OPEN FILE REPORT #82-6.

Geothermal Gradients on the West Side of Okanagan Lake, B.C.

By T.J. Lewis

Pacific Geoscience Centre

P.O. Box 6000

Sidney, B.C. V8L 4B2

And Len Werner

11937-230 Street

Maple Ridge, B.C. V2X 6R3

Date: 14 April, 1982

Earth Physics Branch

Energy, Mines and Resources Canada

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RÉSUMÉ

Deux trous verticaux ont été forés au diamant dans la partie ouest de la vallée de l'Okanagan en vue d'étudier le régime géothermique près de deux bassins datant du Tertiaire. Dans cette région où la température du flux de chaleur est anormalement élevée, ces bassins sédimentaires sont des sources potentielles d'énergie géothermique.

Chaque jour, avant que le forage ne commence, des levés de la température au fond des trous ont été effectués en vue d'obtenir une température d'équilibre de la roche. Dans le trou qui a été foré jusqu'à une profondeur de 470 m au lac Paynter, juste à l'ouest de la butte-témoin Kelowna datant du Tertiaire, les gradients géothermiques variaient de 27 à 33 mK/m. Ce trou a été foré principalement à travers les monzonites quartzifères de la formation de Valhalla qui date du Crétacé. Les gradients géothermiques variaient de 27 à 35 mK/m dans le trou d'une profondeur de 370 m qui a été foré dans les roches plutoniques de Nelson, au ruisseau Trout, au sud de la caldeira Summerland.

ABSTRACT

Two vertical diamond drill holes were completed on the west side of the Okanagan Valley to investigate the geothermal regime near two Tertiary Basins. Such sediment filled basins in this area of above normal heat flow are possible geothermal energy resources.

Bottom hole temperatures were measured each day before the drilling started, to obtain near-equilibrium rock temperatures. The Paynter Lake hole just west of Kelowna Tertiary Outlier, drilled to a depth of 470 m, had geothermal gradients between 27 and 33 mK/m. It penetrated mostly quartz-monzonites of the Cretaceous Valhalla rocks. South of the Summerland Caldera the Trout Creek hole, 370 m deep, had geothermal gradients between 27 and 35 mK/m. It was collared in Nelson plutonic rocks.

GEOTHERMAL GRADIENTS ON THE WEST SIDE OF OKANAGAN LAKE, B.C.

Introduction

In the Okanagan valley some small Tertiary basins may contain hot water which can be used for space heating. Low enthalpy (hot water) geothermal resources are economically used for heating homes, buildings, green houses and other structures in many areas of the world. In providing such heat, the hot water is replacing other types of energy which are more easily transported and which are usually more suitable for many other uses.

The purpose of this report is to describe the drilling of, and temperatures within two cored holes on the west side of Okanagan Lake. The locations of the holes are given in Table 1 and shown in Figure 1. This drilling is the first phase in assessing the geothermal potential of the Kelowna Tertiary Outlier and the Summerland Caldera.

Heat flow was previously measured at 5 sites within White Lake Basin to the south (see Figure 1). Four holes drilled for mineral exploration were logged as well as a single hole drilled for geothermal measurements (Jessop and Judge, 1971). These measurements indicated (Lewis, in preparation) that warm water for space heating may be available in the lower formation. Heat flow to the northwest in the Guichon batholith is 72, nearer to Kamloops it is 86 (Lewis et al., in preparation), and to the east in the Coryell Syenites it is 130 mW m^{-2} (Lewis et al., 1979). Therefore heat flow in the entire region is probably above the world average of 60 mW m^{-2}.

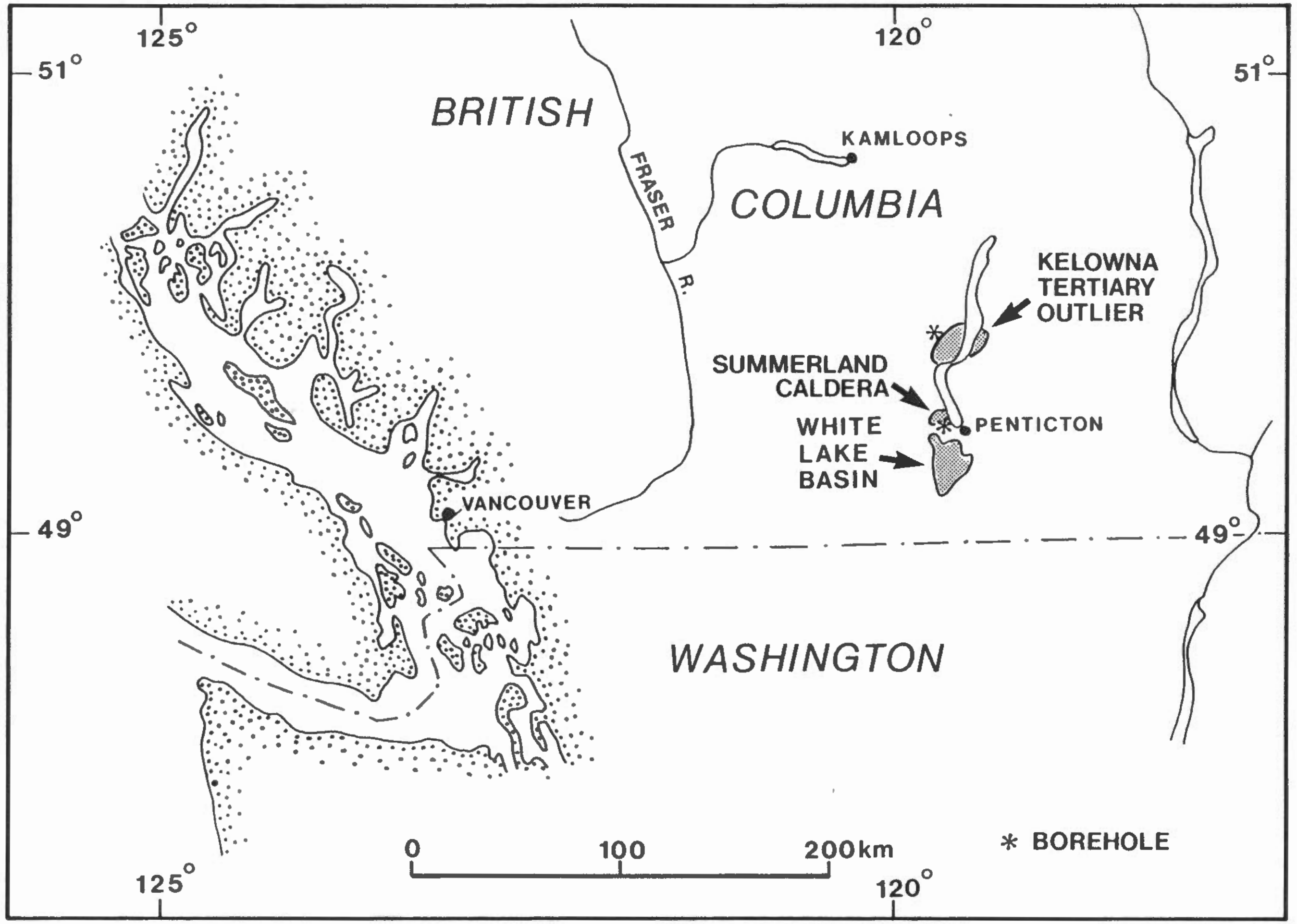

FIG. 1: Location of three Tertiary Basins in south central B.C. The drill sites are shown by asterisks.

Table 1: Borehole Parameters

				Collar Elev. (m asl)	Total Depth (m)
310-1	Paynter Lake	49° 57.5'N	119° 47.2'W	1311	368
310-2	Trout Creek	40° 34.2'N	119° 39.1'W	389	468

To evaluate the potential of a basin, the heat flowing up into the basin from beneath it should be known. Then the maximum temperatures within the basin may be calculated, using the thermal conductivities of the various members forming the basin. Within volcanoclastic basins water flows, both through formations and, more often, along individual volcanic flow tops. Such water movement may re-supply geothermal reservoirs, but it disturbs borehole temperatures directly by flowing into the boreholes, and indirectly by flowing beneath or adjacent to the holes.

Drilling in such rock is usually much more difficult and costly than in the surrounding granitic rock. Consequently we drilled a single hole at a suitable site just outside each basin to determine the regional heat flow near each basin.

Before this project commenced, B.N. Church of the B.C. dept. of Energy, Mines and Petroleum Resources and T.J. Lewis visited the municipal officials listed in Appendix 1. As well as making a presentation of our plans to them, we gave them copies of an outline of our plans, included here in Appendix 2. The responses showed interest and enthusiasm for geothermal energy.

The provincial officials of the Departments of Forestry and of Energy, Mines and Petroleum Resources, as listed in Appendix 3, were advised of our plans.

Geological Setting

The Cretaceous and Early Tertiary volcanic rocks, confined to the Intermontane belt and eastern flank of the Coast Mountains, erupted at approximately the same time as the evolution and uplift of the Coast Plutonic Complex (Souther, 1977). Paleocene and Eocene volcanic rocks include the Marron, and parts of the White Lake and Kettle River Formations of southern British Columbia. The eruption of the rocks was closely associated with block faulting and many deposits are preserved in grabens, half grabens and cauldron-subsidence complexes. Close relationships between acid eruptive rocks and large epizonal plutons suggest that they are comagmatic. In the area west of Okanagan Lake, Armstrong and Peto (1981) note that the younger intrusive remnants are thought to be epizonal feeder and vent systems which formed during a post batholithic period of acid volcanism. They date the porphyritic rhyolite intrusions in this area at 52 Ma, the same as the Shingle Creek intrusion (Church, 1979) just to the south.

The remnants of what was once probably a continuous belt of mainly volcanic rocks in central Washington and central B.C. now form Tertiary "basins". Church (1973) has published the general geology and structure of the White Lake Basin, and has also described the Summerland Caldera (Church, 1980a) and the Kelowna Tertiary Outlier (Church, 1980b). These three basins lie along the Okanagan lineament. Their depths of over a kilometre and the types of formations allow the possibility of hot water reservoirs.

Borehole 310-1 at Paynter Lake was drilled 6.4 km from the western edge of the Kelowna Tertiary Outlier (see Figure 2) in Cretaceous Valhalla plutonic rocks (Little, 1961). The core from this hole is logged mostly as quartz-monzonite (see Appendix 4). Zones throughout the hole are extremely fractured, broken, shattered, sheared, and crumbly. The hole is located in a very small valley formed by Powers Creek.

Borehole 310-2 at Trout Creek is located in the creek gravels at the bottom of a canyon on the property of Agriculture Canada (Summerland Research Station). The Summerland Caldera (see Figure 3), bounded by the Summerland fault on the southeast (Church, 1980a) is 1 km from the drill site. The hole is collared in Nelson plutonic rocks (Little, 1961).

