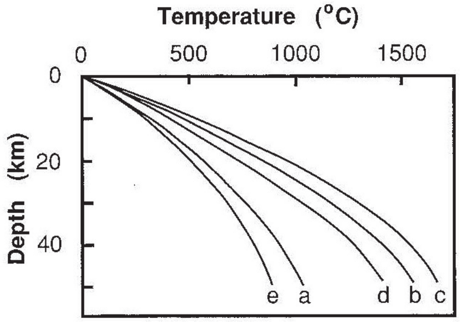
GEOL 460 Lab 9: Heatflow and Geotherms

Name: ____ Date: _______________



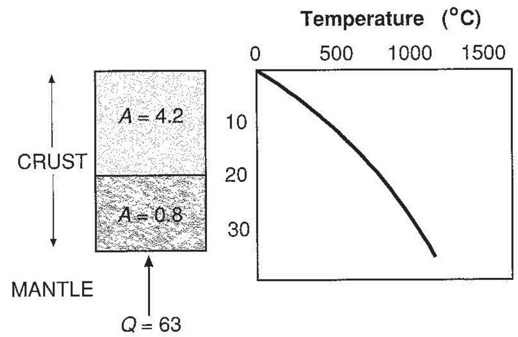


Fig. 7.3. Equilibrium geotherms (7.28) Fig. 7.4 A two layer model for the crust.

Fig 7.3 shows a geotherm for a rock column with 50 km thickness. Curve a: standard model with conductivity 2.5 W/m °C. Curve b: standard model with conductivity reduced to 1.7 W/m °C. Curve c: standard model with radioactive heat generation increase to 2.5 W/m °C. Curve d: standard model with basal heat flow increased to 42 x 10^{-1} W/m^2. Curve e: standard model with basal heat flow reduced to 10.5 x 10^{-3} W/m^2.

Fig 7.4 shows a two-layer model for the crust and equilibrium geotherm in the Archean. Heat generate A is in μW/m^{-3}; heat flow from the mantle Q is in 10^{-3} W/m^2. Recall that during the Archean, heat generation was much great than t is now (Table 7.2).

Table 7.1 *Typical concentrations of radioactive elements and heat production of some rock types*

	Granite	Tholeiitic basalt	Alkali basalt	Peridotite	Average continental upper crust	Average continental crust	Average oceanic crust	Undepleted mantle
Concentration by weight								
U (ppm)	4	0.1	0.8	0.006	2.8	1.1	0.9	0.02
Th (ppm)	15	0.4	2.5	0.04	10.7	4.2	2.7	0.10
K (%)	3.5	0.2	1.2	0.01	3.4	1.3	0.4	0.04
Heat generation (10^{-10} W kg^{-1})								
U	3.9	0.1	0.8	0.006	2.8	1.1	0.9	0.02
Th	4.1	0.1	0.7	0.010	3.0	1.2	0.7	0.03
K	1.3	0.1	0.4	0.004	1.2	0.5	0.1	0.007
Total	9.3	0.3	1.9	0.020	7.0	2.7	1.7	0.057
Density (10^3 kg m^{-3})	2.7	2.8	2.7	3.2	2.7	2.7	2.9	3.2
Heat generation (μW m^{-3})	2.5	0.08	0.5	0.006	1.8	0.7	0.5	0.02

Table 7.2 *Relative abundances of isotopes and crustal heat generation in the past relative to the present*

	Relative abundance					Heat generation	
Age (Ma)	^{238}U	^{235}U	U[a]	Th	K	Model A[b]	Model B[c]
Present	1.00	1.00	1.00	1.00	1.00	1.00	1.00
500	1.08	1.62	1.10	1.03	1.31	1.13	1.17
1000	1.17	2.64	1.23	1.05	1.70	1.28	1.37
1500	1.26	4.30	1.39	1.08	2.22	1.48	1.64
2000	1.36	6.99	1.59	1.10	2.91	1.74	1.98
2500	1.47	11.4	1.88	1.13	3.79	2.08	2.43
3000	1.59	18.5	2.29	1.16	4.90	2.52	3.01
3500	1.71	29.9	2.88	1.19	6.42	3.13	3.81

[a] This assumes a present-day isotopic composition of 99.2886% ^{238}U and 0.7114% ^{235}U.
[b] Model A, based on Th/U = 4 and K/U = 20 000.
[c] Model B, based on Th/U = 4 and K/U = 40 000.
Source: Jessop and Lewis (1978).

I. Geothermal Gradient

The expressions below can be used to calculate a conductive geothermal gradient for the lithosphere.

T(z)= Qz/K + Aoz(b - z/2)/K+ Ts   z < b

T(z)= Qz/K + A b2/(2K)+ T   b ≤ z ≤ L   where L=100 km

where:	typical values
• Ts = surface temperature (°C)	15
• Q = mantle heat flow (mW/m2)	30
• K = thermal conductivity (W/m/deg)	2.5
• A = ρH = heat production (μW/m3)	2.0
• b = characteristic depth of Ao (km)	10
• z = depth (km)	

Using a spreadsheet (e.g. Excel), plot temperature (°C) vs. depth (km) for

a) the entire lithosphere (100 km), and

b) the upper 35 km. Plot depth as the y-axis and "negative" (i.e. going down the page from 0 km).

