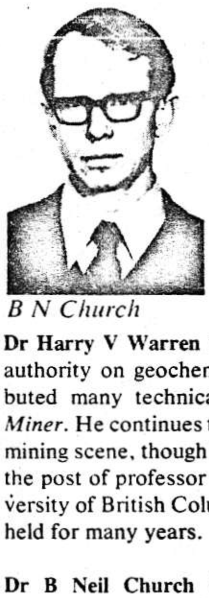
The study of the relative and absolute concentration of barium and strontium in country rocks may prove useful in searching for mineral deposit extensions. Data are given from two properties (silver and copper) in British Columbia.

Barium-Strontium relationships

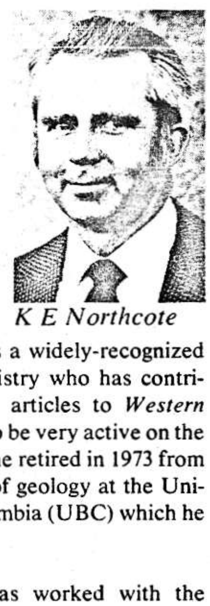
possible geochemical tool in search for ore bodies

H V Warren, B N Church, K E Northcote

H V Warren



B N Church



K E Northcote

Dr Harry V Warren is a widely-recognized authority on geochemistry who has contributed many technical articles to *Western Miner*. He continues to be very active on the mining scene, though he retired in 1973 from the post of professor of geology at the University of British Columbia (UBC) which he held for many years.

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Dr K E Northcote has had wide geological experience in Canada and Colombia (S America), and has been for several years with the BC Department of Mines and Petroleum Resources; he has been engaged in geological mapping on Vancouver Island.

Much is known about the distribution and concentration of barium and strontium in minerals and rocks but relatively little use has been made of the wide variations that are found in eruptive rocks, particularly in the vicinity of some ore bodies.

This paper indicates how the study of the relative and absolute concentrations of barium and strontium in country rocks may prove useful in searching for mineral deposit extensions such as at two well known British Columbian properties, the Dusty Mac, a silver occurrence in the southern Okanagan, and Island Copper mine in northern Vancouver Island.

Rock geochemistry has recently become important as a standard exploration tool and is especially useful in heavily drift-covered areas.

Initially, rock geochemistry was concerned with the concentrations in apparently barren rock of the metals which were being sought, such as copper, zinc, molybdenum, and gold. More recently attention has been turned to other elements whose distribution in rocks near mineral deposits may be useful because they provide haloes more easily recognizable than those provided by the metals which are sought. Barium and strontium, the elements with which this paper is primarily concerned, are both relatively abundant and readily determined in most rocks.

Concentrations of Ba and Sr in eruptive rocks

The concentrations of barium and strontium in various rocks and minerals have been documented by many writers, and there is a general agreement between most of them, including Goldschmidt (1954), Rankama and Sahama (1949), Turekian and Wedepol (1961), Holmes and Harwood (1937), and Hawkes and Webb (1962).

Strontium is present in both plagioclase and in alkali feldspar, but significant amounts of barium are found only in alkali feldspar and biotite.

One of us (BNC) has studied the concentrations of barium and strontium in some feldspars and femic minerals. Biotite and anorthoclase contain the greatest amounts of barium but the plagioclases tend to show more strontium. Unfortunately only seventeen determinations were made and consequently more detailed work might modify these findings although they do appear to be in accordance with the results obtained by other workers.

Goldschmidt suggested an average concentration of 430 ppm (parts per million) of barium for the igneous rocks of the earth's crust, and Hawkes and Webb gave 640. All these writers have stated that in the sequence from gabbros, basalts, and anorthosites to granites and syenites the barium concentrations rise from something under 100 ppm to well in excess of 1000 ppm, being especially high in some syenites, trachytes, and phonolites.

In basic rocks strontium generally exceeds the barium content but the reverse is normally found in granites, syenites, and related volcanic rocks.

Grove (1971) drew attention to barren vein material relatively enriched in barium in a mineralized zone extending about 60 feet above known bonanza ore shoots in the Silbak Premier vein system, and suggested rock geochemistry would be a useful exploration method in that area.

I. Dusty Mac

The Dusty Mac property is situated one mile east of the south end of Skaha Lake and the village of Okanagan Falls in the southern part of the Okanagan Valley. The property has been described in detail (Church, 1973) and only a brief resume of the general geology is given here (Fig 1).

