51.

GEOCHEMISTRY OF COPPER, LEAD, AND ZINC MINERALIZATION IN PROTEROZOIC ROCKS NEAR GILLESPIE LAKE, YUKON

Project 770025

W.D. Goodfellow
Resource Geophysics and Geochemistry Division

Goodfellow, W.D., Geochemistry of copper, lead, and zinc mineralization in Proterozoic rocks near Gillespie Lake, Yukon; in Current Research, Part A, Geol. Surv. Can., Paper 79-1A, p. 333-348, 1979.

Abstract

Interpretive studies of intensive and extensive coincident Pb, Zn and Cu sediment anomalies in streams intersecting Middle Proterozoic carbonate and clastic rocks located east of Gillespie Lake revealed the presence of previously unrecorded base metal mineralization. The mineralization occurs in a variety of geological settings including stratabound sphalerite finely dispersed throughout stromatolitic rocks, coarse grained sphalerite and galena occurring in fractures and fault-related breccias, and chalcopyrite disseminated in dolostone and intersecting fractures.

Although the stratigraphical and lateral dimensions of the mineralization are not known, the stream sediment and water geochemistry suggests that this area and other areas underlain by rocks of similar age and composition warrant further evaluation from an economic point of view.

Introduction

Regional stream sediment geochemical data released for the Nadaleen River (106C) and Nash Creek (106D) map areas (Geological Survey of Canada, 1978) showed extensive and intensive Pb, Zn and Ag anomalies in areas underlain primarily by Proterozoic carbonate and clastic rocks. In order to ascertain whether these geochemical anomalies reflected bedrock mineralization or were due to fortuitous environmental factors, one area located immediately east of Gillespie Lake was selected for detailed investigations. Rock exposures were examined and drainage systems were traversed to determine whether or not base metal mineralization was present and, if present, to characterize the type and style of mineralization. The physical and chemical factors affecting the availability of metals from the underlying rocks and the subsequent transport and deposition of metals in the drainage system were investigated by determining the chemistry of sediments and waters collected from streams intersecting the area.

Physiography and Geology

The area of study is located in the central-eastern Yukon Territory (Fig. 51.1) and forms part of the Rackla Ranges which are situated in the Wernecke Mountains. The geomorphology of the area has been affected strongly by several successive advances and retreats of glaciers during Pleistocene time. The Wernecke Mountains are characterized by jagged commonly fault-bounded ridges which are separated by deeply incised U-shaped stream valleys. Rock glaciers present in some of the cirques are a common feature on north-facing slopes.

Glacial deposits, that have been described by Ricker (1974) for the Nadaleen River map area, are composed of terminal moraines, ground moraines, drumlins and lateral and medial moraines. However, in the area of detailed study (Fig. 51.2), the surficial geology is represented by recent nonglacial deposits comprising alluvial sands and gravels and extensive talus.

The Nadaleen River map area has a continental climate characterized by low precipitation and broad temperature ranges. Most streams are fed by snow and ice melt and from groundwater. The Bonnet Plume River is the repository of thick alluvial fans comprising gravel and sand deposited during the heavy spring runoff. Silt-size stream sediment was difficult to obtain in torrential streams and where the underlying carbonates contributed very little fine sediment to the stream system.

The area of study is situated in the zone of discontinuous permafrost as outlined by Brown (1967). In general, the south-facing slopes are relatively free of permafrost. Solifluction of varying intensities has affected most slopes (Ricker, 1974).

The first extensive geological investigation of the area was carried out by Wheeler (1954). The area was subsequently remapped by Blusson and Tempelman-Kluit (1970) and Blusson (1974a, b). Recently, stratigraphic sections through Middle Proterozoic sedimentary rocks have been measured and described by Bell and Delaney (1977) and Delaney (1978).

The geology in the area of detailed investigation (Fig. 51.2) comprises a thick sequence of Middle and Upper Proterozoic carbonate and clastic rocks and minor mafic volcanic flows at the base of the "Pinguicula Group". The Middle Proterozoic rocks, referred to as the Wernecke Assemblage (Eisbacher, 1978) and alternatively as the Wernecke Supergroup (Delaney, 1978) have been subdividied into three major groups which are informally named from oldest to youngest the "Fairchild Lake Group", the "Quartet Group" and the "Gillespie Lake Group" (Fig. 51.3 and 51.4). The "Fairchild Lake Group" is composed of a thick sequence of light grey weathering, thinly bedded to laminated siltstone, slate, argillite with some interbedded carbonate. Rocks of this group have, in general, been regionally metamorphosed to the lower greenschist facies and locally metamorphosed to phyllites and chloritoid and garnet-chloritoid schist around breccia complexes. The "Quartet Group", which overlies the "Fairchild Lake Group" is composed of dark grey weathering interbedded siltstone, slate, argillite, sandstone and dolostone. The contact relation between the "Fairchild Lake Group" and "Quarter Group" is unclear because it is masked by structural complications (Young et al., in press). The "Gillespie Lake Group", which is in transitional contact with the underlying "Quartet Group", is composed of a thick (more than 4 km, Delaney, 1978) sequence of buff to orange to locally grey weathering dolostone with minor siltstone and sandstone. In the Gillespie Lake area, representative stratigraphic sections contain parallel laminated to wavy bedded dolosiltite which contain bioherms and biostromes of both bifurcating and isolated columnar stromatolites as well as algal debris (Delaney, 1978).

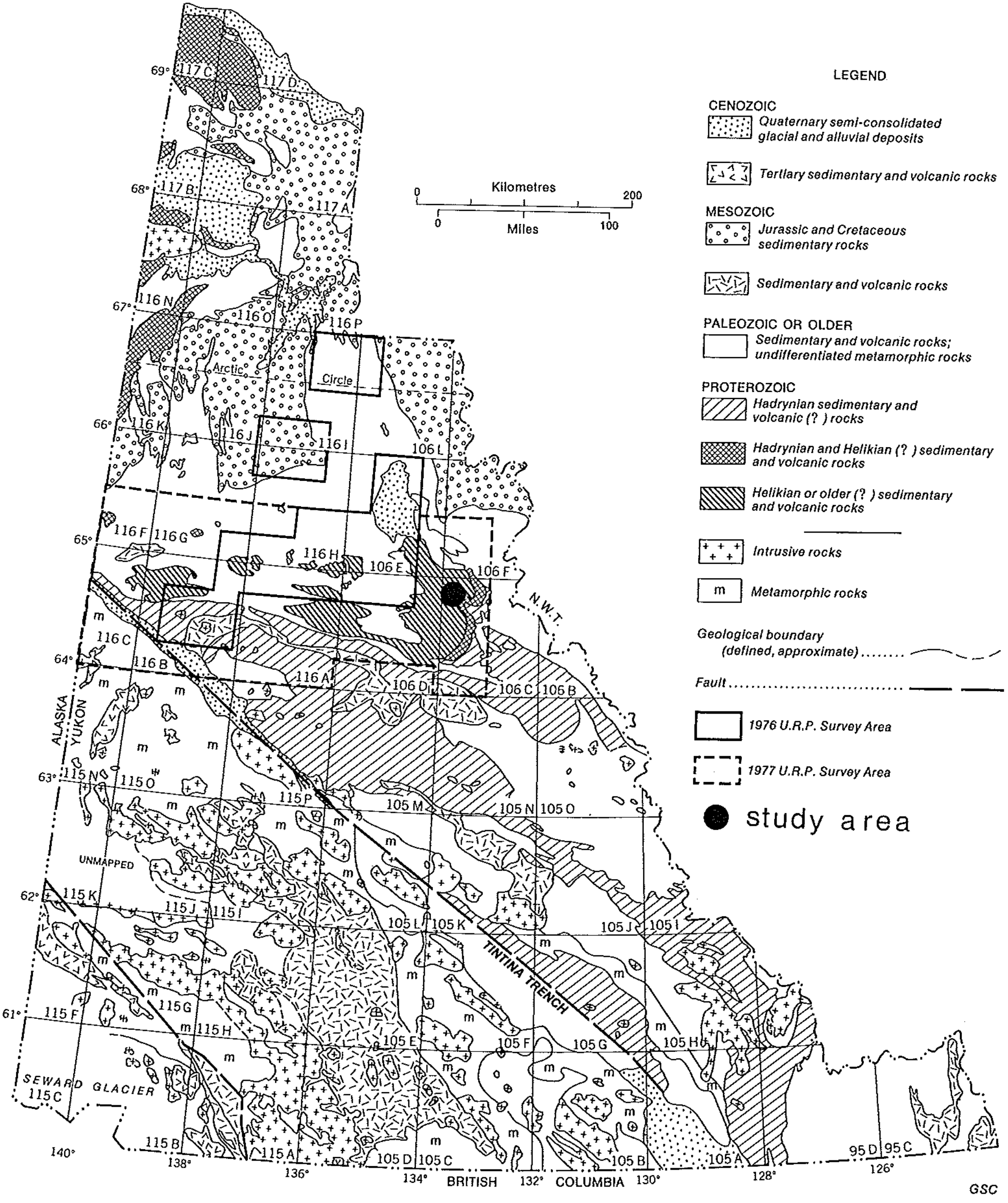


Figure 51.1. General geology of the Yukon showing the location of the study area (after Findlay, 1975).

