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Morphogenetic evolution of the Têt river valley (eastern Pyrenees, France) using $^{10}\text{Be}/^{21}\text{Ne}$ cosmogenic burial dating

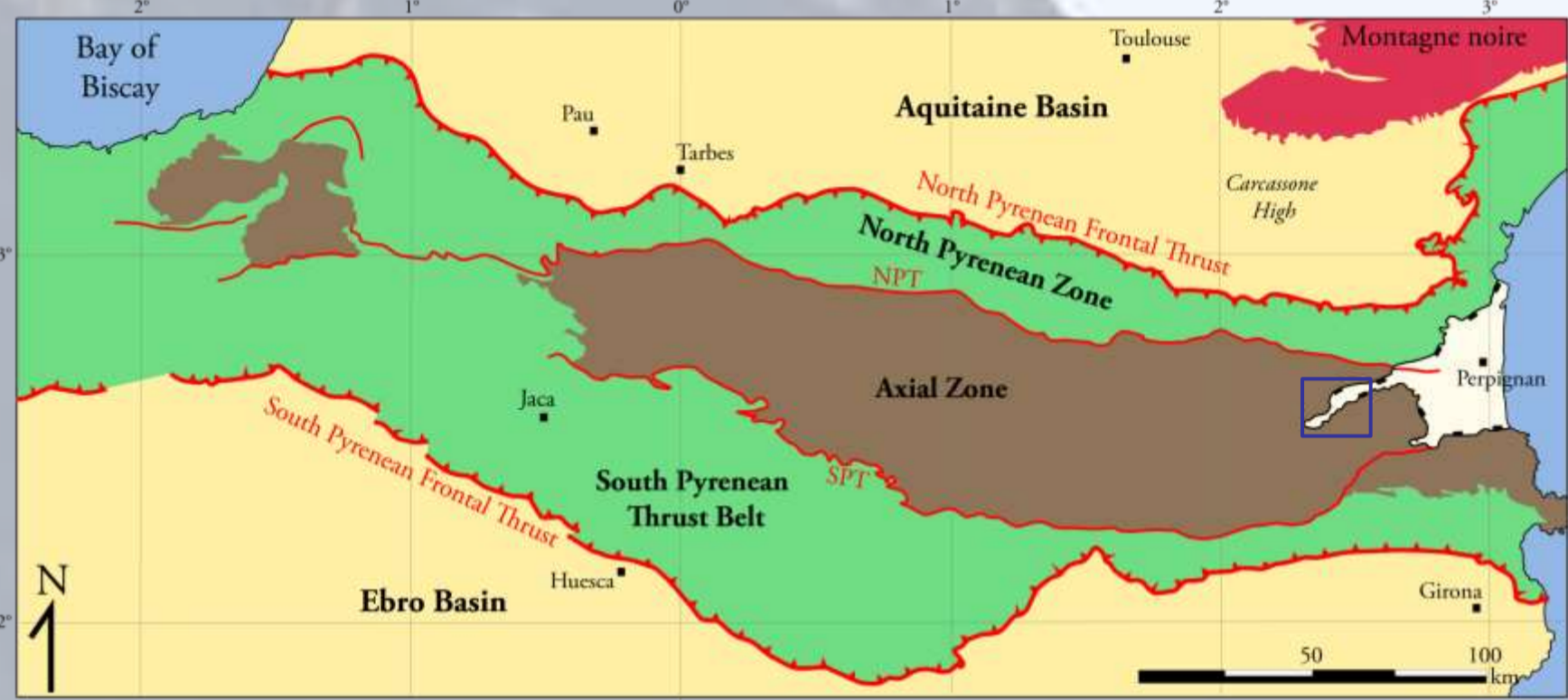
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Why this study ?

