11. Denudation rates

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

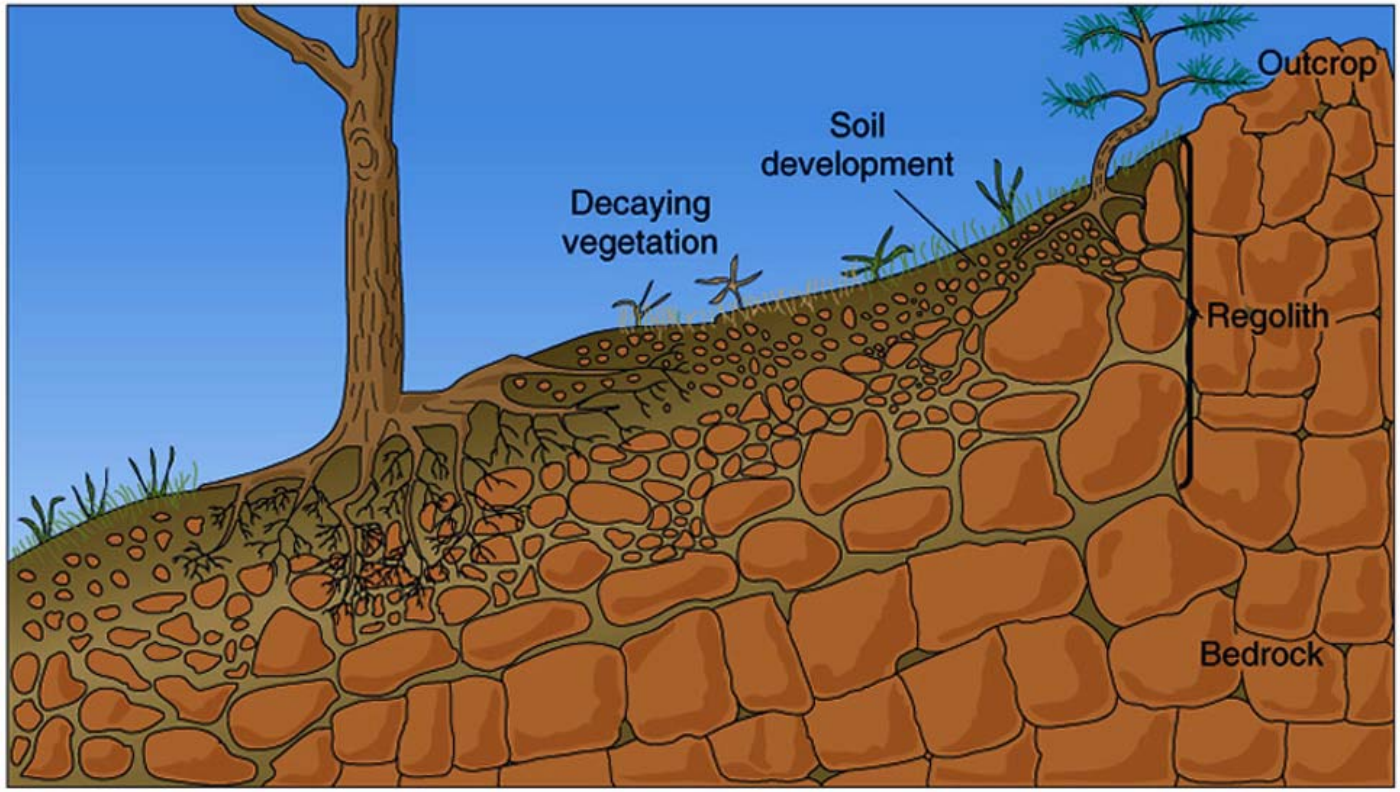
The answer, my friend, is blowing in the wind…

Bob Dylan's song cited in:
Cerling and Craig (1994): Annu. Rev. Earth Planet. Sci 22: 273-317

…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

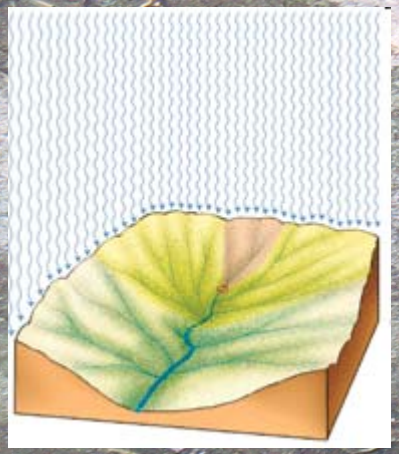
What processes regulate chemical weathering and physical erosion?

