Shear in the west part of the North Aegean Trough in a 100+ years scale

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The question:

Are **slip rates** along major active strike slip faults **constant**?

The answer from a theoretical point of view is **YES**

However,

● it is not known what happens at the **edges** of major strike slip faults

● there is no direct long-term geodetic evidence

►GPS data currently cover up a to few tens of years

A related question:

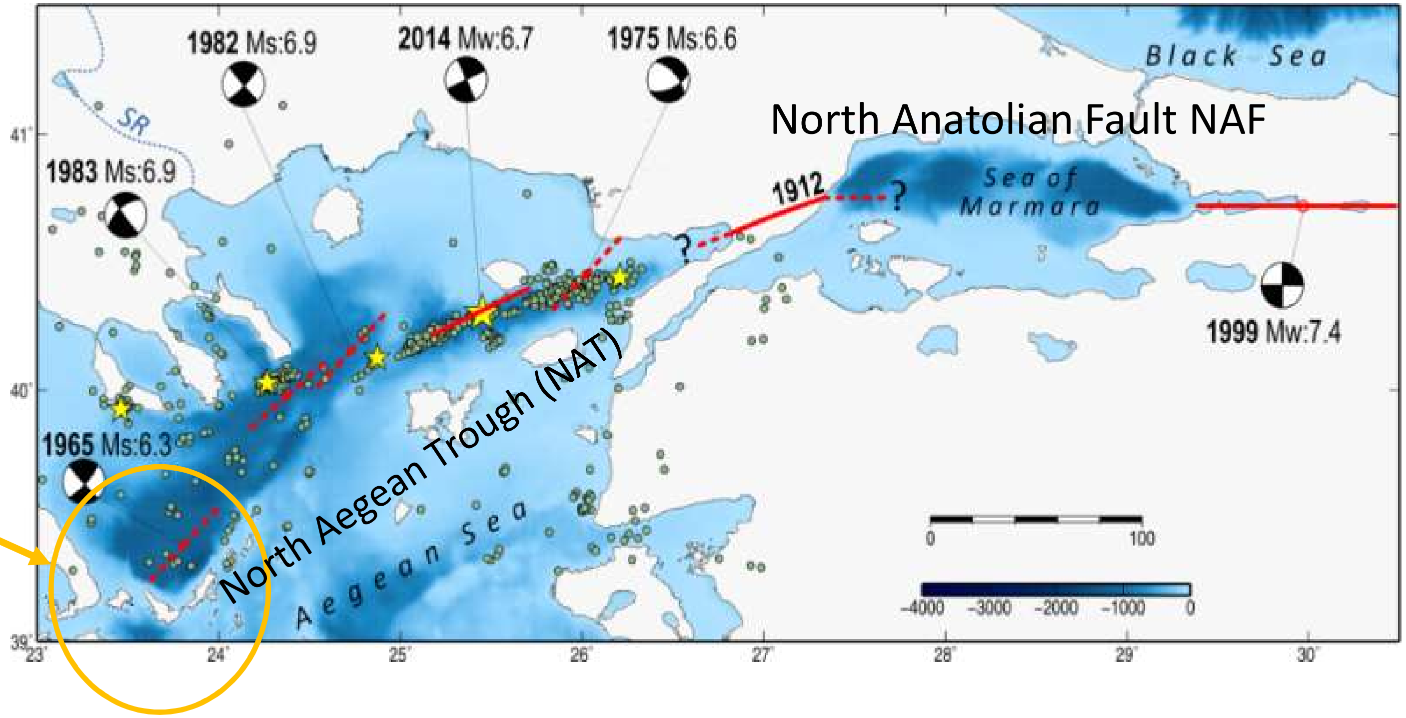
How major strike slip faults terminate?

*"Are **slip rates** along major active strike slip faults **constant**?"*

An opportunity to contribute in an answer to this problem,
focusing on

- the west edge of the North Aegean Trough (**NAT**),
  an active strike slip fault
  at the continuation of the North Anatolian Fault (**NAF**)
- expand the observations record to 100+ years using triangulation data
  (conventional geodetic data, rarely available) and GPS data
- examine seismological evidence

