HEAT FLOW NEAR THE J. TUZO WILSON KNOLLS - A POSSIBLE SPREADING CENTER SOUTH OF THE QUEEN CHARLOTTE ISLANDS

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Initial Report

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Introduction

The triple point junction between the Juan de Fuca, Pacific and America plates is located at the edge of the continental shelf between the northern end of Vancouver Island and the southern end of the Queen Charlotte Islands. The junction is of the ridge-trench-transform fault type. The convergence zone off Vancouver Island meets the Queen Charlotte transform fault from the north and the spreading ridge from the west. The detailed location of the junction is difficult to determine because of a series of short en-echalon spreading centers extending from the north end of the Juan de Fuca ridge, i.e. the Explorer 'ridge' and the Delwood spreading center (e.g. Srivastava et al., 1971; Barr and Chase, 1974) a situation similar to the Gulf of California. The possibility of yet another very short spreading segment just south of the Queen Charlotte Islands has recently been raised by R.L. Chase (e.g. Chase et al., 1976). He and D.L. Tiffin both have dredged fresh basalts from two knolls in this area, named the J. Tuzo Wilson Knolls. The magnetic anomalies do not resolve the segment because of its short length, and neither are the earthquake epicenter locations of sufficient accuracy. One way of testing the area for active spreading is to look for high heat flow. Spreading centers are characterized by high heat flux although the measured values are usually variable because of the effects of hydrothermal circulation in the crust (e.g. Lister, 1972).

The region of the Juan de Fuca - Explorer spreading centers, in addition, have particular importance in the theoretical study of the heat flow of ocean ridges. This is the only region where there is a sufficiently high sedimentation rate to completely cover a spreading ridge and thus permit the measurement of the total heat released by the cooling oceanic lithosphere. Hydrothermal circulation in the oceanic crust is sealed off from the ocean by the sediment cover. Previous measurements some distance offshore suggest the total heat flux depends on plate age approximately according to (Lister, 1975; Davis and Lister, 1976):

$$\mathrm{HF}\ (\mu\mathrm{cal\ cm^{-2}s^{-1}}) = 12/\sqrt{\mathrm{age\ (m.y.)}}$$

Further measurements close to the continental slope where the sedimentation rate is highest should permit a better estimate of this relation.

Because of the spreading center coming very close to land and the thick sediment cover that produces high crustal temperatures, it is interesting to consider this area as a potential source of geothermal power.

Measurements

The gradient measurements were made with a 1.2 cm diameter 2.5 m long Bullard type probe with 4 temperature sensors and a self contained recording unit giving a gradient accuracy, after extrapolation to equilibrium, of about ± 5%. Good results with penetration of 3 or 4 sensors were obtained at 5 of the 7 stations attempted (Figures 1 and 2). The gradients ranged from 210 to 430 m°C m^{-1} and all are linear to within the measurement accuracy. At one site very close to the Knolls the probe hit rock and was scraped and bent so no gradient was obtained. At one other site (76-10-10) in quite shallow water (1000 m) to the east of the Queen Charlotte fault trace, a very disturbed record was obtained because the ship drifted rapidly.

Thermal conductivity was measured using the transient needle probe technique on a 6 cm diameter 2 m long gravity core at the central station, 76-10-6, and two 3.5 cm diameter 0.5 m long cores, 76-10-2, and 76-10-4. The overall mean corrected for seafloor temperature and pressure of 1.93 mcal $cm^{-1}s^{-1}$ $°C^{-1}$ for 13 measurements was used for all stations. The gradient measurements were within an area 60 km across so the conductivity estimate probably is within ± 5%. The heat flows then have an estimated accuracy of ± 10%.

Results

All 5 of the measured heat flows are high, ranging from 3.8 to 8.4 μcal $cm^{2}s^{-1}$ (Figure 1). At first sight they substantiate the proposed Knolls spreading center. However, the values do not increase toward the Knolls but rather, increase to the south toward the Dellwood and Explorer spreading centers about 75 and 150 km respectively to the south. Such high heat flow is not usually found so far from spreading centers. However, as noted above, the total heat given off by the cooling lithosphere at this distance (an age of 2.5 to 5 m.y.) is very high, and in this area of high sedimentation rate most of the heat must be conducted through the sediment and is measured by the heat probe, rather than being lost to the sea through hydrothermal circulation.

The age of the crust in this area is poorly determined by magnetic anomalies, but taking an average spreading rate of 3 cm yr^{-1}, the measured heat flows are plotted as a function of crustal age assuming the crust was produced a) from the Explorer ridge and b) from the Dellwood spreading center in Figure 2. For comparison the estimates of Davis and Lister (1976) also is given. The measured values are in rather good agreement with the Davis and Lister relation assuming the lithosphere was produced at the Explorer spreading center.