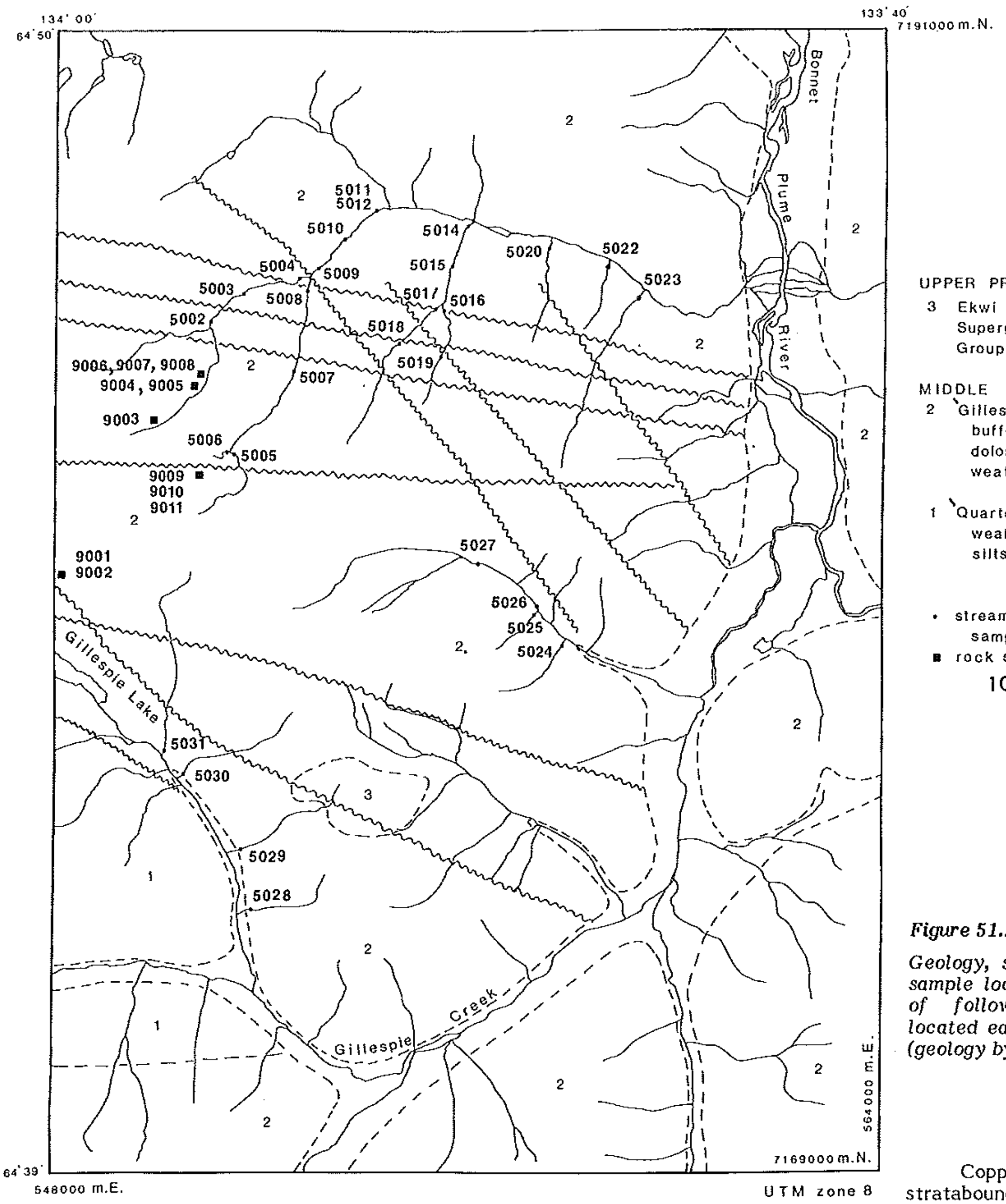


Figure 51.2

Geology, stream drainage and sample locations for the area of follow-up investigations located east of Gillespie Lake (geology by Delaney, 1978).

The structure of Proterozoic rocks in the Wernecke Mountains is characterized by open folds whose axes trend west-northwest. In the Gillespie Lake area (Fig. 51.2) high angle normal faults with two preferred directions (azimuth 095 and 140) and varying vertical displacements are common. Associated with these faults are extensive breccias, some of which host Pb and Zn mineralization.

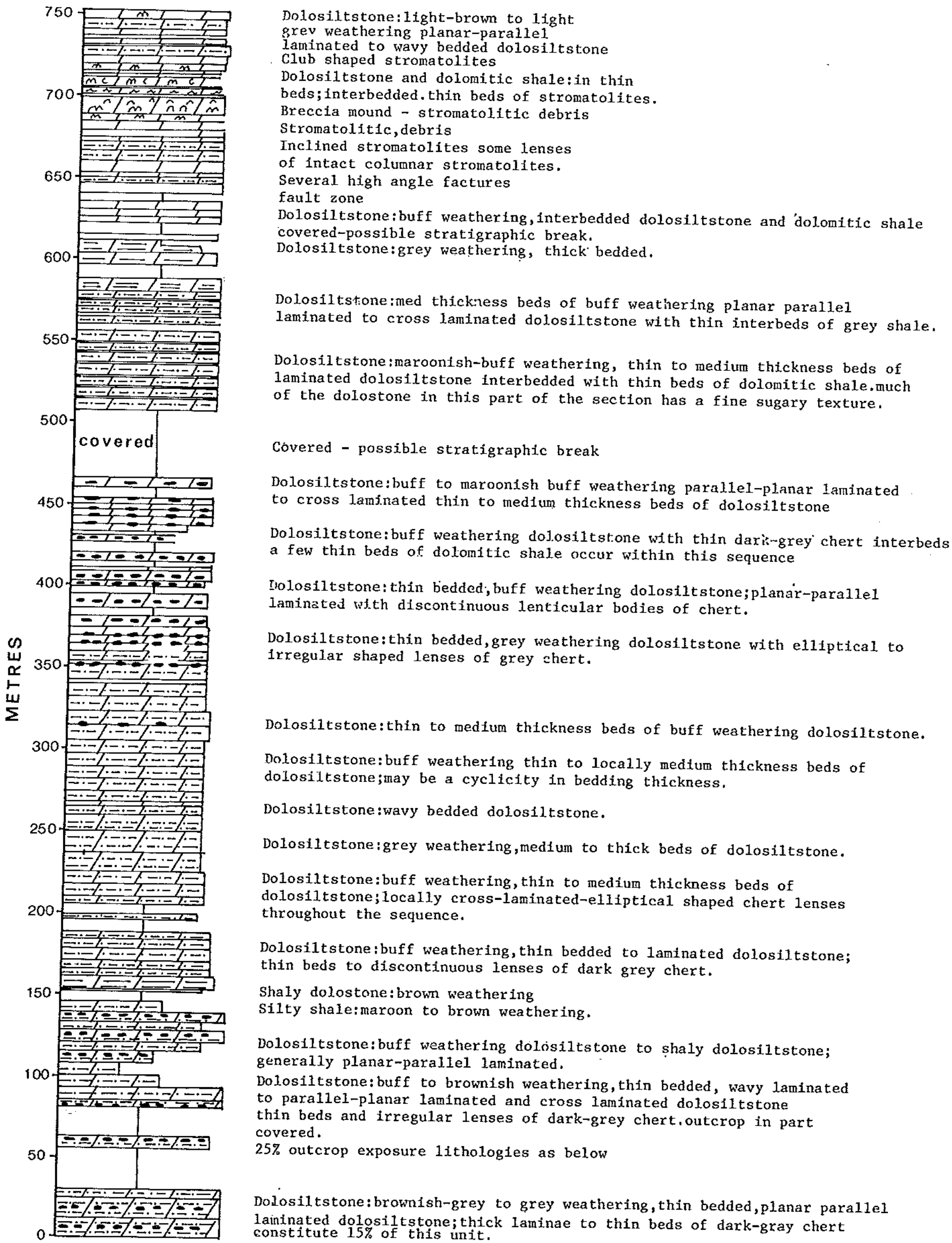
Mineralization

Minor showings of Pb-Zn mineralization occurring mostly in fractures intersecting the "Gillespie Lake Group" of rocks have been previously observed by Green (1972) and Delaney (1978). From follow-up investigations in the area east of Gillespie Lake (Fig. 51.2), Cu, Pb and Zn mineralization was discovered to occur in a variety of geological settings.

Copper can occur as stratabound finely disseminated chalcopyrite in brown weathering light grey dolosiltstone (Fig. 51.5.1). In other samples, fracture surfaces intersecting laminated stromatolite are covered with a thick coating of malachite (Fig. 51.5.2). Chalcopyrite is also present as disseminations in fractures through grey dolostone (Fig. 51.5.3) associated with a small fault zone.

Zinc occurs as stratabound sphalerite disseminated throughout brown dolosiltstone that is rhythmically interbedded with pale green stromatolite and recrystallized coarser grained white curved dolomite (Fig. 51.5.4). In sample 789008, it is disseminated throughout laminated cream coloured stromatolite (Fig. 51.5.2). Zinc is also present as massive brown sphalerite associated with pyrite filling open space in brecciated stromatolite (Fig. 51.5.6). Some of the white recrystallized dolomite appears to postdate the sulphide mineralization.

SECTION GD-106D-77-4



Dolosiltstone:light-brown to light grev weathering planar-parallel laminated to wavy bedded dolosiltstone

Club shaped stromatolites

Dolosiltstone and dolomitic shale:in thin beds;interbedded.thin beds of stromatolites.

Breccia mound - stromatolitic debris

Stromatolitic,debris

Inclined stromatolites some lenses of intact columnar stromatolites.

Several high angle factures

fault zone

Dolosiltstone:buff weathering,interbedded dolosiltstone and dolomitic shale

covered-possible stratigraphic break.

Dolosiltstone:grey weathering, thick bedded.

Dolosiltstone:med thickness beds of buff weathering planar parallel laminated to cross laminated dolosiltstone with thin interbeds of grey shale.

Dolosiltstone:maroonish-buff weathering, thin to medium thickness beds of laminated dolosiltstone interbedded with thin beds of dolomitic shale.much of the dolostone in this part of the section has a fine sugary texture.

Covered - possible stratigraphic break

Dolosiltstone:buff to maroonish buff weathering parallel-planar laminated to cross laminated thin to medium thickness beds of dolosiltstone

Dolosiltstone:buff weathering dolosiltstone with thin dark-grey chert interbeds a few thin beds of dolomitic shale occur within this sequence

Dolosiltstone:thin bedded,buff weathering dolosiltstone;planar-parallel laminated with discontinuous lenticular bodies of chert.

Dolosiltstone:thin bedded,grey weathering dolosiltstone with elliptical to irregular shaped lenses of grey chert.

Dolosiltstone:thin to medium thickness beds of buff weathering dolosiltstone.

Dolosiltstone:buff weathering thin to locally medium thickness beds of dolosiltstone;may be a cyclicity in bedding thickness.

Dolosiltstone:wavy bedded dolosiltstone.

Dolosiltstone:grey weathering,medium to thick beds of dolosiltstone.

Dolosiltstone:buff weathering,thin to medium thickness beds of dolosiltstone;locally cross-laminated-elliptical shaped chert lenses throughout the sequence.

Dolosiltstone:buff weathering,thin bedded to laminated dolosiltstone; thin beds to discontinuous lenses of dark grey chert.

Shaly dolostone:brown weathering

Silty shale:maroon to brown weathering.

Dolosiltstone:buff weathering dolosiltstone to shaly dolosiltstone; generally planar-parallel laminated.

