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A Sulfuric Acid Speleogenesis in the Northern Pyrenees (France)?

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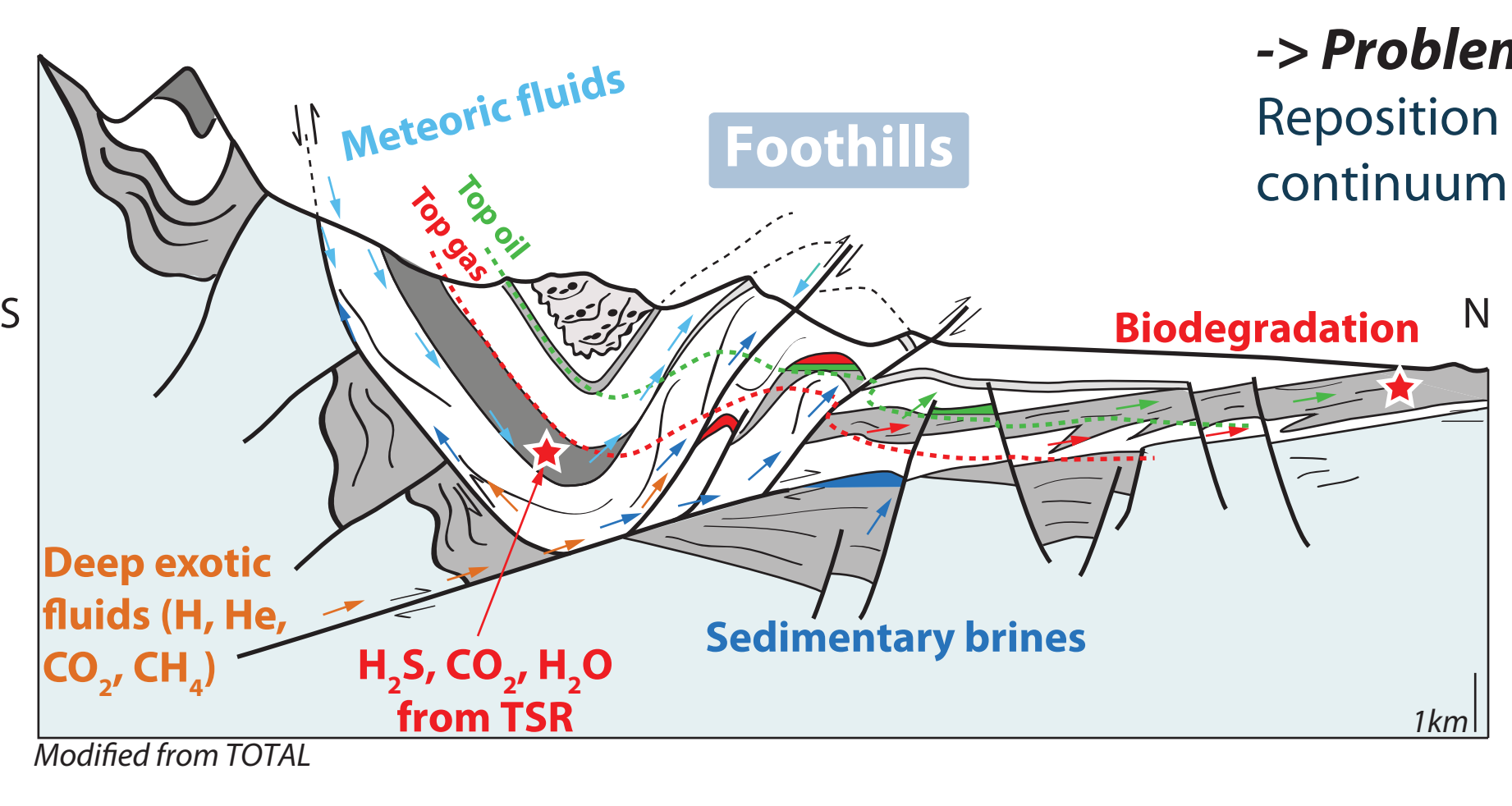
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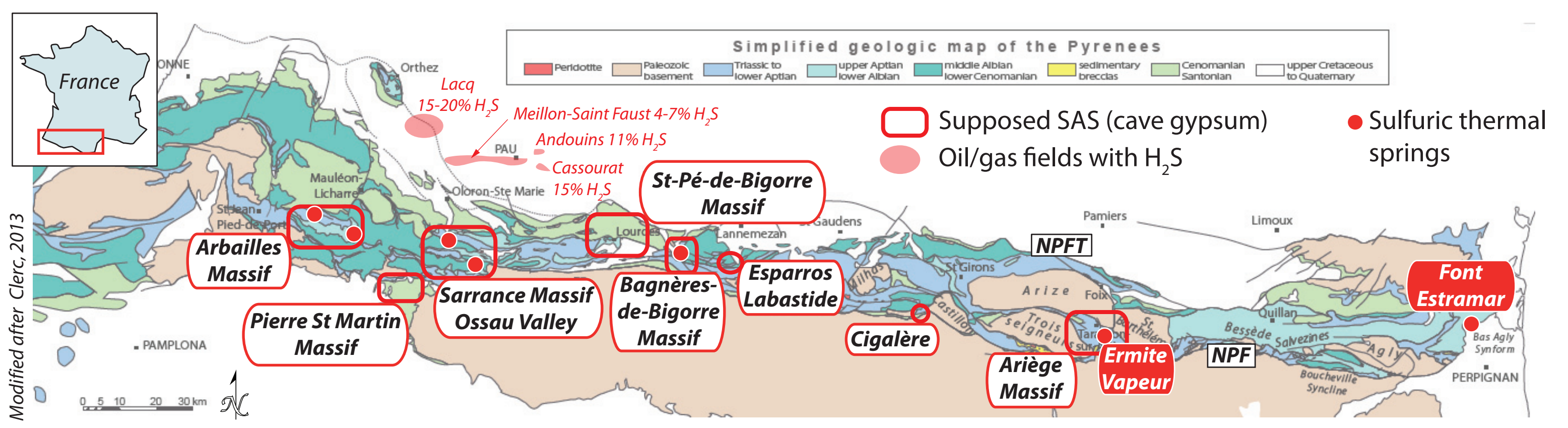
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1- Introduction: hypogenic caves in the Northern Pyrenees?

