Geothermal gradient
Temperature fluctuation
Alert Bay Volcanic Belt
Triassic
Port McNeill

Geothermal Service of Canada

PRELIMINARY RESULTS FROM SHALLOW DRILLING IN THE ALERT BAY VOLCANIC BELT, 1982.

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Abstract

Eight shallow boreholes have been drilled into Triassic basement rocks in the vicinity of the Late Tertiary Alert Bay Volcanic Belt to provide heat flow data for evaluation of geothermal potential. The holes are located southwest of Port McNeill on northern Vancouver Island.

The observed geothermal gradients range from 9.6 to 35.3 mKm^{-1}. Near-surface water flows and surface temperature fluctuations affect the gradients to depths of 50 m. The average geothermal gradient, based on the four deepest holes, is estimated at 31.8 mKm^{-1}. No apparent thermal anomalies were found near the volcanic belt so the potential for a geothermal resource is low.

Résumé

Des chercheurs ont foré huit sondages peu profonds dans des roches du socle triassique, aux environs de la zone volcanique d'Alert Bay qui date de la fin du Tertiaire, afin de recueillir des données sur les flux de chaleur et ainsi de pouvoir en évaluer le potentiel géothermique. Les sondages se trouvent au sud-ouest de Port McNeill, dans le nord de l'île Vancouver.

Les gradients géothermiques observés varient de 9,6 à 35,3 mKm^{-1}. Les écoulements d'eau proches de la surface et les fluctuations des températures superficielles influent sur les gradients jusqu'à une profondeur de 50 m. Le gradient géothermique moyen, calculé d'après les quatre trous les plus profonds, est estimé à 31,8 mKm^{-1}. Aucune anomalie thermique apparente n'a été relevée à proximité de la zone volcanique, ce qui laisse supposer que le potentiel géothermique est faible.

Introduction

Areas of recent tectonic and volcanic activity where thermal anomalies still exist are potentially large sources of geothermal energy. The Garibaldi Volcanic Belt in southern British Columbia is one such region where much work on geothermal resource evaluation is being undertaken. This study focuses on the Alert Bay Volcanic Belt, another area of recent tectonic activity about which little is known in terms of the regional thermal regime.

The Alert Bay Volcanic Belt, a northeasterly trending belt, crosses northern Vancouver Island from Brooks Peninsula to Port McNeill (Fig. 1). These Late Tertiary volcanic rocks range from basalt to andesite and dacite. The tectonic setting of the volcanic belt has not been clearly established. However, the proximity to the continental margin and the subducting Juan de Fuca plate suggests the Alert Bay magmas arise from a descending plate edge (Muller et al., in preparation).The end of the volcanic activity is inferred from shifting subduction patterns associated with plate reorientation (Riddihough, 1977).

Only one heat flow value has been previously measured in this region, at Island Copper Mine near the head of Rupert Inlet (Fig. 1). Eight shallow boreholes (100 m) have been drilled for the present study to assess the regional heat flow and to determine whether thermal anomalies associated with the volcanic belt exist.

This report presents preliminary work including measured geothermal gradients and heat generation data.

