

# **The Algerian Margin: A Case Study of Interaction between Plio-Quaternary Sedimentation and Tectonics\***

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## **Abstract**

Offshore Algeria is a key area to study the reactivation in compression of a Cenozoic passive margin. This region is often affected by Mw=6-7.5 earthquakes: for example the 2003 Boumerdes event (Mw=6.8) which occurred on a previously unknown offshore reverse fault. This earthquake was associated with mass-transport deposits like debris flows and turbidites that lead to cable ruptures further in the basin. Here we summarize the multi-scale structures observed in the offshore Algerian margin based on the MARADJA'03 and MARADJA2/SAMRA'05 cruises data (multibeam bathymetry, seismic-reflection, side-scan sonar, backscattering, CHIRP).

The morphology of the margin and the structure of the Neogene sediments on the slope and in the basin, particularly the Plio-Quaternary sediments, are shaped by recent fault-related folds and near-surface faults distributed across the margin and also found far on land. Morphological and structural interpretation of the available data along the ~1000 km of the margin leads us to characterize several fault segments with a variable length and position. In Central Algeria (Algiers region), the main contractional structures are active blind thrusts (Plio-Quaternary) generally located near the ocean-continent transition and verging to the north (opposite to pre-existing features). They form generally large asymmetrical folds sub-perpendicular to the present-day convergence direction, which are often arranged in en echelon segments at different scales. Offshore Boumerdes (east of Algiers), we show that the faults have

typically a flat-and-ramp geometry creating a succession of perched basins from the mid-slope down to the deep basin, and prograding towards the basin. Although the Messinian salt tectonics and the sedimentary fluxes at the outlets of canyons play a significant role, the sediment deposition as well as the morpho-structure of the margin appear to be controlled at first order by these slow-rate tectonic movements, indicating a clear interaction between crustal-scale tectonics and sedimentation. We discuss the implications of these results in terms of seismic hazard and sedimentary architecture (turbidites) in deep environments.

# The Algerian Margin : a Case Study of Interaction between Plio-Quaternary Sedimentation and Tectonics


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The background image is a seascape with a dramatic sky. The sky is filled with heavy, grey clouds, with a bright patch of light breaking through near the horizon. In the distance, a range of mountains is visible. The foreground shows the dark, choppy surface of the ocean with white foam from a wake or breaking waves.

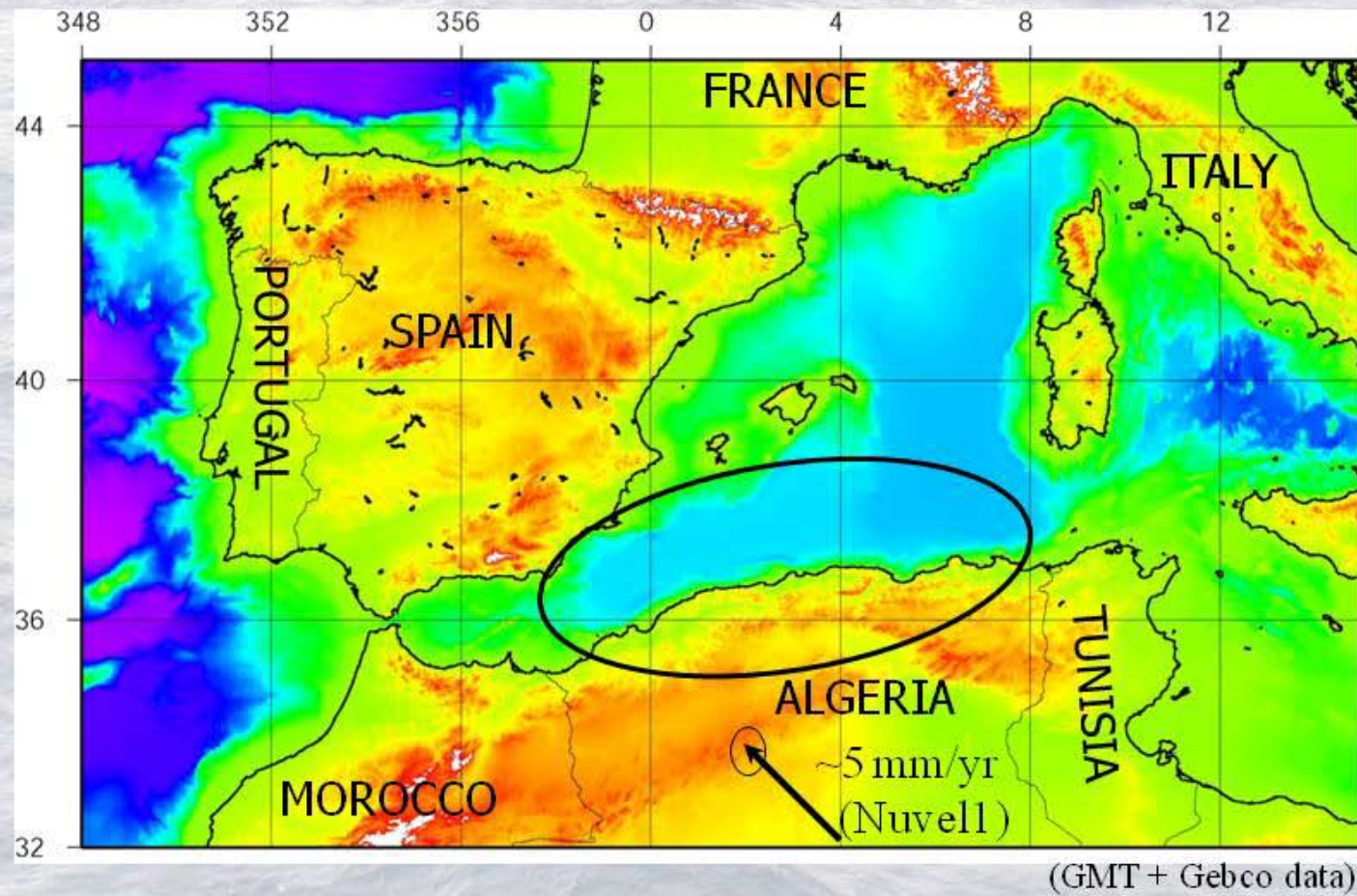
**I. Geological and seismological context**

II. Different styles of faulting/folding along the margin

III. Interaction between tectonics and sedimentation

Notes by presenter: Aim of this talk, I, II, and III (Interaction: on the morphological point of view, as well as on the geometry of the Plio-Quaternary sediments)

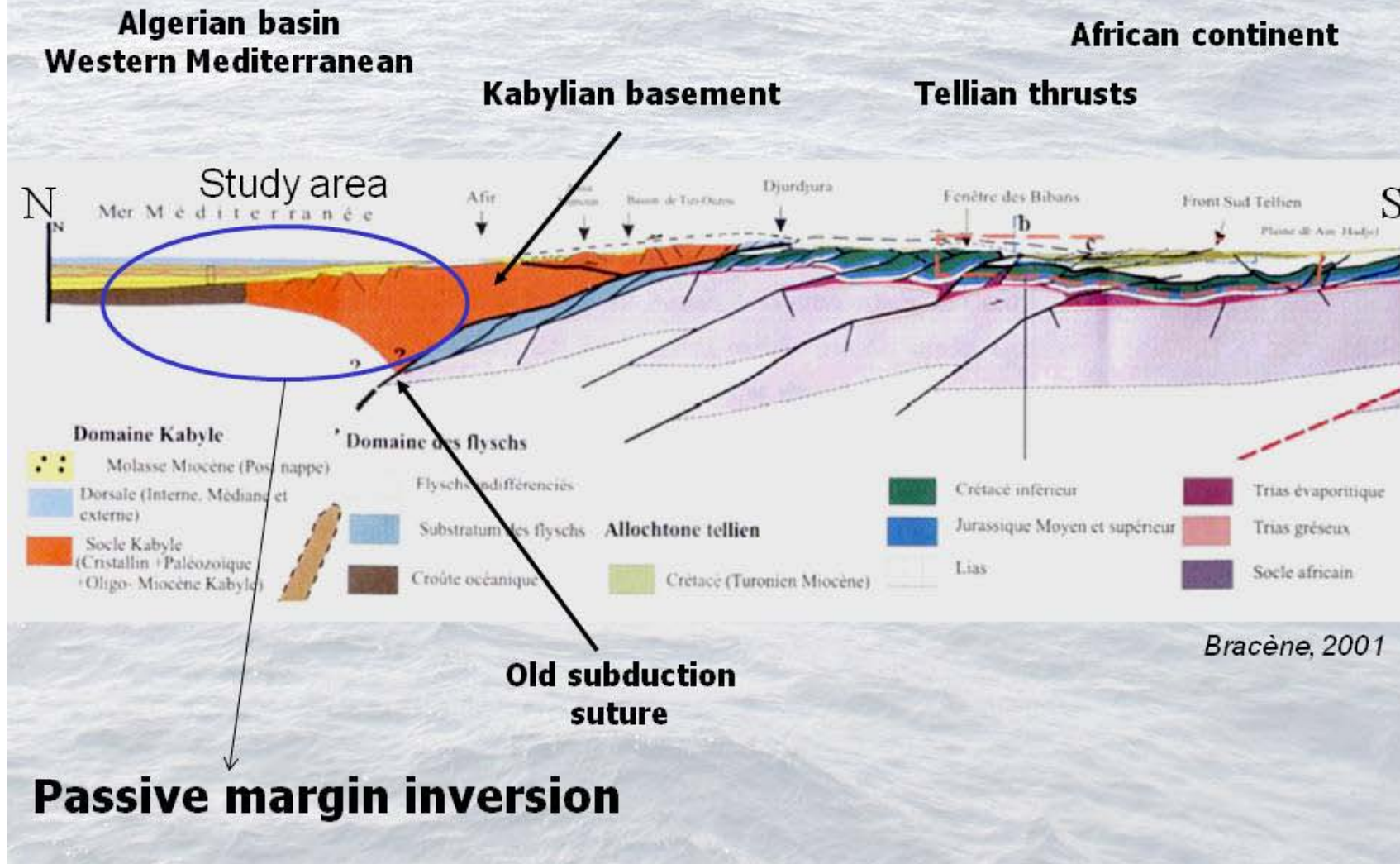
## Northern Algeria: geological and seismological setting



Notes by presenter: The study zone is located on the southern margin of the Algero Provencal basin, along Algeria, in Western Mediterranean.



