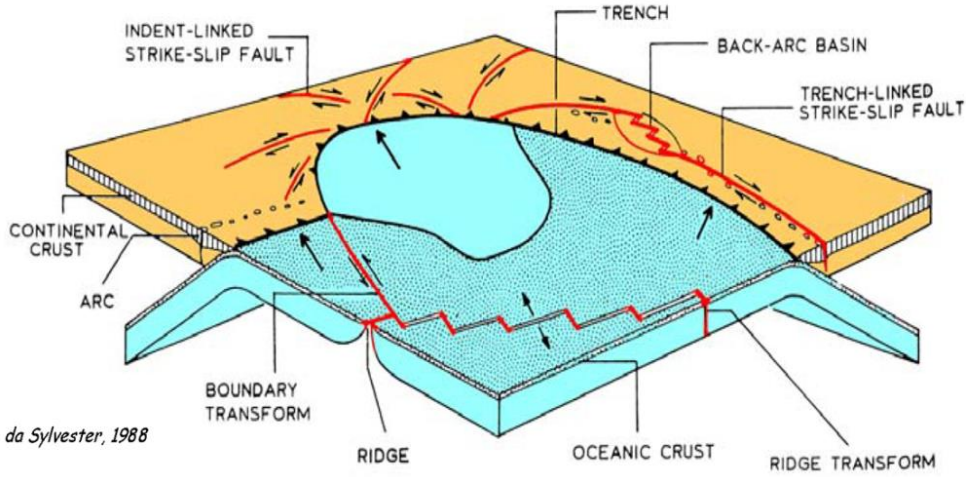
Strike-slip Faults



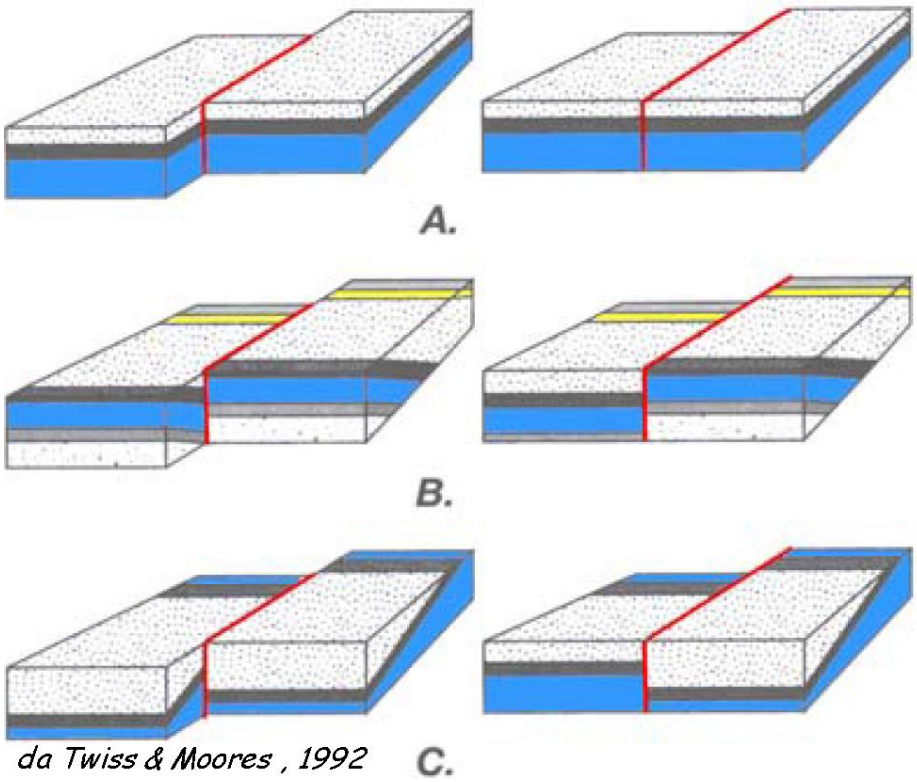
- Transform faults: related to plate margins, they cut the entire lithospheric thickness

- Transcurrent faults: limited to the crustal thicknesess, they are generally intra-continental.

- A third group of faults are the *strike-slip*, related to horizontal shift within extensional or compressional tectonic regimes. Generally, they have small throw and depth.

- The strike-slip faults generally produce second order faults and peculiar fracture systems, as that one with the *en-echelon* geometry.

Right and left strike-slip and apparent throw.

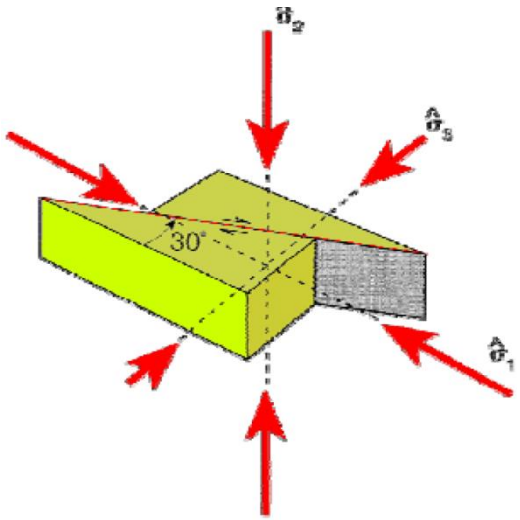


The right and left attribution, is unambiguous, whatever the block in which we place ourselves.

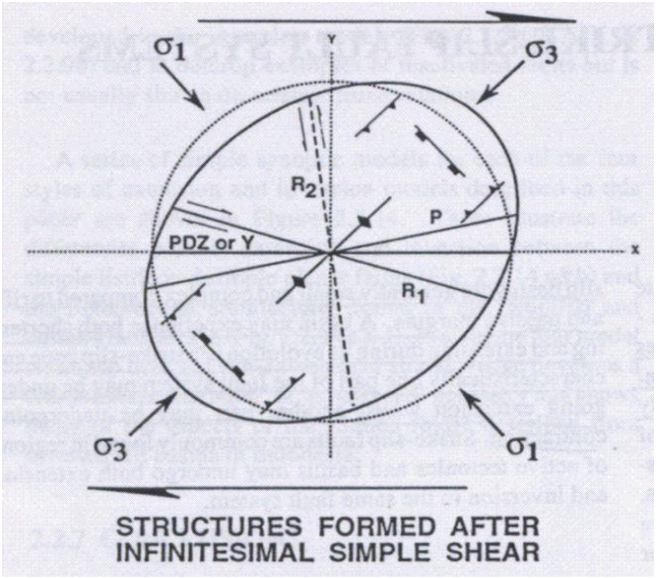
← Apparent effects

The best observation point is perpendicular to the displacement vector and therefore from above

Strike-Slip Faults

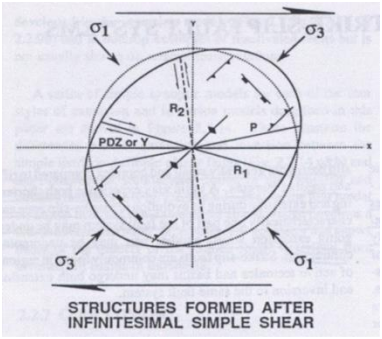


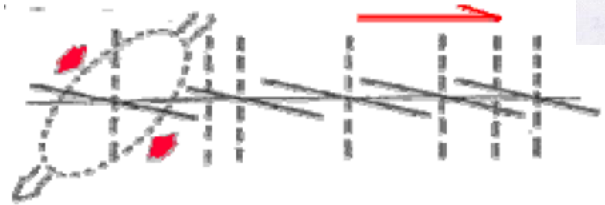
Example of
right strike-slip



The Stike-Slip systems are characterized by association of correlated structures, which can be interpreted in terms of the classic stress ellipsoid. With the first initial deformation along the PDZ segment, the Shears R1 (typically oriented between 15 ° and 20 °) and R2 (typically oriented between 70 and 75 °) and the low angle P Shear (10 ° -15 °) will develop. There will also be associated minor structures, such as extensional faults (perpendicular to σ_3) and compression folds and faults (perpendicular to σ_1). As the deformation evolves (increase in horizontal rejection) these structures will rotate ...

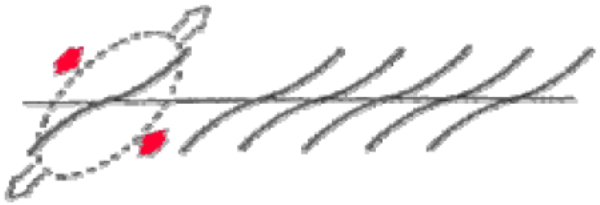
Caratteristiche principali



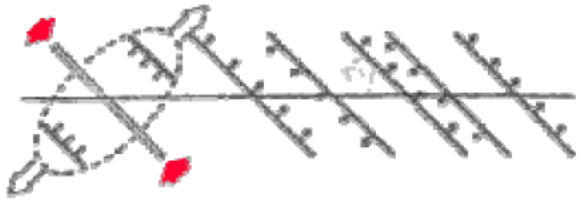


Fratture R e R'

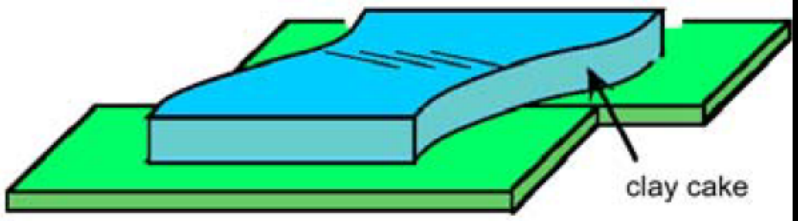
Presenza di numerose elementi strutturali legati ad una fascia di trascorrenza (esperimento di Riedel)



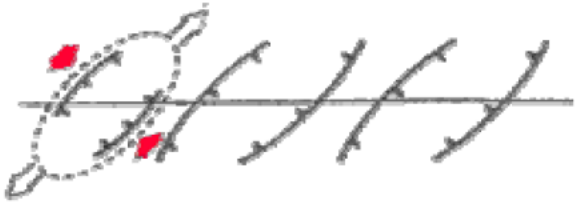
Pieghe



Faglie normali

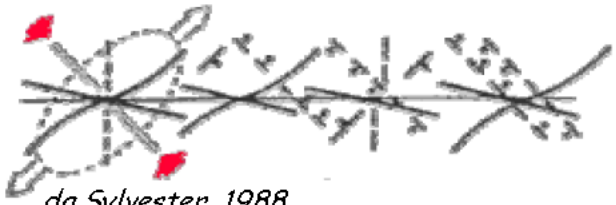


da Allmendinger



Faglie inverse

Contemporaneità di strutture distensive e compressive



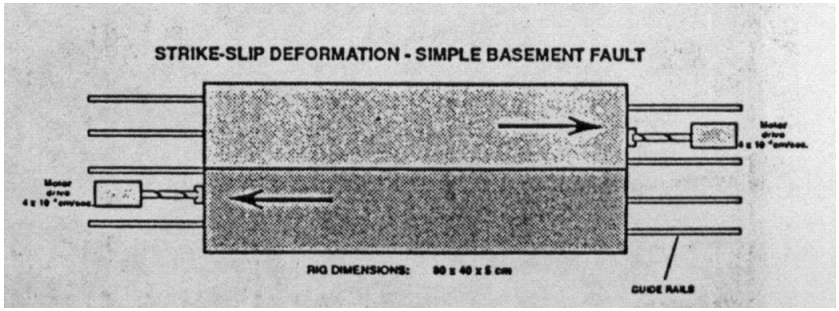
Tutte le strutture insieme

Disposizione "en echelon" delle strutture associate

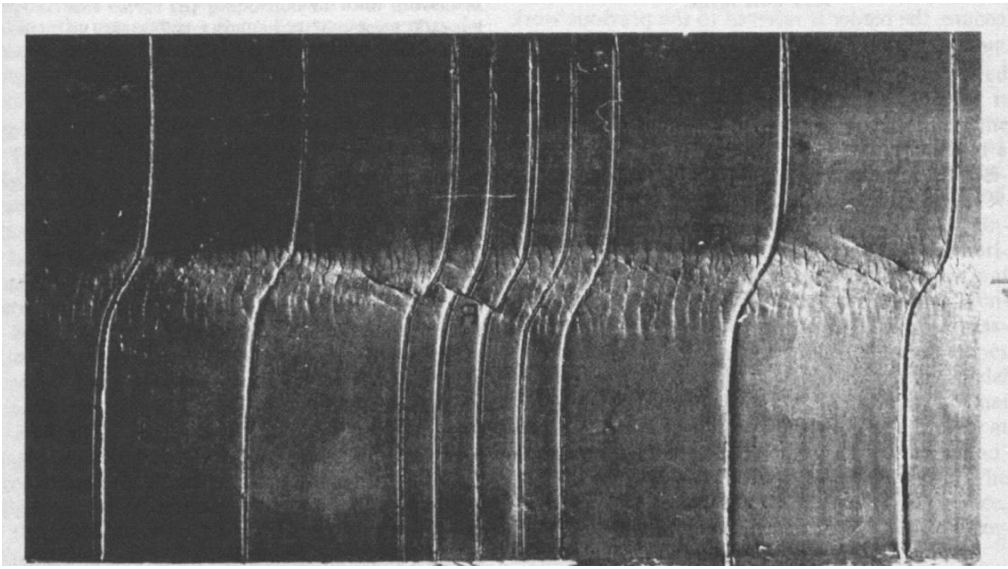
da Sylvester, 1988

Strike-Slip Faults

Shear box test:
to analyze the evolution of the structure systems related to a Strike-slip, a *Box Test* is often utilized



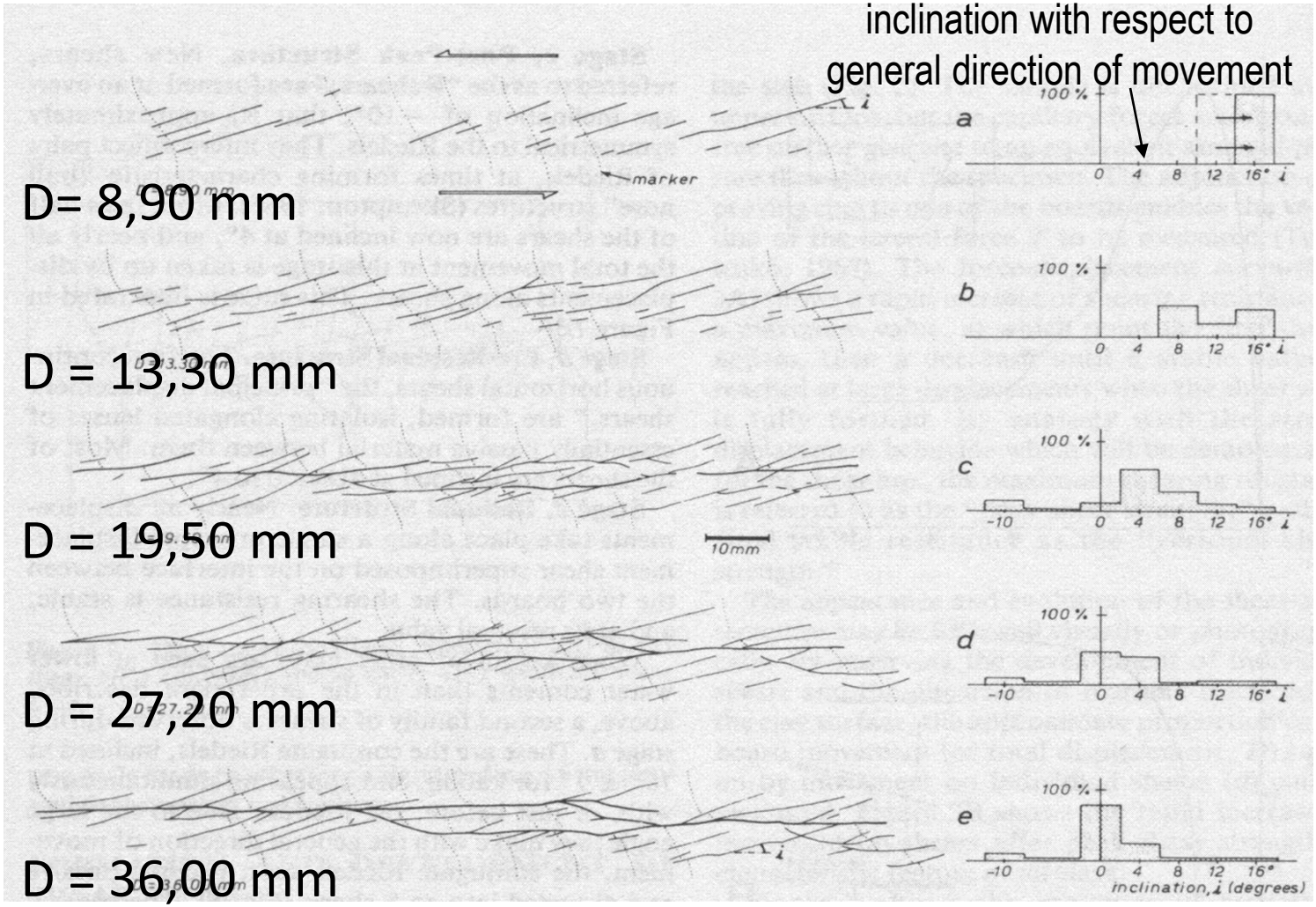
Scheme of a box-test with application of a stress field related to a right strike-slip.



Picture of a box-test: the effect of a right strike-slip can be analyzed in two different times of the deformation evolution.

Strike-Slip Faults

Evolution of the Riedel structures with the increasing horizontal throw D



Strike-Slip Faults

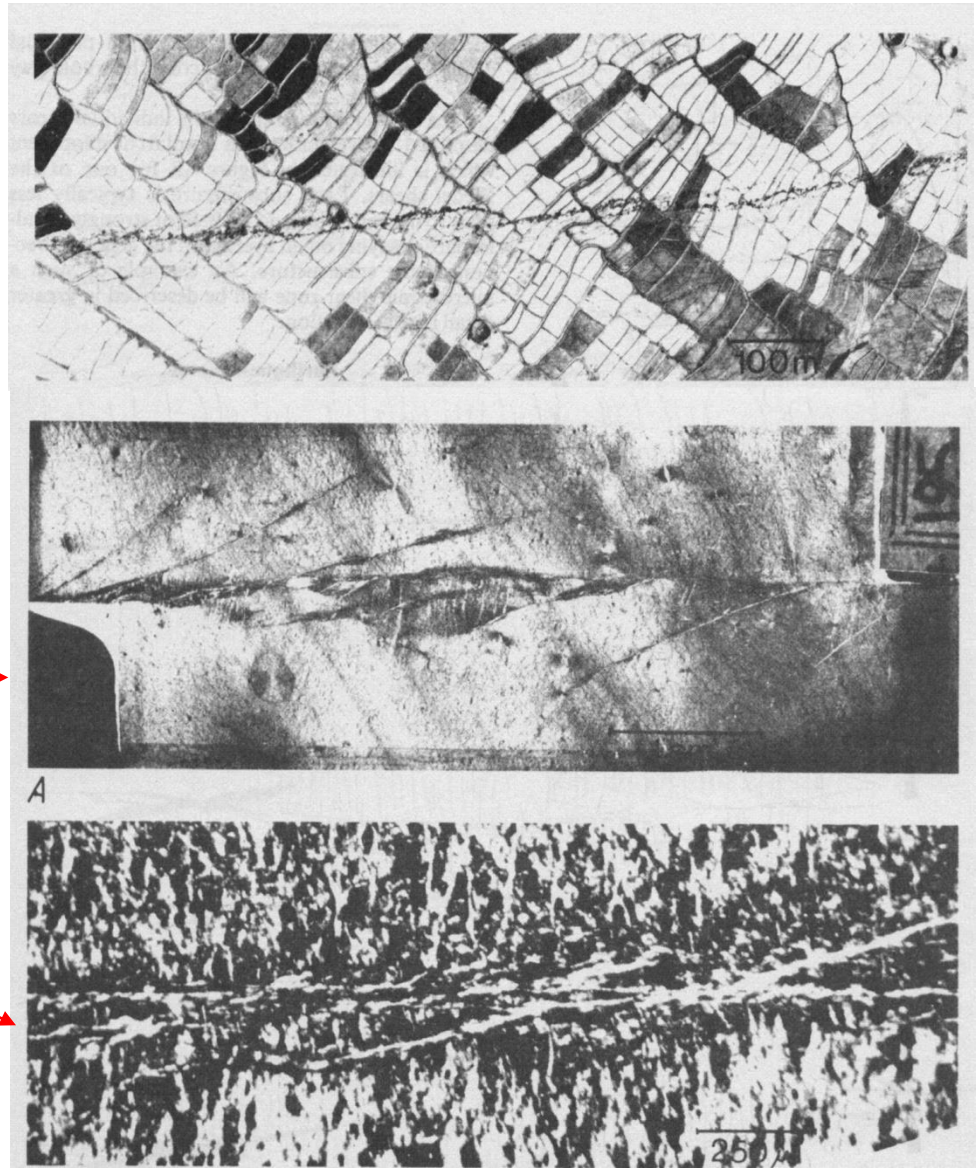
Structures related to a strike-slip develop in a similar way at different scales.

