First quantitative evidence of ghost-rock karstification controlling the regional karst geometry

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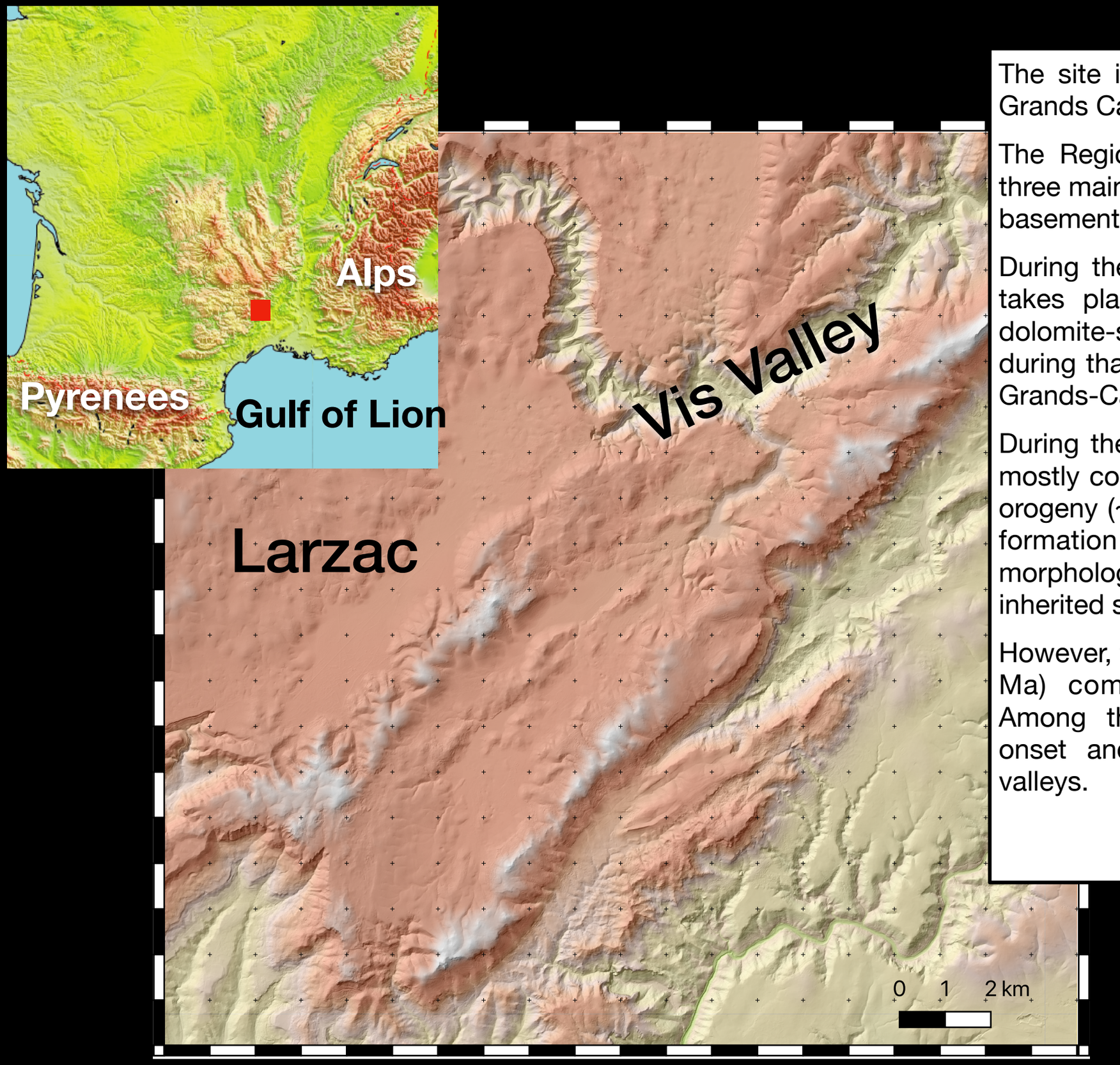
Geological setting



The site is located in Southern-France: the Grands Causses region.

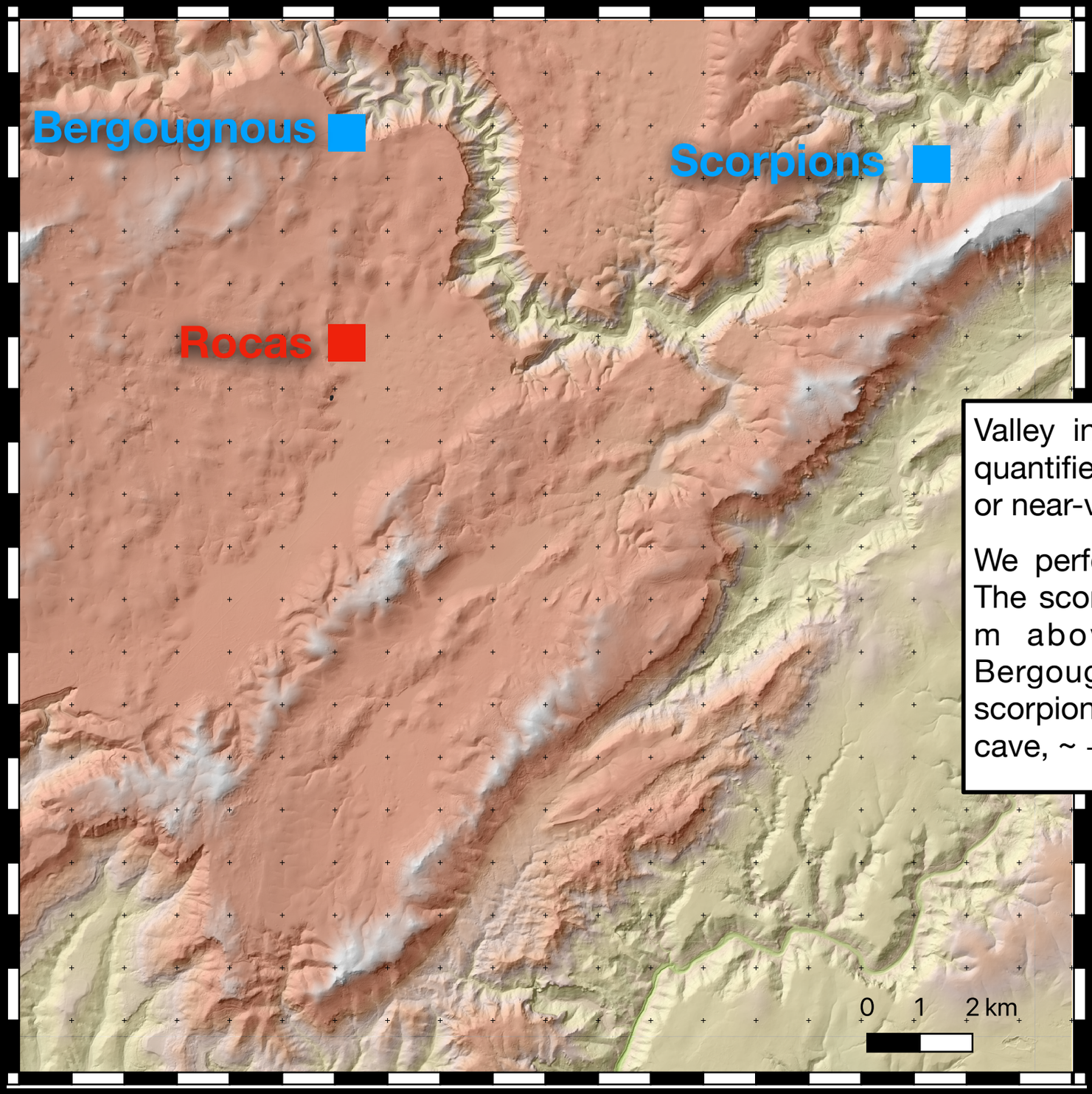
The Regional geologic history is driven by three main events: During the Palaeozoic, the basement is formed (Hercynian orogen).