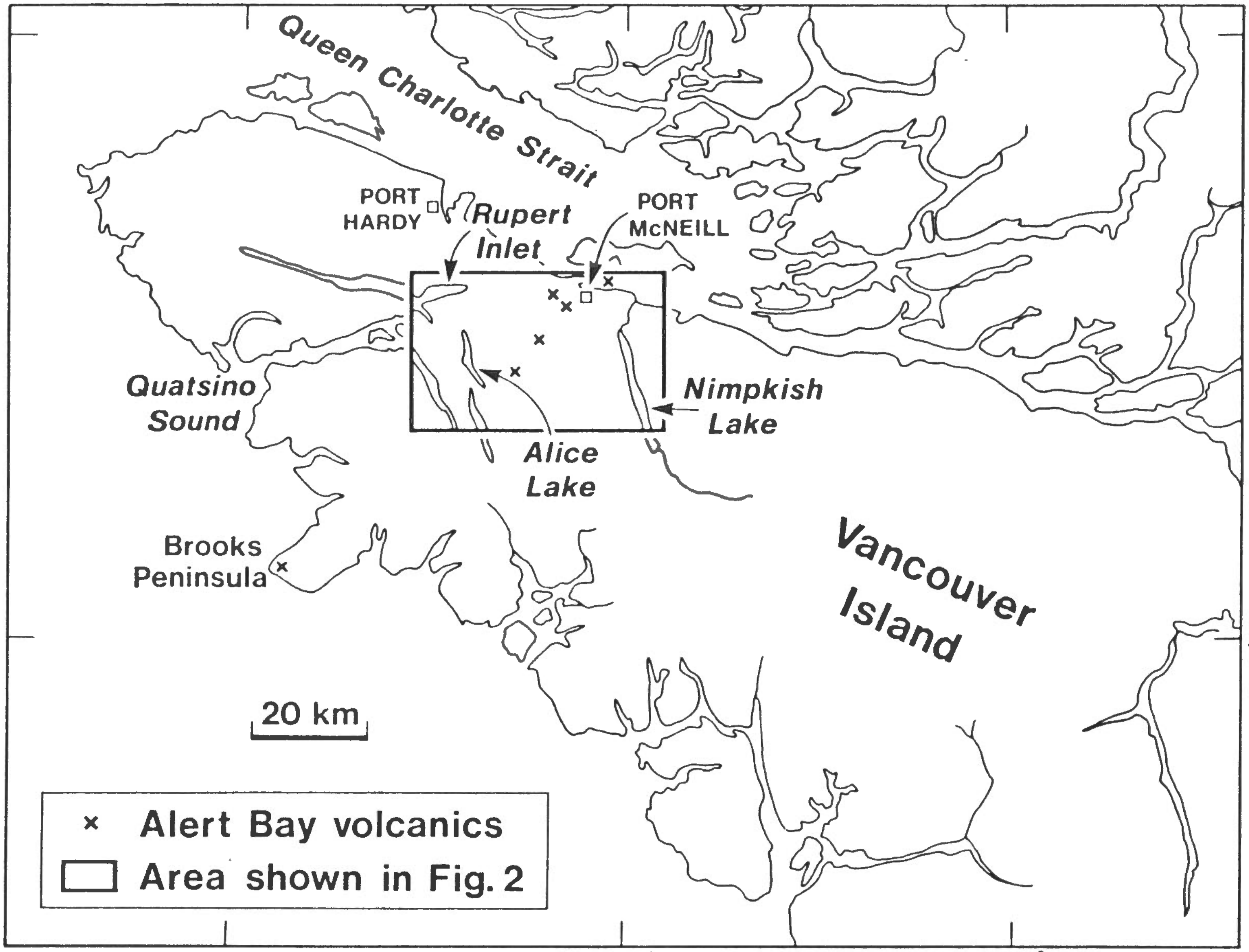

Figure 1 Location map

Site Locations

Site selections were based on accessibility to a truck-mounted drill rig, proximity to exposed bedrock, availability of water and the absence of rugged topography. Access is by logging roads maintained by MacMillan Bloedel and Western Forest Products. Sites are located west of Alice Lake northeast to O'Connor Lake (Fig. 2). The majority of sites are in quarries blasted by the logging companies.

Five sites are in a north-south line east of Alice Lake across the trend of the volcanic belt over a distance of about 12 km (hole numbers 468, 469, 470, 471, 472). Two sites (466, 467) are north and northwest of Twin Peaks, a remnant of the late Tertiary volcanics, and one site (473) is west of Alice Lake north of the volcanic trend. Distances from exposed volcanic successions range from 2 to 8.5 km.

All holes were drilled in basaltic flows and pillow lavas of the Karmutsen Formation of the Vancouver Group, the thickest and most widespread formation on Vancouver Island (Muller et al., 1979). Latitude and longitude for the sites are given in Table 1.