If D s the horizontal throw:

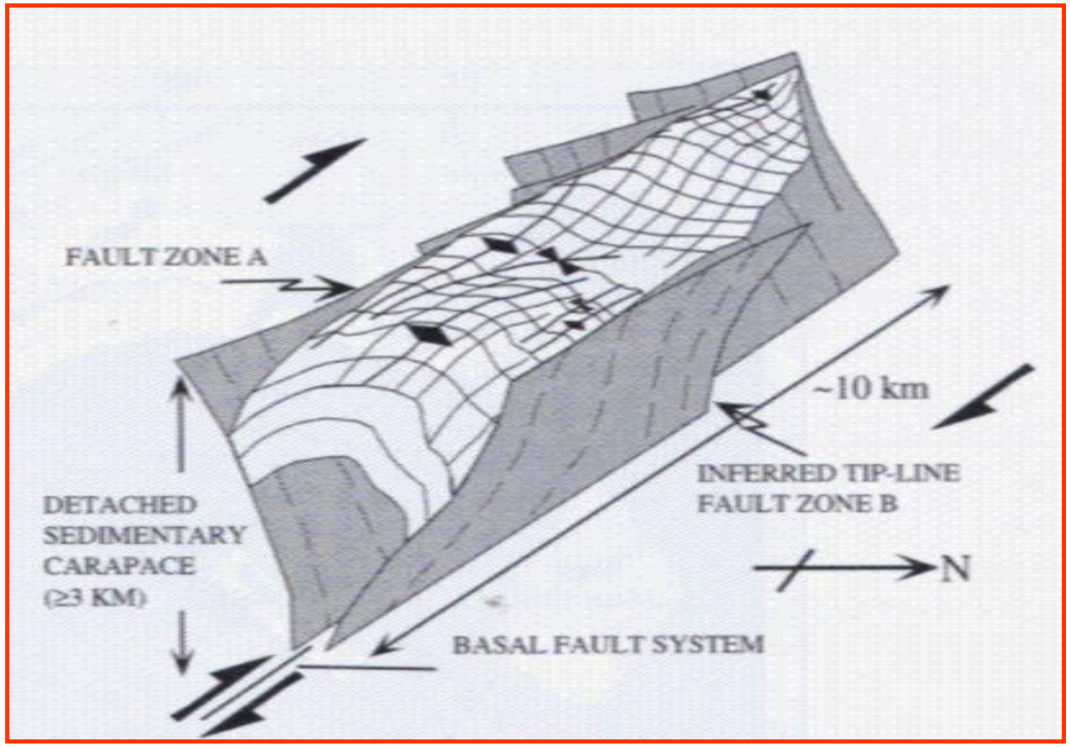
Es.: Seismic fault,
aerial photo,
D = 250 cm

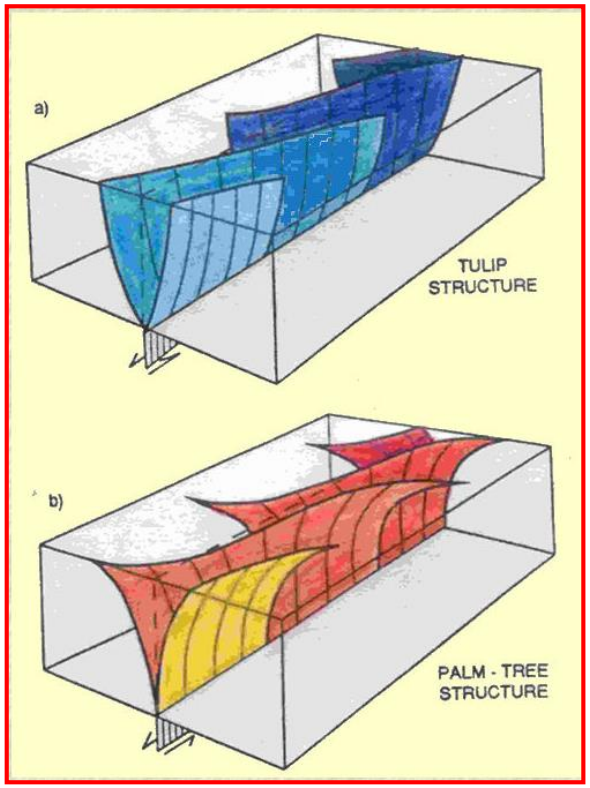
Es.: Shear Box test with kaolin,
D = 8mm

Es.: Shear Box test with kaolin,
detail,
D = 3mm



The outcropping SS faults are characterized by fracture systems, with a prevalent common direction arranged in an *en-echelon geometry*.



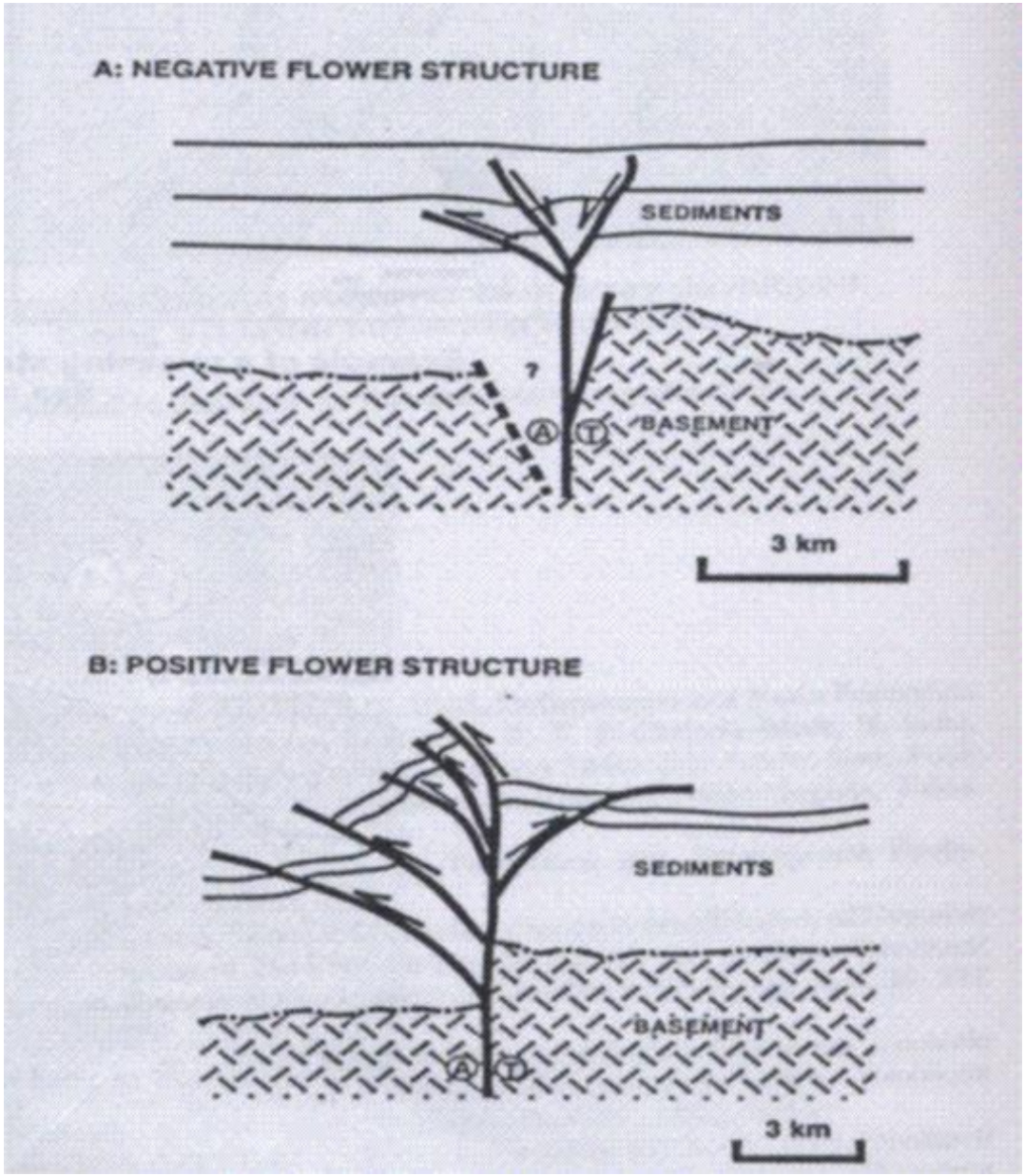


Along a seismic section, these structures could be more or less complex, generally they tend to draw flower structures

The
flower structures
could be:

- **negative**
when transtension
is present,

- **positive**
when
transpression
is present.

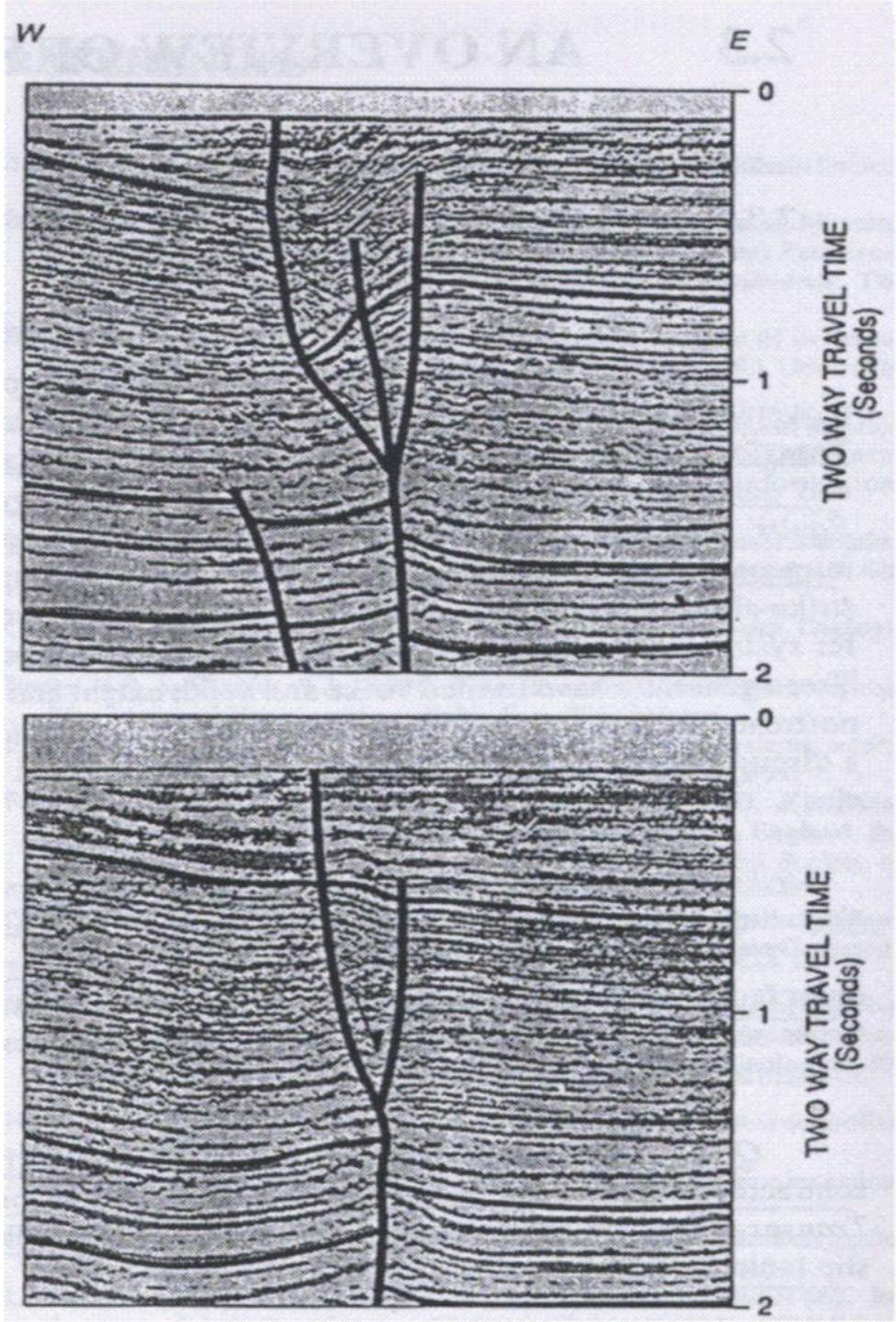


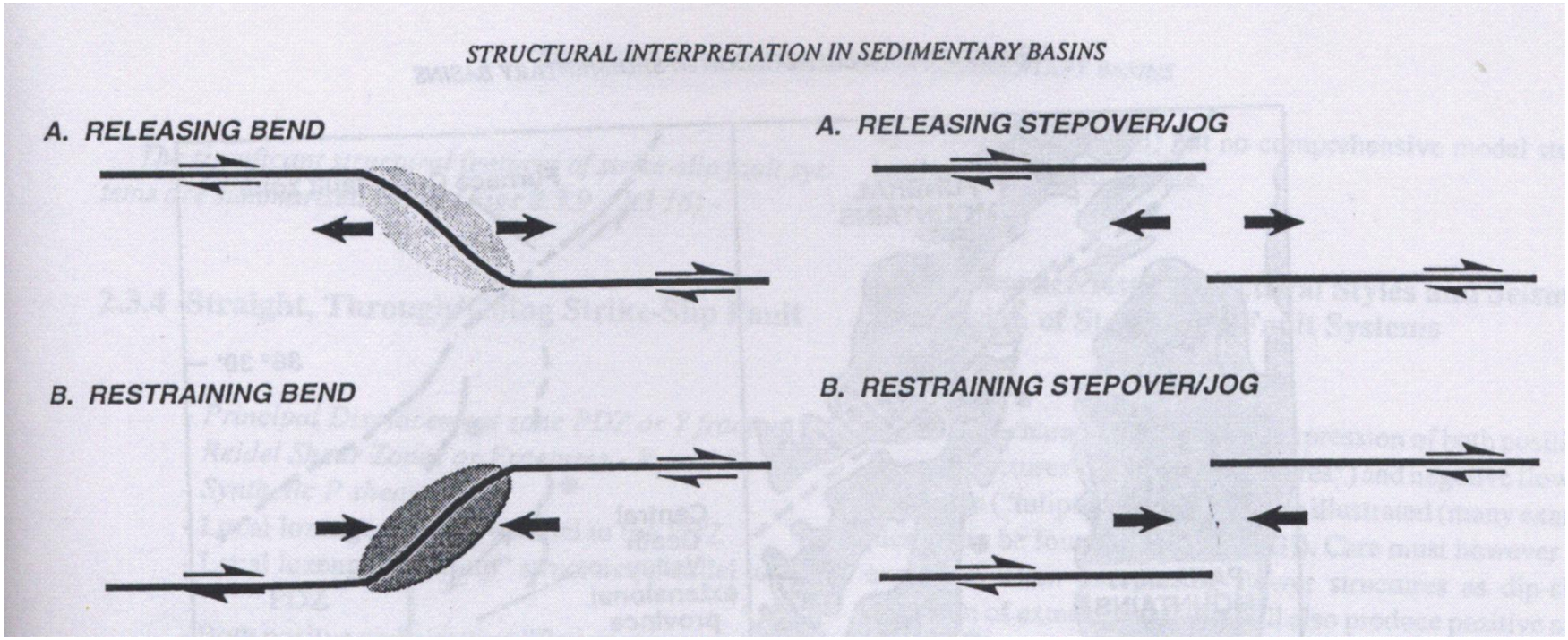
OBLIQUE FAULTS

Examples along some seismic profiles crossing the same tectonic structure:

negative flower structure →
transtension

positive flower structure
transpression →



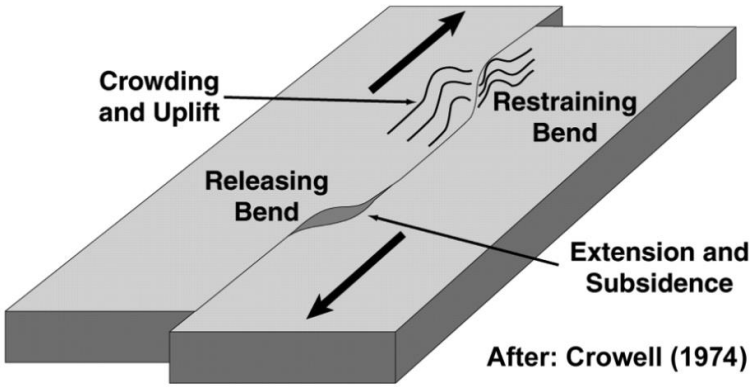


Similar structures may also developed with segmented faults and *en-echelon geometries.*

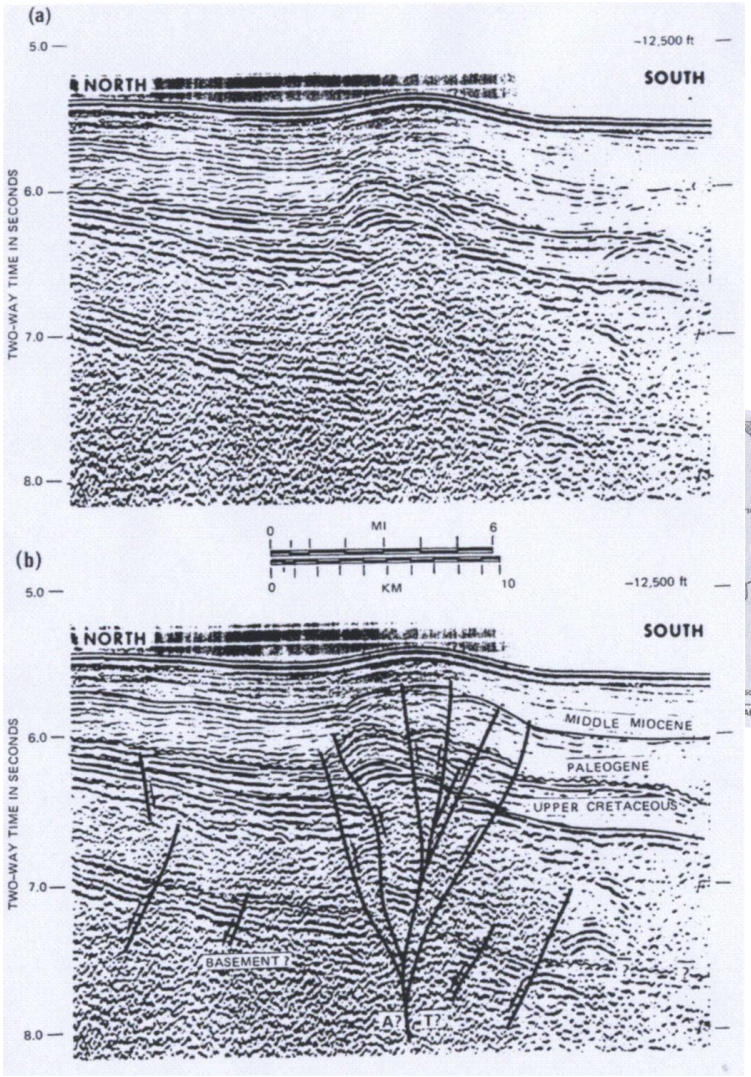
Different curvilinear shape of the strike-slip fault:

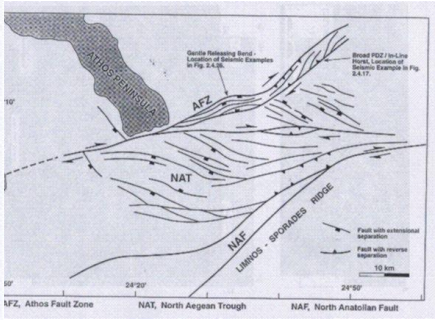
- *Releasing Band* → possible extensional basins
- *Restraining Band*, → possible folds and *thrusts*

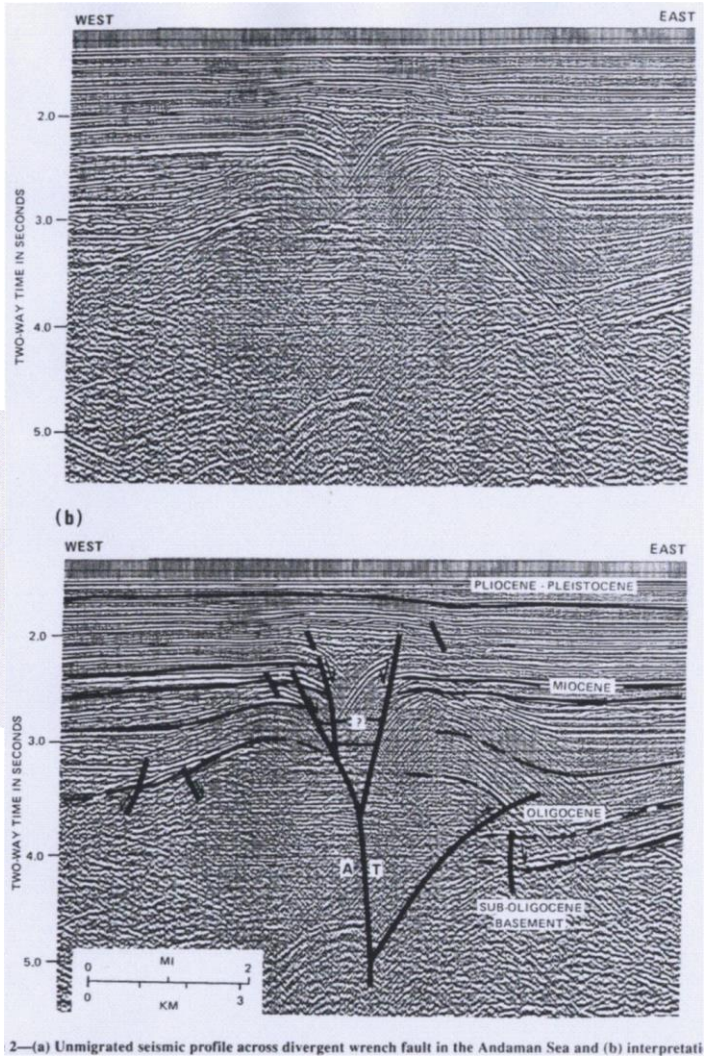
The shallow faults converge in a deep, single, sub-vertical fault.



