EGU2020-19818 – Inversion tectonics during post-orogenic extensional collapse: a comparison between ancient (North Sea, UK) and recent (Fucino Basin, central Apennines Apennines) intermontane systems

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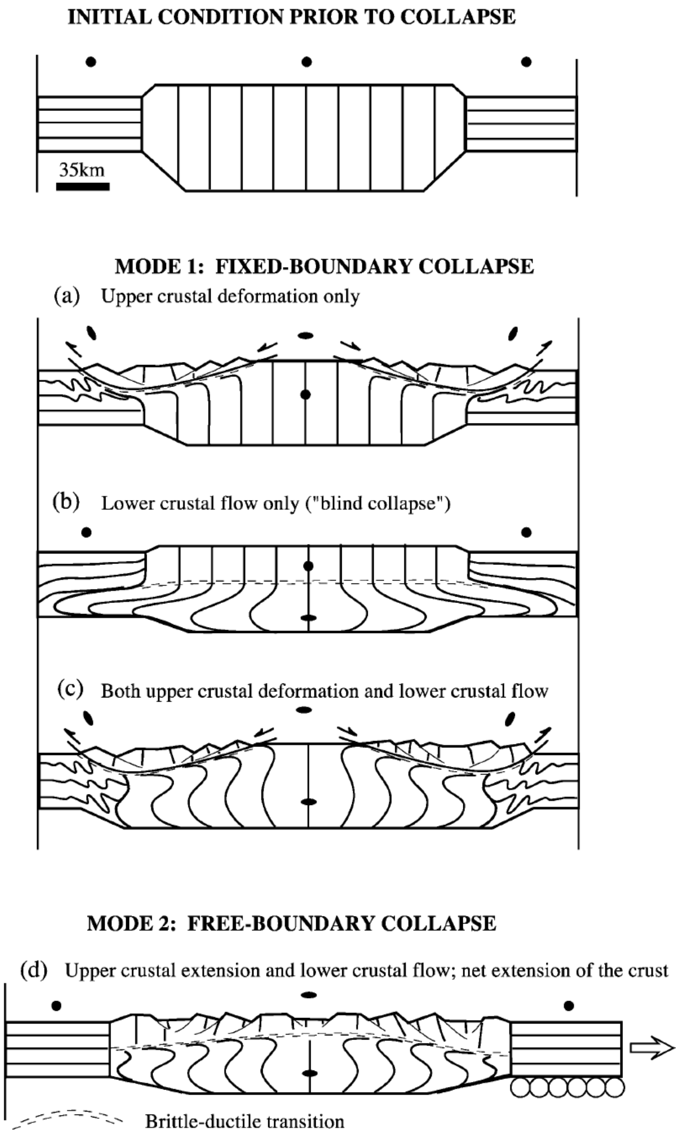
Introduction

STUDY AIMS

Study aims



From: Rey et al. (2001)

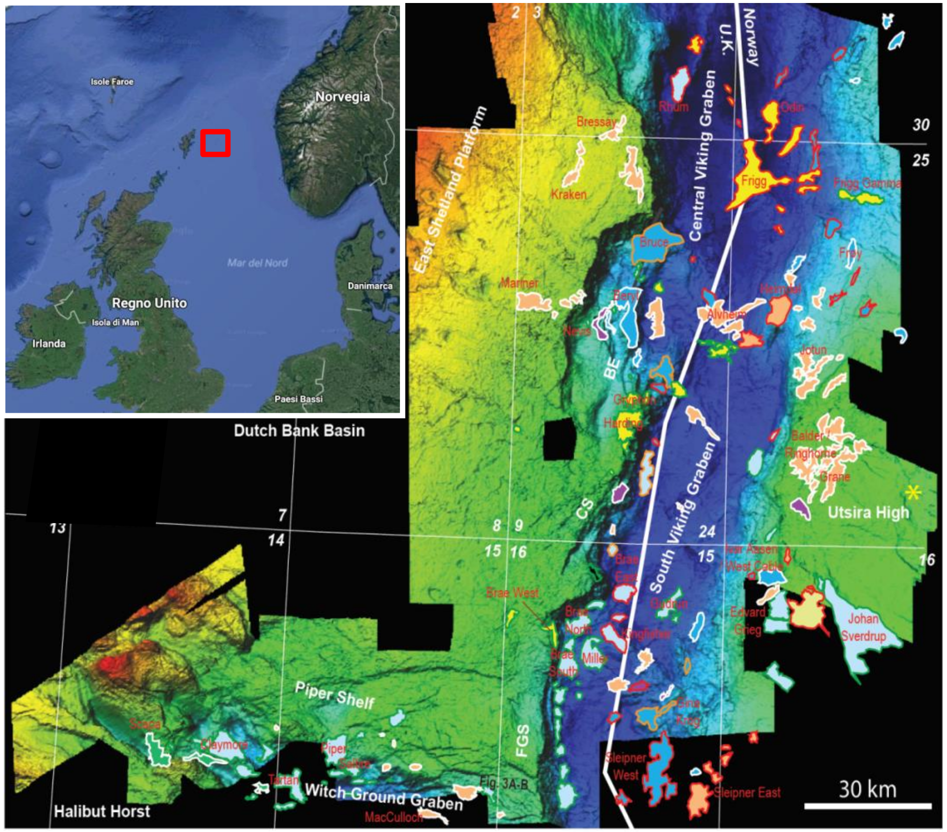
- **Post-orogenetic extensional/gravitational collapse events**
  - Very high tectonic subsidence, leading to the accumulation of very thick post-orogenetic sedimentary successions
  - Quick and effective dismantling of the thickened crust and topographic bulge of fold-and-thrust belt edifices

- Relatively poorly understood tectonic processes – different models
- They are linked to obvious natural resources and hazards:
  - Formation of **petroleum systems** in areas that were characterized by post-orogenetic collpase in the geological past – e.g., Northern North Sea
  - Active tectonic with **seismic hazards** in areas that are currently characterized by post-orogenic collapse with active extension – e.g., intra-mountain basins of the Central Apennines

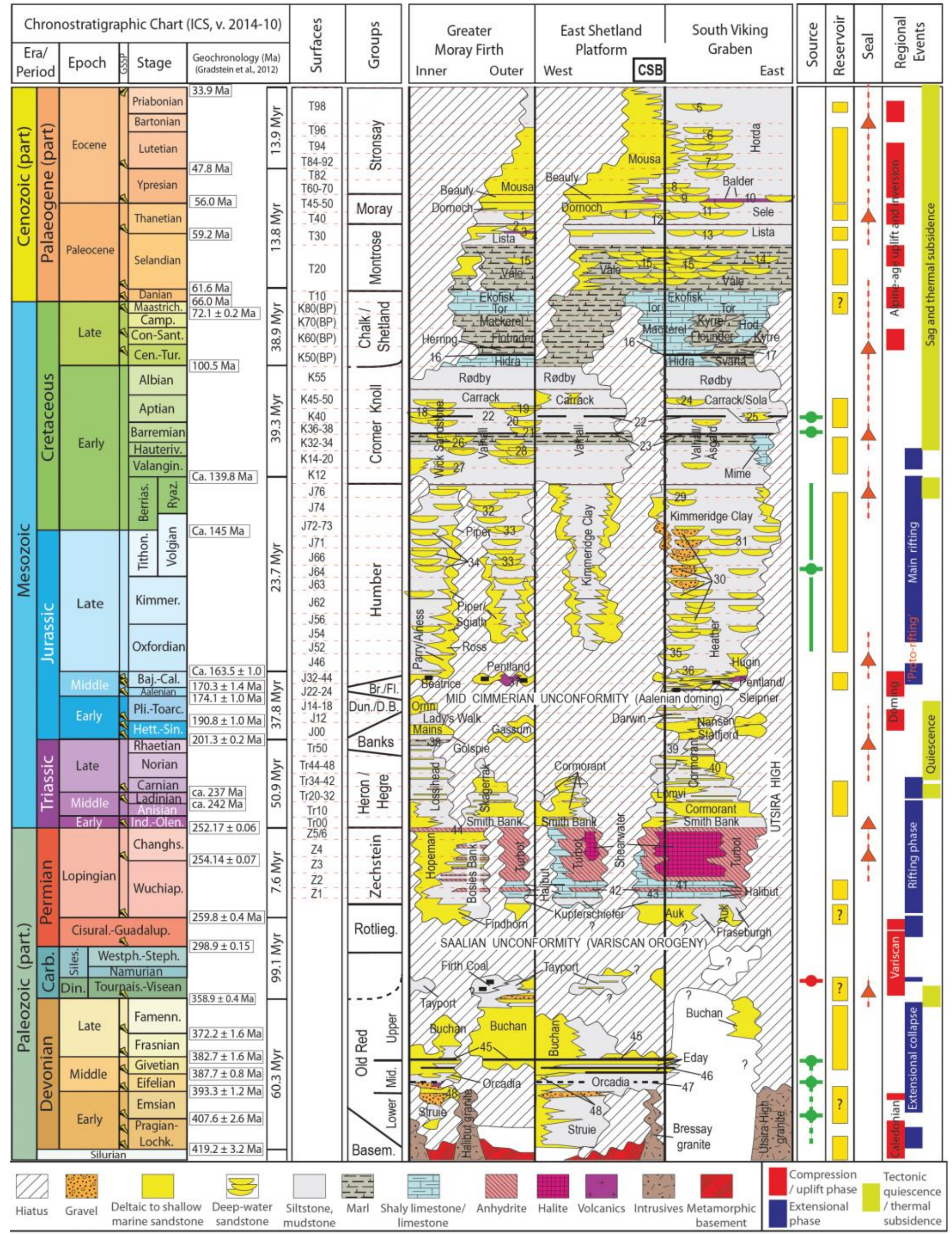
- Here, the major Pliocene-Quaternary basin of the central Apennines (Fucino) has been compared with the East Shetland Platform of the Northern North Sea
  - Well-based stratigraphic analysis
  - Seismic interpretation
  - Basin analysis
  - Literature review

