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EXPORT OF SEDIMENTS FROM THE ALPS TO THE FORELAND BY RIVERS

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From various literature sources the present-day sediment yield of ca. 200 Alpine catchments have been compiled. Analysis of the data comprised (1) correlation analysis for all catchments with basic controlling parameters such as relief, water discharge, and glaciated area, (2) grouping into morpho-tectonic zones and quantification of further controlling parameters e.g. slope, forest cover, unvegetated land, snow and ice, crystalline rocks, sedimentary rocks using a GIS, (3) estimation of the present-day export rate of sediments from the Alps (HINDERER & KAMELGER, in prep.) and form Swiss Alpine drainage basins (KAMELGER, 2001).

Plots of sediment yield of all 200 measuring stations versus maximum elevation in the catchments, river discharge, and glaciated area show the expected positive correlations. In contrast, sediment yield declines with the size of the drainage area. These patterns together with a relatively strong scatter of the data was found in many earlier studies on sediment yield (e.g. MILLIMAN & SYVITSKI, 1992; HOVIUS, 1998). In a second step, the sediment yield data have been grouped into six morpho-tectonic zones. These are: (1) Northern Helvetian Alps, (2) Western Crystalline Alps, (3) Southern Crystalline Alps, (4) Northern Calcareous Alps, (5) Eastern Crystalline Alps, (6) Southern Calcareous Alps (HINDERER & KAMELGER, 1999). The characteristic statistic values of sediment yield are higher for the Western Alps (zones 1 to 3) than for the Eastern Alps (zones 4 to 6). Within the western Alps the crystalline part (zone 2) exhibit the highest mean, median, and quartiles of sediment yield whereas the Northern Helvetian Alps and the Southern Crystalline Alps show lower values. The transsect from zone 4 to zone 6 shows a similar pattern, however, the sediment yield of the Southern Calcareous Alps are almost equal to the Eastern Crystalline Alps. The relief, land cover, and lithology of the morpho-tectonic zones have been quantified using a GIS. Relief parameters such as slope, maximum, minimum, and mean elevations have been derived from a DEM with a resolution of 100 m horizontal and 18 m vertical. Forest cover, unvegetated areas, and snow- as well as ice-covered areas have been quantified by global land cover data from satellite surveying which are provided by the USGS. Portions of crystalline and sedimentary rocks have been determined from a generalised geological map (HINDERER & KAMELGER, 2001). In addition to quantify how different lithologies affect the sediment discharge in a drainage area, a modified version of the Swiss geotechnical has been used.

Correlation analysis show significant correlations ($p < 0.05$) of the mean or median of sediment yield with mean elevation, difference between maximum and minimum elevation, forest cover, unvegetated area, and snow and ice cover. All are positive correlations except forest cover which is negative.

In a third step, mean sediment yield of rivers leaving the Alps from the various morpho-tectonic zones are used to estimate the total sediment export. We end up with a total of $50*10^6$ [t/y]. This converts to a mean denudation rate of the Alps of 0.125 [mm/y] at present.

The denudation rates of the Swiss Alpine drainage basins range from 10 [mm/ky] to 700 [mm/ky]. For the entire Swiss Alpine study area including parts of the foreland a total sediment discharge of about 6.3×10^6 tons per year yields a mean denudation rate of 0.11 [mm/y] (KAMELGER, 2001). This rate corresponds to mean denudation rate measurements found by (KEMPE, MYCKE & SEEGER, 1981) for central Europe. Obviously, the mean denudation rate for the entire Swiss territory is strongly reduced by the extended low-elevated areas of the Molasse basin. If the drainage basins of the Penninic units, the Helvetic units, the Eastern Alpine units and the Southern Alps are treated separately from the drainage areas located in the Molasse basin, a mean denudation rate of 0.21 [mm/y] and 0.03 [mm/y] respectively can be calculated. Taking into account the mean surface uplift rates in each area, the recent mean surface uplift is roughly 5 to 8 times faster than the mean denudation rate from river loads.

Comparison with the mean sediment yield of small rivers (<500 km^2) inside the Alps show that ca. 52% of the sediments transported by headwaters are stored, e.g. in alluvial plains or lakes and do not leave the Alps.

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