General geology

In the vicinity of the Dusty Mac silver-gold mineralization three rock assemblages are important. They are parts of the Tertiary Marama and White Lake Formations, and a tectonic breccia characterized by quartz veining, much silicification and gossan.

The zone of potential economic mineralization is where silicification is greatest on what is believed to be the limb of a faulted syncline in rock identified as part of the White Lake Formation (Fig 2 & Fig 3).

Silicification and gossan are the best local guides in looking for ore but outcrop is sparse in much of the area of best potential. Fortunately many rock samples taken both from the available outcrops and from drill cores have been available for study and trace element analysis.

Barium, strontium, chromium, nickel, silver, and lead were determined at the Department of Geological Sciences, University of British Columbia, by Don Marshall using a large Hilger spectrograph. Tellurium, arsenic and quartz analyses were carried out in the laboratories of the British Columbia Department of Mines and Petroleum Resources, in Victoria.

Five tables of data were prepared from these results: A: Seventeen representative samples of the Marama Formation. B: Eleven from the White Lake Formation. C: Nine from the 'ore', obtained by drilling. D: Six from within fifty feet of the 'ore' as outlined by drilling. E: Seventeen samples from cores taken from drill holes unsuccessful in finding ore. The locations from which all these samples were taken are given in maps (Fig 3 & 4).

Discussion of Dusty Mac results

On the basis of the data contained in table 1 some conclusions may be drawn:

(1) In only one sample (DDH 14-8') with a quartz content of more than 50% is the silver content below 15 ppm, or 0.5 oz per ton.

(2) In only one sample (DDH 8-19') with a quartz content of less than 50% is the silver content more than 25 ppm, or 0.83 oz per ton.

(3) In general the 'no ore' holes are all in non-silicified White Lake Formation.

(4) The low barium and strontium values in 'ore' cannot readily be explained simply by the abundance of quartz and a relative deficiency of alkali feldspar. Only in the 'ore' samples are strontium values greater than barium. Only in basic and ultra mafic rocks could this be considered normal.

(5) Silver values cannot be related directly to either lead or arsenic and it seems probable that some lead and silver can be attributed to telluride minerals.

