KEY

ES322 In-Class Exercise
Part 1. Estimating Lithostatic Pressure inside the Earth

Let's consider an area of the Earth's surface 1 km x 1 km square, and project it as a rectangular prism of rock to a depth of 5 km inside the crust. Assume a uniform average rock density of 2.9 g/cm3, from top to bottom in the rectangular slice of rock. Draw a block diagram to illustrate the above relationships. Using your conversion tables and rock property equation lists, calculate the following values (SHOW ALL OF YOUR MATH WORK AND UNIT ALGEBRA):

Total of mass of rock in the prism in kg __________

Total mass of rock in the prism in metric tons (t) __________

The total weight of rock in Newtons (N) __________

Total pressure equivalent at base of prism in Pascals (Pa) __________

Total pressure equivalent at base of prisim in MPa __________

Hints / Equations and conversions:

Vol = A x d   D = M/V   Wt = Mg   g = 9.8 m/sec^2 P = F/A

1 Pa = 1 N/m^2 1 N = 1 kg-m/sec^2 1 MPa = 1 x 10^6 Pa

Part 2. Understanding Erosion Rates and the Power of Big Geologic Time

Assuming that the mass of rock at the very bottom of the rectangular prism in Part 1 above, is subject to long-term uplift and erosion, with long term average erosion rates on the order of 100 mm/ka. How many years would it take to exhume and expose the basement rocks at the foot of the rectangular prism in Part 1 above? SHOW ALL OF YOUR UNIT ALGEBRA.

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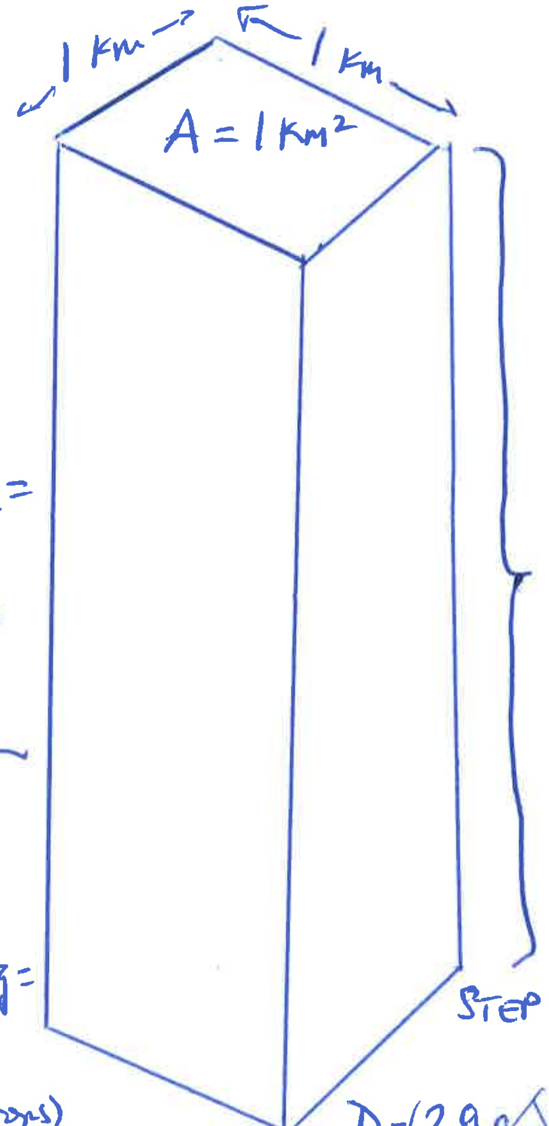
PART 1 SOLUTION — LITHOSTATIC PRESSURE



ROCK DENSITY = $2.9 \frac{g}{cm^3}$

SURFACE AREA = 1 Km x 1 Km

TOTAL DEPTH = 5 Km

$VOL = A \cdot d = 1\,Km^2 \cdot 5\,Km = 5\,Km^3$

$DENSITY = \frac{MASS}{VOLUME}$

NEWTON'S SECOND LAW

$Wt = mg$ where

m = mass in Kg

g = acceleration due to gravity = $9.2\ m/sec^2$

Wt UNITS = $\frac{Kg\text{-}m}{sec^2}$ = N (newtons)

$PRESSURE = \frac{F}{A} = \frac{Wt}{A}$

UNITS = $\frac{N}{m^2}$ = 1 Pa

$1\ MPa = 1 \times 10^6\ Pa$

STEP 1: CONVERT UNITS TO Kg-m-sec

$D = \left(2.9 \frac{g}{cm^3}\right)\left(\frac{1 \times 10^6\ cm^3}{m^3}\right)\left(\frac{1\ Kg}{1000\ g}\right) = 2900 \frac{Kg}{m^3}$

$DEPTH = 5\ Km \left(\frac{1000\ m}{Km}\right) = 5000\ m$

$AREA = 5\ Km^2 \left(\frac{1 \times 10^6\ m^2}{1\ Km^2}\right) = 5 \times 10^6\ m^2$

STEP 2 SOLVE FOR MASS

$$D = \frac{mass}{volume} = \frac{mass}{A \cdot d}$$

REARRANGE:

$$MASS = D \cdot A \cdot d = \left(\frac{2900\,Kg}{m^3}\right)(5\times10^6\,m^2)(5000\,m) =$$

$$m = 7.25\times10^{13}\,Kg$$

STEP 3. CONVERT MASS FROM Kg TO t (metric tons)

$$m = 7.25\times10^{13}\,Kg\ \frac{1\,t}{1000\,Kg} = 7.25\times10^{10}\,t$$

STEP 4. CALCULATE WEIGHT

$$Wt = mg = (7.25\times10^{13}\,Kg)\left(9.8\,\frac{m}{sec^2}\right) = 7.1\times10^{14}\,N$$

STEP 5. CALCULATE PRESSURE

$$P = \frac{F}{A} = \frac{Wt}{A} = \frac{7.1\times10^{14}\,N}{5\times10^6\,m^2} = 1.42\times10^8\,Pa$$

STEP 6. CONVERT TO MPa

$$P = 1.42\times10^8\,Pa\left(\frac{1\,MPa}{1\times10^6\,Pa}\right) = 142\,MPa$$

PART 2 SOLUTION — EXHUMATION RATES

$$EROSION\ RATE = 100\,mm/Ka = \frac{100\,mm}{1000\,yrs}$$

$$TOTAL\ EXHUMATION\ THICKNESS = 5\,Km\left(\frac{1000\,m}{Km}\right)\left(\frac{1000\,mm}{m}\right) = 5\times10^6\,mm$$

$$TOTAL\ TIME = \frac{EXHUMATION\ THICKNESS}{EROSION\ RATE} = \frac{5\times10^6\,mm}{100\,mm/1000\,yrs} = 5\times10^7\,yrs = 50\,M.y.$$