EVALUATING THE USE OF TILL GEOCHEMISTRY TO DEFINE BURIED MINERAL TARGETS: A CASE STUDY FROM THE BELL MINE PROPERTY (NTS 93L/16, 93 M/1), WEST-CENTRAL BRITISH COLUMBIA

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KEYWORDS: Bell mine, drift exploration, geochemistry, porphyry copper mineralization, surficial geology, Quaternary history, Babine Lake

INTRODUCTION

Mineral exploration programs conducted in the Interior Plateau of British Columbia have typically been hampered by the presence of thick glacial till mantling bedrock. In these areas, trenching, rotary drilling and soil sampling can be used to obtain a better understanding of the underlying geology. Unfortunately the use of these techniques are often limited by an inadequate understanding of the Quaternary geology and regional glacial history.

In support of mineral exploration, regional surficial geology studies were undertaken in central British Columbia, by the Geological Survey of Canada and the British Columbia Geological Survey. This joint-governmental study was part of the much larger Nechako NATMAP Project. Two main objectives of this study are, to determine changes in the regional ice flow directions, during the Pleistocene in central British Columbia and also to examine the use of till geochemistry in mineral exploration. In the summer of 1995 and 1996, regional till geochemistry surveys were conducted by the British Columbia Geological Survey, in the Babine Lake area; encompassing the Fulton Lake (93 L/16), Old Fort Mountain (93 M/01) and Nakinilerak (93 M/08) map areas (Figure 1).

The Bell mine, a porphyry copper deposit was chosen as a model for this study because of its well defined zone of mineralization and the occurrence of an extensive blanket of glacial till. In this report the effectiveness of till sampling for the delineation of buried mineralization is examined by a comparison of till geochemistry with the known ore-body at Bell mine. The study will contribute to the development of a model of glacial dispersal, which can be used in future exploration programs in the region and in other glaciated areas.

STUDY AREA LOCATION AND PHYSIOGRAPHY

The Bell Mine study area is located in the central part of the Babine Lake basin, approximately 10 km northeast of the town of Granisle (Figures 1, 2). It is situated on the

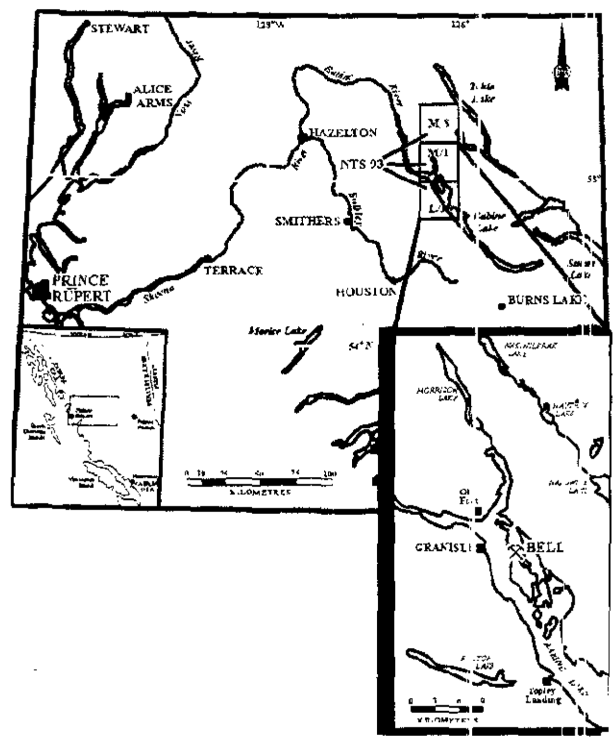

Figure 1 - Location of study area in British Columbia.

Newman Peninsula which straddles the Fulton Lake (93 L/16) and Old Fort Mountain (93 M/01) NTS map sheets. The mine property can be accessed by the Hagan Forest Service Road, via the Northwoods barge from Mitchell Bay or by private barge operated by Noranda Mines Limited

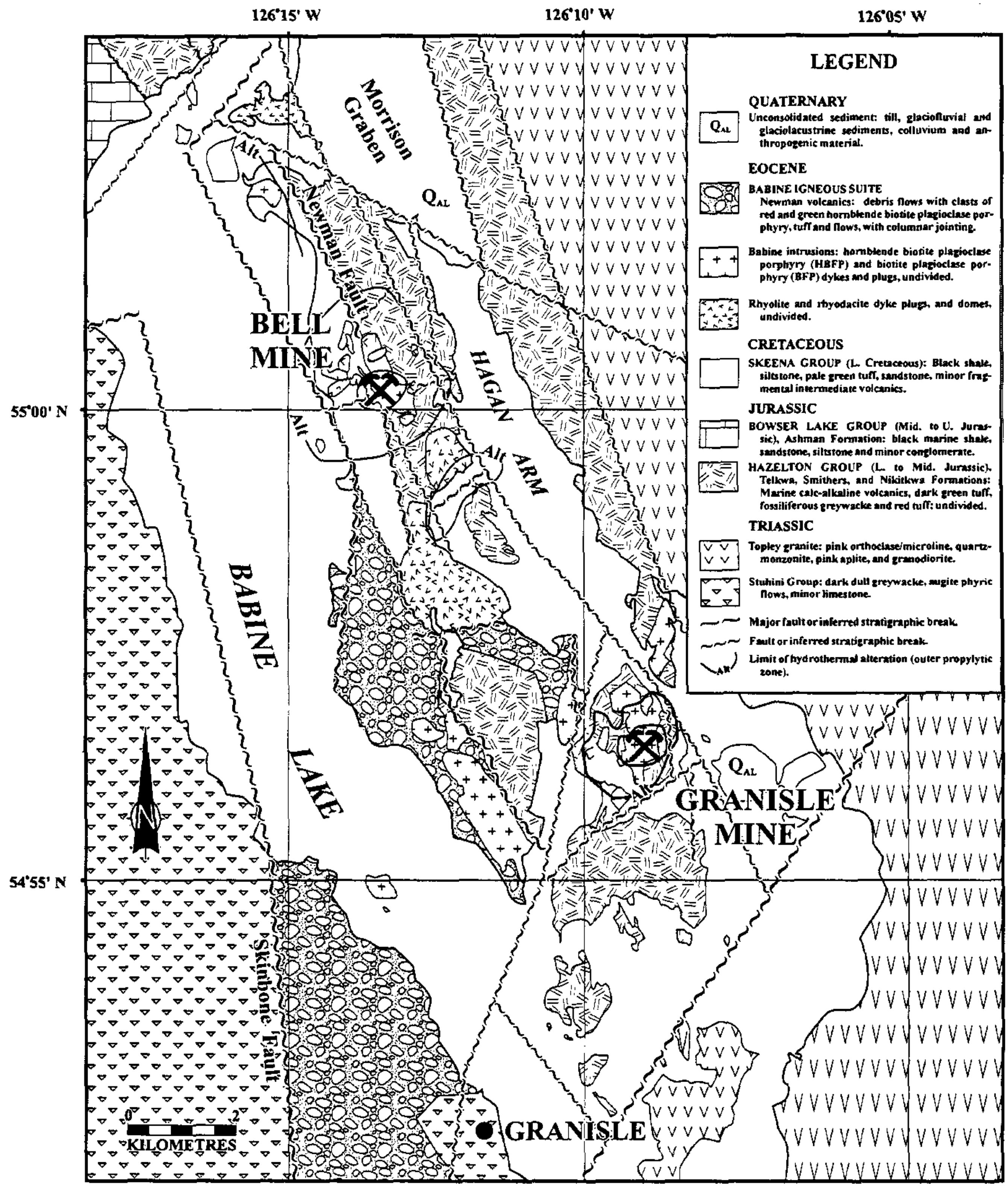

Figure 2 - Bedrock geology of the northern Babine Lake area, including the Newman Peninsula (after Dirom *et al.*, 1995)

from the mine to a gravel road 8 km north of Granisle.

Much of the property has a subdued topography, with elevations ranging from 715 to 850 metres. Locally, some bedrock knobs occur at elevations over 900 metres. To the west and east of Babine Lake lie a series of parallel, northwest-southeast trending bedrock ridges reaching a maximum elevation of 1200 metres. Drainage from the property enters Babine Lake at approximately 712 metres (2350 feet). Babine Lake drains into the west-draining Babine and Skeena rivers.

BEDROCK GEOLOGY AND MINERALIZATION

The study area lies within the Stikinia Terrane of the Intermontane Tectonic Belt of west-central British Columbia (Wheeler and McFeely, 1991; McMillan and Struik, 1996). Bedrock geology in the Babine Lake area was mapped by Carter (1973), Tipper and Richards (1976), MacIntyre *et al.* (1996b) and Richards (*in press*). Regional geology consists of uplifted, tilted and folded fault blocks of rocks ranging in age from the pre-Permian to the Eocene (MacIntyre *et al.*, 1996a). The oldest strata are comprised of shallow-water carbonates and island-arc volcanic and volcaniclastic rocks of the Stikine assemblage (Monger, 1977).

As Stikinia evolved in the Middle Jurassic to Early Cretaceous, molasse-type marine and non-marine sedimentary rocks accumulated in the Bowser and Nechako successor basins. These rocks are correlative to the Bowser Lake and Skeena Group units found in the Bell Mine study area (Richards, 1988). Subduction of oceanic crust under the North American plate in the Middle Cretaceous led to intense magmatic activity during the Late Cretaceous and Early Tertiary. Andean-type volcanic piles were constructed on uplifted and eroded blocks of Stikinia (Dirom *et al.*, 1995). Products of the associated dikes and plugs of this magmatism include the Middle to Late Cretaceous Bulkley and Eocene Babine intrusions. These intrusive rocks are host to the major mineral deposits found in the area (Carter, 1976).