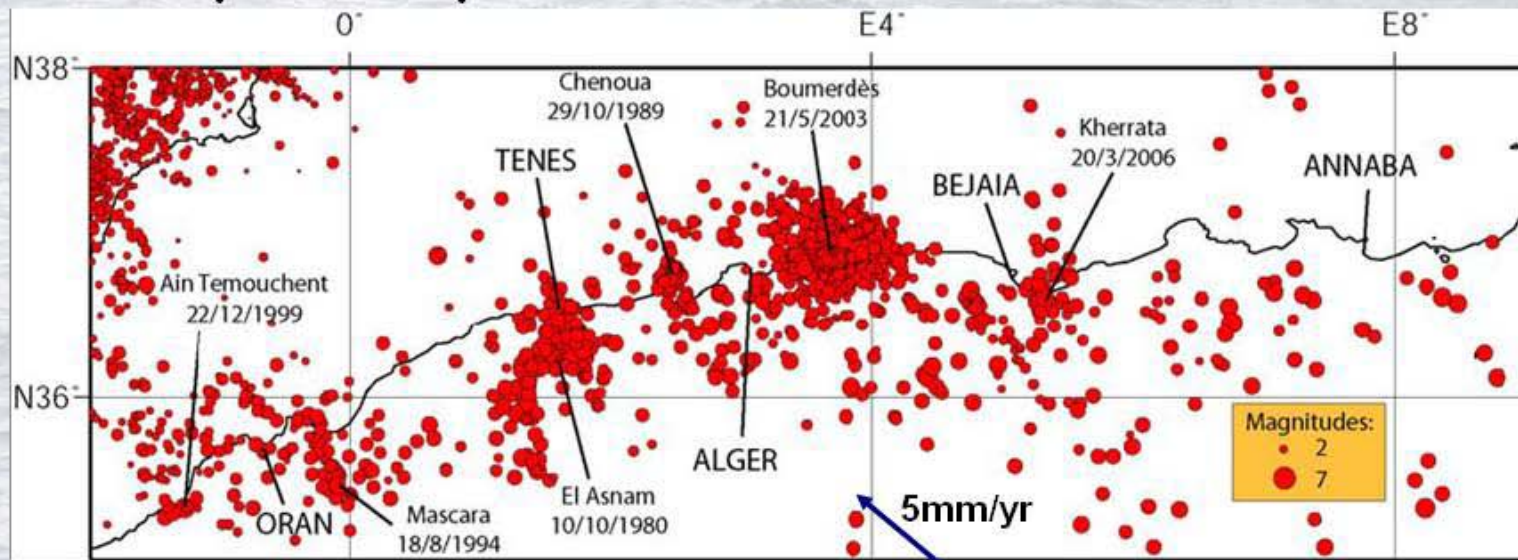
## Present-day geological setting



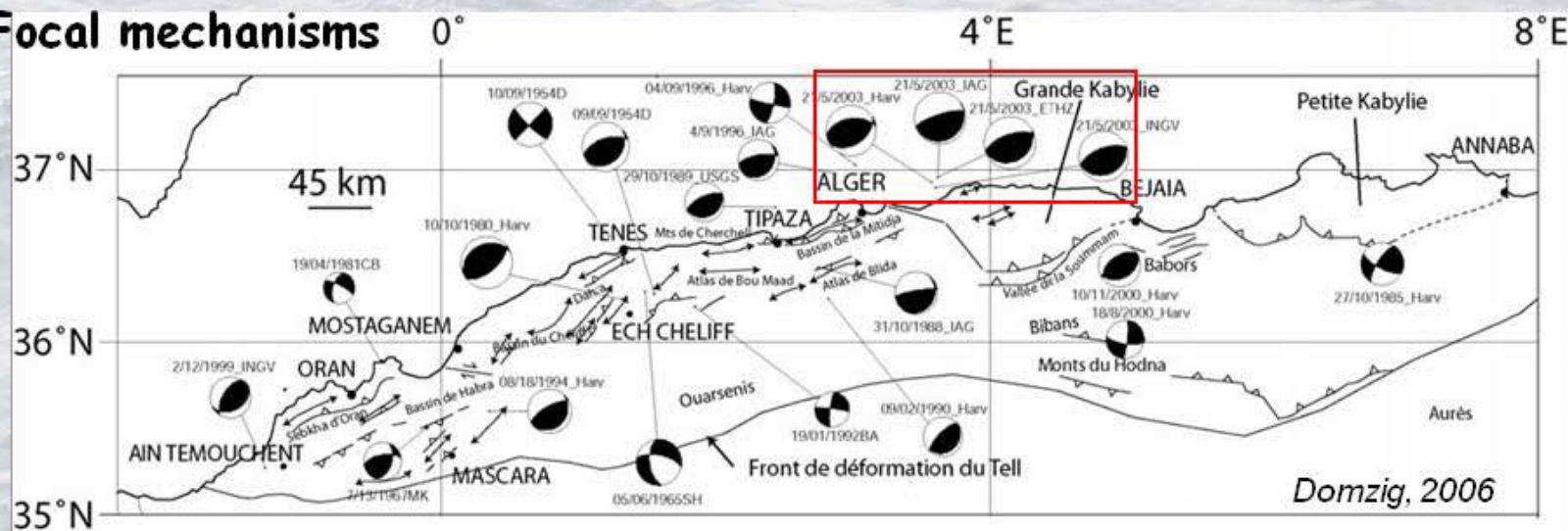
Notes by presenter: The study zone is located on the southern passive margin of the Algerian basin, behind the former subduction suture after the closure of the Tethys ocean. To the south: south-verging Tellian fold and thrust belt.

## Present-day seismicity

I Introduction



## Focal mechanisms



Notes by presenter: Important seismicity (shallow hypocenters) along the Algerian margin. Focal mechanisms **mainly compressive**, rarely strike-slip. Large recent earthquakes  $\Leftrightarrow$  Faults ; but problem for offshore events. Among them : Boumerdes, May 21st 2003, M:6.8



## The Boumerdes earthquake, 21/5/2003, Mw: 6.8

Boumerdes 21/5/2003  
rupture plane:

Length : 50-55 km

Direction: N54-70°E

Dip: 40-55° SE

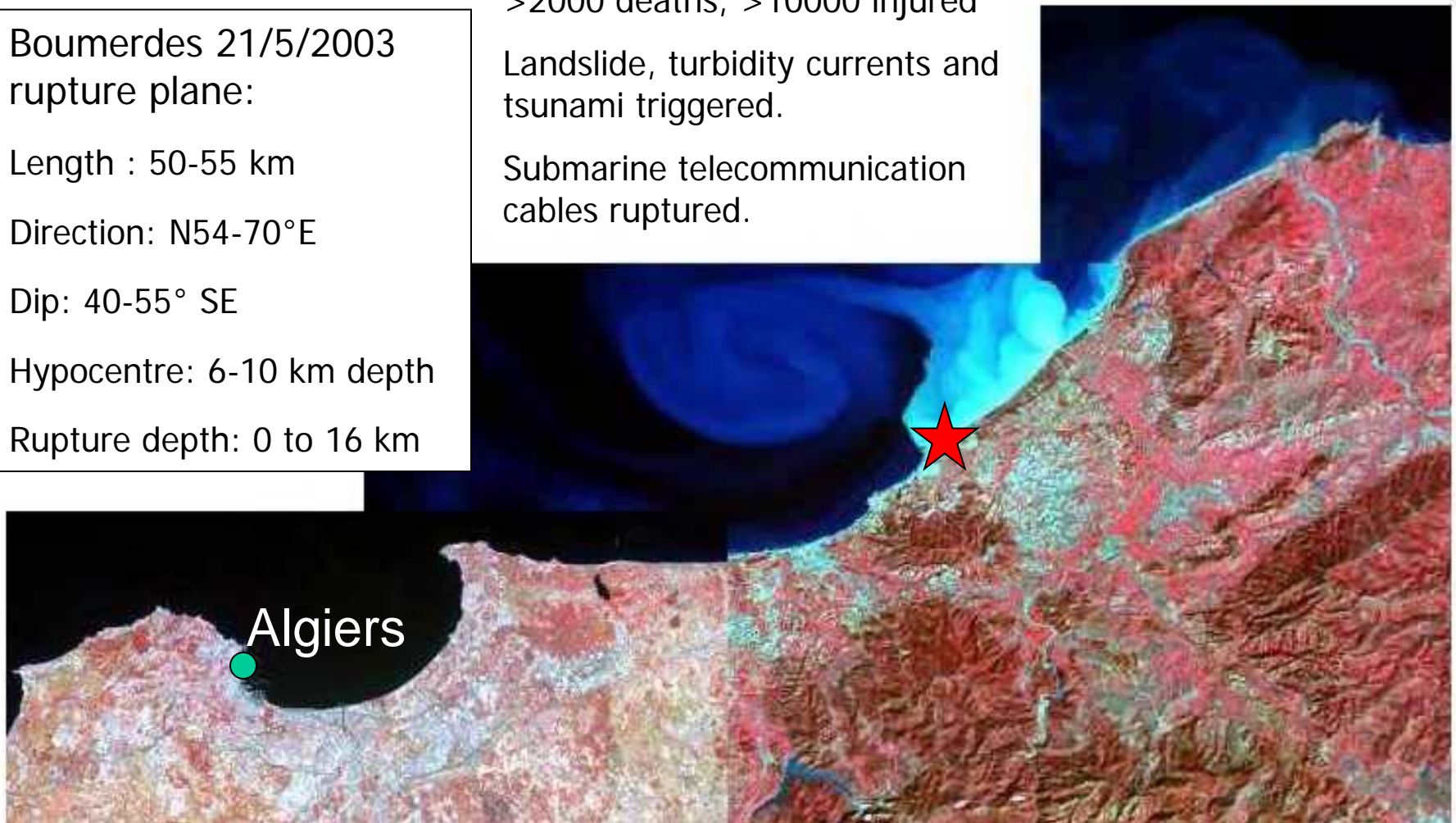
Hypocentre: 6-10 km depth

Rupture depth: 0 to 16 km

>2000 deaths, >10000 injured

Landslide, turbidity currents and  
tsunami triggered.