Drilling

Tonto Drilling Co. of Burnaby, B.C. began drilling on October 28 and finished on November 12. A truck-mounted percussion drill was used to drill 57.2 mm (2-1/4") diameter holes to a depth of 100 m. Drill cuttings were collected over 3 m intervals spaced every 6 m.

After total depth was drilled, a string of 1" ID schedule 40 PVC pipe was lowered to the bottom of the hole with a latching collar attached at the bottom. A cement grout mix consisting of cement, salt, bentonite and water was pumped through the pipe and up the annulus. A latch down plug was then pumped down the casing with clear water to clean the pipe and

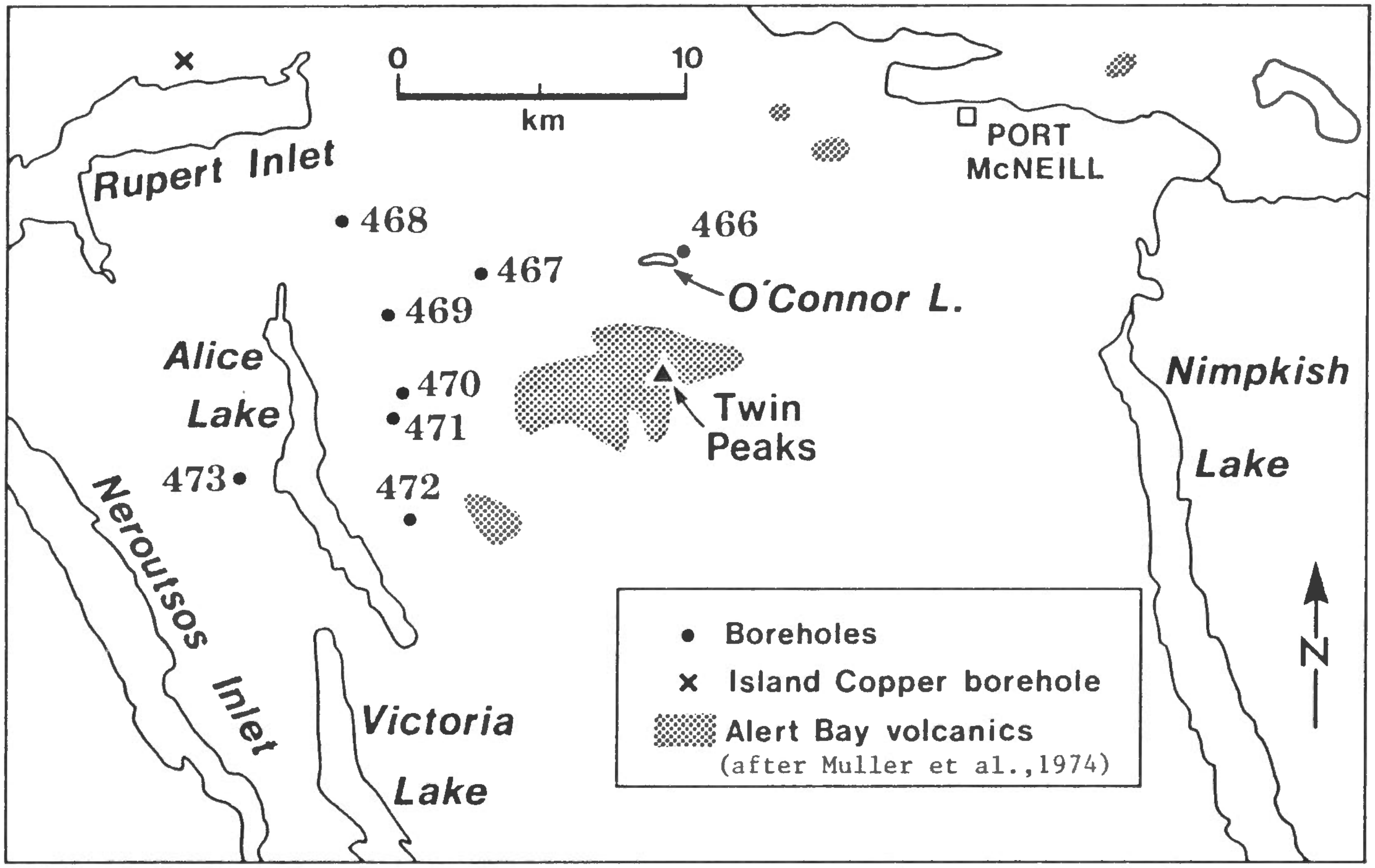

Figure 2 Borehole locations

Table 1

Geothermal Drilling - Alert Bay Volcanic Belt, October-November 1982

Hole No.	Location Latitude	Longitude	Elevation (m)	Total Depth (m)	Date of Drilling Start	Date of Drilling Finish	Date of Logging 1982	Date of Logging 1983
466	50°32.36'	127°14.28'	183	100	Oct. 27	Oct. 29	Nov. 22	Aug. 16
467	50°32.28'	127°20.13'	137	100	Oct. 29	Nov. 1	Nov. 23	Aug. 16
468	50°33.16'	127°24.19'	61	100	Nov. 2	Nov. 4	Nov. 23	Aug. 16
469	50°31.70'	127°22.96'	91	100	Nov. 4	Nov. 5	Nov. 23	Aug. 16
470	50°29.88'	127°22.34'	244	100	Nov. 5	Nov. 7	Nov. 23	Aug. 16
471	50°29.34'	127°22.43'	213	100	Nov. 7	Nov. 8	Nov. 23	Aug. 16
472	50°27.74'	127°22.51'	183	85	Nov. 9	Nov. 11	Nov. 23	Aug. 16
473	50°28.36'	127°27.32'	396	88	Nov. 11	Nov. 12	Nov. 24	Aug. 17

latched on to the collar to seal the casing. This casing and grouting procedure ensures subsequent access to the hole for temperature measurement and prevents axial water flow (Moses and Sass, 1979).

Although holes 466 and 470 were drilled to 100 m depth, these holes could be measured to depths of only 67 and 52 m respectively, due to casing problems. It seems that some defective PVC pipe was used, resulting in the grout and clean water escaping through hairline fractures. Thus the latch down plug was not under enough pressure when pumped down the casing and could not reach the end of the casing.

