Challenging Intraplate Orogens: from geomorphology to lithospheric dynamic.

The French Massif Central Case study

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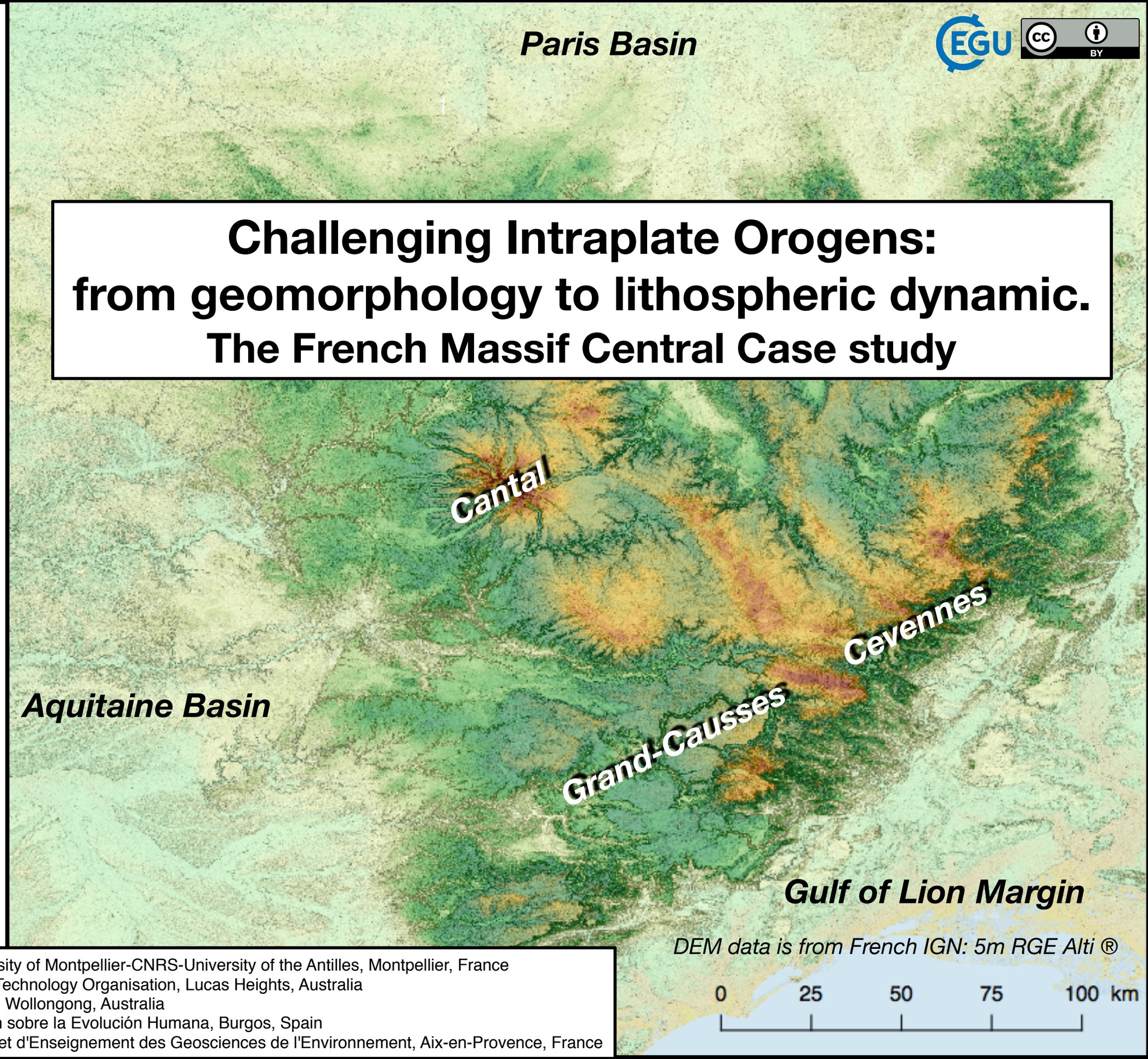