GEOLOGICAL FRAMEWORK

Study areas: (1) Shetland Platform

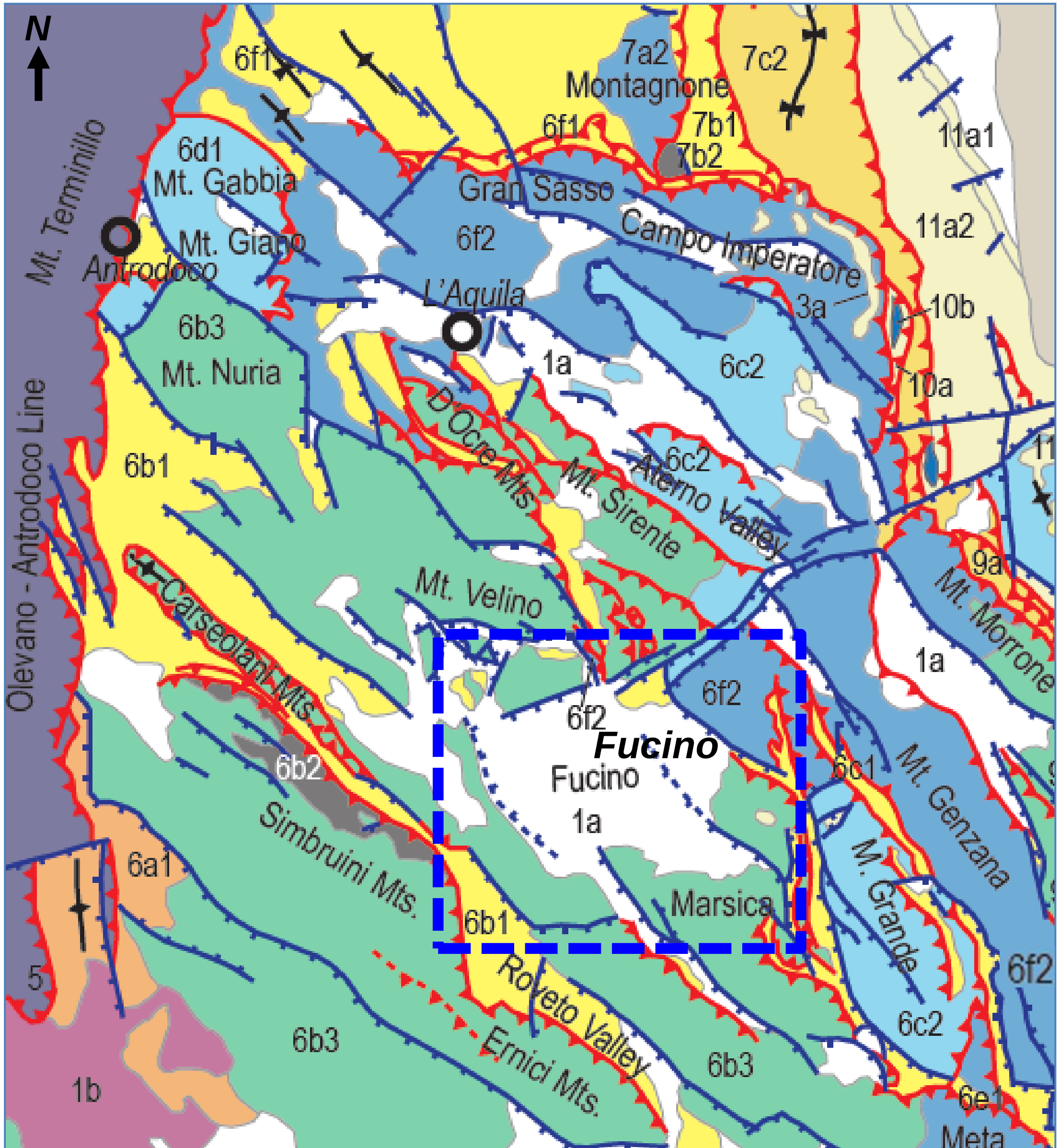


Structure map (Base Cretaceous). Modified after: Patruno & Reid (2016)



- Underexplored Mesozoic platform area
- Situated beyond the western flanks of the Viking Graben
- Characterized by a thick Devonian-age succession due to the collapse of the Caledonian Orogeny
  - Possible Devonian source- and reservoir rocks
- Repeated tectonic inversions and reactivations

