UNIVERSITY OF WOLLONGONG AUSTRALIA

Ifremer

UBO Université de Bretagne Occidentale

Sediment residence time variations in an Alpine river system inferred by uranium isotopes.

Maude Thollon[1,2], Anthony Dosseto[1], Samuel Toucanne[2] and Germain Bayon[2]

[1] Wollongong Isotope Geochronology Laboratory, School of Earth and Environmental Sciences, University of Wollongong, Wollongong, NSW 2522, Australia

[2] IFREMER, Marine Geosciences Unit, 29280 Plouzané, France.

Context

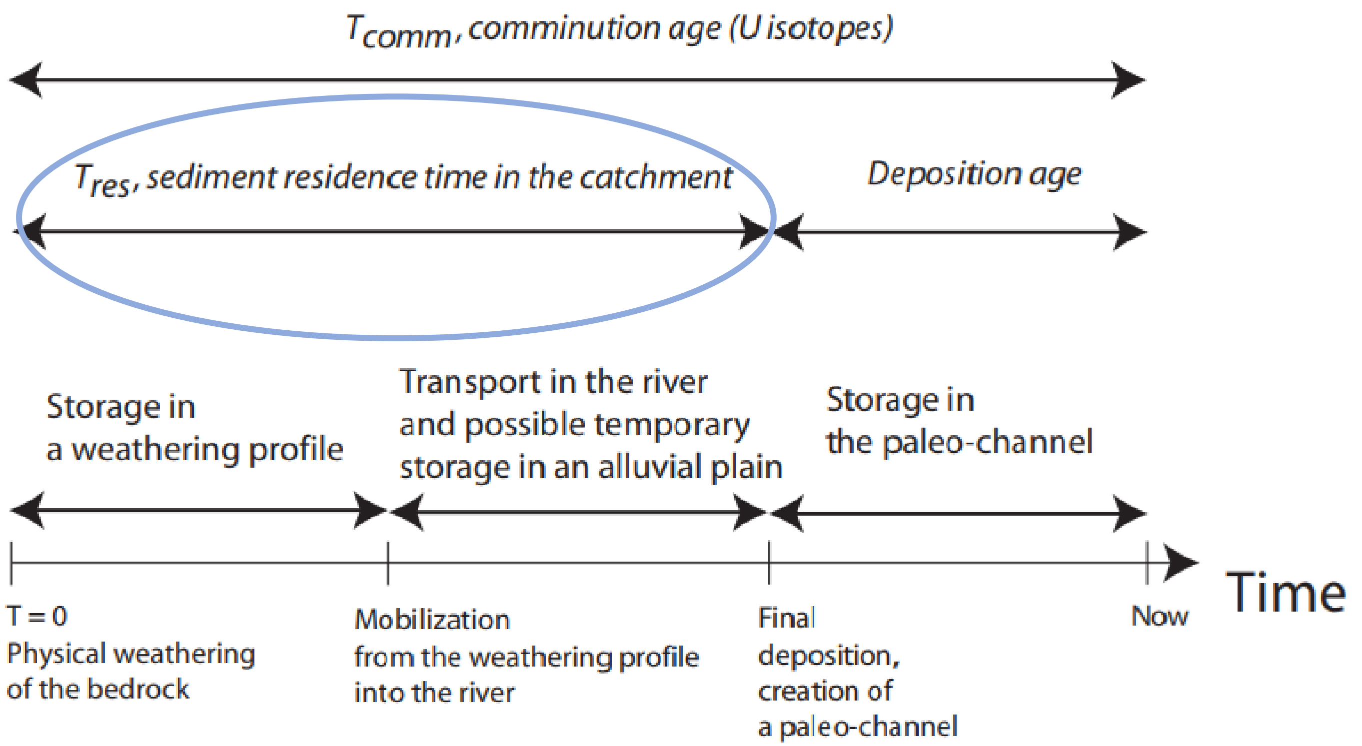
- In the context of climate change, it is important to better understand the responses of the processes (e.g. weathering, transfer, deposition) occurring in a source to sink system.

- One of the challenging goals is to quantify the timescale of sedimentary processes such as sediment weathering and transfer. In the last decades the uranium isotope activity ratio, ($^{234}U/^{238}U$) has been used to estimate sediment residence times (i.e. the time spent by the sediment in the catchment between its formation by weathering and its deposition at the end of the system).

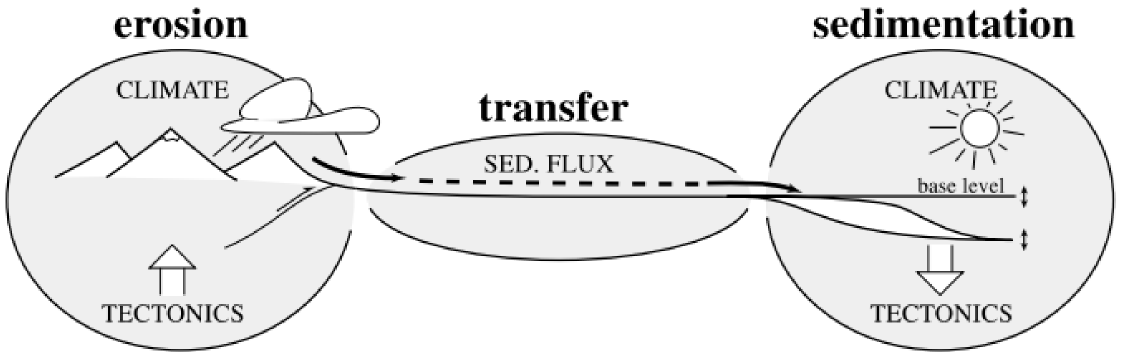
- By studying the spatial ($^{234}U/^{238}U$) variation of an actual catchment it will be possible to understand how the sediment residence time evolves according to different geomorphological parameters (e.g. elevation, slope).

- Later, these results could be applied on sediment cores to acquire a better understanding of the evolution of sediment residence time through past climate variations.

