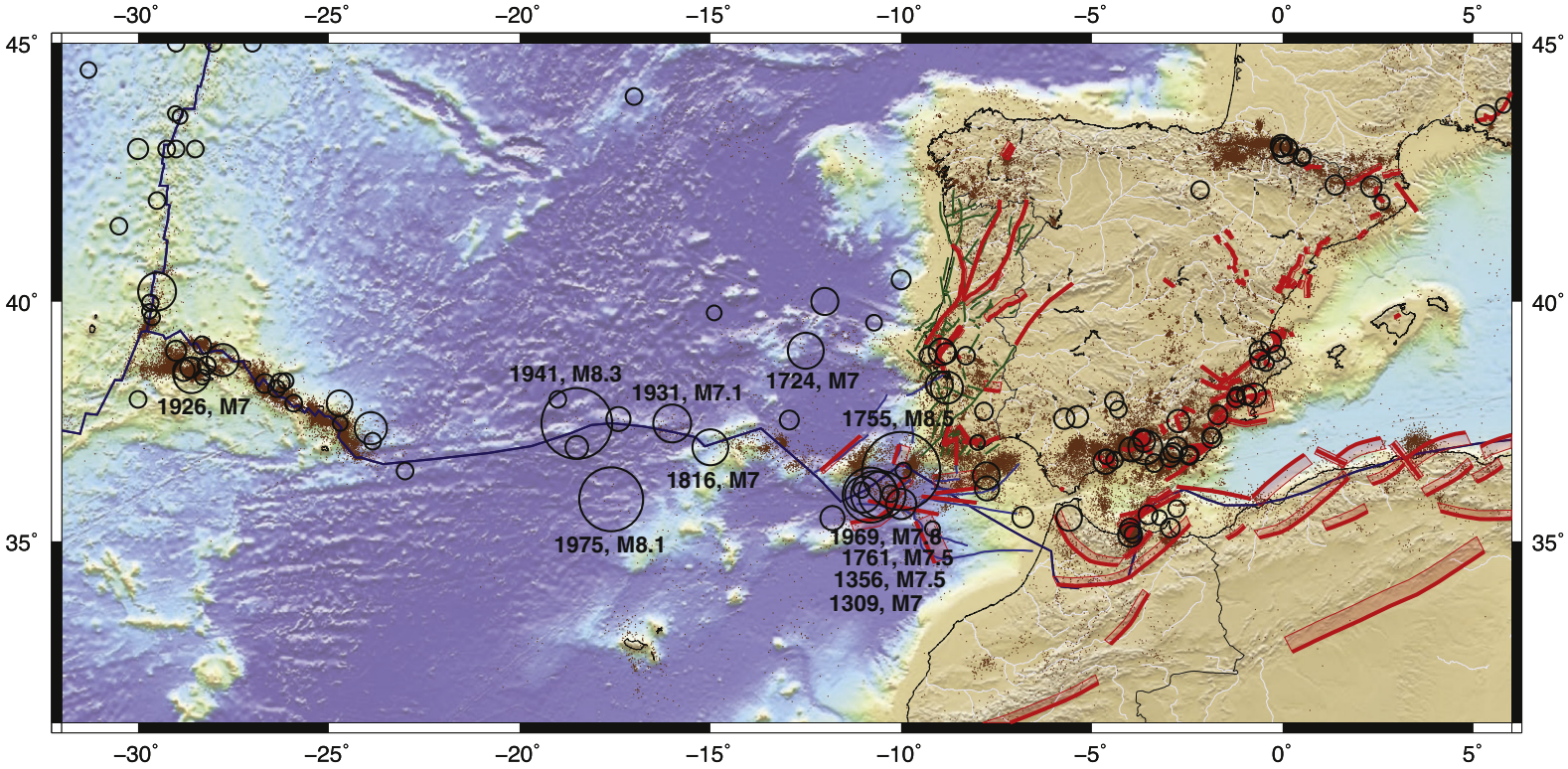
Earthquakes in low strain regions: Challenges and Opportunities

An example from West Iberia

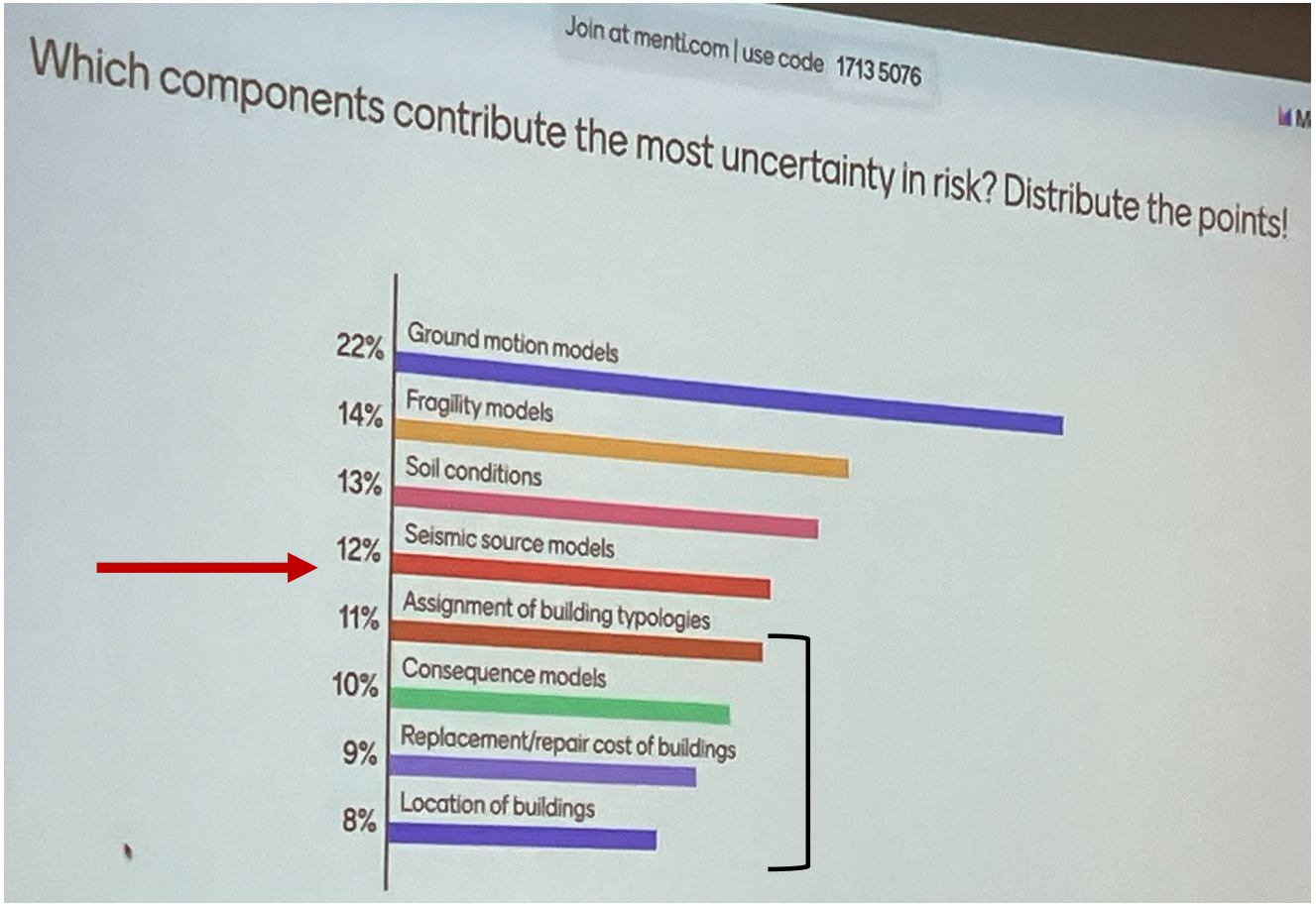


Susana Custodio (susana@fc.ul.pt) and many others…

INSTITUTO DOM LUIZ

Ciências ULisboa

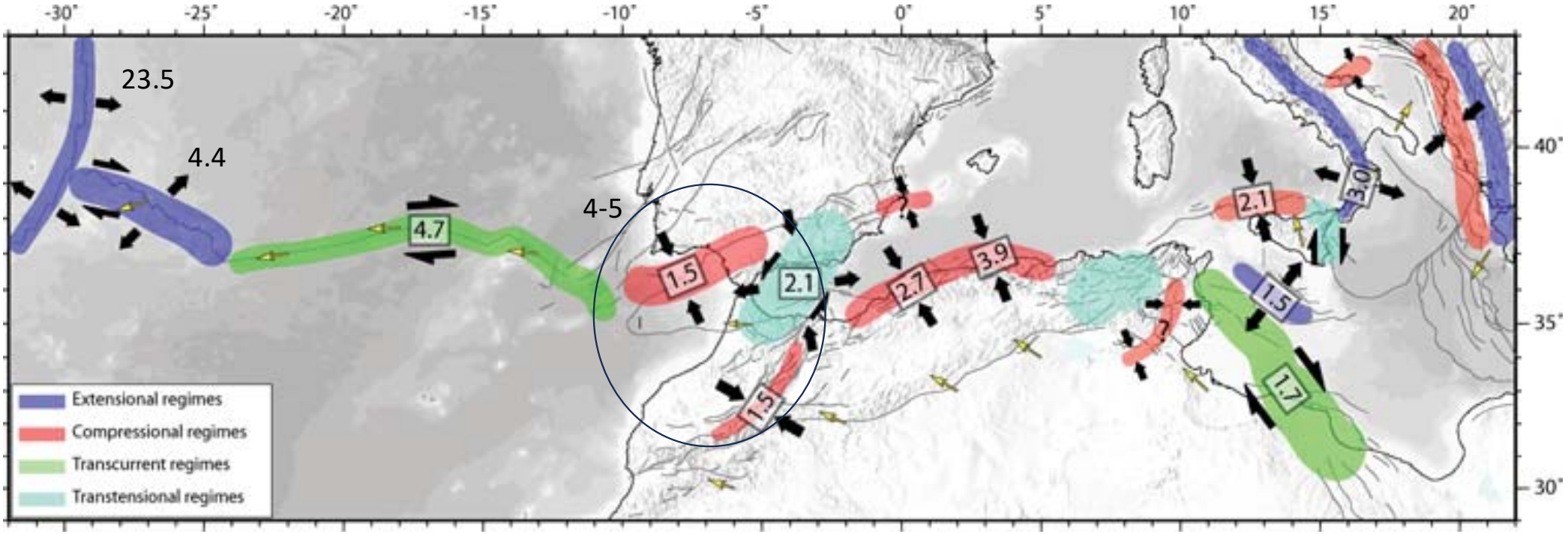
Back to Seismic Sources…



Courtesy of Salvatore Iacoletti

Tectonic Setting

Deformation rates (mm/yr)

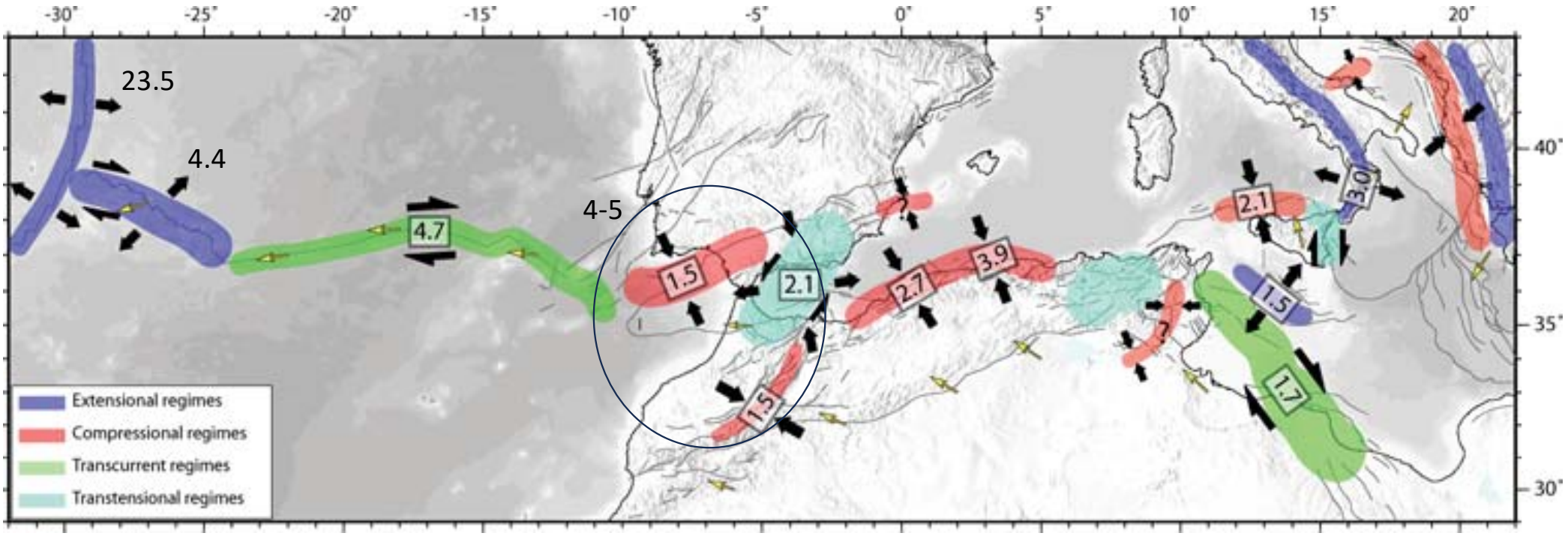


Serpelloni et al, 2007

Tectonic Setting

Do we need to worry about earthquakes in low strain rate regions?