Two holes (472 and 473) were drilled to depths of only 85 and 88 m respectively due to a loss of drill rods. Hole 472 was measured to only 55 m because of the problem associated with the fractured PVC pipe. Table 1 summarizes hole depths and drilling times.

Temperature Measurements

The temperatures have been measured twice after completion of the drilling program. The holes were first logged from 12 to 24 days after hole completion and again approximately 9 months later. Dates of logging are shown in Table 1.

The temperatures were measured with a calibrated bead-type thermistor encased in a brass probe. This was lowered on a four-conductor cable down the water-filled casing using a back-pack winch. Resistance of the thermistor and cable, and the cable by itself were measured with a Wheatstone bridge. Temperatures were then calculated for that particular thermistor to an absolute accuracy of .01^{o}C and to a relative accuracy of .002 K. Readings were taken every 3 m along the entire depth of the holes. The probe depths were recorded by a pulley attached to the top of the casing with the zero reference point at ground level. Corrections to depth as a result of cable slippage were applied when necessary using 7 m markings on the cable as reference points.

Geothermal Gradients

The geothermal gradients range from 9.6 to 35.3 mKm^{-1} and are shown in Figure 3. All holes have a temperature reversal to depths of up to 43 m, some with minor temperature disturbances in the upper 12 m of the hole.

Holes 466, 470, 472 and 473 have the lowest gradients of 15.1, 22.9, 9.6 and 13.2 mKm^{-1} respectively. Since these holes could not be measured to 100 m for reasons previously discussed, the measured gradients are probably not representative of the gradients at depth.