Context

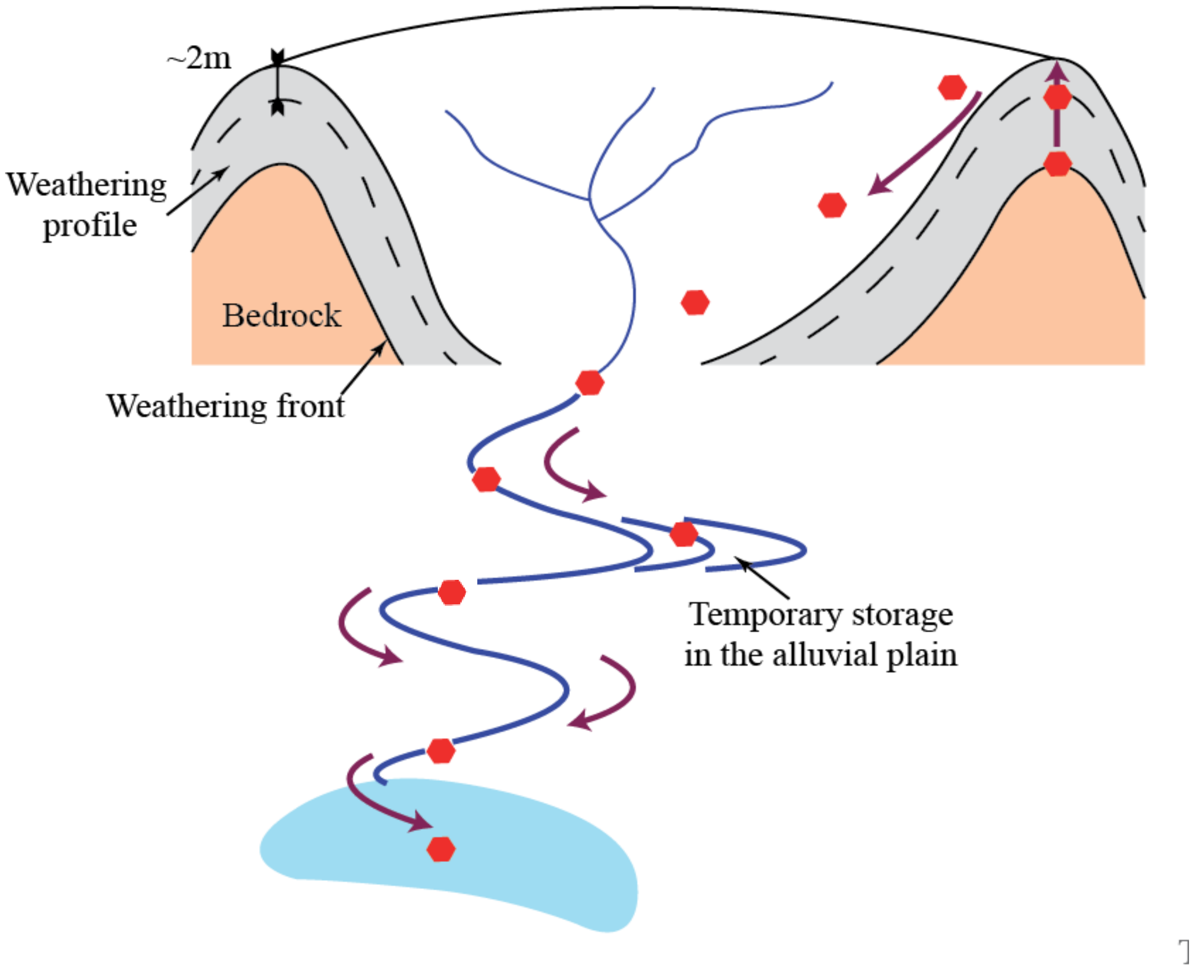


From Dosseto et al., 2010



Idealized source to sink system. From Castelltort et Van Den Driessche., 2003.

Sediment residence time



Conceptual representation of sediment (red polygone) transport from the source to the sink in a catchment.
From Dosseto and Schaller, 2016.

Hillslope storage

Sediment residence time

Alluvial storage

Sediment residence time

Calculated with ($^{234}U/^{238}U$)
from DePaolo et al. (2006) equation

$$t_{comm} = -\frac{1}{\lambda_{234}} ln\left[\frac{A_{meas} - (1 - f_\alpha)}{A_0 - (1 - f_\alpha)}\right]$$

- t_{comm} is the comminution age (yrs)
- λ_{234} is the ^{234}U decay constant (yrs)
- A_{meas} is ($^{234}U/^{238}U$) measured
- A_0 is ($^{234}U/^{238}U$) at t=0, in unweathered bedrock
- f_α is the recoiled fraction estimated with the specific surface area of the grain

In river sediments:

$$t_{comm} = t_{res} \qquad (deposition\ age = 0)$$

Estimated from soil thickness

$$estimated\ t_{res} = \frac{denudation\ rate\ (\frac{mm}{yrs})}{soil\ thickness\ (mm)}$$

- denudation rate from Mariotti et al. (2019) on the 50-100µm fraction (or 100-250µm when not available)
- estimated soil thickness from SoilGrids (*(https://www.soilgrids.org)*