Dolosiltstone:buff to brownish weathering,thin bedded, wavy laminated to parallel-planar laminated and cross laminated dolosiltstone thin beds and irregular lenses of dark-grey chert.outcrop in part covered.

25% outcrop exposure lithologies as below

Dolosiltstone:brownish-grey to grey weathering,thin bedded,planar parallel laminated dolosiltstone;thick laminae to thin beds of dark-gray chert constitute 15% of this unit.

Figure 51.3. Stratigraphic section through the "Gillespie Lake Group" located north of Gillespie Lake (after Delaney, 1978).

Proterozoic stratigraphy in the vicinity of Fairchild Lake, Y.T.

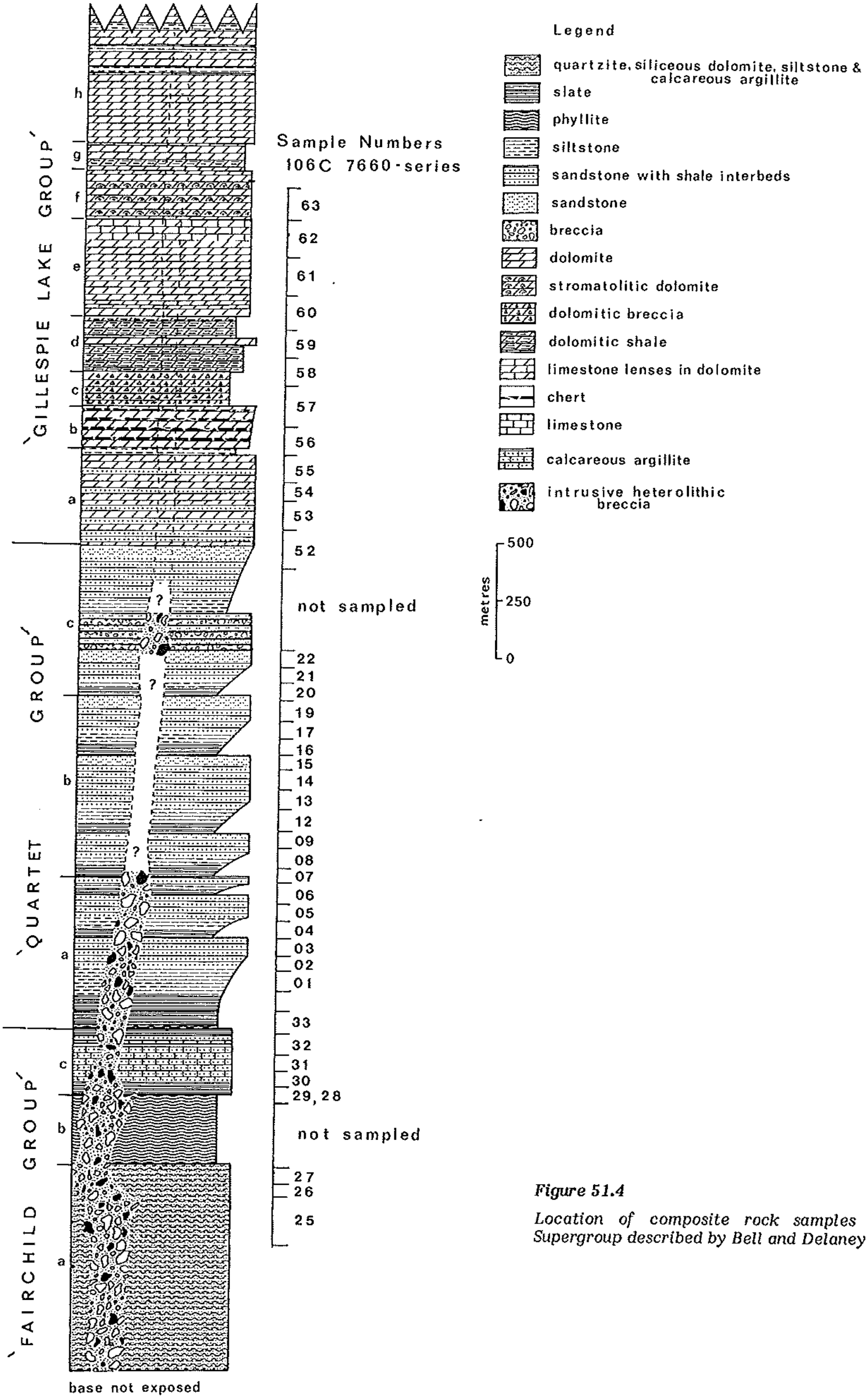
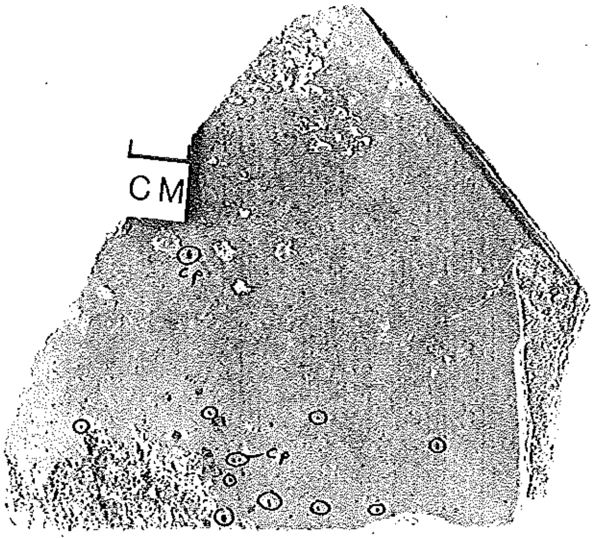
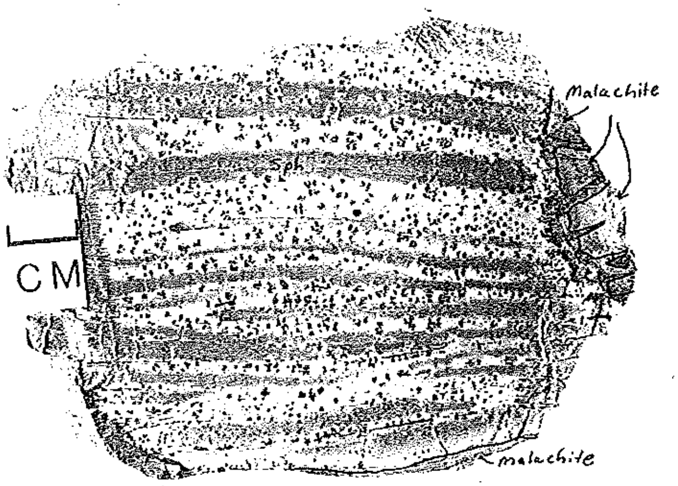


Figure 51.4

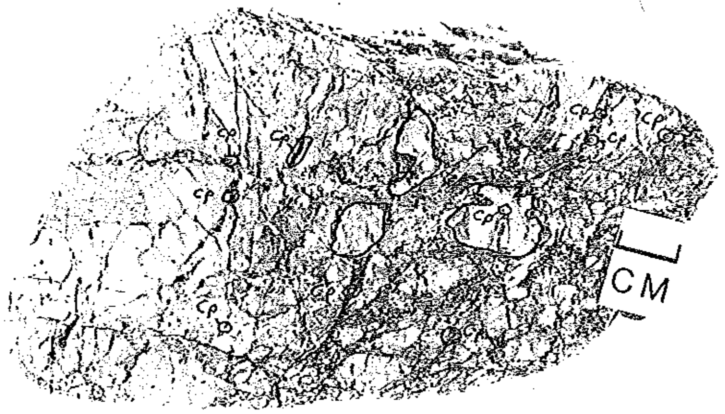
Location of composite rock samples from the Wernecke Supergroup described by Bell and Delaney (1977).


CM
Cp
Cp

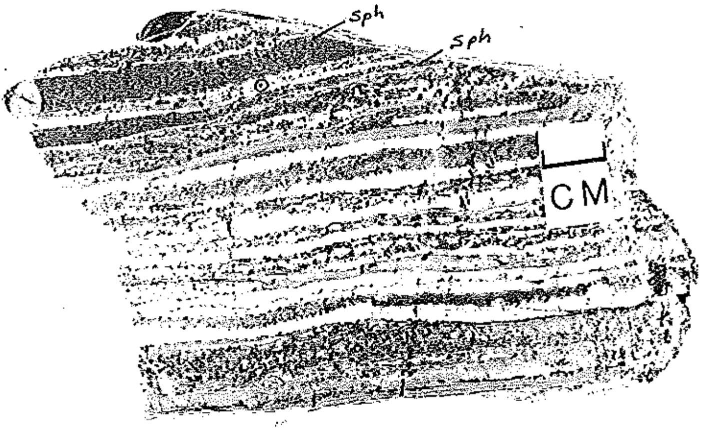
1


Malachite
Sph
CM
malachite

2


Cp
Cp
Cp
Cp
Cp
Cp
Cp
Cp
Cp
CM

3


Sph
Sph
CM

4


Gn
CM
Gn

5


Sph
Py
Py
CM
Sph
Sph
Sph

6

Table 51.1

Chemistry of rocks collected from the "Gillespie Lake Group"

SAMPLE NO.	Zn	Cu	Pb	Ni	Co	Ag	Mn	Fe**	Mo	V	Cd	ROCK TYPE
106C 789001	26	151	60	45	25	0.6	1084	12.92	2*	9	1*	Pyritic Quartzite
02	20	6	1	10	2	0.2*	541	1.54	2*	19	1*	Grey Dolostone
03	41	28	58	63	21	0.9	2139	5.99	2*	9	1*	Dolostone Breccia
04	898	12	18500	10	9	3.1	3276	1.74	2*	9	4	Dolosiltstone and Dolomicrite
05	1766	10	1359	6	9	0.7	3808	1.85	2*	9	10	Dolosiltstone and Dolomicrite
06	54	666	1	39	10	0.2*	1462	2.04	2*	24	1*	Light Grey Dolostone
07	55	23	14	33	6	0.2*	470	2.05	2*	57	1*	Light Grey Dolostone
08	38000	26500	118	19	21	0.2*	4441	1.21	2*	19	42	Stromatolite
09	98	1668	20	49	16	0.2*	1585	2.93	2*	30	1*	Dolosiltstone Breccia
10	7420	29	6	10	5	0.2	1789	1.68	2*	19	12	Dolostone Breccia
106C 789011	295000	41	335	72	6	36.9	213	4.12	4	5	1770	Stromatolite Breccia

* Lower detection limit

** Fe expressed in %; all other elements express in ppm

Lead most commonly occurs as coarse grained galena accompanying recrystallized white dolomite filling fractures intersecting in this case rhythmically interbedded dolosiltstone, stromatolite and white dolomite (Fig. 51.5.5). From chemical analysis, most of the galena is relatively low in Ag.