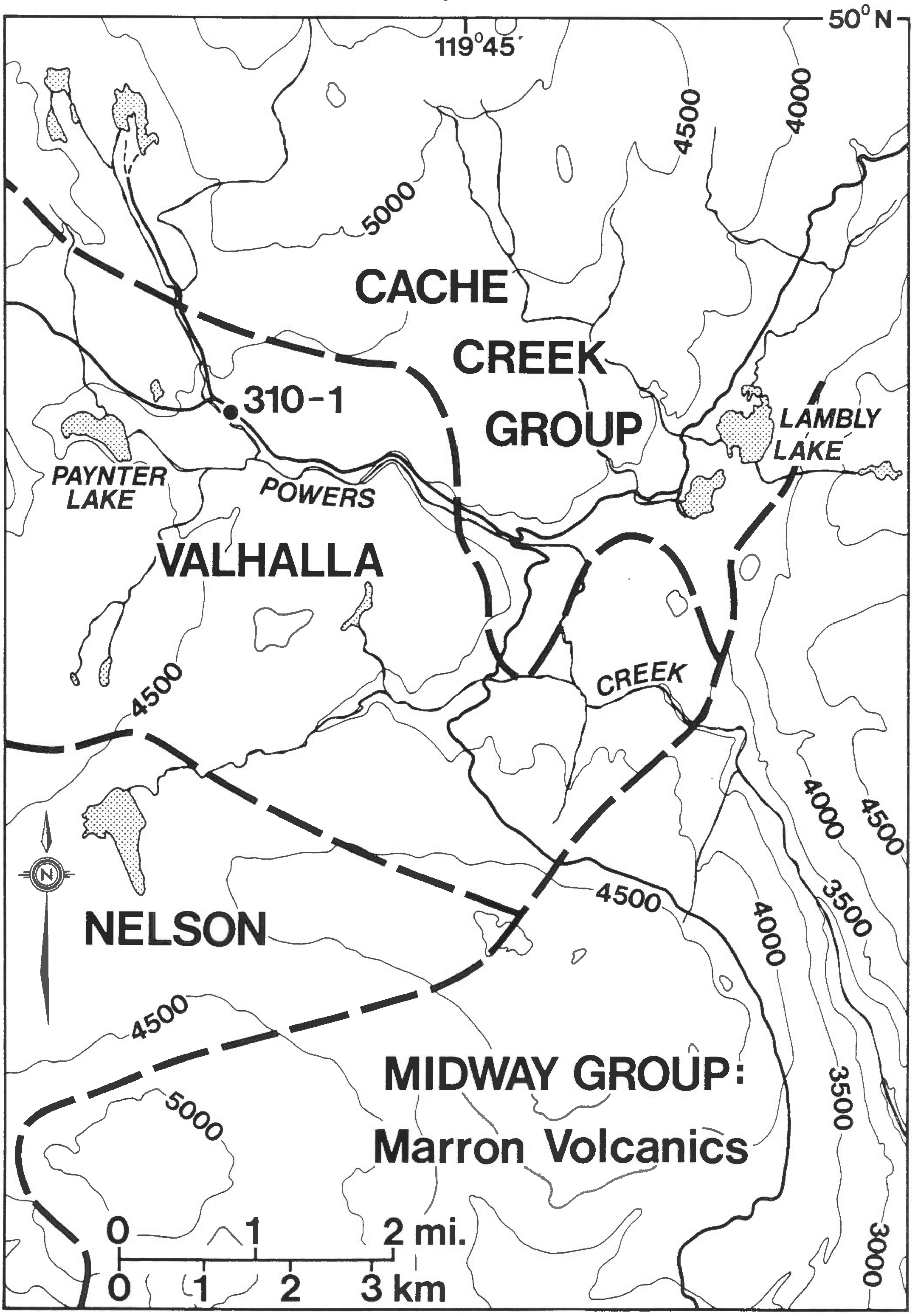

FIG. 2: The geology surrounding drill hole 310-1

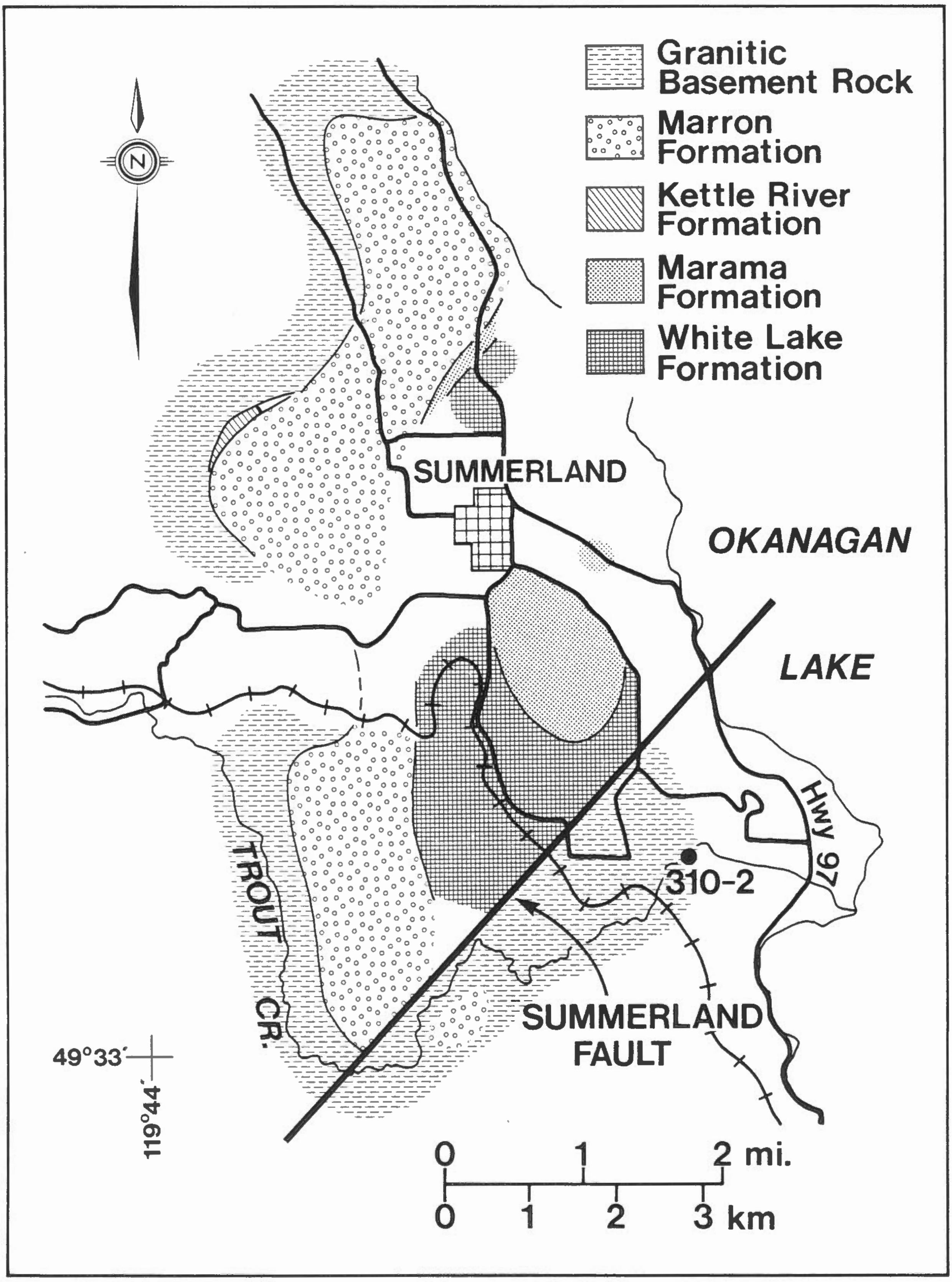

FIG. 3: The geology surrounding drill hole 310-2, from Church

Drilling Program

Two cored boreholes were drilled in the Fall of 1980 by Interior Diamond Drilling Ltd. of Summerland, B.C. Our requisition for the Drilling went to D.S.S. on August 11, the drilling went out for tender, bids were received and evaluated by us on September 4 and the contract was let on September 19. The drilling progress of the two holes is shown in Figures 4 and 5. The hole size was BQ. The second hole was completed on November 19, 1981. The total cost of drilling was $56,073. Only surface casing was left in the holes.

The core is stored at the Geological Survey of Canada in Vancouver, B.C. During the drilling representative samples were chosen for thermal conductivity measurements and for heat generation measurements. The depths of these samples are listed in Tables 2 and 3.

Appendix 4 contains a detailed geological log of the core from both holes. The number of fractures as well as the degree of alteration present at nearly every depth indicate the possibility of water movement, both past and present.

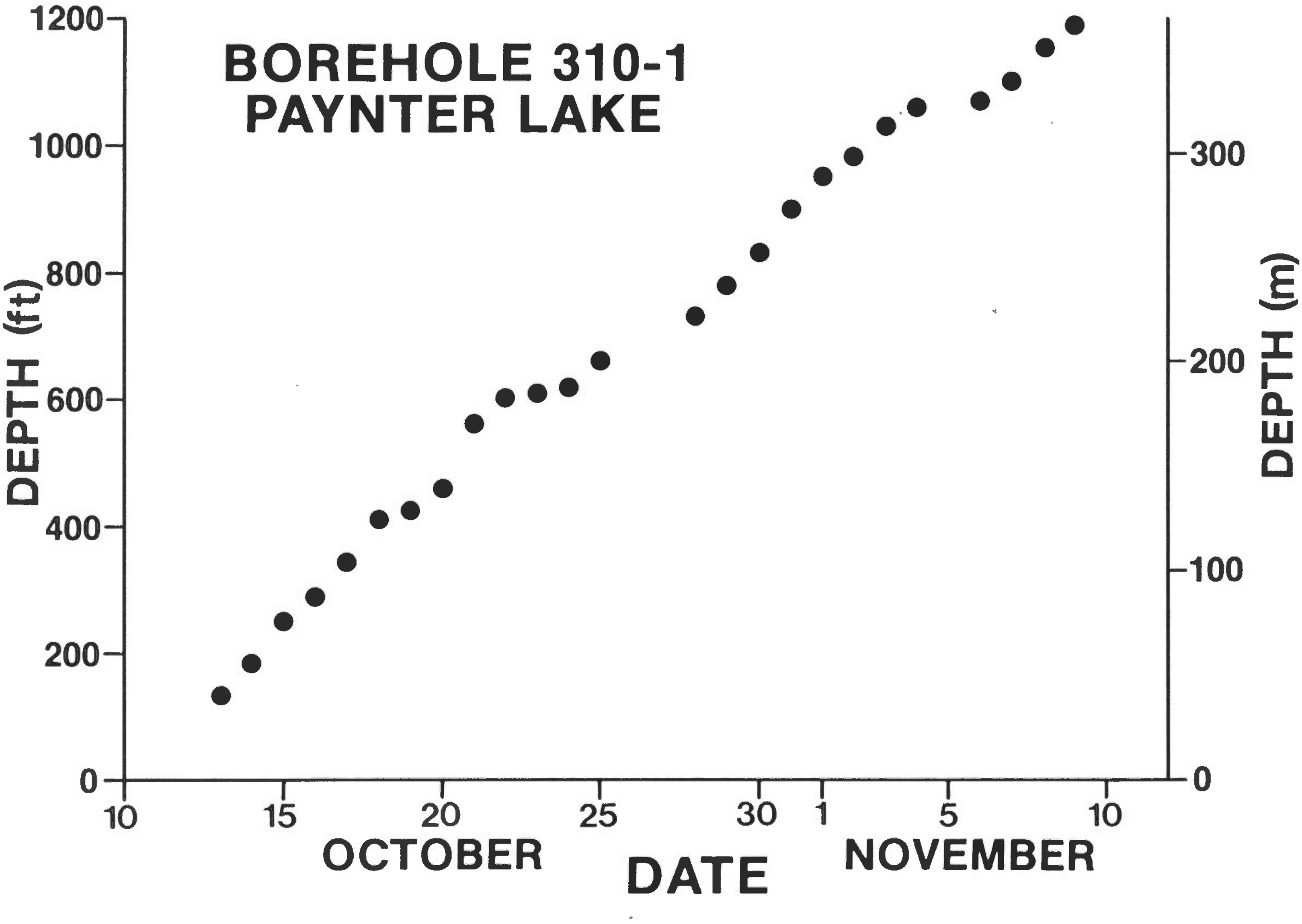

FIG. 4: Drilling progress in hole 310-1.

