent on fractures. The galena penetrates into the rock bordering these fractures; dolomite bordering the fractures contains numerous galena inclusions. The "clean" medium grained dolomite and the spar also contain numerous galena inclusions, which are concentrated just inside the dolomite rims. This suggests replacement of dolomite by galena since both the rock and the gangue dolomite have been affected and the galena appears to penetrate along dolomite grain boundaries. Galena at least partly postdates sphalerite.

Sphalerite is nonluminescent except where cut by a late calcite vein. The luminescent sphalerite is depleted in Cd — 0.43% compared with 1.42% in the nonluminescent sphalerite, and Fe — 0.03% compared with 0.78%, and correspondingly higher in Zn (Appendix B). Part of the sphalerite is replaced by galena where cut by this vein.

The dolostone host rock consists of dolomitized ooids and rounded intraclasts surrounded by medium grained matrix dolomite. Cathodoluminescence shows the dolomite that replaces ooids has dark red cores and bright red rims, the dolomite in intraclasts luminesces uniform medium-red, and the medium grained matrix dolomite is zoned bright red.

Disseminated pyrite within the host rock commonly has euhedral hexagonal cross-sections similar to that from Fish Point. Detailed examination showed that this pyrite originally consisted of tiny crystals which filled intercrystalline spaces in the rock. In places these were originally spheroids which were recrystallized to form pyrite with hexagonal cross-sections (Fig. 22, 23).

Dolomite spar has early bright red zones similar to those in the medium grained dolomite, plus a later thick nonluminescent zone which rims spar crystals and forms the core of spar veins.

Beaver Pond (Raft Pond)

The Beaver Pond (12H/4-Zn002) occurrence is particularly interesting because some of the sphalerite mineralization is contained within small quartz-feldspar veins. Fine grained disseminated brown to straw-coloured sphalerite is also associated with disseminations, conformable bands, and veinlets of fine grained iron sulphide. Only minor rusty pyrite was observed in outcrop but sphalerite and pyrite were sampled from drill core.

The host rock consists of dolostone of the Hughes Brook Formation which is equivalent to the Petit Jardin Formation. Sphalerite fills minute intergranular pore spaces and, in places, occurs with white sparry dolomite in the matrix to angular spar breccia fragments. Mineralization is minor and appears to be limited in extent. The sulphides rim rock fragments and formed early relative to dolomite spar. Fine grained pyrite occurs as thin parallel bands.

A sample of dolostone from outcrop consists of irregular patches of very fine grained dolostone surrounded by medium grained dolostone. In places, coarser grained white dolomite occurs in clots and vugs. Some of the fine grained dolostone appears to be replacing ooids. The fine grained dolostone luminesces medium-red while the spar has early bright to dull red zones followed by a thick nonluminescent zone. Locally, the spar displays a late thin very bright-red zone that is very similar to that found in samples from the Goose Arm area.

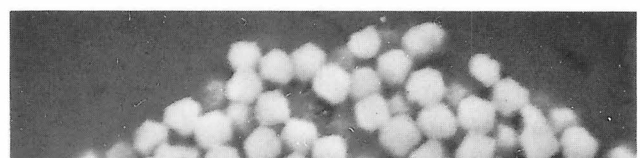

Figure 22. SEM photograph of a spheroidal aggregate of pyrite crystals. Goose Arm.

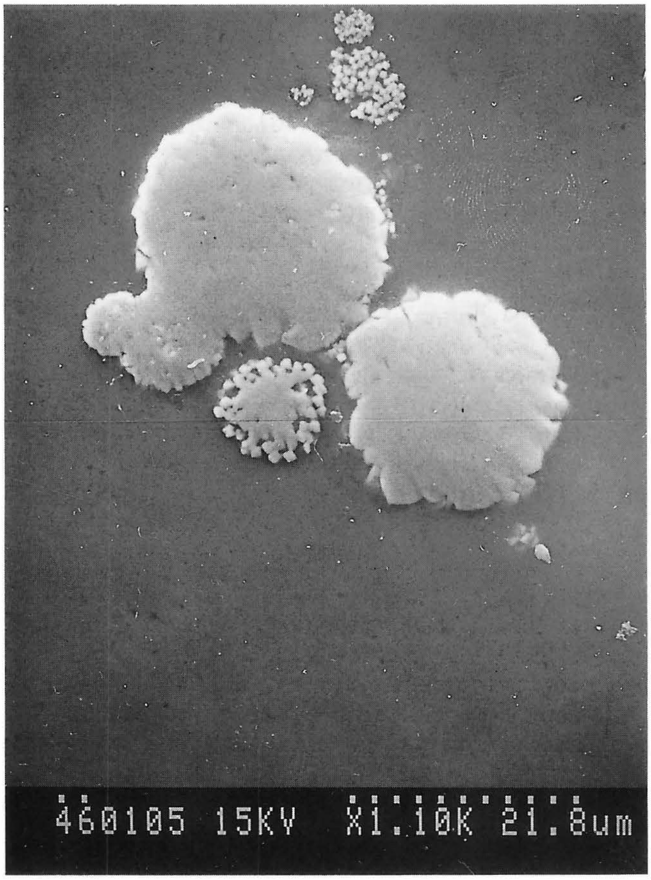

Figure 23. SEM photograph showing wholly to partly annealed pyrite spheroids. Note that lower right spheroid has begun to assume a straight-sided outline. Goose Arm.

There appears to be at least two stages of mineralization. Pyrite commonly occurs as bands and disseminations in fine- to medium-grained dolostone. In some samples relict marcasite morphology is preserved. In DDH-74-7, pyrite is intergrown with reddish-brown botryoidal sphalerite. Locally the sphalerite is cut by granular sphalerite. Also in DDH-74-7 feldspar veins containing albite, K-feldspar, quartz, dolomite, rutile, sphalerite, pyrite, and minor apatite were noted (Fig. 24). Dolostone luminesces red, K-feldspar luminesces yellow, and the apatite bright blue. Rutile is surrounded by K-feldspar. The sample also contains minor dolomite spar and earlier pyrite, but sphalerite is definitely contemporaneous with the feldspar.

This feldspar has been dated by the $^{40}Ar/^{39}Ar$ laser microanalytical dating technique (Hall et al., 1989) suggesting that this occurrence has been affected by at least two thermal events, one at 350 to 370 Ma and one at about 210 Ma. Although these ages correlate with well-known Devonian and Triassic thermal events in Eastern Canada, it is not clear whether the feldspar ages are primary or reflect resetting by these events.

DDH-74-5 contains brecciated dolostone in which pyrite has nucleated on fragments. Fragments of similar pyrite are also found in the breccia, indicating that there has been more than one pulse of brecciation. Locally, coarse, strain-free quartz forms the matrix to the breccia and is preceded by a thin zone of dolomite which rims the fragments. Dolomite is followed by a thin zone of quartz, a zone of pyrite and sphalerite, and then by the bulk of the quartz. This assemblage is also present in the veins. Dolostone luminesces uniform bright red while the dolomite in the breccia matrix and the quartz veins is duller red.

In the same drill hole, sphalerite and pyrite line cavities which are filled by fine grained dolomite. Pyrite commonly occurs along one edge of the cavities with sphalerite along the opposite edge. Although the sphalerite appears to be later, pyrite and sphalerite are commonly intergrown in cavities and in stringers, possibly indicating two stages of pyrite. The pyrite clearly pseudomorphs marcasite. One sheaf of pyrite is cut by a dolomite-sphalerite vein. The botryoidal sphalerite along with the sphalerite in the geopetal cavities may be relatively early and appears to be similar to other Type Ib mineralization.

Type Ic

Salmon River #3

The Salmon River #3 (12P/1-Zn003) showing is contained in a zone of epigenetic dolomite developed in a 30 cm thick conformable zone in flat-lying massive grey dolostone of

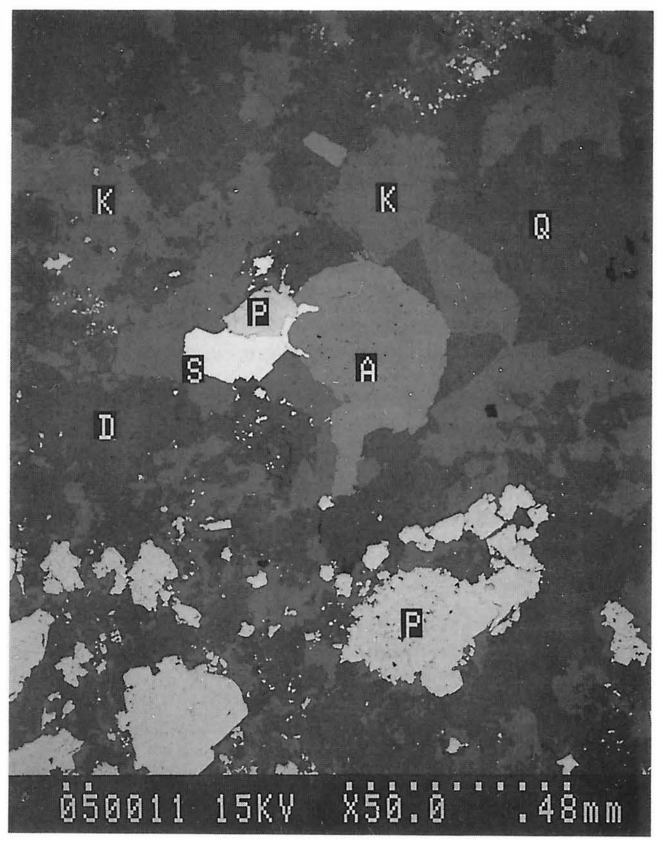

Figure 24. SEM photograph showing intergrown sphalerite (S), pyrite (P), apatite (A), and K-feldspar (K). Also visible are quartz (Q) and dolomite spar (D). Raft Pond.

the Petit Jardin Formation. The dolostone consists predominantly of anhedral tightly packed dolomite with bands of finer grained dolomite. The dolostone luminesces uniform dull to medium red. Rock below the epigenetic dolomite zone consists of fine grained, thinly-laminated grey dolostone; well laminated, medium grained, light brown dolostone lies above the epigenetic dolomite. The dolomite spar forms a very regular texture similar to pseudobreccia, i.e. round "fragments" of fine grained dolostone surrounded by dolomite spar.

The "fragments" consist of medium grey, fine grained dolostone and are surrounded by white dolomite spar followed by intergrown pyrite and sphalerite, pink dolomite spar, and euhedral quartz. Early white saddle dolomite luminesces uniform bright red and is followed by pink dolomite that is brightly zoned under cathodoluminescence (Fig. 25*).

Sphalerite is present in a variety of colours that include metallic black, metallic blue, resinous brown, reddishbrown, yellow-brown, yellow, and orange. The sphalerite is botryoidal and luminesces yellow and purple. Grains of sphalerite are as large as 5 mm while pyrite forms anhedral grains or euhedral pyritohedrons up to 1 cm in size. Angular spar breccia occurs locally.

In one sample, minute marcasite inclusions are aligned along the sphalerite cleavage (Fig. 26) and where marcasite is abundant, the sphalerite appears to be opaque. The sphalerite surrounds euhedral quartz crystals, the centres of which contain marcasite and sphalerite inclusions. In places, sphalerite has been slightly replaced by dolomite. Sphalerite is followed by fine grained, red-luminescing geopetal dolomite and pyrite (Fig. 25*) which, in turn, is followed by quartz, and then the pink dolomite which is brilliantly zoned under cathodoluminescence.

Late, clear, red sphalerite was identified in geopetal cavities. This sphalerite contains large fluid inclusions and appears to be contemporaneous with the late dolomite spar.

Green Island Brook #1

The Green Island Brook #1 (12P/7-Zn002) occurrence displays characteristics intermediate between Type Ia and Ib mineralization, i.e. there is local development of dolomite pseudobreccia. Host rock to this occurrence consists of fine grained, black dolostone with poorly developed pseudobreccia texture. The rock has a somewhat mottled appearance caused by a bimodal grain size distribution. Patches of fine grained, subhedral dolomite with minor amounts of intercrystalline brown organic material are replaced by medium grained, anhedral interlocking dolomite (white in hand-sized sample) that is contemporaneous with the spar forming the pseudobreccia. Fine grained dolomite luminesces dull red while the spar and medium grained secondary dolomite luminesce a slightly brighter red.

Small green crystals of sphalerite, together with pyrite, are associated with the spar and the patches of medium grained secondary dolomite.

Hidden Pond

At Hidden Pond (12P/8-Zn045) disseminated sphalerite occurs in medium- to coarse-grained, light brown dolostones of the Watts Bight Formation immediately below the contact with the Boat Harbour Formation. The host rock has

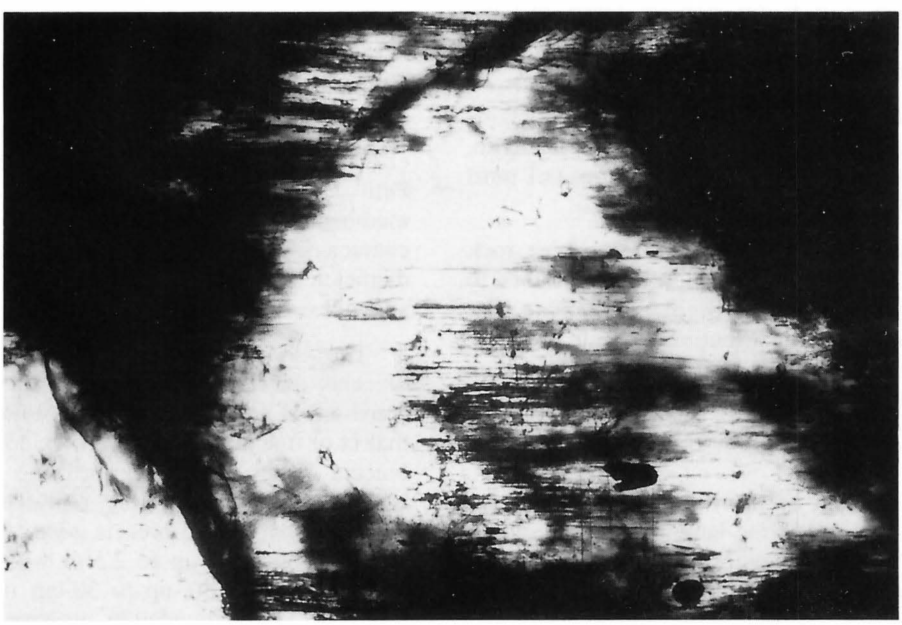

Figure 26. Photomicrograph of sphalerite that contains numerous marcasite inclusions. The marcasite is aligned along sphalerite cleavages and is so abundant that in places sphalerite appears black. Salmon River #3. Field of view about 1 mm.

a bimodal grain size; irregular patches of very fine grained, tightly packed, light brown dolostone are replaced by coarse grained secondary dolostone. The coarse grained dolostone consists of intimately mixed brown and white dolomite grains resulting in a patchy appearance; the latter is also irregularly distributed in stringers and clots and fills vugs. A polymictic breccia, occurring at the Watts Bight-Boat Harbour contact, consists of angular fragments ranging in size from <1 to >60 cm, of grey chert, fine grained, thinly-laminated dolostone, medium grained dolostone, and grey micritic limestone.

Knight (1980) interpreted this breccia as a basal disconformity but subsequent study (Knight, 1986) revealed that the breccias are stratabound collapse breccias that include discordant and concordant types.

In the host Watts Bight Formation, below the polymictic breccia, very fine grained (<0.5 mm) straw-coloured sphalerite is disseminated within the coarse grained dolostone and tends to be concentrated near the edges of patches of the fine grained earlier dolostone. Sphalerite also tends to be concentrated in bands and stringers. Minor pyrite is disseminated throughout the rock.

The rock contains numerous small, laminated, shaley clasts which are partly replaced by dolomite. These clasts occur preferentially in the coarse grained dolostone. Locally, the shale is replaced by secondary dolomite and only small remnants of the original shale are visible in the intercrystalline areas. Many of the shale clasts have been rotated although large clasts are commonly brecciated in place by dolomite veins (Fig. 27). A majority of the shale clasts contain euhedral dolomite crystals which locally are flattened in the plane of shale laminations suggesting a precompaction, syngenetic (?) origin. Ghosts of the early euhedral dolomite are surrounded by later, coarse grained dolomite (Fig. 27). The tendency for shale fragments to be located in the coarse grained dolostone suggests that the shale fragments were sites of preferential nucleation of the later formed dolomite.

Drill core from two holes at Hidden Pond contains minor pyrite; core from one hole contains sphalerite. Uniform disseminations of small sphalerite grains (<1 mm) comprise <1% of the rock.

At North Hidden Pond (12P/8-Zn046) the host rock consists of patchy dark grey, laminated, medium grained to shaley dolostone of the Watts Bight Formation. The patchiness is due to irregular distribution of white dolomite as small clots, as fracture-fillings, and disseminations. Fine grained strawcoloured sphalerite is disseminated in the rock and tends to be concentrated on the edges of white dolomite clots.

The shaley component of the dolostone ranges from massive to laminated. Locally the laminations are convoluted suggesting soft-sediment deformation. As at Hidden Pond, the shale contains euhedral dolomite crystals; laminations within the shale are commonly draped around the dolomite (Fig. 28). Locally a later, coarse grained dolomite consisting of round clots overprints the rock. Cores of the earlier euhedral dolomite are contained within the coarse grained dolomite. Abundant fine grained, subhedral sphalerite forms around and just inside the rims of the dolomite clots. The sphalerite is intergrown with shale in intercrystalline areas.

The early euhedral dolomite is thinly zoned under cathodoluminescence. Coarser grained dolomite is bright red and tends to replace the zoned dolomite; cores of the sphalerite luminesce bright purple and contain small primary fluid inclusions (Fig. 29*).

Round Head Island

The showing at Round Head Island (12I/14-PYR001) is hosted by an oligomictic dolostone breccia developed in the Boat Harbour Formation. Fragments in the fine rock matrix breccia are 1-30 cm, angular, light grey, anhedral, algal-laminated dolostone.

Nearby outcrops outside the breccia consist of heavily bioturbated, finely-crystalline, grey dolostone. The presence of these dolostones suggest that the algal-laminated fragments within the dolostone breccia originated from an overlying unit.

Pyrite rims the breccia fragments and occurs as cubes and anhedral clots within the breccia matrix. In much of the breccia pyrite completely replaces the matrix to form thick, massive zones. In places pyrite forms botryoidal masses of cubes that are zoned: pyrite, pyrite-marcasite intergrowth, pyrite. The pyrite-marcasite intergrowth appears to be primary. Marcasite is irregular, skeletal in places, and is partly to wholly replaced by pyrite. Marcasite "ghosts" occur in the middle of botryoids and are overgrown by an outer zone of coarse, euhedral pyrite, such that only the pyrite morphology may be distinguished externally. Pyrite is followed by white dolomite spar which in places has rounded and corroded the dolostone breccia fragments.

Chambers Island

The showing on Chambers Island (Seal Islands) (12P/7-Zn001) is located in the Stromatolite member of the Petit Jardin Formation. In this locale, the Stromatolite member consists of a finelycrystalline, light-grey dolostone, characterized by domal stromatolites averaging 0.5 m in diameter. Algal laminations are visible on weathered surfaces.

The showing consists of spectacular pyrite-filled breccias developed in fault breccia zones that originally consisted of angular laminated dolostone fragments set in a matrix of fine grained, dark brown dolostone. The precursor breccia occurs at the seaward end of the longest pyrite breccia zone and is partly replaced by pyrite and pink dolomite spar. Three breccia zones are visible. They are 5 to 40 m long and up to 2.5 m wide and contain angular dolostone fragments up to 30 cm in size. The dolostone fragments are surrounded by massive pyrite. Void spaces in the pyrite are filled with pink dolomite spar and rare 1 to 2 cm clots of resinous, anhedral dark brown sphalerite. Quartz and grey dolomite spar are visible in one vug.

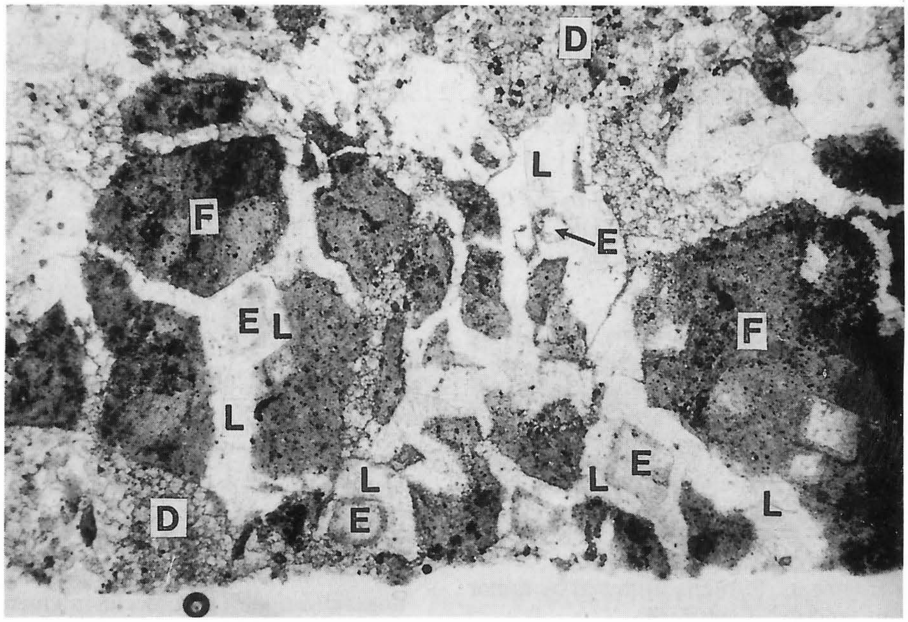

Figure 27. Photomicrograph showing shale fragments (F) surrounded by very fine grained dolostone (D). Early euhedral dolomite crystals (E) within the shale have been overgrown by later dolomite (L) which also occurs in veinlets. Hidden Pond. Field of view 3 mm.

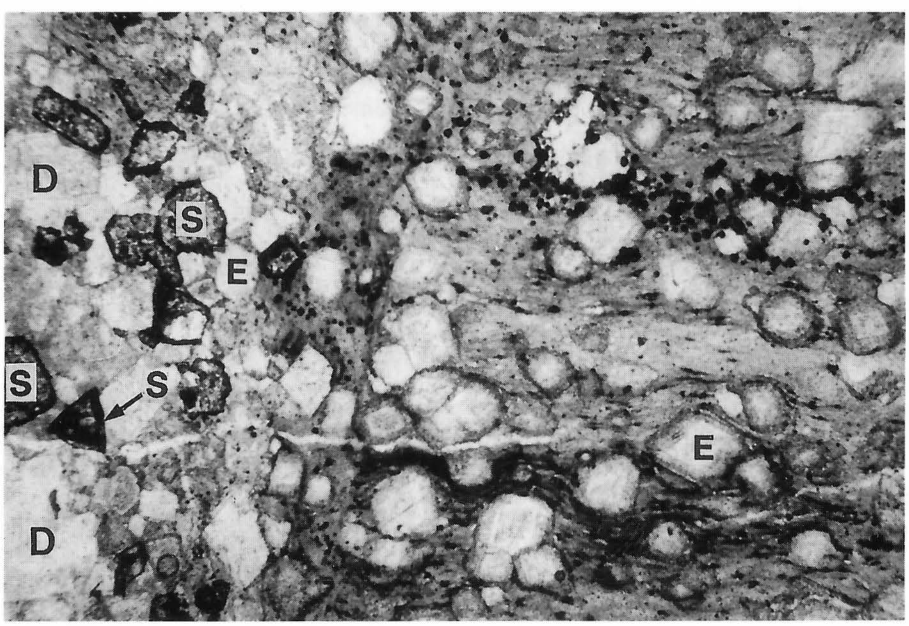

Figure 28. Photomicrograph of well laminated shale. Just to the left of centre the laminations are truncated at right angles by another set of laminations. At left are coarse grained dolomite (D) and disseminated sphalerite (S). Note draping of shale laminations around early euhedral dolomite (E). North Hidden Pond. Field of view 3 mm.

Zoning is pyrite-grey dolomite spar-pink dolomite spar-sphalerite-quartz. Sphalerite and quartz were not observed together hence their order of precipitation is unknown. The dolostone fragments luminesce dark red whereas early grey dolomite spar luminesces bright red and the later pink dolomite spar is nonluminescent.

Mineralization also occurs in veins lined by pyrite then pink dolomite spar, and in places, clots of sphalerite. The veins and breccias trend between 50° and 60° and dip vertically.

A grab sample of the massive pyrite is extensively internally brecciated. Elsewhere the pyrite consists of a mosaic of anhedral grains. Rare marcasite "ghosts" were identified. Voids in the pyrite are filled with fine grained (0.05 mm) dolomite, euhedral 0.1-0.3 mm dolomite crystals, very fine grained subhedral pyrite, broken fragments of pyrite, and rare broken sphalerite.

A second sample displays pyrite rimming fine grained, laminated dolostone fragments. Pyrite is followed by minor dolomite, followed by crystals of sphalerite.

Brig Bay

Four pyrite occurrences were visited in the Brig Bay area. Two of these, St. Barbe Harbour, and Forresters Point, are hosted by the Petit Jardin Formation. The other two, at Dog Cove and Seal Cove are contained in rocks of the Boat Harbour Formation and Watts Bight Formation, respectively.

The St. Barbe Harbour (12P/2-PYR001) occurrence host rock is a light to dark grey and beige, finely-crystalline dolostone, displaying shallow-water features such as rip-up clasts, algal laminations, and oolites. The dolostone consists of anhedral to subhedral, tightly packed dolomite.

Mineralization at St. Barbe Harbour consists of minor pyrite associated with quartz and dolomite spar gangue. The quartz creates a fabric similar in form to dolomite pseudobreccia. The quartz is arranged in bands of radial needles which surround round patches of dolostone. The quartz needles are followed by medium grained and then coarse grained quartz. Growth zones and fractures containing minute fluid inclusions are visible in the quartz, although the inclusions are too small for microthermometric study.

Locally, thin bands of quartz are followed by a thin zone of pyrite crystals and abundant pink dolomite spar. Elsewhere quartz is the abundant phase with pyrite and dolomite spar absent or restricted to small cores of voids. Quartz also occurs as euhedral crystals lining vugs. In one sample vuggy quartz crystals contain hydrocarbon residue, visible in hand-sized specimen.

At Forresters Point (12P/2-PYR002), host rocks consist of massive, fine grained dolostone of the Petit Jardin Formation. Mineralization is confined to a linear 2-5 cm wide, vertically dipping, angular vein-breccia zone which trends 45°. Walls of the vein and angular fragments of country rock are surrounded in places by an aggregate of pyrite and marcasite ranging in abundance from a few grains to thick coatings. Parts of the vein are completely filled with this aggregate over a length of several centimetres. The iron sulphide aggregate is followed by pink dolomite spar, in places cored by calcite spar. At the eastern end of the vein, reddish sphalerite crystals occur along the rims of the rock fragments.

