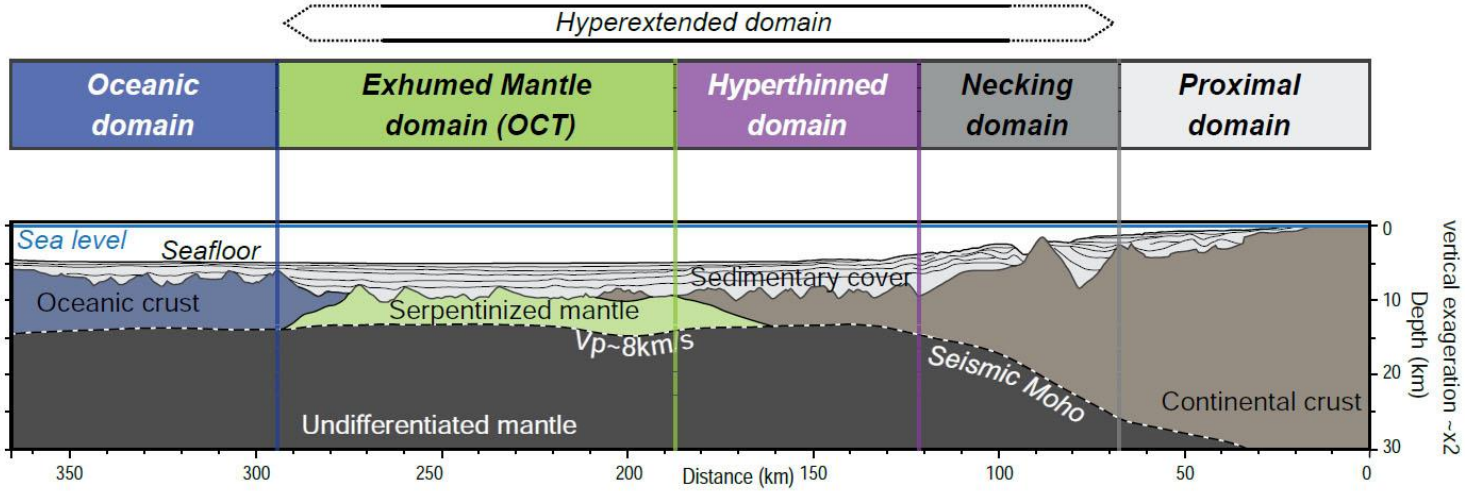
Mechanisms of continental break-up : tectonic, stratigraphic and structural constraints from a preserved distal rifted margin (Agly massif, eastern Pyrenees)

Martin Motus, Yoann Denèle, Frédéric Mouthereau, Élise Nardin

Introduction



(Tugend, 2013)

Although some common characteristics such as mantle exhumation and the individualization of necking zones, studies of rifted margin have highlighted a large variety with contrasted morphologies and characteristics

We need to find markers to understand the various mechanisms leading to continental break up :

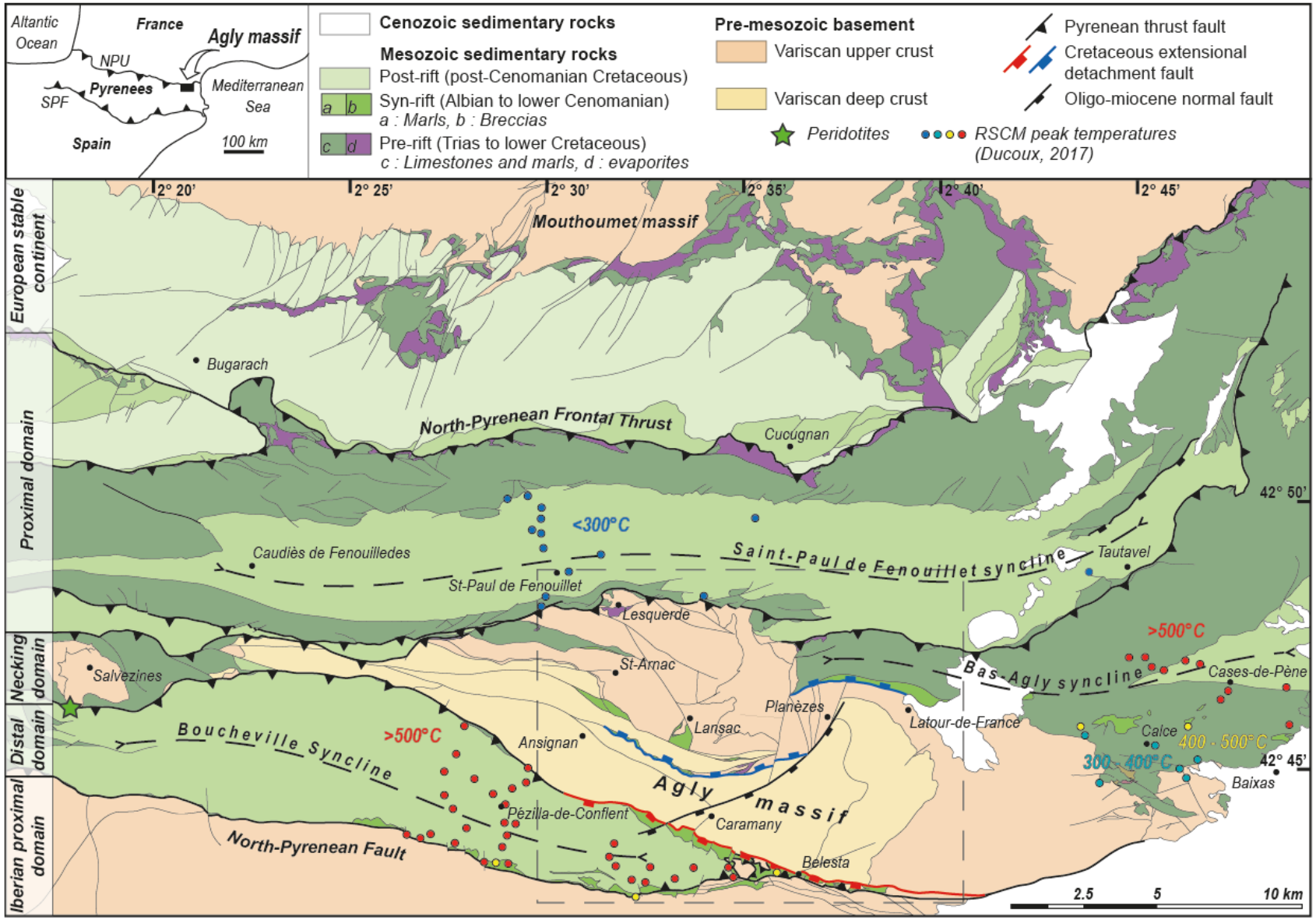
- Presence and localization of extensional detachment faults, ductile shear zone?
- Coupling vs decoupling between the sedimentary cover and basement?
- Role of tectonic inheritance?

Here, with the example of the Eastern Pyrenees Cretaceous fossile margin we show :

How breccias systems highlight mechanisms of continental break-up ?