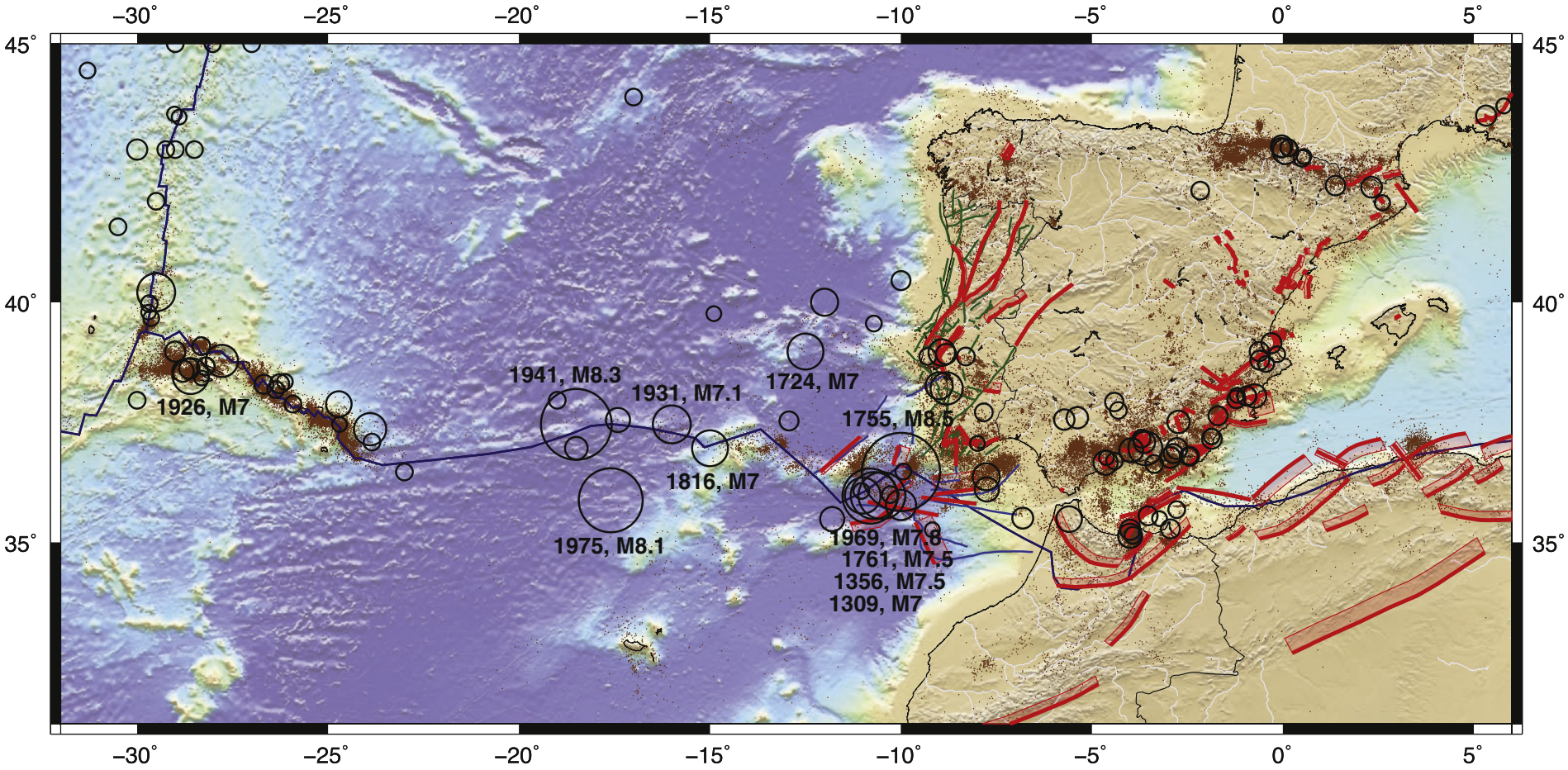
Deformation rates (mm/yr)