Mineralization consists of an intergrowth of pyrite and marcasite. In places a lattice-work of pyrite with a 60°-120° orientation is intergrown with the marcasite on a microscopic scale. Elsewhere pyrite may form fibrous growths which contain "eyes" of marcasite. The latest zone of mineralization is commonly pure pyrite. Locally, the marcasite has been replaced by pyrite, although much of the mineralization appears to be a primary pyrite-marcasite intergrowth.

At Dog Cove (12P/2-PYR006), medium grained, bioturbated, dark- to medium-grey dolostone of the Boat Harbour Formation hosts the mineralization. Fine-rock matrix breccia, with white dolomite spar partly replacing the fine grained dolostone matrix, outcrops in the vicinity of the mineralization. The breccia fragments are up to 30 cm in diameter. About 5% fine grained anhedral to euhedral pyrite is disseminated over a 5.2 km^2 area. Although some of the pyrite occurs with the white dolomite spar in the breccia matrix, most of the pyrite is disseminated within the host dolostone.

A 1 cm wide zone of saddle dolomite from this area luminesces dull red followed by a zone of very thin bands of varying luminosity (medium red to nonluminescent), then a thick dull red, and a thick bright red zone.

The occurrence at Seal Cove (12P/2-PYR004) is hosted by flat-lying, fine grained, grey dolostone of the Watts Bight Formation. White dolomite spar occurs in irregular clots and as poorly developed pseudobreccia. Fine grained, euhedral to anhedral pyrite is associated with the dolomite spar and, to a lesser extent, is disseminated throughout the rock. The pyrite is restricted to an area about 10 m in diameter.

Because the pseudobreccia is only poorly developed and overall pre-spar porosity was probably low, this occurrence is considered to be intermediate between the Type Ia and Type Ib end-members.

Watts Point

The Watts Point (12P/8-Zn002) showing is hosted by the Middle Stromatolite member of the Petit Jardin Formation. Domal stromatolitic mounds in this area average 0.5 m in diameter. The dolostone is medium grey, finely-crystalline, and displays algal laminations on the weathered surface.

Mineralization appears to be restricted to both ends of one large outcrop. At the east end of the outcrop sphalerite and pyrite occur in a stromatolitic mound 1 m in diameter that is cut by a breccia zone. The breccia consists of angular dolostone fragments up to 5 cm in diameter set in a sandy dolostone matrix. Sphalerite and pyrite are disseminated mainly in the breccia matrix but also occur in a 2 cm wide vein.

At the other end of the outcrop, greenish-brown sphalerite and minor pyrite occur in clots and stringers associated with white dolomite spar. The spar tends to form a pseudobreccia texture. Sphalerite precedes the dolomite spar and surrounds rounded "fragments". Pyrite occurs as grains between sphalerite and dolomite. Sphalerite also forms conformable bands, up to several millimetres in width, associated with minor pyrite and white dolomite spar. Figure 30* displays brilliantly cathodoluminescent zoned sphalerite rimming fine grained, dolostone pseudobreccia "fragments". Sphalerite forms a 1 to 3 mm band of subhedral crystals in which bright white to purple luminescing zones alternate with light and dark brown zones. This is followed by zoned saddle dolomite which luminesces medium to dark red. Cavities are filled with very fine grained, dark red luminescing dolomite (Fig. 30*). In places fragments of fine grained dolostone, dolomite spar, and sphalerite float in the cavity-filling dolomite. The rock fragments in this sample are composed of patches of anhedral, fine grained dolomite set in anhedral, medium grained dolomite.

Type IIa

Bellmans Cove

At Bellmans Cove (12B/10-Pb003) mineralization is hosted by limestone breccia and fossiliferous biohermal limestone of the midVisean Big Cove Formation of the Codroy Group which unconformably overlies the Table Head Group in a paleokarst valley (Dix, 1982; Dix and James, 1989). Mineralization consists of pyrite, marcasite, sphalerite, calcite, and barite. Pyrite is the dominant sulphide on the west side of the cove, marcasite is typical of the east side. Galena was not observed at Bellmans Cove. Sphalerite is exposed on the east side of the cove, in vugs with calcite and, less commonly, marcasite and barite. The sphalerite forms black euhedral to subhedral crystals up to 2 cm across. Pyrite and marcasite form massive lenses, as clots and disseminations in veins, cavities, and vugs, and in the matrix to limestone breccia. Marcasite is abundant, especially near the unconformable contact between the Codroy Group and the Table Head Group where a heavy gossan is developed. Here marcasite and calcite spar surround limestone breccia fragments and locally completely replace the matrix. Marcasite, which forms up to 30% of the rock, is present as anhedral masses or rosettes of bladed crystals, which commonly contain numerous calcite gangue inclusions and appear to be a replacement feature. On the west side of the cove sphalerite was not observed but pyrite occurs as massive lenses up to 40 by 20 cm in size in cavities and in veins with calcite and barite. Zoning in the veins consists of pyrite-calcite-barite. Pyrite forms massive clots or aggregates of round grains surrounded by calcite grains. In places, the pyrite contains minor marcasite and sphalerite inclusions. Dix (1982) noted that pyrite appeared to be localized in fault-related gossan zones and suggested it may result from late fluid movement. Calcite spar from this occurrence luminesces orange to yellow.

Lead Cove

The Lead Cove (12B/10-Pb002) occurrences are hosted by Big Cove Formation limestones located in a paleokarst valley formed in Table Head Group limestone (Fig. 5). Galena and marcasite occur as disseminations, replacements, and in veins and vugs in brecciated limestone. Breccia fragments are subangular, 1 mm to several centimetres and are set in a limy matrix. Locally the limestone breccia passes into massive oncolitic limestone. Marcasite and calcite spar surround limestone fragments and replace matrix adjacent to the oncolites. Mineralization occurs predominantly in the breccia matrix and in irregular veins with no consistent orientation. It consists of galena cubes up to 1 cm in size, marcasite rosettes up to 1 cm in diameter, and clear calcite spar. In one sample, sheaves of marcasite up to 1 cm across have nucleated on fine grained limestone. Marcasite is followed by medium grained, anhedral calcite which contains tiny marcasite needles. This, in turn, is followed by cubes of galena, fine grained calcite and then coarse grained calcite spar. Galena crystals are surrounded and corroded by fine grained marcasite and calcite.

Zoning in vugs and veins, when complete, is marcasite-galena-calcite. Galena-calcite veins cut disseminated marcasite. Minor amounts of barite were identified in vuggy coarsely-crystalline calcite veins. Sphalerite was not observed.

In a limestone pebble conglomerate, which passes upwards into sandstone, the matrix of granular, fine grained calcite is extensively replaced by marcasite and calcite spar. In places marcasite has partly or completely replaced fragments; where this has occurred, it contains numerous limestone inclusions which define the shape of the original fragment.

The rock and the calcite spar in the samples luminesce yellow. The spar shows limited zoning, defined by varying shades of yellow.

Aguathuna Road

At Aguathuna Road (12B/10-Ba007), fossiliferous Big Cove Formation limestone overlies Table Head Group limestone. Barite occurs in veins and vugs but also forms a semi-massive banded unit at one end of the outcrop. This unit is 20 m long, has a maximum width of about 3 m and pinches out towards the centre of the outcrop. Fine grained barite forms alternating pink and white to bluish-white bands. Euhedral crystals of barite were identified in vugs. Although celestite has been reported from this occurrence, it was not recognized by Dix (1982) nor did samples taken for this study confirm its presence. The Ronan deposit, 4 km to the west, has, however, returned analyses as high as 68% $SrSO_4$ (Johnson, 1954). Rare, fine grained, euhedral galena is locally disseminated.

Marcasite and calcite were identified in veins, vugs, and in the matrix to oncolites and fossils. In places, marcasite forms bladed crystals which have nucleated on rims of oncolites. The marcasite is followed by dogtooth calcite and barite. Zoning is marcasite-calcite-barite. Calcite and the wall rock oncolites luminesce yellow to orange whereas the barite is nonluminescent.

Miners Brook

At Miners Brook (12B/10-Pb007) the Big Cove Formation overlies the Table Head Group in a steep-sided stream valley. Two mineralized outcrops of brecciated and fossiliferous Big Cove Formation limestone, one of which contains a collapsed adit, were located in the stream valley. The breccia consists of angular fragments, up to several centimetres across, surrounded by marcasite and calcite which have replaced the matrix. Mineralization surrounds fossils and limestone breccia fragments, and fills veins and vugs. In one vug zoning consists of minor marcasite-galena-minor sphaleritemarcasite-calcite spar. The second stage of marcasite forms coarse sheaves which have nucleated on sphalerite grains and dogtooth calcite crystals. A boulder located in a rubble pile near a collapsed adit contains semimassive mineralization. Zoning is marcasite-galena-marcasite-calcite spar-barite. Marcasite forms radial sheaves which surround sphalerite grains. Galena forms cubes up to 1 cm in size which in places have nucleated on rims of marcasite sheaves. Calcite spar luminesces bright orange to yellow and in places is coarsely zoned (Fig. 31*).

Piccadilly Brook

At Piccadilly Brook (12B/10-Pb008) oncolitic Codroy Group limestone outcrops along a brook at the edge of a field. Matrix to the oncolites is replaced by calcite spar, fine grained marcasite, pyrite, minor galena, sphalerite, and barite. Marcasite forms tiny rosettes of several micrometres to 0.3 mm across. Pyrite forms equally tiny spheroids similar to those occurring in samples from Goose Arm Narrows (Fig. 22, 23). As at Goose Arm Narrows, many of these spheroids are composed of individual crystals which have locally recrystallized. Commonly, spheroids of pyrite are rimmed by radially oriented marcasite blades. The larger clots of marcasite contain cores of pyrite. Sphalerite and galena form isolated clots and grains.

Limestone on a hill on the opposite side of the brook is quite different. A zone of fossiliferous limestone outcrops at the base of the hill and passes upwards into peloidal limestone followed by micritic limestone and cryptalgal laminates. These rocks are probably part of the Ship Cove Formation which, according to Dix (1982), is found in the area between Piccadilly and Boswarlos. Here, thin galena- and sphalerite-bearing calcite veinlets cut grey micritic limestone. Sphalerite occurs as 0.1 mm black grains along the borders of calcite veins. Galena forms crystals up to 3 mm long. The limestone luminesces dark orange; the spar luminesces slightly brighter orange.

Type IIb

Goodyear Prospect

Numerous mineralized calcite veins were described by Watson (1943) at the Goodyear Prospect or Spider Pond (12B/11-Pb001). Host rocks are flat-lying grey micritic limestones of the Table Head Group. Most mineralization is in rubble piles in and around collapsed trenches within a heavily wooded area. Watson (1943) reported the following zoning for the veins: calcite-galena-sphalerite-marcasite-calcite, representing the five middle zones previously outlined in the generalized paragenetic sequence for Type IIa occurrences. One 2 cm wide, massive, coarse galena vein was identified in outcrop. Zoned galena, sphalerite, and marcasite was sampled from the rubble. Galena is followed by colloform banded sphalerite which is also draped over bright orange-luminescent dogtooth calcite crystals. Sphalerite contains minor chalcopyrite inclusions and Watson (1943) reported minor wurtzite intergrown with the sphalerite. In places the galena is embayed by sphalerite which contains inclusions of the galena, apparently the result of galena replacement by sphalerite. This was also reported by Watson (1943). Sphalerite is followed by zoned, radially arranged marcasite, which in places forms nodules. The earliest zone in the nodules consists of a soft, easily tarnished marcasite which has relatively weak anisotropy and is very difficult to polish. Watson (1943) attributed its anomalous behavior to very fine grain size. Most nodules are cored by a void filled with a very fine grained, black powder which X-ray diffraction confirmed as marcasite (Watson, 1943). The marcasite is commonly followed by colloform banded sphalerite. Where marcasite nodules pinch out, sphalerite is continuously banded. Marcasite and sphalerite are followed by a final zone of intergrown marcasite and pyrite. Watson (1943) has also reported pyrite spherules located at the centres of marcasite nodules.

Piccadilly Harbour

The Piccadilly Harbour (12B/10-Pb001) showing is located in a coastal exposure where a swarm of heavily mineralized calcite veins cuts fine grained, grey, fossiliferous, wackestone of the Table Head Group. The wackestone is overlain by graptolitic shales and argillaceous limestone of the Table Cove Formation. The limestones and shales trend 015° and dip 30°E. Mineralized veins strike from 100° to 130° and dip vertically to subvertically. Mineralization includes coarse blue galena; euhedral, dark blue to black sphalerite; brown, anhedral resinous sphalerite; marcasite; and minor bladed pink barite. Zoning in the largest vein (approximately 10 cm wide) is as follows (from the walls inward): calcite-marcasite-calcite-intergrown galena + brown sphalerite-calcite-intergrown marcasite + euhedral metallic blue sphalerite (Fig. 32). This is similar to zoning on Type IIa deposits except for an extra sphalerite zone at Piccadilly Harbour. Smaller veins are zoned as calcite-intergrown marcasite, sphalerite, galena, or calcite-marcasite. Other veins contain only calcite. One calcite-marcasite vein was observed to be cored by barite while another vein is zoned calcite-barite-marcasite-calcite.

A sample taken from the 10 cm thick vein contains a band of intergrown brown sphalerite and euhedral galena crystals. The sphalerite consists of unzoned, vertically elongated, anhedral crystals orientated perpendicular to vein walls. This is followed by coarse dogtooth calcite spar in turn followed by minor fine grained sphalerite. A band of

COLOUR SECTION

CATHODE LUMINESCENCE

PHOTOMICROGRAPHS

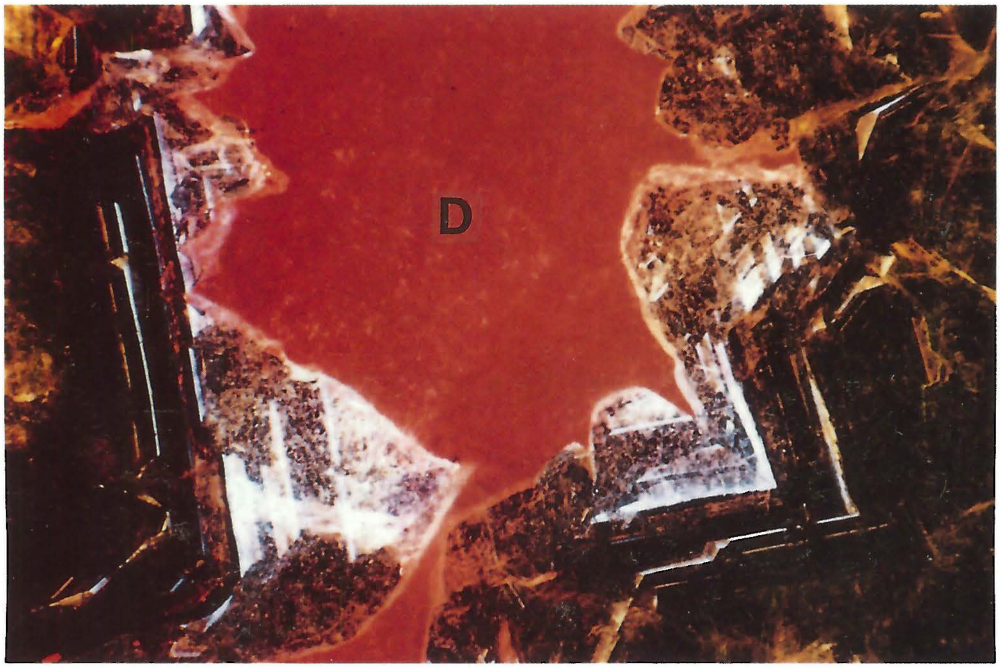

Figure 7. Cathode luminescence photomicrograph of sphalerite (brown) which has bright purple luminescing zones. Sphalerite is followed by bright red luminescing saddle dolomite (D). Round Pond. Field of view 4 mm.

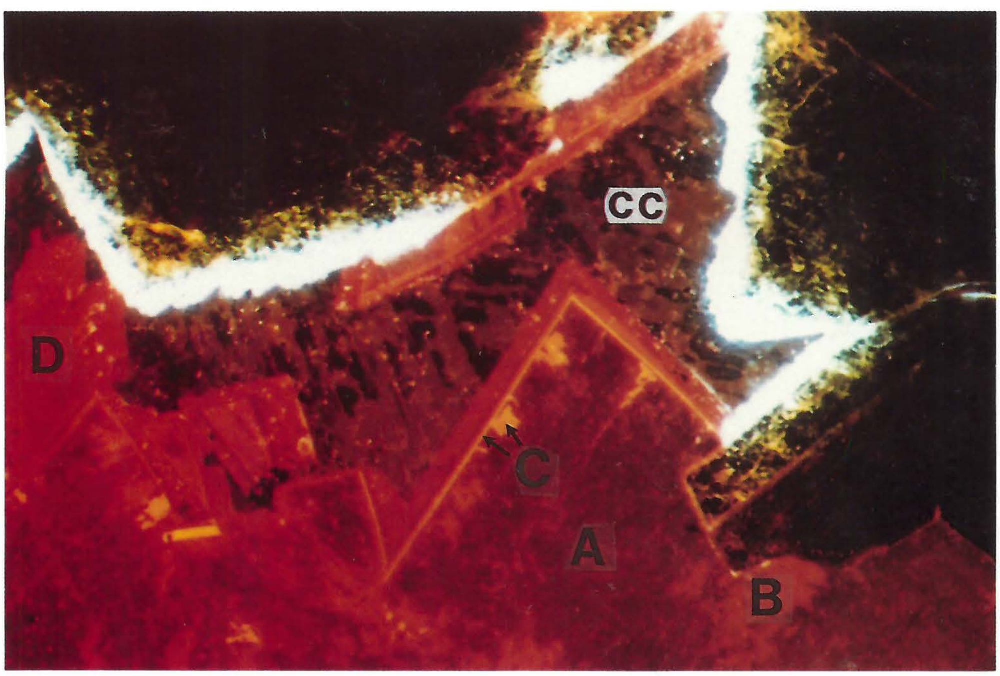

Figure 9. Cathode luminescence photomicrograph. Dolomite luminesces medium red (A), followed by thin irregular bright red (B) and yellow (C) zones, a final bright red zone (D) and brown calcite spar (CC). Sphalerite (top and right) is nonluminescent except along the rims especially where it is in contact with calcite. Salmon River #6. Field of view about 2 mm.

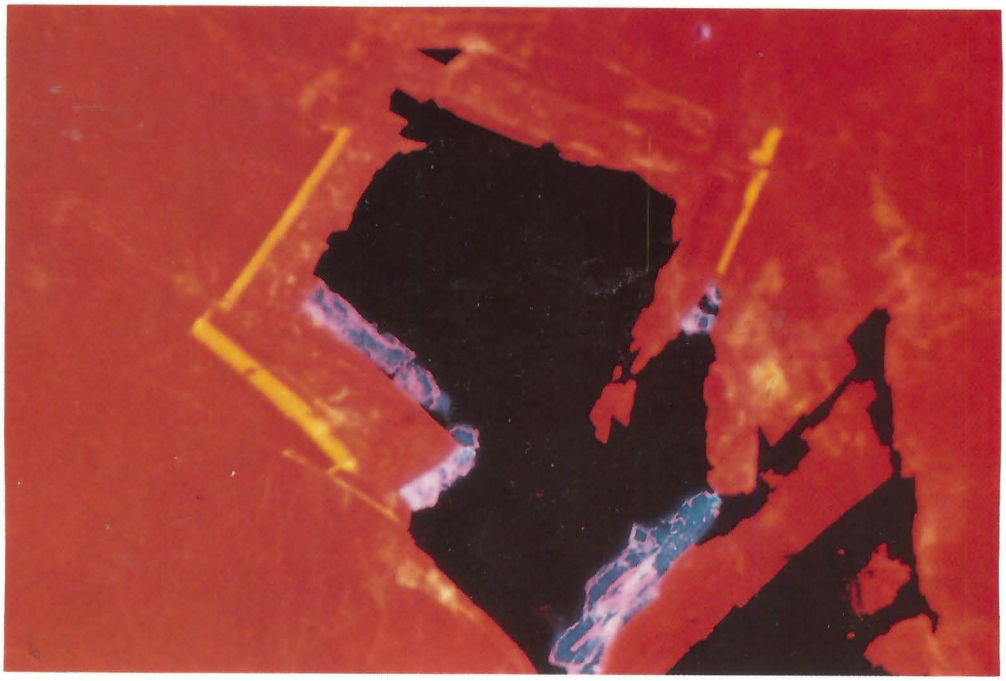

Figure 10. Cathode luminescence photomicrograph. Smithsonite (pink to blue) lines void in saddle dolomite (red and yellow). Salmon River #6. Field of view 2 mm.

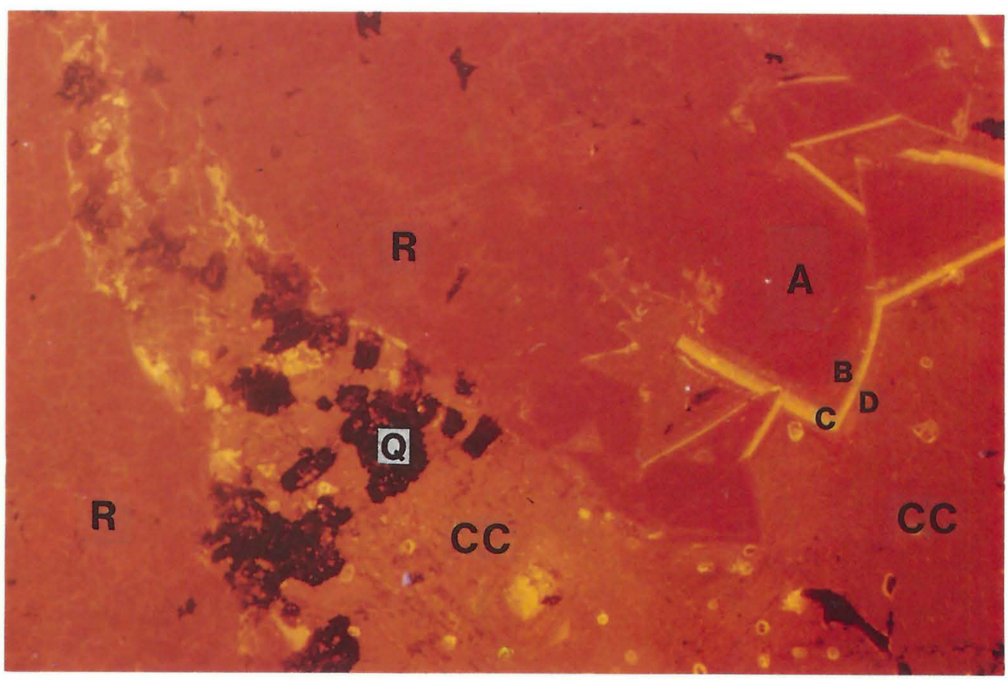

Figure 11. Cathode luminescence photomicrograph. Fine grained dark red-luminescing dolomite (R) luminesces lighter red along grain boundaries. Saddle dolomite luminesces uniform red (A) with outer bright red (B), yellow (C), and bright red (D) zones. Quartz (Q; nonluminescent) and calcite (CC) fill the vein. Salmon River #6. Field of view 6 mm.

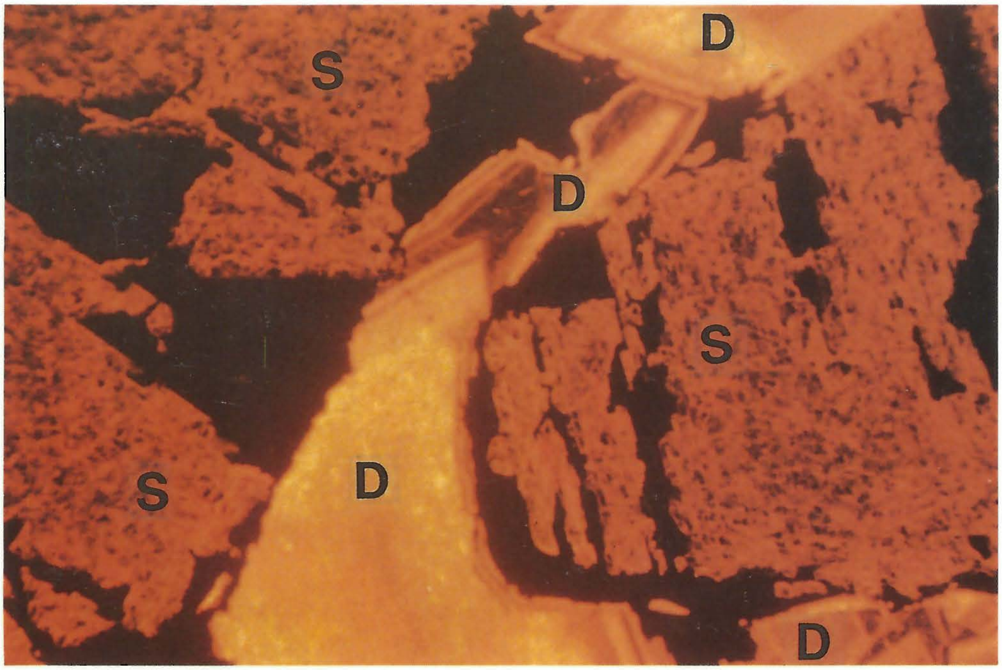

Figure 13. Cathode luminescence photomicrograph of coarse grained sphalerite (S) followed by zoned saddle dolomite (D). Note draping of zones around sphalerite. Photograph Point. Field of view 3 mm.

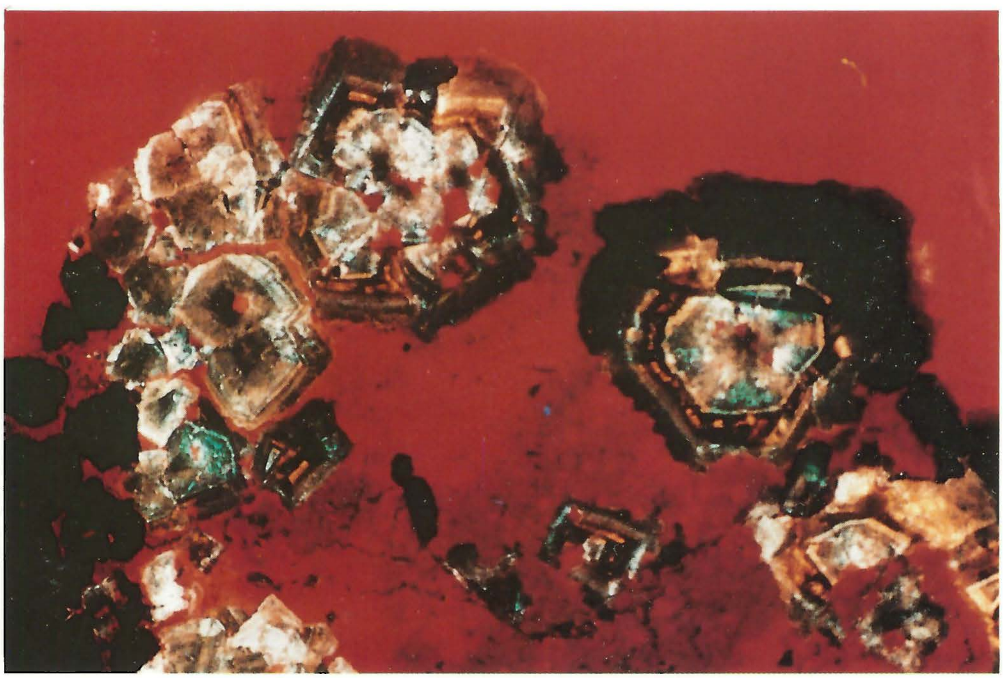

Figure 14. Cathode luminescence photomicrograph showing brightly zoned botryoidal sphalerite. The latest zones are not luminescent. At bottom of photo is dark to medium red-luminescing fine grained dolomite which locally replaces sphalerite. At top is uniformly bright red spar. At left is pyrite. Fish Point. Field of view 4 mm.

