

Sedimentary and Geodynamical 2D-3D Modeling of the Provence Continental Shelf during Mio-Pliocene Eustatic Events*

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Search and Discovery Article #50788 (2013)**

Posted June 17, 2013

*Adapted from oral presentation given at AAPG European Regional Meeting, Barcelona, Spain, April 8-10, 2013

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Abstract

Provence continental shelf is a complex geological domain situated between the Alpine arc and the continental margin of the Liguro-Provençal back-arc basin which was influenced by the high amplitude Neogene eustatic changes, especially during the Messinian Salinity Crisis (MSC). Offshore Cassis Calanques, Cassidaigne Canyon deeply (>1700 m) incises the narrow (7-20 km) Provence continental shelf. Onland, the higher elevation of wave-cut surfaces and marine Miocene deposits matched up to Mio-Pliocene eustatic levels, evidences topographic anomalies suggesting that Provence margin geodynamic was controlled by tectonic processes.

The objectives of the study are to constrain the large wavelength deformation rate of the topography and to constrain the chronology of landscape evolution from land to sea. The topographic variations are estimated by integrating geomorphology, sedimentology, and structural geology of the Provence continental shelf. This approach consists in (1) reconstructing the Messinian-Pliocene eustatic signal given by a 2D seismostratigraphic analysis of Messinian incisions sedimentary filling, and (2) paleo-topographic restorations in a 3D model that integrates eustatic signal and large wavelength tectonic deformation.

Cassidaigne Canyon sedimentary functioning study is performed together with the Bandol Canyon that is genetically linked. Two hypothesis of stratigraphic modeling are discussed to explain the sedimentary filling of these canyons using some key newly acquired seismic profiles.

A land to sea 3D topographic model of the Provence continental shelf was performed in the gOcad software, which integrates all sedimentary strata and geomorphologic benchmark levels localized on the continental shelf since the end of the Miocene. Paleo-topographic restorations of the 3D model evidence a tilting of the margin from SW to NE and reliefs rejuvenization (from 300 to 600 m mean Tortonian massifs elevation to 500 to 1100 m at present-day). Since the Miocene, Provence Continental Shelf is localized at the transition zone between the Gulf of Lion subsided margin and the Ligurian uplifted margin. Consequently, the Provence Margin land-sea topography is acquired since the Miocene and is part of the Mediterranean regional geodynamics.

This Bandol-Cassidaigne Canyons sedimentary study has implications on the sedimentary and petroleum geology of the more distal areas in the Gulf of Lion.

Selected References

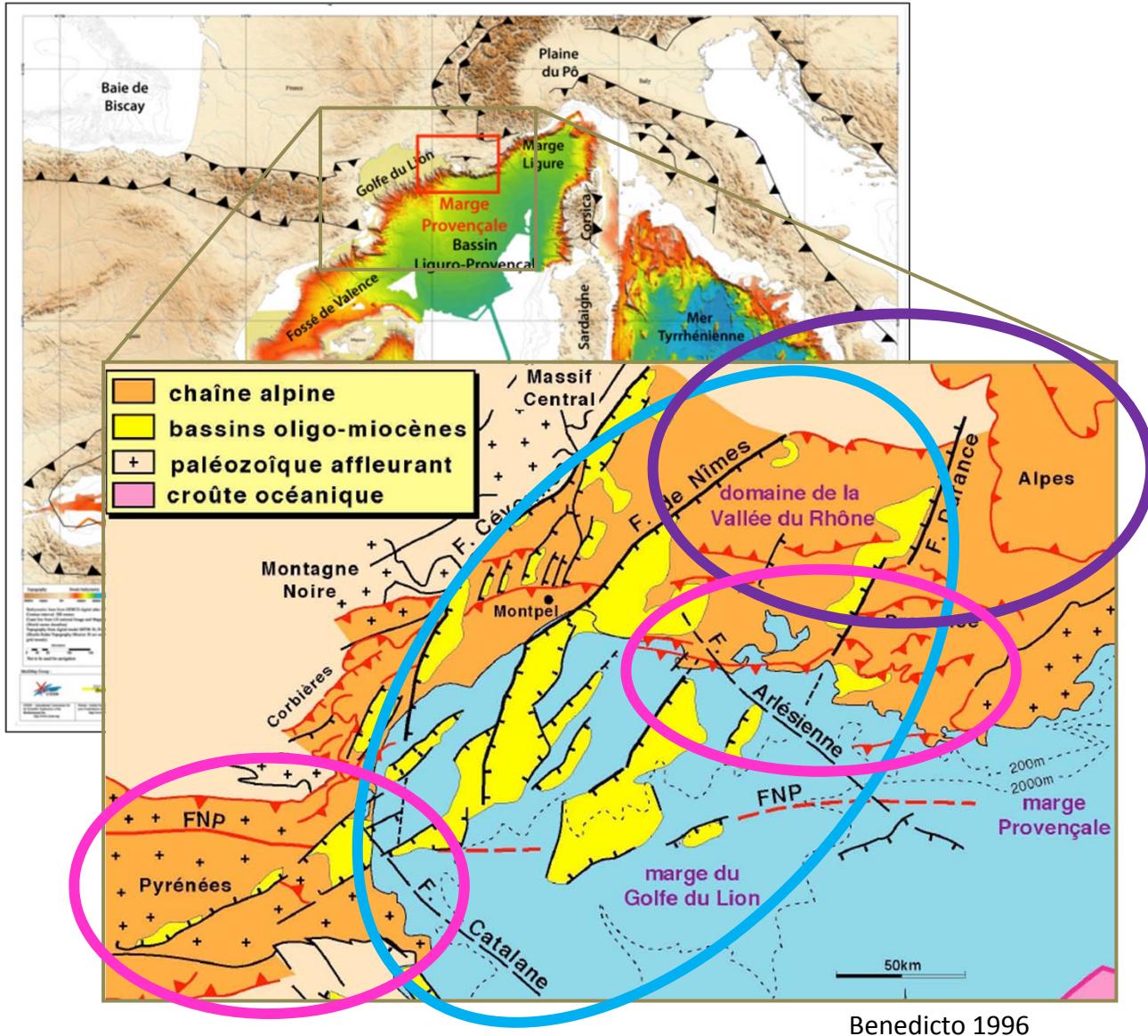
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Sedimentary and geodynamical 3D modeling of the Provence Continental Shelf during Mio-Pliocene eustatic events

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Cenozoic geodynamical context



Cenozoïc main tectonic events :

Pyrenean compression
(Upper Cretaceous to upper Eocene)

Gulf of Lion extension
(Oligo-Aquitanian)

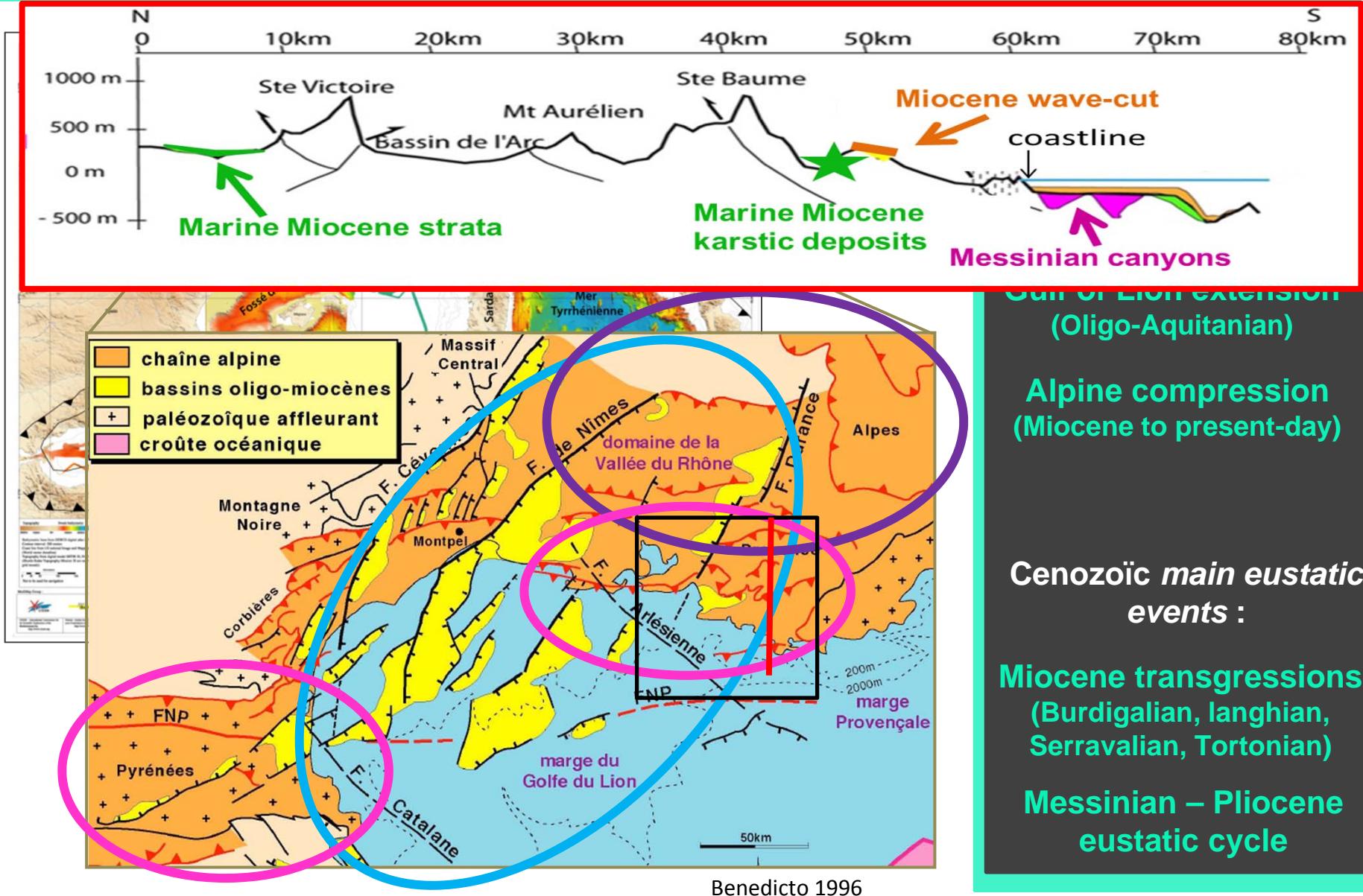
Alpine compression
(Miocene to present-day)

Cenozoïc main eustatic events :

