ESO213

Fundamentals of Earth Science

Indian Institute of Technology, Kanpur

Mandar Bapat (190475)

Assignment 4

Date of Submission: 21st November, 2020

---

1 Question 1

1.1 Determining the required values for solving the question

My roll number $= 190475$
Sum of the digits $= 26$
Average $= \frac{26}{6}$
≈ 4.34
Hence , the moment magnitude value , $M_w = 4.34$
Round off integer value of $4.34 = 4$.
Hence , the fault plane area is (as given in the table) $= 1 km^2$
Hence , fault length is $= 1$ km.
ν (Poisson's Ratio) $= 0.3$
Average density of Earth's crust $= 2.6\ gm/cc$
$= 2.6 \times 10^3\ kg/m^3$
Average displacement of the fault plane , D is :
D = (fault slip vs fault length ratio)$\times$(fault length)
Hence $D = \frac{1}{20{,}000}$ km.

1.2 Part I

We use the formula

$$M_w = \frac{2}{3} \log_{10}(M_0) - 10.7$$

where M_w is dimensionless and M_0 has units Dyne-cm.
Now , we calculated M_w above.Putting $M_w = 4.34$, we get

$$4.34 = \frac{2}{3}\log_{10}(M_0) - 10.7$$

$$15.04 = \frac{2}{3}\log_{10}(M_0)$$

$$22.56 = \log_{10}(M_0)$$

$$10^{22.56} Dyne - cm = M_0$$

$$M_0 = 10^{0.56} \cdot 10^{22} Dyne - cm$$

$$M_0 = 3.63 \times 10^{22} Dyne - cm$$

So , $M_0 = 3.63 \times 10^{22}$ Dyne-cm

1.3 Part II

We use the formula

$$M_0 = \mu S D$$

where μ = shear modulus of the rock
S = Affected area of the fault plane and
D = average displacement

Note that from Precalculations , we have :
S = 1 km^2
$D = \frac{1}{20,000}$ km

$$\mu = \frac{M_0}{S \times D}$$

$$\mu = \frac{3.63 \times 10^{22} \times 10^{-7}}{\frac{1}{20,000}} \frac{N - m}{km^3}$$

$$\mu = 3.63 \times 2 \times 10^{15} \times 10^{4} \times 10^{-9} \frac{N}{m^2}$$

$$\mu = 7.26 \times 10^{10} \frac{N}{m^2}$$

$$\mu = 7.26 \times 10^{1} GPa$$

So , $\mu = 72.6$ GPa

1.4 Part III

We use the formula :

$$V_p = \sqrt{\frac{k + \frac{4}{3}\mu}{\rho}}$$

and

$$V_s = \sqrt{\frac{\mu}{\rho}}$$

where μ = shear modulus
ρ = density the rocks through which the waves travel
k = bulk modulus

First we calculate V_p . Now , we know that

$$\nu = \frac{3k - 2\mu}{6k + 2\mu}$$

So ,

$$6k\nu + 2\mu\nu = 3k - 2\mu$$

$$k = \frac{2\mu\nu + 2\mu}{3 - 6\nu}$$

Substituting the above formula in the formula for V_p :

$$V_p = \sqrt{\frac{\frac{2\mu\nu + 2\mu}{3-6\nu} + \frac{4}{3}\mu}{\rho}}$$

$$V_p = \sqrt{\frac{6\mu\nu + 6\mu + 12\mu - 24\nu\mu}{3(3-6\nu)\rho}}$$

$$V_p = \sqrt{\frac{18\mu - 18\mu\nu}{3(3-6\nu)\rho}}$$

$$V_p = \sqrt{\frac{2\mu - 2\mu\nu}{(1-2\nu)\rho}}$$

$$V_p = \sqrt{\frac{2\mu(1-\nu)}{(1-2\nu)\rho}}$$

Now , plugging in the value ν , we get :

$$V_p = \sqrt{\frac{7\mu}{2\rho}}$$

$$V_p = \sqrt{\frac{7 \times 7.26 \times 10^{10}}{2 \times 2.6 \times 10^3}} \qquad m/s$$

$$V_p = \sqrt{\frac{5082 \times 10^6}{52}} \qquad m/s$$

$$V_p = \sqrt{97.7} \times 10^3 \qquad m/s$$

$$V_p = 9.88 \qquad km/s$$

Now , we calculate V_s .