Example of flower structures along a stack profile in the Aegean Sea, western prosecution of the North-Anatolian SS fault

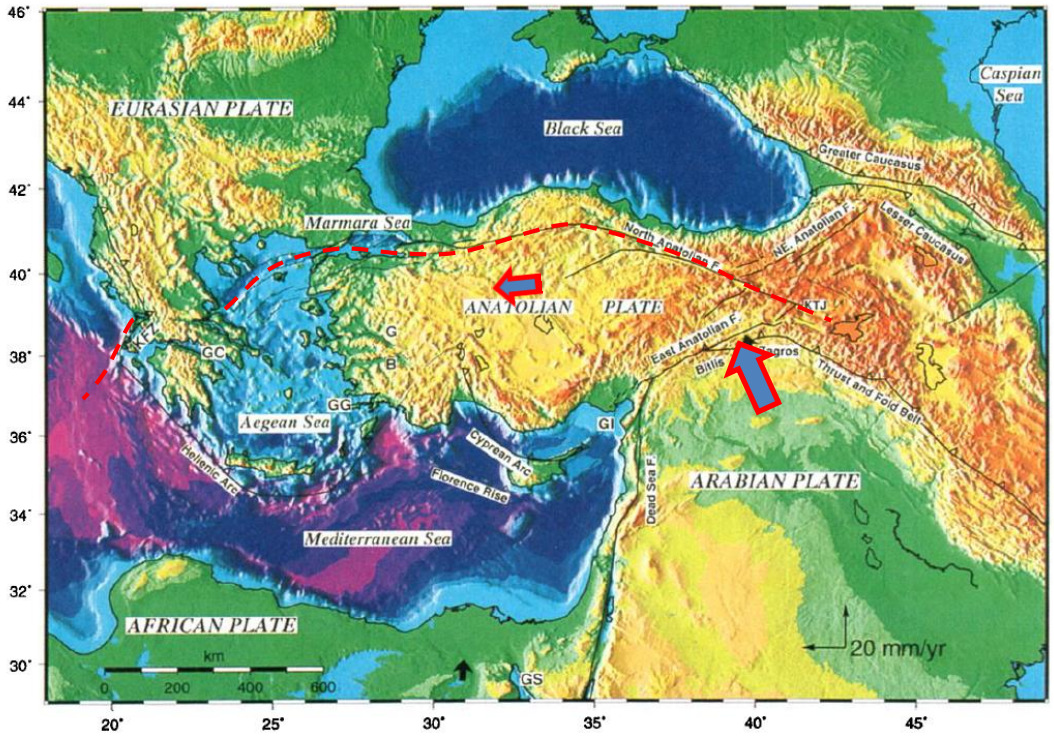




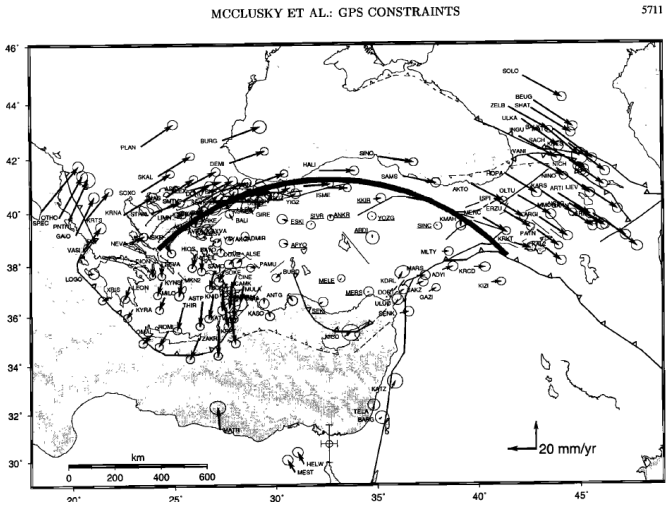


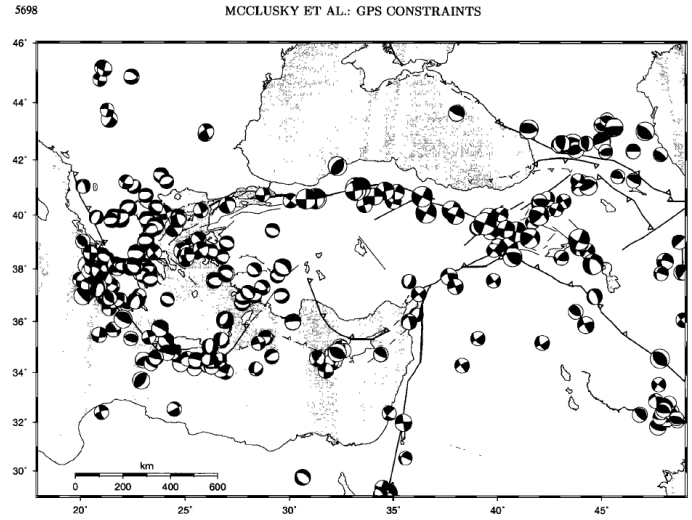
2—(a) Unmigrated seismic profile across divergent wrench fault in the Andaman Sea and (b) interpretati

Flower structures in the Aegean Sea, western prosecution of the North-Anatolian strike-slip fault



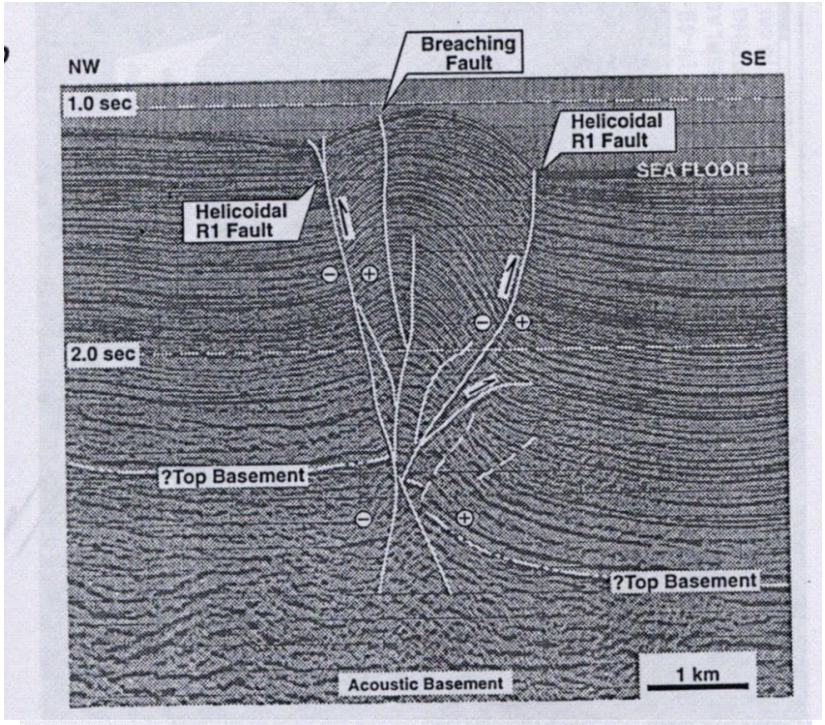
McClusky et al., 2000



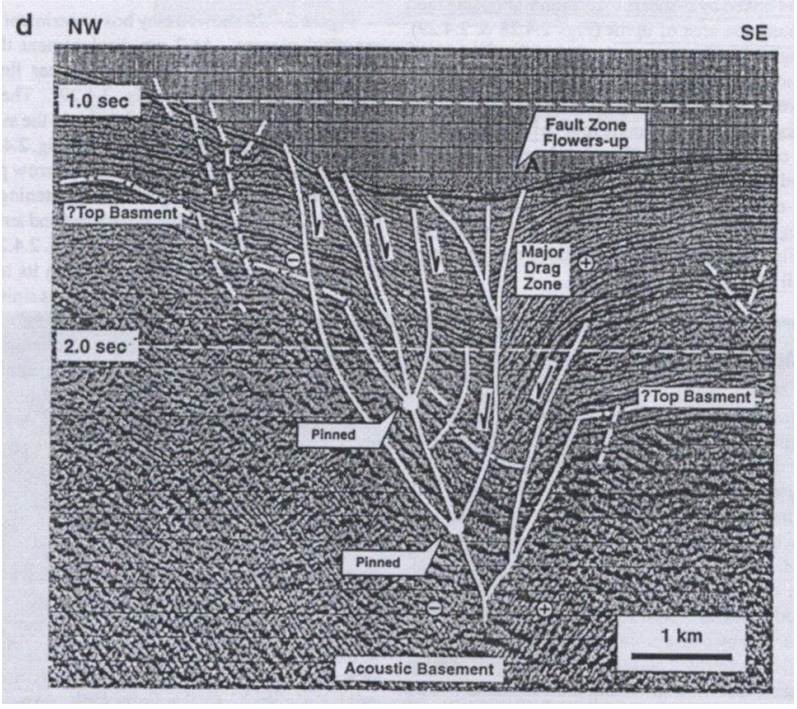


North-Anatolian SS System:

transpression evidence
(right-lateral reverse
oblique-slip fault)
→



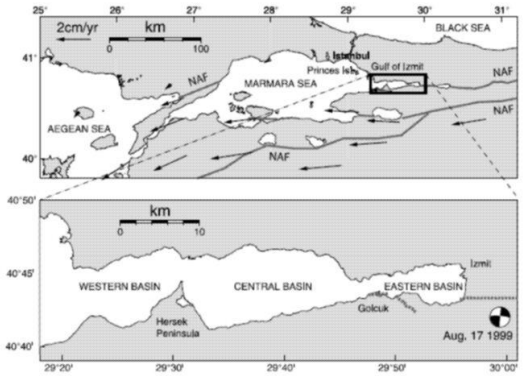
transtension evidence
(right-lateral normal
oblique-slip fault)
→

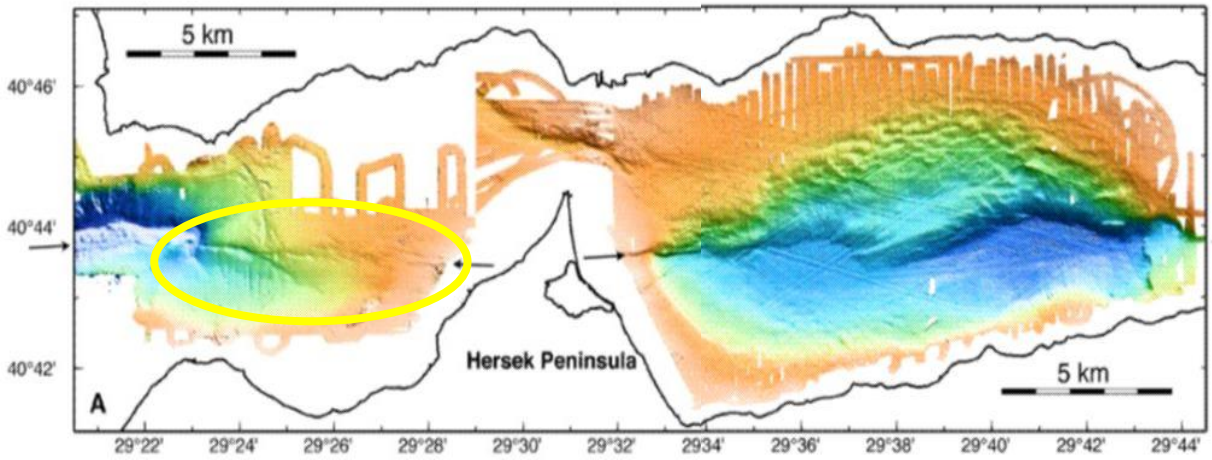


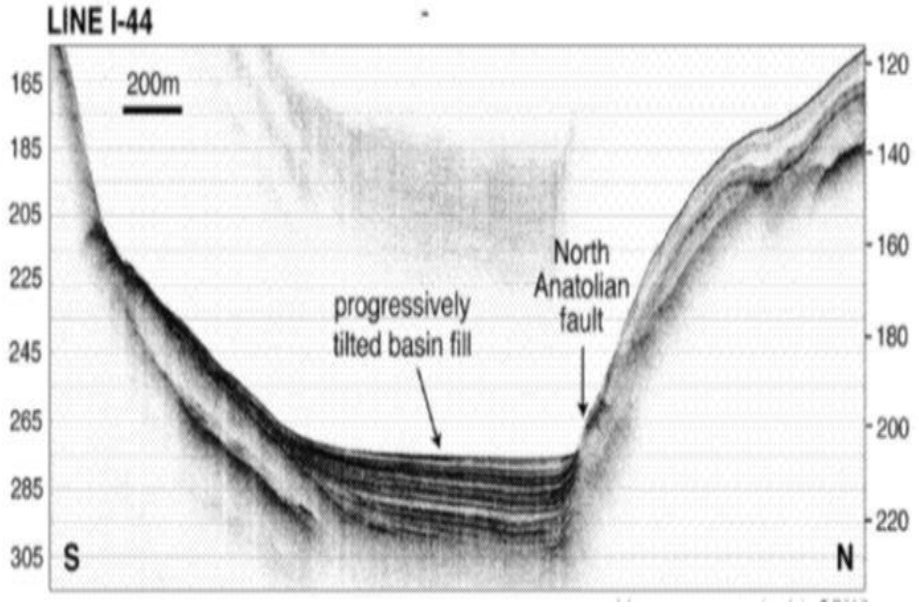
Example of regional strike-slip

North-Anatolian System

Gulf of Izmit







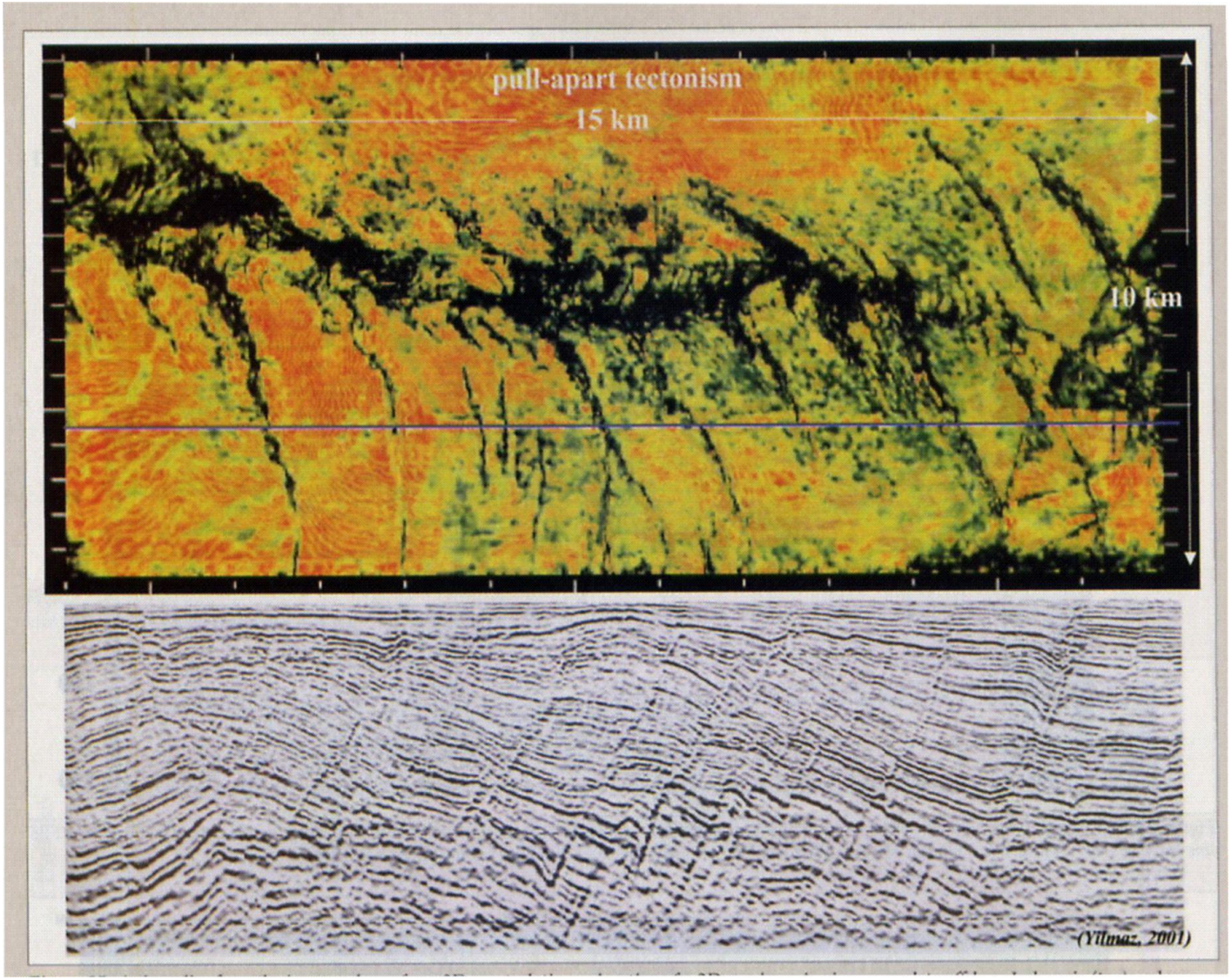
Multibeam evidences the *en-echelon* faults which cut the sea bottom.

CHIRP profile evidences *growth strata* Shallow growth stratum suggests recent deformation and tectonic activity.

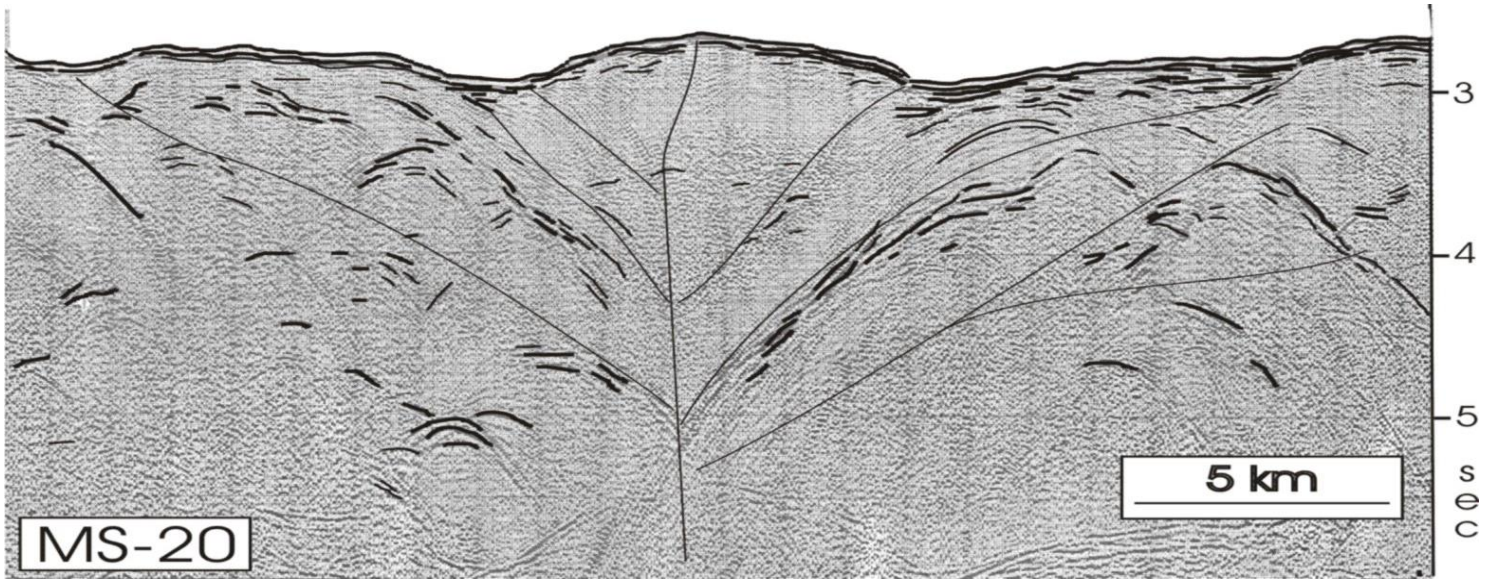
Regional Strike-slip and related *Riedel* structures

