

# Quantifying incision rates since the early Miocene with karstic networks: potentialities and limitations

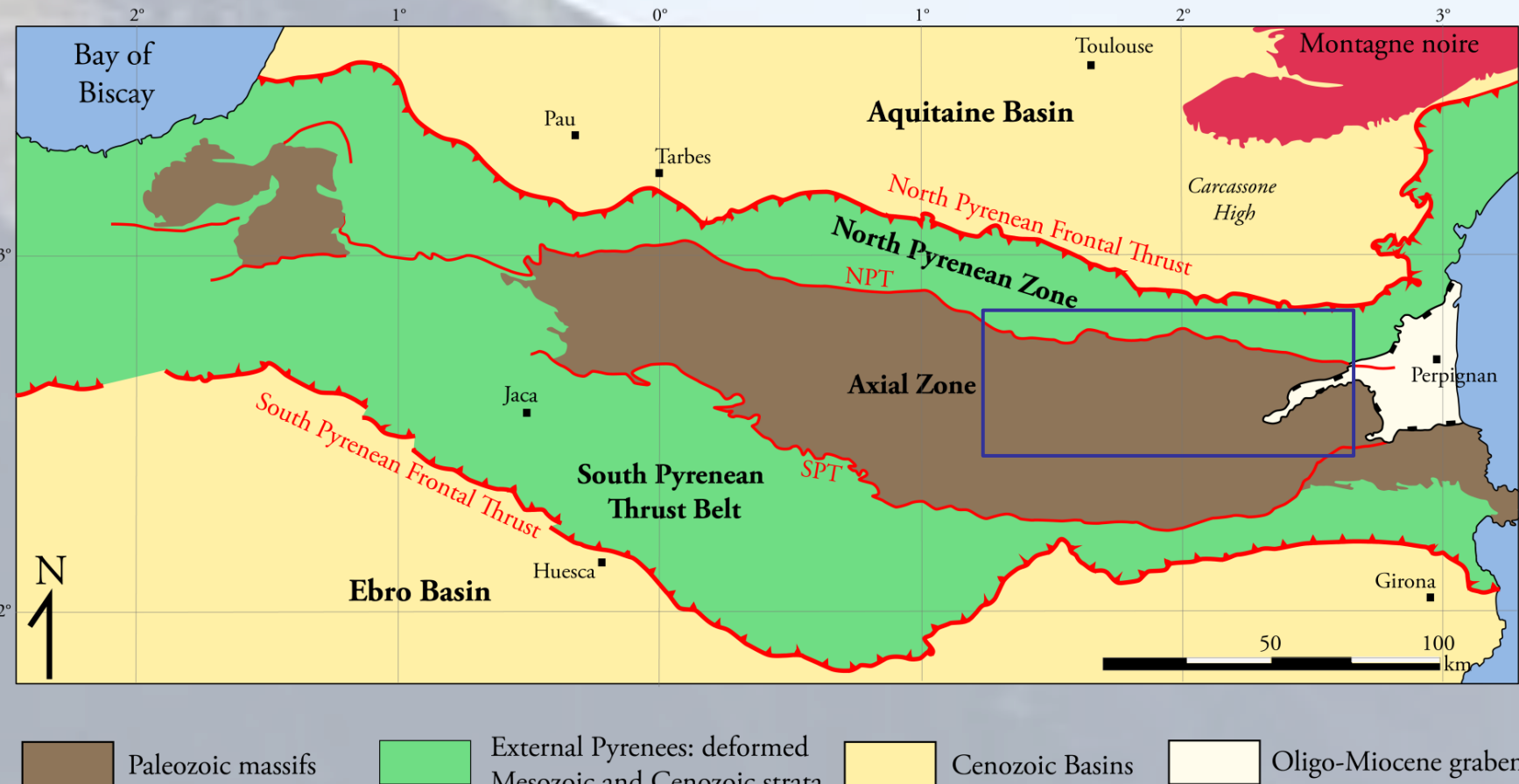