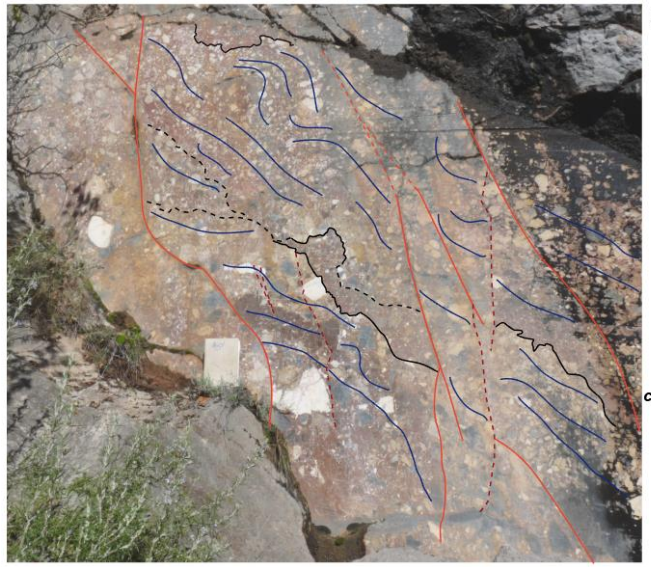
The Agly massif and its neighboring Mesozoic basins : a fossil continental margin

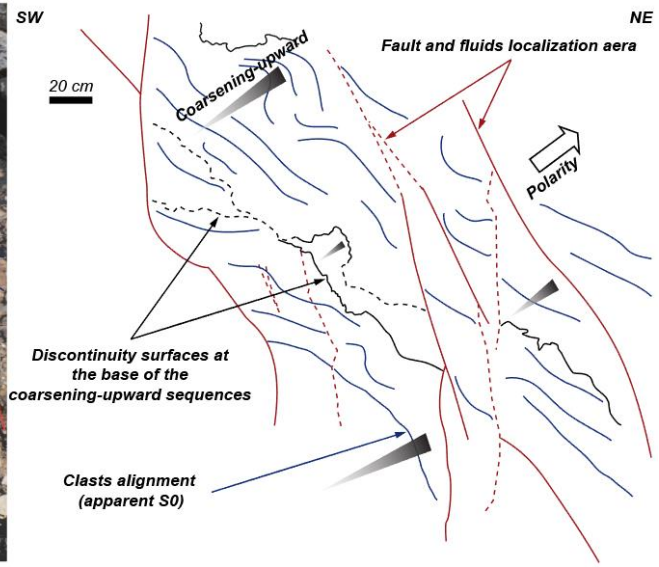
- Highly subsidents syn-rift basins (Albo-Cenomanian flyschs) *(Debroas, 1990)*
- HT metamorphism affecting pre- and syn-rift deposits *(Clerc et al., 2016, references therein, Ducoux, 2017)*
- Evidences of MT Cretaceous deformation affecting the basement and hydrothermal alteration *(Oldum and Stockli, 2019, Poujol et al., 2010)*
- Evidences of ductile to brittle deformation affecting the mesozoic cover *(Vauchez et al., 2013, Clerc et al., 2016, Chelalou et al, 2016,)*
- Exhumed mantle in contact with pre- and syn-rift deposits (Boucheville syncline, Salvezines massif)



Breccias systems are used in this study as a marker of syn-extensional relationships between basement and its Mesozoic cover

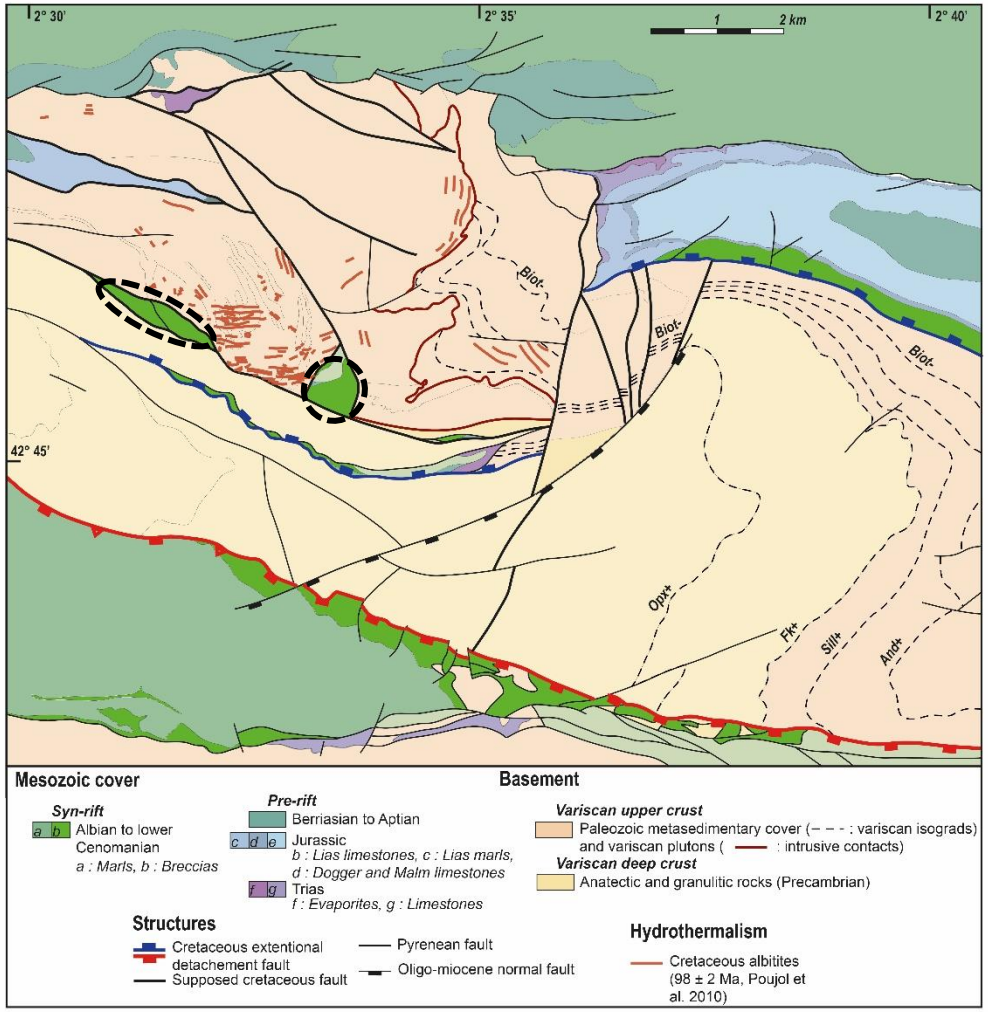
Field observations : *Sedimentary breccias at the contact between upper and deep Variscan crust*





- Sedimentary breccias contain marble and marls clasts from the pre-rift cover, with rare elements from the upper crust (granit and schists) in matrix
  → emphasize a decoupling between the basement and the Mesozoic cover

- Albititic circulation in the footwall of faults at the contact breccias/basement
  → link with cretaceous albitization