Study area



Faulting

observed

inferred

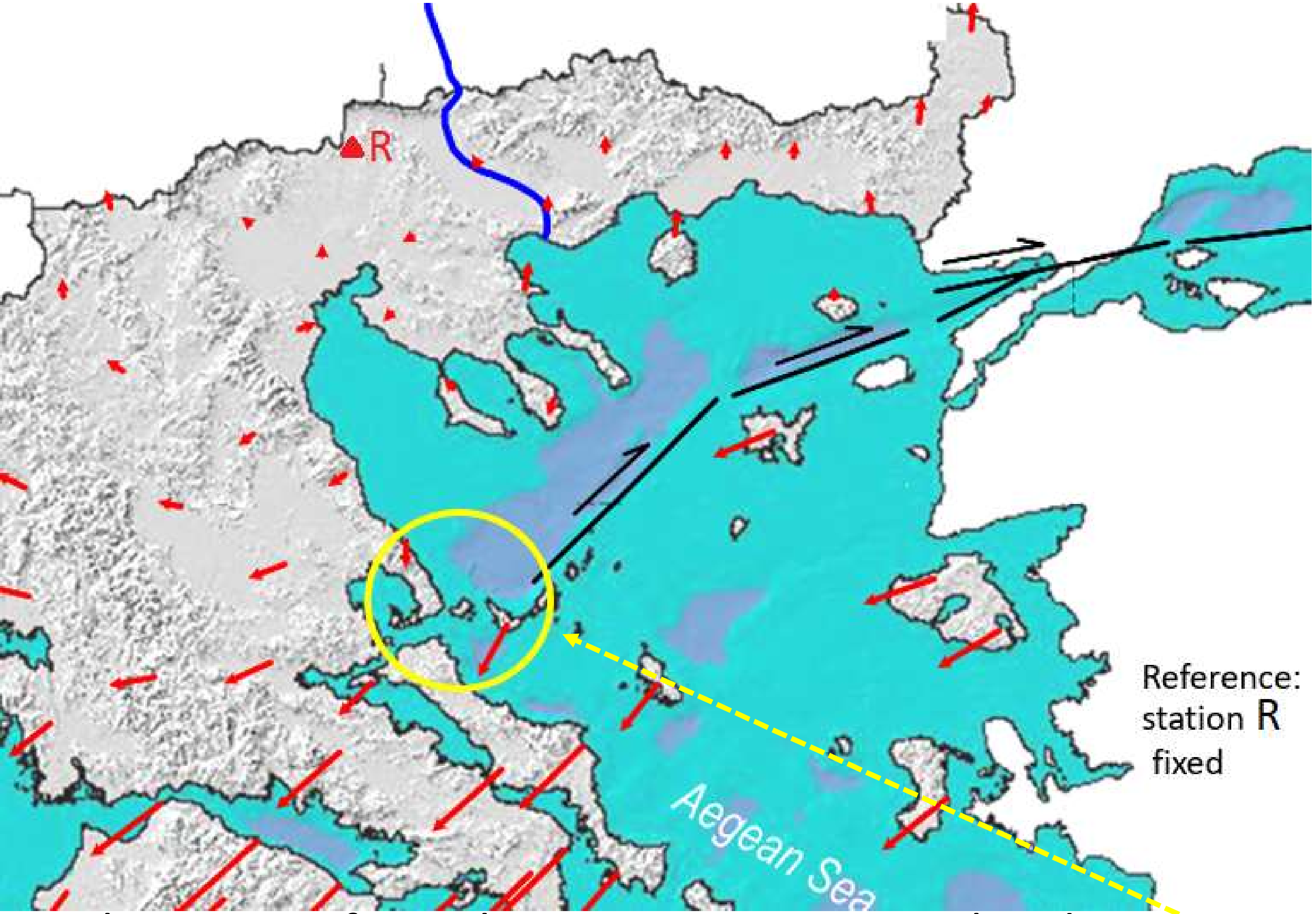
- The North Aegean Trough (NAT) at the continuation of the North Anatolian Fault (NAF):
- a >1000m deep major marine basin,

  narrow and **simple** to the east, wider and **diffuse** to the west
- A tectonically active strike slip zone

  Several major (M>6.0) strike slip earthquakes since the 1960's

  (the 2014 Mw6.7 earthquake precisely modeled using GPS, teleseismic & accelerometer data)
- Earthquakes spread in the wider region

Displacement Field along the NAT:
Evidence from
the HEPOS GPS network
(only homogeneous data)