Most of the stratabound sphalerite is associated with bioherms and biostromes that have been described by Delaney (1978) to occur in the upper sections of the "Gillespie Lake Group" of rocks located just north of Gillespie Lake (Fig. 51.3). The chalcopyrite, however, occurs below the stromatolitic rocks in brown weathering grey dolostone. The structurally controlled mineralization appears more widely distributed occurring in faults and fault-related breccias intersecting lower dolostones as well as stromatolites. The lateral dimensions and stratigraphic thicknesses of zones of base metal mineralization is not known although the surficial geochemistry suggests they could be extensive.

Sample Preparation and Analysis

Rock samples weighing approximately 2 kg were crushed, pulverized and ground to minus -150 mesh (100 μ) and analyzed for Zn, Cu, Pb, Ni, Co, Ag, Mn, Fe, Mo, V, and Cd by atomic absorption spectrophotometry after decomposition with a strong HF-$HClO_4$-HNO_3 acid mixture. Uranium was determined by both fluorometry (Smith and Lynch, 1969) and a delayed neutron activation procedure developed by Atomic Energy Canada Limited (Boulanger et al., 1975). Fluorine was determined by ion-selective electrode following sample fusion with sodium carbonate-zinc oxide flux. Major and minor element oxides were determined by X.R.F. on a glass pellet formed by fusing lg of sample with lithium metaborate. CO_2 and S were determined by the standard Leco furnace combustion method.

Stream sediments were air-dried, disaggregated, sieved to minus -80 mesh (177 μ) and analyzed for Zn, Cu, Pb, Ni, Co, Ag, Mn, Fe, Mo, V and Cd by atomic absorption spectrophotometry following a strong HF-$HCLO_4$-HNO_3 decomposition.

Stream waters were collected unfiltered and analyzed for Zn and Cu by atomic absorption spectrophotometry, F by ion-selective electrode and HCO_3^- by titration methods. Copper is not tabulated since it was below the detection limit of 1 ppb.

Rock Geochemistry

The trace and minor element chemistry of "grab" samples collected from both mineralized and unmineralized rocks from the "Gillespie Lake Group" is presented in Table 51.1. The sample locations are shown in Figure 51.2. In general, Cu contents range up to 2.65 per cent in one sample (sample no. 789006) of rhythmically interbedded stromatolite covered with a thick coating of malachite. The dolostone hosting what appears to be stratabound disseminated chalcopyrite, however, contains 0.067 per cent Cu. The zinc content of mineralized samples shows tremendous variation depending on the style of mineralization and ranges up to 3.80 per cent in laminated stromatolite and 29.5 per cent in brecciated stromatolite. Cadmium which substitutes readily for Zn in samples containing sphalerite grades up to 1770 ppm in sample 789011 containing 29.5 per cent Zn. The association of Ag with high Pb in sample 789004 in one case and high Zn in sample 789011 in the other case is less readily explained. The mineralized samples contain generally higher contents of Fe reflecting the presence of pyrite and siderite which are present in most of the rocks hosting sphalerite and galena.

In order to compare the chemistry of mineralized rocks from the "Gillespie Lake Group" with stratigraphically equivalent unmineralized rocks, whole rock and trace element data for an unmineralized stratigraphic section (Fig. 51.4) of the "Wernecke Supergroup" measured and described by Bell and Delaney (1977) are presented in Table 51.2 and 51.3. The carbonate rocks (mostly dolosiltstone) comprising the "Gillespie Lake Group" are low in all of the trace elements determined. The whole rock chemistry for the "Gillespie Lake Group" is controlled primarily by the relative proportion of carbonate (mostly dolomite) and silicate (mostly quartz)

Figure 51.5 (opposite)

1. *Light grey dolostone hosting stratabound disseminated chalcopyrite. Sample 789006.*
2. *Laminated stromatolite hosting malachite along fracture surfaces and stratabound sphalerite. Dark brown manganese with a dendritic habit disseminated throughout. Sample 789008.*
3. *Brecciated light grey-brown dolosiltstone hosting disseminated chalcopyrite along fractures. Sample 789009.*
4. *Rhythmically interbedded dolosiltstone, stromatolite lamina and white recrystallized dolomite hosting finely dispersed sphalerite associated with the dolosiltstone. Sample 789005.*
5. *Coarse grained galena associated with recrystallized dolomite in fracture intersecting sample 789005.*
6. *Dark grey brecciated stromatolite hosting coarse grained brown sphalerite and pyrite. White recrystallized dolomite also forms part of the matrix. Sample 789011.*

Table 51.2

Major element oxides in Proterozoic sedimentary rocks, Yukon

Map Sheet	No.	SiO_2	Al_2O_3	TiO_2	FeO	Fe_2O_3	CaO	MgO	K_2O	Na_2O	P_2O_5	MnO	CO_2	H_2O	S	
106C	766001	59.1	18.1	0.58	1.7	2.1	2.93	1.8	6.18	0.0	0.14	0.16	5.0	2.9	0.16	'QUARTET GROUP'
106C	766002	72.0	6.4	0.26	1.7	0.1	4.54	3.3	1.01	1.8	0.09	0.27	7.1	1.1	0.34	
106C	766003	75.3	12.7	0.60	3.1	0.3	0.06	1.1	2.49	1.8	0.09	0.05	0.0	2.5	0.25	
106C	766004	91.0	2.1	0.08	1.5	3.4	0.13	0.31	0.21	0.7	0.13	0.11	0.0	0.9	0.25	
106C	766005	80.8	9.6	0.33	3.2	0.0	0.07	0.81	1.26	1.7	0.07	0.03	0.0	1.8	0.12	
106C	766006	82.1	10.3	0.30	0.3	0.5	0.62	0.15	0.88	3.5	0.08	0.11	0.4	0.9	0.16	
106C	766007	82.7	8.5	0.10	0.1	2.0	0.42	0.43	2.37	0.9	0.09	0.19	0.5	1.3	0.27	
106C	766008	82.1	6.7	0.17	0.1	4.4	1.39	0.21	2.24	0.2	1.20	0.12	0.0	1.3	0.11	
106C	766009	87.1	5.1	0.08	0.8	2.4	0.17	1.0	1.17	0.0	0.10	0.22	0.1	1.8	0.07	
106C	766012	75.2	11.1	0.36	4.3	0.2	0.81	1.0	0.83	3.0	0.08	0.19	1.4	2.0	0.27	
106C	766013	72.0	15.7	0.49	2.1	0.1	0.05	0.68	3.53	2.7	0.08	0.01	0.0	2.4	0.25	
106C	766014	74.4	14.2	0.46	1.7	1.0	0.12	0.63	3.26	2.5	0.08	0.04	0.0	2.0	0.24	
106C	766015	67.5	19.2	0.57	2.3	0.4	0.02	0.75	5.15	1.0	0.10	0.01	0.0	3.0	0.05	
106C	766016	70.7	15.5	0.55	2.6	1.2	0.21	0.90	3.76	2.4	0.08	0.05	0.1	2.3	0.21	
106C	766017	75.0	12.1	0.30	3.8	0.4	0.26	0.81	1.59	3.8	0.08	0.05	0.1	1.8	0.25	
106C	766019	73.1	15.1	0.44	1.9	0.6	0.03	0.79	4.06	1.7	0.09	0.03	0.0	1.9	0.09	
106C	766020	80.6	10.8	0.27	1.4	0.2	0.16	0.71	2.12	2.1	0.08	0.04	0.0	1.5	0.11	
106C	766021	72.2	14.2	0.53	3.3	0.5	0.08	1.33	3.82	1.3	0.11	0.03	0.0	2.6	0.22	
106C	766022	67.1	17.5	0.70	3.1	1.3	0.05	1.22	4.86	1.2	0.07	0.03	0.0	3.0	0.08	
106C	766025	39.2	8.9	0.33	2.3	0.4	21.7	0.79	2.39	0.0	0.20	1.40	21.6	1.3	0.24	'FAIRCHILD GROUP'
106C	766026	61.1	19.3	0.75	0.6	0.8	0.98	1.10	5.93	4.9	0.19	0.03	0.6	1.3	0.23	
106C	766027	48.1	14.0	0.32	0.2	0.1	7.20	0.36	9.24	1.6	0.50	0.12	6.6	0.5	0.21	
106C	766028	63.0	14.0	0.58	3.1	1.0	7.45	0.90	3.89	0.6	0.13	0.09	0.4	2.4	0.21	
106C	766029	70.6	10.1	0.38	4.0	0.5	2.70	2.31	2.19	0.2	0.27	0.15	4.4	2.1	0.11	
106C	766030	65.7	5.7	0.19	2.3	0.0	7.60	4.22	1.52	0.2	0.09	0.32	10.7	0.9	0.23	
106C	766031	69.4	6.3	0.10	0.8	0.0	7.90	2.70	2.90	0.2	0.10	0.60	9.4	0.7	0.31	
106C	766032	65.8	18.6	0.74	3.9	0.1	0.14	2.40	4.10	0.4	0.11	0.04	0.0	3.4	0.05	
106C	766033	64.3	18.6	0.73	0.0	4.1	0.19	2.40	3.66	1.4	0.17	0.06	0.0	3.7	0.21	
106C	766052	69.9	14.7	0.60	2.3	0.9	0.33	2.5	4.5	0.7	0.09	0.03	0.4	3.2	0.23	
106C	766053	73.1	13.5	0.52	2.1	0.3	0.06	2.2	4.8	0.6	0.10	0.01	0.0	2.6	0.19	'GILLESPIE LAKE GROUP'
106C	766054	81.2	9.7	0.35	1.3	0.4	0.03	1.1	4.1	0.0	0.06	0.00	0.0	1.6	0.08	
106C	766055	73.1	13.4	0.53	2.2	0.1	0.52	2.4	4.7	0.1	0.09	0.03	0.7	2.3	0.09	
106C	766056	67.0	7.5	0.23	2.1	0.1	5.0	3.3	3.3	0.3	0.09	0.37	9.6	1.0	0.20	
106C	766057	56.0	5.0	0.15	2.5	0.0	9.2	6.0	2.4	0.0	0.04	0.35	17.5	0.8	0.09	
106C	766058	38.0	5.0	0.20	3.2	0.0	14.8	9.0	2.4	0.0	0.08	0.45	26.5	0.7	0.04	
106C	766059	60.0	7.0	0.28	2.0	0.1	6.5	5.2	3.0	0.4	0.09	0.18	13.4	1.7	0.19	
106C	766060	31.0	4.0	0.12	1.6	0.0	18.6	13.0	1.2	0.0	0.05	0.17	29.3	0.9	0.08	
106C	766061	15.0	0.6	0.00	1.7	0.0	24.7	17.0	0.1	0.3	0.4	0.26	39.5	0.3	0.23	
106C	766062	15.0	6.0	0.26	3.8	1.0	12.0	9.0	2.7	0.8	0.18	0.60	25.0	1.8	0.21	
106C	766063	33.0	5.8	0.11	4.4	0.0	16.0	10.6	3.1	0.5	0.07	0.56	24.0	1.7	0.32	