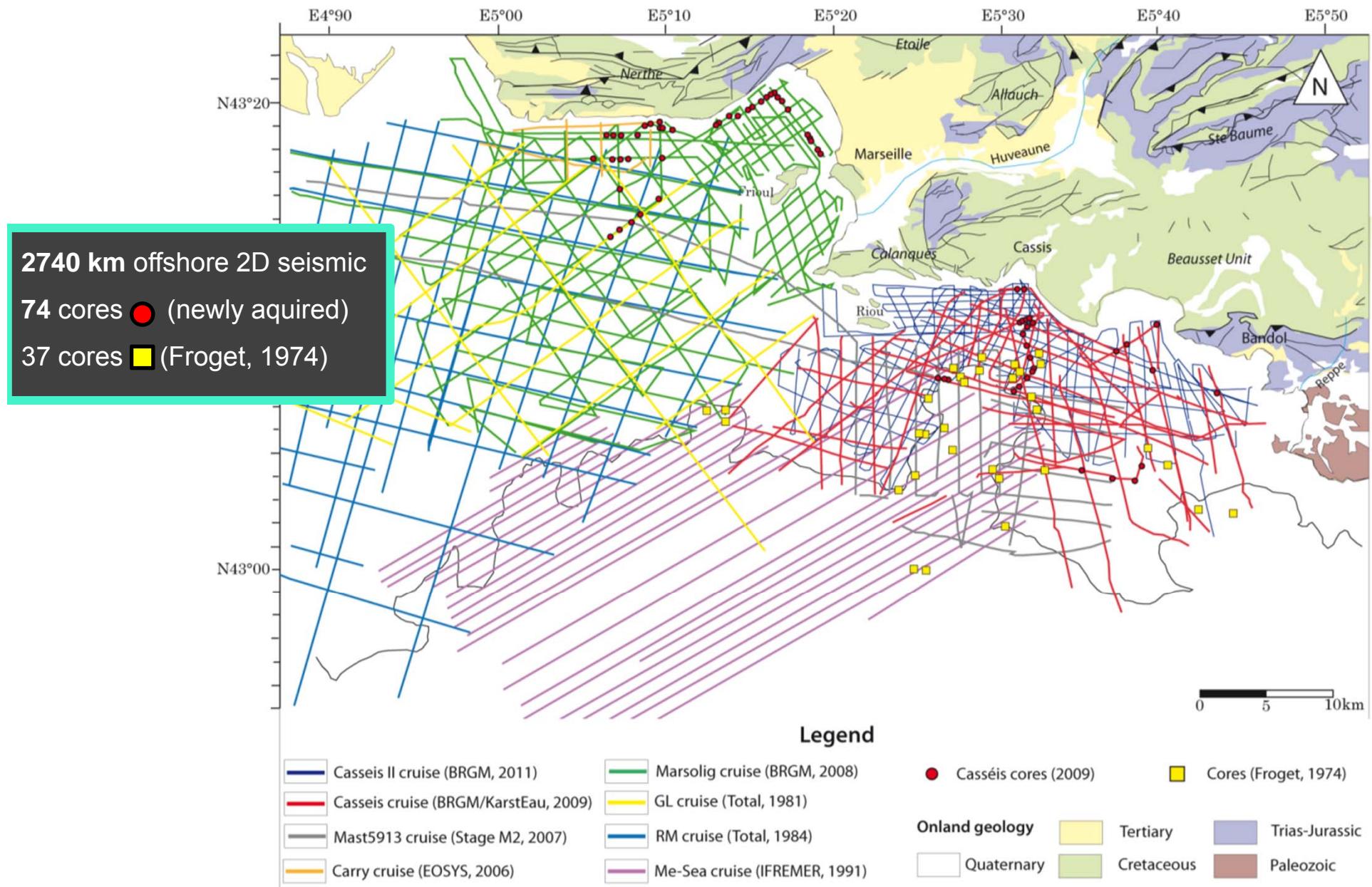
Miocene transgressions
(Burdigalian, langhian, Serravalian, Tortonian)

Messinian – Pliocene eustatic cycle

Cenozoic geodynamical context

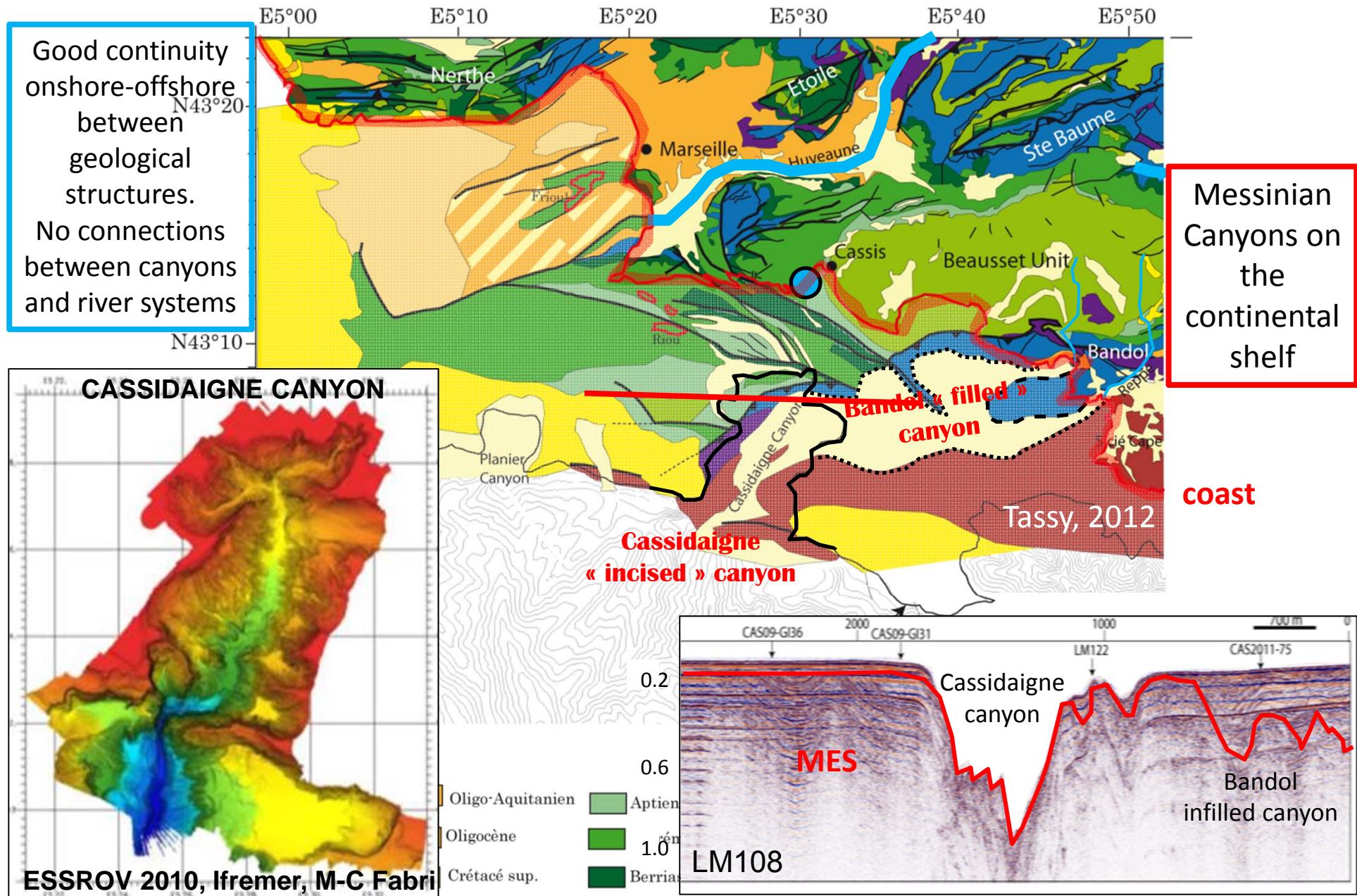


Seismic and cores database of the Provence shelf



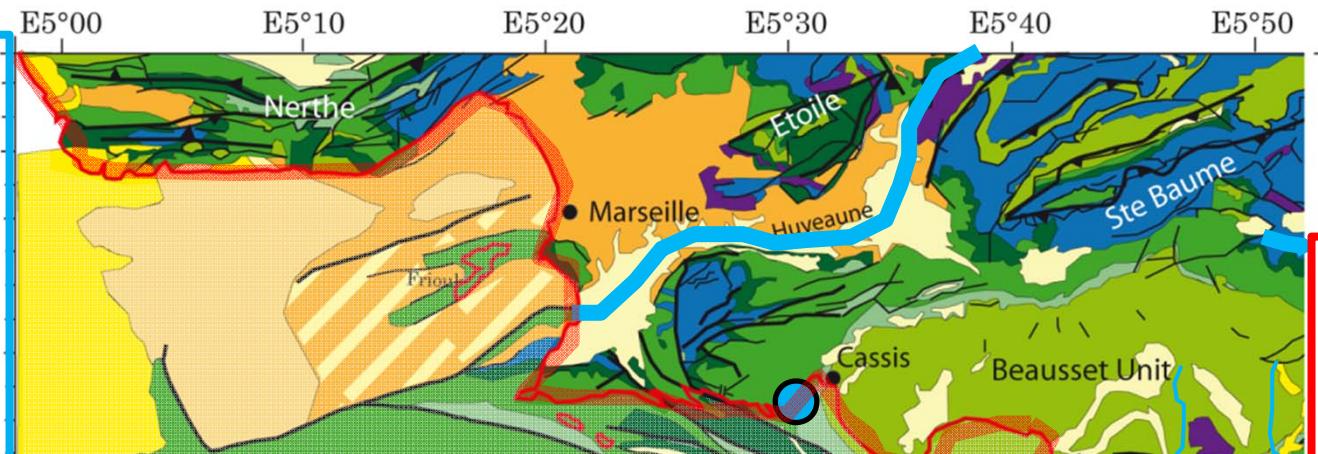
Onshore-offshore geological framework

Good continuity
onshore-offshore
between
geological
structures.
No connections
between canyons
and river systems



Onshore-offshore geological framework

Good continuity onshore-offshore between geological structures.
No connections between canyons and river systems



