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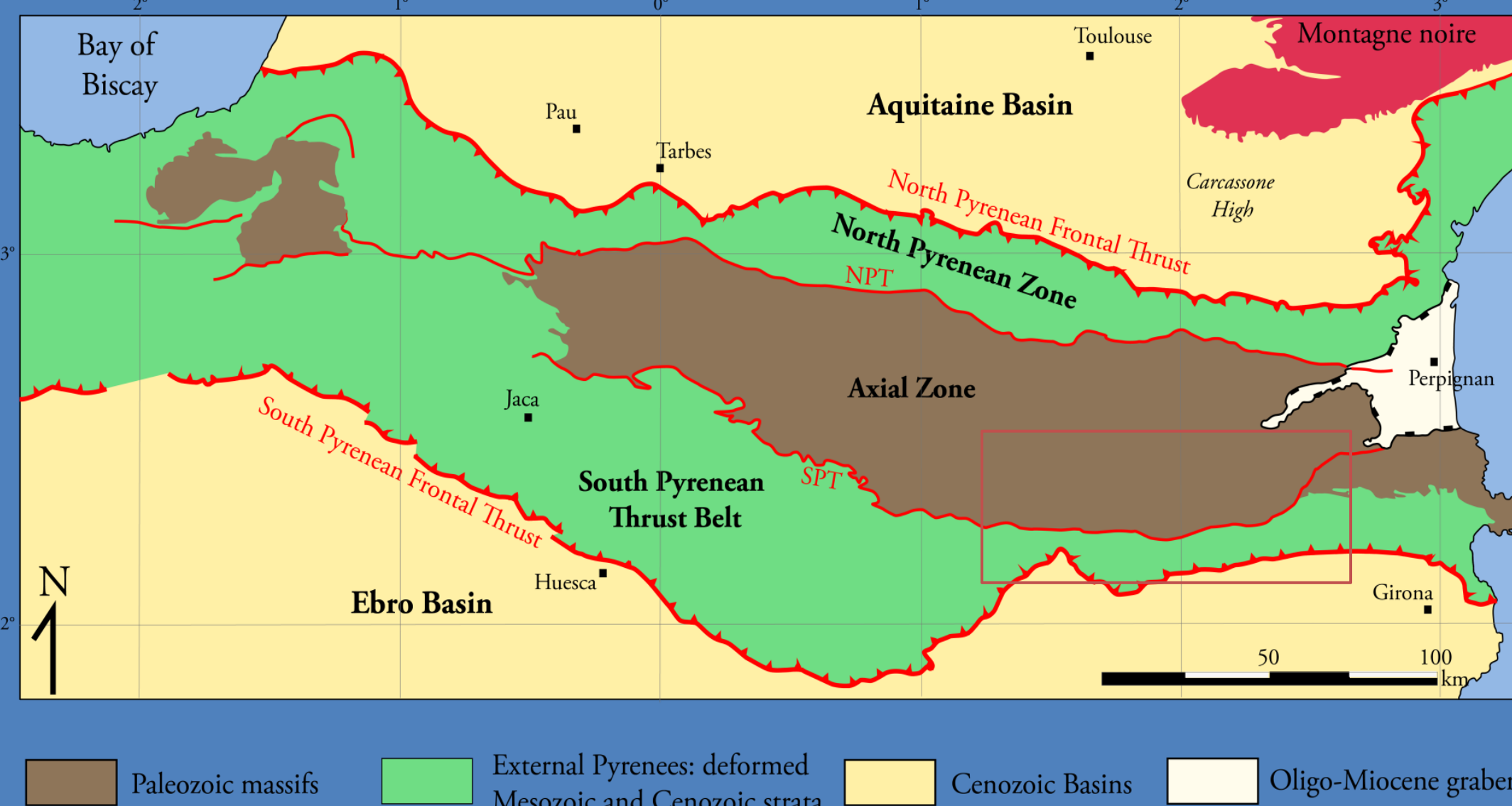
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Why this study ?