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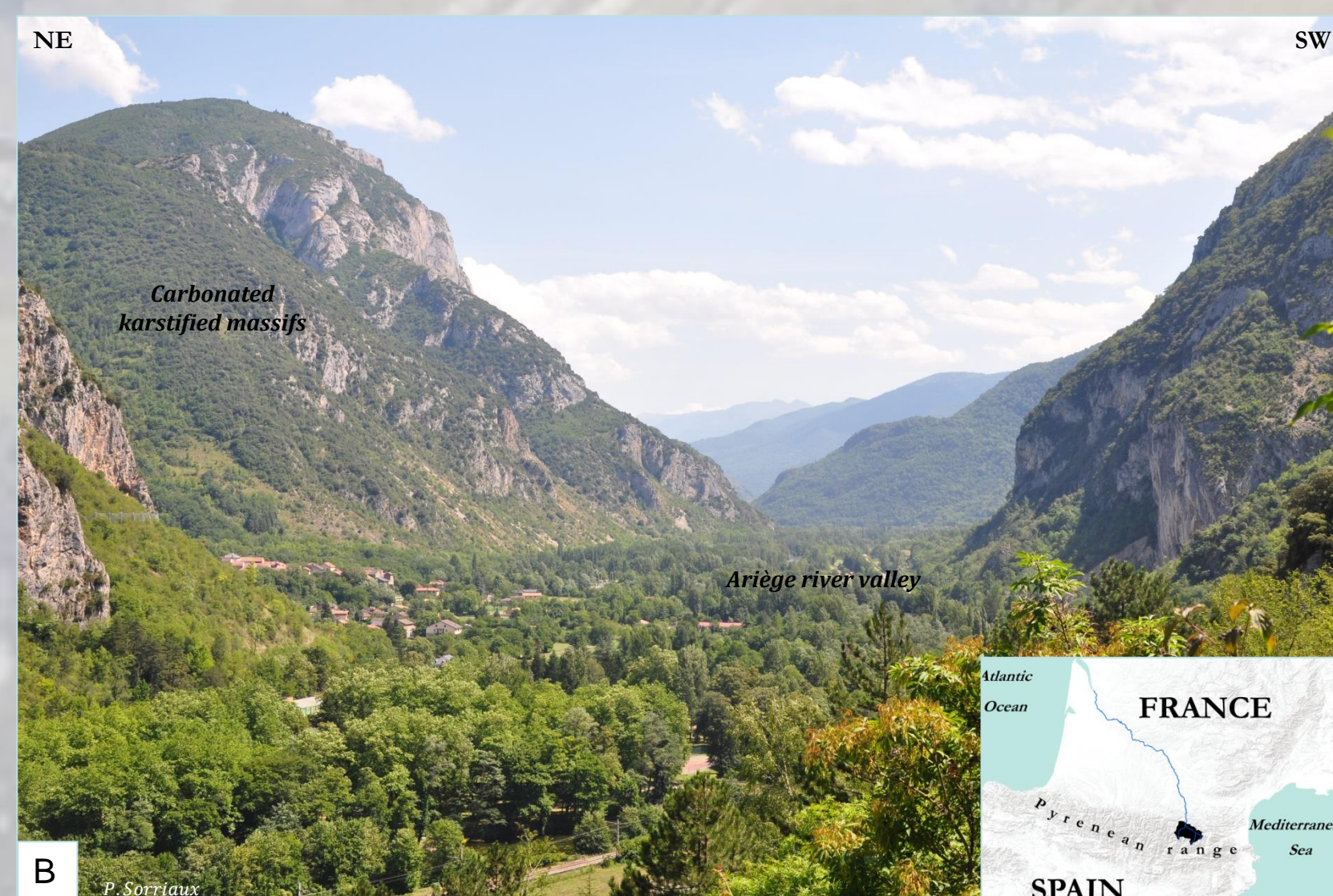
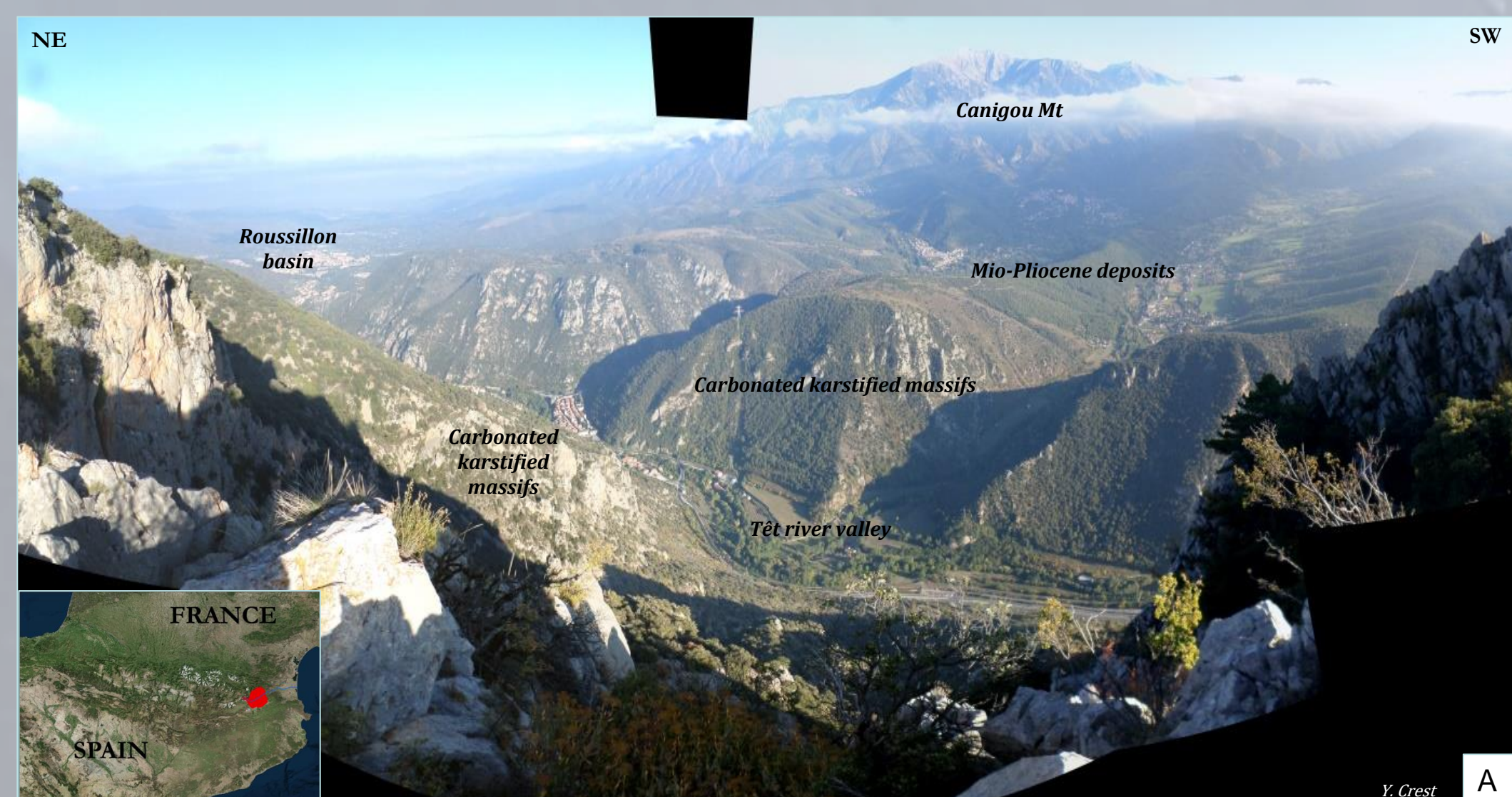
## Why this study ?