During the Mesozoic, a large sedimentation takes place. A ~1000 m thick limestone-dolomite-shales rock formation is in placed during that period that and will later give the Grands-Causses plateaus.

During the Cenozoic, the region evolution is mostly continental. Because of the Pyrenean orogeny (~ 50 - 30 Ma) and later gulf of Lion formation (~ 30-20 Ma). The first order morphological shape of the region is in inherited since then.

However, the recent (Plio-Quaternary, last ~ 5 Ma) comprehension lacks of precision. Among the unknown parameters are the onset and rates of incision of the main valleys.

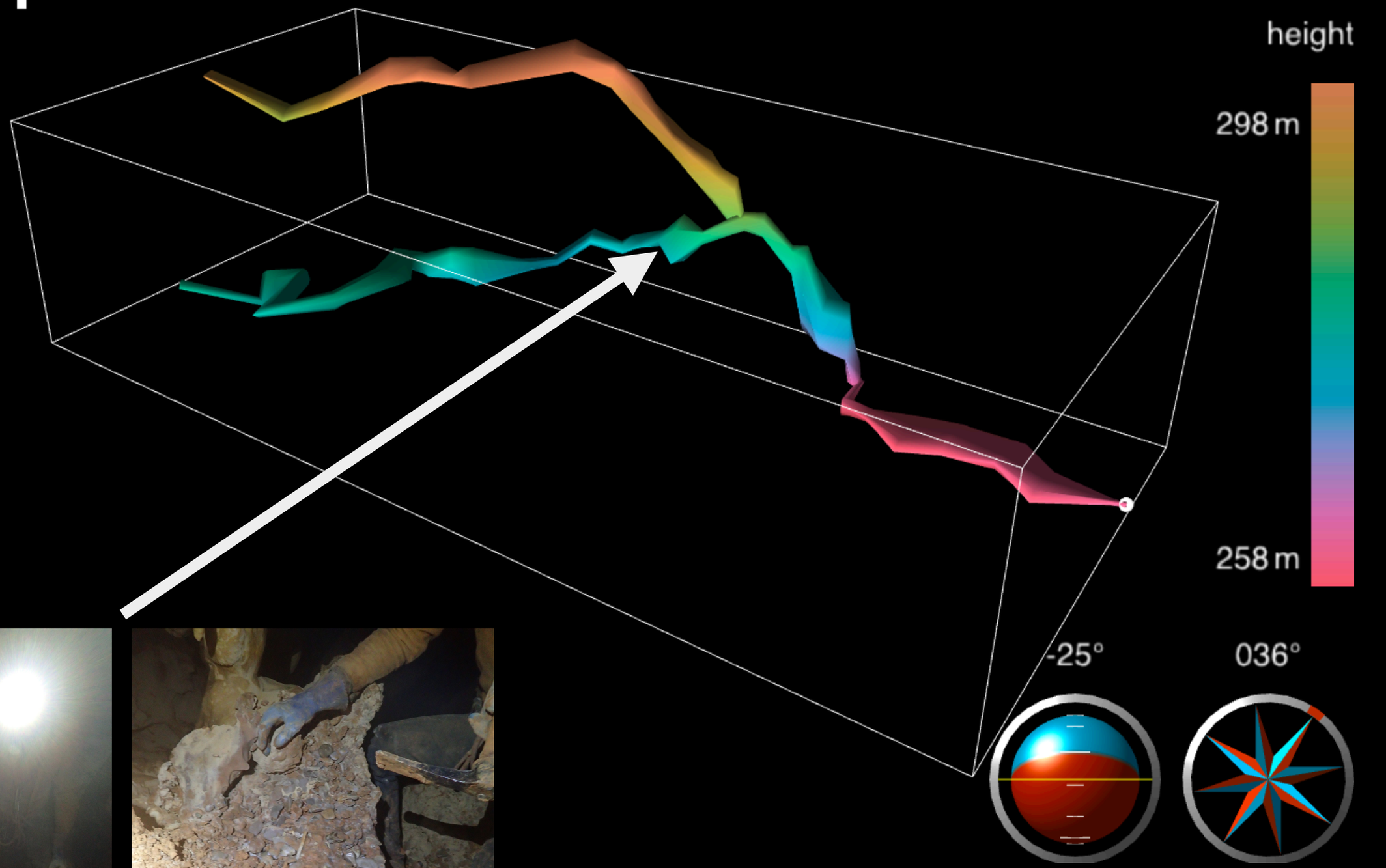
Geological setting



Valley incision in karstic area is classically quantified using tiered caves along the valley or near-valley flank and burial ages.

We performed this analysis in three caves: The scorpion cave (a karstic loop at ~ +100 m above the river level (a.b.l); the Bergougnous cave (upstream from the scorpions, ~ +100 m a.b.l.) and the Rocas cave, ~ +300 m a.b.l.)

