

River incision, climate and vertical motions since the LGM in south-western Alps (France)

Carole Petit¹, Rolland Yann², Braucher Régis³, Boulès Didier³, Cardinal Thibaut¹, Mariotti Apolline⁴, and Audin Laurence⁵ and the ASTER Team³

1- Université Côte d'Azur, CNRS, Observatoire de la Côte d'Azur, Géoazur, Valbonne Sophia Antipolis, France
(petit@geoazur.unice.fr)

2- Environment, Dynamics and Territories of the Mountain (Edytem), Université Savoie Mont Blanc, CNRS, Chambéry, France

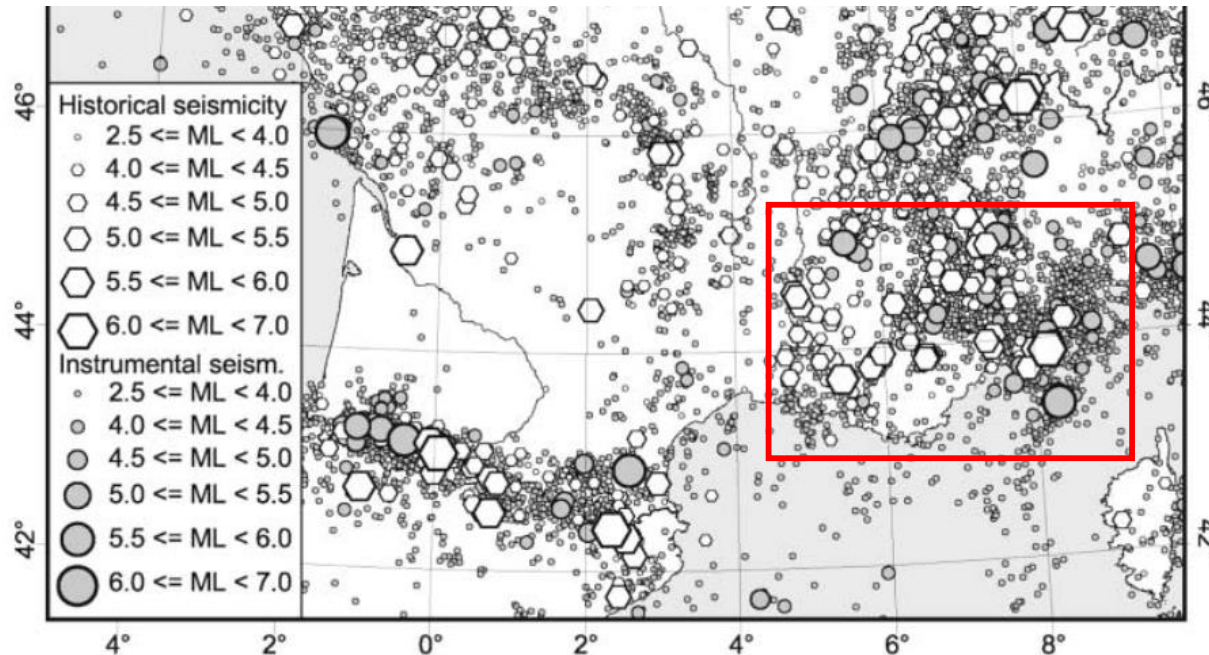
3- Aix Marseille Univ, CNRS, IRD, INRAE, Coll France, CEREGE, Aix-en-Provence, France

4- CRPG, CNRS - Université de Lorraine, Vandoeuvre-lès-Nancy, France

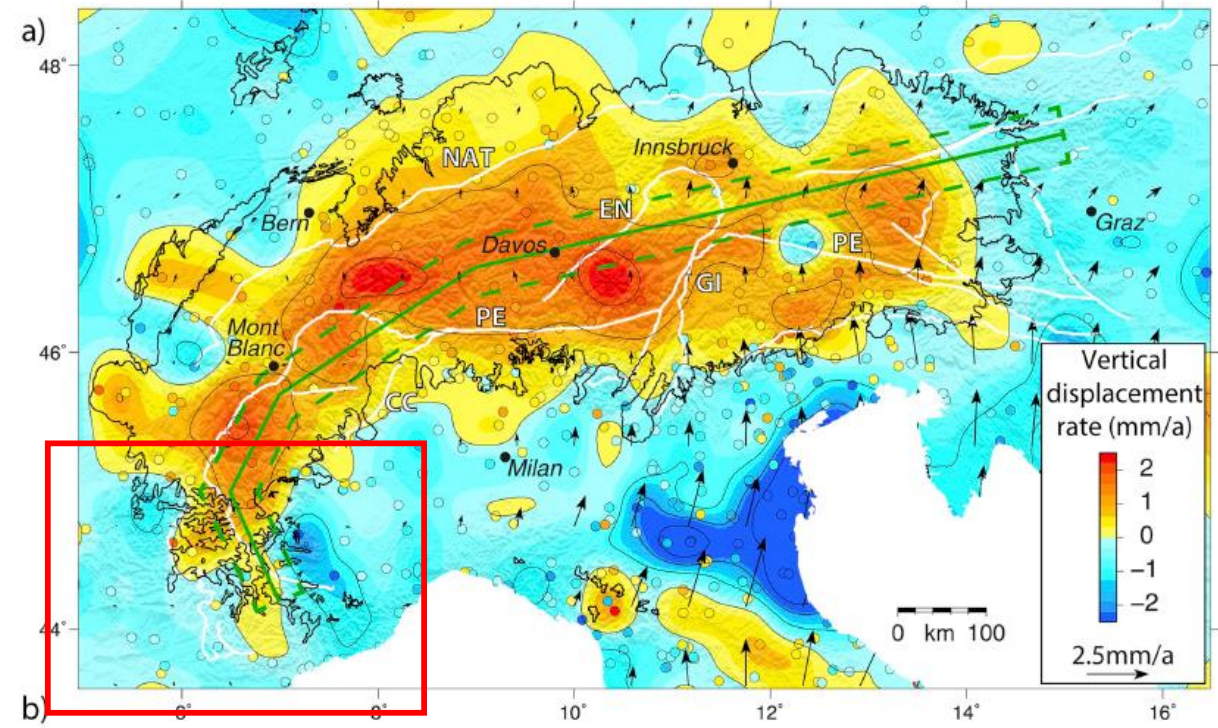
5- Univ. Grenoble Alpes, Univ. Savoie Mont Blanc, CNRS, IRD, IFSTTAR, ISTerre, Grenoble, France

- SW Alps and Provence: apparently slow uplift rates (≤ 0.5 mm/yr)
- Small magnitudes but intense seismicity
- Apparently no (or very slow) current horizontal shortening

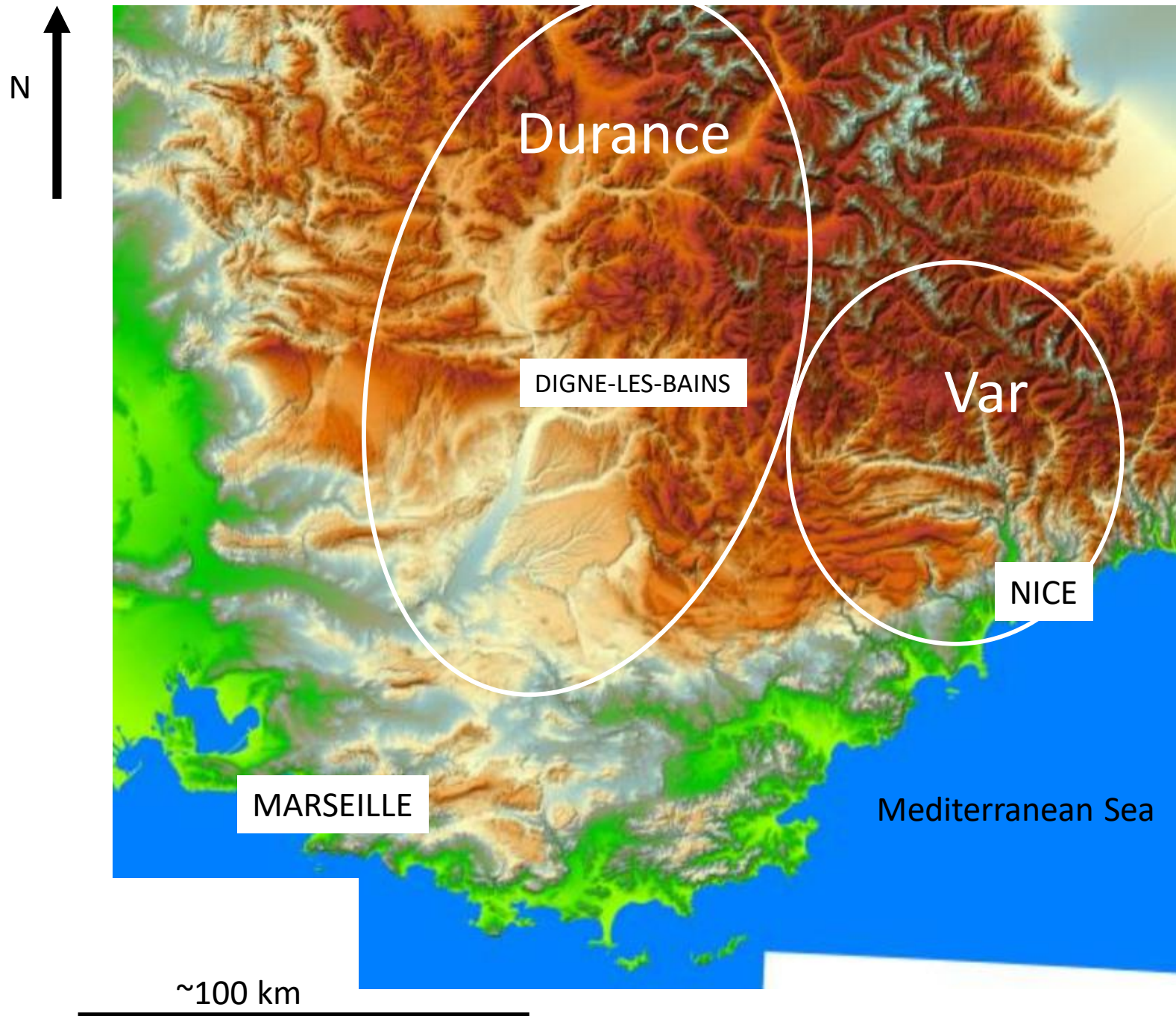
Seismicity map in Southern France (Marin et al., 2004)



