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Geothermal Energy

Geothermal resource assessment of Atlantic Canada: progress report, 1982

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This report complements and brings up to date an earlier one (Drury, 1981) that described the initial stages of the federal programme, coordinated and managed from the Earth Physics Branch, to assess the geothermal potential of Atlantic Canada. Only the three Maritime Provinces (New Brunswick, Prince Edward Island, and Nova Scotia) are discussed; results from Newfoundland will be discussed in a future report.

The Atlantic Margin of Canada is geologically much older than the Western Cordillera. The absence of Tertiary or younger volcanism means that steam resources are not expected, so that only hot water in aquifers in the sedimentary basins, and possibly hot, dry rock (HDR) in Palaeozoic intrusives, are considered as potential resources. Of the sedimentary basins, the largest and deepest is the Magdalen Basin (Fig. 1), which extends over parts of northern Nova Scotia and south-eastern New Brunswick, and all of Prince Edward Island. On-shore, the deepest part of this is the Cumberland Basin, which is considerably smaller than the western sedimentary basin. The geothermal potential of the Atlantic Margin is therefore considerably less than that of western Canada; nevertheless, the high economic need for alternative energy sources in Atlantic Canada justifies the project for the assessment of the region's potential geothermal resources.

Under eastern Prince Edward Island there are up to 8 km of sediments, mainly Permo-Carboniferous sandstones and shales. Under the western part of the island the sediments thin out, to less than 4 km. In eastern New Brunswick, a narrow sub-basin contains up to 4 km of sediments. Much of east-central New Brunswick consists of a Carboniferous platform. Sediment thicknesses may reach 3 km in the Fredericton graben, which extends north-easterly under the New Brunswick Platform. Sediment thicknesses in the platform are generally less than 1 km, and they reach 3-4 km only near the coast. In Newfoundland the Deer Lake and Codroy are the most prominent sedimentary basins, with maximum sediment thicknesses of approximately 3 km. If temperature gradients are sufficiently high, and if aquifers that can provide and sustain a sufficient flow of water exist at great enough depths, the region could have an economically exploitable low enthalpy geothermal resource.

During the various phases of the Appalachian orogeny granitic rocks were intruded in various parts of the Atlantic Margin. These may represent a HDR resource if they are sufficiently heated from the decay of the radiogenic elements that they contain. The youngest granites are of late Devonian - early Permian age, and hence their potential for a HDR resource is, perhaps, marginal. However, work being done in the eastern United States suggests that some granitic plutons that are buried beneath a thermally insulating layer of sediments present a valuable potential resource. Such a resource is essentially a hybrid between a true HDR resource of the type examined at Los Alamos, and the conventional type of low-grade, direct heating resource of the type to be exploited at Regina.

The project for assessing the geothermal potential of Atlantic Canada has been underway since 1980 when an initial contract was let to John A. Leslie and Associates Ltd. (JALA), of Bedford, N.S. The philosophy of the approach to date has been to obtain relevant data that are freely available, and to obtain relatively cheap new data. Hence, the 1980-81 contract called for the compilation of existing data from Nova Scotia and Prince Edward Island, and for the collection of new temperature data from any boreholes that were available. In 1981-82, this work, also undertaken by JALA, was extended to include New Brunswick and Newfoundland. The data that were to be collected were temperatures, thermal properties of rocks, heat generation, age of granites, and hydrological data such as formation pressures, water chemistry etc. Temperature data included accurate logs of boreholes using Earth Physics

Branch (EPB) equipment, and bottom-hole temperatures from both on-shore and off-shore wells. The contracts have resulted in two reports (Leslie, 1981, 1982), both of which have been released as EPB open file reports. An assessment of the data presented in the 1981 report has been made by Drury (1981).