Submarine telecommunication  
cables ruptured.



Landsat image taken just after the earthquake

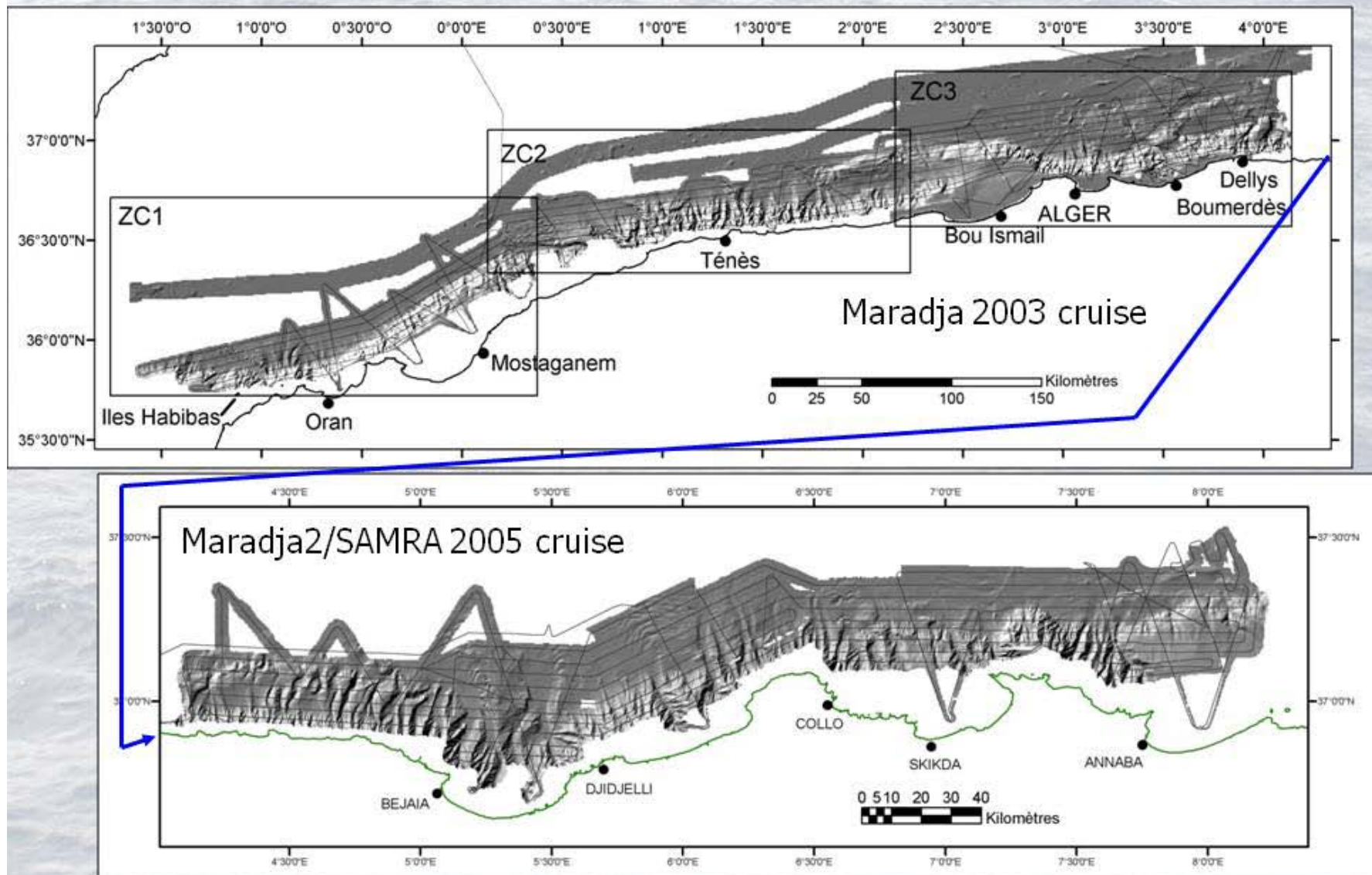


I. Geological and seismological context

**II. Different styles of faulting/folding  
along the margin**

III. Interaction between tectonics and  
sedimentation

## High resolution bathymetry (up to 25m resolution)

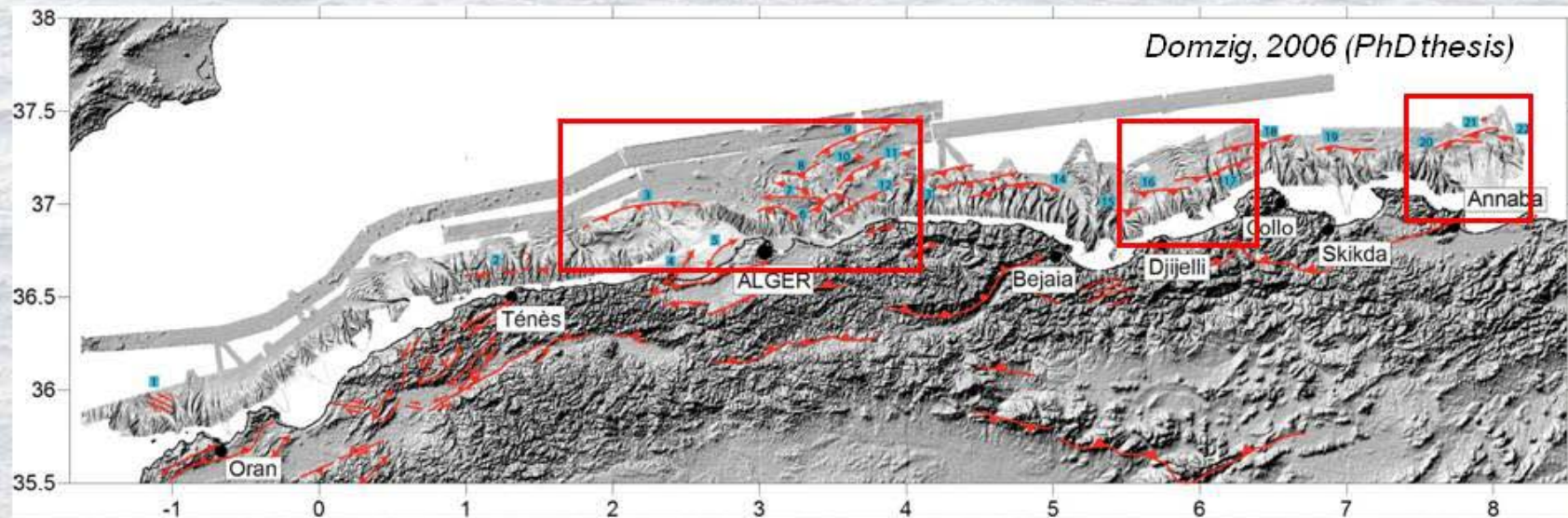


Domzig, 2006, PhD thesis

Notes by presenter: Quick description of the main features: linear slope segments, perched basins, and antiforms in deep basin



## Different tectonic styles along the margin



**Principal active structures:** folds and thrusts, SW-NE to WSW-ENE oriented

Offshore: Young (Quaternary) active blind thrusts on the central and eastern margin:

- at the foot of the margin (piggy-back basins) or on the slope (roll-over basins), roughly perpendicular to the plate convergence direction
- often an en-echelon pattern
- northern vergence (opposite to the onland thrusts, and the Miocene subduction suture zone)

Notes by presenter: Apart from the strike-slip structures found along the western margin, we have mainly folds and thrusts, and we will focus on them, in the central and eastern margin.

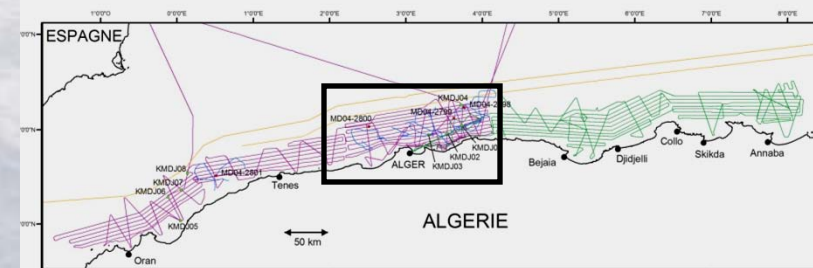
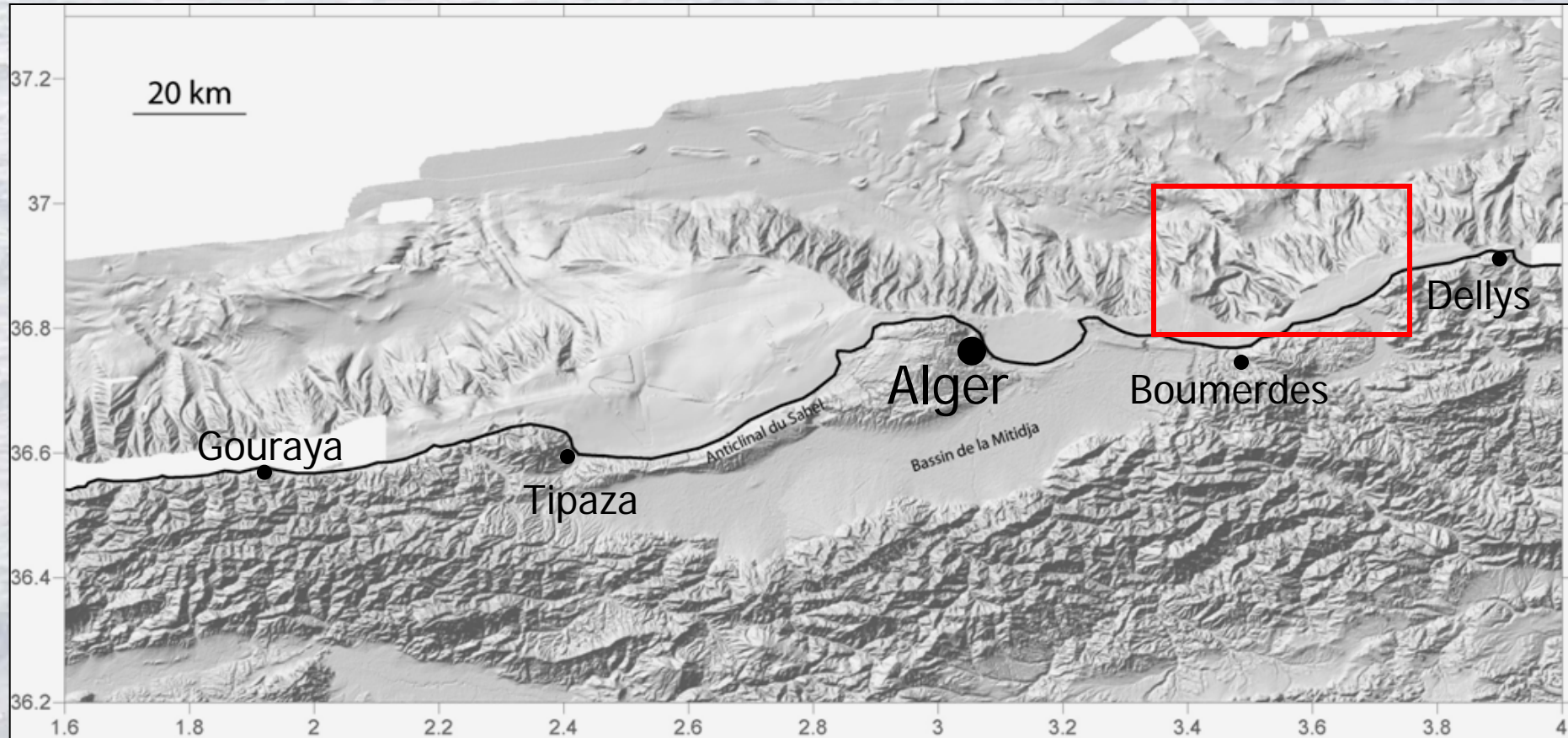
- I. Geological and seismological context
- II. Different styles of faulting/folding along the margin
- III. Interaction between tectonics and sedimentation**