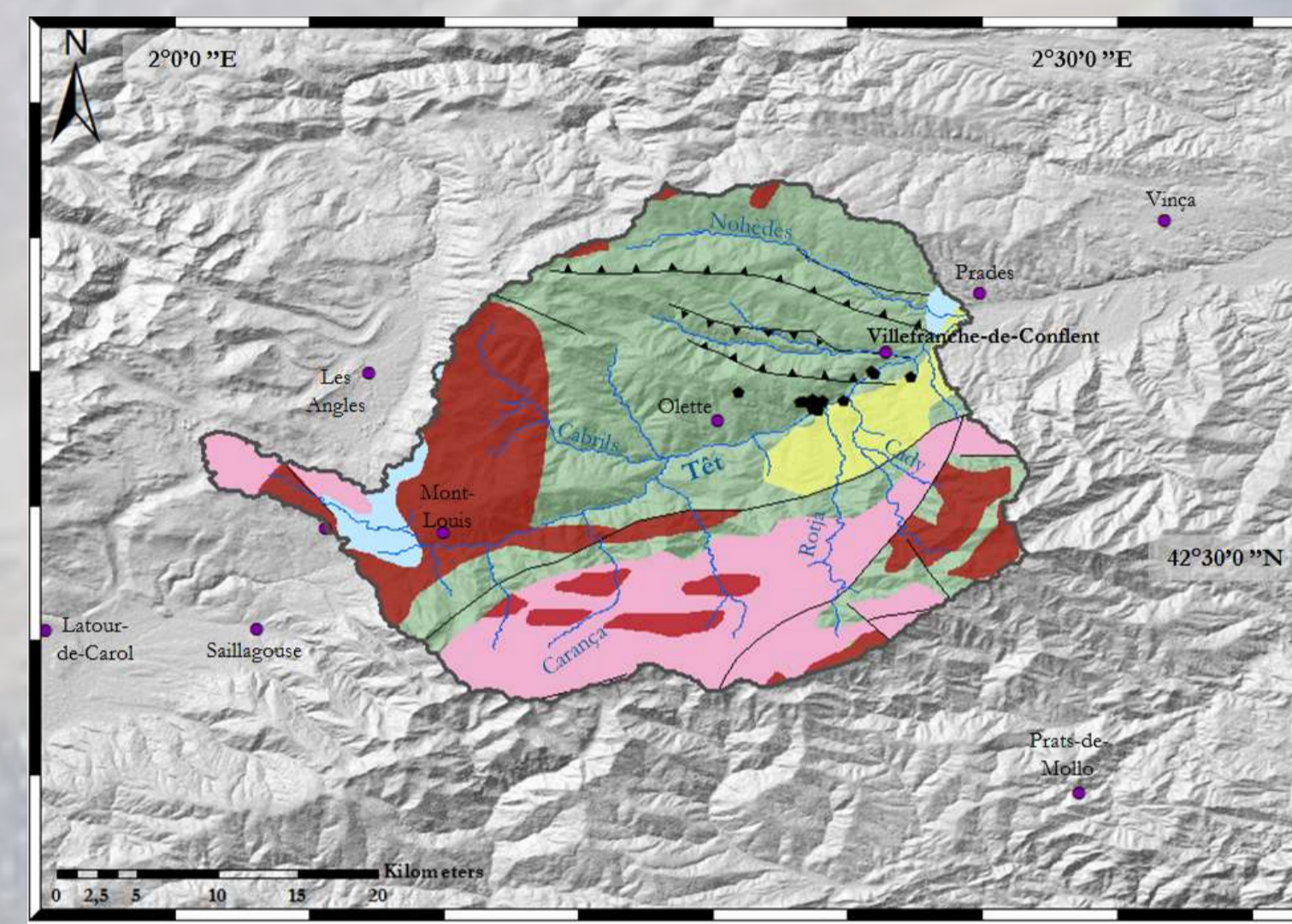
The rates and chronologies of valley incision are closely modulated by the tectonic uplift of active mountain ranges and were controlled by repeated climate changes during the Quaternary (e.g. Molnar et England, 1990; Reiners *et al.*, 2003). The continental collision between the Iberian and Eurasian plates induced a double vergence orogen, the Pyrenees, which has been considered as a mature mountain range in spite of significant seismicity (e.g. Chevrot *et al.*, 2011) and evidence of neotectonics (e.g. Goula *et al.*, 1999). Nevertheless, recent studies indicate that the range may have never reached a steady state (Ford *et al.*, 2016). One option for resolving this controversy is to quantify the incision rates since the Miocene by reconstructing the vertical movement of geometric markers such as fluvial terraces. However, the few available ages from the Pyrenean terrace systems do not exceed the middle Pleistocene. Thus, to enlarge the time span of this dataset, we studied alluvium-filled horizontal epiphreatic passages in limestone karstic networks. Such landforms are used as substitutes of fluvial terraces because they represent former valley floors (e.g. Palmer, 2007; Audra *et al.*, 2013). They record the transient position of former local base levels during the process of valley deepening.