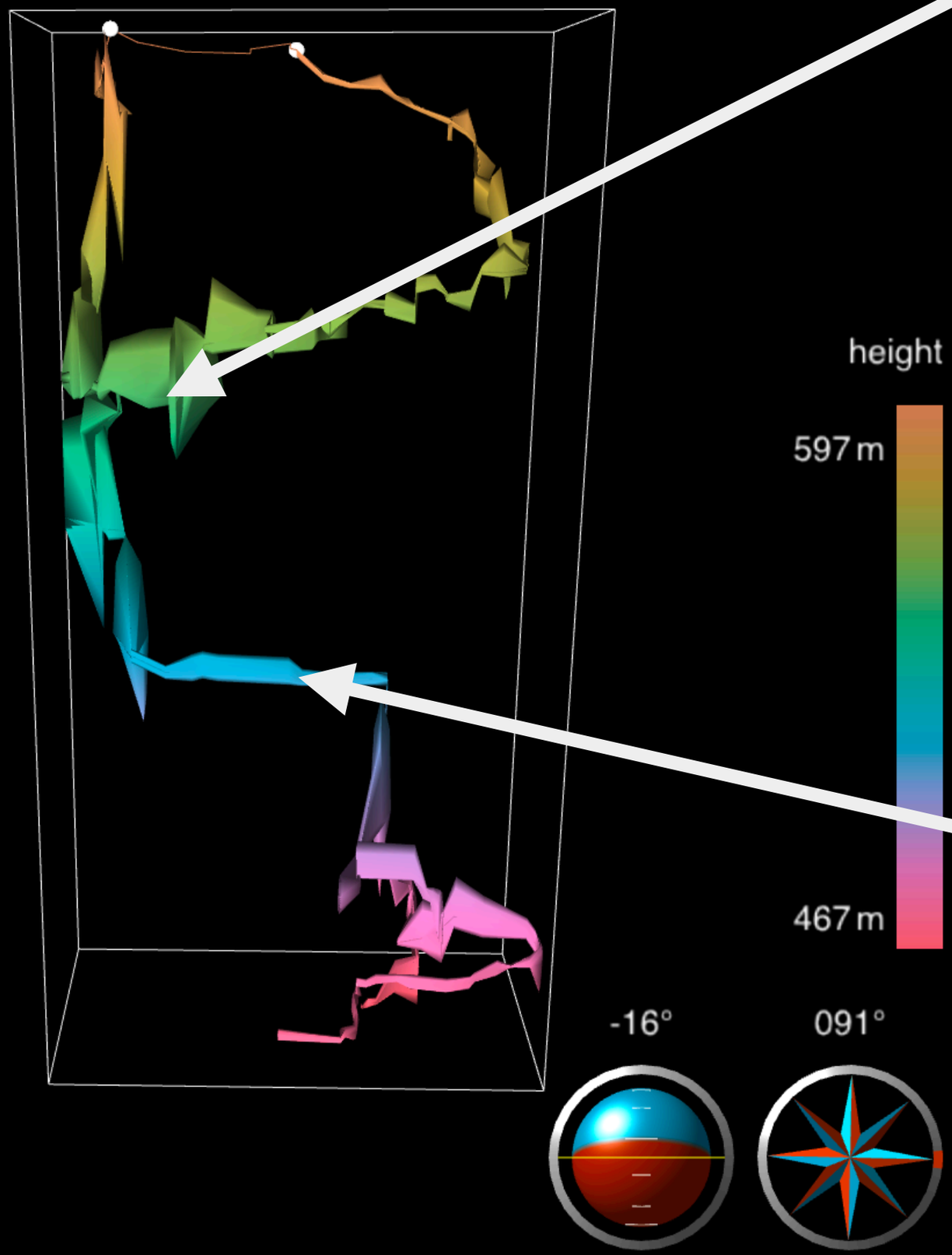
The Scorpions Cave



The scorpions cave seems to be an abandoned karstic loop of the Vis river. Mapping show that one extremity joint the valley. The other one has been cut by a secondary drain. Allochthonous sediments are trapped inside the cave, including quartz cobbles.

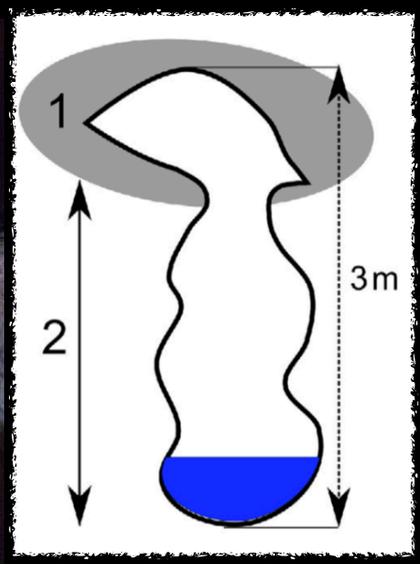
3D cave survey at: https://data.oreme.org/karst3d/karst3d_map

The Rocas cave



The Rocas cave is hydrologically connected to the Vis river.

From the Entrance, down to ~ 50 m, quartz cobbles are presents. Below, there is no known allochthonous infilling. Gallery morphologies are similar to the ones described by Dubois et al. (2014) concerning ghost-rock phenomenon



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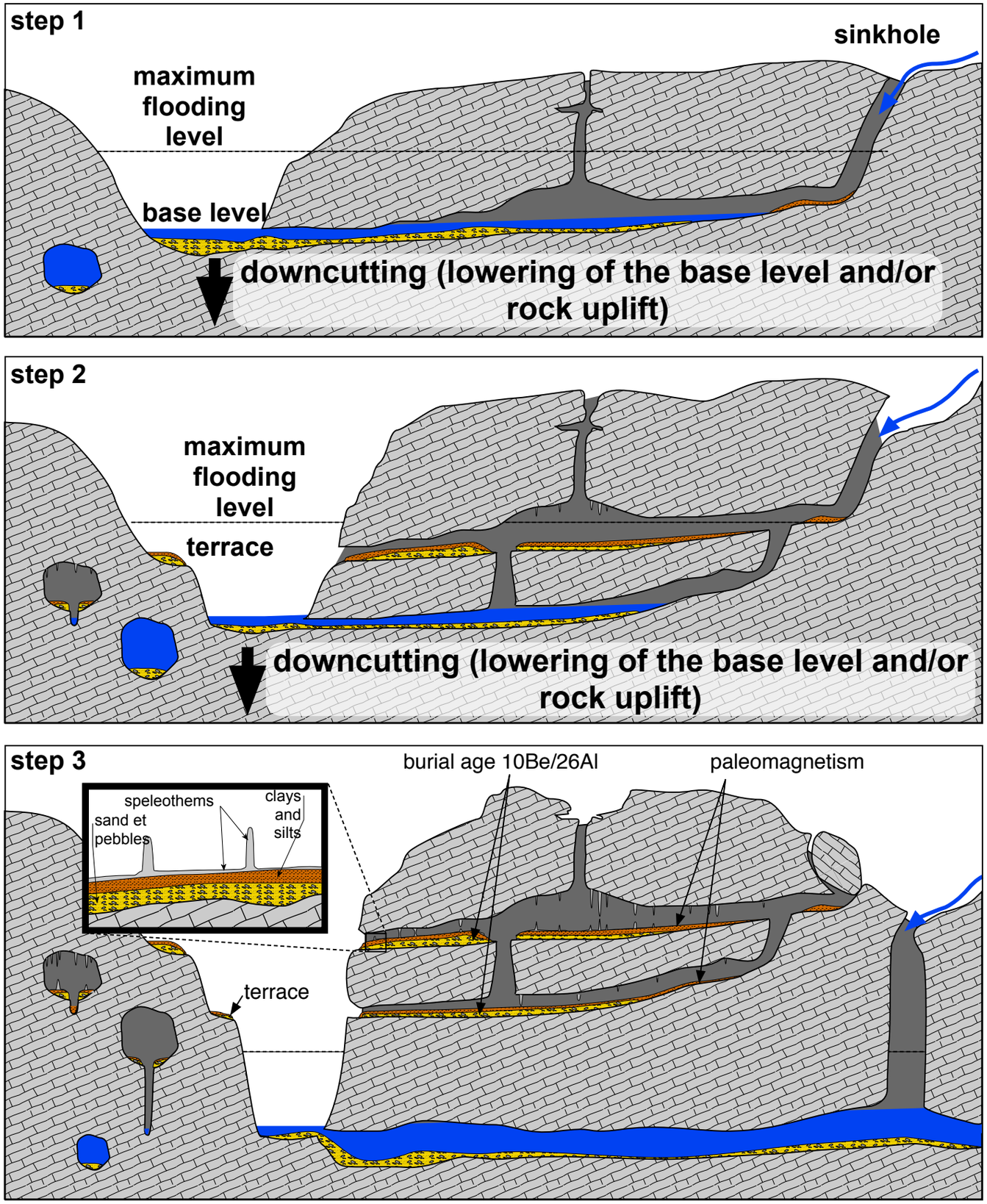
Expected relationship