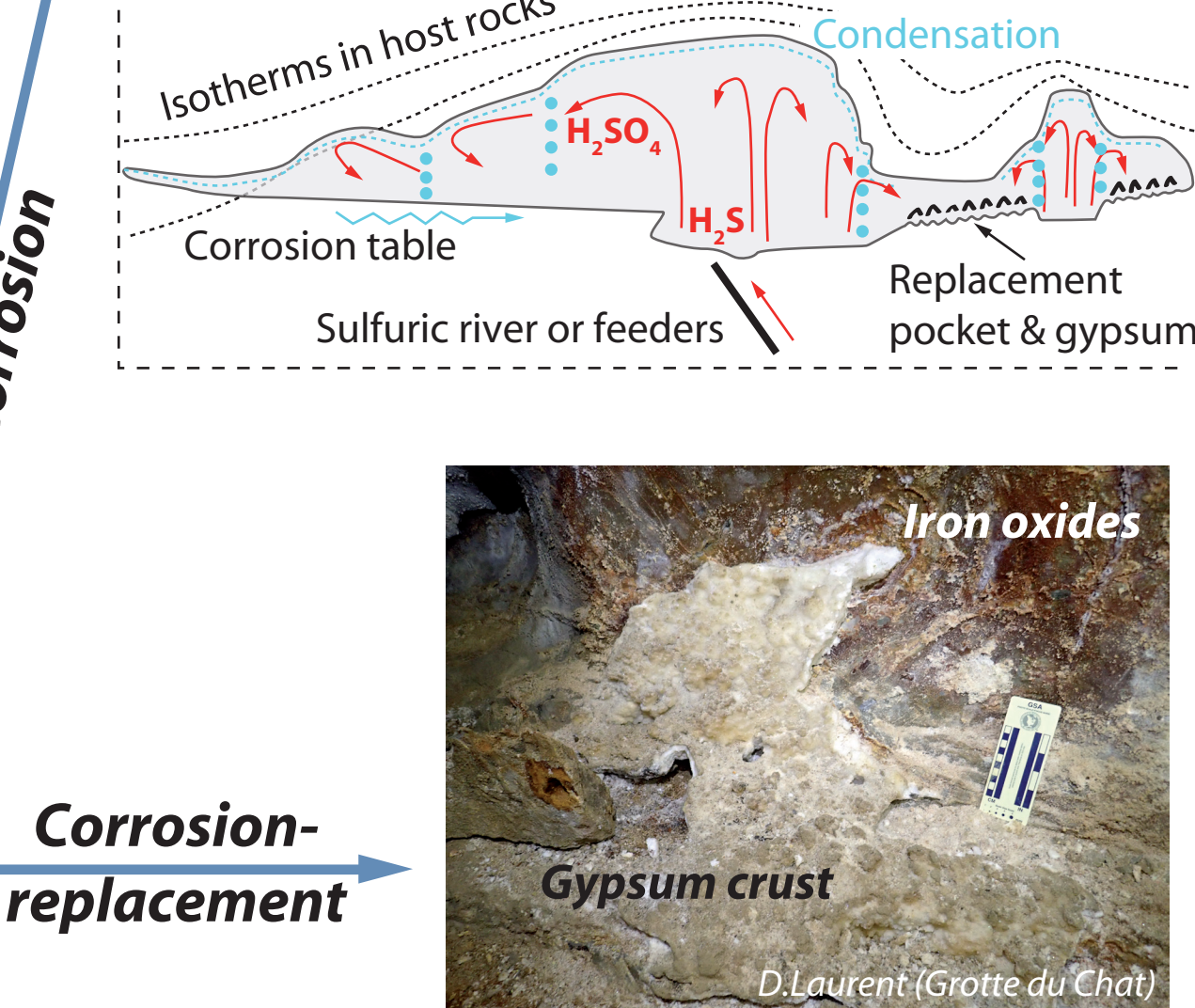
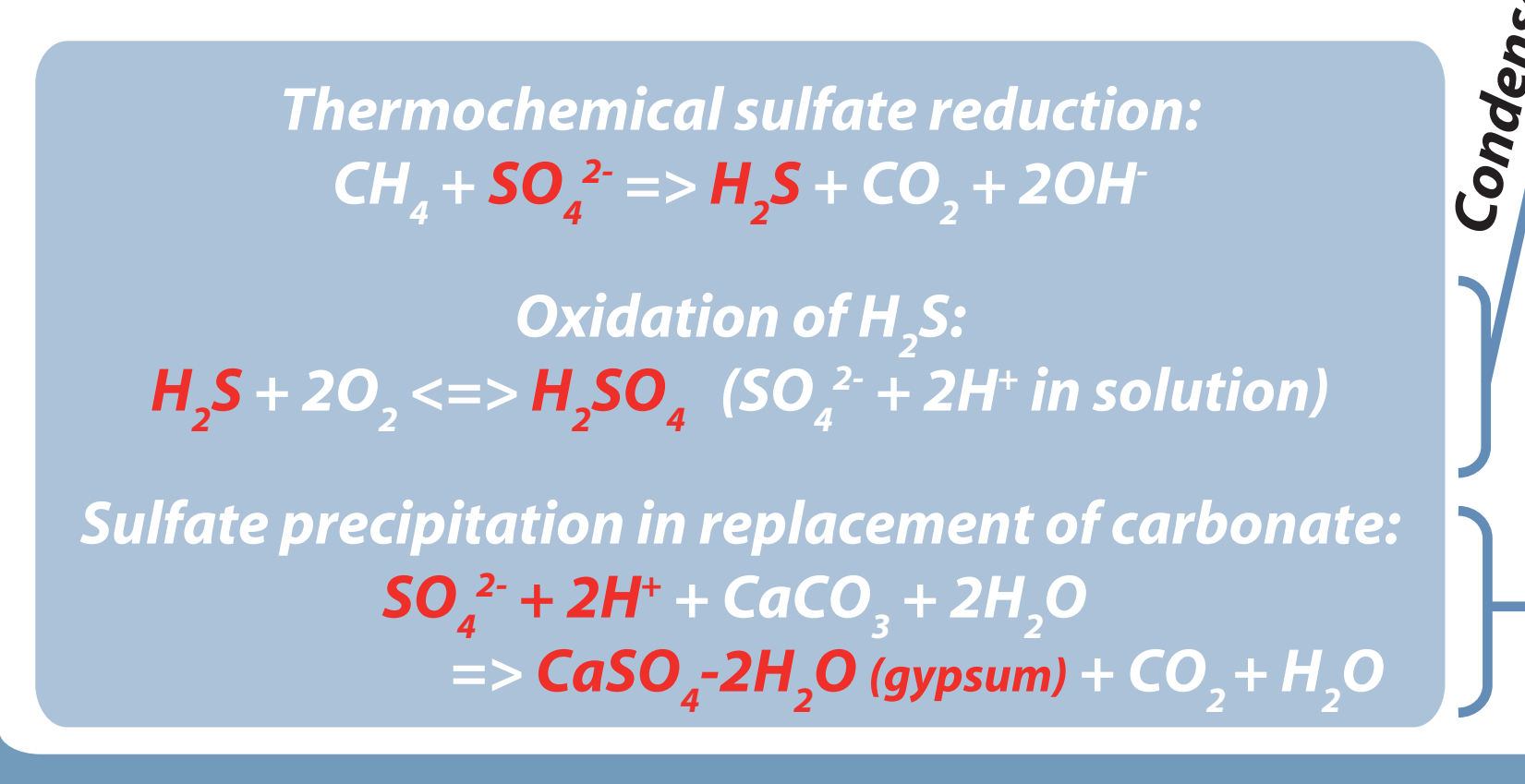