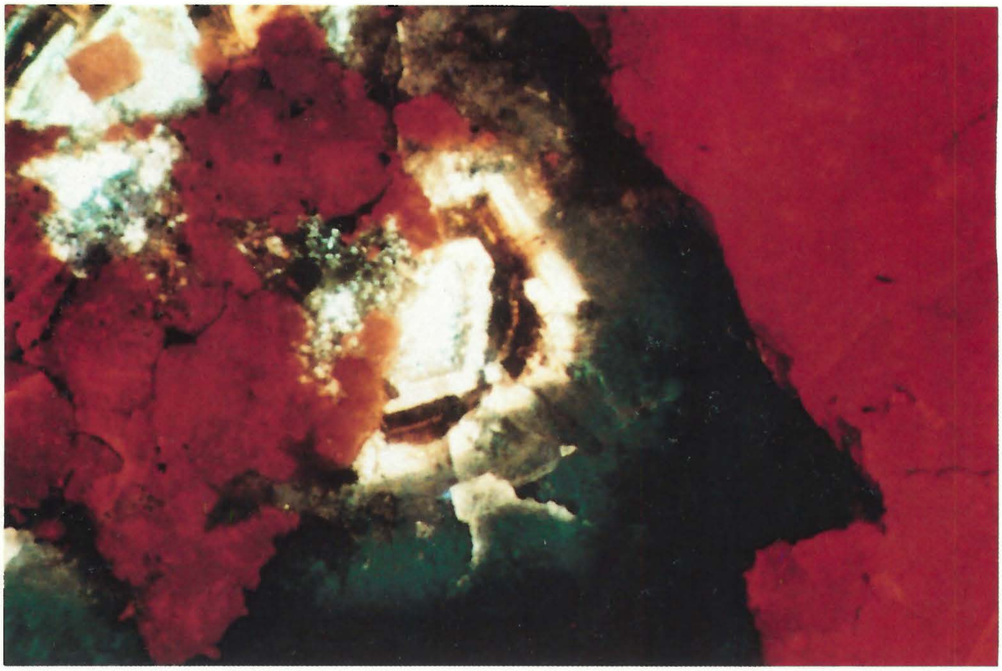

Figure 15. Close-up of part of Figure 14 showing brightly zoned sphalerite replaced by fine grained dolomite (left). Note ragged remnants of sphalerite. At right is slightly brighter red uniformly luminescent late dolomite spar. Field of view about 1.5 mm.

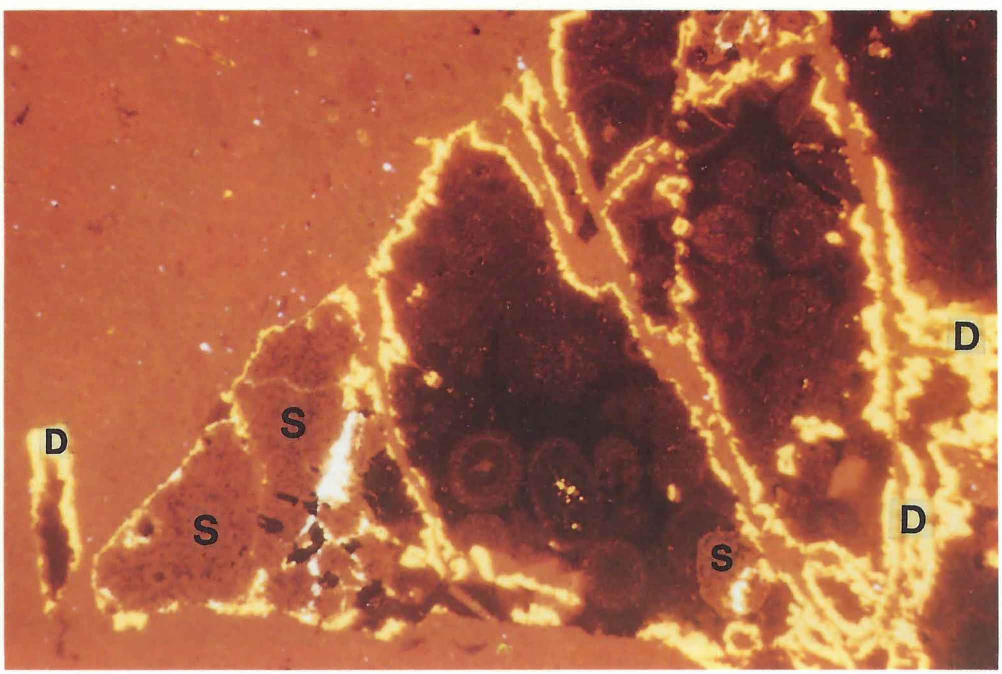

Figure 18. Cathode luminescence photomicrograph of chalcedony fragment partly replaced by sphalerite (S). The chalcedony spherules are partly replaced by microcrystalline quartz. Fragment rims are replaced by dolomite (D) which luminesces green, red, yellow, and orange, but appears uniform yellow in the photo. Twin Ponds. Field of view 8 mm.

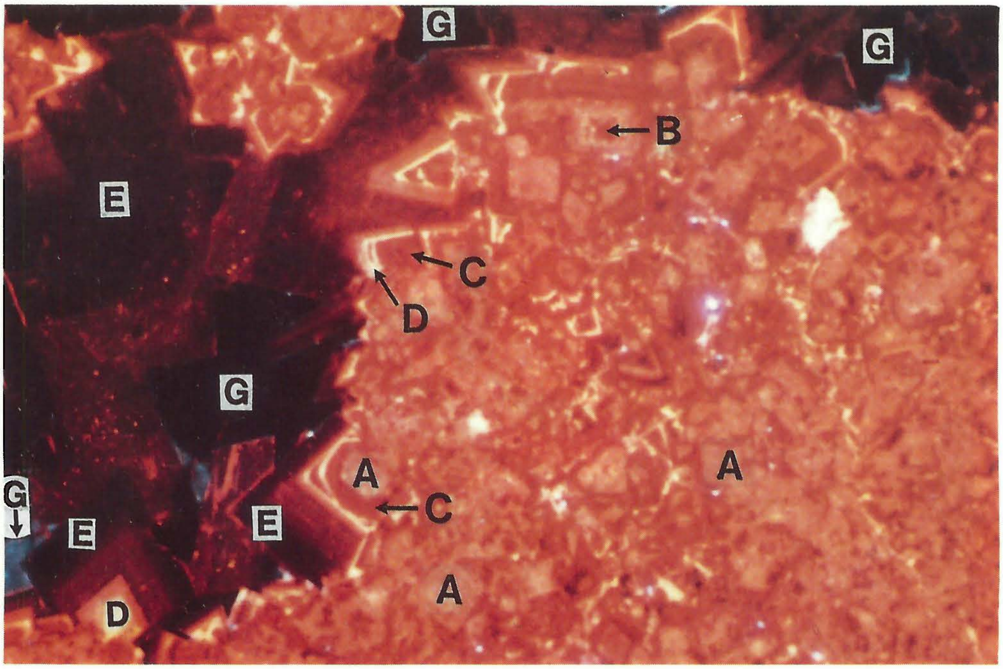

Figure 19. Cathode luminescence photomicrograph showing sharply zoned dolomite. Fine grained dolomite luminesces bright red (A; rarely earlier dark red cores (B) are visible). This is followed by a dull red zone (C). Where pore spaces were originally large, additional zones, forming dolomite spar, are present. These vary from very bright yellow (D) to nonluminescent red (E). Galena (G) commonly luminesces blue where it is in contact with the spar. Eddies Cove. Field of view 1.5 mm.

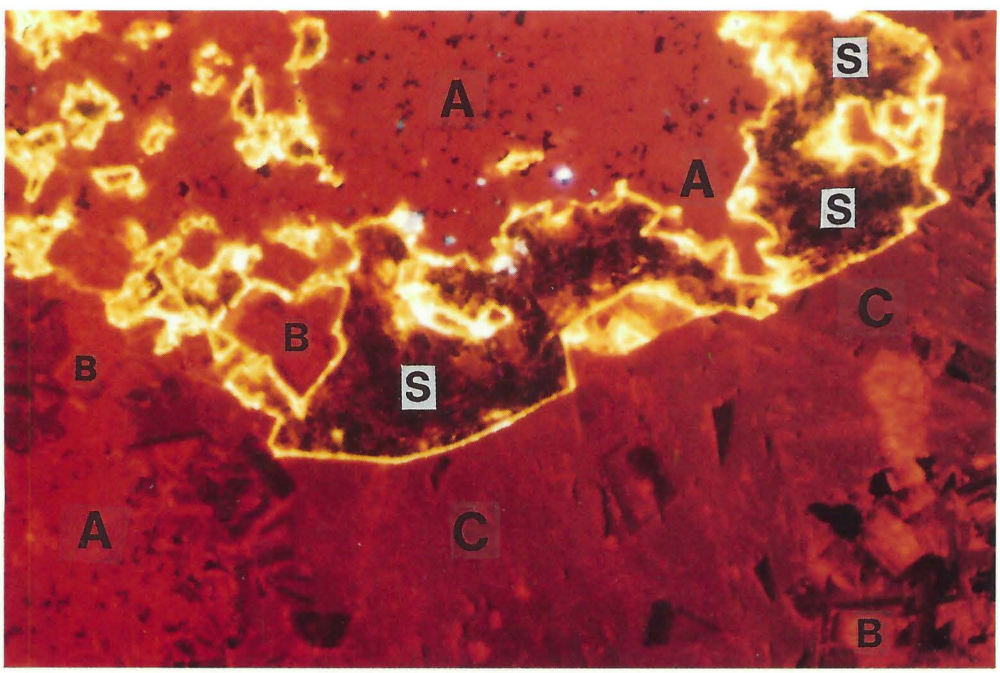

Figure 20. Cathode luminescence photomicrograph showing sphalerite (S) replaced by dolomite. Fine grained dolomite (A) luminesces uniform red. Euhedral medium grained dolomite is zoned (B); coarse grained spar luminesces dark red (C). Sphalerite luminesces bright yellow where it is in contact with all types of dolomite. Dolomite that replaces sphalerite is high in Zn. Contact Brook. Field of view 1.5 mm.

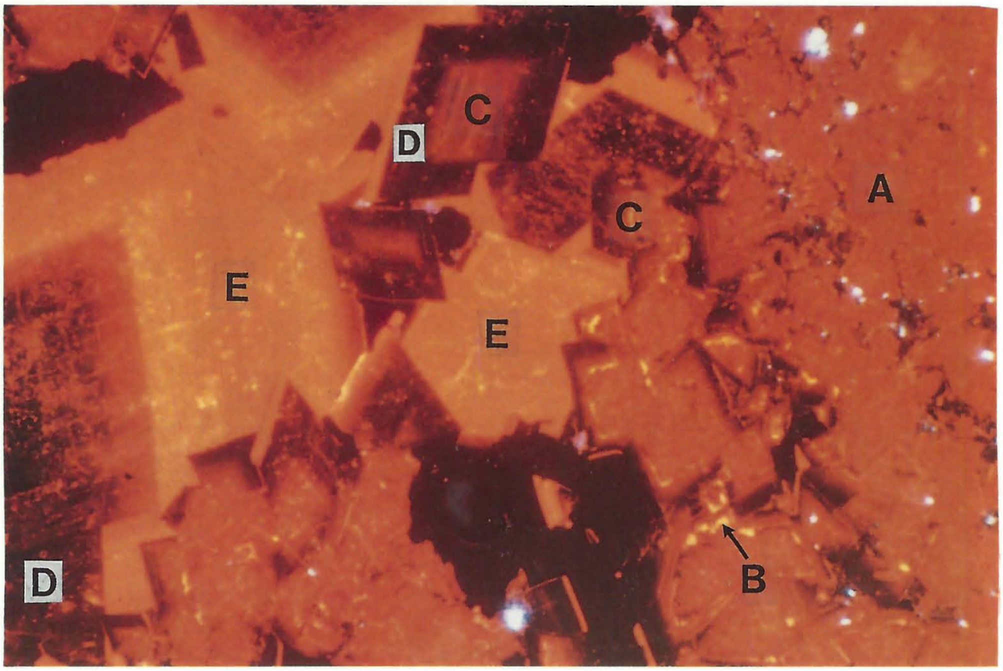

Figure 21. Cathode luminescence photomicrograph of zoned dolomite. Fine grained dolomite (A) luminesces uniform red. In places it is overgrown by zones of varying luminosity including bright yellow (B), dull red (C), nonluminescent (D), and dull yellow (E). Pikes Feeder Pond. Field of view 2.5 mm.

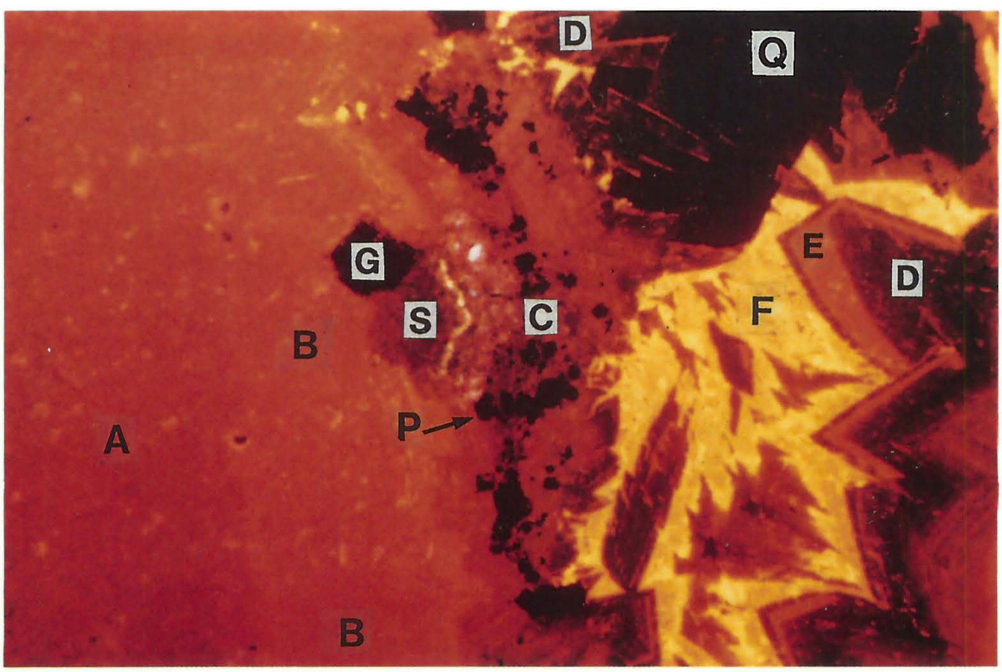

Figure 25. Cathode luminescence photomicrograph. Dolostone (A) is cut by bright red spar (B), followed by yellow and purple luminescing sphalerite (S), fine grained, red, cavity-filling dolomite (C), and pyrite (P). Vug core is filled with nonluminescent quartz (Q) and sharply zoned nonluminescent (D) to bright red (E) to yellow (F) dolomite spar. Salmon River #3. Field of view 8 mm.

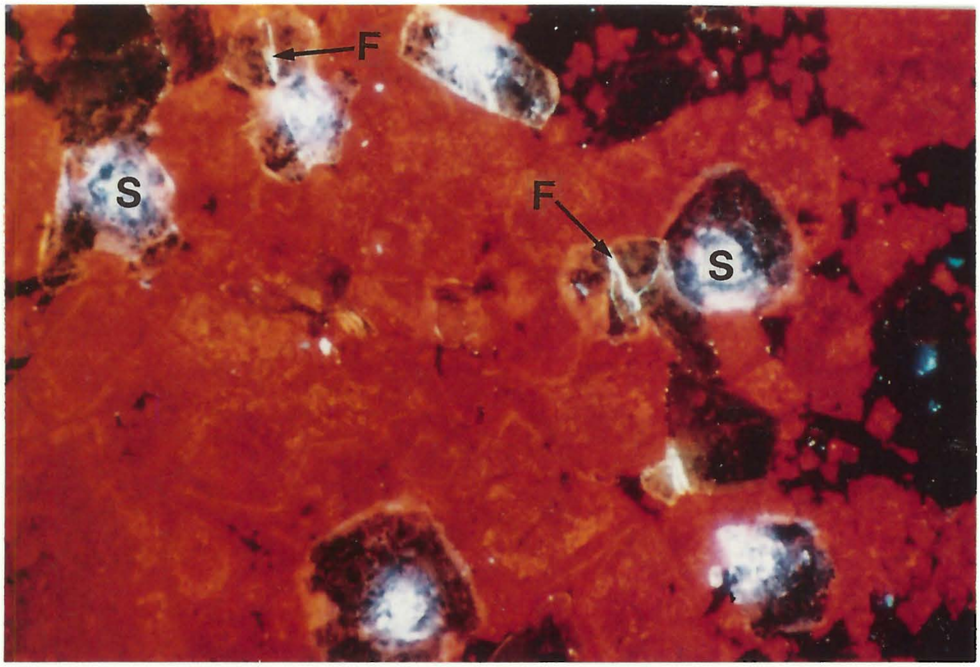

Figure 29. Cathode luminescence photomicrograph. Centres of sphalerite (S) luminesce bright purple. In places later fractures (F) luminesce greenish-white. Note remnants of earlier dolomite zones. North Hidden Pond. Field of view 1.7 mm.

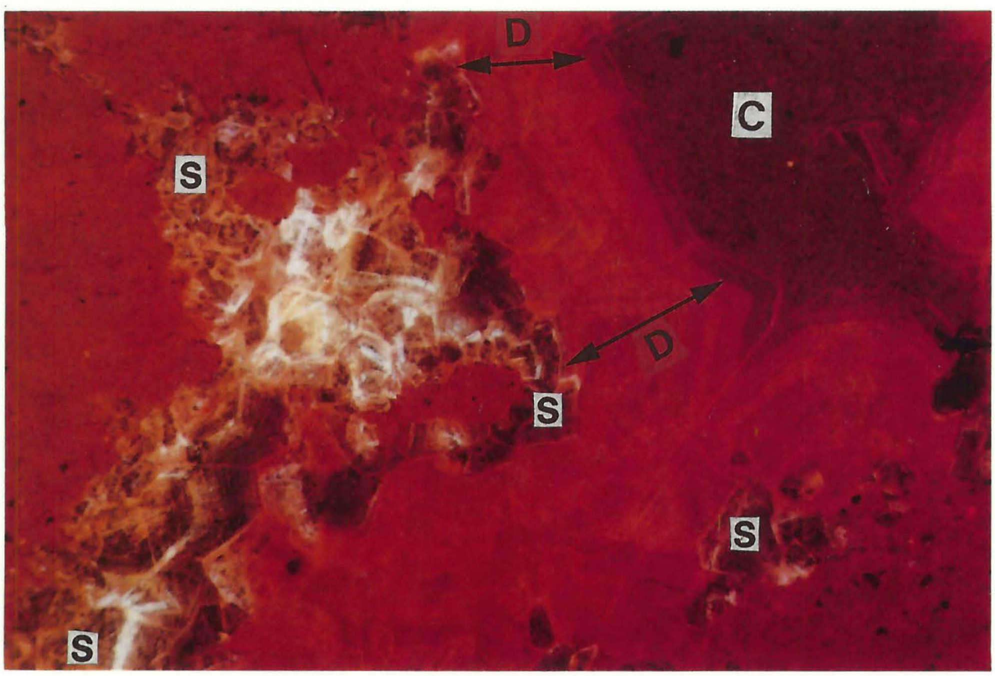

Figure 30. Cathode luminescence photomicrograph. Zoned white to purple and "fragments" of nonluminescent sphalerite (S) rims red-luminescing dolostone clasts in pseudobreccia. Sphalerite is followed by zoned medium to dark red saddle dolomite (D) and finally dark red, fine grained cavity-filling dolomite (C). Watts Point. Field of view about 6 mm.

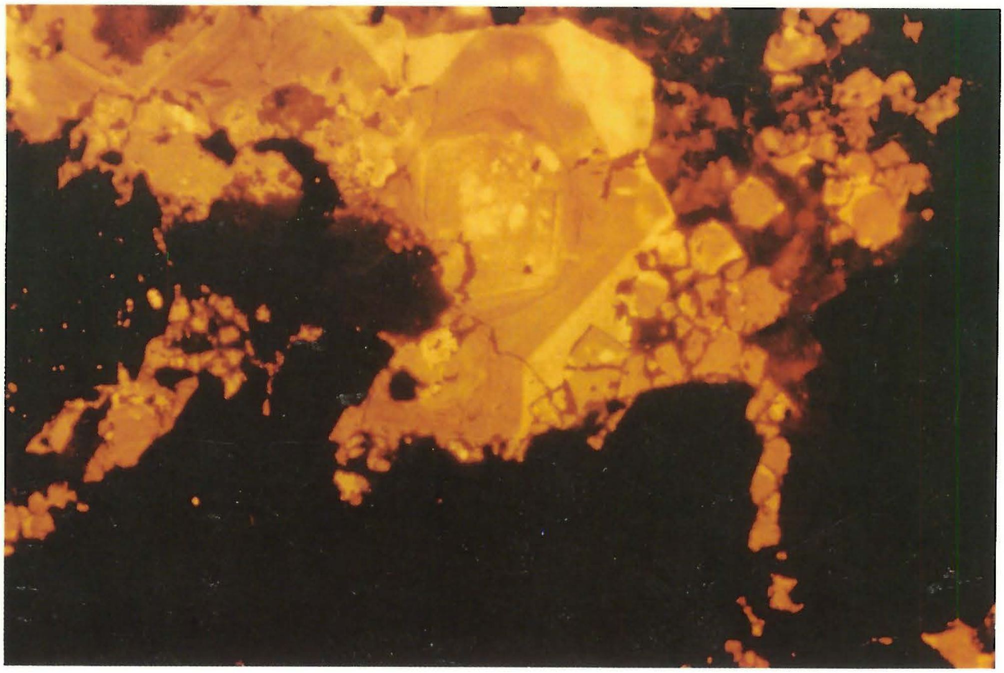

Figure 31. Cathode luminescence photomicrograph showing zoned yellow to orange calcite spar gangue. Black areas are possible marcasite. Miners Brook. Field of view about 1.5 mm.

Figure 35. Cathode luminescence photomicrograph of thinly zoned calcite vein. Calcite varies from nonluminescent to orange to yellow. In places thin bands of iron oxide are draped over dogtooth calcite crystals. Felix Cove. Field of view 8 mm.

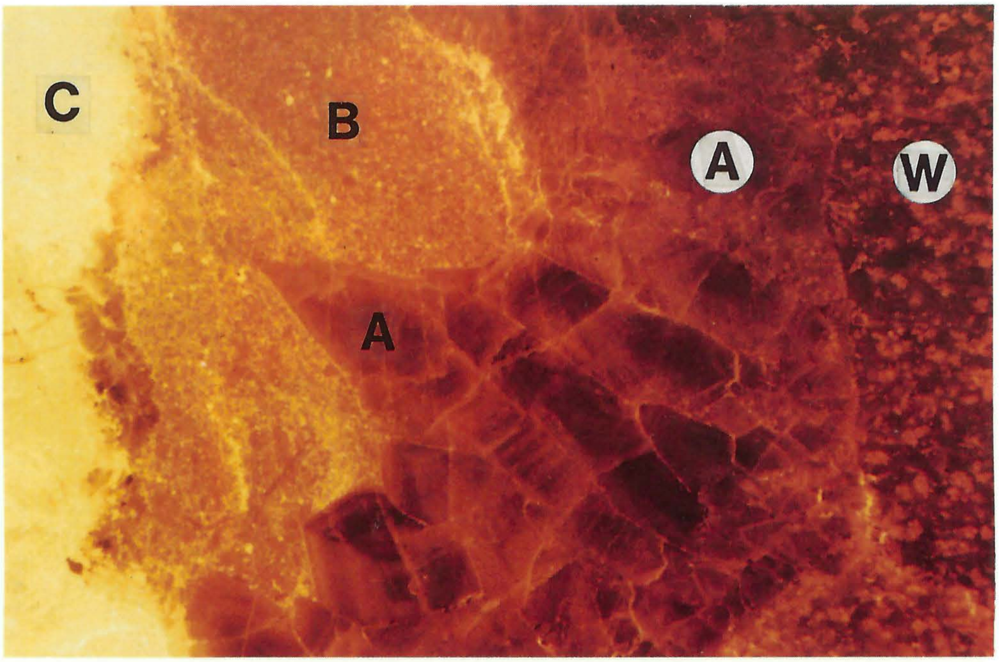

Figure 37. Cathode luminescence photomicrograph of calcite vein. At far right is wall rock (W), followed by slightly luminescent calcite (A), carbonate sediment (B), and yellow core calcite (C). Victors Brook West. Field of view 8 mm.