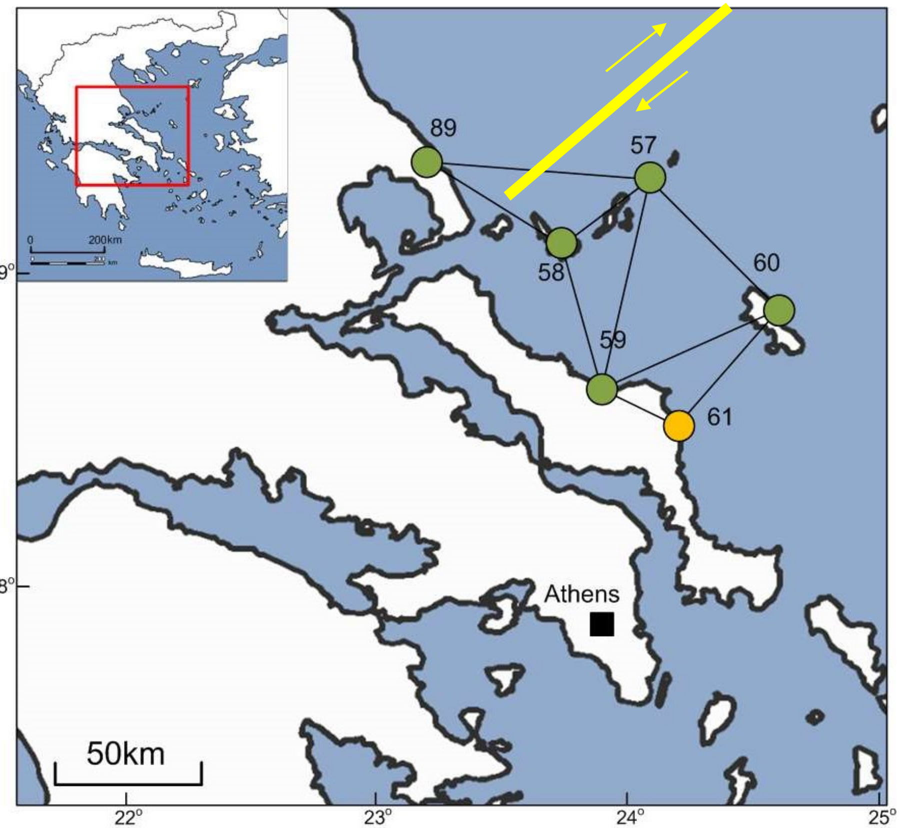


GPS Slip vectors computed using **only**

- uniform hardware
- continuous stations
- high accuracy data
- representative data sets
- data with common noise
- uniform processing

Slip vectors from the HEPOS GPS network indicate

- A characteristic slip discontinuity around NAT
- Clear shear deformation in the central and east part of the NAT (till the coast)
- But deformation pattern tends to change to the west, in the mainland
  - ► Kinematic pattern changed in the mainland -no clear shear discontinuity



Triangulation measurements

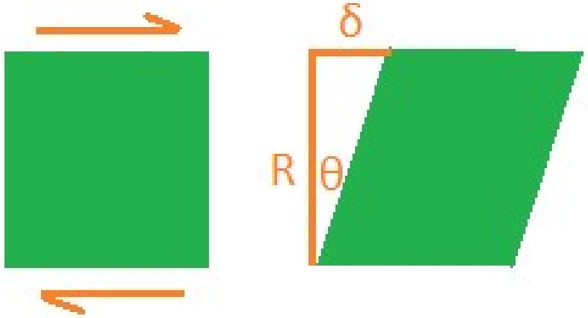
Survey 1, 1890-1892
Survey 2, 1929-1930
Survey 3, 1950-1966

Examine **only** measurements from stations *stable/common* in all surveys

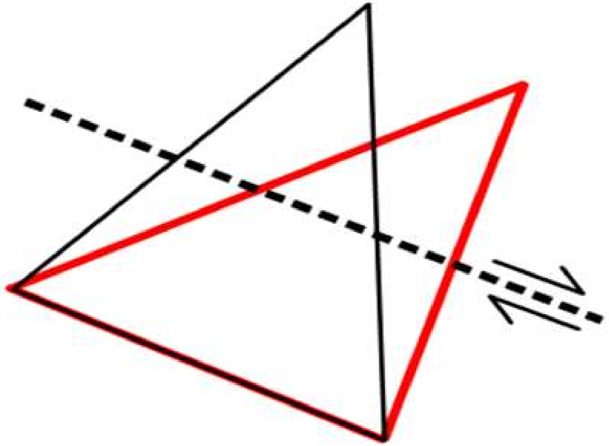
- Data double checked to avoid errors (changing positions, etc.) -all dubious stations rejected
- Measurements from point on top of mountains peaks → limited atmospheric noise
- Very precise: average values from >24 valid sets of measurements, lasting weeks/months
  precision in angles better than 0.00016 grads
- Very accurate: control through misclosure errors in several triangles (ideally, sum of 180^{o})
  ► Maximum misclosure error in 76 triangles: 0.0002 grads (Stiros 1993).

Shear from triangulation data

Triangulation data cannot describe well displacements, but describe excellently angle changes & shear



Typical shear deformation
→ angle change



Shear deformation accurately deduced from slight changes of angles in a triangle

- Estimates of shear **γ** (or of shear rate $\dot{\gamma}$), of its direction **ψ** & of their uncertainties computed using only approximate coordinates and angle measurements

$\dot{\gamma}$ = *f* (angle changes, approximate coordinates of triangulation stations, time**)**

(algebraic formula in symbolic form)

- Precision/accuracy in estimates of shear increase with number of triangles
- No need for assumptions, approximations, etc.