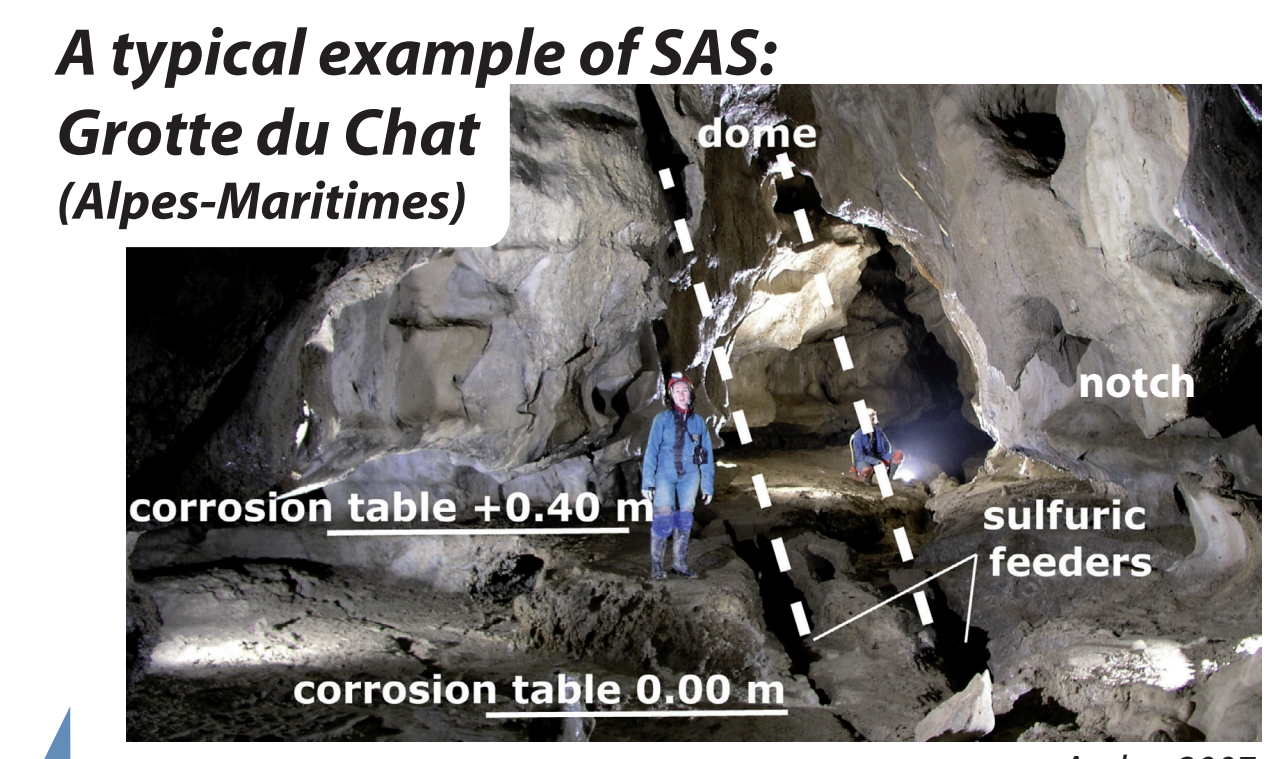
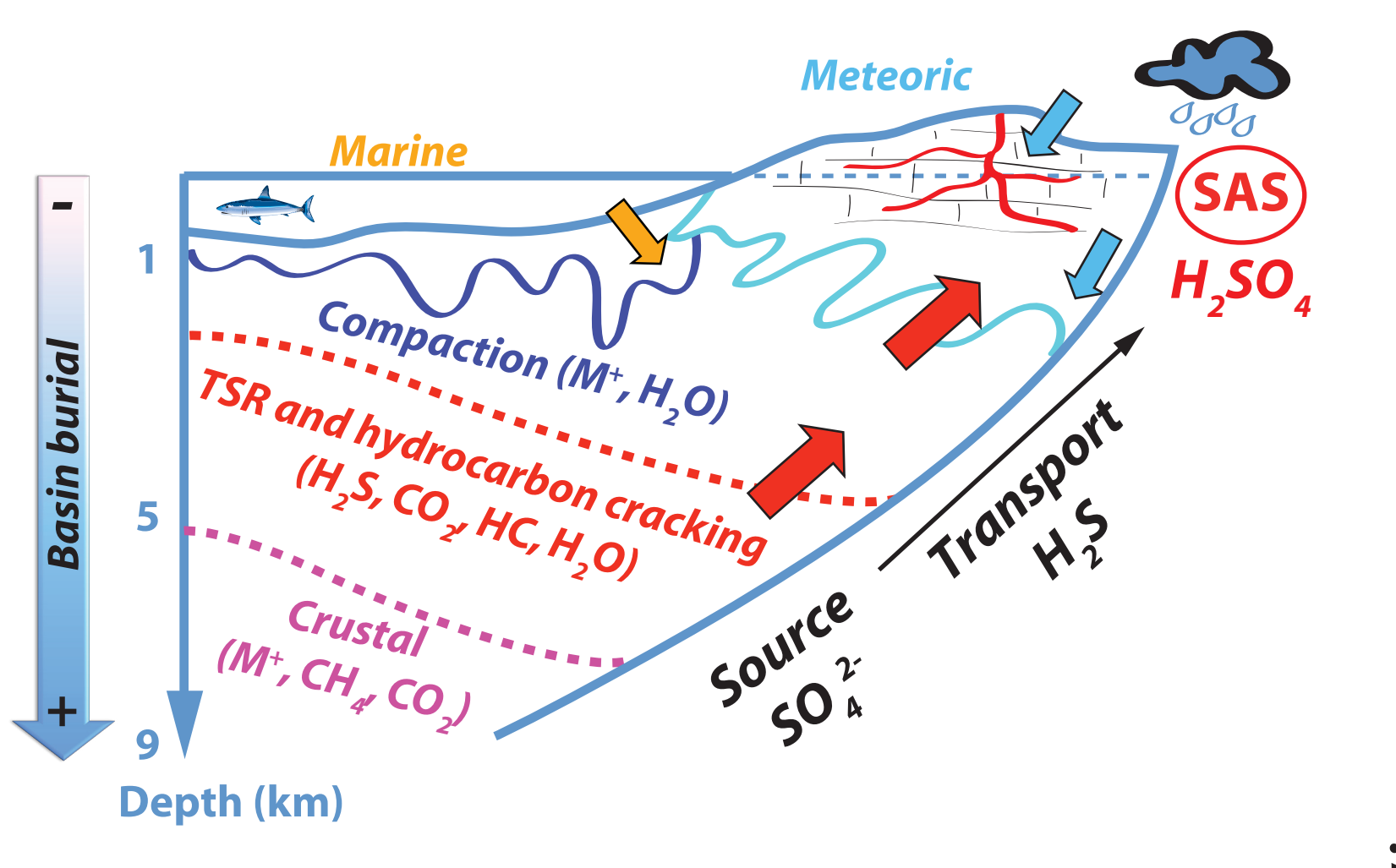