Fig. 1 shows the simplified regional geology of the region, and the location of on-shore sites that yielded temperature data. Bottom-hole temperature (BHT) data from oil and gas wells are usually of poor quality; however they can be used to define trends. The average regional thermal gradient derived from the on-shore BHT data in combination with accurate BHT data from holes logged with the EPB equipment is 17 mKm^{-1}, with a surface temperature of 8°C. (Fig. 2). These values are not particularly encouraging; they suggest a depth of greater than 3000 m would be necessary for the water at 60°C to be found. The offshore data suggest a regional gradient of 23 mKm^{-1} (Drury, 1981). The detailed temperature logs that were obtained with EPB equipment generally showed temperature gradients of approximately 22-26 mKm^{-1}, and some, near New Glasgow, Nova Scotia, showed gradients in the range 29 to 32 mKm^{-1} (Fig. 3). If these gradients continue to greater depth, then water at 60°C could be found at depths of 1600-2000 m. In the Fredericton graben, the combination of sediment thickness of up to 3000 m (Chandra, pers. comm., 1981) and gradient of approximately 26 mKm^{-1} (Drury, 1981), could also provide a resource if sufficient water exists at a depth of at least 2000 m. The minimum temperature of water that can be considered as a resource depends on factors such as economic need and available exploitation technology. The value of 60°C considered here is chosen to provide a comparison with the situation at Regina, where water at a temperature of 62° is available from an aquifer at 2200 m.

One common problem that was encountered during the logging of twenty-eight holes was that of vigorous water flow in the borehole, which commonly destroyed the true thermal gradient. The effect of such flow is always to reduce the gradient in the flow zone at points near the entry point of the water. When flow is particularly vigorous, the gradient may be destroyed entirely. Hence the low apparent regional gradient may reflect severe disturbances due to the movement of water.

The regional gradients in the sedimentary basins of the Atlantic Margin are not well-defined, therefore, but they appear to be in the range 22-26 mKm^{-1}, with localised higher values, at least in the upper few hundred metres. If such gradients can be extrapolated to greater depths, there is good potential, in terms of temperatures, for a geothermal resource for space heating or other direct uses. However, an adequate supply of water is also necessary, and it is here that information is lacking. Very little is known of the hydrological state of the sedimentary basins at depths greater than a few hundred metres. Porosity and permeability of the basin may be locally as high as 35-40% and 650-700 md, but in general values are less than these, and nothing is known of the deep circulation patterns of water.

The radiogenic heat production, at least at the surface, of some of the granitic intrusions appears to be quite high; for example, the mean heat production of 12 surface samples from the St. George batholith in New Brunswick is 4 μWm^{-3}, with individual values reaching 7.5 μWm^{-3}. This compares with a mean for Nova Scotia, Newfoundland and other New Brunswick granites of 2 μWm^{-3}. In terms of the heat flow versus heat production relationship for Atlantic Canada (Hyndman et al., 1979), such an average value implies a regional average heat flow in the granites of approximately 55 mWm^{-2}, which implies an average thermal gradient of less than 18 mKm^{-1}. The higher mean heat production of the St. George granites suggests a higher gradient, of the order 23-26 mKm^{-1}. This value is significantly lower than the measured gradient in the Carnmenellis granite of south-west England (38 mKm^{-1}) that is considered to be economically exploitable for a HDR resource.

Fig. 4 shows a simplified version of a portion of a map prepared by Chandra and Wallace (1980) of the New Brunswick Department of Natural Resources, that uses airborne gamma-ray spectrometric surveys for radiogenic, and hence heat-producing, elements (U, Th and K) to estimate surface heat-generation (Chandra, 1982). Comparison of heat generation values taken from the map with those obtained from measurement on a small number of surface rock samples suggests that the former may be low by a factor of 1.5 - 2 (see data in Leslie, 1982).