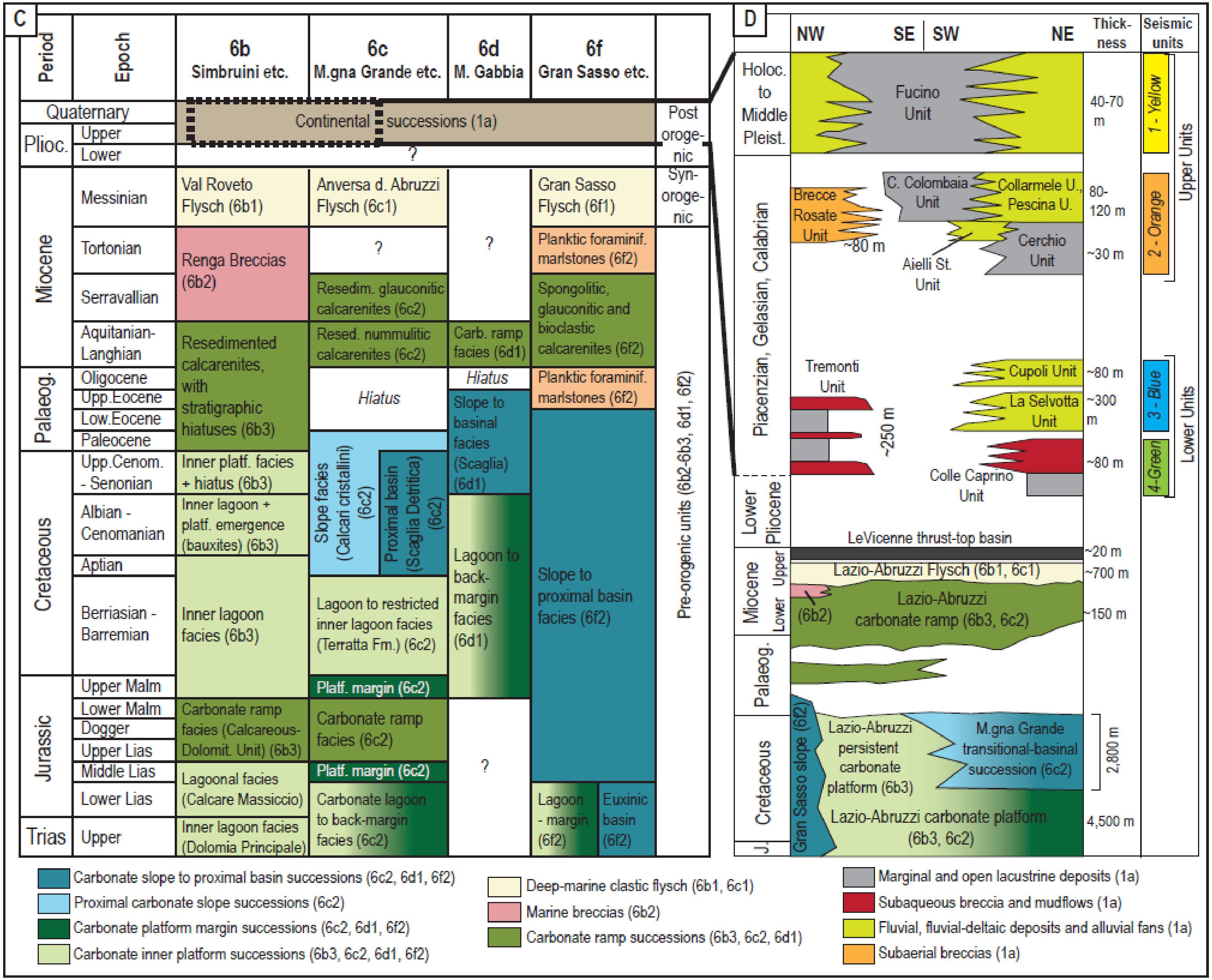
Study areas: (2) Central Apennines



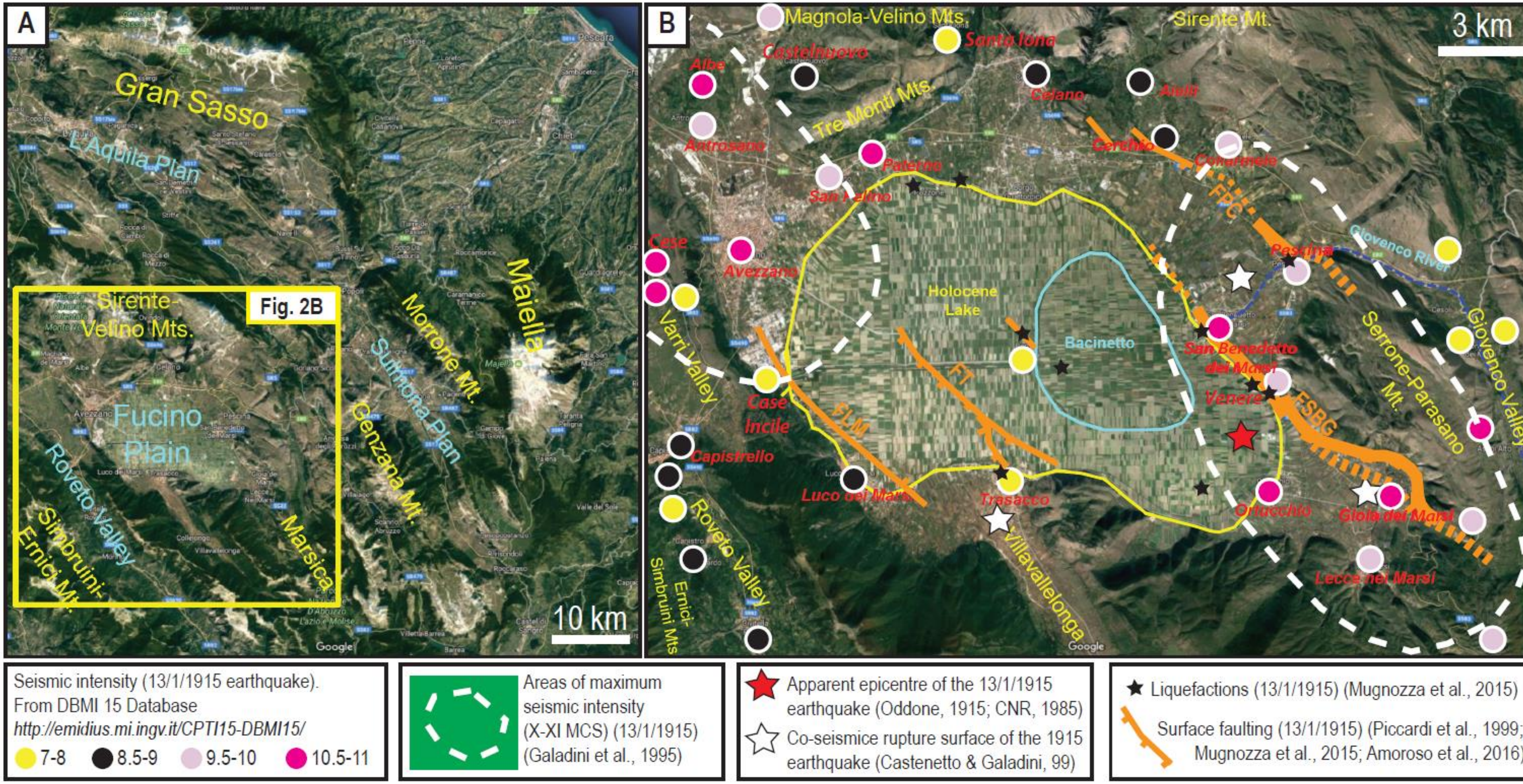
Structural-stratigraphic scheme (after Ghisetti & Vezzani, 1998)

Post-orogenic continental successions	1a) Continental Quaternary successions 1b) Potassic Pleistocenic volicanic rocks
Syn-orogenic marine successions	Siliciclastic Messinian flysch (6b1, 6c1, 6f1)
Pre-orogenic marine carbonate successions (Umbria-Marche domain)	5) Undifferentiated pelagic and hemipelagic units of the **Umbria-Marche-Sabian Basin** (Mid Jurassic – Miocene)
Pre-orogenic marine carbonate successions (Lazio-Abruzzi domain)	6f2) **Gran-Sasso Genzana Unit**: Carbonate platform (Trias-Lias) followe upward by Mid Lias – Eocene slope and proximal basin facies 6d1) **Monte Gabbia Unit**: lower Cretaceous carbonate platform., followed by slope and proximal basin facies (Cenom.-Eocene) 6c2) **Montagna Grande – Rocca Calascio Unit**: Triassic – Lower Cretaceous platforma & margin facies, followed by slope to proximal basin facies (Aptian-Paleocene) 6b3) **Simbruini-Ernici, Sirente-Velino-d'Ocre and western Marsica Unit**: persistent carbonate platform and ramp facies (Trias-Paleogene)