I conclude that the heat flow data does not support spreading of more than a few km at the region of the J. Tuzo Wilson Knolls. The recent basalts dredged thus must come from seamount or "hot spot" vulcanism of the Hawaii type. The sea floor heat flow very close to the active Hawaii volcanic centers is no higher than at 100 km distance and is similar to that predicted for the crustal age, indicating that the thermal influence of "hot spot" vulcanism is very restricted in extent. The Delwood spreading center probably also is of very recent origin.

The measured heat flows with sediment thicknesses of several km from seismic measurements imply crustal temperatures of at least 300°C and probably much higher, up to 800°C. Since these temperatures exist at shallow depth over hundred of km^2, the potential for geothermal power is indeed great, although the 2 km water depth will make exploitation very difficult.

References

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Table 1 Heat Flow Data

Station	Lat.	Long.	Water Depth (m)	Probe Penetr. (m)	Grad. ($m°C\ m^{-1}$)	Cond. ($mcal\ cm^{-1} s^{-1} °C^{-1}$)	Heat Flow ($\mu cal\ cm^{-2} s^{-1}$)
76-10-3	51°16.3'	131°0.3'	2286	2.6	245	(1.93)	4.7
76-10-4	51°36.3	130°50.8'	1947	1.7	210	(1.93)	4.1
76-10-6	51°23.0'	130°45.8'	2057	2.5	255	1.93	4.9
76-10-7	51°30.2'	130°36.8'	1338	2.9	197	(1.93)	3.8
76-10-8	51°13.9'	130°32.4	2002	1.8	432	(1.93)	8.3