-> **Problematic (in Total «Fluid» program):**
 Reposition Sulfuric Acid Speleogenesis (SAS) in the continuum of fluid-rock interactions in the foothills.

- > **Main questions:**
- Timing of karst formation (hyper-extension, compression...)?
 - Controlling factors of karst development (structural, geochemical...)?
 - Nature and origin of fluids involved in the dissolution (CO₂, H₂S, meteoric...)?
 - Link with petroleum and ore deposits?



2- Thermochemical Sulfate Reduction (TSR) and SAS



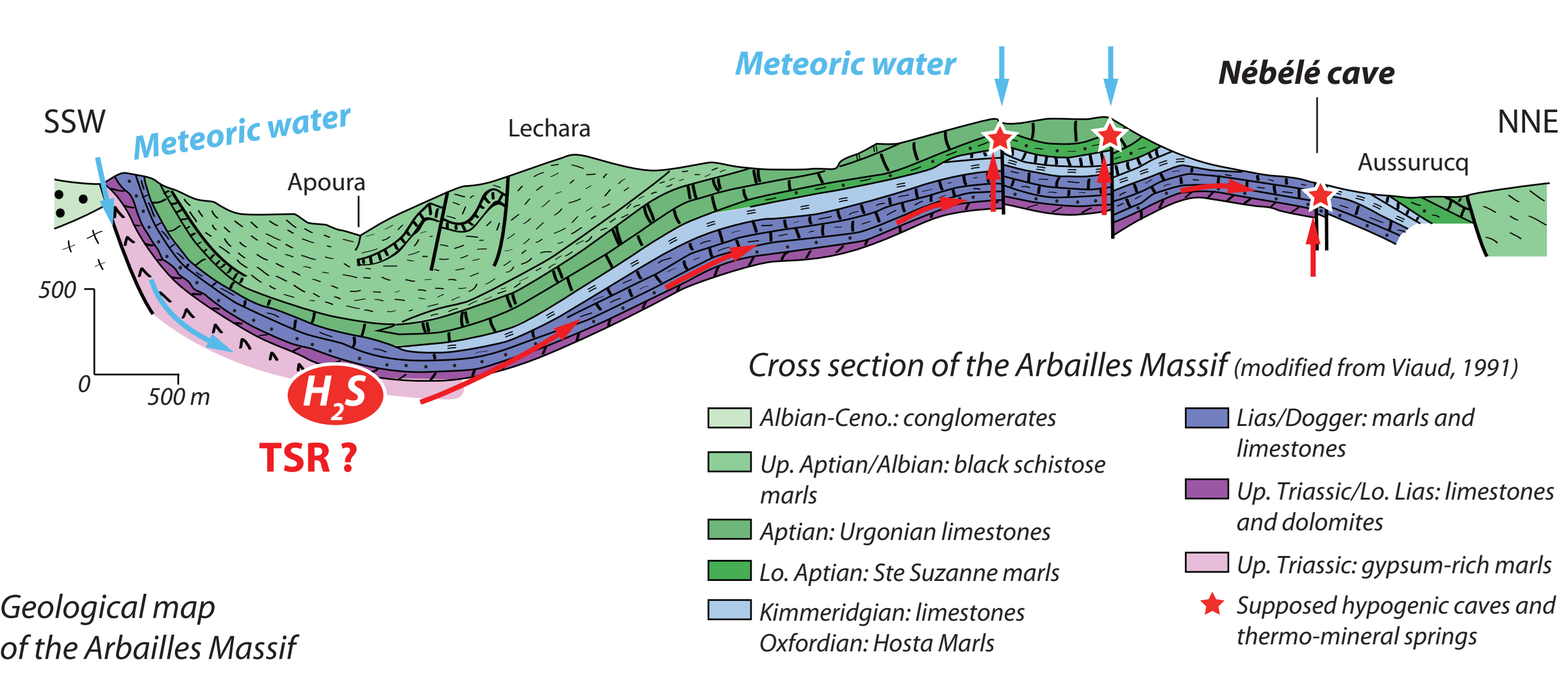
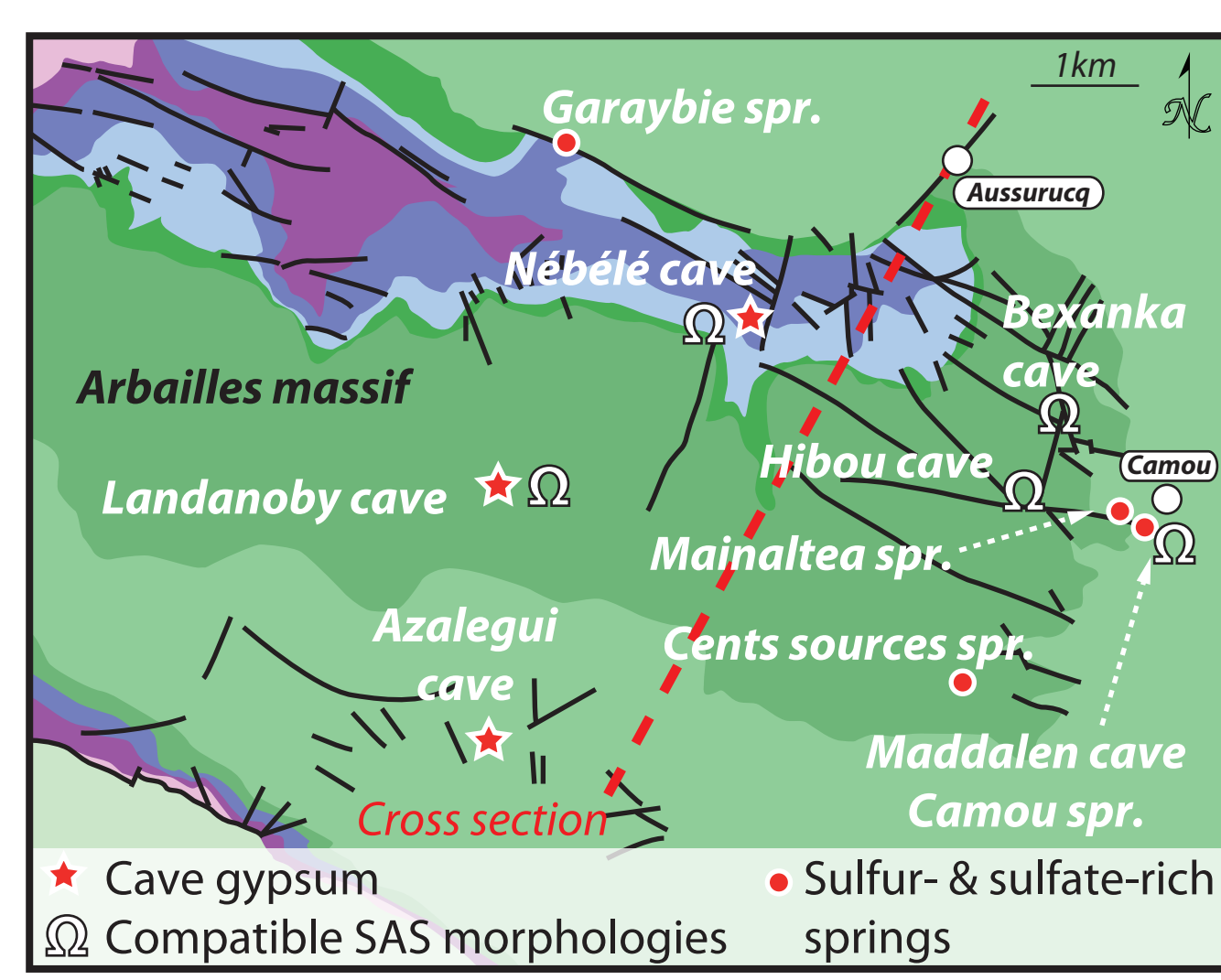
3- Field evidences of cave sulfates in the Arbailles massif: SAS or evaporite leaching?