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

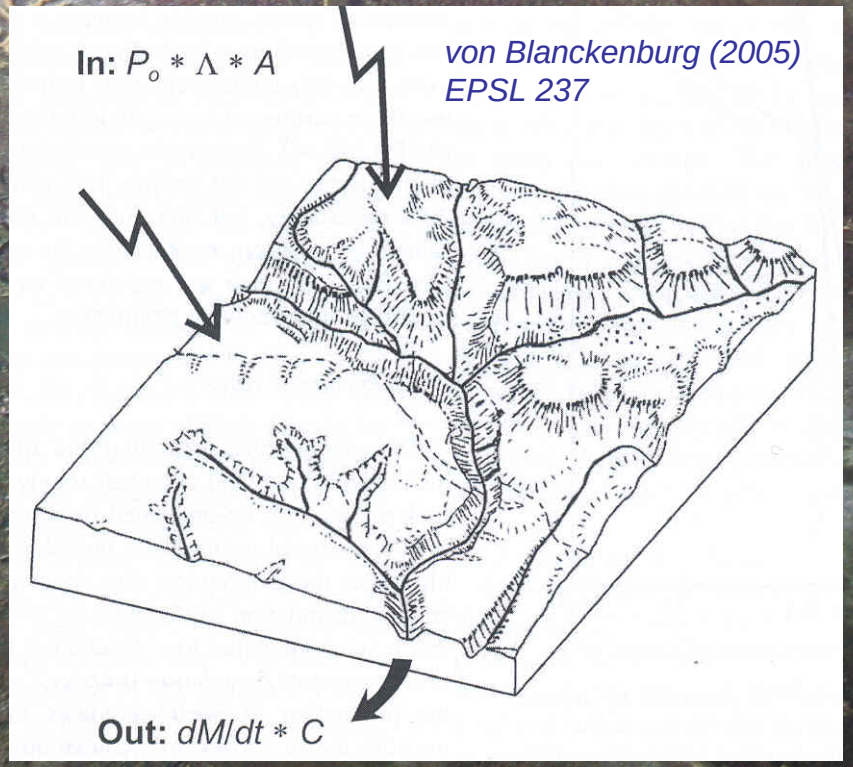


11. Catchment wide denudation rates

11. Catchment wide denudation rates

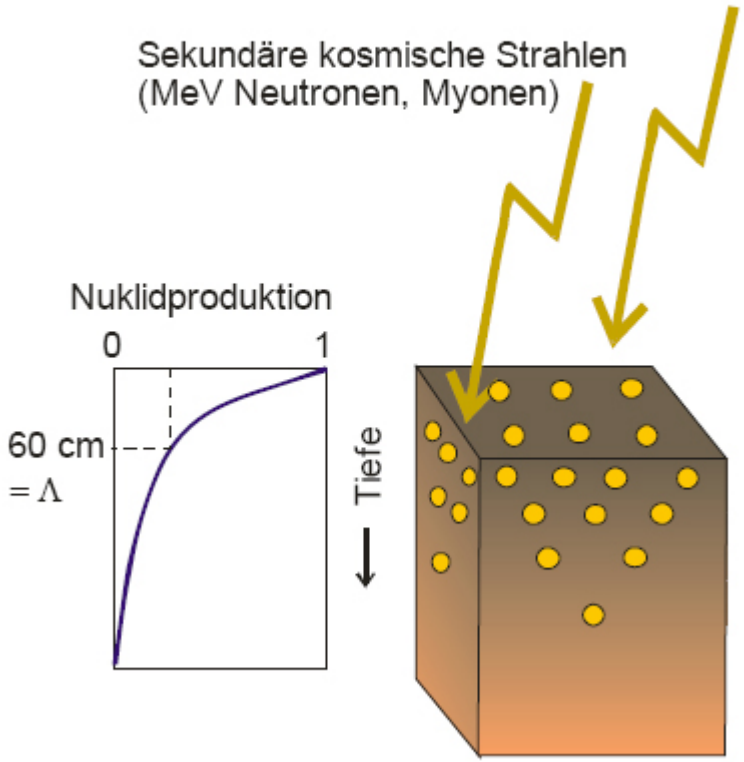
$C = P_{\Lambda}/D$

C = concentration
P = production rate
Λ = penetration length scale
D = denudation rate