Study areas: (2) Central Apennines



The Fucino and the 1915 earthquake

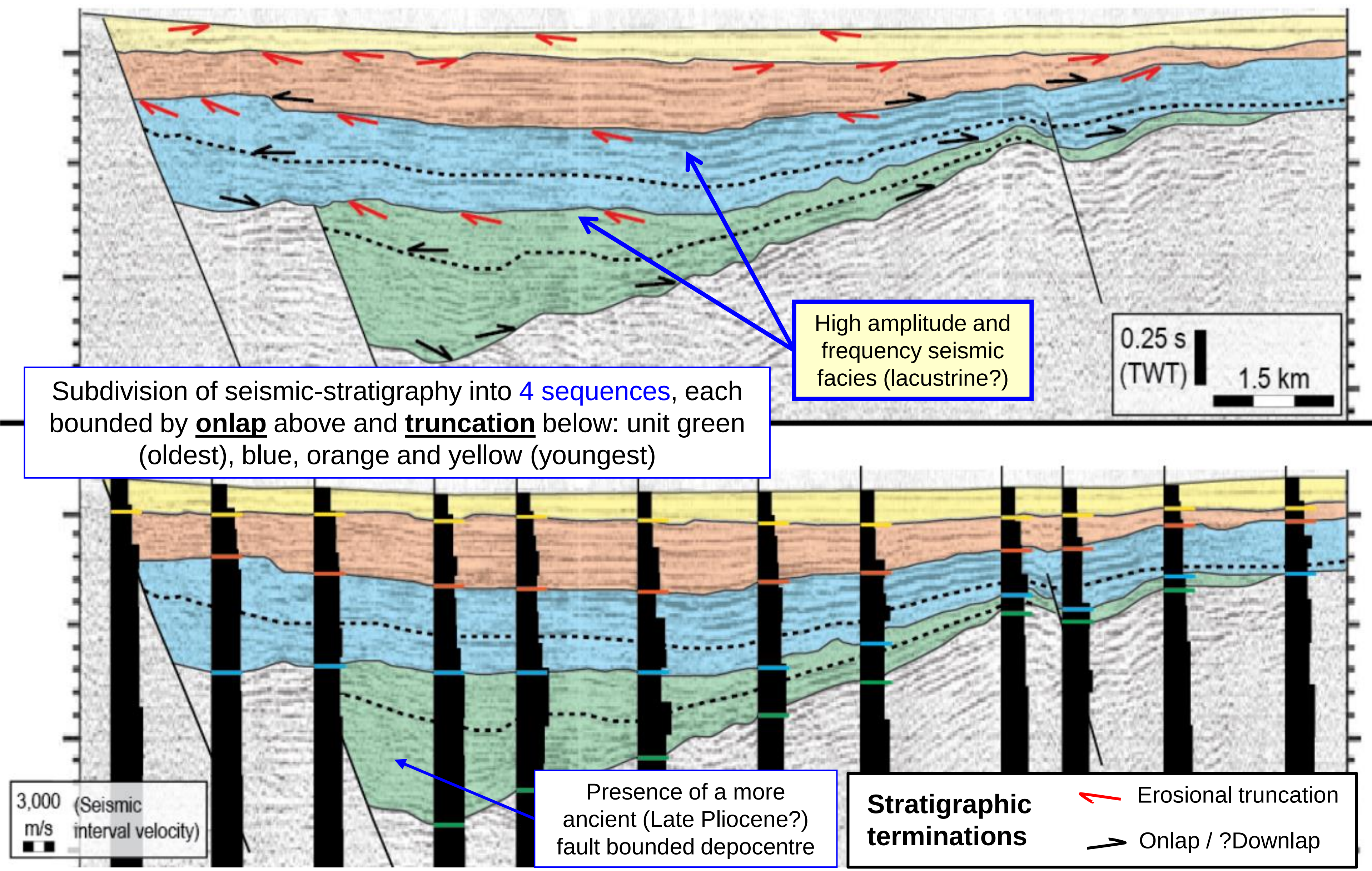


- The 1915 Avezzano earthquake reached a magnitude 7.0 and completely destroyed most of the nearby towns and villages, killing more than 30,000 people (Mugnozza et al., 2015; Oddone, 1915).
- Most traumatic damages along a NW-striking narrow belt between Magliano and Lecce dei Marsi (Mugnozza et al., 2015) and particularly concentrated in two areas: (1) to the north-west, the area between Avezzano and Magliano; and (2) to the south-east, the area between San Benedetto and Gioia dei Marsi

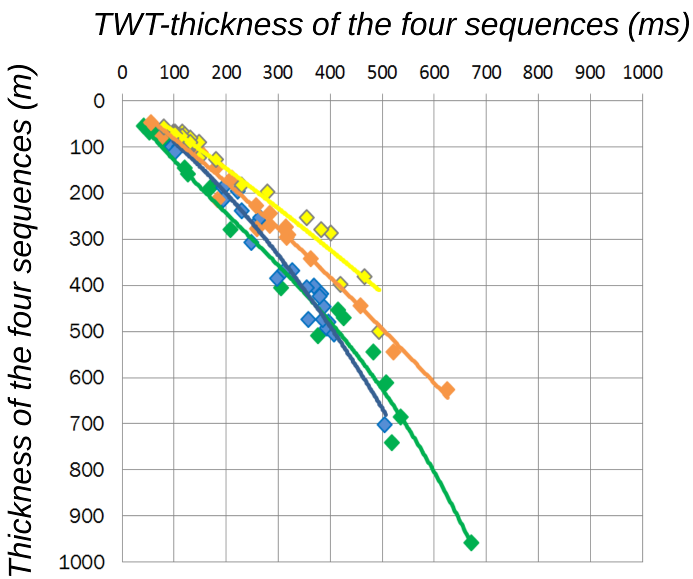
Introduction

SEISMIC INTERPRETATION

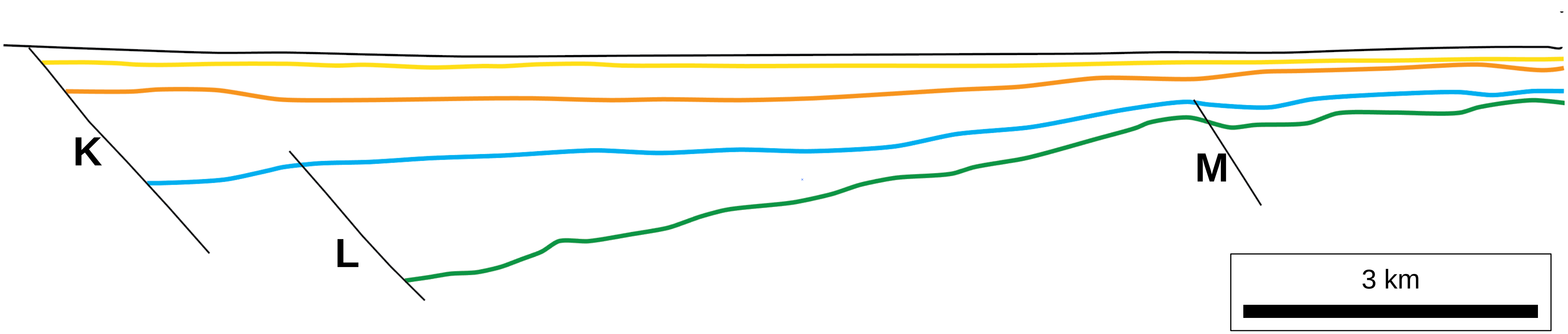
Main interpreted seismic line 1 and velocity profiles



Methodology: (2) mapping; (3) time to depth conversion

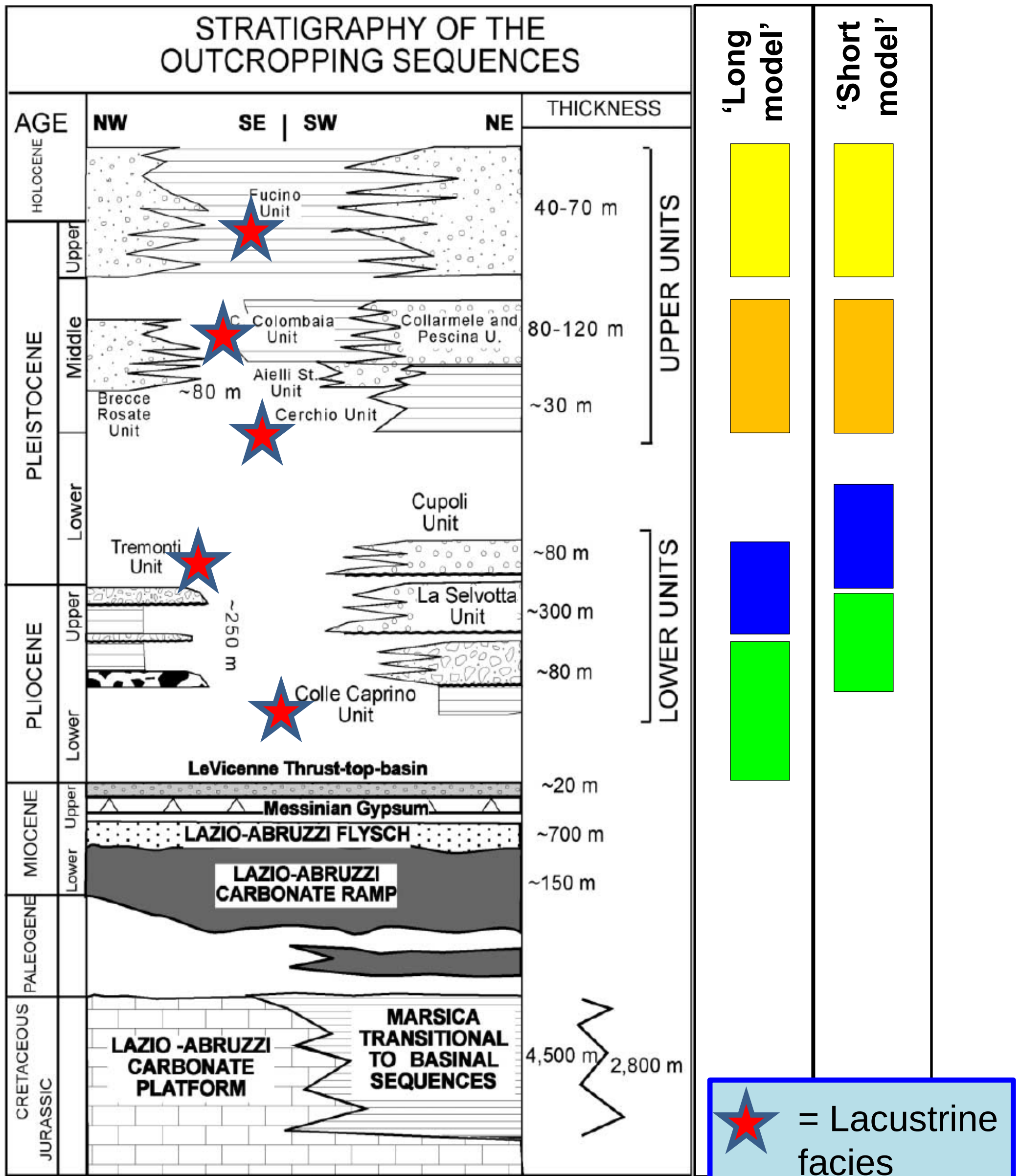


	TWT thickness (ms)	Yellow thickness (m)	Orange thickness (m)	Blue thickness (m)	Green thickness (m)
	100	66.8	84.6	89.5	129.2
	200	146.9	175.1	201.1	244.3
	300	233.0	271.7	334.6	357.5
	400	323.1	374.3	490.2	480.7
	500	416.4	482.9	667.7	625.9
	600		597.4	867.2	805.0
	700				1030.2
	800				1313.4
yellow (CDP 940, Line 80-AZ-3)	378	303.0			
orange (CDP 940, Line 80-AZ-3)	391		364.8		
blue (CDP 940, Line 80-AZ-3)	623			916.2	852.3