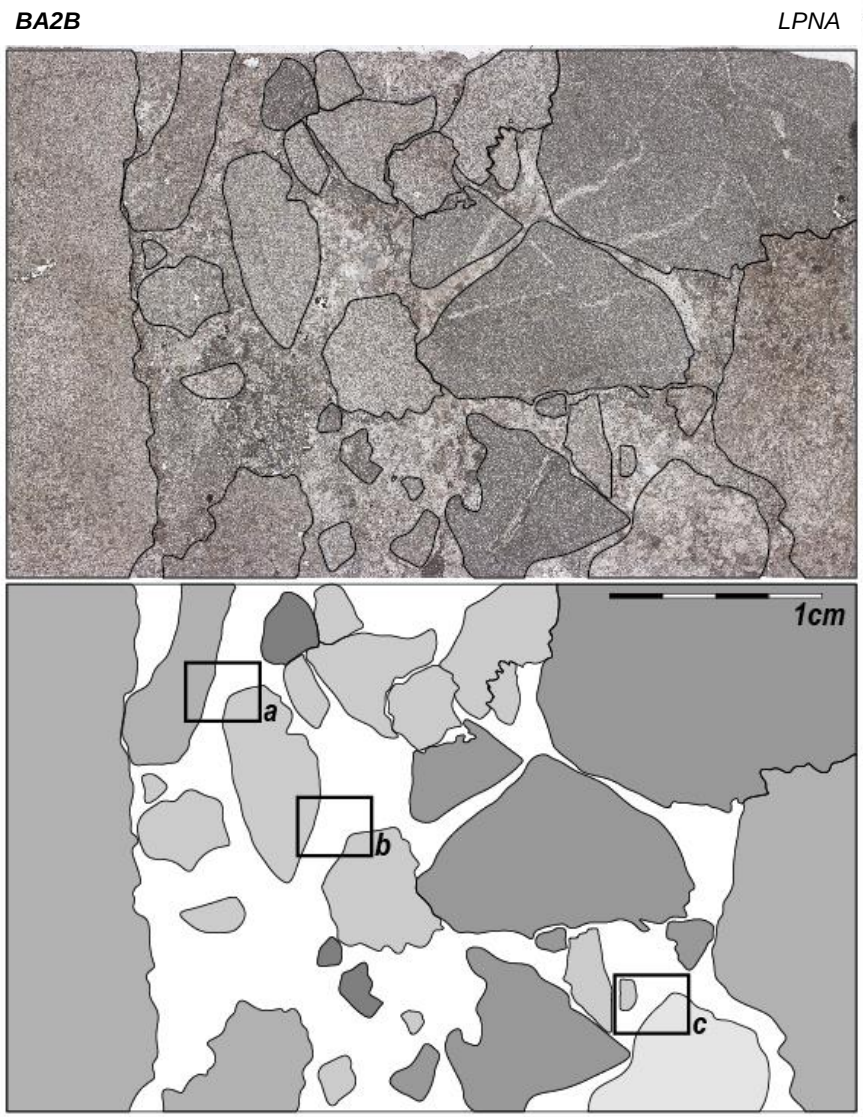


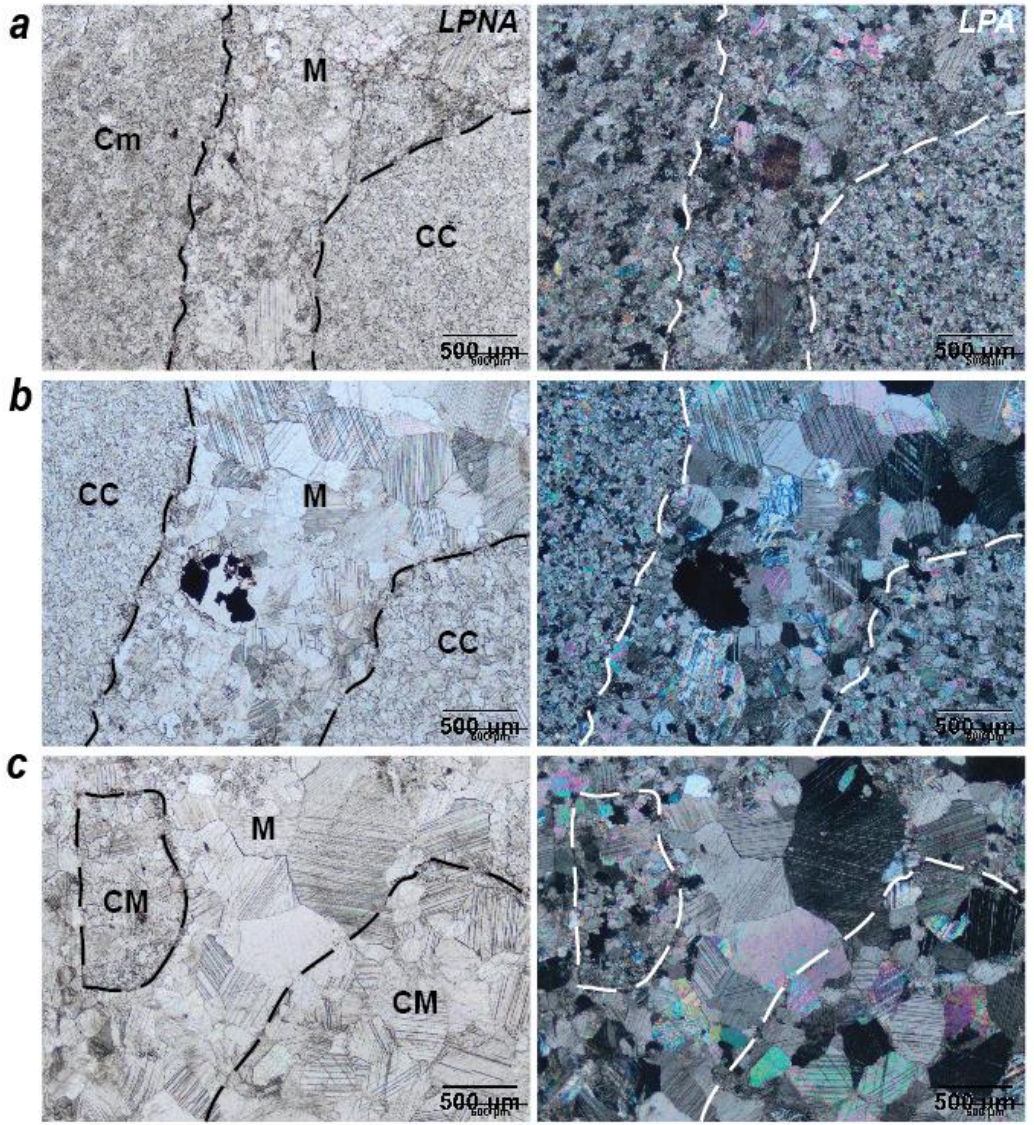
- *Matrix-supported to clast-supported*
- *Monogenic to polygenic*

Macroscopic and microscopic observations : *Evidences of recristallization of the sedimentary breccias*

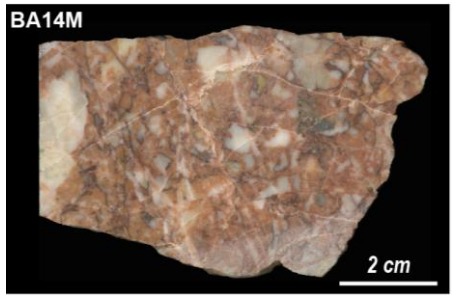
→ link with the HT Cretaceous metamorphism

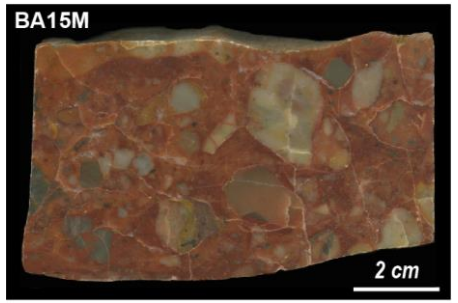
Thin sections :

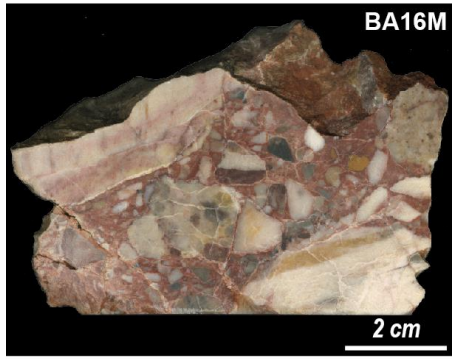




Polished sections :