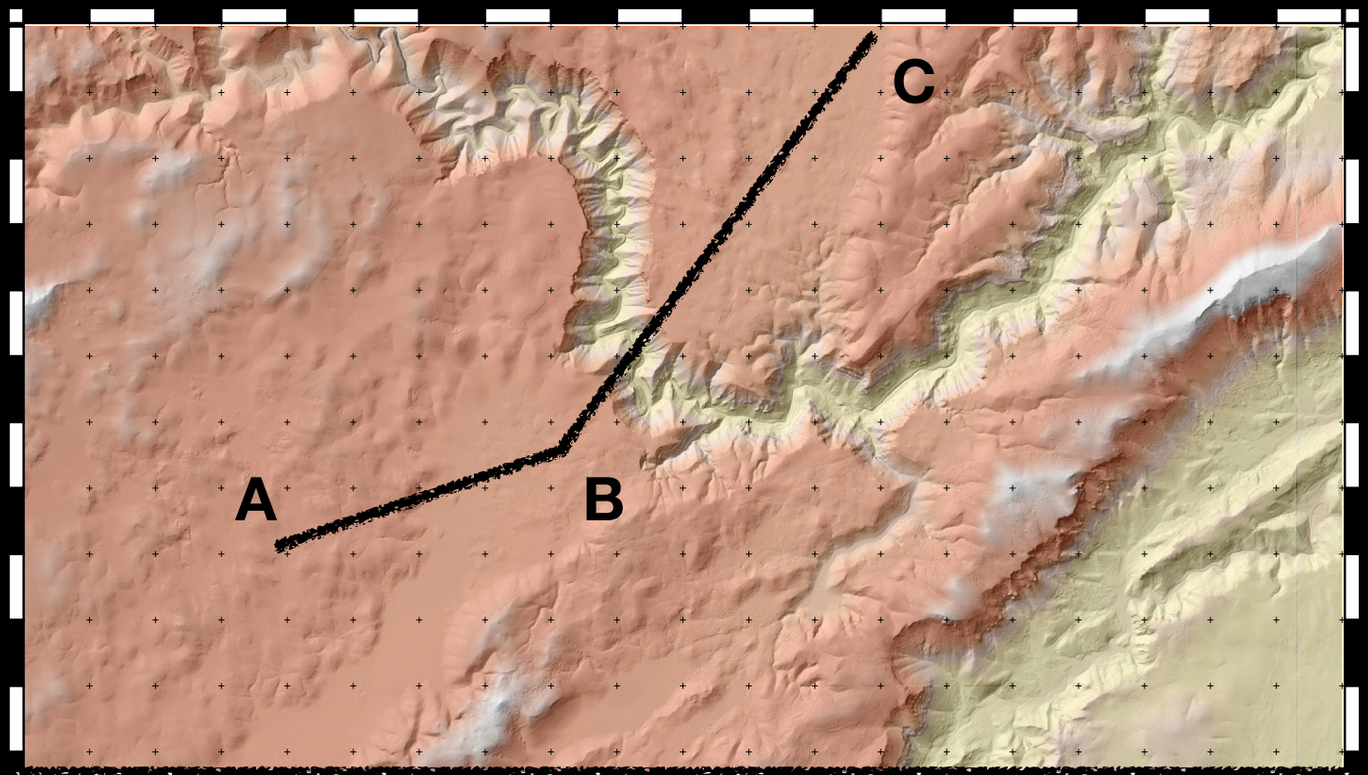


According to the classical scheme that leads to karst evolution (e.g. Palmer 1987; Granger et al., 2001, Harmand et al., 2017), the regional karst geometry is controlled by the position of the base level (i.e. the river elevation). Except if an important aggradation period was documented (Moccohain, 2007), the landscape and karst network evolution is created *per descensum*.

In this model, when the relative incision is null, horizontal galeries are formed and allochthonous sediments can be trapped inside. When the incision is high enough, karst geometry evolve to shaft and chimney (i.e. vertically). Using this model leads to interpret each level of horizontal galleries as part of a cycle of incision, and relative stability controlled by the base level.

Thanks to TCN (Terrestrial Cosmogenic Nuclides), it is possible to date the burial age of the sediments inside a cave system. The evolution model is therefore predictable: younger ages are expected near the present river elevation while older deposits are expected to be found inside the highest galleries.