The highest gradients were measured in holes 467, 468, 469 and 471 with values of 30.0, 28.2, 33.5 and 35.3 mKm^{-1} respectively. Hole 467 has two uniform segments of 25.2 mKm^{-1} from 43 to 55 m and 30.0 mKm^{-1} from 58 to 100 m. Three uniform gradients were measured in hole 468; 19.4 mKm^{-1} from 37 to 55 m, 26.7 mKm^{-1} from 58 to 82 m and 30.0 mKm^{-1} from 85-100 m. Hole 471 also has two gradients of 27.4 mKm^{-1} from 43 to 61 m and 35.3 mKm^{-1} from 64 to 100 m. The abrupt changes in temperature gradient within individual holes are probably the result of constant water flows along fractures intersected by the hole at the depths where the gradient changes. Varying thermal conductivity may also affect the gradient, but until thermal conductivity measurements are made, this effect cannot be evaluated. These three holes (467, 468, 471) also have temperature disturbances in the upper 12 m which are due to subsurface water flows.

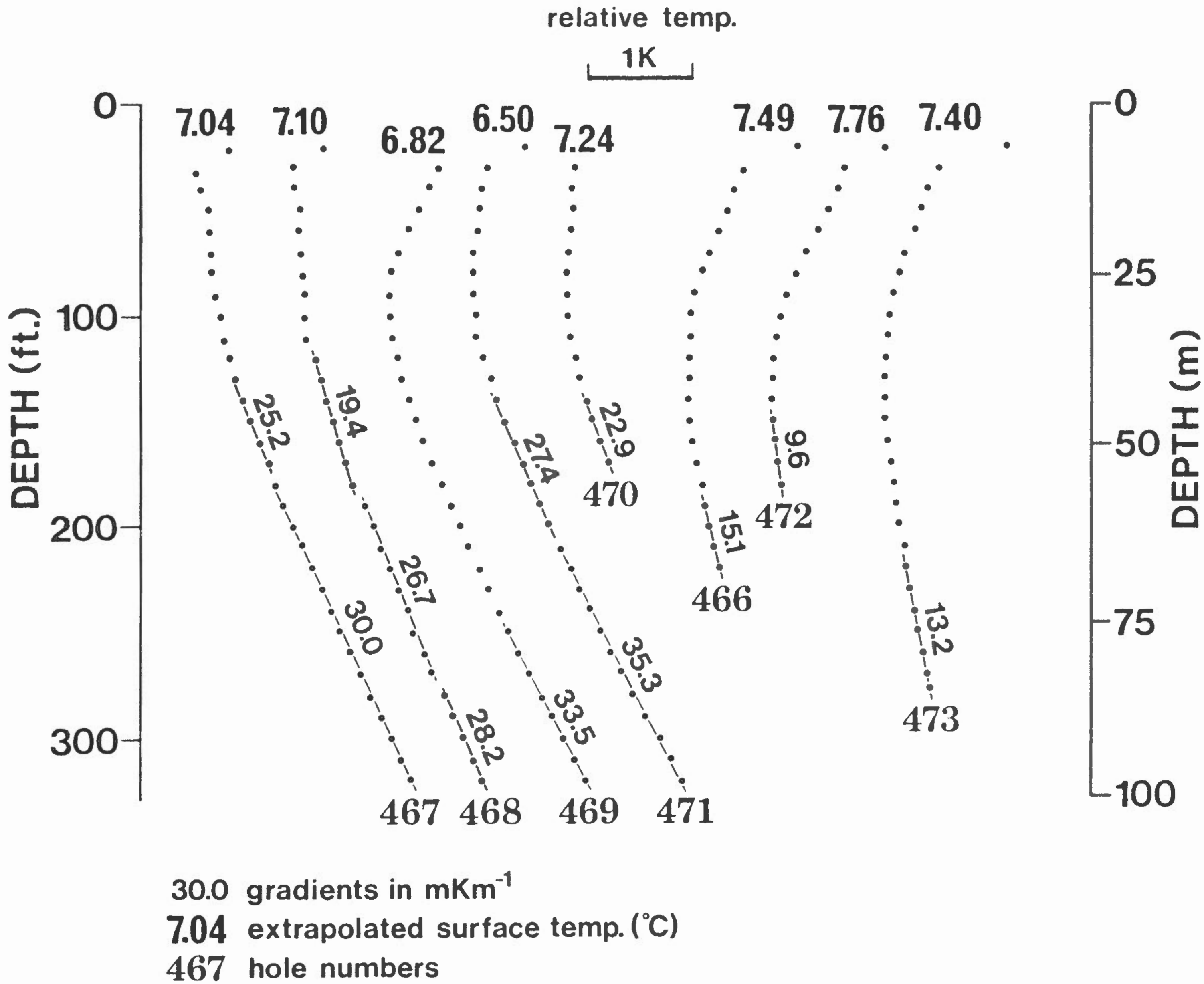
relative temp.
1K
DEPTH (ft.)
0
100
200
300
DEPTH (m)
0
25
50
75
100
7.04
7.10
6.82
6.50
7.24
7.49
7.76
7.40
25.2
30.0
19.4
26.7
28.2
33.5
27.4
35.3
22.9
15.1
9.6
13.2
467
468
469
471
470
466
472
473
30.0 gradients in mKm-1
7.04 extrapolated surface temp. (°C)
467 hole numbers