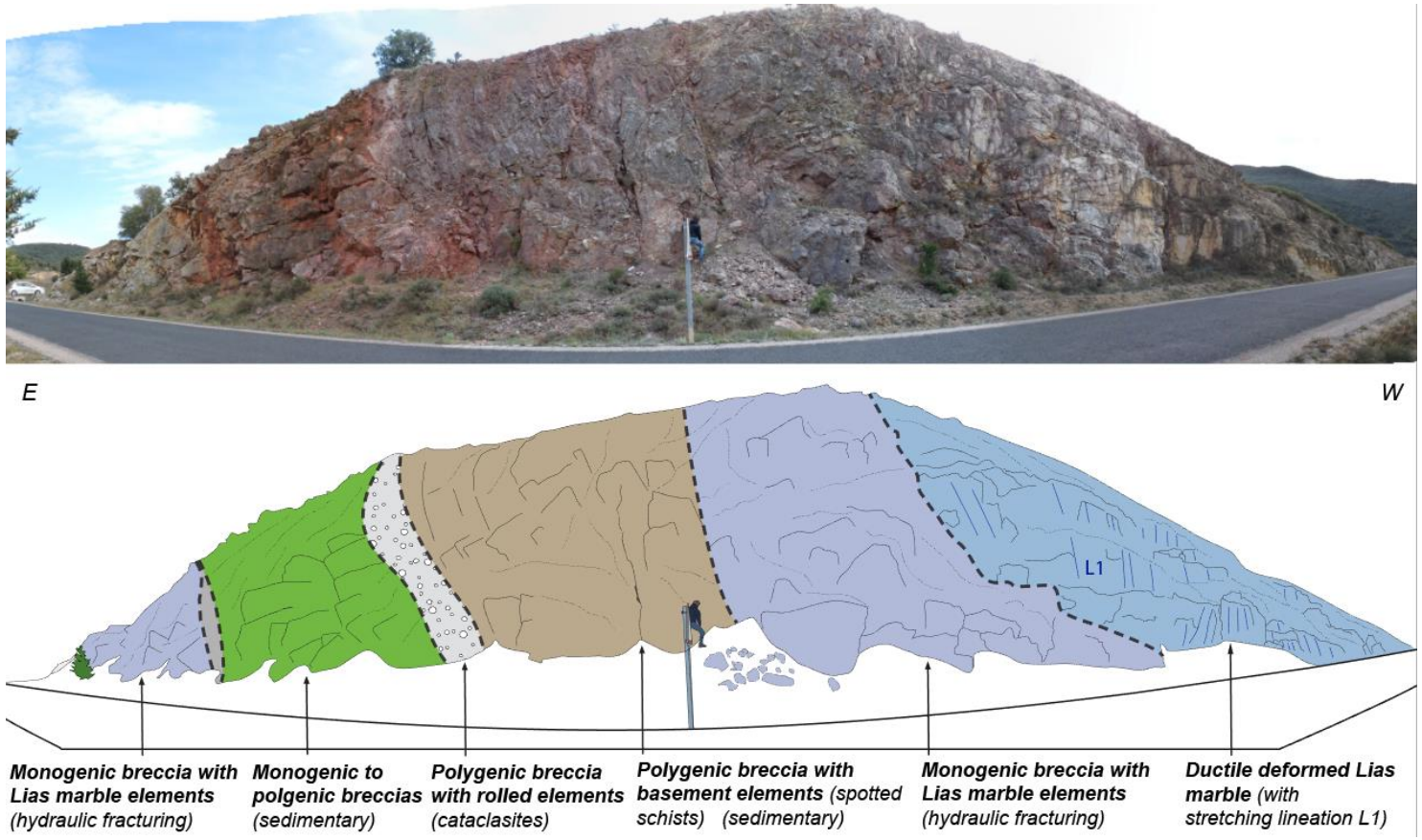


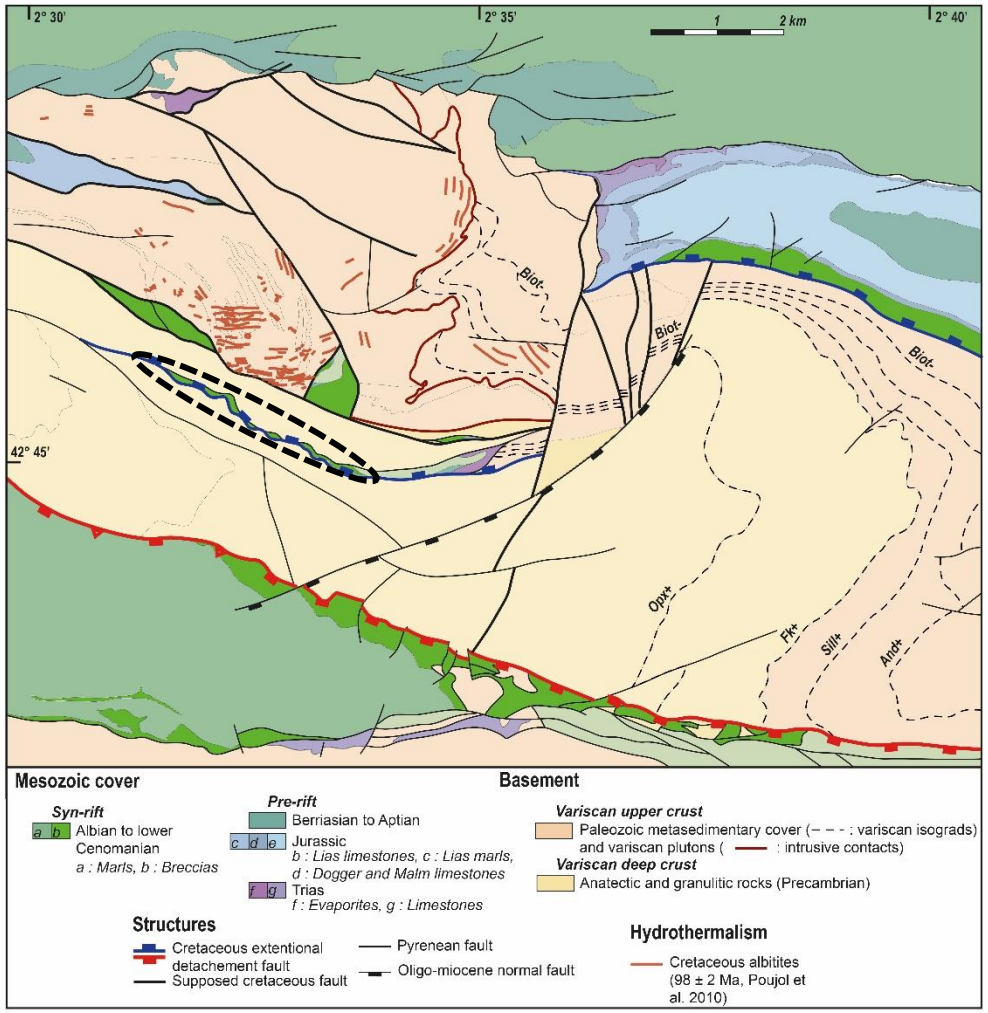




Cm : marl clast / CC : limestone clast / CM : marble clast / M : matrix

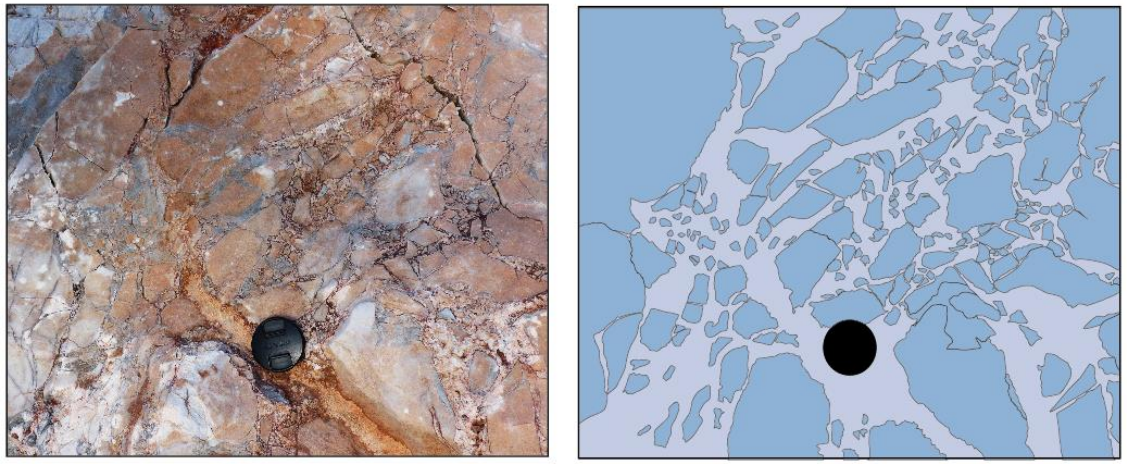
Field observations : *A mix-breccias system at the hangingwall of a major extensional detachment and at the contact with the deep crust*





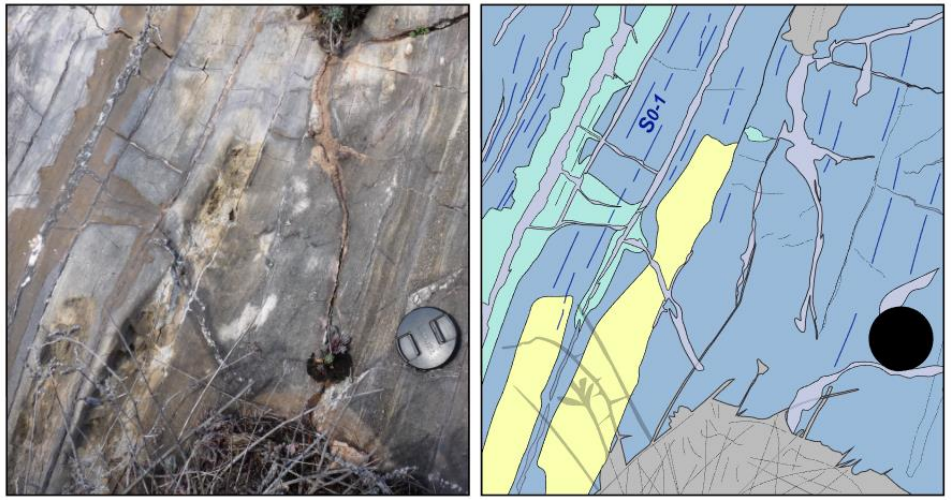
Field observations : *Brecciation of the Liasic limestones (base of the pre-rift cover) by hydraulic fracturing*