Note: All element oxides expressed in %

Table 51.3

Minor and trace elements in Proterozoic sedimentary rocks, Yukon

Map Sample No.	Zn	Cu	Pb	Ni	Co	Ag	U(F)	U(NA)	F	
106C 766001	11	149	2	20	10	0.2	2.0	3.5	915	'QUARTET GROUP'
106C 766002	12	1230	2	7	10	0.2	4.8	7.5	451	
106C 766003	47	17	15	24	15	0.2	2.6	3.8	405	
106C 766004	26	16	15	3	7	0.8	18.4	21.9	93	
106C 766005	42	12	2	20	11	0.7	1.6	2.1	150	
106C 766006	9	8	12	7	10	0.5	1.5	2.1	73	
106C 766007	39	17	27	10	13	0.4	1.2	1.3	183	
106C 766008	48	10	34	7	14	0.4	2.2	2.4	405	
106C 766009	25	6	14	5	8	0.2	1.3	1.6	170	
106C 766012	68	14	11	12	12	0.2	2.6	4.2	162	
106C 766013	42	5	2	7	10	0.2	3.6	3.7	328	
106C 766014	43	14	15	8	11	0.2	2.8	3.3	279	
106C 766015	35	7	9	11	10	0.2	8.8	11.5	572	
106C 766016	44	7	8	13	13	0.2	2.4	3.4	370	
106C 766017	55	12	18	13	12	2.3	2.0	3.2	154	
106C 766019	18	17	2	16	12	0.2	2.6	3.5	314	
106C 766020	21	8	2	10	10	0.2	4.4	4.9	160	
106C 766021	30	22	2	16	13	0.2	2.0	3.6	470	
106C 766022	37	9	2	17	13	1.6	4.8	6.2	493	
106C 766025	11	45	15	22	18	0.2	0.7	3.2	230	'FAIRCHILD GROUP'
106C 766026	12	890	15	17	11	0.2	40.0	45.2	900	
106C 766027	10	38	2	4	5	0.2	1.2	1.5	154	
106C 766028	15	12	2	19	24	0.2	1.5	2.9	370	
106C 766029	19	16	2	10	10	0.5	14.0	1.6	450	
106C 766030	20	29	2	10	7	0.8	3.8	4.3	314	
106C 766031	8	7	2	5	1	0.2	2.6	2.0	341	
106C 766032	58	3	8	28	12	0.2	2.4	3.3	470	
106C 766033	58	3	2	7	8	0.2	8.8	11.6	470	
106C 766052	18	10	2	20	11	0.2	1.6	2.8	660	
106C 766053	13	10	2	11	7	0.2	3.2	5.0	425	'GILLESPIE LAKE GROUP'
106C 766054	11	20	8	11	6	0.2	2.0	3.0	380	
106C 766055	12	13	4	13	7	0.2	2.4	3.1	456	
106C 766056	10	22	2	6	8	0.2	10.4	2.1	271	
106C 766057	10	7	8	5	4	0.2	0.7	1.7	226	
106C 766058	12	5	7	6	4	0.2	0.7	1.7	261	
106C 766059	12	6	4	13	5	0.2	1.1	1.9	195	
106C 766060	11	5	2	5	3	0.2	1.3	1.1	271	
106C 766061	12	5	2	2	2	0.2	1.2	0.6	982	
106C 766062	26	6	7	8	4	0.2	1.1	2.0	665	
106C 766063	34	11	8	6	4	0.2	1.2	2.5	1065	

Note: All elements expressed in ppm.

minerals present. Although samples 766062 and 766063 represent composite samples of stromatolitic dolomite (Fig. 51.4), there is only a minor chemical indication of an organic component from the higher phosphorus content of sample 766062. Most of the iron, which is in the Fe^{+2} oxidation state, is present as siderite and pyrite.

The "Fairchild Lake Group" and the "Quartet Group" are generally enriched in Cu, Ag, U and occasionally Pb. These enrichments do not include mineralized breccias that contain high contents of U, Cu, Fe, Pb, Co, Mn and, in some breccia complexes, Ag, Mo, F, P, Y, Ce and As. The whole rock and trace element chemistry of the "Quartet Group" and "Fairchild Lake Group" are in most regards very similar with at least two notable differences; rocks of the "Fairchild Lake Group" are generally higher in Mg and lower in Na, possibly reflecting magnesium-alkali metasomatism commonly associated with intrusive breccia complexes.

Stream Sediment and Water Geochemistry

The regional distributions of Pb and Zn in sediments deposited from streams draining the western half of map area 106C and the eastern half of map area 106D are shown by contour plots in Figures 51.6 and 51.7. In general, there is a string of coincident Pb-Zn anomalies that have greater than 500 ppm Pb and greater than 1000 ppm Zn in areas underlain by mostly orange weathering grey, pink and buff fine grained dolomite mapped by Blusson (1974a). These rocks are equivalent to the "Gillespie Lake Group" named and described by Delaney (1978). An examination of the regional geochemical data reveals a close spatial association of high Pb-Zn anomalies with bioherms and biostromes described by Delaney (1978) as forming part of the "Gillespie Lake Group" in the area north and east of Gillespie Lake. This association of Pb and Zn with the presence of stromatolitic rocks in the "Gillespie Lake Group" was confirmed during follow-up investigations carried out east of Gillespie Lake.

Table 51.4

Chemistry of sediments and waters from streams intersecting the "Gillespie Lake Group" of rocks

	STREAM SEDIMENTS											STREAM WATERS				
SAMPLE NO.	Zn	Cu	Pb	Ni	Co	Ag	Mn	Fe	Mo	V	Cd	COND	pH	HCO_3	Zn	F
106C 785002	375	61	47	32	20	0.2	2000	3.75	2*	50	1*	158	7.9	103	0.5*	75
03	281	35	47	21	16	0.2	2237	2.81	2*	42	1*	153	8.1	110	0.5*	68
04	563	43	105	25	15	0.2	1895	2.81	2*	42	1*	164	8.1	115	0.5*	83
05	469	38	165	21	18	0.2	2000	2.96	2*	42	1*	105	7.6	72	0.5*	48
06	406	63	726	26	16	1.2	2895	5.13	2*	62	1*	208	8.2	87	0.5*	58
07	1897	40	300	24	11	0.5	1289	2.96	2*	38	2	181	8.3	100	3.3	58
08	1552	38	347	24	10	1.0	1053	3.90	2*	33	1*	195	8.3	113	7.9	83
09	1897	112	989	29	10	2.5	1474	7.79	2*	28	2	217	8.3	117	9.0	130
10	1983	106	705	27	9	2.5	1700	7.50	2*	24	2	223	8.1	121	9.3	200
11	2112	99	674	26	12	2.2	1605	7.79	2*	28	2	245	8.0	119	9.0	220
12	2069	99	642	26	11	2.0	1632	8.09	4	28	2	244	7.9	11	9.3	230
14	531	25	215	18	8	0.2	800	2.35	4	42	1*	205	8.0	129	5.0	97
15	594	29	165	25	10	0.2	775	2.65	4	66	1*	208	8.3	133	7.1	100
16	531	31	185	25	13	0.4	1053	3.12	4	47	1*	207	8.4	137	3.3	120
17	1336	33	275	26	12	0.8	900	2.81	4	52	1*	205	8.1	116	17.7	125
18	2328	33	453	24	13	0.8	1105	3.12	4	38	2	218	7.9	109	21.1	145
19	772	39	185	28	19	1.0	1316	3.51	4	47	1*	181	8.2	115	0.5*	61
106C 765020	469	48	79	28	6	0.2	1211	2.50	4	57	1*	184	8.3	134	5.0	55
106C 785022	238	26	53	20	8	0.2	875	2.50	2*	57	1*	231	8.3	151	0.5*	50
23	250	33	84	22	9	0.2	925	3.12	2*	66	1*					
24	200	33	47	21	14	0.2	925	3.12	2*	66	1*					
25	772	45	295	31	16	1.0	1895	5.39	2*	28	1*	260	8.3	138	1.7	97
26	619	40	195	29	15	0.5	1816	5.07	2*	47	1*	181	8.1	116	0.5*	100
27	563	57	235	35	18	0.2	1789	4.53	2*	64	1*					
28	219	29	63	24	12	0.2	1289	2.96	2*	74	1*	282	8.0	172	0.5*	65
29	219	31	84	27	12	0.2	1368	3.12	2*	57	1*	257	8.2	160	0.5*	65
30	281	115	115	26	12	1.0	1368	3.75	2*	57	1*	215	7.6	133	0.5*	60
106C 785031	438	33	205	21	9	0.2	1842	3.43	2*	42	1*	223	8.2	125	0.5*	60

* Lower than detection limit

NOTE: all elements determined in stream sediments expressed in ppm except Fe which is expressed in %; elements determined in stream waters expressed in ppb except HCO_3 which is express in ppm; specific conductivity is expressed in micro mhos.