The Newman Peninsula is dissected by a number of northwest-southeast trending fault systems (Figure 2). Here, intrusions of Eocene Babine Igneous Suite rocks; rhyolite, rhyodacite and biotite feldspar porphyry (BFP) were emplaced across the trace of the Newman Fault at sites of transcurrent faulting (Dirom *et al.*, 1995). These rocks intrude Lower to Middle Jurassic Hazelton Group volcanics and Skeena Group sedimentary rocks (MacIntyre *et al.*, 1996a).

The ore-body at the Bell mine is a classic high-level, symmetrically zoned porphyry copper-gold deposit. Zones of biotite-magnetite and propylitic alteration are associated with multiple-phase subvolcanic intrusions of the Babine Igneous Suite (Carter, 1981; Dirom *et al.*, 1995). These intrusions are overprinted by pervasive quartz-sericite alteration (Carson *et al.*, 1976).

Copper-gold mineralization at the Bell mine occurs predominantly in the Eocene-age quartz-sericite altered rhyodacite and biotite-feldspar porphyry, with a maximum grade of 0.47% copper. Lesser amounts of copper mineralization are present in disseminated sulphides and stockworks in Hazelton rocks (Dirom *et al.*, 1995). Pyrite and chalcopyrite occur in disseminations, fracture fillings and as coatings in the main stockwork, and across the propylitic/biotite-magnetite alteration zones. Trace molybdenite and bornite also occur within the biotite-altered biotite-feldspar porphyry (Carson *et al.*, 1976). Other minerals present include silver, chalcocite, sphalerite and galena.

REGIONAL GLACIAL HISTORY

The Babine Lake area has undergone a complex history of multiple glacial and interglacial cycles throughout the Quaternary. Broad U-shaped valleys, streamlined and scoured bedrock surfaces and the presence of thick deposits of till, glaciofluvial and glaciolacustrine sediments are remnant features of the Late Wisconsinan glaciation.

Pre-late Wisconsinan fluvial and lacustrine sediments are rarely exposed in the Babine area. Lacustrine sediments uncovered at the Bell mine contain mammoth skeletal remains and charred plant material which have returned an Olympia nonglacial age ranging between *ca.* 43800±1860 to 34000±690 BP (Harrington *et al.*, 1974). Possible advance stage glaciofluvial sediments, underlying Fraser Glaciation till, are exposed along the Hagan Road (Huntley *et al.*, 1996a).

The onset of Late Wisconsinan Fraser Glaciation (approximately 25 ka; Clague, 1981), was marked by ice accumulation in the southern Skeena and Babine Mountains, located to the north and north-west of the study area. Glaciers from these sources flowed south-east along the Babine, Fulton and Takla lake valleys (Figure 3).

Basal till lies unconformably over glaciolacustrine sediments, suggesting a glacial lake was ponded in the Babine valley during ice advance. Advance phase glacial lake sediments were deposited to a maximum elevation of 790 metres (2600 feet), before being overridden by Fraser Glaciation ice (Huntley *et al.*, 1996a).

At the glacial maximum, south-east flowing glaciers coalesced to form part of the Cordilleran Ice Sheet. This ice sheet probably overtopped many mountain peaks in the Babine area with elevations of less than 1818 metres (6000 feet), as indicated by the presence of striated and polished bedrock, exposed at approximately 1727 metres (5700 feet) on the peak of Dome Mountain (Figure 3). Along the southern part of the Babine Lake area, this ice mass coalesced with ice originating from the Coast Mountains and moved northeastward into the Stuart Lake basin (Plouffe, 1991, 1995, 1996; Tipper, 1994).

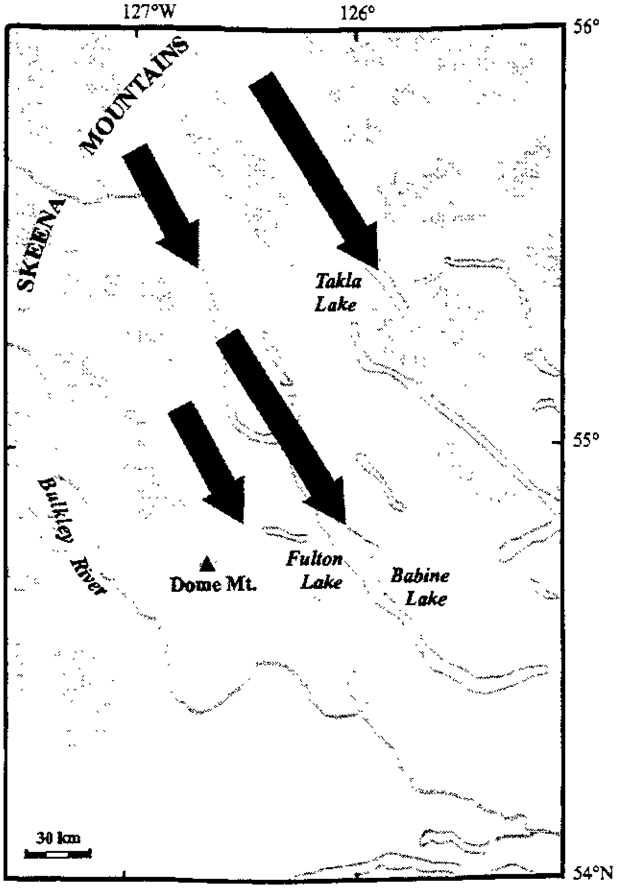

Figure 3 - Ice flow patterns in central British Columbia during the advance phase of the Late Wisconsinan, Fraser Glaciation (after Plouffe, 1996).

Multiple ice flow directions, indicated by the orientation of streamlined landforms and glacial erosional features, are recorded throughout the Babine Lake area and are evidence of a complex glacial history in this area of west-central British Columbia (Levson *et al.*, 1997b). Of these ice flow directions, the south-east movement deposited the majority of the till composing most of ground moraine in the area as indicated by surficial mapping (Stumpf *et al.*, 1996b; Huntley *et al.*, 1996b). Streamlined and striated bedrock surfaces also indicate a regionally dominant south-southeast ice flow direction, with striae and landforms oriented between 130° and 180° (Figures 4a, b). Cross-cutting striae in the Babine Lake area are suggestive of topographically-controlled ice flow which took place after the culmination of glaciation.

Following climate amelioration, glaciers retreated step-wise from the highlands into Babine and Fulton lake valleys (Huntley *et al.*, 1996a). Stagnant ice confined to valleys, deposited a veneer of supraglacial and glaciofluvial sediments. During the later stages of ice retreat, glacial lakes were dammed by moraines and/or ice in these valleys, depositing glaciolacustrine silt and clays at elevations from 760 metres (2500 feet) to 830 metres (2750 feet). A similar range of lake base-levels has been documented by Plouffe (1996) and Clague (1988), in the "glacial lake Fraser" basin, suggesting that "glacial lake Babine" was likely part of a much larger lake system in central British Columbia (Huntley *et al.*, 1996a).

SURFICIAL SEDIMENTS AT THE BELL MINE PROPERTY

The surficial geology of the Fulton Lake (93L/16) and Old Fort Mountain (93 M/01) NTS sheets was mapped by the British Columbia Geological Survey, in 1995 at a 1:50,000 scale (See Huntley *et al.*, 1996b; Stumpf *et al.*, 1996b). At the Bell mine, the surficial geology was mapped (Figure 4a, b), to provide a database of surficial materials which may be encountered during mine reclamation at the property. A variety of surficial materials are present at the Bell mine property. Basal lodgement till is the most abundant and aerially extensive surficial deposit, with lesser amounts of ablation moraine, colluvium, glaciolacustrine, glaciofluvial, lacustrine and anthropogenic sediments.

Pre-Late Wisconsinan silt and clay are exposed in drainage and pit cuts along the eastern and southern walls of the open pit excavation at Bell mine. These sediments are finely laminated, highly deformed and contain dropstones which increase in abundance towards the base of the unit. Locally, on the eastern wall these sediments overlie a gravelly, stony diamicton, which in turn overlies striated bedrock.

Throughout the study area, basal till occurs as a blanket (1m thick) or veneer (<1m thick) over glacially-streamlined bedrock surfaces. It is massive, dense, varies in colour from dark-brown to maroon, and is highly jointed and fissile. The till matrix varies from a silty sand to a clayey silt and contains an abundance of dark-coloured sedimentary rock fragments, derived from distal bedrock source units. Locally, the till contains clasts of weathered mineralized bedrock, especially down-ice of the Bell ore-body (Figure 5). A unit of winnowed basal till locally occurs as a veneer over lodgement till or bedrock (Stumpf *et al.*, 1996a). It has similar characteristics of lodgement till, but is less compact and much sandier in texture. When overlying clay-rich lodgement till, winnowed basal till often fines downwards to a silty sand. It may also occur beneath glaciofluvial or glaciolacustrine sediments.