Current uplift rate in the Alps (Sternai et al., 2019)

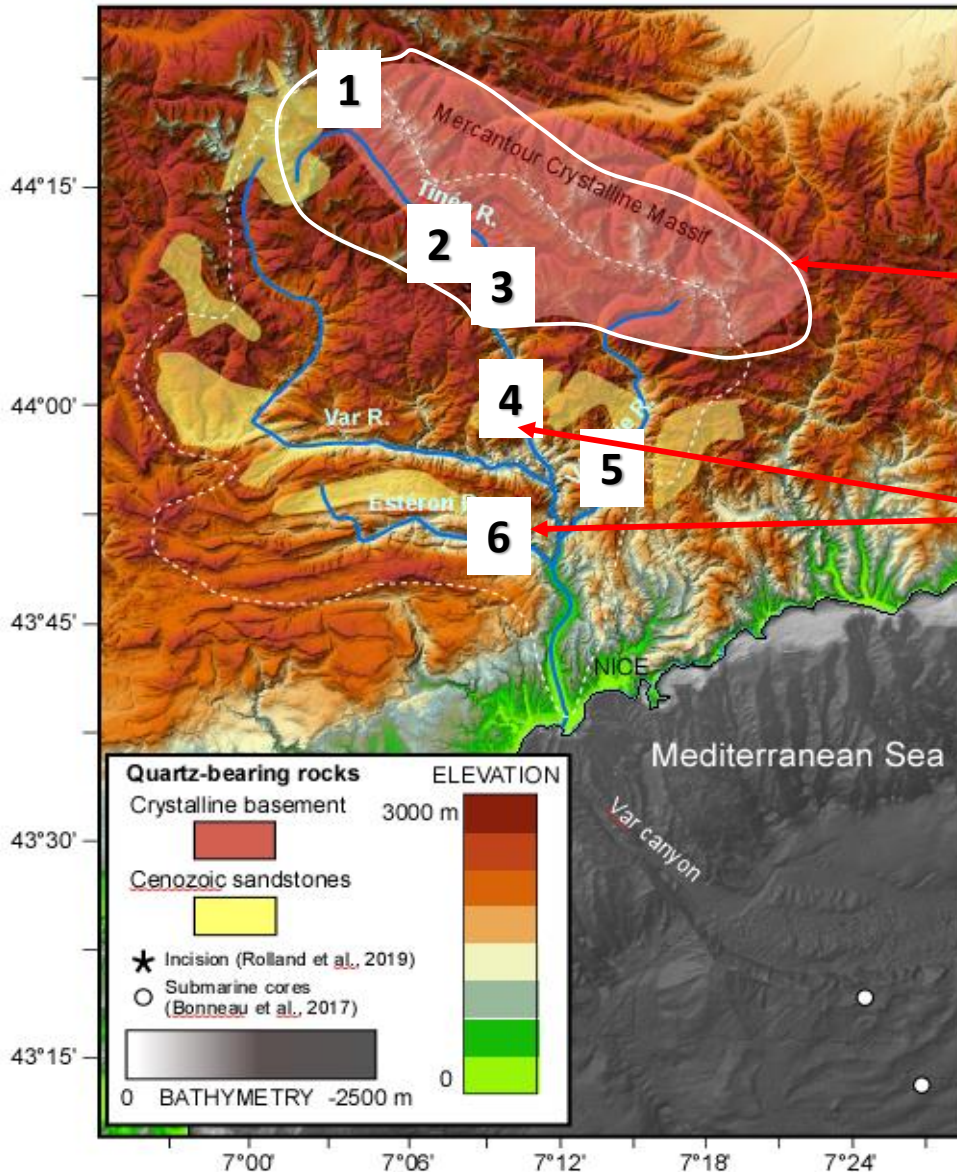


What causes the seismic deformation ?
Is erosion in equilibrium with uplift ?
What is the role of post-glacial erosion ?



Two catchments of different size and slopes drain the southwestern Alps and Provence

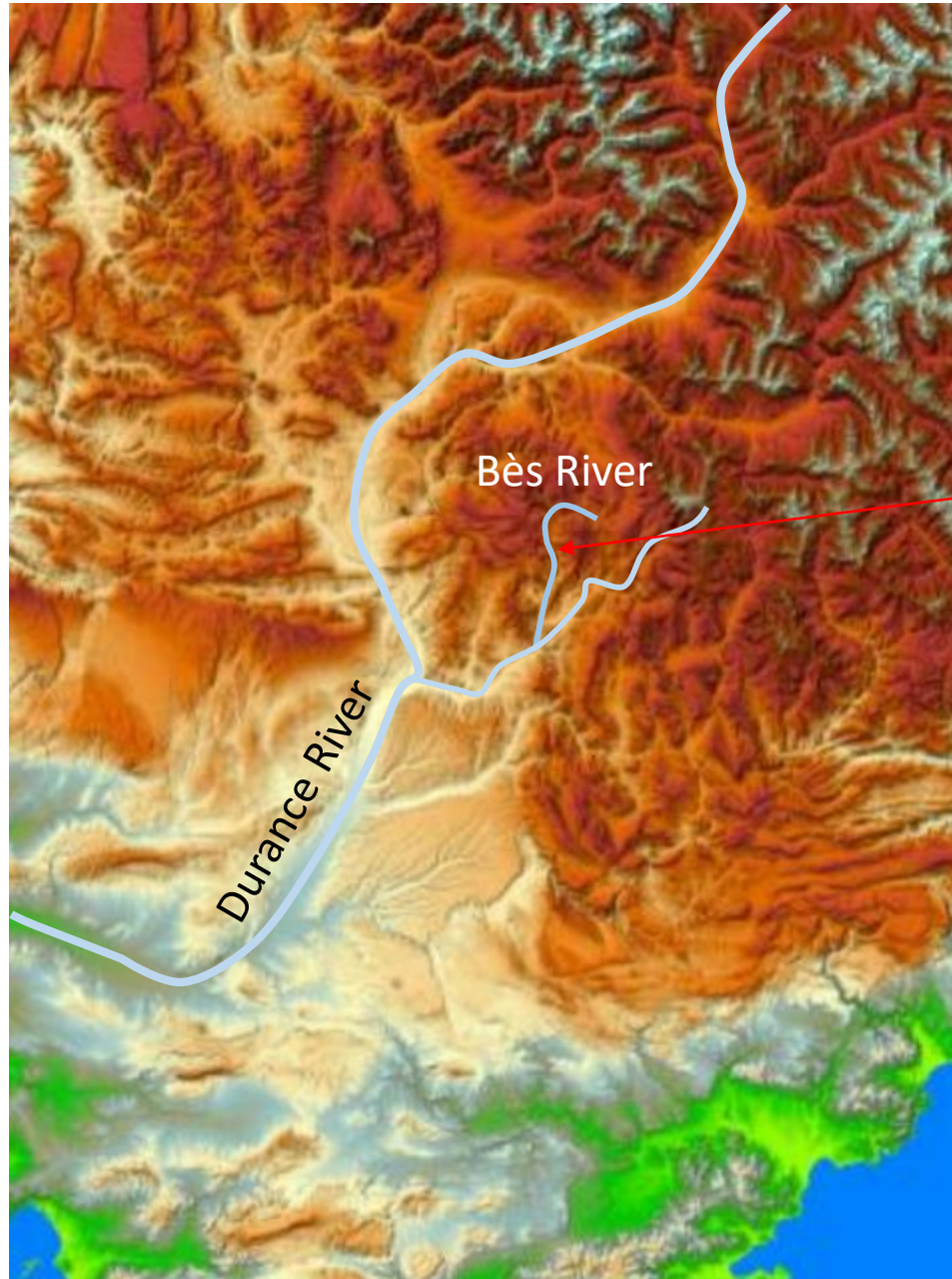
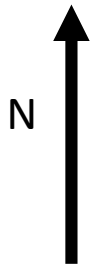
Building a database of river incision rates



SW French Alps (Var catchment)

