11. Denudation rates

How many years must a mountain exist
Before it is washed to the Sea?

The answer, my friend, is blowing in the wind...

Bob Dylan’s song cited in:

...for geomorphologists the answer is provided by cosmogenic isotopes...
11. Denudation rates

Sediments and soils dominate at the Earth’s surface, and both are ultimately produced by interaction of water with crystalline rocks - via a combination of chemical and physical weathering.
10. Denudation rates

What processes regulate **chemical weathering** and **physical erosion**?

What are the driving forces for landscape denudation?

- Climate?
- Precipitation?
- Tectonics?

Does erosion drive weathering or does weathering drive erosion?
11. Catchment wide denudation rates
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11. Catchment wide denudation rates

\[ C = \frac{P_{\Lambda}}{D} \]

- \( C \) = concentration
- \( P \) = production rate
- \( \Lambda \) = penetration length scale
- \( D \) = denudation rate

von Blanckenburg (2005) EPSL 237
11. Catchment wide denudation rates

Erosionsraten aus *in situ*- produzierten kosmogenen Nukliden

\[
C = \left( \frac{P_0}{\varepsilon/\Lambda + \lambda} \right)
\]

- \( \varepsilon \): Erosionsrate
- \( C \): Nuklidkonzentration
- \( P_0 \): Nuklid Produktionsrate an der Gesteinsoberfläche
- \( t \): Expositionsalter
- \( \Lambda \): Mittlere Abschirmtiefe
- \( \lambda \): Zerfallskonstante
11. Catchment wide denudation rates

Averaging time scale for denudation rate (von Blankenburg 2005) → is a function of the denudation rate itself
11. Catchment wide denudation rates

Lithological dependence of erosion rates as determined from cosmogenic nuclides and river load data (Bauer 1993, Morel et al. 2003).
11. Catchment wide denudation rates

derived from river loads:

derived from alluvial sediments:

Fig. 1: Neckar denudation rates from river load data

Fig. 2: Neckar total denudation rates from cosmogenic nuclides

von Blanckenburg et al.

Cosmogenic isotopes measure total denudation rate - chemical part and physical part
11. Catchment wide denudation rates

Geological map of the Wutach basin, with erosion rates from cosmogenic nuclides (mm kyr\(^{-1}\)).

Morel et al. 2003 Terra Nova
11. Catchment wide denudation rates

Sri Lanka: antropogen bedingter Anstieg der Erosion

von Blanckenburg 2008 GMIT 33
11. Catchment wide denudation rates

Mittelgebirge/Europa:

kosmoge Denudationsrate höher als in Sri Lanka!

Grund: quartäre tektonische Aktivität (Hebung, Grabenbildung)

Raten aus Schwebstoffen unterschätzen die wahre Abtragung

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11. Catchment wide denudation rates

Schweizer Alpen:

kosmogene Denudationsrate sehr hoch

Grund: starke isostatische Ausgleichsbewegung infolge von Eisverlust

Schwebstoffe unterschätzen die wahren Erosionsraten

von Blanckenburg 2008 GMT 33
11. Denudation rates

Conventional sediment-yield measurements can greatly under- and overestimate long term average erosion rates.

Some studies show that tectonics and not climate controls erosion rate.

→ erosion rates in the Middle European Uplands higher than in tropical areas (Sri Lanka)
11. Denudation rates and topography

Middle Europe: denudation rates show strong dependence on relief – influenced by Neogene tectonic

Appalachians: denudation rate uniform, independent of relief – geomorphic steady state

Swiss Alps: very high denudation rates but more or less uniform – effect of glaciation?

von Blanckenburg 2005
11. Climate, erosion and rock weathering

In order to avoid lithology-dependent effect only granitic catchments are shown

von Blanckenburg 2005
11. Paleo-denudation rates

Well-dated and deposits from rapidly accumulated river terraces

These sediments must be shielded from post-depositional irradiation
12. Cosmic-ray exposure age of meteorites

Cosmogenic nuclides are produced in meteorites in space and the production is positively correlated with time. Cosmogenic nuclide production stops when meteorites fall on Earth. If production rate is known it can be calculated how long meteorites stayed in space → *transit time* or *exposure age*
Radioactive isotopes like C-14 are formed in a meteorite, in space, as it is bombarded by cosmic rays. With its relatively short half-life (5730 years), meteorites achieve a saturation level in a time generally short compared to the life-time of a fragment in space.
Radioactive isotopes like C-14 are formed in a meteorite, in space, as it is bombarded by cosmic rays. With its relatively short half-life (5730 years), meteorites achieve a saturation level in a time generally short compared to the life-time of a fragment in space.

When the meteorite impacts the Earth, it becomes shielded from cosmic-ray bombardment. If the saturation level of C-14 is known, the amount of C-14 remaining in the meteorite is proportional to the time that the meteorite has spend on the Earth's surface.