In the late autumn of 1982 two boreholes were drilled in granites of New Brunswick, one in the Pokiok, and one in the St. George batholith, under contract to EPB. The locations of the holes (Fig. 1) were both compromises between desired location based on heat-generation data, and practical location based on accessibility, land ownership, etc. The Pokiok hole was drilled to a depth of 398 m; the St. George hole was stopped at 370 m as a result of recurring technical problems. BHT measurements were made during shift changes, but owing to both the high drilling rates and, for the St. George hole, the technical breakdowns, few BHT data are available for the holes. In the Pokiok hole, the BHT data suggest a gradient of approximately 25 mKm^{-1}, but a precision temperature log run 84 hours after the end of drilling indicates a gradient of only 18 mKm^{-1}. A similar gradient was measured in the St. George hole 72 hours after the end of drilling. In principle the series of BHT data should give a good approximation to the actual gradient, as each BHT measurement is subject to only minor perturbation by the drilling process. As the drilling disturbance decays the measured gradient should change; in the New Brunswick holes it should increase. It is unlikely that it will increase by 40%, so that the true gradient in the Pokiok hole is likely to be between 18 mKm^{-1} and 20 mKm^{-1}. Assuming that the thermal conductivity of the granite is 3.3 $Wm^{-1}K^{-1}$, the heat flow would be approximately 66 mWm^{-2}, which is close to the value measured at Mount Pleasant (Hyndman et al., 1979). It appears that the high values of heat generation measured on some samples from the St. George granite may reflect surface conditions only. The anticipated heat generation at both borehole sites, based on Fig. 4, is approximately 1.5 - 2 μWm^{-3}; this implies a gradient of less than 18 mKm^{-1}. Measurements of U, Th and K content, and hence estimates of heat generation, are currently being made on core samples from both the Pokiok and St. George holes, and on more surface samples from the vicinity of each borehole. Such measurements should help in explaining the discrepancy between predicted thermal gradient, from heat generation measurements on surface samples or based on Fig. 4, and directly measured thermal gradient. A detailed analysis of the results of the New Brunswick drilling will be presented in a future report.

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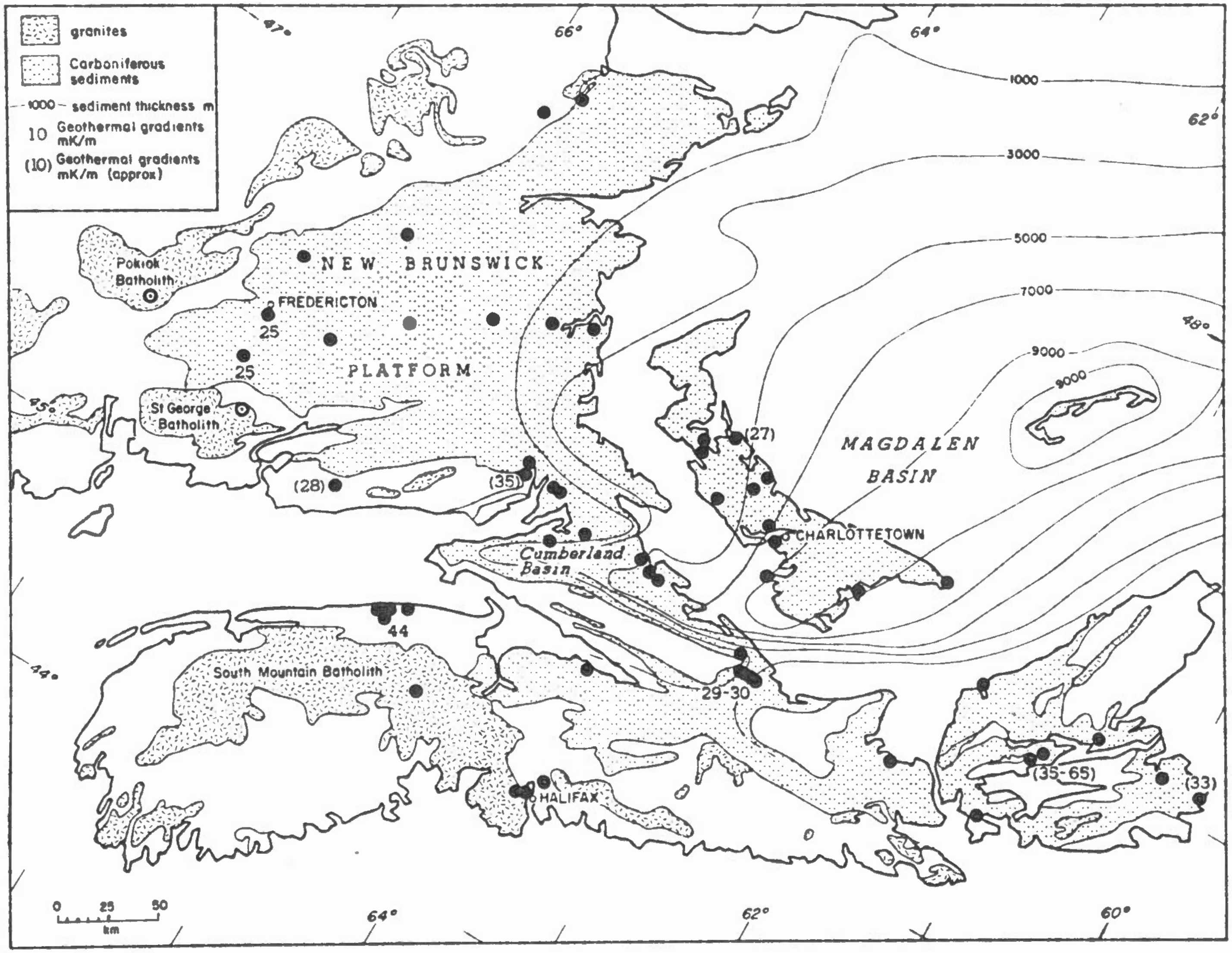