  ► results precise & reliable

Results: Estimates of shear strain rate at the west edge of the NAT

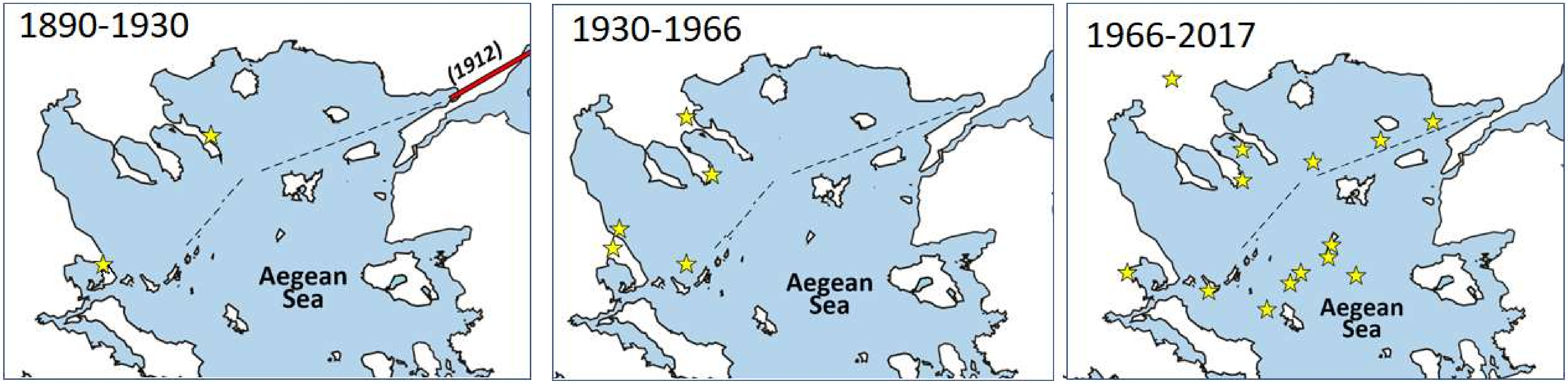
Between surveys	**1 to 2**	**2 to 3**
Time interval	1890/1892 to 1929/1930	1929/1930 to 1950/1966
$\dot{\gamma}$ (μrad/yr)	**0.05**±0.04	**0.48**±0.10 (a few cm/yr/50km)
Ψ (º)	**-40.5º**±12.9º	**30.2º**±0.6º

No significant shear

Significant shear
at a direction compatible to the strike of NAT

► No evidence of shear strain before the 1930's

West edge of NAT, correlation between seismicity & computed shear strain



no shear strain,
limited seismicity, M>6.0

shear strain,
important seismicity, M>6.0

No artefact of poor knowledge of seismicity before the 1930's
Structural relationship between shear strain and seismicity?

Questions arising:

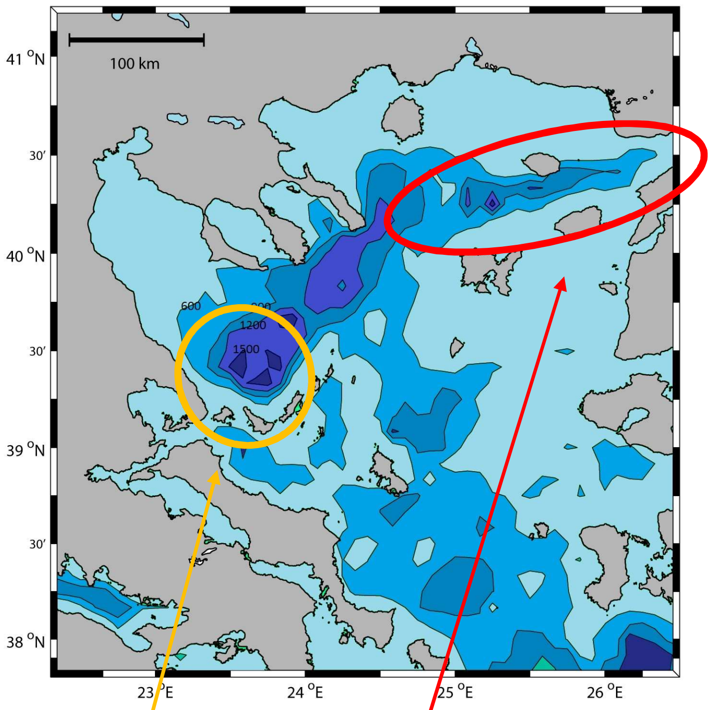
If the geodetic evidence for instability of shar is accurate
(no reasons to doubt!),