11. Catchment wide denudation rates

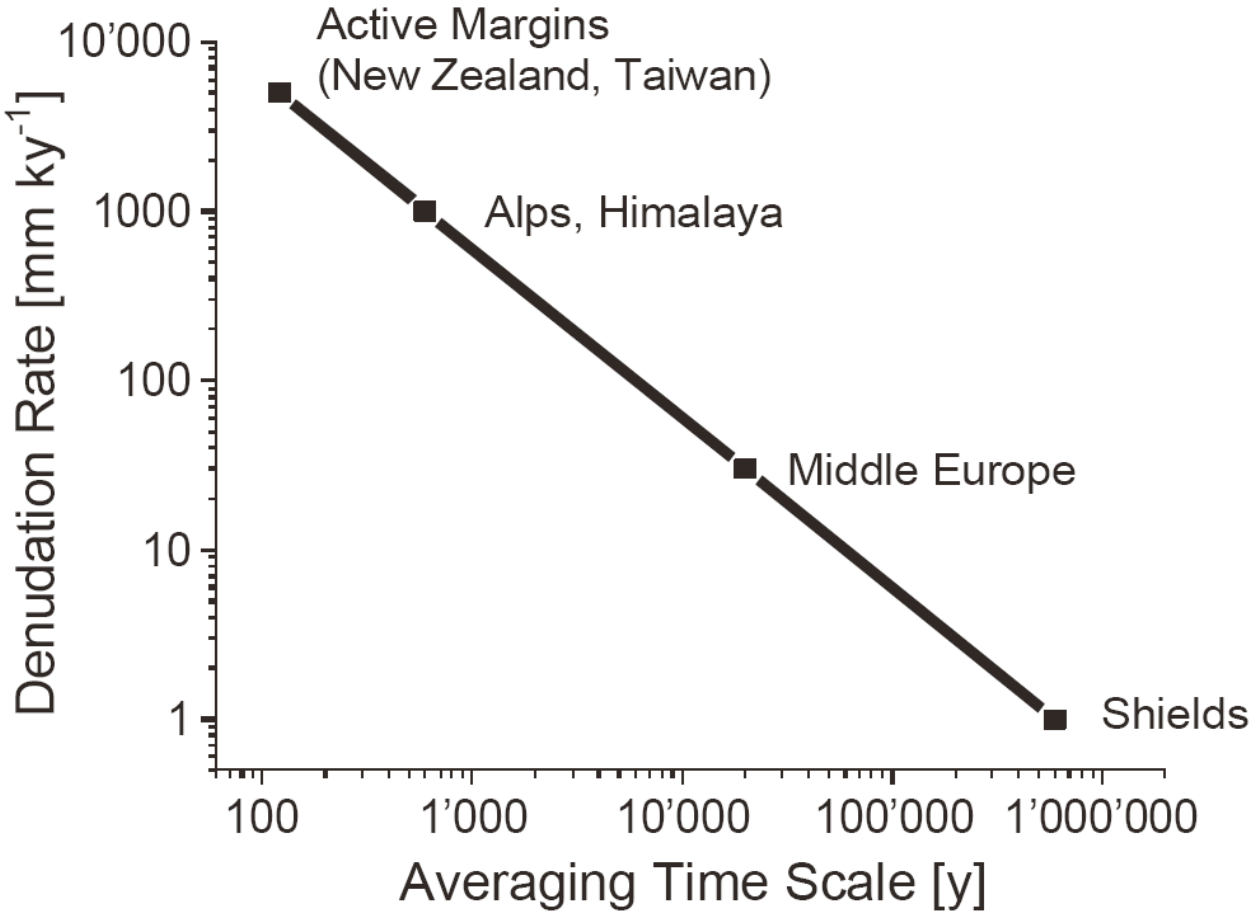
Erosionsraten aus *in situ*- produzierten kosmogenen Nukliden



$$C = \left\langle \frac{P_o}{\varepsilon/\Lambda + \lambda} \right\rangle$$

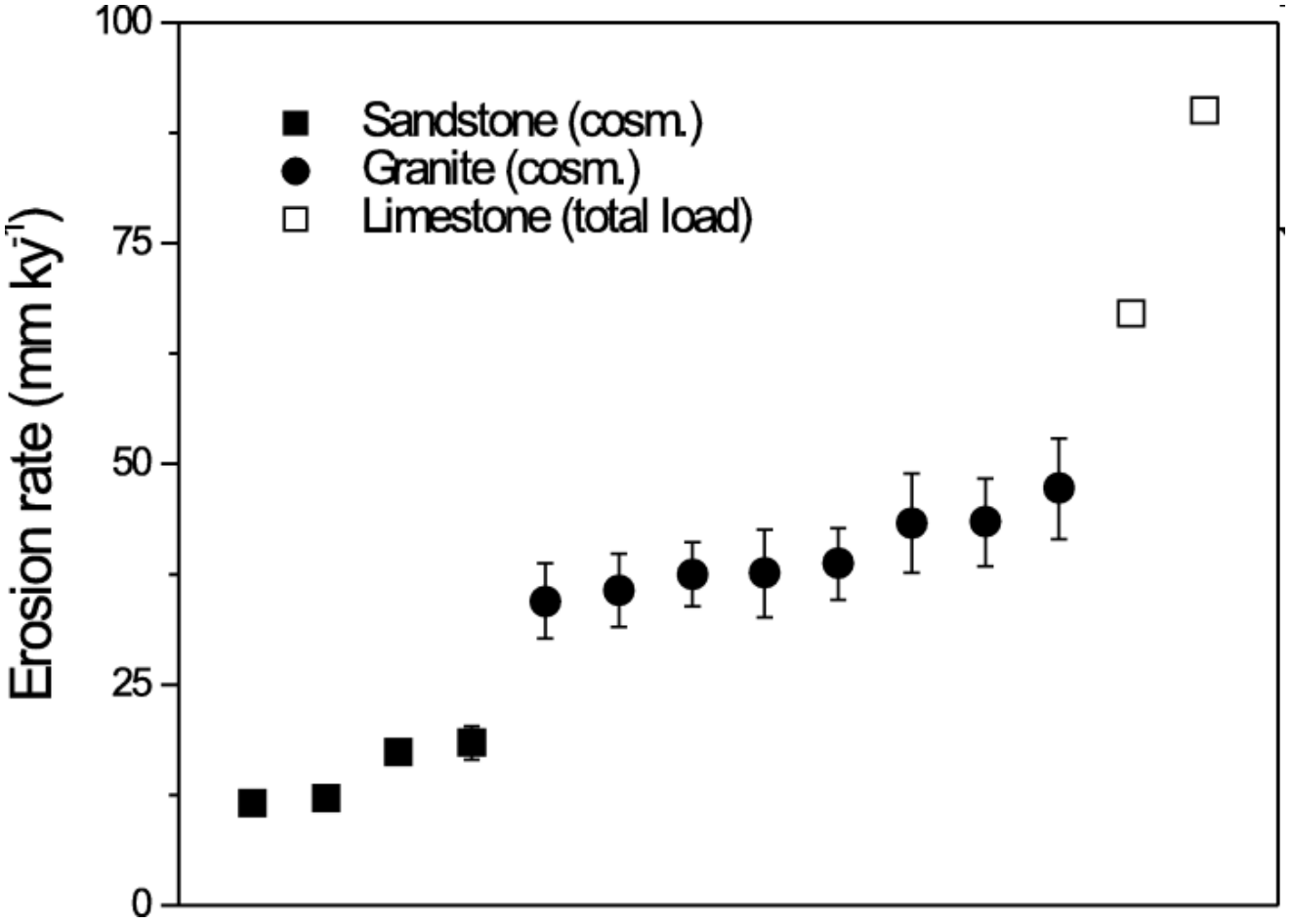
- ε : Erosionsrate
- C : Nuklidkonzentration
- P_o : Nuklid Produktionsrate an der Gesteinsoberfläche
- t : Expositionsalter
- Λ : Mittlere Abschirmtiefe
- λ : Zerfallskonstante