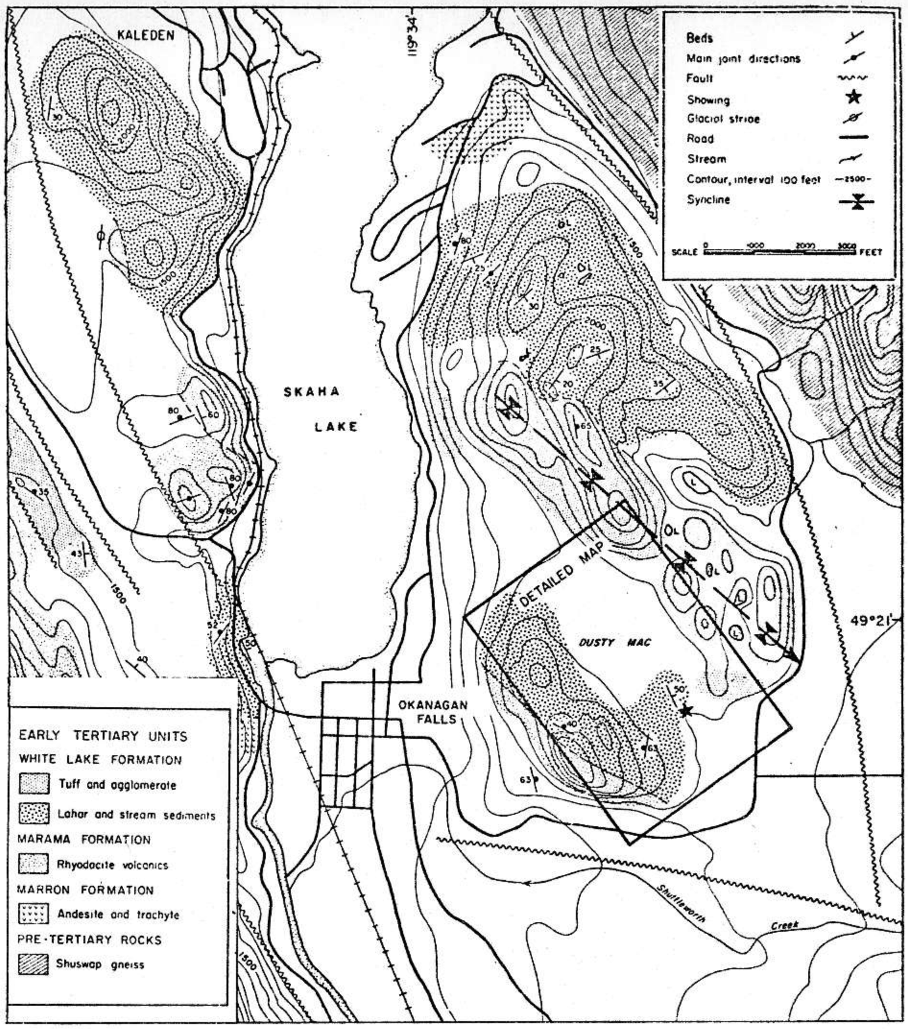
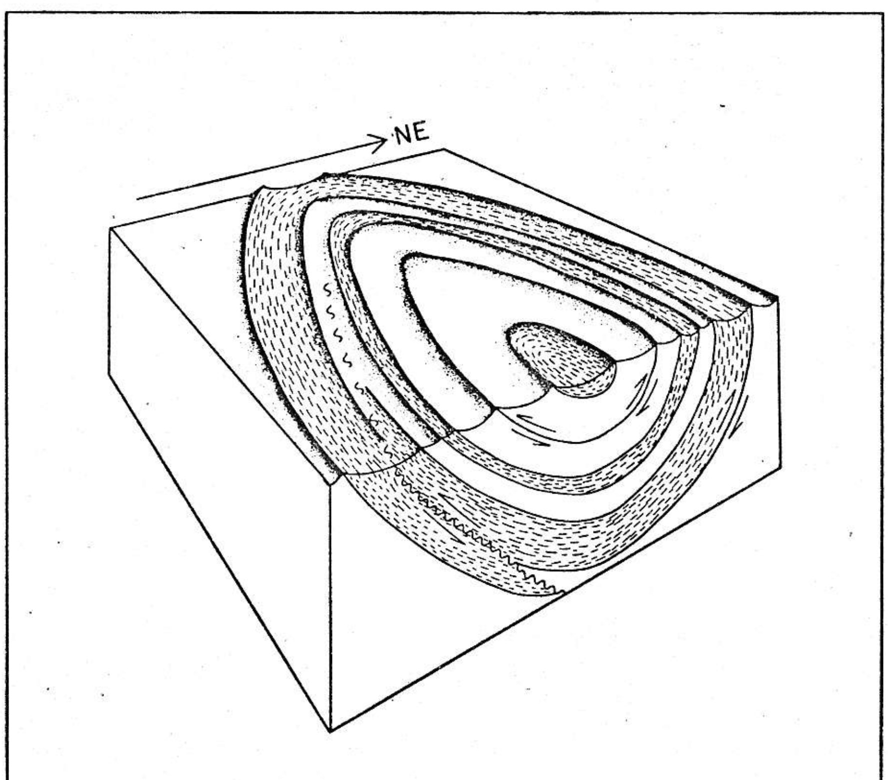


Fig. 1. Dusty Mac: general location map

Fig. 2. Dusty Mac: faulted synclinal structure



II. Island Copper and Red Dog

Both properties are situated in the Rupert Inlet — Cape Scott Map-Area in the northern part of the Nanaimo Mining Division of British Columbia.

Two eruptive rock units, the Karmutsen Formation and the Bonanza Subgroup, are important in this discussion. Northcote (1970) has described the general geology of the area and the following two paragraphs are summarized from his report.

The Karmutsen Formation is of Triassic age and the rocks are characteristically medium to dark green-grey, interbedded massive porphyritic and amygdaloidal flows of basaltic composition. Tuff is interbedded with flows and some pillow breccia, and poorly developed pillows occur.

The Bonanza Subgroup ranges from Upper Triassic to Upper Lower Jurassic. We are concerned with an upper volcanic unit, made up of bedded and massive tuff, lapilli tuff, tuff breccia, and some interbedded lava flows. These volcanic rocks range from basaltic andesite to rhyolite in composition.

Northcote selected the following samples as representatives of these rock units: A, 7 Karmutsen; B, 12 Bonanza (fresh); C, 6 Bonanza (altered); D, 3 Intrusive rocks; E, 2 Bonanza (Island Copper ore zone); F, 1 Bonanza (fringe of Island Copper ore); G, 5 Bonanza (Red Dog mineralization). The locations of these samples are shown on Figure 5.