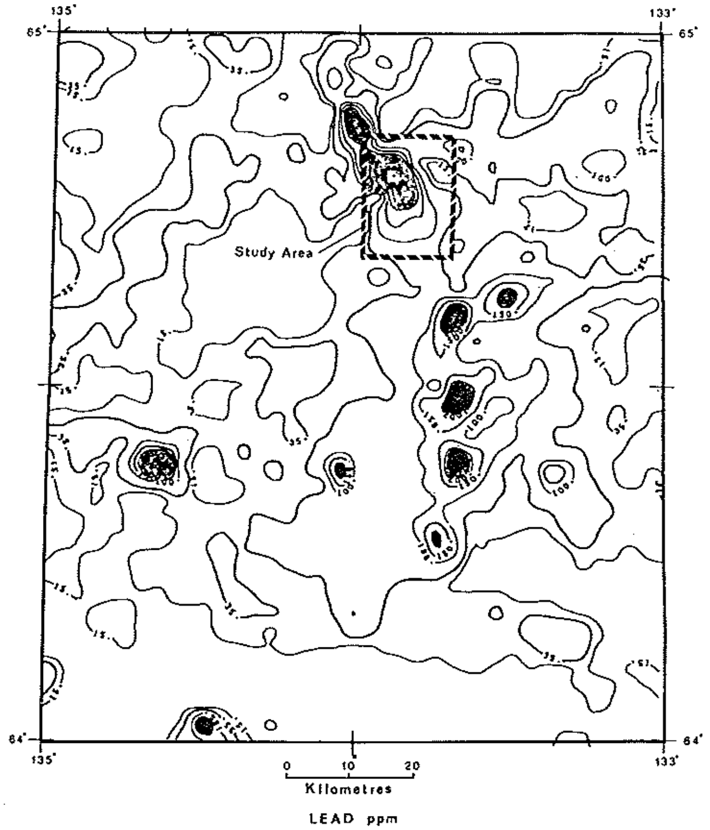


Figure 51.6. *Regional distribution of Pb in sediments from streams intersecting the west half of the Nadaleen River map area and the east half of the Nash Creek map area.*

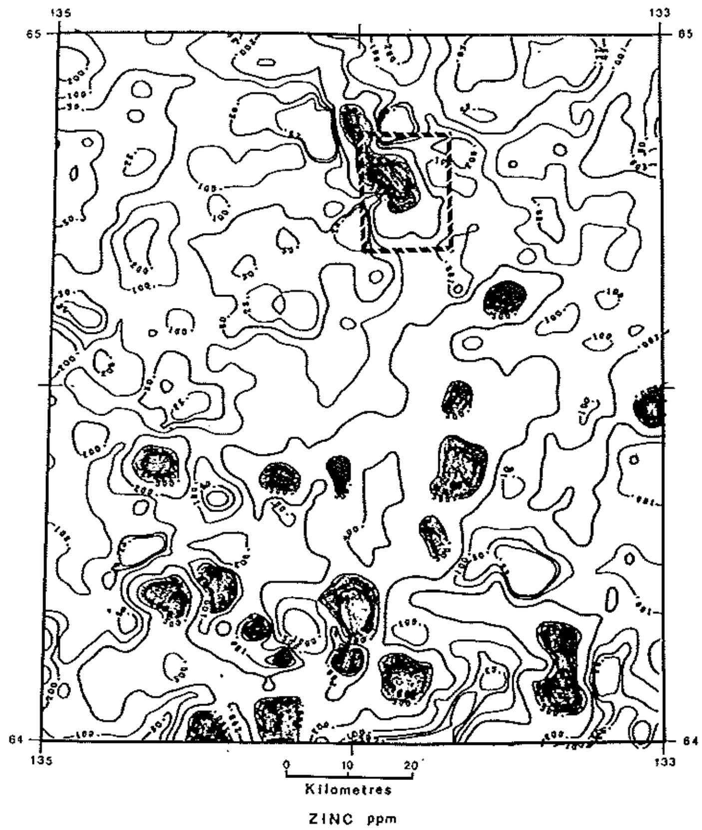


Figure 51.7. *Regional distribution of Zn in sediments from streams intersecting the west half of the Nadaleen River map area and the east half of the Nash Creek map area.*

Table 51.5

Chemistry of rocks from the Redstone Copper Belt, N.W.T.

Sample No.	Formation	Sub-Unit	Lithologies	Zn	Cu	Pb	Ni	Co	Ag	Mo	F	U
CJ-77-19	Coppercap	C-2	Shales and limestones	17	59	5	32	16	0.2*	2	970	1.5
CJ-77-423	Redstone River	RR-8	Redbeds,evaporites and carbonates	5200	190000	45	18	25	17.0	29	700	4.4
CJ-77-38D	Redstone River	RR-8	Redbeds,evaporites and carbonates	38	28000	84	7	3	7.8	74	195	1.2
CJ-76-698BF	Redstone River	RR-8	Redbeds,evaporites and carbonates	15	70000	1*	12	1*	8.8	8	310	2.0
CJ-76-36	Redstone River	RR-8	Redbeds,evaporites and carbonates	81	26	1*	41	11*	0.2*	1*	850	3.1
CJ-76-12	Redstone River	RR-4	Red mudstone	18	8	1*	20	10	0.2*	1*	750	0.8
CJ-76-559	Redstone River	RR-1	Evaporites and Redbed Breccias	7	75	1*	12	1*	0.2*	1*	825	1.4
CJ-76-234	Upper Little Dal	LD-16	Limestones and Stromatolites	7	49	10	8	1*	0.2*	1*	1350	1.2
CJ-76-157B	Upper Little Dal	LD-15	Sandstones	10	2600	1*	5	4	0.2*	1*	120	1.5
CJ-76-276	Upper Little Dal	LD-14	Vericoloured shales	8	15	5	18	1*	0.2*	1*	575	0.5
CJ-76-375	Unnamed	H5-5	Sandstones	5	18	1*	6	5	0.2*	1*	185	2.3

	SiO_2	Al_2O_3	TiO_2	$Fe_2O_3^{**}$	CaO	MgO	K_2O	Na_2O	P_2O_5	MnO	CO_2	H_2O_T	S
CJ-77-19***	28	6	0.6	3.19	9	11	3	0.7	0.1	0.038	11.3	15.1	5.0
CJ-77-423***	9	4	0.3	2.10	8	16	1	0.1	0.1	0.227	30.4	2.5	4.6
CJ-77-38D***	21	2	0.2	1.39	22	14	0.2	0.7	0.0	0.219	32.8	1.2	0.62
CJ-77-698BF***	20	4	0.4	1.86	20	14	0.6	2.0	0.1	0.157	28.1	1.0	1.4
CJ-76-36	44.0	8.9	1.10	5.62	9.0	11.8	2.05	0.1	0.14	0.073	13.2	4.4	0.06
CJ-76-12	35.8	7.1	0.42	3.39	12.8	12.0	2.52	0.3	0.08	0.054	18.8	5.5	2.0
CJ-76-559***	13	2	0.1	0.54	9	32	0.3	0.0	0.0	0.007	26.8	2.1	5.2
CJ-76-234***	64	14	1.0	3.93	0	1	8	0.0	0.0	0.002	0.0	1.8	1.2
CJ-76-157B	90.6	4.3	0.19	1.03	0.0	0.13	1.06	0.0	0.01	0.002	0.0	0.8	0.33
CJ-76-276	53.4	25.1	1.20	5.01	0.0	0.78	7.67	0.0	0.01	0.002	0.0	4.8	0.22
CJ-76-375	88.2	5.1	0.23	2.99	0.0	0.10	1.08	0.1	0.02	0.004	0.0	1.6	0.77

*	element concentration below the lower detection limit
**	total Fe express as Fe_2O_3
***	major element oxide content approximate only
Note:	Oxides expressed in %; trace elements express in ppm

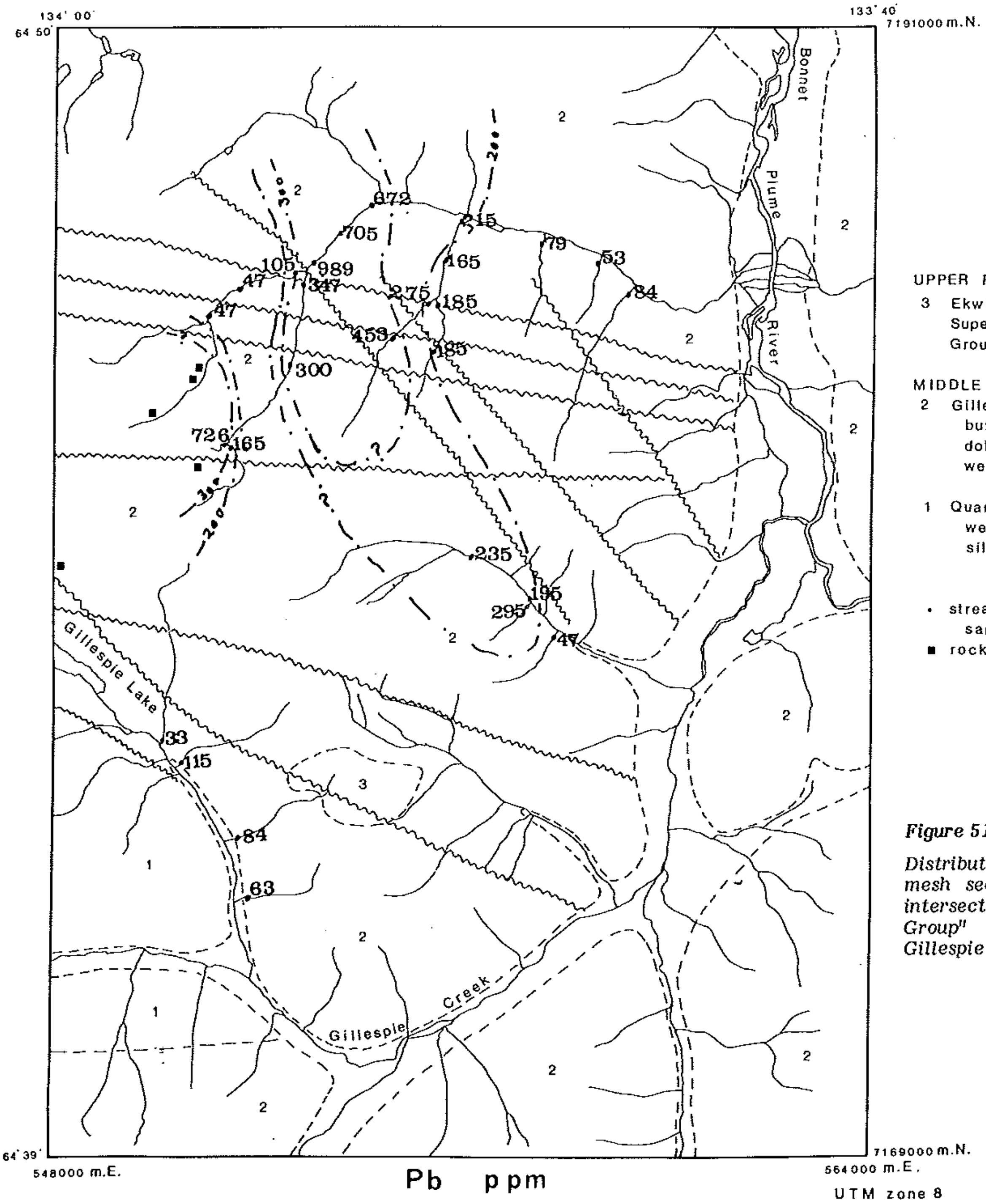


Figure 51.8

Distribution of Pb in minus -80 mesh sediments from streams intersecting the "Gillespie Lake Group" situated east of Gillespie Lake.