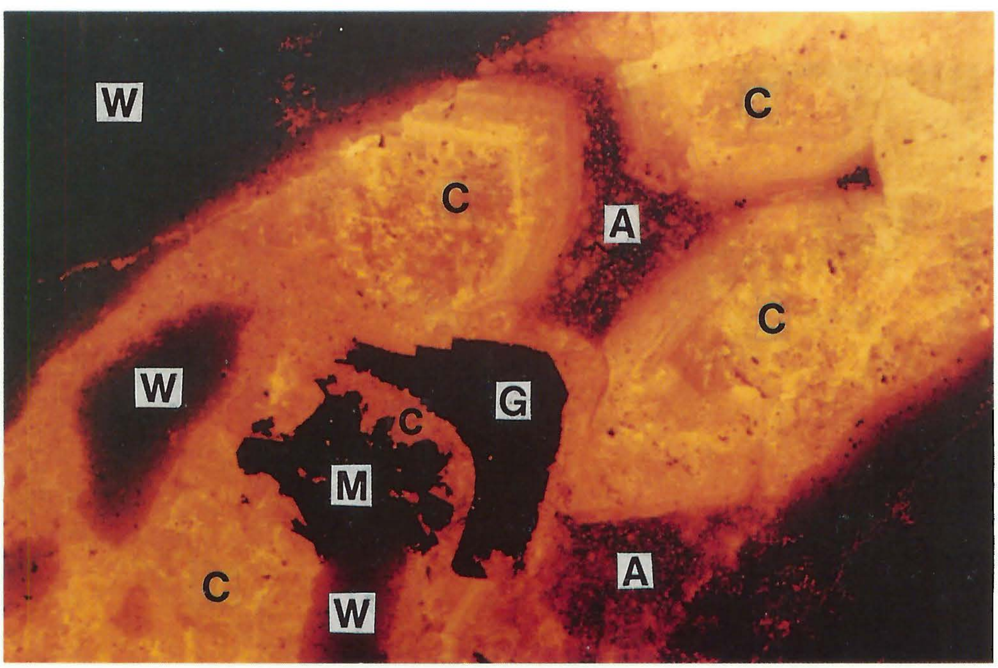

Figure 38. Cathode luminescence photomicrograph of yellow luminescing calcite vein (C). Fragments of nonluminescent wall rock limestone (W) have been incorporated. Voids between zoned calcite crystals are filled with fine grained material (A). Marcasite (M), followed by calcite (C) and galena (G), has nucleated on a fragment. Victors Brook West. Field of view about 7 mm.

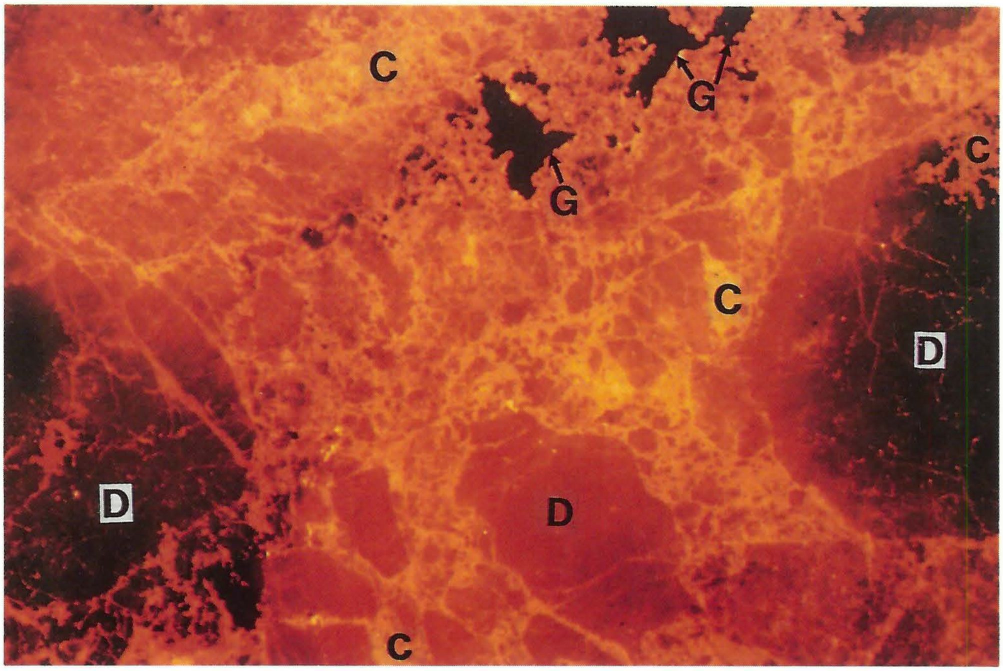

Figure 41. Cathode luminescence photomicrograph showing intensely shattered fine grained dolostone (D). Matrix is yellow-orange luminescing calcite (C) which in places has replaced parts of fragments. At top is galena (G). Turners Ridge. Field of view about 2.5 mm.

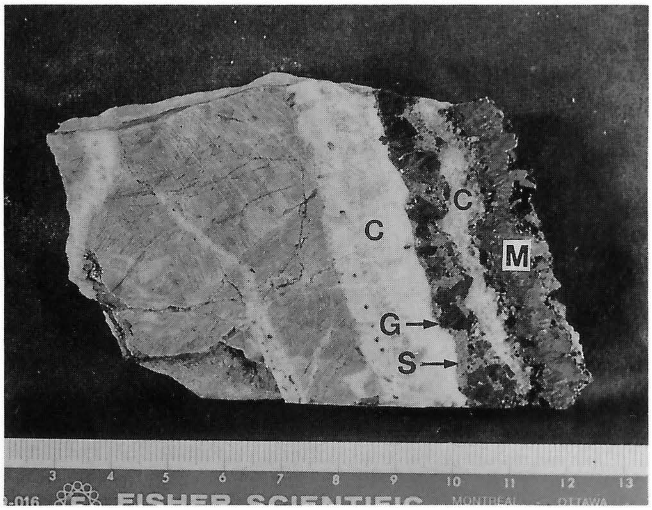

Figure 32. Half of symmetrically zoned calcite vein cutting Table Head limestone, Piccadilly Harbour. C=calcite, G=galena, S=sphalerite, M=marcasite. GSC 1991-563G

Figure 33. Zoned calcite vein cutting St. George Group limestone, Fiods Cove. SP=speleothem calcite; C=later calcite spar; M=marcasite; W=wallrock. GSC 1991-563H

marcasite sheaves has nucleated on the dogtooth calcite and sphalerite crystals. The marcasite is followed by euhedral metallic sphalerite which projects into the remaining open space in the veins.

Another sample contains alternating marcasite and sphalerite with grain size increasing towards the centre of the vein. The sulphides are preceded by calcite spar and followed by calcite spar and bladed barite. The sphalerite luminesces green and purple; the calcite luminesces yellow.

Fiods Cove

At Fiods Cove (12B/10-Pb005) vertical to subvertical calcite veins cut flat-lying limestone of the Boat Harbour Formation exposed in steep coastal cliffs. The calcite veins also cut Upper Mississippian limestone boulder conglomerates and breccias of the Lower Cove Formation of Dix and James (1989).

The Boat Harbour limestone is hematitic, well laminated in places, and has shallow water and subaerial depositional features such as rip-up clasts and mud cracks. The veins strike 85° to 110° and are emplaced along pre-existing faults. Many veins are cored by cavities, some of which are large enough to walk into, suggesting they may be paleocaves. Most contain only variably-coloured banded calcite followed by dogtooth calcite crystals which project into the large voids. The banded calcite that forms the vein margins (Fig. 33) is characteristic of speleothem deposits (Dix, 1982). Minor marcasite may also be present (Fig. 33). In places, veins contain angular fragments of wall rock which are surrounded by banded calcite. The calcite veins and fractures are commonly bordered by a 10 to 20 cm wide, green reduction-alteration zone. Hematite, which is characteristic of the country rock, and which has been interpreted to be Carboniferous in age (I. Knight, pers. comm., 1990) has been removed from these alteration zones, a phenomenon which the authors attribute to reaction of wall rock with reducing hydrothermal fluids.

In one sample, marcasite occurs as isolated clots surrounded by calcite spar. Two types of marcasite appear to be present: 1) a readily-polishable variety is intergrown with, 2) a tarnished, crumbly marcasite that polishes poorly, similar to that observed in samples from the Goodyear Prospect. Some of the marcasite crystals are terminated by a thin band of pyrite. In places the marcasite has a pronounced finely-serrated edge which appears to be the result of replacement of small dogtooth calcite crystals. Minor fine grained chalcopyrite occurs in the vein.

Calcite veins also locally cut limestone boulder conglomerate and breccia red beds of the Lower Cove Formation which is of probable Late Mississippian age (Dix and James, 1989). These red beds locally overlie the Ordovician carbonates in several paleokarst valleys along the southern shore of the Port au Port Peninsula. One of these veins, shown cutting the conglomerate in Figure 34, is bordered by a green reduction-alteration zone which cuts both boulders and matrix.

Felix Cove

At Felix Cove (12B/10-Pb006) the host upper Cambrian rocks, exposed in steep coastal cliffs, consist of well bedded, red limestone of the Petit Jardin Formation, Port au Port Group. The limestones are very hematitic due to Carboniferous weathering and diagenesis and exhibit such features as oolitic beds, rip-up clast conglomerates, mud cracks, and crossbedding, indicative of an intertidal depositional environment.

Veins emplaced along fault zones in the limestone contain variably coloured, banded speleothem calcite, coarse grained calcite spar, and minor sulphides. One 20-30 cm wide vein, cored by a large cavity, trends 045° and dips 70° NW. It is zoned as follows: minor galena-coarse dog tooth calcite-minor barite. Calcite in this vein luminesces yellow to orange or is nonluminescent (Fig. 35*). Calcite forms

Figure 34. Calcite vein cutting both boulders and matrix, Codroy Group limestone conglomerate, Fiods Cove. Arrows indicate contact between red hematitic limestone and green alteration zone surrounding vein. GSC 1991-563I

dogtooth crystals over which limonite is draped. A thick zone of yellow luminescing calcite spar fills the core of the vein. Breccia, consisting of angular, collapse fragments of wall rock set in a muddy limy matrix, borders the lower part of the vein. Thinner veins of zoned fibrous, variably coloured, speleothem, calcite with calcite spar and minor marcasite occur locally. Some of the veins are bordered by green reduction-alteration zones similar to those at Fiods Cove. One of these alteration zones contains fine grained disseminated marcasite.

Abrahams Cove

At Abrahams Cove (12B/10-Pb004) vertical calcite veins cut flat-lying limestones of the Watts Bight Formation exposed in steep, high coastal cliffs. The limestone contains thick laminated beds with rip-up clasts, oolitic beds, grey micritic beds, and local dolomitic units. Veins, striking dominantly 120° to 130°, range from 1 to 20 cm thick and contain only calcite or minor marcasite. One 2 cm wide calcite spar vein contains octahedral galena concentrated at the vein edges. A second vein cutting a large boulder contains calcite spar, coarse barite, and rare rosettes of brown resinous sphalerite. Locally the lower parts of veins contain angular wall rock fragments surrounded by zoned speleothem calcite.

Figure 36 displays the typical habit of marcasite in this and many other occurrences. In this particular sample the marcasite grain boundaries have been oxidized. A calcite vein in this locality is bordered by a thin zone of brownish calcite that luminesces bright orange, a 1 cm wide zone of pink calcite, and a core zone composed of brecciated calcite spar and marcasite. The pink calcite zone consists of anhedral, fine grained calcite which has brown luminescing cores and later yellow-orange overgrowths. Marcasite has nucleated on the fragment rims and partly replaced the matrix.

Harry Brook, Victors Brook East, Victors Brook West, and Western Port-au-Port

The Harry Brook (12B/11-Pb002), Victors Brook East (12B/11-Pb003), and Victors Brook West (12B/11-Pb004) occurrences (Appendix A) were not visited in the field but representative samples were selected from drill core. Drill locations and logs are presented in Dickie et al., (1975), Saunders and Hardy (1975), and Lyn (1979). Most mineralization occurs in 1 to 3 cm wide calcite veins. Marcasite and sphalerite are the most abundant minerals; galena and barite occur locally. Sulphide zoning is generally marcasite-sphalerite-galena, although the latter two are seldom seen together. In places there is more than one marcasite or sphalerite zone. Sulphides are commonly preceded by a thin zone of banded or dogtooth calcite and followed by a thicker zone of calcite spar. The earlier calcite is commonly only slightly luminescent and the later spar luminesces bright orange to yellow (Fig. 37*). In places the spar is slightly zoned (Fig. 38*). Barite tends to occur late with galena.

The wall rock is generally nonluminescent limestone or dolostone that may luminesce dull red. Fragments of the wall rock are incorporated into the vein. Breccias include angular fragments of varying lithologies surrounded by sulphides and calcite spar. These may be localized fault breccias or collapse breccias.

Marcasite forms rosettes and sheaves that locally nucleated on pyrite grains or framboids. Primary marcasite-pyrite intergrowths are rarely observed.

Sphalerite occurs as subhedral crystals or as an anhedral cement to breccia fragments or calcite spar crystals. Locally, sphalerite is intergrown with marcasite and commonly contains sharply defined dark zones. In hand-sized specimen or polished section under crossed-nicols these zones appear black whereas in fluid inclusion sections they are dark purple. The dark purple zones generally occur at the centres of crystals; they either parallel the external crystal morphology or are hour-glass or radially oriented. These zones commonly contain primary fluid inclusions. Sample DDH-78-11 M3 contains early dark, subhedral sphalerite followed by yellow-brown sphalerite that has early and late dark zones. The dark sphalerite contains sharply defined, thin, bright yellow and emerald green luminescing zones.

Galena is locally abundant and has nucleated on marcasite sheaves (Fig. 38*). In one sample, a calcite vein is bordered by marcasite sheaves followed by calcite and galena. The galena forms octahedra up to 1 cm across and is embayed by marcasite and calcite (Fig. 38*) in a similar manner to that seen in samples from Lead Cove.

Type IIc

Wolf Brook

The Wolf Brook (12H/4-Pb003) showing outcrops along a brook in a remote heavily wooded area and is very similar to the Piccadilly Harbour showing. The Wolf Brook

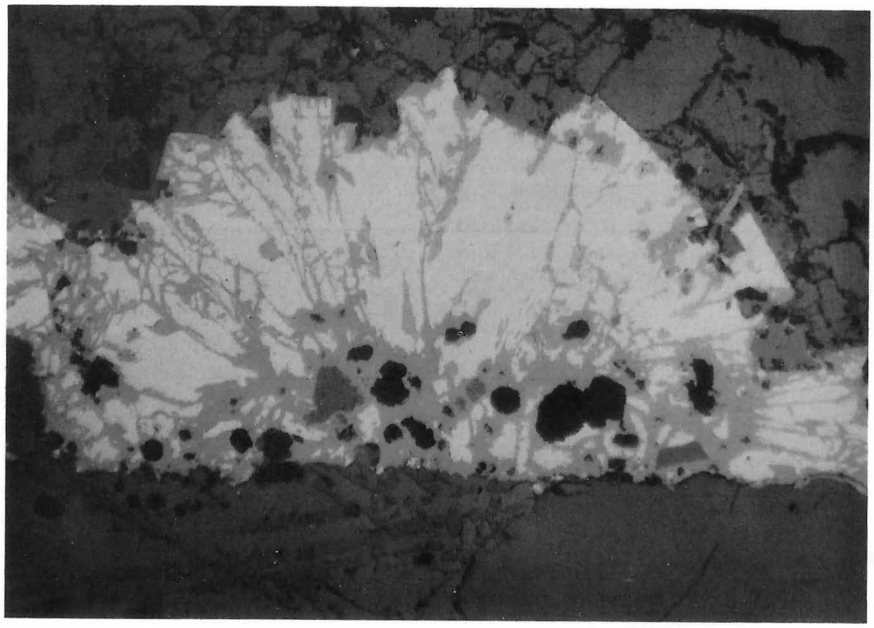

Figure 36. Reflected light photomicrograph showing typical habit of marcasite. The grey alteration is iron oxide. Abrahams Cove. Field of view 1.4 mm.

showing consists of a 10-20 cm wide, 18 m long, sub-vertical, bifurcating vein of black calcite-galena-sphalerite-white calcite which cuts dolostone of the Hughes Brook Formation. The host dolostone is fine grained, dark bluish-grey, and has an attitude of 120°/35°S. In places it contains argillaceous limestone beds. The main part of the vein trends 145° with near-vertical dip; at the bifurcation, the second vein strikes 155° and dips 65° north. Galena forms euhedral cubes on the edges of the veins. Sphalerite is anhedral, brown, resinous and occurs in masses on either side of the vein with white calcite spar in the centre. A zone of very fine grained, black calcite occurs between the galena and the country rock.

The fine grained, black calcite zone consists of a pervasive network of dull orange luminescing calcite which is extensively intergrown with quartz which, in places, constitutes more than 70% of the zone. The quartz-calcite rock contains stylolites that are overprinted by euhedral dolomite crystals, which luminesce dull red to greenish brown. The calcite-quartz zone is followed by galena, sphalerite, and bright orange luminescing calcite spar, which crosscuts the earlier quartz and fine grained calcite and also truncates stylolites indicating that it postdates pressure solution.

Goose Arm Brook

The Goose Arm Brook showing (12H/4-Pb001) consists of a flat-lying, crusty gossan zone about 10 cm wide which outcrops for a distance of 20 m in a bank along Goose Arm Brook. The host rock consists of fine grained, grey, hematitic dolostone of the Hughes Brook Formation which is locally extensively brecciated. Fragments in the breccia are cemented by white to pink hematitic dolomite spar. The breccia zone strikes roughly 40° and dips gently west. Rusted pyrite was the only sulphide identified in the gossan, although sphalerite and galena have been reported (Lilly, 1963). The mineralized zone consists of tiny anastomosing pyrite-calcite veinlets. Limonite (dominantly goethite) was identified in the veinlets and along fractures in fine grained dolostone and is commonly accompanied by anhedral, medium grained quartz and calcite spar. Crystalline calcite also coats grain boundaries between fine grained dolomite. Calcite coating several adjacent dolomite grains is in optical continuity with them. Dolomite luminesces uniform dull red. Calcite is nonluminescent.

Dons Brook/North Brook

The showing at Dons Brook (12B/9-Pb001), located along a small brook in a heavily wooded hilly area, is hosted by black oolitic limestone of the Petit Jardin Formation. The showing is somewhat unusual in that the vein contains abundant quartz and quartz breccia with associated calcite spar and black to brown anhedral sphalerite. Sphalerite occurs in clots within the quartz and calcite. Zoning is irregular and nonsymmetrical. Minor galena occurs in tiny veinlets cutting the quartz at one edge of the vein. The vein splits; one limb has a strike of 150° and the other a strike of 125°. Heavy sphalerite mineralization is reported to be present in several boulders further upstream (occurrence 12B/9-Zn002) although these were not observed.

A sample from the quartz-rich zone contains clots of sphalerite (brown in hand specimen; yellow in thin section) surrounded by coarse grained, anhedral quartz. Intergranular areas are filled with calcite.

A calcite-rich zone, located at the centre of the vein, appears to be truncated by the quartz and quartz-breccia zones. Sphalerite, black in hand specimen and dark honey-coloured in thin section, is intergrown with quartz in a sample from this zone. Quartz postdates calcite and occurs in veinlets and along fractures. Sphalerite in both zones contains abundant chalcopyrite and pyrite inclusions and less common marcasite and galena inclusions. Pyrite also forms along sphalerite rims and along fractures that do not extend beyond the sphalerite. Chalcopyrite forms rounded inclusions or is aligned along sphalerite cleavages. Fluid inclusions are commonly attached to chalcopyrite and/or contain chalcopyrite inclusions.

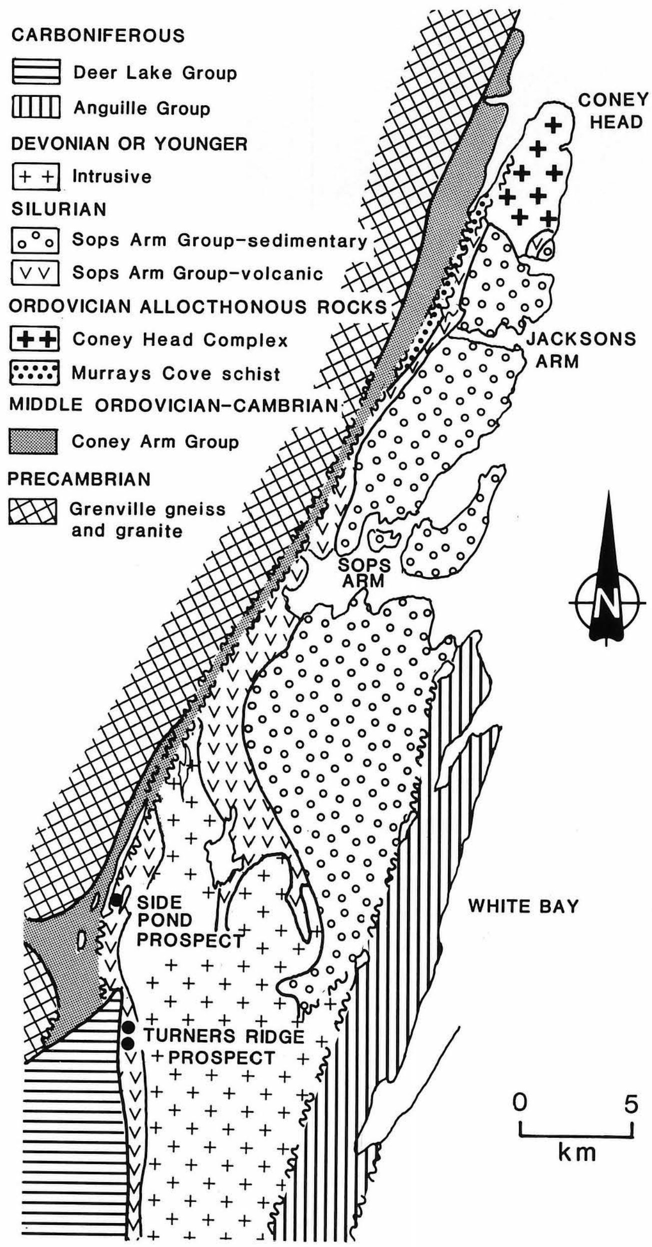

Figure 39. Regional setting of Turners Ridge and Side Pond deposits (from Strong, 1982).

Type III

Turners Ridge

The Turners Ridge showing (12H/11-Pb001) outcrops along the Sops Arm road and drilling has traced mineralization over a distance of several kilometres. Figure 39 shows the regional setting of the deposit which contains about 200 000 tons (203 210 tonnes) of 3 to 4% Pb (Dimmell, 1979). A schematic cross-section through the deposit is shown in Figure 40.

Galena, and subordinate pyrite and sphalerite, are hosted by intensely brecciated dolostones (informally termed the Gales Brook Dolomite by Noranda geologists) of the Lower Volcanic formation of the Silurian Sops Arm Group. Breccia fragments are generally less than 1 cm in diameter. The brecciation is intense, and is normally nondisruptive, i.e. the fragments have not been rotated and there is little matrix. Locally the brecciation does become disruptive, with slightly rounded fragments and a higher proportion of a green limey clay matrix. Fine grained galena, pyrite, and sphalerite locally occur as matrix to fragments and along fractures with quartz and calcite gangue. In places, dark pink to pale pink barite follows the galena.

Polished section study has revealed that mineralization occurred in at least two stages. Pyrite formed earliest and was later brecciated, followed by deposition of sphalerite and galena. Galena surrounds both pyrite and sphalerite, and commonly replaces pyrite. The brecciation of the pyrite resembles that of the dolostone host and probably occurred at the same time; the pyrite therefore predates formation of the dolostone breccia.

The dolostone host rock is essentially nonluminescent although in places it is overprinted by euhedral reddish-brown dolomite that has bright red cores. In places the rock has been extensively calcified; fine grained bright yellow-orange luminescing calcite forms the matrix to breccia and has surrounded grain boundaries and filled hairline fractures and veinlets (Fig. 41*). In one sample a stage of nonluminescent dolomite spar, which occurs in veinlets and overgrowths on earlier dolomite crystals, preceded calcite brecciation.

Sheared rhyolite and rhyolite cataclasite are in fault contact with the dolostone breccia. The cataclasite consists of rounded fragments of rhyolite in a matrix of sand-sized grains believed to be crushed rhyolite (Crowley, 1978). Minor galena occurs in the rhyolite breccia matrix near the contact with the dolostone.

Low angle thrusts have emplaced the rhyolite over the dolostone and the latter over Carboniferous conglomerate (Crowley, 1978; Dimmell, 1979). The low angle thrusts may represent localized late movements on the adjacent Wigwam Fault (Tuach, 1987b). The brecciation of the dolostone has been attributed by the previous workers to dissolution and collapse, but the presence of rhyolite cataclasite and the history of faulting in the area suggest that the brecciation of the dolostone is of tectonic origin. The presence of minor galena in the brecciated rhyolite suggests mineralization postdates thrusting of the rhyolite

SECTION 0+00 - TURNER'S RIDGE LEAD DEPOSIT

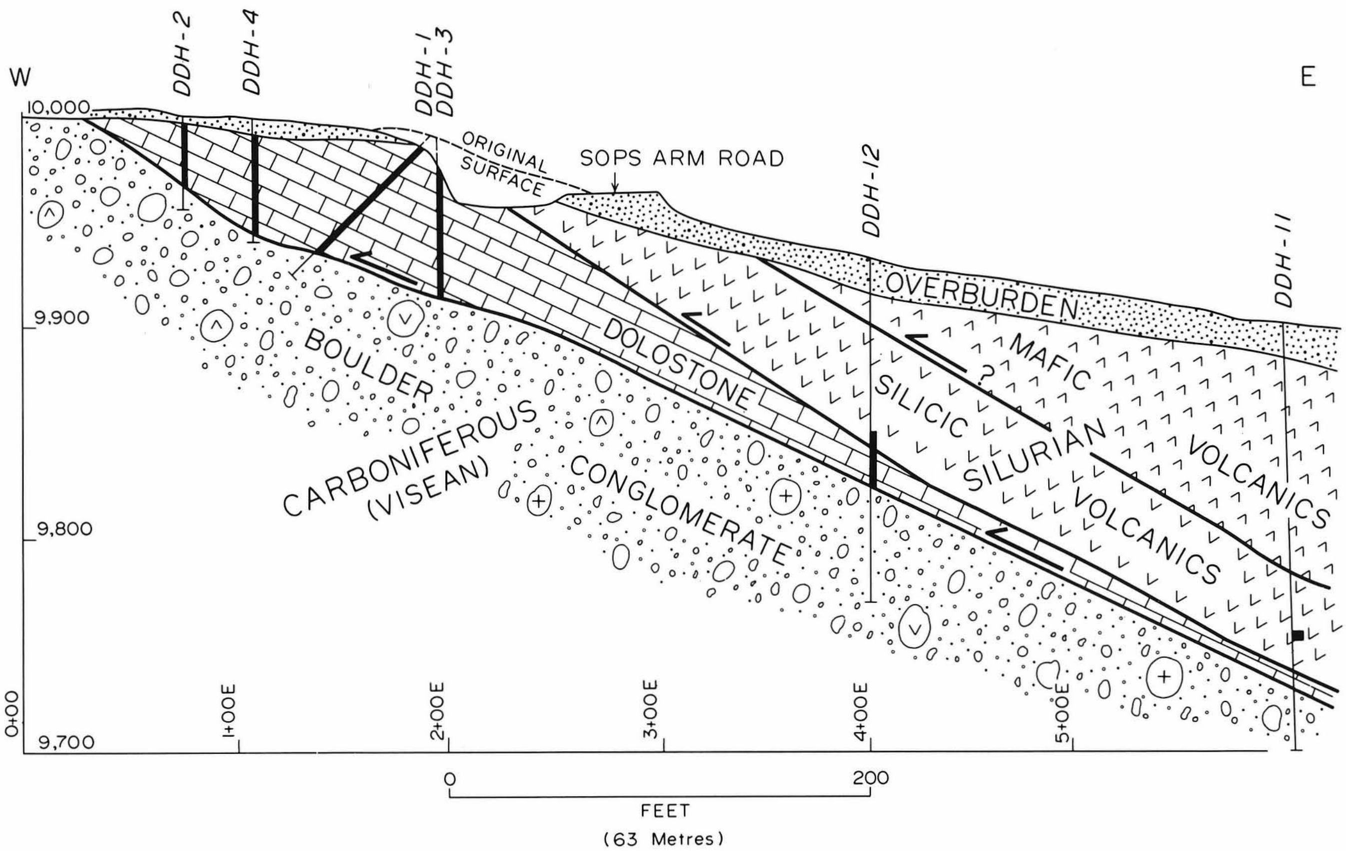

Figure 40. West-east section across Turners Ridge deposit. Mineralized portions of core are indicated by thicker lines. Modified slightly from Tuach (1987b) and Dimmell (1979).

over the dolostone and therefore is at least as young as Carboniferous (Saunders, 1991).