Mr John Lamb, Senior Geologist at Island Copper Mine, kindly sent seven selected samples representing the ore and material on the fringe, respectively, H and I in Table 2.

All of the above samples were analyzed for barium, strontium, chromium, nickel, lead, silver, and copper by Don Marshall at the University of British Columbia.

These results have been tabulated in Table 2.

Discussion of Island Copper and Red Dog results

It can be seen from Table 2E, 2G, and 2H that the barium concentrations fall below those of strontium in the samples taken from ore zones in marked contrast to fringe samples 2F and 2I. Table 2B, for unaltered Bonanza rocks shows average barium values are greater than strontium values.

Table 2C, for altered Bonanza rocks, shows two groups of contrasting barium-strontium ratios of six analyses listed, four have barium values less than strontium. The remaining two samples are enriched in barium relative to strontium. It is of interest to note that three of the four samples with low barium-strontium ratios can be related to alteration associated with copper mineralization but were not taken from ore zones.

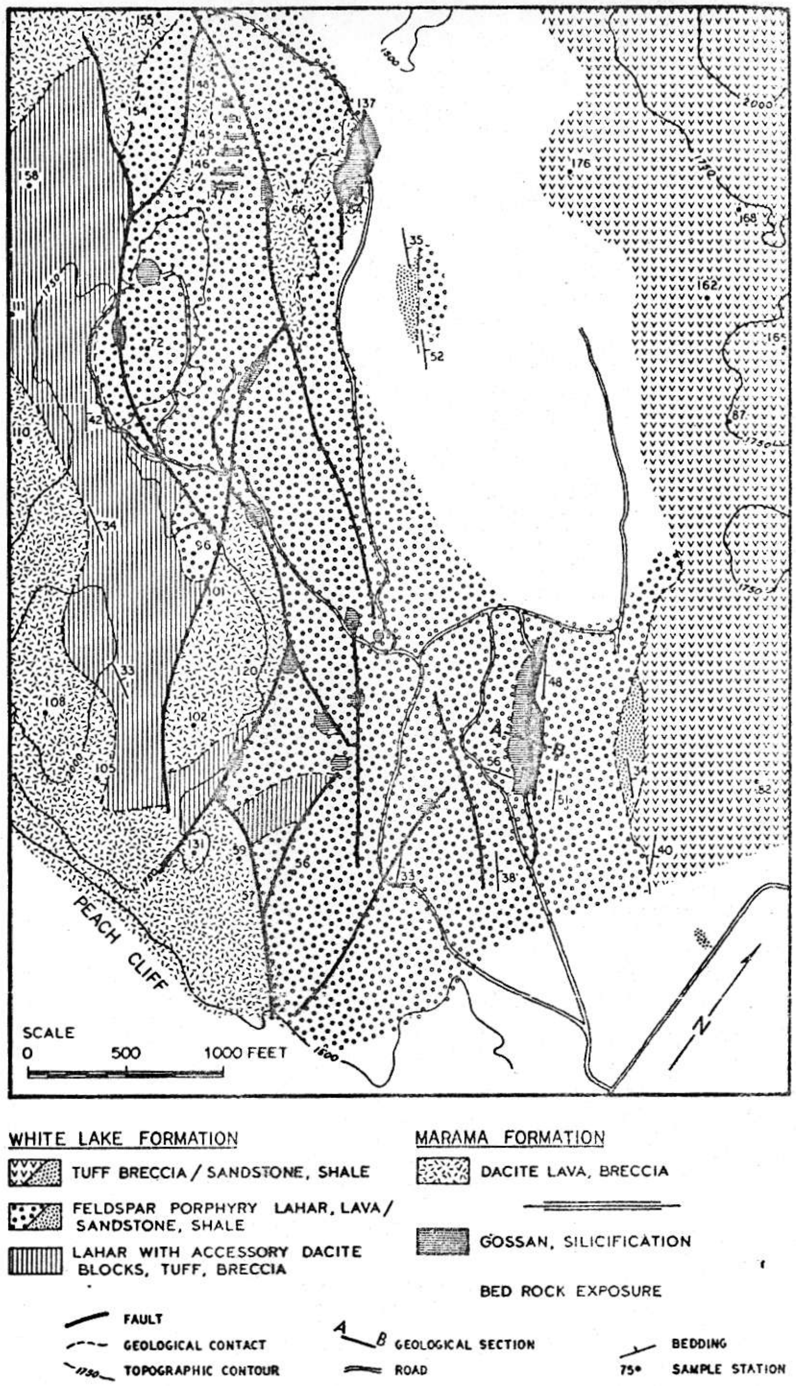


Fig. 3. Dusty Mac: location of samples (Table 1)

The two samples with high barium-strontium ratios show epidotization and/or pyritization but are not known to be associated with copper mineralization.

