

# Uplift at the foot-wall of a low-angle normal fault from kinematic reconstructions and paleothermal and thermochronological indicators

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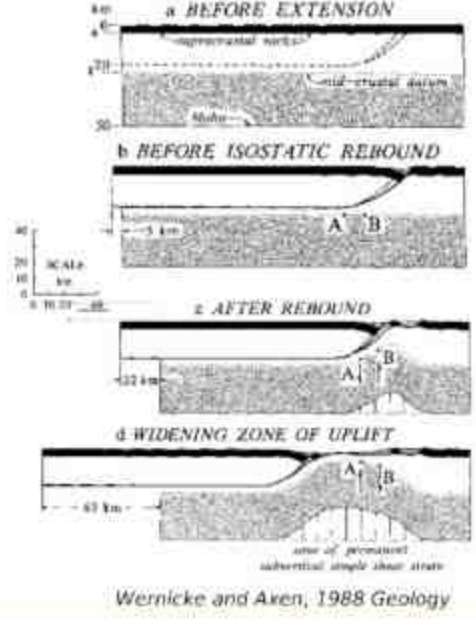
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## 1 Introduction

Many surface and subsurface geological datasets show that low-angle extensional systems accommodate significant amounts of crustal extension. Such detachments can be active, release earthquakes and often trigger uplift at their footwall.

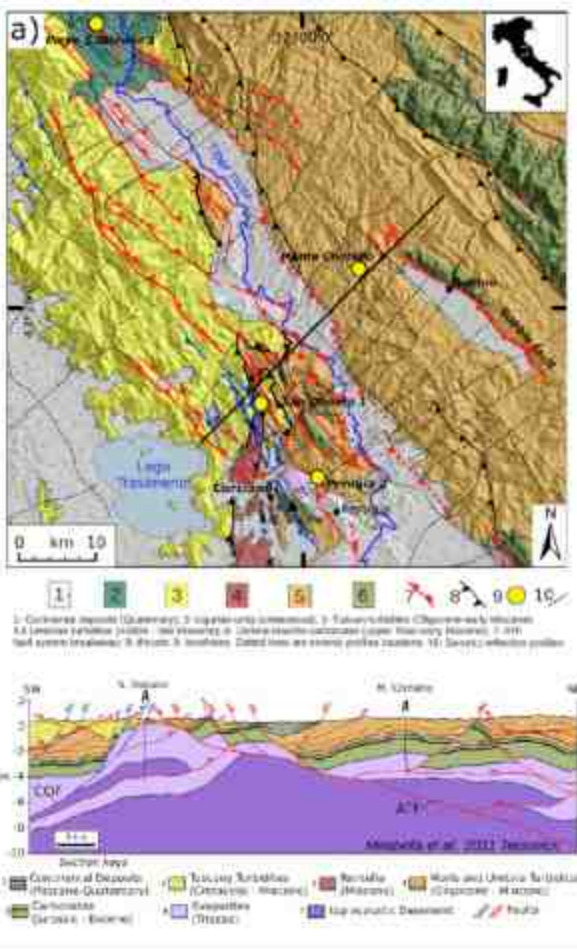
We present a reconstruction of the extensional history of the Altotiberina normal fault (ATF), a low-angle extensional detachment in the Northern Apennines of Italy. The extensional history is shown by means cross-section balance techniques and thermochronological and paleothermal analyses.