Expected relationship



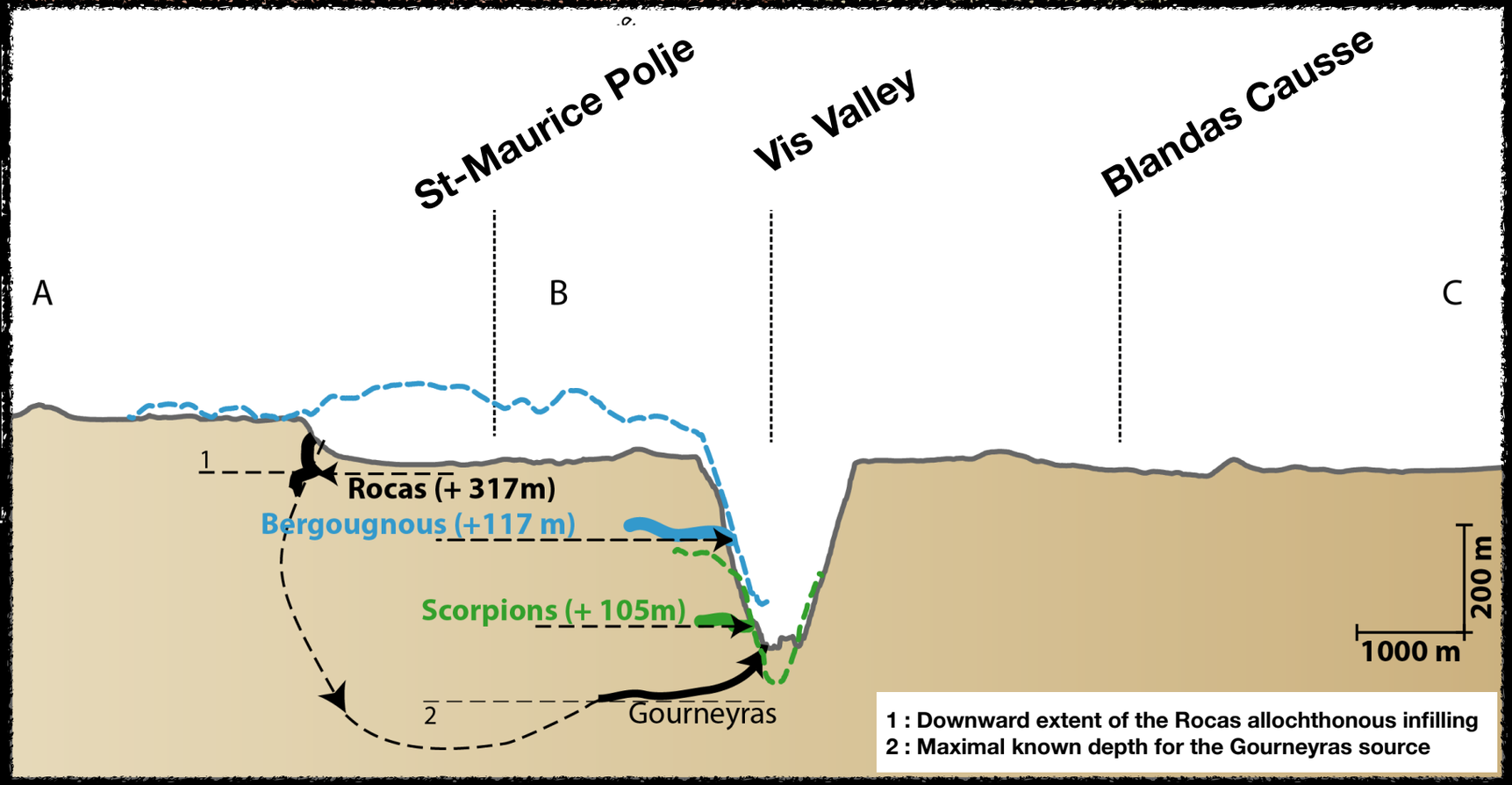
Given the vertical relationship, The Rocas (+317 a.b.l.) infilling are expected to be older than the Scorpions or the Bergougnous ones (+105 and +117 m a.b.l. respectively).

Using the newly proposed incision rate of 85 ± 35 $m.Ma^{-1}$ (Malcles et al., 2020) from neighbors valleys and karst systems, expected ages are:

Rocas : 3.4 ± 1.4 Ma

Scorpions : 1.3 ± 0.5 Ma

Bergougnous : 1.4 ± 0.5 Ma



Refuting the classical model

Concerning the two caves opened on the major valley (Scorpions and Begougnous): the obtained burial ages are in good agreement with the expected ones.

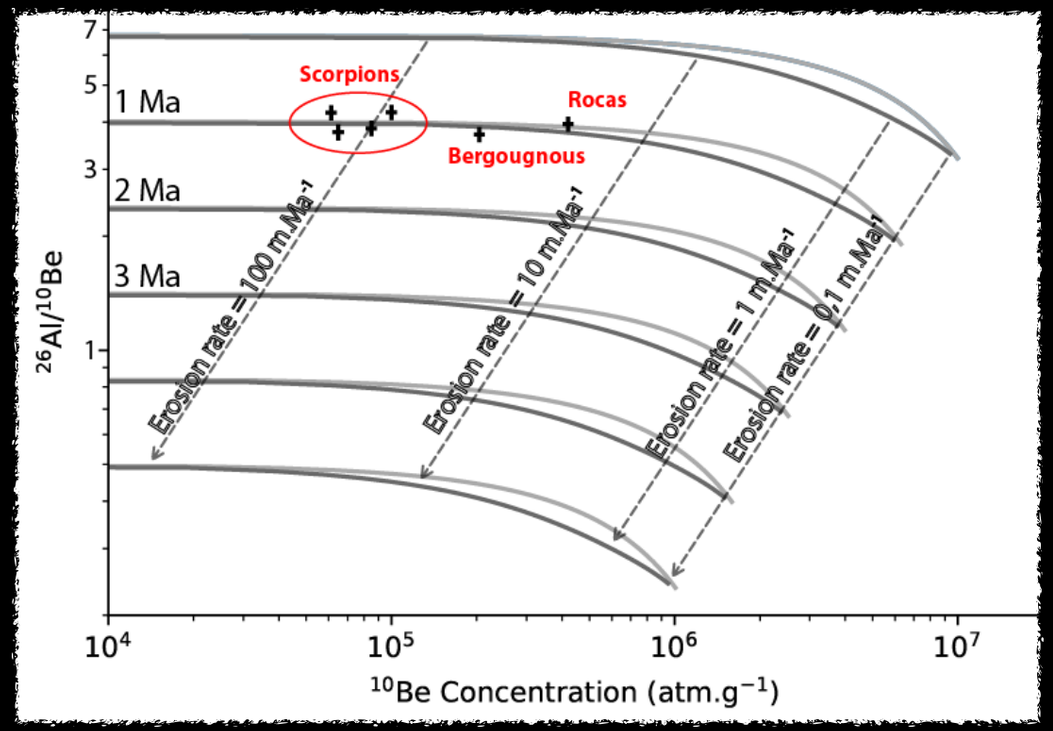
Scorpions (from 4 individual cobbles ages) = 1 ± 0.2 Ma