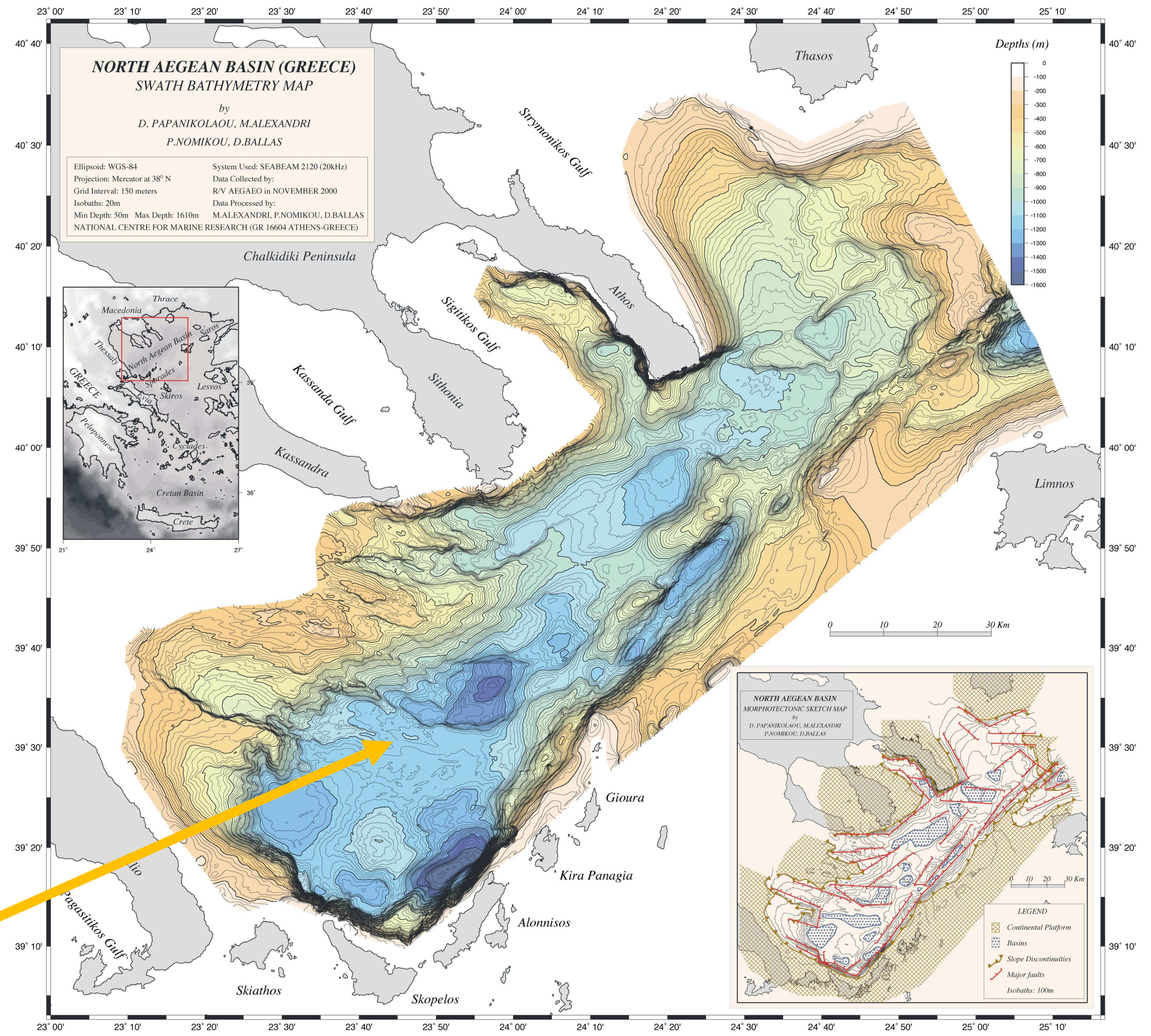
what is the reason for the inferred
change in the kinematic pattern
in the west part of NAT after ~1930?

and what are its geodynamic implications?