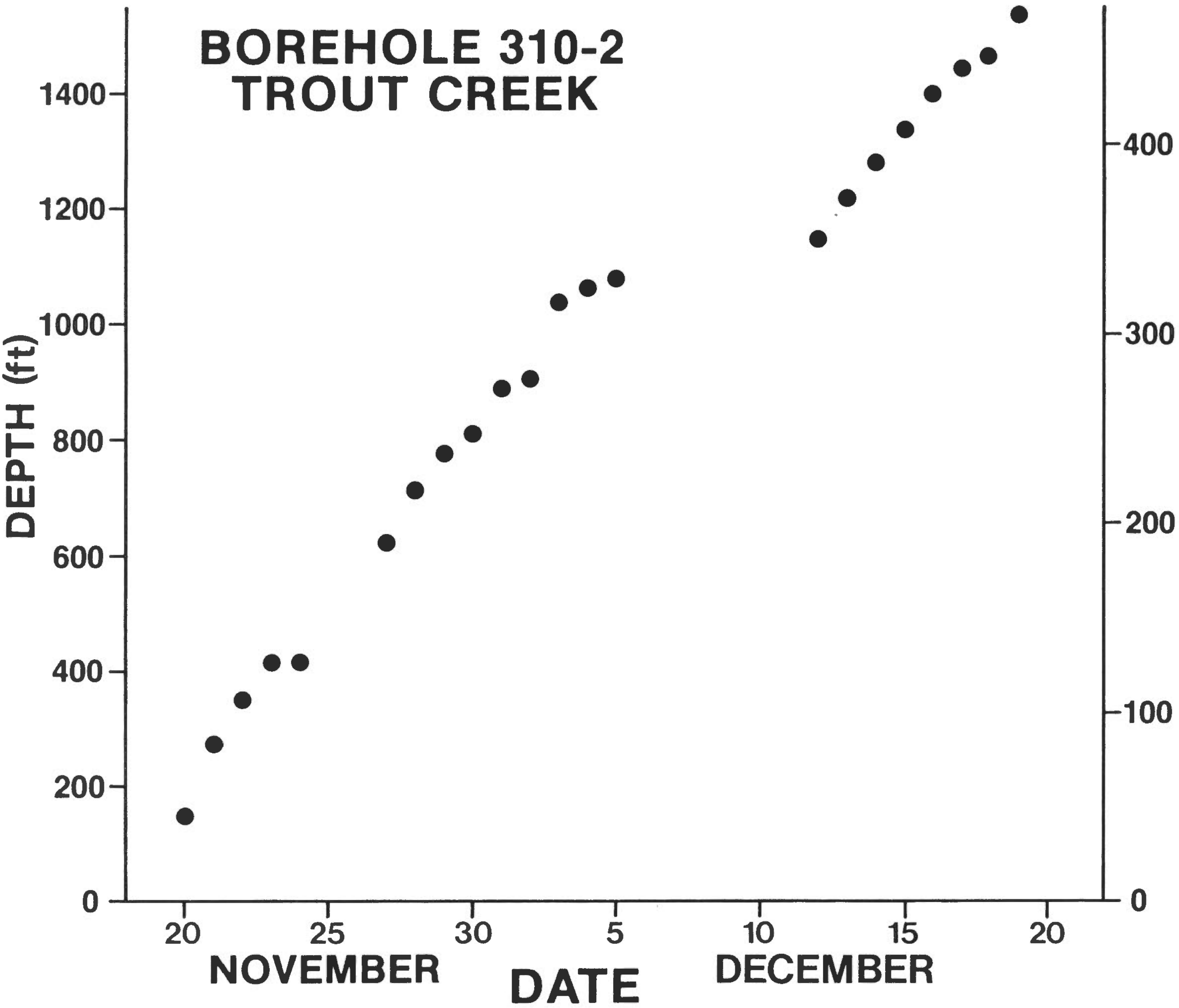

FIG. 5: Drilling progress in hole 310-2.

Table 2: Depths from which conductivity samples were chosen

Hole 310-1 Paynter Lake				Hole 310-2 Trout Creek			
(ft)	(m)	(ft)	(m)	(ft)	(m)	(ft)	(m)
36	11	657	200	65	20	844	257
70	21	674	205	103	31	872	266
110	34	699	213	130	40	907	276
136	41	726	221	149	45	921	281
162	49	751	229	175	53	953	290
216	66	777	237	199	61	982	299
244	74	800	244	218	66	1006	307
268	82	824	251	242	74	1023	312
300	91	849	259	275	84	1044	318
324	99	877	267	325	99	1069	326
349	106	909	277	347	106	1080	329
376	115	949	289	377	115	1102	336
398	121	977	298	389	119	1124	343
431	131	1000	305	416	127	1145	349
447	136	1029	314	453	138	1162	354
476	145	1052	321	489	149	1187	362
506	154	1076	328	505	154	1213	370
526	160	1099	335	557	170	1233	376
555	169	1122	342	566	173	1255	383
573	175	1150	351	583	178	1274	388
607	185	1176	358	625	191	1305	398
627	191	1201	366	643	196	1330	405
				665	203	1352	412
				684	208	1370	418
				703	214	1396	426
				737	225	1424	434
				757	231	1450	442
				785	239	1471	448
				808	246	1484	452
				825	251	1539	469

Table 3: Depths from which heat generation samples were chosen.

Hole 310-1 Paynter Lake				Hole 310-2 Trout Creek			
(ft)	(m)	(ft)	(m)	(ft)	(m)	(ft)	(m)
119	36	707	215	102	31	805	245
213	65	821	250	201	61	895	273
291	89	913	278	299	91	989	301
397	121	1000	305	390	119	1097	334
502	153	1117	340	501	153	1204	367
604	184	1202	366	624	190	1301	397
				698	213	1397	426
						1497	456

Temperature Measurements

Temperatures were measured each day, just before commencement of drilling. Since there was only a single drilling shift each day, the water equilibrated with the surrounding rock for about 12 hours after the drilling circulation stopped before the temperature was logged. At the bottom of the hole both the temperature disturbance caused by drilling and the chances of a disturbance caused by water entering the hole from a fracture and flowing up the hole are minimal (Lewis et al., 1979). Consequently bottom hole temperatures measured during stops in the drilling best indicate the undisturbed temperature gradient within the rock. If water does not flow in the hole from fracture to fracture, or from fractures to the surface, then the final temperature log taken weeks after the hole is completed should agree with the bottom-hole temperatures.

A thermistor sensor mounted in a water- and pressure-proof brass probe was used to measure down-hole temperatures. The probe was lowered down the drill hole on a four-conductor cable from a light-weight backpack winch, and the absolute resistance of the thermistor was determined on surface with a sensitive Wheatstone Bridge. Temperatures were then determined from previous calibration of the thermistor. The instrumentation was described in detail by Lewis (1975).

Figure 6 shows a typical temperature log measured 12 hours after circulation stopped, as well as an additional log taken 24 hours later. There was no drilling nor circulation between the two logs. The higher temperatures caused by drilling operations decayed about 0.4^{o}C during the 24 hours; the bottom hole temperature is the least disturbed. At a

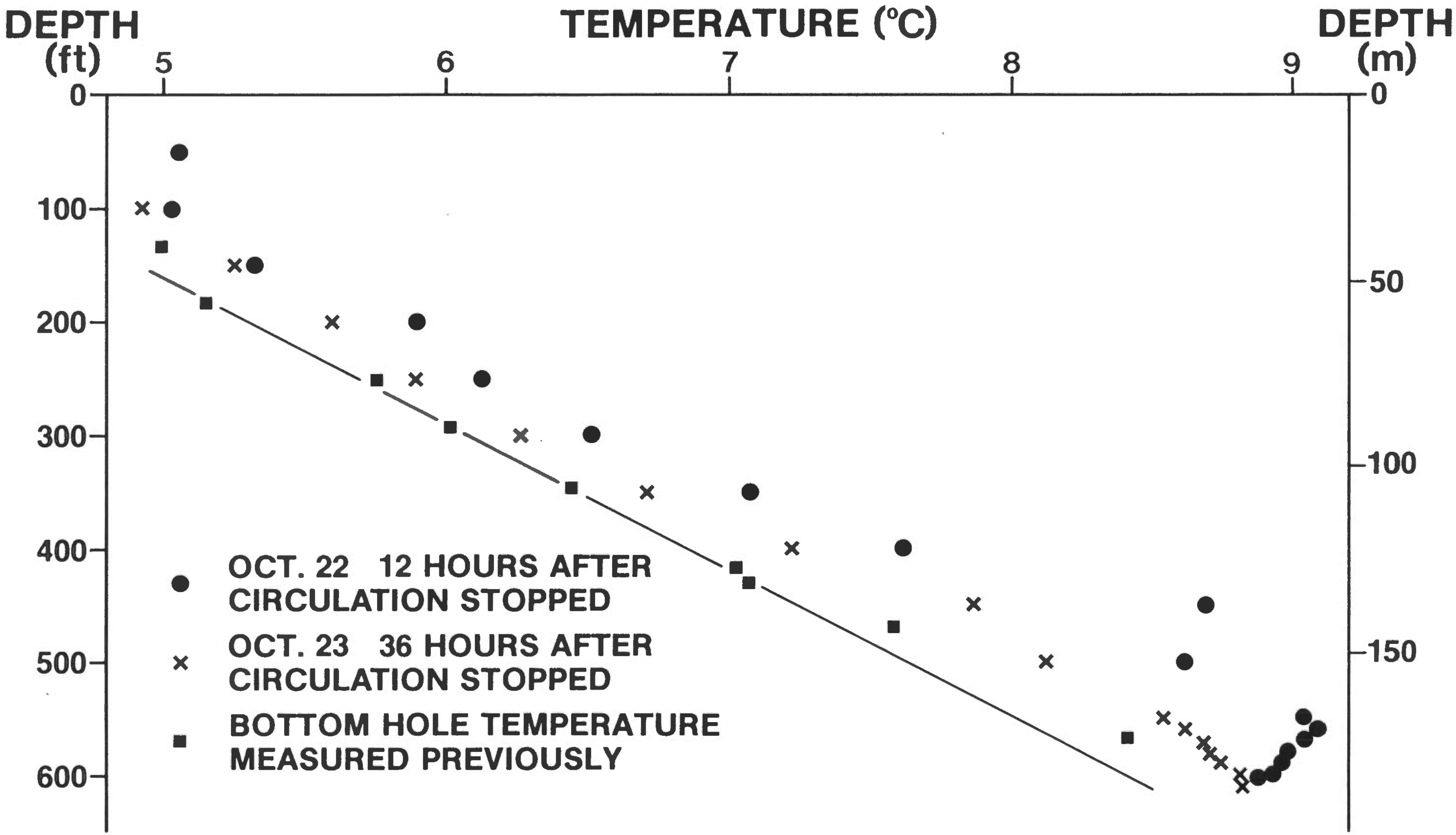

FIG. 6: Two temperature logs of hole 310-1 and bottom hole temperatures. These data illustrate the temperature disturbance caused by drilling, and the return to equilibrium temperatures.

depth of 425 ft (130 m) a relatively higher temperature was encountered the previous day, which we interpret as the effect from relatively warm water entering the hole near that depth.