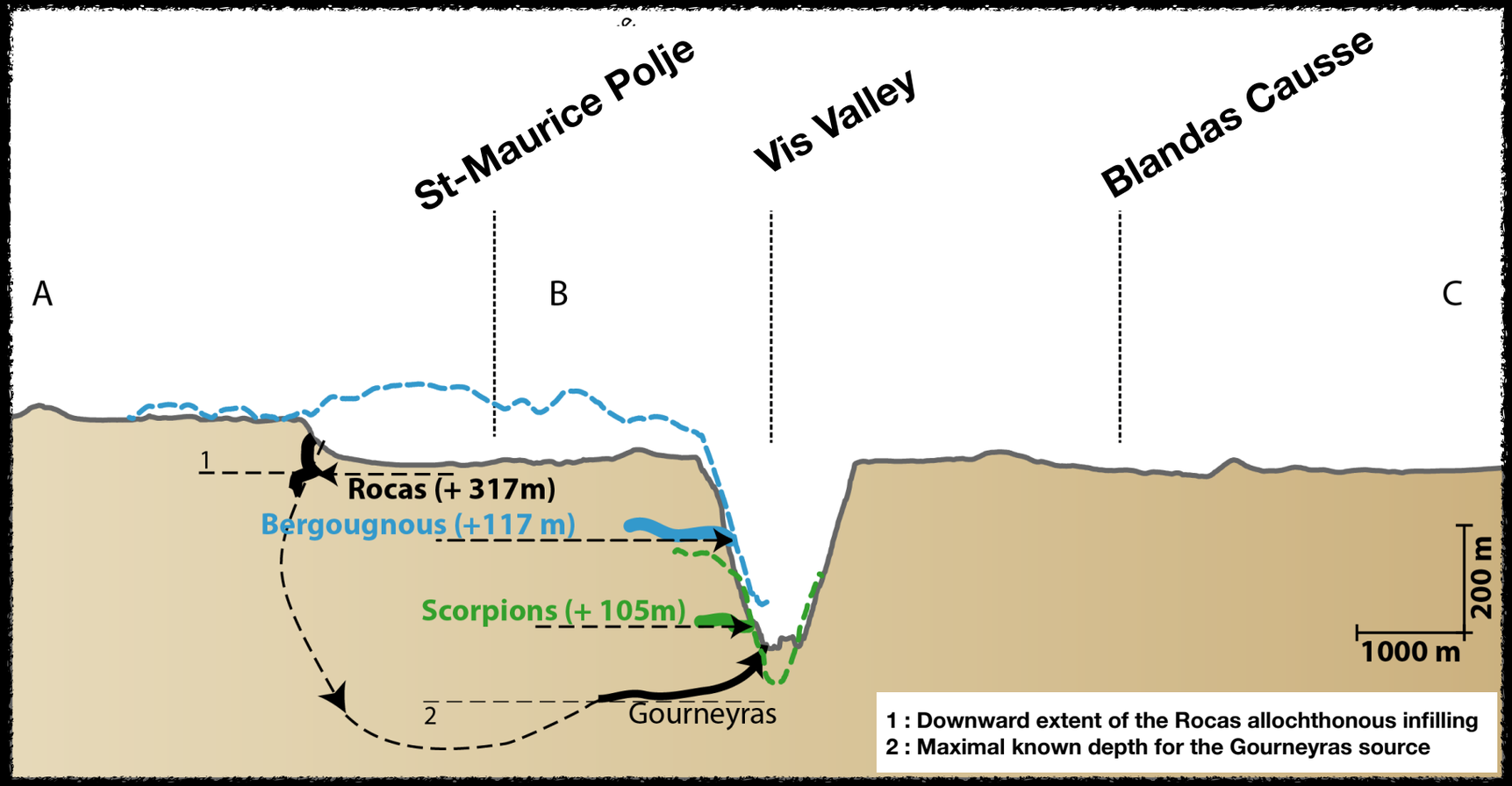
Bergougnous (from amalgams) : 1.1 ± 0.2 Ma

The Rocas cave challenges the *per descensum* model :

0.9 ± 0.2 Ma

That is to say 2.5 Ma too young !!!