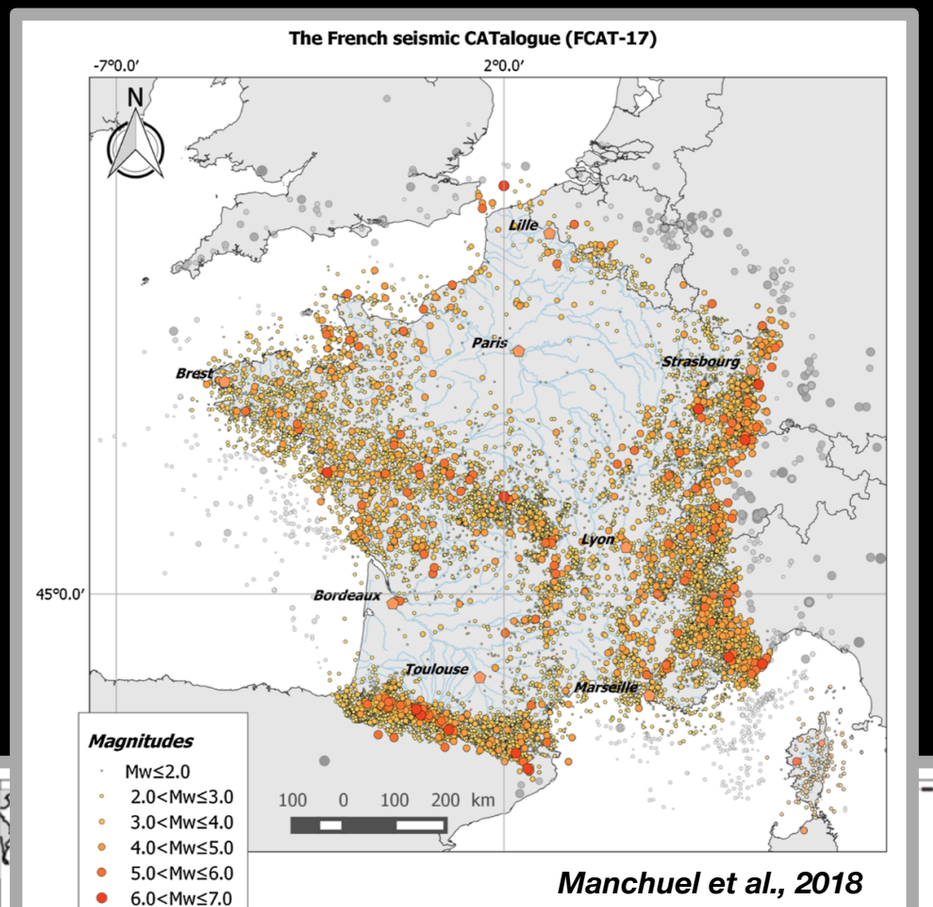
The Intraplate deformation

There are many evidences that intraplate are experiencing **active deformations**. Mainly, it can be highlighted by the seismic activity and by direct measurement of strain rates through Geodetic (GPS-like) survey.