Wernicke and Axen, 1988 Geology

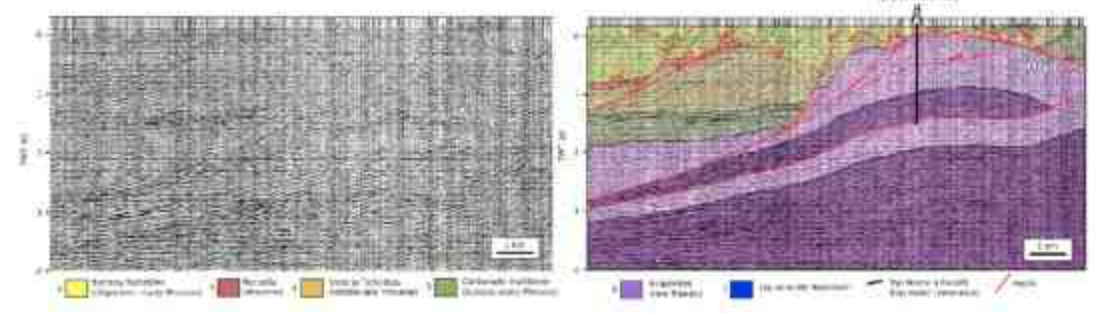
## 2 Tectonic setting

The study area is located west of the Tiber river in the Northern Apennines of Italy. The area is presently affected by extensional tectonics which started about 3 MA ago and which has dissected the previously formed compressional structures. The main extensional structure in the area is the Altotiberina normal fault (ATF), a ENE-dipping regional detachment which has accommodated up to 10 km of extension during the last 3 MA. The structure is still active as shown by GPS data and microseismicity and is the detachment for the higher angle normal faults in the area antithetic to the ATF and dipping both to the SW and to the NE.



## 3 Subsurface data

We interpreted and converted to depth a set of seismic reflection profiles which image the subsurface setting of the area. The seismic reflection profiles were calibrated with deep boreholes in the area.



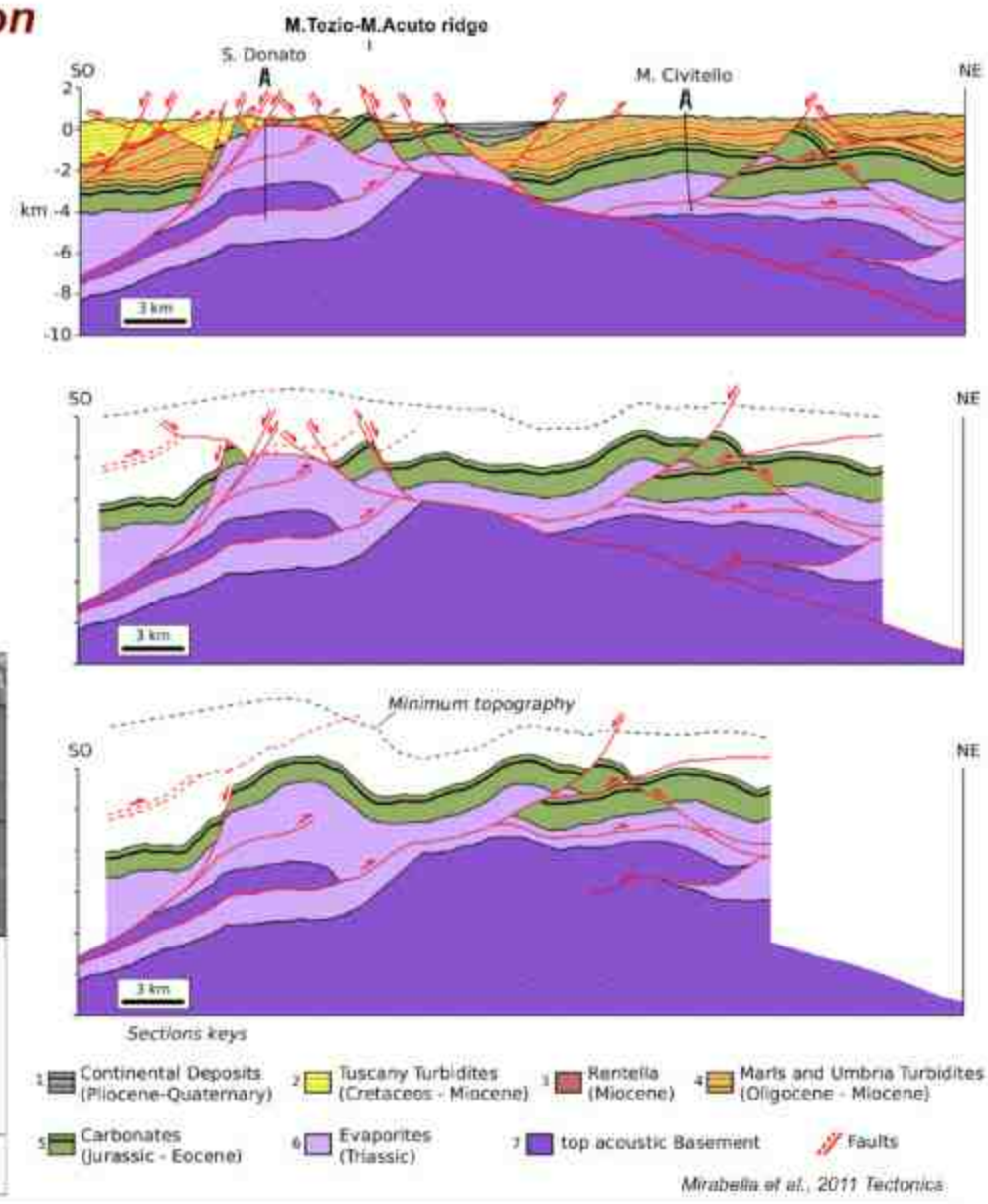
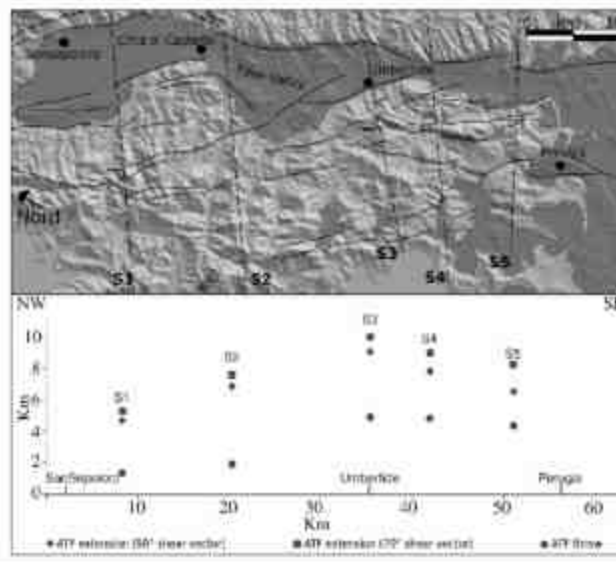
The seismic reflection profiles show the dome-shaped geometry of the ATF.