→ link with the syn-rift fluids circulations



Stretched marble clasts (ductile deformed Lias)

Inter-clasts filling of calcitic cement and crushed marble

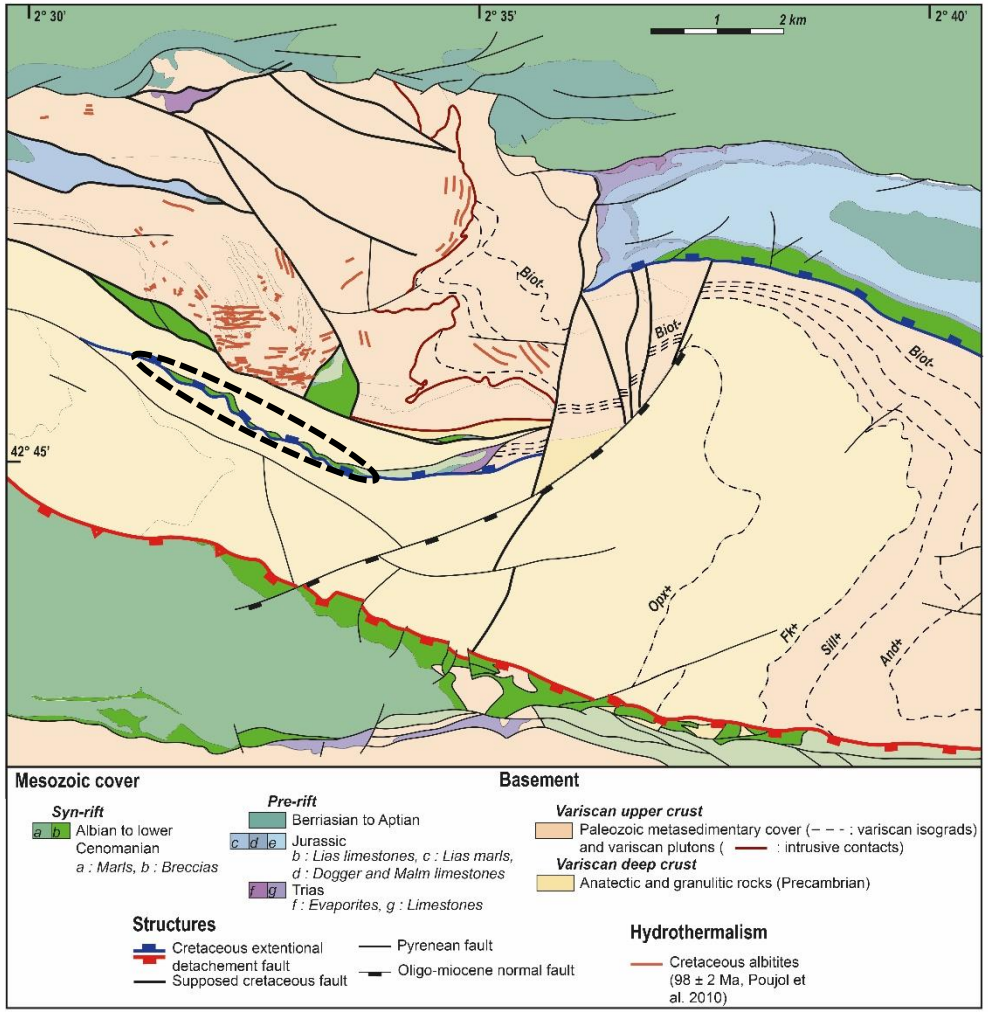


Ductile deformed Liasic marble (apparent S0-1)

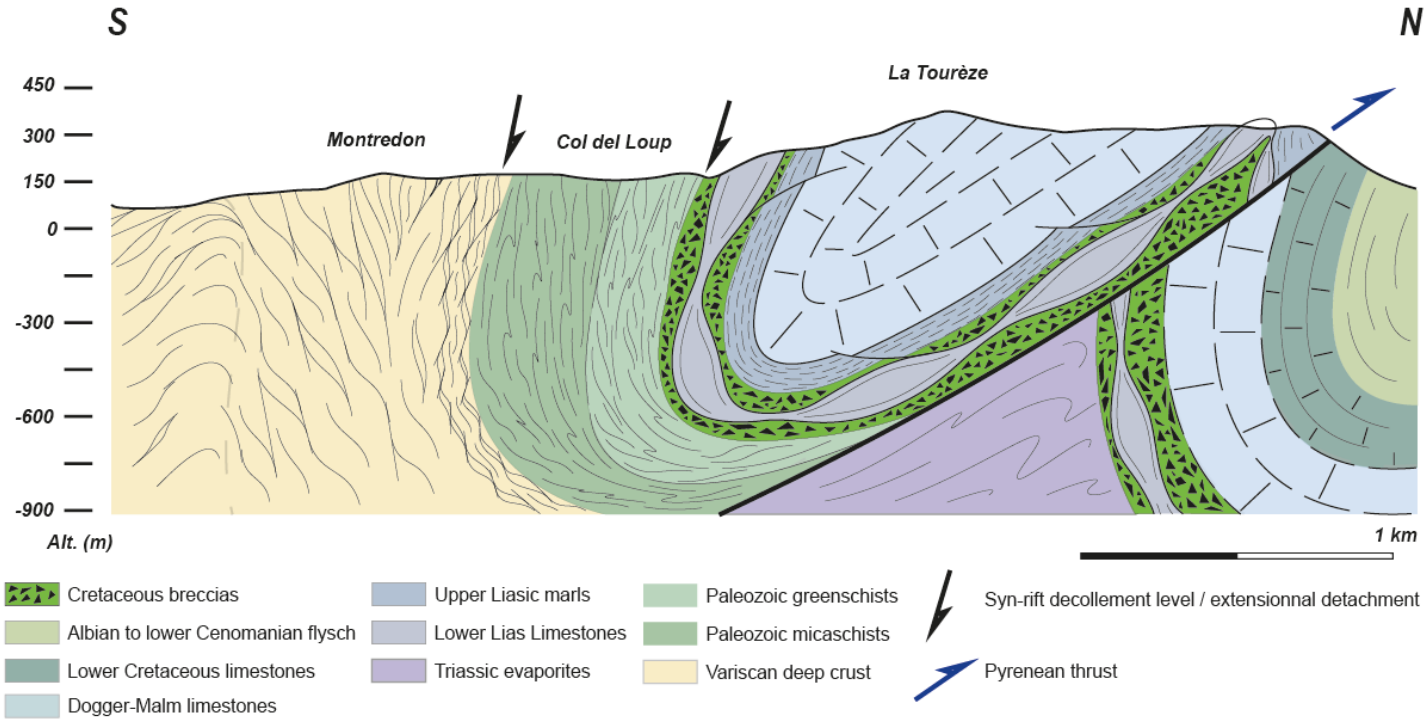
Calcitic cement (ex carbonate fluids)