Figure 3

Hole 469 has a significant temperature reversal to a depth of 30 m. Only in the bottom 24 m interval is there a uniform gradient of 33.5 mKm^{-1}. Above this interval, the effects of the temperature reversal are propagated downwards resulting in a non-linear curve.

Figure 4 shows the distribution of measured temperature gradients.

Heat Generation

The concentration of U, Th and K were measured with a gamma-ray spectrometer (Lewis, 1974) to determine the radioactive heat generation of outcrop samples taken at six of the drill sites (Table 2). All samples are basalts of the Triassic Karmutsen Formation with an average value of .21 μWm^{-3}.

Discussion

Although there is a wide variation in measured geothermal gradients from 9.6 to 35.3 mKm^{-1}, it is likely that surface temperature fluctuation and subsurface water flows significantly affect the gradients in the four shallowest holes. The depth of the temperature reversal depends on the extent of water flow near the surface, below which heat flow will be predominantly conductive. Also surface temperature variations, whether caused by seasonal changes, or longer term fluctuations caused by logging or quarrying, in part determine the extent of the temperature reversal. Considering these perturbations, it seems likely that the four lowest gradients are not representative of the regional gradient.

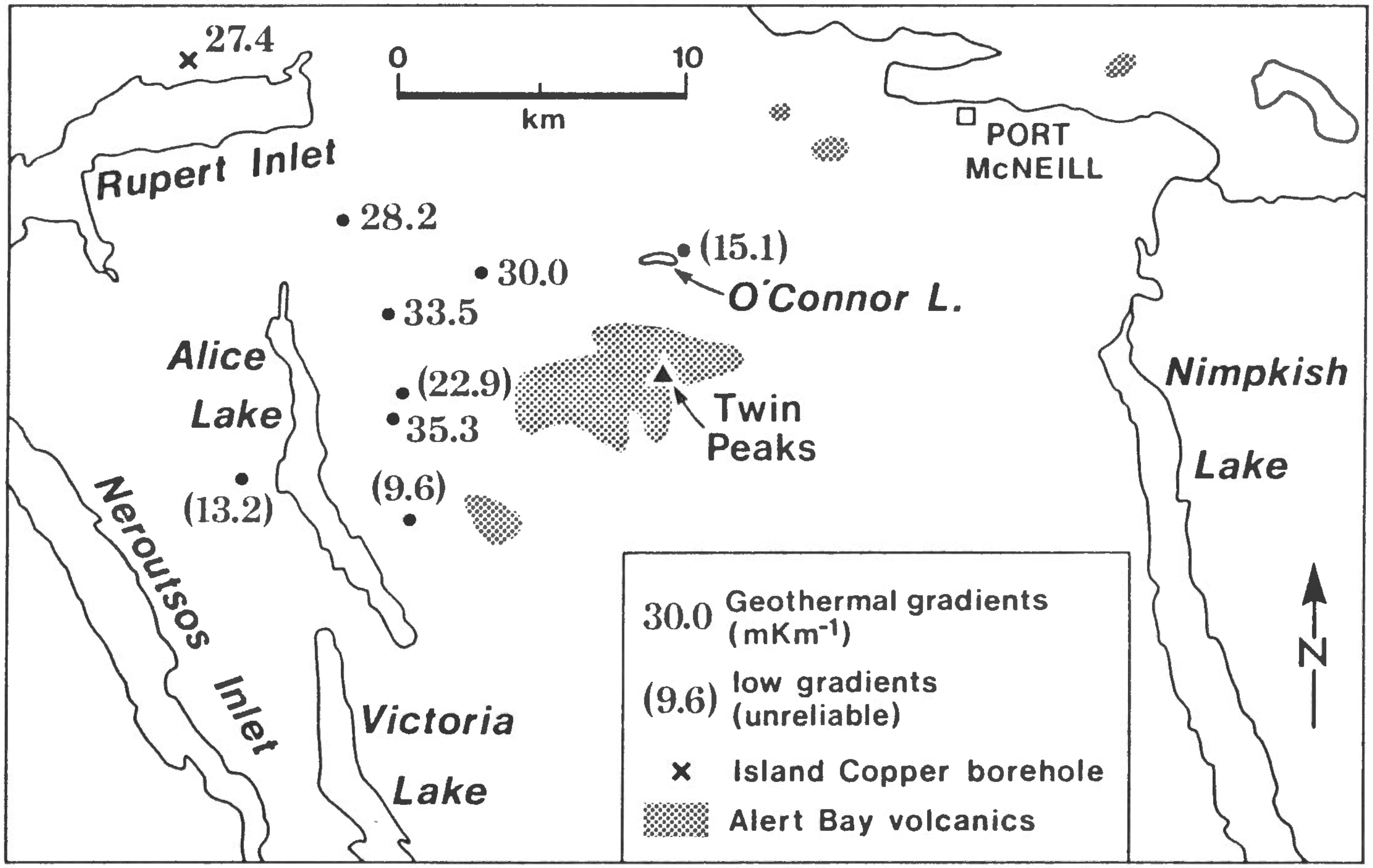

Figure 4 Distribution of geothermal gradients

Table 2

Heat Generation

Hole #	U (ppm)	Th (ppm)	K %	Heat Generation* (μWm^{-3})	Count Error (%)
466	.22	.68	.28	.13	15
467	.37	1.35	1.42	.33	26
468	.15	.59	1.18	.19	35
469	.04	.14	.30	.05	27
472	.20	.90	0	.11	91
473	1.61	.01	.01	.42	12
Average				.21	