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;

Geology et tectonic structures of the Têt catchment



Legend for geological units: Paleozoic massifs, External Pyrenees: deformed Mesozoic and Cenozoic strata, Cenozoic Basins, Oligo-Miocene graben.

➤ The Têt: river connected to the Mediterranean domain and affected by the Messinian Salinity Crisis (e.g. Clauzon *et al.*, 2015);

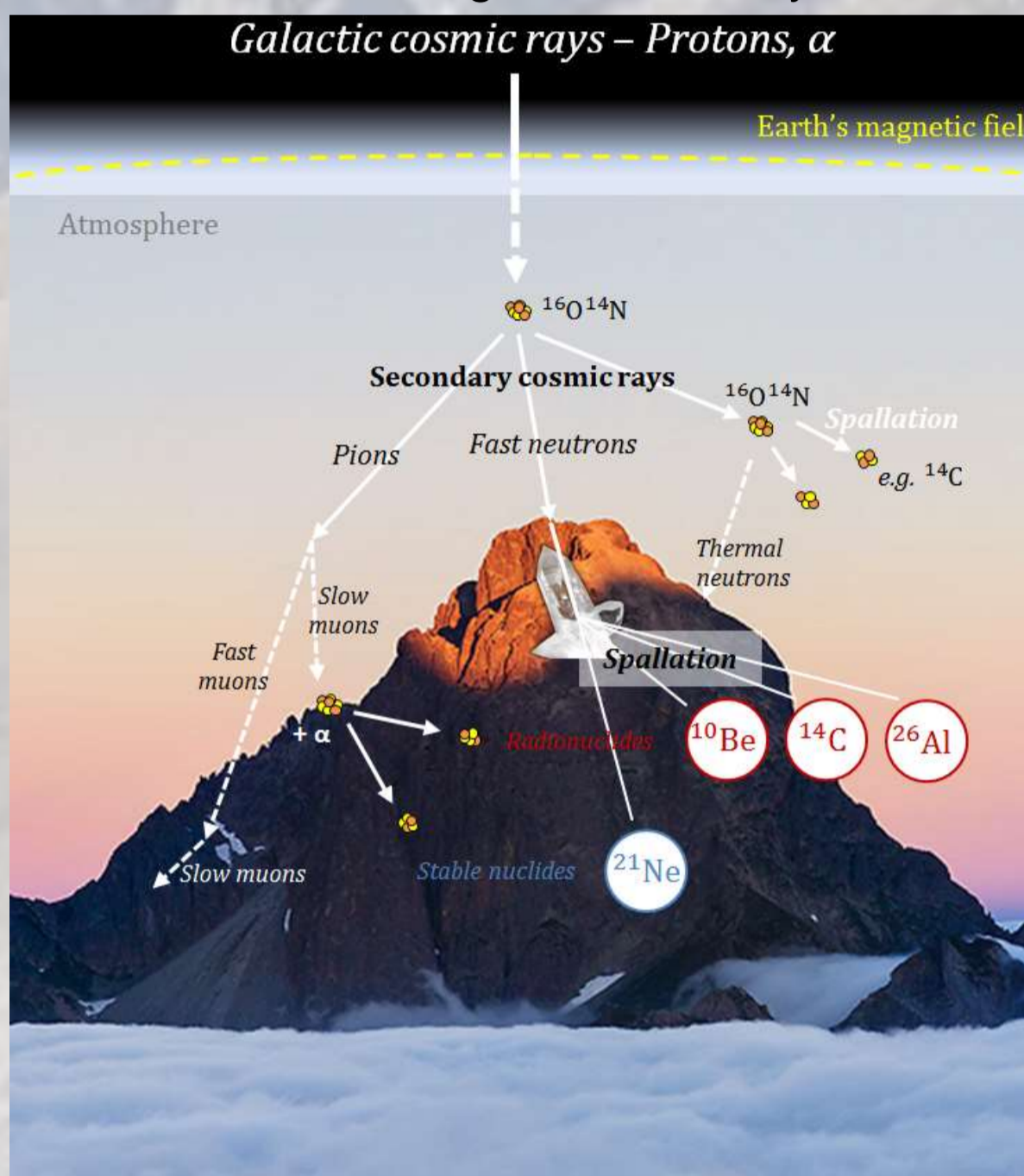
➤ Sediment provenance in the investigated catchment: Paleozoic crystalline massifs (gneiss, granites) and metasediments. But also Mio-Pliocene deposits due to the Miocene extension phase;

➤ Poor conservation of alluvial terraces into the Villefranche-de-Conflent gorges;

➤ Important karstification of Devonian limestones massifs;

How to determine alluvium burial duration?