Glaciolacustrine silt and clay occur below 790 metres (2600 feet) in low-lying areas along Babine Lake. These sediments occur as both a veneer and blankets (up to several metres thick), commonly overlying morainal deposits. Subordinate glaciofluvial sediments are exposed along modern channel cuts and small ice-contact ridges to the north-east of the Newman Peninsula. Anthropogenic

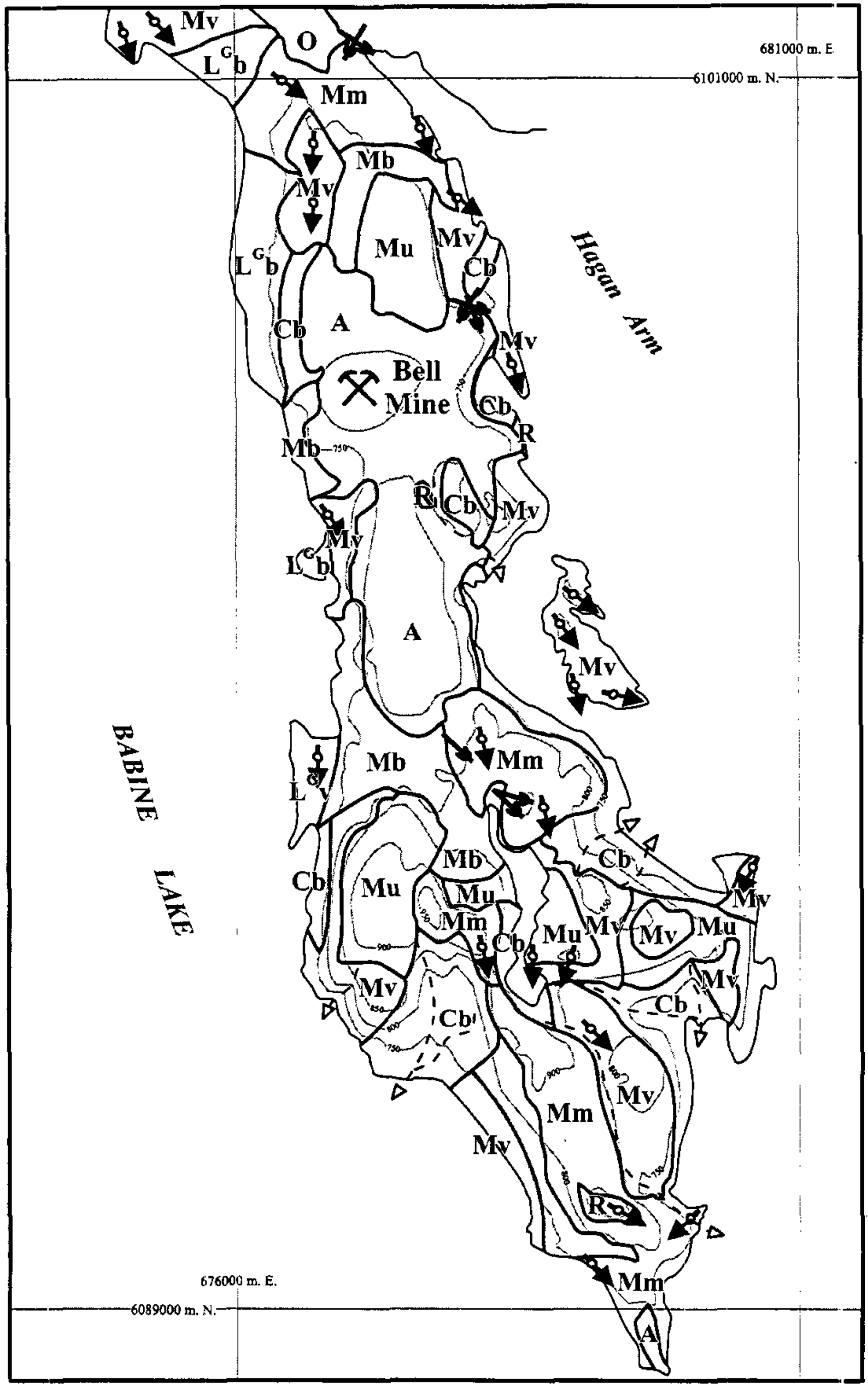

Figure 4a - Surficial Geology of the Newman Peninsula, Babine Lake, British Columbia. See figure 4b for legend.

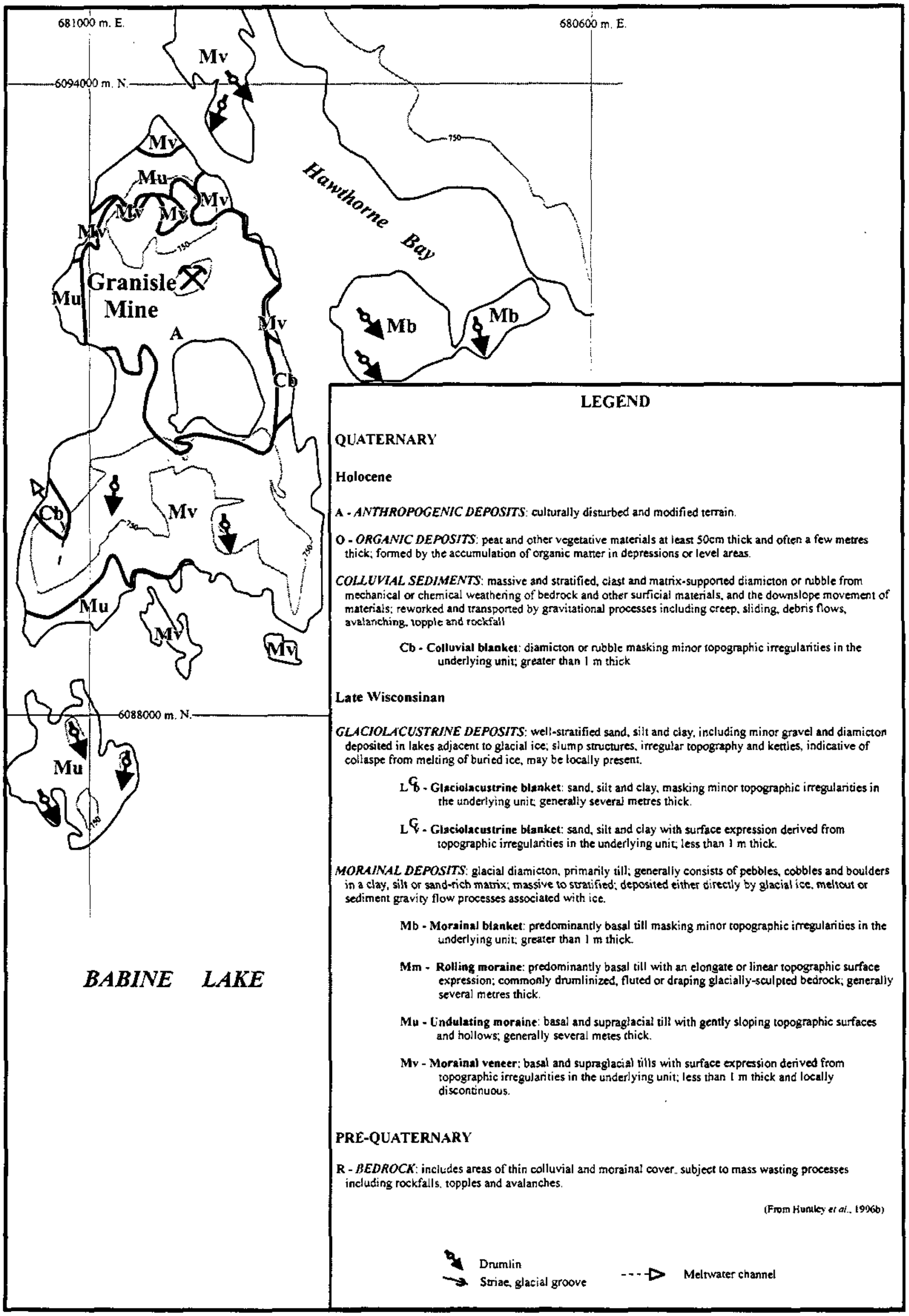

Figure 4b - Surficial Geology of McDonald Island, Babine Lake, British Columbia.

Figure 5 - Deformed weathered rhyodacite boulder in basal lodgement till. Photo taken at sample site 3180, north-east of the Bell mine.

deposits occur throughout the property, mainly in the vicinity of the open pit and tailings piles. Extensive mining and overburden extraction has greatly altered the original topography. Thus, it is often difficult from surface characteristics alone to determine the original, *in situ* materials from those which were culturally modified. Particular caution was taken when describing these features and collecting till samples for analysis.

SAMPLING METHODS

Sixty-four samples of glacial drift were collected on the Bell mine property (Figure 6), with a sample spacing of 300 to 500 metres. Samples were collected from hand-dug pits, road cuts and open pit exposures, from the C-soil horizon, at a minimum depth of 75 cm below the surface. Vertical profile samples were collected around the Bell open pit where till exposures exceeded 3 metres in thickness, in order to investigate geochemical variability (samples 95-1177 and 95-1178; 95-2309 to 95-2315 in Table 1). To compare the geochemistry of variable sediment types, multiple samples were collected from