The Arbailles Massif, a good candidate for SAS...

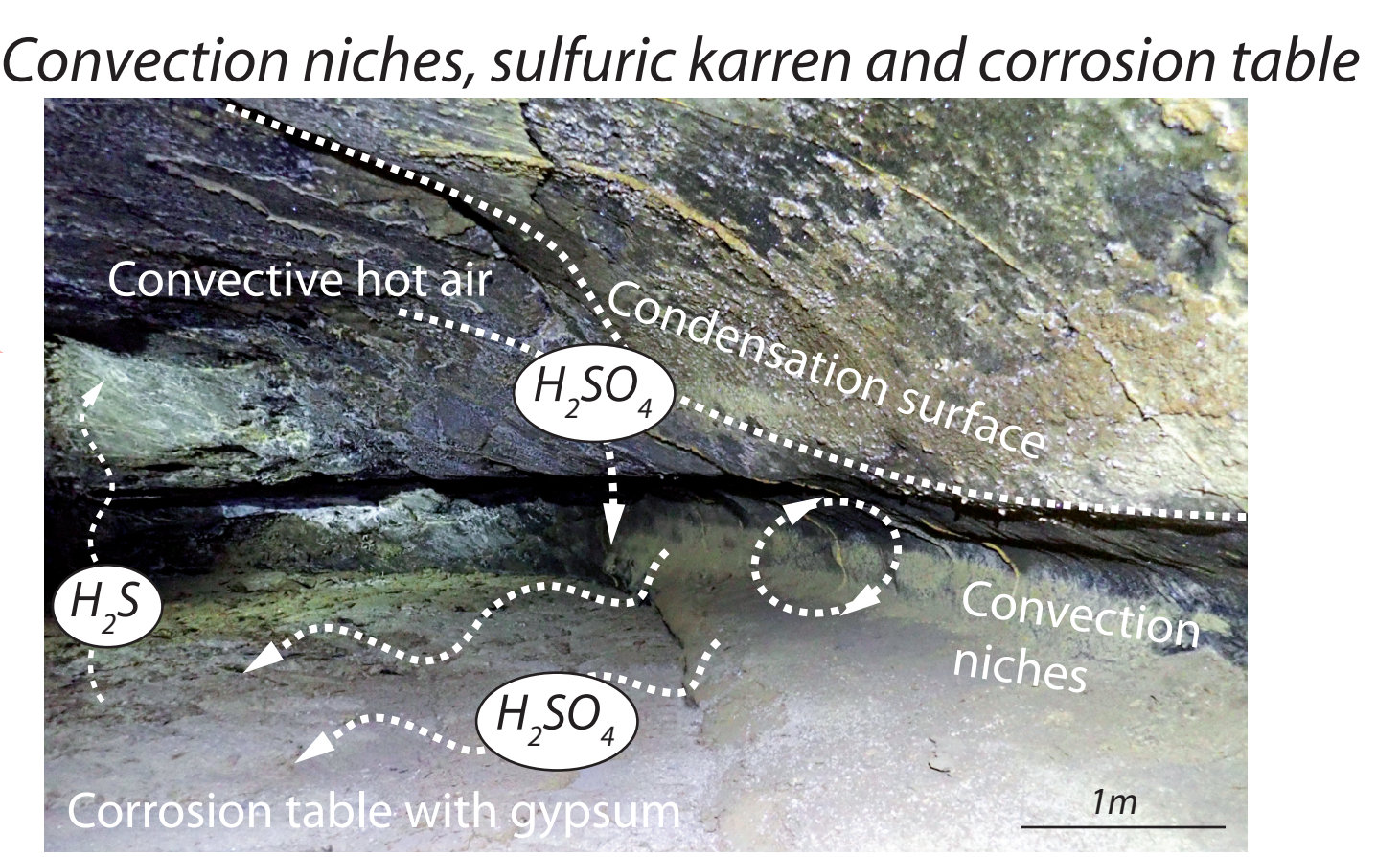
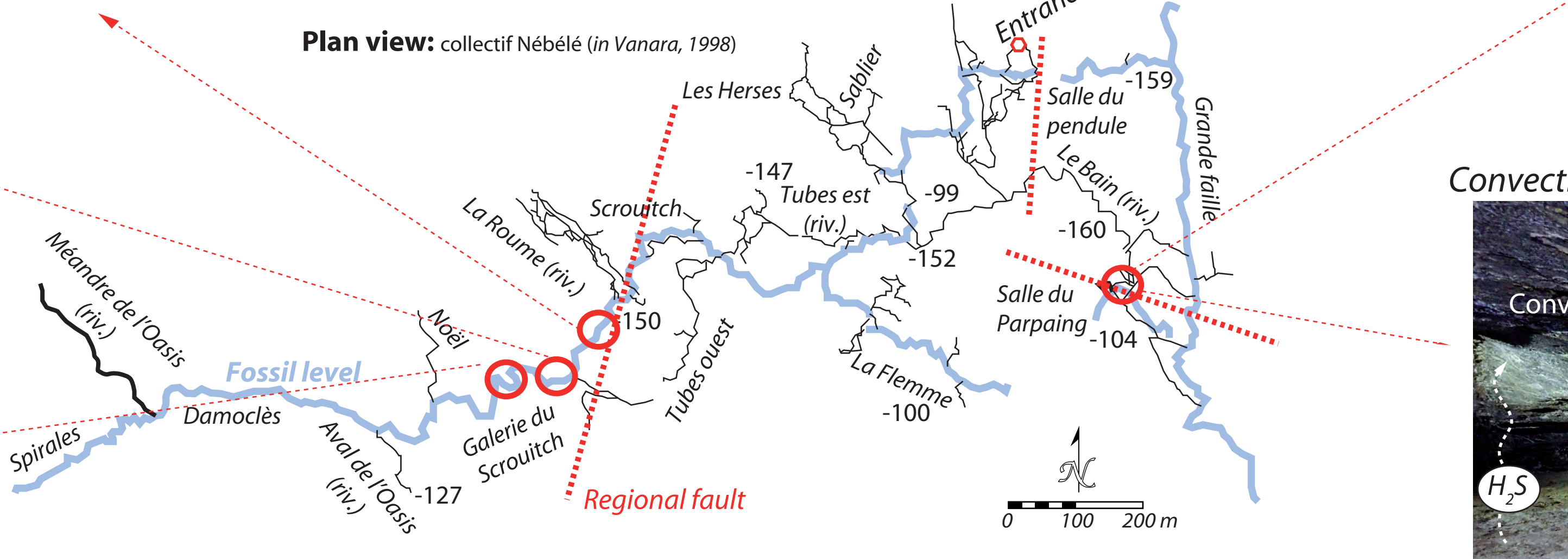
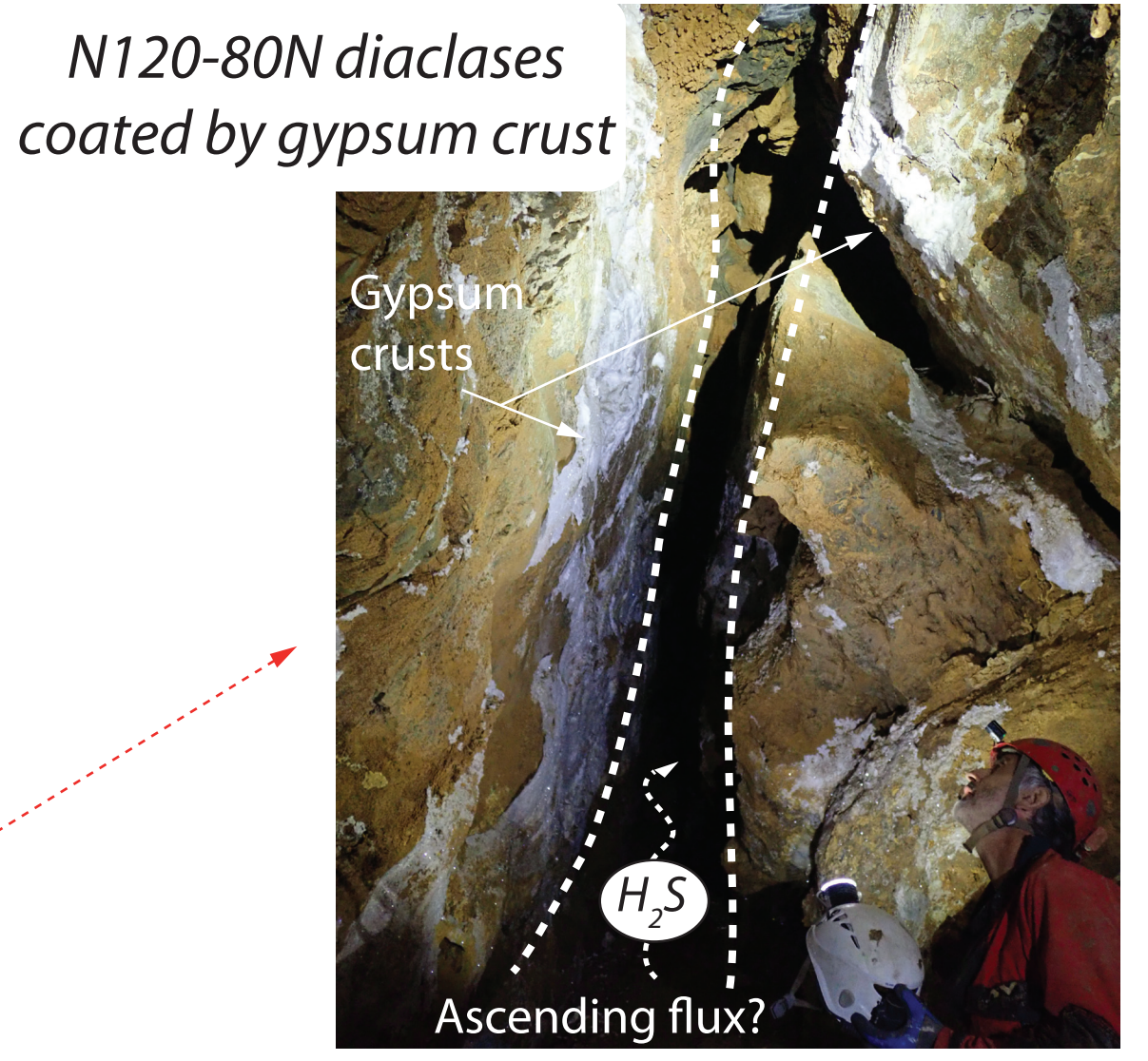
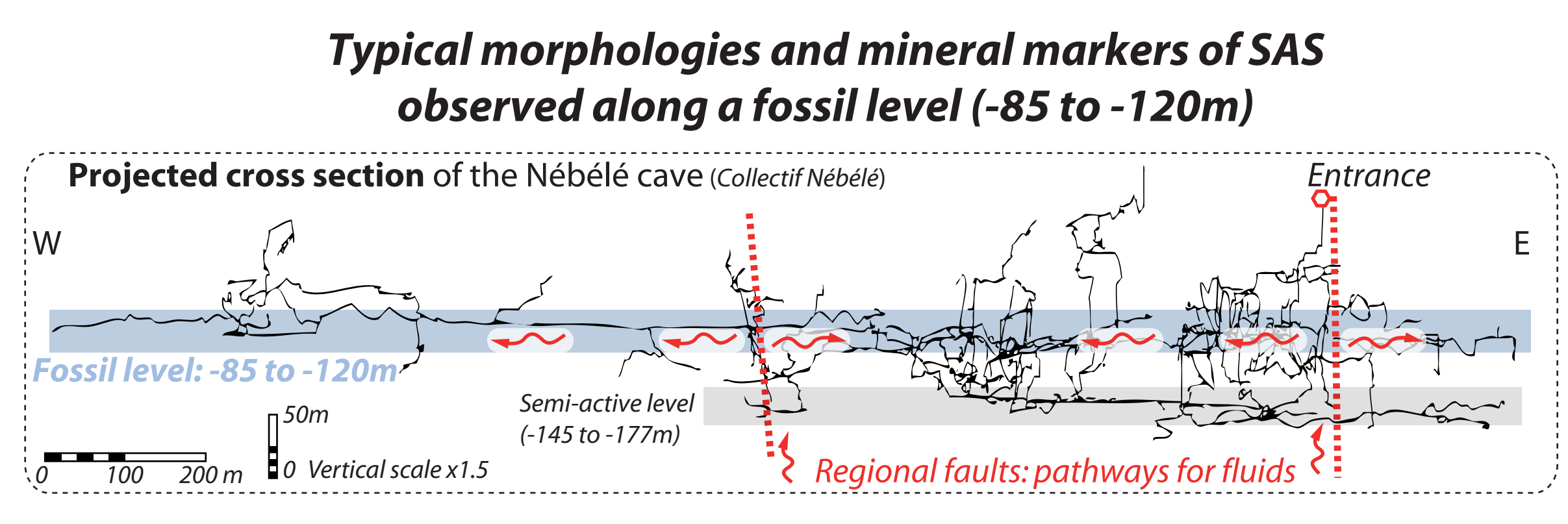
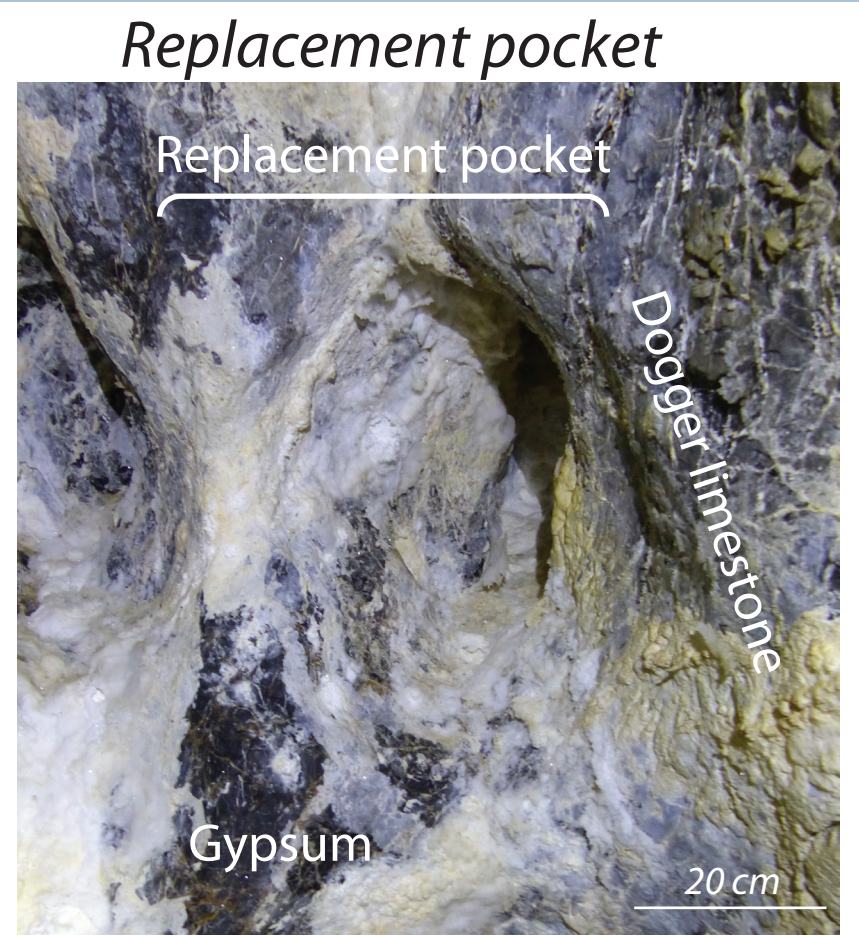
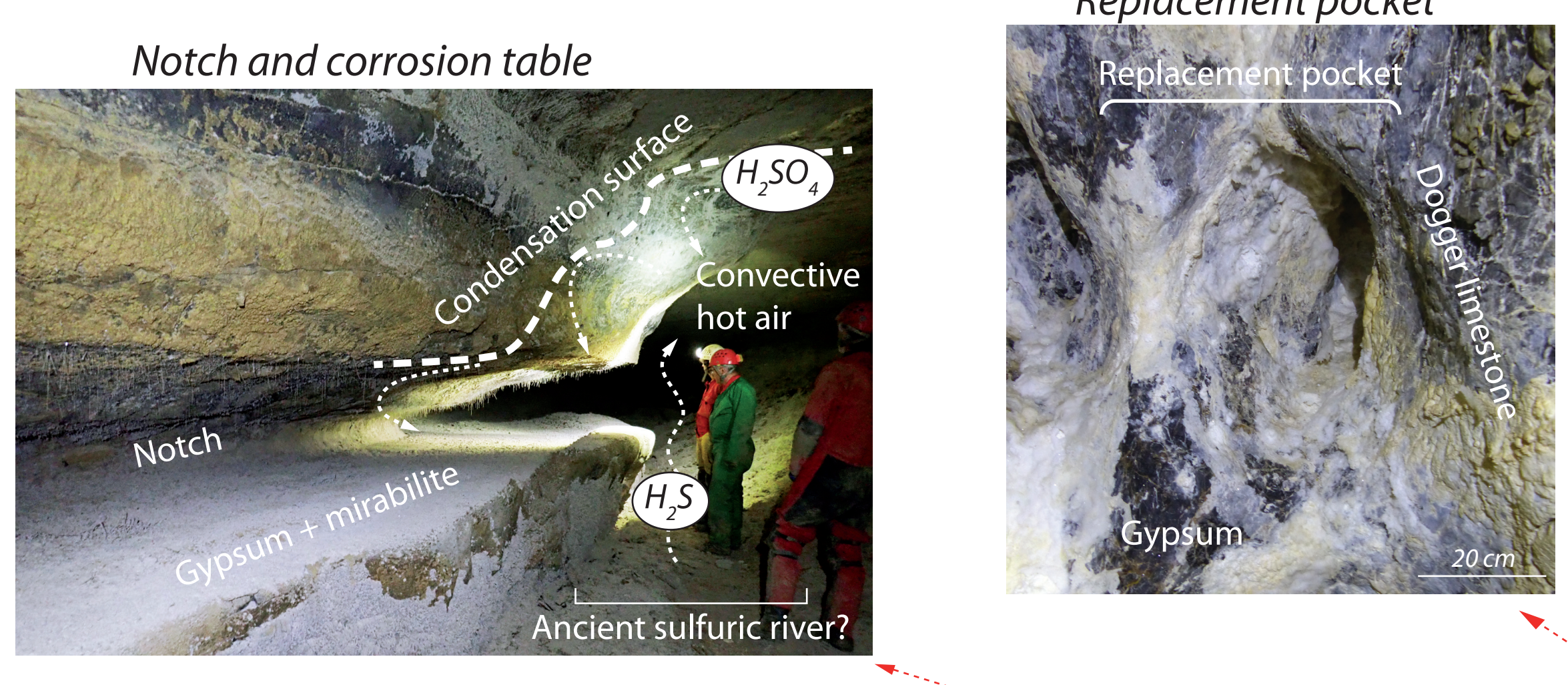
- > Numerous caves in Aptian and Dogger limestones
- > Caves located close to regional faults connected to Triassic evaporites
- > Current thermo-mineral springs = sulfate/sulfur-rich deep fluids circulation
- > Gypsum precipitation in karst systems
- > Relative proximity with oil seeps and hydrocarbon fields