Recent studies indicate that the Pyrenees may have never reached steady state. Quantifying incision rates since the Miocene through the reconstruction of the vertical movement of geometric markers may allow to confirm or infirm such conclusions. Because the nowadays available chronologies of the Pyrenean terrace systems do not exceed the middle Pleistocene, we enlarge the investigable time span using cosmogenic nuclides and dosimetric based methodologies. The  $^{26}\text{Al}/^{10}\text{Be}$  and  $^{10}\text{Be}/^{21}\text{Ne}$  were determined to estimate the burial duration of intrakarstic alluvial deposits that may fill horizontal epiphreatic passages in limestone karstic networks. These networks indeed record the transient position of former local base levels during the process of valley deepening. The potentialities and limitations of such an approach as well as the obtained results are discussed considering the geomorphological and geodynamical contexts.

## The Eastern Pyrenees: a key zone to understand the late evolution of the orogen



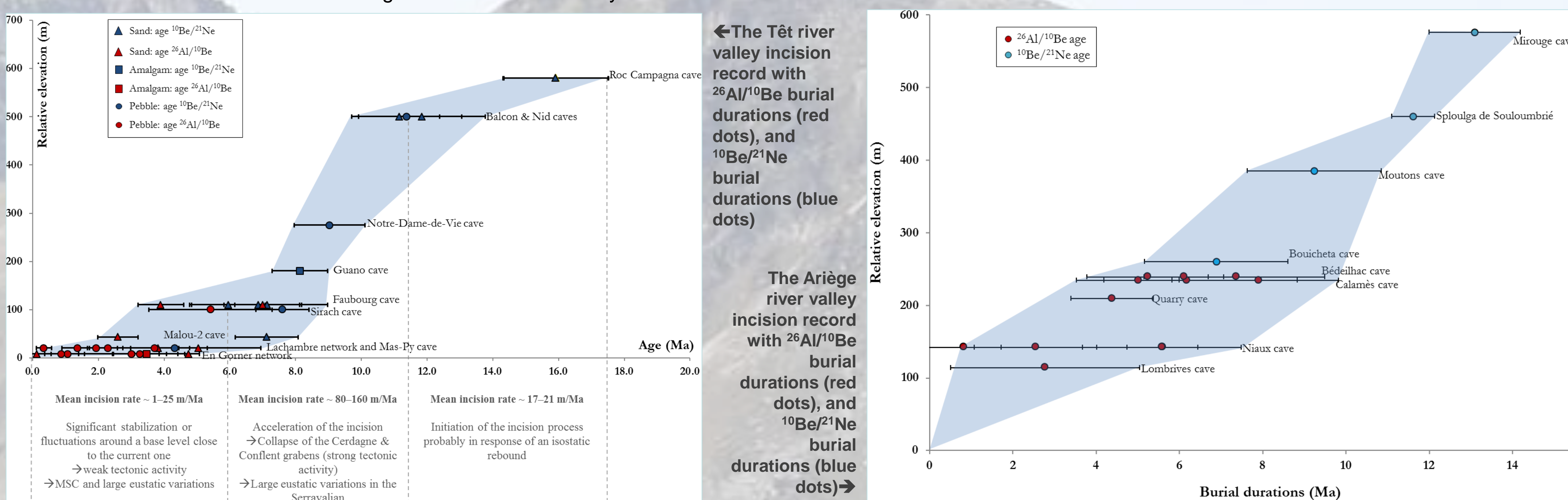
- The Pyrenees were formed along the boundary between the Iberia and European plates and result from the Late Cretaceous–Cenozoic inversion of a Cretaceous transcurrent hyper-extended rift created during the opening of Bay of Biscay;
- After the collision or during the last phase of plate convergence, the eastern Pyrenees were affected by a period of crustal thinning related to the well-defined Oligocene–Early Miocene rifting seen in the Gulf of Lions;
- Three studied river valleys: the Têt catchment (connected to the Mediterranean domain and affected by the Messinian Salinity Crisis), the Aude catchment, the Ariège catchment;
- Sediment provenance in the investigated catchment: Paleozoic crystalline massifs (gneiss, granites) and metasediments. But also Mio-Pliocene deposits due to the Miocene extension phase for the Têt valley;
- Poor conservation of alluvial terraces into the three valleys but important karstification of limestones massifs.



