Geothermal Resources Council, TRANSACTIONS Vol. 7, October 1983

HEAT FLOW IN THE VICINITY OF THE MEAGER VOLCANIC COMPLEX, SOUTHWESTERN BRITISH COLUMBIA

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ABSTRACT

Since 1973, twenty-five diamond drill holes have been put down at the Meager Creek Geothermal Project in southwestern British Columbia. One hundred sixty-six samples of core from fifteen of these holes are measured for thermal conductivity. From straight line segments of bottom hole temperature profiles, heat flow calculations are made. A large high temperature convective zone has been identified on the south flank of the volcanic complex. Heat flow values indicate a possible western extension to this southern thermal anomaly. A well defined difference in heat flow regimes between the north and south flanks of the Mount Meager is attributed to variations of thermal conductivity and a possible unseen hydrothermal system. The technique of determining heat flow values is concluded to be primarily useful as a tool for developing large scale models of entire thermal systems, as opposed to a method for detailed exploration such as may be used for targeting drill holes.

INTRODUCTION

The Meager Creek Volcanic Complex is located within the Coast Mountains of southwestern British Columbia about 150Km north of Vancouver (see Figure 1). The complex is the northernmost major volcanic centre of the Garibaldi Volcanic Belt which is the northern continuation of the High Cascades into Canada. The volcano was identified as a potential geothermally active area in regional work performed by Nevin Sadlier-Brown Goodbrand Ltd. for British Columbia Hydro and Power Authority in 1973 and independently by Energy, Mines and Resources Canada in the same year.

Details of the project geology, geochemistry and geophysics have been presented in several previous papers: Nevin,et.al.,1978; Shore, 1978; Fritz,et al., 1980; Fairbank, et al., 1981. This paper will describe the data collection and the interpretation of results in a study of thermal conductivity of rock and heat flow in diamond drill gradient holes at Meager Creek. The purpose of the study was to delineate the heat flow regimes and also to evaluate the use of this technique as an exploration tool.

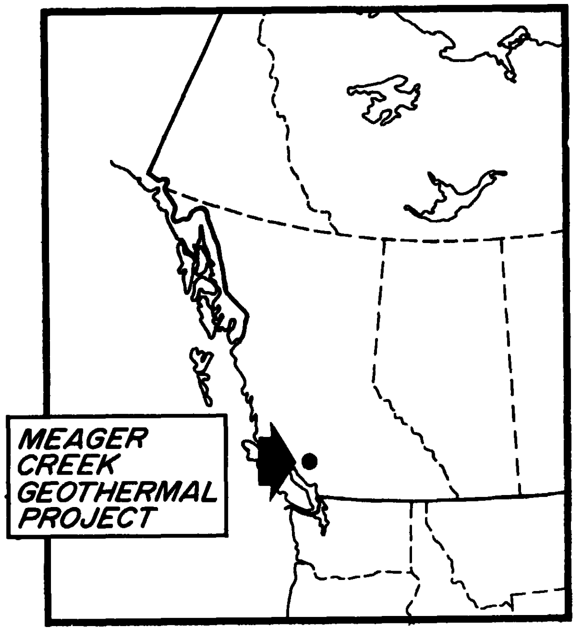

FIGURE 1: Location Map

DATABASE

Temperature gradients in the vicinity of Mount Meager have been measured in twenty-five diamond drill holes to date (Figures 2 and 3). For the purpose of calculating heat flow a total of 166 samples of diamond drill core from fifteen holes displaying generally conductive gradients were measured for thermal conductivity. Samples were cut to standard size and the faces ground parallel. Divided bar apparatus, similar to that described in Goss and Combs (1976), was used to determine the conductivity.

Holes chosen for study were those exhibiting significant straight portions of their temperature profile at depths great enough to minimize the effects of near surface cold groundwater flow and surface temperature variations (generally below 200 metres depth). Bottom hole temperatures, taken between drilling shifts after an eight to twelve hour stabilization period, were analyzed with a least-square regression technique to determine the gradient. Correlation co-efficients of 0.99 or better were obtained.

Exceptions to the above include three holes (M6, M7, L1) where convective fluid flow is the dominant influence on rock temperature. Approximate gradients through the disturbed areas were used and corresponding heat flow values were evident by their great magnitude, representing the approximate heat flux over the top of convective cells.

Corrections for the effects of topography, erosion, sediment deposition, past climatic variations and sediment wedges are commonly made to temperature gradients in heat flow studies of a regional nature. No corrections have been applied in this study for several reasons. First, the gradients are consistently well defined and deep enough in most cases that many of the effects will be minimal and can be ignored. Secondly, standard analytical corrections assume homogeneous half spaces and uniform thermal flux at depth, neither of which are valid in the geologically complex and thermally active Meager Creek Geothermal Area. Finally, the utility of corrected gradients is somewhat questionable in an exploration context since the heat flow in its uncorrected state will be the final target of a geothermal exploration program.