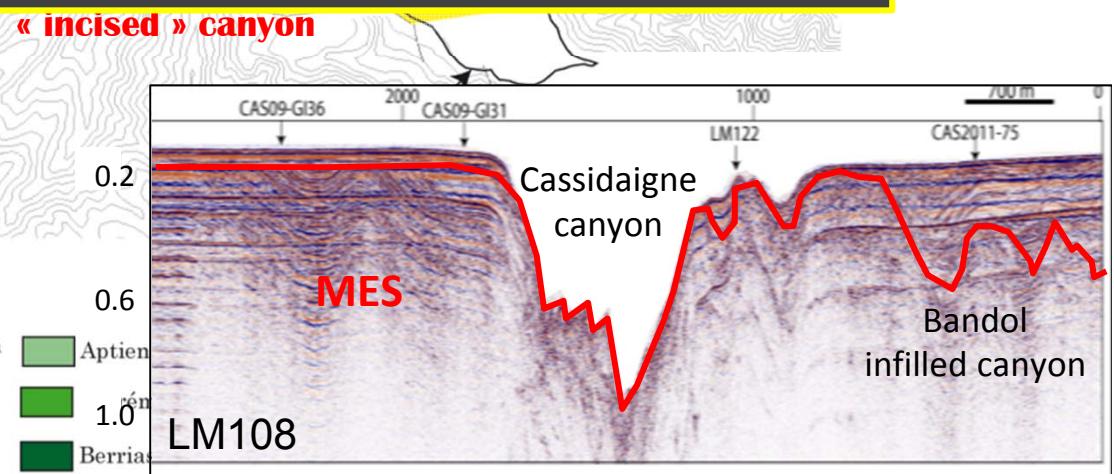
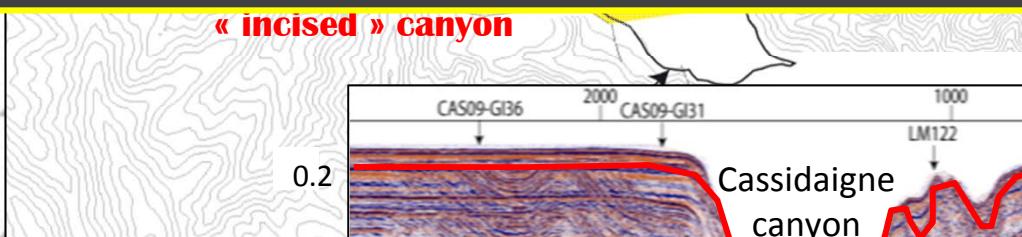
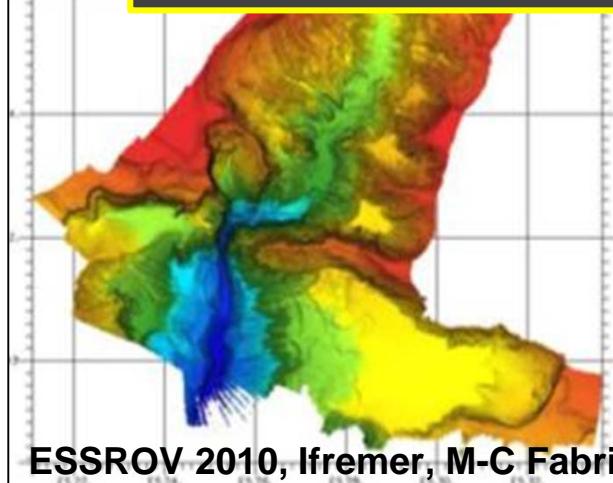
Messinian Canyons on the continental shelf

Key questions:

Quantification of tectonic and eustatic controls since the Miocene?

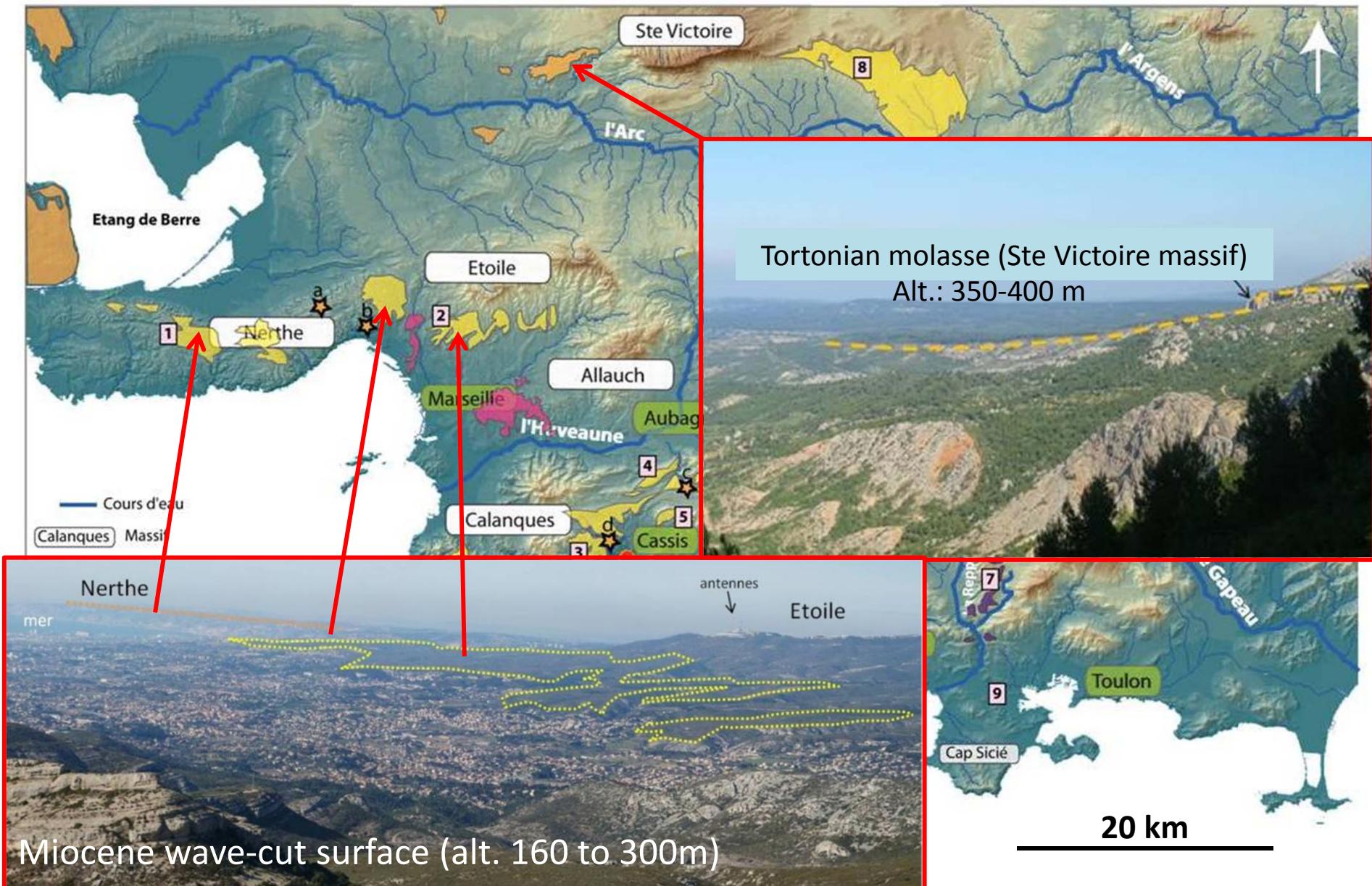
Only the Messinian crisis?

What are the relationships between hydrographic network and submarine canyons?



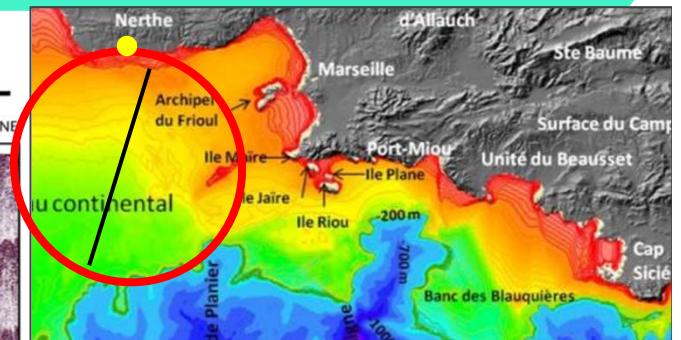
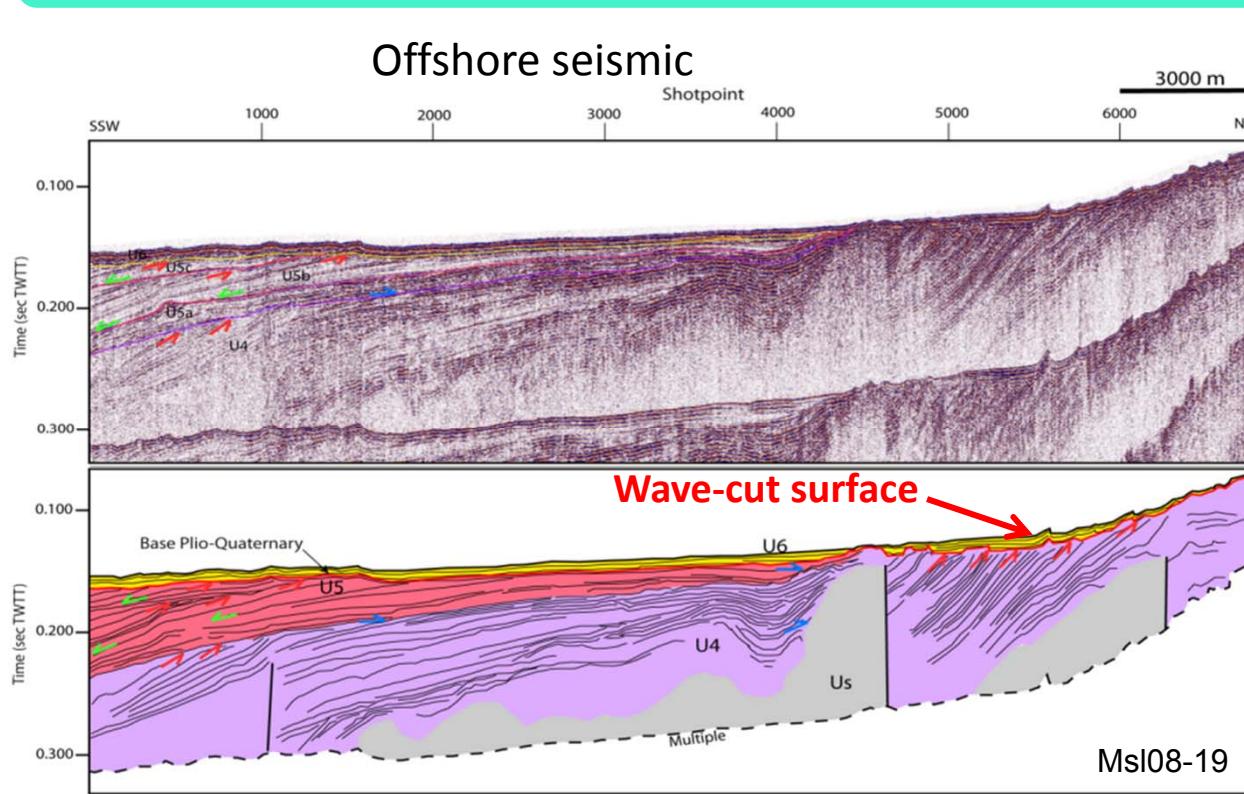
Onshore geomorphology

Uplifted Miocene marine transgressions (onshore)