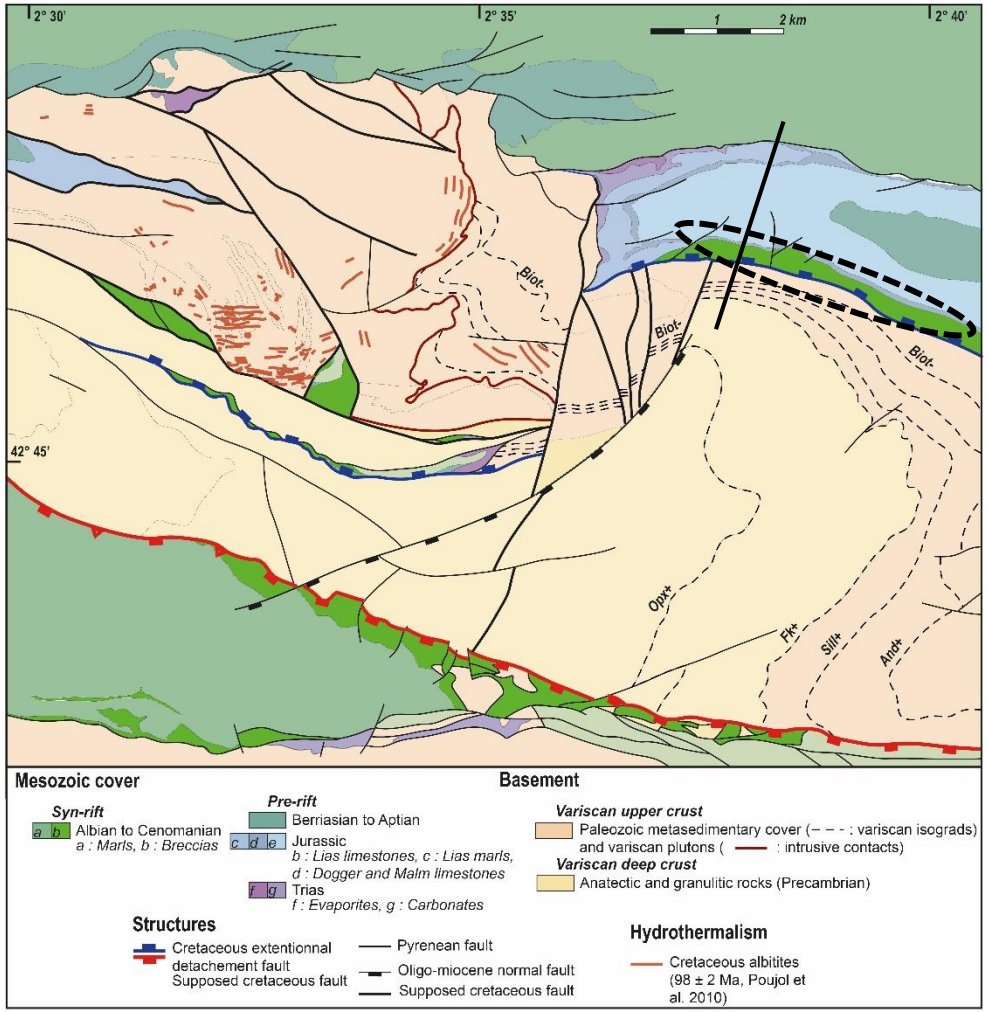
in situ alteration of marble at the vicinity of fluids circulation zones

Penetrative alteration and cargneule



Field observations : *Tectonic breccias localized at a major syn-rift contact between upper Variscan crust and Mesozoic cover*



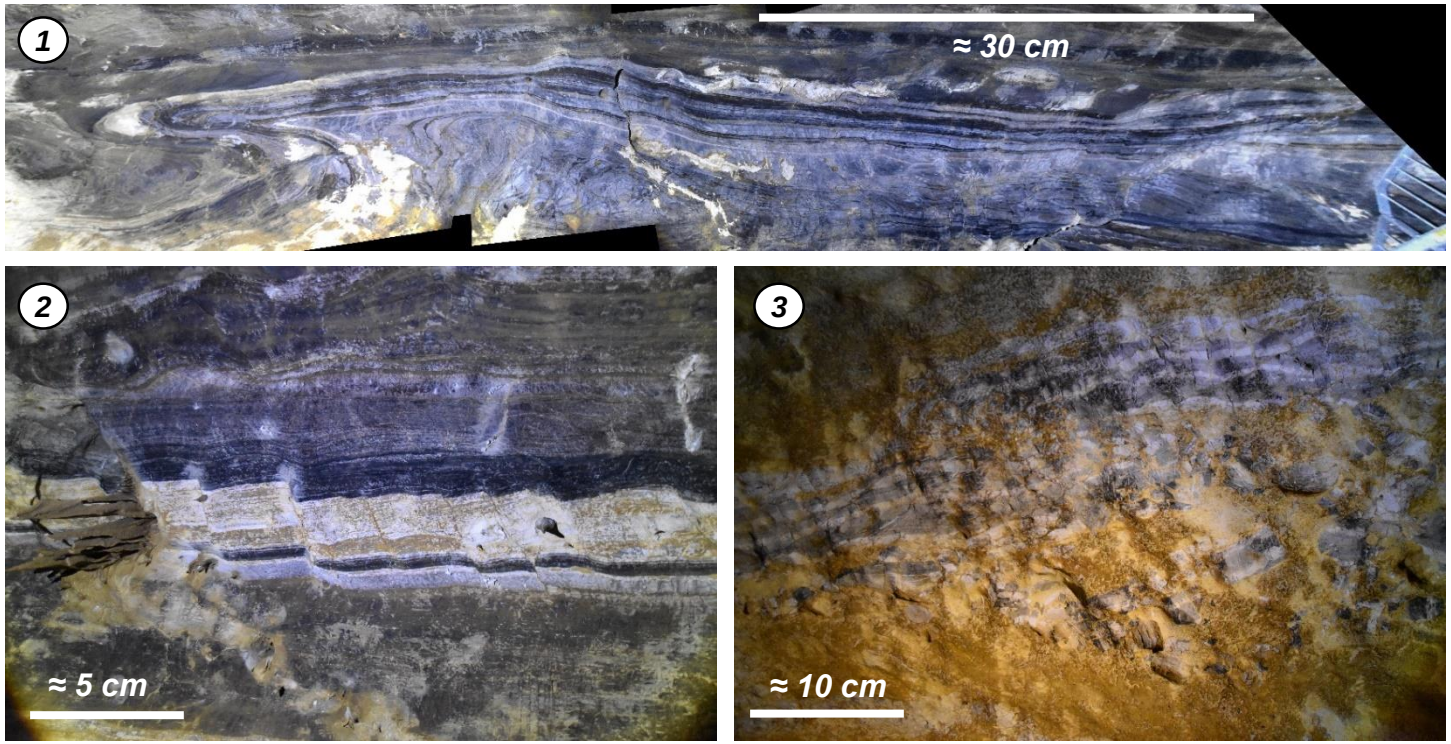


- Stretching, boudinage and brecciation of the Liasic limestones above a decoupling level at the base of the pre-rift cover (i.e. thick triassic evaporites, c. 1km)
- Kinematic (top to the N20) compatibility between extensional shear zones in the basement and ductile to brittle deformation in the Mesozoic cover

→ breccias mark relationships between basement and basins (i.e. pre- and syn-rift cover) respective deformation during rifting

Field observations : *Ductile to brittle deformation at the base of the syn-rift basins (i.e. in the pre-rift cover)*

- Exceptional outcrop condition to studying the extensional deformation at the base of Cretaceous syn-rift basins : the Gouffre d'Esparros (Central Pyrenees)



(Photographs : V. Regard)