Serpelloni et al, 2007

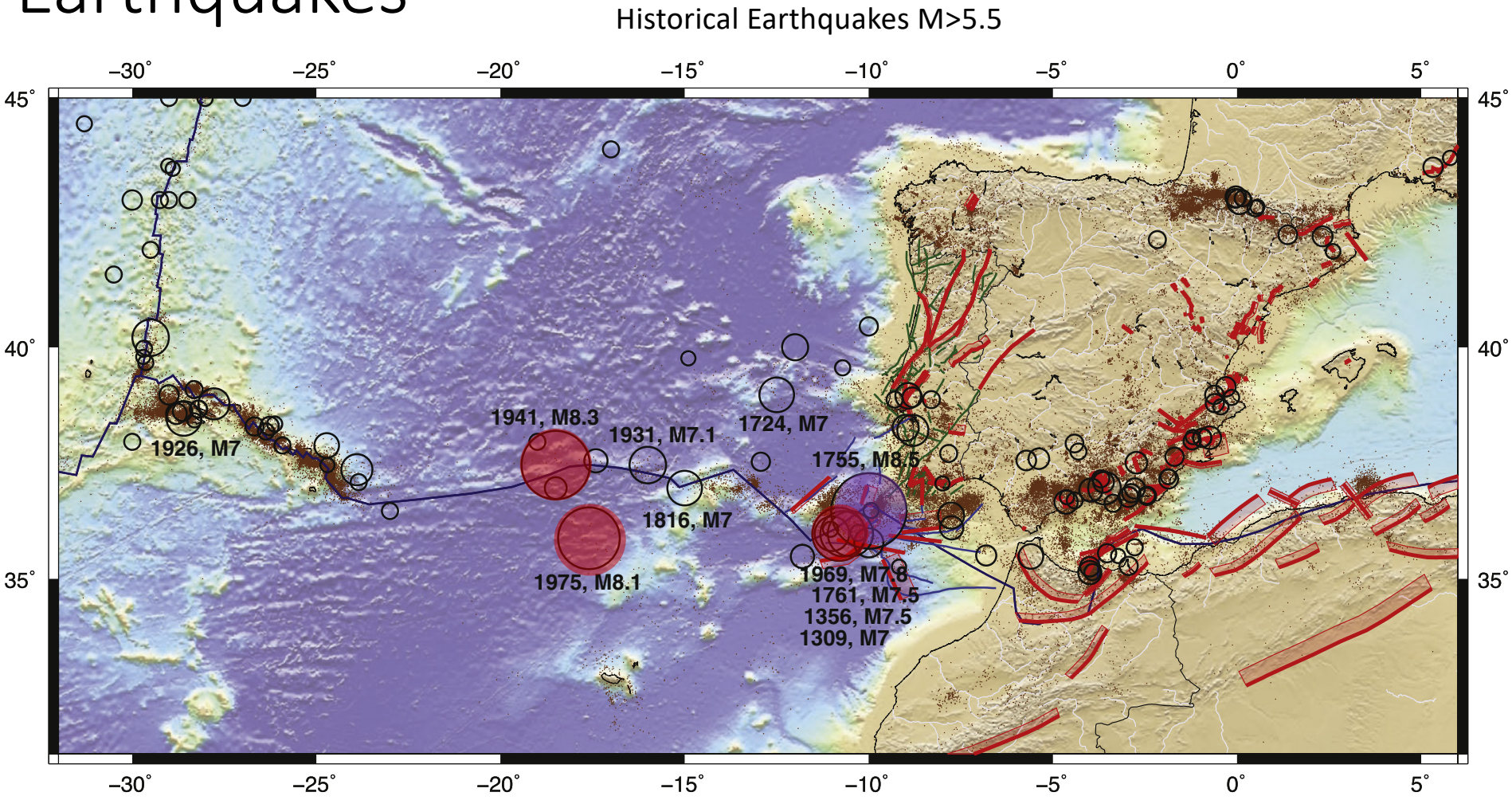
Earthquakes

Historical Earthquakes M>5.5

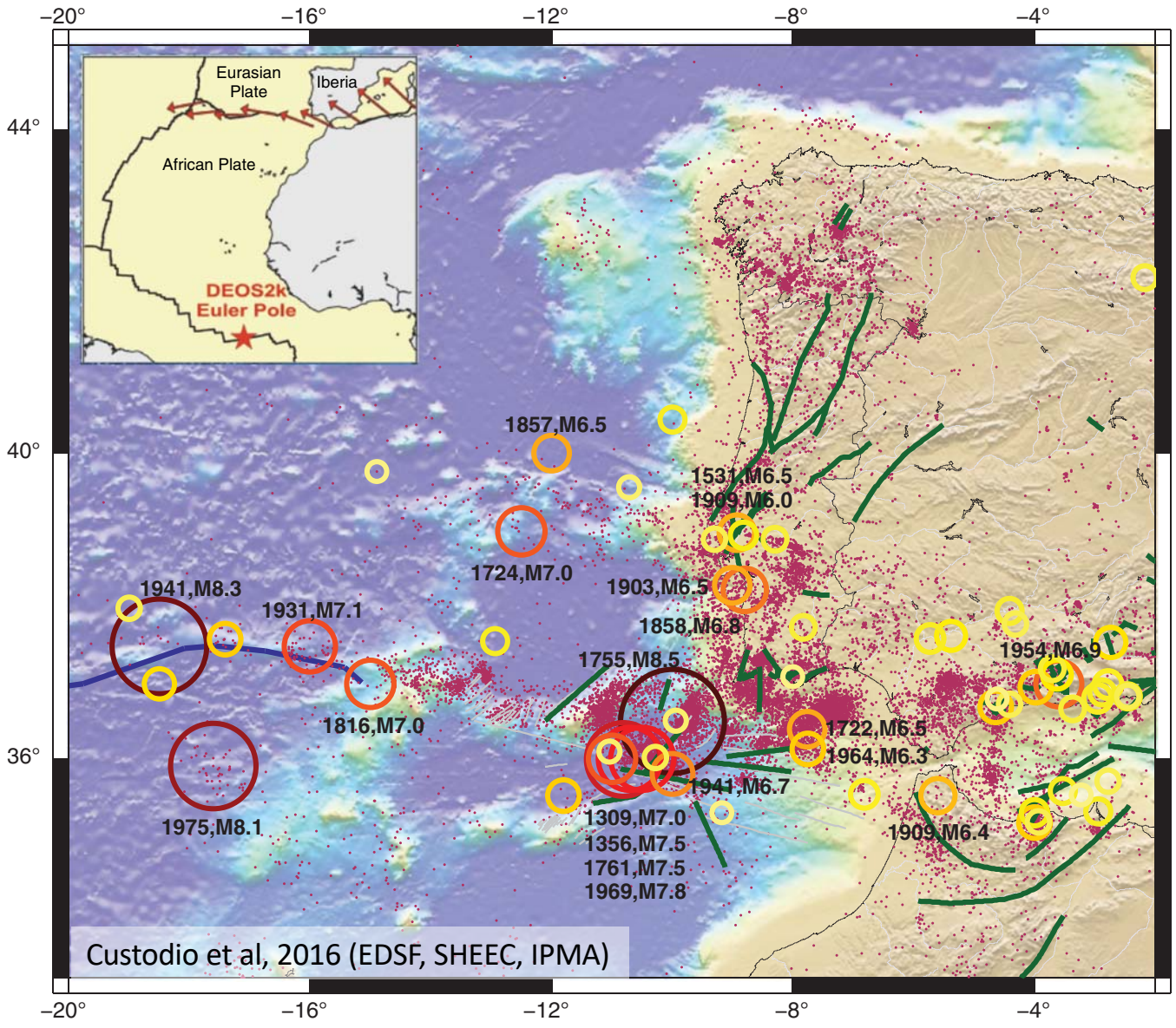


Custodio et al, 2016

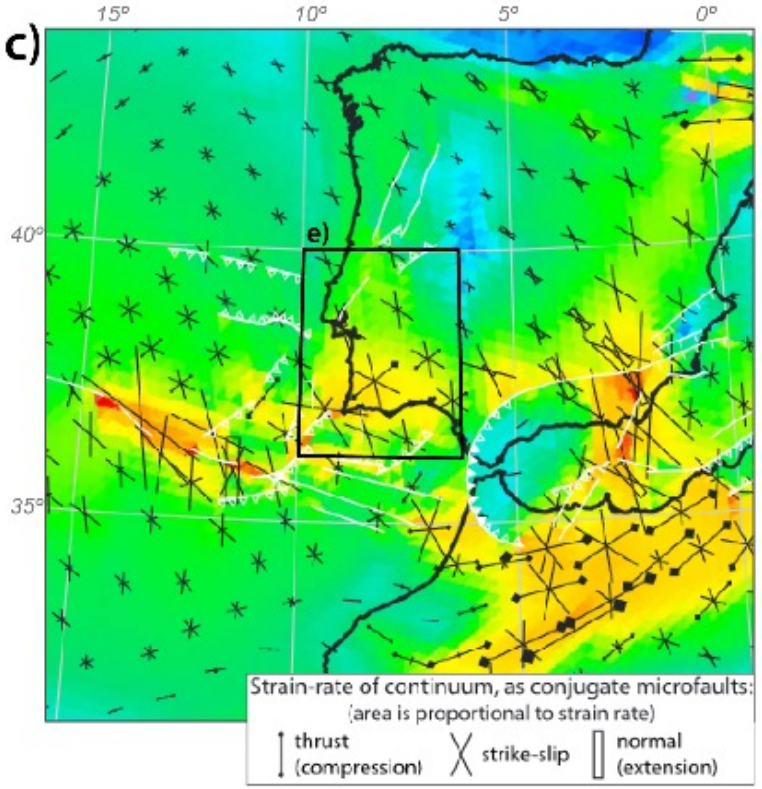
Earthquakes



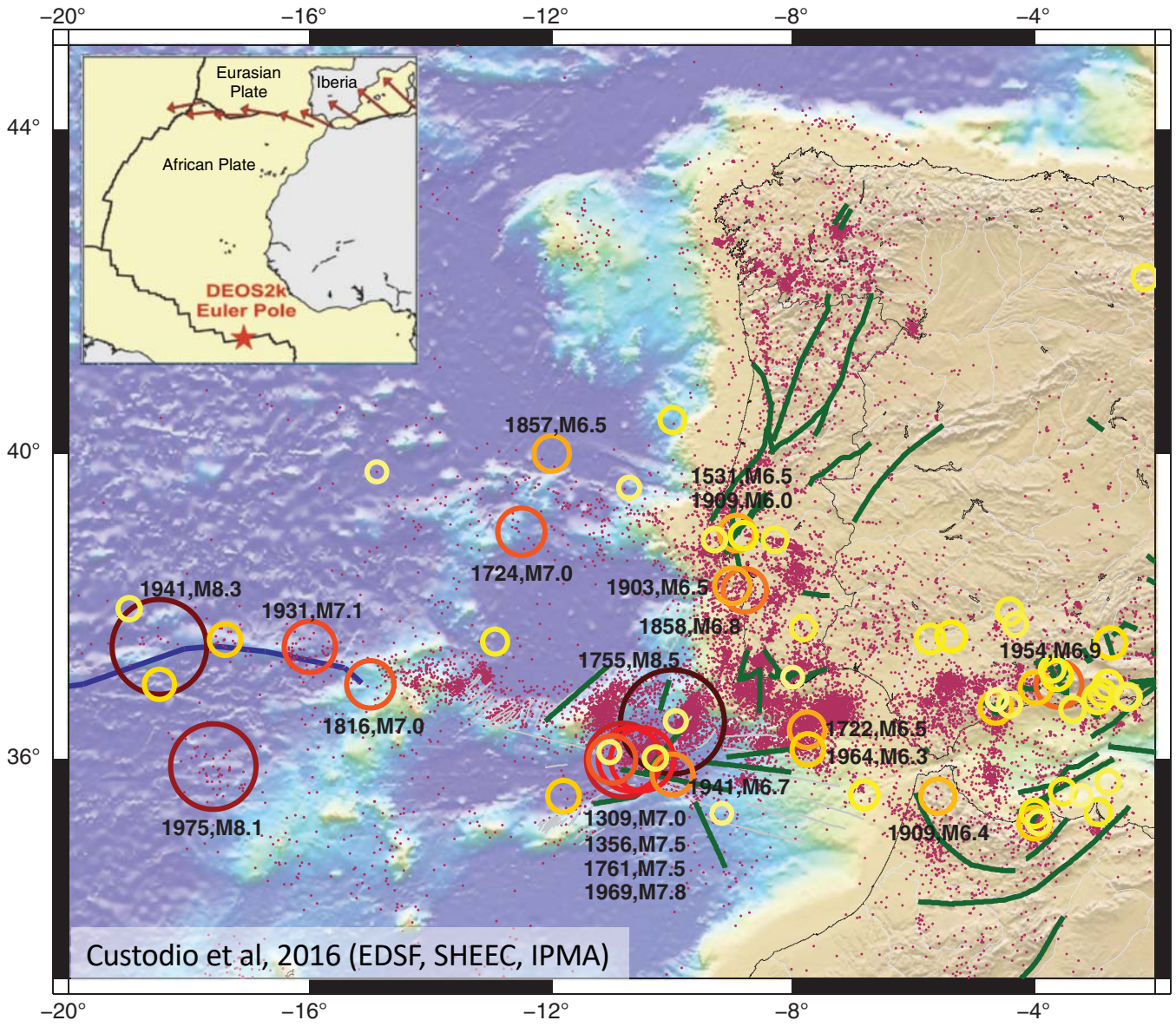
Custodio et al, 2016



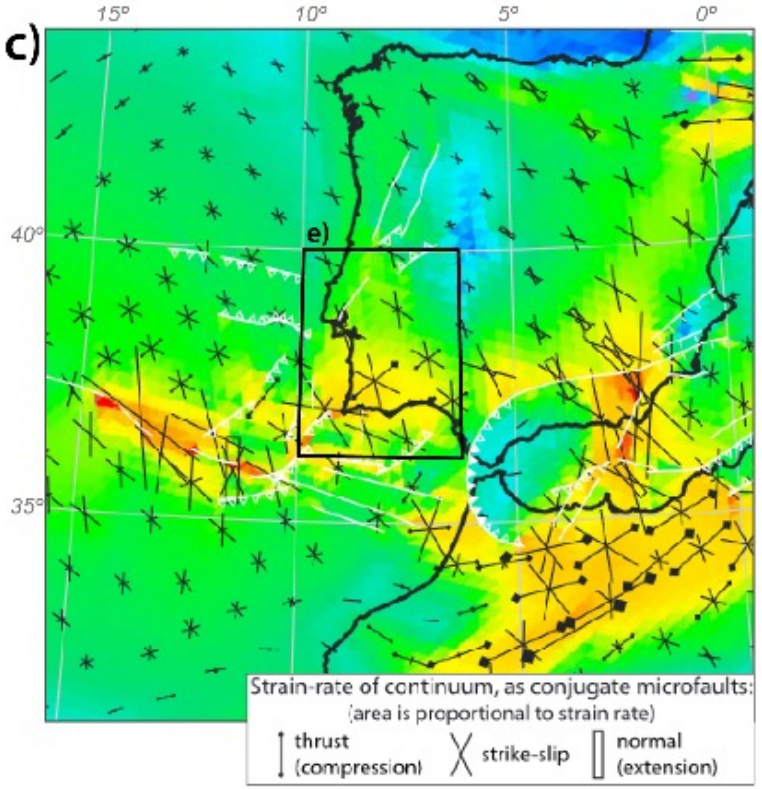
Strain rates from geodynamic modeling



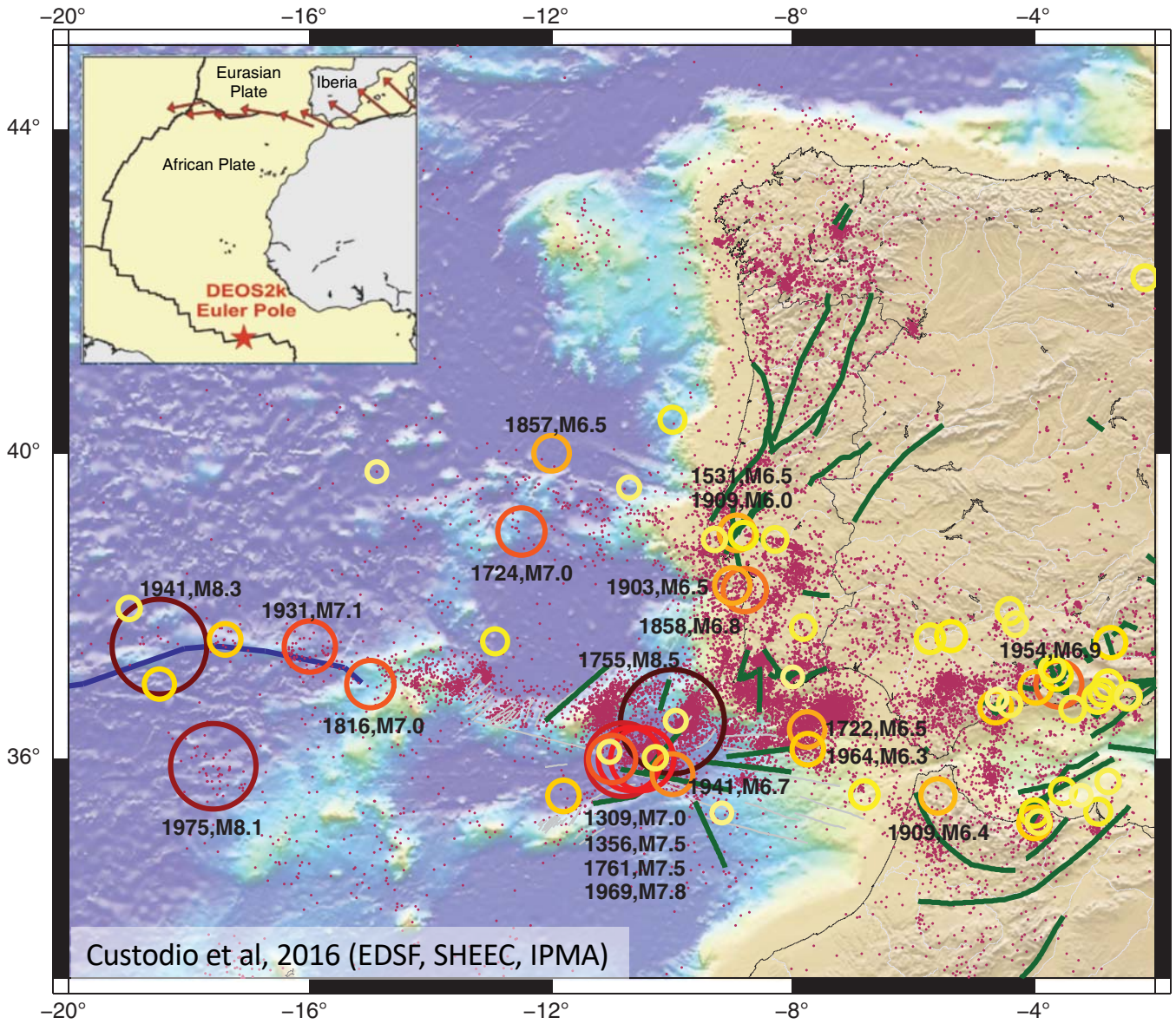
Neres et al, 2016



Outstanding Question: What are the faults that unleashed the historical earthquakes??



Neres et al, 2016



Challenges

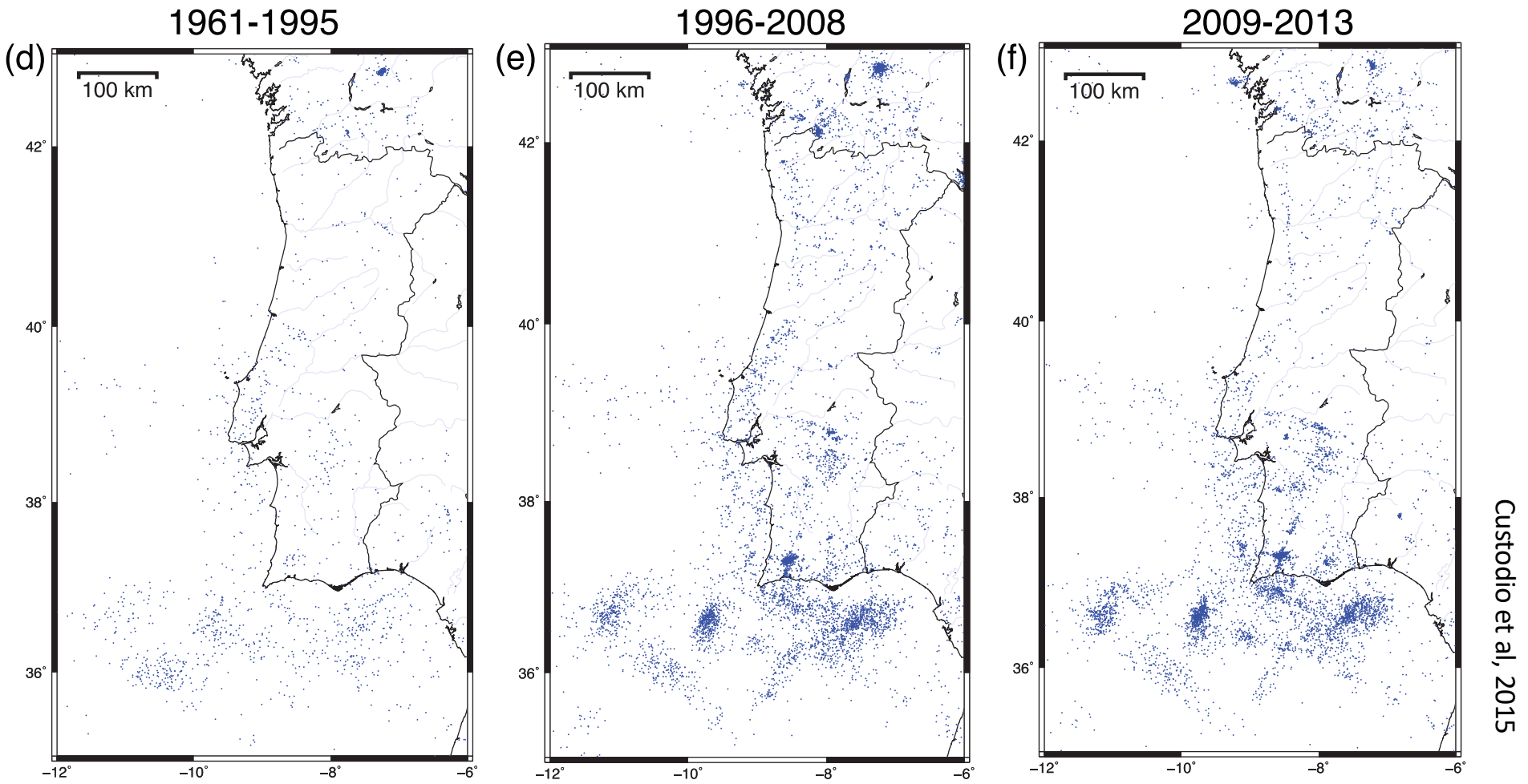
Seismicity:

- Few earthquakes
- Sparse networks

Geological record:

- Sedimentation
- Erosion
- Human activities

Instrumental seismicity



Custodio et al, 2015

Clusters and Lineations

Do you interpret these? 🤔

Cluster/ lineation	Location	Orientation	Number of earthquakes	Percentage of earthquakes	Observations
A	Porto-Tomar fault	N–S	107	0.73 per cent	Clear lineation
B	Seia-Lousã and Vilariça faults	NNE–SSW, NE–SW	66	0.45 per cent	Clear lineation
C	Montejunto-Aires-Candeeiros range	NNE–SSW	268	1.84 per cent	Diffuse (2?)
D	Arraiolos	WNW–ESE	334	2.29 per cent	Clear lineation
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F	–	No orientation	111	0.76 per cent	Very diffuse
G	–	NNE–SSW	64	0.44 per cent	Clear lineation
H	Monchique	NNE–SSW, E–W	1804	12.36 per cent	Clear, 2 lineations
I	–	No orientation	140	0.96 per cent	Very diffuse
J	Gorringe	NNE–SSW	598	4.10 per cent	Clear, diffuse cluster
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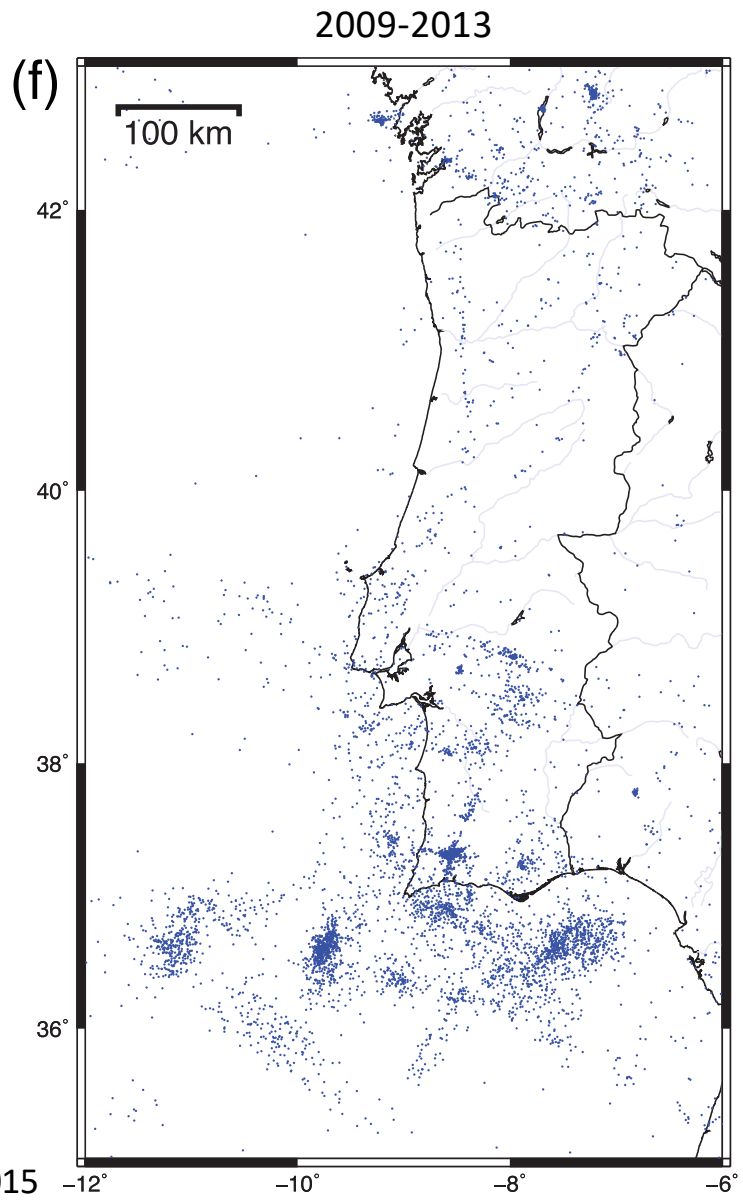
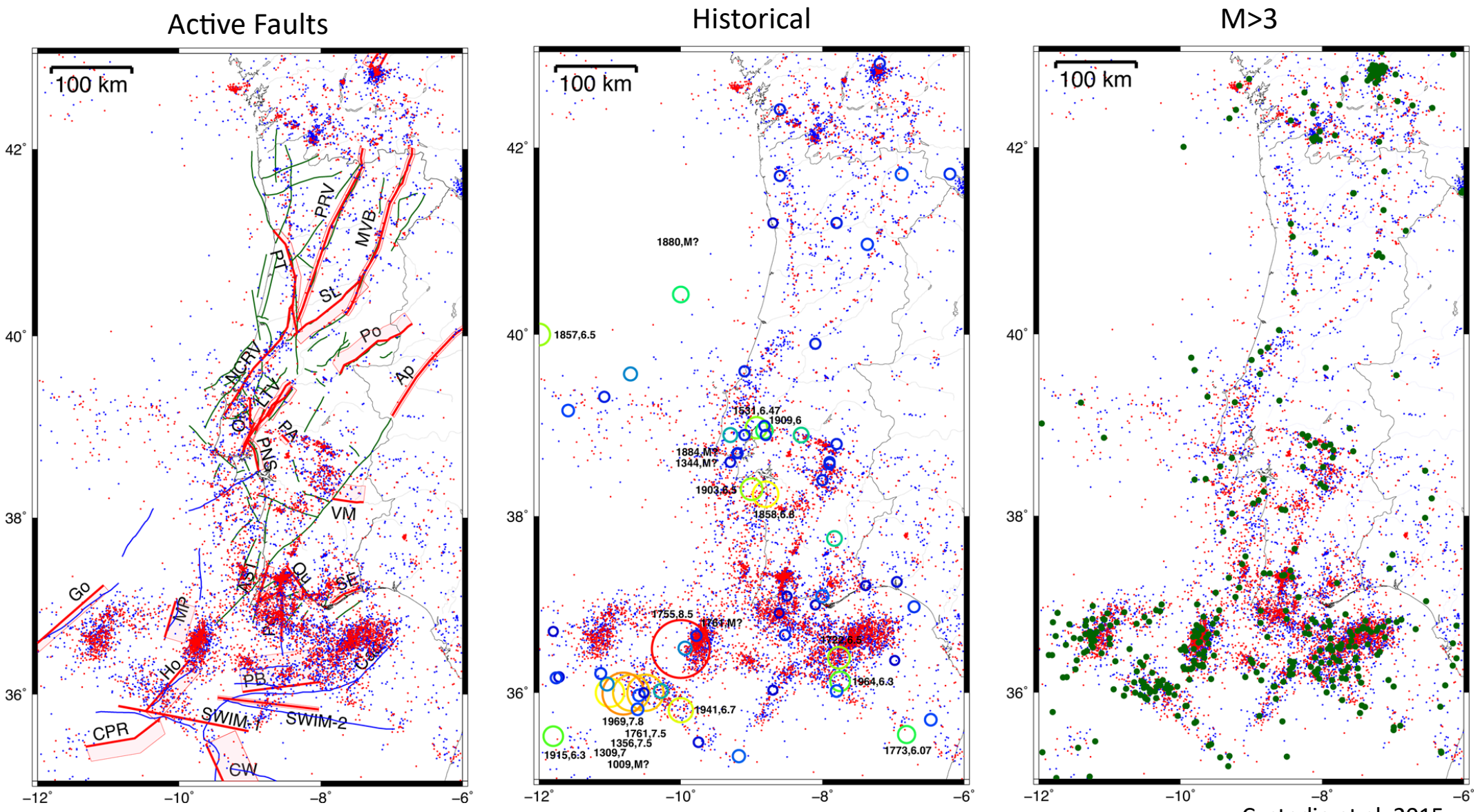
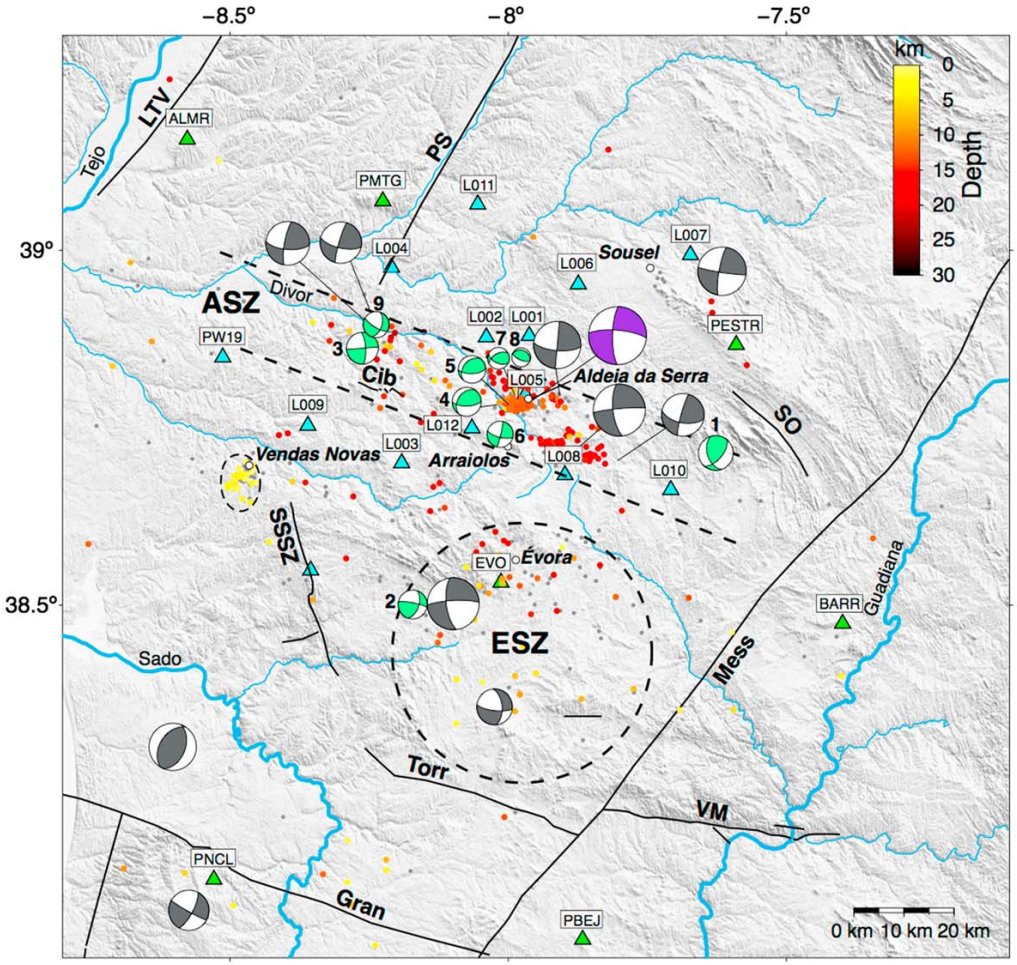