In order to determine the spatial significance of base metal mineralization and to assess the physical and chemical factors affecting dispersion of elements from this mineralization, one geochemically anomalous area located immediately east of Gillespie Lake was selected for more detailed study. Close-interval stream sediments and waters were collected and analyzed for most trace elements thought to be associated with this type of mineralization (Table 51.4).

The distribution of Pb and Zn, presented in Figures 51.8 and 51.9, outline an extensive and intensive northwest-southeast zone which parallels most of the bedding strikes recorded for the area as well as the surface projection of one of the major faults in the area. This relationship is not surprising considering that all the mineralization examined was either stratigraphically or structurally controlled.

Silver and Cd behave very similarly to Pb and Zn, no doubt reflecting their ability to substitute into the lattice of galena and sphalerite, respectively. The low contrast between mineralized and unmineralized areas for Ag and Cd is probably due to the high lower detection limit for analytical methods used for these elements (Table 51.4). Iron, which is present as pyrite or siderite in mineralized rocks, is distributed similarly to Pb and Zn.

Unlike Pb and Zn, the spatial distribution of Cu in stream sediments (Fig. 51.10) defines a relatively restricted and less intensive geochemically anomalous zone. Since most elements in this area are dispersed predominantly by the abrasive action of streams, the subtle Cu anomaly observed is most likely derived from low-grade Cu mineralization in the underlying rocks. The stream waters are characteristically

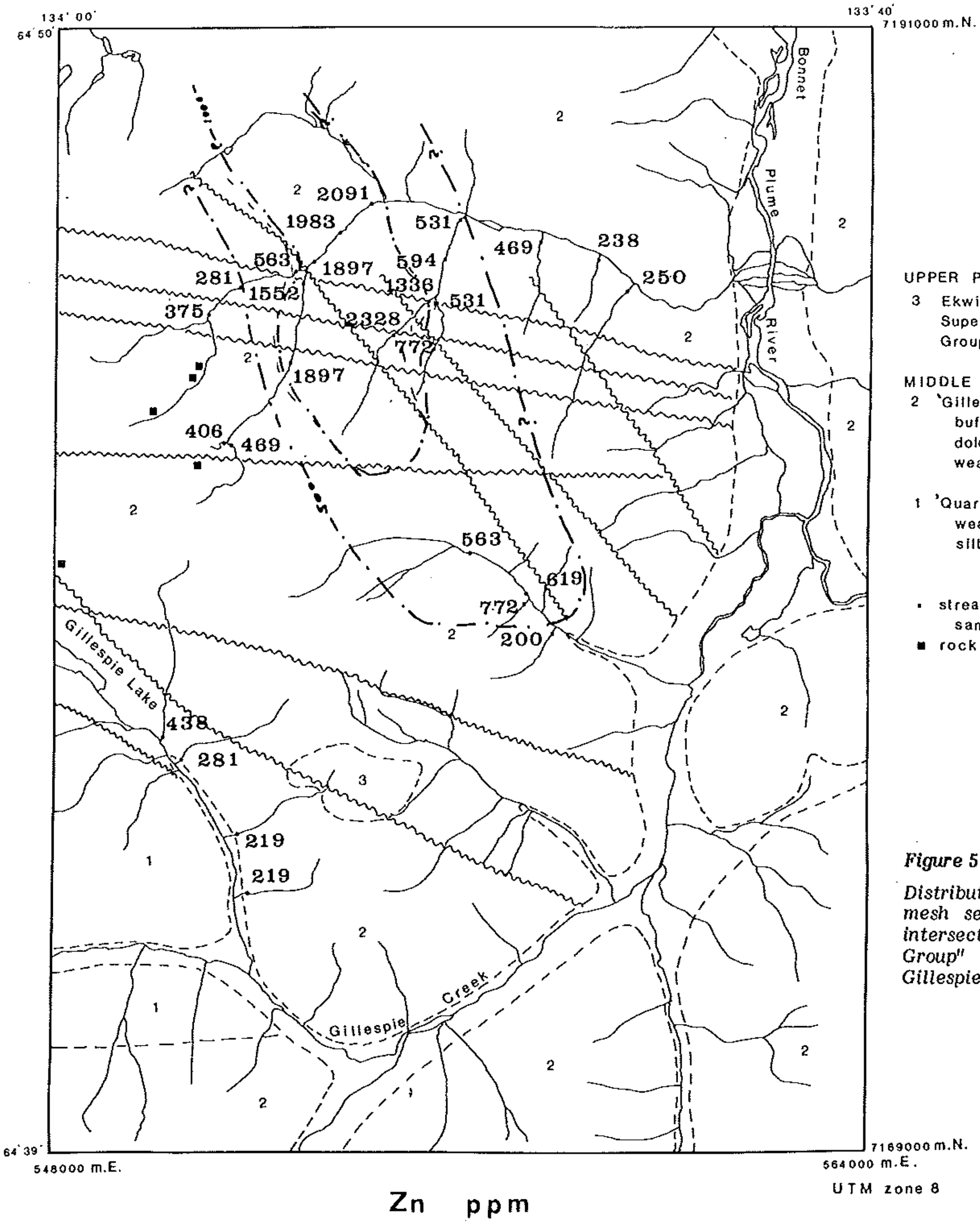


Figure 51.9

Distribution of Zn in minus -80 mesh sediments from streams intersecting the "Gillespie Lake Group" situated east of Gillespie Lake.

alkaline (Table 51.4) due to the buffering action of carbonate dissolved from the underlying dolomitic rocks. Under these conditions, Cu and Pb form relatively insoluble carbonates as evidenced in the case of Cu by green malachite coating the fracture surface of mineralized rocks. Zinc, on the other hand, is more soluble under these conditions as shown by the relatively high Zn content of stream waters which coincides with anomalous Zn in stream sediments.

Fluorine in stream waters is dispersed similarly to Zn although the reason for this is not clear. It is possible that F may be associated with calcium phosphates that form an important constituent of algae. The association of high F with P in stromatolites of the "Gillespie Lake Group" (Tables 51.2, 51.3) would tend to support this conclusion. Also, F is a common constituent of carbonate hosted base metal deposits described elsewhere.

Discussion and Conclusions

The presence of Pb, Zn and Cu mineralization associated with stromatolitic rocks and faults and fault-related breccias of the "Gillespie Lake Group" opens up a large area with base metal potential in the central Yukon Territory. The size and magnitude of stream sediment geochemical anomalies indicate that this type of mineralization should be investigated further to assess its true economic potential.

The controls on the mineralization would at first glance appear to be the presence of bioherms and biostromes in the "Gillespie Lake Group" that have been intersected by faults. The presence of faults is reflected by the high Hg in stream sediments from the area east of Gillespie Lake (Geological Survey of Canada, 1978). The stromatolites in the upper

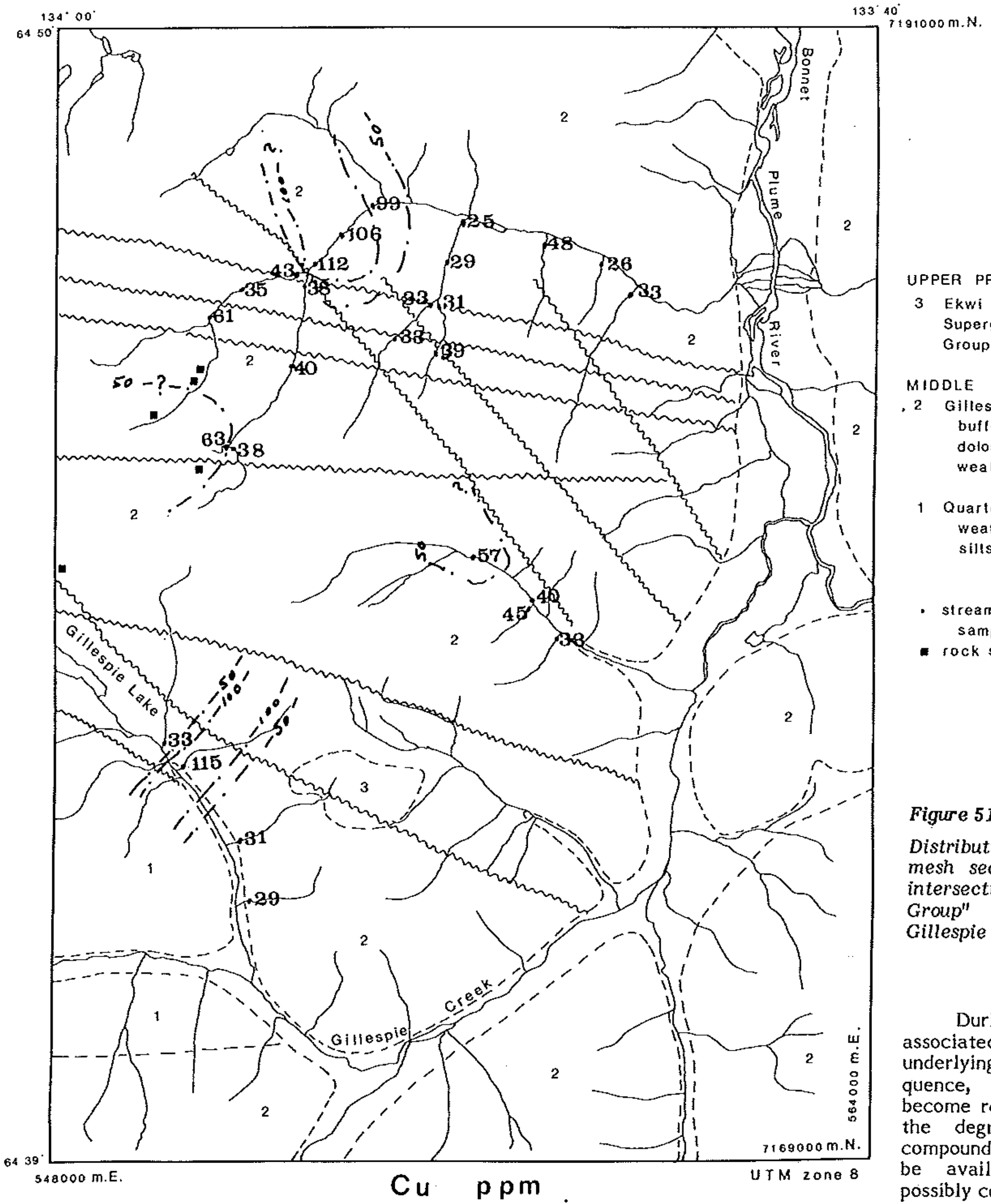


Figure 51.10

Distribution of Cu in minus -80 mesh sediments from streams intersecting the "Gillespie Lake Group" situated east of Gillespie Lake.