# Algiers area

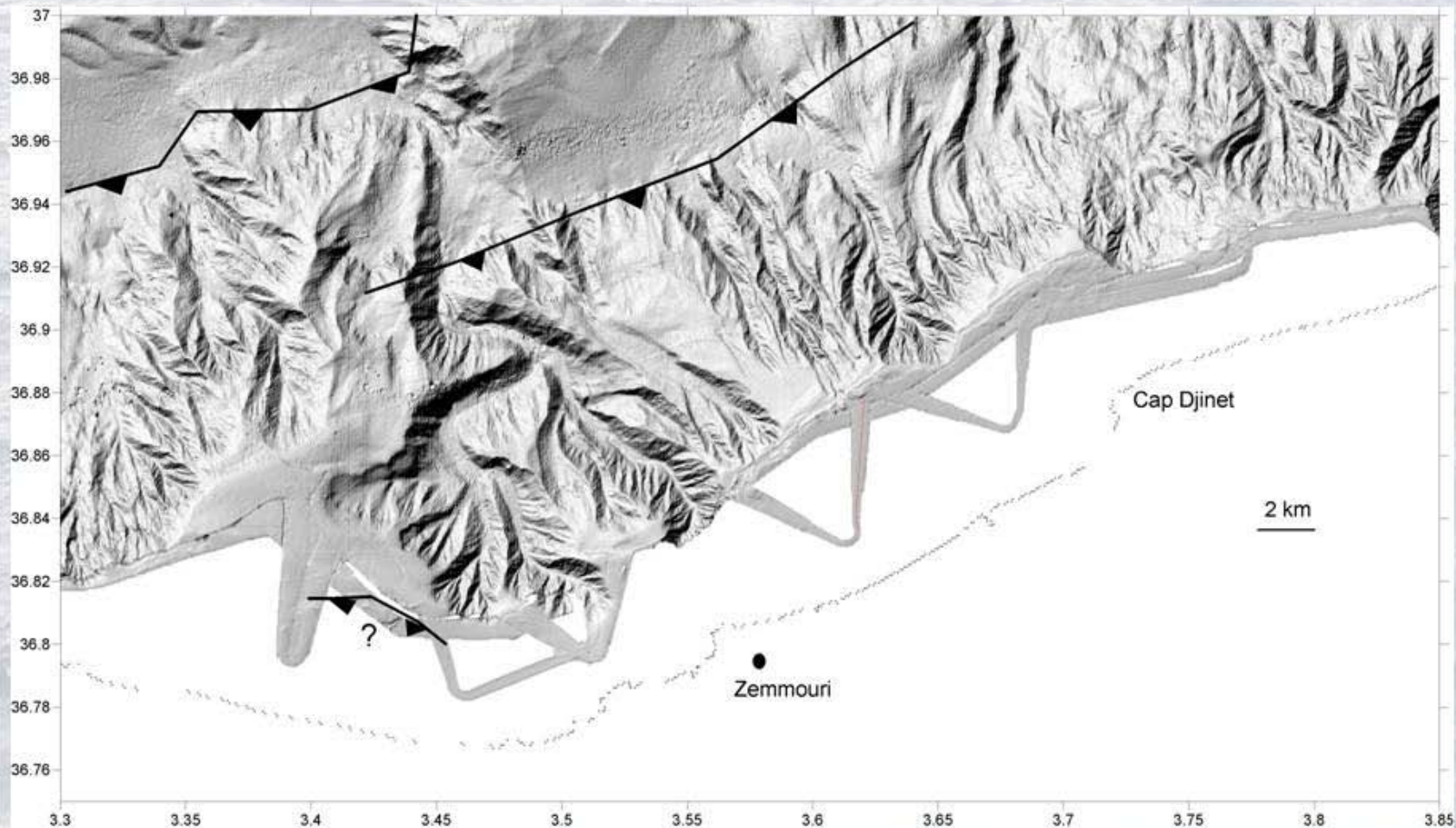
## III East Algiers

Identification of offshore active structures, from a) bathymetry



# Offshore Boumerdes

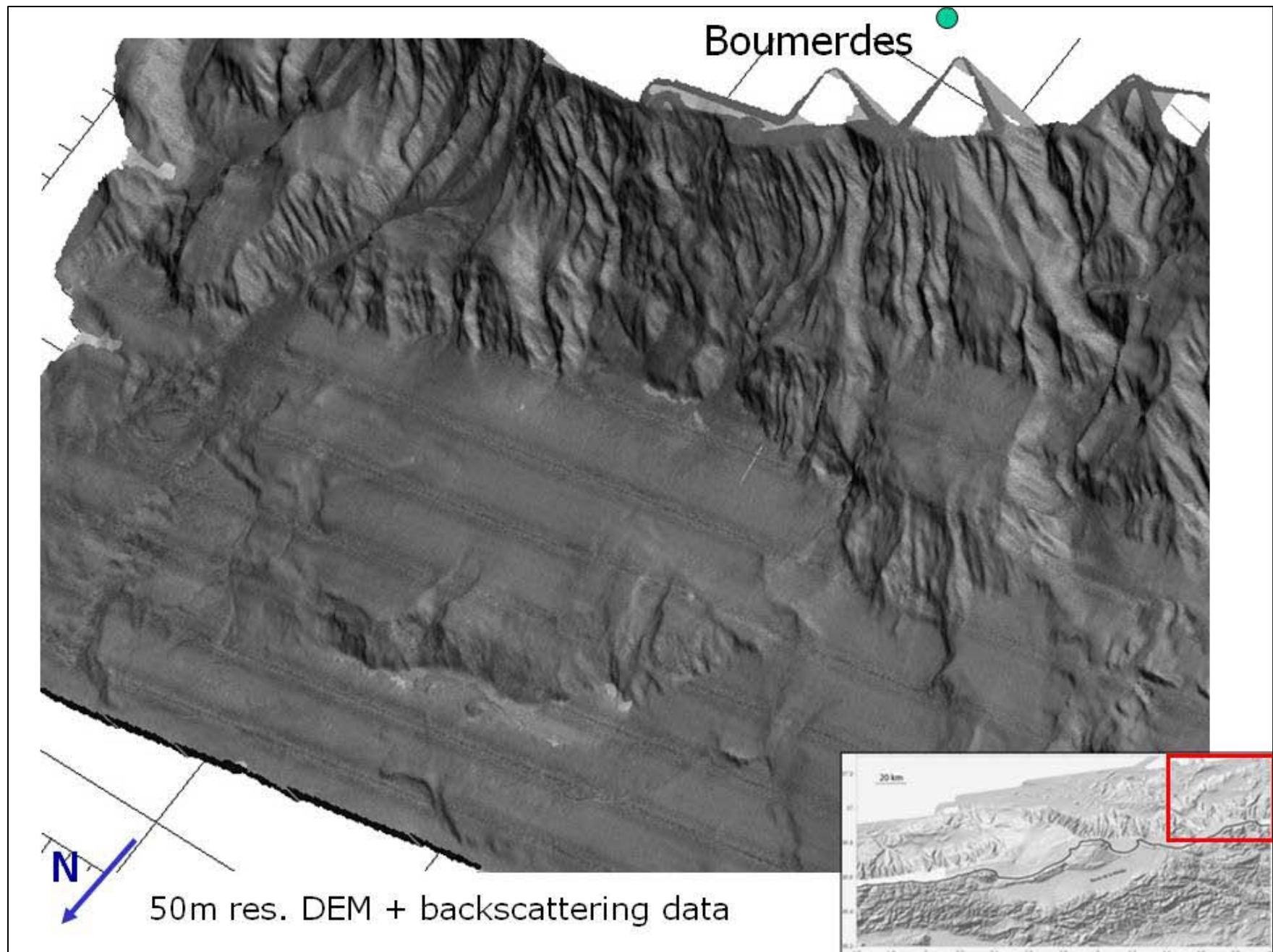
III East Algiers



Shape of canyons influenced by active folding

Notes by presenter: Interaction of tectonics with morphology -> deviated canyons. Example of the Algiers canyon