Uranium activity ratio

Bedrock
$(^{234}U/^{238}U) = 1$

Weathering

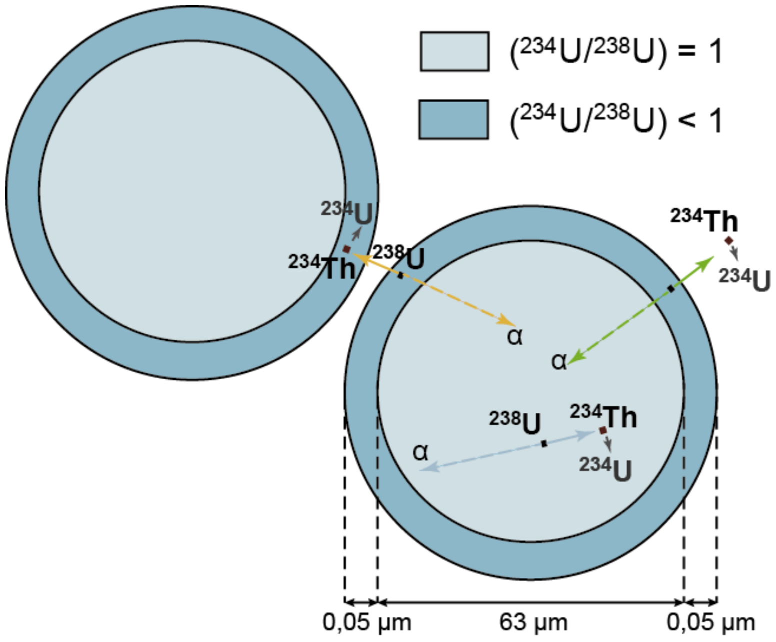
Sediments
$(^{234}U/^{238}U) < 1$

River
$(^{234}U/^{238}U) > 1$

Chemical fractionation

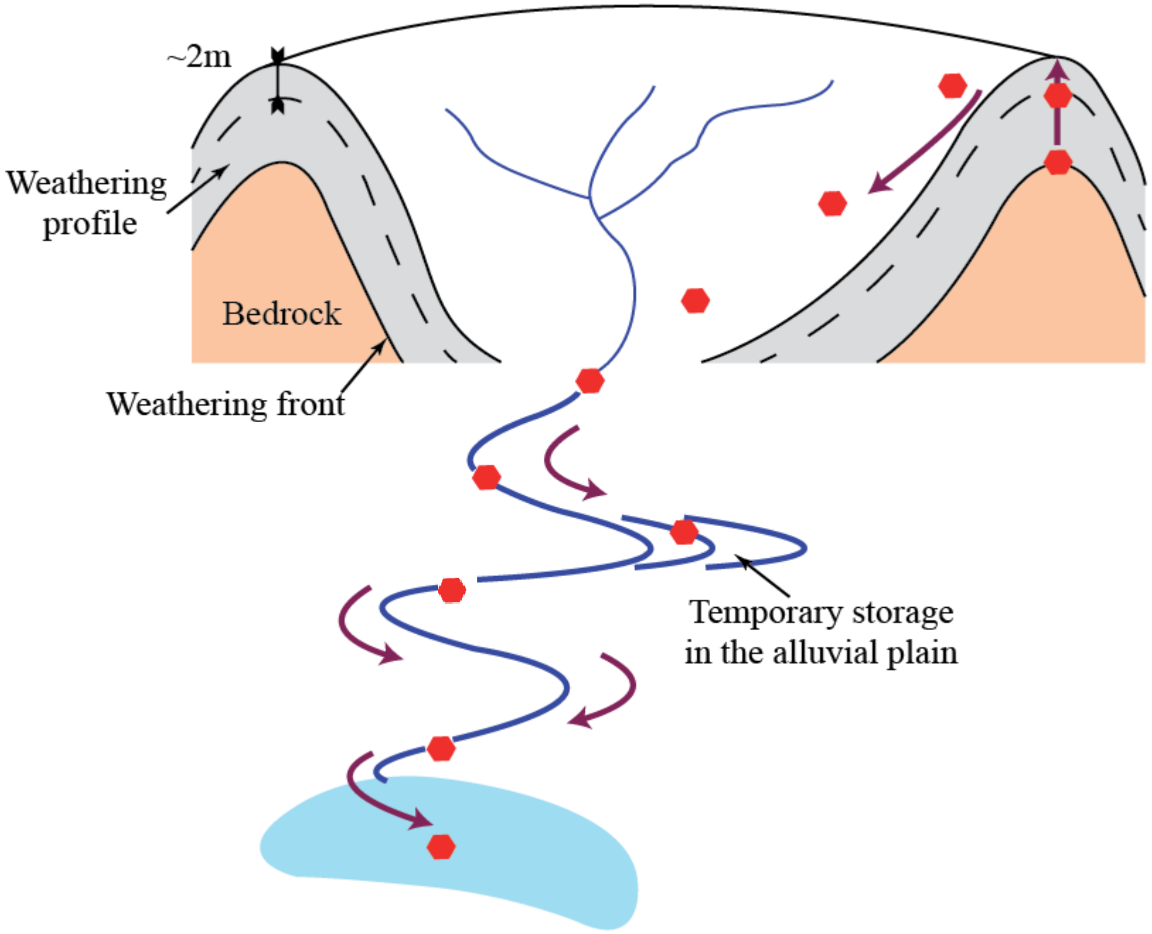
- Preferential leaching of ^{234}U compared to ^{238}U
- Preferential oxidation of ^{234}U compared to ^{238}U

Recoil effect



Schema of recoil effect. Adapted from DePaolo et al., 2006.

Objectives



Conceptual representation of sediment (red polygone) transport from the source to the sink in a catchment.
From Dosseto and Schaller, 2016.

- Quantifying the actual sedimentary residence time

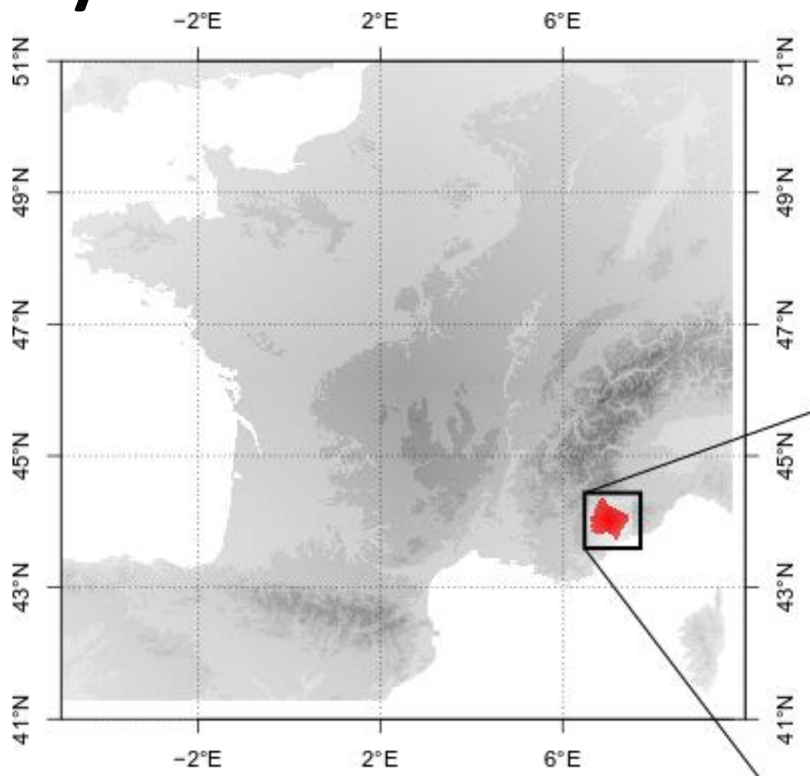
→ better constrain the source to sink system

- Analyzing the sedimentary residence time depending on geomorphologic parameters