"Gillespie Lake Group" provide an excellent source for base metals that are available for mobilization and concentration after their initial deposition. Although algae are unlikely to accumulate large quantities of base metals by biochemical processes, organic matter derived from the bacterial degradation of algae on the seafloor is an efficient absorber of these metals from both sea and connate waters. An alternate source (not to mention a host) for base metals is provided by the underlying "Quartet Group" which is composed, in part, of what was originally organic-rich muds containing abundant organic matter and clays to act as efficient absorbers of base metals. This conclusion is supported by the generally higher contents of Cu, Pb, Zn and Ag present in rocks collected from the "Quartet Group" (Table 51.3).

During compaction and associated diagenesis of the underlying sedimentary sequence, these metals would become relatively labile due to the degradation of organic compounds and would therefore be available for transport, possibly complexed as chlorides, in connate saline fluids. This type of transporting mechanism has been demonstrated by Roedder (1967) from fluid inclusion studies of strataform Mississippi Valley Type ore deposits.

Fluid migration would follow pathways of least restriction such as the numerous fault zones intersecting the "Gillespie Lake Group". The precipitation of metal sulphides in open space may be achieved either by a biological process involving the reduction of SO_4^{-2} to S^{-2} by sulphate-reducing bacteria using in this case decomposing algal material as a nutrient source or by an inorganic process using methane in the following reaction proposed by Barton (1967):

$$CH_4 + ZnCl_2 + SO_4^{=} + Mg^{++} + 3\,CaCO_3 \rightarrow ZnS + CaMg\,(CO_3)_2 + 2Ca^{++} + 2Cl^- + 2HCO_3^- + H_2O$$

This reaction would not only account for the production of metal sulphide but would also explain the generally observed dolomitization of carbonate rocks. Evidence supporting this interpretation of the preliminary field and chemical data includes the close spatial association of Pb-Zn mineralization with rocks of organic derivation that are commonly intersected by faults, the presence of white recrystallized curve dolomite associated with stratabound and fault-controlled sphalerite mineralization, and the presence of accompanying elements (e.g. Cd, Ag, Fe) that characterize carbonate-hosted Mississippi Valley Type mineralization described elsewhere (Jackson and Beales, 1967). In regard to certain aspects, the Pb-Zn mineralization in the "Gillespie Lake Group" is similar to the Gayna River Pb-Zn mineralization that occurs in oolitic dolostones near bioherms (Hewton, 1977) that form part of the Little Dal Group of Upper Proterozoic age (Delaney et al., in press). The mineralization at Gayna River was described by Hewton (1977) to occur either as brightly coloured sphalerite within breccias or as pale to colourless sphalerite disseminated in fragments and in the matrix of sedimentary breccias.

The Cu mineralization in the "Gillespie Lake Group" occurs as fine grains disseminated throughout dolosiltstone and intersecting fault zones. In the former case, it appears to be stratabound although the regional geochemical data indicates that it is not laterally extensive. In general, Zn and Pb are associated with rocks that are mineralized with Cu (Table 51.1). This elemental association is not unlike that characterizing Cu-bearing rock specimens from the Redstone Copper Belt that contain, in addition to Zn and Pb, above normal contents of Ag and Mo (Table 51.5).

Sedimentary rocks hosting Cu mineralization in the Little Dal Group, Redstone River Formation and Coppercap Formation of the Redstone Copper Belt and in the "Gillespie Lake Group" of the Wernecke Mountains appear to represent different environments of deposition. Sabkha conditions during a marine transgression are indicated for sedimentary rocks from the Redstone Copper Belt that are transitional between gypsiferous red beds and fetid detrital limestone (Jefferson, 1975) while the "Gillespie Lake Group" is more characteristic of a shallowing intertidal to subtidal arid environment as evidenced by the presence of carbonates, stromatolite lamina, flat chip conglomerate and oolitic dolostone. Furthermore, red beds, evaporites and basalts have not been described for the "Gillespie Lake Group" which is considered by Yeo et al. (1978) to be older than the Little Dal Group.

Acknowledgments

The author wishes to thank C.W. Jefferson for providing rock samples from the Redstone copper occurrences and G. Delaney and R.T. Bell for providing rock samples from a composite section of the Wernecke Supergroup. H.E. Dunsmore and I.R. Jonasson are also thanked for stimulating discussions on the subject of Pb-Zn mineralization in carbonate rocks. P. Friske and C. Orssich provided able assistance during the field program. Trace elements were determined in the Geochemical Laboratories of the Geological Survey by A. MacLaurin and G. Gauthier. G. Lachance made arrangements for X.R.F. analyses.

References

Barton, P.B.
1967: Possible role of organic matter in the precipitation of the Mississippi Valley ores; in J.S. Brown (ed.), "Genesis of Stratiform Lead-Zinc-Barite-Fluorite Deposits"; Economic Geology Monograph no. 3, p. 371-378.

Bell, R.T. and Delaney, G.D.
1977: Geology of some uranium occurrences in Yukon Territory; in Report of Activities, Part A, Geological Survey of Canada, Paper 77-1A, p. 33–37.

Blusson, S.L.
1974a: Nadaleen River map-area of Operation Stewart; Geological Survey of Canada Open File no. 205.

1974b: Nadaleen River map-area; Yukon Territory (106C-6, 7, 10, 11, 13, 14, 15); Geological Survey of Canada Open File no. 206.

Blusson, S.L. and Tempelman-Kluit, D.J.
1970: Operation Stewart, Yukon Territory, District of Mackenzie (105N, O; 106B, C); in Report of Activities, Part A, Geological Survey of Canada, Paper 70-1A, p. 29-32.

Boulanger, A., Evans, D.J.R., and Raby, B.F.
1975: Uranium analysis by neutron activation delayed neutron counting; Proceedings of the Seventh Annual Symposium of Canadian Mineralogical Analysts, Thunder Bay, Ontario, 10 p.

Brown, R.J.E.
1967: Permafrost in Canada; Geological Survey of Canada Map 1246A.

Delaney, G.D.
1978: A progress report on stratigraphic investigations of the lowermost succession of Proterozoic rocks, northern Wernecke Mountains; Dept. of Indian and Northern Affairs Open File Report EGS 1978-10, 12 p.

Delaney, G.D., Jefferson, G.W., Yoe, G.M., McLennan, S.M., Bell, R.T., and Aitken, J.D.
Some Proterozoic sediment-hosted metal occurrences of the northeastern Canadian Cordillera; Society of Economic Geologists, Couer d'Alene Field Conference, Wallace, Idaho, November 3-5, 1977. Idaho Bureau of Mines Special Publication. (in press)

Eisbacher, G.H.
1978: Two major Proterozoic unconformities, northern Cordillera; in Report of Activities, Part A, Geological Survey of Canada, Paper 78-1A, p. 53–58.

Findlay, D.C.
1975: Map showing the geology and mineral deposits of Yukon Territory and parts of the southwest District of Mackenzie, Northwest Territories; Geological Survey of Canada Open File 87.

Geological Survey of Canada
1978: Uranium Reconnaissance Program National stream sediment and water geochemical reconnaissance data, northern Yukon Territory; Geological Survey of Canada Open File no. 518.

Green, L.H.
1972: Geology of Nash Creek, Larsen Creek, and Dawson map-areas, Yukon; Geological Survey of Canada, Memoir 364, 157 p.

Hewton, R.S.
1977: Geology and mineralization at Gayna River, N.W.T. (abstract) Geological Association of Canada Annual Meeting, Vancouver, 1977. Program with Abstracts, v. 2, p. 24.

Jackson, S.A. and Beales, F.W.
1967: An aspect of sedimentary basin evolution: the concentration of Mississippi Valley-type ores during the late stages of diagenesis; Bulletin of Canadian Petroleum Geology, v. 15, p. 383-433.

Jefferson, C.J.W.
1975: Stratigraphy and sedimentology, Upper Proterozoic Redstone Copper Belt, Mackenzie Mountains, N.W.T. - a preliminary report; in Mineral Industry Report 1975, Northwest Territories; Indian and Northern Affairs Economic Geology Series 1979.

Ricker, K.E.
1974: Surficial geology of the Nadaleen River map-area, Yukon Territory - Northwest Territories; Geological Survey of Canada Open File no. 207, 34 p.

Roedder, E.
1967: Environment of deposition of stratiform (Mississippi Valley Type) ore deposits, from studies of fluid inclusions, in J.S. Brown (ed.), "Genesis of Stratiform Lead-Zinc-Barite-Fluoride Deposits", Economic Geology Monograph no. 3, p. 371-378.

Smith, A.Y. and Lynch, J.J.
1969: Field and laboratory methods used by the Geological Survey of Canada in geochemical surveys. No. 11, uranium in soil, stream sediment and water; Geological Survey of Canada, Paper 69-40, 9 p.

Wheeler, J.O.
1954: A geological reconnaissance of the northern Selwyn Mountains region, Yukon and Northwest Territories; Geological Survey of Canada, Paper 53-7, Map 53-7.

Yeo, G.M., Delaney, G.D., and Jefferson, C.W.
1978: Two major Proterozoic unconformities, northern Cordillera: discussion in Current Research, Part B, Geological Survey of Canada, Paper 78-1B, p.225-230.

Young, G.M., Jefferson, C.W., Long, D.G.F., Delaney, G.D., and Yeo, G.M.
Upper Proterozoic stratigraphy of northwestern Canada and Precambrian history of North American Cordillera; Society of Economic Geologists, Couer d'Alene Field Conference, Wallace, Idaho, November 3-5, 1977. Idaho Bureau of Mines Special Publication. (in press)