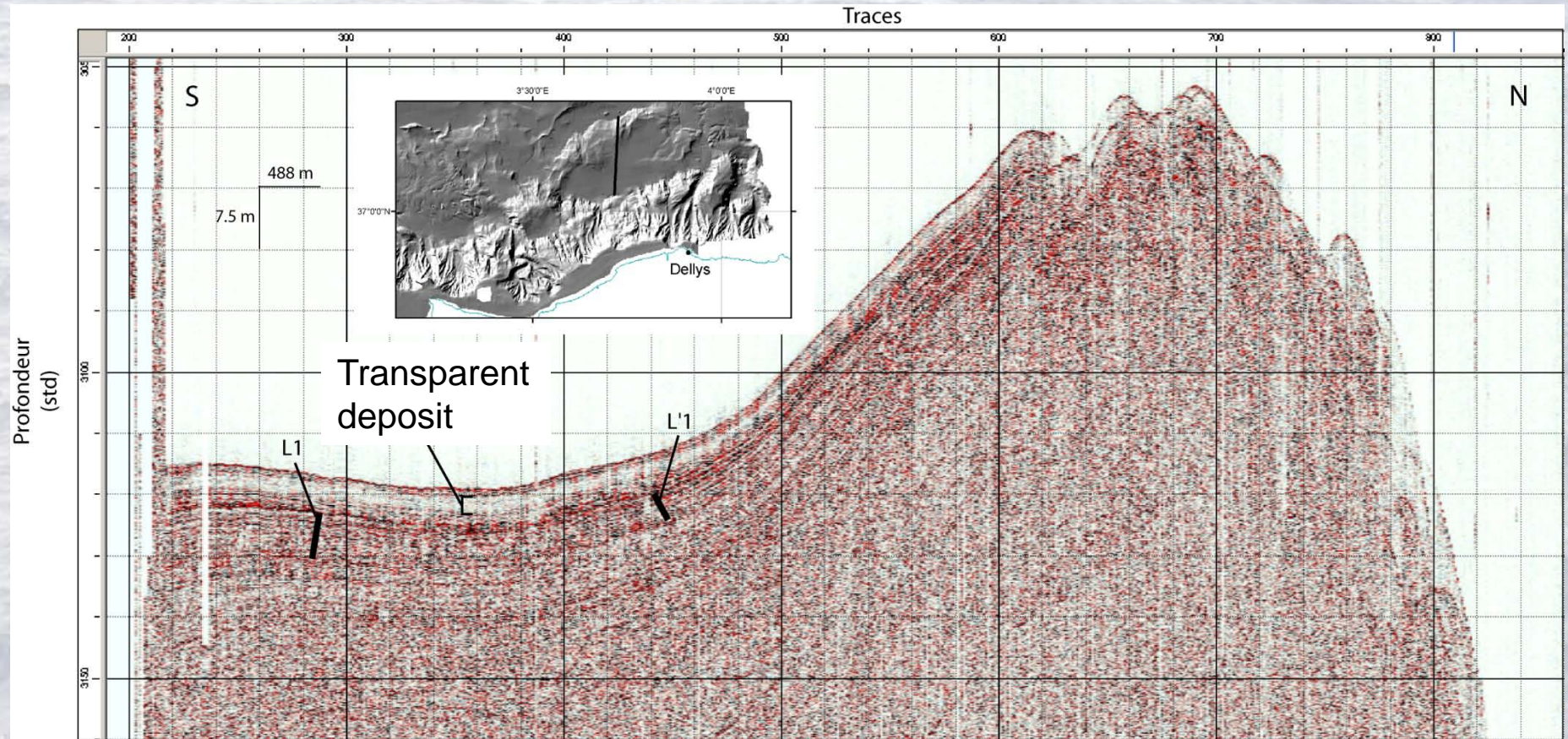




Notes by presenter: A little bit further east: on backscattering, whiter areas correspond to slide deposits and mass-transport deposits



## b) Chirp line



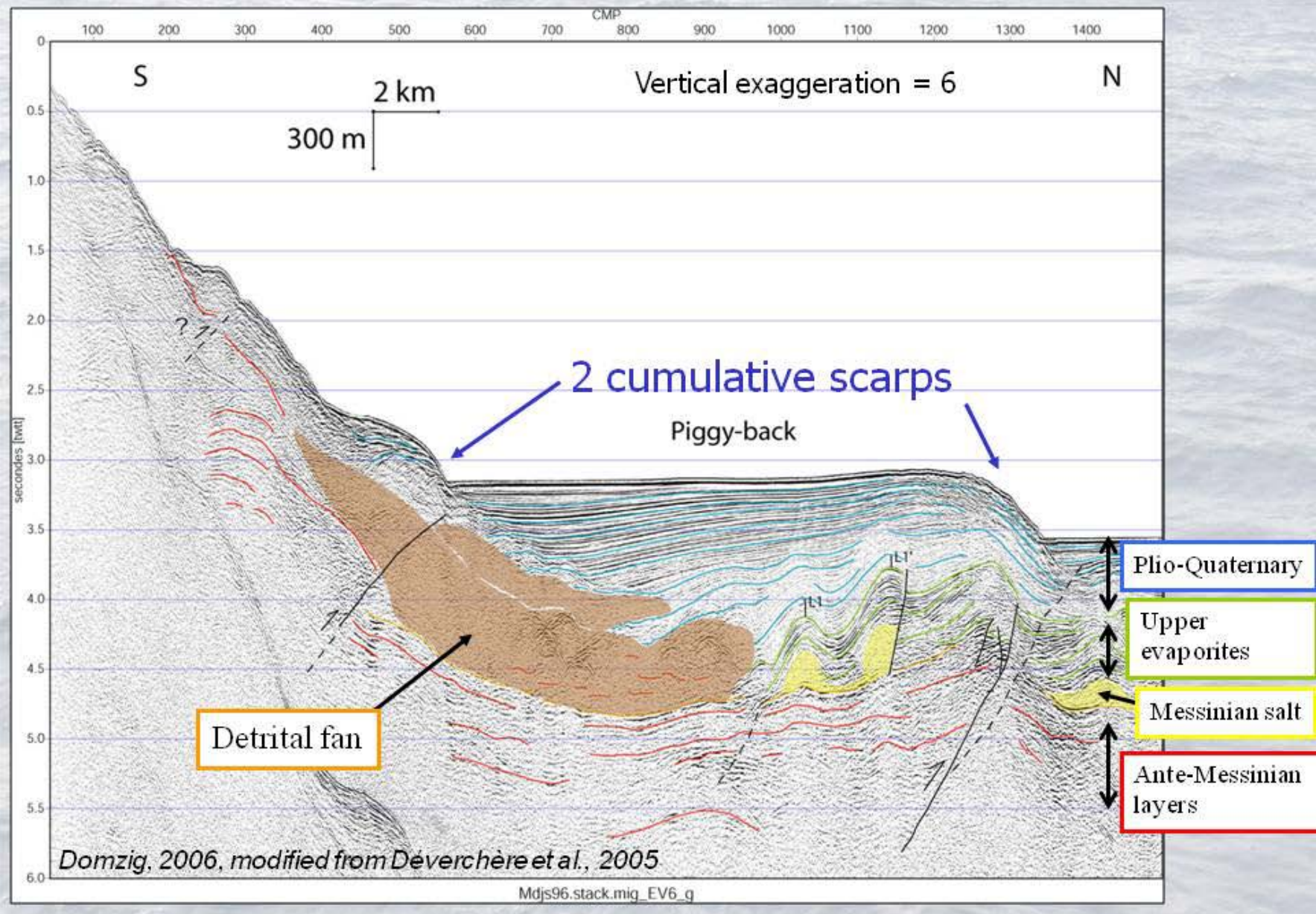
No clear onlap, progressive thinning towards the axis of the fold

→ Favors a recent activity of the fold.



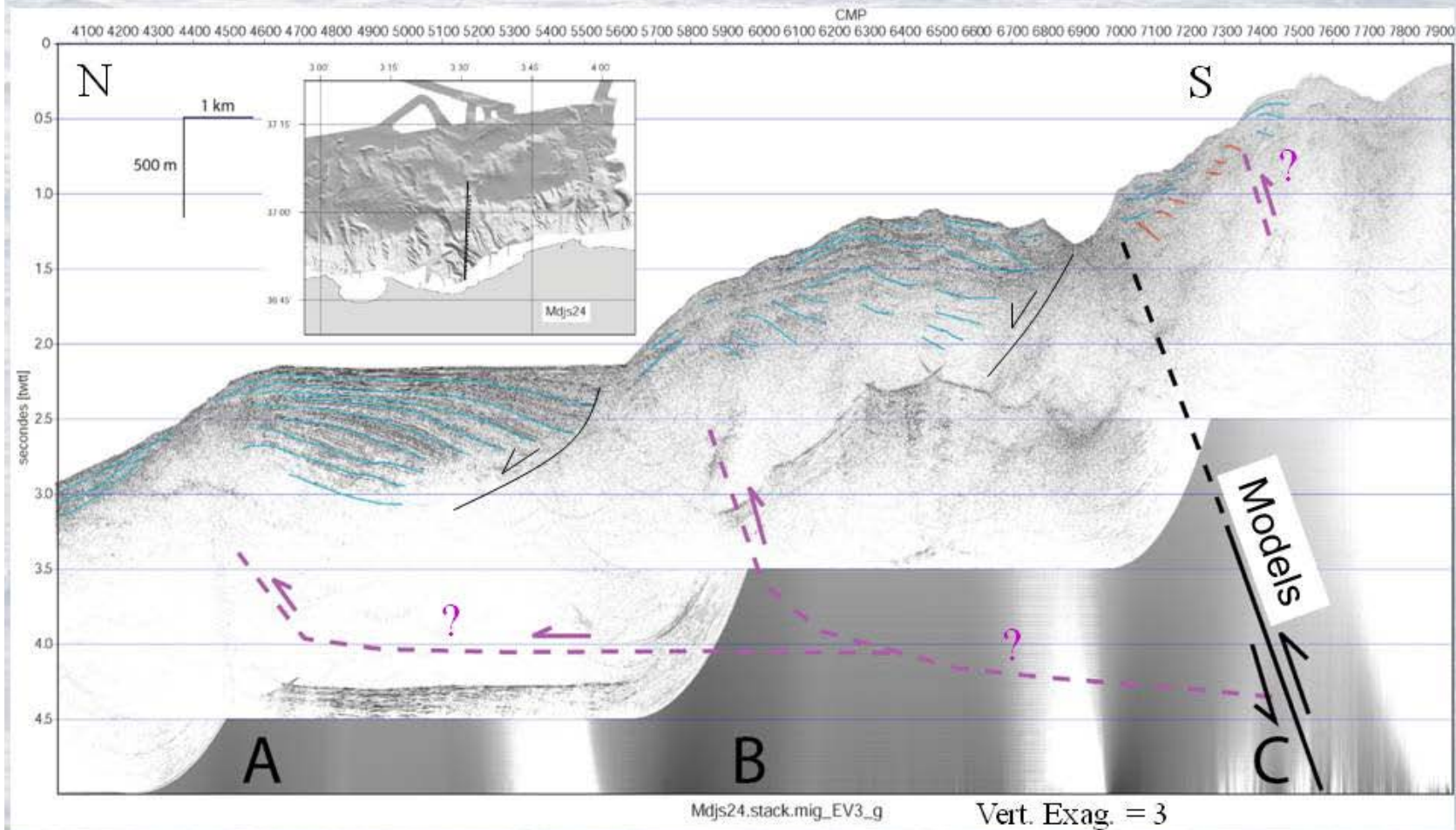
### c) Seismic lines

III East Algiers



Notes by presenter: Depocenter/growth strata on the backlimb of the anticline, as the underlying fault tilts the sediment cover towards the south  
Distinction between salt tectonic and larger wave-length deformation (s.s. tectonics)