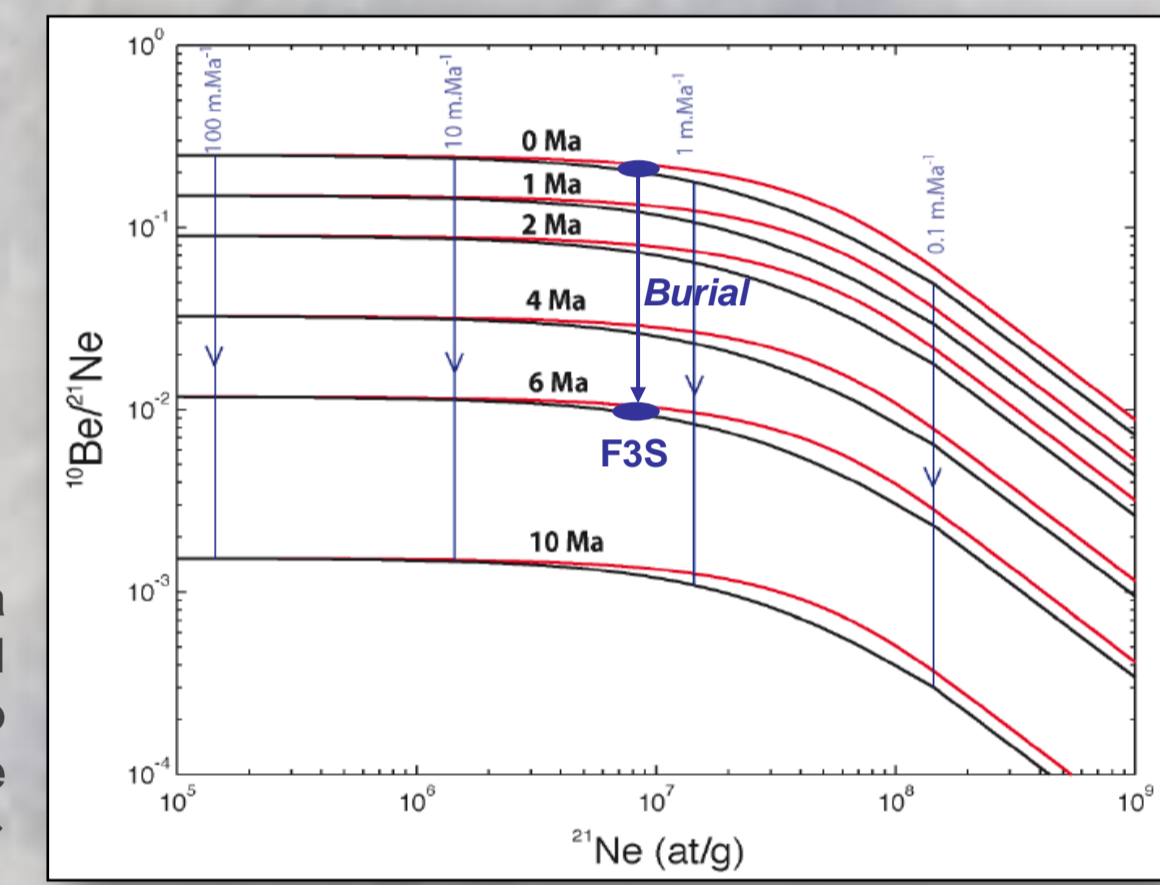
Terrestrial cosmogenic nuclides (TCN) are produced from nuclear reactions between cosmic ray particles and atoms constituting the Earth's crust minerals. When sediment is buried and efficiently shielded from cosmic ray flux into the cave, the concentration of TCNs in the buried minerals, for example quartz, will decrease according to their decay rate. The stable noble gases concentrations, such as ^{21}Ne , will remain constant.