Offshore-onshore stratigraphy

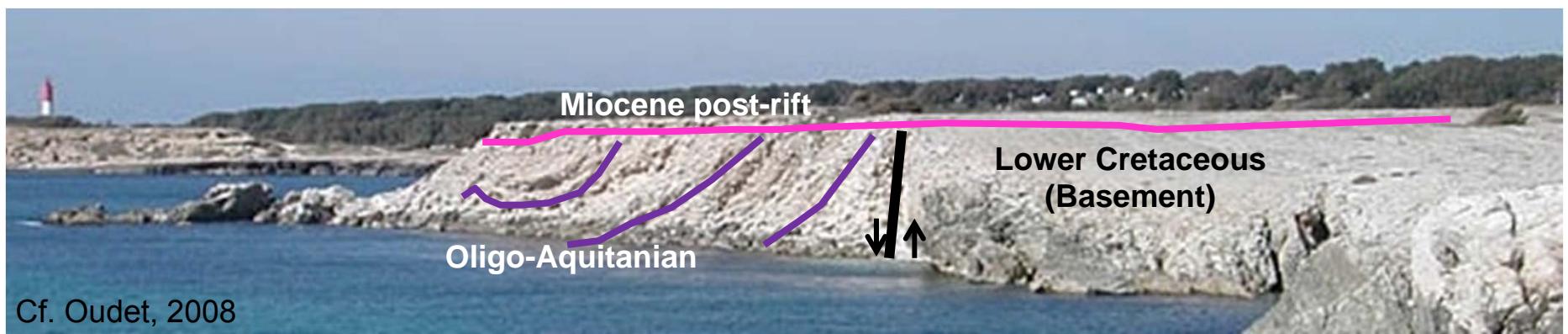
Miocene marine transgressions (offshore-onshore)



Nerthe area:

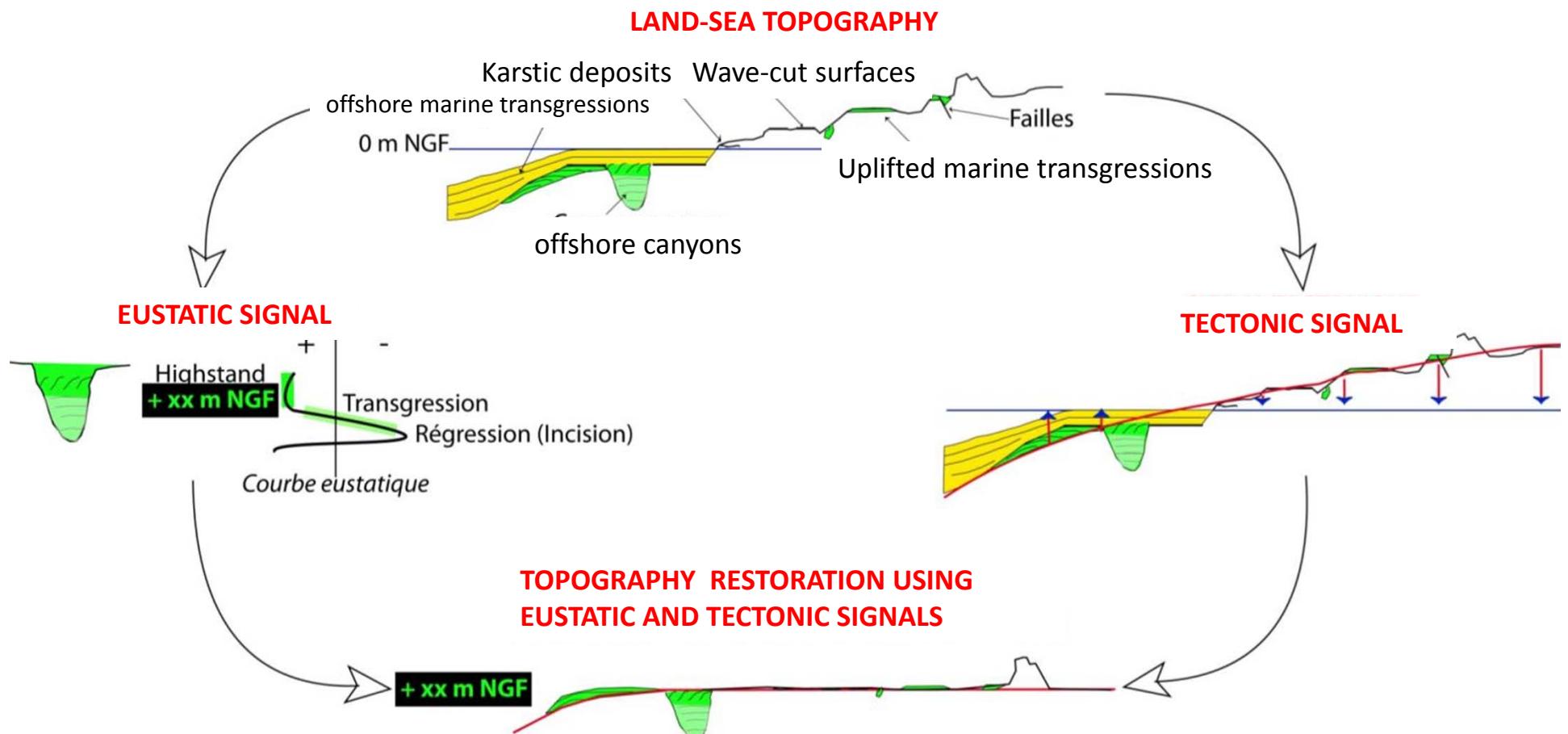
Tertiary transgressions onto Cretaceous limestones basement

Seismic reflectors are truncated by a planar surface (base Plio-Quaternary)



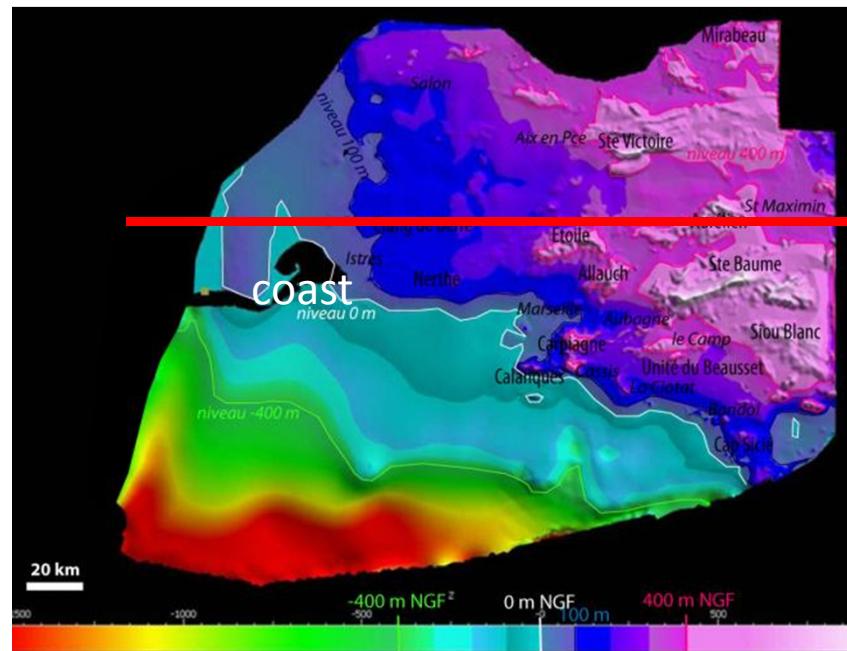
From sedimentary record to topographic variations

Topographic variations estimated by integrating geomorphology, sedimentology and structural geology.