↑ A: The Têt river valley near Villefranche-de-Conflent. The V-shape of this valley suggests that the incision rate was not too fast relative to the slope denudation rate. Eight epiphreatic levels are identifiable on a height difference of ~ 600 m. The floors close to the current base level are the most developed. B: The Ariège river valley near Tarascon-sur-Ariège. Ten karstic levels are identifiable on a height difference of ~ 900 m, one being particularly well developed. The U-shape of this valley suggests that glacial erosion has significantly contributed to the current morphology of the landscape.

## Determination of alluvium burial duration with TCN

As long as one of the measured TCN is a radionuclide, the evolution with time of the ratio of the concentration of two different TCNs measured in the same sample depends on its burial duration at the sampling depth and on the pre- and post-burial denudation rates. The surface  $^{26}\text{Al}/^{10}\text{Be}$  ratio over the 0.20 – 6.5 Ma investigable time interval is  $6.61 \pm 0.50$  within the range of the most commonly encountered denudation rates

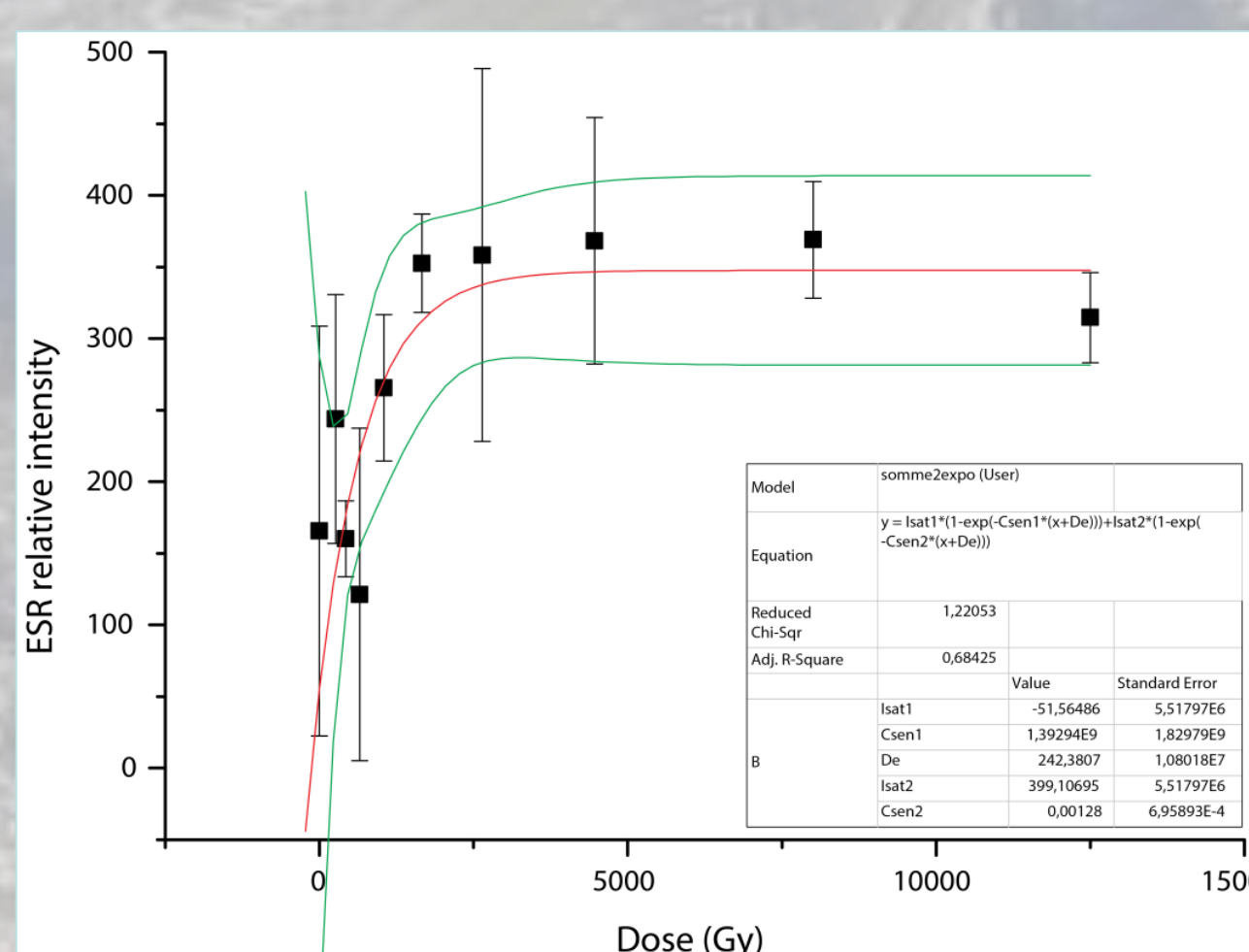


- $^{26}\text{Al}/^{10}\text{Be}$  burial durations. Two major uncertainties: 1/ the deposited sediment initial ratio and 2/ intrakarstic mixing. Sediments may indeed have undergone at least one former cycle of exposure / burial before being remobilized (Mio-Pliocene formation in the Têt valley). In the case of barred karsts or variations of the base level due to glaciations or eustatic fluctuations, mixing between alluvial deposits of several generations can occur;
- $^{10}\text{Be}/^{21}\text{Ne}$  burial durations. The deduced burial durations are at most maximum burial durations because they may integrate several burial-exposure cycles. This is nevertheless a potential powerful tool to reconstruct incision record since early Miocene.