First, a look at the tectonic structure of the NAT

Contrast between the east and west edge of the NAT





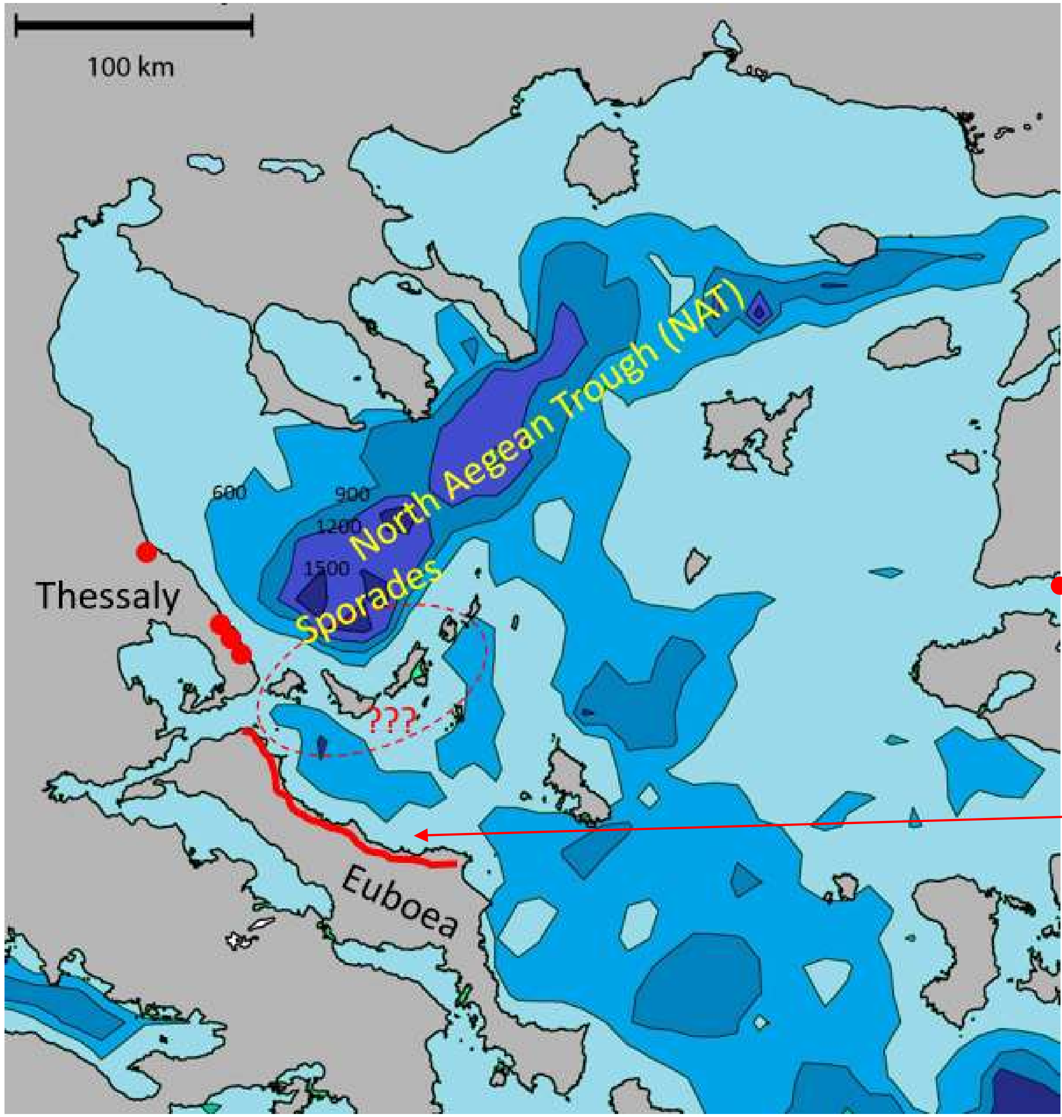
Papanikolaou et al, 2002)

East part of NAT:
a simple narrow deep basin at the continuation of the NAF, strike slip controlled

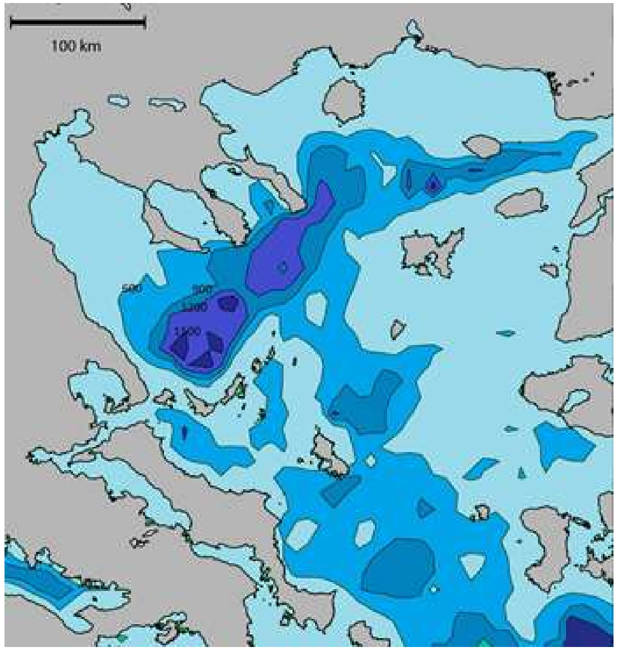
West part of NAT: structural complexity

The west part of the NAT abuts to a system of raised Holocene and Quaternary shorelines,
usually poorly developed/recognized (especially in the Sporades Isles) because of lithological and biological limitations