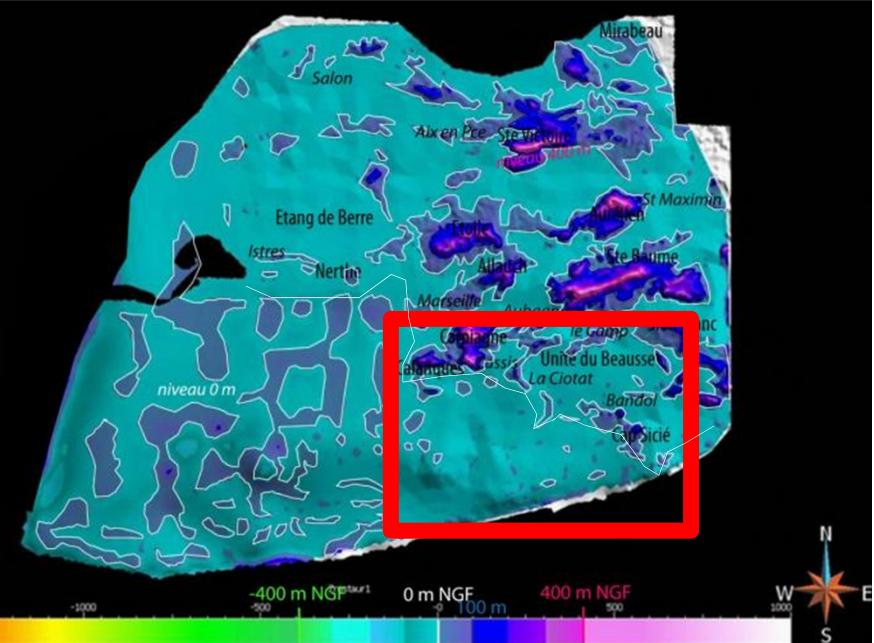


3D restorations of onshore-offshore paleo-topography

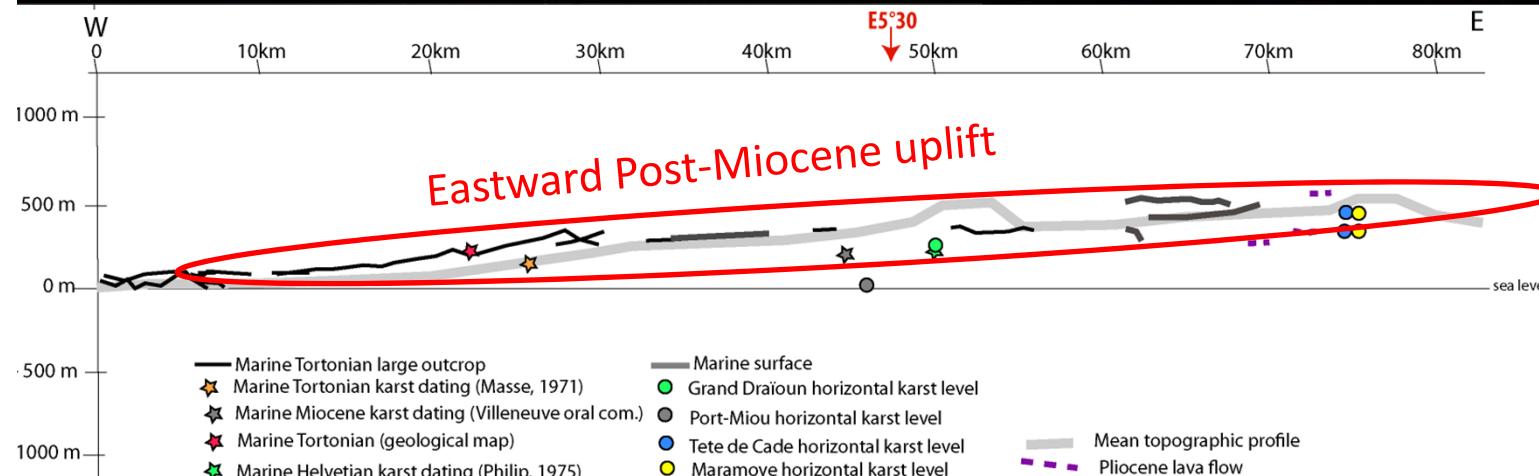
Smoothed present day surface



Tortonian surface
General transgression with highlands



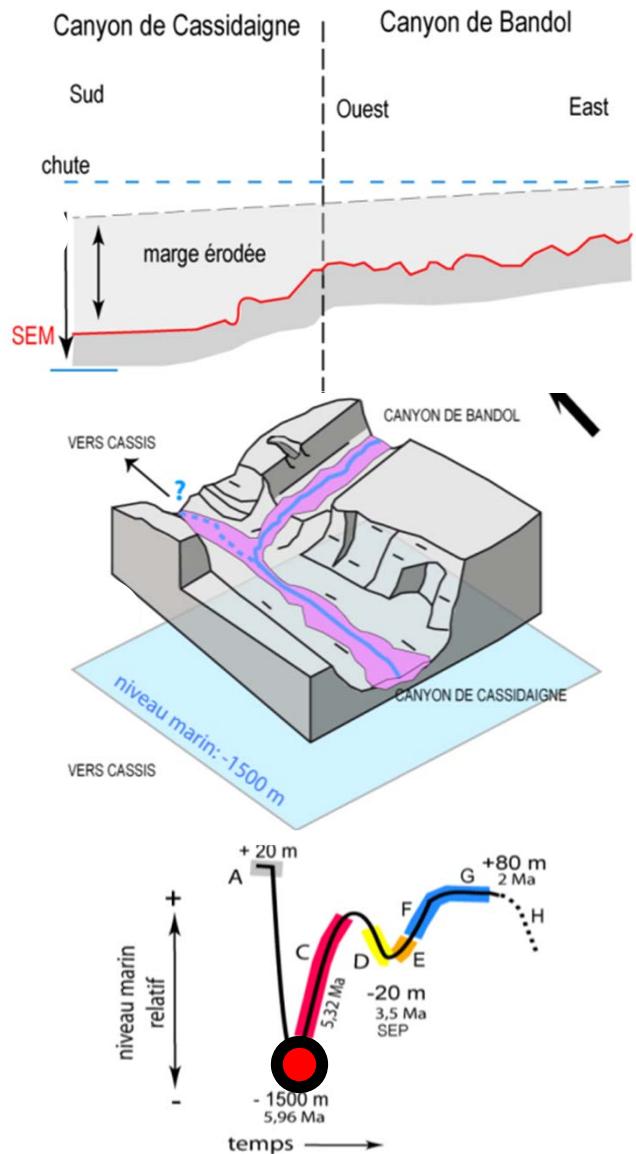
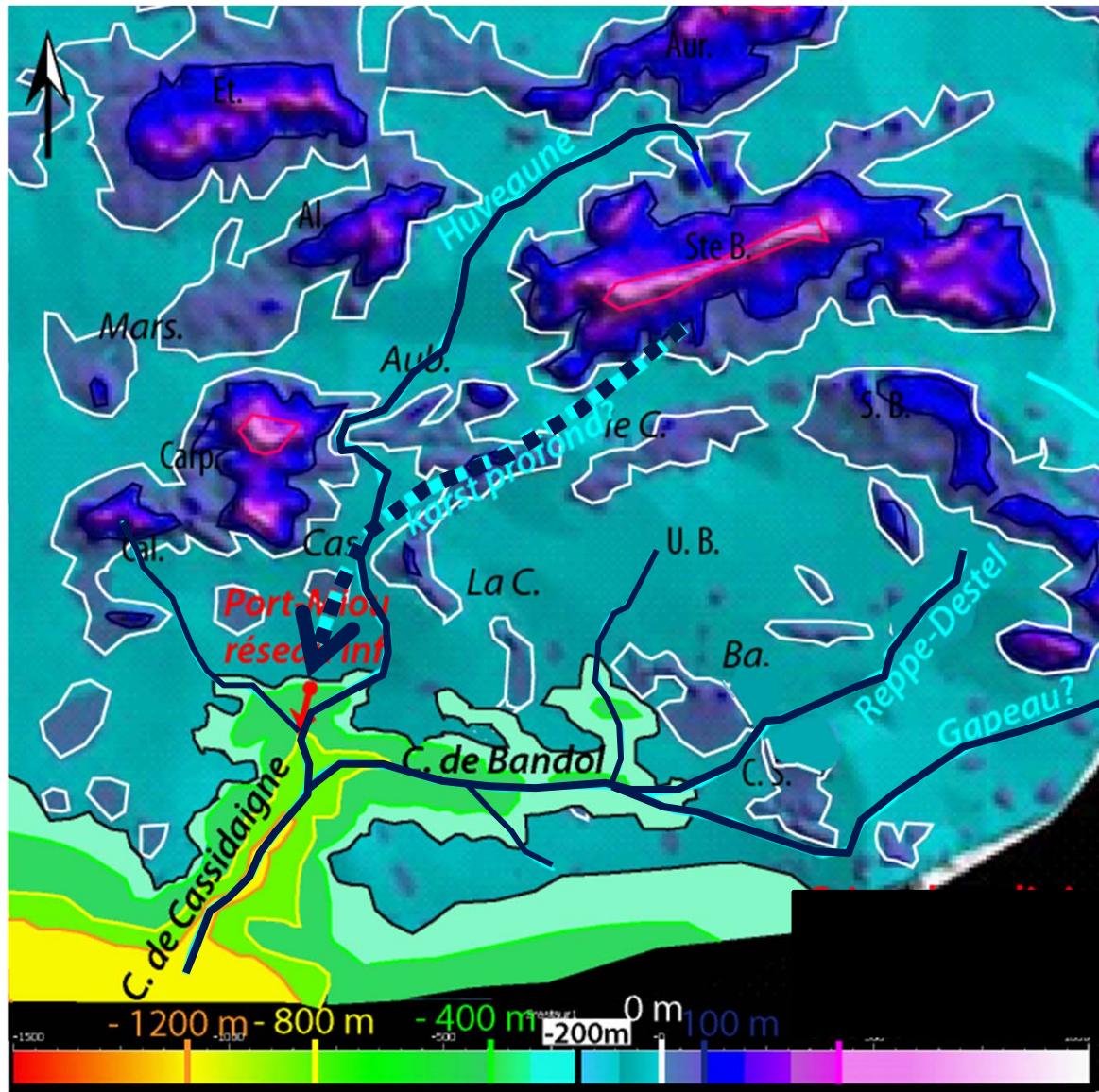
Eastward Post-Miocene uplift



