Laboratory 7 - Mechanical Evolution of Oceanic Lithosphere

Objectives:

Investigate the relationship between maximum intraplate earthquake depths and ages of oceanic lithosphere in terms of the lithospheric temperature structure to infer the mechanical properties of oceanic lithosphere.

Background: The attached Table 1 lists locations, depths of focus (below ocean floor) and dates for a set of oceanic intraplate earthquakes. The maximum depth at which earthquakes may occur as been postulated to mark the transition from dominantly brittle (seismic) to dominantly ductile (aseismic) deformation. In this exercise we wish to test if there is a thermal control on the depth of the transition from brittle to ductile deformation.

Exercise:

Using the information in Table 1., determine a relationship between *maximum* depth of earthquakes and lithospheric age. You will need to either use the Cande et al map or the Muller et al database to determine the lithospheric ages of the events listed in the table.

Plots of *Depth of Earthquake* vs *Age*, and *Depth of Earthquake* vs *sqrt(Age)* both might be useful. (Why do you think the second plot might help?)

The temperature structure of oceanic lithosphere as a function of age is given approximately by:

$$T(z,t) = T_o \, \mathrm{erf}\left(\frac{z}{\sqrt{4\kappa t}} \right)$$

where T is temperature, z is depth in km, t is time in Ma, T_o is initial temperature (≈ 1300° C) and κ is thermal diffusivity (≈ 32 km^2 Ma^{-1}).

In MATLAB, y=erf(x) gives the temperature ratio (T/To) while x=erfinv(y) will give the ratio of z to the squareroot of t given a temperature ratio.

Construct a Depth/Age cross section showing temperature contours for the oceanic lithosphere. On this cross section, plot the depth-age position of the earthquakes from Table 1. Discuss your results.

The base of the oceanic lithosphere as determined by thermal models and seismic surface wave studies is given approximately by:

$$z_L = 1.1 \sqrt{4\kappa t}$$

How does this thickness of lithosphere compare with the thickness of the seismogenic layer ? Discuss your results.

Be sure to consider and discuss the consequences of uncertainties in data.

Table 1. Oceanic Intraplate Earthquakes

Depth Beneath Ocean Floor (km) [± 5 km]	Date	Location	Latitude ° N	Longitude ° E
17	May 25, 1964	Ninetyeast Ridge	-9.1	89.9
30	Oct. 23, 1964	Lesser Antilles	19.8	-56.1
7	Sept. 9, 1965	Cocos Ridge	6.5	-84.4
15	Sept. 12, 1965	Chagos Bank	-6.5	70.8
5	Oct. 7, 1965	S. China Sea	12.5	114.4
24	Oct. 31, 1965	Indian Ocean	-14.2	95.3
13	Nov. 25, 1965	Nazca Plate	-17.1	-100.2
10	Apr. 28, 1968	Emperor Trough	44.8	174.6
10	Aug. 20, 1968	Caroline Basin	5.4	147.1
27	Sept. 3, 1968	Puerto Rico	20.6	-62.3
8	May 9, 1971	SE Pacific	-39.8	-104.9
32	June 26, 1971	Sumatra	-5.2	96.9
13	Sept. 30, 1971	East Atlantic	-0.5	-4.9
10	May 21, 1972	Fiji Basin	-27.1	175.0
20	Oct. 20, 1972	North Atlantic	20.6	-29.7
48	Apr. 26, 1973	Hawaii	20.0	-155.2
15	May 3, 1973	Kerguelen	-46.1	73.2
23	Aug. 30, 1973	Bay of Bengal	7.1	84.3
7	Apr. 12, 1974	Philippine Sea	14.3	134.4
8	Nov. 20, 1974	South Atlantic	-53.6	-28.3
28	Aug. 30, 1976	Caroline Basin	1.0	147.6
15	Feb. 5, 1977	Antarctic	-66.5	-82.4
25	Dec. 13, 1977	Lesser Antilles	17.4	-54.8
11	Mar. 24, 1978	Bermuda	29.8	-67.4
40	Aug. 3, 1978	Indian Ocean	-16.3	92.9
5	1968-1976 [swarm]	South Pacific	-71.4	-148.3
5	1965-1969 [swarm]	South Pacific	-18.4	-132.8