Not a “typical” strike-slip environment



Holocene and Quaternary uplifted shorelines (Stiros et al 1992, 1994)



Summary:

In the *westernmost part* of the NAT

- complex tectonics (fault splaying & interaction?)
- evidence of ***instability*** in the displacement field (shear)

Possible explanations

Kinematics in this structurally composite area are likely to reflect

- cumulation of different tectonic processes at different time scales
- boundary effects / influence of adjacent tectonic provinces / fault interaction

Superimposition of short-term deformation rates from different sources

- *temporarily* obscure certain regional effects (e.g. shear from the east),
- emphasize transient effects
- lead to alternation of periods of strong earthquakes with relatively short aseismic intervals.

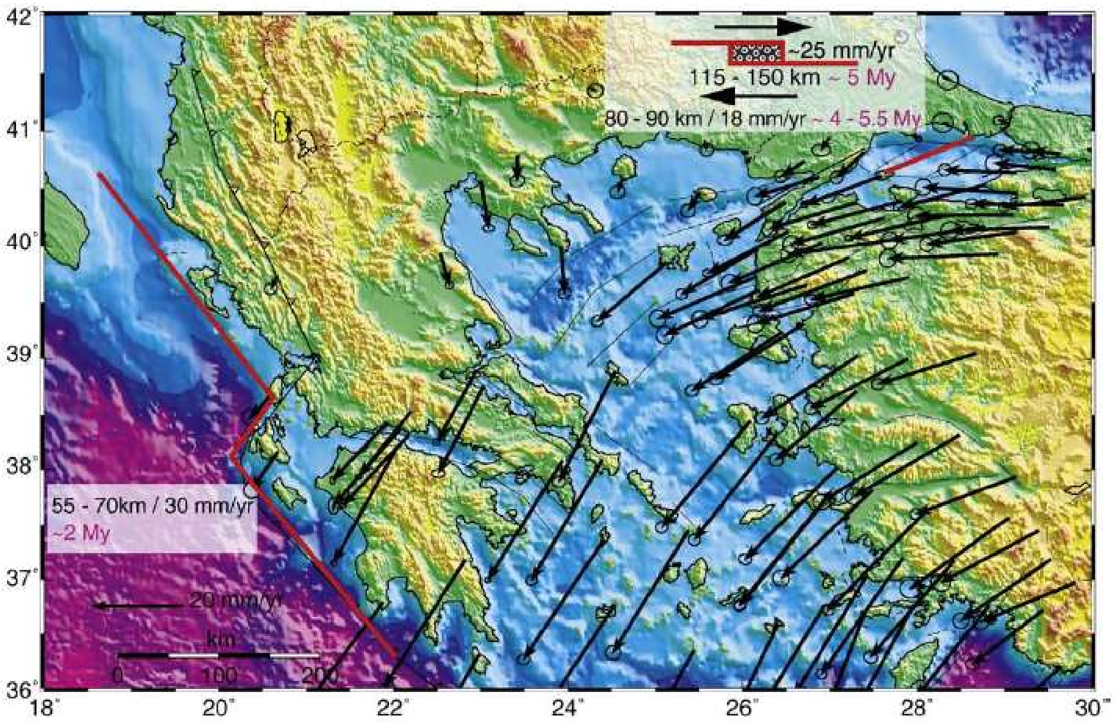
Conclusions

- In the west termination of the North Aegean Trough (NAT)
  we were able to expand the time scale of geodetic observations
  from tens of years (satellite data) to 100+ years (using triangulation data), and
- we found evidence of **shear strain instability** in periods of a few tens years,
  not recorded by shorter term GPS data
  most likely correlating with changes in seismicity rates