Figure 1 Simplified geological map of Maritime Provinces to show distribution of granite batholiths, and of Carboniferous and younger sediments. Dots show locations of boreholes from which temperature data have been obtained, with gradient indicated if it is greater than 25 mKm^{-1}. Open circles with dots indicate location of holes drilled for EPB in 1982.

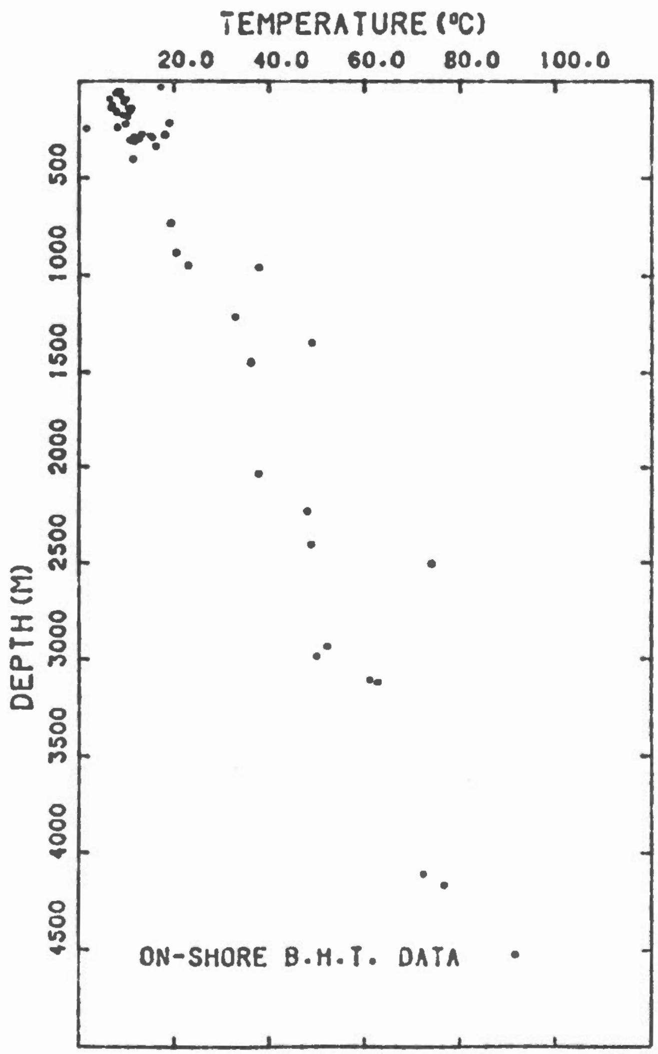

Figure 2 Plot of on-shore BHT data from all holes drilled into sediments.