Figure 7 shows the final temperature log of hole 310-1 (Paynter Lake) measured 9 days after the hole was completed, as well as the bottom hole temperatures. Tables 4 and 5 contain the data. The hole is now blocked at 1100 ft (335m) depth. The general agreement between the final log and the bottom hole temperatures indicates that very little, if any, water is flowing up or down the hole. The bottom hole temperature at 1000 ft (305 m) is much higher, indicating that at this depth a large volume fracture accepted the warm water being circulated, and took much longer to cool afterwards. The core log shows fracturing in many places, but severe fracturing occurred in only a few places, including 987 to 997 feet (301-304 m). If the temperature were not measured in such a fracture zone then the prolonged thermal disturbance associated with the zone would not be detected.

If the bottom hole temperatures from hole 310-1 are plotted in detail, as is partially done in Figure 6, the data are best approximated by five straight line segments:

1 from 185 (56) to 430 ft (131 m) with a gradient of 26.7 mK/m

2 from 467 (142) to 629 ft (192 m) with a gradient of 28.2 mK/m

3 from 629 (192) to 796 ft (243 m) with a gradient of 32.5 mK/m

4 from 837 (255) to 1037 ft (316 m) with a gradient of 30.3 mK/m

5 from 1067 (325) to 1207 ft (368 m) with a gradient of 30.8 mK/m

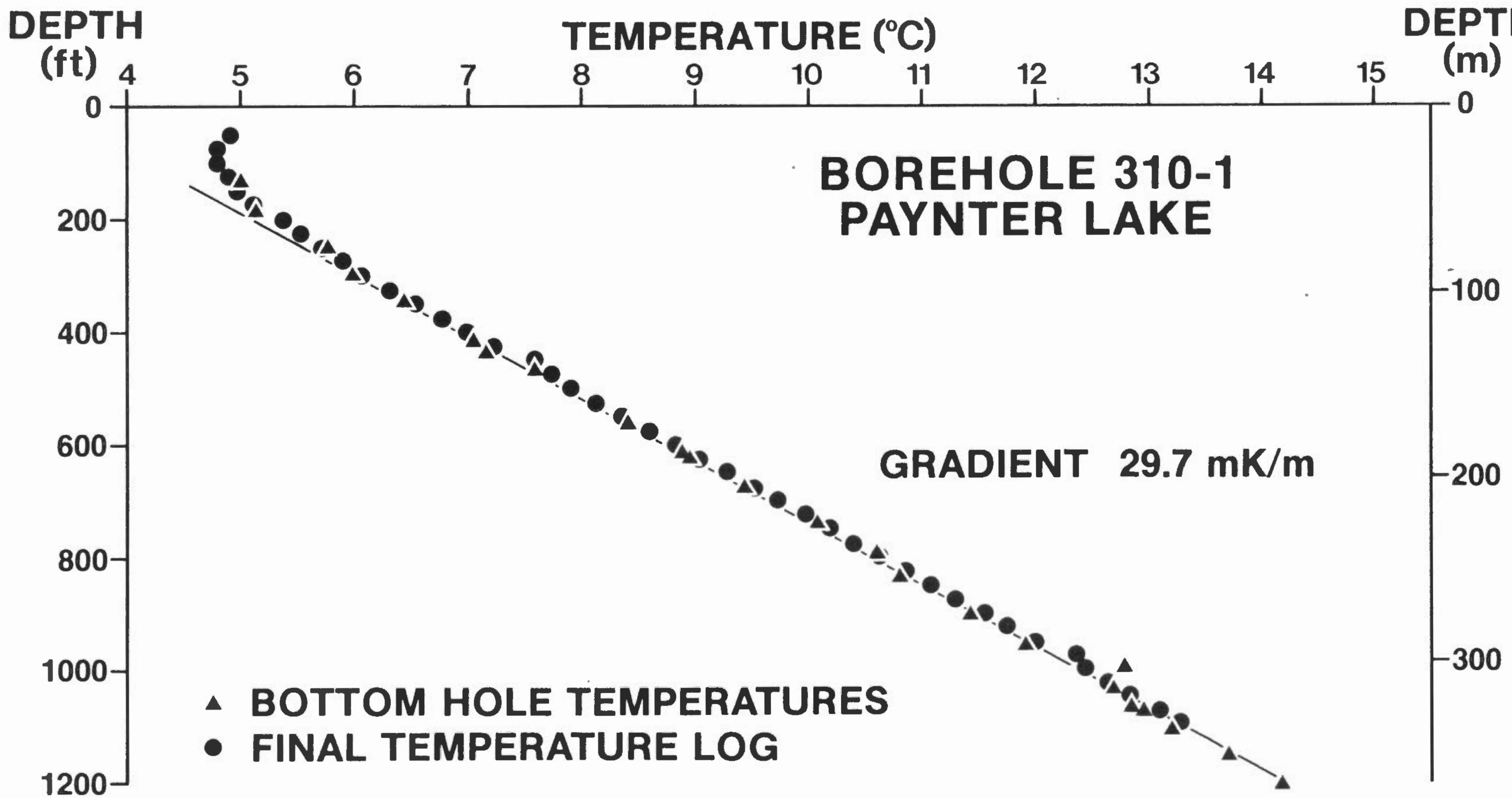

FIG. 7: Temperatures in borehole 310-1.

Table 4: Bottom hole temperatures of borehole 310-1 Paynter Lake

Depth (ft)	(m)	Temperature (°C)	Date Measured
135	41	4.99	13 October
185	56	5.15	14
252	77	5.75	15
293	89	6.01	16
347	106	6.44	17
417	127	7.05	18
430	131	7.17	19
467	142	7.58	20
567	173	8.41	21
617	188	8.88	22
629	192	8.96	24
677	206	9.43	25
738	225	10.07	28
796	243	10.60	29
837	255	10.81	30
905	276	11.42	31
957	292	11.92	1 November
1000	305	12.78	2
1037	316	12.65	3
1067	325	12.85	4
1077	328	12.95	6
1107	337	13.22	7
1157	353	13.69	8
1207	368	14.17	9

Table 5: Final Temperatus Log. of Hole 310-1 19 Nov 80

DEPTH (ft)	(m)	TEMPERATURE (°C)	9 days since circulation stopped
0	0	4.949	
25	7.6	6.112	
50	15.2	4.921	
75	22.8	4.796	
100	30.4	4.782	
125	38.1	4.891	
150	45.7	4.979	
175	53.3	5.113	
200	60.9	5.364	
226	68.8	5.520	
250	76.2	5.705	
275	83.8	5.895	
300	91.4	6.072	
325	99.0	6.313	
351	106.9	6.542	
375	114.3	6.760	
400	121.9	6.978	
425	129.5	7.212	
450	137.1	7.584	
475	144.7	7.730	
501	152.7	7.902	
525	160.0	8.123	
550	167.6	8.347	
576	175.5	8.583	
600	182.8	8.805	
625	190.5	9.033	
650	198.1	9.265	
675	205.7	9.509	
700	213.3	9.724	
725	220.9	9.956	
750	228.6	10.166	
775	236.2	10.381	
800	243.8	10.615	
825	251.4	10.850	
850	259.0	11.058	
875	266.7	11.289	
900	274.3	11.552	
924	281.6	11.740	
950	289.5	11.989	
975	297.1	12.349	
1001	305.1	12.426	
1025	312.4	12.632	
1050	320.0	12.844	
1075	327.6	13.065	
1098	334.6	13.271	

These data can be explained by a complex pattern of changing thermal conductivity in the rocks penetrated and/or zones in which convective flow of heat exists. Further interpretation awaits the measurement of the thermal conductivity of the core samples.

Figure 8 shows the bottom hole temperatures of hole 310-2 (Trout Creek) as well as the final temperature log run 26 days after the hole was completed. Tables 6 and 7 contain this data. The final log shows no indication of water moving within the borehole. The bottom hole temperatures are best approximated by three straight line segments as shown in Figure 8:

1. from 227 (84) to 787 feet (240 m) with a gradient of 35.4 mK/m
2. from 817 (249) to 1157 feet (353 m) with a gradient of 33.8 mK/m
3. from 1157 (353) to 1547 feet (472 m) with a gradient of 26.9 mK/m

Again final interpretation awaits the measurement of the thermal conductivity of core samples.

If one combines an approximate gradient of 30 mK/m with an approximate conductivity of 2.5 W/m ^{o}C, this indicates an approximate heat flow of 75 mWm^{-2}. The amount of quartz in hole 310-1 is likely to make the thermal conductivity there higher than in hole 310-2.