Barium is consistently lower than strontium in all Karmutsen samples, presumably because of the more basic nature of these rocks.

From the data presented here it appears that each eruptive rock unit exhibits a characteristic barium-strontium relationship. This relationship, on occasion is varied, in places greatly, where there is mineralization nearby. Further, it is suggested that rocks which have undergone different types of alteration will exhibit different barium-strontium ratios.

In the examples given in this paper, the barium-strontium relationships in the ore bodies are reversed from those of the host rock units.

Although this paper has considered only a few examples, and no final conclusions can be made, enough evidence has been accumulated to justify further studies.

Barium and strontium are two elements which lend themselves admirably to bio-, pedo-, equally well as to lithogeochemistry. This fact may be important in areas where extensive overburden makes rock geochemistry impractical.

Acknowledgements

One of us (HVW) is indebted to The National Research Council (Grant No.1805), a Canada Council Grant (Killam Award), and The Geological Survey of Canada for financial support for investigations which included this project. The study was greatly facilitated through use of the rock library system of the British Columbia Department of Mines and Petroleum Resources.

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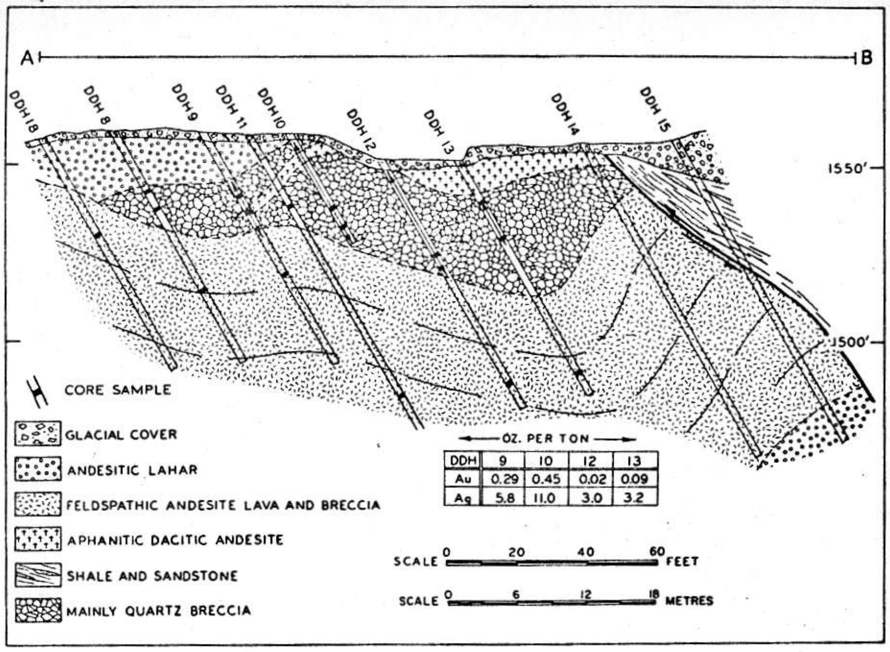

Fig 4. Dusty Mac: location of samples (Table 1)

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Table 1. Some trace elements and quartz in various samples (chemical data in ppm)

A. Marama Formation (Rhyolite – Dacite)

Sample No.	Ba	Sr	Cr	Ni	Pb	Ag	As	Quartz %
57	100	400	15	5	7	—	4	46
59	300	200	8	<4	5	—	8	35
64	500	300	4	<4	10	—	3	40
66	500	300	2	<4	10	—	1	42
101	150	400	10	4	8	—	4	31
102	900	300	10	4	10	—	8	35
105	600	350	8	—	8	—	2	49
108	500	300	9	<4	9	—	3	30
110	400	400	10	7	8	—	1	42
111	400	300	8	4	7	—	2	29
131	200	700	10	4	8	—	5	30
137	600	500	5	<4	7	—	5	31
146	400	300	2	—	10	—	2	47
148	400	300	2	<4	8	—	1	40
154	900	500	10	4	10	—	2	31
155A	300	300	10	5	10	—	2	40
158	400	200	10	5	8	—	1	48
Sum	7550	6050	133	<66	143	—	54	646
Average	445	355	8	<4	8	—	3	38%