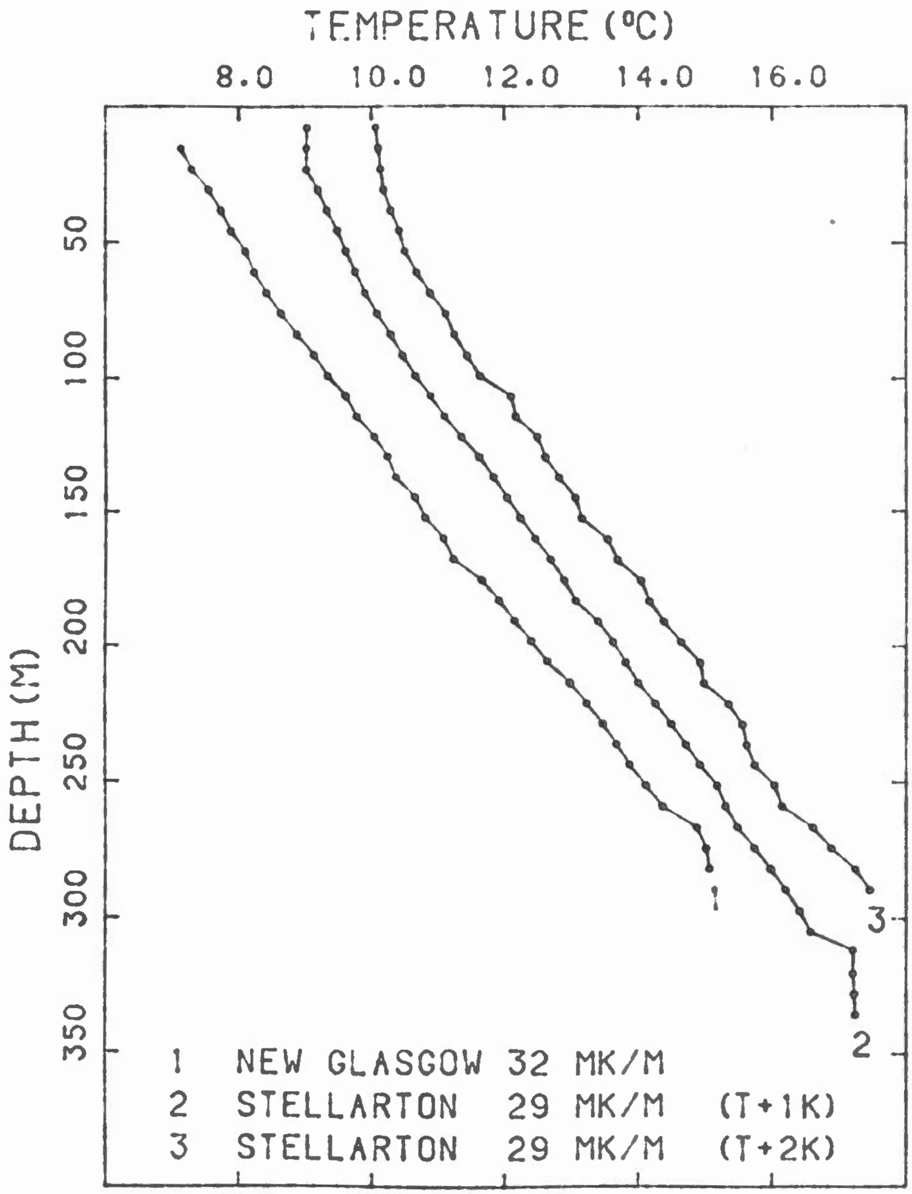

Figure 3 Temperature plots of three holes in the New Glasgow-Stellarton area of Nova Scotia.