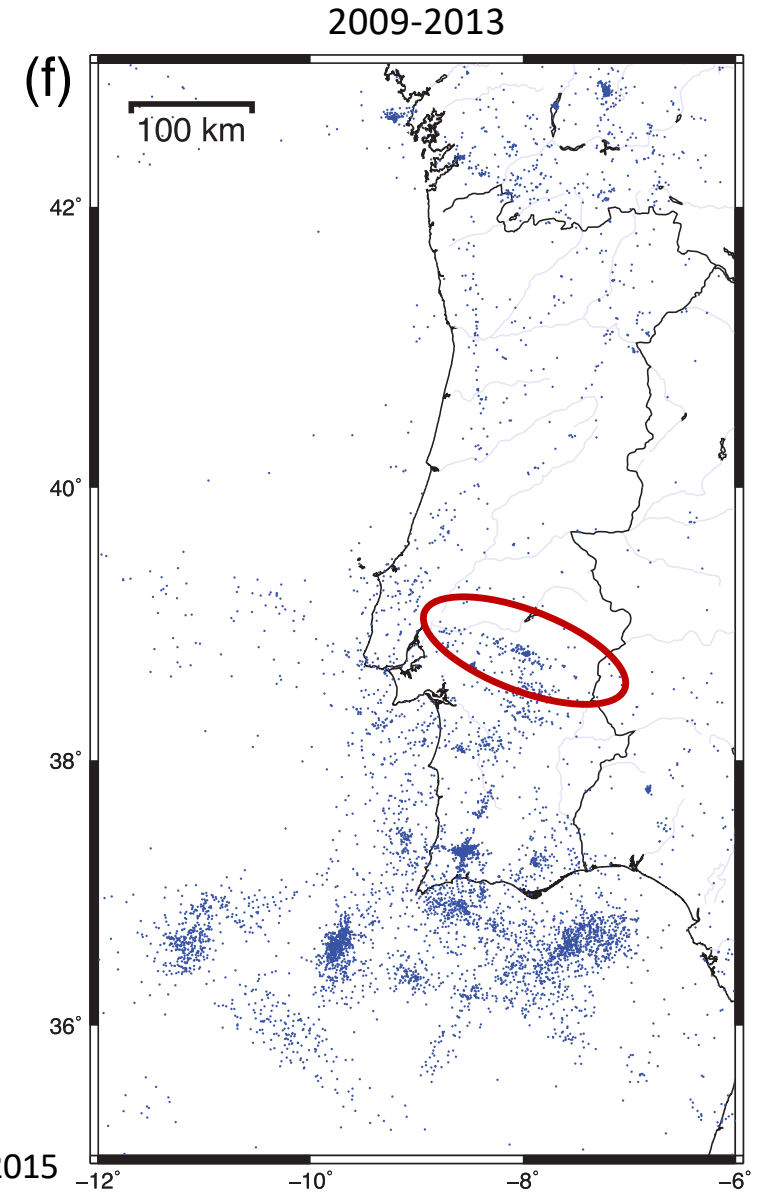
Custodio et al, 2015


Active Faults
Historical
M>3
100 km
100 km
100 km
42°
40°
38°
36°
−12°
−10°
−8°
−6°
PRV
MVB
PT
St
Po
Ap
INCRV
CTVLTV
PA
PNS
VM
AST
Ou
SE
Go
MP
Ho
PB
CPR
SWIM-1
SWIM-2
CW
1880,M?
1857,6.5
1531,6.47
1909,6
1884,M?
1344,M?
1903,6.5
1858,6.8
1755,8.5
1761,M?
1722,6.5
1964,6.3
1941,6.7
1969,7.8
1761,7.5
1356,7.5
1309,7
1009,M?
1915,6.3
1773,6.07
Custodio et al, 2015

1. Arraiolos

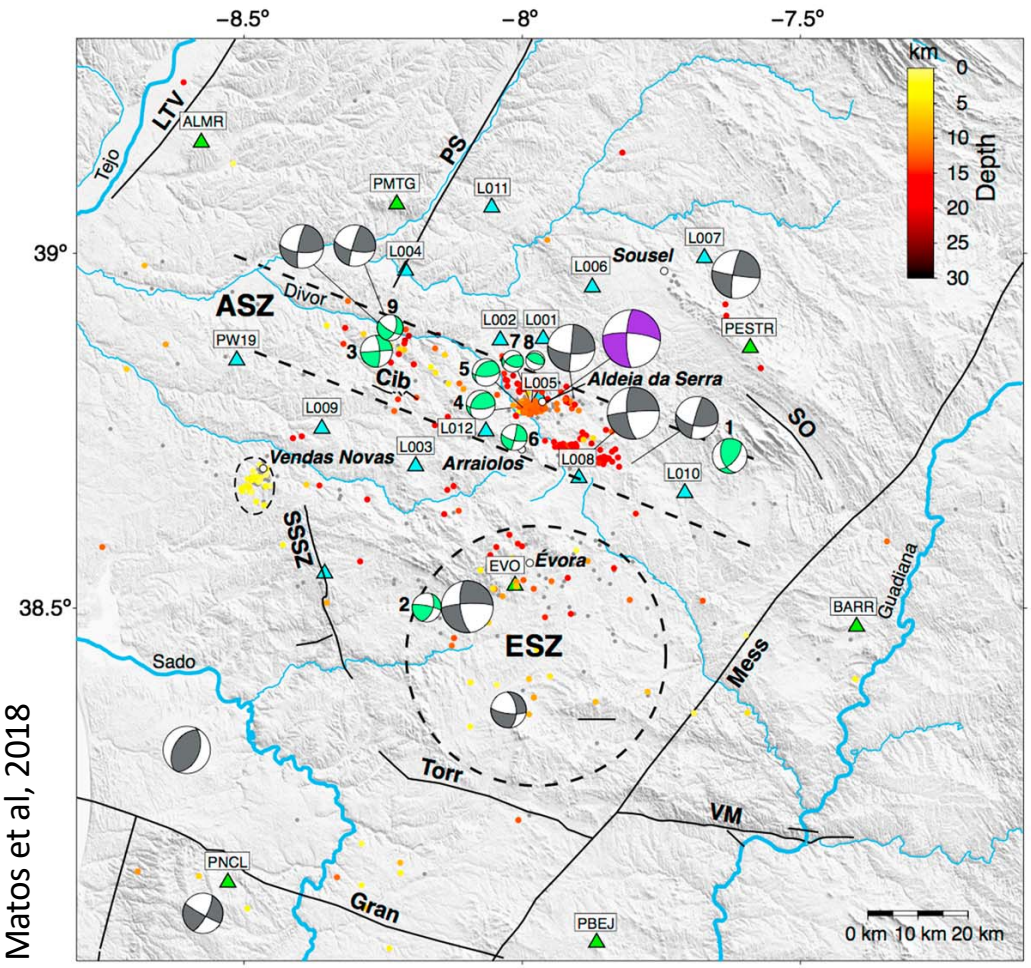


Matos et al, 2018



Custodio et al, 2015

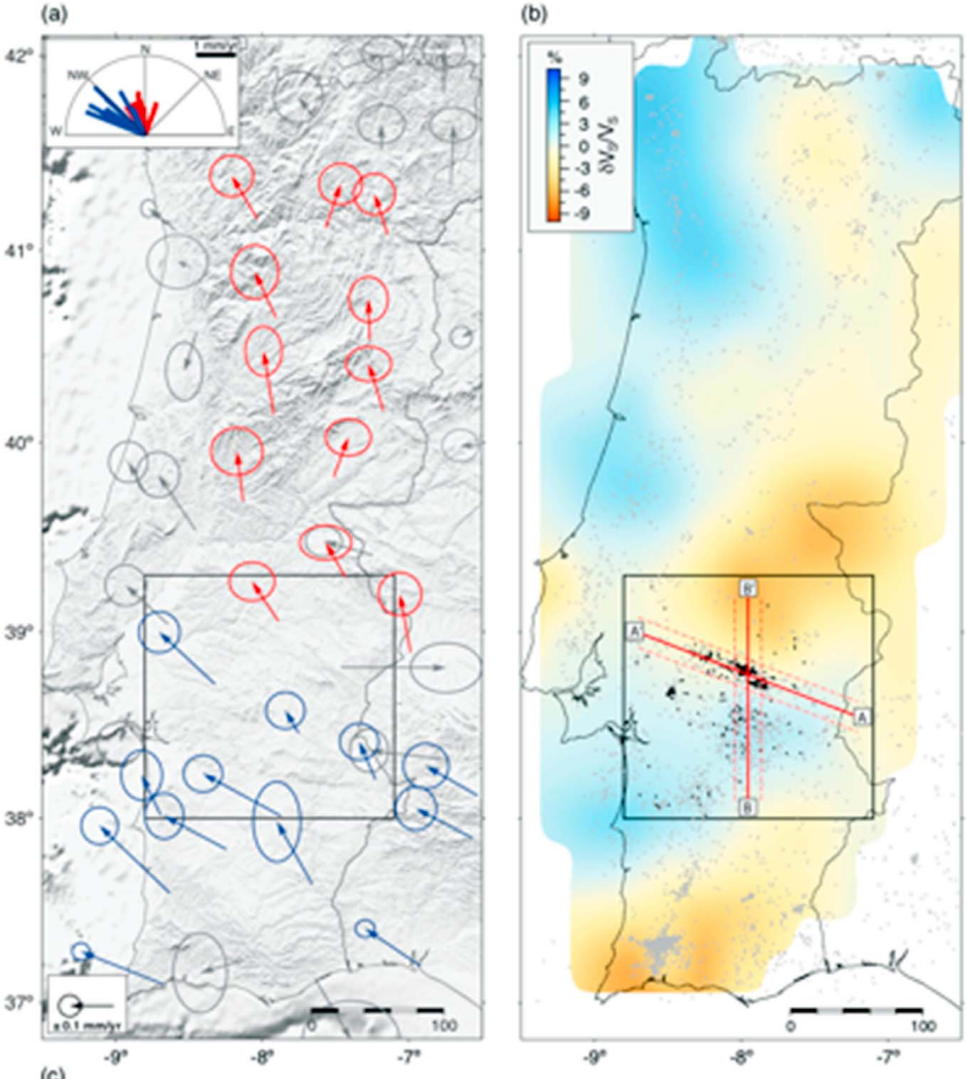
Arraiolos



Matos et al, 2018

GNSS displacement rates

Tomography (z= 25 km)