The change in the ratio of the concentration of two different TCNs in the same sample, as long as one is a radionuclide, depends on burial duration, denudation rate, and depth. Usually, the $^{26}\text{Al}/^{10}\text{Be}$ ratio is suitable in quartz minerals, over the 0,20 – 5,5 Ma time interval (Granger et Muzikar, 2001). Given that $^{26}\text{Al}/^{10}\text{Be}$ cosmogenic burial dating in this setting was limited to the last ~5 Ma (Calvet *et al.*, 2015), here we used the cosmogenic $^{10}\text{Be}/^{21}\text{Ne}$ method (e.g. Balco & Shuster, 2009; McPhillips *et al.*, 2016) in order to restore a more complete chronology of valley incision.

← Interacting with Earth's atmosphere components, cosmic ray energetic particles induced a nuclear cascade, producing in abundance secondary particles like neutrons, which allow formation of TCN. In the lithosphere, production rates exponentially decrease with the crossed material thickness.

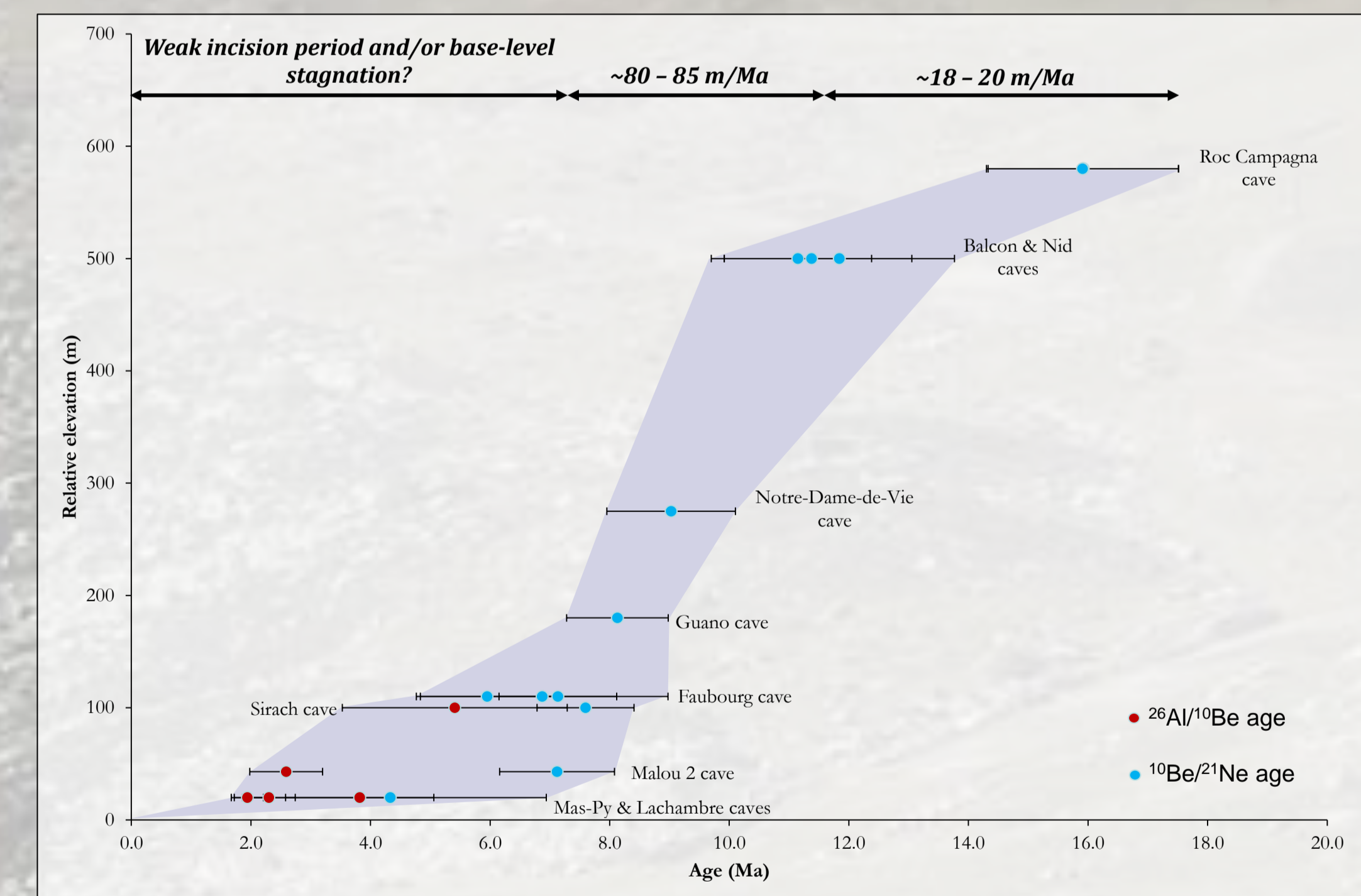
$^{10}\text{Be}/^{21}\text{Ne}$ vs ^{21}Ne plot. Example with a Faubourg cave sample whose burial duration is $6,0 \pm 1,1$ Ma. We can also determinate a paleo denudation rate of 2 m/Ma