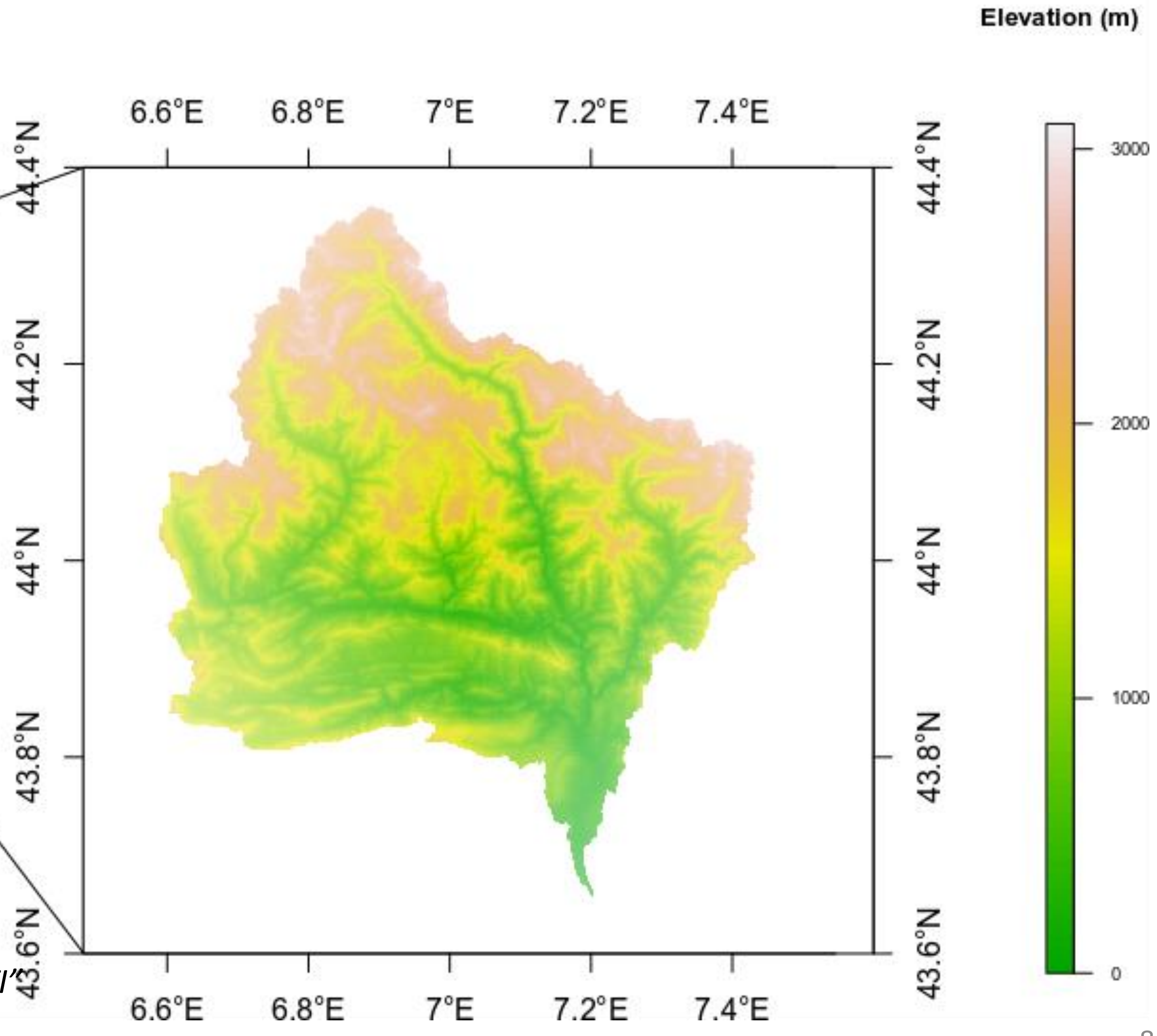
→ study the influence of the landscape morphology

Study site

- Mountainous sedimentary system: sedimentary transfer expected to be rapid
- No fluvial plain: no alluvial storage

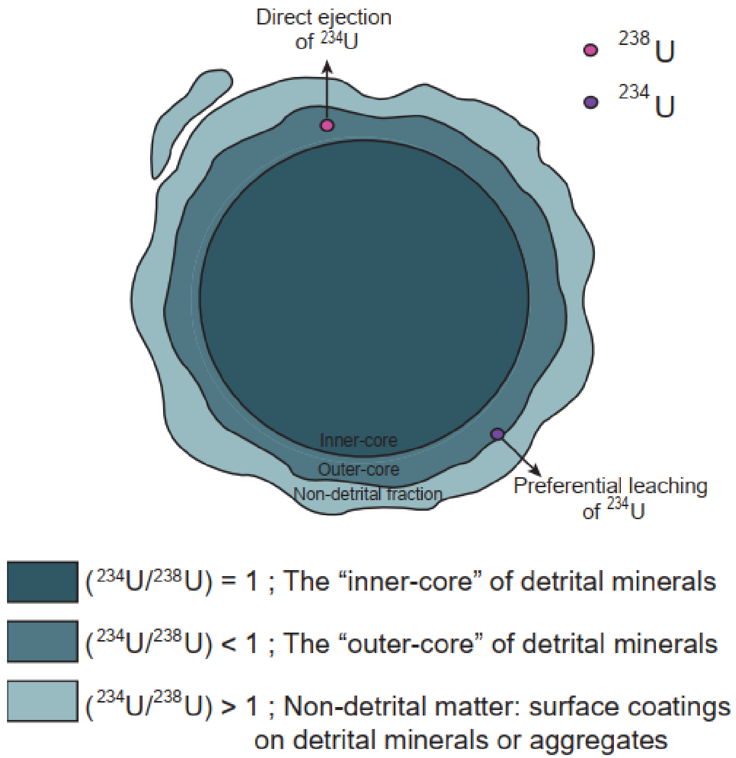


Map of the localisation of the Var catchment (France) on digital elevation model (DEM) background from ETOPO1 Global relief Model (https://www.ngdc.noaa.gov/mgg/global/global.html)



Digital elevation model (DEM) of the Var catchment at a resolution of 5m (DEM "RGE ALTI" produced by the French Institut National de l'Information Géographique et Forestière)

Methods



The sedimentary grains can be separated in three different parts based on their respective ($^{234}U/^{238}U$) activity ratio.
Adapted from Martin el al., 2015.