Answer the following questions:

1. What is the temperature at the base of the lithosphere? ________ at 35 km? ______.

2. Play around with some of the parameters. What do you need to do to get 700°C at 35 km? Is there a unique solution? Which parameters do you think we know best? the least?

3. The equations given above assume that heat flow in the lithosphere is by conduction only. Is this a reasonable assumption? Why or why not?

II. Geotherm Calculation

Calculate the geotherms for the models show in Fig. 7.14. Discuss the reason for the difference at depth between these geotherms and the geotherm show as a solid like in Fig. 7.14.

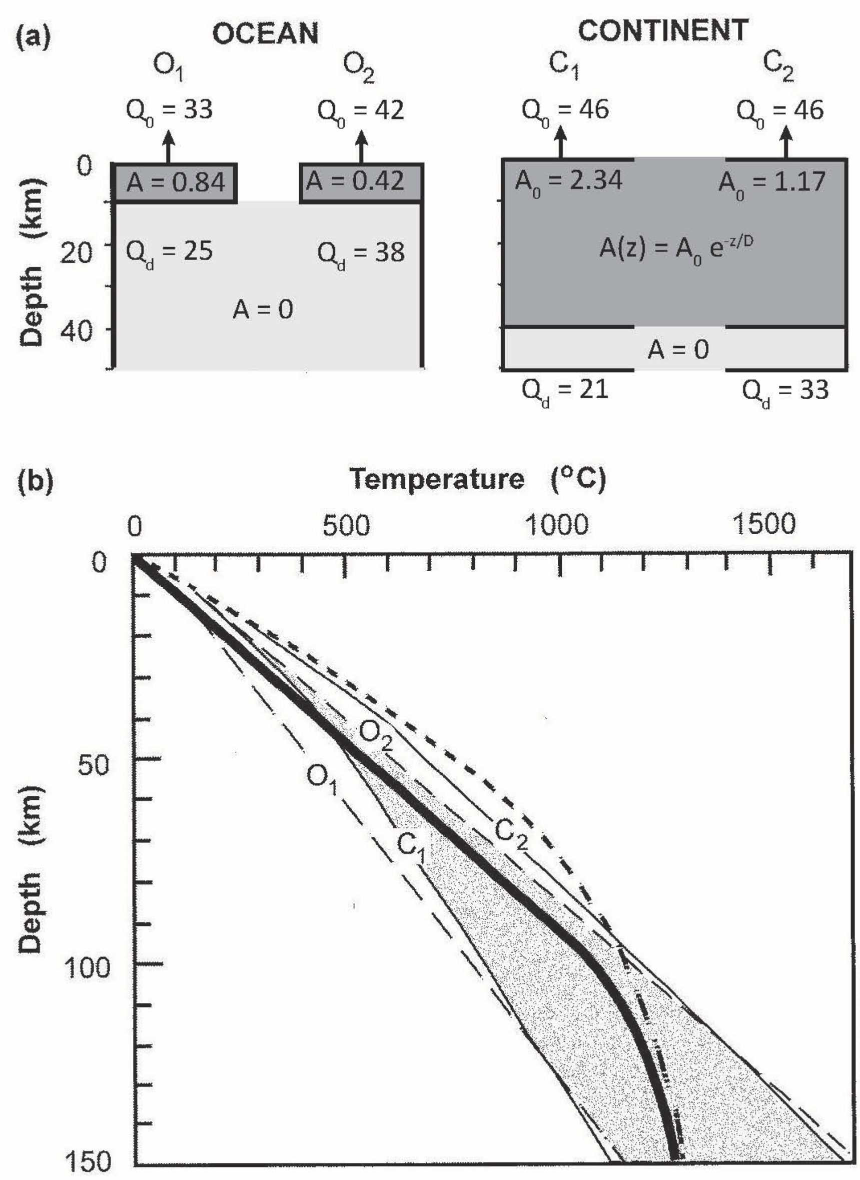


Fig 7.14. (a) Extreme thermal models used to calculate the equilibrium geotherms beneath an ocean, O_1 and O_2, and beneath and old stable continent C_1 and C_2. Heat flows Q_0 and Q_d are in mW/m^2; heat generation A_0 is in μW/m^{-3}. (b) Predicted geotherms for these models. Thin dashed lines, oceanic geotherms; thin solid lines, continental geotherms; heavy solid line, equilibrium geotherm for the PSM plate model, taking into account the small-scale convection occurring at the thermal boundary layer (fig. 7.10). Gray shading, region of overlap. The heavy dashed line is an error function for the geotherm of age 70 Ma. The mantle temperature Ta is taken as 1300 °C.