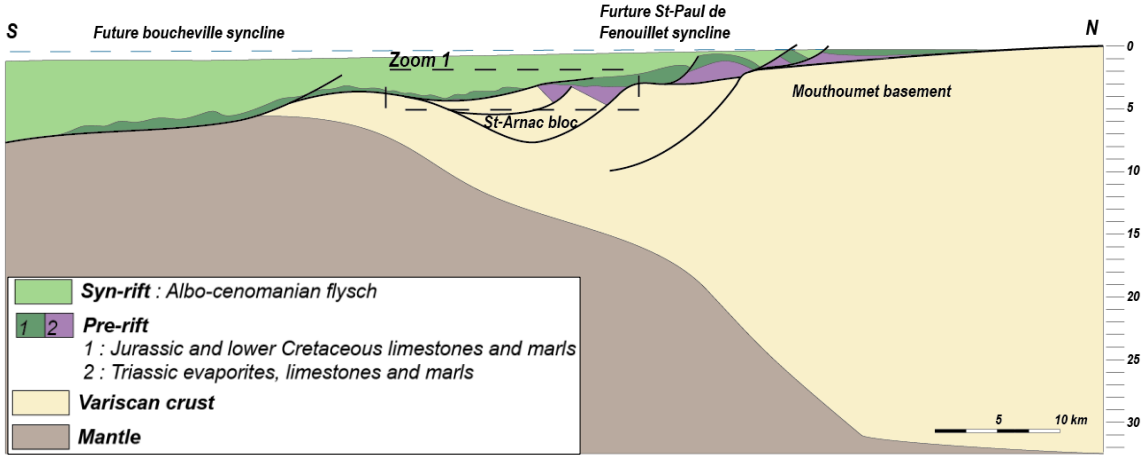
1 : extensional passive folds

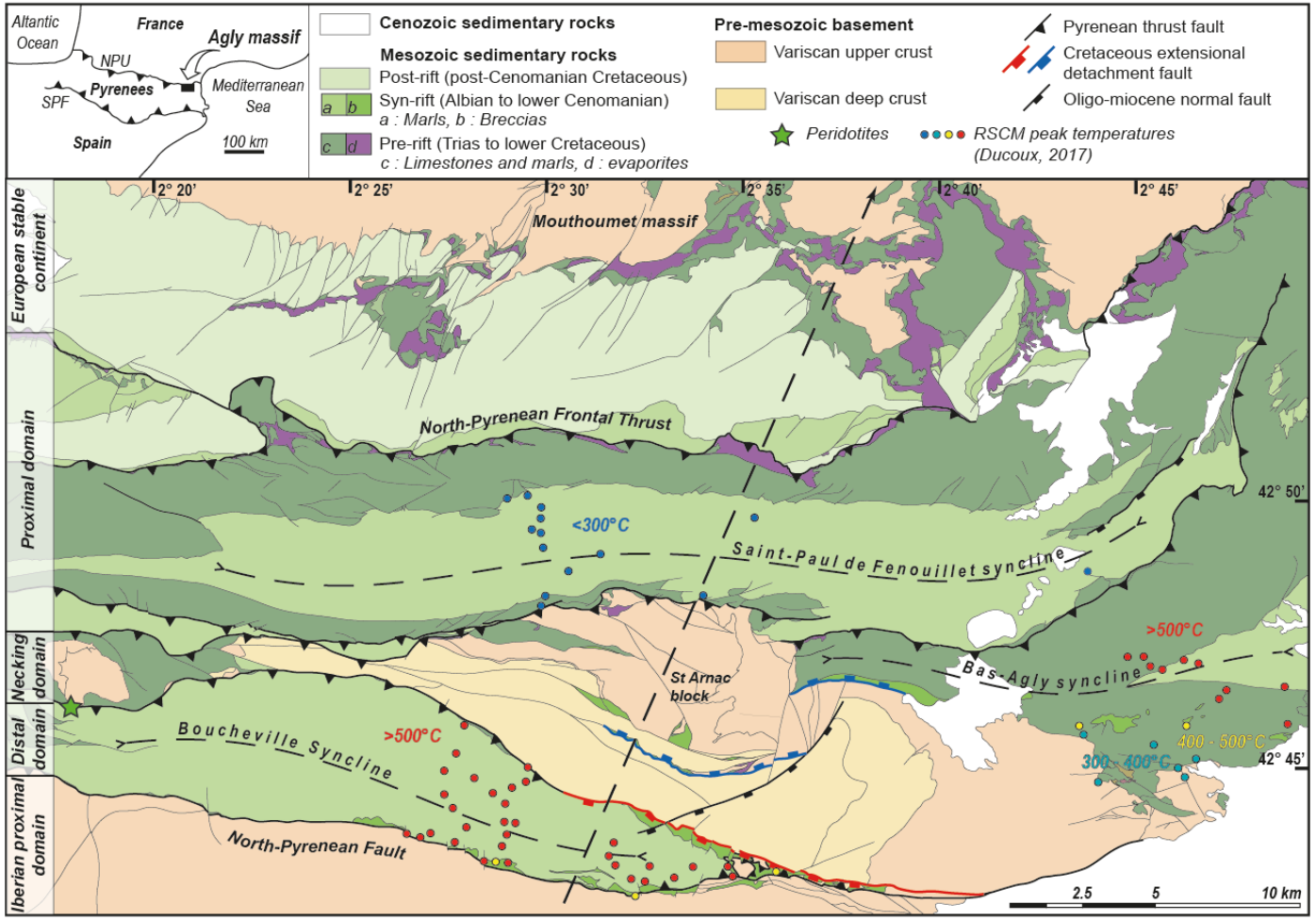
2 : brittle boudinage

3 : clast-supported to matrix-supported cataclastic breccias

- In situ cataclastic breccias at the base of the Boucheville basin

Restored sections of the syn-rift margin



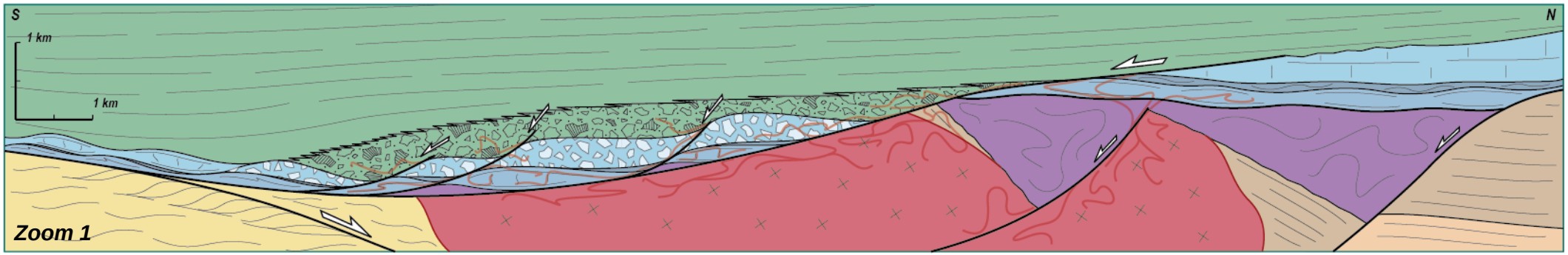


Zoom 1 : Mix breccias system marking the pre-rift deformation and the establishment of a sedimentary breccias system above the decoupling level at the base of the pre-rift cover (i.e. Triassic salt)

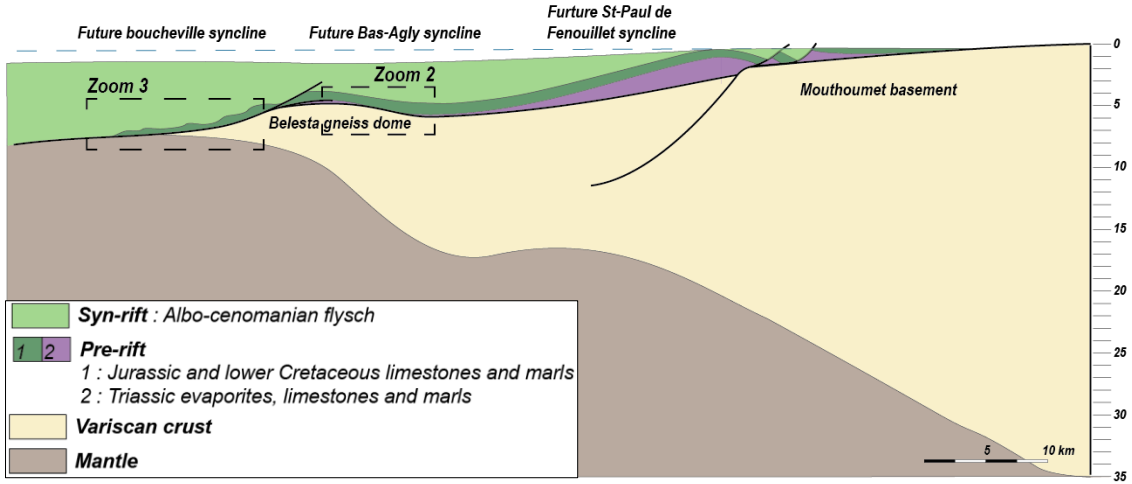
Syn-rift
- Albian to lower Cenomanian flysch
- Sedimentary polygenic breccias
- Intraformationnal monogenic breccias in pre-rift cover (hydraullic fracturing and cataclasites)