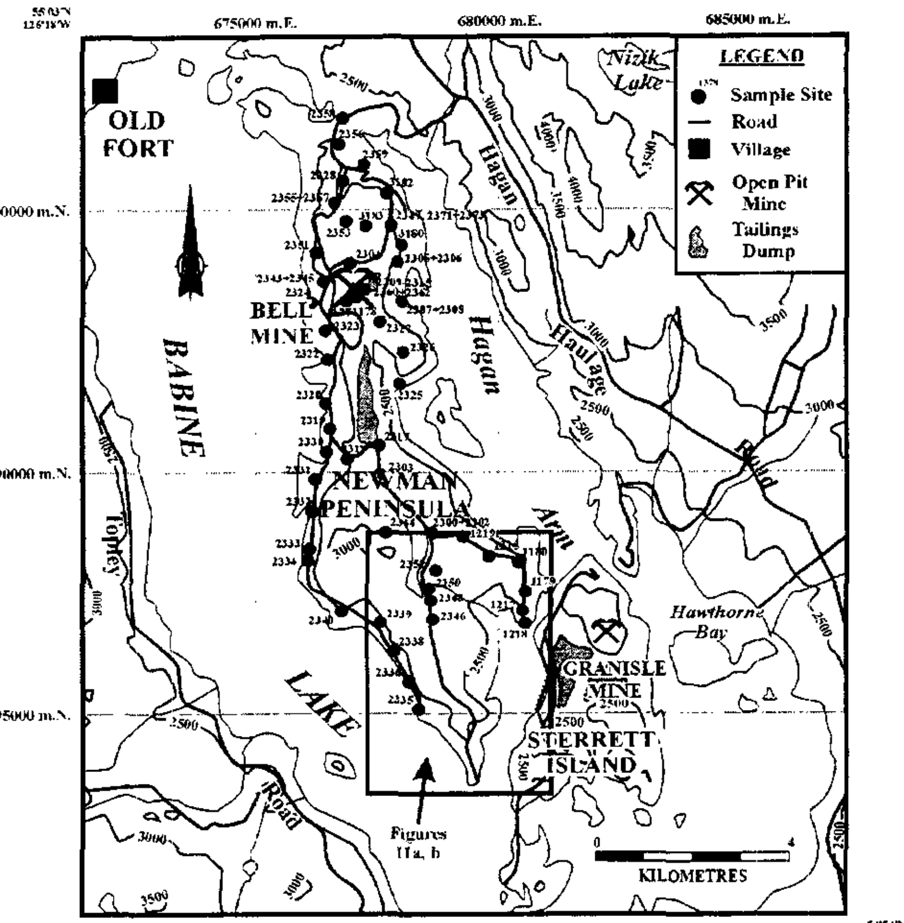

Figure 6 - Sample locations at the Bell mine property. Note, the box outlines the area shown in figure 11.

TABLE 1: ANALYTICAL RESULTS FROM TILL SAMPLES COLLECTED AT NEWMAN PENINSULA

Sample ID.	UTM Eastings	UTM Northings	Map Unit	Mo ppm	Cu ppm	Pb ppm	Zn ppm	Ag ppm	Ni ppm	Co ppm	Mn ppm	Fe %	As ppm	Sr ppm	Cd ppm	Bi ppm	V ppm	Ca %	P %	La ppm	Cr ppm	Mg %	Ba ppm	Ti %	Al %	Na %	K %	Hg ppb	W ppm
95-1177	677538	6098300	Cb	1	45	11	98	< .3	42	14	723	3.81	14	175	0.5	< 2	42	1.07	0.064	8	27	0.59	254	0.02	1.64	0.02	0.11	130	< 2
95-1178	677600	6098350	Mb	1	48	11	112	0.3	40	15	944	4.29	16	117	0.7	< 2	47	1.61	0.064	8	28	0.65	284	0.02	1.91	0.02	0.13	135	< 2
95-1179	680585	6092893	Mb	1	64	21	131	< .3	52	16	1823	5.07	24	59	0.8	< 2	57	0.71	0.065	23	27	0.62	318	0.04	2.16	0.03	0.11	140	< 2
95-1180	680427	6093327	Mb	1	58	13	118	< .3	42	17	1011	4.73	16	79	0.4	3	57	0.79	0.066	14	29	0.65	358	0.02	2.33	0.03	0.11	135	< 2
95-1215	679929	6093472	Mv	3	25	9	60	< .3	17	7	393	2.00	3	47	< .2	2	36	0.42	0.040	13	15	0.40	131	0.05	1.44	0.03	0.08	40	< 2
95-1217	680663	6092393	Mb	1	49	14	90	< .3	34	11	668	4.18	15	56	0.4	4	55	0.56	0.050	14	27	0.56	262	0.03	2.05	0.02	0.09	105	< 2
95-1218	680740	6092209	Mb	1	37	5	74	< .3	29	10	462	3.62	11	41	< .2	< 2	50	0.38	0.057	11	24	0.51	141	0.03	1.69	0.02	0.07	95	< 2
95-1219	679418	6093850	Mb	1	20	6	133	< .3	28	9	333	3.03	4	30	< .2	< 2	48	0.27	0.049	8	19	0.45	202	0.06	2.45	0.02	0.13	40	< 2
95-2300	678652	6094104	Mb	1	47	15	124	0.3	31	17	885	4.28	13	68	0.2	< 2	56	1.85	0.066	13	25	0.70	284	0.02	1.90	0.03	0.12	140	< 2
95-2302	678652	6094104	Mb	2	51	18	126	0.4	34	18	963	4.56	16	61	0.5	2	61	0.65	0.070	15	27	0.71	251	0.03	1.99	0.03	0.13	155	< 2
95-2303	678056	6094686	Mb	1	47	20	116	0.3	38	22	1183	3.99	11	77	0.3	2	50	1.81	0.060	11	22	0.69	293	0.02	1.82	0.03	0.13	185	< 2
95-2304	677150	6098850	Mb	1	47	13	103	0.3	37	15	888	4.33	13	69	< .2	< 2	53	0.49	0.054	11	26	0.58	480	0.01	1.90	0.03	0.12	175	< 2
95-2305	677950	6098900	Mb	3	96	11	97	0.3	33	17	791	3.98	13	80	< .2	< 2	46	0.87	0.054	8	23	0.70	275	0.01	1.59	0.03	0.13	130	< 2
95-2306	677950	6098900	Mb	4	133	13	107	< .3	37	19	823	4.24	15	96	0.2	< 2	49	1.09	0.056	9	25	0.66	288	0.01	1.70	0.03	0.14	150	< 2
95-2307	678150	6098150	Cv	2	58	19	123	< .3	24	10	371	3.40	13	31	< .2	< 2	42	0.29	0.043	12	19	0.37	122	0.05	1.12	0.01	0.06	70	< 2
95-2308	678150	6098150	Mb	2	74	13	128	< .3	31	15	675	4.51	20	37	< .2	< 2	53	0.34	0.042	14	25	0.48	186	0.02	1.83	0.02	0.09	170	< 2
95-2309	677600	6098450	Mb	2	67	15	104	0.4	46	16	666	4.33	14	77	< .2	2	51	0.51	0.052	11	29	0.60	315	0.01	1.97	0.03	0.14	155	< 2
95-2310	677600	6098450	Mb	1	41	10	96	0.3	30	14	664	3.77	12	96	< .2	< 2	47	1.50	0.053	9	22	0.65	255	0.02	1.67	0.03	0.12	185	< 2
95-2311	677600	6098450	Mb	2	65	10	104	0.3	36	16	652	3.95	7	112	0.6	< 2	48	0.99	0.055	9	24	0.68	272	0.01	1.70	0.02	0.14	180	< 2
95-2312	677600	6098450	Mb	1	43	11	105	0.3	36	17	723	4.05	13	116	< .2	< 2	48	1.03	0.056	9	25	0.71	278	0.02	1.69	0.02	0.13	130	< 2
95-2313	677600	6098450	Mb	3	82	14	110	0.3	38	19	838	4.19	18	126	0.7	< 2	48	1.02	0.059	9	24	0.74	277	0.02	1.59	0.02	0.13	120	< 2
95-2314	677600	6098450	Mb	4	68	15	116	< .3	41	20	852	4.38	20	129	0.3	< 2	48	0.86	0.059	9	24	0.71	270	0.02	1.60	0.02	0.13	125	< 2
95-2315	677600	6098450	Mb	1	44	13	102	0.4	38	17	676	3.94	9	118	< .2	< 2	49	0.95	0.056	9	25	0.75	283	0.02	1.69	0.02	0.13	125	< 2
95-2317	677892	6095569	Mb	2	74	19	107	< .3	30	13	585	4.67	18	45	< .2	< 2	55	0.39	0.044	16	26	0.61	267	0.02	2.10	0.02	0.12	195	< 2
95-2318	677410	6095150	Mb	1	41	11	92	< .3	27	15	665	3.50	11	109	0.3	< 2	46	1.82	0.072	11	20	0.70	235	0.04	1.37	0.04	0.10	115	< 2
95-2319	677025	6095666	Mb	1	48	13	98	0.3	32	16	756	4.16	13	74	0.2	< 2	51	0.68	0.054	12	24	0.55	433	0.02	1.82	0.03	0.12	115	< 2
95-2320	676848	6096253	Mb	2	57	13	74	< .3	24	11	437	3.43	13	32	< .2	< 2	44	0.22	0.031	8	19	0.53	128	0.04	1.42	0.01	0.07	80	< 2
95-2322	676891	6096754	Mb	2	65	19	122	0.4	37	20	1234	4.60	21	46	0.6	< 2	53	0.55	0.058	12	24	0.55	459	0.02	1.82	0.02	0.12	125	< 2
95-2323	676740	6097296	Mb	2	366	14	112	< .3	29	11	419	3.37	13	47	0.4	< 2	41	0.35	0.048	10	19	0.40	314	0.03	1.27	0.01	0.09	170	< 2
95-2324	676490	6097642	Mb	2	105	20	176	< .3	40	19	953	4.95	34	65	0.5	< 2	56	0.46	0.067	13	27	0.59	377	0.02	1.88	0.03	0.13	140	2
95-2325	678200	6096600	Mb	2	83	21	107	< .3	35	19	816	4.87	22	37	< .2	2	51	0.39	0.055	13	23	0.47	193	0.02	1.68	0.02	0.08	180	< 2
95-2326	678092	6097275	Mv	2	63	14	95	< .3	35	12	423	4.67	15	48	0.2	2	56	0.40	0.053	13	30	0.54	277	0.01	2.18	0.02	0.12	175	< 2
95-2327	677600	6097492	Mb	2	105	20	104	1.4	38	21	1011	4.58	18	45	< .2	< 2	52	0.51	0.043	14	25	0.47	556	0.02	1.69	0.02	0.18	145	2
95-2328	677050	6100600	Mb	1	52	11	108	< .3	48	23	1245	4.02	20	77	0.7	3	47	3.00	0.080	9	25	0.60	269	0.02	1.78	0.02	0.10	165	2
95-2330	676921	6095422	Mb	1	34	15	73	< .3	26	8	302	4.13	12	36	< .2	< 2	51	0.16	0.031	7	26	0.54	145	0.01	1.94	0.02	0.11	130	< 2
95-2331	676814	6094779	Mv	1	37	14	71	< .3	23	9	483	3.53	9	58	0.2	< 2	46	0.43	0.045	12	21	0.53	168	0.03	1.59	0.02	0.09	125	< 2
95-2332	676727	6094225	Mb	1	44	14	79	< .3	26	11	638	4.08	12	57	< .2	< 2	53	0.45	0.060	15	21	0.51	146	0.04	1.41	0.03	0.10	135	< 2
95-2333	676699	6093494	Lgv	1	30	10	60	< .3	27	9	389	3.02	8	42	< .2	< 2	40	0.30	0.021	11	20	0.42	203	0.04	1.26	0.01	0.08	100	< 2