The coverage provided by the fifteen selected holes gives reasonable data density over the two known thermally active areas, the South and North Reservoirs (Figure 4). The conductivity sample density (6-16 samples/hole) is considered a minimum for the useful application of this technique, due to the considerable local variation in conductivity values. The heat flow interpretation is aided by the information from the ten additional holes. The data from all holes is summarized in Table 1.

TABLE 1: GRADIENT HOLE DATA - MEAGER CREEK GEOTHERMAL AREA

HOLE DESIGNATION	COLLAR ELEV. (m)	DEPTH (m)	DEPTH OF OVERBURDEN (m)	MAXIMUM TEMP (°C)	AVERAGE THERMAL CONDUCTIVITY (W/m-K°)	REPRESENTATIVE GRADIENT (°C/Km) (Interval (m))	HEAT FLOW (mW/m²)
EMR 301-1	587	45	18	60	3.35	-	*
EMR 301-2	583	118	0	33	2.69	44	120*
M1-74D	635	347	124	68.9	3.05	-	100*
M2-75D	774	91	11	15.4	2.69	-	290*
M3-75D	770	87	65	35	2.64	-	930*
M4-75D	808	60	12	20.8	2.44	-	450*
M5-78D	882	250	250	103.7	n.a.	n.a.	n.a.
M6-79D	885	321	15.6	140.8	2.26	733	1660
M7-79D	900	367	26	202.2	2.06	1230	2530
M8-79D	875	497	10	53.5	2.51	123.1	309
M9-80D	765	1142	114	98.3	2.30	52.4	120
M10-80D	807	1070	26	162.5			
M11-80D	791	559.5	15.5	55	2.54	73.0	185
M12-80D	792	604	11.5	47.8	2.42	61	148
M13-81D	899	599.5	25	114			
M14-81D	861	578.5	7	36.5	2.40	60.9	146
EMR 303-1	580	213	0	15.5	3.79	47.4	180†
L1-78D	760	603	47	102.8	3.25	210	680
L2-80D	896	595.4	4.5	42.5	3.26	80.5	262
L3-80D	972	1010	58	87	3.08	104.5	322
L4-81D	1097	1297	5.5	124.8	2.39	86.6	207
L5-81D	774	660	5	44.4	3.18	85.6	272
L6-81D	535	579.2	5	40	4.64	61.1	284
L7-82D	1808	420.7	2.5	32	2.54	89.5	227
L8-82D	960	47.5	3.7	34.2	2.45	72.0	176

* from Lewis and Souther, 1978
† from Lewis and Jessop, 1981

DISCUSSION

General

Regional heat flow in the Coast Plutonic Complex varies from about 40 mW/m² at the coast to around 80 mW/m² inland. In the Garibaldi Volcanic Belt, values range from 60-80 mW/m² (Lewis and Jessop, 1981). At the Meager Creek complex, heat flow varies from 120 mW/m² to 2530 mW/m² in highly disturbed convective areas. Anomalous heat flow occurs in and around the areas where the hydrothermal system is known to be active. Some anomalous holes, however, exhibit undisturbed conductive gradients possibly reflecting a deep heat source.

The basement lithology in the project area is typical of the Coastal Plutonic Complex. Cretaceous quartz diorite is the dominant rock type with two small Tertiary stocks of quartz monzonite occurring on the north flank of the mountain. Numerous pendants of meta-volcanics and meta-sediments strike northwest throughout the area. Considerable variation of thermal conductivity by rock type strongly contributes to the pattern of observed heat flow suggesting that a unique hot zone at depth is the source of heat observed throughout the area (except where transported locally by fluid flow). Table 2 shows conductivity variation with rock type.

TABLE 2

Variation of Thermal Conductivity with Rock Type

Rock Type	Number of Samples	Average (mW/m²)	Standard Deviation
Quartz Diorite and Gneiss	50	2.38	0.31
Metamorphic Rocks	10	2.00	0.47
Quartz Monzonite	30	3.19	0.15
Metamorphic Rocks (all except samples ⊥ to foliation)	43	2.94	0.88
parallel to foliation	12	2.51	0.29
perpendicular to foliation	4	1.91	0.05
L6-81D	16	3.73	0.91
Volcanic Dykes (miscellaneous)	10	2.24	0.59

South Reservoir

The South Reservoir area (Figure 4) shows two distinct heat flow regimes. A background range from 120-185 mW/m² is somewhat above the nominal regional background and clearly displays the presence of a large crustal warm spot. Very high heat flow values to 2530 mW/m² are measured directly over upwelling hot fluids. Non-linear and isothermal gradients in this area confirm the convective nature of the thermal regime. A north-south cross-section through the convective zone (Figure 5) illustrates the Meager Creek Fault Zone which appears to be a structural control for uprising fluid (Fairbank, et al, 1981).