... But several processes may be responsible for cave sulfate precipitation:

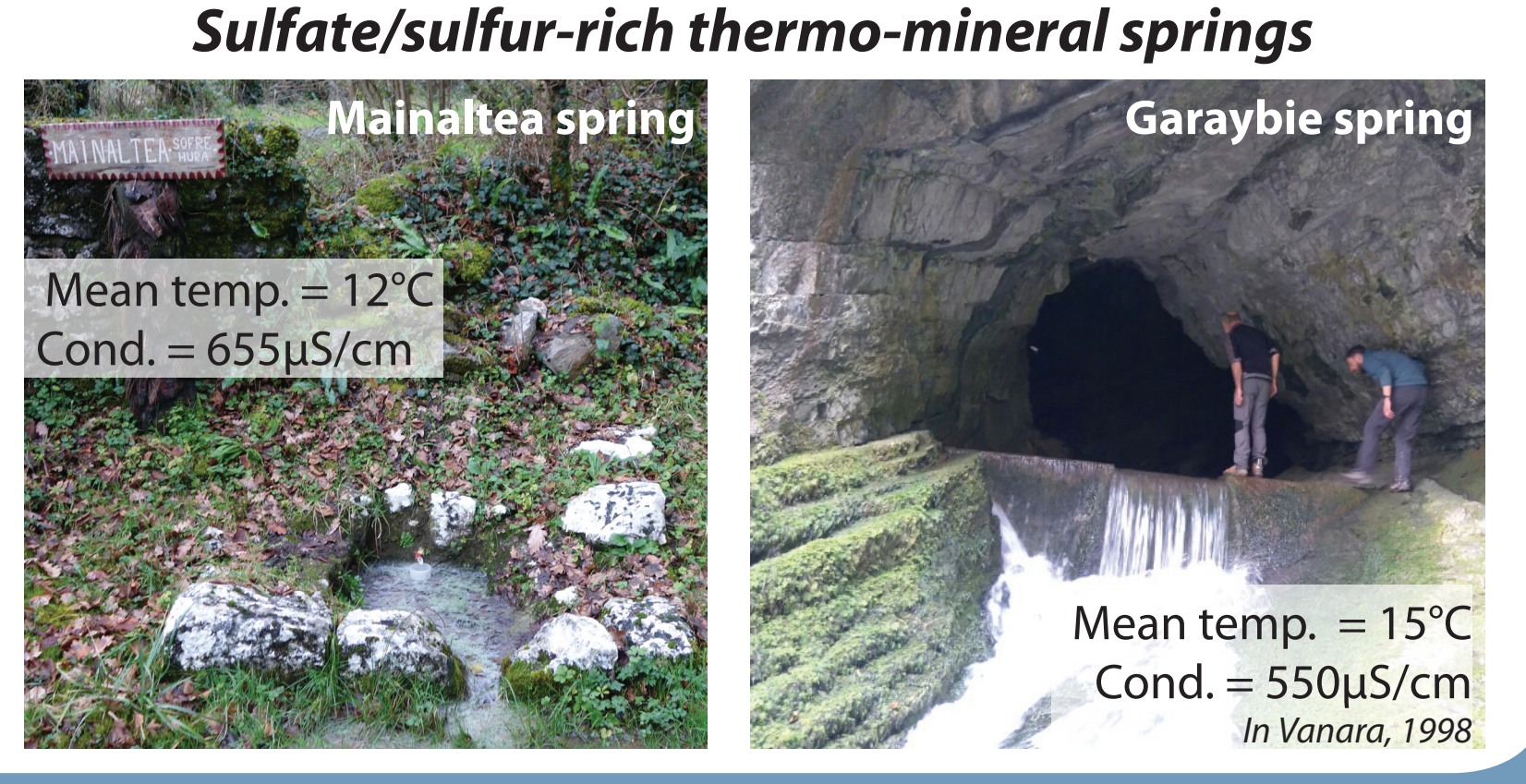
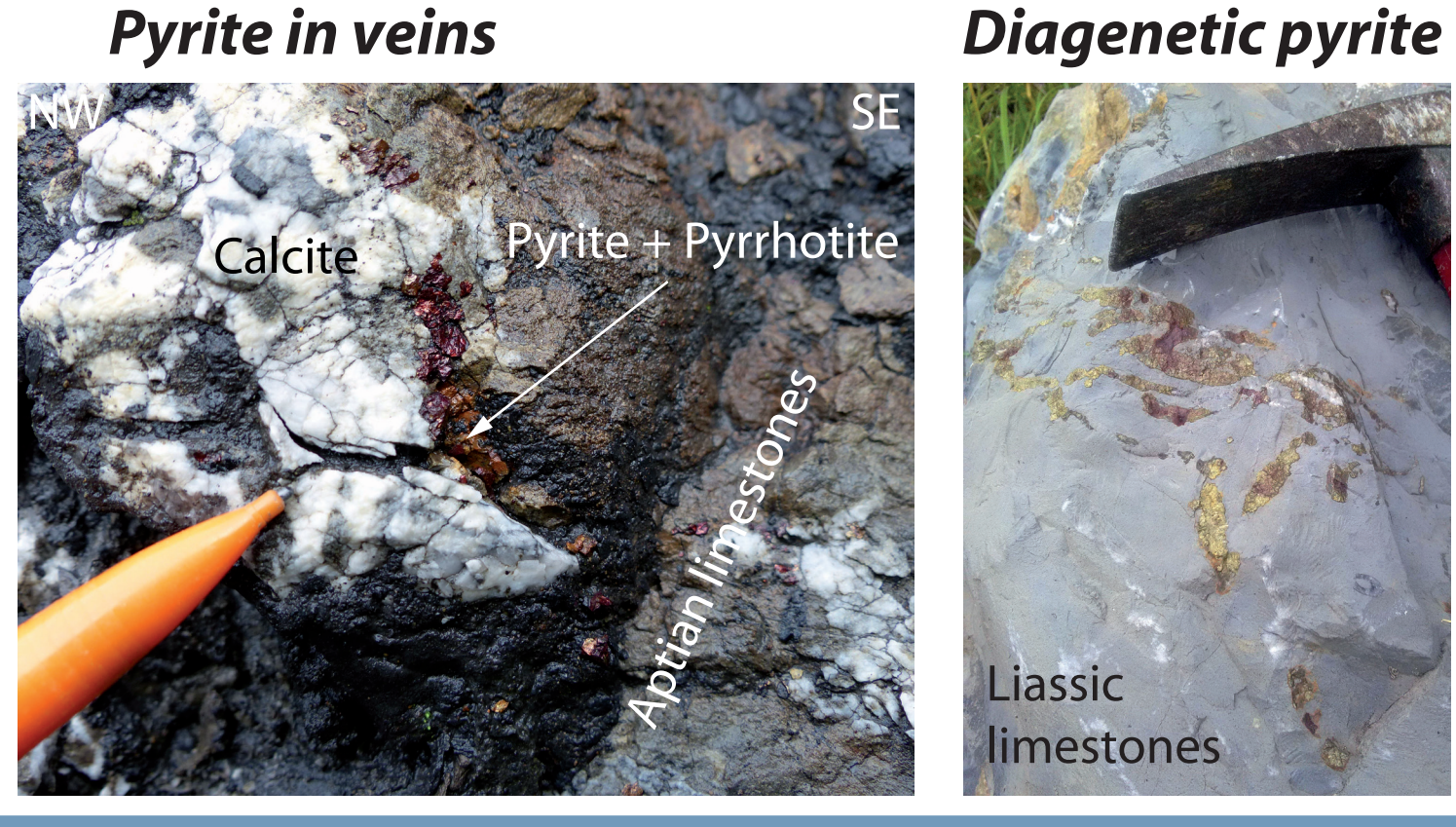
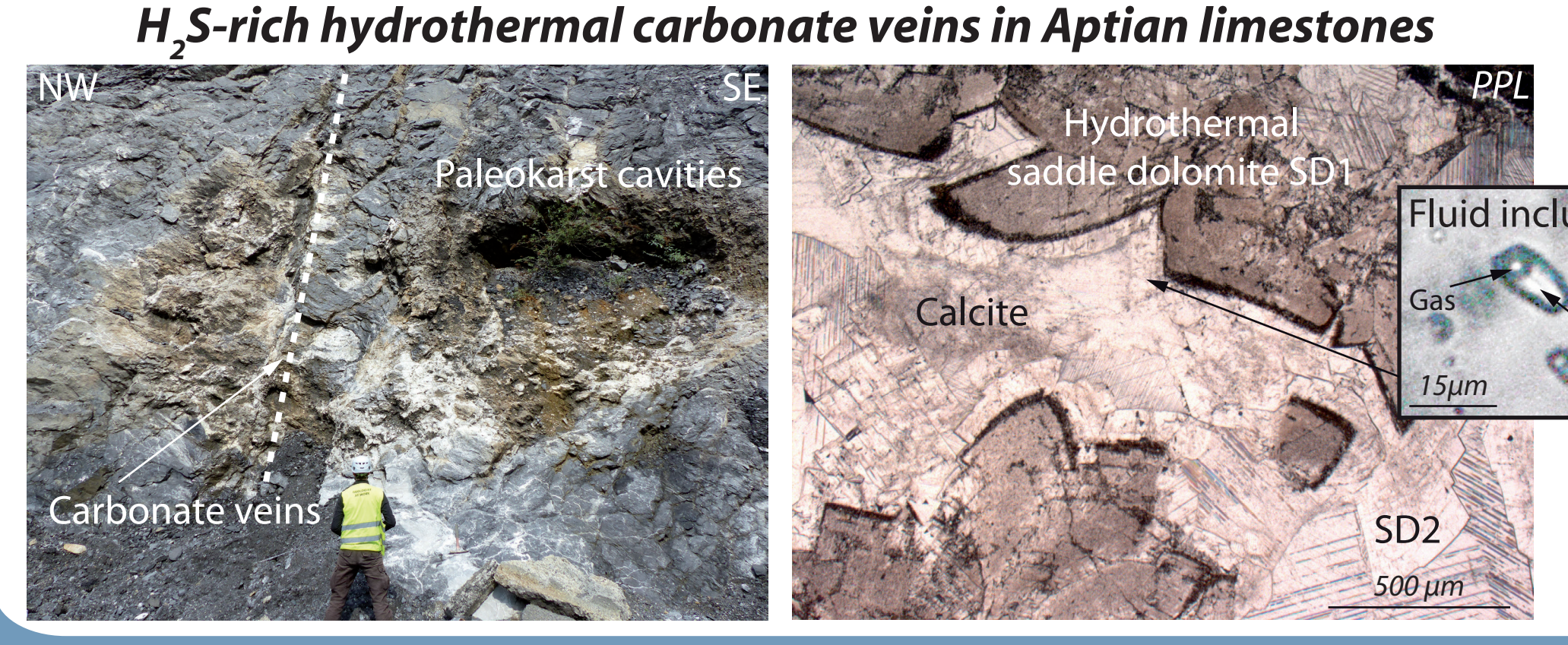
- > SAS
- > Pyrite oxidation
- > Leaching of sulfate-rich sediments (evaporite, carbonate...)
- > Decomposition of organic matter (guano...)