## 4 kinematic reconstruction

We apply cross-sections balance techniques. We plot the values of the horizontal and vertical offsets along the ATF strike in correspondence of the balanced sections.

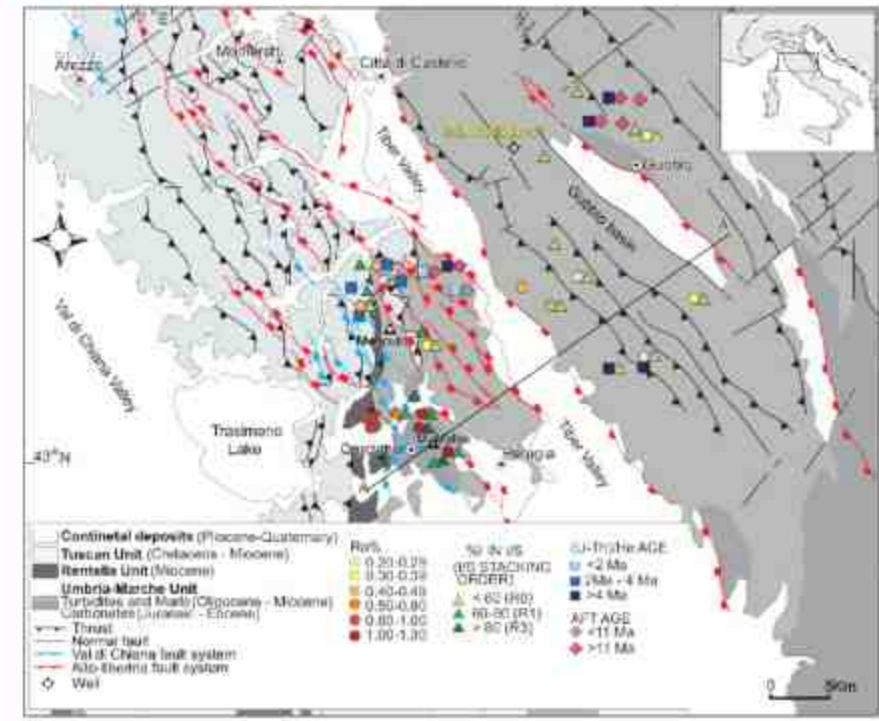
The ATF extension is maximum in the central part of the fault and decreases towards NW and SE. Considering the age of the deformation we draw long-term extension rates of about 2.5 – 3.0 mm/yr which are consistent with geodetic data (2.7 mm/yr – D'Agostino et al., 2009)

We measure a maximum extension accommodated by the ATF in the order of 10 km achieved during the last 3 MA. We also yield a minimum paleo-topography before the onset of extension in the order of 4 km of elevation a part of which possibly due to foot-wall uplift.