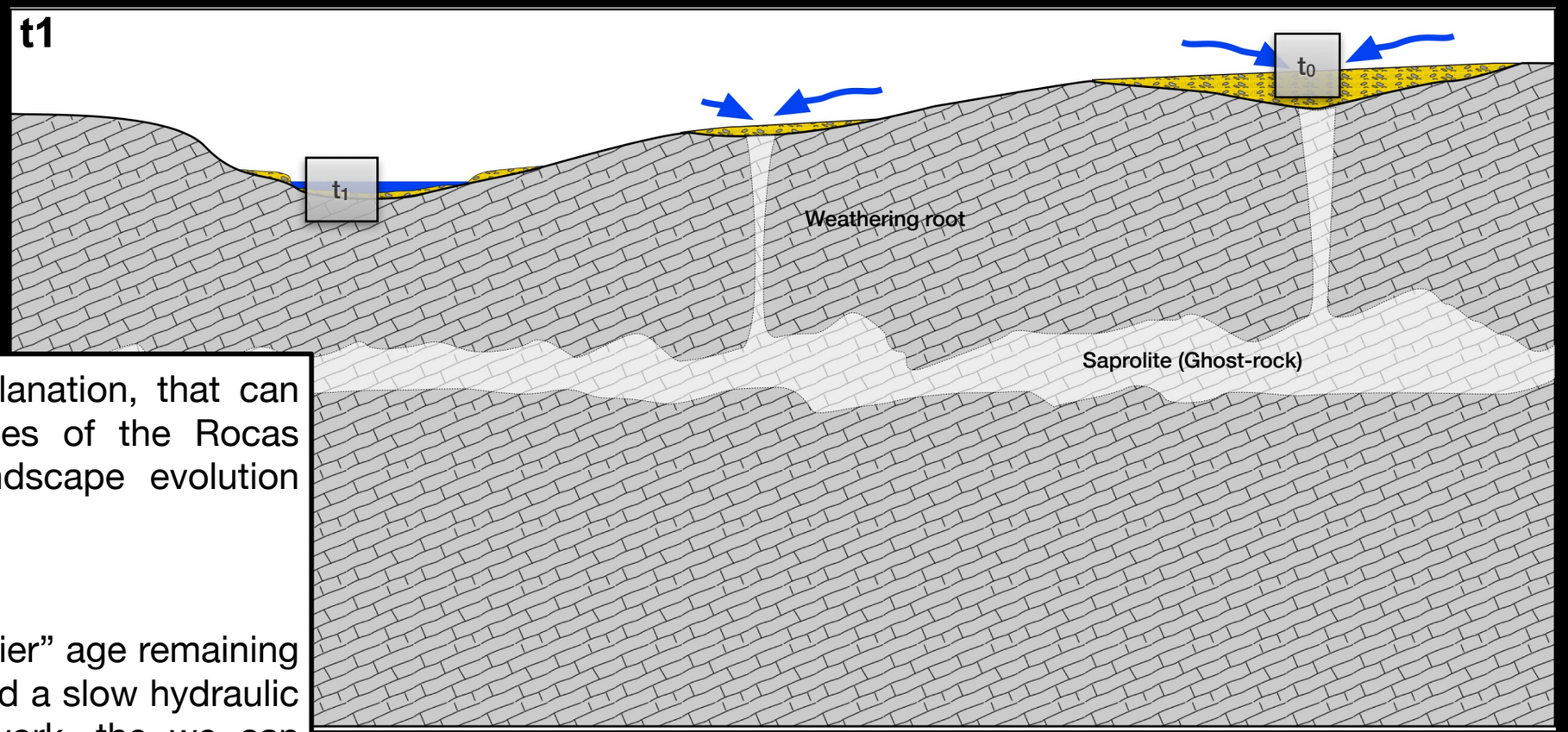


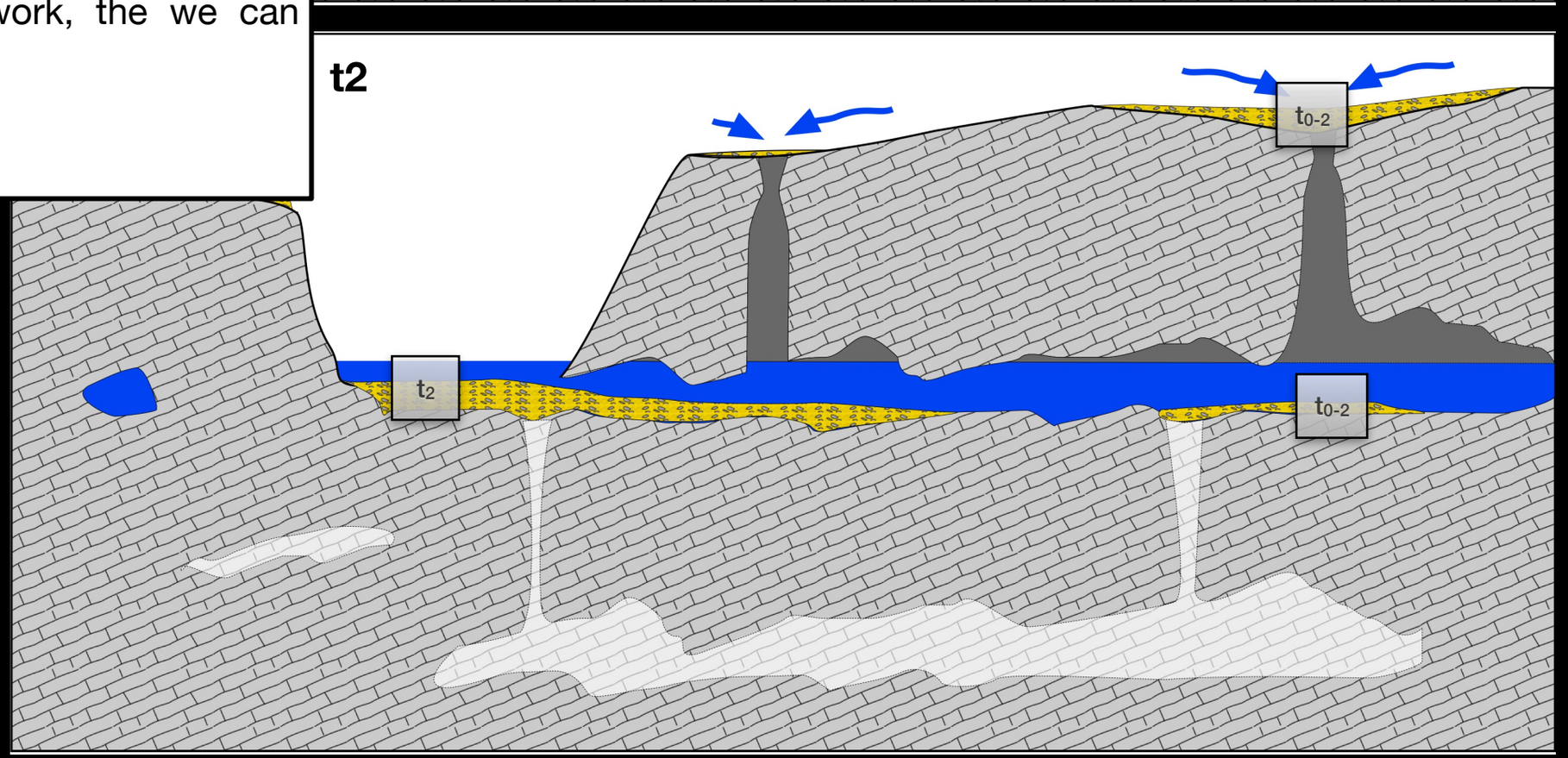


Inherited networks can explain that fact

We didn't find any satisfactory explanation, that can explain the 2.5 Ma too young ages of the Rocas cobbles and fit to a classical landscape evolution model.

If we consider that "earlier" (the "earlier" age remaining to estimate), the whole area sustained a slow hydraulic head creating a proto (ghost) network, the we can propose another evolution model.