Side Pond

The Side Pond occurrence (12H/11-Pb002) is located north of the main Turners Ridge (Fig. 39) showing and was sampled from both outcrop and drill core. Brecciation of the host dolostone is more sporadic and less intense than it is in the Turners Ridge area. Mineralization is similar but tends to be concentrated in veinlets and along fractures rather than in the breccia matrix (Dimmell, 1979). Pyrite and sphalerite are more abundant (and galena less abundant) than at the main showing (Dimmell, 1979). Sphalerite and galena in two samples from Side Pond occur in veins with K-Ba feldspar (hyalophane), albite, barite, and quartz. The hyalophane luminesces bright blue. The fine grained host rock dolomite luminesces patchy medium red and black, locally with bright red rims.

At Side Pond rhyolite breccia underlies the dolostone unit. In places minor galena is found in the matrix of the rhyolite breccia. Dimmell (1979) reported that drill core of rhyolite from Side Pond contains significant galena and pyrite mineralization — a 4.6 m interval assayed 2.85% Pb. This was mainly due to a 30 cm interval that contained about 70% sulphides (mainly galena).

FLUID INCLUSION STUDY

Introduction

Microthermometric data were collected from fluid inclusions in sphalerite from 16 occurrences, and in fluorite from the Eddies Cove West area (near the Fish Point occurrence). Although inclusions were observed in other minerals such as quartz, calcite, and dolomite, these were not included in the microthermometric study due to the uncertainty, in some cases, of the relationships between sulphides and gangue, and because inclusions in carbonates tend to be unsuitable for such study due to their relative ease of stretching and decrepitation.

Inclusions in most samples consisted of aqueous liquid-vapour of varying salinity. Inclusions are dark or clear depending on whether they are flat or spherical. Some inclusions have negative crystal shapes with dark edges (where their facets are inclined relative to the microscope lighting) and clear centres (facets perpendicular to the lighting). This phenomenon is the result of total internal reflection due to the high refractive index of the sphalerite (see Roedder, 1984, p. 151) and is not the result of any compositional difference between dark and clear inclusions.

Several sections, briefly examined under fluorescent light to test for the presence of hydrocarbons, yielded negative results. However, organic liquid-vapour inclusions were observed in two samples, one from St. John Island and one from Dons Brook. Only one organic inclusion was detected in each sample during freezing runs. (Organic liquid inclusions exhibit anomalous freezing behavior; they may remain liquid at temperatures well below -100°C). The organic inclusion in the Dons Brook sample occurs along a cleavage plane and is adjacent to similar looking single-phase aqueous liquid inclusions which occur on cleavages.

Rare CO_2 liquid-vapour inclusions have been detected in some samples from Round Pond. These inclusions homogenized at temperatures approaching -31°C under an ordinary petrographic microscope. These inclusions are part of a group of CO_2-bearing inclusions or are surrounded by aqueous inclusions from which they are difficult to distinguish.

Inclusions in sphalerite from Pikes Feeder Pond and Dons Brook contained crystals of chalcopyrite, and less commonly, pyrite. The chalcopyrite appears to project into the host sphalerite (Fig. 42). If these are actually daughter minerals, then this projection is the result of continued crystallization of the sphalerite from the fluid following early nucleation of the chalcopyrite and pyrite. Roedder (1984, p. 536-537) illustrated this phenomenon in melt inclusions in which ilmenite daughter minerals appear to project into the walls of the host olivine. In places chalcopyrite-bearing inclusions occur along fractures that cut sphalerite (from both occurrences). Sphalerite immediately adjacent to these fractures is commonly barren of both fluid inclusions and chalcopyrite inclusions. This indicates that the chalcopyrite and the fluid inclusions were trapped at the same time whether or not the chalcopyrite is a true daughter mineral or merely a nucleation site for fluid inclusion formation.

The best evidence that chalcopyrite and pyrite are daughter minerals is the constant phase ratio in inclusions in sphalerite from the Pikes Feeder Pond and Dons Brook occurrences. This is especially so for those inclusions which occur in a group. There are, however, also inclusions which do not contain opaque minerals, possibly reflecting difficulty of nucleation, and several which are obviously attached to large chalcopyrite grains. In most inclusions only one daughter is present, but one inclusion from Pikes Feeder Pond contains four opaques (Fig. 43). Three have hexagonal outlines and are probably all of the same composition. Another inclusion from sphalerite at Pikes Feeder Pond contains three opaques. Roedder (1984, p. 93) pointed out that although generally only one crystal of a daughter phase is present in an inclusion, this is not necessarily true for crystals which precipitated during fast cooling or for relatively insoluble crystals. Since there are a large number of solid inclusions of chalcopyrite in the sphalerite the chances of some accidental trapping of chalcopyrite by inclusions (or conversely attachment of inclusions to chalcopyrite) would be high. The latter would explain those that have anomalously high chalcopyrite-liquid ratios. However, the regularity of this ratio in many inclusions strongly suggests a daughter mineral origin.

Conclusive evidence for primary origin of fluid inclusions in this study and in general is rare. However, zoned sphalerite from Port au Port Peninsula drill holes contains definite primary fluid inclusions. These inclusions are mainly restricted to dark purple zones (transmitted light) in the sphalerite (Fig. 44). In some cases they occur on parallel cleavage planes which terminate at a constant distance from the edge of the sphalerite crystal indicating that inclusion-free crystal growth continued after formation of these inclusions. Sphalerite from North Hidden Pond also contains primary fluid inclusions localized on growth zones. These are commonly concentrated in the centres of euhedral to subhedral sphalerite crystals (Fig. 45). Cathodoluminescence study of these crystals reveals bright purple luminescent cores that are occasionally cut by hairline fractures which luminesce green (Fig. 29*). Some of the inclusions are cut by these fractures and may have been altered by later fluids. This may account for the widely varying microthermometric data collected for these inclusions (Appendix D).

Inclusions from Round Pond are random or are localized along zones and appear to be primary.

Sphalerite in a sample from Photograph Point contain black growth zones (Fig. 12). Cleavage planes that occur at the junction between the black growth zones and the surrounding yellow sphalerite contain large high salinity inclusions which may be primary (Fig. 46). Lower salinity inclusions in the yellow sphalerite, observed in other sections may, however, be secondary. In places they are cut by fractures.

In most samples from other occurrences, inclusions occur along cleavage planes (in which case they tend to be flat and clear) or are aligned parallel to a cleavage direction but are not concentrated in one plane (such inclusions tend to be dark and have rounded or negative crystal shapes). In some samples inclusions occur along fractures. Inclusions on fractures and cleavages may be secondary or pseudosecondary but generally it is impossible to determine which. Even if they can be demonstrated to be pseudosecondary, it is certain that inclusions along fractures and cleavages are more prone to leakage than other inclusions.

Microthermometric data

Homogenization temperatures were determined for about 190 inclusions. This is fewer than the number of determinations of salinity due to the vapour bubbles lodging out of sight against the dark walls of the inclusions during heating runs. The data are presented in Appendix D without pressure correction. Most of the inclusions homogenized at temperatures between 100 and 160°C which is typical of carbonate-hosted lead-zinc deposits (Roedder, 1984).

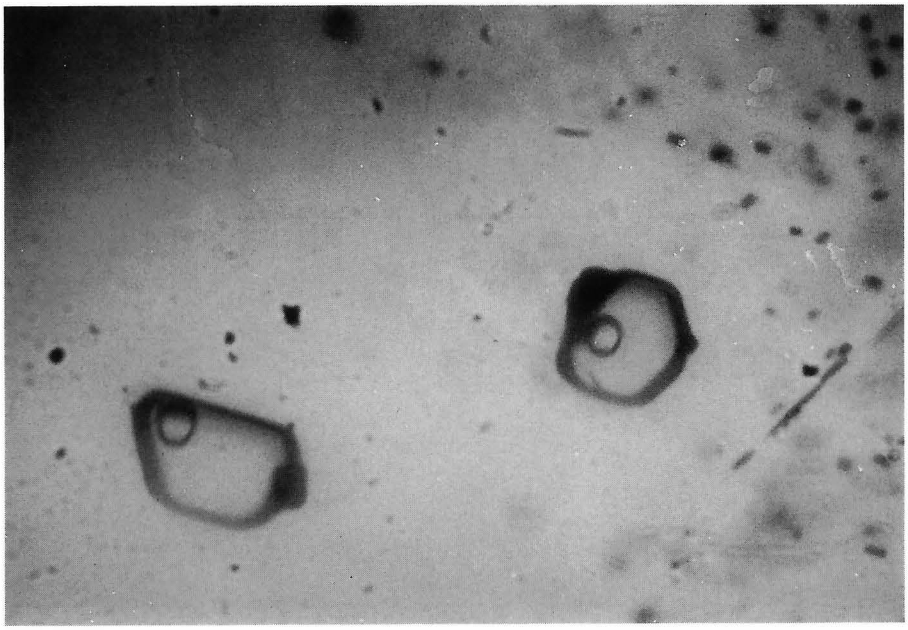

Figure 42. Photomicrograph of aqueous liquid-vapour-chalcopyrite inclusions in sphalerite. The inclusion on the right appears to have two daughter crystals. In the upper right hand corner numerous chalcopyrite inclusions are present. Note that they are of uniform size and are much smaller than the daughter crystals. Pikes Feeder Pond. Field of view about 80 μm.

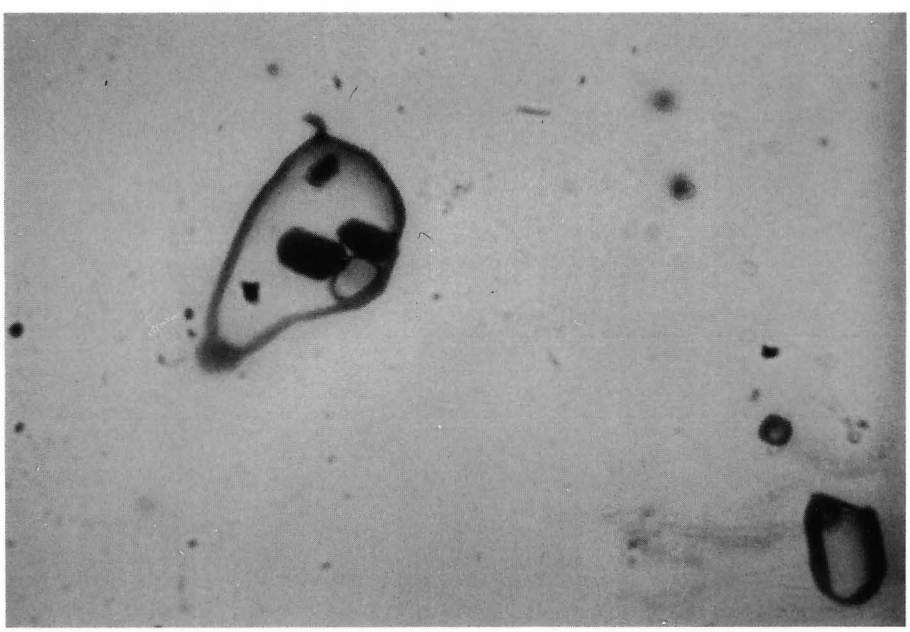

Figure 43. Photomicrograph showing inclusion which contains four daughter crystals. Three of the crystals appear to be hexagonal plates. The fourth is slightly out of focus at the bottom tip of the inclusion. The fifth black spot is dirt on the lens. At lower right is a L-V inclusion. Pikes Feeder Pond. Field of view about 80 μm.

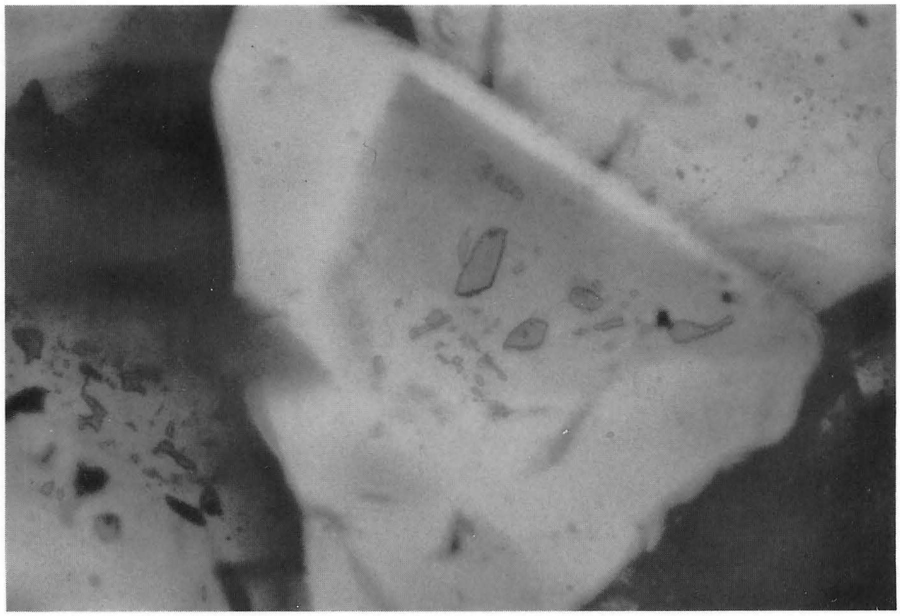

Figure 44. Photomicrograph showing primary aqueous L-V inclusions concentrated in purple growth zones (centre and lower left) in sphalerite. Port au Port. Field of view 0.2 mm.

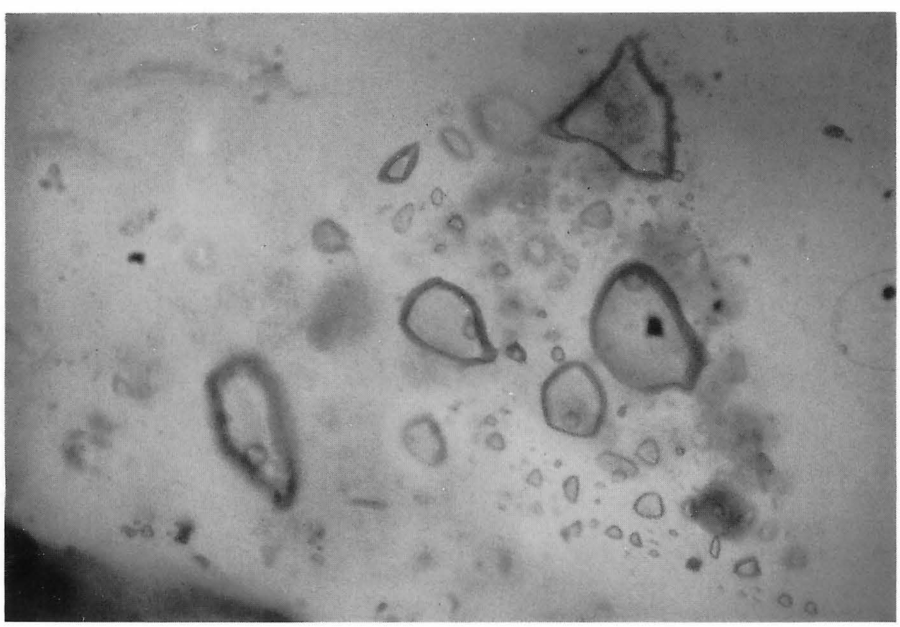

Figure 45. Photomicrograph of primary inclusions in sphalerite. These are found in a central growth zone in the crystal. The black spot in the large inclusion is dirt on the lens. North Hidden Pond. Field of view about 80 μm.

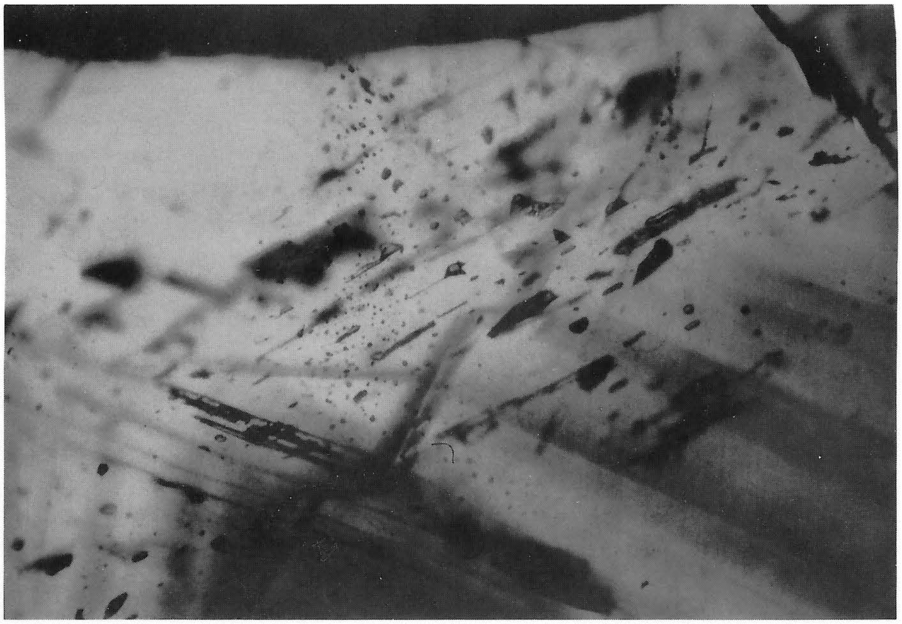

Figure 46. Close-up of area in Figure 12 showing concentration of inclusions on cleavage planes in sphalerite. The inclusions are concentrated at the junction between black and yellow sphalerite, which suggests that they are primary. Photograph Point. Field of view 0.8 mm.

Figure 47 shows histograms for homogenization temperature and salinity for all Type Ia, Ib, and Ic occurrences, and Figure 48 for Types IIb and IIc. Appendix D also contains histograms for individual occurrences. Inclusions in samples from Type Ia occurrences had overall lower homogenization temperatures (mode 120°C) than those of Type Ib (between 135 and 205°C with no clearly defined mode). Type Ic occurrences had intermediate values (mode 140°C). All inclusions homogenized to liquid except one organic L-V inclusion from St. John Island which homogenized to vapour at about 100°C.

Only two samples from Type IIb occurrences contain sphalerite with inclusions. These inclusions are primary and homogenized at temperatures between 67 and 77°C. One inclusion homogenized at 108°C. No inclusions were found in sphalerite from Type IIa deposits, but von Bitter et al., (1990) reported fluid inclusion data from calcite at Lead Cove (see below). Inclusions from Dons Brook (Type IIc) homogenized between 97 and 115°C. These are aqueous L-V inclusions, some with chalcopyrite and some without.

Secondary L-V inclusions, found on fractures in fluorite from the Eddies Cove West area, homogenized at temperatures between 53 and 123°C. The variation in temperatures may be the result of leakage or necking down since these inclusions are on fractures.

Salinity (expressed as equivalent weight % NaCl) calculated from the final melting temperature of ice in the NaCl-H_2O system has been determined for about 240 inclusions. In some very saline inclusions hydrohalite was found to persist after ice but exhibited metastable behavior (Crawford, 1981) and could not be used to determine salinity. In some inclusions hydrohalite was found to persist after ice on a particular warming run, but to melt before ice in the same inclusion when the experiment was repeated. However, since the range of salinities corresponding to hydrohalite melting is very small (23 to 26%), and the ice melting curve is very steep at this point, the difference in salinity determined by using the melting temperature of ice rather than hydrohalite is only about 1 to 3 percentage points.

Although there is a wide range in salinity in Type Ia, Ib, and Ic occurrences from practically pure water to >28% NaCl equivalent (Fig. 47), most inclusions have salinities ranging from 16 to 28%. The temperature of first observed melting (ideally a eutectic) of inclusions was recorded in order to determine the components present. Figure 49 shows a plot of first observed melting temperature against salinity. The data show that the higher salinity inclusions have lower eutectics indicative of multicomponent systems. Scatter in the data may be the result of small undetectable amounts of melting at the eutectic. For example initial melting was observed at about -45°C in some inclusions. This is not a eutectic temperature for any combination of common chlorides; it may mean that melting started at a lower temperature in amounts too small to observe. Metastability may also account for some of the scatter as there is a metastable eutectic at -28°C in the NaCl-H_2O system (Crawford, 1981). Similar metastable eutectics in multicomponent systems may account for first observed melting temperatures as low as -67°C.

Although high salinities were detected in many inclusions, no halite was observed. This is true of inclusions from most Mississippi Valley Type deposits, and suggests that significant amounts of cations other than Na, such as K, Ca, or Mg are present (Roedder, 1984).

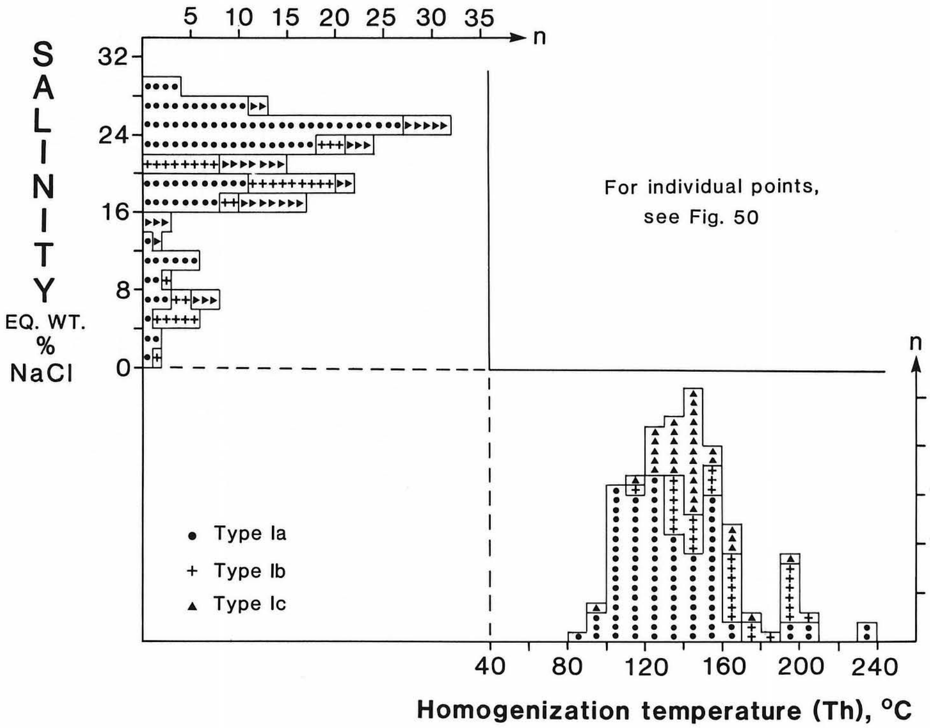

Figure 47. Fluid inclusions in sphalerite, homogenization temperature and salinity histograms, Type Ia, Ib, and Ic deposits. Detail of data points in upper right is shown on Figure 50.

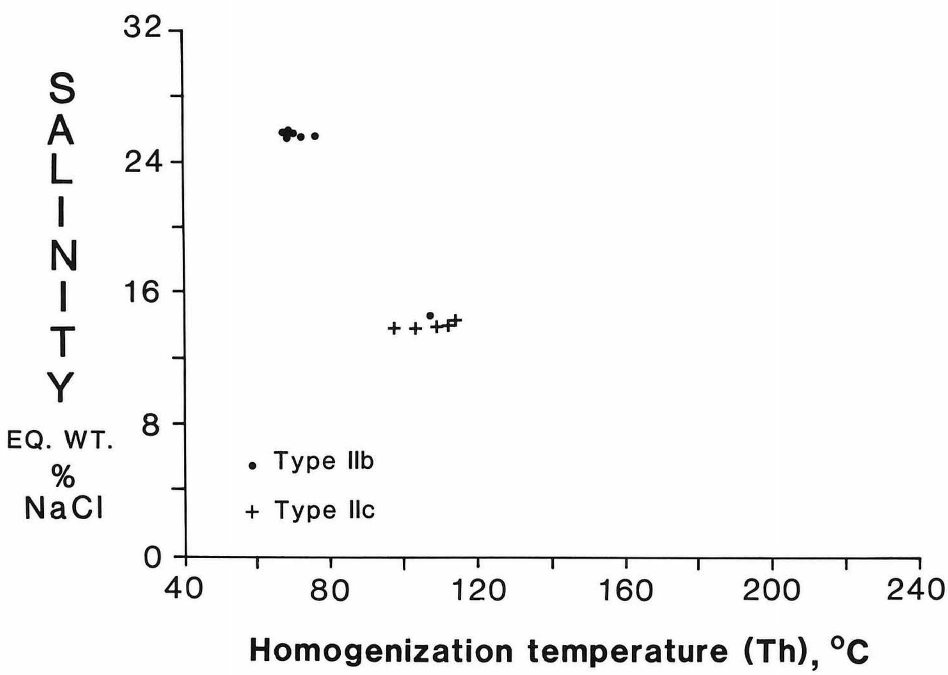

Figure 48. Fluid inclusions in sphalerite, homogenization temperature, and salinity, Type IIb and IIc deposits.