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:

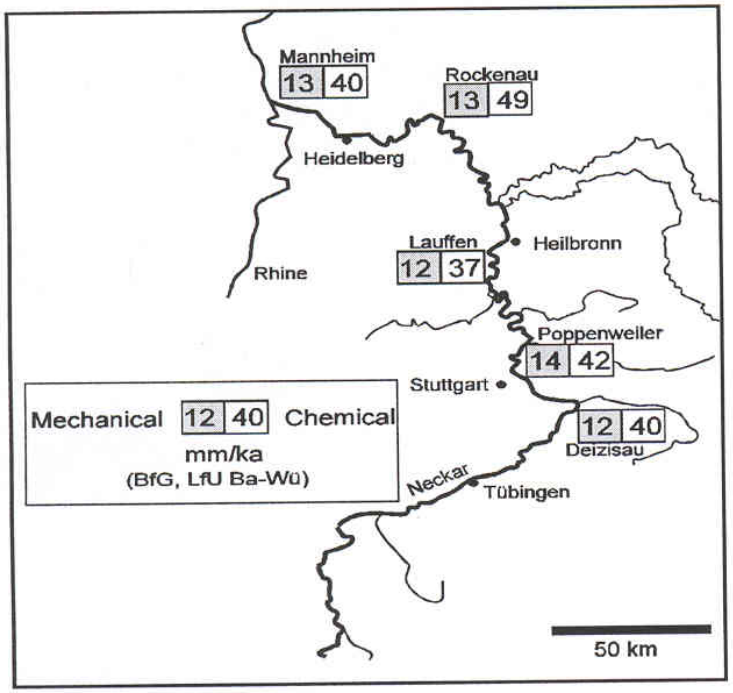


Fig. 1: Neckar denudation rates from river load data

von Blanckenburg et al.

derived from alluvial sediments:

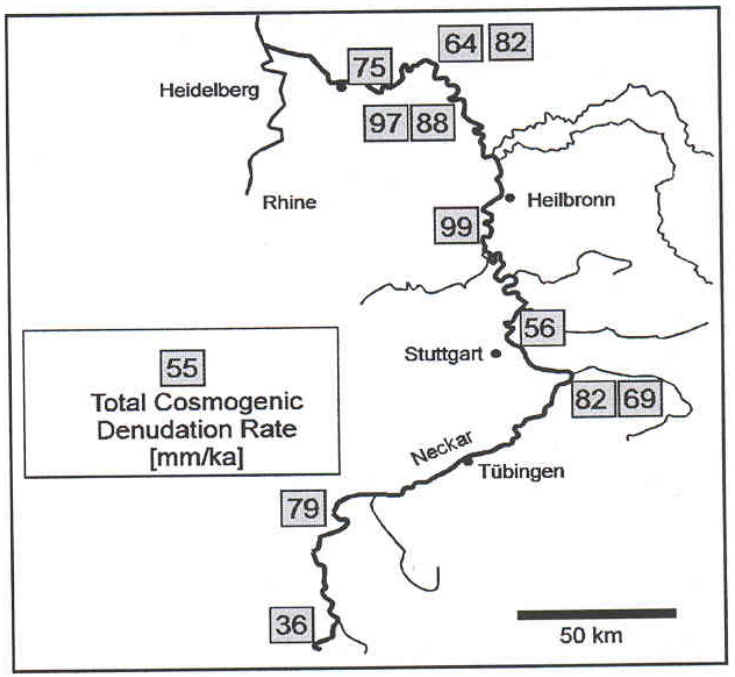
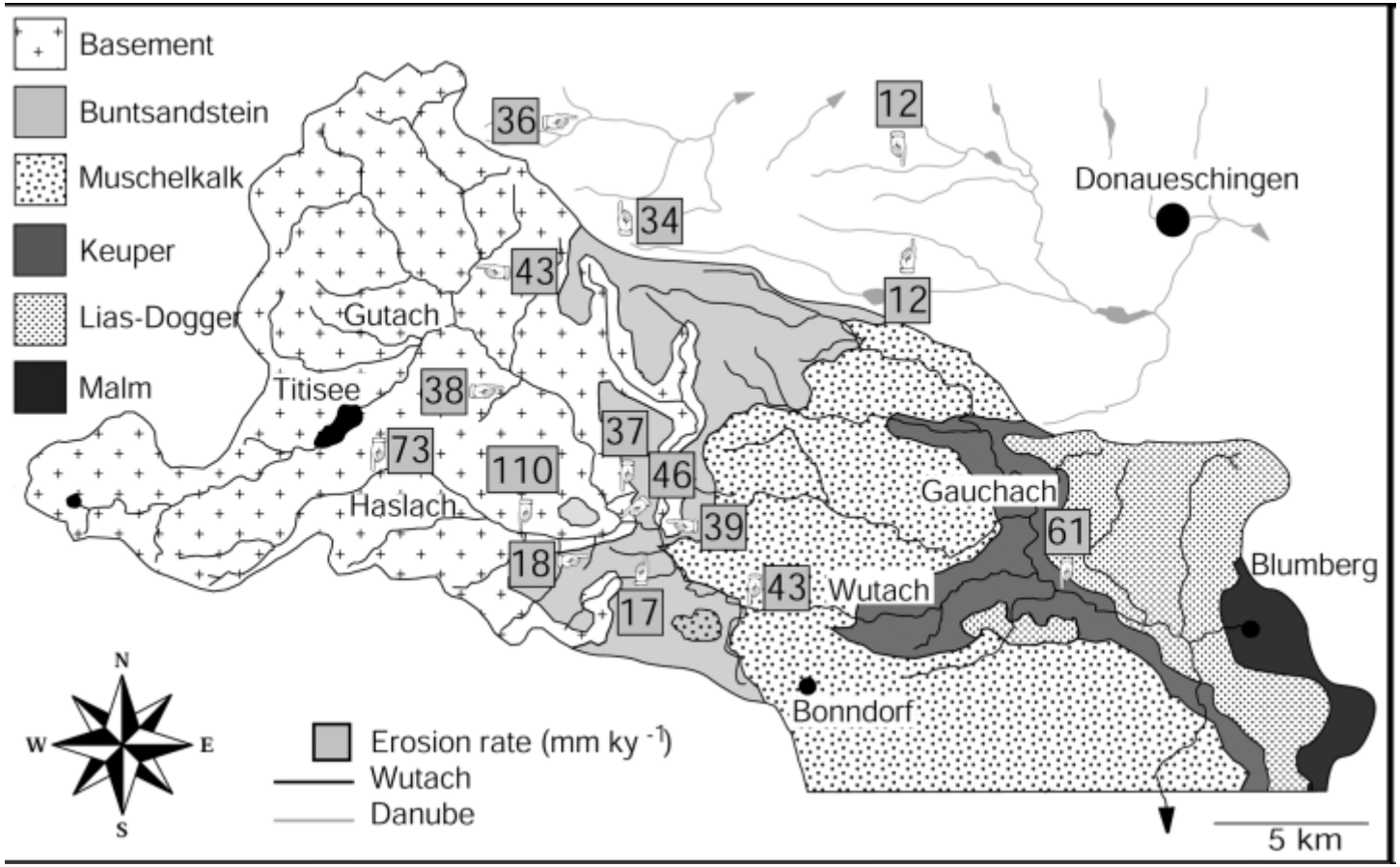


Fig. 2: Neckar total denudation rates from cosmogenic nuclides

Cosmogenic isotopes measure total denudation rate - chemical part and physical part