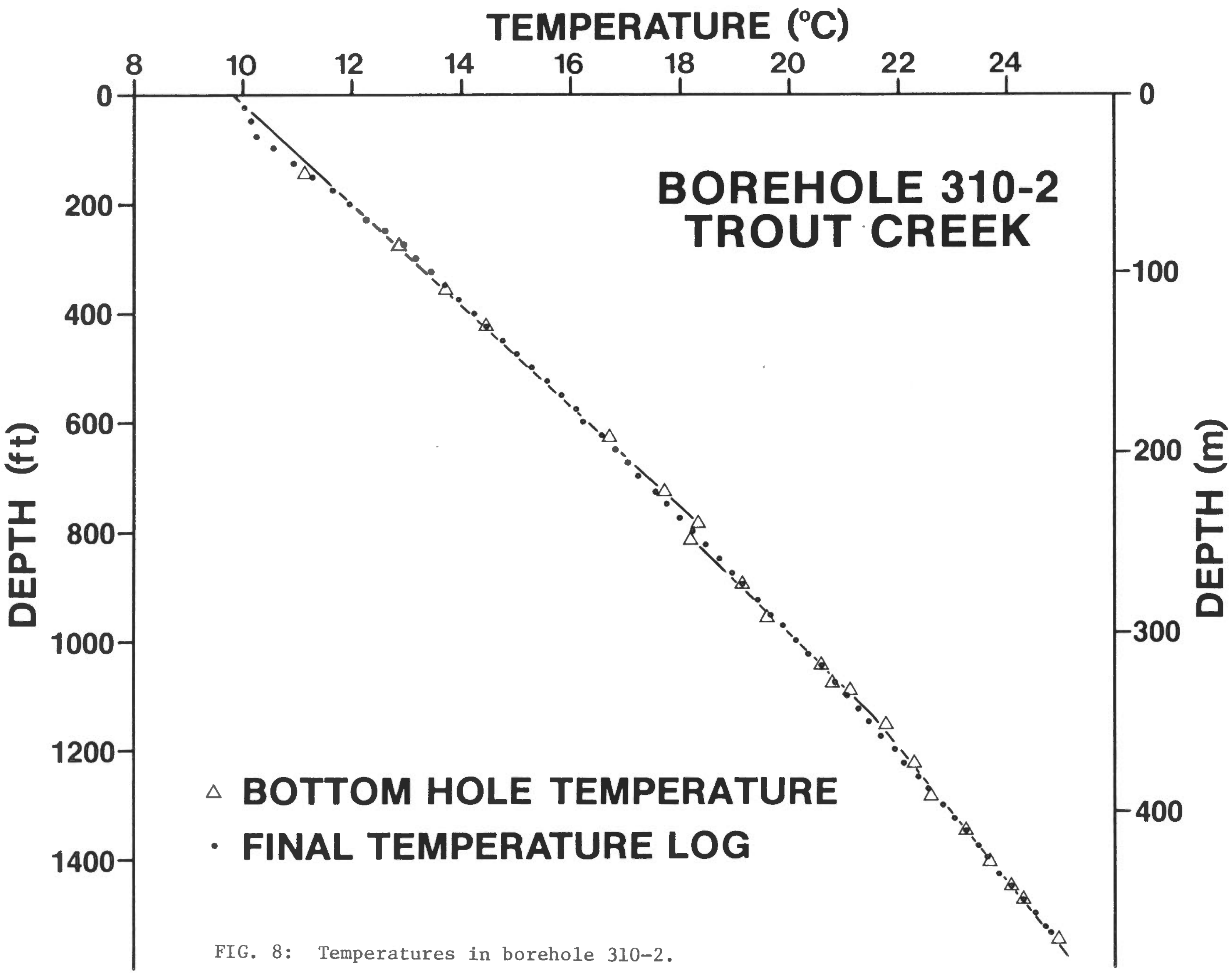

FIG. 8: Temperatures in borehole 310-2.

Table 6: Bottomhole temperatures of borehole 310-2 (Trout Creek)

Depth (ft)	Depth (m)	Temperature (°C)	Date Measured
145	44.2	11.12	20 Nov
277	84.4	12.86	21 Nov
357	108.8	13.71	22 Nov
427	130.1	14.45 (14.39)	23 Nov (24 Nov)
627	191.1	16.72	27 Nov
727	221.6	17.70	28 Nov
787	239.9	18.33	29 Nov *1
817	249.0	18.17	30 Nov *2
897	273.4	19.16	1 Dec
957	291.7	19.62	2 Dec
1047	319.1	20.60	3 Dec
1078	328.6	20.77	4 Dec
1093	333.1	21.08	5 Dec
1157	352.6	21.78	12 Dec *3
1227	374.0	22.28	13 Dec *1
1287	392.3	22.58	14 Dec
1347	410.6	23.22	15 Dec
1407	428.6	23.68	16 Dec
1450	442.0	24.07	17 Dec
1477	450.2	24.31	18 Dec
1547	471.5	24.95	19 Dec

*1 No rods in hole

*2 Poly-drill in hole

*3 Hole cemented 1080-1157

Table 7: Final temperature log of hole 310-2

DEPTH (FROM GROUND) (ft)	(m)	TEMPERATURE CIRCULATION STOPPED (°C) 26 days ago
26	7.9	10.01
50	15.2	10.14
75	22.8	10.25
100	30.4	10.57
125	38.1	10.92
151	46.0	11.29
175	53.3	11.63
201	61.2	11.97
225	68.5	12.28
250	76.2	12.60
275	83.8	12.92
301	91.7	13.16
325	99.0	13.43
350	106.6	13.69
375	114.3	13.96
400	121.9	14.22
425	129.5	14.49
450	137.1	14.74
475	144.7	15.00
500	152.4	15.28
525	160.0	15.56
550	167.6	15.81
575	175.2	16.08
600	182.8	16.21
625	190.5	16.56
650	198.1	16.82
675	205.7	17.05
700	213.3	17.27
725	220.9	17.53
750	228.6	17.74
775	236.2	18.00
800	243.8	18.23
825	251.4	18.48
850	259.0	18.71
875	266.7	18.95
900	274.3	19.15
925	281.9	19.40
951	289.8	19.65
975	297.1	19.88
1000	304.8	20.10
1025	312.4	20.33
1050	320.0	20.55
1075	327.6	20.81
1099	334.9	21.02
1125	342.9	21.26
1149	350.2	21.46
1175	358.1	21.68
1201	366.0	21.91

Table 7 (cont'd)

DEPTH (FROM GROUND) (ft)	(m)	TEMPERATURE CIRCULATION STOPPED (°C) 26 days ago
1225	873.3	22.09
1250	381.0	22.35
1275	388.6	22.57
1300	396.2	22.80
1325	403.8	23.02
1350	411.4	23.22
1375	419.1	23.44
1400	426.7	23.64
1425	434.3	23.87
1451	442.2	24.09
1475	449.5	24.29
1500	457.2	24.51
1525	464.8	24.72
1537	468.4	24.81

Radioactive Heat Generation

The concentrations of the long-lived radioactive isotopes of uranium, thorium and potassium were determined in samples from each hole. The method, as described by Lewis (1974), has since been modified to use samples of a constant mass, 330 g, and a constant absorption. The results are contained in Table 8, where the counting error, given as a percentage of the heat generation, indicates the standard deviation accurately when greater than 8%.

The thirteen samples from the Paynter Lake hole indicate very uniform rock was penetrated with an average heat generation of $1.7 \pm .3$ $\mu W/m^3$. This quartz monzonite is much less radioactive than the Coryell syenites. Three of the samples from the Summerland hole have heat generations greater than 4 $\mu W/m^3$, the largest being 8.7 $\mu W/m^3$. The average result for this hole is affected by the number of such highly radioactive samples included in the average. Two of the high values come from "extensively fractured" and "crumbly" core where ground water flow may have contributed to an enrichment during alteration, although at 696 feet (212 m) the relatively larger concentrations of thorium and potassium might indicate that leeching has occurred.

Table 8: Radioactive Heat Generated in Core Samples

Depth (ft)	U (ppm)	Th (ppm)	K (%)	Heat Generation* ($\mu W/m^3$)	Counting Error (%)	Th/U
	310-1	Paynter	Lake			
	3.75	8.78	2.61	1.83	9.2	2.3
119	4.02	4.56	2.87	1.63	14.1	1.1
213	4.10	9.01	2.85	1.97	6.2	2.2
291	3.29	5.95	2.91	1.54	14.6	1.8
397	2.32	5.68	2.63	1.25	18.2	2.5
502	3.16	6.68	2.60	1.53	16.0	2.1
604	3.97	8.97	3.06	1.95	8.4	2.3
707	4.55	7.68	2.59	1.96	9.0	1.7
821	3.51	6.61	2.82	1.63	9.4	1.9
913	3.70	6.99	2.96	1.72	9.9	1.9
1000	3.83	12.1	2.86	2.10	11.2	3.2
1117	3.72	6.87	2.81	1.71	2.6	1.8
1202	2.75	4.30	1.97	1.20	2.8	1.6
Averages:	3.59	7.24	2.73	1.70		
St. Deviation	±.57	±2.02	±.26	±.31		
	310-2	Summerland				
102	28.7	14.1	3.93	8.75	1.6	.5
201	2.33	4.19	1.57	1.04	19.9	1.8
299	12.1	16.2	2.20	4.47	4.1	1.3
390	3.08	3.92	2.07	1.26	18.5	1.3
501	2.90	6.21	1.99	1.38	16.6	2.1
624	.59	2.57	2.02	.53	32.5	4.3
696	6.38	33.1	4.57	4.42	4.2	5.2
805	1.00	2.85	2.05	.65	33.3	2.9
895	1.32	3.08	1.62	.72	29.	2.3
989	1.04	5.28	2.17	.85	21.7	5.1
1097	.81	4.85	2.30	.77	21.1	6.0
1204	1 .71	13.3	2.62	1.63	9.7	7.8
1301	2.58	10.6	2.74	1.68	8.8	4.1
1397	1.78	6.79	2.04	1.13	18.6	3.8
1497	1.08	1.96	3.62	.76	27.3	1.8
Averages:	4.48	8.63	2.49	2.00		
St. Deviation	±7.03	±7.91	±.83	±2.86		

* Assuming $\rho = 2.67\ g/cm^3$

Conclusions and Recommendations

It is necessary to measure the thermal conductivity of the core samples to determine if the measured vertical heat flux is constant, or if this flux is modified by regional water flows. This is also necessary in order to obtain accurate heat flow values.

It is also necessary to measure the thermal conductivity of members of all formations forming these basins, so that the maximum temperatures at the bottoms of the basins can be calculated.

The approximate measured heat flow, without any corrections, is 75 mWm^{-2}. This is approximately the same as nearby sites referred to earlier.

This heat flow through a sediment filled basin such as the Summerland Caldera, will produce at a given depth, higher temperatures than in the surrounding crystalline rock. It is recommended that a hole be drilled in these basins to determine the rate at which water can be produced and the temperature of the water.

Acknowledgements

We wish to thank Interior Diamond Drilling and its personnel for drilling under contract in a competent manner, and Dr. Glen Russell, Director of the Agriculture Research Station at Summerland, for allowing us to drill the second hole on the station.

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Appendix 1: Elected or Staff Municipal Officials with whom we spoke:

Mr. Donald W. Barcham, Director of Planning
Regional District of Central Okanagan
540 Groves Avenue,
Kelowna, B.C.
763-4918

Mr. K.M. Blagborne, Mayor
The Corporation of the District of Summerland
P.O. Box 159
Summerland, B.C.
VOH 1ZO
494-6451

Mr. R.G. Game, Senior Planner
Regional District of Okanagan - Similkameen
1101 Main Street
Penticton, B.C.
V2A 5E6
492-4918

Mr. A.T. Harrison, Administrator
Regional District of Central Okanagan
540 Groves Avenue
Kelowna, B.C.
763-4918

Appendix 2: Program Description

ASSESSMENT OF THE GEOTHERMAL ENERGY POTENTIAL OF TERTIARY BASINS OF THE OKANAGAN VALLEY

Geothermal energy is one of the alternate sources of energy which the Federal Government of Canada is anxious to see assessed and developed. Therefore the government has been conducting its own research programs as well as funding contracts to encourage the development of geothermal energy.