$$V_s = \sqrt{\frac{\mu}{\rho}}$$

$$V_s = \sqrt{\frac{7.26 \times 10^{10}}{2.6 \times 10^3} \frac{N-m}{kg}}$$

$$V_s = \sqrt{\frac{726}{26}} \qquad km/s$$

$$V_s = 5.28 \qquad km/s$$

1.5 Part IV

Time delay = Sum of the digits of my roll number
Hence , Time delay = 26 sec

Assume the distance between the hypocenter and the station is d kilometers.
Let t_1 be the time taken by Primary waves to reach the station and t_2 be the time taken by the secondary waves to reach the station.Then :

$$t_1 = \frac{d}{V_p}$$

$$t_2 = \frac{d}{V_s}$$

Since , secondary waves are slower , $t_2 > t_1$. Hence,

$$t_2 - t_1 = 26 \qquad sec$$

$$\frac{d}{V_s} - \frac{d}{V_p} = 26 \qquad sec$$

$$d = \frac{26V_sV_p}{V_p - V_s} \qquad km$$

$$d = \frac{1356.32}{4.60} \qquad km$$

Hence , $d = 294.85$ km

2 Question 2

Graph is attached.

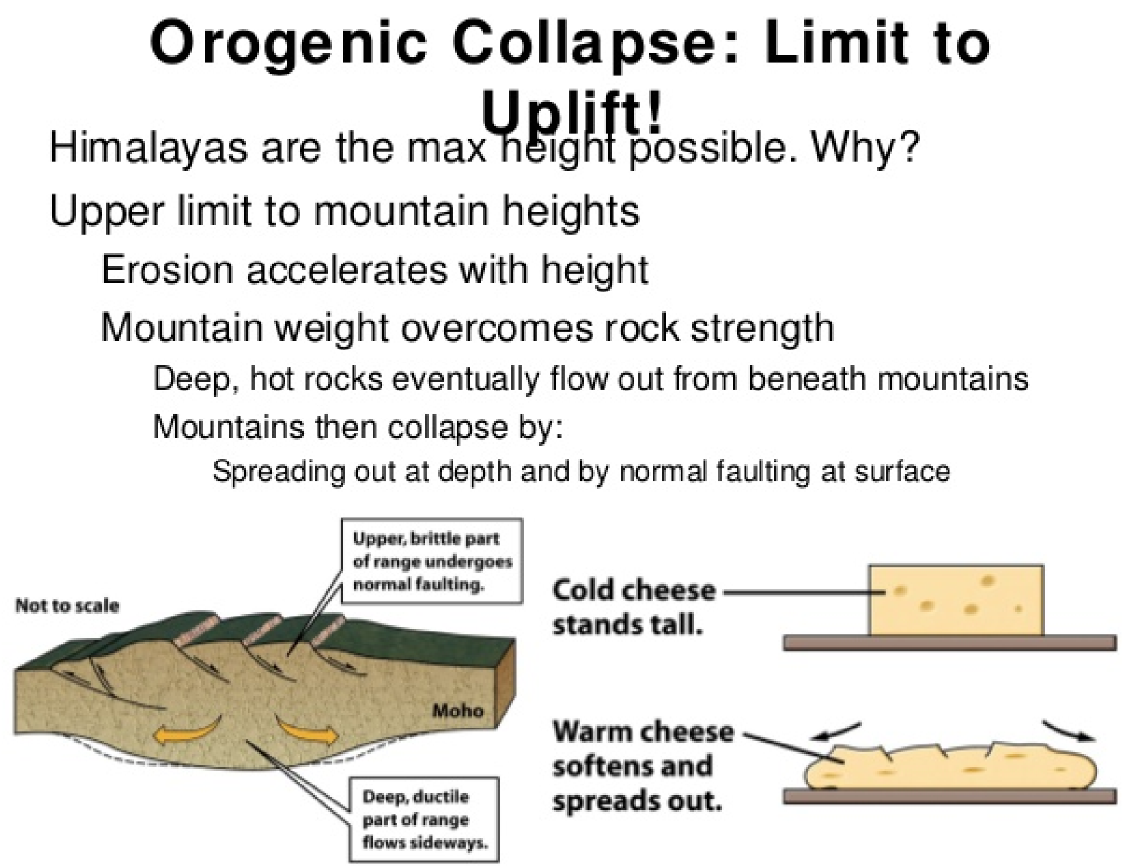
3 Question 3

The Himalayan oregon initiated with the Paleocene continental collision of India and Asia.
The reason that possibly explains the younger age of normal faults is a process called **orogenic collapse**.The mechanism of **orogenic collapse** is:

Pressure at the base of the mountain increases with height.Once the mountain has reached a certain height , deep hot rocks at the bottom start to flow like fluid.This causes the spreading of the mountains with normal faults being developed at the surface.The process can be better visualised by giving an analogy of cold and hot cheese.Cold cheese stands tall while hot cheese is soft and spreads out when place on a table.A similar process happens in high mountains.

Note that we are not talking about a complete orogenic collapse; just a similar event on a small scale.