Time slice

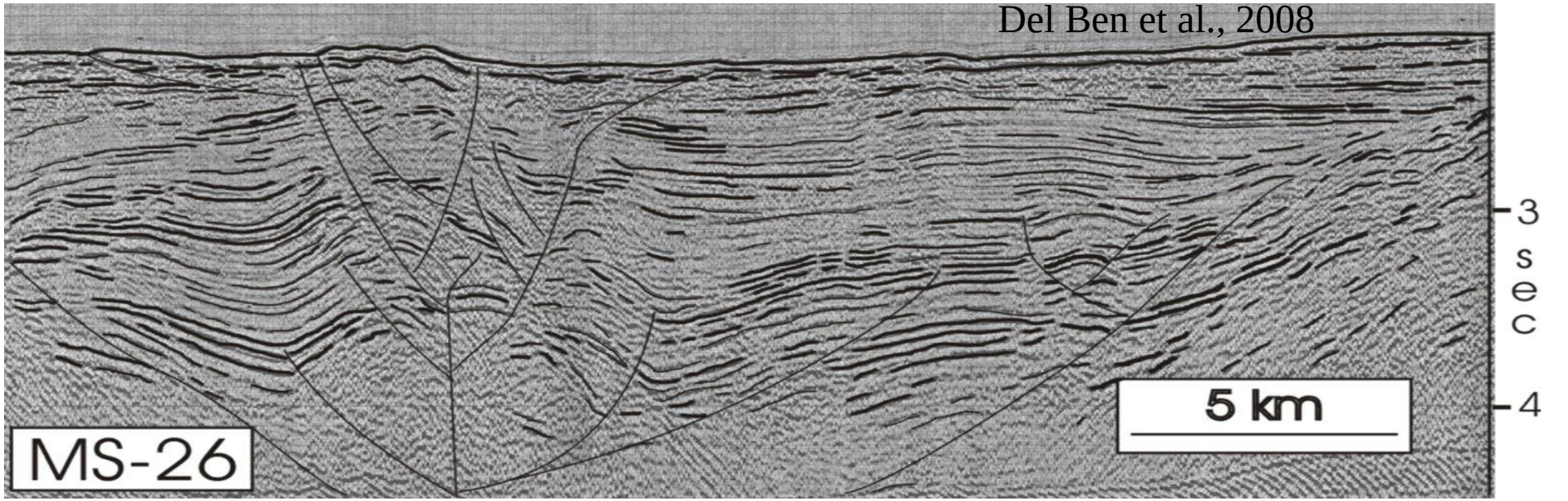
Seismic profile



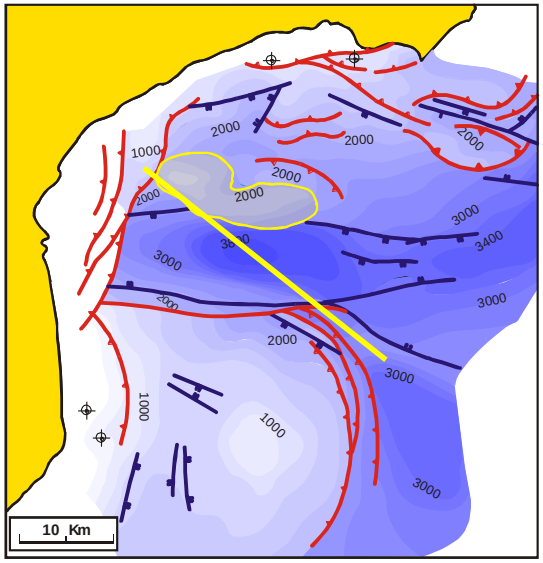
SS in the Calabrian Arc: transpression



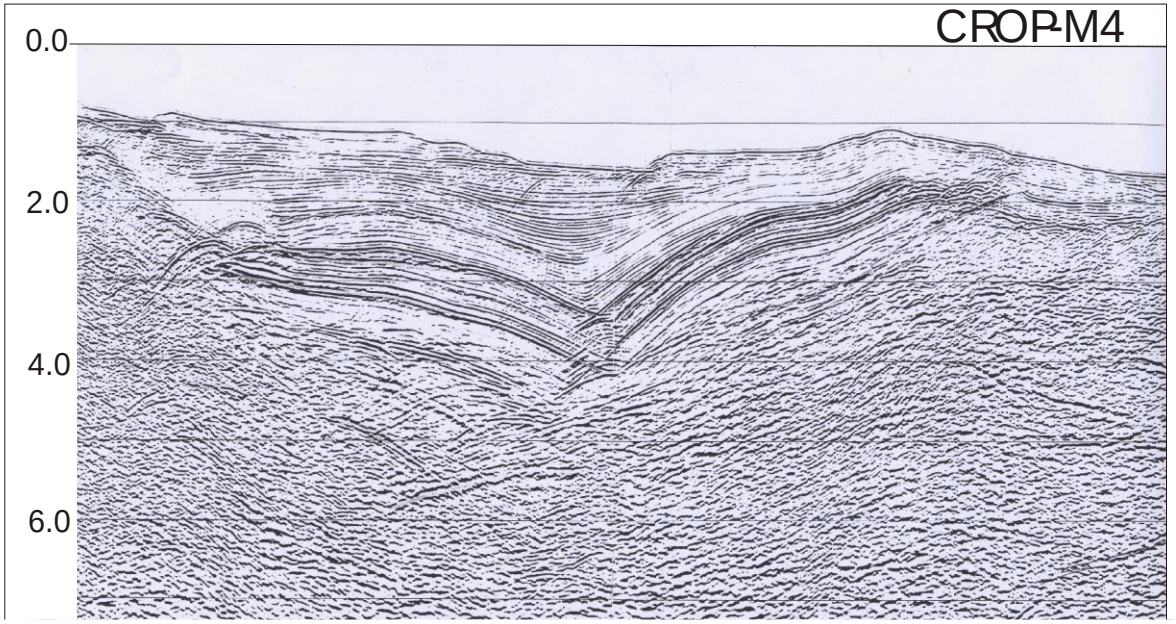
Del Ben et al., 2008

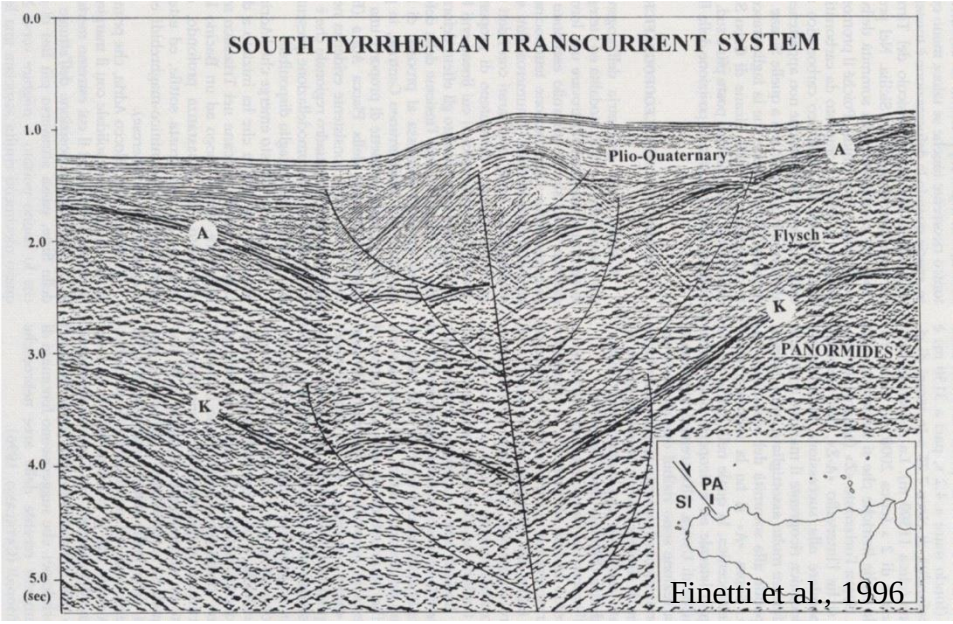


Strike-slip in the Calabrian Arc: recent/active transpression (positive flower deforms the sea bottom), following an older transtension (deeper negative flower)

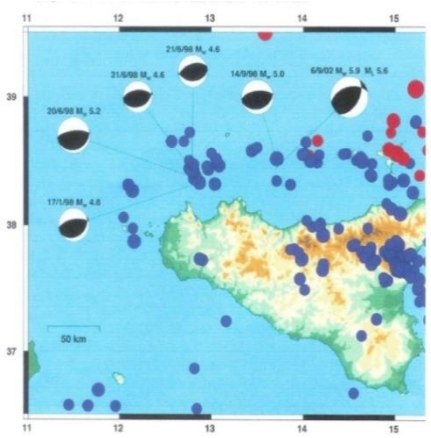


Calabrian Arc: transtension→

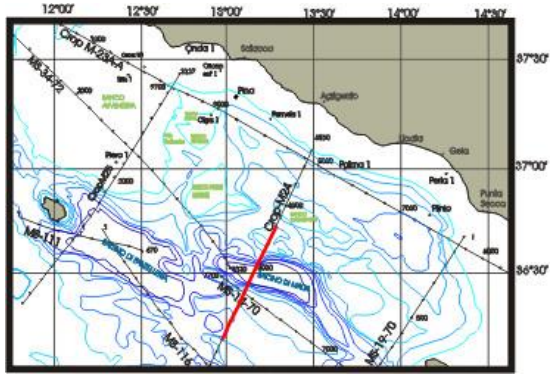




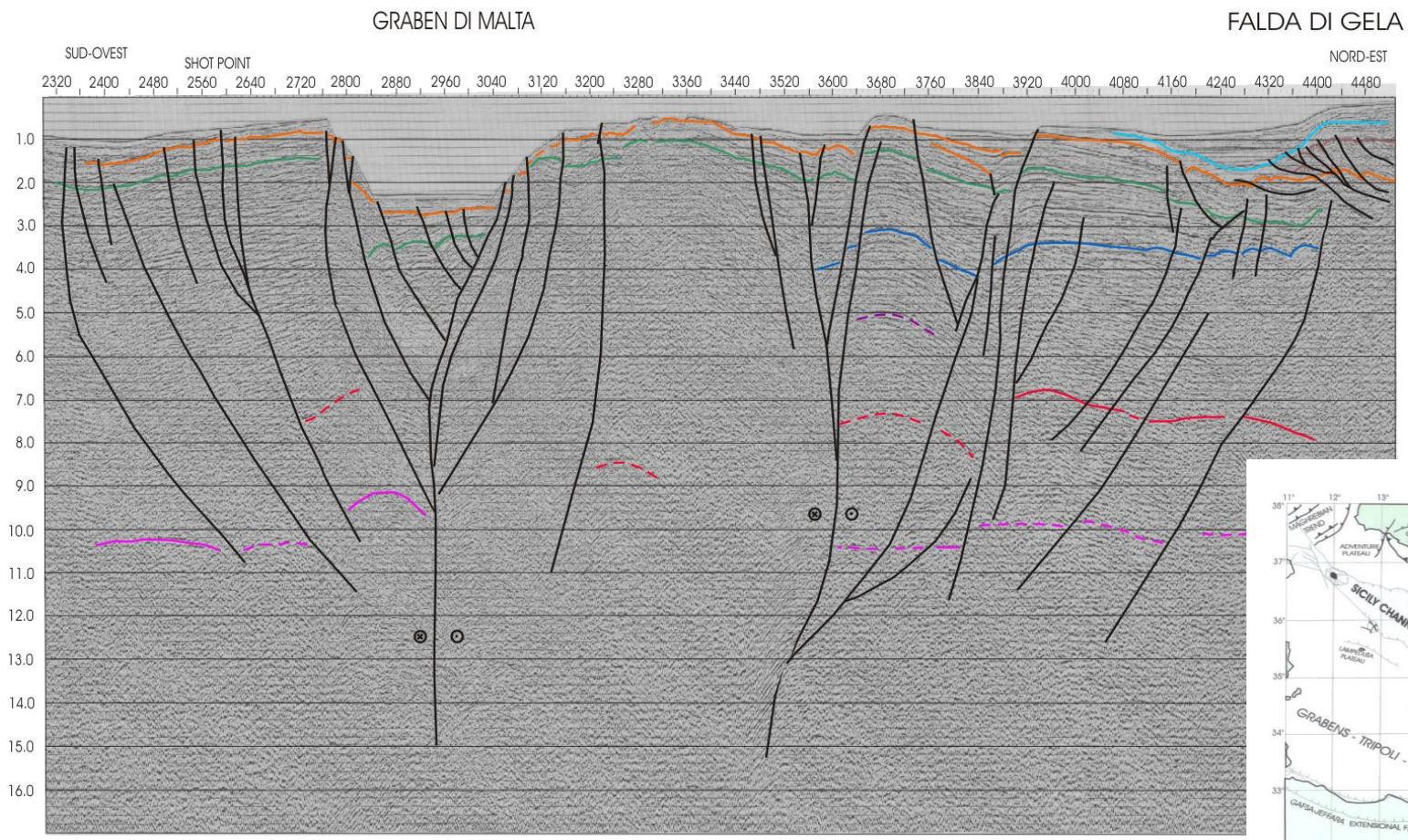
← SS in the south Tyrrhenian Sea: active transpression (?!). The focal mechanism evidence a regional compressive regime after a prevalent SS tectonics



Right SS System in the Sicily Channel: example of regional transtension



SEZIONE SISMICA CROP M 24 S.P. 2320-4480



Top Middle Pliocene

Ms

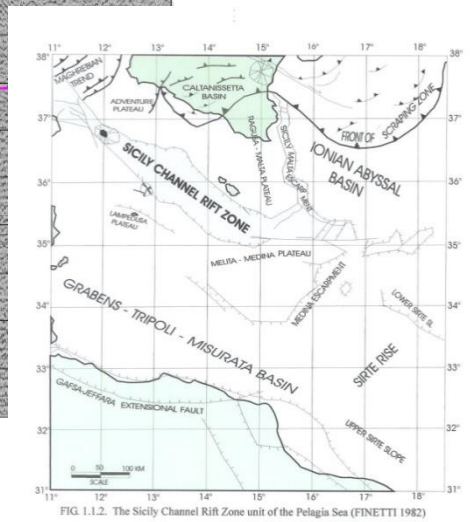
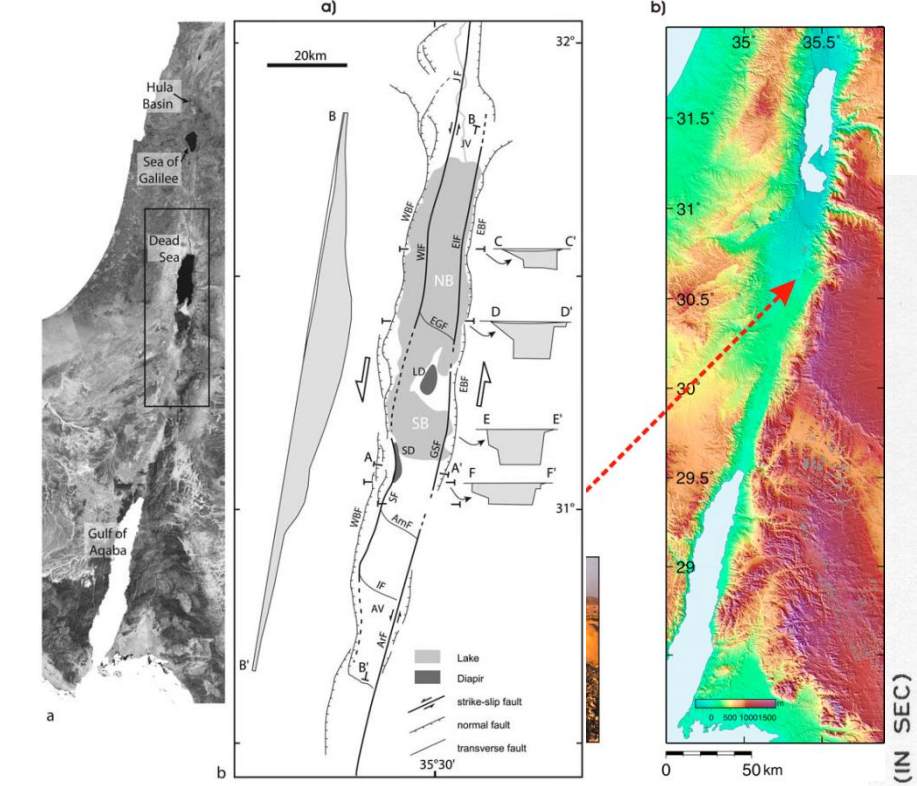
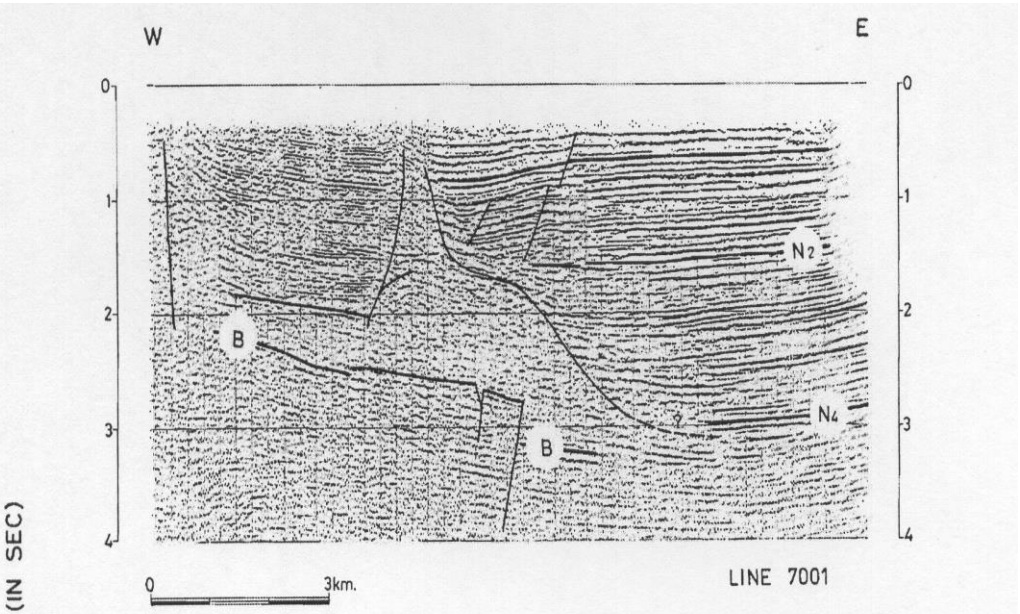


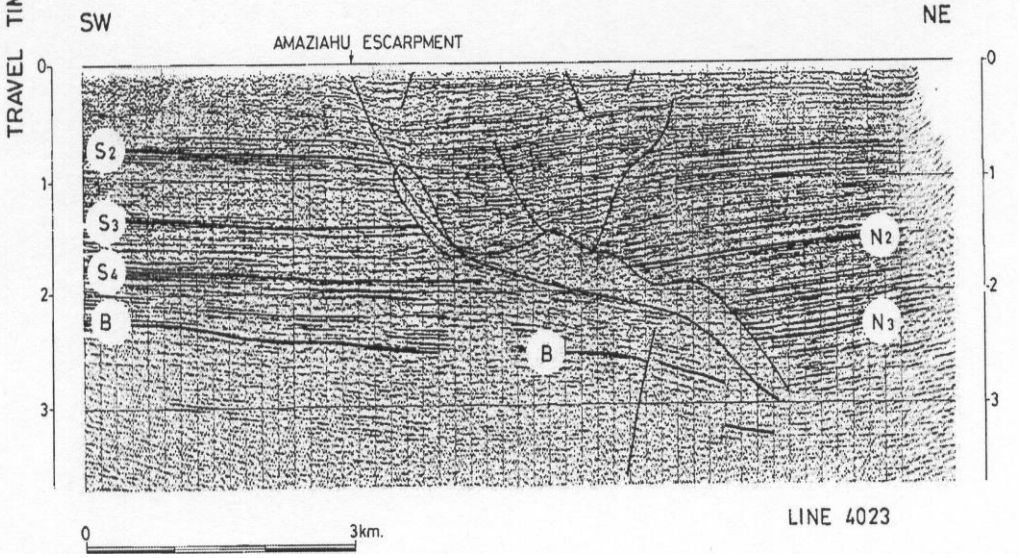
FIG. 1.1.2. The Sicily Channel Rift Zone unit of the Pelagia Sea (FINETTI 1982)

Strike-slip of the Death Sea

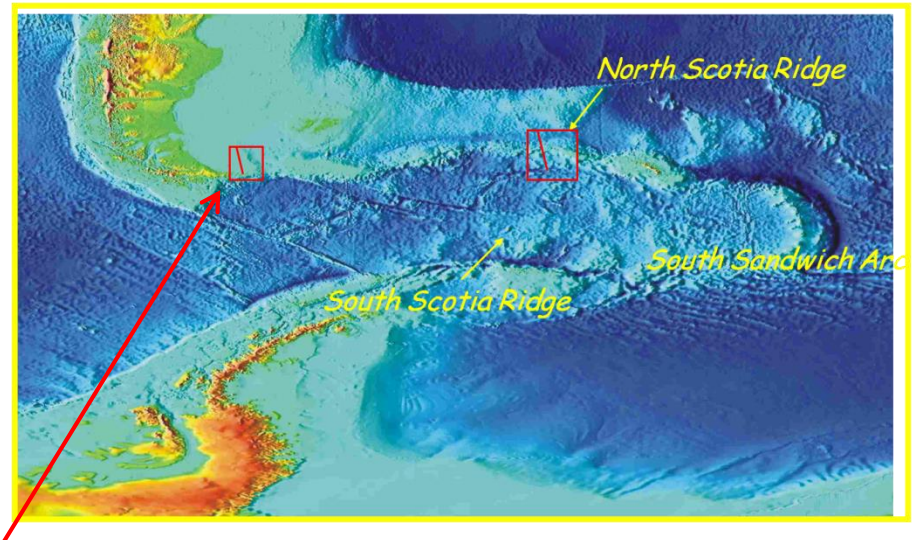
the strike-slip tectonic is not always clear:
there are not evidence of flower structures