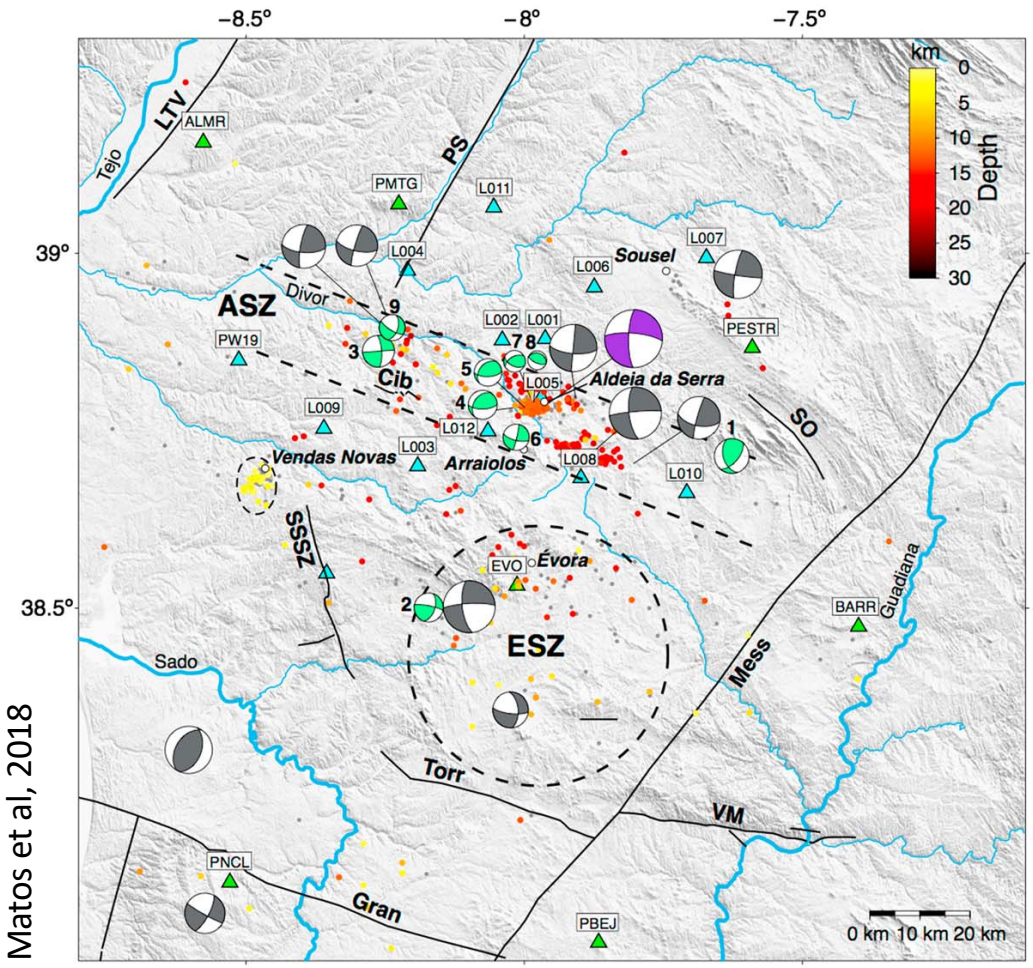


Arraiolos

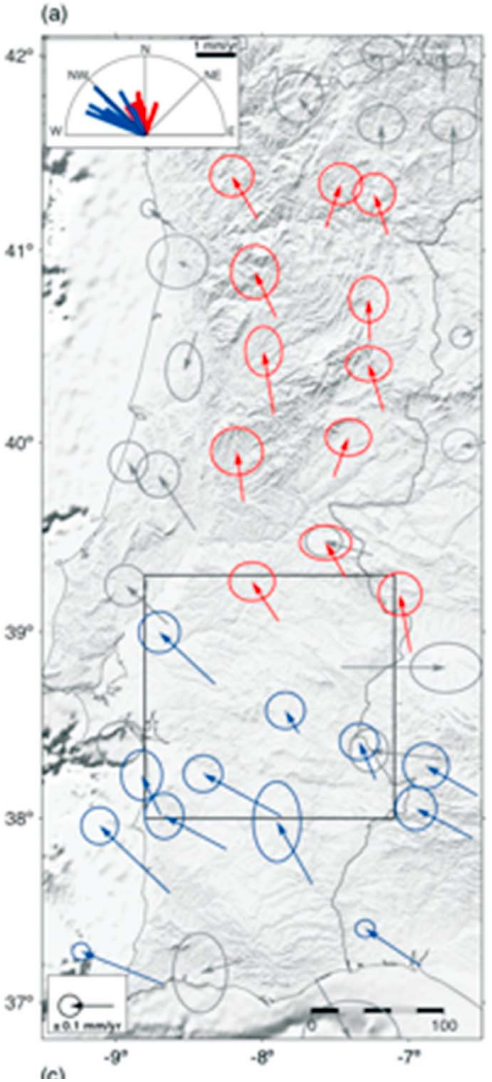
Opportunity!

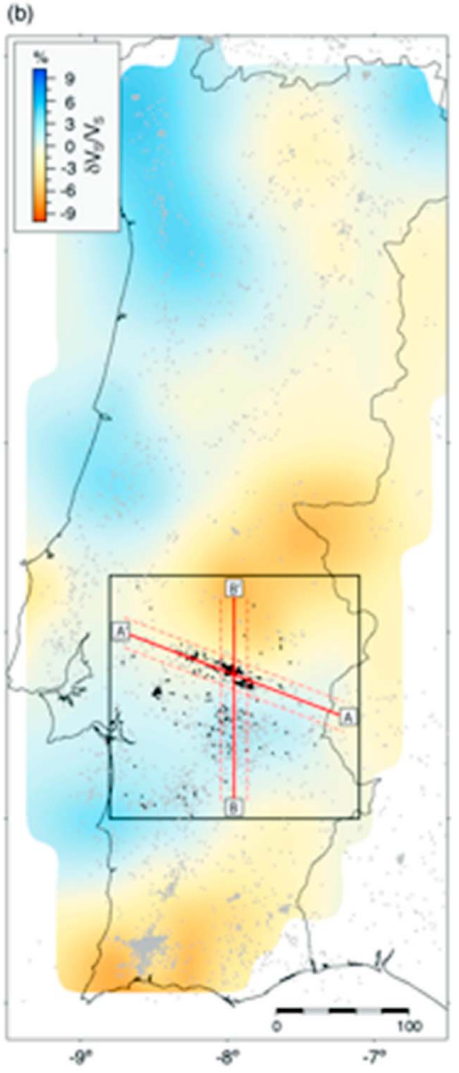
GNSS displacement rates

Tomography (z= 25 km)

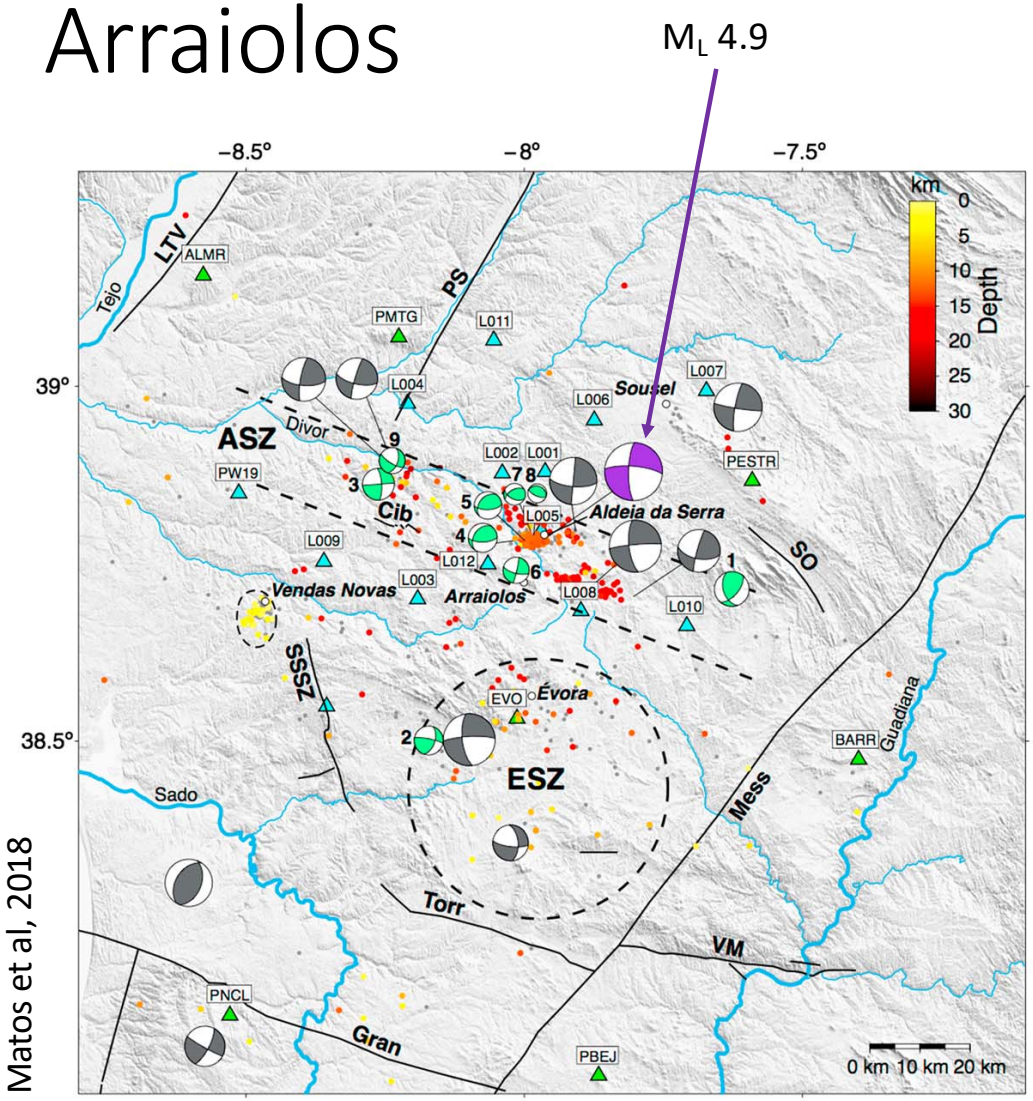


Matos et al, 2018





Arraiolos



Matos et al, 2018

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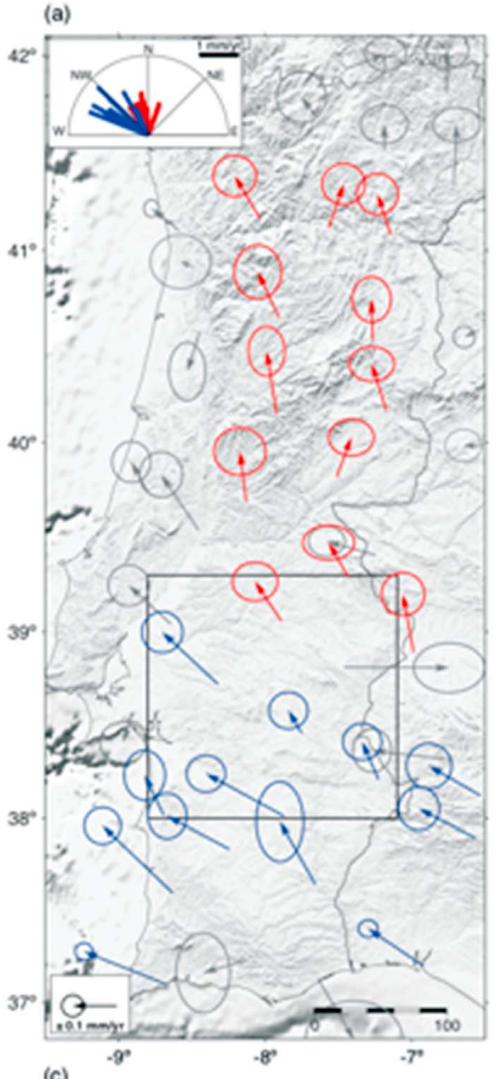
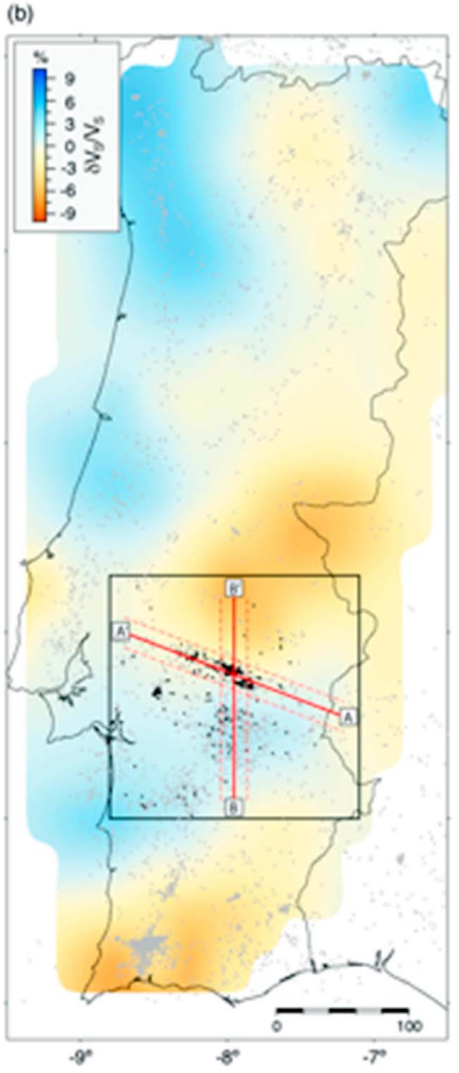
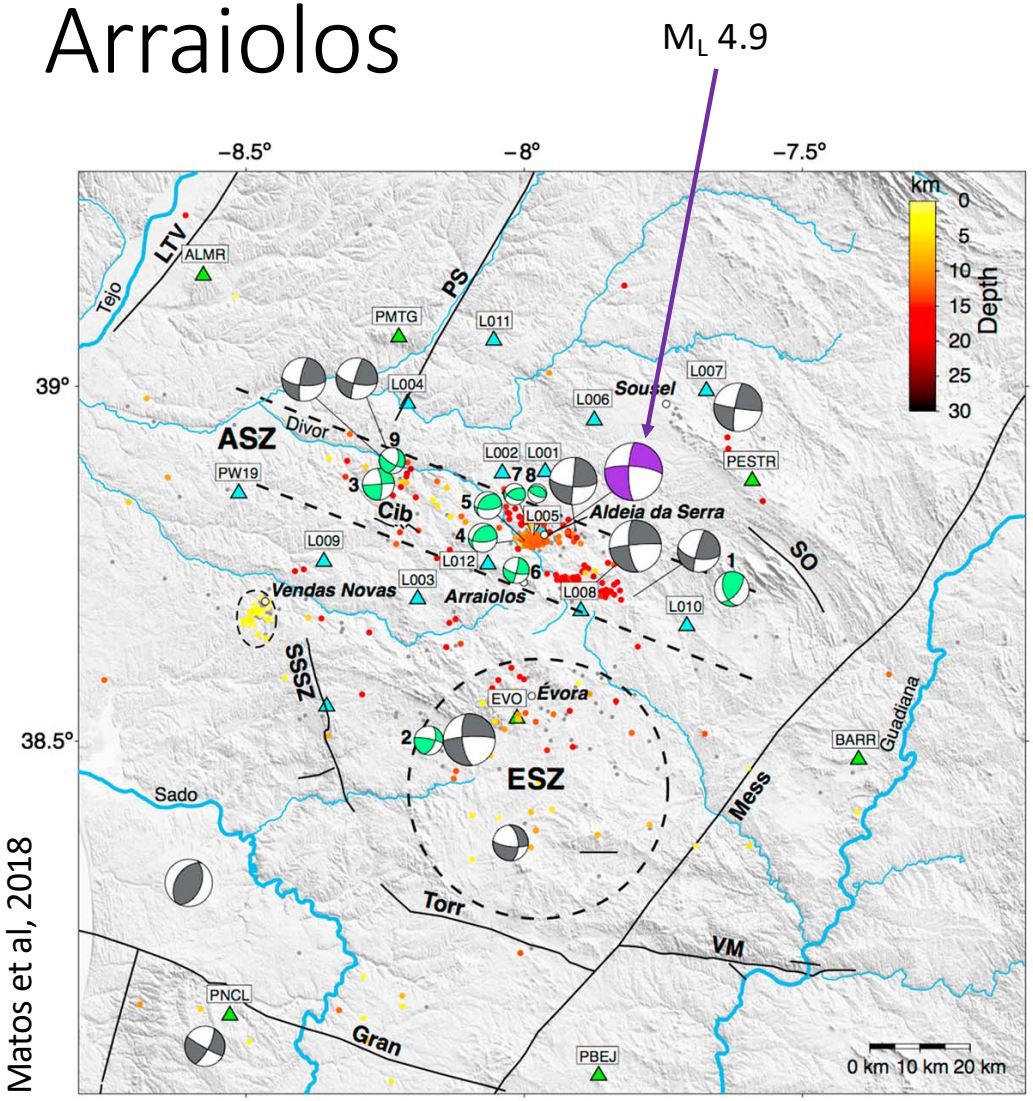