Mirabella et al., 2011 Tectonics

## 5 Paleothermal and thermochronological analyses

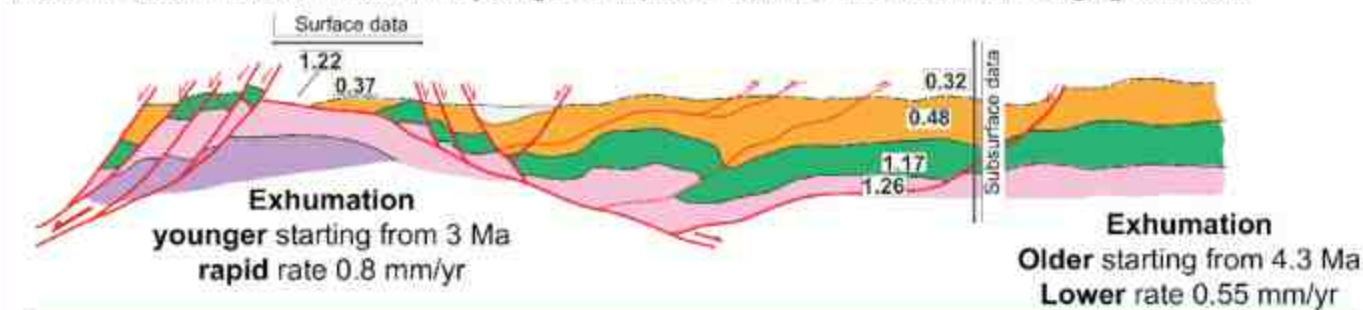


### Paleothermal data

The oldest sediments (Upper Triassic black shales) are in the mid oil window and in the late diagenetic zone (Ro%: 1.03-1.22% and illite content in mixed layers I-S from 72%-85%). The early Cretaceous sediments (black shales) indicate catagenesis and late diagenetic conditions (Ro%: 0.78% and illite content in mixed layers I-S of 75%). Umbrian turbidites (Marnoso Arenacea Fm.) reach on one hand immature to early mature stage of hydrocarbon generation (Ro%: 0.42-0.26) on the other the lower part of late diagenetic zone and early diagenetic zone (illite content in mixed layers I-S from 38% to 70%). A similar trend characterized by an almost regular thermal maturity has been recorded in the Mt. Civitello 01 well, located to the NW of the Gubbio town and deep about 5.600 m.

### Thermochronological data

New and already published (Thomson et al., 2010) U-Th/He data (carried on the Marnoso Arenacea Fm.) are totally reset apart from two samples. Moving from the west (ATF system) to the east (Gubbio ridge) three clusters of data can be distinguished. To the west of the Tiber Valley ages range between 1.8 and 3.6 Ma. To the east of the Tiber Valley in the Gubbio basin data indicate partial retention and no retention of He; further to the east mean age is 4.4 Ma. Already published AFT data (Zattin et al., 2002) are no reset with exception of one sample in Mt. Acuto area that confirms younger exhumation ages when compared to the rest of the study area. The exhumation in the ATF foot-wall is younger and quicker than that recorded in the hanging-wall block.