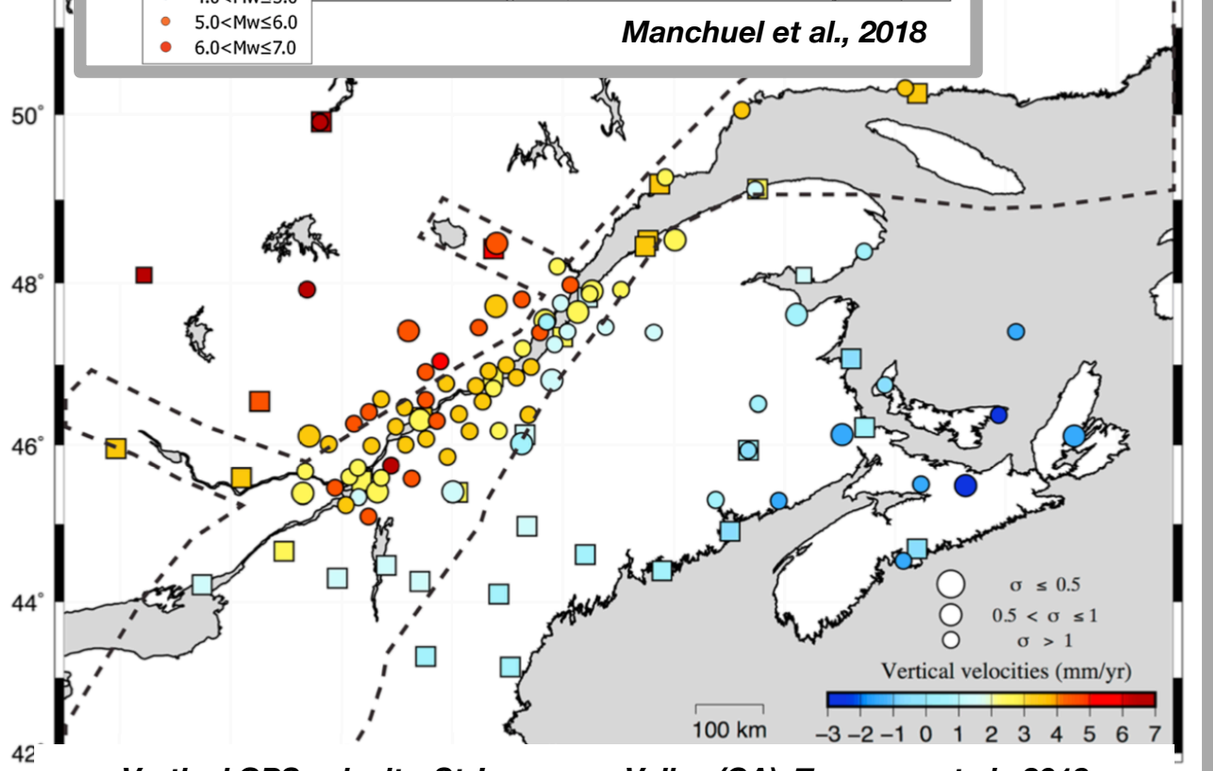
For instance: the New-Madrid Seismic Zone with a cluster of 3 Mw ~ 7-8 earthquakes in 1811-1812 or the significant French seismic background. If evidencing short-term, brittle strain, the completed of the seismic catalog is a serious limit that could help propagating to use the seismicity-derived information into a long-term evolution model.

In some cases, quantification of total strain can be performed, mostly where PGA (Post Glacial Adjustment) amplify the signal as in Fennoscandia or in Canada. These deformations, however are of low magnitude (mostly below 10^{-9} yr^{-1} or 10^{-10} yr^{-1}). And, most of the time, no significant signal can be extracted from the noise background and, in that case, the relative contribution of elastic, brittle and ductile strain is unknown. Furthermore, because of its link with the PGA, such regional or local studies could be questionner when try to be applied to non-PGA related area.

So far, the main concern is that we don't know if these evidences are significant in a long-term, lithospheric strain study, or if they mostly reflects transient or local phenomenons.