**Stratigraphic and
geomorphologic
Miocene
markers of the
shelf projected
on a W-E axis**

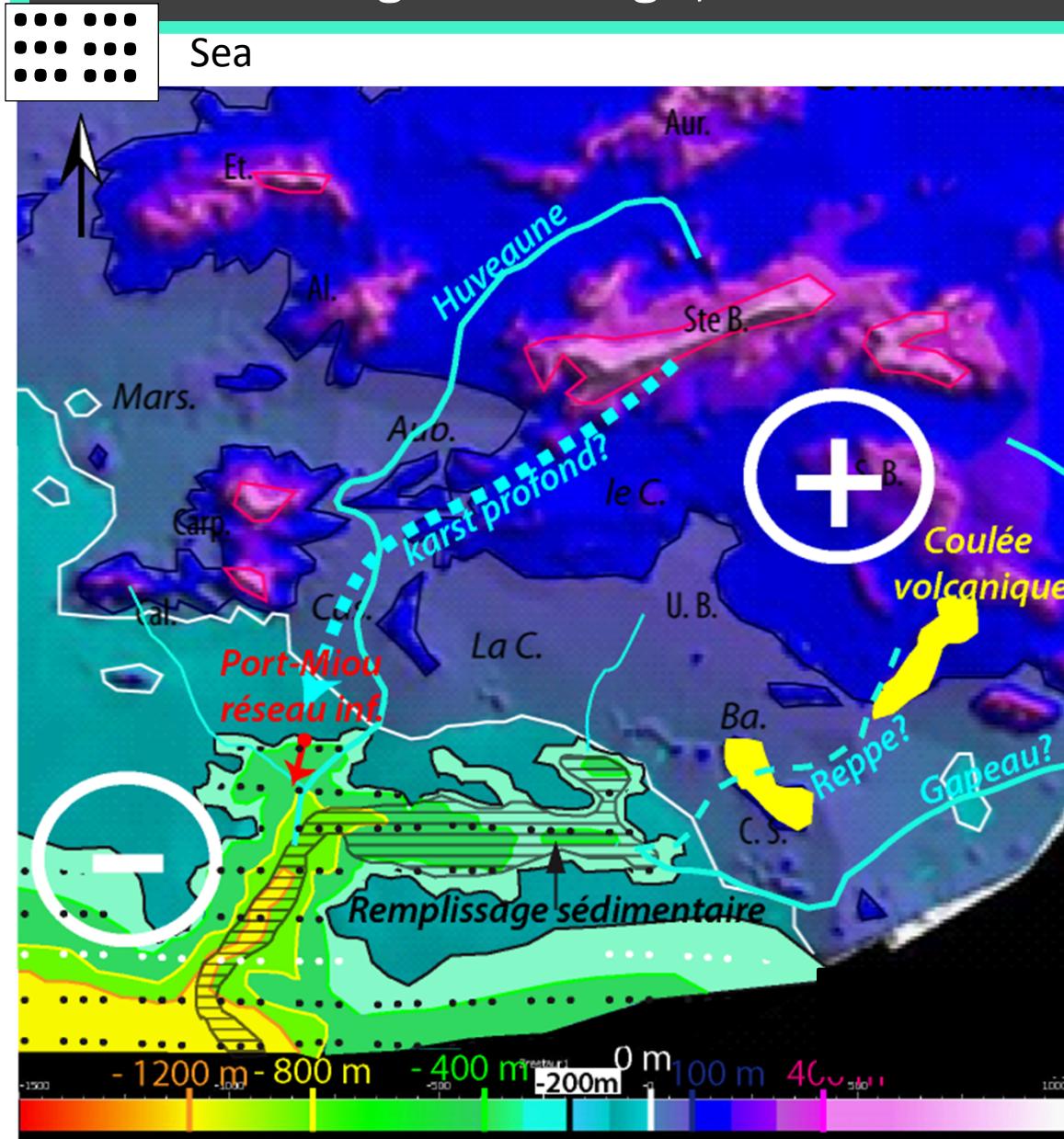
Messinian regression

Incision of Bandol and Cassidaigne canyons by paleo-rivers

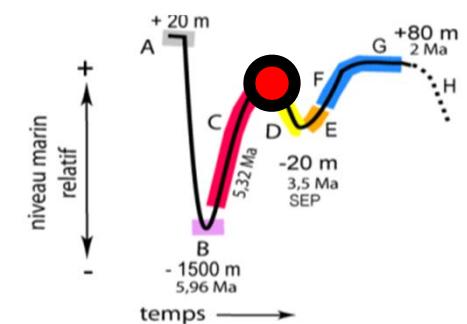
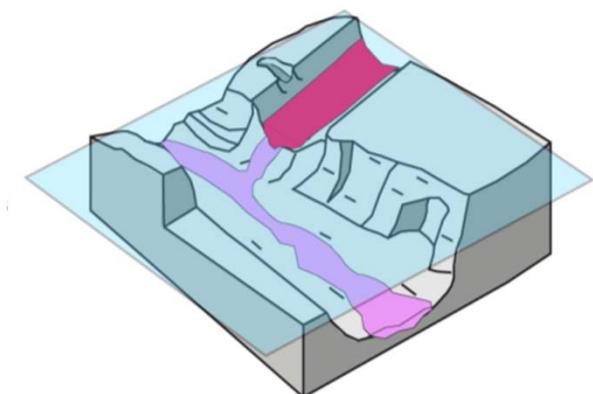


Lower Pliocene Highstand

Tilting of the margin, sedimentation in the Bandol canyon

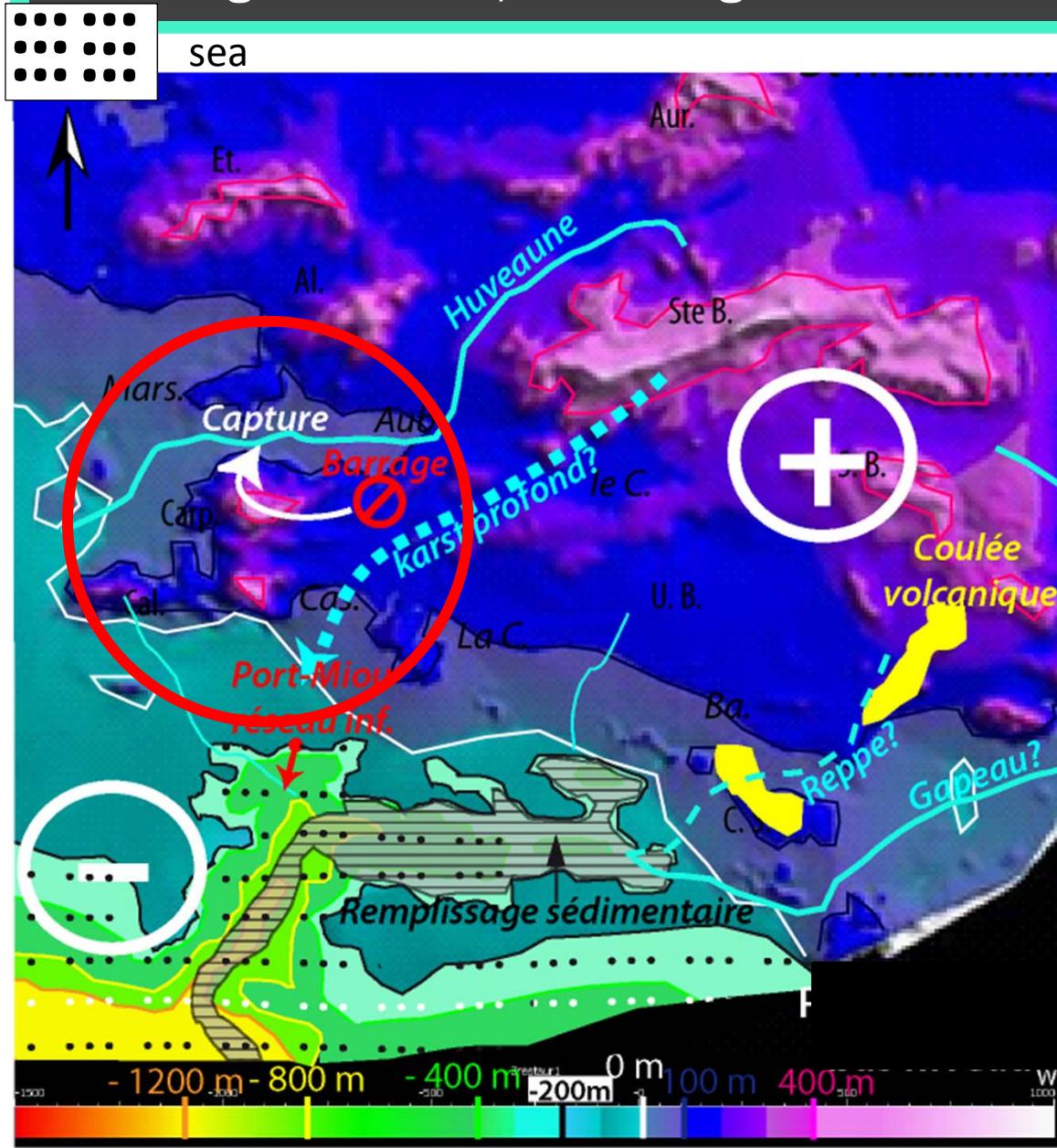


Good connection between rivers and canyons

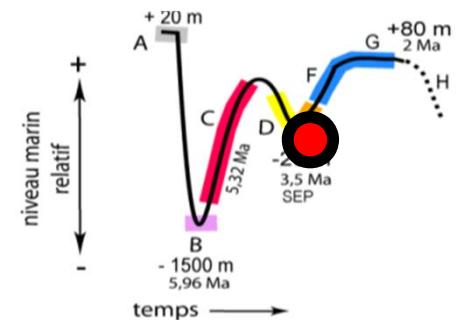
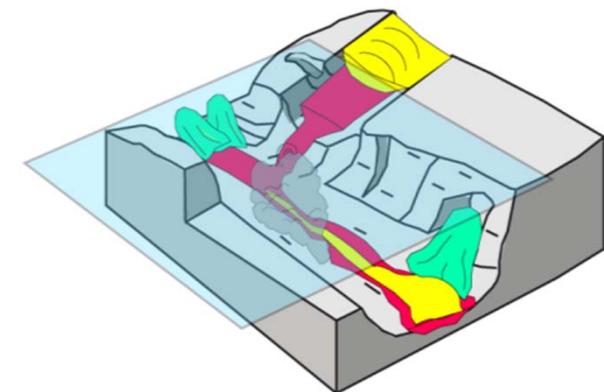
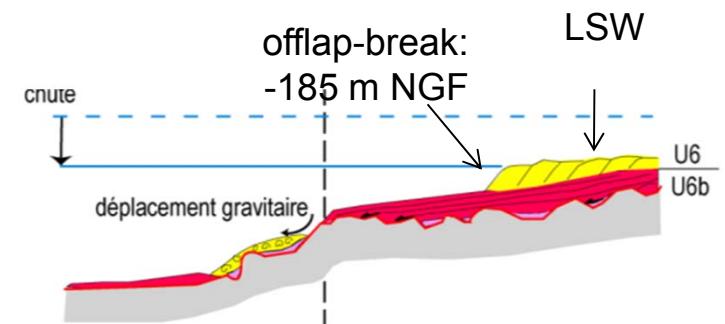


Mid Pliocene low stand.