B. White Lake Formation (Andesite)

Sample No.	Ba	Sr	Cr	Ni	Pb	Ag	As	Quartz %
56	1800	500	250	40	15	—	8	20
72	1000	500	50	8	10	—	3	19
82	2000	1000	100	15	30	—	11	20
87	2000	600	125	25	15	—	8	26
96A	1000	1000	150	30	20	—	3	24
96B	1350	950	100	25	12	—	5	24
147	6000	700	70	12	10	—	2	31
162	1000	400	100	20	10	—	1	20
165	2000	650	100	25	15	—	1	25
168	1000	500	100	20	10	—	1	20
176	2000	700	70	10	18	—	2	21
Sum	21150	7500	1215	230	165	—	45	250
Average	1920	680	110	21	15	—	4	23%

— not detectable by analytical method employed

SUMMARY

	Ba	Sr	Cr	Ni	Pb	Ag	As	Quartz %
A. Marama	445	355	8	<4	8	—	3	38
B. White Lake	1920	680	110	21	15	—	4	23
C. 'Ore'	<280	325	<6	<7	235	285	22	84
D. Near 'ore'	1420	415	<5	<1	11	—	8	37
E. No 'ore' holes	2040	875	40	8	15	—	10	25

C. Mixed Quartz Breccia (Silver 25 ppm or more)

Sample — DDH	Ba	Sr	Cr	Ni	Pb	Ag	Te	As	Quartz %
9-21'	250	175	3	<4	50	25	<15	5	93
9-26'	400	250	30	<4	30	500	<15	7	100
8-19'	500	500	2	<4	500	50	23	6	35
8-26'	350	400	5	—	100	100	<15	4	100
10-24'	<100	300	3	30	400	500	375	148	75
10-31'	<100	500	<1	15	150	200	<15	8	100
11-23'	<100	100	<1	—	35	100	<15	5	100
12-32'	500	500	4	—	50	100	<15	6	90
13-25'	300	200	<1	—	800	1000	105	10	66
Sum	<2500	2925	<50	<57	2115	2527	<593	197	759
Average	<280	325	<6	<7	235	285	<65	22	84%

D. Within 50 feet of 'ore' zone (silver less than 25 ppm)

Sample — DDH	Ba	Sr	Cr	Ni	Pb	Ag	As	Quartz %
9-47	1000	400	4	—	8	—	6	41
8-51	1000	400	1	<4	10	—	5	29
11-87	1000	400	<1	4	10	—	10	38
12-73	2000	400	1	<1	15	—	12	32
13-7	2500	500	20	—	10	—	7	47
13-69	1000	500	2	—	15	—	10	37
Sum	8500	2600	<29	<4	68	—	50	224
Average	1420	415	<5	<1	11	—	8	37%

E. Unsuccessful drill hole samples

Sample — DDH	Ba	Sr	Cr	Ni	Pb	Ag	As	Quartz %
14-8'	1500	700	12	—	12	10	11	83
14-101'	3000	700	2	—	8	10	11	28
15-14'	2000	1000	100	30	20	—	8	24
15-96'	2000	600	2	—	18	—	11	29
18-31'	1000	500	1	—	15	—	13	39
23	2000	1000	40	4	15	—	13	14
24-52'	2000	800	100	20	15	—	—	—
39-75'	1000	400	<1	—	8	2	16	—
39-145'	1000	500	3	—	10	—	13	27
40-55'	1500	1000	2	—	18	—	11	18
40-140'	1750	700	2	—	20	—	12	24
42-18'	4000	1000	200	30	15	—	15	17
42-105'	1500	500	30	—	10	—	13	23
45-31'	3500	1500	30	4	18	—	6	25
45-45'	2500	1000	35	20	20	—	5	15
45-73'	2500	2000	125	20	15	—	10	13
45-155'	2000	1000	15	<4	40	—	7	20
Sum	34750	14900	700	132	277	22	175	399
Average	2040	875	40	8	15	1	10	25%

Table 2. Some trace elements in various samples (in ppm)

A. Karmutsen

Sample no.	Ba	Sr	Cr	Ni	Pb	Ag	Cu
PN 70 131 A	<100	500	40	<10	3	<2	40
PN 70 153	<100	200	200	100	20	<2	1000
PN 70 140	<100	200	200	100	2	<2	100
KN 68 244	100	500	300	50	25	<2	1000
KN 68 295	<100	500	400	100	7	<2	500
CN 70 83	<100	400	1000	150	5	<2	1000
KN 68 70	200	800	200	40	10	<2	500
Sum	<800	3100	2340	550	72	<14	4540
Average	<110	445	335	80	10	<2	650