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

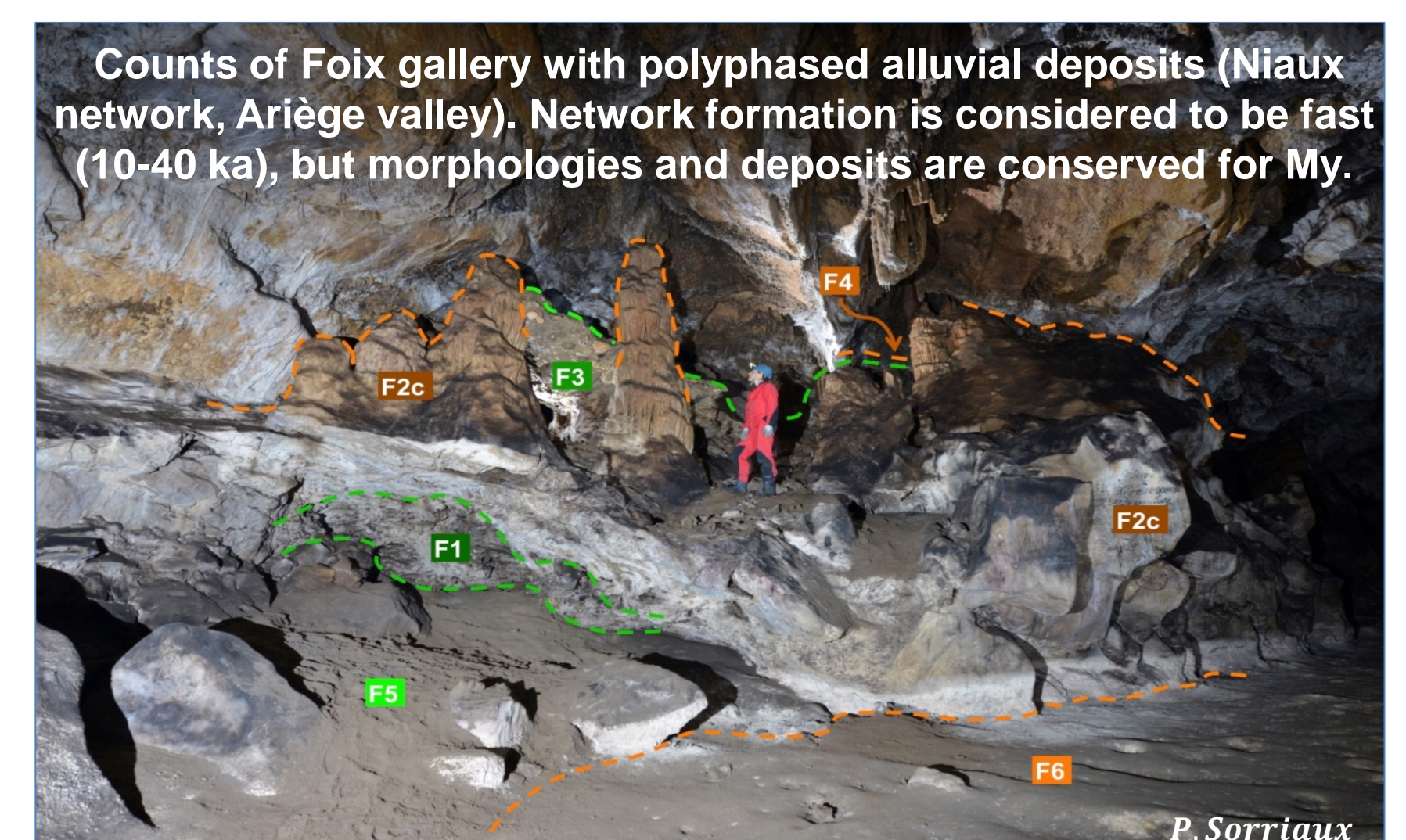
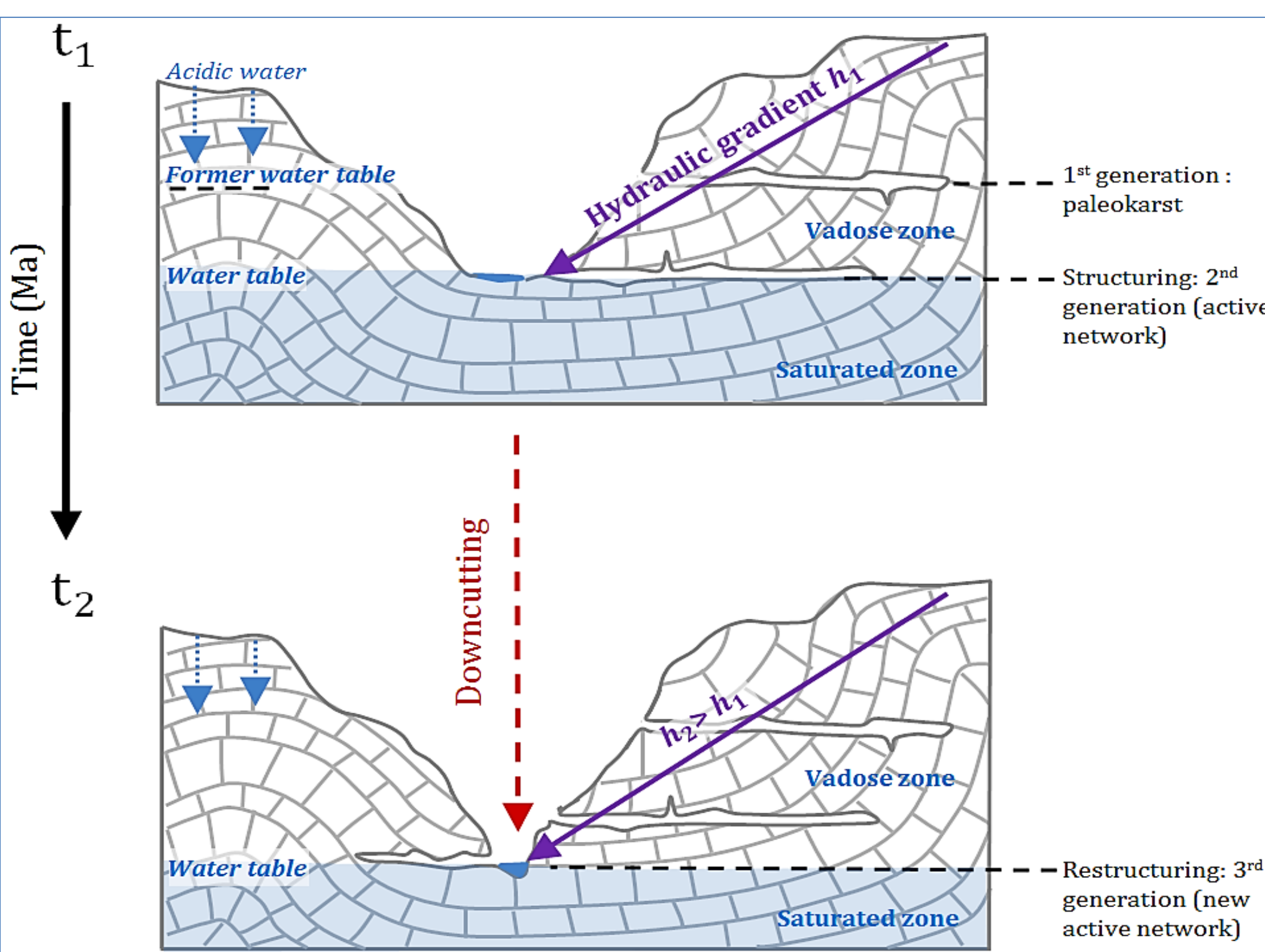