LGM glaciers restricted to high altitude areas (Mercantour Massif) and upper river (Tinée, Vésubie) valleys

Fluvial incision dated by Cosmic Ray Exposure (CRE) in different points of the catchment (Saillard et al., 2014; Rolland et al., 2017; Petit et al., 2019)



Provence (Durance catchment)

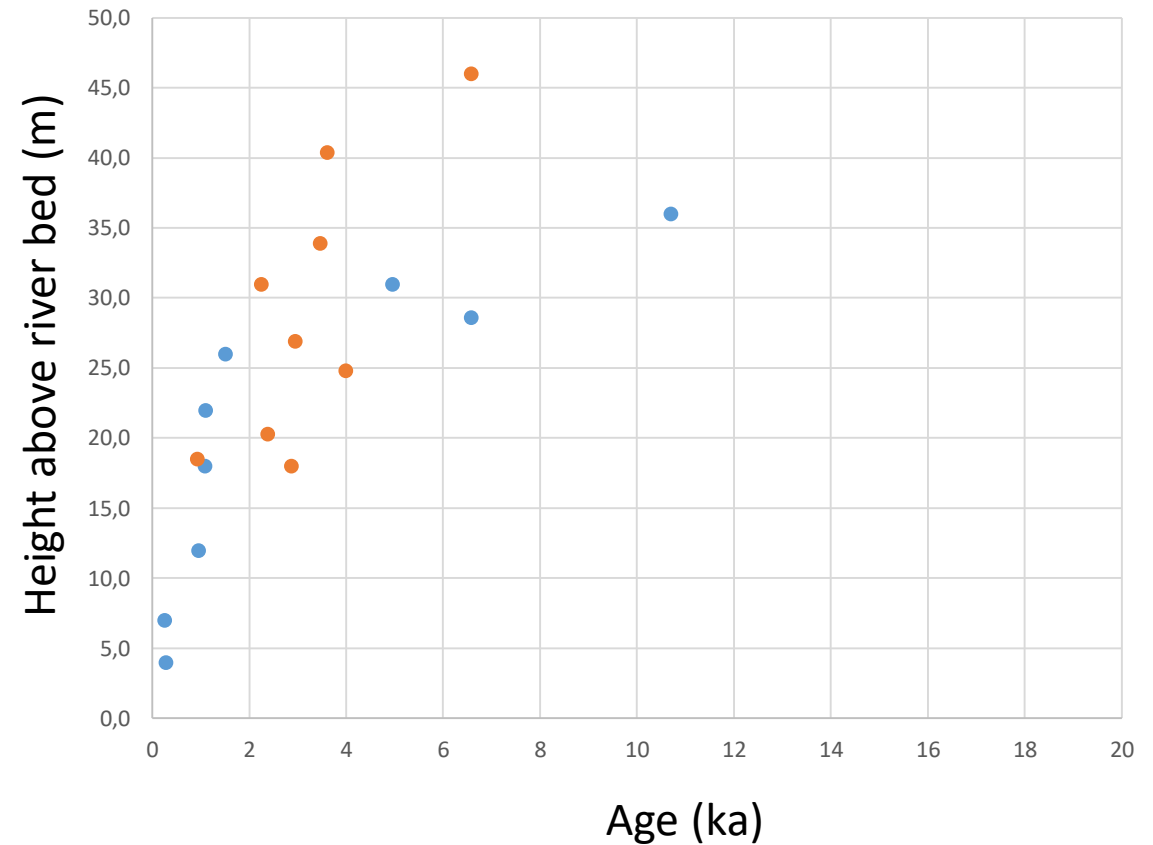
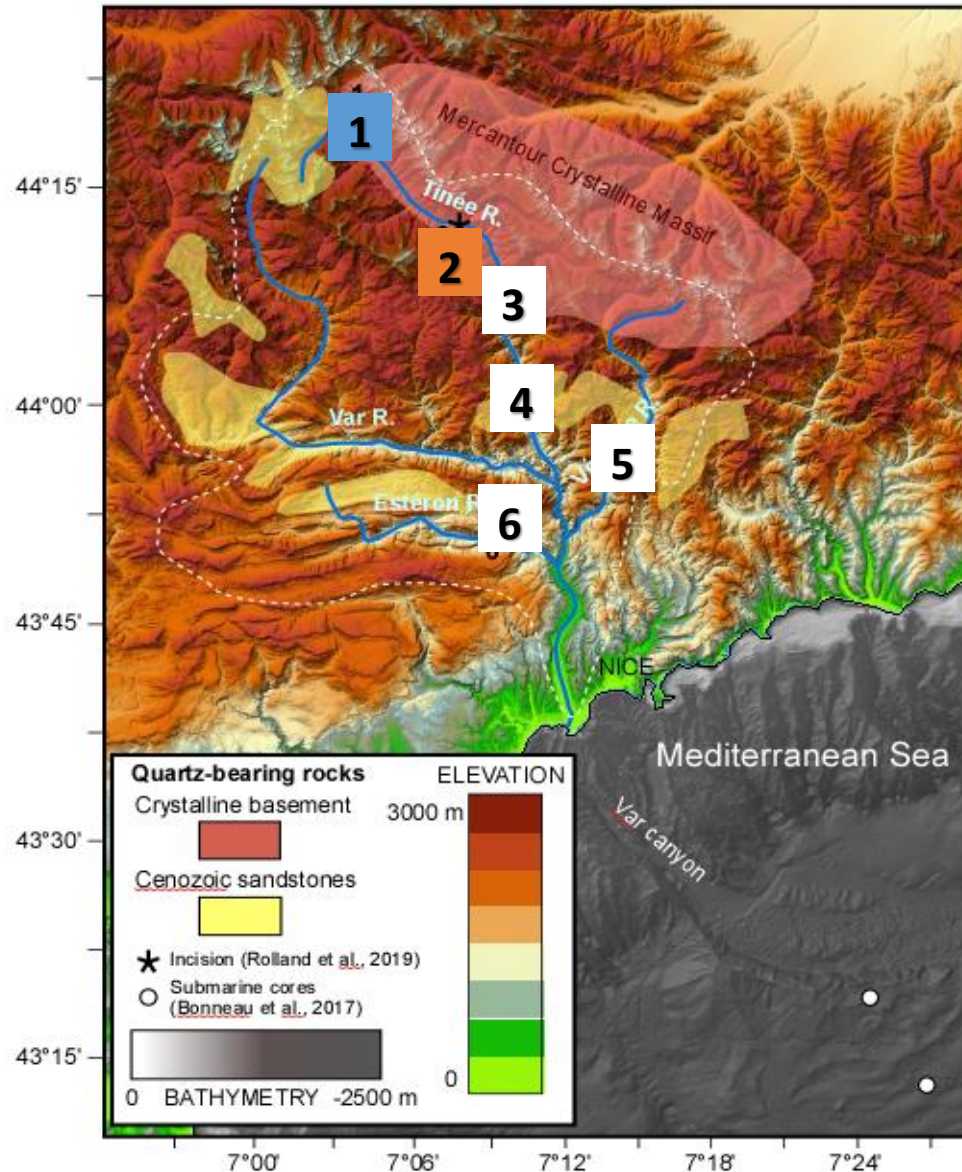
The Bès River, a tributary of the Durance River runs ~NS across the subalpine and Provence fold and thrust belt.

Its headwaters are at relatively low altitude (~2000m) and out of influence of quaternary glaciers.