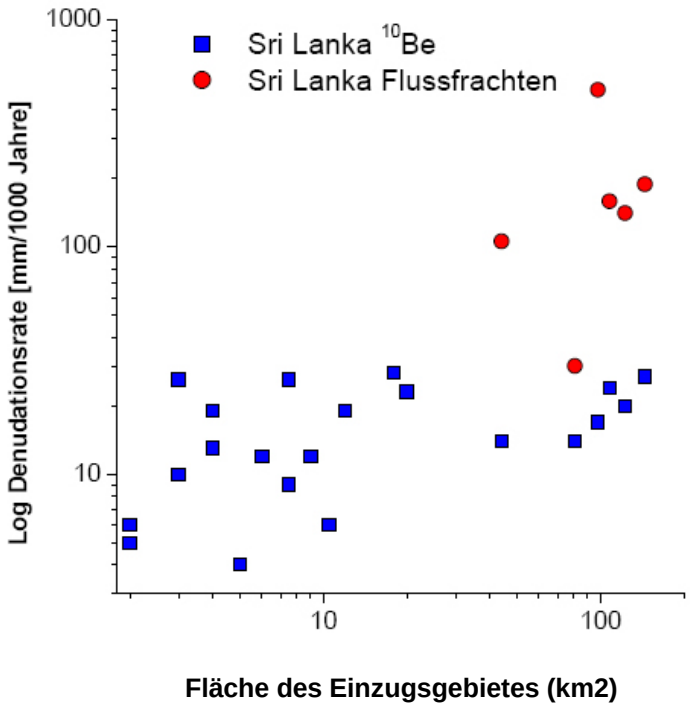
11. Catchment wide denudation rates



Morel et al. 2003 Terra Nova

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

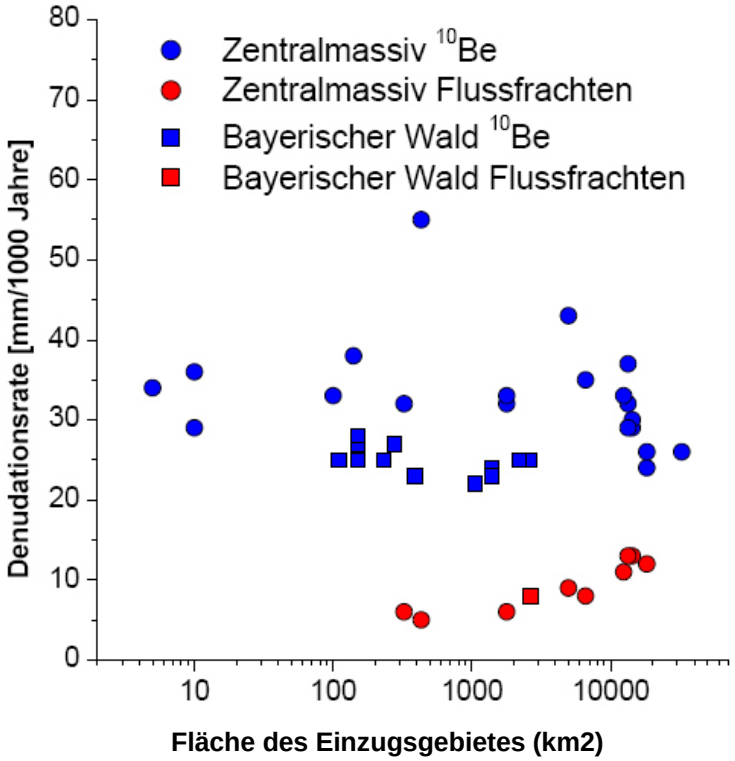
11. Catchment wide denudation rates



von Blanckenburg 2008 GMIT 33

Sri Lanka: antropogen bedingter Anstieg der Erosion

11. Catchment wide denudation rates



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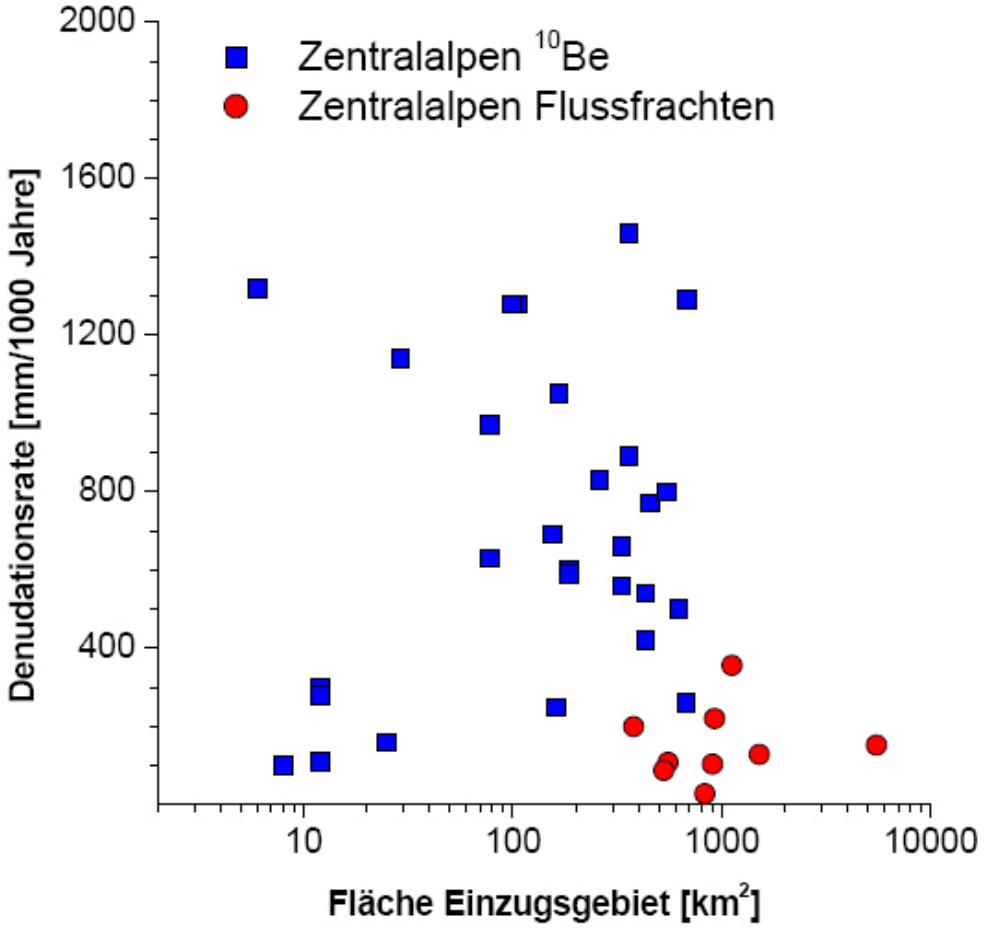
Mittelgebirge/Europa:

kosmoge Denudationsrate höher als in Sri Lanka!