Geothermal energy is energy in the form of heat which comes from the ground. Nearly everywhere on the earth's surface there is a small net amount of heat flowing out of the ground. But for geothermal energy to be useful, we need it at high temperatures, and concentrated in small volumes from which we can extract if efficiently. This occurs in several different ways in nature.

Steam coming directly up wells from underground formations is the most valued type of resource. The steam can turn turbines which generate electricity. At Meager Mountain 160 km north of Vancouver the federal Dept. of Energy, Mines and Resources and B.C. Hydro have been exploring for such a resource since 1973. This steam comes from very hot rocks in geologically young areas.

The hot water stored in sedimentary basins is another, different source of energy. Although not able to turn turbines directly, it is ideal for space heating: heating homes, buildings, schools, greenhouses, etc. At the University of Regina the Federal Government and the Province of Saskatchewan have drilled a well to 2200 m depth to test production of such warm water for heating a new University building.

In the Okanagan Valley there exist small Tertiary basins which may contain reservoirs of hot water which could be used for space heating. In the Okanagan the net amount of heat flowing up through the rocks, the terrestrial heat flow, may be much larger than normal. This would cause the increase in temperature with depth to be larger than normal, and under the insulating layers of sedimentary rocks, temperatures of 70°C might occur at depths of just over one kilometre.

High values of terrestrial heat flow have been measured to the south in the White Lake Basin (Penticton Inlier) between Penticton and Keremeous, to the west in the Highland Valley and to the east in the Coryell Syenites north of Grand Forks.

During 1980-81, with a limited budget, we would like to measure the terrestrial heat flow near two of the Tertiary Basins: near Summerland and near Westbank. This would entail having a contractor drill a cored hole near each basin in which we would accurately measure temperatures. We would also measure the thermal conductivity of core samples as well as samples from the sedimentary formations. We have not chosen the exact drill sites yet but we have decided not to drill entirely within sedimentary formations.

This outline is presented to inform people within the area of our plans. We have contacted or are contacting the Regional Boards, Regional Officials, and Municipal Councils for the areas in which we plan this work to inform them of our plans and to receive from them their response and/or questions concerning the project. No development is without advantages and disadvantages. However, geothermal power is generally considered an ideal source of energy.

For further information please contact:

Dr. Trevor Lewis
Pacific Geoscience Centre
Earth Physics Branch
Energy, Mines and Resources
9860 West Saanich Road
Sidney, B.C. V8L 4B2
656-8447

Dr. Neil Church of the B.C. Dept. of Energy, Mines and Petroleum Resources has studied the geology of these basins and is assisting us in locating the drill sites.

Appendix 3: Officials of Provincial Departments of Forestry and Energy, Mines and Petroleum Resources

Dept. of Energy, Mines and Petroleum Resources

Mr. Gordon White
101-2985 Airport Drive
Kamloops, B.C.
V2B 7W8
376-7201

Mr. George Addey
310 Ward Street
Nelson, B.C.
V1L 5S4

B.C. Forest Service
District Forrestor
R.R.#2
Highway 97 North
Kelowna, B.C.
V1Y 7P2
765-5178

Appendix 4: Core log of hole 310-1 (Paynter Lake)

For each interval a description of the rock type is given, followed by 6 columns giving the number of fractures in the rock in each 15^{o} - interval measured from the horizontal. The next column is the fracture density per foot. The next two pairs of columns each consist of a first column giving the scale of alteration:

1. Unaltered: fresh surfaces only, no indications of secondary mineral formed.
2. Mild alteration: low grade secondary minerals evident, small cavities from dissolved minerals; fine-grained precipitation of minerals in pores and fractures.
3. Moderate alteration: coarse-grained precipitation of secondary minerals, mafic minerals chloritized; feldspars beginning to alter along fractures.
4. High alteration: chloritization or epidotization pervasive throughout the rock, hardness of all mafic minerals affected, alteration of silicic minerals pervasive from fractures into rock. Kaolinization evident.
5. Severe alteration: all minerals altered, rock competency lost. Includes gouge, shear zones, faults.

The second column describes the alteration. The first pair describes the fracture alteration and the second pair, the rock alteration.

INTERVAL	ROCK TYPE	15	30	45	60	75	T	PT		FRACTURE ALTERATION		ROCK ALTERATION	REMARKS
5-10	Hb-Bi granodiorite 50% recovered weathered , brocken to crumbly, sandy in features.								4	Powdery sand, rust	3	chlorite	Low recovery, fractures not counted
10-17	Bi Hb qtz. monzonite 80% recovered	....		.	....	......	35	6.9	4	"	2	"	
17-19	" 100% rec.	......				....	12	6.0	4	Chlorite, rust	2	"	
19-27	Hb Bi QZMZ	....	..	....	..	....	29	3.6	3	Chlorite still sandy	2	"	Still lots of sand in fractures
27-37	" , apatite bearing	.....	.	...	..	......	17	1.7	4	Kaolinite rust, feldspars dissolved	2	"	Moderately competent
37-47	H Bi QZMZ, apatite; mafic orbicular inclusions	......	..		...	.....	16	1.6	2	Calcite	2	Chlorite	
47-55	"	....	....	.	.....	.....	25	3.1	2	"	2	"	
55-57	Pink granite, blended change over 2' from QZMZ	.....			...	..	10	5.0	2	"	2	"	
57-63.5	Variable, granite to QZMZ	....	....	.	......	.....	23	3.5	2	Chlorite, Calcite	2	Minor Chlorite	
63.5-74.5	Granite, highly fractured and weathered. Crumbly. 85% recovery	Crumbly						10	3-5	"	4-5	Feldspears weathered, kaolinized	
74.5-77	QZMZ	...	....	....		..	17	6.8	2	Calcite, Chlorite, minor hematite along slickensides		Chlorite, some rust stain in feldspars near fractures	
77-87	QZMZ - Granite	variably crumbly where not crumbly 2.0						10	2	Calcite	2	Chlorite	

87-96	QZMZ	"	10	2.5	2	Calcite, Chlorite	2	"	
96-112.5	QZMZ-Granite	"			2	Calcite, Chlorite	2	Minor chlorite	Common solution of minerals adjacent to fractures.
112.5-123	", 90% recovery		41	3.9	2	"	2	"	
123-127			13	3.3	2	Calcite, minor chlorite, bleaching	2	"	
127-137			24	2.4	2	"	2	"	
137-147			19	1.9	2	" Quite Sandy	2	"	Sandy in fractures
147-157	QZMZ-GNDT	extensive sub-vertical fractures	8		3	Calcite, bleaching solution cavities	2	"	
157-167	QZMZ		36	3.6	2	Minor calcite, minor chlorite	2	"	
167-177	QZMZ, occasional dark inclusions (ie 181)		33	3.6	2	" Some bleaching adjacent wallrock	2	"	
177-187	QZMZ		38	3.8	2	"	2	"	
187-197	QZMZ-GNDT		48	4.8	3	Calcite, chlorite			
197-207	QZMZ		25	2.5	2	"	2	"	Possible apatite
207-217	"		27	2.7	2	"	2	"	
217-227	"				2	"	2	"	
227-235.5	QZMZ-Granite, becoming crumbly highly fractured		8		3	"	2	"	Crumbly, into 5-10cm chunks
235.5-241.5	QZMZ-granite, extremely crumbly.		10+		3	"	2	"	1-2 cm chunks

241.5-256	QZMZ-Granite	... ...	49	3.4	3	"	2	"	
256-266	"	Variable to powder in shear zone			3	"	2	"	Shear with gouge at 264
266-276	"	... .	29	2.9	2	"	1		
276-283.5	QZMZ	... .	12		2	"	1	"	
283.5-293.5	"	... ...	10	1.0	2	Very minor chlorite, calcite	1		Quite competent
293.5-296.5	"	... . .	6	2.0	1-2	"	1		
296.5-306.5	"	... .	14	1.4	1		1		
306.5-316.5	QZMZ-Granite	... ...	20	2.0	2	Calcite, Chlorite	1		
316.5-326.5	Granite	... ...	14	1.4	2	"	1		
326.5-336.5	"	... ...	27	2.7	2	"	2	Chlorite	
336.5-347	QZMZ-Granite, becoming shattered			8	3	"	3	Chlorite, kaolinite	
347-358	Broken granite, highly fractured, altered 90% recovery			8	3	"	3	"	
358-365	"			10+	3	"	5	Chlorite, Kaolinite	often only grains recovered
365-371	"			10+	2	"	4	"	slightly more competent, 1-10cm chunks
371-381	"			10+	3	"	4-5	"	

381-391.5	"							10+	3	"	5.4	"	Last 5' more competent
391.5-401.5	Variable, moderately competent to crumbly granite	x	x			x		8	2	"	2	Chlorite	
401.5-407	" , mostly crumbly							10+	2	"	3	Chlorite, kaolinite	
407-413	"							10+	2	"	4	"	
413-417	"							10+	3	"	4	"	
417-423	", crumbly to grains							10+	4	"	5	"	
423-427	"							10+	3	"	5	"	
427-430	Granite QZMZ; sheared 427-428, then massive, competent.		...		...	......	9	3.0	3-2	"	5-2	"	
430-437	QZMZ	.	.		..	..	6	1.2	2	Minor calcite	1		
437-447	QZMZ	.....	...	.	..	.	12	1.2	1		1		
447-457	"	....	....	.	....	...	27	2.7	2	Calcite	1		
457-467	"	......	....	.	..	....	22	2.2	1		1		
467-477	"	....	..		....	..	22	2.2	2	Minor calcite	1		
477-487	"	....	....	..	......	...	28	2.8	2	"			
487-497	"	......	....		.....	....	27	2.7	2	"	2	Calcite, chlorite	

497-507	"	18	1.8	2	"	1	
507-517	",becoming shat-tered, crumbly	8		3	Calcite,chlorite	2-5	Calcite, Chlorite
517- 527	QZMZ	42	4.2	2	"	2	"
527-537	", becoming shattered	44	4.4	3	"	3	"
537-547	", highly fractured	6		3	"	3	"
547-557	QZMZ, massive competent	15	1.5	2	"	1	
557-567	"	13	1.3	1		1	
567-577	QZMZ, dense fractures	5		3	Calcite, chlorite	3	chlorite
577-597	"	5		3	"	3	"
597-607	QZMZ, more competent	26	2.6	2	"	1	
607-617	Granite, occasionally crumbly	42	4.2	2	"	2	Calcite, chlorite
617-627	Granite-QZMZ,dark inclusions	25	2.5	2	"	2	"
627-628	"	4	4.0	2	"	4	"