## Upward prolongation of the Boumerdès fault

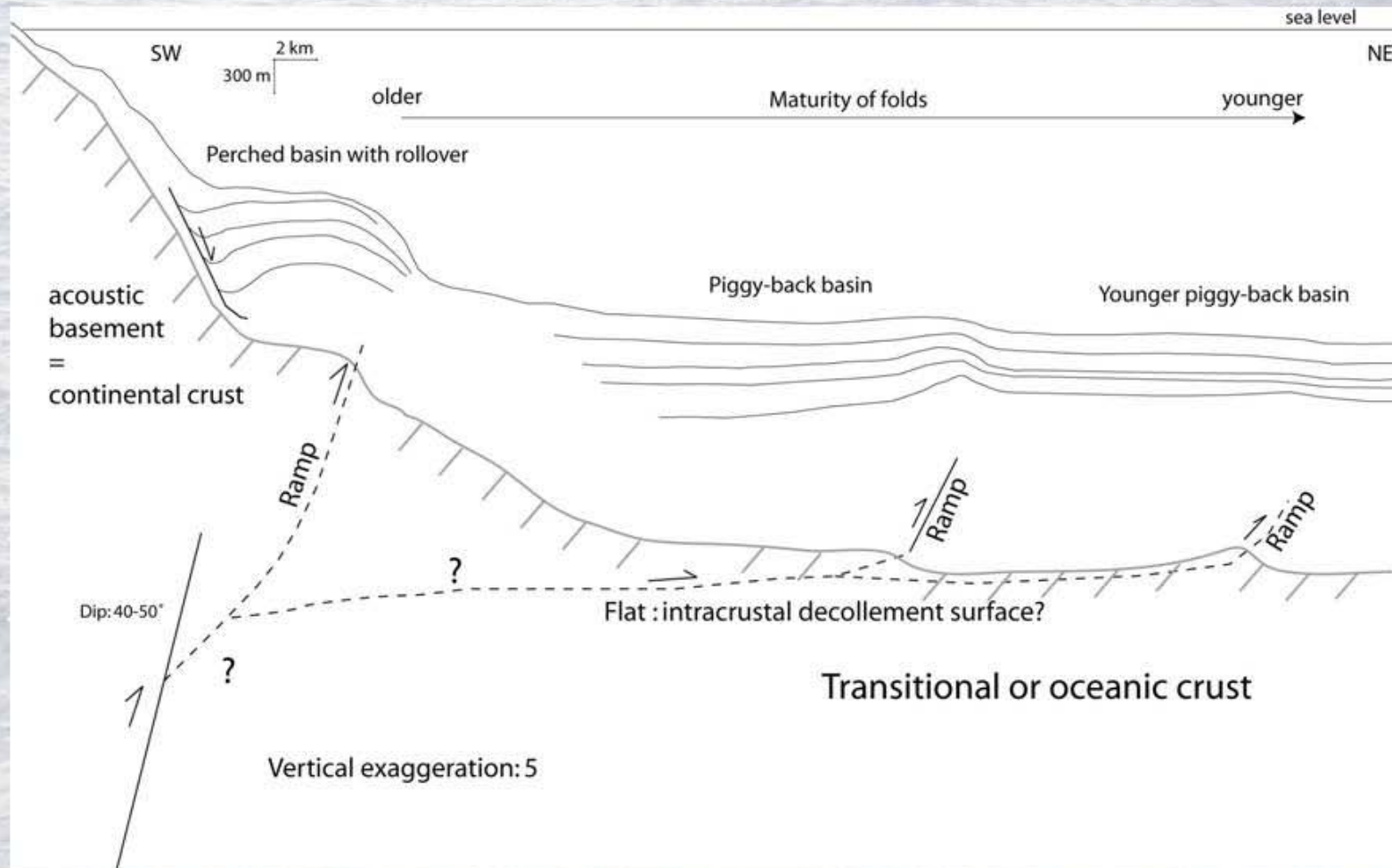


Domzig, 2006 (PhD thesis)

Notes by presenter: Another example of distribution of the deformation, further west, crossing 2 perched basins. Growth strata in Plio-quaternary layers in the hangingwall of the faults, and rollovers upslope. The patterns observed on the seismic lines lead us to propose a scheme for the fault pattern in the Algiers area (next slide)



## Synthetic geometry of structures offshore Algiers

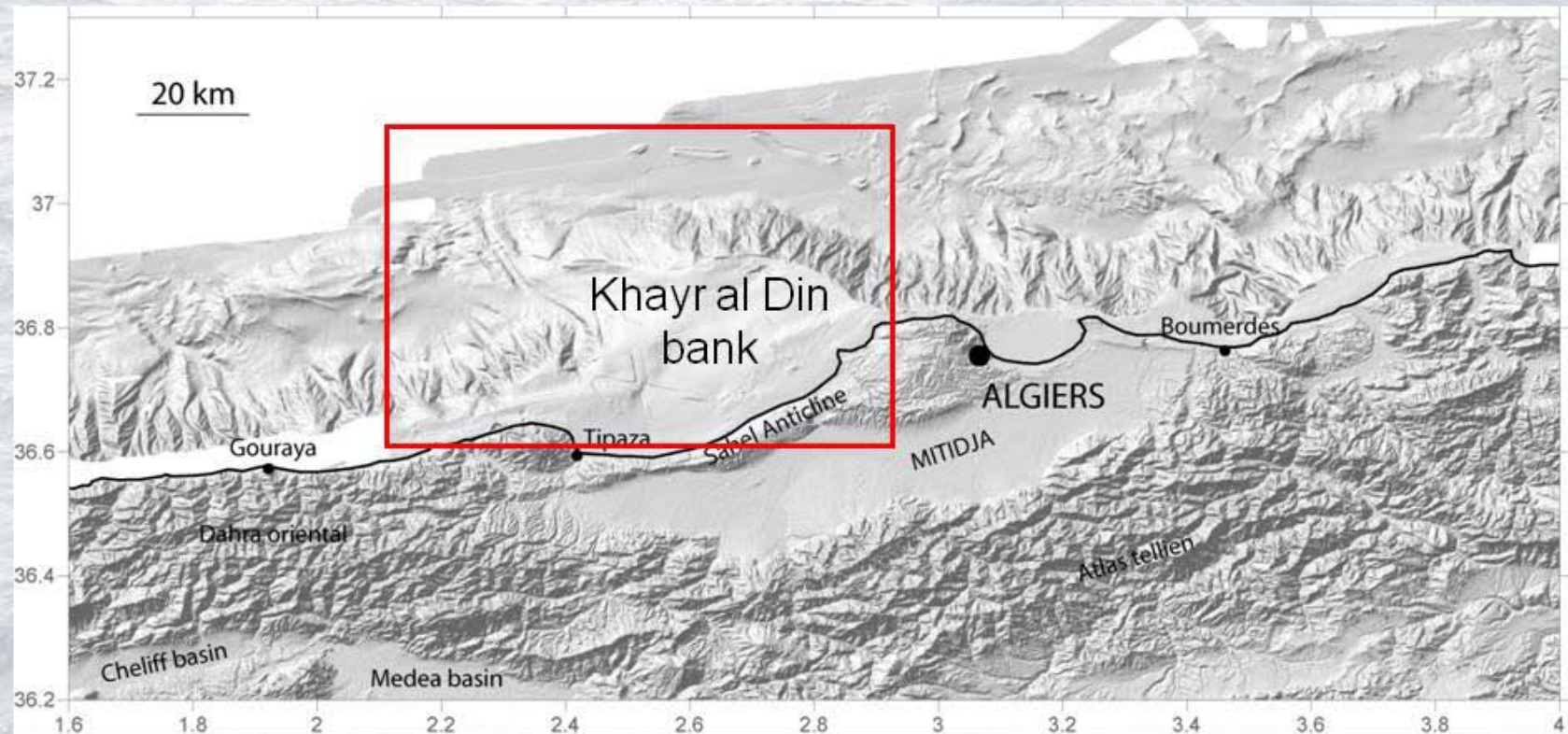


Modified from Domzig, 2006 (PhD thesis)

Notes by presenter: With the available seismic, it is currently not possible to directly visualize the faults at depth. So these assumptions need to be confirmed/strengthened by modelling, for example forward modelling by testing different fault geometries.

