Geology 334: HOMEWORK 1

Comparing Sediment Discharge and Denudation Rates: Ganges-Brahmaputra and Mississippi Rivers

Due Date: Thursday April 11, 2019

As discussed in class, regional erosion and denudation rates can be determined by doing simple calculations that combine information about sediment discharge from rivers and the size of associated drainage basins. In this homework, you will work through a set of these calculations for the Ganges-Brahmaputra River which drains the massive Himalayan Mountains, and the Mississippi River which drains the interior United States. After doing the calculations, you will be asked to compare your results from the two areas and explain the difference between them.

Please give your answers on a separate piece of paper. Show all of your work, and type your answers to Part 3. Everything must be neat and legible and follow the organization used here. In your calculations, use the following values: 1 L = .001 m^3; 1 kg = 1000 g; 1 ton (t) = 1000 kg; density of rock = 2700 kg/m^3. For volume conversions, remember that 1000 m = 1 km, so 1 km^3 = 10^9 m^3. Recall that g, kg, and t are units of mass; and m and km are units of length.

Part 1. Ganges-Brahmaputra. Figure 1 shows the Ganges and Brahmaputra River systems and their drainage divides in India and southern Tibet. You can see that these two large rivers join together in Bangladesh and empty into the Bay of Bengal in a large delta system. Decades of river monitoring at the mouth of these rivers has yielded the following information:

The annual water discharge is 970 km^3/yr. Average suspended sediment concentration is 1.6 g/L; this does not include sediment moving in bedload. The bedload is estimated to be about 25% of the total load. The drainage basin shown in Figure 1b has an area of 1.54 * 10^6 km^2. Using the methods introduced in class, answer the following questions.

(a) What is the annual suspended sediment discharge (in g/yr, kg/yr, and t/yr)?

(b) What is the total annual sediment discharge, including bedload (in t/yr)?

(c) Convert your answer in (b) to total annual sediment discharge by volume (km^3/yr).

(d) Considering the area of eroding uplands that are drained by these rivers, what is the average vertical rate of erosion (also called denudation) in the drainage basin? Give your result in mm/yr.

Part 2. Mississippi River. A paper by Milliman and Syvitski (1992) states that the modern suspended-sediment discharge exiting the mouth of the Mississippi River is 2.1 * 10^8 t/yr, and that the pre-dam discharge was 4.0 * 10^8 t/yr. An earlier paper by Milliman and Meade (1983) states that the annual water discharge is 580 km^3/yr. Bedload transport in the lower Mississippi River is very minor, only about 2-4% of the total load, so it can be ignored in this problem. The area of the drainage basin for the Mississippi River is 3.3 * 10^6 km^2. See conceptual diagram on next page.

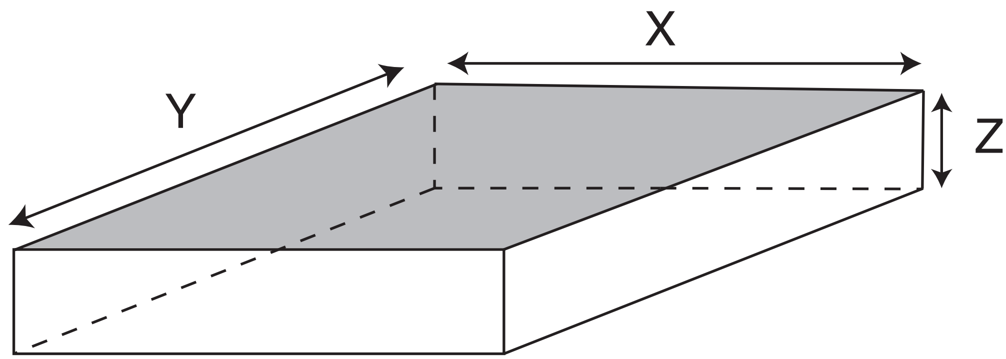
(a) Using above numbers, what is the average modern suspended sediment concentration (in g/L)?

(b) Assuming that annual water discharge has remained the same from pre-dam to modern times, what is the average pre-dam suspended sediment concentration (in g/L)?