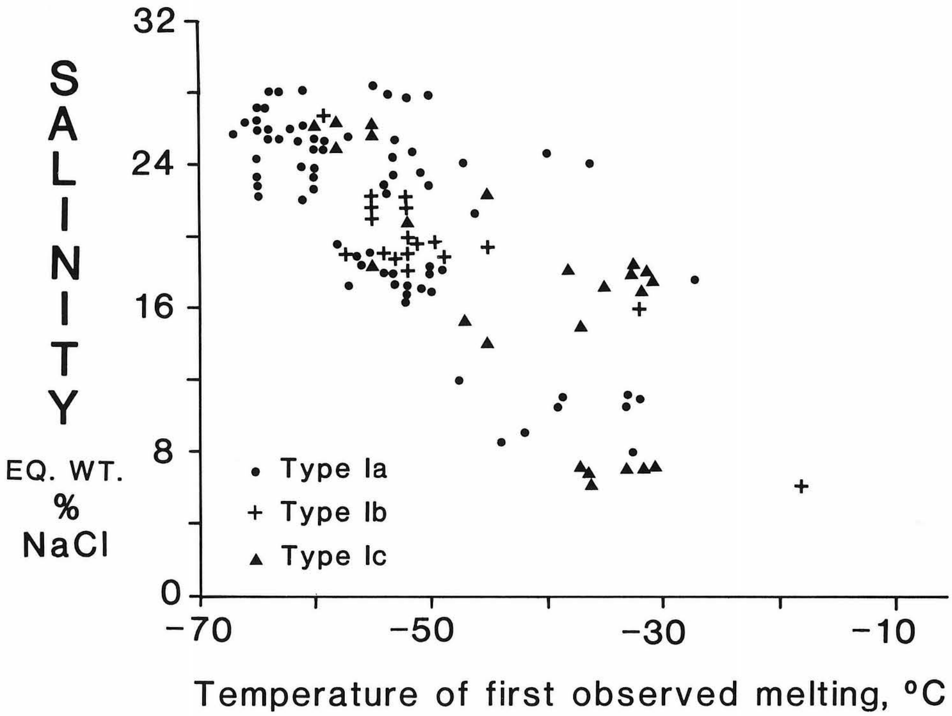

Figure 49. Type Ia, Ib, and Ic deposits. Fluid inclusions in sphalerite, salinity vs. temperature of first observed melting.

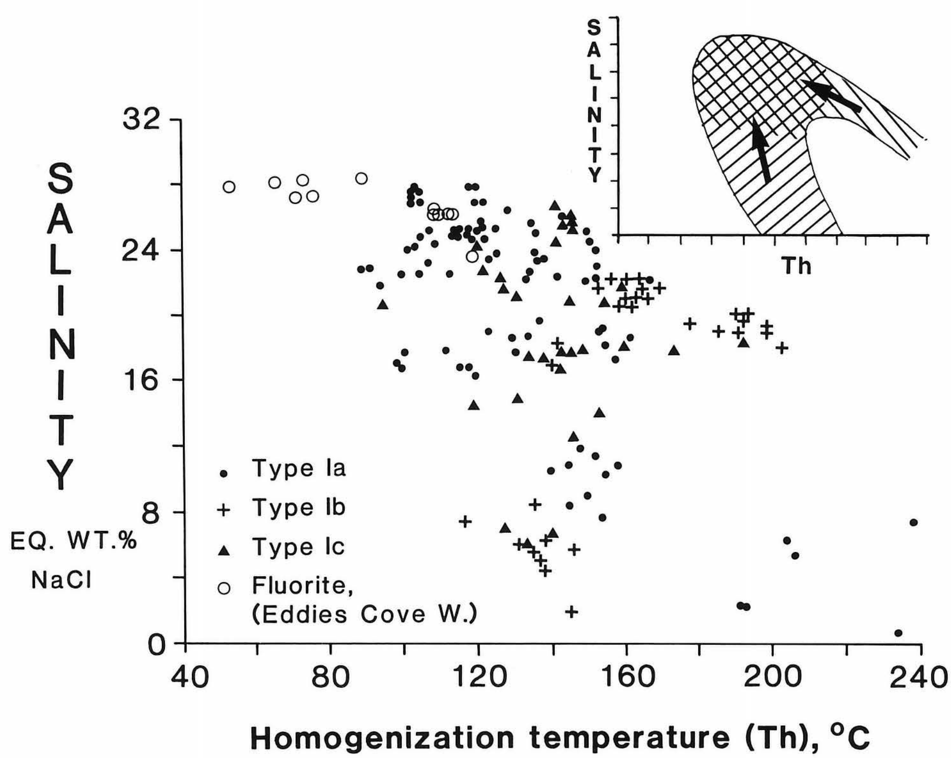

Figure 50. Fluid inclusions in sphalerite, Type Ia, Ib, and Ic deposits and in fluorite (Eddies Cove West), homogenization temperature vs. salinity. Inset diagram shows trends of two fluids (lined patterns). Hatched pattern indicates area of mixing.

Salinity histograms for Type Ia (Fig. 47) are skewed towards high salinity. Type Ic data fall between 12 and 26% except for a small cluster at 6% (the result of bimodal distribution of salinities from Salmon River #3).

Salinities for Type Ib samples show a bimodal distribution. The low salinity group (mode 6%) is from Goose Arm Narrows. The higher salinity group (mode 19%) is from Eddies Cove and Pikes Feeder Pond, plus two inclusions from Goose Arm Narrows. The bimodal distribution of data from Salmon River #3 matches that from Goose Arm.

Primary inclusions in sphalerite from Port au Port (Type IIb) have salinities which fall in a tight cluster at about 25%. One inclusion had lower salinity (14.8%).

Most inclusions in sphalerite from Dons Brook (Type IIc) have salinities which fall between 12 and 17%.

Secondary inclusions which occur on fractures in fluorite from the Eddies Cove West area have salinities ranging from 24 to 28%.

von Bitter et al. (1990) reported that primary L-V fluid inclusions in calcite gangue from Lead Cove homogenized at temperatures ranging from 65 to 187°C with most between 80 and 120°C; calcite from mineralized veins cutting Ordovician carbonates at Gillams Cove homogenized at temperatures between 73 and 178°C. The authors reported salinities between 15 and 21 equivalent weight % NaCl.

Interpretation

A detailed plot of homogenization temperature against salinity (Fig. 50) shows an inverse relationship among Type Ia, Ib, and Ic occurrences, i.e. higher salinity inclusions have lower homogenization temperatures. The data fall into two converging trends. If these trends are mixing lines then there are three end-members: a cool, highly saline, brine; and two hotter, less saline, fluids.

The brines that were trapped along fractures in the fluorite samples from Eddies Cove West (Fig. 50) could represent the low temperature, high salinity brine (although the homogenization temperature may be innacurate due to inclusion necking)

Sphalerite from several occurrences contains inclusions which have a clearly bimodal salinity. High salinity inclusions from Photograph Point are confined to early black sphalerite, but low salinity inclusions occur in yellow sphalerite. High salinity primary inclusions in sphalerite from Port au Port are mainly confined to purple zones that formed relatively early. A lower salinity inclusion is found in colourless sphalerite. High salinity inclusions from Goose Arm occur in early, dark brown sphalerite; low salinity inclusions occur in later, yellow sphalerite. High salinity inclusions from Salmon River #3 are found in a single reddish sphalerite grain; low salinity inclusions are found in a similar looking, apparently contemporaneous reddish sphalerite grain. Zoned sphalerite from St. John Island contains inclusions which have a wide range of salinities including a tight cluster at about 10%. Neither salinity nor homogenization temperatures vary systematically with zoning.

For each of these occurrences the high salinity inclusions plot along the gently sloping trend and the low salinity inclusions plot along the steep trend. The steeper trend may be the result of secondary inclusions, although evidence is not conclusive for or against this possibility. Alternatively it may be caused by changing conditions of the fluid during sphalerite deposition because, in some of the occurrences, the higher salinity inclusions occur in relatively early sphalerite and the low salinity inclusions occur in later sphalerite.

The fluid inclusion data of von Bitter et al. (1990) were obtained from calcite gangue from a Type IIa occurrence (Lead Cove) and from a mineralized vertical calcite vein cutting Ordovician carbonates at Gillams Cove that would be classified as a Type IIb occurrence (although it was not sampled in the present study). The data from the two occurrences are comparable and support a genetic link between the two. Data for Type IIb from the present study fall in the lower end of von Bitter et al.'s thermal range and are somewhat more saline. These differences may reflect the fact that sphalerite was sampled in the present study whereas calcite was analyzed by von Bitter et al. (1990). The source of these fluids may have been the Carboniferous Bay St. George sub-basin to the south.

It is difficult to make any conclusions about the origin of the Dons Brook showing (a Type IIc occurrence) which is widely removed from any others and has differing mineralogy (i.e. sphalerite hosted by quartz-carbonate veins). Limited fluid inclusion data suggest it formed from moderate temperature, moderate salinity fluids (Fig. 47).

CONCLUSIONS

1. The 40 occurrences included in this study can be classified into three main types and seven subtypes.
2. Type Ia includes the Newfoundland Zinc (Daniels Harbour) deposit, the only economically viable one, and all other major showings on the Great Northern Peninsula, e.g. Round Pond, Salmon River #6.
3. Although all occurrences included in this study are lead-zinc and carbonate-hosted, only Type Ia exhibits most of the major characteristics of Mississippi Valley-type deposits.
4. Type III occurrences (e.g. Turners Ridge and Side Pond), although substantial in size, significantly differ from all others in this study in being the only ones hosted in carbonates of Silurian age.
5. Fluid inclusion studies show that Type Ib deposits of the Great Northern Peninsula formed from fluids of high temperature and intermediate salinity; Type Ia formed from low temperature, highly saline brines; and fluids that formed Type Ic were intermediate between these two end-members. Although data are limited, Type IIb and IIa deposits appear to have formed from low temperature, relatively saline brines, possibly emanating from offshore Carboniferous sediments.

6. The Carboniferous Deer Lake Basin south of the Turners Ridge-Side Pond occurrences may have been a possible source of fluids for these deposits.

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Appendix A

Characteristics of carbonate-hosted Pb-Zn deposits western Newfoundland

TYPE 1a									
OCCURRENCE			HOST ROCK			MINERALIZATION			
NAME	CODE	LOCATION	UNIT NAME	LITHOLOGY	AGE	STATUS	FORM	SULPHIDES	GANGUE
Salmon River #5	12P/1-Zn005	556000E 5664400N	Catoche Fm.	dolomite pseudobreccia, limestone	L. to M. Ordovician	indication	disseminations	sphalerite	dolomite
Salmon River #6	12P/1-Zn006	557300E 5665700N	Catoche Fm.	dolomite pseudobreccia, limestone	L. to M. Ordovician	showing	disseminations, matrix to pseudobreccia	sphalerite galena	dolomite calcite
Twin Ponds Quarry	12P/8-Zn043	556750E 5691260N	Boat Harbour Fm.	angular spar breccia, pseudobreccia	L. Ordovician	indication	matrix to angular breccia disseminations	sphalerite galena	dolomite
Twin Ponds #2	12P/8-Zn042	555180E 5690800N	Watts Bight Fm.	dolomite pseudobreccia	L. Ordovician	indication	matrix to pseudobreccia	galena sphalerite	dolomite
Twin Ponds #5	12P/8-Zn040	555000E 5690320N	Watts Bight Fm.	dolomite pseudobreccia	L. Ordovician	showing	matrix to pseudobreccia, disseminations	sphalerite pyrite	dolomite quartz
Watts River #4	12P/9-Zn002	567820E 5711230N	Boat Harbour Fm.	dolomite pseudobreccia	L. Ordovician	indication	disseminations	sphalerite	dolomite
St.John Island South Cliff	12I/14-Zn004	482800E 5626850N	Table Point Fm.	epigenetic dolomite	M. Ordovician	showing	disseminations and clots	sphalerite galena pyrite	dolomite calcite
Shorts Harbour (St. John I.)	12I/14-Zn005	483900E 5631060N	Table Point Fm.	epigenetic dolomite	M. Ordovician	showing	disseminations and clots	sphalerite galena	dolomite
Photograph Pt. (St. John I.)	12I/14-Zn001	481620E 5627340N	Table Point Fm.	epigenetic dolomite	M. Ordovician	indication	disseminations and clots	sphalerite galena	dolomite
Fish Point	12I/14-Zn002	490100E 5623660N	Boat Harbour Fm.	dolomite pseudobreccia angular breccia	L. Ordovician	showing	botryoidal clots and disseminations	sphalerite marcasite pyrite	dolomite
North Boat Harbour #1	2M/12-Zn001	570370E 5711370N	Catoche Fm.	dolostone, dolomite pseudobreccia	L. Ordovician	showing	disseminations	sphalerite	dolomite quartz
North Boat Harbour #3	2M/12-Zn003	570090E 5711700N	Catoche Fm.	dolomite pseudobreccia	L. Ordovician	showing	disseminations, matrix to pseudobreccia	sphalerite	dolomite calcite
North Boat Harbour #4	2M/12-Zn004	569970E 5711750N	Catoche Fm.	dolomite pseudobreccia	L. Ordovician	showing	disseminations, matrix to pseudobreccia	sphalerite galena	dolomite calcite
Watts River #6	12P/9-Zn004	567480E 5711720N	Boat Harbour Fm.	dolomite pseudobreccia	L. Ordovician	indication	disseminations, matrix to pseudobreccia	sphalerite	dolomite
Round Pond*	12P/8-Zn015	551260E 5678480N	Boat Harbour Fm.	dolomite pseudobreccia, angular breccia	L. Ordovician	prospect	matrix to breccias, disseminations	sphalerite pyrite galena	dolomite calcite

brackets - mineral reported but not observed by author
* sampled from drill core only

Appendix A (cont.)

TYPE 1a									
OCCURRENCE			HOST ROCK			MINERALIZATION			
NAME	CODE	LOCATION	UNIT NAME	LITHOLOGY	AGE	STATUS	FORM	SULPHIDES	GANGUE
Whale Pond*	12P/8-Zn049	554940E 5678940N	St. George Group	dolostone, dolomite pseudobreccia	L. Ordovician	showing	matrix to pseudobreccia, disseminations	sphalerite	dolomite quartz

TYPE 1b									
OCCURRENCE			HOST ROCK			MINERALIZATION			
NAME	CODE	LOCATION	UNIT NAME	LITHOLOGY	AGE	STATUS	FORM	SULPHIDES	GANGUE
Pikes Feeder Pond	12I/10-Pb001	500500E 5608700N	Petit Jardin Fm.	dolostone	U. Cambrian	showing	disseminations, clots, veinlets	pyrite galena sphalerite chalcopyrite	dolomite quartz
Rocky Pond West	12I/16-Zn001	561720E 5633630N	Petit Jardin Fm.	dolostone	U. Cambrian	showing	disseminations, rims clots of gangue	sphalerite pyrite	dolomite calcite quartz
Green Island Brook #3	12P/7-Zn004	534089E 5693540N	March Point Fm.	dolostone	M. Cambrian	indication	sparse clots	sphalerite	dolomite quartz
Green Island Brook #4	12P/7-Pb001	534100E 5693200N	March Point Fm.	dolostone	M. Cambrian	indication	on fractures, sparse clots	galena sphalerite	dolomite calcite
Eddies Cove Trenches	12P/8-Pb002	539230E 5695390N	Petit Jardin Fm.	dolostone	U. Cambrian	showing	stringers, clots	galena	dolomite
Eddies Cove #11	12P/8-Zn006	538220E 5695290N	March Point Fm.	dolostone	M. Cambrian	indication	sparse clots	sphalerite	dolomite
Eddies Cove #12	12P/8-Zn005	538120E 5695480N	March Point Fm.	dolostone	M. Cambrian	indication	veinlets, clots	galena sphalerite	dolomite
Eddies Cove #13	12P/8-Zn004	538230E 5695490N	March Point Fm.	dolostone	M. Cambrian	indication	sparse clots	sphalerite	dolomite
Contact Brook	12P/8-Zn011	536960E 5695499N	March Point Fm.	dolostone	M. Cambrian	showing	clots, on fractures	galena sphalerite	dolomite
Contact Brook #3	12P/8-Zn009	537150E 5694540N	March Point Fm.	dolostone	M. Cambrian	indication	sparse clots	sphalerite	dolomite
Contact Brook #4	12P/8-Zn007	537430E 5694870N	March Point Fm.	dolostone	M. Cambrian	indication	sparse clots	sphalerite	dolomite
Contact Brook #5	12P/8-Zn008	537140E 5695190N	March Point Fm.	dolostone	M. Cambrian	indication	veinlets, on fractures, clots	sphalerite	dolomite
Beaver Pond	12H/4-Zn002	447500E 5451910N	Hughes Brook Fm.	dolostone, angular spar breccia	U. Cambrian	showing	disseminations, veinlets, matrix to angular spar breccia	sphalerite pyrite	dolomite
Goose Arm Narrows*	12H/4-Pb004	432370E 5443380N	Hughes Brook Fm.	dolostone	U. Cambrian	showing	clots, veins, on fractures, disseminations	sphalerite galena pyrite	dolomite

TYPE 1c									
OCCURRENCE			HOST ROCK			MINERALIZATION			
NAME	CODE	LOCATION	UNIT NAME	LITHOLOGY	AGE	STATUS	FORM	SULPHIDES	GANGUE
Round Head I. (St. John I.)	12I/14-PYR001	486980E 5628560N	Boat Harbour Fm.	angular spar breccia	L. Ordovician	showing	matrix to angular spar breccia	marcasite pyrite	dolomite
Salmon River #3	12P/1-Zn003	553550E 5663400N	Petit Jardin Fm.	epigenetic dolomite	U. Cambrian	showing	clots within epigenetic dolomite	sphalerite pyrite	dolomite quartz
St. Barbe Harbour	12P/2-PYR001	515320E 5670420N	Petite Jardin Fm.	dolostone, epigenetic quartz-dolomite	U. Cambrian	indication	clots within epigenetic quartz-dolomite	pyrite	quartz dolomite
Forresters Pt. (Brig Bay)	12P/2-PYR002	512950E 5669900N	Petite Jardin Fm.	dolostone	U. Cambrian	indication	matrix to linear angular breccia zone	pyrite sphalerite	dolomite calcite
Seal Cove (Brig Bay)	12P/2-PYR004	509300E 5662200N	Watts Bight Fm.	dolostone, dolomite pseudobreccia	L. Ordovician	indication	disseminations, matrix to pseudobreccia	pyrite	dolomite
Dog Cove (Brig Bay)	12P/2-PYR006	503250E 5655590N	Boat Harbour Fm.	angular spar breccia	L. Ordovician	indication	matrix to angular spar breccia	pyrite	dolomite
Chambers Island	12P/7-Zn001	516750E 5681880N	Petite Jardin Fm.	dolostone angular spar breccia	U. Cambrian	showing	veins, matrix to linear breccia zones	pyrite sphalerite	dolomite quartz
Green Island Brook #1	12P/7-Zn002	532470E 5693620N	March Point Fm.	dolostone, dolomite pseudobreccia	M. Cambrian	showing	disseminations	sphalerite pyrite	dolomite
Hidden Pond	12P/8-Zn045	559400E 5691520N	Watts Bight Fm.	dolostone	L. Ordovician	indication	stringers, disseminations	sphalerite pyrite galena	dolomite
North Hidden Pond	12P/8-Zn046	559820E 5691670N	Watts Bight Fm.	dolostone	L. Ordovician	indication	disseminations	sphalerite pyrite	dolomite
Watts Point	12P/8-Zn002	545400E 5700330N	Petit Jardin Fm.	dolostone angular spar breccia	U. Cambrian	showing	disseminations, stringers, clots, veinlets	sphalerite pyrite	dolomite quartz

TYPE IIa									
OCCURRENCE			HOST ROCK			MINERALIZATION			
NAME	CODE	LOCATION	UNIT NAME	LITHOLOGY	AGE	STATUS	FORM	SULPHIDES	GANGUE
Lead Cove	12B/10-Pb002	371400E 5379760N	Big Cove Fm.	limestone, limestone breccia	Mississippian	showing	vein and open space-filling	galena marcasite pyrite	calcite barite
Bellmans Cove	12B/10-Pb003	370700E 5379800N	Big Cove Fm.	limestone, limestone breccia	Mississippian	showing	vein and open space-filling	sphalerite pyrite marcasite	calcite barite
Aguathuna Road	12B/10-Ba007	368750E 5380040N	Big Cove Fm.	limestone	Mississippian	indication	vein and open space-filling	marcasite galena (sphalerite)	(celestite) barite calcite
Miners Brook	12B/10-Pb007	367400E 5379960N	Big Cove Fm.	limestone, limestone breccia	Mississippian	showing	vein and open space-filling	marcasite galena sphalerite	calcite barite
Piccadilly Brook	12B/10-Pb008	358960E 5378950N	Codroy Gp.,	limestone	Mississippian	indication	vein and open space-filling	galena pyrite marcasite sphalerite	calcite barite

TYPE IIb									
OCCURRENCE			HOST ROCK			MINERALIZATION			
NAME	CODE	LOCATION	UNIT NAME	LITHOLOGY	AGE	STATUS	FORM	SULPHIDES	GANGUE
Felix Cove	12B/10-Pb006	367320E 5376620N	Port au Port Gp.	limestone, limestone breccia	M. to U. Cambrian	indication	vein	galena	calcite barite
Fiods Cove	12B/10-Pb005	355850E 5374800N	St. George Gp. and Lower Cove Fm.	limestone, limestone boulder conglomerate	L. Ordovician, Mississipian	indication	vein	marcasite	calcite
Abrahams Cove	12B/10-Pb004	357900E 5375200N	St. George Gp.	limestone	L. Ordovician	showing	vein	galena marcasite sphalerite	calcite barite
Piccadilly Harbour	12B/10-Pb001	359150E 5381050N	Table Head Gp.	limestone	M. Ordovician	indication	vein	galena marcasite sphalerite	calcite barite
Goodyear Prospect	12B/11-Pb001	349900E 5387290N	Table Head Gp.	limestone	M. Ordovician	prospect	vein	galena sphalerite marcasite	calcite
Port au Port (Harry Brook*)	12B/11-Pb002	351960E 5382080N	Table Head Gp.	limestone	M. Ordovician	indication	vein	galena marcasite sphalerite	calcite barite
Port au Port (Victors Brook East*)	12B/11-Pb003	350610E 5384210N	Table Head Gp.	limestone	M. Ordovician	indication	vein	galena marcasite sphalerite	calcite barite
Port au Port (Victors Brook West*)	12B/11-Pb004	349400E 5383700N	Table Head Gp.	limestone	M. Ordovician	indication	vein	galena marcasite	calcite barite

TYPE IIc									
OCCURRENCE			HOST ROCK			MINERALIZATION			
NAME	CODE	LOCATION	UNIT NAME	LITHOLOGY	AGE	STATUS	FORM	SULPHIDES	GANGUE
Dons Brook	12B/9-Pb001	407450E 5394450N	Petit Jardin Fm.	limestone	U. Cambrian	showing	vein	sphalerite galena	quartz calcite
Goose Arm Bk.	12H/4-Pb001	438090E 5449350N	Hughes Brook Fm.	dolostone	U. Cambrian	past producer -dormant	vein	pyrite (sphalerite) (galena)	calcite (cerussite)
Wolf Brook	12H/4-Pb003	430280E 5441130N	Hughes Brook Fm.	dolostone	U. Cambrian	indication	vein	galena sphalerite	calcite

Appendix A (concl.)

TYPE III									
OCCURRENCE			HOST ROCK			MINERALIZATION			
NAME	CODE	LOCATION	UNIT NAME	LITHOLOGY	AGE	STATUS	FORM	SULPHIDES	GANGUE
Turners Ridge	12H/11-Pb001	499680E 5492860N	Lower Volcanic Fm.-Sops Arm Gp.	massive and brecciated dolostone and limestone	Silurian	developed prospect	matrix to breccia	galena pyrite sphalerite	barite calcite quartz
Side Pond	12H/11-Pb002	499530E 5497950N	Lower Volcanic Fm.-Sops Arm Gp.	massive and brecciated dolostone and limestone	Silurian	developed prospect	matrix to breccia, veins	pyrite sphalerite galena	barite calcite quartz albite hyalophane

Appendix B

Sphalerite geochemistry

Sample	Point	S	Zn	Fe	Cd	Cu	Mn	Ag	Total	Normal colour	Luminescence	Position
St. John Island South Cliff	1	32.69	65.68	0.27	0.50	0.05	0.01	0.00	99.20	Yellow		Centre
	2	33.30	67.04	0.23	0.43	0.04	0.02	0.01	101.07	Yellow		
12I14 Zn004 M3	3	33.40	66.76	0.31	0.44	0.03	0.03	0.00	100.97	Yellow		
	4	33.36	66.93	0.32	0.00	0.19	0.01	0.00	100.81	Pale Orange		
	5	33.33	66.36	0.49	0.13	0.23	0.02	0.11	100.67	Pale Orange		to
	6	32.62	66.49	0.45	0.14	0.07	0.02	0.03	99.82	Pale Orange		
	7	33.63	68.22	0.64	0.13	0.04	0.03	0.03	102.72	Yellow		
	8	32.83	65.76	1.27	0.07	0.28	0.02	0.06	100.29	Dark Orange		
	9	33.31	66.64	0.98	0.05	0.21	0.01	0.04	101.24	Dark Orange		
	10	32.74	65.30	0.71	0.05	0.24	0.01	0.03	99.08	Dark Orange		Rim
	Average	33.12	66.52	0.57	0.19	0.14	0.02	0.03	100.59			

Sample	Point	S	Zn	Fe	Cd	Cu	Mn	Ag	Total	Normal colour	Luminescence	Position
Round Pond	1	33.34	67.45	0.04	0.16	0.07	0.04	0.07	101.17	Light	-	Centre
	2	33.22	67.18	0.23	0.17	0.00	0.00	0.00	100.80	Light	-	
GNP-68-1 M1	3	33.34	67.00	0.19	0.15	0.10	0.03	0.00	100.81	Dark	-	
	4	33.43	66.65	0.19	0.09	0.06	0.03	0.08	100.53	Light	-	
	5	31.85	66.71	0.08	0.09	0.00	0.04	0.04	98.81	Dark	-	
	6	32.54	65.48	0.03	0.09	0.07	0.00	0.00	98.21	Light	-	
	7	33.54	67.28	0.27	0.09	0.01	0.00	0.02	101.21	Dark	-	
	8	33.23	67.25	0.08	0.20	0.02	0.05	0.06	100.89	Light	Purple	to
	9	33.02	67.05	0.05	0.16	0.05	0.00	0.00	100.33	Light	Purple	
	10	32.88	66.71	0.37	0.09	0.06	0.01	0.00	100.12	Rust	-	
	11	32.77	66.54	0.37	0.13	0.06	0.02	0.06	99.95	Dark	-	
	12	33.26	67.21	0.26	0.02	0.00	0.03	0.04	100.82	Rust	-	
	13	32.36	65.53	0.00	0.15	0.04	0.03	0.00	98.11	Light	Purple	
	14	32.25	67.25	0.03	0.21	0.07	0.03	0.00	99.84	Dark	Faint Purple	
	15	32.40	65.49	0.01	0.23	0.07	0.02	0.00	98.22	Dark	Purple	Rim
	16	32.88	67.22	0.02	0.22	0.02	0.02	0.00	100.38	Dark	Purple	Rim
	17	32.64	67.18	0.02	0.13	0.00	0.02	0.04	100.03	Dark	Yellow	Middle
	Average	32.88	66.78	0.13	0.14	0.04	0.02	0.02	100.01			

Sample	Point	S	Zn	Fe	Cd	Cu	Mn	Ag	Total	Normal colour	Luminescence	Position
Salmon River #6	1	33.20	68.27	0.31	0.15	0.02	0.00	0.02	101.97	Red	-	Centre
	2	32.94	66.05	0.80	0.55	0.00	0.04	0.04	100.42	Red	-	Centre
12P1 Zn006 M3	3	31.98	66.62	0.35	0.13	0.02	0.05	0.00	99.15	Red	-	Centre
	4	33.41	66.25	0.31	0.10	0.09	0.00	0.00	100.16	Red	-	Centre
	5	33.29	67.45	0.28	0.11	0.07	0.01	0.02	101.23	Red	-	Centre
	6	33.11	64.66	0.51	0.30	0.09	0.03	0.04	98.74	Red	-	Centre
	7	33.14	66.20	0.36	0.21	0.05	0.01	0.02	99.99	Red	-	Centre
	8	33.48	67.20	0.36	0.14	0.00	0.02	0.00	101.20	Red	-	Centre
	9	32.68	66.76	0.42	0.40	0.00	0.01	0.00	100.27	Red	-	Centre
	10	33.10	66.34	0.33	0.17	0.03	0.02	0.04	100.03	Red	-	Centre
	Average	33.03	66.58	0.40	0.23	0.04	0.02	0.02	100.32			
	11	32.69	66.47	0.00	0.18	0.09	0.04	0.02	99.49	Red	Bright Yellow	Rim
	12	32.45	66.94	0.00	0.18	0.09	0.03	0.03	99.72	Red	Bright Yellow	Rim
	13	32.57	67.08	0.02	0.15	0.07	0.05	0.02	99.96	Red	Bright Yellow	Rim
	Average	32.57	66.83	0.01	0.17	0.08	0.04	0.02	99.72			

Sample	Point	S	Zn	Fe	Cd	Cu	Mn	Ag	Total	Normal colour	Luminescence	Position
Watts River #4	1	32.02	65.95	0.07	0.81	0.13	0.02	0.05	99.05	Straw	-	Centre
	2	32.97	66.87	0.02	0.89	0.03	0.00	0.00	100.78	Straw	-	Centre
12P9 Zn002 M1												
	Average	32.50	66.41	0.05	0.85	0.08	0.01	0.03	99.92			

Note: Luminescence: blank indicates sample was not luminesced; "-" indicates area of sample was nonluminescent
Colours are only reported for thin sections

Appendix B (cont.)