Tilting of the shelf, Forced regression lowstand wedge in Bandol canyon

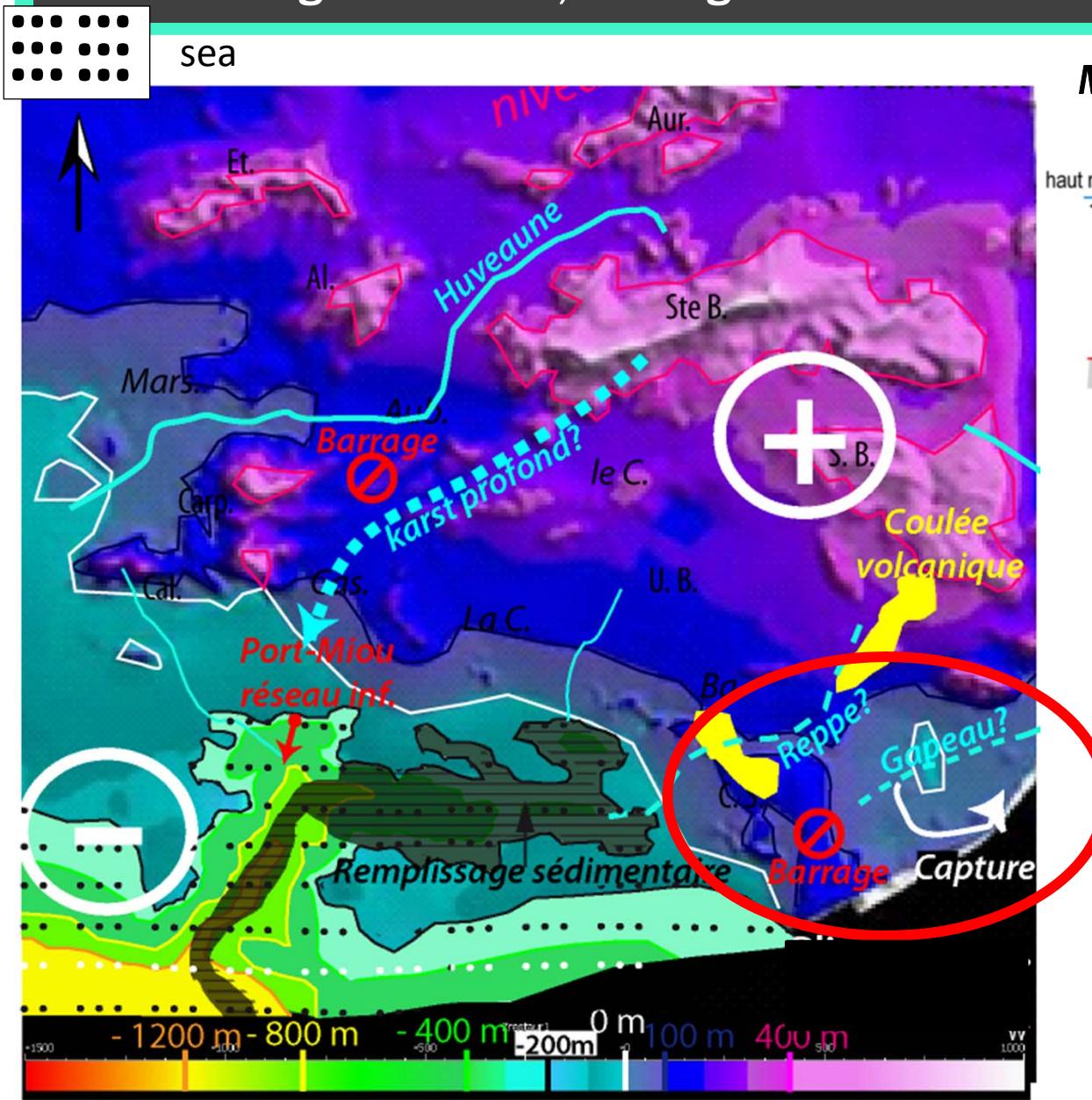


**165 m of subsidence
since 3.8 Ma**

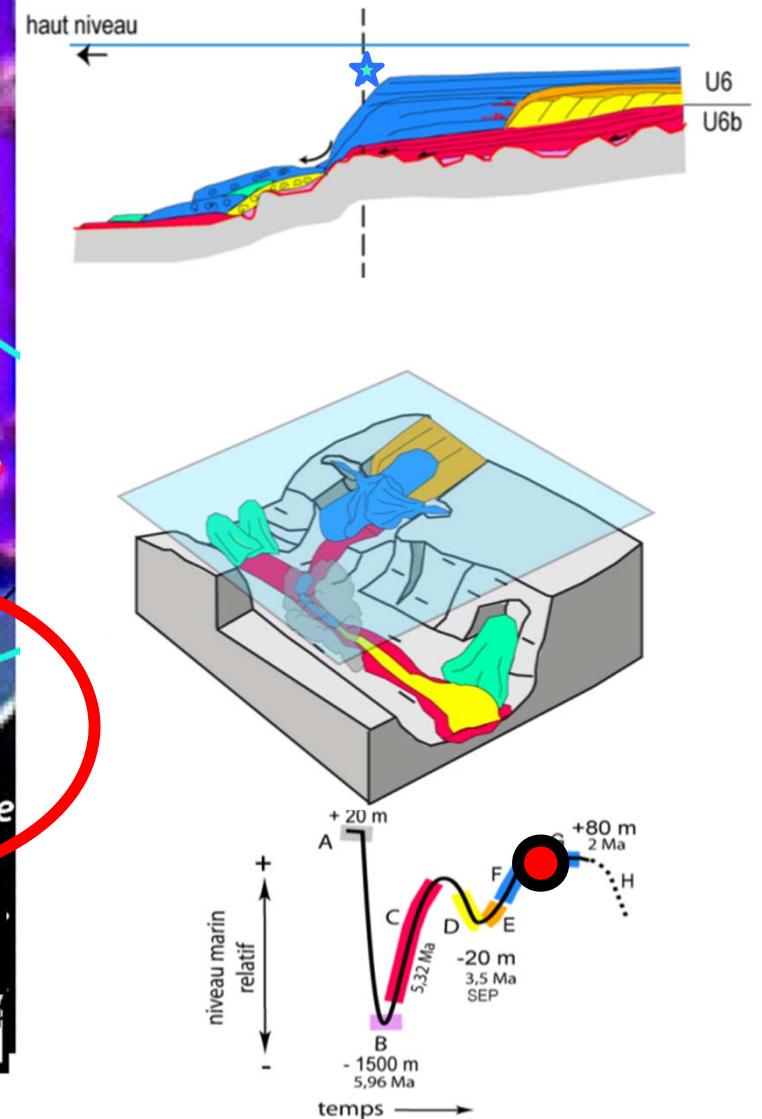


Upper Pliocene highstand

Tilting of the shelf, Infilling of the Bandol canyon by carbonates?