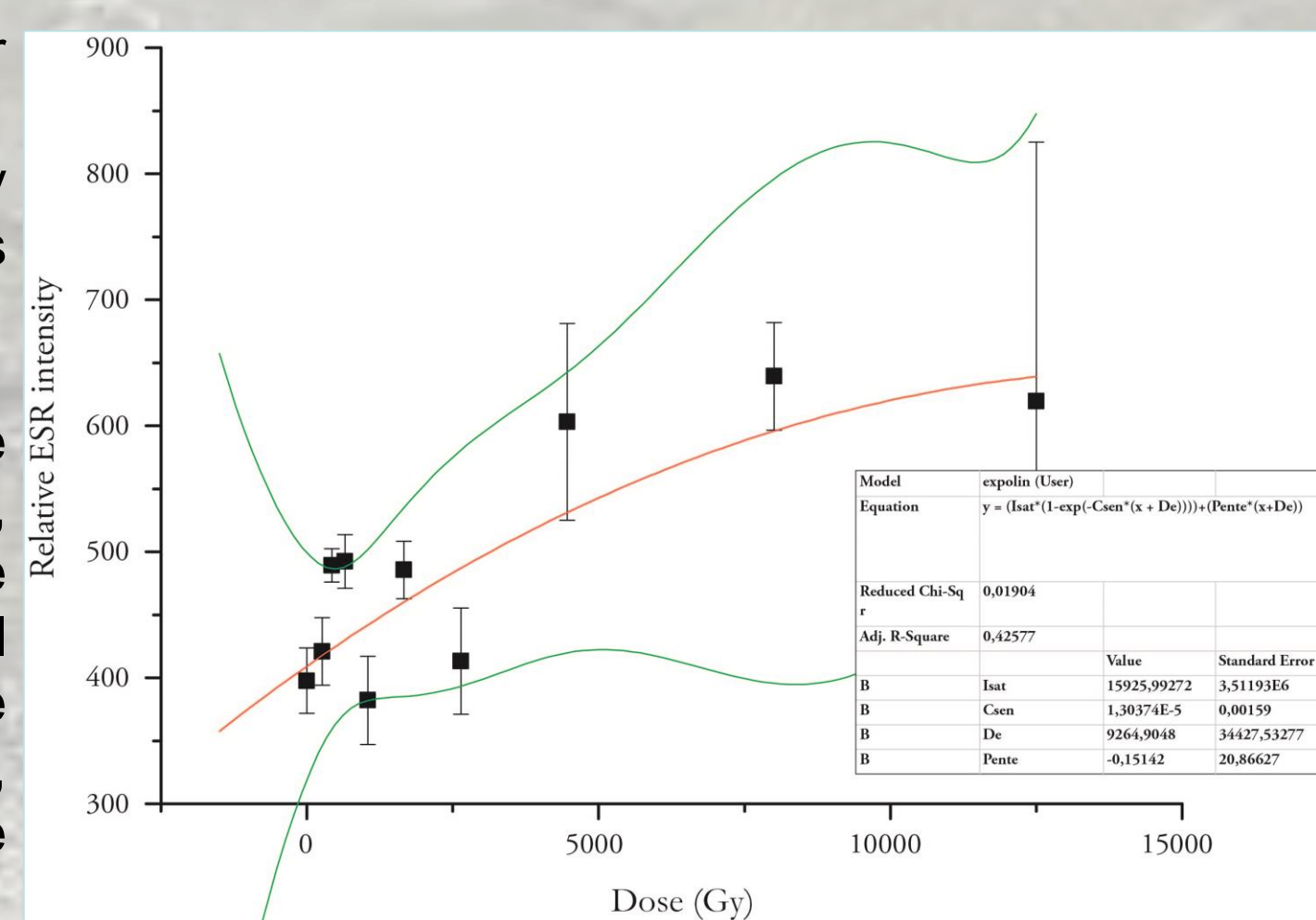
## Determination of alluvium burial duration with ESR/OSL

### ESR burial dating

The main hypothesis is that the mineral grains acquired their signal through exposure to ionizing radiation during their burial period, the signal being reset (bleaching) when they are exposed to light concomitant to sediment erosion and transportation.



- Only Al-centers being measured: strong angular dependence, measurements not reproducible;
- The measured doses are often scattered and the majority of the samples having experienced low irradiation doses emitted signals weaker than the bleached sample.



### OSL burial dating

Same basic postulate as for the ESR method. The signals obtained are at saturation but seem to indicate radio-sensitivity problems without obliterating the other hypotheses emitted above.