## Offshore west of Algiers

### III West Algiers

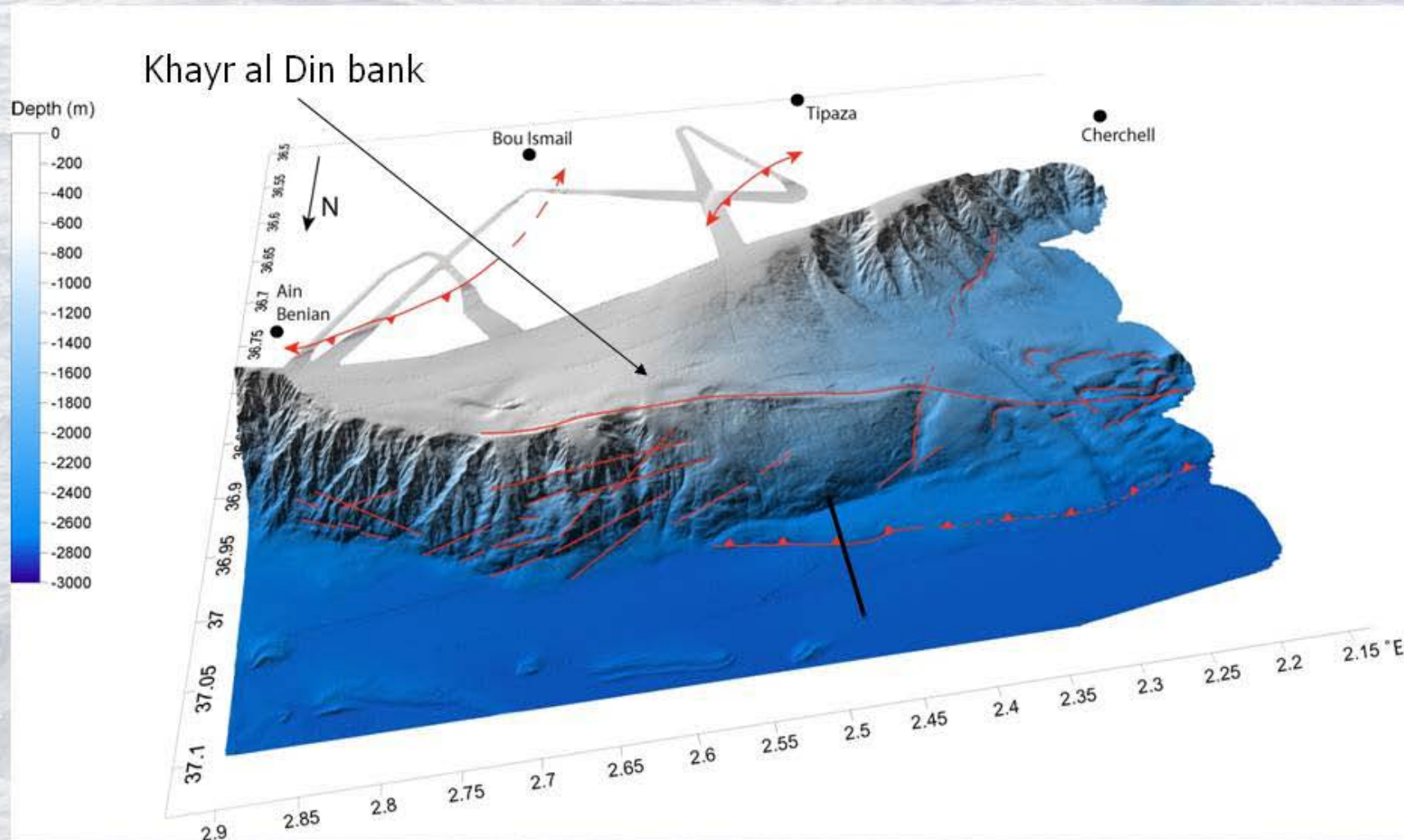


Notes by presenter: Quickly another example west of Algiers, of a different tectonic pattern, due to the presence of a basement block, the Khayr al Din bank.



## Offshore west of Algiers

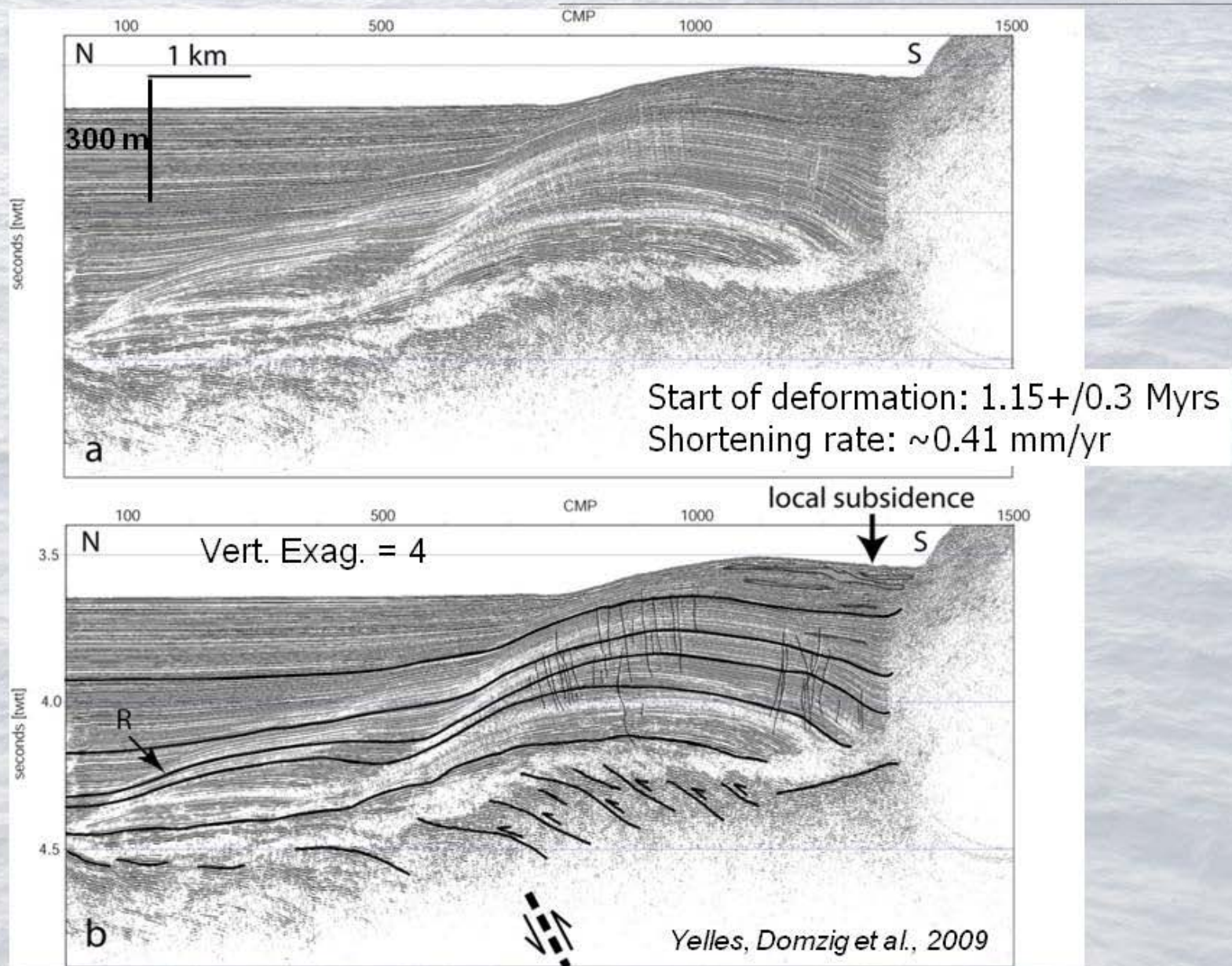
### III West Algiers



*Yelles, Domzig, et al., 2009*

Notes by presenter: The bank in 3D... and a seismic line at the foot.

### III West Algiers

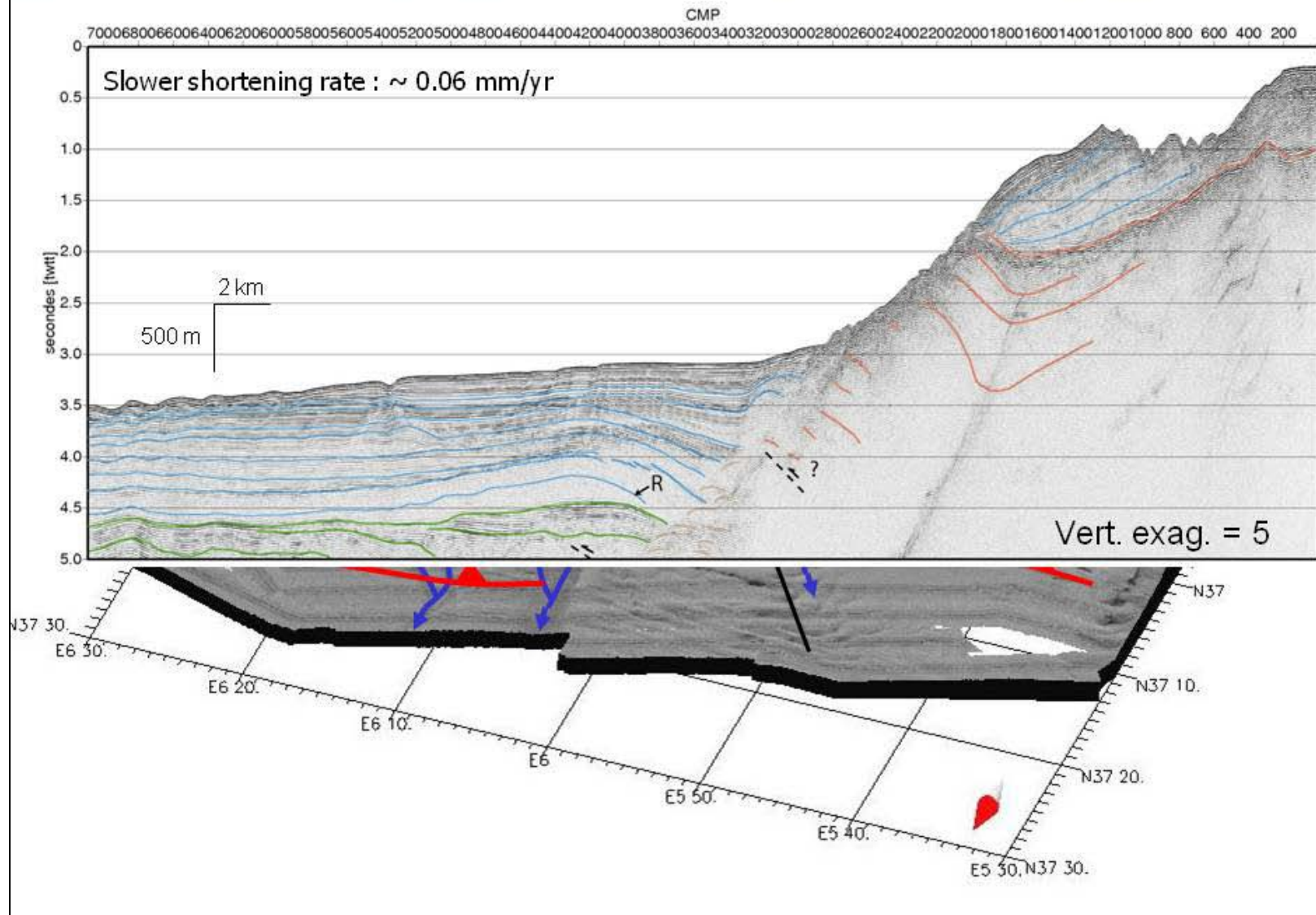


Notes by presenter: Ecaillage at depth, contourites to the north, upper Plio-Quat: growth strata due to the folding underneath