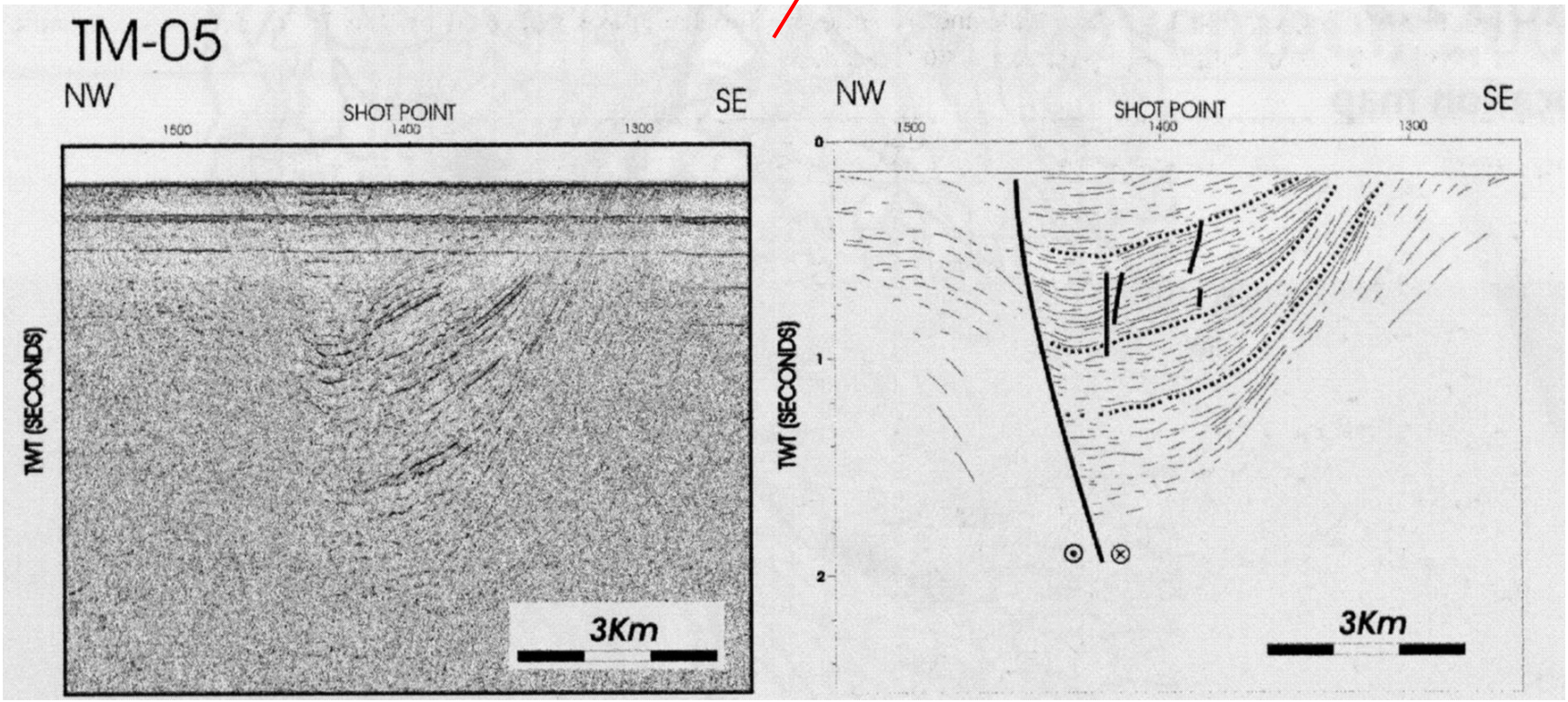




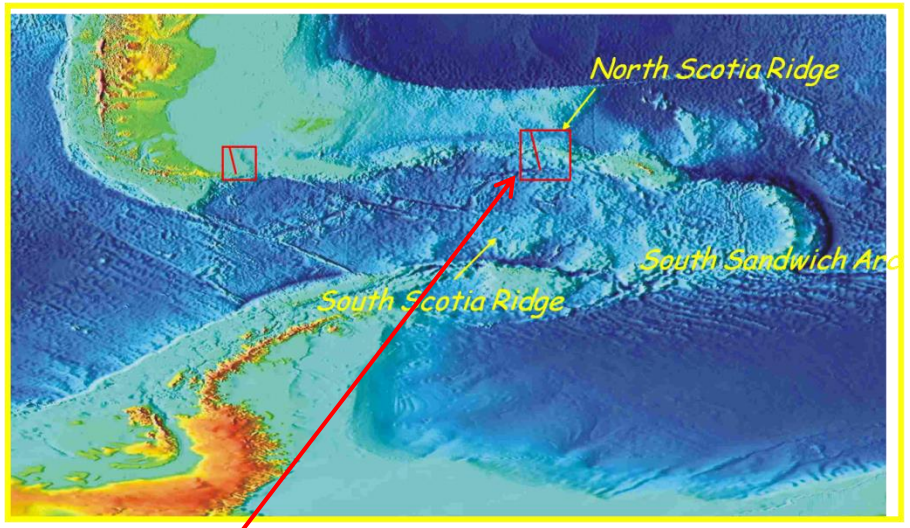


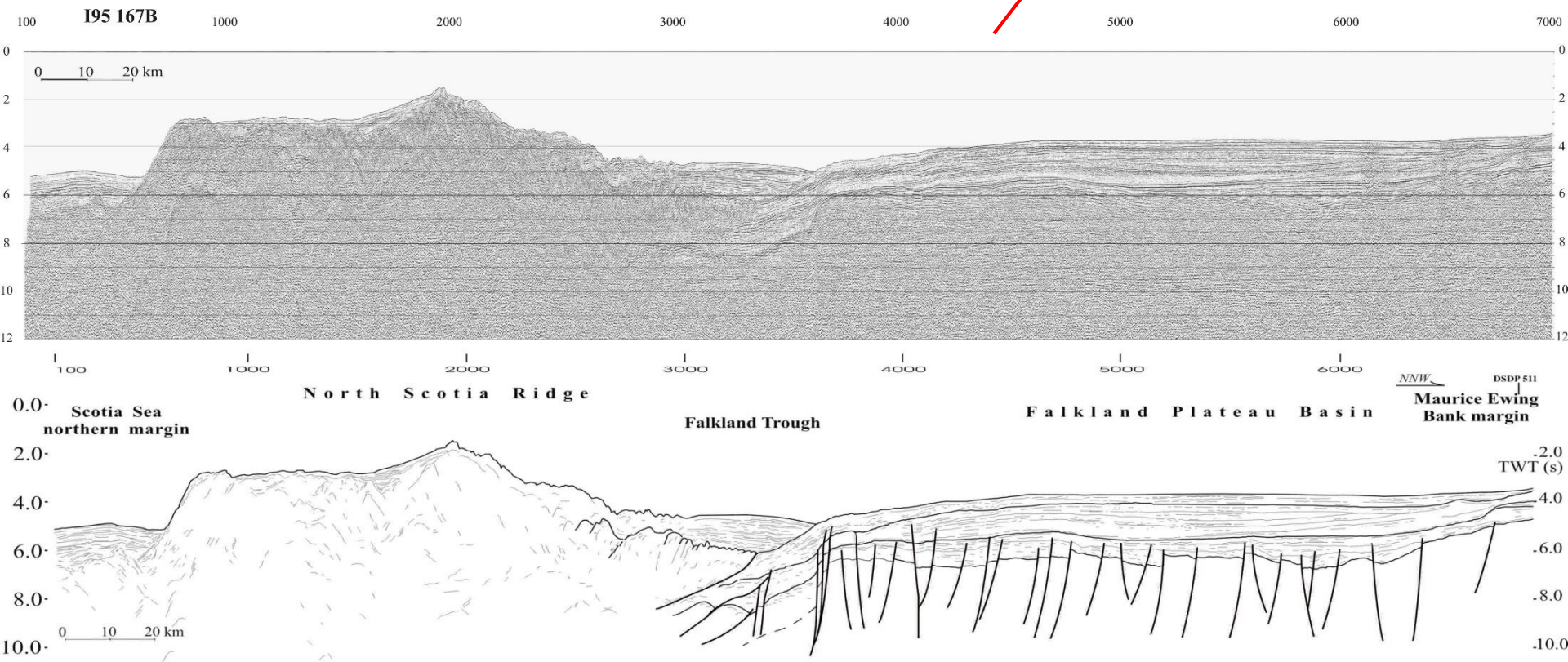
Trasforme sinistra del
North Scotia Ridge
in cui si ipotizza
tettonica di transtensione:
evidenze sismiche



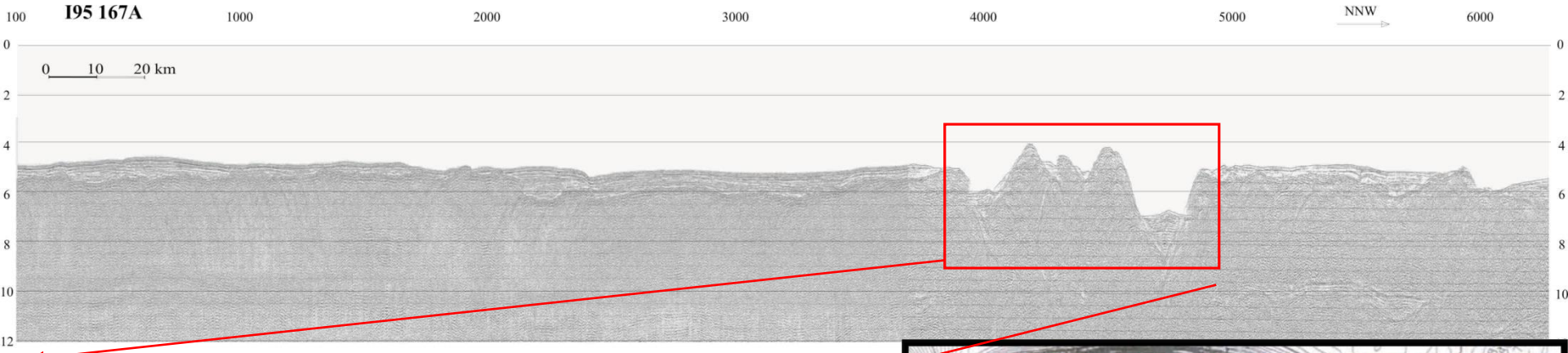


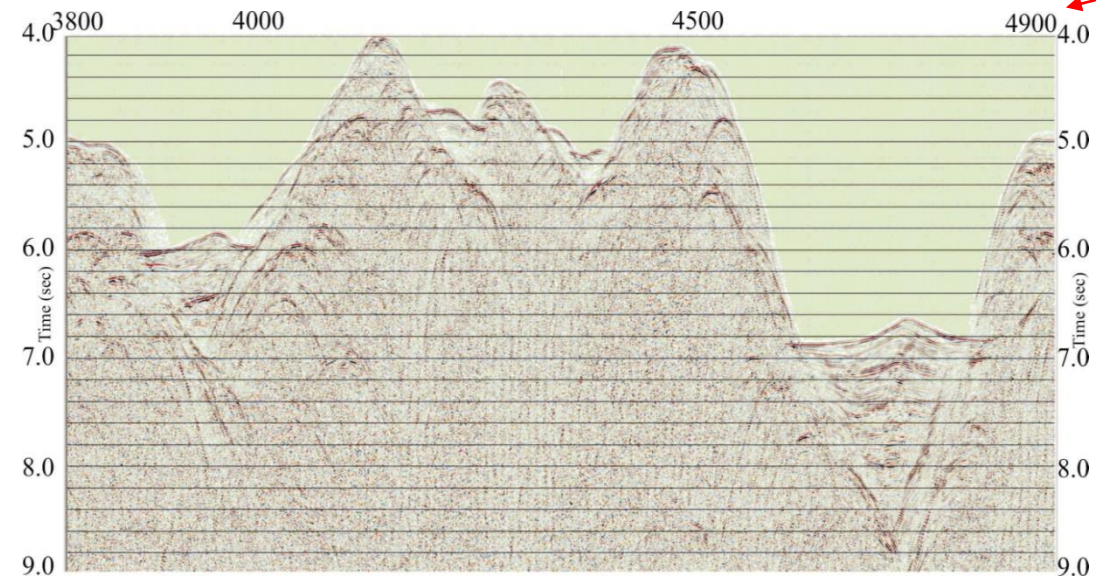
Trasforme sinistra del North Scotia Ridge: evidenze sismiche di transpressione

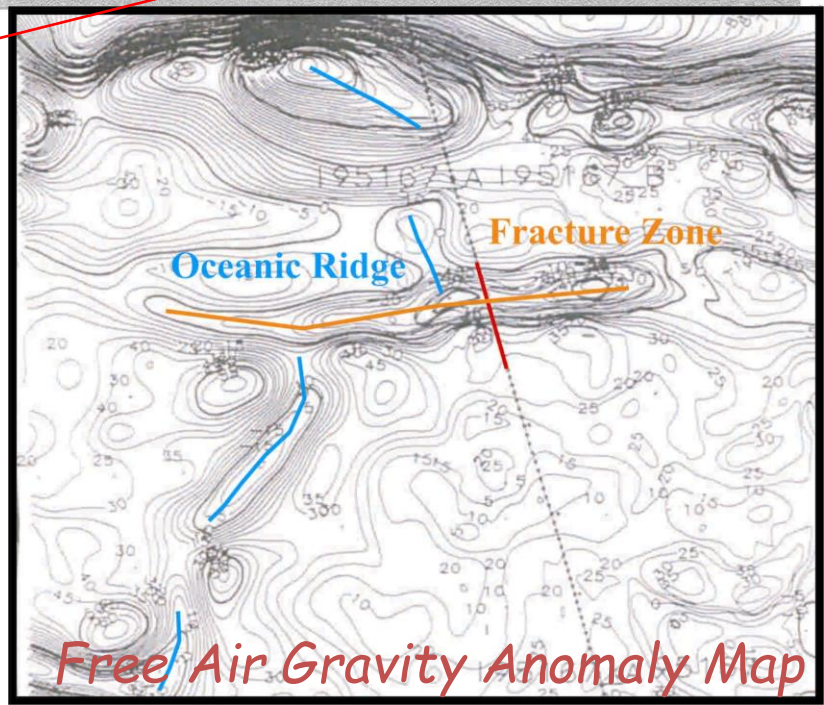




Trasforme trasversale al *ridge*, non più attivo, nella Placca dello *Scotia Sea*







INVERSION TECTONICS

Tectonic Inversion

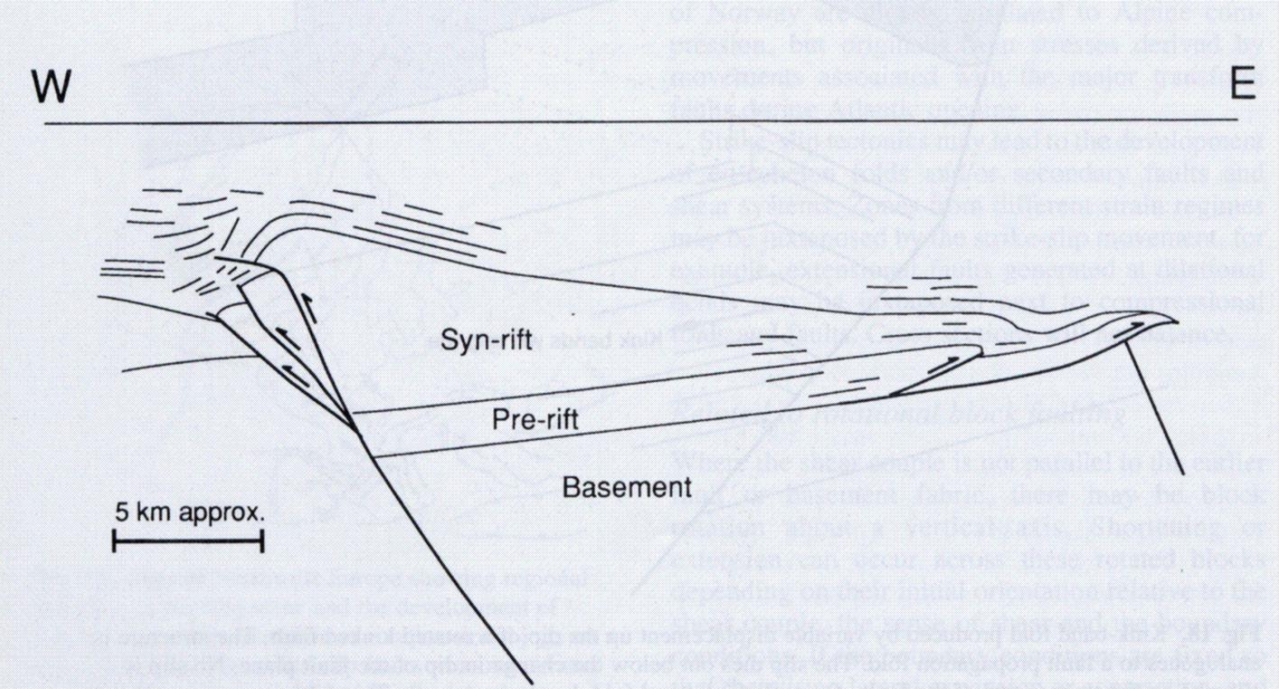


Fig 16. Sketch section through an inverted fault block showing the range of possible structures associated with rotation of a kinked fault.

The concept of tectonic inversion involves the reactivation of
- A normal fault through a compressive deformation: in this case we speak of Positive Tectonic Inversion (es. in the figure)
- A compressive fault through an extensional deformation: in this case we speak of Negative Tectonic Inversion

es. of Positive Tectonic Inversion

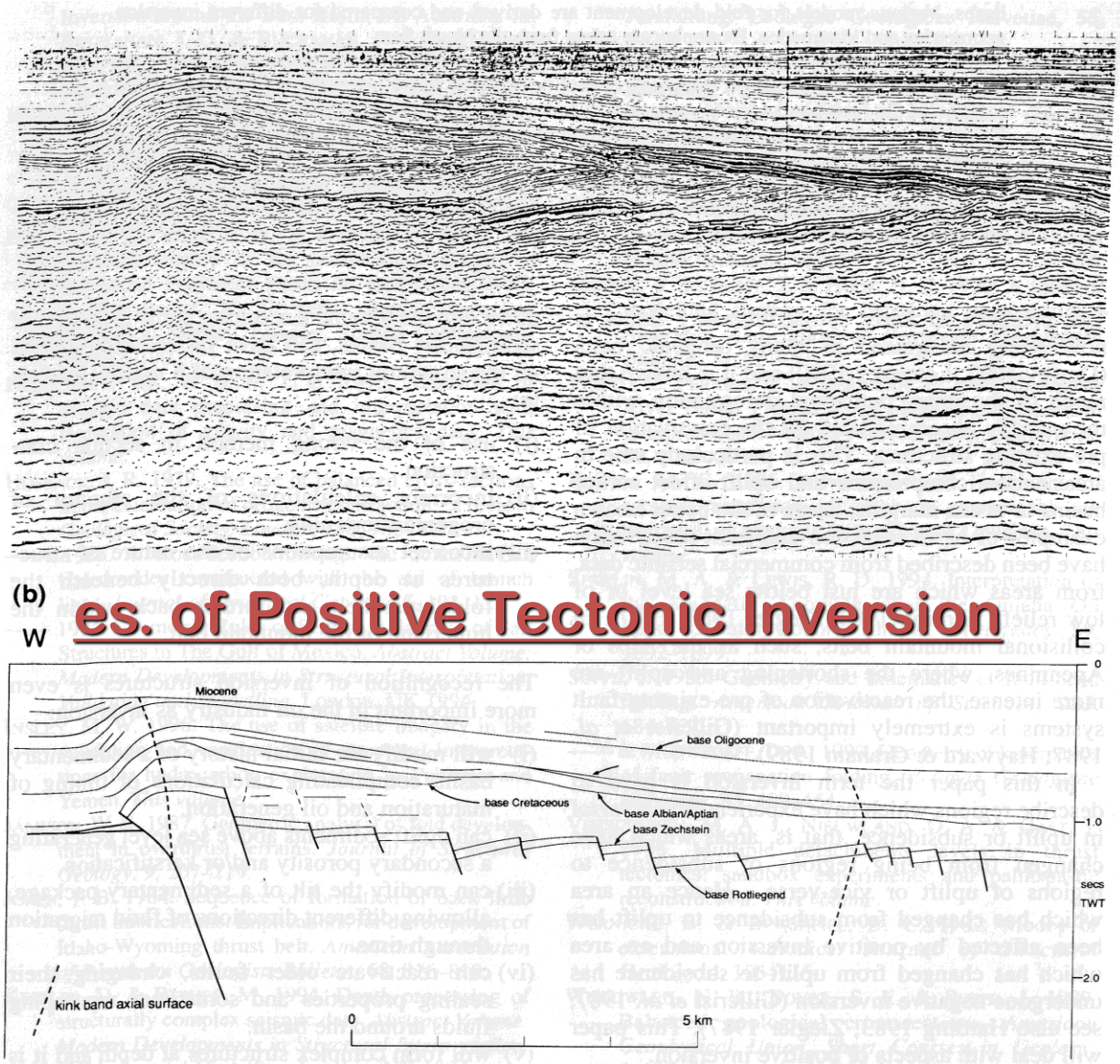


Fig. 1. An example of a fold produced by rotational faulting from the southern part of the North Sea. (**a**) Uninterpreted seismic data. (**b**) Line drawing showing the major stratigraphic picks. Note the long, gently-dipping back limb and the short hooked forelimb. (From the South Hewett Fault Zone. Drawn from Badley *et al.* 1989).