628-637	QZMZ	16		1		1		
637-647	"	39	3.9	2	Calcite,chlorite			
647-657	"	11	1.1	2	"	1		Competent care
657-667	"	22	2.2	2	"	1		
667-677	"	36	3.6	2	"	1	except in faulted zone, where extensive chlorite, calcite	Fault zone (6") @ 670
677-687	"	43	4.3	2	Calcite	2	Calcite, chlorite, sol'n of feldspars	Fault zone 6" 682
687-697	", dark inclusions to 6"	16	1.6	2	Calcite, minor chlorite	1		
697-707	"	26	2.6	2	Calcite			
707-717	"	34	3.4	2	Calcite, chlorite	1		
717-727	"	10	1.0	1				Competent
727-737	"	23	2.3	2	Chlorite	1		
737-747	"	22	2.2	1		1		
747-757	"	8	0.8	1		1		Very competent

757-767	"	... ...		....	.		11	1.1	1		2	orange staining of feldspars	
767-777	"	... ...	... ..	...	..	... ...	28	2.8	2	Minor chlorite	2	"	
777-787	"	... ..	... .	... ..	... ...	... ...	36	3.6	2	Calcite, chlorite	2	Minor chlorite, staining of feldspar	1 fracture in 1st 6'; all rest in last 4'.
787-796	QZMZ, dense fractures, weathered in zones to much	x			x	x		8	3				
796-806.5	QZMZ	... ...	... ...	...	... ...	... ...	42	4.2	3	"	2	Minor chlorite	
.5-816.5	"	... ...	.	..	..	... ...	40	4.0	2	Calcite	1		
816.5-827	"	... ...	...	...		... ...	30	3.0	2	"	2	chlorite	
827-831	", very broken, bleaky							8	2	"	2	"	
831-837	QZMZ,distinctly altered	... ...	...	.	... ...	... ...	28	4.7	3	Calcite, chlorite	3	chlorite	
837-847	QZMZ, competent, minor mafic inclusions	...	.	..	...	...	12	1.2	2	Calcite	1		
897-857	"	... ...	...	...	... ...	...	29	2.9	2	Calcite, chlorite	1		
857-867	"	... ..	... ...	... ...	... ...	... ..	49	4.9	2	"	1		

867-877	", competent	15	1.5	2	"	1		
877-887	QZMZ, gauge zone 882-883	32	3.2	3	"	2	chlorite	
887-897	QZMZ	31	3.1	2	"	1		
897-905	QZMZ, shattered		10+	3	Chlorite, calcite	4	chlorite, clays	Should be zone of water flow (check profiles)
905-911	"		10+	3	"	4	"	
911-917	QZMZ	26	4.3	2	Calcite	2	Minor chlorite	
917-927	"	35	3.5	2	Calcite, quartz	2	Some sol'n of feldspars	
927-937	QZMZ, dense fractures		8	3	Calcite, chlorite, minor quartz.	3	Sol'n of feldspars, clays	
937-943	QZMZ, shattered		10+	3	Calcite, chlorite	3	"	
943-951.5	QZMZ, shattered to dense fractures		8	2	Calcite, chlorite	3	Chlorite	
951.5-957.	QZMZ, dense fractures	23	4.0	2	"	2	"	
957-967	"	31	3.1	2	"	2	"	Gouge at 962

967-977	QZMZ	...	...	.	...	...	13	1.3	2	"	2	Minor chlorite, staining	Distinctly more massive
977-987	"	:..	:::	..	:::.	:::.	29	2.9	2	"	2	Minor chlorite, minor pyrite	
987-997	"	x	x		x			6	2	Minor calcite	1		Most frx inlst 5'; gouge at 996
997-1000	"	..		.	..	.	6	2.0	2	Calcite, chlorite	1		
1000-1007	"	:::.	.	.	:::	..	17	1.7	2	Calcite	1		
1007-1017	"	..	..	.	:..	:..	13	1.3	1				Competent; 30" unbroken to 1015.
1017-1027	"	::.		..	:::::	:::::	25	2.5	3	Calcite,chlorite	2	Bleaching of feldspars in 1025-1027	
1027-1037	", shattered 1st foot	..	:::	..	...	::::.	21	2.3	2	"	1		Fracture count ignores shattered 1027-1028
1037-1047	" "	...	.	::.	...	:::::.	20	2.0	2	"	1		
1047-1057	QZMZ	...	.	::.	:::::	::::::	32	3.2	2	"	1		Hemative (old) coated slicker sides at 1047, horizontal movement.
1057-1067	"	..	..	::.	::::.	...	22	2.2	2	Minor chlorite	1		

1067-1077	"	:::	...	...	...	:::	33	3.3	2	"	1			45
1077-1086.5	"	...	:::	.	:::	:::	27	3.0	2	Chlorite	2	Minor chlorite	Last foot shattered	
1086.5-1096.5	" , crumbly							6	3	Calcite., quartz	2	Bleaching	Losing competency	
1096.5-1107.	", crumbly								3	"	2	"	Only 3' recovered, core tube not locked	
1107-1117	Crumbly to mush to 1113,then competent QZMZ								N.A. 10+		5	Clay		
1117-1126	QZMZ,variable competent to crumbly	x	x		x			8	2	Calcite, chlorite	2	chlorite	crumbly zones probably due to core following vertical fractures	
1126-1136.5	QZMZ	:::	:::	..	:::	:::	50	5.0	2	"	2	"		
1136.5-1146.5	"	:::	...			...	16	1.6		Minor chlorite	1			
1196.5-1157	QZMZ	:::	:::	.	:::	...	31	3.1	2	Calcite-epidote, chlorite	1		Several calcite epidote filled fractures at	
1157-1167	"	:::	:::	...	.	....	22	2.2	2	Calcite	1			
1167-1177	QZMZ extremely competent	:::	...	.			18	1.8	2	Calcite	1			
1177-1187	QZMZ competent up to 1184, then altered	:::	:::	.	...	:::	38	3.8	3	Calcite, chlorite	2	Chlorite		
1187-1197	QZMZ, competent	:::	...	.		.	12	1.2	2	Calcite	1			
1197-1207	",altered @1205-6	:::	.			..	13	1.3	3	Calcite, chlorite	1			

Appendix 5: Core log of hole 310-2 (Trout Creek)

For each interval a description of the rock type is given, followed by 6 columns giving the number of fractures in the rock in each 15^{o} - interval measured from the horizontal. The next column is the fracture density per foot. The next two pairs of columns each consist of a first column giving the scale of alteration:

1. Unaltered: fresh surfaces only, no indications of secondary minerals formed.
2. Mild alteration: low grade secondary minerals evident, small cavities from dissolved minerals; fine-grained precipitation of minerals in pores and fractures.
3. Moderate alteration: coarse-grained precipitation of secondary minerals, mafic minerals chloritized; feldspars beginning to alter along fractures.
4. High alteration: chloritization or epidotization pervasive throughout the rock, hardness of all mafic minerals affected, alteration of silicic minerals pervasive from fractures into rock. Kaolinization evident.
5. Severe alteration: all minerals altered, rock competency lost. Includes gouge, shear zones, faults.

The second column describes the alteration. The first pair describes the fracture alteration and the second pair, the rock alteration.

INTERVAL	ROCK TYPE	15	30	45	60	75	T	PT		FRACTURE ALTERATION		ROCK ALTERATION	REMARKS
21-26.5	Altered, crumbly pink granite, highly weathered Aplitic zones							10+	2	Dolomite?, Chlorite	4	General weathering to clays	
26.5-37.	Altered, crumbly, included green shistose metamorphics							10+	2	Dolomite?, Chlorite	4	General weathering to clays	
37-47	Altered, crumbly, included green shistose metamorphics							10+	3	Dolomite?	5	General weathering to clays	
47-57	Pink granite/greenschist migmatite							8	2	Dolomite?	4	Weathering to clays, chlorite, poss. minor epidote in greenschist	
57-67	Pink granite/greenschist migmatite							10	2	Dolomite, Chlorite	3	"	
67-77	"							7	2	"	2	"	Local competent zones
77-87	"							8	2	"	3	"	
87-97	"							8	3	"	3	"	
97-107	", extremely crumbly							10+	2	Dolomite	4-5	Weathered to complete loss of cohesiveness	
107-117	"							10+	3	"	5	"	
117-126	Folded, banded chlorite-epidote schist							10+	2	Chlorite, calcite	3	chlorite, Calcite epidote	
126-135	"							10+	2	"	3	"	slickensides in chlorite at 131
135-145	", 1-3 cm aplite veins	6	13	5	8	22	54	5.4	2	"	2	"	
145-155	"	13	14	1	15	7	50	5.0	2	"	2	chlorite, calcite	
155-165.5	Folded, banded chlorite schist, becoming migmatitic by 160							8	2	"		"	Mush 159-161

165-175.5	Migmatite, mixture of pegmatitic aplite and greenschist or green gneiss							8	3	Chlorite, calcite	3	chlorite, calcite	some cavities 2-4 cm, filled with rhombohedral calcite (167)
175.5-185.5	" becoming dominantly banded gneissic schist by 180	14	11	8	8	14	55	5.5	3	"	3	"	
185.5-196.	green to grey, folded, banded gneiss	10	21	13	13	5	62	6.2	2	"	2	chlorite, epidote	
196-206.5	migmatite, becoming crumbly by 203		X	X				10+	3	chlorite, minor calcite	3	extensive chlorite	
206.5-216.5	migmatite, greenschist & aplite	17	34	8	6	8	74	7.4	3	chlorite, calcite	3	"	extensive breaks// schistosity
216.5-226.5	"		X					7	3	chlorite, calcite	3	chlorite, epidote	"
226.5-237	", chlorite-filled fault breccia 229-231.5	X	X					7	3	"	4	chlorite	
237-247	Migmatite, mostly green-schist-banded gneiss	3	20	7	7	3	40	4.0	2	"	3	chlorite, epidote	
247-257	Migmatite, mostly aptite	8	15	7	8	12	50	5.0	2	calcite	2	minorchlorite	
257-267	Migmatite, mostly greenschist		X			X		8	3	chlorite	3	chlorite	chlorite mush @ 261
267-277	"		X					8	2	chlorite, calcite	3	"	
277-287	"	2	21	8	7	5	43	4.3	2	"	2	"	
287-297	Green chlorite schist/ gneiss	2	21	6	12		41	4.1	2	"	3	"	
297-307	Green gneiss, locally diorite-gneiss	4	12	5	2	7	30	3.0	2	chlorite	2	"	