SIEVING
keep the finest fraction (<63µm)

LEACHING
remove the non detrital matter
(protocol from Francke et al., 2018)

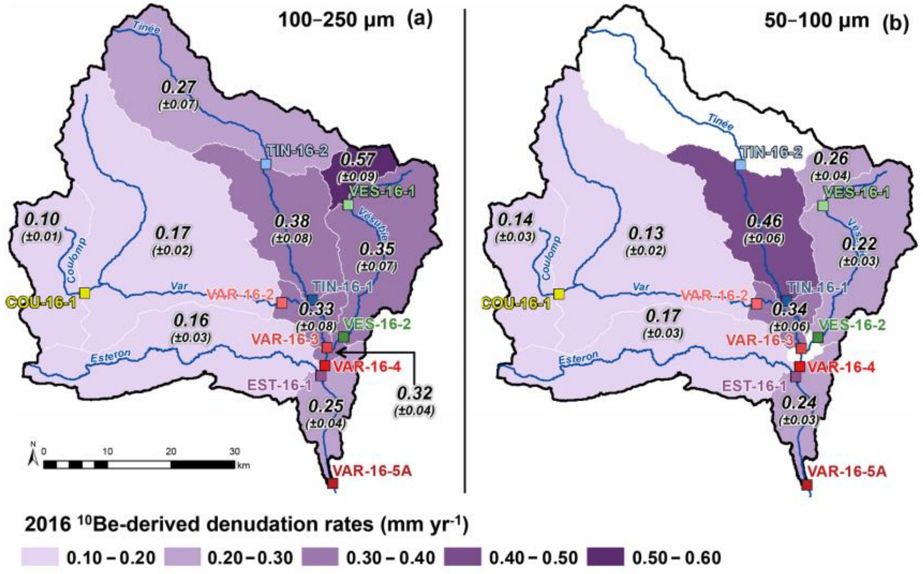
BET analyses
Measurement of the specific surface area

DIGESTION
put the sediment sample into solution

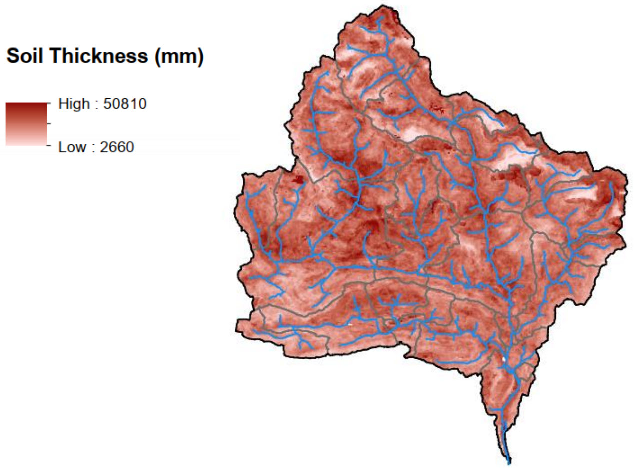
U ELUTION
isolate the U fraction from the matrix

U ISOTOPES ANALYSIS
by MC-ICP-MS

Methods



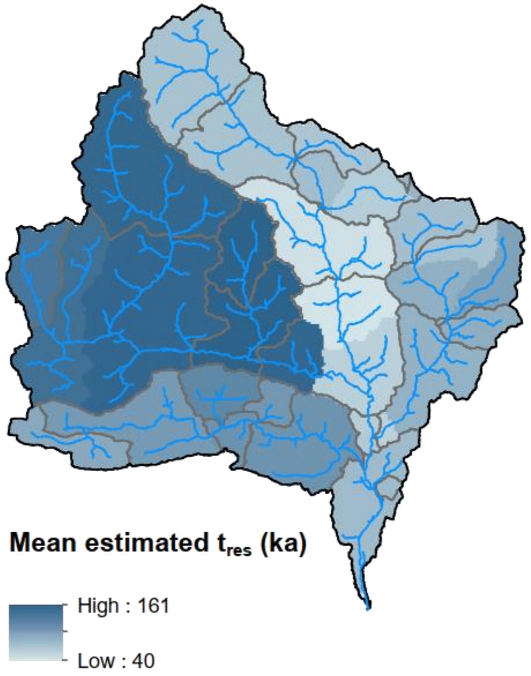
Denudation rate inside the Var cachment on two sediments size fractions (Mariotti et al., 2019)



Estimated depths to bedrock (mm) from the soilGrids database used as soil thickness data for the study

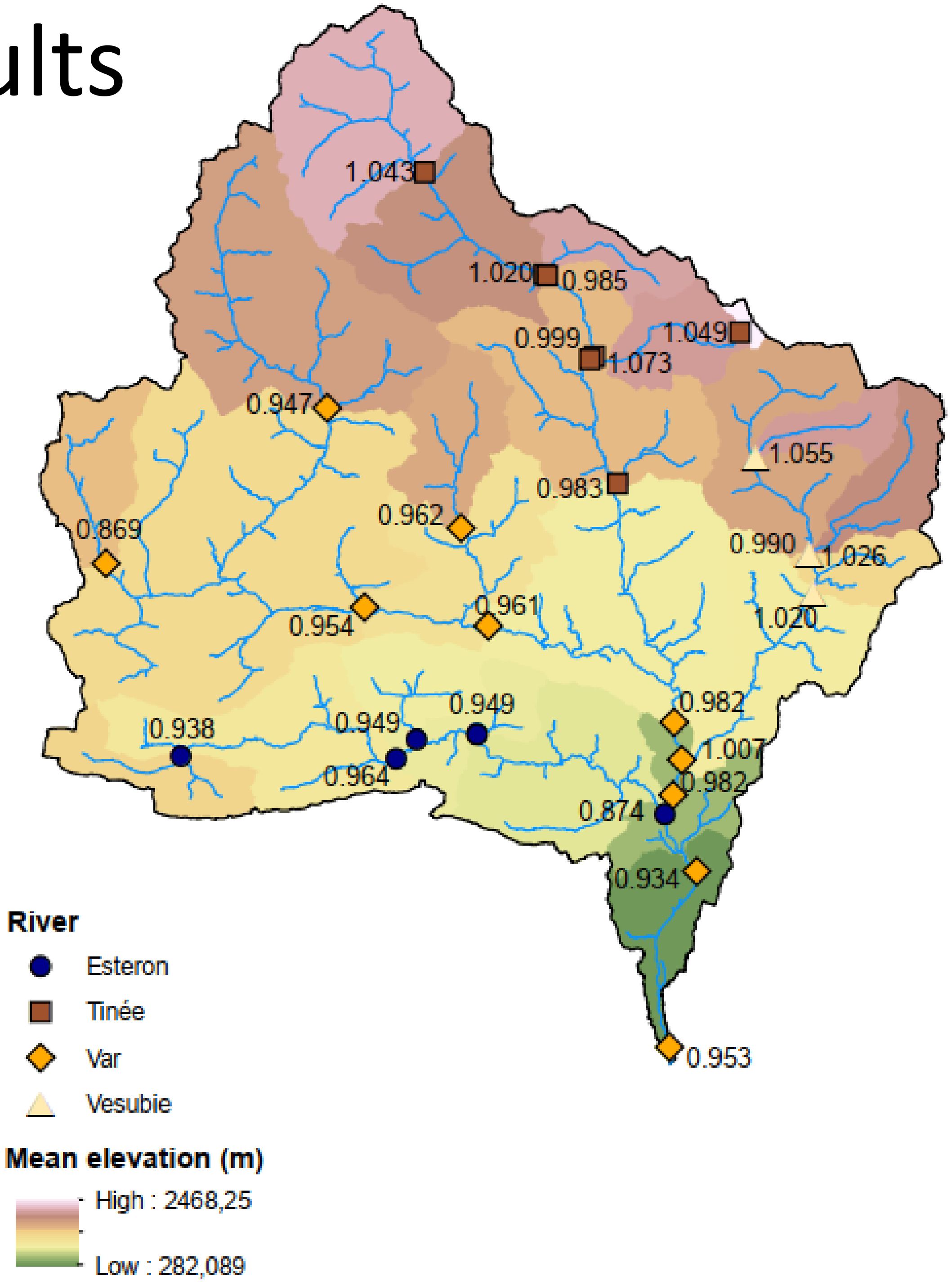
$$estimated\ t_{res} = \frac{denudation\ rate\ (\frac{mm}{yrs})}{soil\ thickness\ (mm)}$$