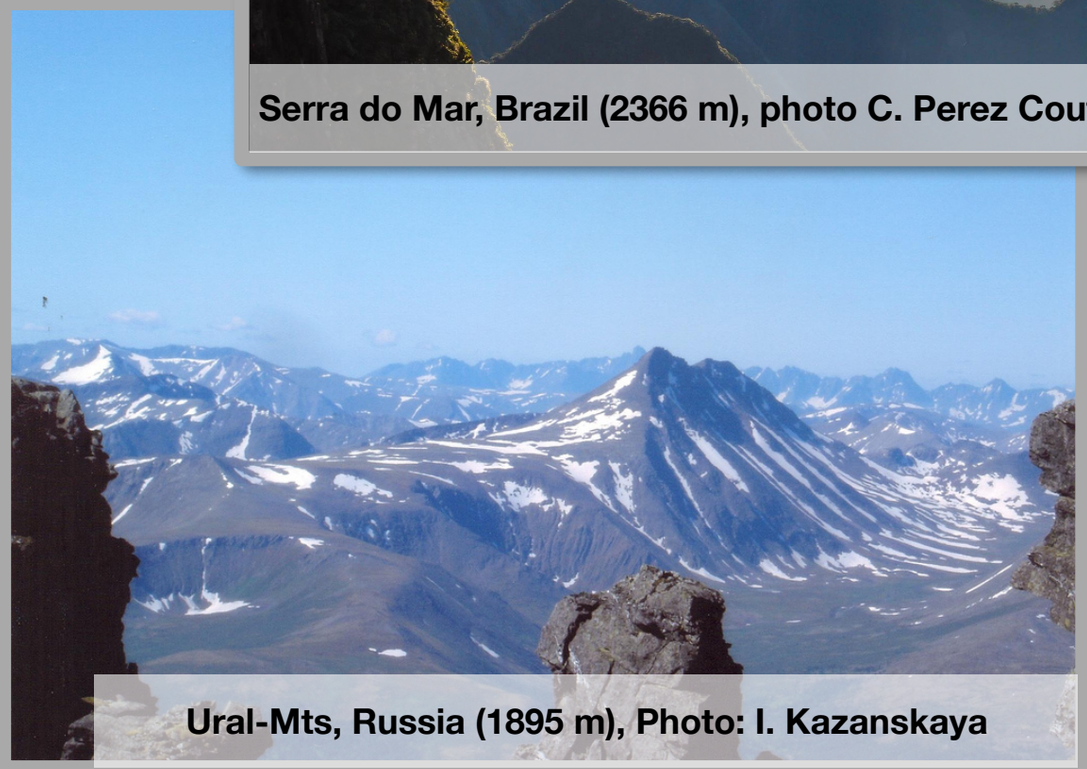
Manchuel et al., 2018



Vertical GPS velocity, St-Lawrence Valley (CA). Tarayoun et al., 2018

The Intraplate deformation


Serra do Mar, Brazil (2366 m), photo C. Perez Couto


Ural-Mts, Russia (1895 m), Photo: I. Kazanskaya

Places with **topography anomalies** (regional high reliefs) are also present in intraplate domains. These topography anomalies are the evidences of **significant finite deformation**.

If they are often located in a passive margin setting, this relationship isn't ubiquitous (e.g. Ural mountains).

Furthermore, the commonly used scheme in order to explain such landscapes, using a scarp retreat and slowly subsiding area rises questions because:

1) not every passive margins displays such topographic anomaly (even paired margins) and;

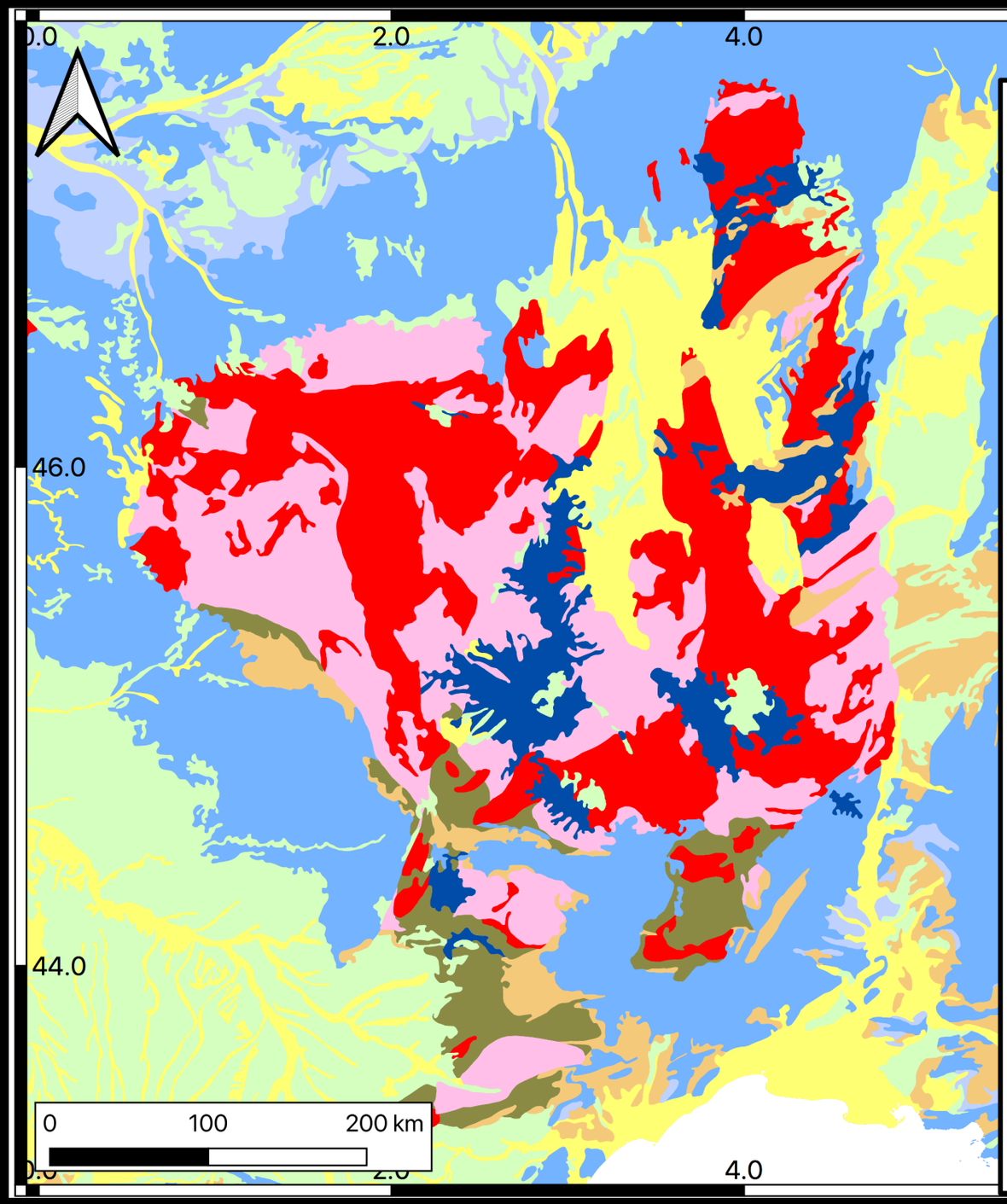
2) different ages should leads to different first-order topographic parameters. (except by using ad hoc hypothesis). This isn't verified when comparing, for instance, the 100 My old South-East Brazilian margin and the 50 My old East-Australian margin.