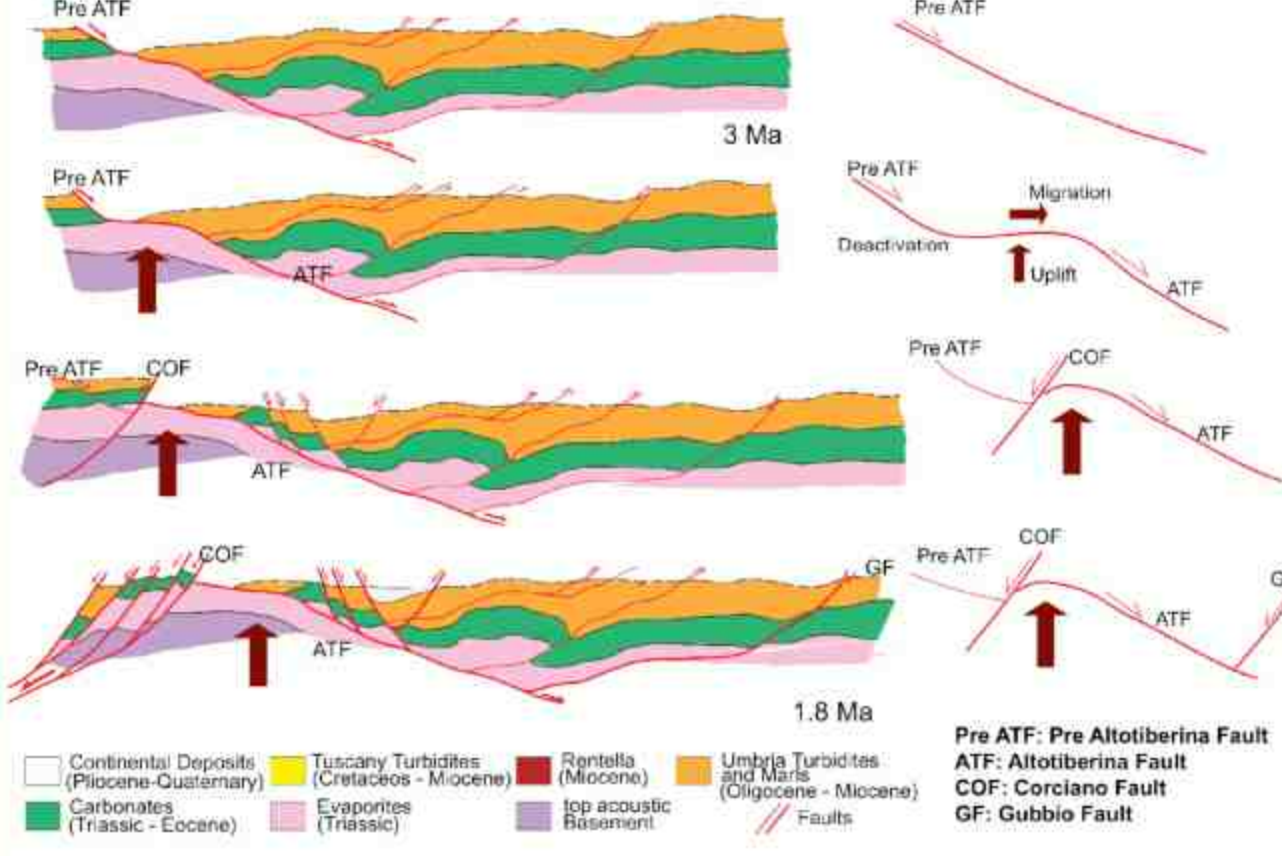


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## 6 Tectonic model



## 7 Present day drainage and relief

The uplift of the M. Tezio - M. Acuto ridge has affected the drainage pattern of the area in recent times: the two main drainages were flowing to the NE and were depositing a pond-type sequence in correspondence of the Nese and S.G. Pantano basins. Recently the two basins have experienced a different behaviour due to the differential uplift: while the Nese river has overcome uplift and managed to keep its NE drainage direction, within the S.G. Pantano river the drainage was inverted towards SW by the Caina river.



## Conclusions

- > We constrain the late orogenic cooling and exhumation history of the ATF low angle detachment system.
- > The ATF is bent near the surface and has a total extension of about 10 km.
- > We provide a time constrain of about 3 MA for the beginning of exhumation.
- > We find a constant exhumation rate of 0.80-1.0 mm/yr at the fault foot-wall.
- > Towards the East the exhumation rates sharply decrease at the fault hanging-wall to about 0.6 mm/yr.
- > The hanging-wall area between the ATF and its main antithetic fault shows only very low exhumation.
- > We suggest the fault bent is due foot-wall uplift triggered by tectonic unloading.
- > The foot-wall uplift has been active in recentmost times as shown by the drainage inversion.