(c) Convert the modern sediment discharge (t/yr) to sediment discharge by volume (km^3/yr).

(d) Calculate the average modern vertical rate of erosion in the drainage basin (in mm/yr).

Geometric relationship between drainage area, volume discharge, and vertical denudation rate:



3-D block represents volume of rock eroded during a period of time.
X * Y = Area of region being eroded. **Z** = vertical denudation rate.

Part 3. Synthesis and Interpretations.

(a) Compare the rates of vertical erosion (denudation) that you calculated for the two river systems. What are the rates that you got (reiterate them from your calculations)? Which one is greater?

(b) Do your results make sense to you?** Explain why. That is, what is the tectonic setting of the two areas, and (based on that) what would you expect their comparative rates of denudation to be?

(c) At the rate of erosion that you calculated for the Ganges-Brahmaputra drainage area, how long would it take for a mountain range of 5,000 meters average elevation to be eroded to sea level?

(d) Geologic studies have shown that the Himalayan Mts. have existed for the past ~ 40 million years. Considering your answer in part (c), why does a mountain range still exist there today?

(e) Does the denudation rate that you calculated for the Mississippi River drainage area accurately represent erosion rates in the uplands? What might be a better value of sediment discharge to use in the calculation, and why is it better? (Hint: Think about the modern versus pre-dam discharge numbers that I gave you. Obviously, sediment is being trapped in reservoirs; has there been a true decrease in the rate of erosion in the uplands that drain into the reservoirs?)

** the reason for asking this question is to remind you of a good rule of thumb: when you do comparative calculations like this you should always ask yourself if the results are logical, and are they consistent with other things that you know about the areas being compared. In this case, you can compare what you know about the physiography and tectonics of the two regions. The results of your calculations should be consistent with your background information, even if it is very basic. Sometimes results of an analysis might contradict your previous intuition (or bias), in which case you have to find out which was in error: the analysis or your intuition.

<u>Note</u>: the last page of this assignment shows an example of similar calculations for the Columbia River basin. Be sure to study and understand that example before doing these problems.