A: The Têt river valley near Villefranche-de-Conflent. The V-shape of this valley suggests that the incision rate was not too fast relative to the slope denudation rate. Eight epiphreatic levels are identifiable on a height difference of ~ 600 m. The floors close to the current base level are the most 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.

- 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.

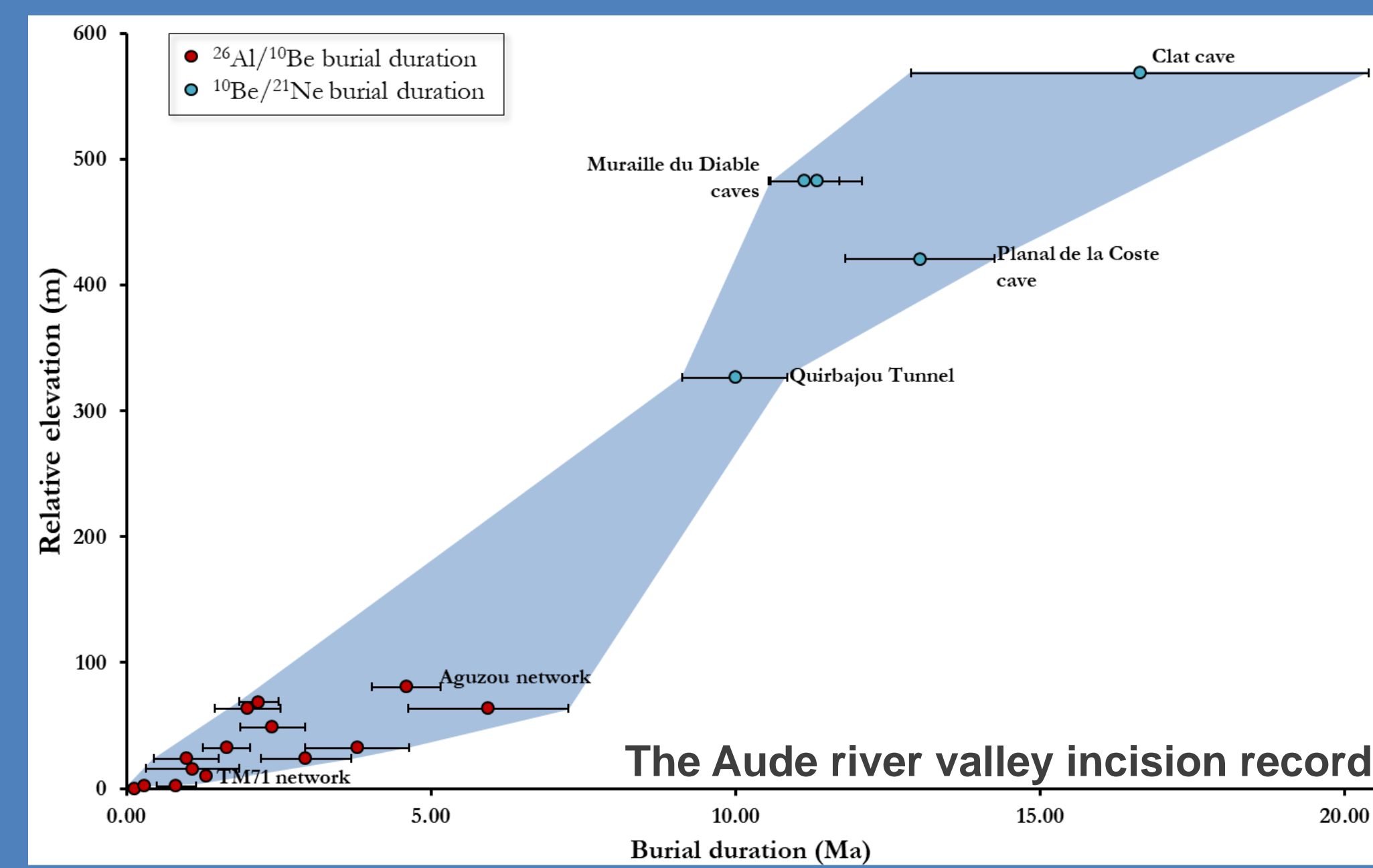
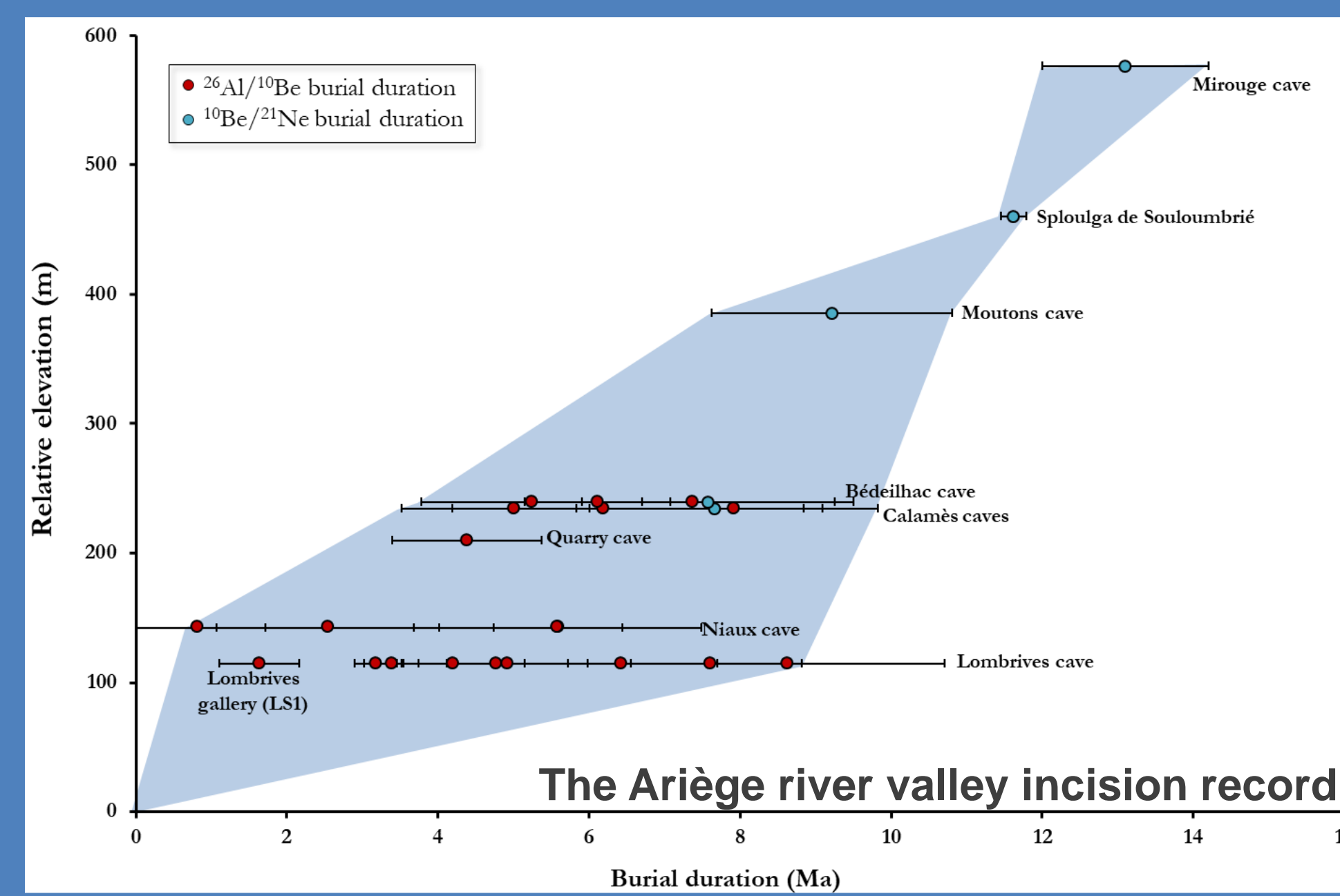
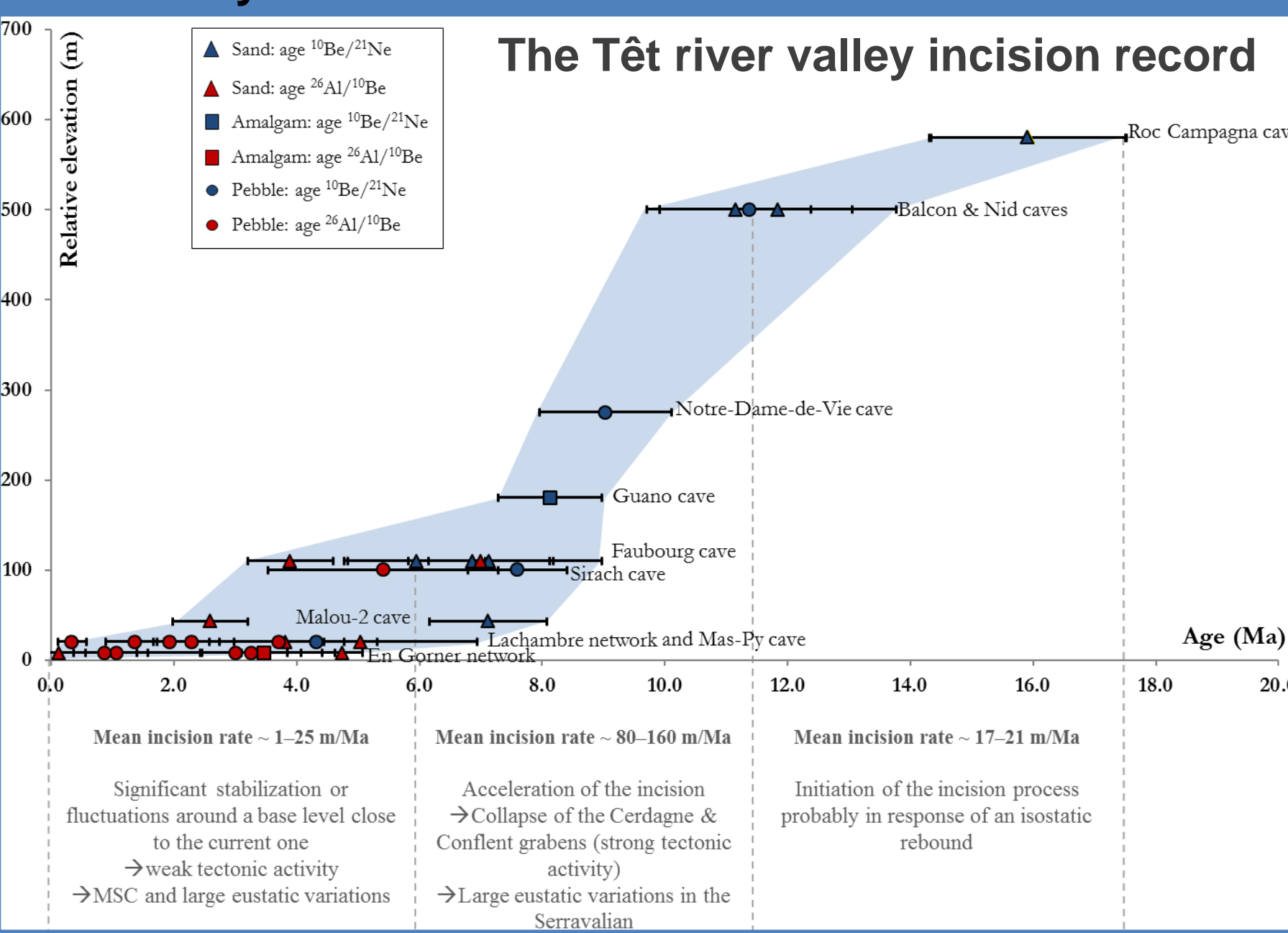
How to quantify incision with karstic networks?