~50 km

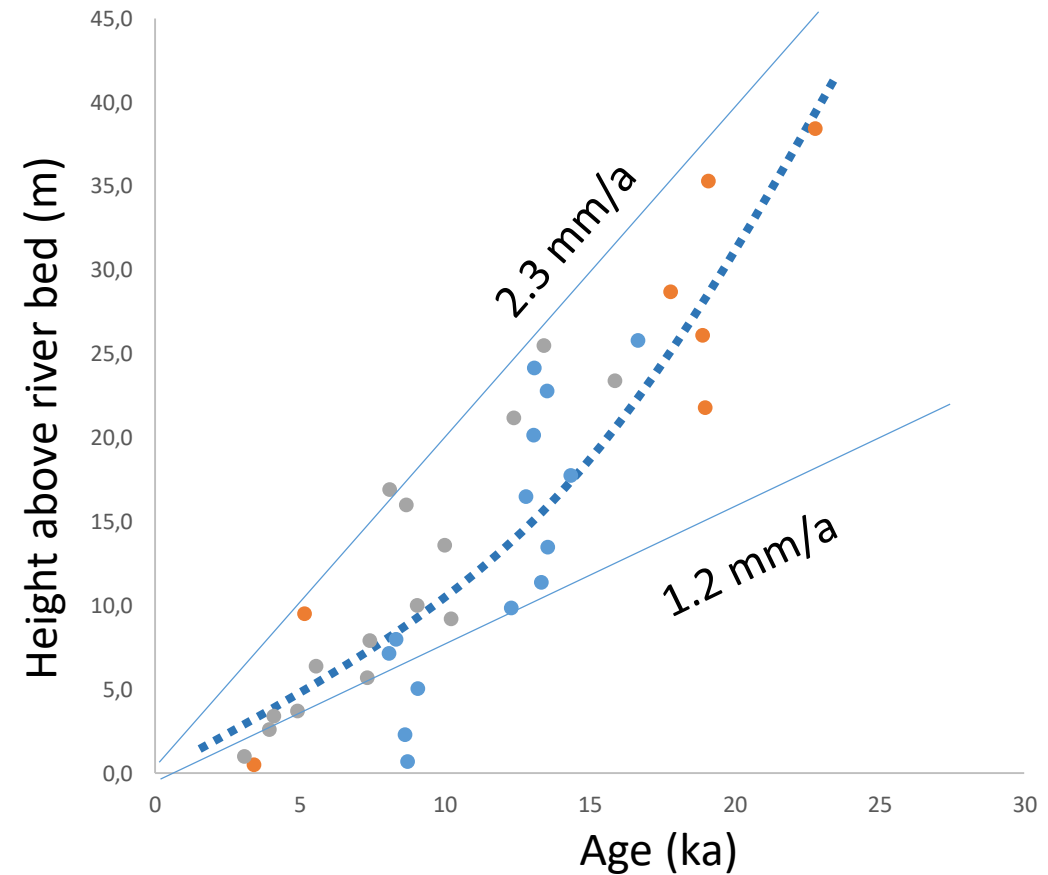
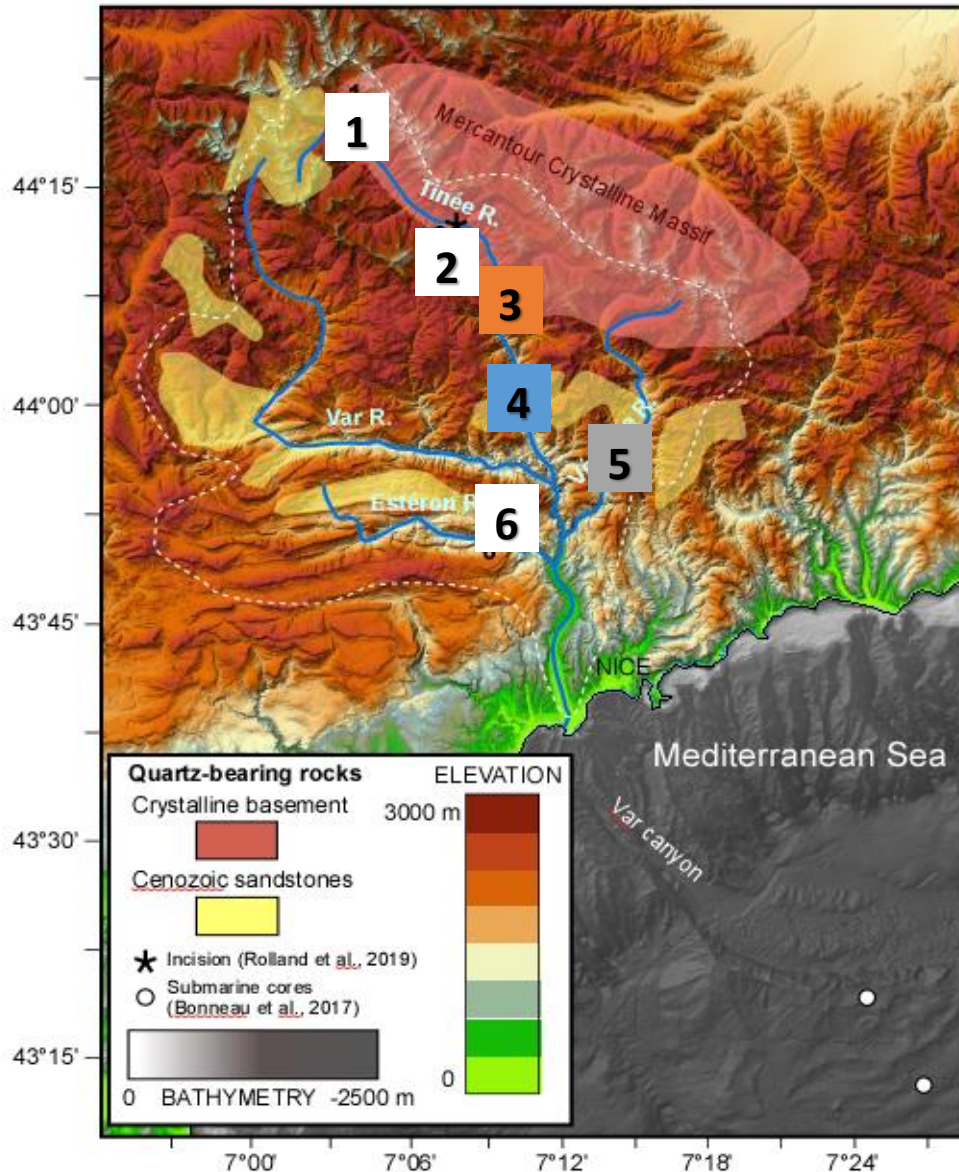


What do we know ?



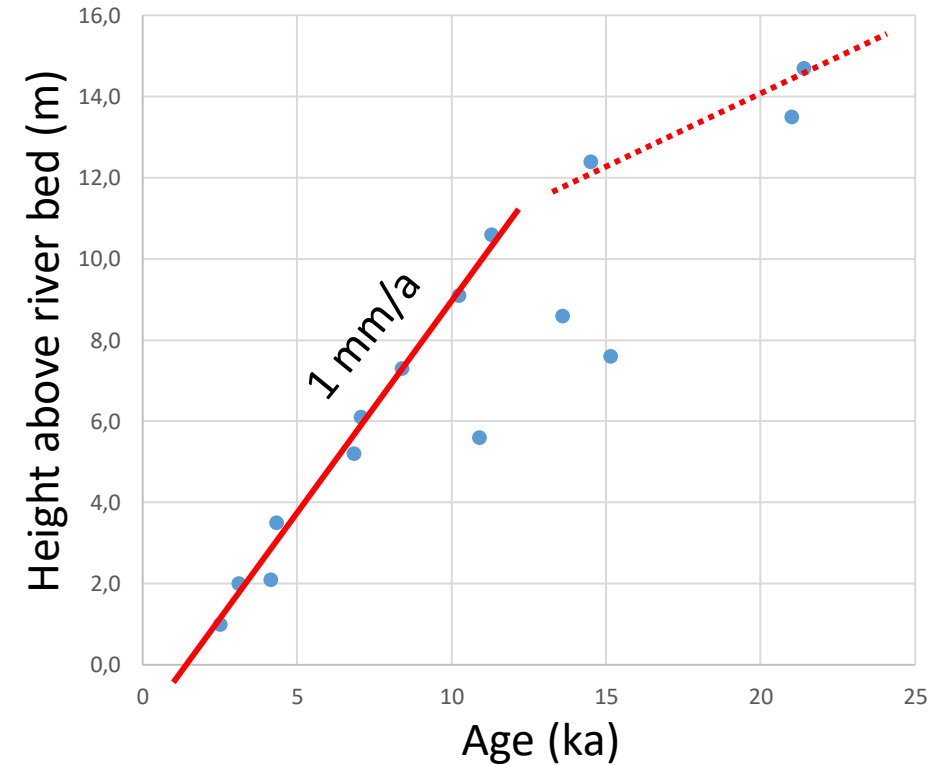
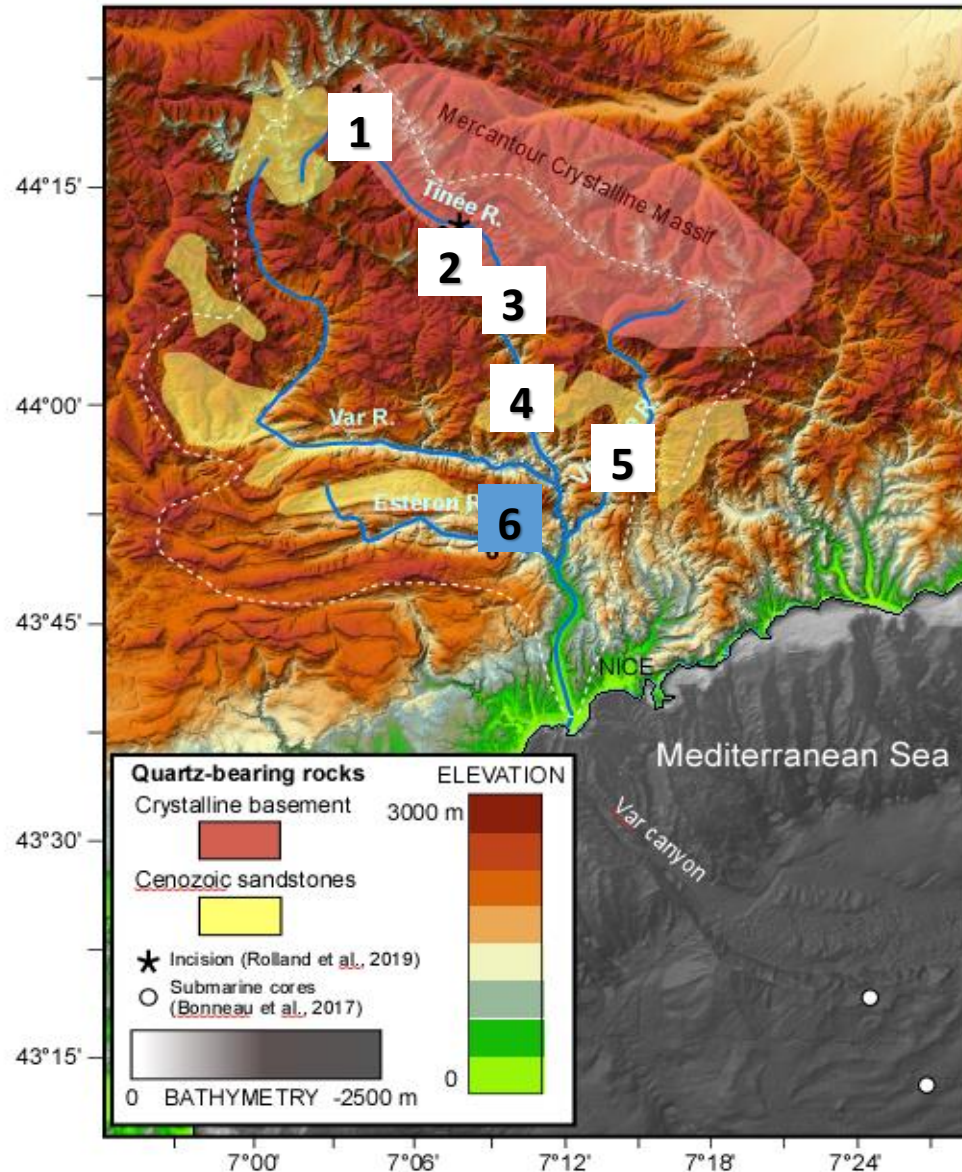
Points 1 and 2: recent (10-12 ka) and extremely fast incision (7-10 mm/a): transient (post glacial) process ?