Grund: quartäre tektonische Aktivität (Hebung, Grabenbildung)

Raten aus Schwebstoffen unterschätzen die wahre Abtragung

11. Catchment wide denudation rates



von Blanckenburg 2008 GMIT 33

Schweizer Alpen:

kosmogene Denudationsrate sehr hoch

Grund: starke isostatische Ausgleichsbewegung infolge von Eisverlust

Schwebstoffe unterschätzen die wahren Erosionsraten

11. Denudation rates

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

Some studies show that tectonics and not climate controls erosion rate

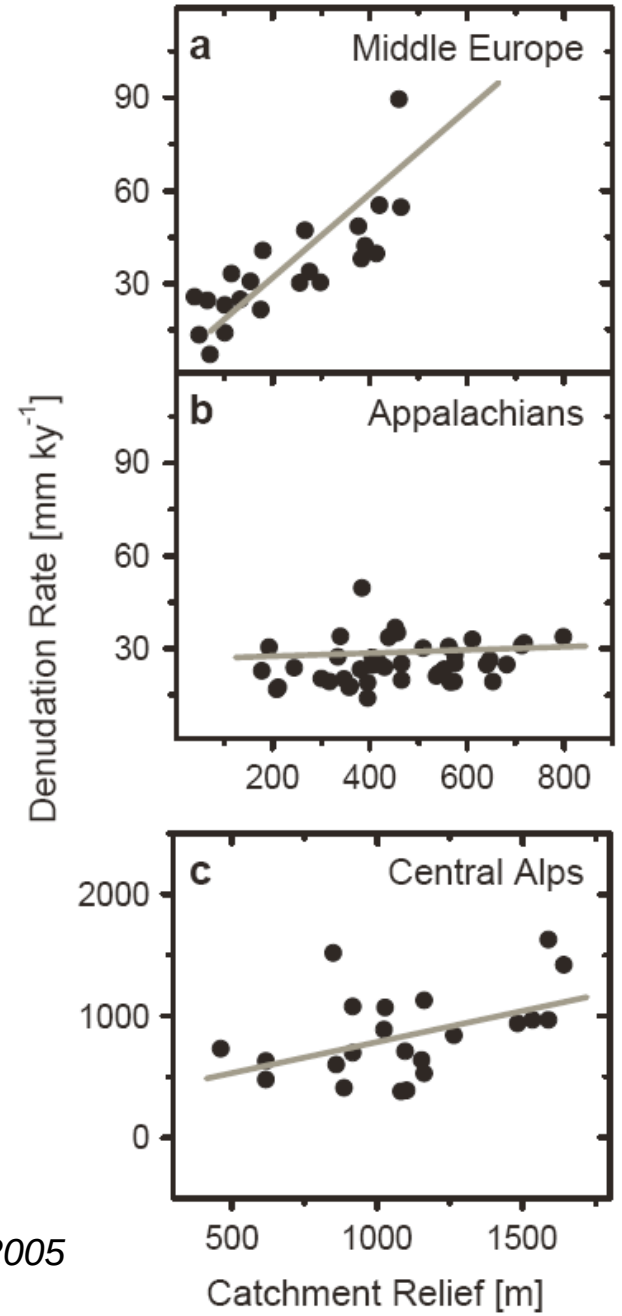
→ erosion rates in the Middle European Uplands higher than in tropical areas (Sri Lanka)