To the west of the main convective system a purely conductive gradient in drill hole M8 results in a 309 mW/m² heat flow. This value, well above background, suggests a continuation of the fluid flow system at depth and leaves the thermal anomaly open to the west.

North Reservoir

The northern flank of the volcanic complex (the North Reservoir Area) is characterized by thermal conductivity in quartz monzonite and metamorphic rock (Table 2) and background heat flow values which are considerably higher than to the south. Heat flows range from 176-322 mW/m² (Figure 4). Heat productivity in Tertiary quartz monzonite (2.5 μW/m³) is higher than the Coast Plutonic quartz diorite to the south (<1.0 μW/m³). Simple calculations, assuming a nominal volume of the stock, indicate that a contribution to the net heat flow of more than 10 mW/m² is unlikely. A very rough concentric pattern of heat flow, centered about the one conductive hole (L1) on the north side suggests that some contribution to the elevated values is due to an unseen hydrothermal system.

To the east, two holes (L6 and 303-1) on opposite sides of the Lillooet River display contrasting heat flow values. The apparent disparity is attributed to a much higher thermal conductivity in metamorphic rocks intercepted in L6 as opposed to the quartz diorite in 303-1, rather than a local heat anomaly.

Conclusions

Several salient points can be established concerning the Meager Creek Geothermal Area with the aid of heat flow data. A westerly extension at a depth of the southern convective system is indicated by a high conductive heat flow in drill hole M8. This thermal anomaly is not clearly indicated by other surface exploration methods. A distinct difference in thermal conductivity in basement rocks on the north and south flanks of the volcanic complex is well defined. Overall, higher heat flow in the north is due to a combination of relatively high thermal conductivity, higher heat productivity and probably an as yet unseen geothermal system. The primary use of thermal conductivity and heat flow determination is in refining the quality of raw temperature profile data. It has been found in this study that heat flow calculations are not particularly valuable for developing distinct exploration targets for deep drilling (above and beyond those developed from raw gradient information), but the additional insight gained is useful for defining a large scale model of an entire area. In the so-called "blind" geothermal system of the Cascade-type volcanos, the development of such a model is an essential aspect of the exploitation of the resource. Heat flow study, therefore, proves to be a useful tool in the development of large and complex geothermal environments.

ACKNOWLEDGEMENTS

This work was performed under contract to B.C. Hydro and Power Authority. We would like to thank Mr. J.J. Stauder, Senior Project Engineer, Meager Creek Project, for the permission to write this paper. Thanks are also due to Dr.T.J. Lewis of the Earth Physics Branch of Energy, Mines and Resources Canada, for providing heat productivity data, as well as helpful comments.

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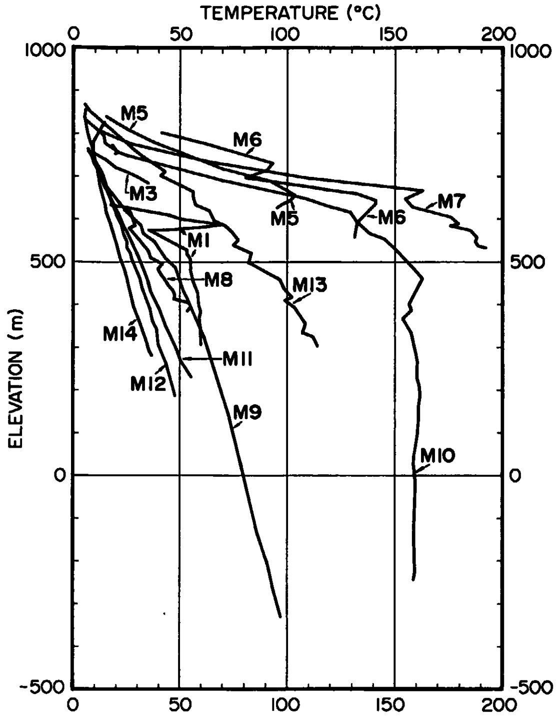