Sample	Point	S	Zn	Fe	Cd	Cu	Mn	Ag	Total	Normal colour	Luminescence	Position
Watts River #4 12P9 Zn002 M1	3	32.10	67.12	0.02	0.15	0.21	0.00	0.02	99.62	Straw	Blue-green	Rim
	4	32.53	65.31	0.10	0.27	0.13	0.02	0.00	98.36	Straw	Blue-green	Fracture
	5	31.50	66.72	0.02	0.21	0.05	0.05	0.05	98.60	Straw	White	Rim
	Average	32.04	66.38	0.05	0.21	0.13	0.02	0.02	98.86			
Sample	Point	S	Zn	Fe	Cd	Cu	Mn	Ag	Total	Normal colour	Luminescence	Position
Watts Point	Avg. (10)	33.00	67.35	0.06	0.18	0.03	0.02	0.02	100.66	Straw	Purple	Centre
											Yellow	to
12P8 Zn002 M4											Brown	Rim
Sample	Point	S	Zn	Fe	Cd	Cu	Mn	Ag	Total	Normal colour	Luminescence	Position
Twin Ponds	1	33.27	64.26	0.08	0.20	0.06	0.02	0.05	97.94	Brown	-	Rim
	2	33.14	64.22	0.25	0.12	0.02	0.00	0.00	97.75	Brown	-	Centre
DDH 12P1 0019 M1	3	33.55	65.22	0.21	0.23	0.08	0.03	0.04	99.36	Brown	-	Centre
	Average	33.32	64.57	0.18	0.18	0.05	0.02	0.03	98.35			
	4	33.17	64.88	0.64	0.11	0.09	0.04	0.05	98.98	Brown	Yellow	Rim
	5	32.82	65.86	0.21	0.18	0.05	0.03	0.05	99.20	Brown	Yellow	Rim
	6	33.22	64.19	0.32	0.19	0.04	0.02	0.05	98.03	Brown	Yellow	Rim
	Average	33.07	64.98	0.39	0.16	0.06	0.03	0.05	98.74			
	7	32.87	65.27	0.05	0.13	0.07	0.05	0.03	98.47	Brown	Purple	Fracture
Sample	Point	S	Zn	Fe	Cd	Cu	Mn	Ag	Total	Normal colour	Luminescence	Position
Salmon River #3	1	32.94	66.68	0.18	0.27	0.07	0.02	0.00	100.16	Brown	-	Early
		32.82	65.71	0.06	0.29	0.07	0.05	0.03	99.03	Brown	-	
12P1 Zn003 M5		33.02	67.89	0.02	0.33	0.04	0.02	0.05	101.37	Brown	Yellow	to
		32.45	65.49	0.03	0.08	0.05	0.03	0.02	98.15	Brown	Yellow	
		31.67	67.32	0.03	0.14	0.01	0.03	0.05	99.25	Brown	Purple	Late
	Average	32.58	66.62	0.06	0.22	0.05	0.03	0.03	99.59			
Sample	Point	S	Zn	Fe	Cd	Cu	Mn	Ag	Total	Normal colour	Luminescence	Position
Eddies Cove #11	Avg.(6)	33.48	67.71	0.01	0.04	0.04	0.01	0.03	101.32	Green-Yellow		Centre to Rim
Sample	Point	S	Zn	Fe	Cd	Cu	Mn	Ag	Total	Normal colour	Luminescence	Position
Goose Arm	1	32.76	64.30	0.79	1.37	0.07	0.00	0.05	99.34	Brown	-	Early
	2	33.09	64.50	0.77	1.47	0.05	0.04	0.00	99.92	Brown	-	Early
DDH 460-84-3 M2												
	Average	32.93	64.40	0.78	1.42	0.06	0.02	0.03	99.63			
	3	32.56	66.15	0.03	0.32	0.04	0.00	0.08	99.18	Brown	Blue-White	Altered
	4	33.05	66.13	0.03	0.54	0.12	0.00	0.00	99.87	Brown	Blue-White	Altered
	Average	32.81	66.14	0.03	0.43	0.08	0.00	0.04	99.53			

Sample	Point	S	Zn	Fe	Cd	Cu	Mn	Ag	Total	Normal colour	Luminescence	Position
Goose Arm	Avg.(9)	32.77	65.84	0.74	0.12	0.03	0.02	0.03	99.55	Rust to Brown		Early to Late
DDH 460-84-5 M3												

Sample	Point	S	Zn	Fe	Cd	Cu	Mn	Ag	Total	Normal colour	Luminescence	Position
Raft Pond	1	32.90	63.95	0.96	0.16	0.04	0.00	0.00	98.01	-		
	2	32.69	64.68	1.53	0.17	0.07	0.00	0.06	99.20	-		
DDH 74-7 M3												
	Average	32.80	64.32	1.25	0.17	0.06	0.00	0.03	98.61			
	3	35.15	15.65	32.53	0.03	0.00	0.02	0.04	83.42			Altered
	4	32.62	53.98	5.08	0.07	0.04	0.04	0.02	91.85			Altered
	5	7.23	46.46	0.08	0.03	0.08	0.00	0.04	53.92			Altered

Sample	Point	S	Zn	Fe	Cd	Cu	Mn	Ag	Total	Normal colour	Luminescence	Position
Bellmans Cove	1	32.30	64.25	1.48	0.05	0.07	0.02	0.03	98.20			
	2	32.46	65.26	0.66	0.02	0.05	0.00	0.00	98.45			
12B10 Pb003 M7	3	32.81	65.07	1.26	0.05	0.00	0.07	0.08	99.34			
	Average	32.52	64.86	1.13	0.04	0.04	0.03	0.04	98.66			

Sample	Point	S	Zn	Fe	Cd	Cu	Mn	Ag	Total	Normal colour	Luminescence	Position
Miners Brook	1	31.87	65.81	0.04	0.04	0.02	0.02	0.04	97.84			Centre
	2	32.29	65.83	0.27	0.04	0.11	0.03	0.02	98.59			to
12B10 Pb007 M4	3	32.57	64.77	0.90	0.02	0.07	0.02	0.02	98.37			Rim
	Average	32.24	65.47	0.40	0.03	0.07	0.02	0.03	98.27			

Sample	Point	S	Zn	Fe	Cd	Cu	Mn	Ag	Total	Normal colour	Luminescence	Position
Goodyear Prospect	1	32.39	62.84	0.58	0.38	0.35	0.03	0.07	96.64		-	Early
	2	32.12	64.53	0.48	0.22	0.29	0.03	0.04	97.71		-	
12B11 Pb001 M4	3	32.90	65.34	0.34	0.71	0.16	0.04	0.00	99.49		-	
	4	32.49	64.77	0.18	0.51	0.22	0.00	0.00	98.17		-	
	5	32.21	64.93	0.79	0.05	0.06	0.02	0.04	98.10		-	
	6	32.57	65.08	0.48	0.05	0.06	0.00	0.05	98.29		-	to
	7	32.00	65.63	0.36	0.20	0.00	0.02	0.04	98.25		-	
	8	32.34	65.84	0.38	0.07	0.02	0.00	0.07	98.72		-	
	9	32.29	63.06	0.84	0.05	0.03	0.05	0.00	96.32		-	
	10	32.55	63.89	1.63	0.05	0.00	0.04	0.05	98.21		-	
	11	32.52	67.23	0.13	0.06	0.13	0.03	0.07	100.17		-	Late
	Average	32.40	64.83	0.56	0.21	0.12	0.02	0.04	98.19			

Sample	Point	S	Zn	Fe	Cd	Cu	Mn	Ag	Total	Normal colour	Luminescence	Position
Piccadilly Hbr.	1	32.34	64.99	0.04	0.09	0.10	0.03	0.05	97.64			Early
	2	32.54	63.46	0.08	0.12	0.11	0.02	0.04	96.37			Early
12B10 Pb001 M1	3	32.59	63.79	0.13	0.04	0.07	0.04	0.04	96.70			Early
	4	32.52	65.24	0.06	0.06	0.08	0.02	0.00	97.98			Middle
	5	32.63	63.55	0.34	0.09	0.04	0.02	0.04	96.71			Middle
	6	32.21	63.64	1.06	0.04	0.00	0.01	0.03	96.99			Late
	7	32.48	63.94	0.80	0.11	0.05	0.01	0.02	97.41			Late
	Average	32.47	64.09	0.36	0.08	0.06	0.02	0.03	97.11			

Appendix B (concl.)

Sample	Point	S	Zn	Fe	Cd	Cu	Mn	Ag	Total	Normal colour	Luminescence	Position
Wolf Brook	1	31.72	67.07	0.42	0.66	0.08	0.00	0.03	99.98	Black	-	Middle
	2	32.89	67.11	0.47	0.60	0.06	0.02	0.03	101.18	Black	-	Middle
12H4 Pb003 M3	3	32.89	67.38	0.39	0.66	0.04	0.01	0.00	101.37	Black	-	Middle
	Average	32.50	67.19	0.43	0.64	0.06	0.01	0.02	100.84			
	4	33.21	68.07	0.05	0.38	0.05	0.02	0.04	101.82	Yellow	-	Middle
	5	32.80	67.68	0.20	0.38	0.09	0.02	0.05	101.22	Yellow	-	Middle
	6	33.24	68.17	0.10	0.10	0.21	0.03	0.02	101.87	Yellow	-	Middle
	7	32.98	66.81	0.19	0.38	0.17	0.00	0.03	100.56	Yellow	-	Middle
	Average	33.06	67.68	0.14	0.31	0.13	0.02	0.04	101.37			

Sample	Point	S	Zn	Fe	Cd	Cu	Mn	Ag	Total	Normal colour	Luminescence	Position
Turners Ridge	Avg.(3)	32.54	66.89	0.26	0.36	0.09	0.04	0.03	100.21		-	
DDH 77-2 M2												

Appendix C

Dolomite geochemistry

Sample	Point	Mg	Ca	Mn	Fe	Zn	Pb	Total	Luminescence	Type
Round Pond	1	22.15	28.85	0.04	0.11	0.05	0.00	51.20	red	fine grained
	2	21.72	28.20	0.04	0.16	0.08	0.00	50.20	red	fine grained
GNP-68-M1										
	Average	21.94	28.53	0.04	0.14	0.07	0.00	50.70		
	3	22.46	28.40	0.00	0.16	0.30	0.00	51.32	dull red	spar
	4	22.25	28.27	0.01	0.11	0.14	0.00	50.78	bright red	spar
	5	21.37	29.11	0.04	0.02	0.01	0.05	50.60	bright red	spar
	6	21.59	29.34	0.02	0.00	0.06	0.00	51.01	bright red	spar
	7	21.49	28.54	0.02	0.00	0.10	0.18	50.33	bright red	spar
	Average	21.83	28.73	0.02	0.06	0.12	0.05	50.81		
12P80005M1	1	19.24	27.81	0.00	0.10	0.01	0.00	47.16	variable	med. grained
	2	19.94	31.45	0.01	0.01	0.13	0.00	51.54	variable	med. grained
	3	19.07	30.48	0.02	0.05	0.08	0.10	49.80	variable	med. grained
	4	20.05	30.55	0.03	0.17	0.04	0.00	50.84	variable	med. grained
	Average	19.58	30.07	0.02	0.08	0.07	0.03	49.84		
	5	21.18	29.48	0.00	0.09	0.05	0.05	50.85	dull red	replacement
	6	20.79	28.82	0.02	0.09	0.05	0.00	49.77	medium red	replacement
	7	21.30	28.82	0.02	0.07	0.07	0.00	50.28	bright red	replacement
	8	22.15	31.01	0.00	0.07	0.03	0.00	53.26	dark red	replacement
	9	20.91	30.75	0.00	0.01	0.03	0.00	51.70	bright red	replacement
	Average	21.27	29.78	0.01	0.07	0.05	0.01	51.17		
	10	20.15	30.87	0.06	0.02	0.00	0.00	51.10	red	fine grained
	11	21.17	31.94	0.01	0.44	0.05	0.13	53.74	brown	late vein
	12	19.86	30.41	0.02	0.23	0.13	0.11	50.76	brown	late vein
	Average	20.52	31.18	0.02	0.34	0.09	0.12	52.25		

Sample	Point	Mg	Ca	Mn	Fe	Zn	Pb	Total	Luminescence	Type
Salmon River #6	1	21.74	29.10	0.06	0.04	0.05	0.00	50.99	dull red	fine grained
	2	20.64	28.73	0.00	0.02	0.01	0.00	49.40	dull red	fine grained
12P1Zn006M3										
	Average	21.19	28.92	0.03	0.03	0.03	0.00	50.20		
	3	22.39	27.95	0.00	0.28	0.00	0.00	50.62	dull red	spar
	4	21.79	28.28	0.03	0.00	0.18	0.03	50.31	bright red	spar
	5	21.74	27.05	0.14	0.00	0.11	0.00	49.04	bright yellow	spar
	6	21.98	27.80	0.06	0.02	0.02	0.02	49.90	bright red	spar
	Average	21.98	27.77	0.06	0.08	0.08	0.01	49.97		

Note: Luminescence: blank indicates sample was not luminesced; "-" indicates area of sample was nonluminescent

Appendix C (cont.)

Sample	Point	Mg	Ca	Mn	Fe	Zn	Pb	Total	Luminescence	Type
Twin Ponds Quarry	1	21.87	29.67	0.04	0.13	0.04	0.08	51.83	bright red	replaces PbS
	2	21.27	27.30	0.03	0.10	0.02	0.15	48.87	bright red	replaces PbS
12P8Zn043M1										
	Average	21.57	28.49	0.04	0.12	0.03	0.12	50.35		
	3	16.43	26.68	0.14	7.28	0.03	0.05	50.61	brown	replaces PbS
	4	16.46	16.79	0.23	13.42	0.03	0.09	47.02	brown	replaces PbS
	Average	16.45	21.74	0.19	10.35	0.03	0.07	48.82		
	5	20.67	27.93	0.05	0.15	0.09	0.00	48.89	bright red	interfragment
	6	21.57	29.34	0.02	0.13	0.02	0.00	51.08	medium red	fragment
	7	21.56	28.93	0.00	0.13	0.06	0.00	50.68	medium red	fragment
	Average	21.27	28.73	0.02	0.14	0.06	0.00	50.22		

Sample	Point	Mg	Ca	Mn	Fe	Zn	Pb	Total	Luminescence	Type
Fish Point	1	21.82	28.57	0.04	0.10	0.38	0.00	50.91	medium red	replaces ZnS
	2	21.45	28.75	0.00	0.10	0.19	0.00	50.49	medium red	replaces ZnS
12I14Zn002M1	3	21.43	28.50	0.01	0.14	0.25	0.00	50.33	medium red	replaces ZnS
	Average	21.57	28.61	0.02	0.11	0.27	0.00	50.58		
	4	21.50	28.36	0.02	0.10	0.08	0.04	50.10	medium red	surrounds ZnS
	5	21.26	28.61	0.05	0.11	0.00	0.00	50.03	medium red	surrounds ZnS
	6	21.83	27.96	0.05	0.13	0.20	0.00	50.17	bright red	later spar
	Average	21.53	28.31	0.04	0.11	0.09	0.01	50.10		

Sample	Point	Mg	Ca	Mn	Fe	Zn	Pb	Total	Luminescence	Type
North Hidden Pond	1	22.00	29.55	0.04	0.09	0.00	0.00	51.68	medium red	fragment
	2	20.95	27.87	0.01	0.05	0.05	0.07	49.00	medium red	fragment
12P8Zn046M1	3	20.91	30.30	0.01	0.05	0.17	0.00	51.44	dark red	fragment
	Average	21.29	29.24	0.02	0.06	0.07	0.02	50.71		
	4	21.16	28.84	0.02	0.05	0.09	0.05	50.21		

Sample	Point	Mg	Ca	Mn	Fe	Zn	Pb	Total	Luminescence	Type
Salmon River #3	1	21.40	28.83	0.00	0.00	0.00	0.00	50.23	dark red	fine grained
12P1Zn003M3	2	22.33	28.10	0.02	0.00	0.08	0.05	50.58	dull red	spar
	3	22.41	27.28	0.04	0.11	0.04	0.05	49.93	bright red	spar
	4	21.74	27.81	0.04	0.13	0.09	0.00	49.81	red-brown	spar
	5	20.98	28.94	0.03	1.63	0.02	0.00	51.60	black	spar
	6	21.71	27.84	0.05	0.00	0.08	0.00	49.68	bright red	spar
	7	22.09	28.45	0.10	0.02	0.07	0.00	50.73	yellow	spar

Sample	Point	Mg	Ca	Mn	Fe	Zn	Pb	Total	Luminescence	Type
Watts Point	1	23.14	28.86	0.02	0.09	0.14	0.03	52.28	red	fine grained
12P8Zn002M4	2	21.56	28.70	0.04	0.03	0.13	0.00	50.46	red	fine grained
	3	21.61	28.49	0.00	0.12	0.36	0.03	50.61	red	fine grained
	Average	22.10	28.68	0.02	0.08	0.21	0.02	51.12		
	4	21.69	27.91	0.07	0.30	0.02	0.00	49.99	medium red	spar
	5	22.16	28.74	0.15	0.30	0.05	0.00	51.40	medium red	spar
	6	21.39	27.99	0.14	0.09	0.00	0.00	49.61	bright red	spar
	7	21.87	27.98	0.07	0.24	0.00	0.00	50.16	medium red	spar
	8	21.22	28.95	0.04	0.36	0.10	0.02	50.69	dark red	spar
	Average	21.67	28.31	0.09	0.26	0.03	0.00	50.37		
	9	21.87	27.57	0.00	0.10	0.02	0.00	49.56	dark red	cavity
	10	22.59	29.39	0.03	0.10	0.04	0.00	52.15	dark red	cavity
	Average	22.23	28.48	0.02	0.10	0.03	0.00	50.86		
	AVERAGE	21.91	28.46	0.06	0.17	0.09	0.01	50.69		

Sample	Point	Mg	Ca	Mn	Fe	Zn	Pb	Total	Luminescence	Type
Contact Brook	1	22.18	27.84	0.02	0.14	0.18	0.00	50.36	medium red	replaces ZnS
12P8Zn011M3	2	21.36	28.03	0.00	0.18	0.34	0.00	49.91	medium red	replaces ZnS
	3	21.39	30.47	0.02	0.38	1.41	0.00	53.67	bright red	replaces ZnS
	4	21.66	28.06	0.03	0.38	1.38	0.00	51.51	bright red	replaces ZnS
	5	23.29	28.91	0.01	0.18	0.30	0.05	52.74	medium red	replaces ZnS
	6	22.64	27.55	0.03	0.05	0.87	0.00	51.14	bright red	replaces ZnS
	Average	22.09	28.48	0.02	0.22	0.75	0.01	51.56		
	7	22.22	30.73	0.07	0.41	0.16	0.00	53.59	dark red	spar
	8	21.74	28.61	0.01	0.52	0.02	0.11	51.01	dark red	spar
	Average	21.98	29.67	0.04	0.47	0.09	0.06	52.30		

Sample	Point	Mg	Ca	Mn	Fe	Zn	Pb	Total	Luminescence	Type
Pikes Feeder Pond	1	22.22	28.64	0.04	0.55	0.03	0.00	51.48	brown	spar
12I10Pb001M1	2	21.52	27.74	0.09	1.74	0.04	0.02	51.15	black	spar
	3	22.15	29.59	0.06	0.12	0.08	0.00	52.00	bright red	spar
	4	21.28	29.71	0.05	1.95	0.05	0.00	53.04	brown	spar
	5	22.61	30.15	0.05	0.70	0.05	0.00	53.56	dark red	med. grained
	6	22.05	28.76	0.02	0.59	0.04	0.00	51.46	dark red	fine grained

Sample	Point	Mg	Ca	Mn	Fe	Zn	Pb	Total	Luminescence	Type
Raft Pond	1	21.64	28.35	0.04	0.18	0.03	0.03	50.27	bright red	spar
	2	22.43	29.33	0.02	0.16	0.07	0.01	52.02	bright red	spar
DDH-74-7M3										
	Average	22.04	28.84	0.03	0.17	0.05	0.02	51.15		

Sample	Point	Mg	Ca	Mn	Fe	Zn	Pb	Total	Luminescence	Type
Raft Pond	3	21.85	29.60	0.00	0.06	0.02	0.00	51.53	medium red	fine grained
DDH-74-7M3	4	21.21	28.73	0.04	0.03	0.05	0.00	50.06	medium red	fine grained
	Average	21.53	29.17	0.02	0.05	0.04	0.00	50.80		

Appendix D

Fluid inclusion characteristics and data. All refer to sphalerite unless noted otherwise.

Type Ia

SAMPLE	PHASES	APPEARANCE	CONTROL	COMMENTS	SALINITY	Th	EUTECTIC
Twin Ponds # 5 12P8Zn040 M2	L-V	rounded, negative crystals flat, clear & dark	random, cleavage, fractures	A group on fractures has slightly lower salinity.	18.2 to 26.3 %	94 to 169	−49 to −65
Twin Ponds Quarry 12P8Zn043 M2	L-V	clear, flat rounded negative crystals	random, cleavage	Similar to Twin Ponds No. 5	22.8 to 23.6 %	90 to 113	−60 to −65
North Boat Harbour 2M12Zn003 M1	L-V	flat & clear rounded, negative crystals with dark rims	random, cleavage	Th varies but salinity is very consistent. Some inclusions are cut by tiny fractures.	25.2 to 26.1 %	107 to 150	−55 to −67
Photograph Point 12I14Zn001 M-1	L-V	negative crystals & irregular, clear & dark	cleavage, fractures	High salinity primary incl. on cleavages in black sphalerite; low salinity on fractures in yellow sphalerite.	16.5 to 18.3 % & 27.1 to 28.3 %	99 to 155 103 to 105	−50 to −57
Shorts Harbour 12I14Zn005 M3	L-V	flat, clear irregular & rounded with dark rims	cleavage planes	Very abundant primary inclusions on cleavage planes in black sphalerite. Consistent salinity & Th.	26.3 to 28.1 %	119 to 144	−59 to −65
St. John Island South Cliff 12I14Zn004 M3	L-V one organic	flat, clear & rounded, dark	cleavage, random	Salinity & Th do not vary systematically relative to sphalerite zoning. Salinity highly variable even in adjacent inclusions. One organic inclusion had Th(V) of 100°C.	0.9 to 25.4 %	100 to 234	−32 to −56 one is pure water
Round Pond GNP-77-M1 & GNP-68-M2	L-V rare pure CO_2	rounded to irregular, dark & flat, clear	poorly defined growth zones	Salinity varies systematically and inversely with Th.	17.5 to 24.6 %	102 to 158	−27 to −53.7
Salmon River # 6 12P1Zn006 M3	L-V	flat, clear & dark, negative crystals to rounded	cleavage, fractures	May all be secondary. Low salinity incl. have very high Th. Higher salinity incl. have lower Th (2 measurements only)	2.2 to 7.6 % & 19.3 to 20.1	193 to 238 & 159	−58

Appendix D (cont.)

