

**Purpose:** Hooke (2000), shows us one example of how you can quantify landscape change due to human influence. We will explore the details of Hooke's calculation and get some familiarity with typical sediment transport rates for glaciers and rivers (Hallet et al., 1996).

The calculations from this problem set will walk you through how to read a quantitative article critically. As you read other articles this semester, you should carefully examine any numbers and equations presented. Is the author internally consistent? Do the numbers match your intuition/expectations? What are the implications? Importantly, do not just take the author(s) at his/her/their word that the numbers work out!

**Readings:**

Hallet, B., Hunter, L., and Bogen, J., 1996, Rates of erosion and sediment evacuation by glaciers: A review of field data and their implications: Global and Planetary Change, v. 12, p. 213-235.  
Hooke, R.L., 2000, On the history of humans as geomorphic agents: Geology, v. 28, p. 843-846.

**Questions:**

1. Hooke (2000) estimates that 115 Gt/yr (1 Gt =  $10^9$  t =  $10^{12}$  kg) of earth is currently moved by humans. See Figure 4 (provided on the back page of the problem set) and be sure you can see where this number comes from. Let's compare this rate with "natural" rates of sediment transport.

(a) Critical information (\*=look up online) (1 pt.):

\*Typical rock density      2600   kg/m<sup>3</sup>

115 Gt/yr =                  4.4x10<sup>10</sup>   m<sup>3</sup>/yr

\*Earth's radius              6,370,000   m

Earth's surface area        5.1x10<sup>14</sup>   m<sup>2</sup>

- (b) Suppose we took the volume of one year's worth of human sediment transport and spread it across Earth's continents. How thick would this layer be? Note that the continents cover 29% of Earth's surface. (3 pts.)

$$\frac{4.4 \times 10^{10} \text{ m}^3 / \text{yr}}{(0.29)(5.1 \times 10^{14} \text{ m}^2)} = 3 \times 10^{-4} \text{ m} / \text{yr} = 0.3 \text{ mm} / \text{yr}$$

- (c) Typical rates of sediment transport by glaciers and rivers are 1 mm/yr and 0.1 mm/yr, respectively (Hallet et al., 1996). Glaciers cover about 10% of Earth's continents, and we'll assume that rivers drain the remaining 90% of the continents (note: there is minimal erosion on the seafloor). Determine an expected mass of sediment transported naturally each year. (3 pts.)

Mean rate for glaciers (kg/yr):

$$(0.001 \text{ m} / \text{yr})(0.1)(0.29)(5.1 \times 10^{14} \text{ m}^2)(2600 \text{ kg} / \text{m}^3) = 3.8 \times 10^{13} \text{ kg} / \text{yr}$$

Mean rate for rivers (kg/yr):

$$(0.0001 \text{ m} / \text{yr})(0.9)(0.29)(5.1 \times 10^{14} \text{ m}^2)(2600 \text{ kg} / \text{m}^3) = 3.5 \times 10^{13} \text{ kg} / \text{yr}$$

Total sediment transport (kg/yr):

$$3.5 \times 10^{13} \text{ kg} / \text{yr} + 3.8 \times 10^{13} \text{ kg} / \text{yr} = 7.3 \times 10^{13} \text{ kg} / \text{yr}$$

2. Hooke's "Bottom Line" is that the total earth moved in the past 5000 years would be equivalent to a mountain range that is 4000 m high, 40 km wide, and 100 km long.

(a) What is the mass of this theoretical mountain range? Assume the range is shaped like a box. Give the result in Gt. (1 pt.)

$$\frac{(4000 \text{ m})(40,000 \text{ m})(100,000 \text{ m})(2600 \text{ kg/m}^3)}{1 \times 10^{12} \text{ kg/Gt}} = 41,600 \text{ Gt}$$

(b) Hooke's value comes from integrating the area under his time series of transport rates. Do this manually with a ruler for the Hooke figure, and give the final number below. Show your work on the figure on the back page. (1 pt.)

**Approximate area using triangles:**

*Intentional:*  $0.5(150 \text{ yr})(37 \text{ Gt/yr}) = 2775 \text{ Gt}$

*Unintentional:*  $0.5(5000 \text{ yr})(10 \text{ Gt/yr}) + 0.5(360 \text{ yr})(70 \text{ Gt/yr}) = 37,600 \text{ Gt}$

*Total:*  $2775 \text{ Gt} + 37,600 \text{ Gt} = 40,375 \text{ Gt}$

**Note: this will almost certainly not match Q2a, but it should be close.**

(c) To get perspective on this theoretical mountain range, give us the dimensions of two North American ranges. You will need a topographic map and a ruler. Do not worry about the fact that the ranges' topography is complicated. Just use a reasonable mean width, height, and length. (1 pt.)

Sierra Nevada, CA:

$$(650 \text{ km})(100 \text{ km})(4 \text{ km}) = 260,000 \text{ km}^3$$

Wind River Range, WY:

$$(180 \text{ km})(50 \text{ km})(4 \text{ km}) = 36,000 \text{ km}^3$$

**Note: students should realize that the Wind River Range is closer to size of Hooke's theoretical mountain range. Discuss with students whether this is an alarming or reassuring result.**

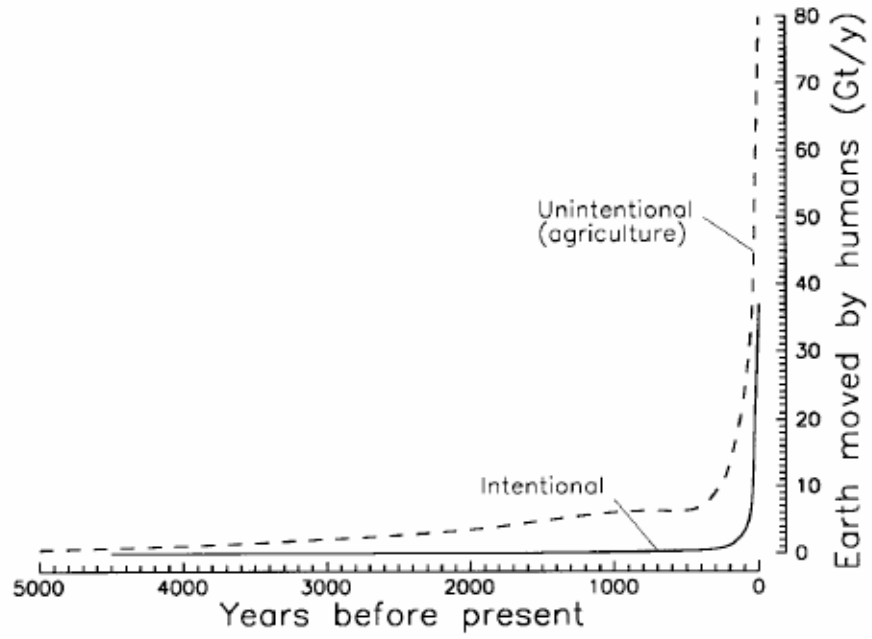


Figure 4. Estimate of total amount of earth moved annually by humans at various times in the past. Curves were obtained by multiplying earth moved per capita (Fig. 2) by population (Fig. 3).