Standard Deviation				$\pm$.14	

* assuming = 2.67 g cm^{-3}

The four highest gradients average 31.8 mKm^{-1} below depths affected by surface temperature variation and water flows. This is comparable to the previously measured gradient at Island Copper of 27.4 mKm^{-1}, to a depth of 750 m. The distribution of these geothermal gradients, including the measurement from Island Copper, suggests a slight increase in gradient to the south toward the axis of the volcanic belt (cf. Fig. 4). However, because the increase is minimal, the variation may be due to differences in thermal conductivities.

Assuming a value of 2.0 $Wm^{-1}K^{-1}$ for the thermal conductivity of the Karmutsen basalts, a heat flow of 63.6 mWm^{-2} is obtained. The measured heat flow at Island Copper is 64.5 mWm^{-2} (Lewis et al., in preparation).

In order to understand the tectonics of this area, it is important to note that the probable terrestrial heat flow is much higher than in other areas of the Insular Belt to the north (Hyndman et al., 1982) and to the south (Lewis et al., in preparation). This probably reflects the various positions of the triple junction at the northern end of the Explorer Plate during past plate reorientation.

Conclusions

A value of 64 mWm^{-2} has been estimated for the regional heat flow. There may be a broad thermal anomaly associated with the volcanic belt, but this cannot be evaluated until thermal conductivity measurements are completed. Thus this study suggests that the crust was slightly heated when the volcanics erupted, but the potential for a geothermal resource at present probably is low in the Alert Bay Volcanic Belt.

Acknowledgements

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