Tectonic Inversions are more likely to occur when:

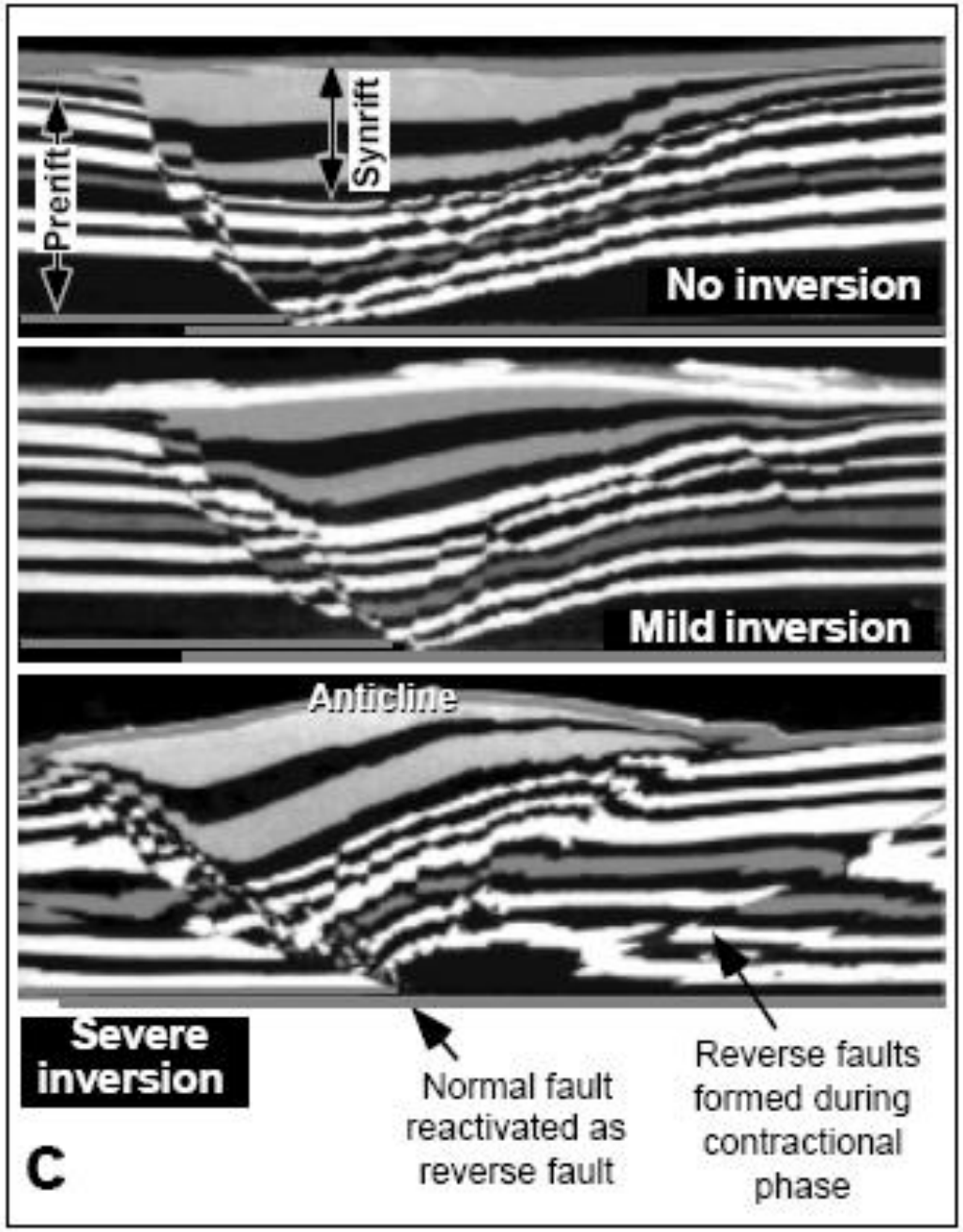
- Variation of the stress field following a variation in the motion of the plates;

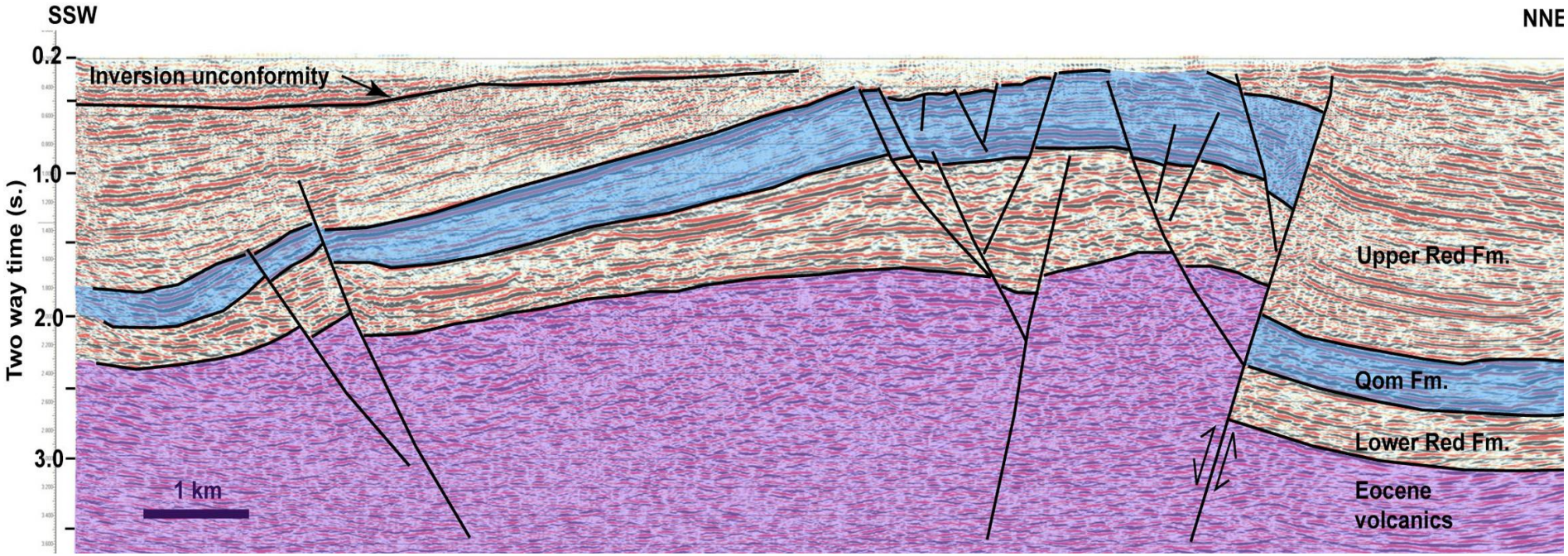
- Inversion resulting from subduction (extensional faults of the foreland inverted in compression when the foreland is involved in compressions);

-Inversion resulting from isostatic uplift;

-Inversion due to halokinesis;

- Inversion due to slumping.





Normal fault activity during deposition of the Lower Red and Qom Formations. Numerous secondary normal faults are present.

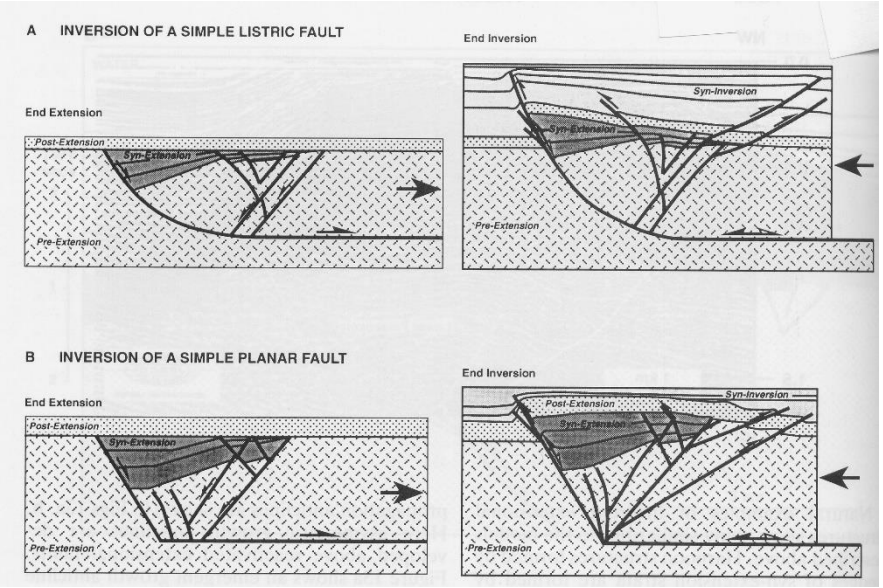
Inversion during deposition of the Upper Red Formation is clearly marked by a shallow angular unconformity present in the southern half of the seismic line.

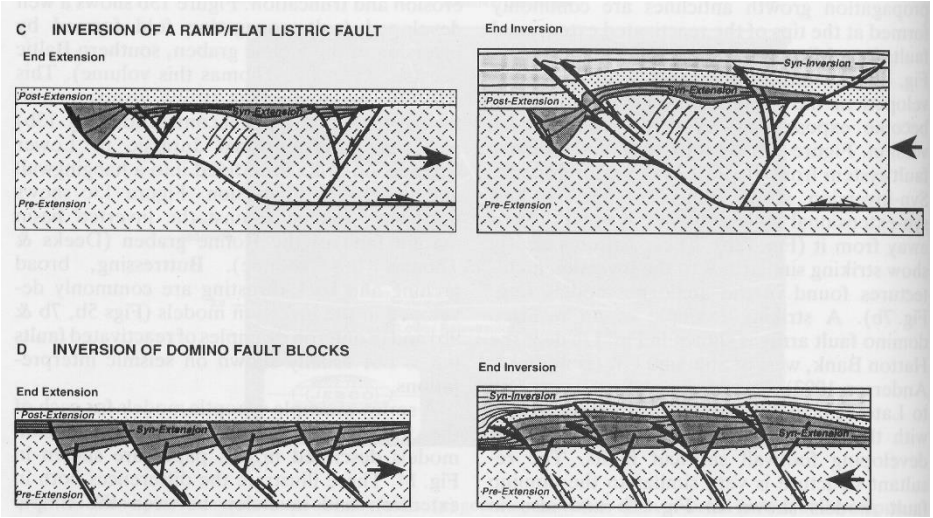
Image from Morley et al. (2009)

Structural development of a major Late Cenozoic basin and transpressional belt in Central Iran: the Central Basin in the Qom-Saveh area.

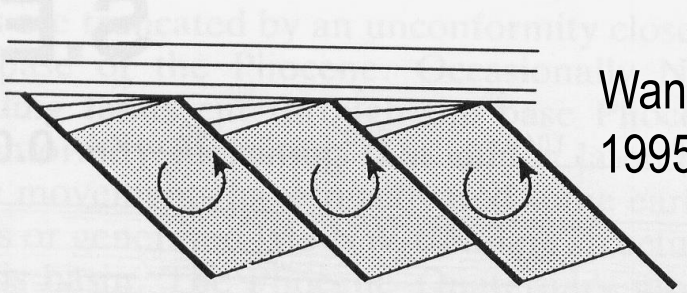
Virtual Seismic Atlas: www.seismicatlas.org

The geometries produced by the Tectonic Inversion directly depend on the geometries related to the previous tectonic phase

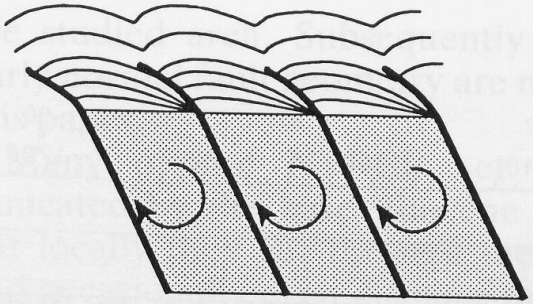




In the literature, the positive inversion prevails over the negative one:
this would be due, at least in part, to the better possibility of recognizing positive inversion along the seismic profiles.



Wang et al., 1995



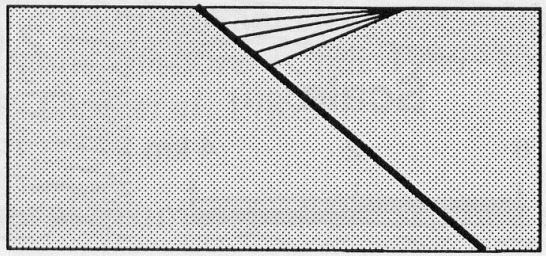
Rifting: Block Rotation

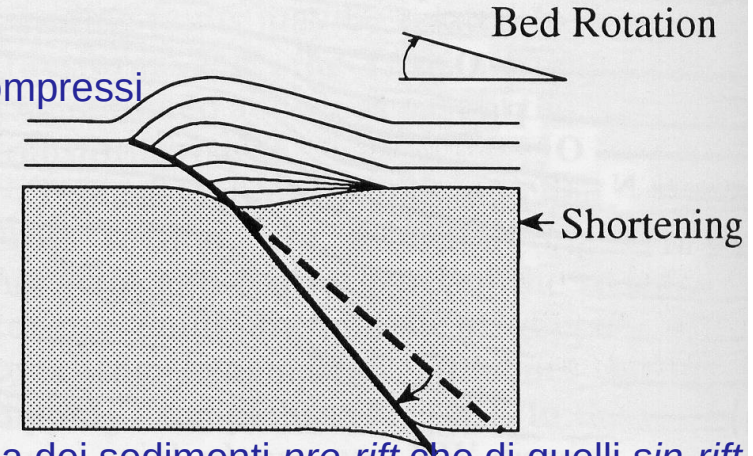
Pre-rift: block rotation and extension
Syn-rift: growth sedimentation

Inversion: Back Rotation

Pre-rift: reverse block rotation & contraction
Syn-rift: folding

Durante la *back-rotation* i sedimenti *sin-rift* saranno compressi in una serie di pieghe e faglie compressive.





Rotazione dell'*hangingwall*: comporta deformazione sia dei sedimenti *pre-rift* che di quelli *sin-rift*.

Rifting

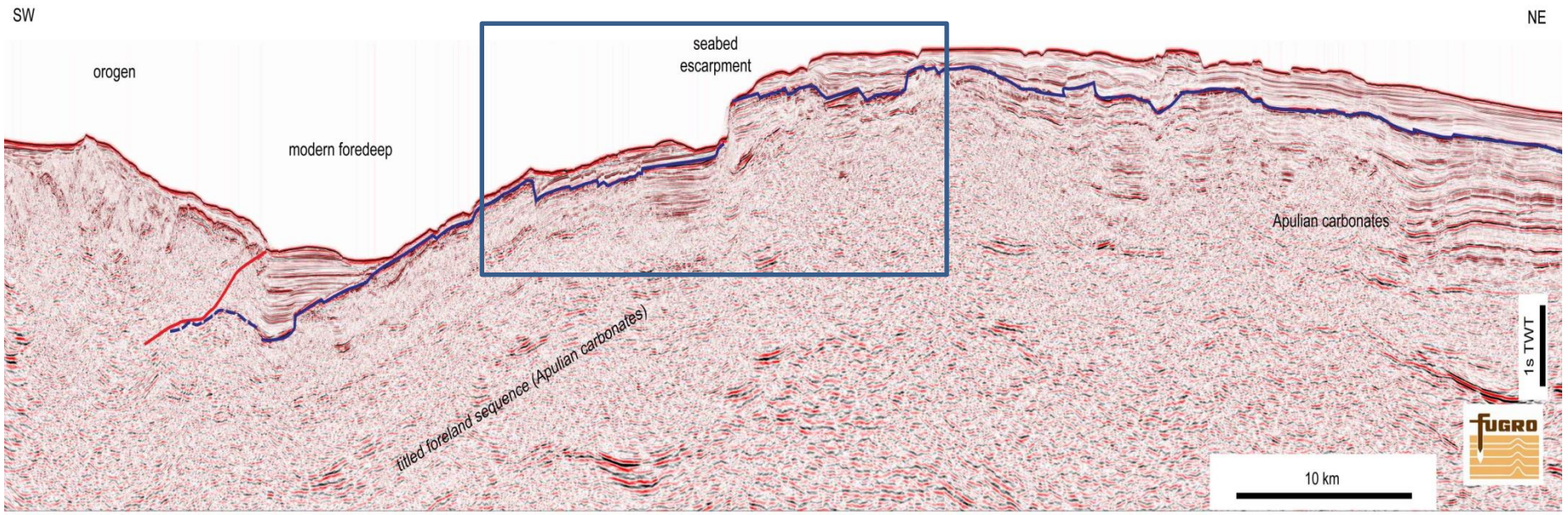
Pre-rift: extension
Syn-rift: growth sedimentation

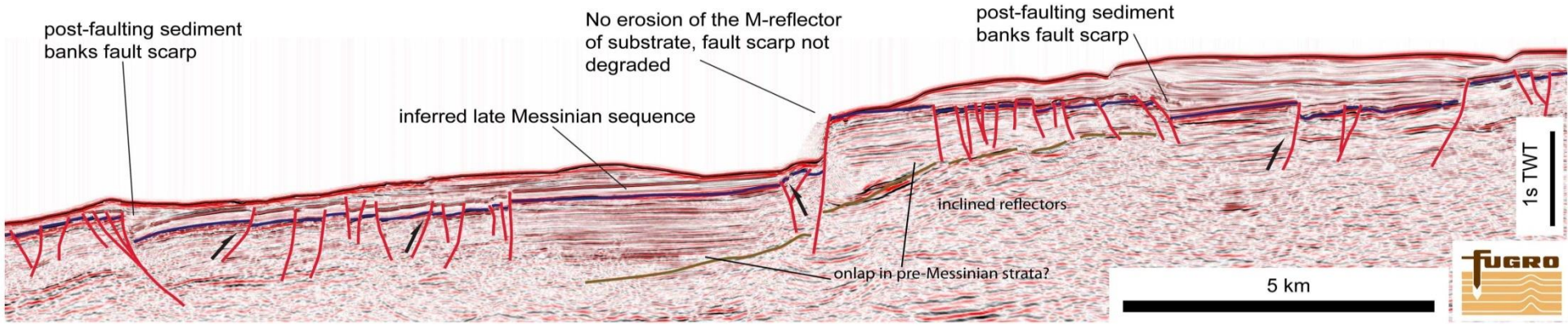
Wang et al., 1995

Inversion: Fault Block Flexural Cantilever

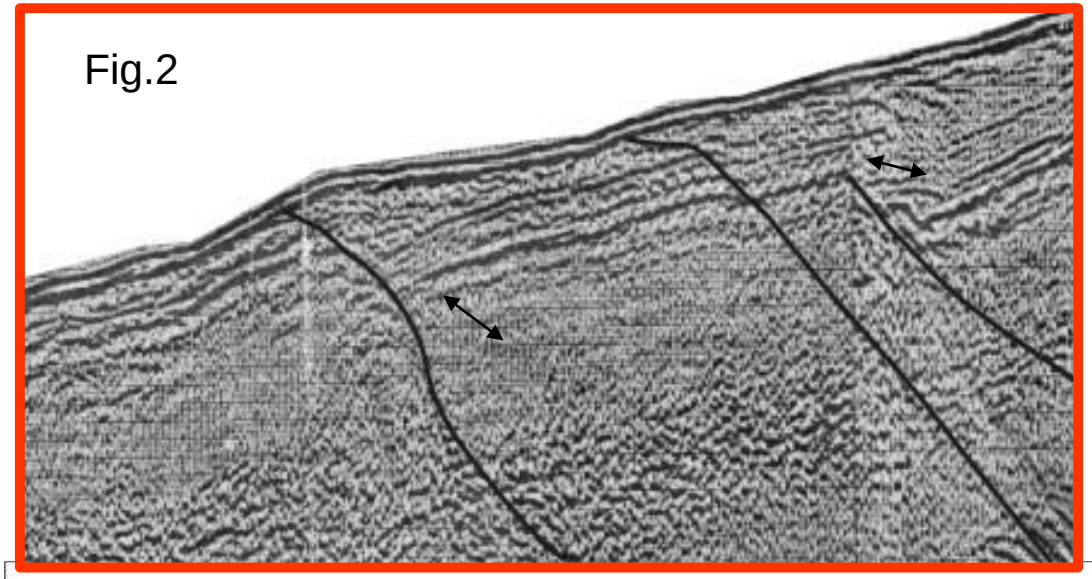
Pre-rift: contraction & cantilever flexure
Syn-rift: folding and rotation

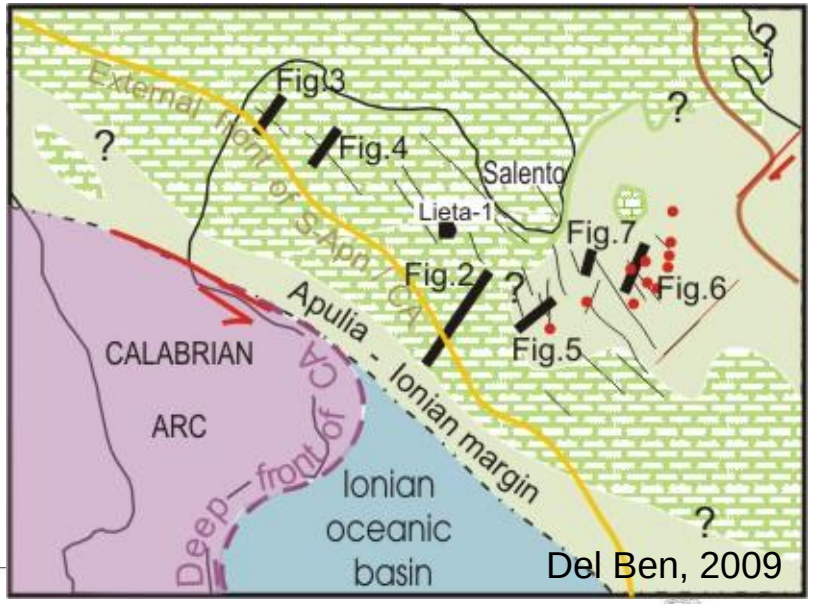
Ipotesi di inversione tettonica nell'avampaese Apulo





da Virtual Seismic Atlas:
www.seismicatlas.org



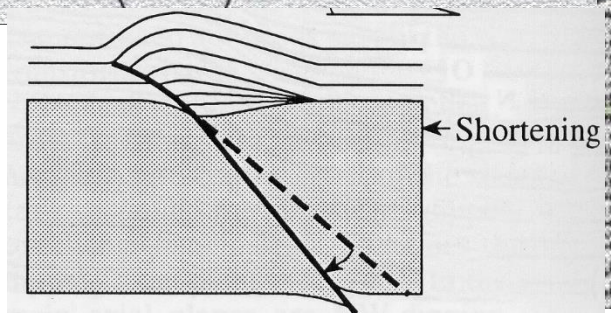


Fronte
Arco Calabro

10 km

Bacino di
foredeep
Plio-Quat.