Soil thickness data processes for each mean, maximum and minimum values for each subcatchment



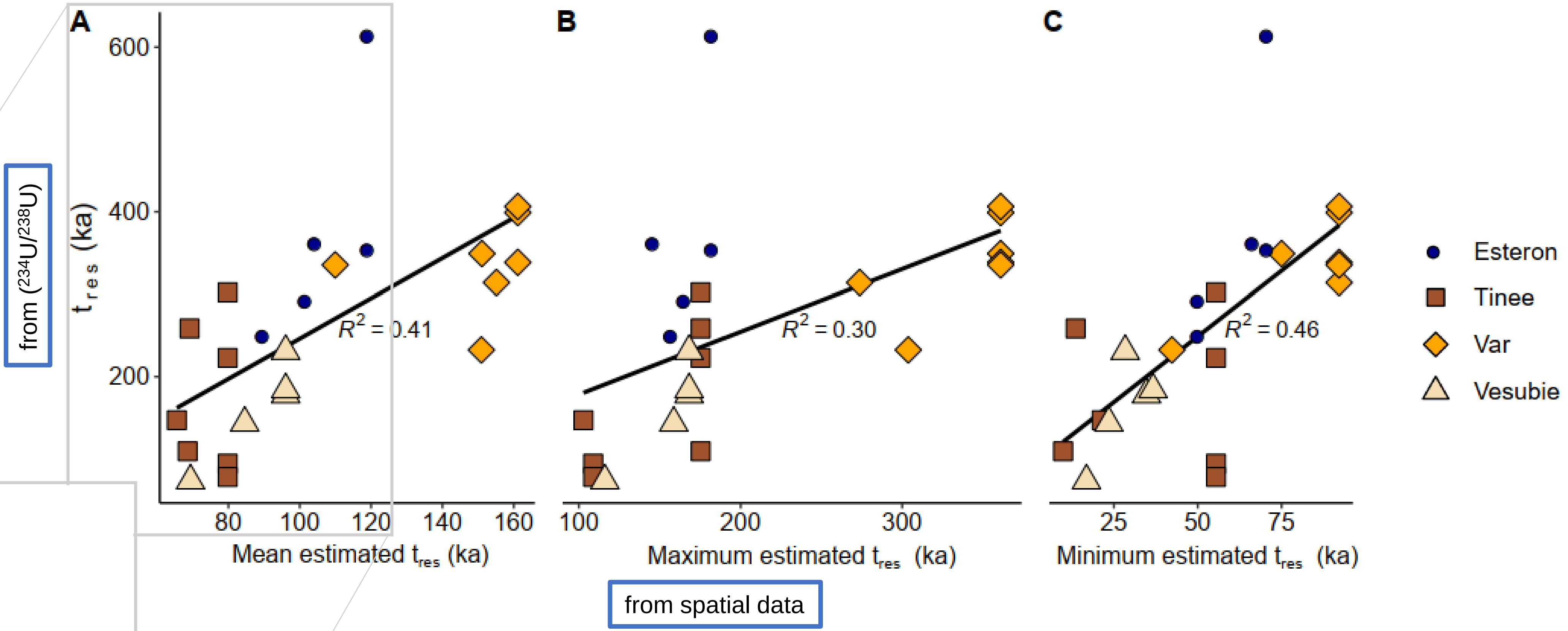
Exemple of the mean estimated residence time (ka) calculated for each subcatchment

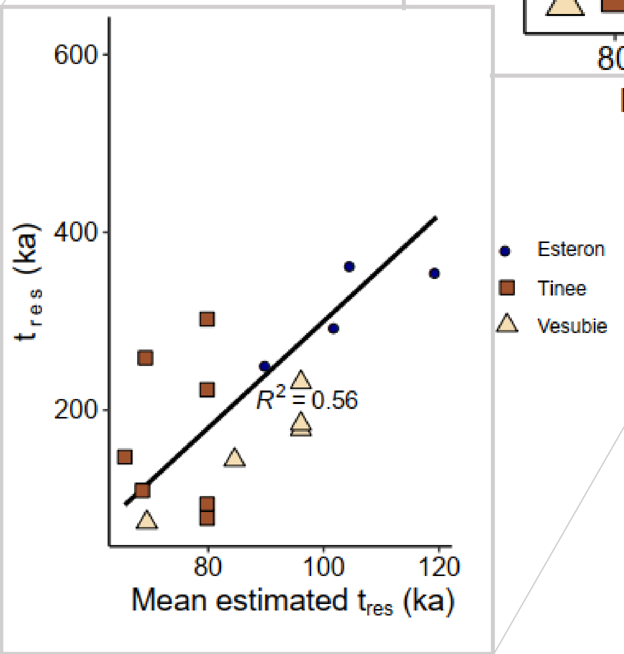
Results



- High ($^{234}U/^{238}U$) values for Esteron and Tinée river sediments
- Low ($^{234}U/^{238}U$) values for Var and Vesubie river sediments