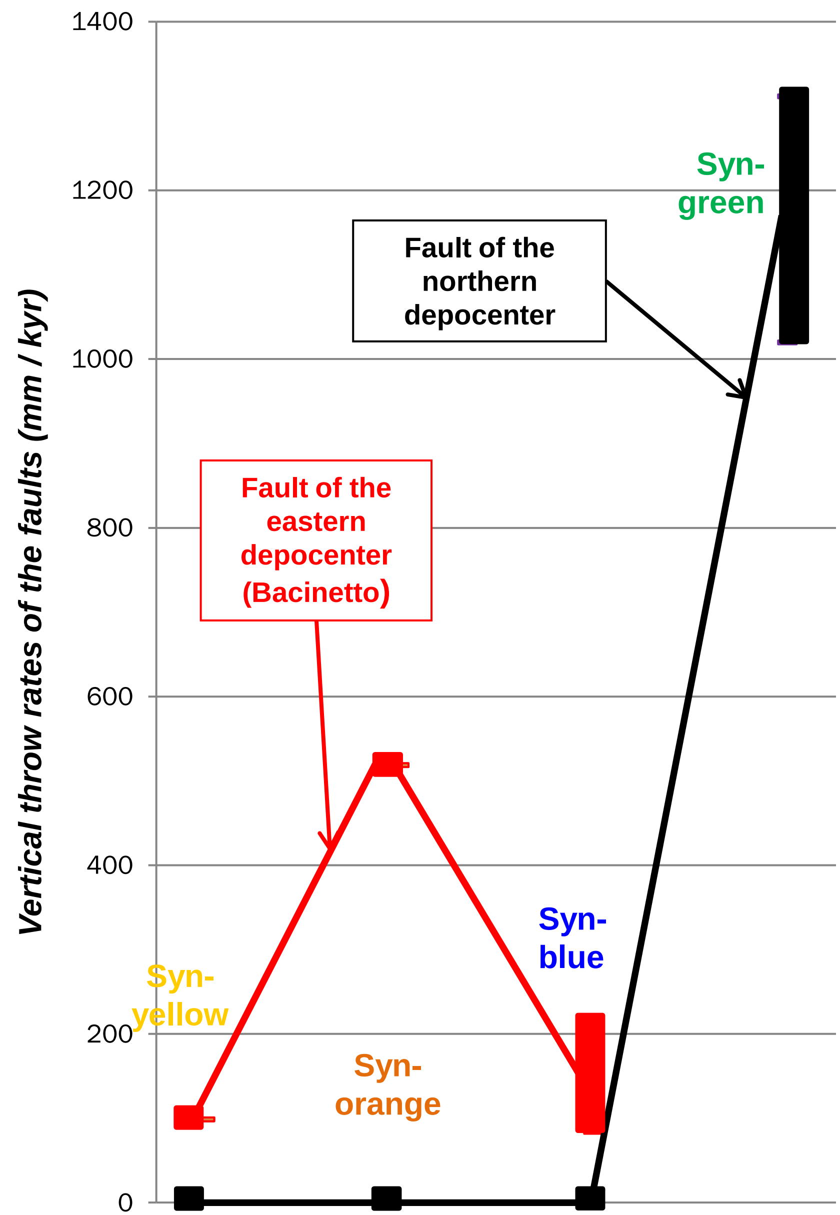


- 26 CDPs (in 2 lines) with Vrms measurements → Dix equation → Interval velocity calculation
- The four sequences have therefore been characterized in terms of statistic interval velocity
- At the same depth, mean Interval velocities are progressively higher for progressively older sequences
- Regression equations between thickness (in m) and TWT-thickness (isochrons) in ms have been obtained for each of the four sequences, with high coefficient of determination (R^2 > 96.8%).

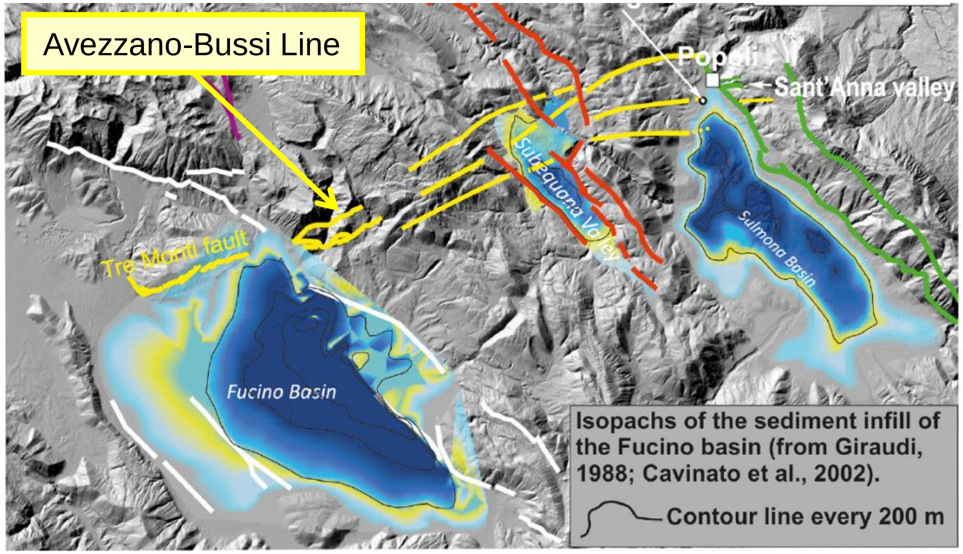
Chronostratigraphy and throw rates

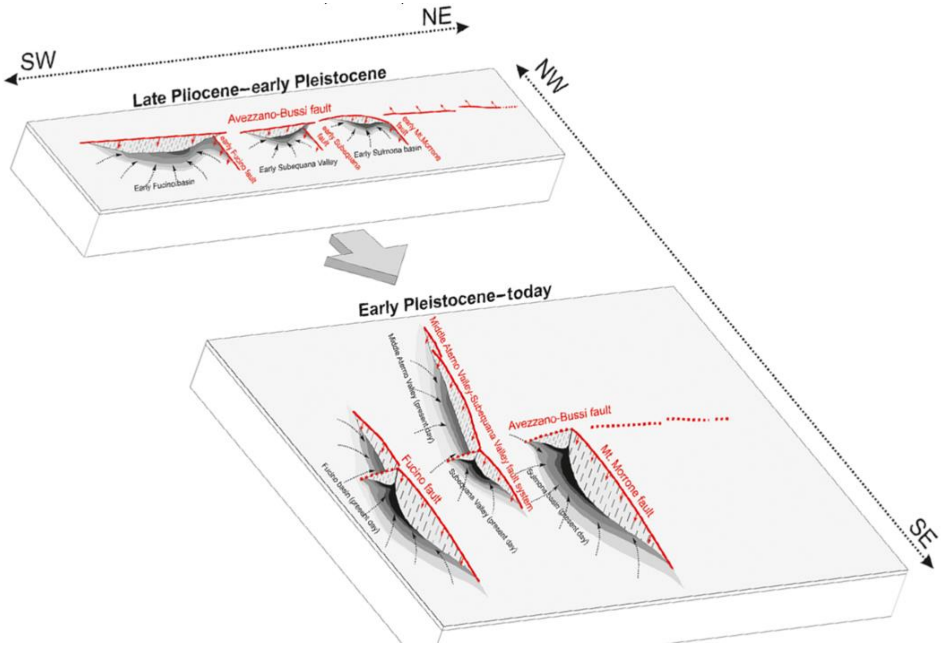


Stratigraphic scheme from: Cavinato et al. (2002)



Tectono stratigraphic cycles





Tratto da: Gori et al. (2017)

- Fucino Basin (but also the Subequana Valley & Sulmona basins): composite half grabens (= double polarity)
  - Pliocene: significant transtension along the Avezzano-Bussi Line (ENE-striking and south-throwing)
  - Quaternary: active extensional tectonics along eastern border faults (NNW-striking and W-throwing)

- The four mapped units in the Fucino basin are seismic sequences bounded by slight angular unconformities
- Internally, each of the four sequences can be subdivided into a lower and upper part:
  - Lower part: typically, high amplitude and frequency seismic facies (lacustrine?), with syn-rift wedging
  - Upper part: less well-defined seismic facies (fluvio-alluvial?) and more isopachous architectures
- The deposition of each sequence, as a consequence, can be divided into two phases:
  - First phase: acceleration of the tectonic subsidence (fault syn-rotational pulse stage), leading to the lacustrine flooding of the depositional interface, and to the formation of syn-rift wedges
  - Second phase: post-rotational pulse stage, with temporary abatement of active faulting and alluvial-fluvial progradation into the lacustrine basins, slowly smoothing the previous fault-driven topography