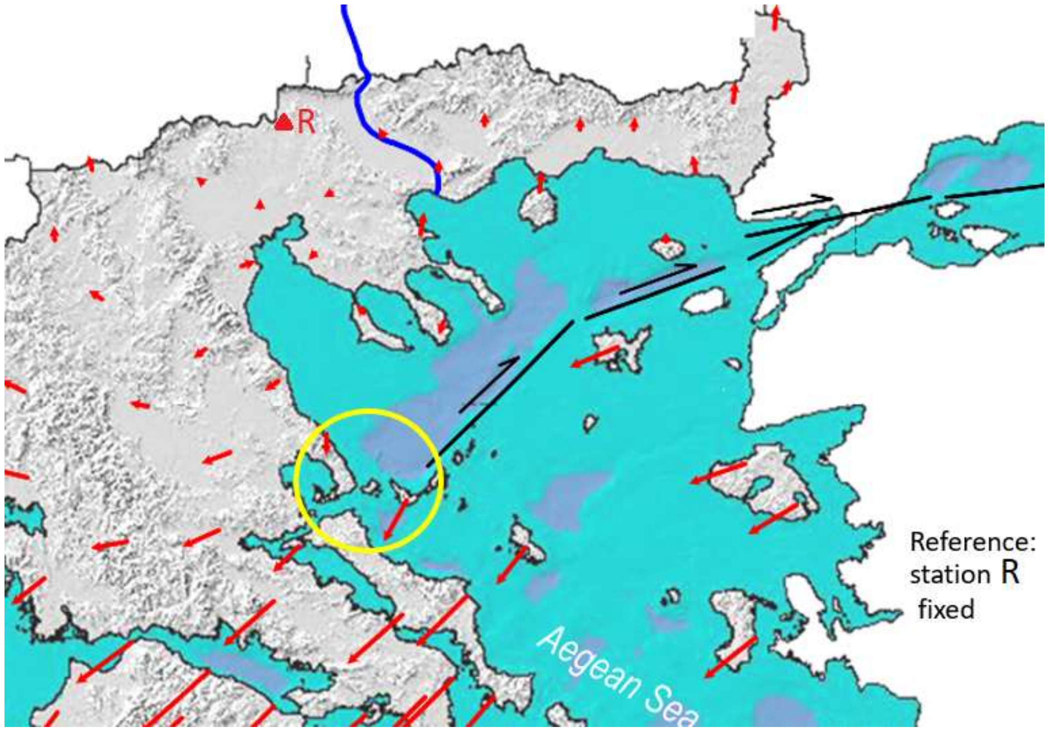
The likely explanation:

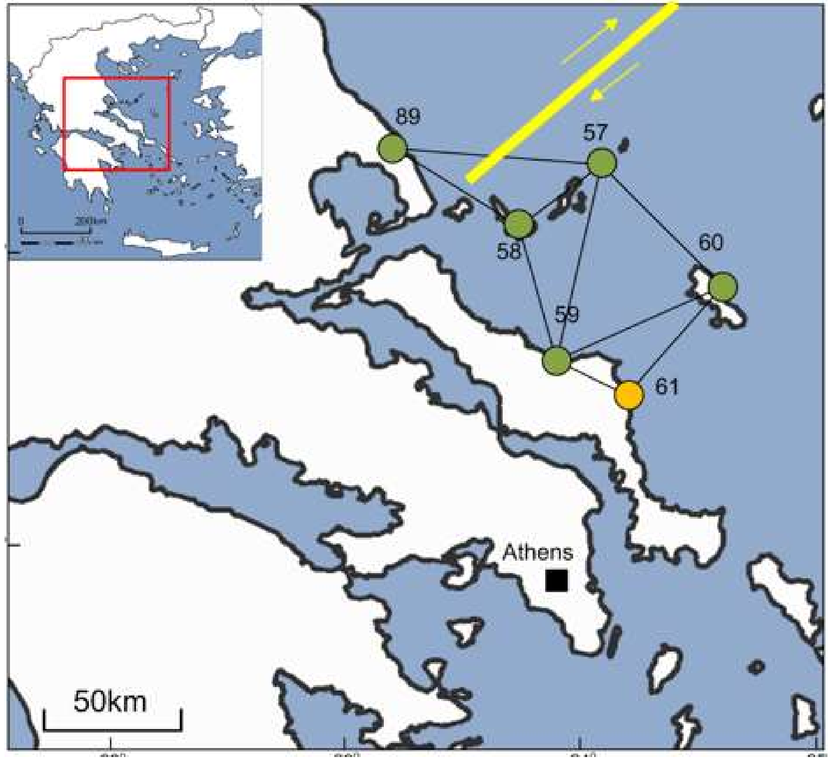
- tectonic complexity at the termination of the fault
- influence from adjacent areas (boundary effects)
- superimposition of short and longer-term processes

A question/perspective
Similar pattern/effects in other major strike slip faults??



McClusky 2010





epochs	I-II	II-III
	whole network	
$\dot{\gamma}_1$ (μrad/yr)	**0.05**±0.04	**-0.42**±0.09
$\dot{\gamma}_2$ (μrad/yr)	0.01±0.05	**0.24**±0.10
$\dot{\gamma}$ (μrad/yr)	**0.05**±0.04	**0.48**±0.10
Ψ(°)	**-40.5**±12.9	**30.2**±0.6
	triangle *57- 58- 89* (NAT)	
$\dot{\gamma}_1$ (μrad/yr)	0.00±0.01	**-0.34**±0.24
$\dot{\gamma}_2$ (μrad/yr)	0.00±0.01	**0.09**±0.40
$\dot{\gamma}$ (μrad/yr)	0.00±0.01	**0.35**±0.31
Ψ(°)	2.2±61.9	**37.6**±14.2