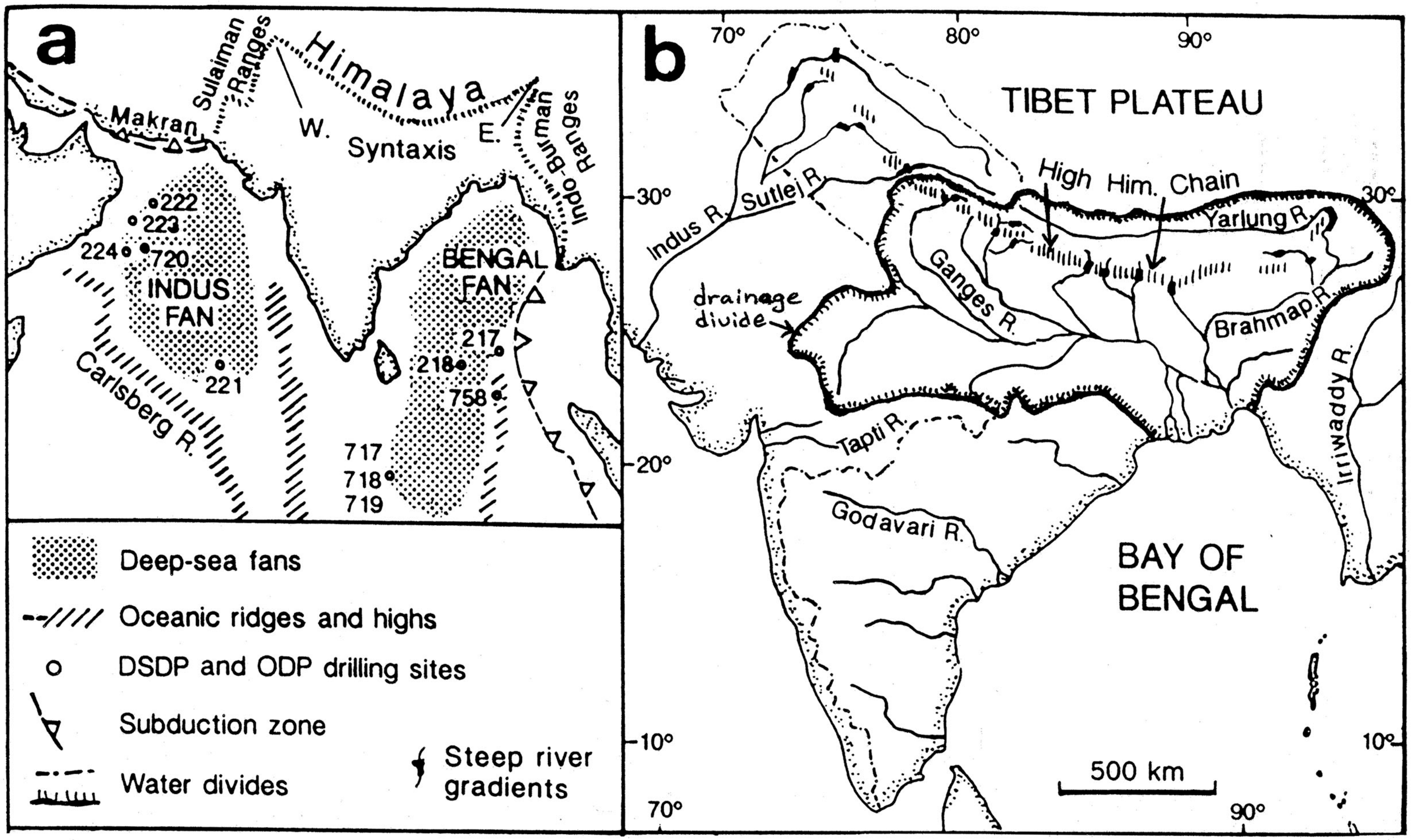


Figure 1. Simplified maps showing: (a) India and neighboring oceans, and (b) the areas drained by the Ganges and Brahmaputra river systems. From Einsele et al. (1996).

Columbia River (#s from Milliman + Meade, 1983):

Water Discharge = 250 km^3/yr

Drainage area = $.67 \times 10^6\ km^2$ = $.67 \times 10^{12}\ m^2$

Average Susp. Sed Concentration = 0.13 g/L

(1) First consider Suspended Load Sed Discharge,

what is the susp. sediment concentration? (g/L)?

can Calculate:

$$250 \frac{\cancel{km^3}}{yr} \times \frac{10^9\ \cancel{m^3}}{\cancel{km^3}} \times \frac{.13g}{\cancel{L}} \times \frac{1\cancel{L}}{.001\ m^3} = 3.25 \times 10^{13}\ g/yr$$

= susp. sed discharge

(2) Calculate Total Sed Discharge:

if bedload = ~25% of total load, Then susp load = 75%, and

$3.25 \times 10^{13}\ g/y = .75\ X$, and: X (total) = $4.33 \times 10^{13}\ g/yr$

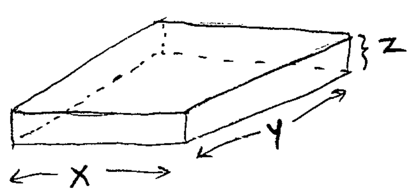
$= 4.33 \times 10^{10}\ kg/yr$

(= total annual sedim. discharge, mass)

(3) Convert to Volume:

$$4.3 \times 10^{10} \frac{\cancel{kg}}{yr} \times \frac{m^3}{2700\ \cancel{kg}} = 1.6 \times 10^7\ m^3/yr$$

(4) Convert to vertical denudation rate: we know: $\boxed{\frac{\text{volume}}{yr}}$ and $\boxed{\text{area}}$...



volume = X · Y · Z (known)

area = X · Y (known)

solve for Z = $\frac{\text{vol}/yr}{\text{area}}$ =

$$1.6 \times 10^7 \frac{m^3}{yr} \div .67 \times 10^{12}\ m^2 = 2.4 \times 10^{-5} \frac{m}{yr} = 2.4 \times 10^{-2} \frac{mm}{yr}$$

$\boxed{= .024 \frac{mm}{yr}}$ denud. rate