B. Bonanza (fresh)

Sample no.	Ba	Sr	Cr	Ni	Pb	Ag	Cu
KN 68-41	400	400	200	50	5	<2	400
KN 68-22	2000	1000	500	50	5	<2	500
KN 68-18	200	800	300	100	18	<2	1000
KN 68-66	1500	1000	200	40	35	<2	600
KN 69-75	700	600	190	30	7	<2	250
KN 69-74-I	400	400	200	60	2	<2	150
KN 69-96-V	500	300	100	20	10	<2	400
KN 69-147	1000	800	100	30	15	<2	400
KN 69-272A	3000	1000	50	10	10	<2	200
PN 70-178	200	300	180	25	100	<2	300
CN 70-34	500	500	200	30	15	<2	400
CN 70-69A	200	500	200	40	15	<2	500
Sum	10600	7600	2420	485	237	<24	5100
Average	885	635	200	40	20	<2	425

*C. Bonanza (altered)**

Sample no.	Ba	Sr	Cr	Ni	Pb	Ag	Cu
KN 68-21	<100	800	200	20	15	<2	5000
KN 69-143	3000	600	180	20	20	<2	500
KN 69-166A	5000	800	100	10	20	<2	200
KN 69-202-I	<100	300	100	15	15	<2	200
CN 70-36-I	<100	300	150	15	15	<2	400
CN 70-162	<100	400	200	40	8	<2	5000
Sum	<8400	3200	930	120	93	<12	11300
Average	<1400	535	155	20	16	<2	1883
Omitting KN 69-143	<400	1800					
166A	<100	450					

* Epidotized, sericitized, pyrophyllitized, silicified and/or pyritized.

D. Intrusive rocks

Sample No.	Ba	Sr	Cr	Ni	Pb	Ag	Cu
KN 70-2-1	200	700	200	20	15	<2	500
PN 70-167B	200	500	150	30	100	<2	500
CN 70-127A	<100	100	400	150	80	<2	800
CN 70-132	<100	80	150	18	10	<2	300
Sum	<600	1380	900	218	205	<8	2100
Average	<150	345	225	55	51	<2	525

E. Bonanza (Island Copper ore zone)

Sample No.	Ba	Sr	Cr	Ni	Pb	Ag	Cu
KN 68-93	100	400	200	30	8	<2	500*
KN 68-89	<100	1000	100	30	10	<2	200
KN 68-78	<100	1000	200	50	70	<2	800
Sum	<300	2400	500	110	88	<6	1500
Average	<100	800	170	37	29	<2	500

* Pyrophyllite-dumortierite

F. Bonanza (fringe of Island Copper ore)

Sample No.	Ba	Sr	Cr	Ni	Pb	Ag	Cu
KN 68-335	1500	400	200	15	4	<2	200

G. Bonanza (Red Dog mineralization)

Sample No.	Ba	Sr	Cr	Ni	Pb	Ag	Cu
KN 70-5	<100	600	800	200	10	<2	5000
KN 70-6	<100	500	1000	500	5	<2	5000
KN 70-6-III	100	800	400	100	5	<2	5000
KN 70-7-VIII	<100	<300	200	2000	60	<2	5000
Sum	<400	<2200	2400	2800	80	<8	20000
Average	<100	<550	600	700	20	<2	5000

