Denudation - sediment accumulation systems: Quantitative aspects of terrestrial sediment yield and basin filling

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Course and University Lectures topic

The role of terrestrial sediment supply in basin filling and sequence stratigraphy has been frequently mentioned, but quantitative data have been rarely presented and evaluated. Average mechanical denudation rates, Dr_{me}, or specific sediment yields, SY, of drainage areas associated with sedimentary basins largely vary. Mean Dr_{me} values of large regions typically range from 10 to 500 mm/ka, corresponding to SY values from 25 to more than 1000 $t/km^2/a$) ion relation to relief, climate, lithology, and other factors. Small mountain areas often shed as much material into a nearby basin as hilly or lowland regions 10 to 50 times larger. A number of selected case studies, including large artificial reservoirs, show that sediment yields of modern rivers draining sparsely populated mountainous areas agree relatively well with long-term data found from dated sediment volumes of well defined denudation-accumulation systems. Many other modern measurements of river loads, however, are strongly biassed by human activities.

Using nonbiassed SY or Dr_{me} data and the ratio A_d/A_b of the drainage and basin areas, the average mechanical (siliciclastic) sedimentation rate, Sr_{me}, can be calculated. Furthermore, it can be demonstrated and to some extent predicted in which way small and larger basins respond to varying sediment influx and are ultimately filled. Non- or slowly subsiding lake basins and artificial reservoirs with a high A_d/A_b ratio may become sediment-filled in relatively short time periods (mostly hundreds of years to tens of ka). The evolution and depositional environment of long-lived subsiding larger basins is mainly controlled by the interplay between the rates of subsidence and sediment accumulation. High values of A_d/A_b and SY lead to oversupplied basins maintaining, e.g. in extensional basins, continental depositional environments for a long time period. Under supplied basins turn early into lakes or deepening marine environments. In contrast, closing basin, e.g. remnant or forearc basins, can be filled up rapidly with sediment in their final stage. Strongly variable SY associated with phases of overthrusting largely controls the evolution of foreland basin fills. For

all types of basin it should be noted that even moderate climatic change, especially from semi-arid to humid, may cause SY to vary by a factor of 2 to 5.

The A_d/A_b controlled relationship between Dr_{me} and Sr_{me} does not take into account uneven sediment distribution within basins. In many cases, large amounts of the river-derived sediment influx are stored in estuaries, prograding lake and marine deltas and their slopes, or they are transported along the shore. Modern deep-sea fans often receive only a minor proportion of the river load. Nevertheless, simple denudation-accumulation models can lead to a better understanding of basin-filling processes. But it should be borne in mind that the processes operating in nature are usually more complex than we tend to assume.

Fig. 1 General scheme displaying the relationship between denudation in the drainage area and sediment accumulation in a lake. *Trap efficiency* (→100%) signifies that all incoming sediment is trapped by the basin. See text for further explanation

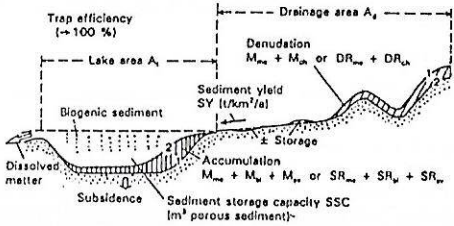
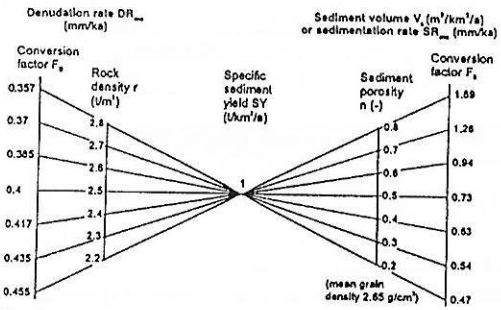


Fig. 2 Conversion of mechanical denudation rates into specific sediment yields as well as sediment volumes or (linear) sedimentation rates of wet sediment of different porosity



Example 1: DR_{me} = 2, ρ = 2.6, n = 0.4

$$SY = \frac{DR_{me}}{F_s} = \frac{2}{0.385} \approx 52 \text{ t/km}^2\text{/a} \; ; \; V_s = SY * F_s = 52 * 0.63 = 33 \text{ m}^3\text{/km}^2\text{/a or 33 mm/ka}$$

Example 2: SR_{me} or V_s = 25, n = 0.6, ρ = 2.4

$$SY = \frac{V_s}{F_s} = \frac{SR_{me}}{F_s} = \frac{25}{0.94} \approx 27 \text{ t/km}^2\text{/a} ; \; DR_{me} = SY * F_s = 27 * 0.417 = 11 \text{ mm/ka}$$