Furthermore, **the current statut of active uplift or only slowly eroding finite uplift isn't resolved for majority of the intraplate orogens.**

This question is however of main importance when one would try to understand the physical control that lead to the current morphologies.

We therefore need to constraint the age of the landscape to constraint explaining models.

The case study: French massif central



Geological sketch French BRGM

Brief geological settings:

~ 350 - 300 Ma: Hercynian Orogens, formation of the major tectonic structures (e.g. the Cevennes Fault system) and of the basement rocks.

~ 300 - 50 Ma: marine transgressions, depositions of the thick sedimentary layers in the surroundings basins.

~ 50 - 30 Ma: Formations of the Alps and Pyrenees orogens.

~ 30 - 20 Ma: regional distension. Formation of the Limagnes, Rhone-Rain grabbers and opening of the Gulf of Lion.

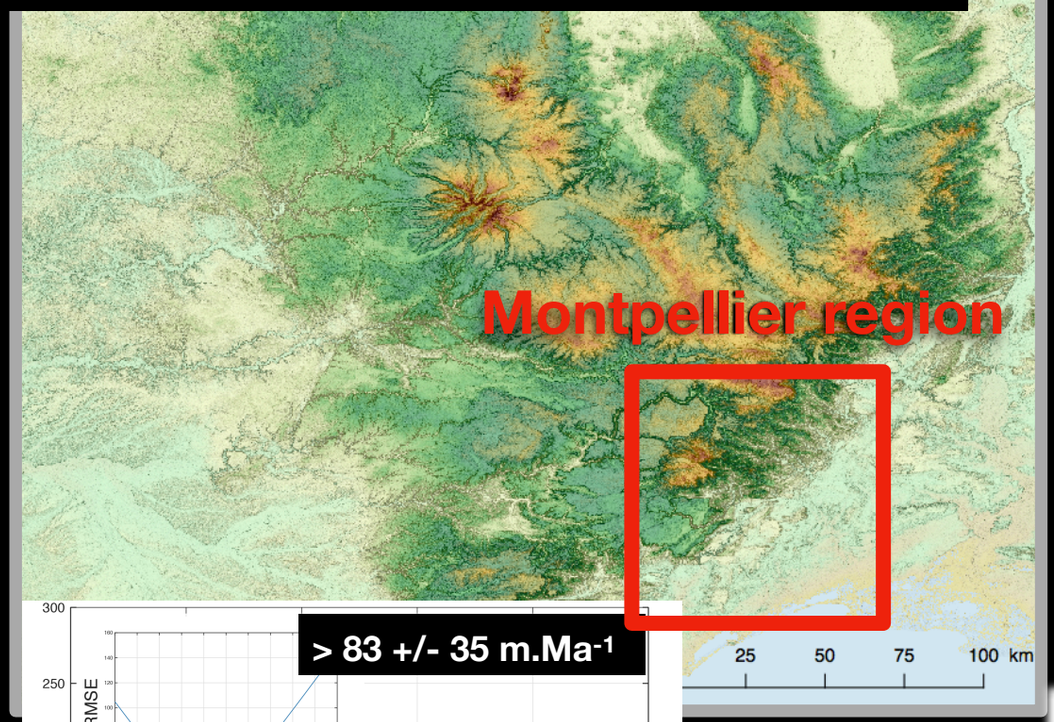
~ 20 Ma to present: different proposal. The current work aim at providing better constraints for the last ~ 5 Ma.