TABLE 1: ANALYTICAL RESULTS FROM TILL SAMPLES COLLECTED AT NEWMAN PENINSULA

Sample ID.	UTM Eastings	UTM Northings	Map Unit	Mo ppm	Cu ppm	Pb ppm	Zn ppm	Ag ppm	Ni ppm	Co ppm	Mn ppm	Fe %	As ppm	Sr ppm	Cd ppm	Bi ppm	V ppm	Ca %	P %	La ppm	Cr ppm	Mg %	Ba ppm	Ti %	Al %	Na %	K %	Hg ppb	W ppm
95-2334	676697	6093493	Mb	1	41	13	74	< .3	26	13	680	3.88	15	59	< .2	< 2	53	0.47	0.060	16	23	0.45	254	0.03	1.73	0.02	0.11	115	< 2
95-2335	678764	6090579	Lgb	1	25	11	72	< .3	26	10	453	3.44	9	44	< .2	3	46	0.33	0.045	8	23	0.60	151	0.03	1.73	0.02	0.14	75	< 2
95-2336	678649	6090915	Cb	< 1	28	5	37	< .3	9	5	238	2.15	< 2	68	< .2	< 2	45	0.74	0.124	21	7	0.58	62	0.06	0.99	0.05	0.09	35	< 2
95-2338	678428	6091420	Mb	1	41	9	67	< .3	21	10	519	3.24	6	76	< .2	< 2	51	0.63	0.080	14	20	0.77	142	0.06	1.36	0.05	0.11	45	< 2
95-2339	678123	6092110	Mb	1	39	9	58	< .3	22	8	334	3.77	11	55	0.3	< 2	50	0.39	0.038	11	23	0.54	193	0.03	1.83	0.03	0.10	130	< 2
95-2340	677560	6092309	Mb	1	20	10	55	< .3	21	9	392	2.98	7	51	< .2	< 2	45	0.37	0.028	11	20	0.48	116	0.06	1.30	0.02	0.11	165	< 2
95-2343	676760	6098526	Mb	1	46	12	99	< .3	36	13	734	4.14	14	48	0.2	< 2	48	0.37	0.045	11	26	0.50	227	0.02	1.68	0.02	0.11	240	< 2
95-2344	678101	6093996	Mb	1	30	10	71	< .3	26	10	487	3.45	9	41	0.2	< 2	45	0.29	0.037	11	23	0.51	162	0.04	1.54	0.02	0.11	105	< 2
95-2345	676760	6098526	Mh	1	16	5	53	< .3	23	6	243	2.41	5	27	< .2	< 2	31	0.21	0.030	8	19	0.37	120	0.03	1.02	0.01	0.07	155	< 2
95-2346	678819	6092327	Mv	< 1	28	5	59	0.3	17	10	509	3.02	3	57	< .2	< 2	62	0.61	0.094	16	25	0.97	102	0.09	1.42	0.06	0.07	75	< 2
95-2347	677736	6099596	Mb	1	47	16	205	< .3	26	11	636	3.62	11	38	0.4	< 2	45	0.29	0.039	9	23	0.43	231	0.03	1.48	0.01	0.10	160	< 2
95-2348	678927	6092563	Mv	1	42	15	89	< .3	26	12	711	3.96	14	44	0.3	< 2	53	0.47	0.043	16	26	0.64	187	0.03	1.83	0.02	0.10	125	< 2
95-2350	678657	6093077	Mv	1	36	12	78	< .3	22	9	456	3.88	13	47	< .2	< 2	51	0.48	0.057	15	24	0.59	184	0.03	1.88	0.03	0.09	80	< 2
95-2351	676571	6098998	Mb	2	32	12	83	< .3	29	10	286	3.70	12	23	< .2	< 2	45	0.18	0.036	8	23	0.52	96	0.06	1.30	0.01	0.14	140	< 2
95-2352	678841	6093251	Mv	1	42	13	84	< .3	28	11	581	4.00	12	54	< .2	< 2	53	0.49	0.049	15	26	0.56	234	0.03	1.97	0.02	0.12	190	< 2
95-2353	676720	6099646	Mb	1	44	12	98	< .3	43	11	725	4.08	14	52	0.4	< 2	48	0.35	0.041	14	31	0.55	360	0.01	1.81	0.02	0.12	200	< 2
95-2355	676691	6099880	Mb	1	39	11	86	< .3	33	12	625	3.91	12	35	0.4	< 2	44	0.25	0.033	9	26	0.48	157	0.02	1.53	0.02	0.11	300	< 2
95-2356	676692	6100986	Mb	1	29	14	59	< .3	27	8	300	3.16	8	35	0.2	< 2	40	0.20	0.027	9	23	0.47	164	0.02	1.41	0.02	0.09	150	< 2
95-2357	676691	6099880	Mh	1	19	7	56	< .3	25	7	282	2.68	7	28	< .2	< 2	34	0.21	0.033	7	20	0.38	84	0.04	1.00	0.01	0.06	140	2
95-2358	676748	6101509	Mb	1	40	10	88	< .3	36	13	814	3.95	14	58	0.3	< 2	47	0.46	0.052	10	26	0.50	271	0.01	1.51	0.02	0.09	210	< 2
95-2359	677171	6100591	Mb	1	35	11	76	< .3	29	10	450	3.53	10	44	0.4	3	43	0.27	0.035	10	25	0.48	162	0.02	1.44	0.02	0.09	155	< 2
95-2360	678650	6094100	Lgb	1	55	13	103	< .3	37	16	660	4.20	11	101	0.4	< 2	52	0.72	0.039	7	27	0.85	624	0.01	2.25	0.03	0.19	165	< 2
95-3180	677900	6099250	Mb	1	1550	14	434	0.5	47	17	1004	4.35	15	56	2.0	2	56	0.45	0.070	17	28	0.61	460	0.02	2.01	0.02	0.10	180	< 2
95-3182	677750	6100225	Mb	1	44	9	60	< .3	33	10	485	4.13	11	40	<.2	< 2	55	0.36	0.030	9	26	0.57	209	0.01	2.06	0.02	0.10	380	< 2
95-3183	677425	6099950	Mb	1	57	48	101	0.3	37	14	808	4.43	13	53	0.4	< 2	53	0.43	0.050	12	26	0.52	347	0.02	1.92	0.02	0.09	206	4
		max.		4	366	21	176	1	52	23	1823	5.07	34	175	0.8	4	61	3.00	0.080	23	30	0.75	556	0.06	2.45	0.04	0.18	195	2
		min.		< 1	0	0	0	< .3	0	0	0	0.00	< 2	0	< .2	< 2	0	0.00	0.000	0	0	0.00	0	0.00	0.00	0.00	0.00	0	< 2
		mean		1.2	63.1	11.7	90.0	0.2	29.0	11.9	594.1	3.60	11.5	56.6	0.4	2.1	46.1	0.57	0.049	11.0	22.5	0.54	219.6	0.03	1.57	0.02	0.10	133.2	1.2
95-2371	677736	6099600	b/r	1	55	129	2347	0.5	12	17	3005	4.65	23	23	7.8	< 2	100	1.03	0.185	11	18	2.09	38	0.02	2.62	0.04	0.17	11	15
95-2373	677736	6099610	b/r	< 1	12	8	540	0.3	17	17	3255	5.46	38	9	1.1	< 2	110	0.53	0.191	12	23	2.29	43	0.01	2.74	0.01	0.19	20	16
		Detection Limit		1	1	3	1	0.3	1	1	2	0.01	2	1	0.2	2	1	0.01	0.001	1	1	0.01	1	0.01	0.01	0.01	0.01	10	2

Note: Map units; M-morainal, C-colluvium, Lg-glaciolacustrine sediments, b/r-bedrock (assay); terrain modifiers: b=blanket, h=hummocky, v=veneer.

Analytical method: Aqua regia-ICP, analysis by ACME Analytical vertical exposures from a few sites of undisturbed till where basal lodgement till was overlain by winnowed basal till or colluvium.

Each sample weighing between 1 to 3 kg, was stored in 8-mil plastic bags, air dried (at 25-30°C), split, disaggregated, and sieved to < 63μm, i.e. the silt plus clay sized-fraction. Representative splits were analyzed for 47 different elements by aqua regia inductively coupled plasma emission spectroscopy (ICP-ES) and instrumental neutron activation (INA).

In addition to studying the matrix component of till, the lithology of clasts in till were examined to identify source bedrock units of the till and to determine the length of glacial dispersal in the area. At selected sites, 25 pebbles were collected from undisturbed till and their lithologies recorded. In this study the mineralized and sedimentary rock fractions of the total clast counts are plotted to measure the length of dispersal, down-ice of bedrock contacts (Figure 7).