## Evolution of the eastern Pyrenees since Burdigalian

### Incision records

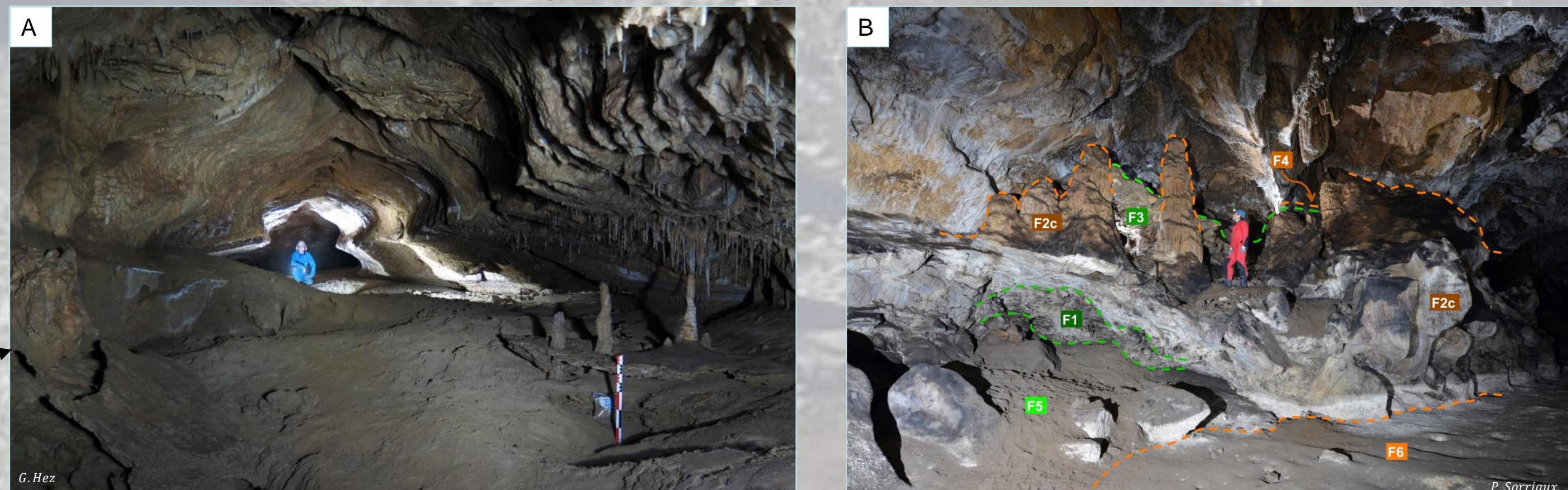
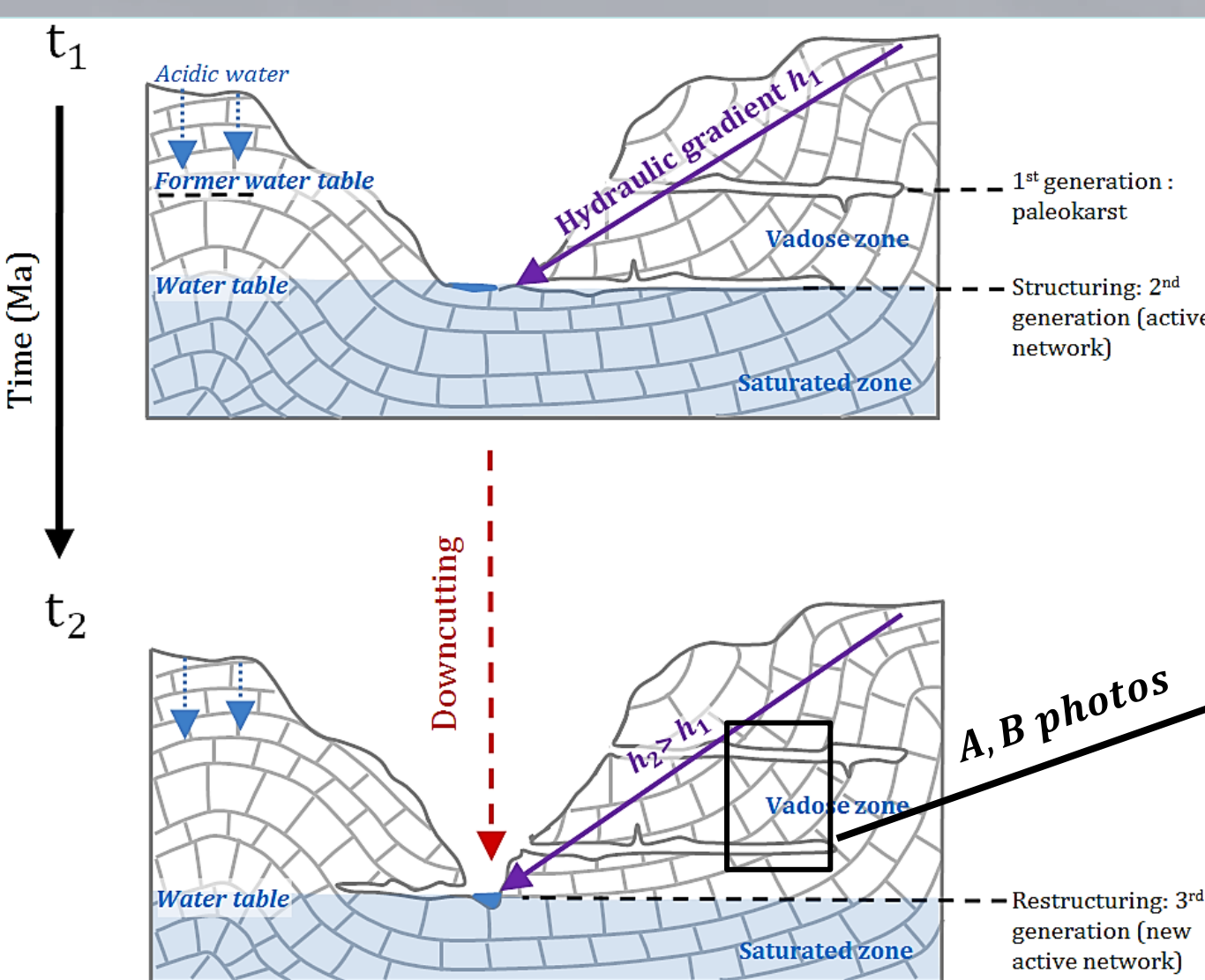
- For the Têt river valley:  
→Continuous record of incision, but in successive stages since the Burdigalian;  
→Low elevation karstic networks indicate a more complex history. The obtained results may be interpreted as due to i) Mio-Pliocene sediments entering the caves, ii) a stagnation phase, iii) base-level fluctuation due to Mediterranean eustatic variations.
- For the Ariège river valley:  
→Continuous record of incision since the Langhian;  
→Thin-plate observations and TCN burial dating indicate alluvial deposits composed of a mixing of glacial and alluvial quartz.