Type Ib

SAMPLE	PHASES	APPEARANCE	CONTROL	COMMENTS	SALINITY	Th	EUTECTIC
Pikes Feeder Pond 12I10Pb001 M1	L-V cpy	flat, clear	cleavage	Many are aligned parallel to cleavage direction, but not all on the same plane. Cpy daughter minerals very common. Salinity and Th are consistent.	20.4 to 22.1 %	153 to 173	−52 to −55
Eddies Cove DDH-12P80006 M2	L-V	flat, clear dark negative crystals & rounded	cleavage, random	Many are aligned parallel to cleavage direction, but not all on the same plane. Salinity and Th are consistent. One high salinity inclusion is intersected by a crosscutting cleavage.	17.9 to 19.9 % & 26.3 %	>178 to 203	−45 to −59
Goose Arm DDH-84-5 M2 & M3	L-V	flat, clear and dark rounded & negative crystals	growth zones & cleavage	Sphalerite occurs as zoned crystals (early brown to late yellow) and in late veins. Higher salinity incl. occur in brown sphalerite; low salinity incl. occur in late yellow sphalerite (veins and crystal rims).	1.7 to 18.0 % (not bimodal)	116 to 146	−18 to −21 & −32

Type Ic

SAMPLE	PHASES	APPEARANCE	CONTROL	COMMENTS	SALINITY	Th	EUTECTIC
North Hidden Pond 12P8Zn046 M1	L-V	flat, clear	growth zones, cleavage	Most are definitely primary, including both high and low salinity and Th. They occur along growth zones, some of which have parallel cleavage	11.7 to 26.5 %	95 to 160	−38 to −60
Watts Point 12P8Zn002 M2 & M4	L-V	clear, flat to rounded	cleavage random	Th is very hard to determine as bubbles tend to fade slowly.	17.8 to 26.0 %	about 145 to 200	−52 to −60
Salmon River # 3 12P8Zn003 M4	L-V	negative crystals with dark rims	random cleavage, fractures	Restricted to late red sphalerite. Bimodal salinity & consistent Th.	6.0 to 7.0 % & 14.8 to 17.9 %	128 to 139 131 to 149	−31 to −37

Type IIb

SAMPLE	PHASES	APPEARANCE	CONTROL	COMMENTS	SALINITY	Th	EUTECTIC
Port au Port DDH-78-2 M2 & DDH-73-20 M3	L-V	flat, clear irregular	growth zones	Definitely primary inclusions, mostly restricted to purple zones in sphalerite. One lower salinity inclusion in yellow sphalerite may be secondary.	24.6 to 26.0 % & 14.8 %	67 to 77 & 108	−58 to −64 & −35

Type IIc							
SAMPLE	PHASES	APPEARANCE	CONTROL	COMMENTS	SALINITY	Th	EUTECTIC
Dons Brook 12B9Pb001 M2 & M3	L-V, cpy, L only, one organic	flat, clear negative crystals dark neg. xtals	cleavage, random, fractures	Many have Cpy daughter minerals, partly protruding. Some are liquid only. One organic inclusion had Th(L) of 57.5°C. A Th(L) between 55 & 60°C was recorded for a L-only inclusion that nucleated a bubble during freezing.	7.9 to 17.4 %	99 to 118 & 55 to 60	−36 & −53

Miscellaneous							
SAMPLE	PHASES	APPEARANCE	CONTROL	COMMENTS	SALINITY	Th	EUTECTIC
Eddies Cove West Fluorite	L-V	clear, rounded	fractures	Secondary inclusions fractures in fluorite. Consistent salinity; varying Th may be the result of necking down or leaking.	23.7 to 28.4 %	53 to 119	−59 to −61

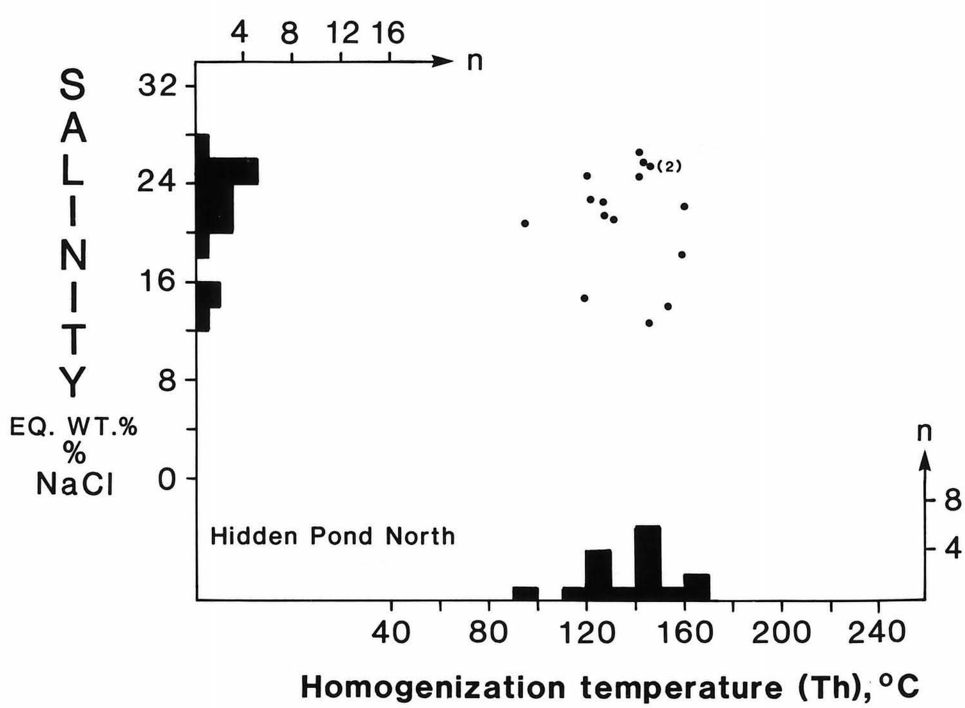

Figure D-1. Sphalerite fluid inclusion salinity and homogenization temperatures, Hidden Pond North.

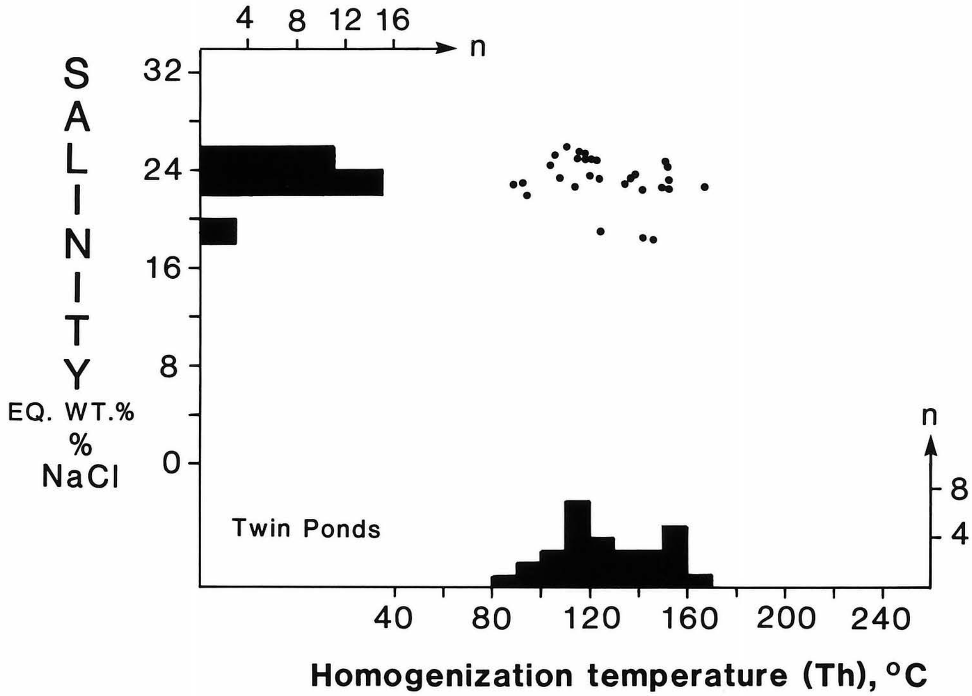

Figure D-2. Sphalerite fluid inclusion salinity and homogenization temperatures, Twin Ponds.

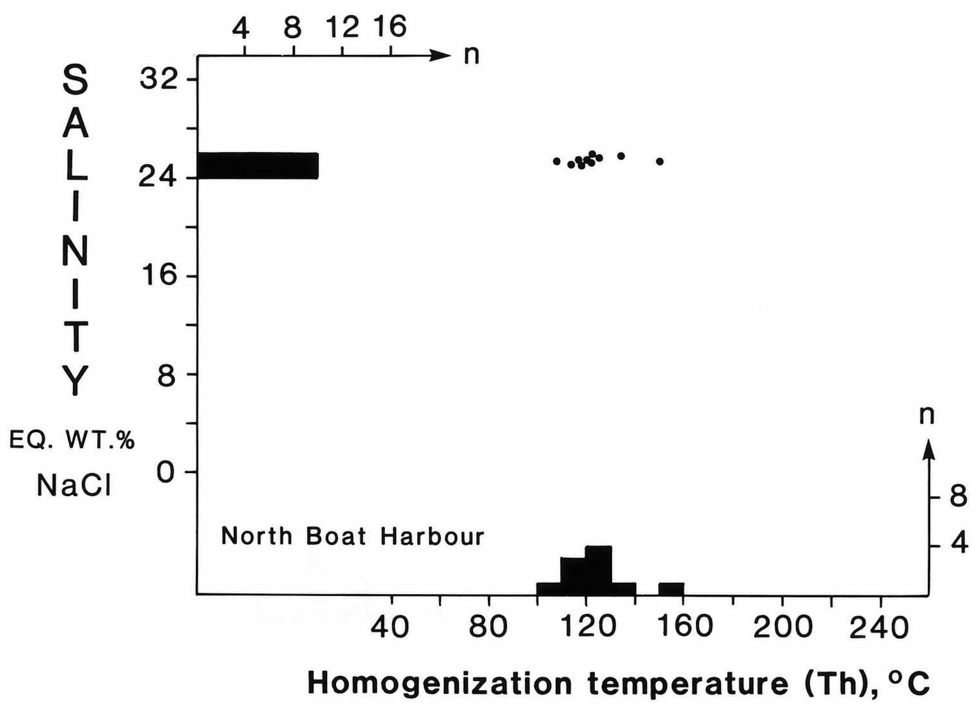

Figure D-3. Sphalerite fluid inclusion salinity and homogenization temperatures, North Boat Harbour.

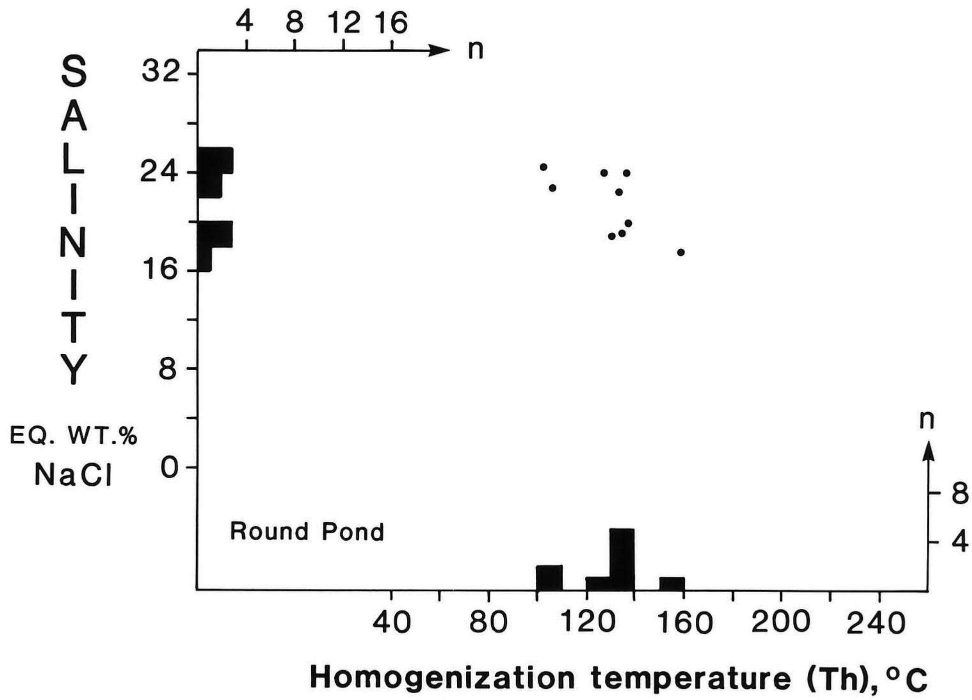

Figure D-4. Sphalerite fluid inclusion salinity and homogenization temperatures, Round Pond.

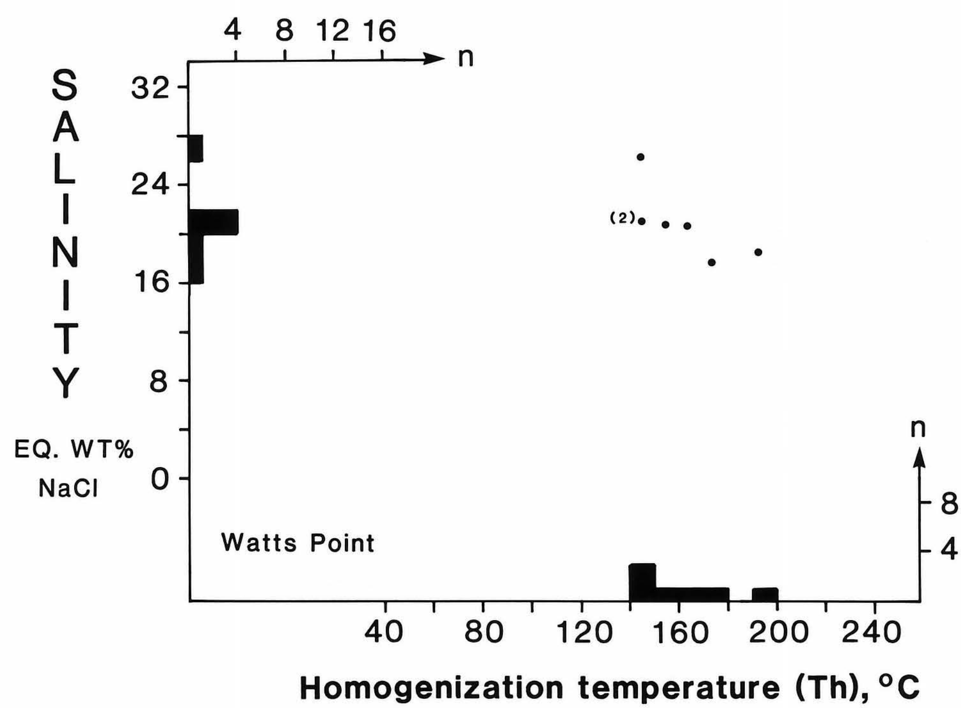

Figure D-5. Sphalerite fluid inclusion salinity and homogenization temperatures, Watts Point.

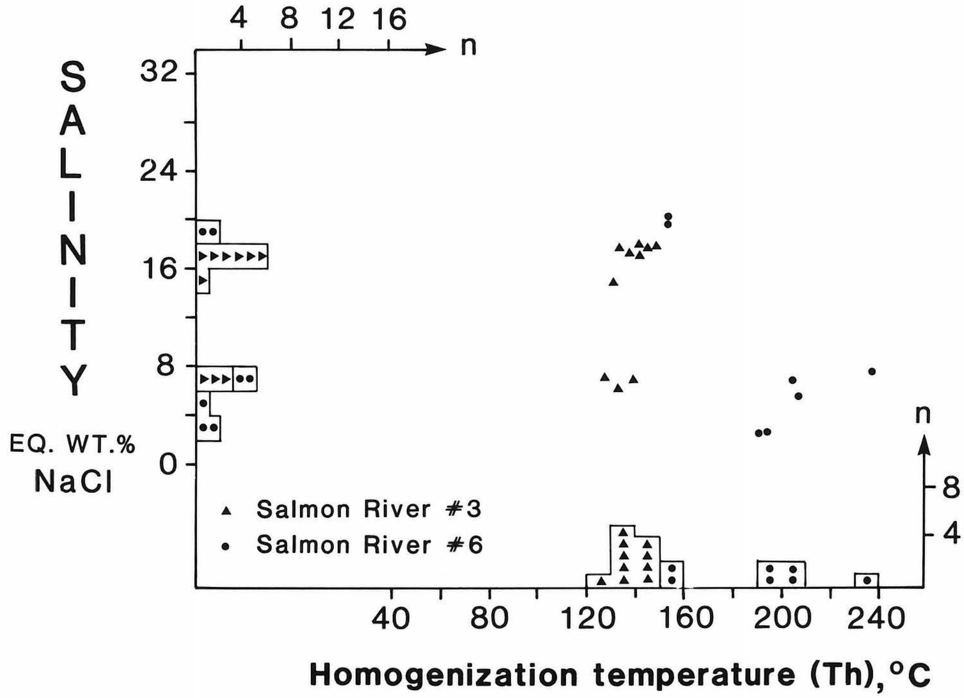

Figure D-6. Sphalerite fluid inclusion salinity and homogenization temperatures, Salmon River #3 and #6.

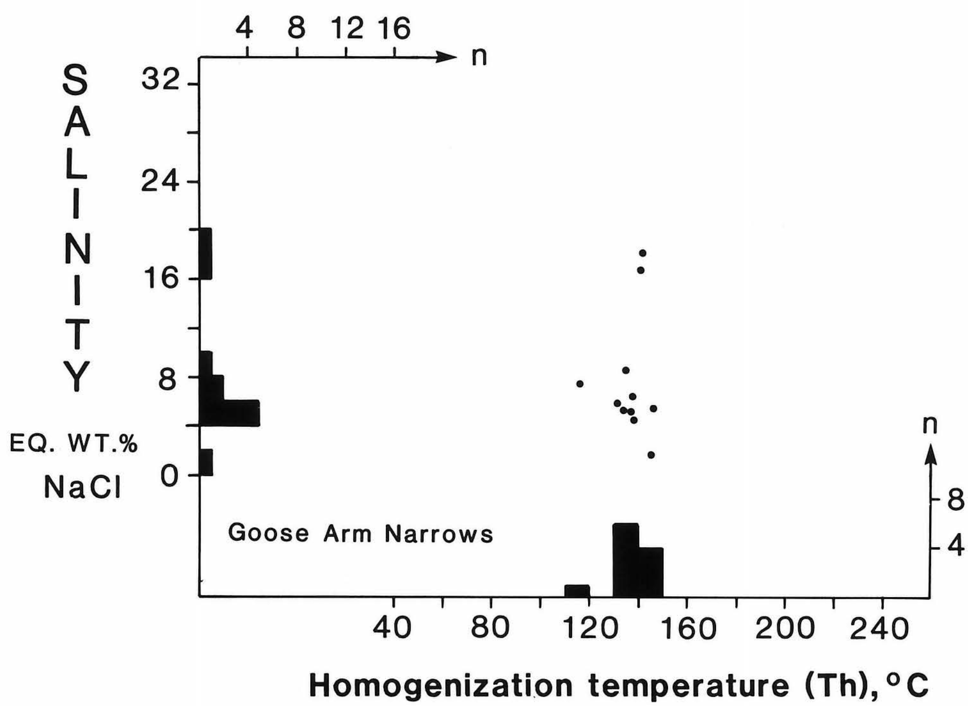

Figure D-7. Sphalerite fluid inclusion salinity and homogenization temperatures, Goose Arm Narrows.

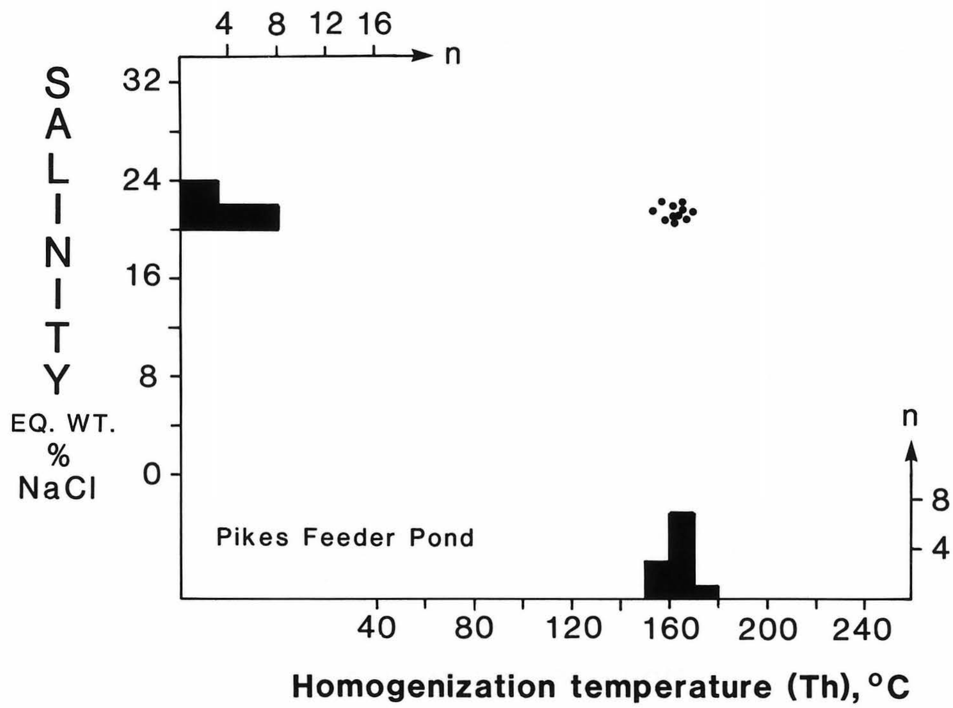

Figure D-8. Sphalerite fluid inclusion salinity and homogenization temperatures, Pikes Feeder Pond.

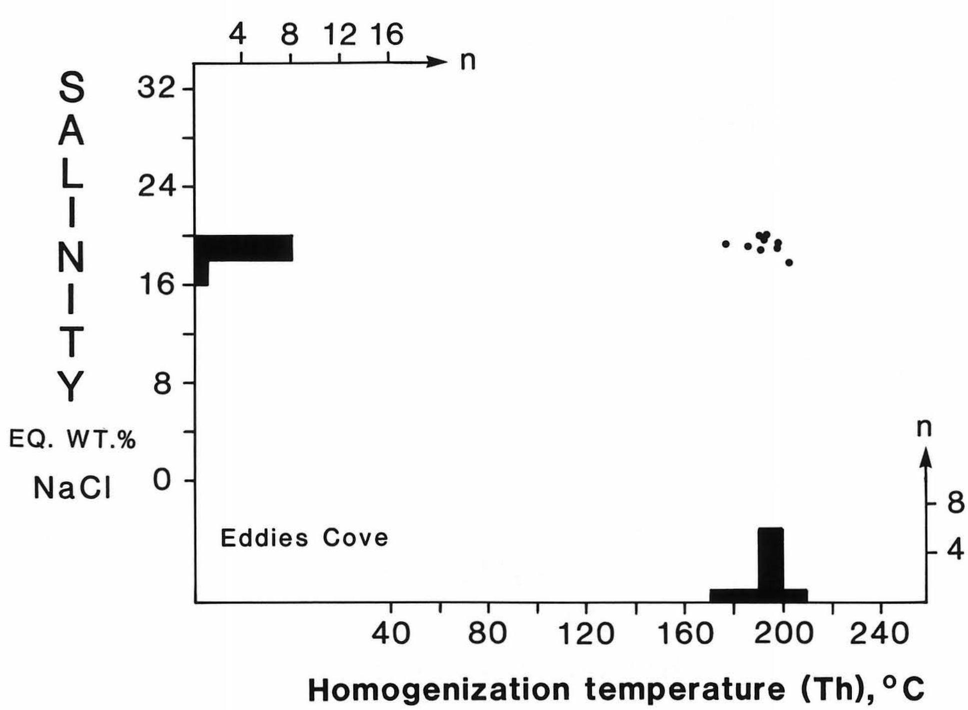

Figure D-9. Sphalerite fluid inclusion salinity and homogenization temperatures, Eddies Cove.

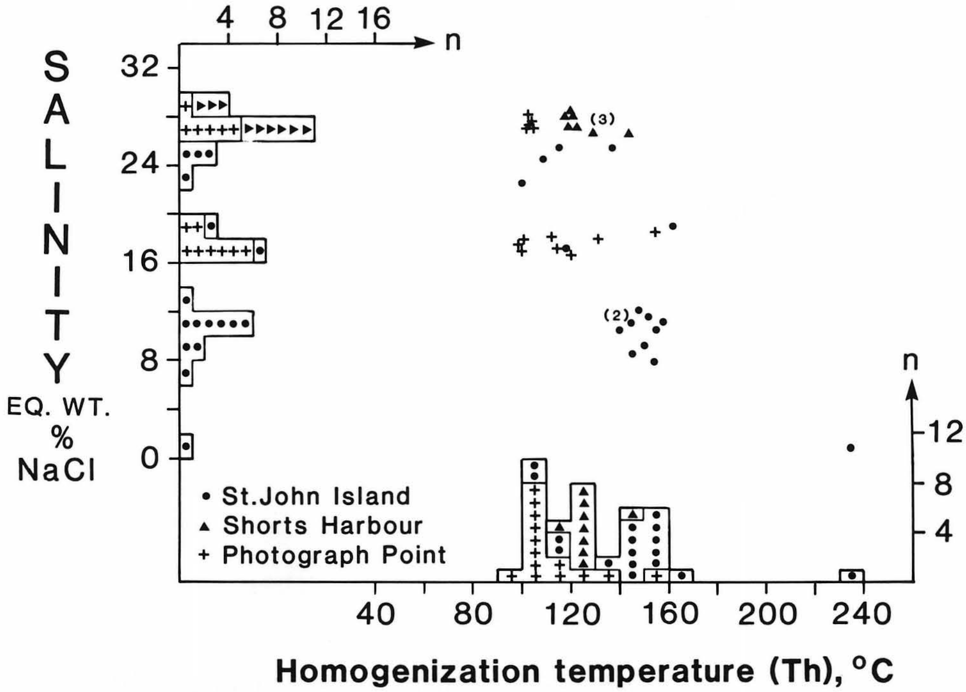

Figure D-10. Sphalerite fluid inclusion salinity and homogenization temperatures, St. John Island, South Cliff, Shorts Harbour, and Photograph Point.

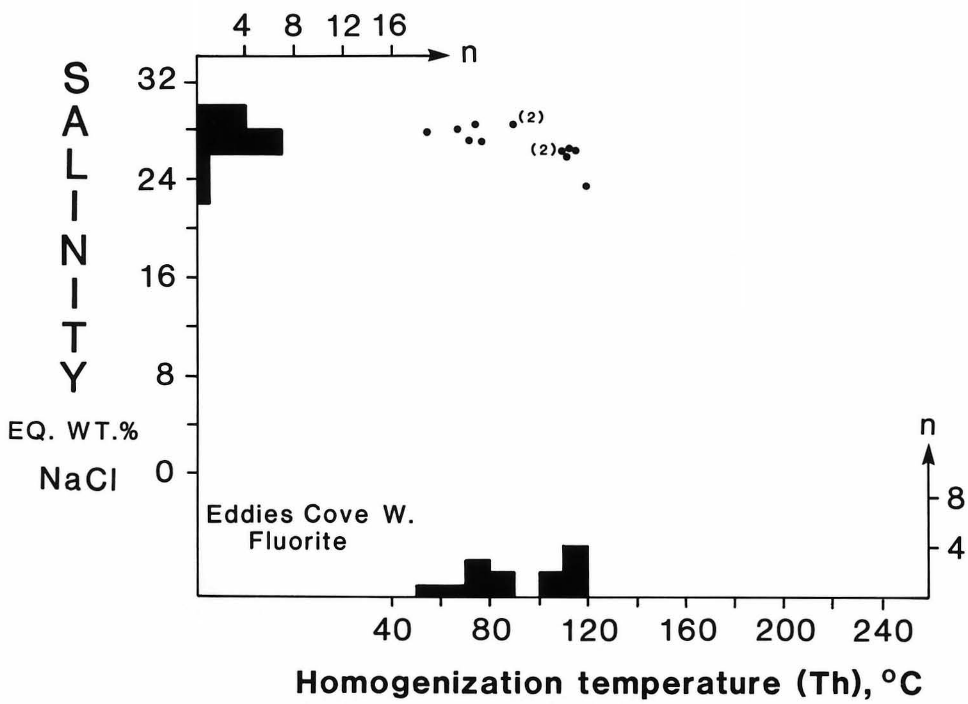

Figure D-11. Fluorite fluid inclusion salinity and homogenization temperatures, Eddies Cove West.