PREVIOUS WORK

In 1981, Noranda Inc. conducted B-horizon soil sampling across the southern part of the Newman Peninsula, to locate new zones of mineralization. Glacial overburden profile sampling was conducted at the Bell mine property in the 1970's (Okon, 1974; Levinson and Carter, 1979), in order to study the vertical distribution of base metal concentrations within overburden overlying mineralized and non-mineralized bedrock. Results from these studies indicate higher copper and molybdenum concentrations in till over mineralized bedrock. In contrast, zinc concentrations in till are often elevated over non-mineralized bedrock. Levinson and Carter (1979) suggest these high zinc values reflect sulphide mineralization in peripheral areas (pyrite halo) rimming the porphyry copper deposit.

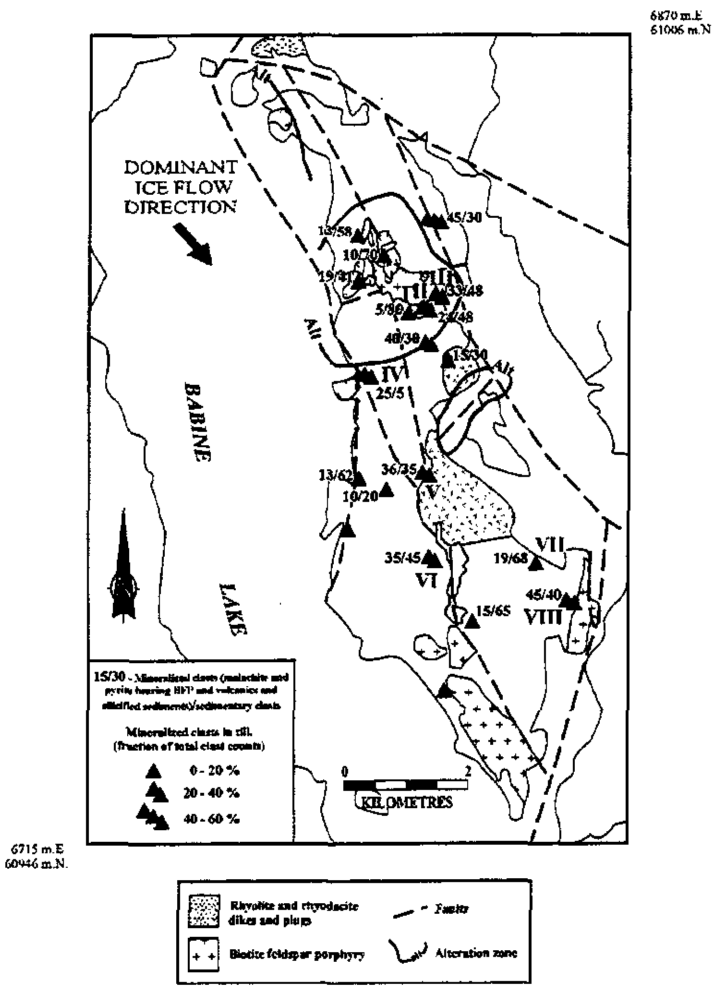

Figure 7 - Distribution of mineralized and sedimentary clasts in till at the Newman Peninsula.

RESULTS

Of the 47 elements analyzed for this study, the distribution of 7 elements (silver, cadmium, copper, mercury, molybdenum, nickel, and zinc), will be discussed here. However, the complete data set for the ICP-ES analysis is presented in Table 1. Elemental concentrations of copper, molybdenum, zinc, silver, mercury, cadmium and nickel in till are plotted on maps using symbols proportional to concentration (Figures 8a, b; 9a, b, c, 10a, b). Statistical analysis of the data identified background and anomalous levels of the geochemical data. In this study, mean till geochemical concentrations measured in a regional till survey from 93 L/16 represent background threshold values, whereas the data above the 95th percentile are considered to be anomalous (Table 2).

Re-contoured plots of Noranda's soil geochemical data show several distinct zones of anomalous copper values, area, higher than background concentrations of these elements occur along major faults and along bedrock contacts (*e.g.* zinc - Figure 9a).

Significant variations in the geochemistry occur in vertical profiles of glacial drift sampled at several sites (Table 3). At locations A and B, where winnowed basal till overlies basal lodgment till, geochemical concentrations in lodgement till are 1.5 to 3 times higher. Lower variability in geochemistry was observed at location C where colluvium overlies lodgement till.

The distribution of mineralized and sedimentary clasts in till recorded at selected sample sites across the Bell mine area reflect the sample's relative location to up-ice bedrock units. For example, an abundance of sedimentary clasts (maximum of 80%) are found in the upper part of the till unit at site I (Figure 7). Less than 100 metes north-east of I at site II and III (Figure 7), the sedimentary clast concentrations decrease to about 50 percent. Site I is located down-ice of Skeena Group sediments whereas sites II and III occur down-ice of Skeena sediments and Hazelton volcanics.

Table 2: Cumulative Frequencies of Selected Geochemical Data

Percentile	Cu (ppm)	Mo (ppm)	Zn (ppm)	Ag (ppm)	Hg (ppb)	Cd (ppm)	Ni (ppm)
REG	44	1	88	0.2	88	0.3	24
50%	44	1	92	0.2	135	0.2	30
75%	57	2	108	0.2	170	0.4	36
90%	83	2	128	0.3	199	0.7	41
95%	98	3	150	0.4	222	0.7	45

(REG - mean of regional till geochemistry data from 93 L/16)

oriented parallel to the main ice flow direction (Figures 11a, b). Additional copper and molybdenum anomalies occur in the area, associated with Babine intrusions or occurring along major faults. In this study, tills sampled in the southern third of the peninsula contain much lower concentrations of copper and molybdenum than the soil. Concentrations in till range from slightly below to slightly above background levels in the soil (Table 1; Figures 8a, b). A single molybdenum anomaly in till located along fault-bounded Babine intrusive rocks on the eastern-most part of the Newman Peninsula (Site B, Figure 8b), is coincident with elevated copper values in soil in the area (Figure 11a).

The majority of the till anomalies identified in this study are located within or along the boundary of alteration encircling the Bell mine ore-body. Here, maximum concentrations in till are observed for copper (1550 ppm), molybdenum (4 ppm), zinc (434 ppm), silver (1.4 ppm), cadmium (2.0 ppm) (Site A, Figures 8a, b; 9a; 10a; Site E, Figure 9b). The highest mercury concentration in till (380 ppb), occurs slightly to the north-east of the zone of alteration (Site F, Figure 9c). Throughout the entire study

DISCUSSION

Differences between soil and till geochemistry in the southern part of the Newman Peninsula could be an artifact of differences in the origin of the sampling media in the soil survey. A large part of the area where the soil sampling program was conducted is covered by a blanket of colluvium (Cb) or a veneer of basal till (Mv) (Figure 4a) These sediments have a simple genesis and their matrix and clast components have been transported over relatively short distances. Therefore, their geochemical composition may reflect the geochemistry of mineralized bedrock in the area. Till collected from the same area was typically sampled in morainal exposures with thicknesses greater than 1 metre. Thicker till units typically contain a greater percentage of more distally derived material. Therefore, the geochemistry of the till will reflect the mineralogy of