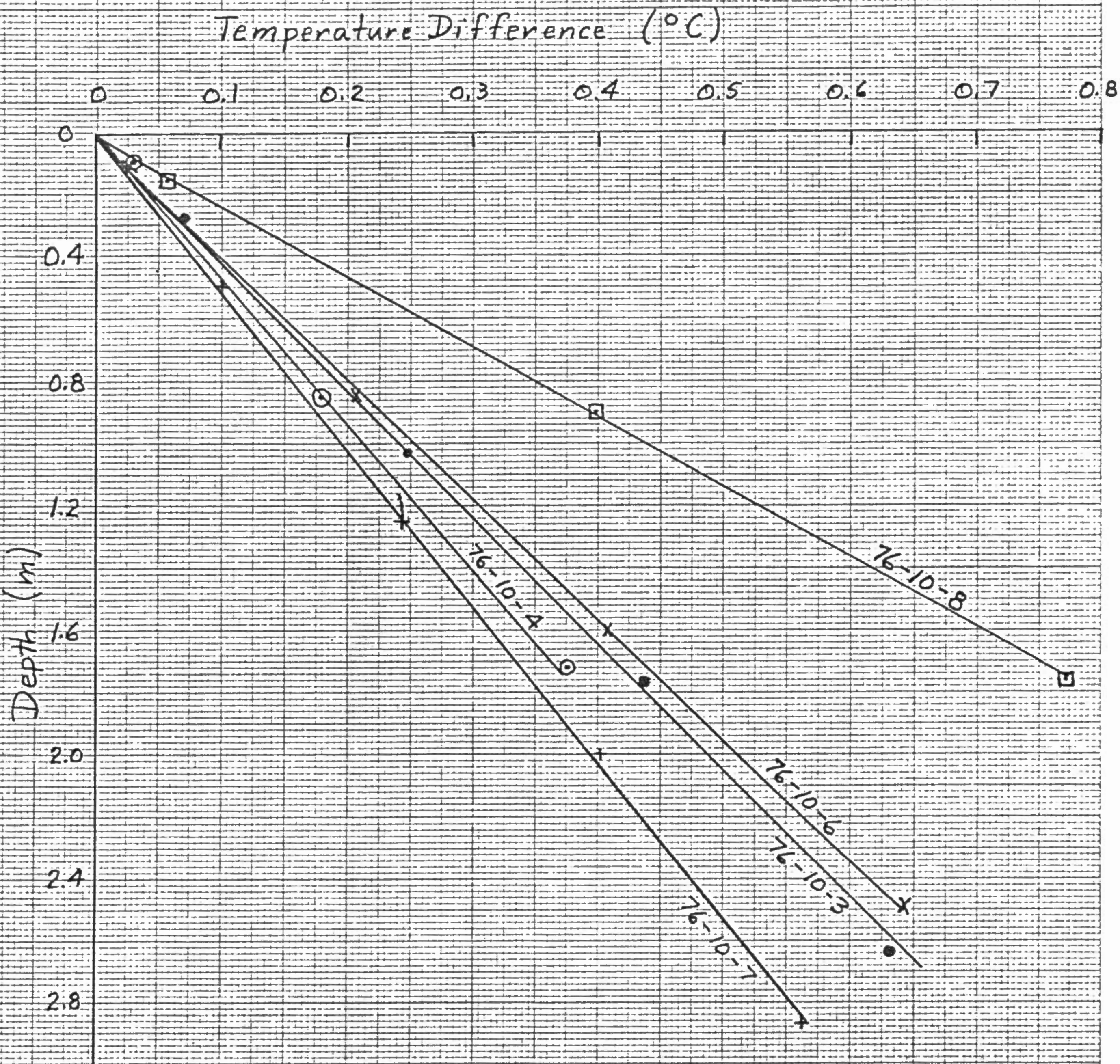

Temperature Difference (°C)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Depth (m)
0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
76-10-8
76-10-4
76-10-6
76-10-3
76-10-7