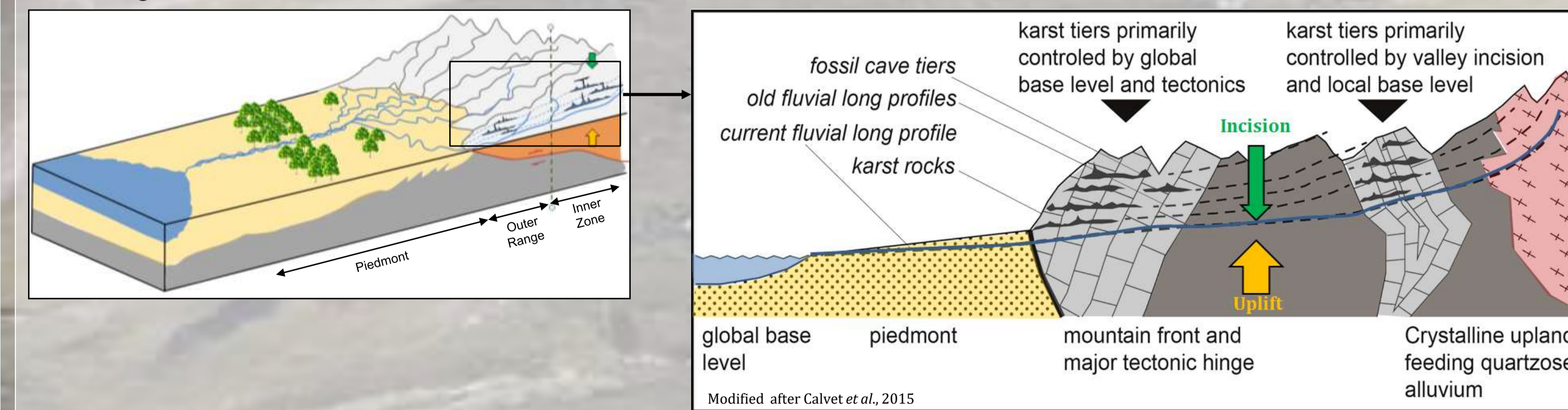
Evolution of the Têt canyon since Burdigalian

Incision record

- Continuous record of incision, but in successive stages since Burdigalian;
- Quartz from Faubourg cave record the same burial duration using both $^{26}\text{Al}/^{10}\text{Be}$ and $^{10}\text{Be}/^{21}\text{Ne}$ methods. But quartz from the low elevation karstic networks indicate a more complex history. In other context the classical interpretation is a complex burial history, but in karstic networks we could interpret this difference as sediments reworking between two connected levels or mixtures due to i) a stagnation phase, ii) base-level fluctuations. This phase could be linked with the Messinian Salinity Crisis (e.g. Clauzon *et al.*, 2015) and the weak tectonic activity of the zone since this epoch (Delcaillau *et al.*, 2004);
- Our results are consistent with previous works based on pollens and mammals records (e.g. Agustí *et al.*, 2006, Suc & Fauquette, 2012);
- Pre-burial catchment derived denudation rates are low. Cosmogenic ^{21}Ne concentrations revealed an initial paleo denudation rate of ~0,3 m/Ma. This potentially indicate a planar poorly-incised surface 16 Ma ago. No acceleration during the Quaternary is recorded in this valley;