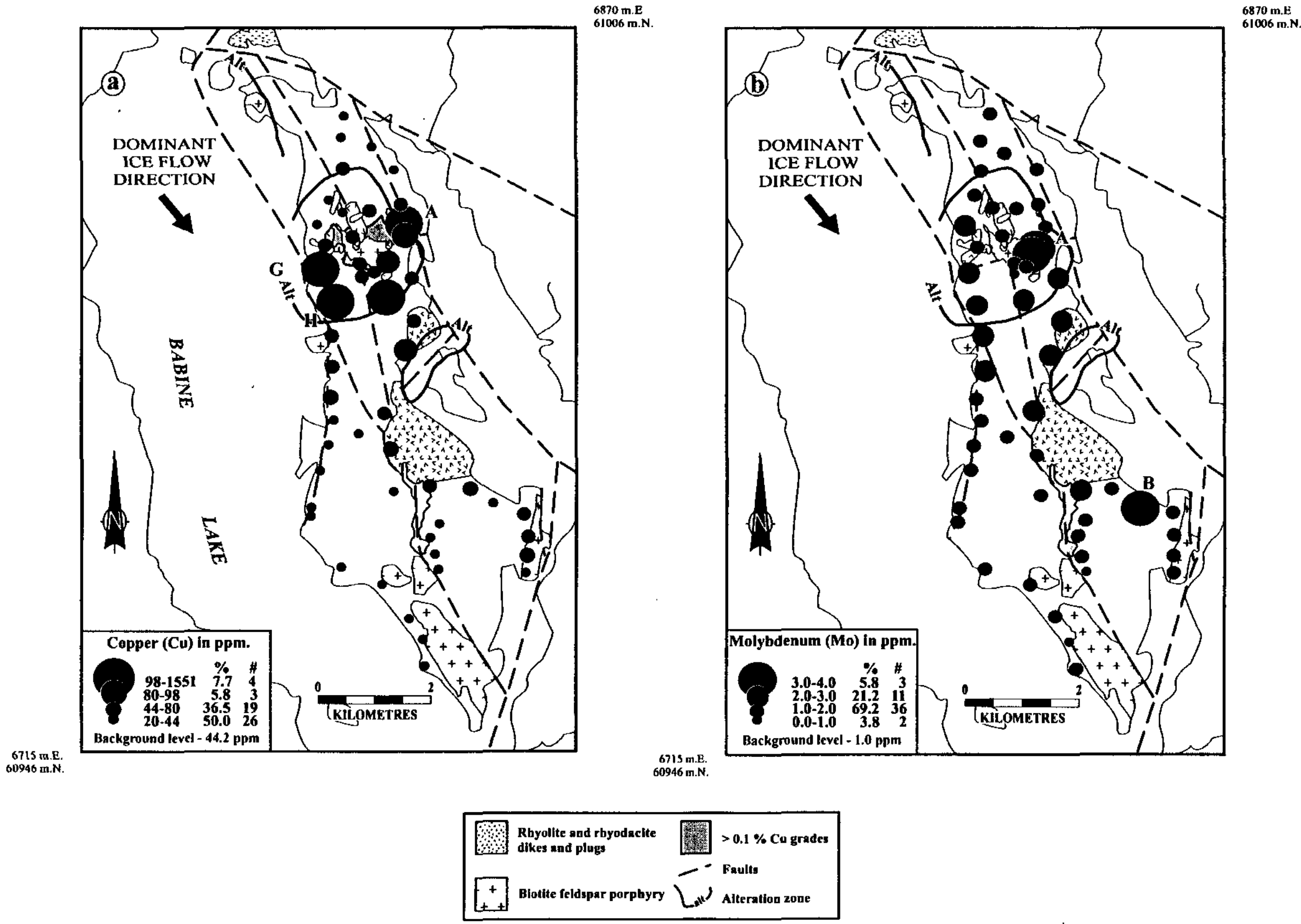

Figure 8 - Copper (a) and molybdenum (b) concentrations in till from the Newman Peninsula.

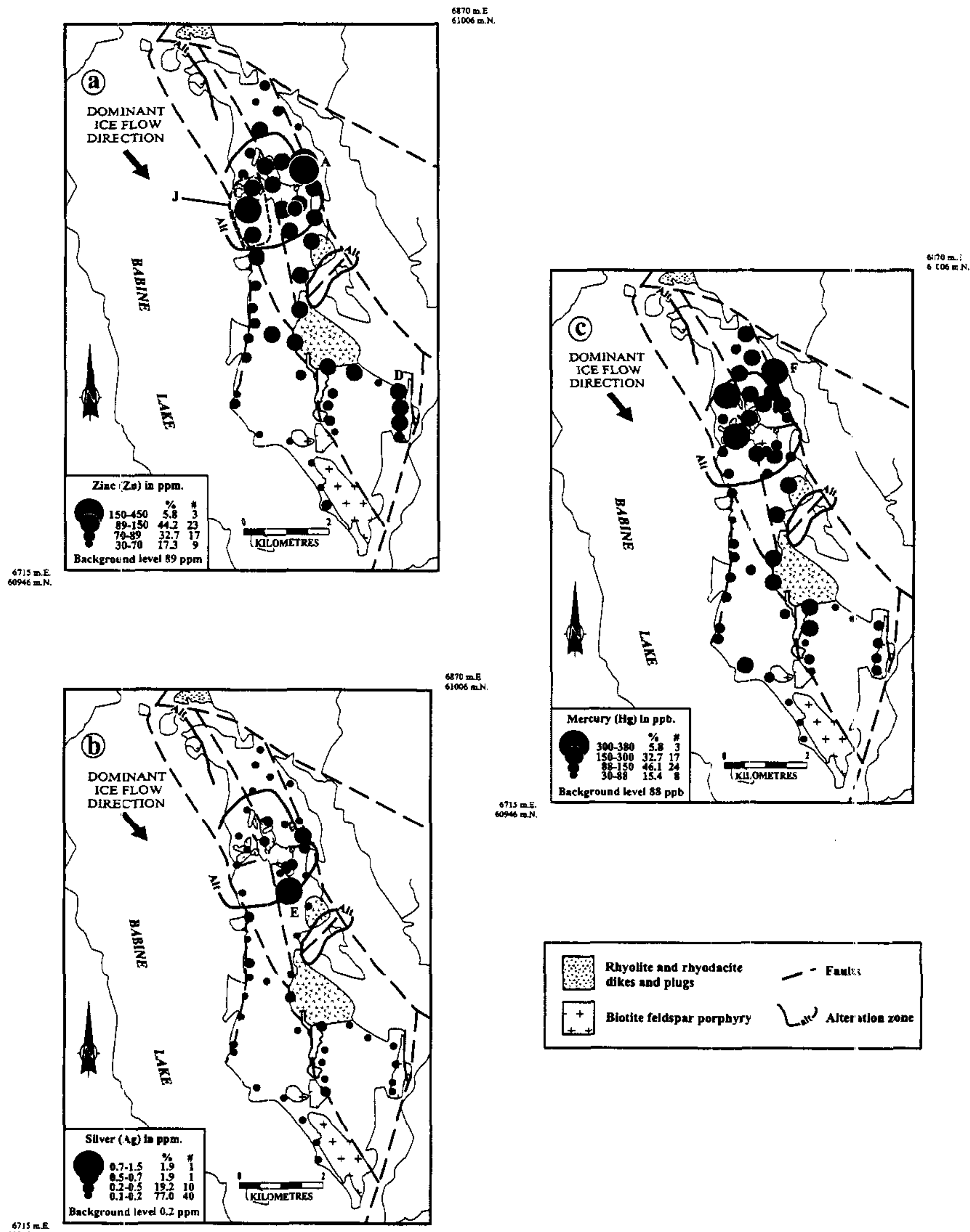

Figure 9 - Zinc (a), silver (b) and mercury (c) concentrations in till from the Newman Peninsula.

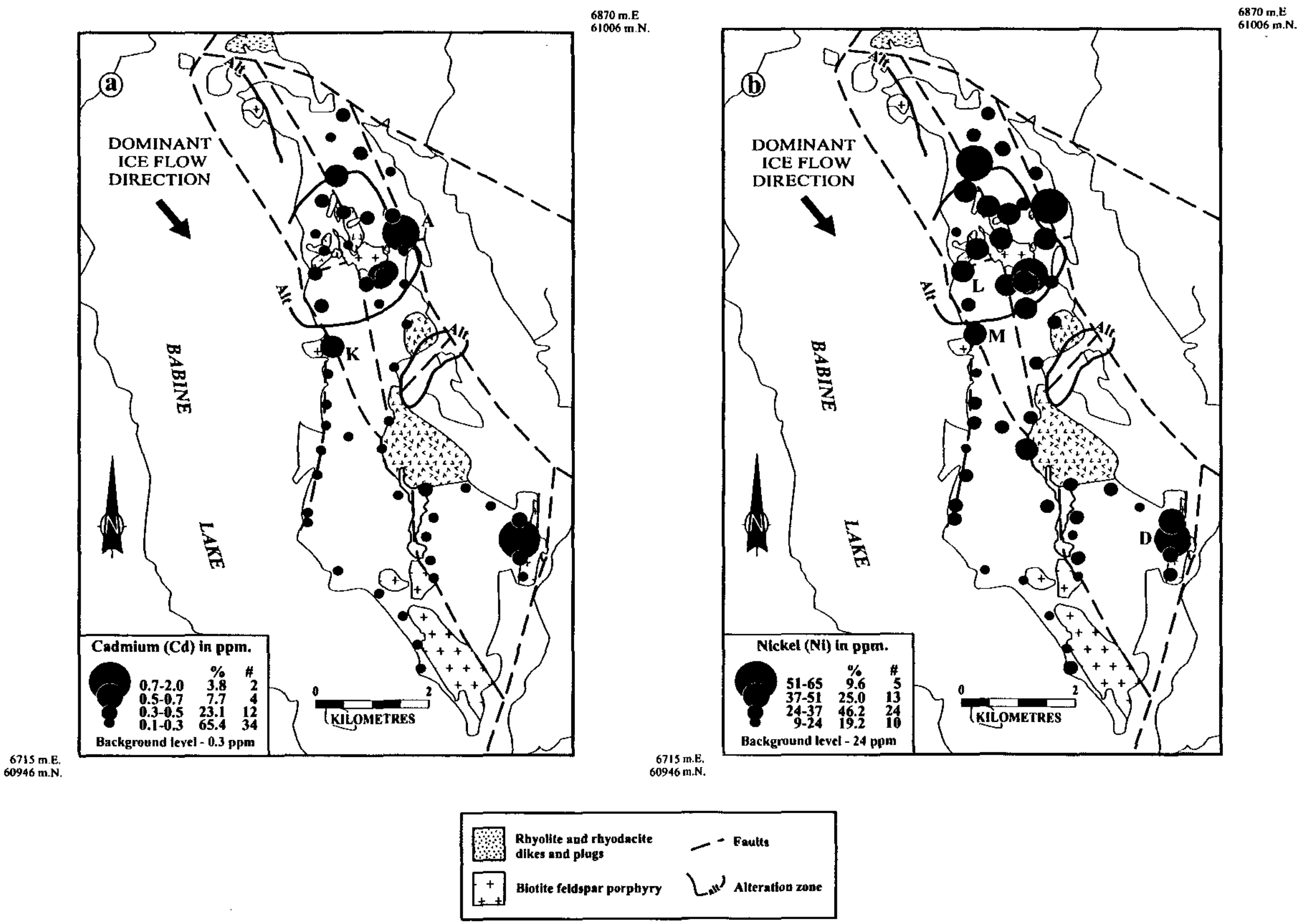

Figure 10 - Cadmium (a) and nickel (b) concentrations in till from the Newman Peninsula.