Figure 1

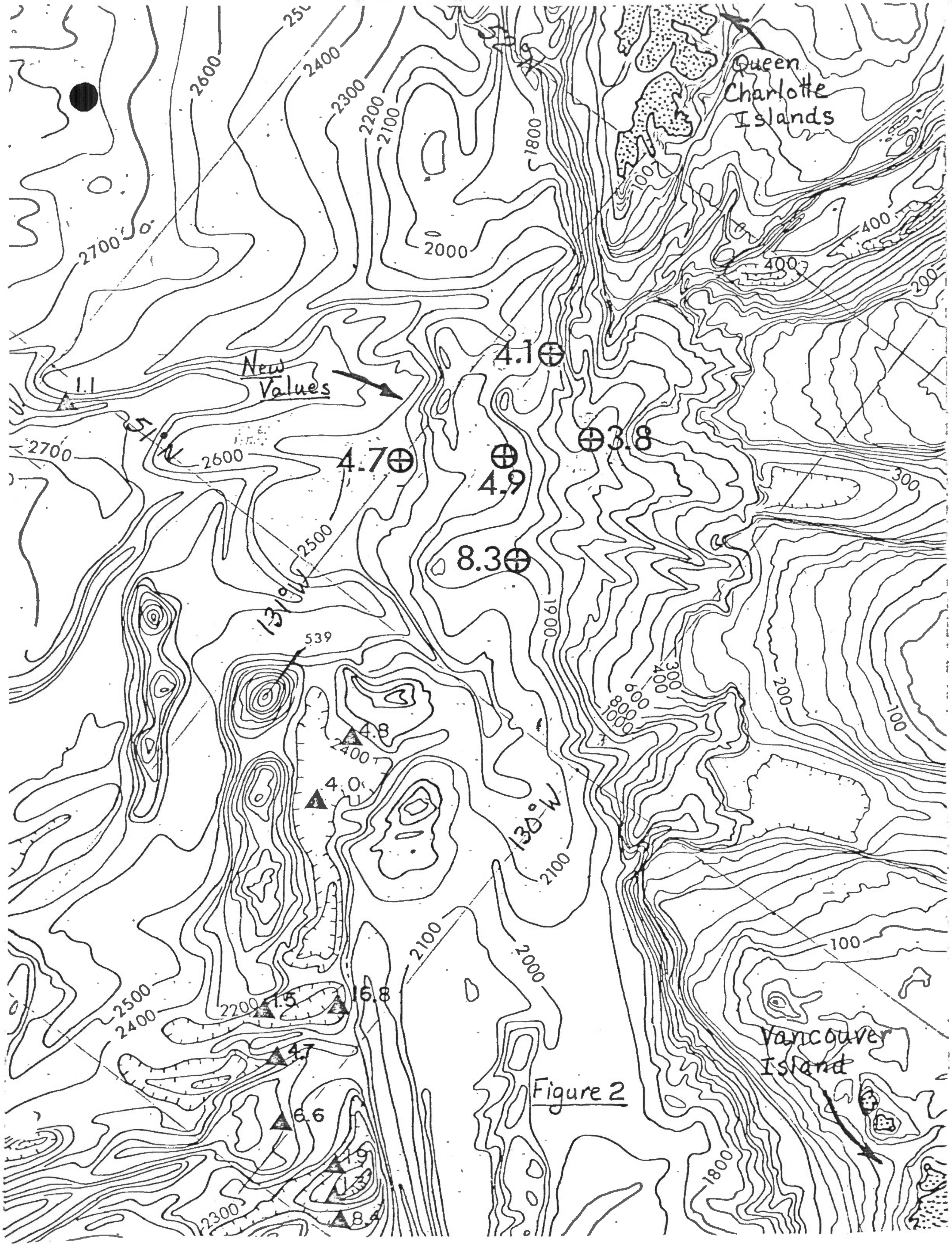
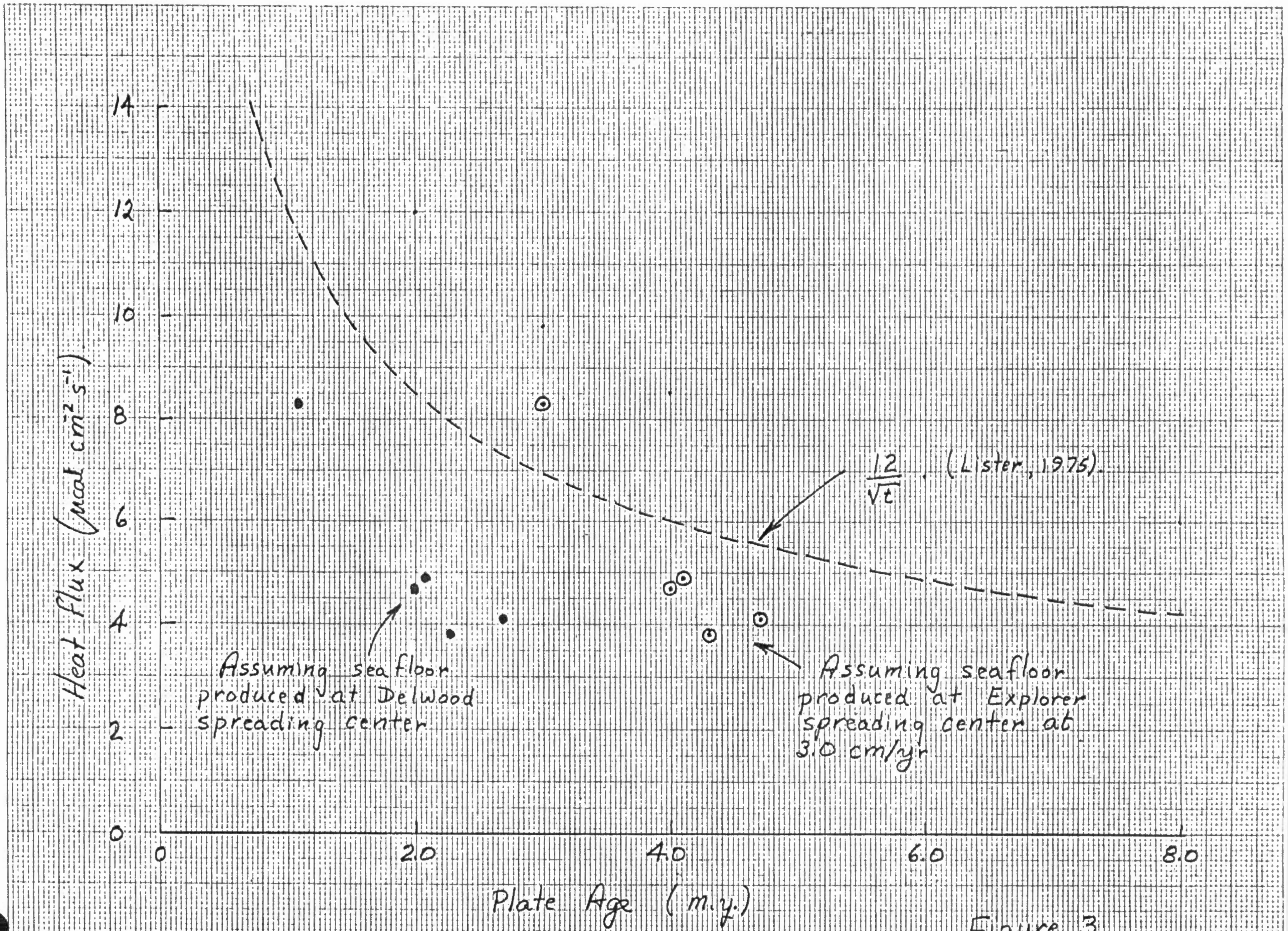

Queen Charlotte Islands
New Values
4.1
3.8
4.7
4.9
8.3
1.1
51°N
131°W
130°W
539
4.8
4.0
1.5
16.8
4.7
6.6
1.9
8.4
Vancouver Island
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1000
800
600
400
300
200
100

Figure 2



14
12
10
8
6
4
2
0
Heat flux (μcal cm⁻² s⁻¹)
0
2.0
4.0
6.0
8.0
Plate Age (m.y.)
12/√t (Lister, 1975)
Assuming seafloor produced at Delwood spreading center
Assuming seafloor produced at Explorer spreading center at 3.0 cm/yr

Figure 3