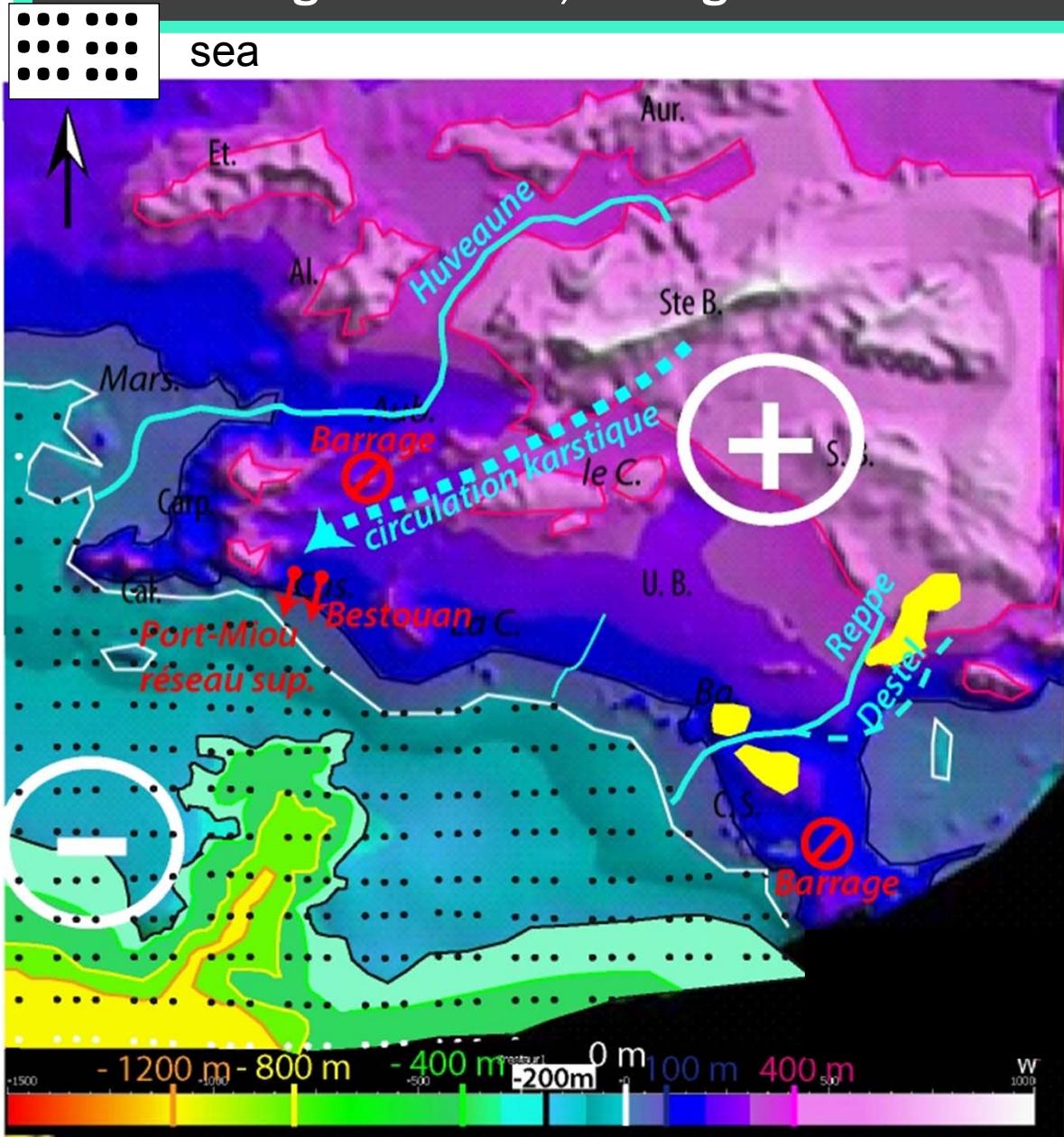


**Major change of river courses
not feeding the canyons**

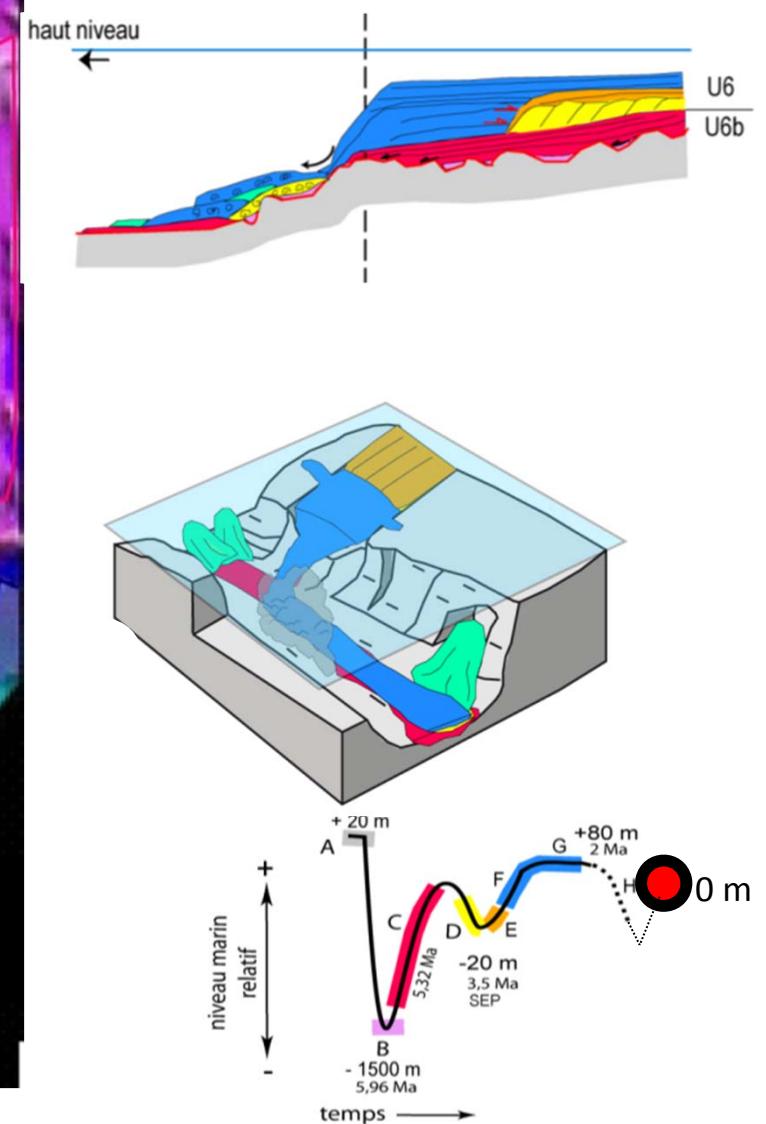


Quaternary highstand

Tilting of the shelf, transgression on the whole continental plate



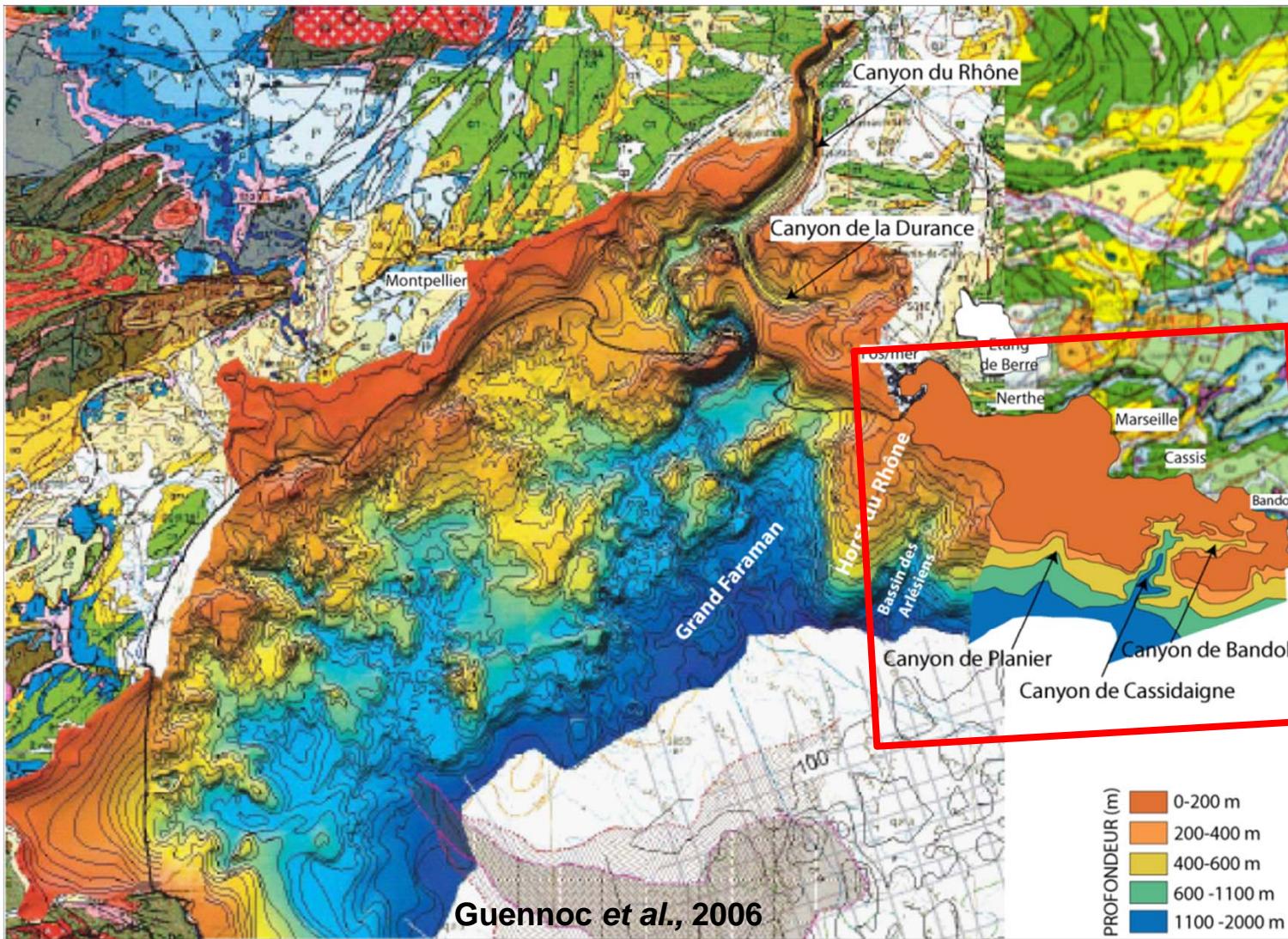
Setting of present-day coastline



Conclusion

Gulf of Lion Messinian erosion surface completed further east

Implication on sediment transfer south of Provence shelf ?

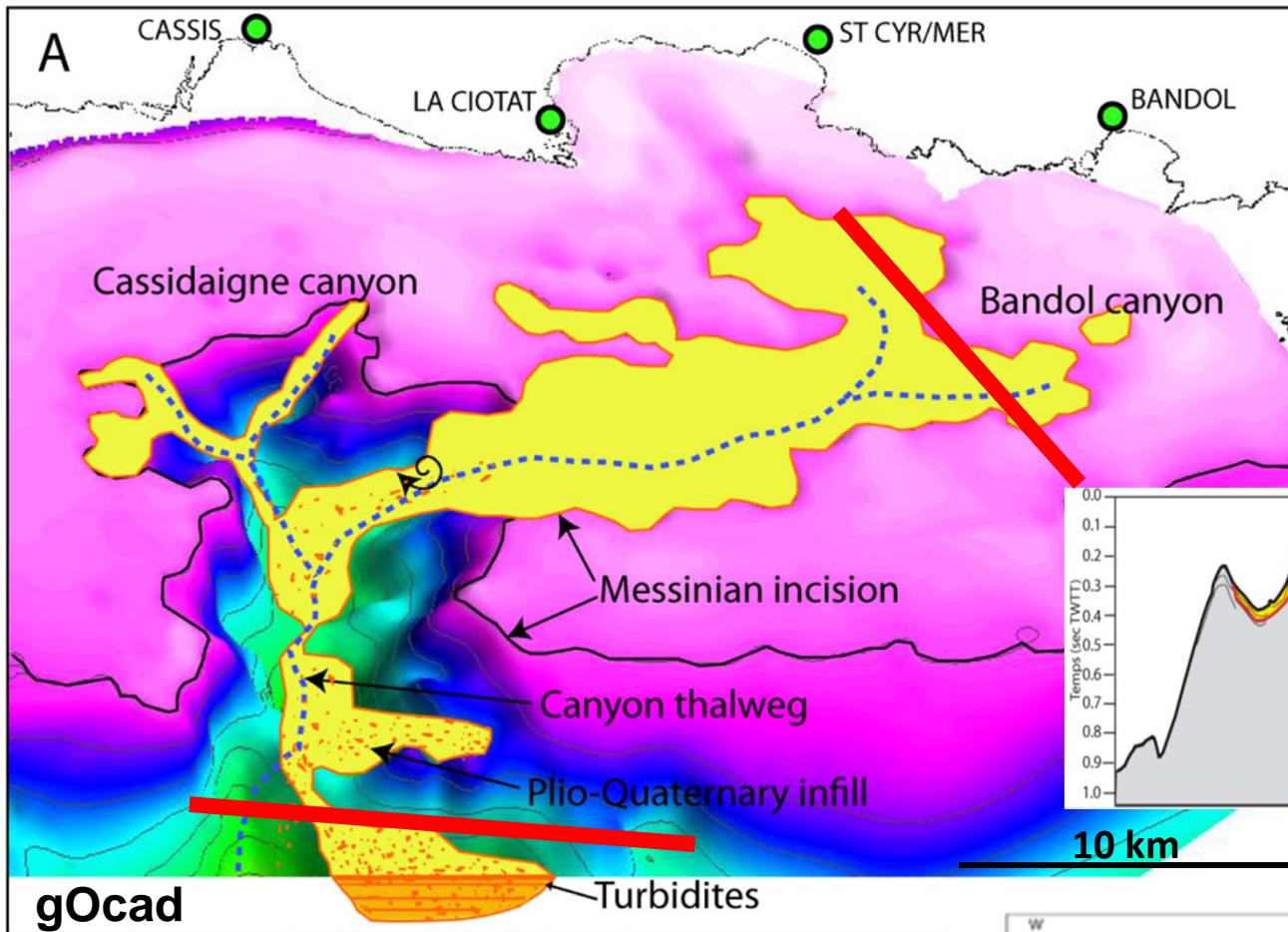


Discovery of
the E-W Bandol
Canyon.

Without post-
Tortonian
tilting, not
possible to
connect rivers
and canyons

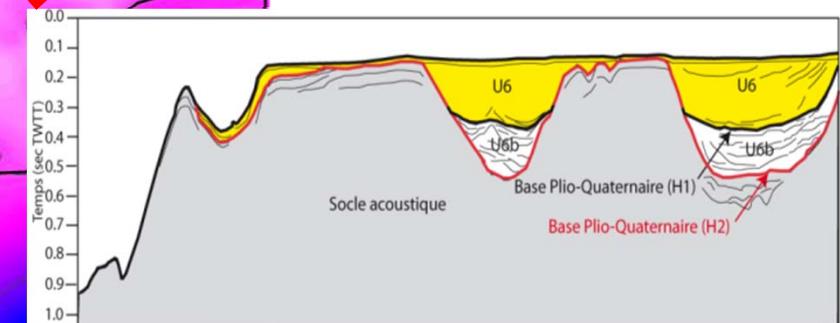
Conclusion

Sedimentary architecture of Bandol and Cassidaigne canyons

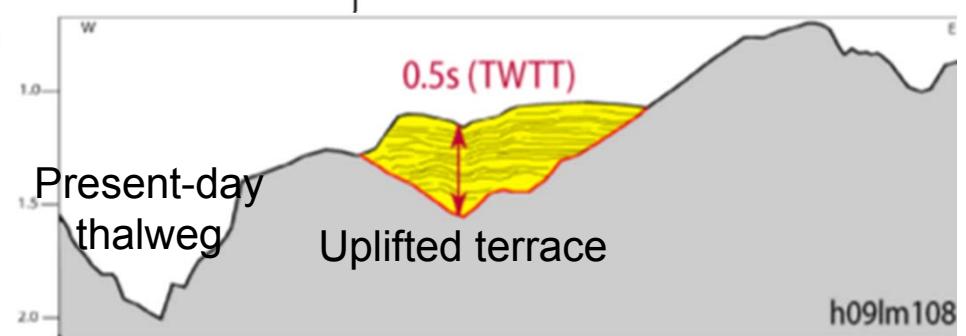


Cassidaigne and Bandol canyons no more associated with rivers.

Sediment transfer within the canyons mainly caused by gravity currents



Unfilled Cassidaigne Canyon (depth =1500m) VS sedimentary filled Bandol Canyon (depth=300 to 500m)



Conclusion

Tilting of the Provence Margin from Tortonian to Quaternary

- Plio-Quaternary tectonics from Apenines to Gulf of Lion (Ascione *et al.*, 2008; Ritz *et al.*, 1990, Clauzon, 1996...)
- Alpine orogenesis
- Dynamic topography: slab retract and mantle upwelling (Jolivet, 2008; Facenna *et al.*, 2001, 2010)
- Post-Messinian isostatic rebound (Norman et Chase 1986, Gargani *et al.*, 2004, 2010)