- Epiphreatic galleries indicate water-table proximity.
- Staged karstic system record the transient position of former local base levels during the process of valley deepening, as fluvial terraces do.
- The $^{26}\text{Al}/^{10}\text{Be}$ and $^{10}\text{Be}/^{21}\text{Ne}$ burial duration of alluvium (sands, pebbles, cobbles) trapped and preserved into horizontal passages have been determined.

Determination of alluvium burial duration with TCN

As long as one of the measured TCN is a radionuclide, the evolution with time of the concentration ratio 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 ± 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.

Evolution of the eastern Pyrenees since Burdigalian

Incision records

Is it possible to decipher uplift evolution ?

- **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 but large dispersion of the results in Niaux and Lombrives networks;
 - ➔ Thin-plate observations and TCN burial dating indicate alluvial deposits composed of a mixing of glacial and alluvial quartz → mixing during glaciation phases.
- **For the Aude river valley:**
 - ➔ Continuous record of incision since the Burdigalian, with a mean incision rate of ~50 m/Ma from the Langhian to the Messinian. From the Messinian, a mean incision rate of ~20 m/Ma is recorded;
 - ➔ At the actual base level, alluvium exhibits burial duration between ~40 and ~700 ka, rising the question of the influence of base level stagnation phases and or time transfer into the karst;
 - ➔ The barred karst of the Cthulhu Démoniaque, which is still experiencing floods, conserved alluvium since ~1,5 Ma. The question of sediment disposal in the case of barred karsts is therefore to be studied
- 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;
- Regarding the Aude river valley, the only question that really arises is the outlet of the watershed (connection to the Atlantic or to the Mediterranean Sea ? What period?).
- However, a common trend emerges;
- Probable rejuvenation of the relief from the lower Miocene, probably because of isostatic rebounds or in response to regional tectonic constraints that may explain some E-W contrasts;
- Plio-Pleistocene evolution generally complex to constrain using this methodology.
- Based on our data and those acquired by other teams further west (Genti, 2015), the central Pyrenees seem more active;
- Similarly, the incision rates obtained by Genti (2015) on the Spanish side are faster. On this slope, the passage of the Ebro basin from an endorheic to exorheic system is probably not negligible.