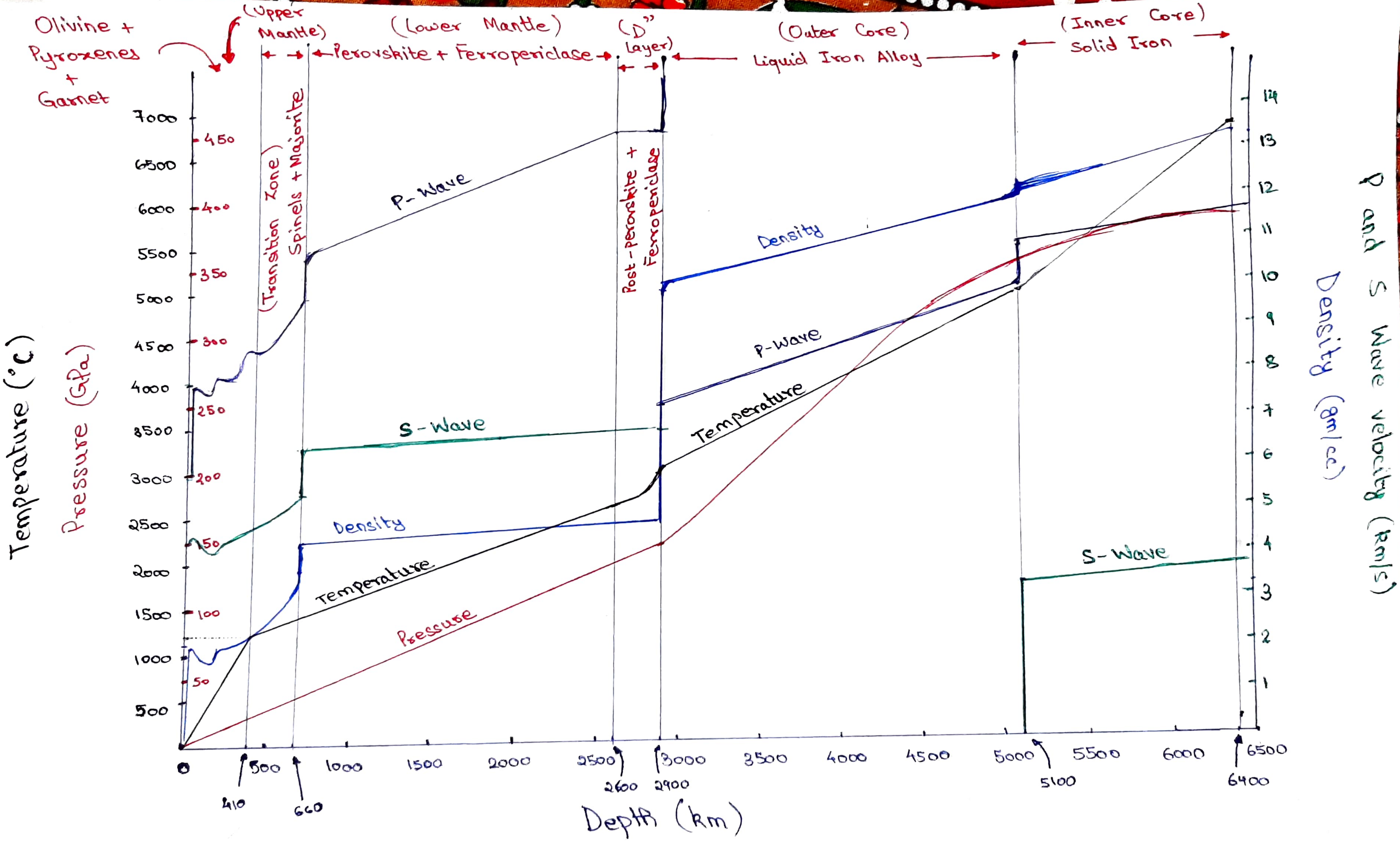
We apply the above reasoning to the Himalayan plateau.Continental collision created the thrust faults.The **law of cross-cutting relationship** says that a structure has to be there first before a fault can occur in it.Since Himalayan-Tibetan plateau were formed as a result of a thrust fault , the normal faults which occur later have to be younger than the thrust faults.



4 References

References

[1] www.researchgate.net


Olivine + Pyroxenes + Garnet
(Upper Mantle)
(Transition Zone)
Spinels + Majorite
(Lower Mantle)
Perovskite + Ferropericlase
(D" layer)
Post-perovskite + Ferropericlase
(Outer Core)
Liquid Iron Alloy
(Inner Core)
Solid Iron
Temperature (°C)
Pressure (GPa)
P-Wave
S-Wave
Density
Temperature
Pressure
P and S Wave velocity (km/s)
Density (gm/cc)
Depth (km)
410
660
2600
2900
5100
6400