What do we know ?



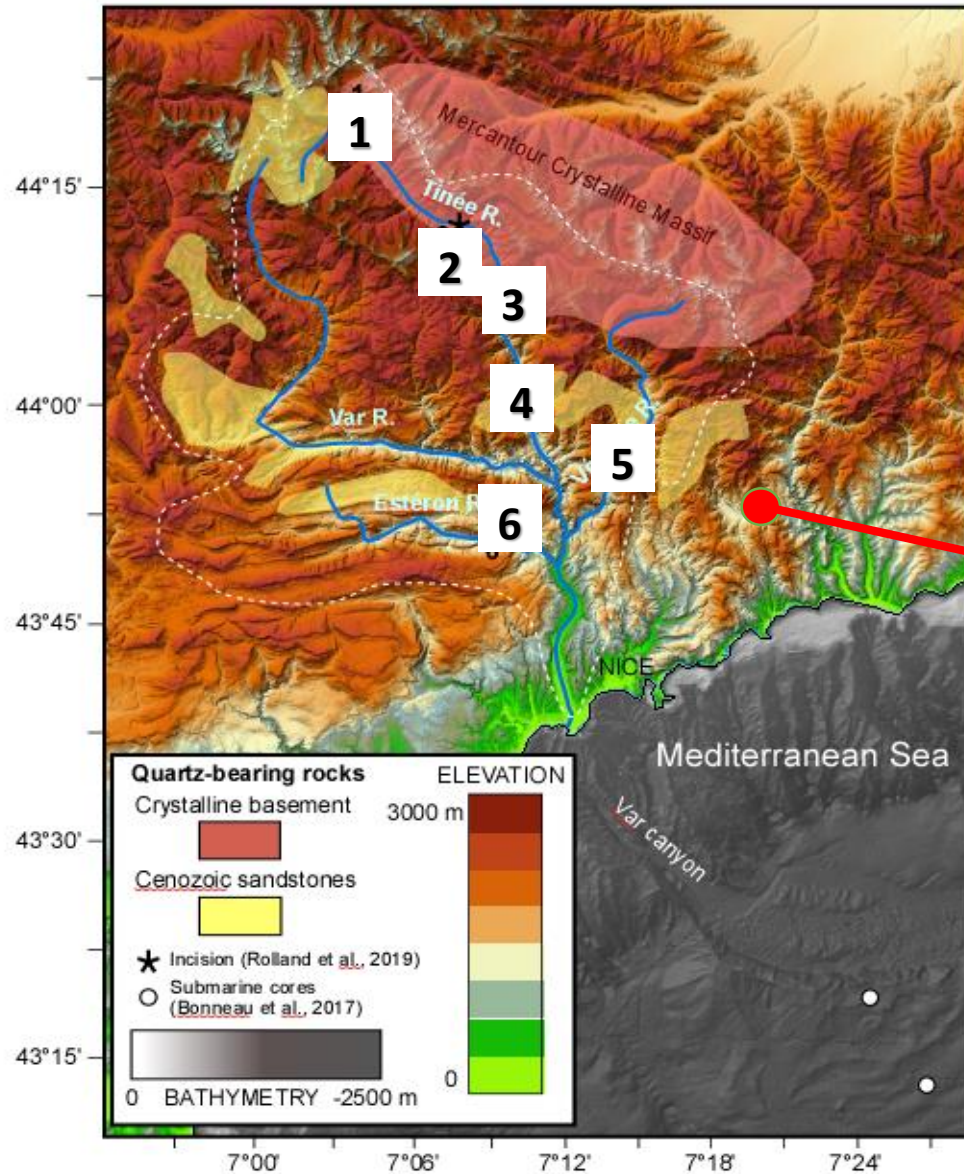
Points 3, 4, 5: rather noisy but mean incision rate between 1.2 and 2.3 mm/a since ~20 ka
Maybe a decrease of the incision rate after 10-15 ka ?

What do we know ?



Point 6: Very nice trend (1 mm/a) after 10ka. Lower incision rate before that time ?

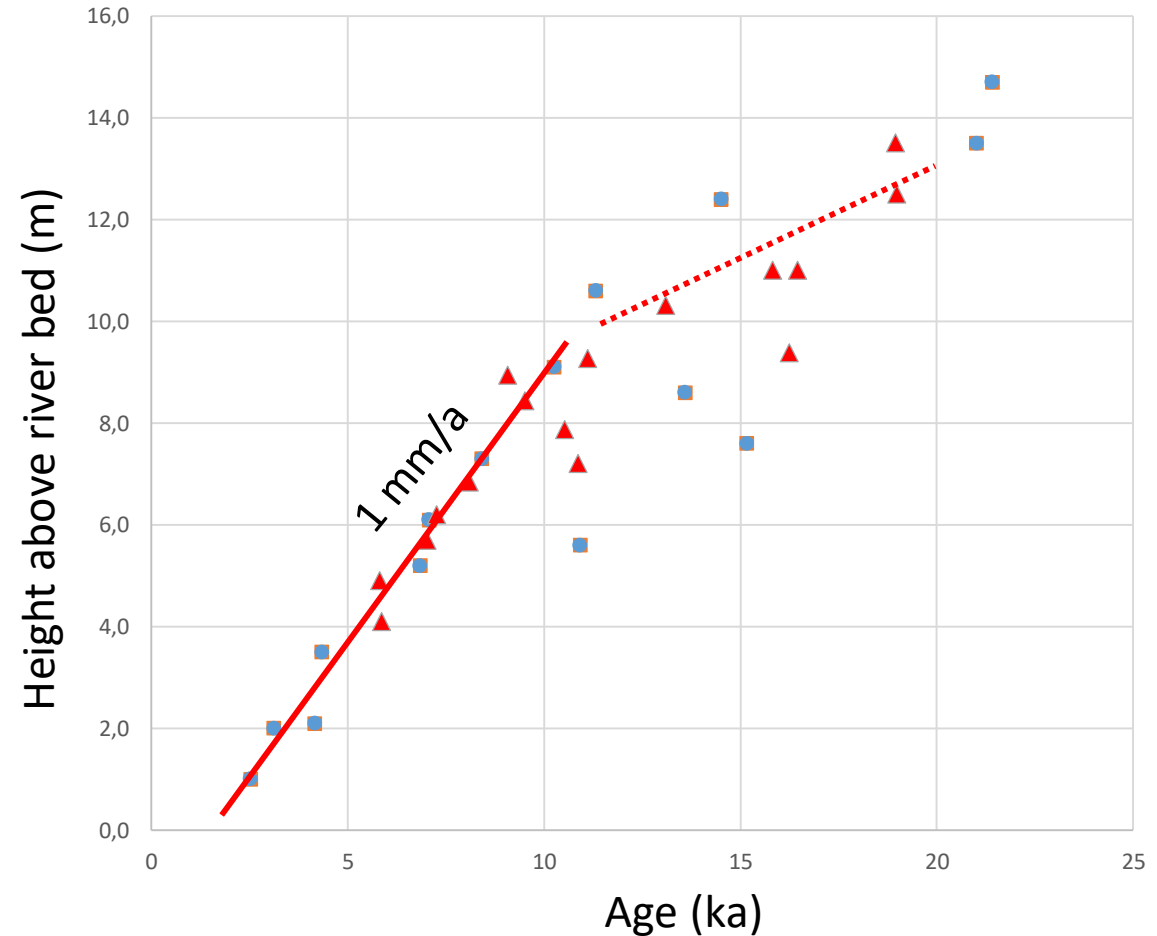
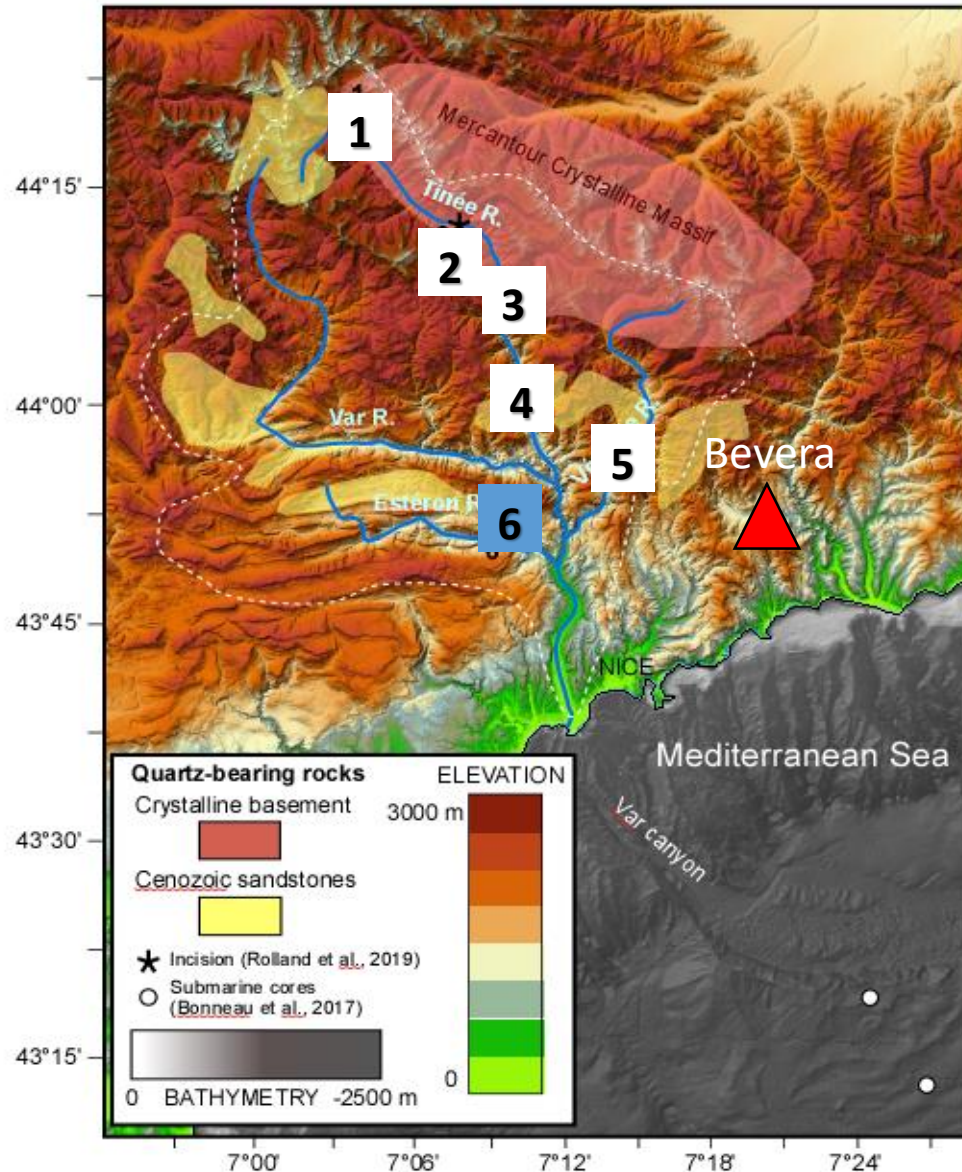
What do we know ? + new data