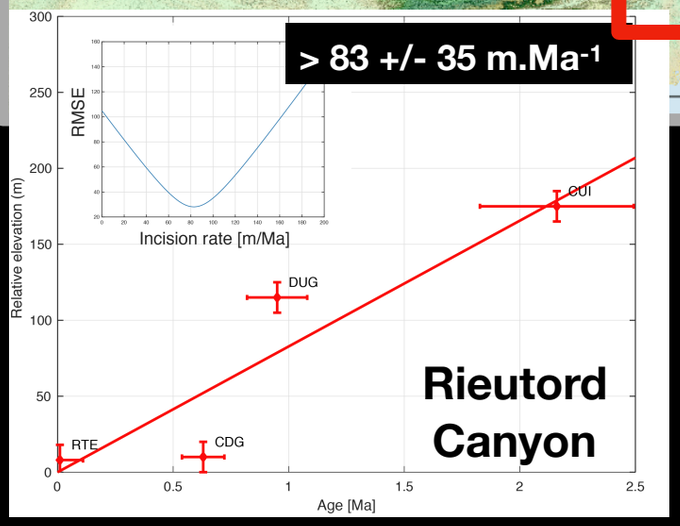
Note: 5.6 to 5.3 Ma: Messinain Salinity Crisis created a major hydraulic head for the Mediterranean basin leading to a strong regressive erosion.

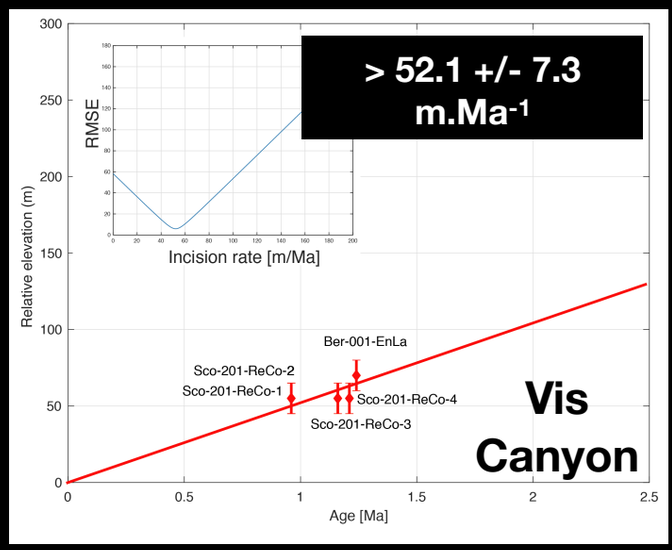
Rock units

- Volcanic rocks (Cenozoic)
- Sedimentary rocks (Permian to present)
- Metamorphic and plutonic rocks