Tilting e fratturazione
della Piattaforma Apula
nel post-Messiniano



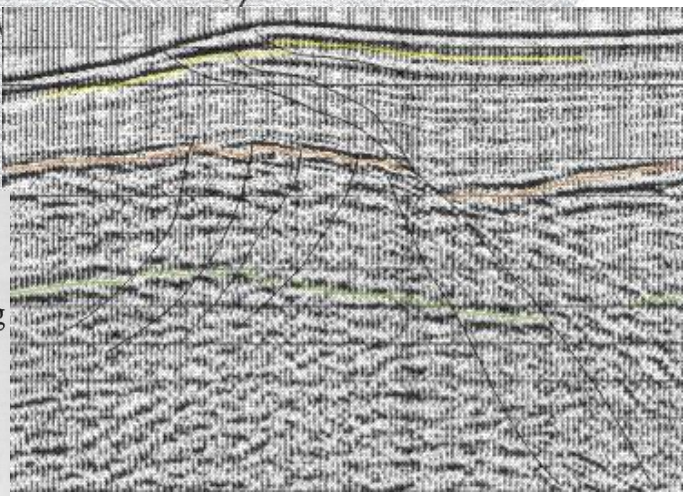
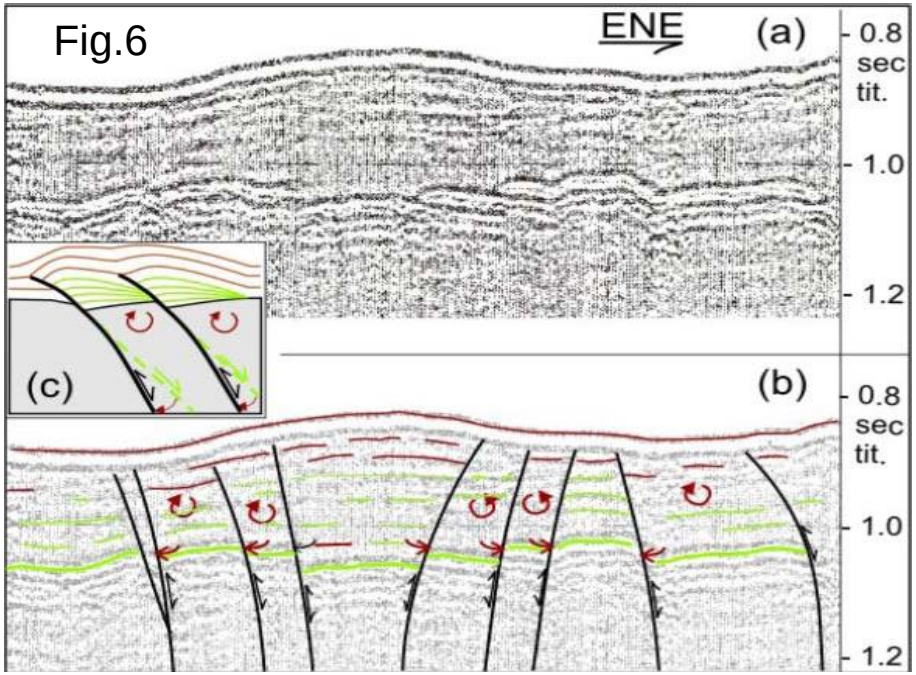
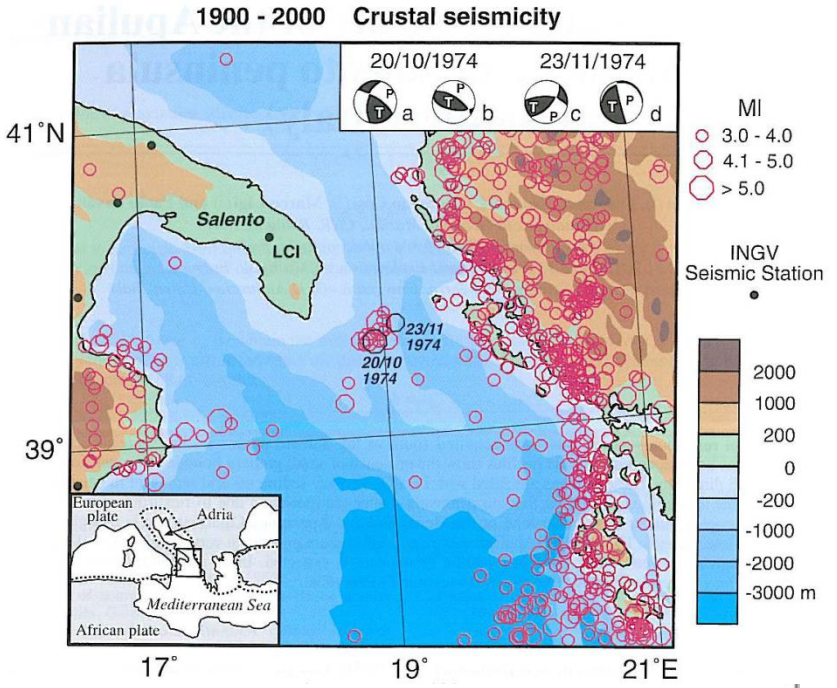
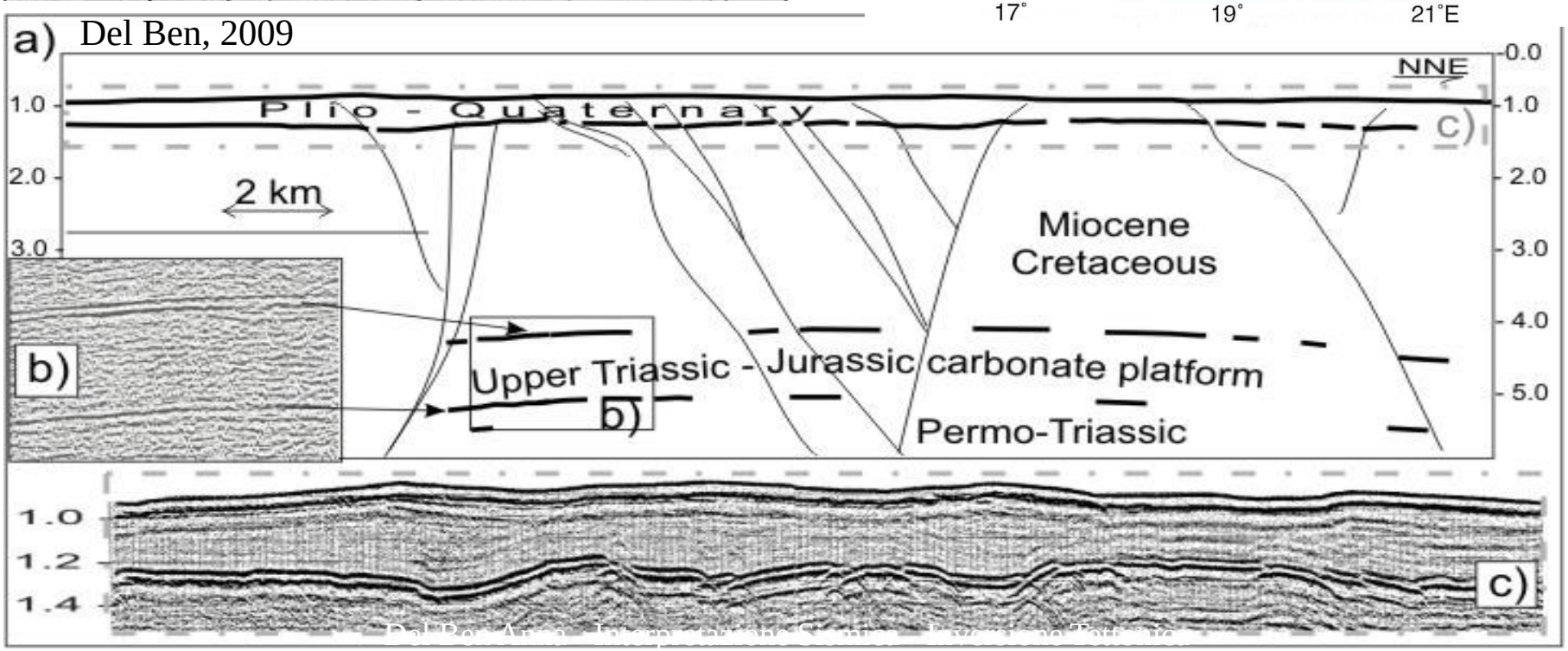
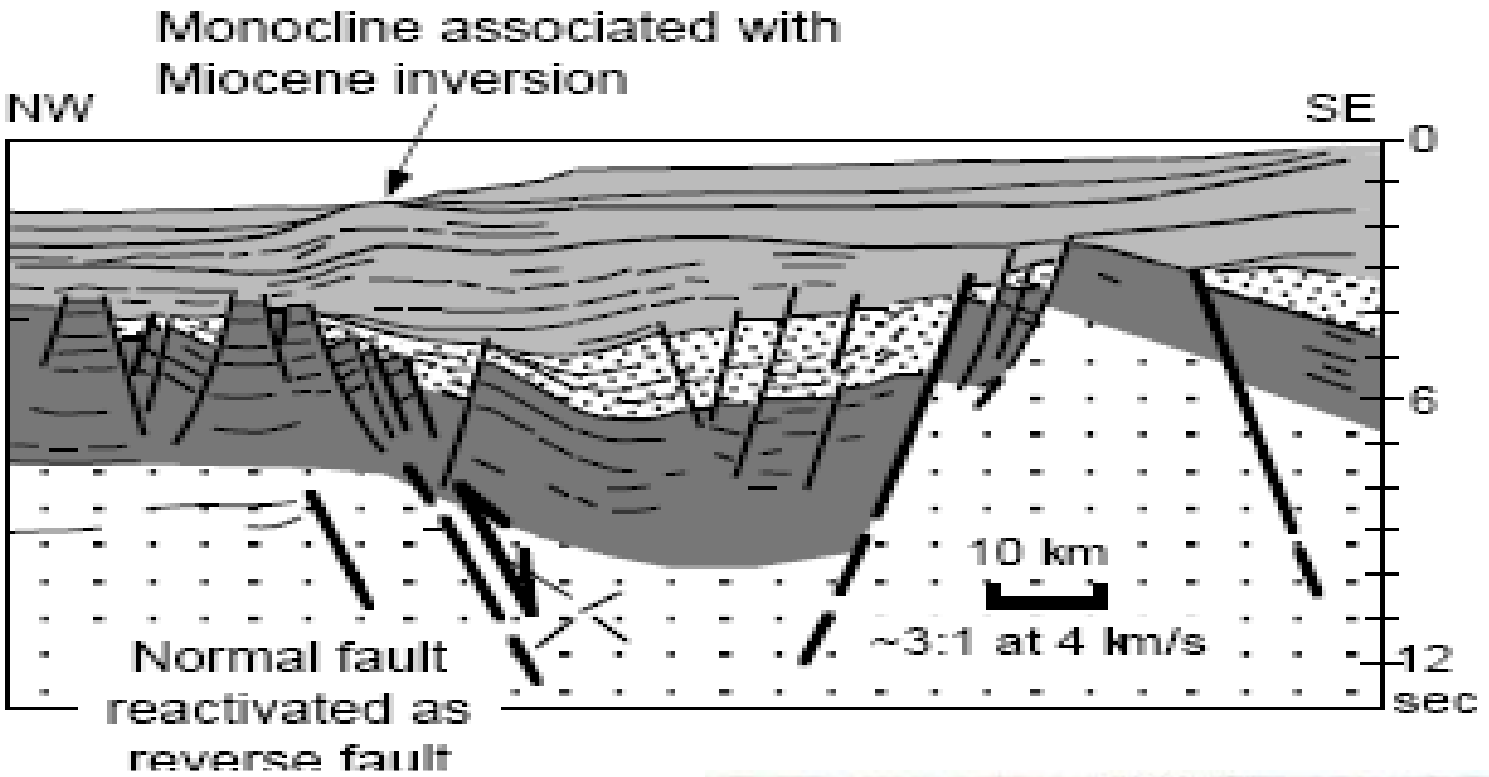


Fig.6

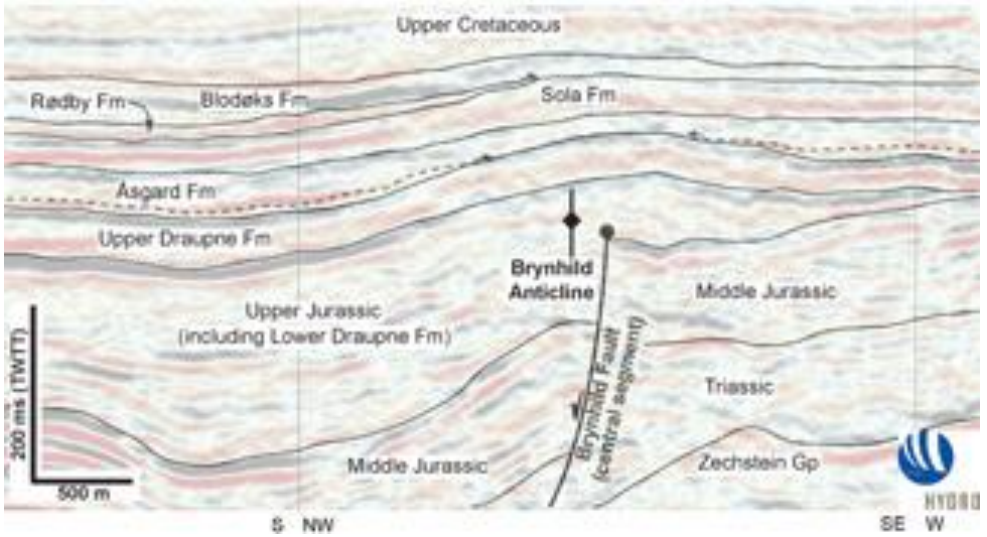

ENE
(a)
0.8 sec tit.
1.0
1.2
(c)
(b)
0.8 sec tit.
1.0
1.2


1900 - 2000 Crustal seismicity
20/10/1974
23/11/1974
a
b
c
d
Ml
3.0 - 4.0
4.1 - 5.0
> 5.0
INGV Seismic Station
2000
1000
200
0
-200
-1000
-2000
-3000 m
41°N
39°
Salento
LCI
23/11 1974
20/10 1974
European plate
Adria
Mediterranean Sea
African plate
17°
19°
21°E


a)
Del Ben, 2009
NNE
Plio - Quaternary
c)
2 km
Miocene
Cretaceous
b)
Upper Triassic - Jurassic carbonate platform
b)
Permo-Triassic
1.0
2.0
3.0
0.0
1.0
2.0
3.0
4.0
5.0
1.0
1.2
1.4
c)



There are many examples of reactivation of faults (planes of weakness) at all scales:
from lithospheric faults to faults or folds affecting a reduced part of the sedimentary series (as in the figure, in the more superficial plastic series).



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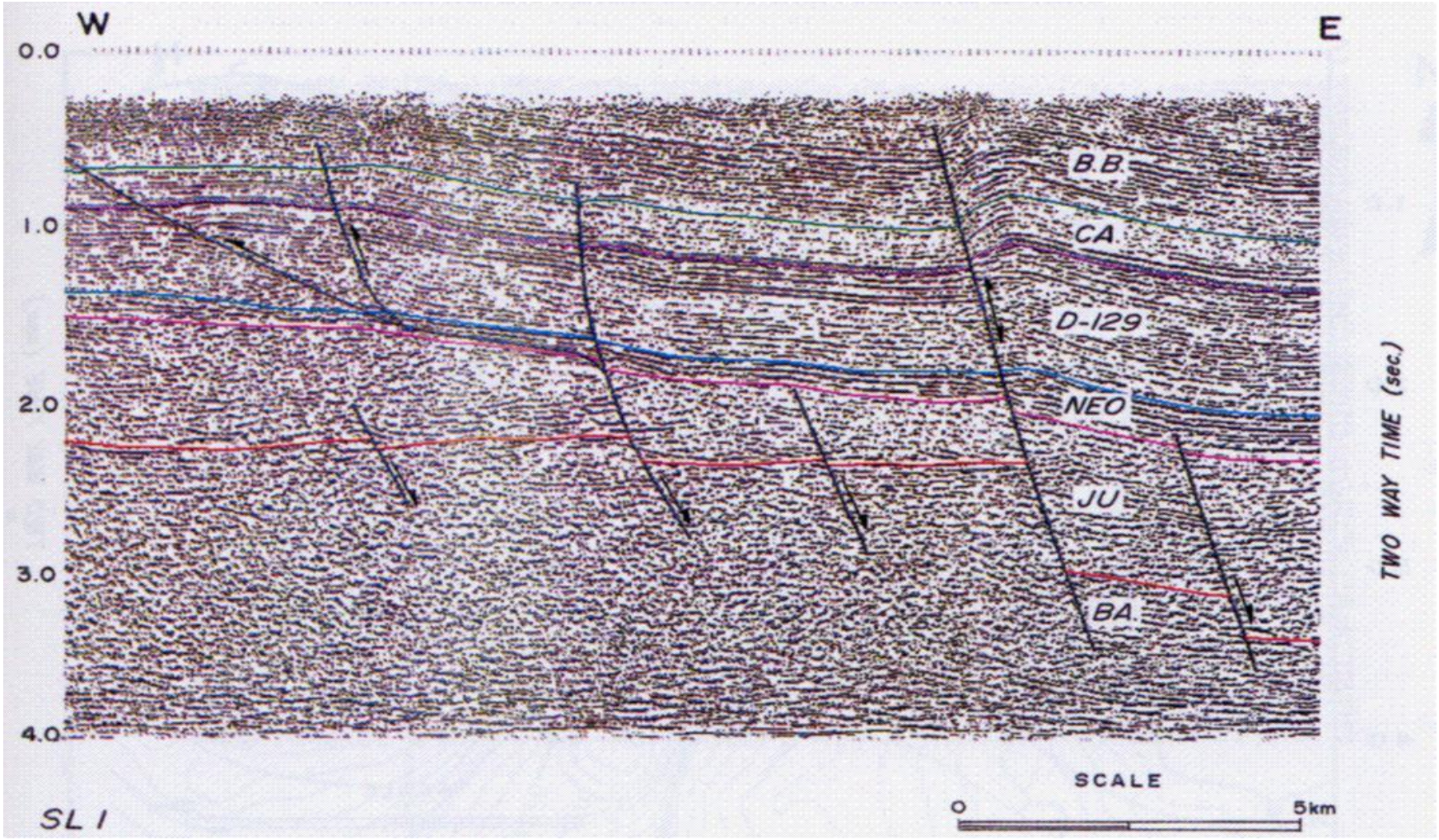
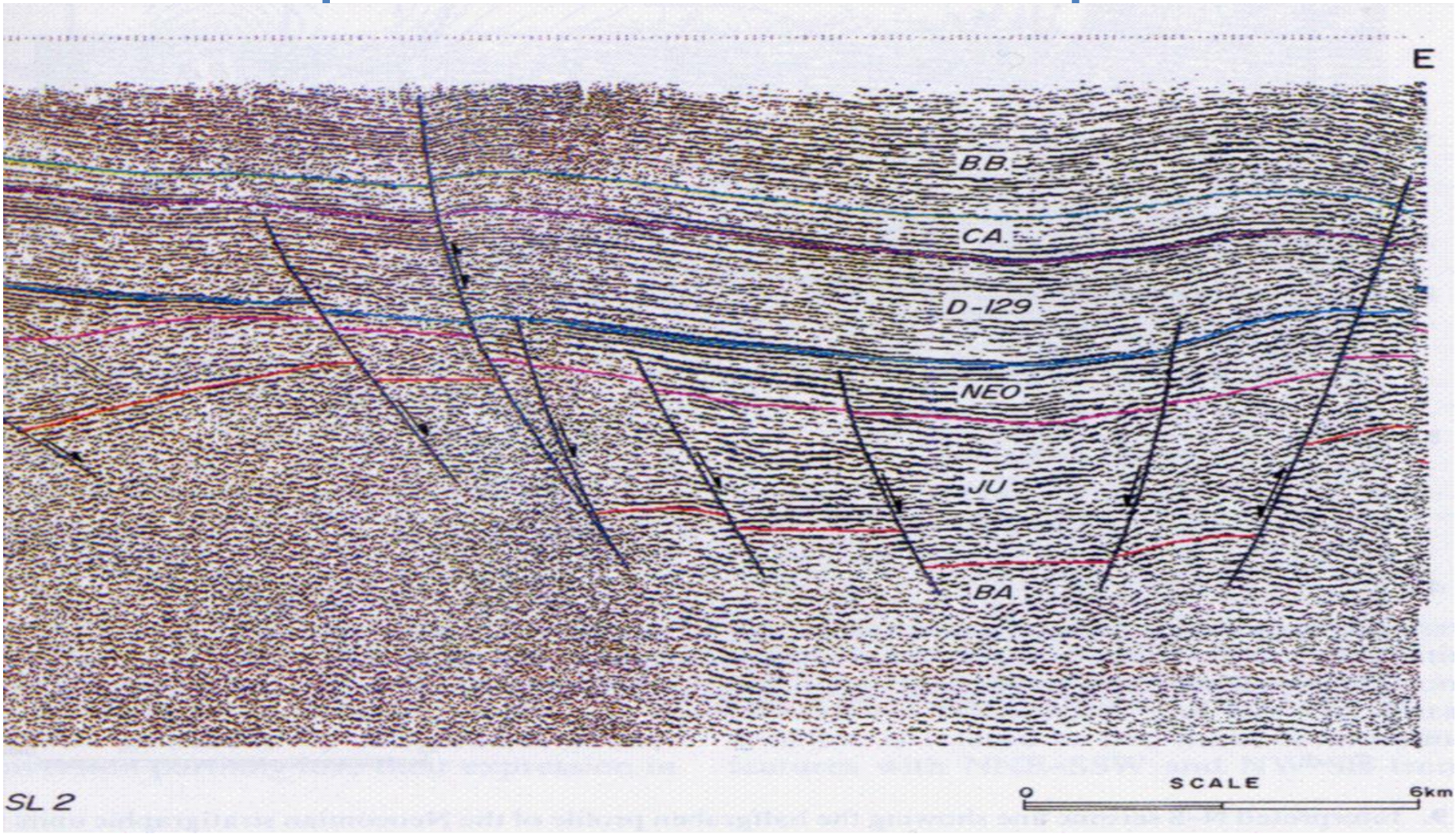
Tectonic Inversion



The tectonic inversion has been highlighted mainly when, during the first compressive phases of an orogen, the pre-existing normal faults of the basins are incorporated into the folds and thrust systems.