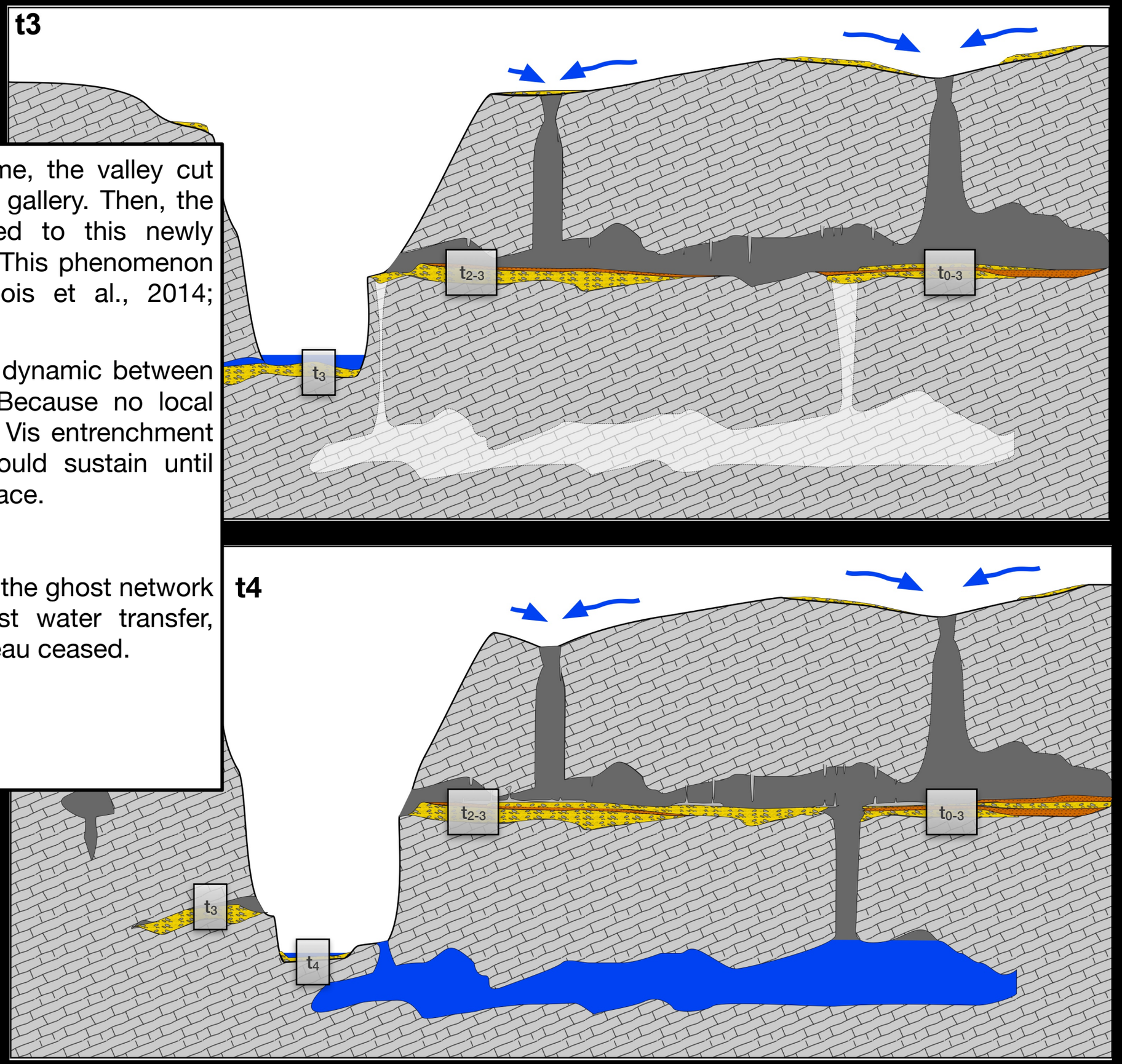


Inherited networks can explain that fact

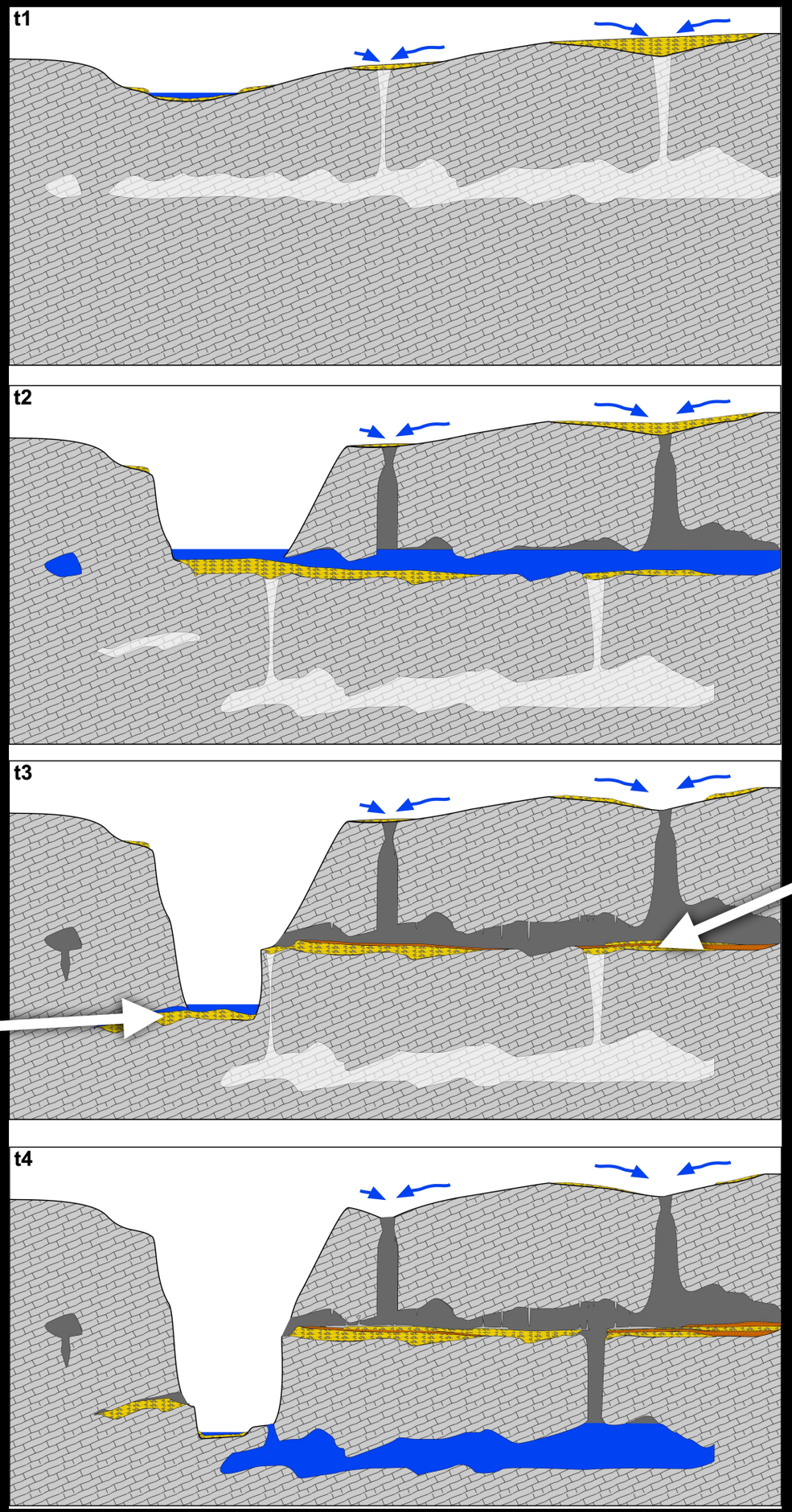
As the river incise, from time to time, the valley cut through an existing horizontal ghost gallery. Then, the whole network that was connected to this newly created output can be washed out. This phenomenon is known for small volumes (Dubois et al., 2014; Dupont et al., 2018).

This lead to a strong decoupling of dynamic between near-field and far-field circulation. Because no local ghost network had been cut by the Vis entrenchment prior to 1 Ma, the Rocas cave could sustain until recently sediment input from the surface.

When, 1 Ma ago, the Vis cut through the ghost network creating an karst network with fast water transfer, surface circulation on top of the plateau ceased.



Summary

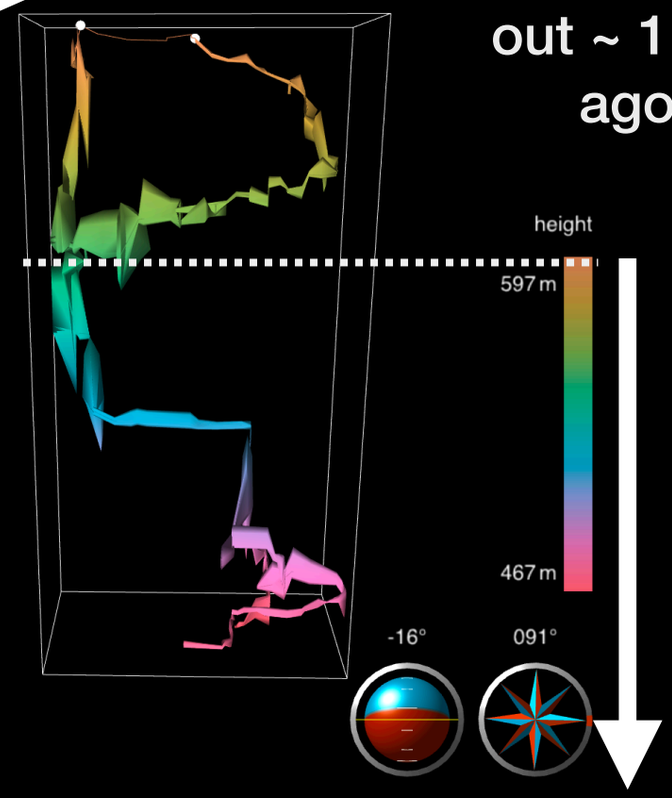


Ghost-network (inherited weathered preferential paths) could play a major role for karstic network development and geometry at regional scale. Elevation of the river could then be reduced to a secondary (triggering) process.

Scorpions / Bergougnous (~ 1 Ma) Location of the Vis at that time

Rocas

Ghost-network washed out ~ 1 Ma ago



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