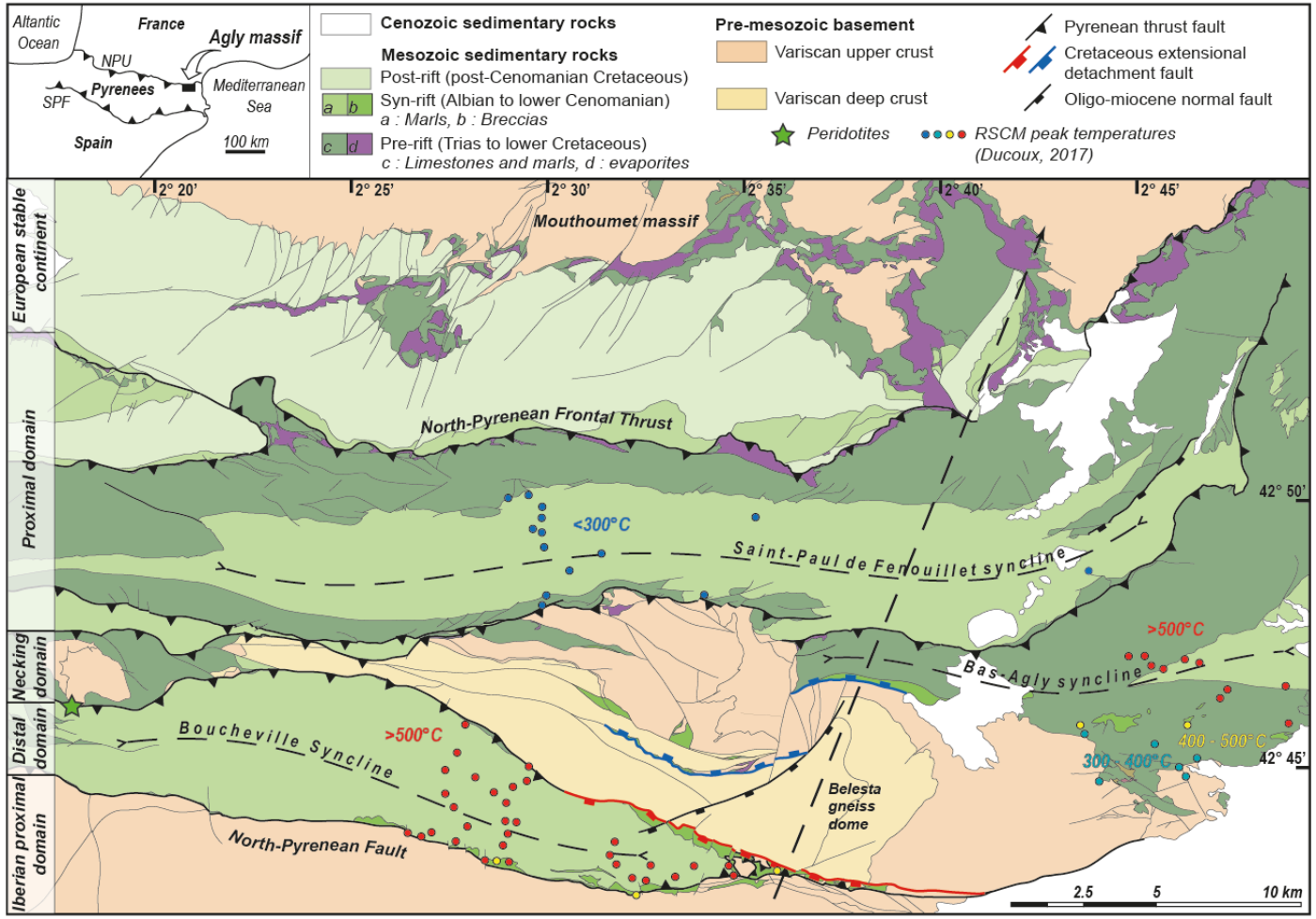
Pre-rift
- Dogger to Aptian limestones
- Lias marls
- Lias limestones
- Triassic evaporites

Basement
- Upper Ordovician to Silurian schistes
- Lower Ordovician micaschistes
- Variscan pluton
- Variscan deep crust



Restored sections of the syn-rift margin





Zoom 2 : Cataclasites and hydraulic breccias marking the décollement of the base of the pre-rift cover

Zoom 3 : « mélange » zone marking the coupling point between the cover, the basement and the mantle → interpreted as the main extensional detachment fault leading to the mantle exhumation

Syn-rift

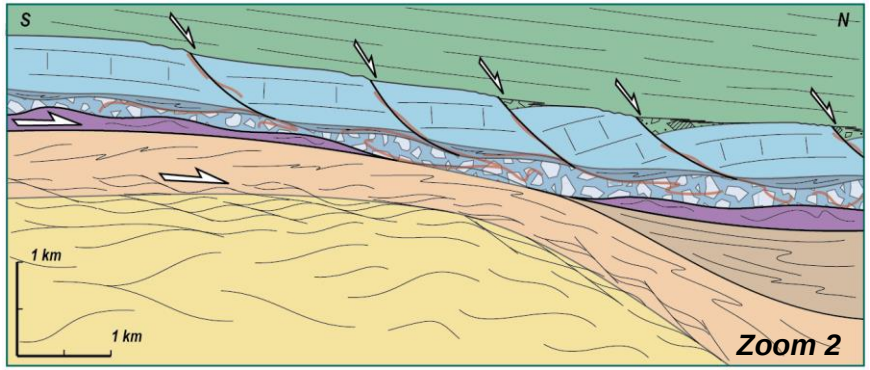
- Albian to lower Cenomanian flysch
- Sedimentary polygenic breccias
- Intraformationnal monogenic breccias in pre-rift cover (hydraullic fracturing and cataclasites)
- Fluid injected «melange zone» with clasts from basement and pre-rift cover
- Fluids

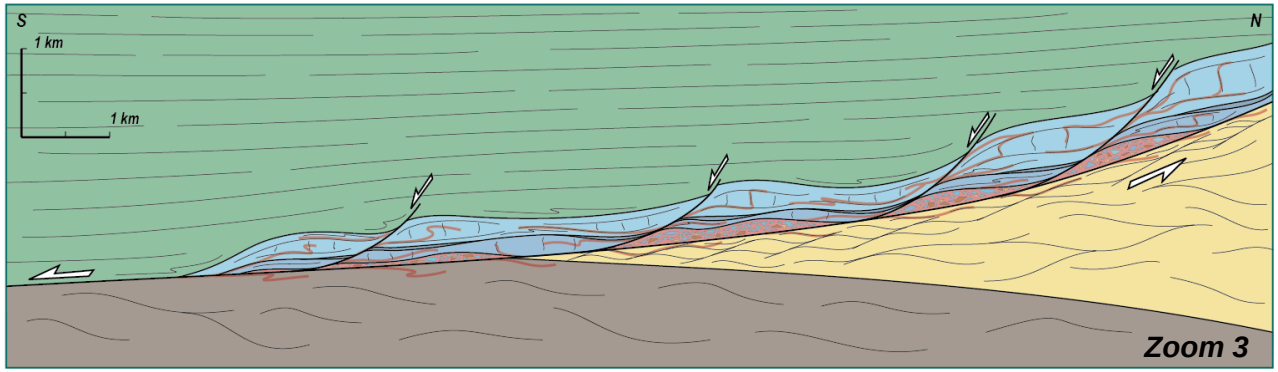
Pre-rift

- Dogger to Aptian limestones
- Lias marls
- Lias limestones
- Triassic evaporites

Basement

- Upper Ordovician to Silurian schistes
- Lower Ordovician micaschistes
- Variscan deep crust





Conclusion

How breccias systems highlight mechanisms of continental break-up ?

Taking the example of the fossilized Cretaceous European margin in Eastern Pyrenees, we show :

- A decoupling level at the base of the pre-rift cover (i.e. Triassic evaporites), marked by intraformational tectonic breccias above the décollement and syn-rift sedimentary breccias containing essentially clasts from the sedimentary cover

- The presence of a major extensional detachment fault in the deep crust, marked by a mix-breccias system and the important hydraulic fracturing on its hanging-wall

- The contrasted behaviour of the crust between
  - a « rigid » domain : St-Arnac Block with a sedimentary breccias system above a tilted blocks tectonic affecting the pluton
  - a « weak » domain : the Belesta Gneiss Dome bounded by intraformational breccias systems developing at the base of smooth-slopes type basins

- The coupling point between the sedimentary cover, the basement and the mantle revealed by a « melange zone » of hydro-cataclastic breccias, interpreted as the main extensional detachment fault leading to the mantle exhumation