11. Denudation rates and topography

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

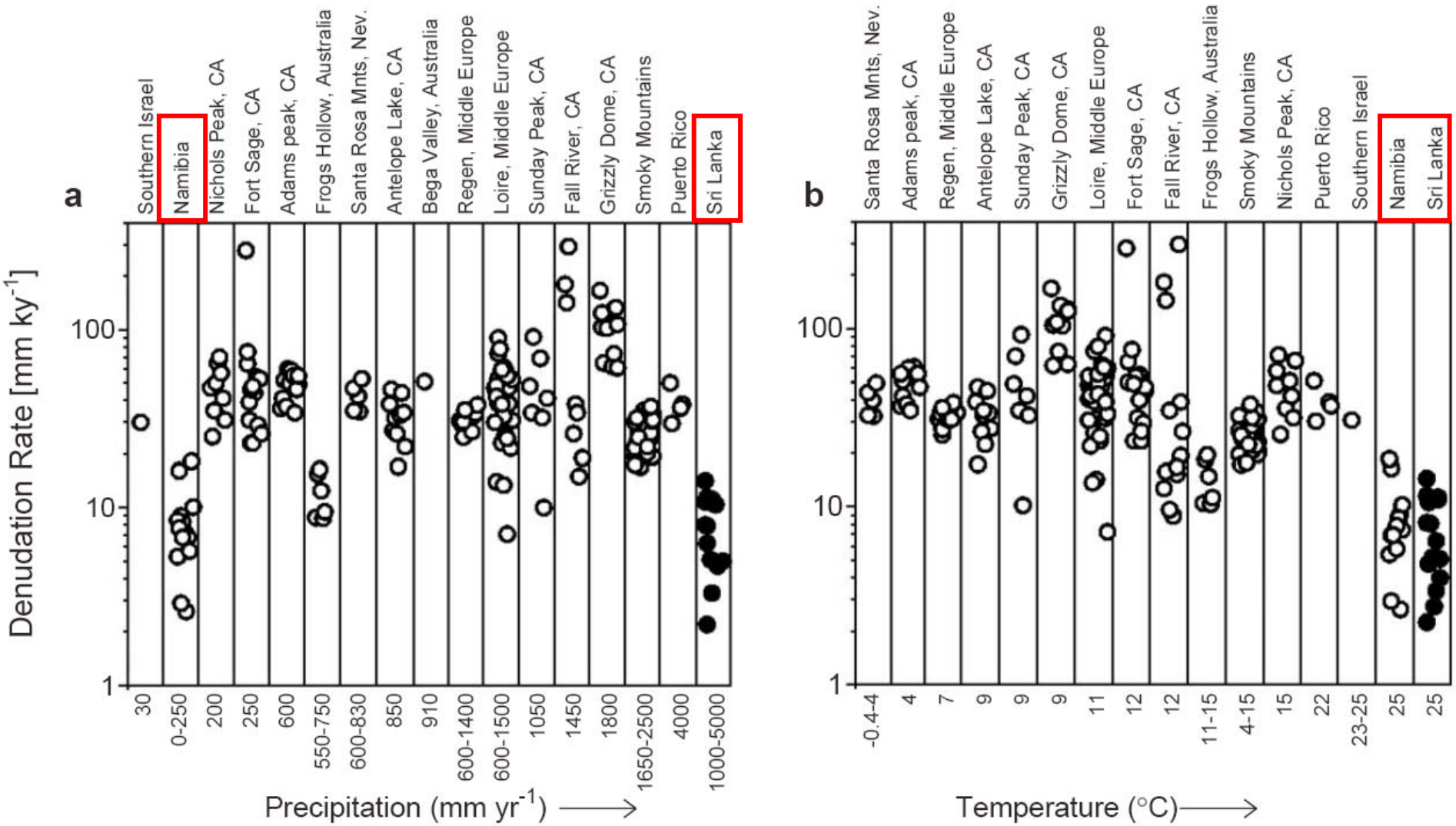
Appalachians: denudation rate uniform, independent of relief – geomorphic steady state

Swiss Alps: very high denudation rates but more or less unifom – 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

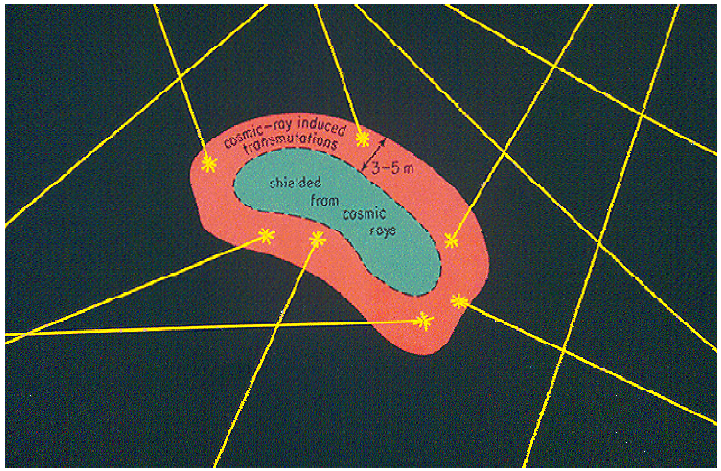
12. Cosmic-ray exposure age of meteorites

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*

12. C-14 in Meteorites

“terrestrial 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.



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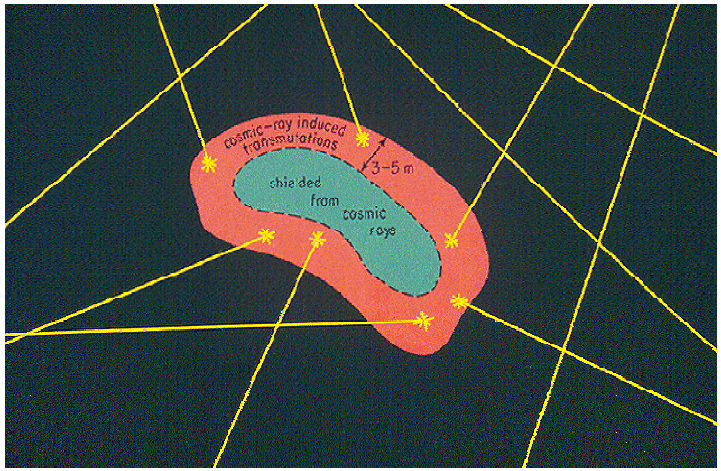

When the meteorite impacts the Earth, it becomes shielded from cosmic-ray bombardment. If the saturation level of C-14 is known, the amount of C-14 remaining in the meteorite is proportional to the time that the meteorite has spend on the Earth's surface.