## Djidjelli area

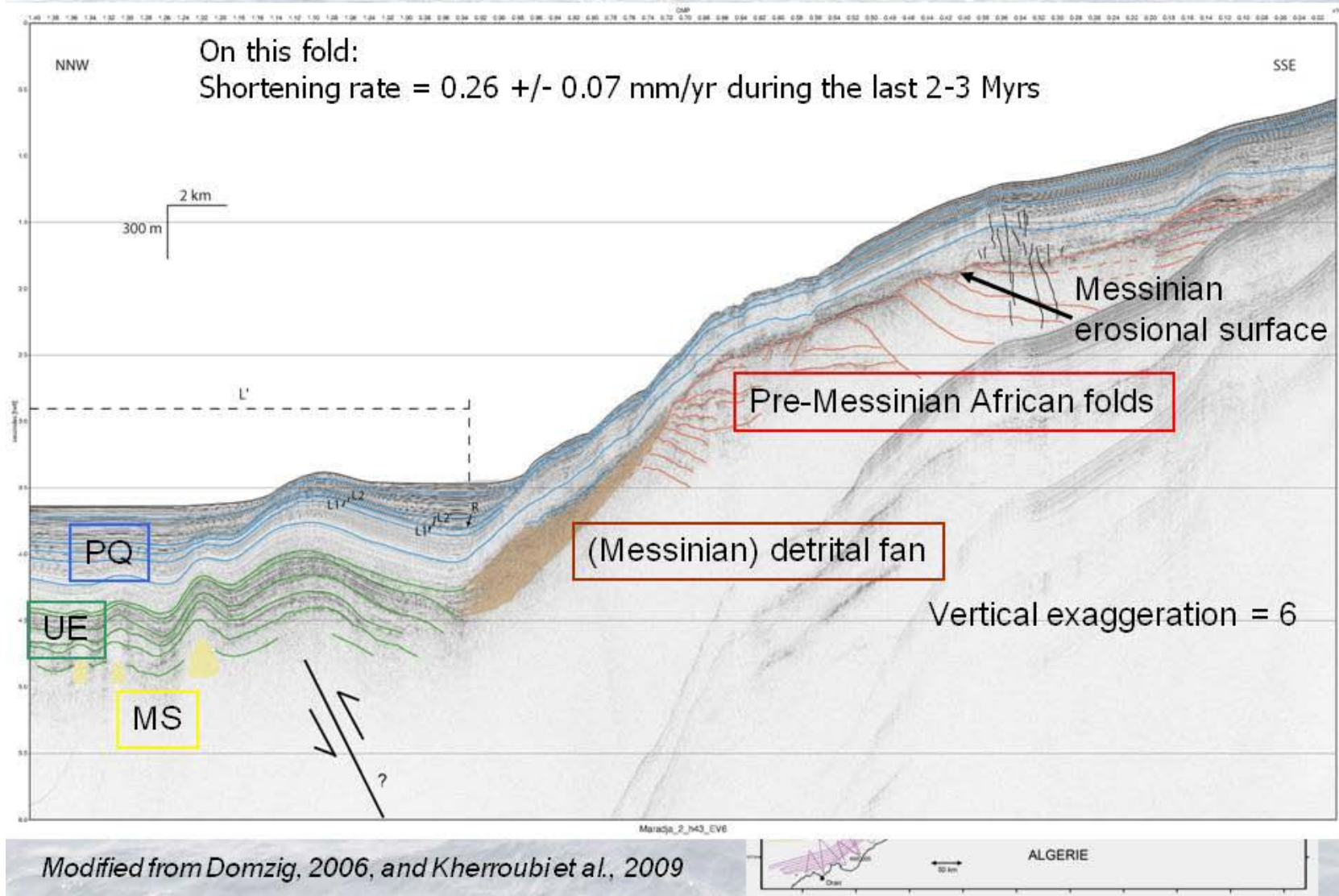
III Djidjelli



Notes by presenter: Further east, in the region of Djidjelli. Canyons deviated. Sediment waves. Barely visible anticlines. If we look at a seismic line, the deformation rate is probably very close to the sedimentation rate. Several processes interact: contourites/turbidity currents creating sediment waves, salt retreat, tectonics.

# Annaba area

III Annaba

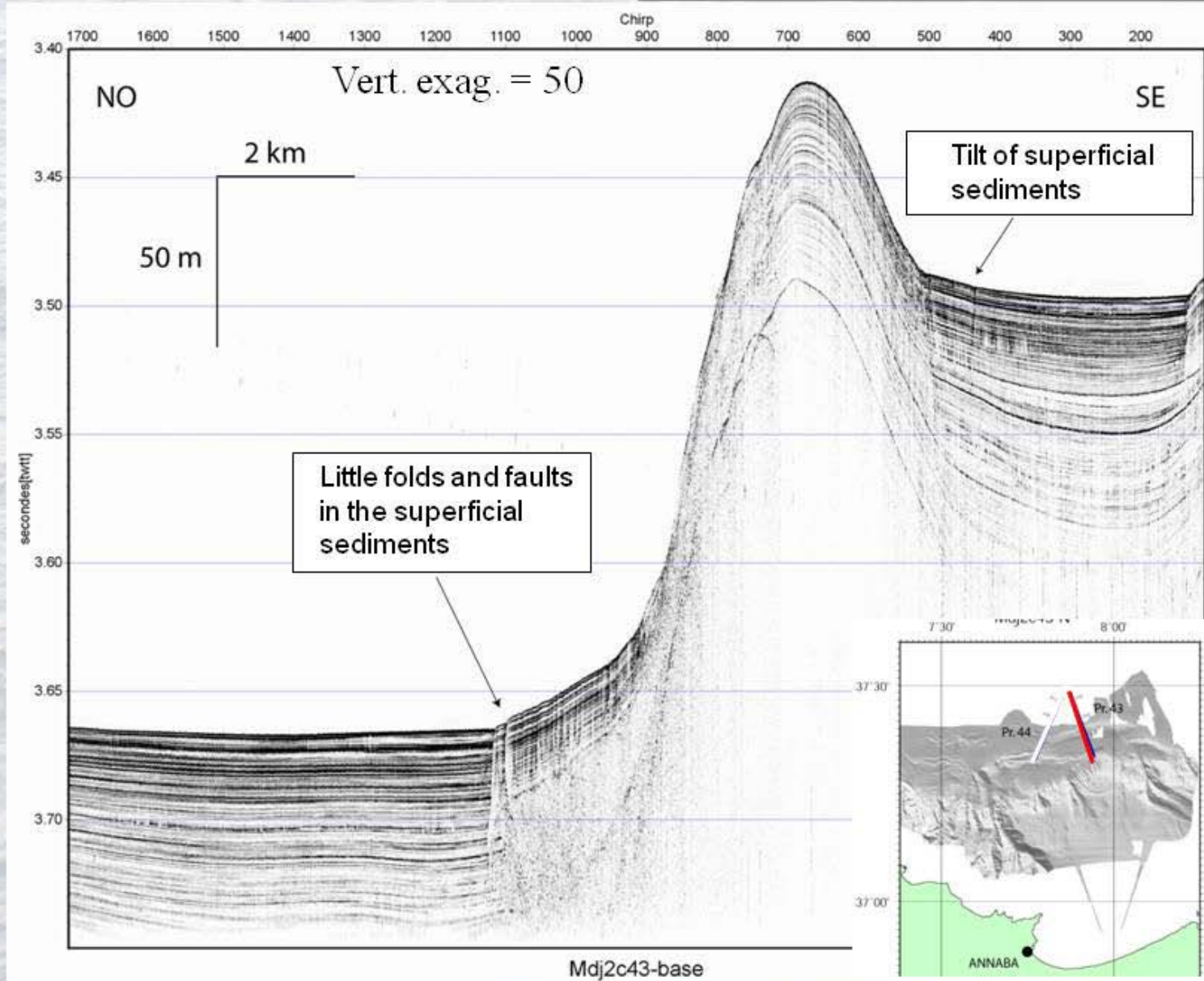


Notes by presenter: Further east, offshore Annaba. More difference between shortening rate and sedimentation rate => more visible anticlines. Folding due to salt domes and larger wave-length “real” folds. Base of growth strata marks the beginning of the deformation. Again, we have no information about the geometry of the fault at depth, and we would need to carry a forward modelling study.



# CHIRP line

III Annaba



Domzig, 2006 (PhD thesis) and Kherroubi et al., 2009

Notes by presenter: Faulting and tilting of the most recent layers -> active faulting/folding

## Conclusions

- Series of active blind thrusts identified along the submarine Algerian margin with vergence opposite to the previous passive margin normal faults
  - Creation of piggy-back basins on the backlimb of the folds
  - This active folding deviates canyons and shapes the margin's slope and basin, and is associated to mass-flow deposits
- Strong interaction of sedimentation and tectonics due to slow deformation rates

## Perspectives

- Constrain the geometry of the faults and folds and the amount of shortening:
    - Forward modelling using MOVE
    - Restoration of cross-sections
  - Geological hazard (seismic and gravity)
    - Several thrusts >50 km long, capable of generating M=6-7.5 earthquakes
- Palaeoseismology, geotechnical and seismic hazard studies, tsunami modelling



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