307-317	Green gneiss, locally diorite-gneiss	7	10	5	9	6	37	3.7	2	chlorite, calcite	1		
317-327	", locally crumbly, mixed with granite	5	5	2	13	8	33	3.3	2	"	1		Fracture readings taken excluding crumbly pores.
327-337	Highly fractured, locally crumbly, diorite-gneiss; andesite 329-734.5							10	2	calcite, chlorite	1		Too crumbly for fracture count
337-347	Gneissic diorite	11	17	15	10	3	56	5.6	2	calcite	1		
347-357	Foliated granodiorite to granite	9	7	6	12	10	44	4.4	2	calcite, chlorite	1		
357-367	"	2	11	6	6	7	32	3.2	2	chlorite	1		
367-377	"	2	2	4	10	1	19	3.8	2	"	1		
377-387	"	11	16	7	9	5	48	4.8	2	calcite, chlorite	1		
387-397	Foliated, gneissic grano-diorite; crumbly, aplitic granite 392-394							8	3	"	2	calcite	
397-407	Migmatitic gneissic granodiorite, crumbled aplite 405-407	4	11	6	9	3	33	4.1	3	calcite, epidote, chlorite	2-5	calcite, epidote (5 in. crumbled aplite)	Fracture readings excluding crumbly zones.
407-417	Altered, foliated granodiorite	9	19	10	10	7	55	5.5	2	calcite, epidote	2	epidote	
417-427	Foliated monzonite-granodiorite	10	16	4	6	6	42	4.2	2	calcite	2	"	
427-437	", extremely altered and crumbly after 433	2	8	5	6	6	27	4.5	3	calcite	4	calcite, epidote	Frx. excluding crumbly zone
437-446.5	Extremely altered aplitic granite, locally to mush, more competent after 443							10+	4		5		

446.5-457.	Monzonite to diorite	11	17	12	24	10	76	7.6	3	Calcite, chlorite	2	chlorite
457-467	Monzonite, dense fractures		X		X			10	3	"	3	calcite, chlorite
467-477	" andesite 470-473		X		X			10	3	"	3	"
477-481	monzonite, shattered							10+	3	"	4	"
481-487	foliated monzonite-diorite	8	4	2	12	13	39	6.5	3	", rust	3	"
487-495	" shattered	3	5		1	3		10+	3	"	4	"
495-505	shattered monzonite to 500, then chlorite-mush-matrix breccia							10+	3	"	5	"
505-515	chlorite-mush-matrix breccia. Highly altered granitic fragments up to 2 cm.							10+			5	"
515-524	shattered monzonite							10+	3	calcite, chlorite	4	"
524-529	"							10+	3	"	4	"
529-537	"							10+	3	"	5	"
537-547	" becoming more competent after 542							10+	3	"	5	"
547-557	shattered monzonite							10+	3	"	4	"
557-567	broken monzonite							8	3	"	3	"
567-577	"							8	3	"	3	"

577-587	broken monzonite, shattered 579-582, 584-586							10	3	calcite, chlorite	4	calcite, chlorite
587-597	shattered monzonite							10+	3	"	4	"
597-607	"							10+	3	"	5	"
607-617	broken monzonite							8	3	"	3	"
617-627	monzonite, foliated	22	8	7		7	47	4.7	2	"	2	"
627-637	", much more competent	23	14	3	1	2	43	4.3	2	"	1	
637-646	"	14	7	1	3	7	32	3.2	2	calcite	1	
646-656	monzonite-diorite	7	5	1	5	2	23	2.3	1		1	
656-666.5	"	18	10	1	5	6	40	4.0	2	calcite	1	
666.5-676.5	"	15	7	3	4	8	37	3.7	2	"	1	
676.5-687	monzonite, broken by extensive vertical fractures					X		8	3	calcite, chlorite	3	calcite, chlorite
687-697	"							10	3	", some silica	4	"
697-707	", qtz. monzonite							10	3	calcite	2	calcite
707-717	broken qzmz		X	X		X		10	2	"	3	calcite, chlorite
717-727	"							8	2	"	2	chlorite
727-737	Qzmz	9	14	6	8	7	44	4.4	2	"	1	
737-747	"	22	13	2	2	8	47	4.7	2	"	2	chlorite
747-757	variable granite to granodiorite	7	6	4	13	10	40	4.0	2	"	1	

757-767	variable granite to granodiorite	12	6	4	9	14	45	4.5	2	calcite	1	
767-777	variable granite	15	7	2	2	12	38	3.8	2	calcite, silica	2	calcite, chlorite
777-786	variable granite to granodiorite	11	4	2	4	7	28	2.8	2	"	1	
786-796.5	", occasionally gneissic	9	8	6	9	6	38	3.8	2	"	1	
796.5-807	"	9	10	6	7	9	40	4.0	2	calcite, rust	2	calcite, chlorite
807-817	"	12	8	4	5	11	40	4.0	3	calcite, chlorite, rust	2	"
817-827	variable granite-granodiorite	11	13	6	3	1	34	3.4	2	"	2	"
827-837	"	11	21	1	6	12	48	4.8	2	"	2	chlorite
837-847	"	11	10		3	7	31	3.1	2	"	2	"
847-857	"	6	5	1	12	4	28	2.8	2	"	2	"
857-867	"	8	10	4	17	5	44	4.2	2	"	1	
867-877	"	6	9	6	12	4	37	3.7	2	calcite	2	chlorite
877-887	"	5	9	3	4	2	23	2.3	2	"	2	"
887-897	"	5	12	8	10	2	37	3.7	2	chlorite	3	"
897-907	monzonite	12	7	3	16	16	54	5.4	2	calcite, chlorite	2	"
907-917	"	10	9	3	12	12	46	4.6	2	chlorite	2	"
917-927	monzonite-granodiorite	5	2	3	24	15	47	4.7	2	calcite, chlorite	2	calcite, chlorite
927-937	"	6	4	3	9	15	37	3.7	2	", rust	2	"
937-947	monzonite	5	9	7	23	10	54	5.4	3	"	3	"

947-957	monzonite	8	13	5	11	9	46	4.6	3	calcite, chlorite, rust		calcite, chlorite
957-967	monzonite	9	9	3	20	9	49	4.9	3	"	3	"
967-977	", broken	1	1	3	4	2		6+	3	"	3	"
977-987	"							6+	3	"	3	"
987-997	monzonite	11	14	6	9	6	46	4.6	2	calcite, chlorite	3	calcite, chlorite
997-1007	"	1	5	7	16	12	38	3.8	2	"	2	"
1007-1017	"	8	13	8	10	13	52	5.2	3	", rust	2	"
1017-1027	variable monzonite	6	4	4	12	9	35	3.5	3	"	3	"
1027-1037	"	9	8	2	9	13	41	4.1	3	calcite, chlorite	3	"
1037-1047	"	19	13		7	18	56	5.6	3	calcite	3	"
1047-1057	"	6	14	6	14	6	46	4.6	2	"	3	"
1057-1067	"	8	12	2	5	15	42	4.2	2	"	2	"
1067-1077	granodiorite	10	10	3	9	9	41	4.1	2	"	1	
1077-1087	monzonite, broken to shattered	3	1		1	6		10	2	"	2	chlorite
1087-1093	"							8	2	"	3	"
1093-1103	monzonite-granodiorite	7	8	6	9	7	37	3.7	2	chlorite, epidote	2	"
1103-1114	monzonite, shattered after 1107							10+	2	"	2	"
1114-1124	broken monzonite		X		X			8	2	chlorite, epidote, calcite	1	
1124-1134	"	9	31	7	10	5	62	6.2	2	calcite, chlorite	1	

1134-1145	broken monzonite	14	19	8	6	3	50	5.0	2	calcite	1	
1145-1155	"	2	3	2	8	4		8	2	"	2	chlorite
1155-1157	"							8	2	calcite, rust	2	"
1157-1167	"							7	2	calcite, chlorite, rust	3	chlorite, epidote
1167-1177	"							7	3	"	3	"
1177-1187	monzonite	12	19	6	6	5	48	4.8	3	"	2	"
1187-1197	"	9	29	7	7	7	62	6.2	2	"	2	"
1197-1207	"	8	19	3	2	9	41	4.1	2	"	1	
1207-1217	"	7	30	9	8	4	59	5.9	3	calcite, chlorite, epidote	2	chlorite, epidote
1217-1227	"	12	17	11	18	8	66	6.6	2	calcite, chlorite	2	calcite, chlorite
1227-1237	"	2	15	8	2	8	33	3.3	2	"	2	"
1237-1247	monzonite-granodiorite	2	13	9	13	9	46	4.6	2	"	2	"
1247-1257	"	12	26	7	5	9	60	6.0	3	"	3	"
1257-1267	monzonite	7	13	9	8	6	43	4.3	3	"	2	"
1267-1277	"	12	9	9	18	3	48	4.8	3	"	3	"
1277-1287	", andesite after 1283	8	1	3	8	11	31	3.1	3	"	2	"
1287-1297	monzonite	7	13	6	6	8	40	4.0	3	"	2	calcite, chlorite epidote
1297-1307	"	9	15	7	9	4	43	4.3	2	"	1	

1307-1317	monzonite	11	21	9	10	2	53	5.3	3	calcite, chlorite	2	chlorite, epidote
1317-1327	", andesite after 1323	7	14	3	10	8	42	4.2	3	"	2	"
1327-1337	andesite? or f. q diorite	7	9	8	6	4	34	3.4	2	calcite	1	
1337-1347	monzonite	20	11	1	3	2	38	3.8	2	"	1	
1347-1357	"	10	7	9	8	3	38	3.8	2	"	1	
1357-1367	"	10	5	3	8	4	30	3.0	3	"	1	
1367-1377	monzonite, occasionally diorite, broken							7	3	"	2	chlorite
1377-1387	"							8	3	"	3	calcite, chlorite
1387-1397	"							10	3	"	3	"
1397-1407	monzonite	2	4	11	15	9	41	4.1	2	"	2	"
1407-1417	f.q. diorite	2	4	8	15	8	38	3.8	2	calcite, chlorite	2	chlorite, epidote
1417-1427	"	2	3	4	9	9	27	2.7	2	"	1	
1427-1437	"	5	4	3	10	20	42	4.2	2	"	2	chlorite
1437-1447	", aplite 1438-1452, broken							6	2	"	2	"
1447-1450	monzonite	5	1	2	2	3	13	4.3	2	calcite	1	
1450-1457	"	3	4	6	10	3	26	3.8	2	"	1	
1457-1467	"	8	12	5	10	3	38	3.8	2	calcite, chlorite	2	chlorite
1467-1477	"	4	6	2	18	14	44	4.4		calcite, chlorite, rust	2	calcite, chlorite
1477-1487	broken monzonite							7	3	"	4	"

1487-1497	broken monzonite							7	4	calcite, chlorite, rust	4	calcite, chlorite	
1497-1507	monzonite-diorite	14	12	3	6	13	48	4.8	3	"	2	"	
1507-1517	"	2	7	3	10	7	29	4.1	3	"	4	"	altered to mush 1513-1516
1517-1527	monzonite	15	9	5	9	7	45	4.5	2	calcite, chlorite	1		
1527-1537	"	9	6	5	10	8	38	3.8	2	"	1		
1537-1547	"	11	4		6	5	26	2.6	2	"	1		
1547-1554	"	2	9	2	2	15	31	4.4	3	"	2	calcite	