FIGURE 2: TEMPERATURE PROFILES - SOUTH RESERVOIR

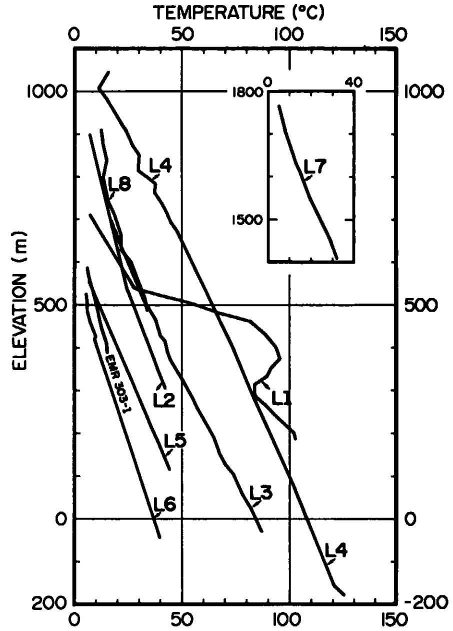

FIGURE 3: TEMPERATURE PROFILES - NORTH RESERVOIR

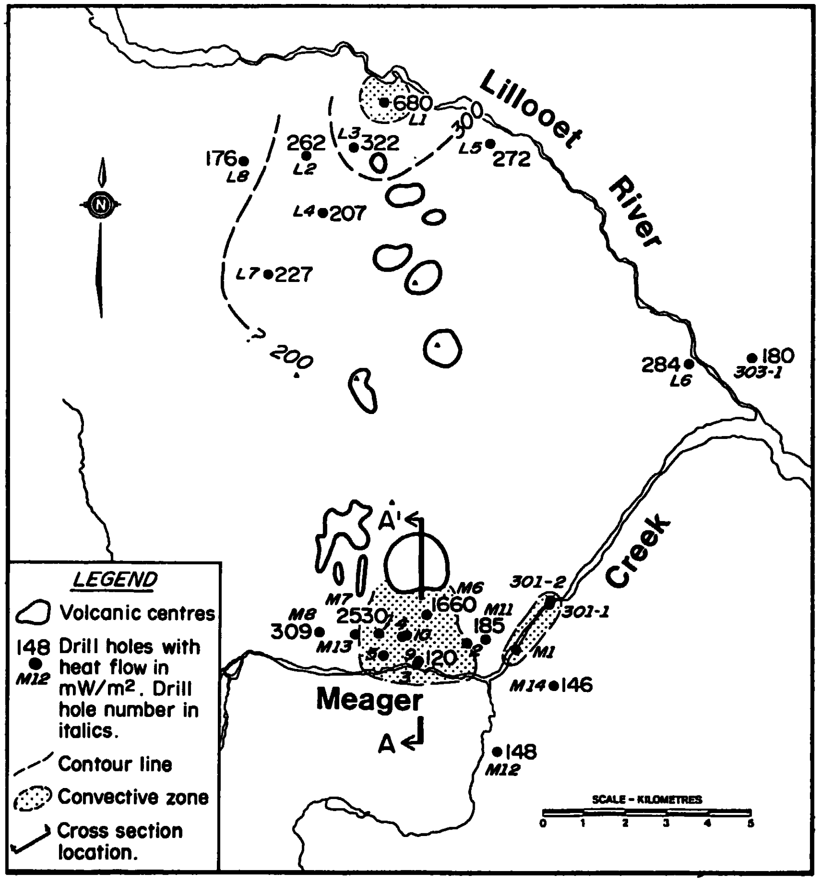

FIGURE 4: MEAGER CREEK HEAT FLOW

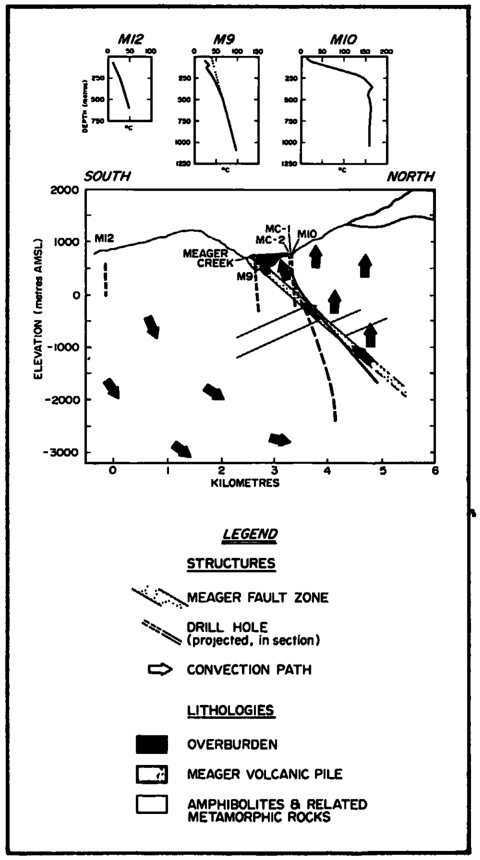

FIGURE 5: CROSS SECTION A-A' - SOUTH RESERVOIR