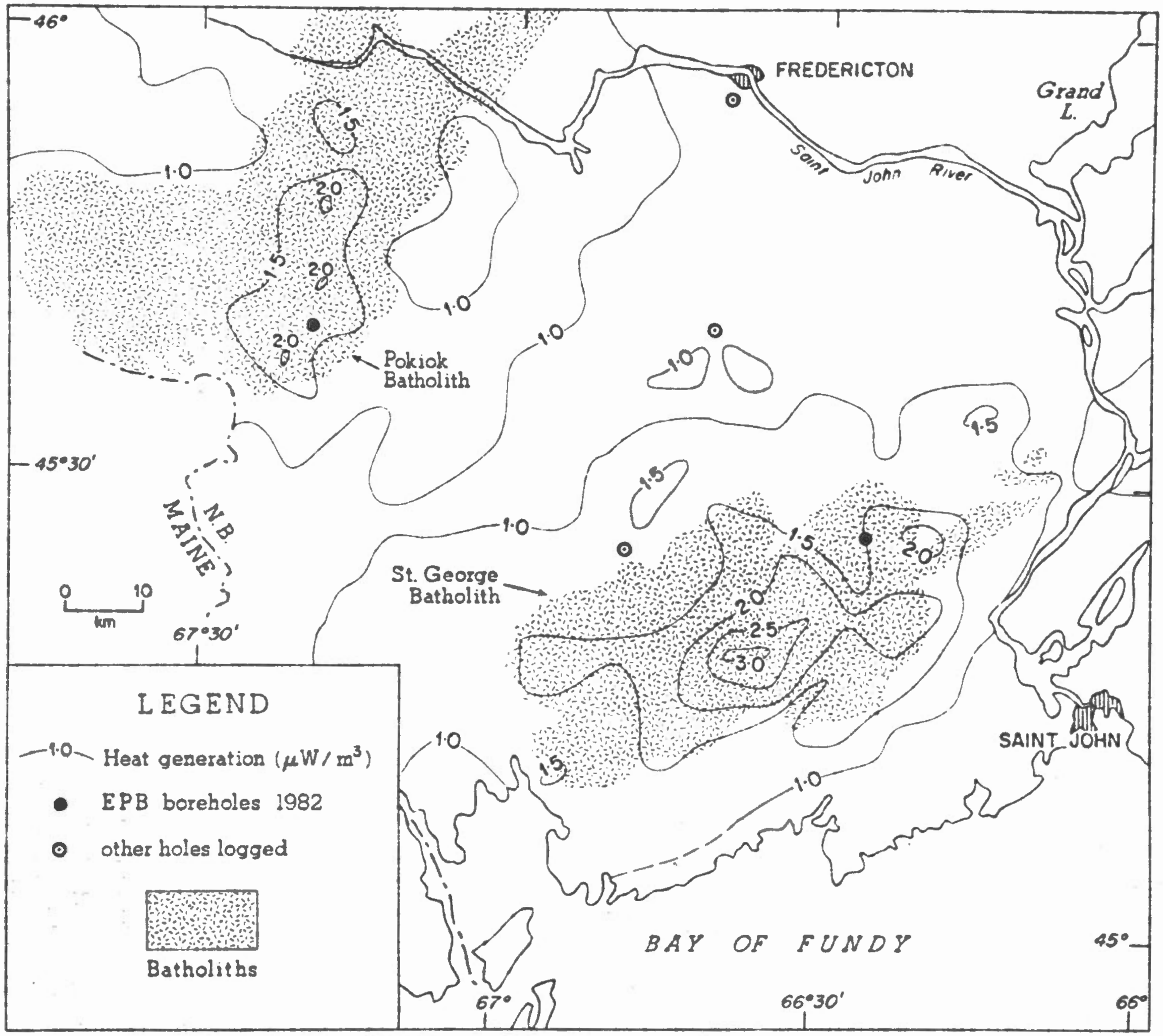

Figure 4 Surface heat generation map for southern New Brunswick, after Chandra and Wallace (1980).