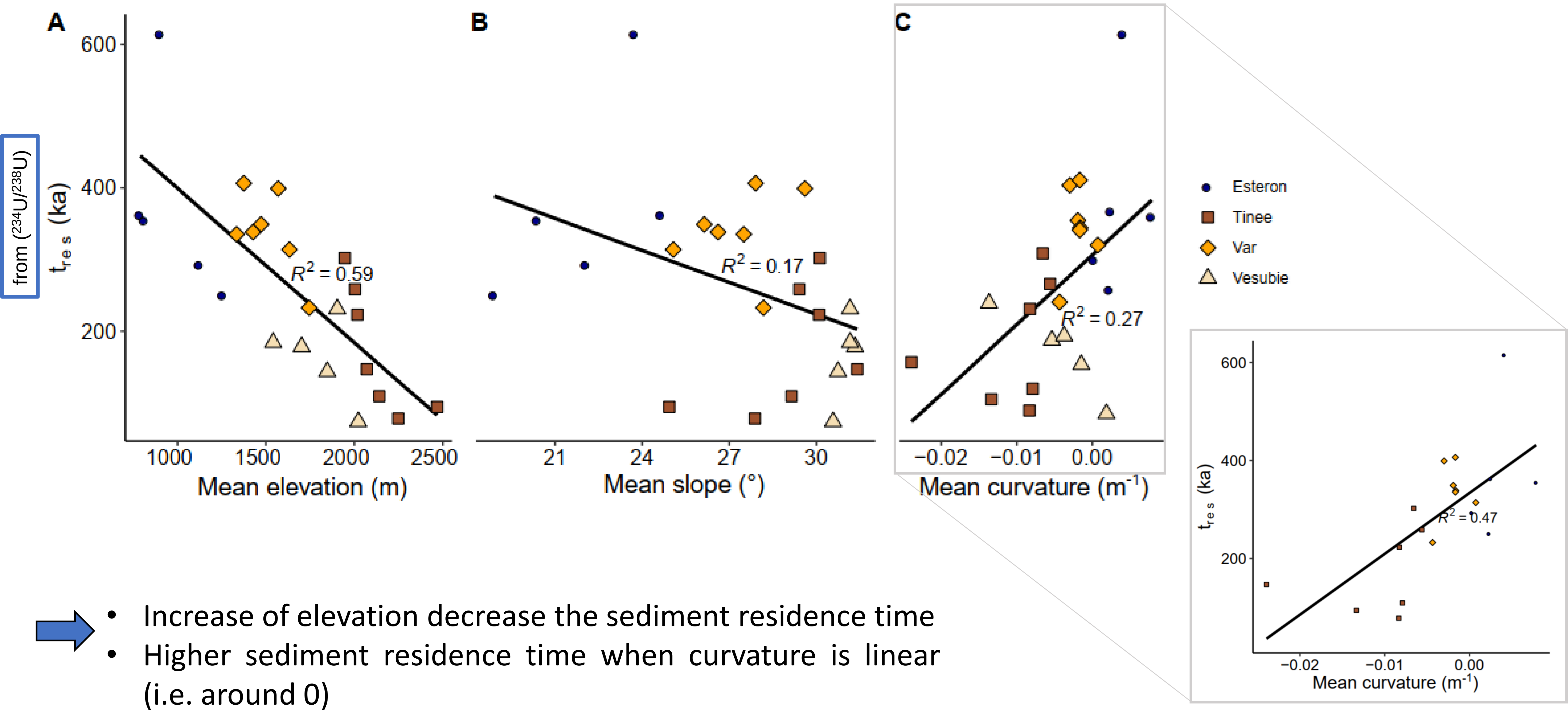
Residence time





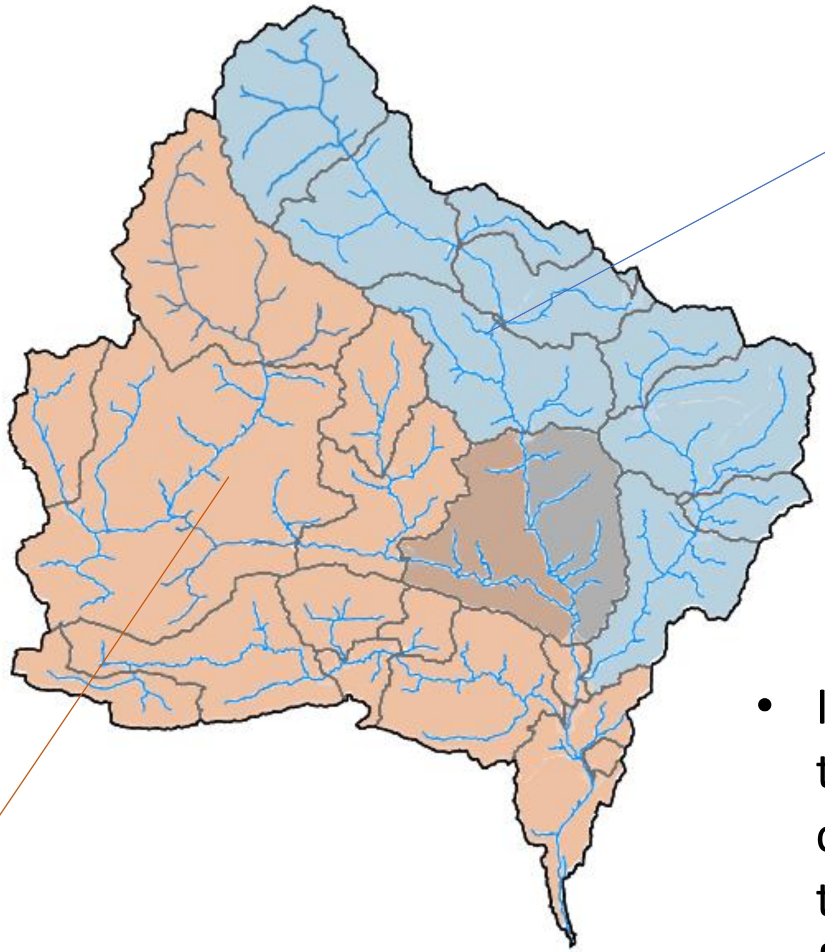
- Estimation of residence time based on denudation rate and soil thickness are underestimated, which can be caused by the denudation rate measurement on a different size fraction
- Var sediments mean estimated residence time might be disturbed by the presence of alluvial cover which have not been considered in the soil thickness estimation.