H. Bonanza (Island Copper ore) (Lamb)

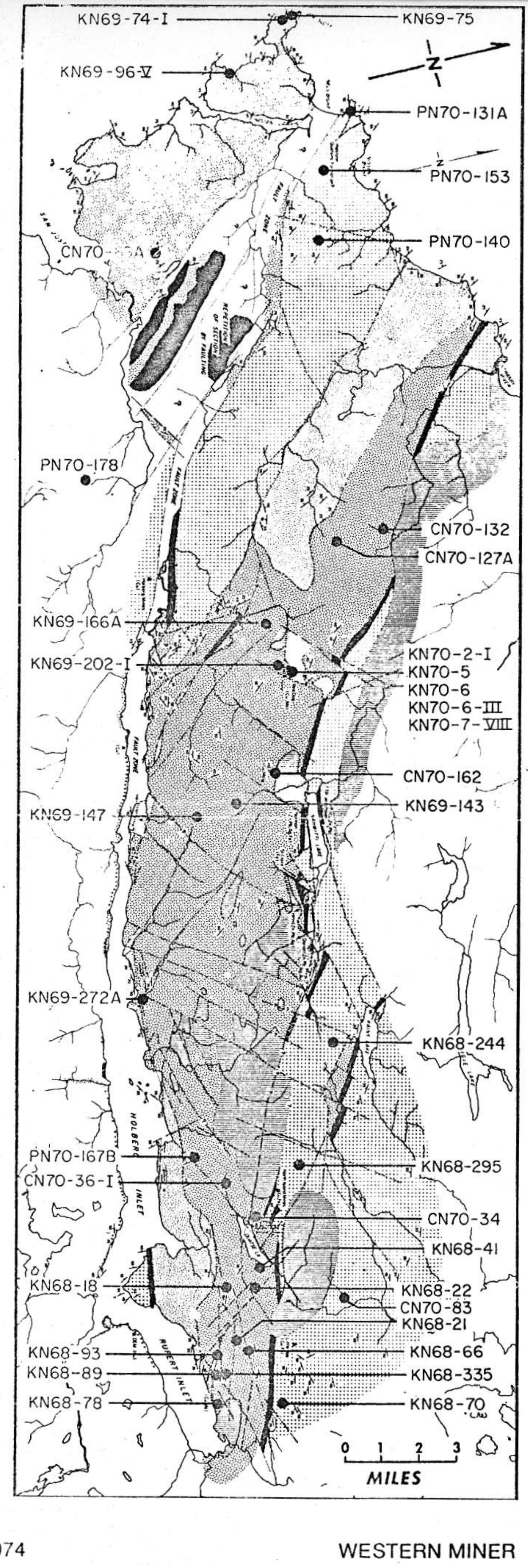
Sample No.	Ba	Sr	Cr	Ni	Pb	Ag	Cu
V 51	150	500	100	8	15	4	3000
W 49	150	400	100	12	10	<2	4000
W 52	200	600	130	12	10	<2	4000
Sum	500	1500	330	32	35	<8	11000
Average	170	500	110	11	12	<3	3670

I. Bonanza (fringe of Island Copper ore) (Lamb)

Sample no.	Ba	Sr	Cr	Ni	Pb	Ag	Cu
P 24	100	100	75	6	5	<2	200
Q 23	300	100	80	10	5	<2	1000
P 22	400	150	110	10	15	<2	1000
Q 21	400	100	50	10	5	<2	3000
Sum	1200	450	315	36	30	<8	5200
Average	300	110	80	9	7	<2	1300

PRELIMINARY GEOLOGICAL MAP
RUPERT INLET – CAPE SCOTT AREA

GEOLOGY BY K.E. NORTHCOTE



LEGEND

INTRUSIVE ROCKS

VARIED COMPOSITION FROM DIORITE TO GRANITE AND INCLUDES PORPHYRITIC PHASES

LOWER CRETACEOUS SEDIMENTARY ROCKS

CONGLOMERATE, SANDSTONE, SILTSTONE, SHALE, CARBONACEOUS HORIZONS

BONANZA SUBGROUP

UPPER VOLCANIC UNIT; LARGELY PYROCLASTIC TUFF, LAPILLI TUFF AND TUFF BRECCIA OF ANDESITE AND BASALT COMPOSITION WITH SOME BASALT AND RHYODACITE FLOWS AT THE TOP OF THE UNIT.

LOWER SEDIMENTARY UNIT; THIN BEDDED ARGILLACEOUS AND CARBONACEOUS LIMESTONE, CALCAREOUS SHALE AND SILTSTONE AND GREYWACKE.

QUATSINO FORMATION

LIMESTONE, MEDIUM TO THICK BEDDED

KARMUTSEN FORMATION

BASALTIC AMYGDALOIDAL AND MASSIVE FLOWS, INTERBEDDED TUFF, SOME PILLOW BRECCIA AND POORLY DEVELOPED PILLOWS. THIN LIMESTONE BEDS NEAR TOP OF FORMATION

SYMBOLS

CONTACTS:

KNOWN
APPROXIMATE
ASSUMED

LINEAMENTS FROM AIR PHOTOGRAPHS SOME OF THESE ARE KNOWN TO REPRESENT FAULTS

BEDDING

MINERAL DEPOSITS

Fig 5. Location of representative rock samples (Table 2)