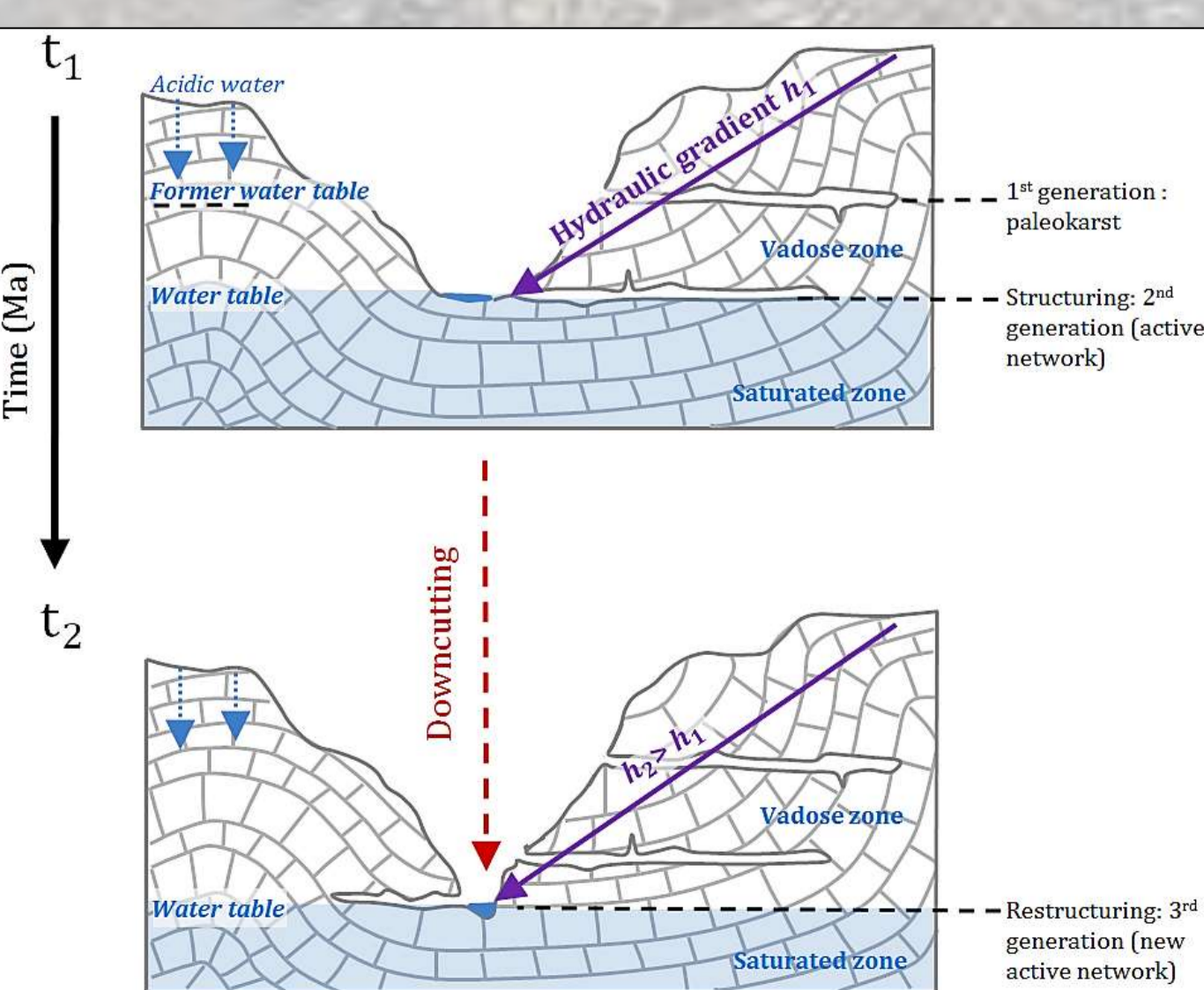
- The Pla des Horts plateau (+ 900 – 1100 m) seems to be Burdigalian in age.



Is it possible to record uplift evolution ?