New point in the Bevera River

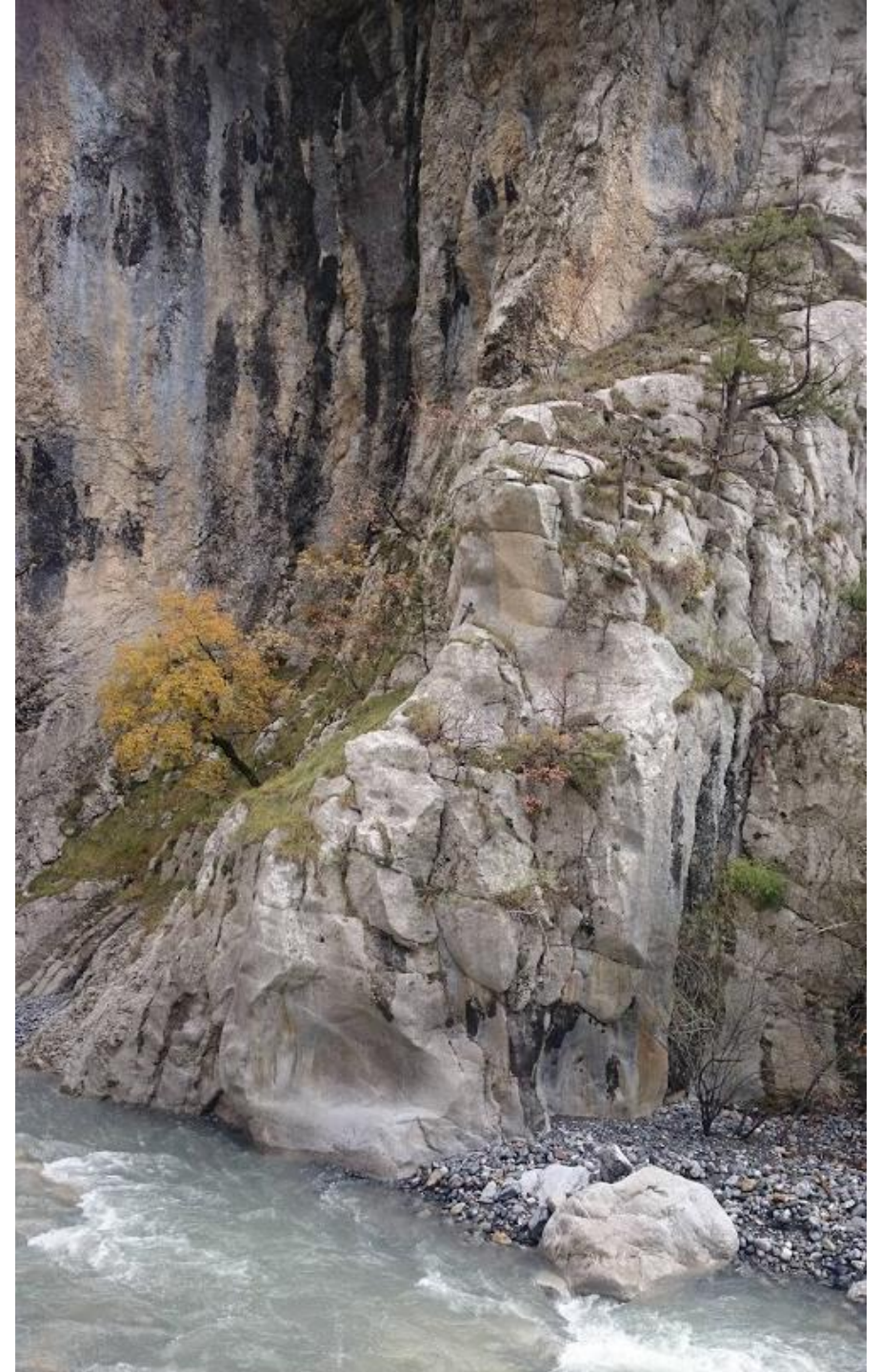
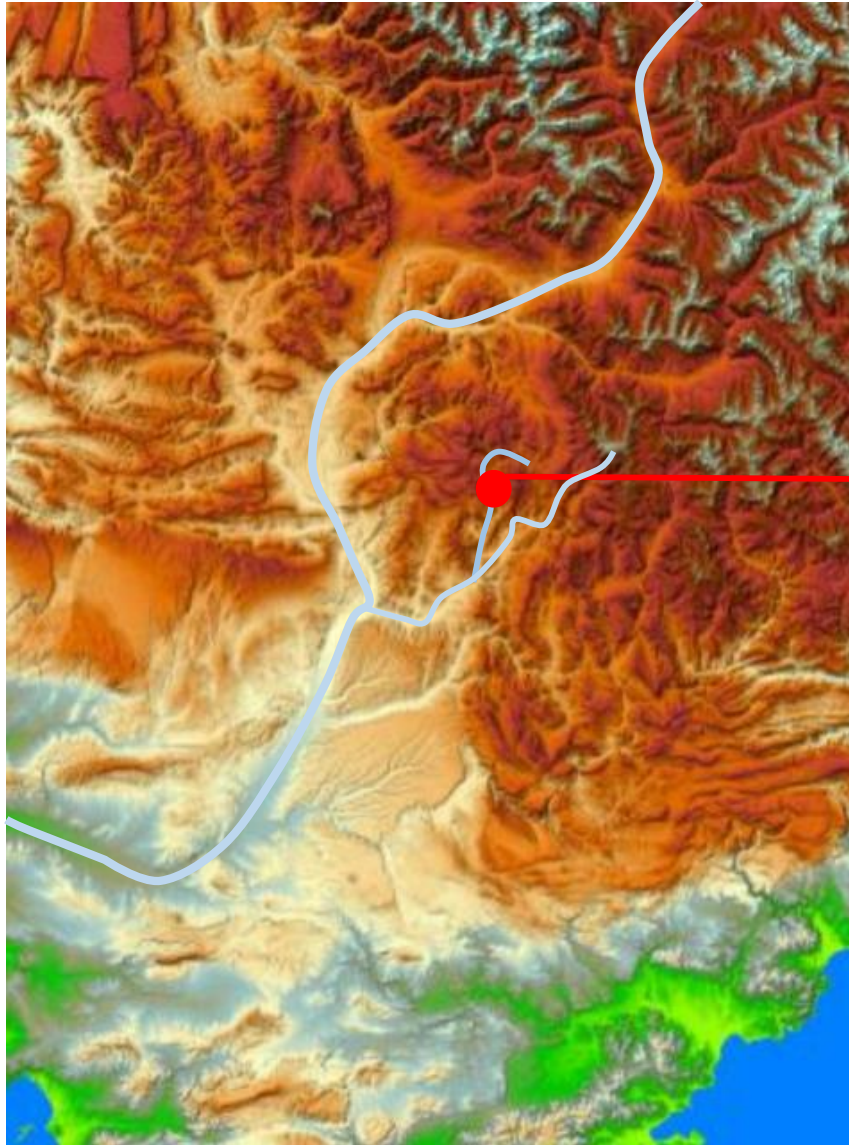