Tomography (z= 25 km)



Arraiolos



Matos et al, 2018

Porto-Tomar fault

GNSS displacement rates

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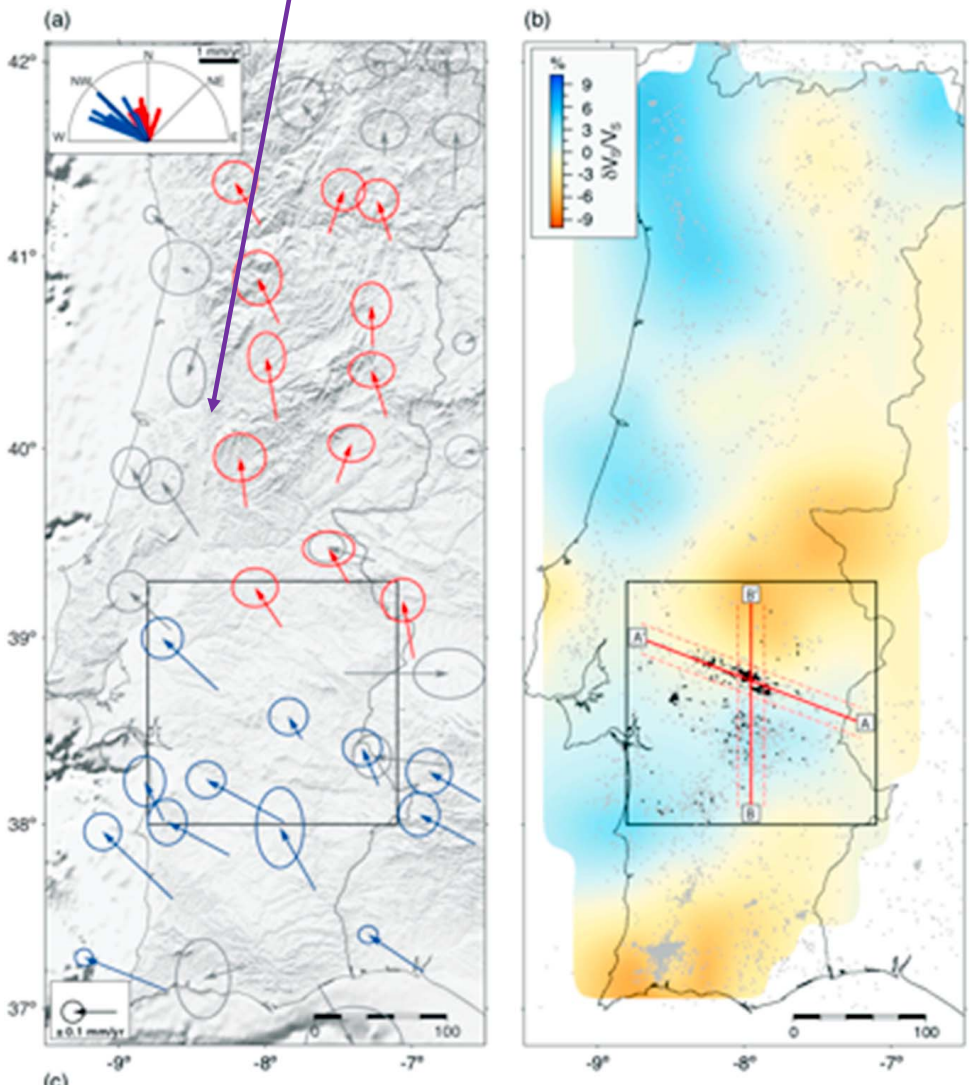

2. Monchique

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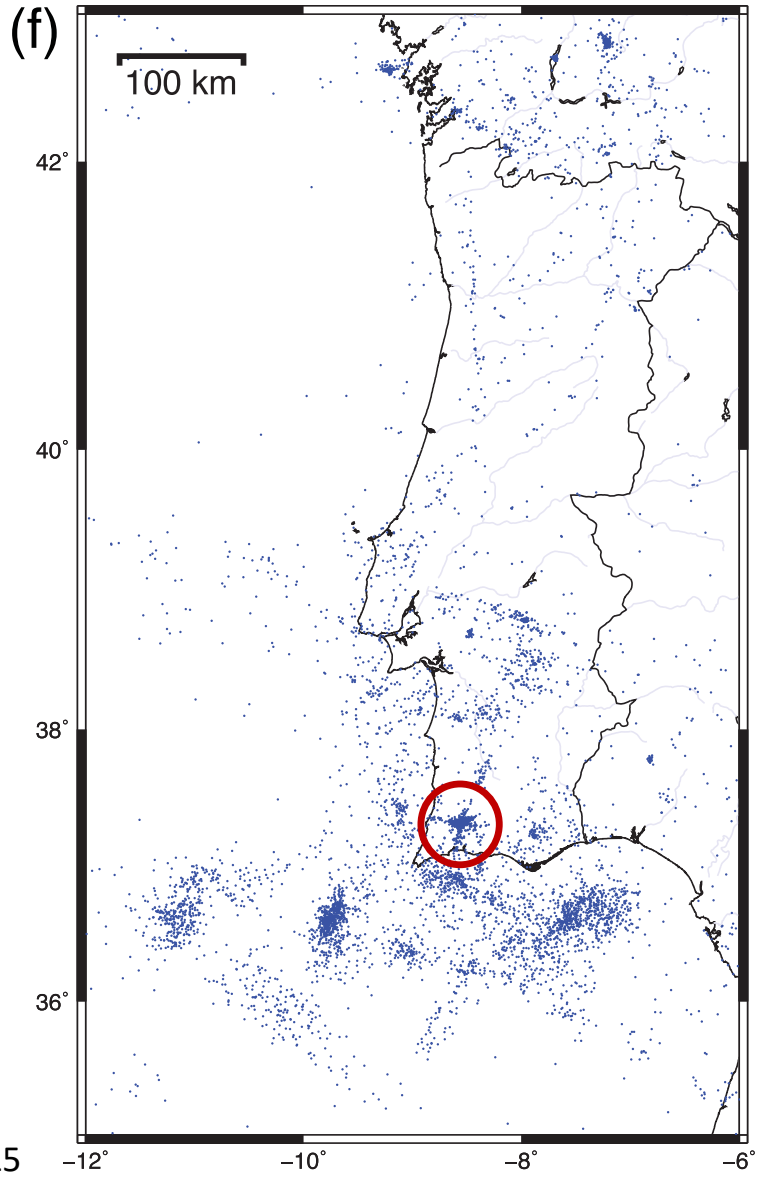
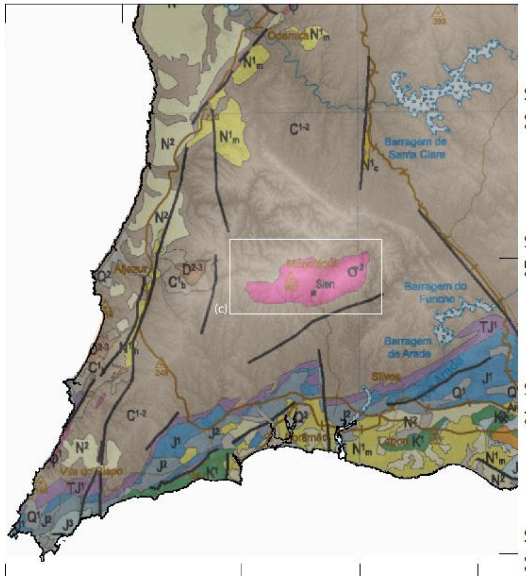