### Is it possible to decipher uplift evolution ?

- Regarding the Têt river valley, it appears difficult to directly link incision and uplift because of the direct Mediterranean Sea connection. The eustatic variations during the Messinian and Pliocene periods may have played a significant role in the process of incision;
- Regarding the Ariège river valley, the influence of glaciation hampers determining the age of the development of the large networks. A non-negligible part of the incision is probably due to a post-glacial rebound.

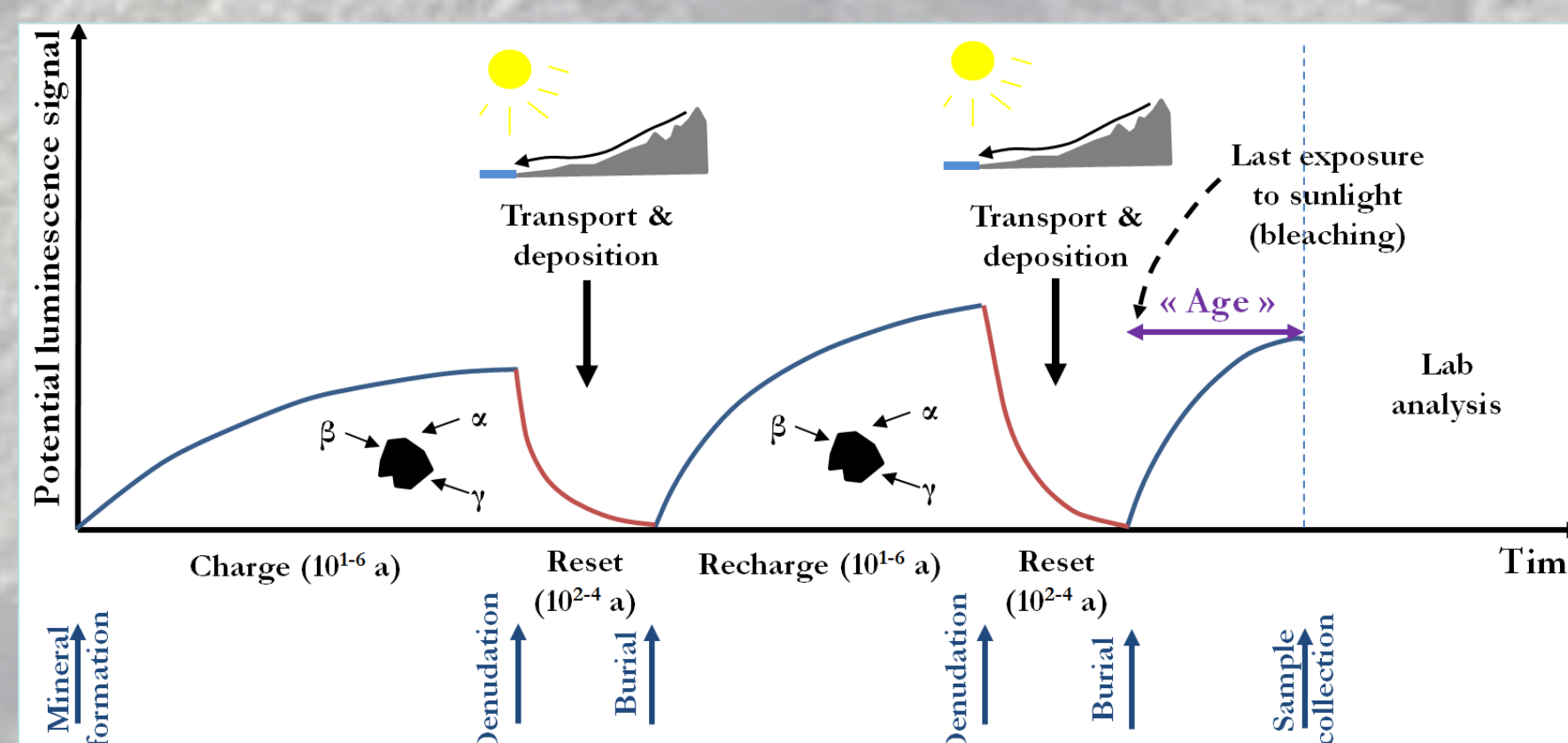
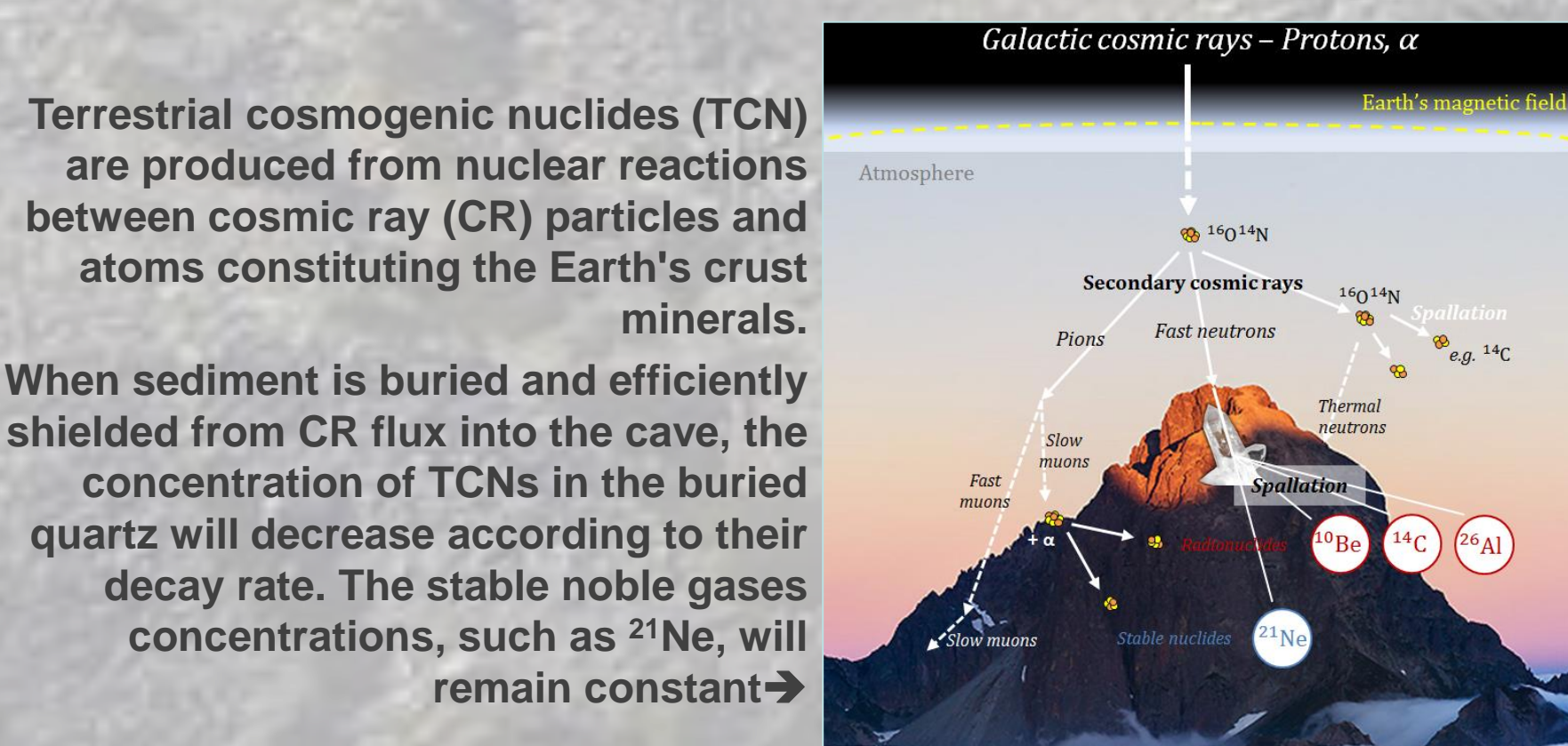
## How to quantify incision with karstic networks?

← Epiphreatic galleries indicate water-table proximity. Due to valley deepening, various generations of horizontal conduits are generated, the more recent networks forming below previous generations.



↑ A: Characteristic morphologies in the Porte de Fer gallery (En Gornet network, Têt valley). B: Counts of Foix gallery with polyphased alluvial deposits (Niaux network, Ariège valley). Network formation is considered to be fast (10-40 ka), but morphologies and deposits are conserved for My.

- Staged karstic system record the transient position of former local base levels during the process of valley deepening, as fluvial terraces do;
- The burial duration of alluvium (sands, pebbles, cobbles) trapped and preserved into horizontal passages have been determined.



←Luminescence (L) is acquired in quartz during its exposure to ionizing radiation and the concomitant trapping and storage of the free electrons in the charge defects within the quartz mineral lattice. The L is "zeroed" (bleaching) by the exposure of the quartz to sunlight during the denudation and transport processes. Then, a new burial episode will permit acquisition of L due to a protected from sunlight exposure to ionizing radiation.