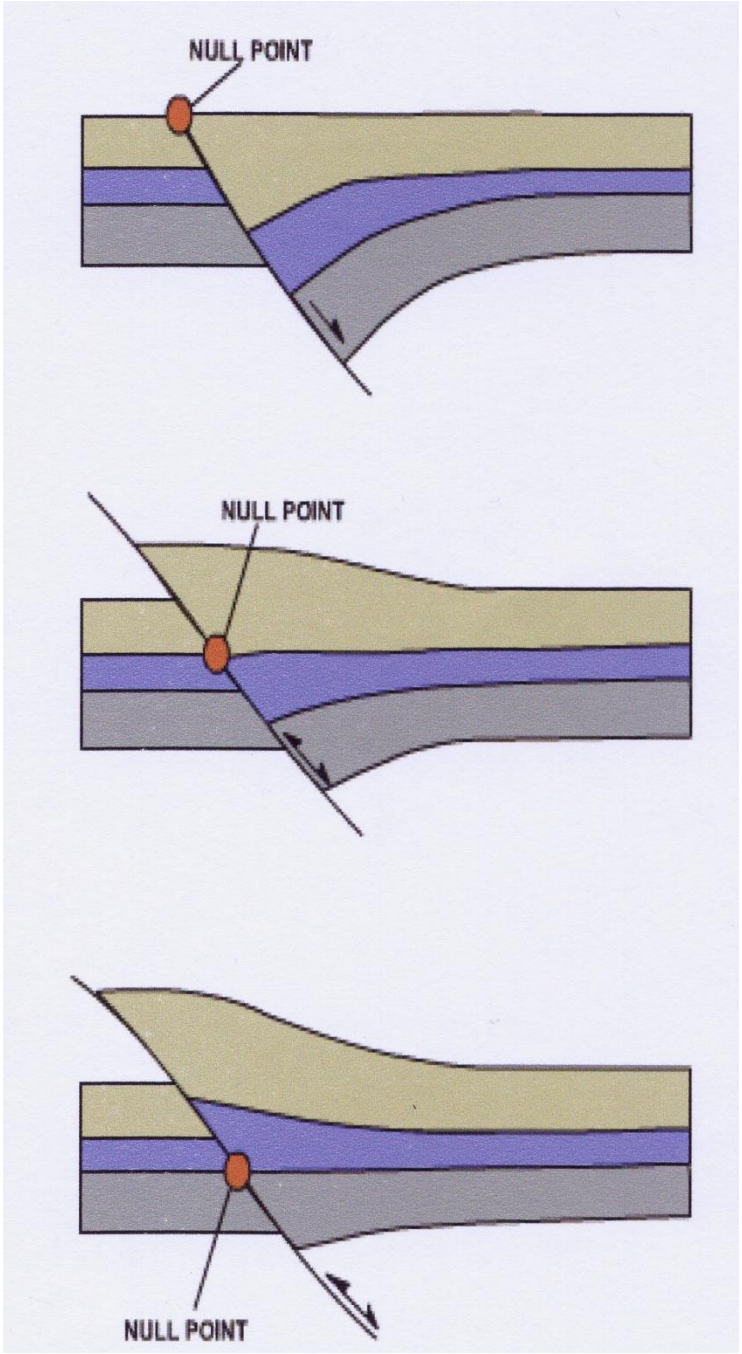
Esempio di inversione tettonica positiva



Here, the old faults, no more active, show extensional tectonics;
the only two faults still active, originally normal, show recent compressive tectonics.

Inversione is **total** when the sequence preceding the two tectonic phases, distinct and opposite, risults in a null throw.

Along the fault a **null point** exists where the throw is zero.
The null point clearly separates an underlying area, where distension is recognized (residual component of the first tectonic phase), from an above, where compression is recognized (vice versa in the negative inversion).
(viceversa nell'inversione negativa).



The geometric elements associated with the tectonic inversion are:

- Fold Growth (anticline above the reactivated fault)

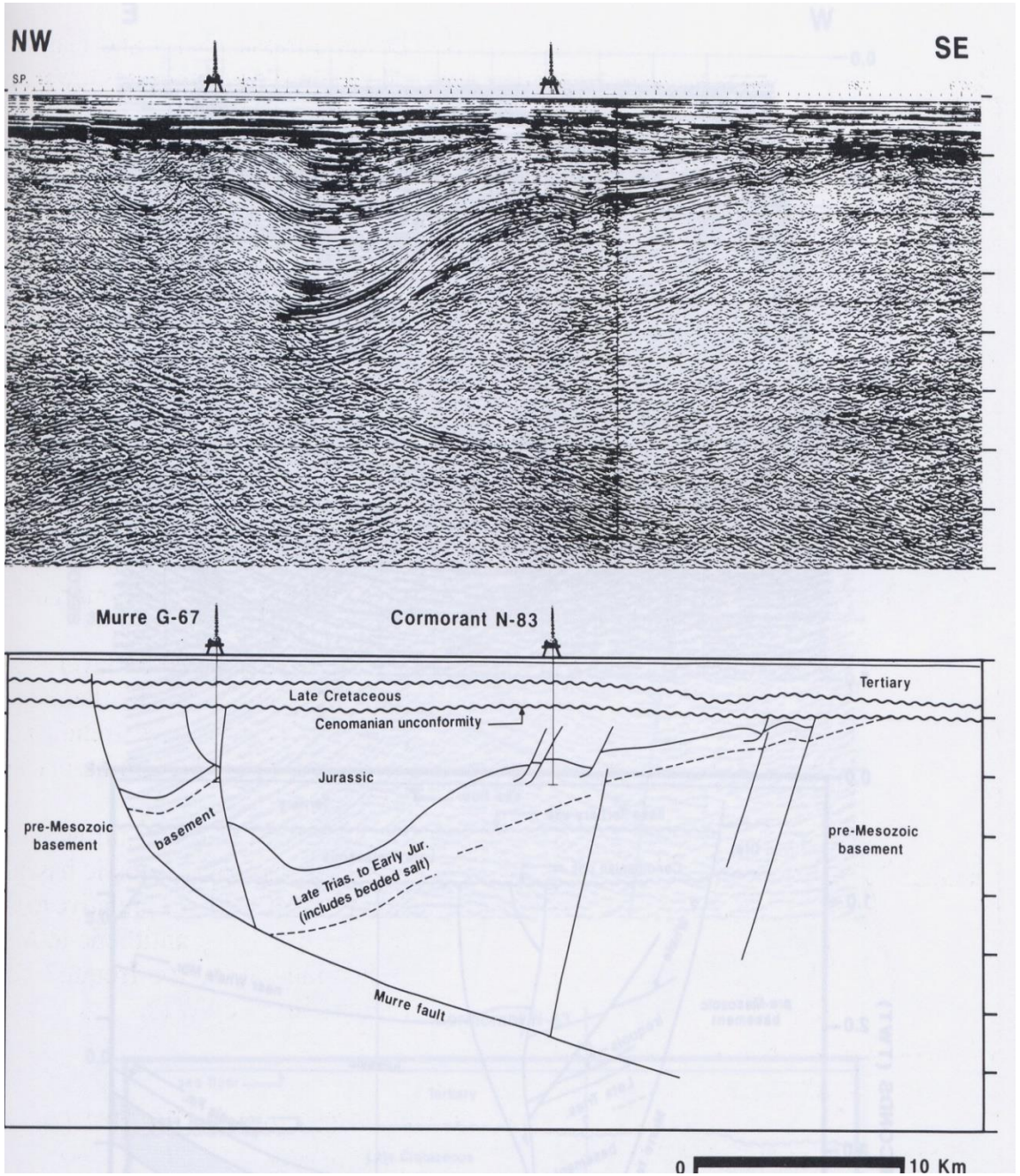
- Displacement of the depocenter away from the fault

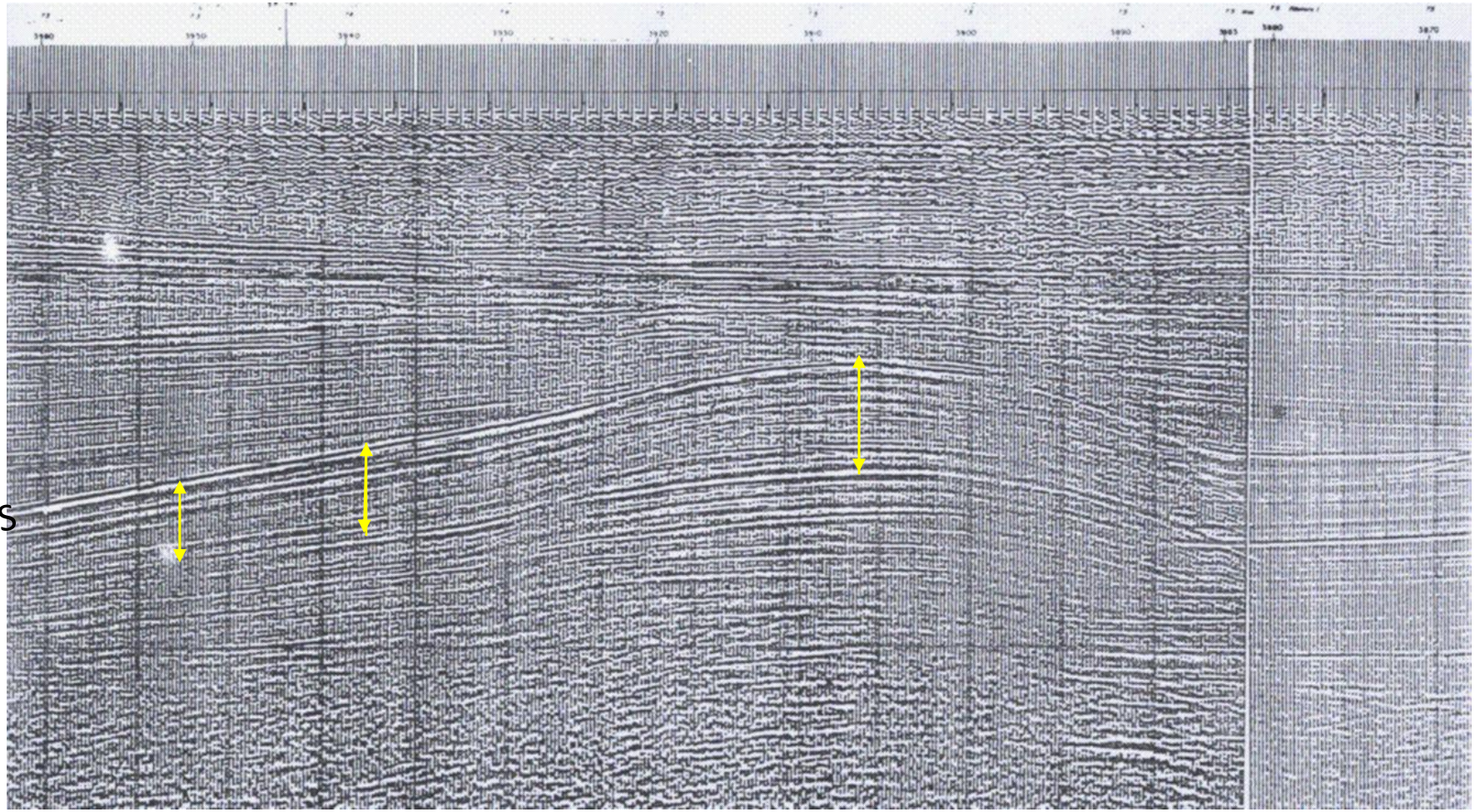
- Wide arching and uplift

- Inversion of tilting in faulted blocks

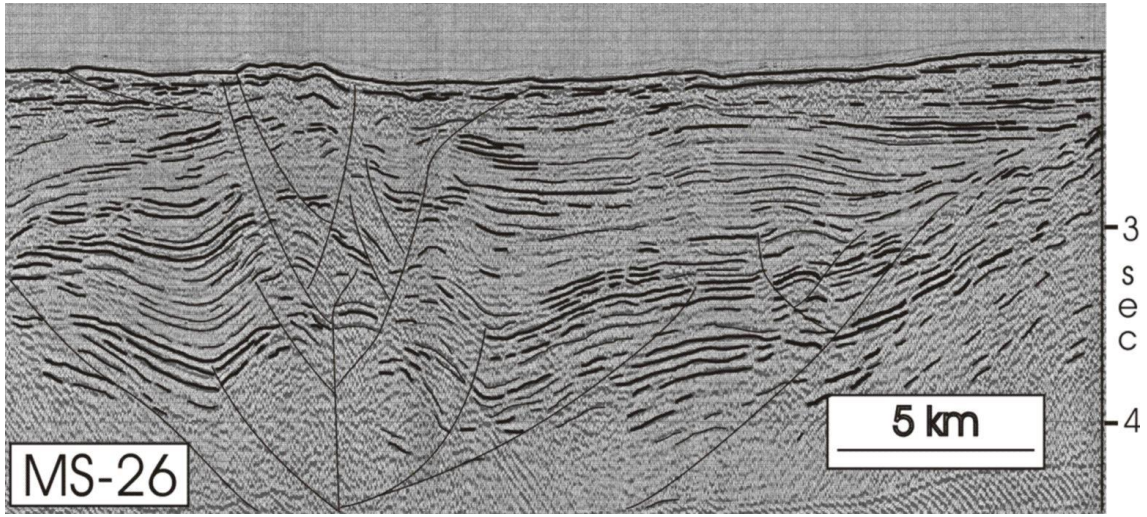
- Presence of back-thrust

- "Pop-up" structures developed against the spreading fault

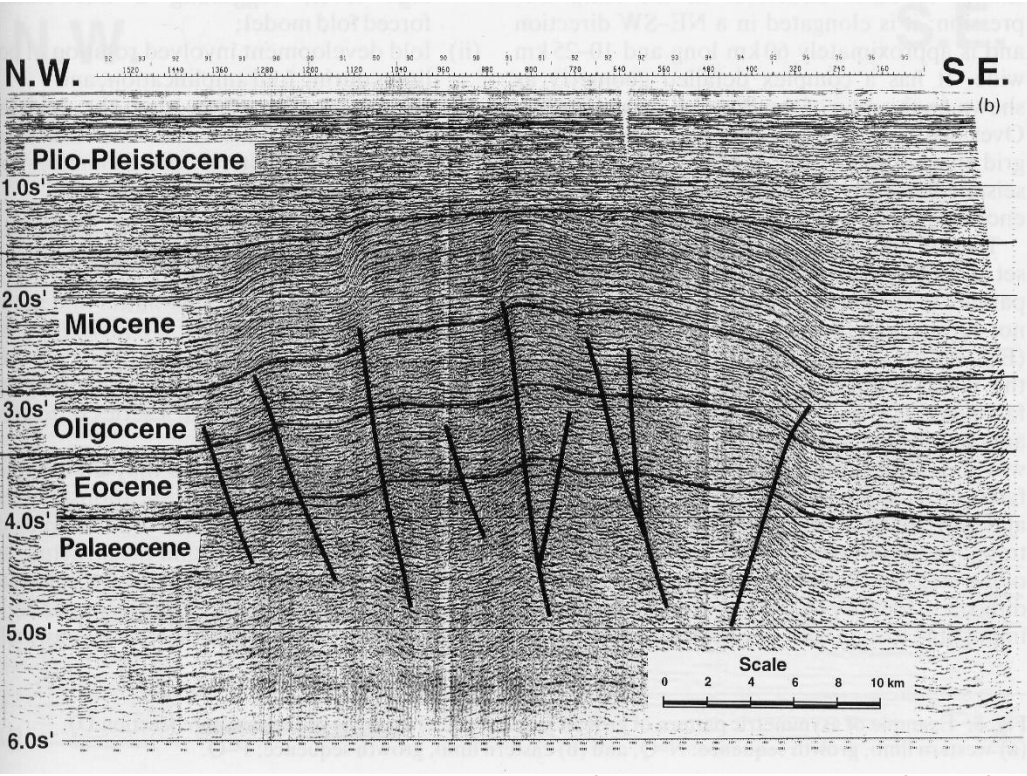


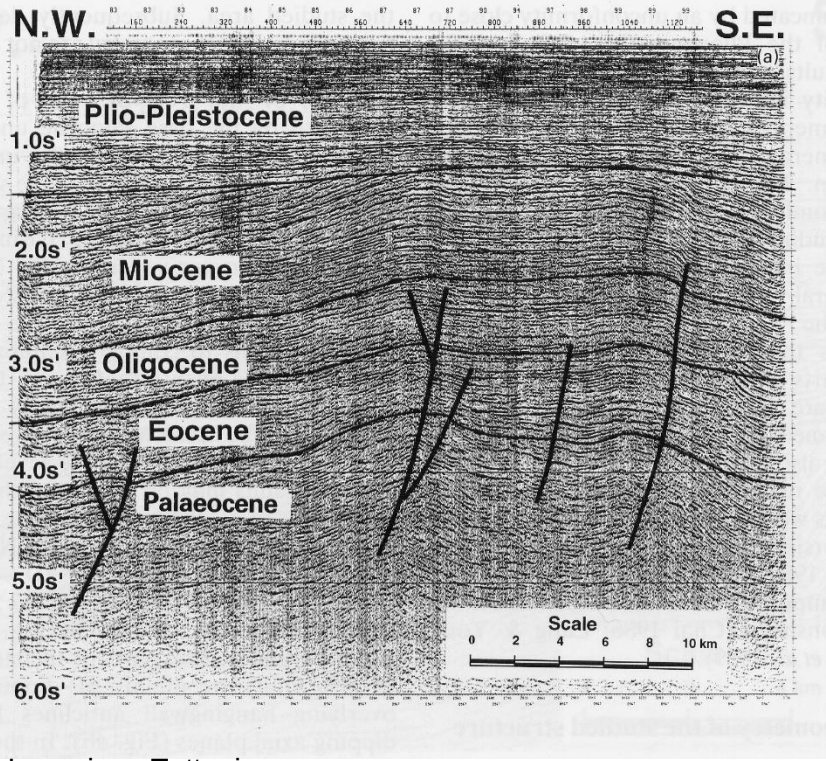


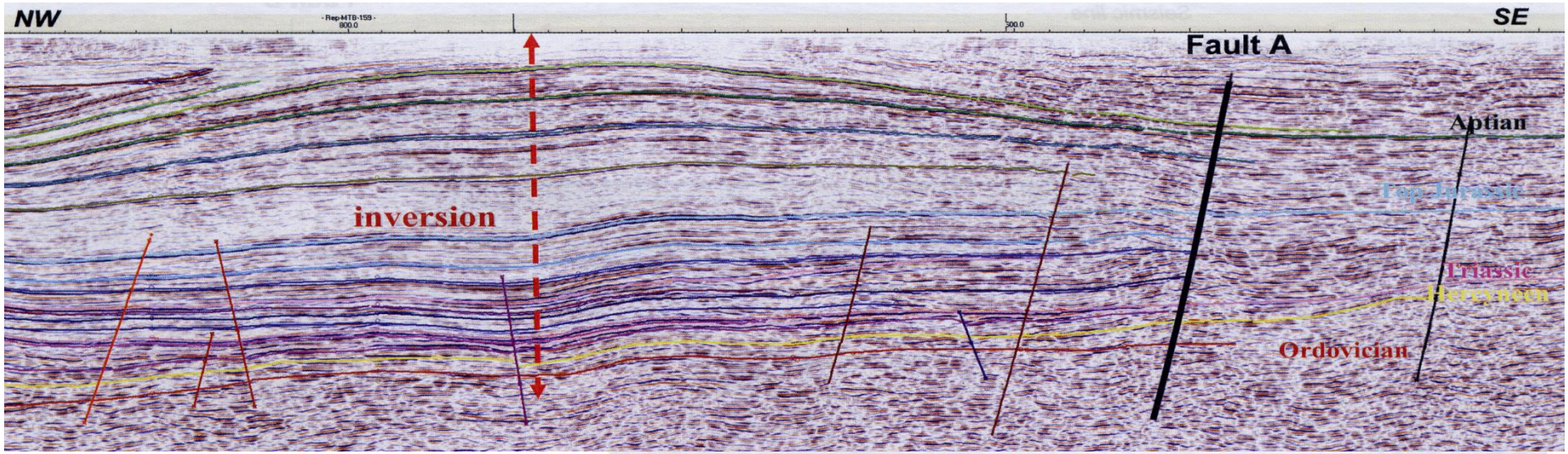
Example of positive tectonic inversion in the central Adriatic Sea:
the pre-Messinian series limited by the two reflectors, is thicker at the top of the anticline produced by the compressive tectonic phase, more recent than the previous relaxing phase.



Along the strike-slip systems the tectonic inversion of the secondary component (notmal or compressive) can occur: the transtension evolves into transpression (example in the figures, offshore left of the Calabrian Arc), or vice versa.







Example of tectonic inversion (Tunisia)

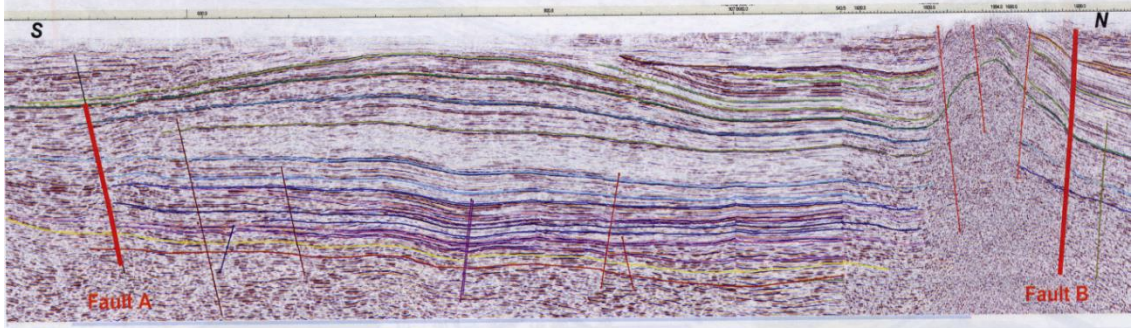


Figure 8 Composite seismic line through the Fejej Graben.