GEOS 312 2. Hour Exam

April 26th, 2006

Name: ___________________________

Please answer four of the following five questions and indicate clearly which question you want to skip. If you work on all five questions only the first four will count towards your score.

1. Heatflow in a Borehole

Temperatures between interfaces between sedimentary layers of different rock types as determined from a well log are given in the table below. The measured thermal conductivity for each layer is also given. Determine the heat flow through each layer and the mean value of the heat flow.

Depth (m)	Temp (˚C)	Rock type	k (W m^{-1} K^{-1})
380	18.362		
		sandstone	3.2
402	18.871		
		shale	1.7
412	19.330		
		sandstone	5.3
465	20.446		

2. Radioactive Isotopes in the Mantle

a) Determine the present mean mantle concentrations of the heat-producing elements if the present value for the mean mantle heat production is 7.38×10^{-12} W/kg and $C^K/C^U = 6 \times 10^4$, $C^{Th}/C^U = 4$.

b) Determine the rates of heat production for the rocks listed in the table below. Where might you be most concerned about naturally occurring radiation?

Rock-Type	C^U (ppm)	Th^U (ppm)	K^U (%)
basalt	0.07	0.19	0.088
granite	4.7	20	4.2
shale	3.7	12	2.7

Isotope	H (W / kg)	$\tau_{1/2}$ (yr)
^{238}U	9.46×10^{-5}	4.47×10^{9}
^{235}U	5.69×10^{-4}	7.04×10^{8}
U	9.81×10^{-5}	
^{232}Th	2.64×10^{-5}	1.40×10^{10}
^{40}K	2.92×10^{-5}	1.25×10^{9}
K	3.48×10^{-9}	

3. Lava Lakes and Baked Contacts

a) A large volume of lava erupts onto a series of sedimentary rocks. Assuming an initial (and constant) lava temperature of $T_{lava} = 1000^\circ C$, and an initial temperature of T_{sed} $0^\circ C$, what is the temperature distribution within the sandstone after one week? (7 points)

b) As a paleomagnetist, should you be concerned? (3 points)

P.S. If you want to see such a contact and its effect on rocks, go down to the base of the cliffs at Zion Street and look for the contact between the dark black basalt flows and the reddish brown sandstones.

4. The Earth's Magnetic Field

The earth's magnetic field can be approximated by a dipole field generated by a magnetic dipole located at the center of the earth. The horizontal and vertical components of the dipole field are given by:

$$B_\theta = \frac{\mu_0 m}{4\pi r^3} \sin\theta_m$$

$$B_r = \frac{\mu_0 m}{2\pi r^3} \cos\theta_m$$

where θ_m is the angle between the point of interest and the dipole axis and m is the magnetic dipole moment of the earth.

a) Assume the Earth's magnetic field is a dipole. What is the maximum intensity of the field at the core-mantle boundary? (3 points)

b) Assuming again a dipole field, at what distance above the earth's surface is the magnitude of the field one-half of its value at the surface? (3 points)

c) Why is it impossible for the Earth's magnetic field being generated by a large bar magnet buried at the center of the Earth? (4 points)

5. Paleomagnetism

a) Name three classes of magnetic materials and explain their different magnetic properties. (3 points)

b) The relaxation time τ describes how long it will take for a magnetic moment to change direction. It is given by the following relationship:

$$\tau = \tau_0 \, e^{\frac{\mu B}{2kT}}$$

- what is the physical explanation for the factor $\mu B/(2kT)$? (1 point)
- Considering that $\mu = M_S \times$ particle volume, the relationship for τ shown above is a simple model that explains how rocks record a magnetic signal and preserve this information over very long time periods (τ has to become very large). Using the given expression for τ discuss two ways a rock can acquire a magnetic remanence signal. (6 points)

<u>Numbers you should have memorized, but probably haven't</u>

M_s	=	480 kA/m	(saturation magnetization of magnetite)
k	=	1.38×10^{-23} J/K	
τ_0	=	10^{-9} s	
μ_0	=	1.26×10^{-6} H/m	
m_{earth}	=	8×10^{22} Am^2	(magnetic dipole moment of the Earth)
r_e	=	6400 km	(radius of Earth)
r_{core}	=	3400 km	(radius of Earth's core)
κ	=	1 mm^2/s	(ballpark value for the thermal diffusivity of rocks)