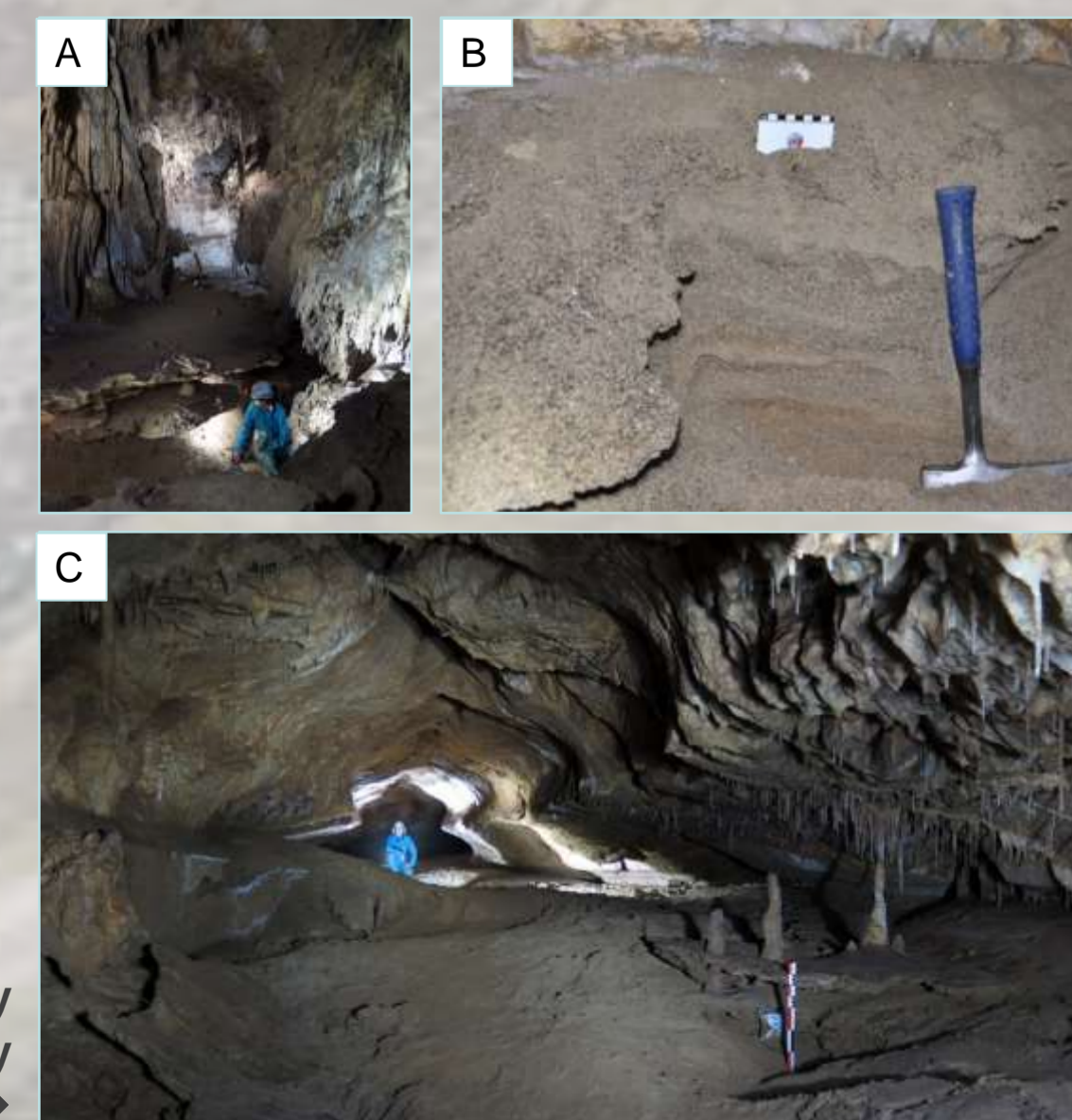
- Using cave levels to reconstruct uplift records is only relevant in the mountain front, where karstic networks are connected to the regional base level (Calvet *et al.*, 2015);
- For the Conflent zone, it appears difficult to directly link incision and uplift because of the direct Mediterranean Sea connection. Thus, the eustatic variations may play a significant role in the process of incision, although our recording resolution does not allow to firmly assert it.

How to quantify incision with karstic networks?



← Due to valley deepening, various generations of horizontal conduits are generated, the more recent networks forming below previous generations

- Network formation is very fast (10-40 ka), but morphologies and deposits are conserved for millions years;
- Epiphreatic galleries indicate water-table proximity: they represent former valley floors;
- Staged karstic system record the transient position of former local base levels during the process of valley deepening, as fluvial terraces;
- We have dated alluvium which are trapped and preserved into horizontal passages.



A: Sand and gravels on the En Gorner network; B: sandy deposits of the Lachambre network; C: Porte de Fer gallery (En Gorner). Ph. G. Hez

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