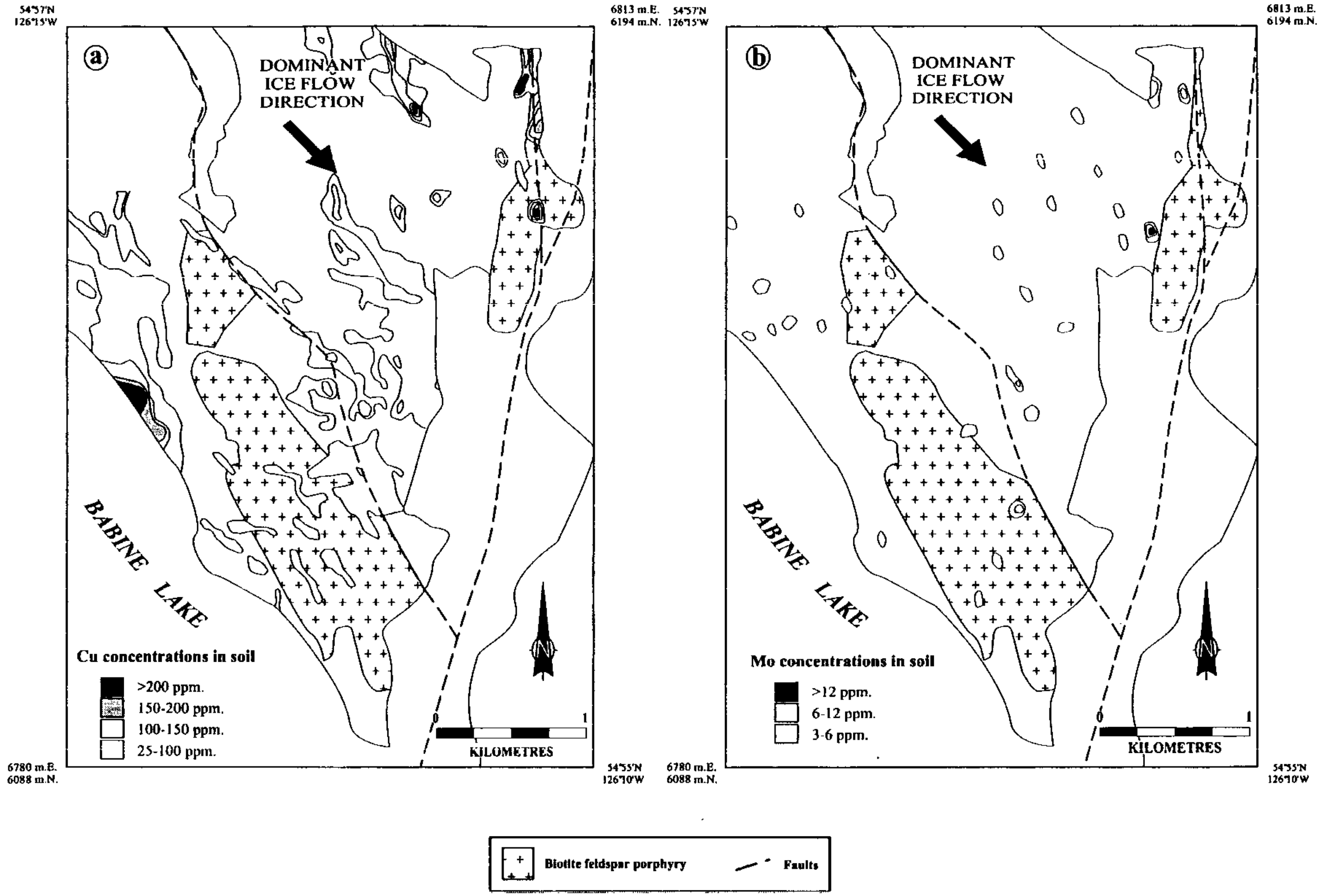

Figure 11 - Copper (a) and molybdenum (b) concentrations in soil, southern part of Newman Peninsula.

Table 3: ICP and INA Data from Selected Vertical Profile Sites

Profile Site	Sample #	Al (%)	As (ppm)	Ba (ppm)	Cu (ppm)	Fe (%)	Hg (ppb)	Mn (ppm)	Sm (ppm)	Yb (ppm)	Zn (ppm)
A	95-2345	1.02	11	670	16	2.41	155	243	4.0	2.6	53
	95-2343	1.66	20	840	46	4.14	240	734	5.7	3.6	99
B	95-2357	1.00	9.9	560	19	2.68	140	282	3.5	2.5	56
	95-2355	1.53	20	820	39	3.91	300	625	4.8	3.4	86
C	95-2307	1.12	18	620	58	3.40	70	371	4.6	2.6	123
	95-2308	1.83	23	770	74	4.51	170	675	5.2	2.9	128

Note: Samples at each profile site lie in stratigraphic order (top to bottom).

bedrock from over a much larger area.

Numerous geochemical anomalies in till (Table 1; Figures 8a, b), occur south and east of the Bell mine site. The intensity of these anomalies and their location with respect to regional ice flow and the limits of alteration outlined by Carter *et al.* (1976); Figures 8a, b), suggest dispersal from mineralized intrusive bodies within the alteration zone. For example, anomalous copper values in till at site A (Figure 8a), indicate that this till may overlie mineralized bedrock (*cf.* Levinson and Carter, 1979). Alternatively, the till at site A may contain material eroded from unknown mineralized intrusive bodies located to the north of the mapped alteration zone.

Above background concentrations (mean regional concentrations) for copper (Sites G and H, Figure 8a), zinc (Area J, Figure 9a), cadmium (Site K, Figure 10a) and nickel (Sites L and M, Figure 10b) in till occur to the south and west of the Bell deposit. Significant copper anomalies along the western edge of the Newman Peninsula (Sites G and H, Figure 8a), suggest dispersal from unknown mineralized bodies located to the north-west, possibly lying beneath Babine Lake

In the southern part of the Newman Peninsula ice flow shifts slightly from a south-east direction towards the east (Figure 4a). Over the south-east half of the peninsula (Figures 8a, b; 9a; 10a, b), geochemical concentrations in till occur above background values for copper, molybdenum, zinc, cadmium and nickel. Mineralized material could be carried in a large dispersal train extending south and eastward of the Bell ore-body. The detectable length of dispersal for the matrix component of till may be up to 5 kilometres down-ice of Babine intrusive bodies.

The distance over which clasts of eroded bedrock material are transported down-ice of source bedrock units are a function of their lithology, the size and relief of the outcrop area and the glacial dynamics (Clark, 1987). High concentrations of mineralized clasts are recorded in till at sample sites along the central and southeastern portions of the Newman Peninsula (Sites IV, V, VI, VII and VIII, Figure 7). The Bell ore-body, and mineralized bodies located within its alteration zone are sources for mineralized clasts at sites IV, V and VI. At sites VII and VIII, mineralized clasts in till may also derived from the Bell deposit. Alternatively, these clasts could be eroded from unknown mineralized bodies within Babine intrusive rocks located approximately 1 kilometre to the north-west. In either case, glacial dispersal of mineralized clasts may extend for over 4 kilometres down-ice of source bedrock units.

For the analysis of till geochemistry data it is essential to understand how changes in depth to bedrock will effect the composition of till. Typically, where thin till cover overlies bedrock, the clast and matrix components of the till are dominated by material derived from relatively local sources. In addition, the lithological and matrix concentrations of till may vary dramatically within vertical profiles (Broster, 1986). The upper part of the till profile usually contains a higher percentage of distally-transported material than compared to the lower part which generally contains a high concentration of material eroded from the underlying units.

In this study, till samples collected from a nine metre exposure along the Bell mine open pit (Site A, Figure 8b), show very little variability in their geochemistry with increasing depth. Moderately high copper, molybdenum and cadmium concentrations occur only within the lowest part of the till profile overlying bedrock (samples 95-2313 and 95-2314 for molybdenum; sample 95-2313 for copper and cadmium, in Table 1). Otherwise, the concentrations of elements discussed in this study show no correlation with an increase in depth (samples 95-2309 to 95-2312 and 95-2315, in Table 1). Similar results of this study were obtained from vertical profile samples at the NAK property (Levson *et al.*, 1997a, this volume). The concentration of mineralized and sedimentary clasts also show no significant variation with depth. Mineralized clast concentrations vary from 24 to 33 % over the whole nine metre profile (Figure 7, sites II and III).

CONCLUSIONS

Till geochemistry can be used to locate mineral deposits in areas of thick glacial drift. In this study, anomalous till geochemistry is only confined to the alteration zone around the Bell mine. Occurrences of copper, zinc, and cadmium anomalies in till to the north-east of the Bell deposit, along the margin of Bell's alteration zone suggest these anomalies may be derived from unknown sources of mineralization at the periphery of the alteration zone. Alternatively, these anomalies could have their source from unknown mineralized bodies located farther to the north-west. Above background concentrations of copper, zinc, cadmium and nickel in till occurring to the south and west of the Bell deposit may have sources to the north-west beneath Babine Lake.

Glacial dispersal of material occurs down-ice of source bedrock units. Till containing above background values for copper, molybdenum, zinc and mercury concentrations extends for up to 5 kilometres southeastward of Babine intrusions. Dispersal trains containing mineralized clasts extend for over 4 kilometres down-ice of bedrock source units. Dispersal trains of both matrix and lithological components of till from, the Bell deposit may extend southeastward into the Hagan Arm.

Geochemical concentrations in basal lodgement till collected from a vertical profile at Bell mine show very little variability with depth. Slightly elevated concentrations of copper, molybdenum and cadmium occur in the lowest part of the till overlying bedrock, but throughout the profile there exists no distinct correlation in geochemistry with increasing depth.

Winnowed basal till and lodgement till collected from vertical sections produced significant geochemical variability. Geochemical concentrations in lodgement till are several times higher than concentrations in the winnowed basal till. Therefore, it is essential to distinguish between these types of sediments encountered in a sampling program in order to accurately interpret geochemical data.

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