Current research : Incision constraints

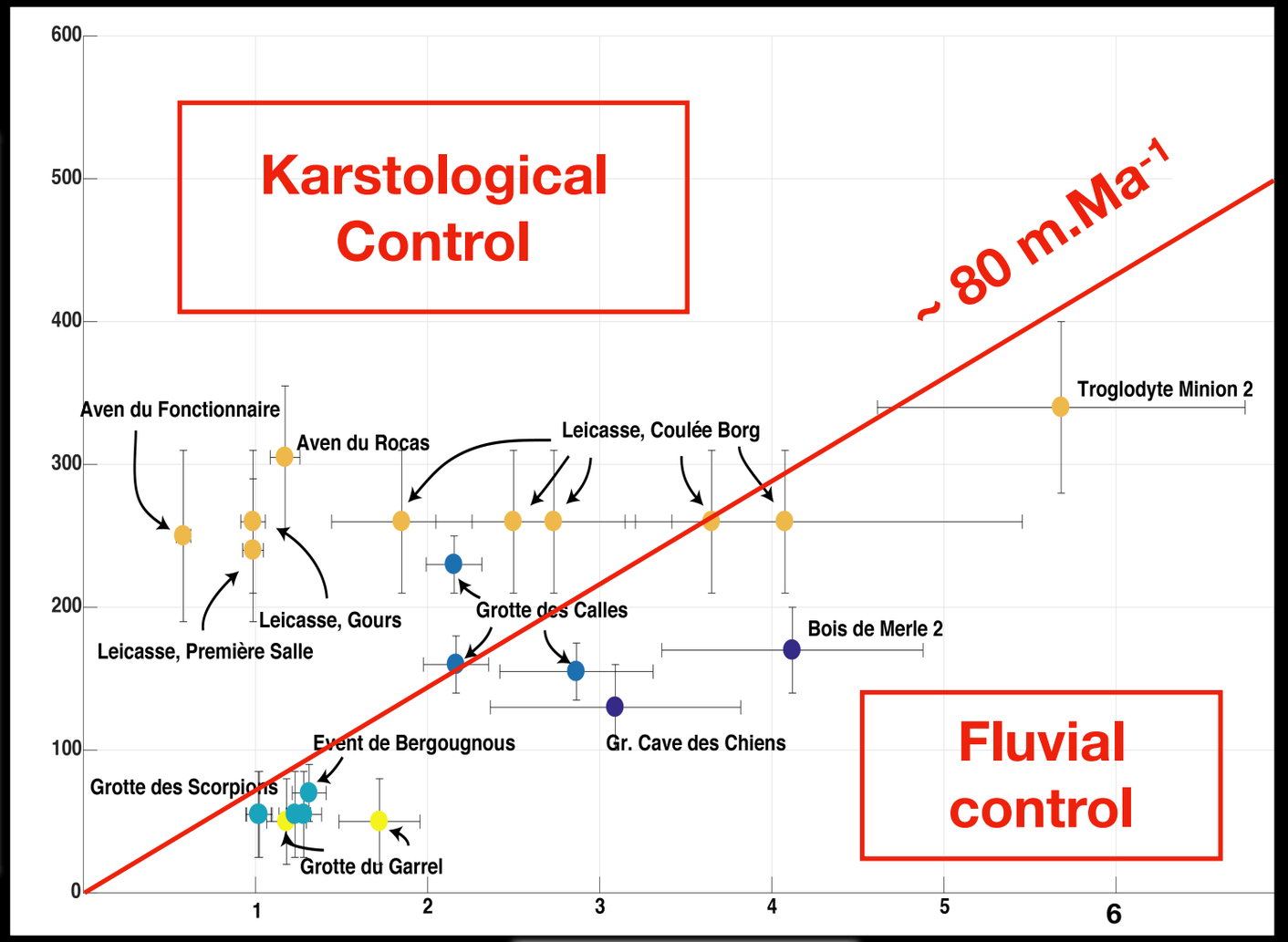




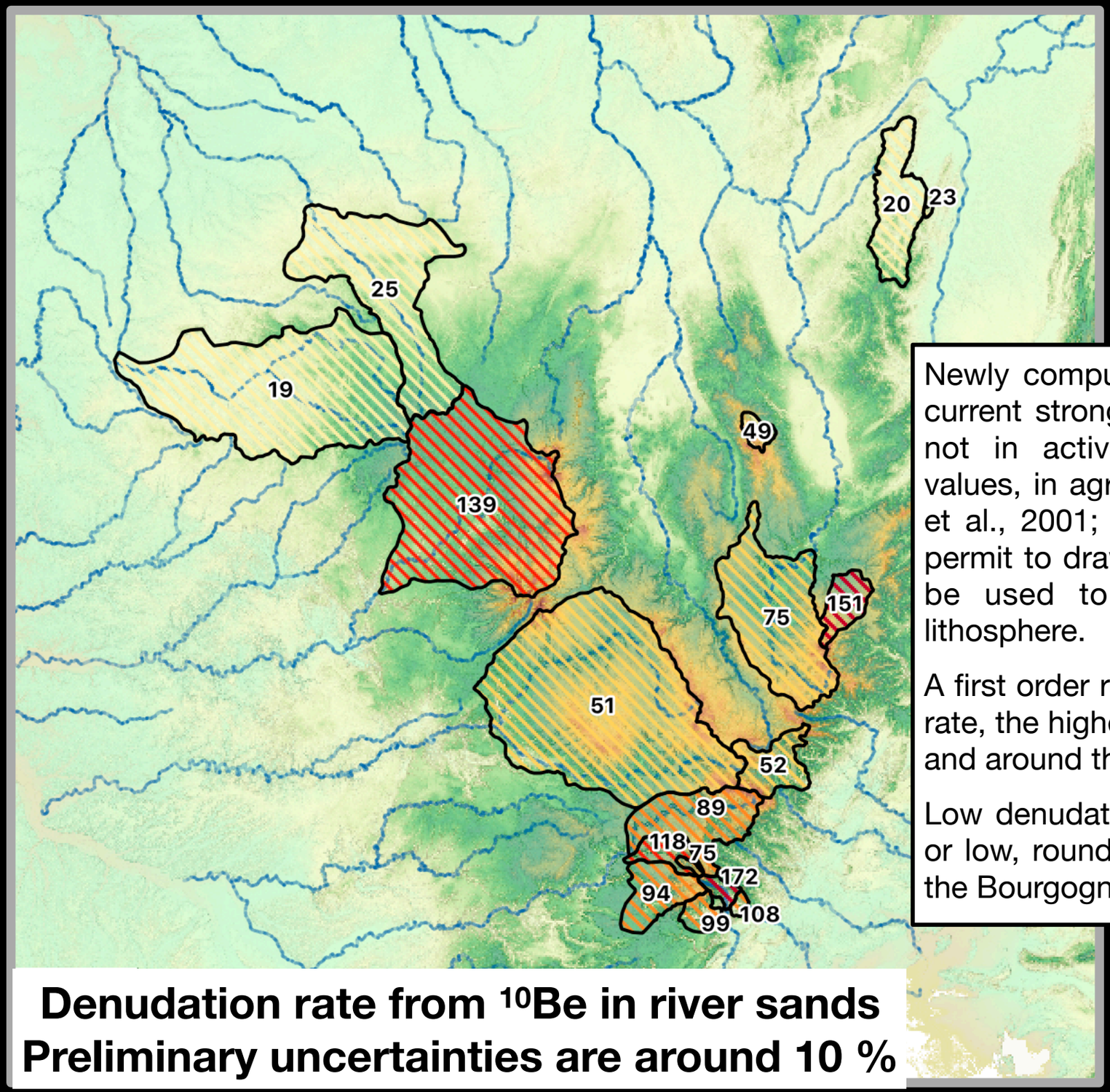


The incision rate can help to better understand the landscape evolution because it bears information concerning the relationship between base-level variations (e.g. regional uplift, eustatic variations) and the regional response (given the system capacity to adjust to such a perturbation).

For our case study, the finite incision is high (more than 300 m). From samples from 5 valleys in the near-Montpellier Region, using $^{26}Al/^{10}Be$ burial ages and classical river incision evolution scheme, we obtain a consistent regional incision rate of ~ 80 ± 30 $m.Ma^{-1}$. This incision rate is expected to be valid for at least the last 3 to 4 Ma. This result is in agreement with the ones obtained in the Tarn and Jontes canyon (Sartegou et al., 2018)



Current research :
Denudation constraints



Denudation rate from ^{10}Be in river sands
Preliminary uncertainties are around 10 %

Newly computed denudation rate for watersheds highlight the current strong denudation rate (given the fact that this area is not in active, plate-boundary location). These preliminary values, in agreement with the ones from the literature (Schaller et al., 2001; Olivetti et al., 2016 and Molliex et al., 2016) will permit to draw a regional synthetic map of denudation that will be used to constraint thermo-mechanical model of the lithosphere.

A first order relationship is found between relief and denudation rate, the higher ones being located toward the Cevennes margin and around the Cantal massif.

Low denudation rates are found toward the peripheral bassins or low, rounded relief (North-east corner of the massif-Central, the Bourgogne region).

Conclusions

- Regional incision rate as proposed previously (Malcles et al., 2020) is confirmed: 80 ± 30 m.Ma^{-1} over c.a. the Plio-Quaternary (last ~ 5 Ma)
- The average denudation rate over the Massif-Central (30 - 100 m.Ma^{-1}) is consistent with the incision rate.
- These results are consistent with a first order dynamic landscape equilibrium and sustain the proposed recent (Plio-Quaternary) and active uplift of the region due, in part by isostatic rebound.

- Results from other regions (South-west and North-East) are in progress to test the regional variations of incision rate.
- Geometric constraints from both geomorphological markers and drainage networks should bring complementary information relative to the possible landscape equilibrium status.

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