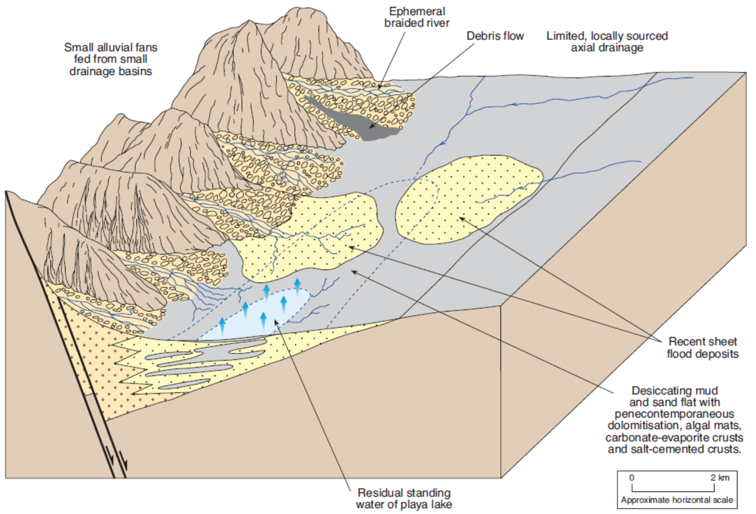
Discussions

FUCINO VS. NORTH SEA

Facies evolution

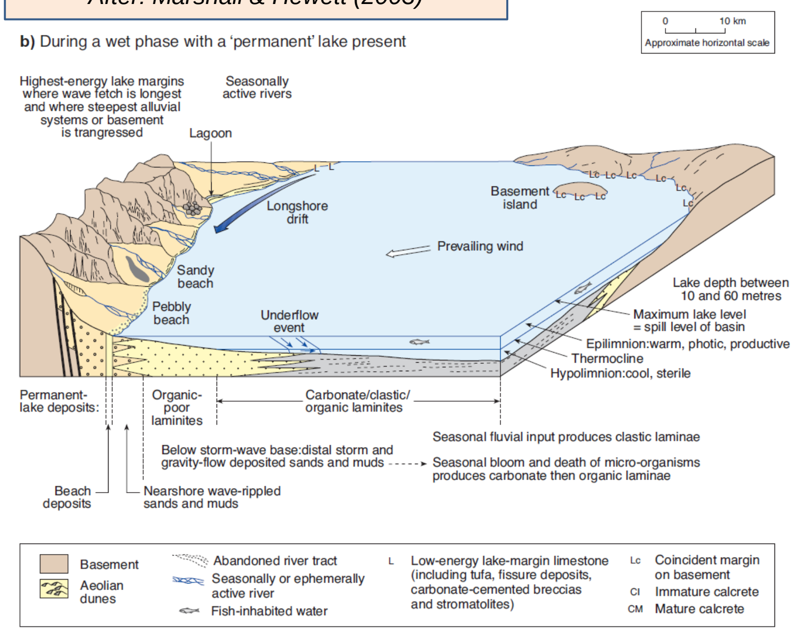
North Sea (Devonian)

Lower Devonian



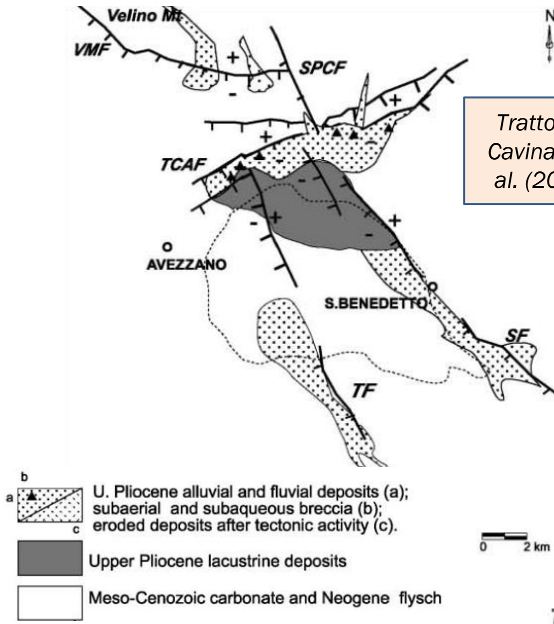
After: Marshall & Hewett (2003)

Mid Devonian



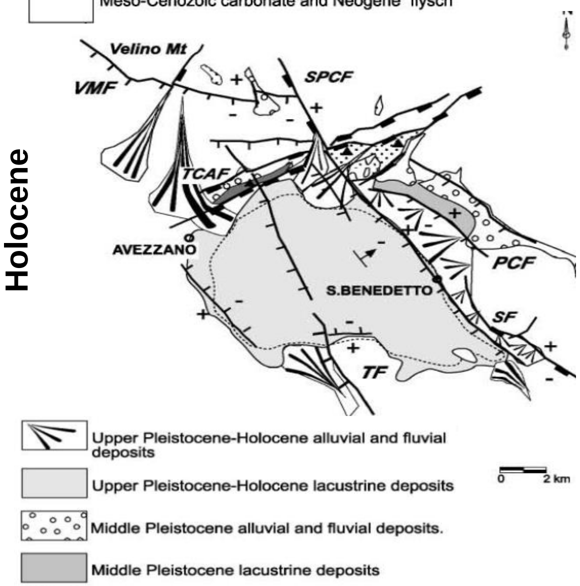
Central Apennines (Plio-Quaternary)

Upper Pliocene



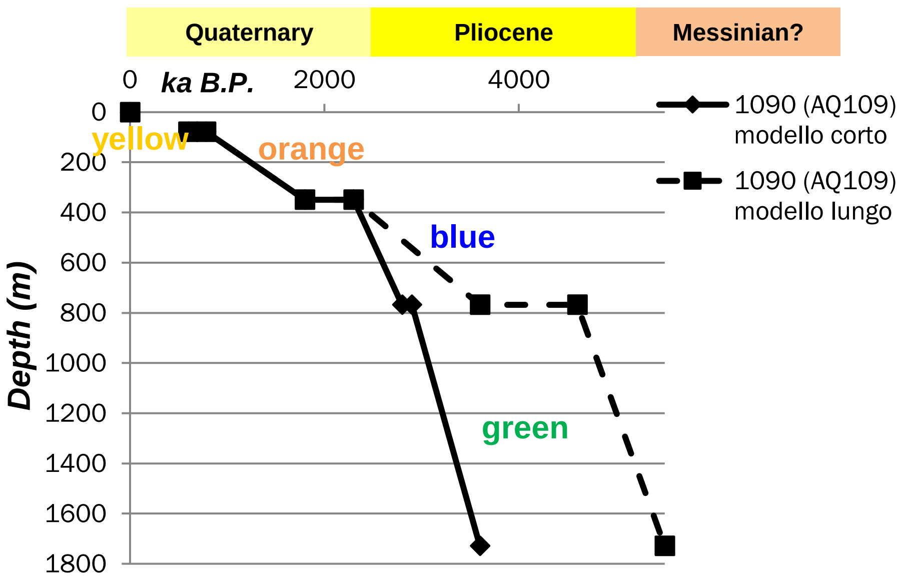
Tratto da: Cavinato et al. (2002)