Geomorphological variations



- Increase of elevation decrease the sediment residence time
- Higher sediment residence time when curvature is linear (i.e. around 0)

Conclusion



Weathering-limited area
High relief
High slope
Non linear-curvature

$(^{234}U/^{238}U) \geq 1$
Low sediment residence time

Transport-limited area
Low relief
Low slope
Linear-curvature

$(^{234}U/^{238}U) < 1$
High sediment residence time

- In low elevation area, the soil is generally thicker leading to an increase of the storage capacity. Thus, the sediment will stay longer in the source to sink system leading to a higher fractionation between ^{234}U and ^{238}U

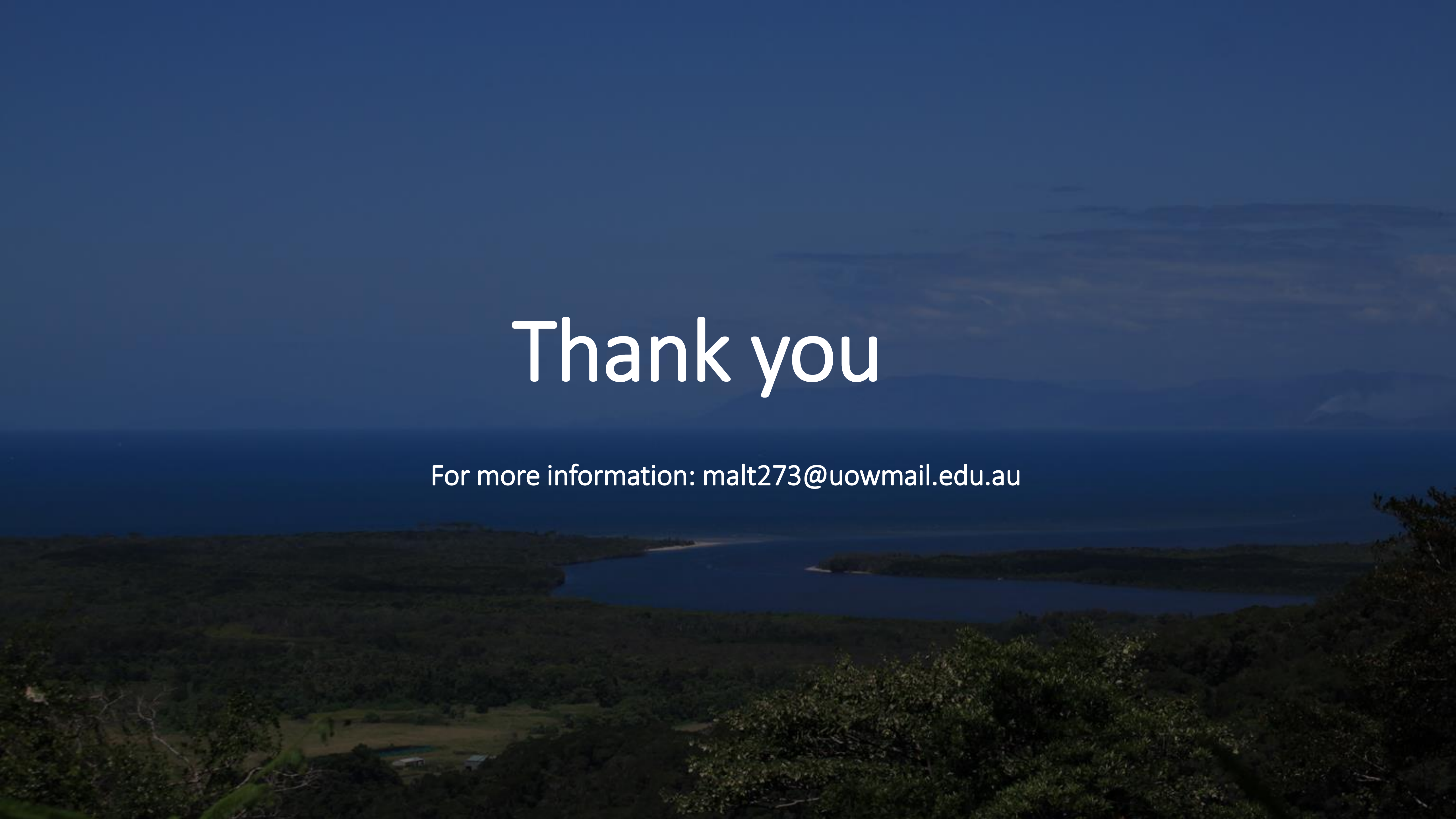
- In mountainous region, the denudation rate is high leading to thin soil thickness. Thus, the sediment will be exported quickly out of the source to sink system leading to $(^{234}U/^{238}U)$ close to 1.

Perspective

- Studying ($^{234}U/^{238}U$) in core sediments samples to measure past sediment residence time variations.

- Linked the past sediment residence time variations with a source tracer (e.g. Nd isotopes) to identify if the U variations are caused by a sediment source change or if it is due to a past geomorphological variations. It could provide information on paleo-weathering as the soil thickness is the balance between soil production and soil denudation.

Sediment residence time could be used to reconstruct paleo-geomorphological variations and linked it with the past climatic variations



Thank you

For more information: malt273@uowmail.edu.au

References

- Castelltort, S. and Van Den Driessche, J., 2003. How plausible are high-frequency sediment supply-driven cycles in the stratigraphic record?. *Sedimentary Geology*, *157*(1-2), pp.3-13.
- Dosseto, A. and Schaller, M., 2016. The erosion response to Quaternary climate change quantified using uranium isotopes and in situ-produced cosmogenic nuclides. *Earth-Science Reviews*, *155*, pp.60-81.
- Martin, A.N., Dosseto, A. and Kinsley, L.P., 2015. Evaluating the removal of non-detrital matter from soils and sediment using uranium isotopes. *Chemical Geology*, *396*, pp.124-133.
- Mariotti, A., Blard, P.H., Charreau, J., Petit, C., Molliex, S. and ASTER Team, 2019. Denudation systematics inferred from in situ cosmogenic 10 Be concentrations in fine (50–100 µm) and medium (100–250 µm) sediments of the Var River basin, southern French Alps. *Earth Surface Dynamics*, *7*(4), pp.1059-1074.