What do we know ? + new data

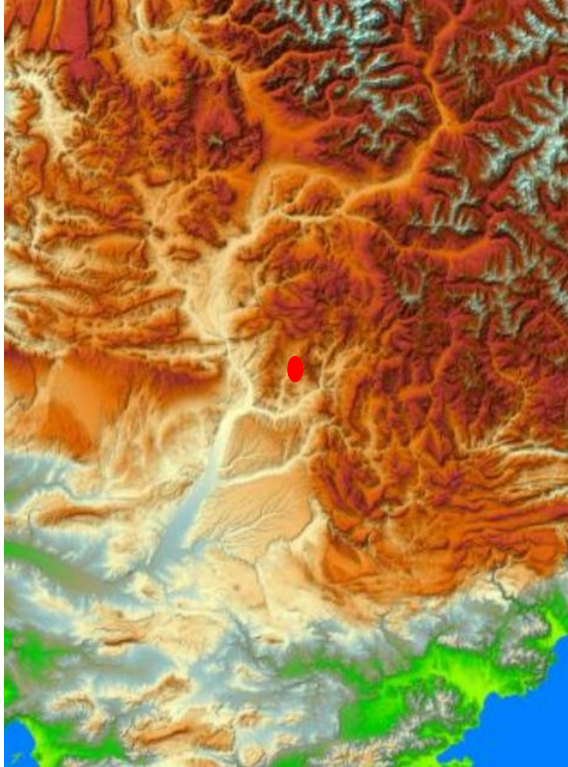


Point 6 + Bevera River : Seems to confirm low (<0.5 mm/a) incision rate before 10 ka and higher (1 mm/a) after that time.

New point in the Bès River (Durance catchment)

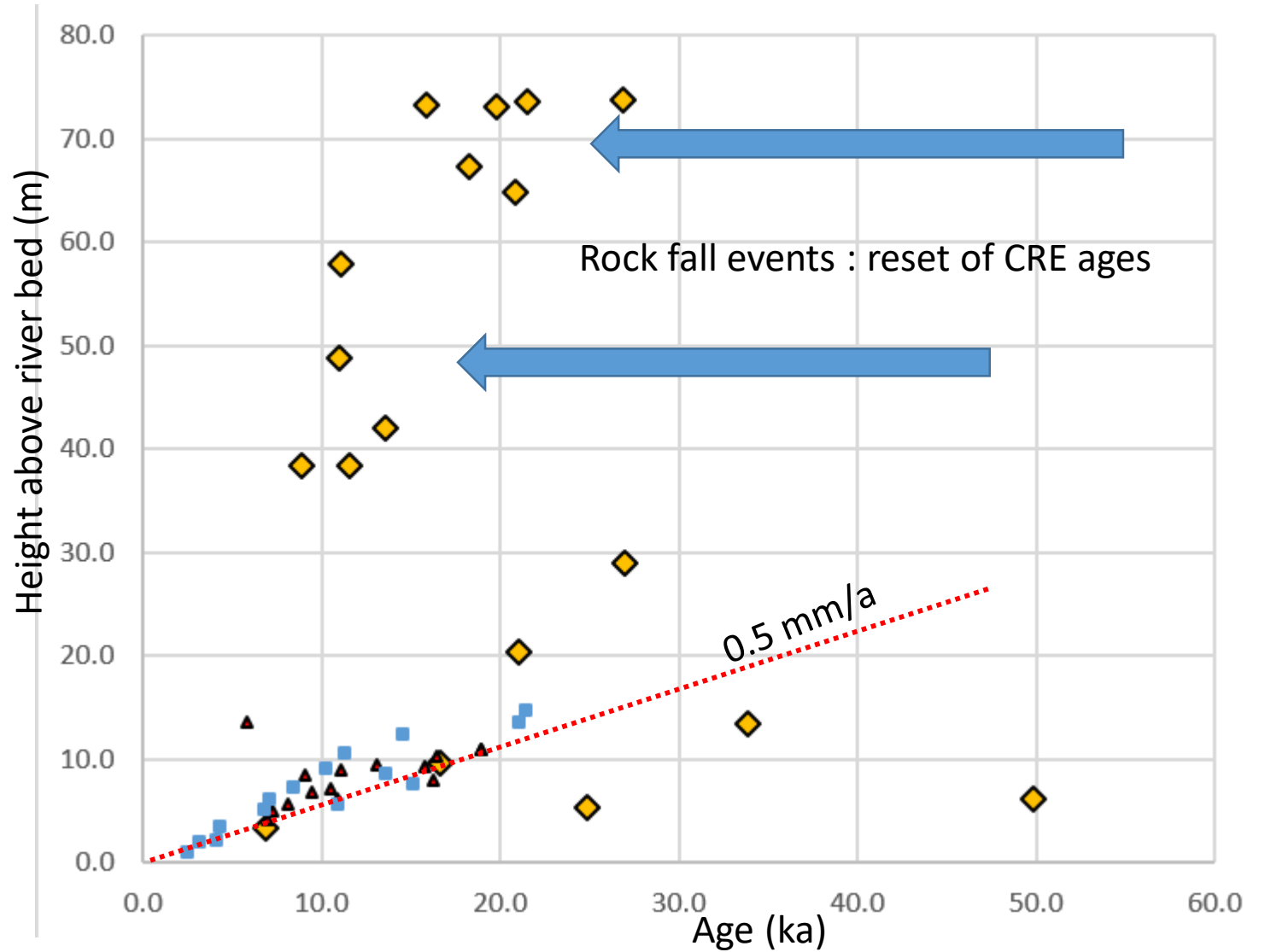


New point in the Bès River (Durance catchment)



Bès River: very noisy. Ages rejuvenation due to rock falls (Cardinal, 2019)

Other points of the Bès River: low incision rates (0.5 ± 0.3 mm/a)