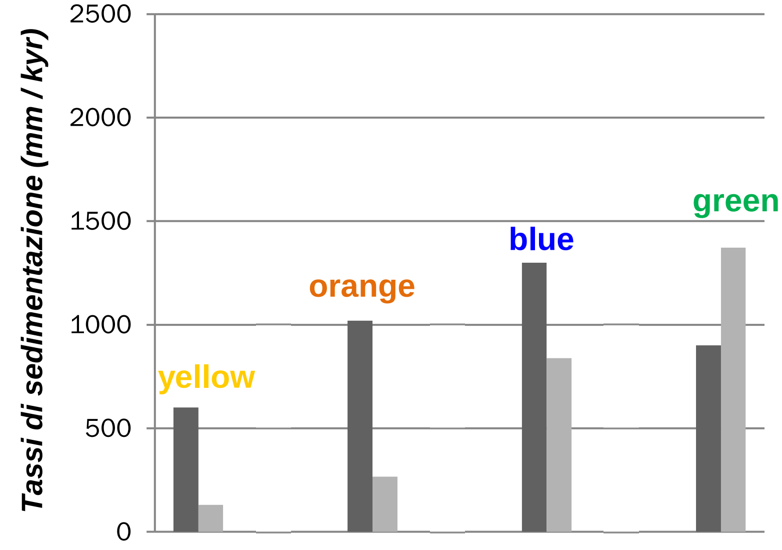
Upper Pleisocene - Holocene



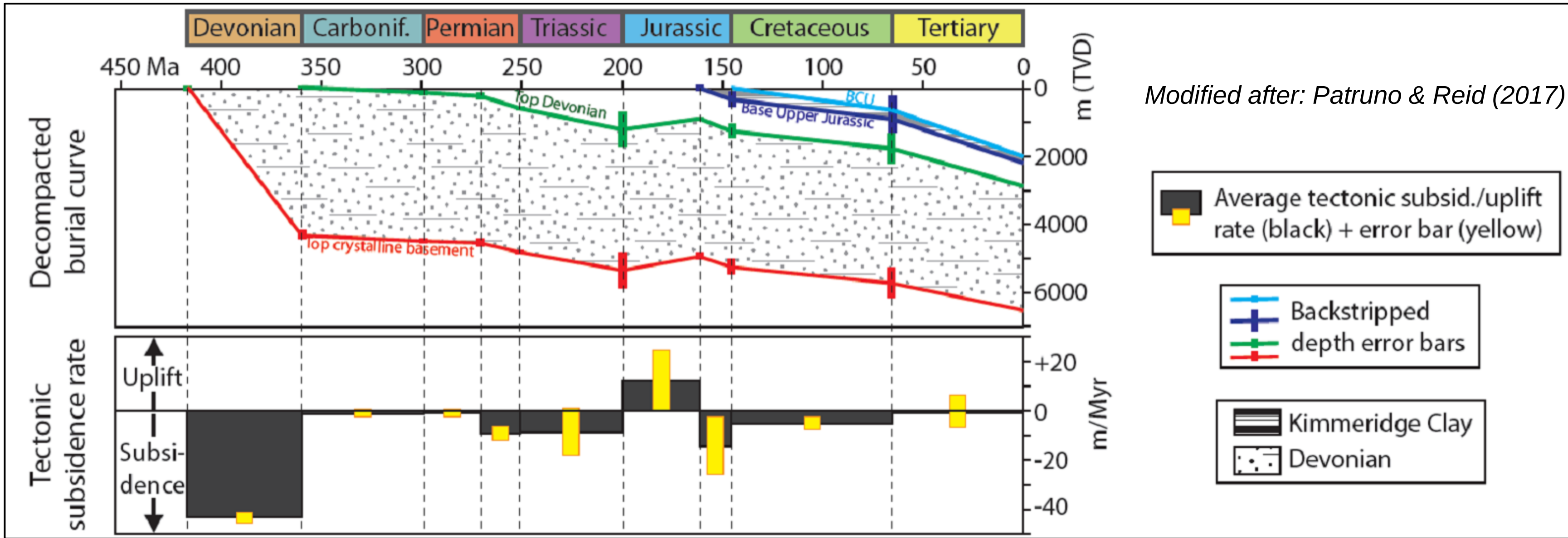
Post-orogenic evolution

Central Apennines (Fucino, northern depocentre)





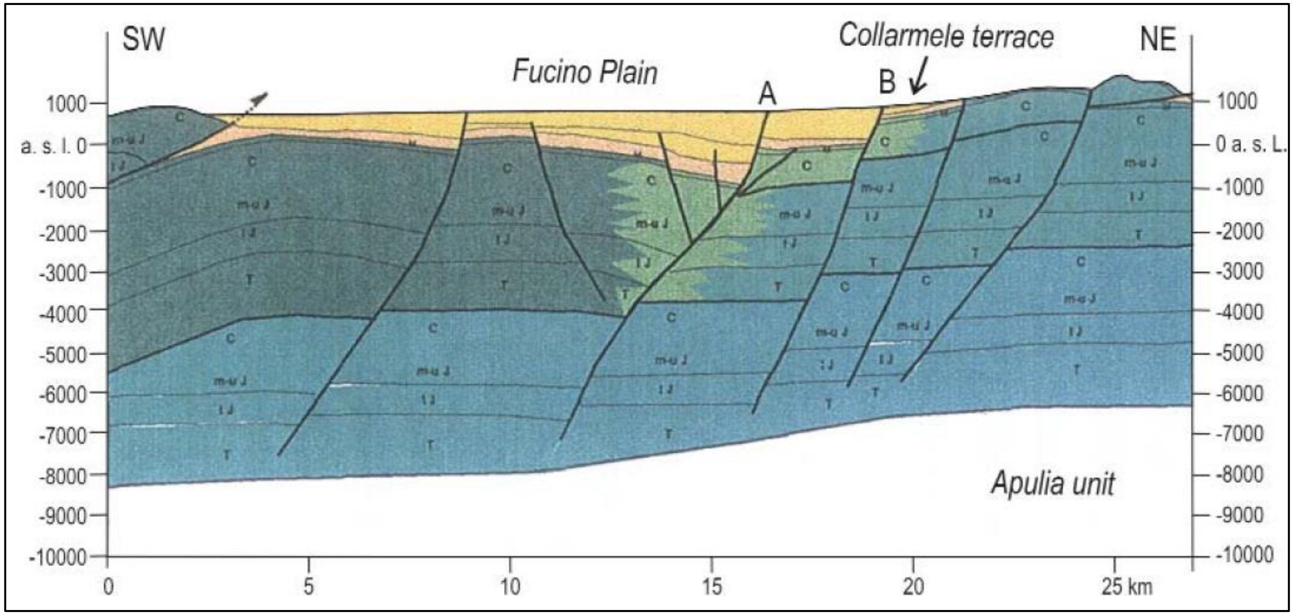
North Sea (ESP)



Modified after: Patruno & Reid (2017)

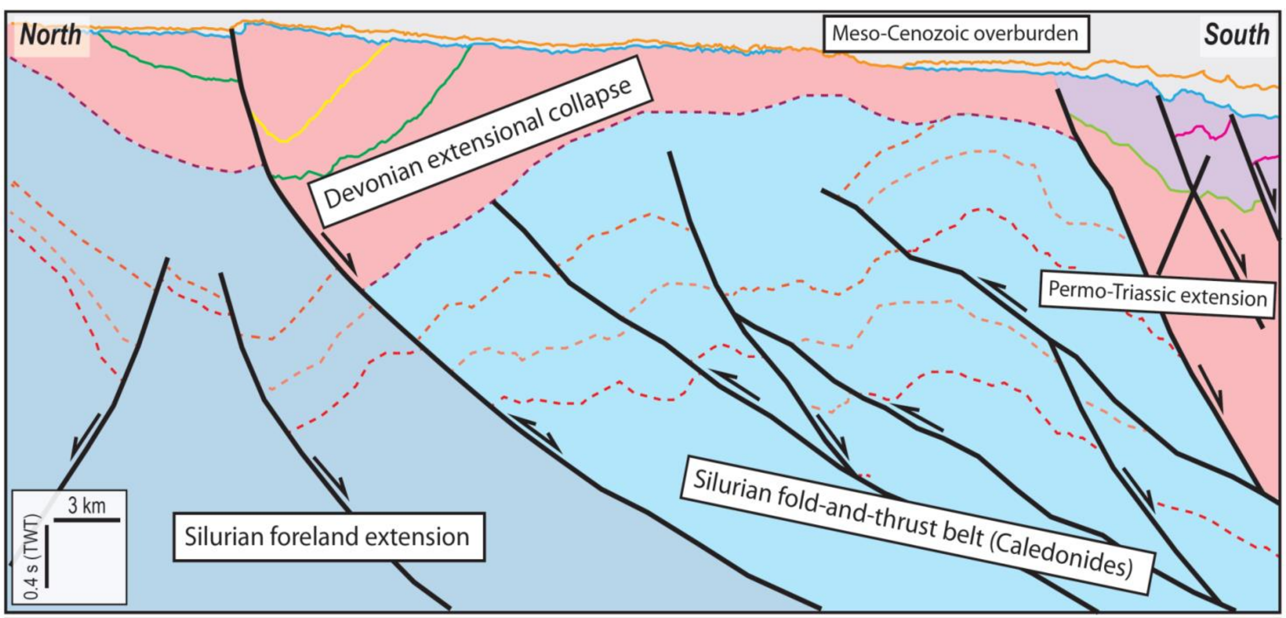
Reactivations and inversions

Central Apennines



Tratto da: Amoroso et al. (2016)