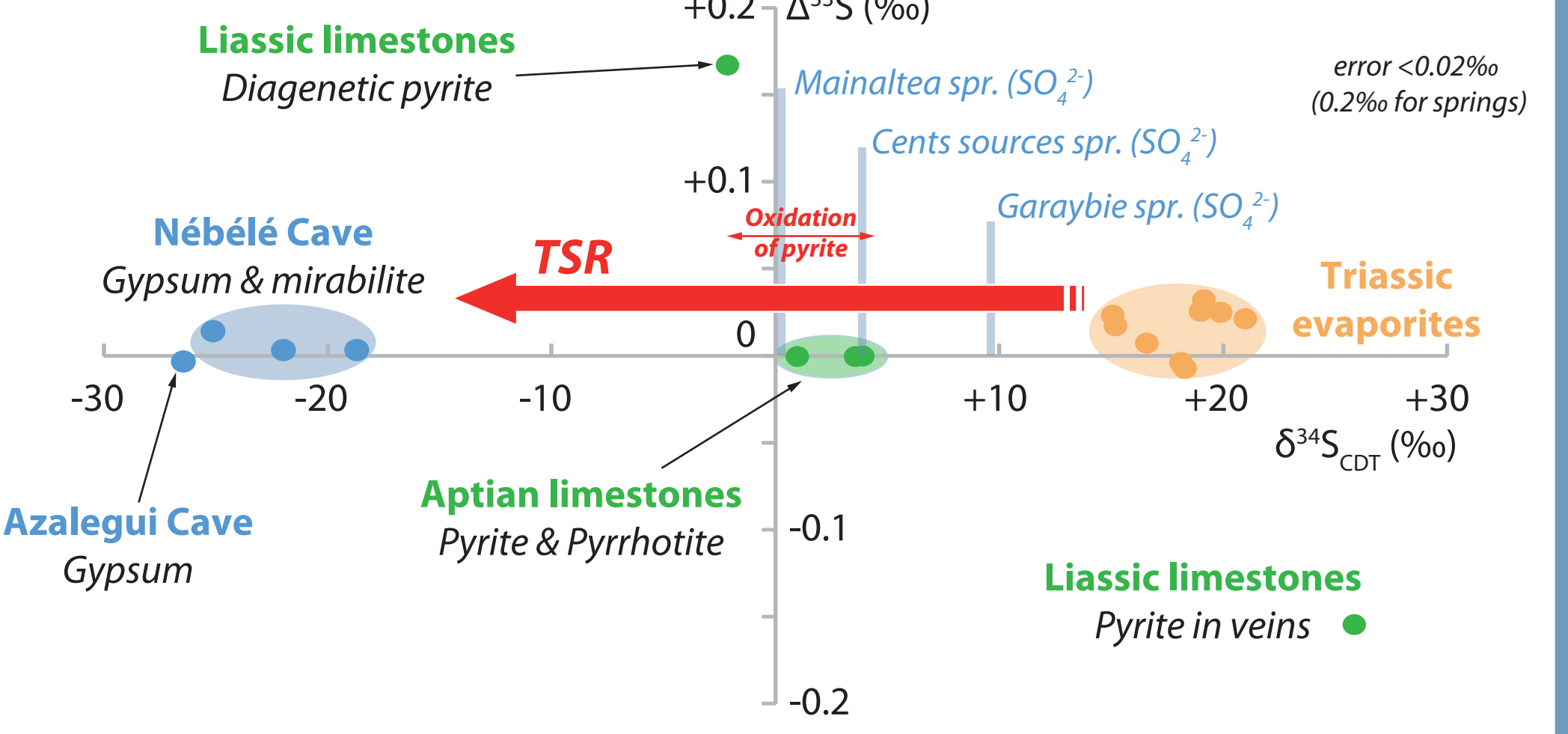
Example of the Nébélé Cave



Potential sources of sulfur in the sedimentary basin



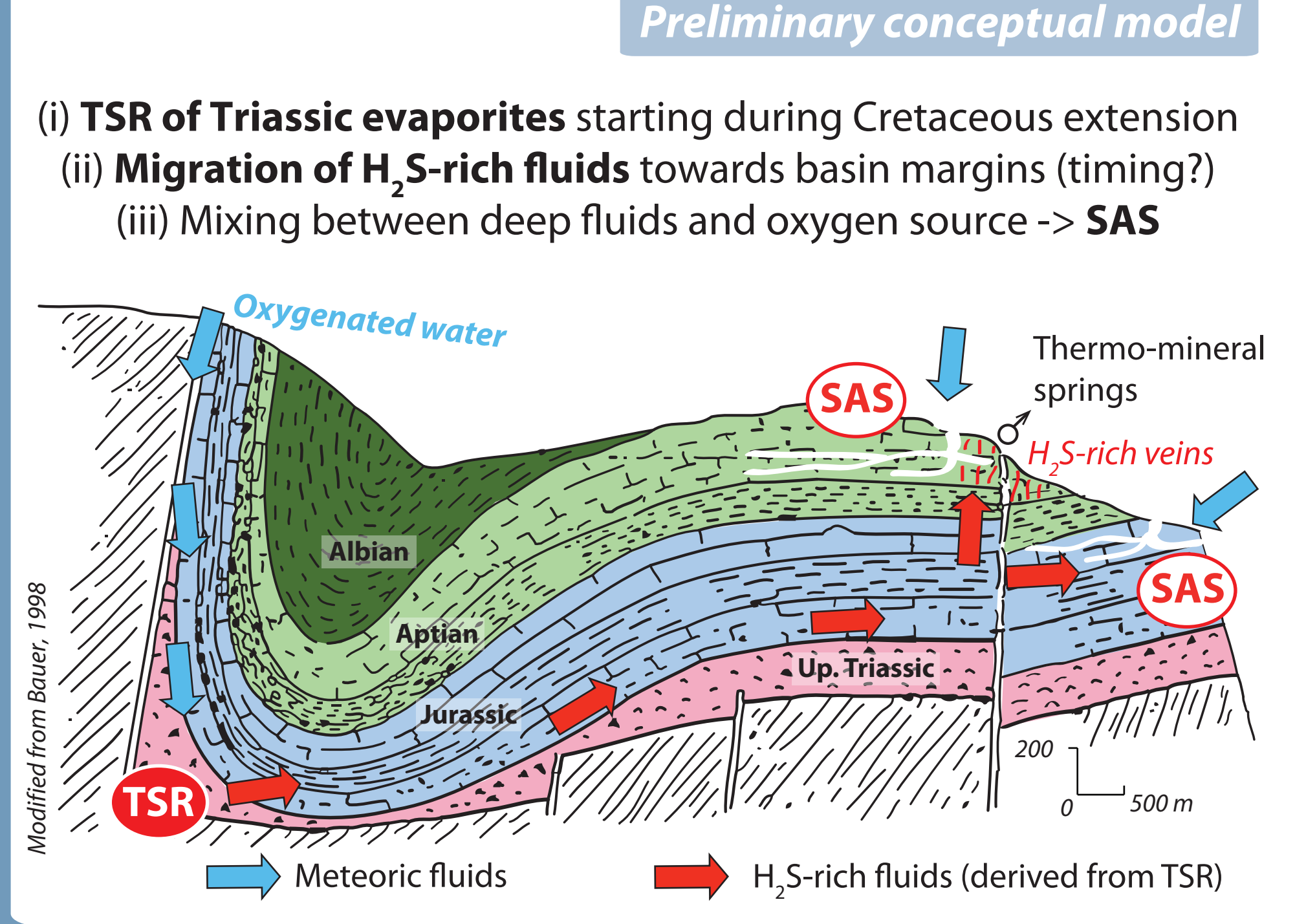
4- Sulfur isotopes: origin and processes



Cave sulfates are not linked to evaporite leaching or pyrite oxidation:

- such processes do not involve significant δ³⁴S fractionation
- very few pyrites in sediments
- > High δ³⁴S fractionation between Triassic evaporites and cave sulfates
- > Evidence of TSR and H₂S-rich fluid migration

5- Conclusions: 1st hypothesis and Perspectives



Perspectives

Methods	Lessons
S isotopes on gypsum & water	S species & origin
O isotopes on gypsum & water	Conditions during SAS
C isotopes on water & veins	Organic matter involved in TSR
Fluid inclusions in veins	P/T of fluids & S species
U/Th on gypsum	Absolute dating of SAS

6- Collaborations

- P. & S. Degouve (GSHP Tarbes)
- M. Douat (ARSIP, ICE Himalayas)
- Collectif Nébélé
- P. Sorriaux & CDS09/SCHS
- CDS64
- Data base Karsteau
- Karsteau
- ARSIP
- CDS 64
- Centre National de la Recherche Scientifique
- Centre de Recherche Géologique Pierre Saint Martin
- Centre de Recherche Géologique Pierre Saint Martin