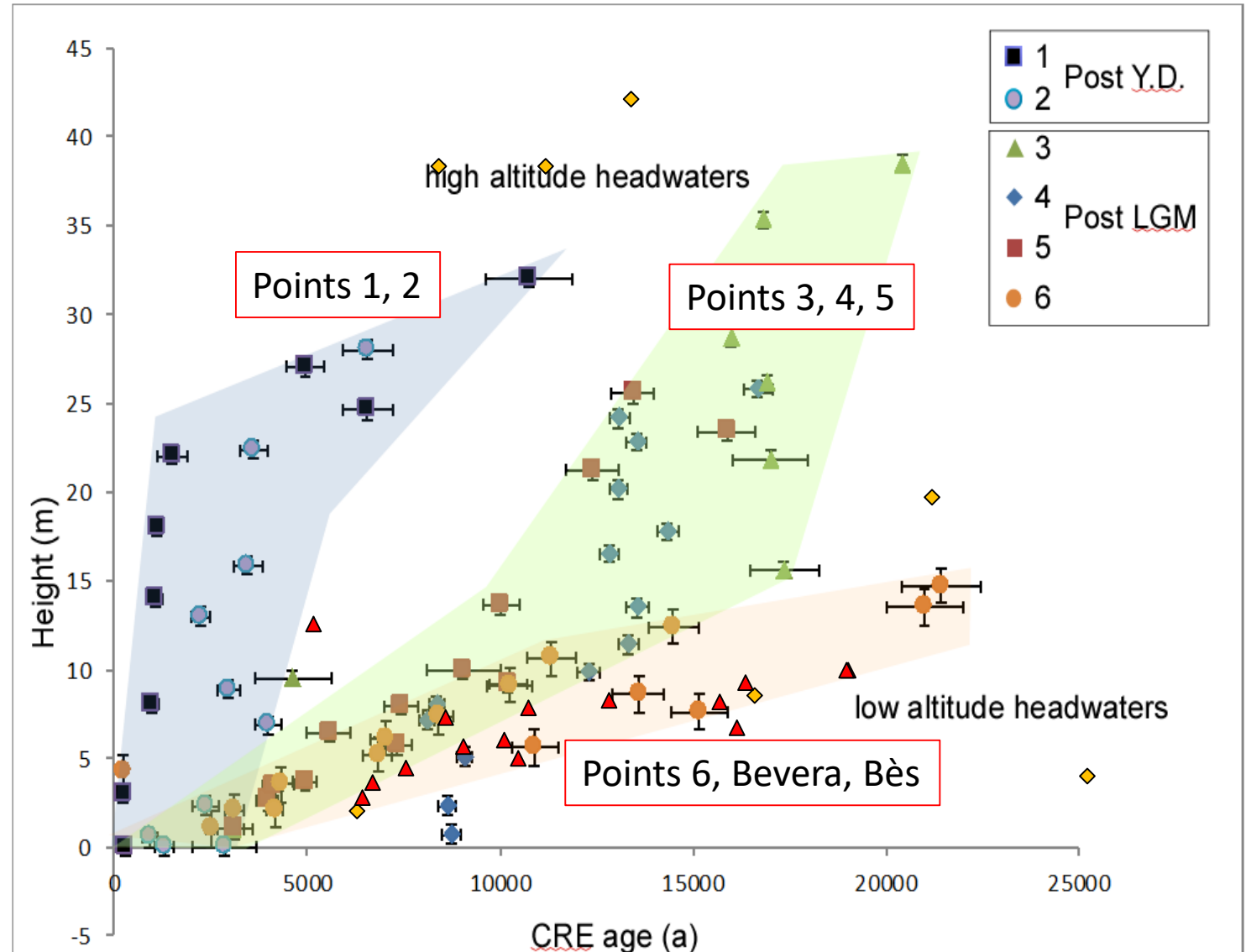
Putting all together

High altitude headwaters:

- High altitude (> 900m) points show transient, fast incision after the Younger Dryas
- Low altitude points show a decrease of the incision rate after 10-15 ka

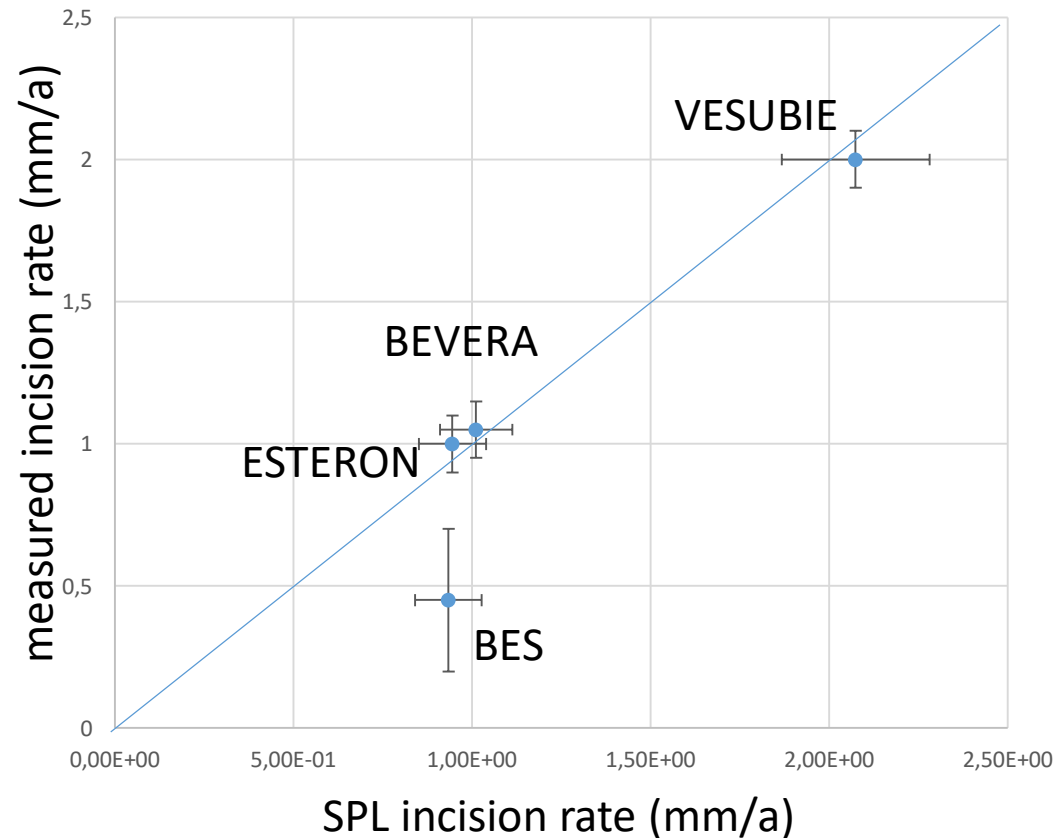
Low altitude headwaters:

- Remarkably constant incision rate after 10 ka around 1 mm/a
- Slightly lower between 20 and 10 ka



Going a bit further...

- Why is the Bès incising slower than the Estéron, Bévéra and Vésubie Rivers ?

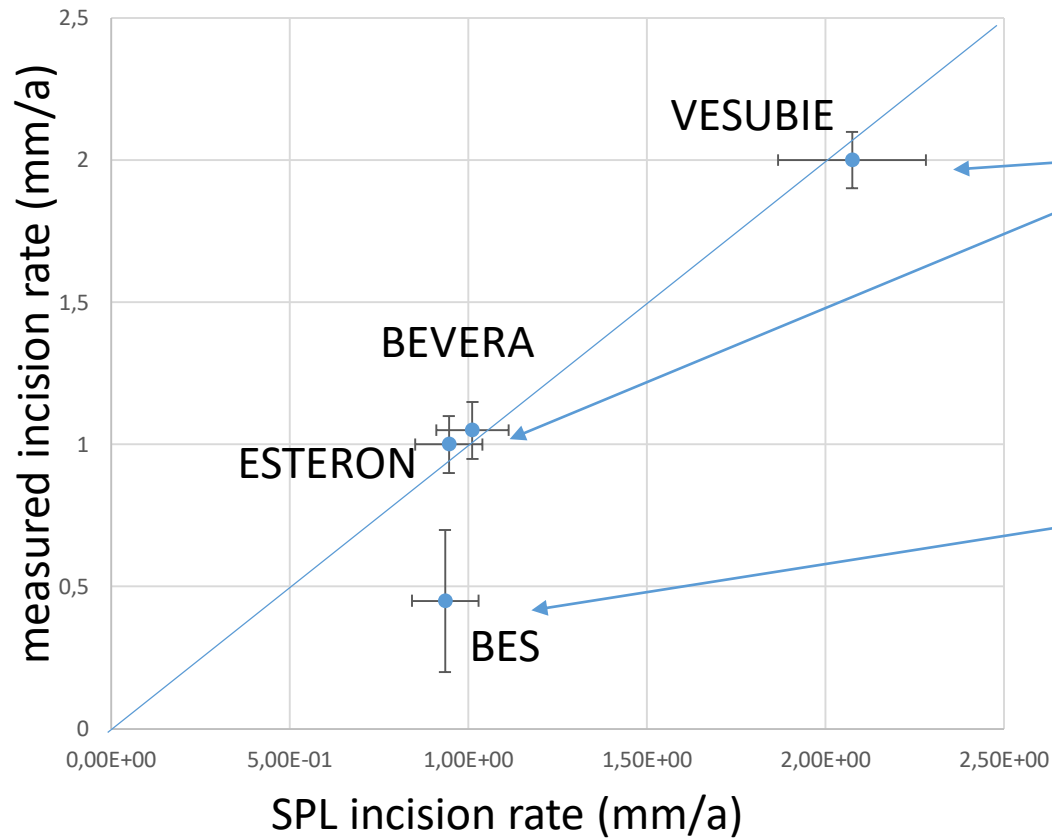


We compare incision rates measured between 10 and 0 ka and those predicted by the stream power law (SPL*) using morphological analysis of the river longitudinal profile and catchment area:

Theoretical incision rate (mm/a)	Measured incision rate (mm/a) / error	River
9.34E-01	0.45	0.25 Bes
0.94525	1	0.1 Esteron
2.07414	2	0.1 Vesubie
1.01122	1.05	0.1 Bevera

$$* \frac{dh}{dt} = KA^m S^n$$

with $m=0.5$, $n=1$ and $K = 5.10^{-7} \text{m}^{1-2m} \cdot \text{s}^{-1}$



Three different catchments in SW French alps, but they obey the same SPL (i.e., the same m , n and K parameters)

Why is this one slower ?

- Different erodibility ? Unlikely (same upper Jurassic carbonates, approx. same precipitation rate)
- Different m/n ratio? Possible (but difficult to measure due to large lithological contrasts)
- Different uplift rate ? Not impossible...

Conclusions

- River incision rates show striking differences depending on whether they were or not under the influence of quaternary glaciers.
- Rivers out of the influence of glaciers show a much lower incision rate just after the LGM compared to those which had glaciated headwaters
 - > strong influence of glacial meltwaters after the LGM
- Catchments of SW Alps show a remarkably constant incision rate of $\sim 1 - 2$ mm/a after 10 ka.
- Incision rate of the Bès River in Provence is not well constrained but probable twice as low.
- Is this due to a different uplift rate ? To be continued...