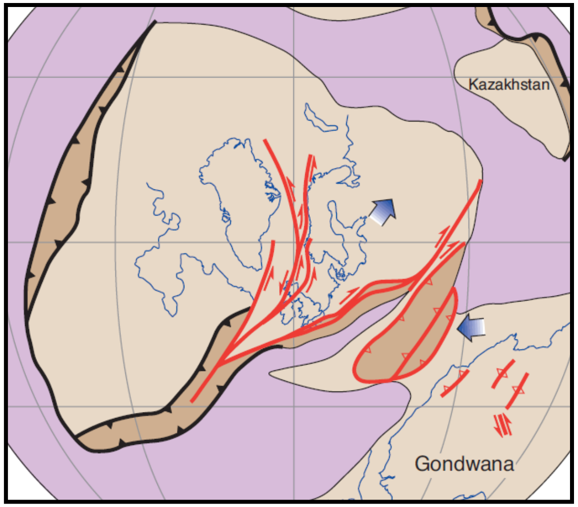
North Sea



Modified from: Patruno et al. (2017)
(Geological Society London abstract)

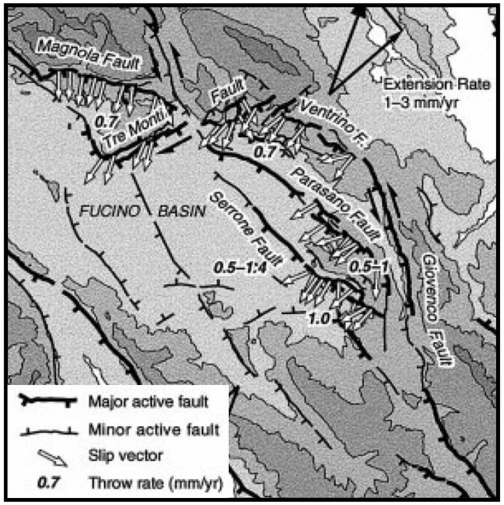
Tettonica trascorrente ed inversione

Mare del Nord (Devoniano)



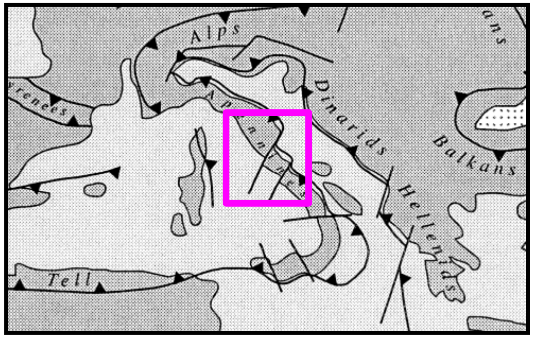
Tratto da: Cowell et al. (2003)

Appennino Centrale (Plio-Quaternario)

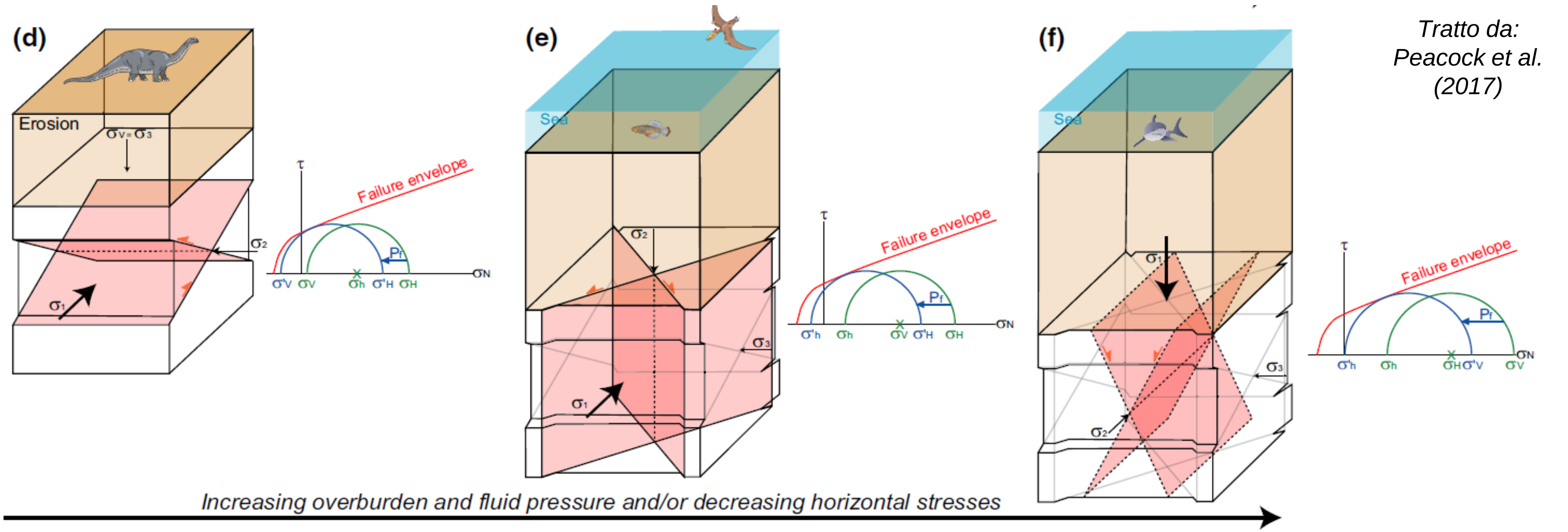


Tratto da: Piccardi et al. (1999)

Pliocene inferiore



Tratto da: Cipollari & Cosentino (1999)



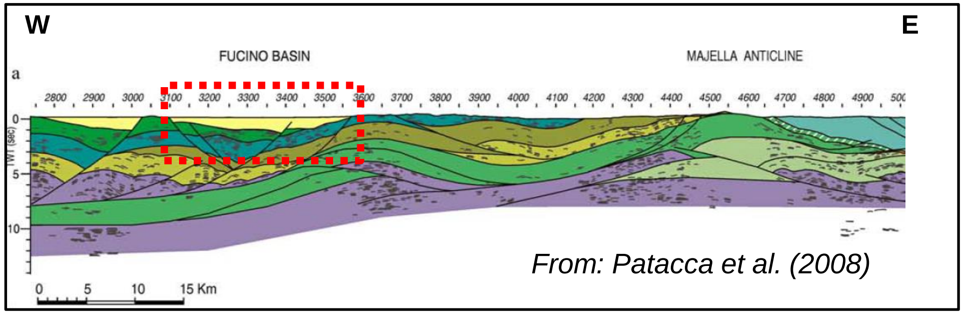
Tratto da: Peacock et al. (2017)

Conclusions

POST-OROGENETIC COLLAPSE

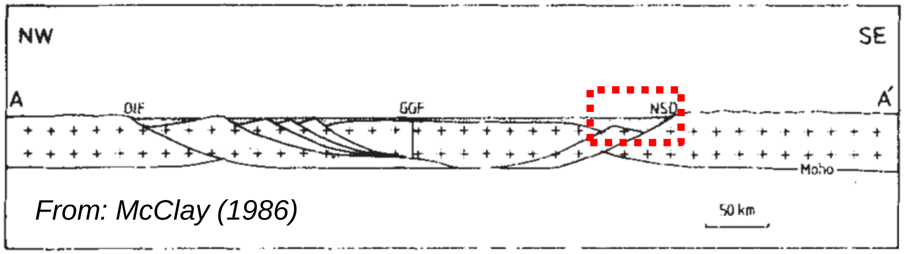
Conclusions

Central Apennines (Pliocene-Quaternary)



From: Patacca et al. (2008)

North Sea (Devonian)



From: McClay (1986)

Devonian of the East Shetland Platoform (ESP) and Pliocene-Quaternary of the Fucino share several characteristics:

- Similar total thickness and seismic-stratigraphic architecture (dominated by syn-depositional half-grabens)
- Very thick continental siliciclastic successions, dominated by lacustrine and alluvial to fluvio-deltaic facies → possible petroleum system
- Stratal architecture evolution: in each sequence, from small & deep tectonic depocentre to broad lacustrine basin
- Very high tectonically-driven subsidence, developed or during or immediately after the cessation of significant processes of custal shortening → post-orogenic extensional / gravitational collapse
- Polyphase tectonic inheritance/inversion: the very extensional collapse normal faults are often interpreted as linked to reactivated or inverted deep-seated weakness lines;
- Strike-slip tectonics taking place during or immediately prior to the extensional collapse normal faulting. This has been interpreted as a consequence of the gradual rotation of the stress vectors around their axes.

Associated geological hazards and resources:

- Generation and accumulation of hydrocarbons:
  - In the ESP, Devnian lacustrine and fluvial facies are potential source and reservoir rocks
- Active tectonics with associated earthquake hazards:
  - In the Fucino, maximum throw rates of the border faults of 1000-1400 mm/kyr
  - Northern border faults (strike ENE) with maximum slip rates in the Pliocene and lower Pleistocene
  - Eastern border faults (strike SE) with maximum slip rates in the lower-middle Pleistocene, but in certain cases (e.g., Gioia dei Marsi) with clear evidence of significant syn-Yellow Unit activity