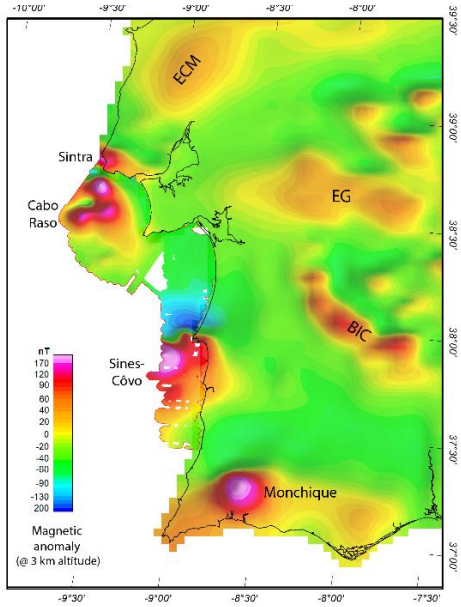
Custodio et al, 2015

Monchique

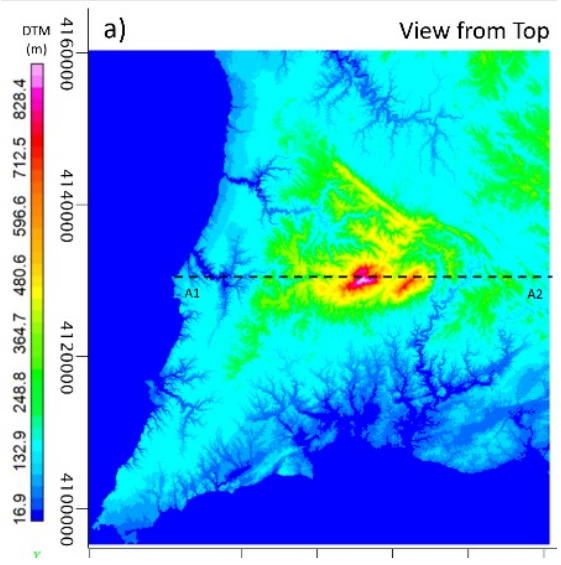
Geology



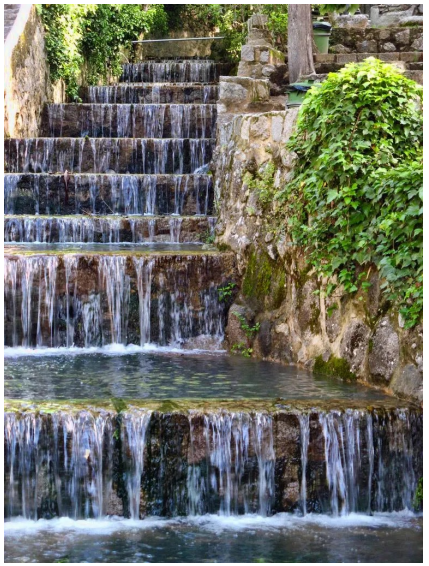
Magnetic Anomaly



Gravity Anomaly

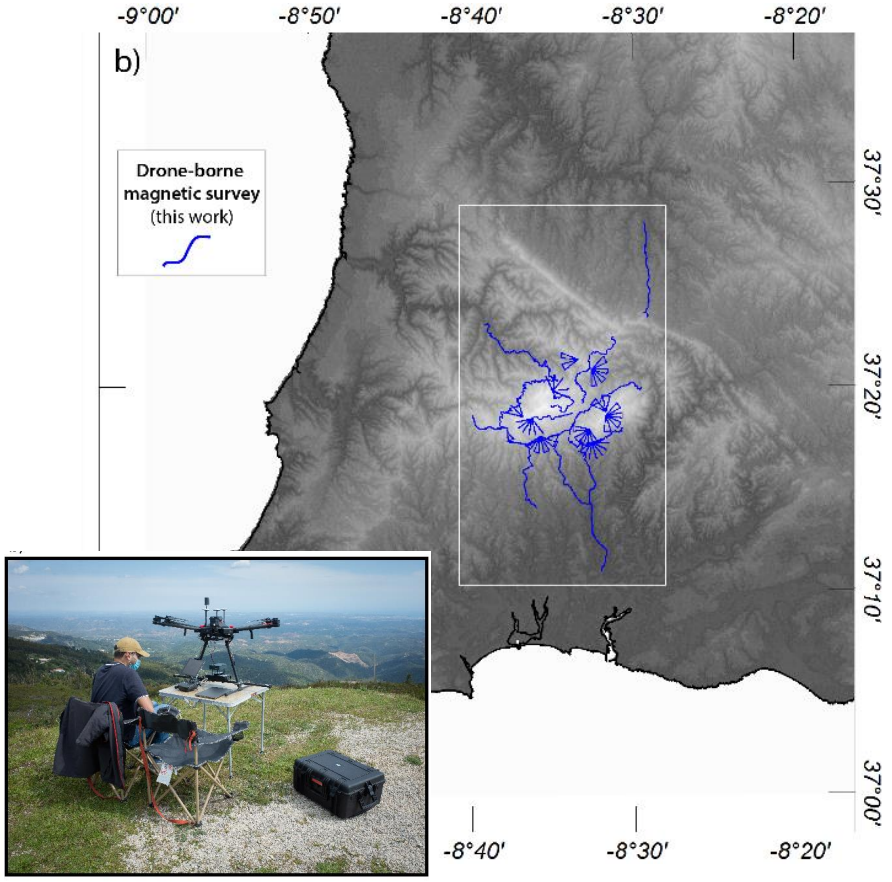


Hydrothermalism

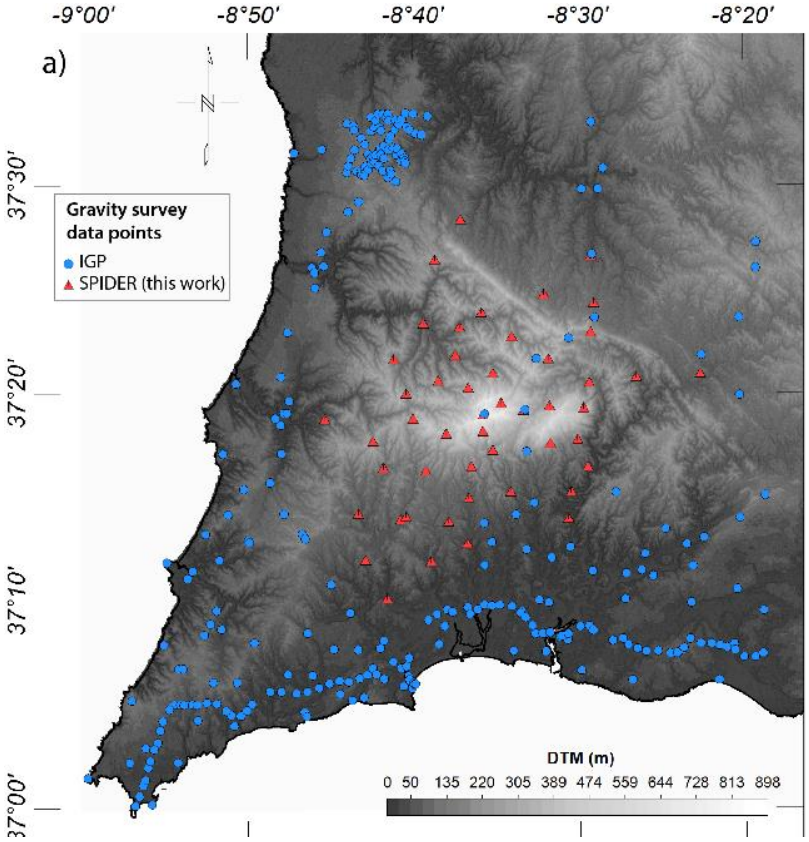


Magnetic and Gravity Surveys

Drone Airborne Magnetic Survey

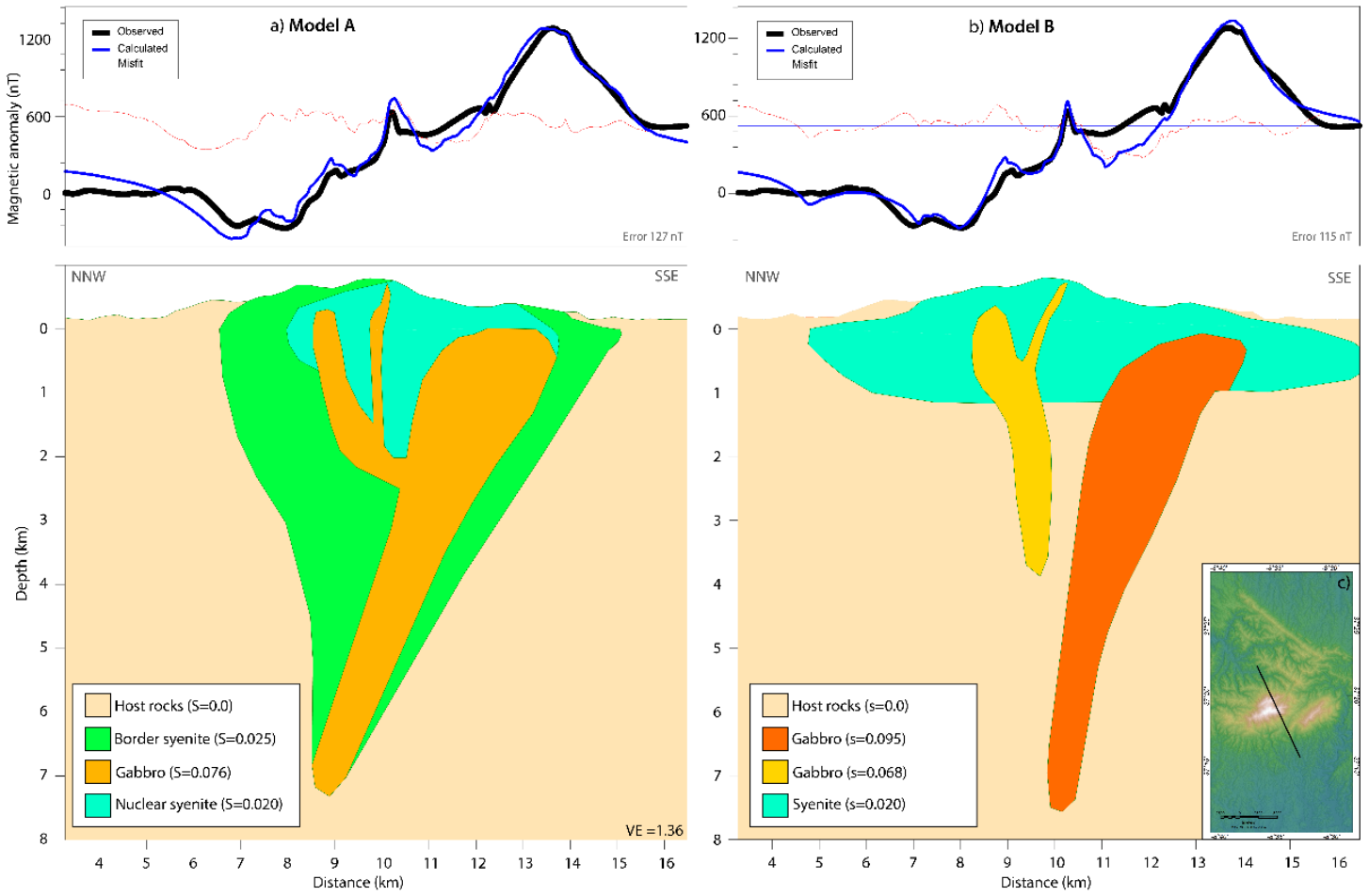


Gravity Survey



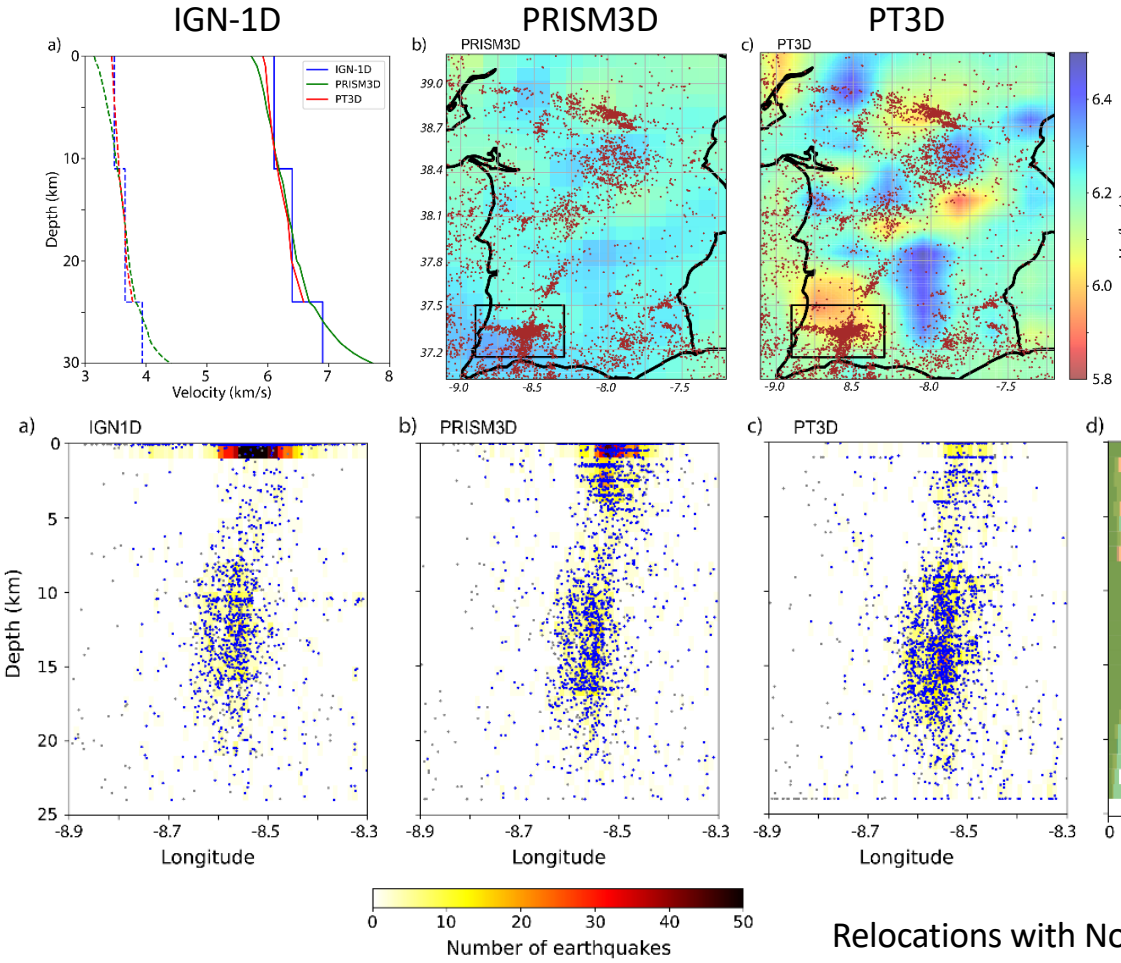
Neres et al, 2024

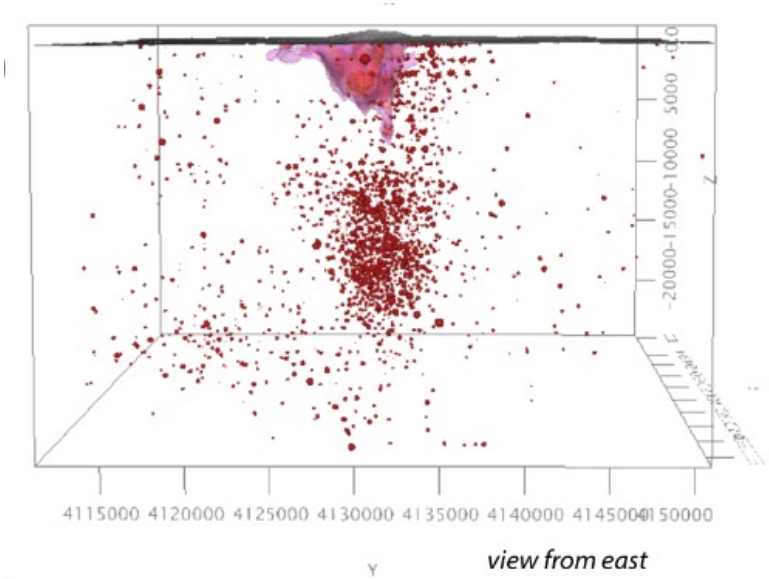
Magnetic Anomaly Modeling



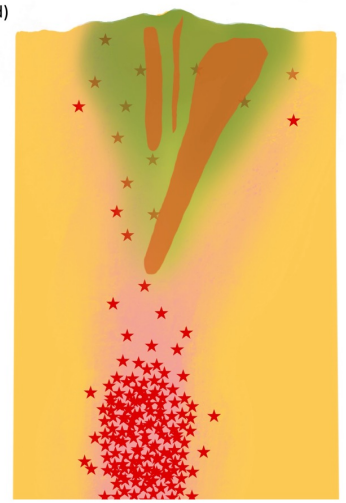
Neres et al, 2024

Seismicity





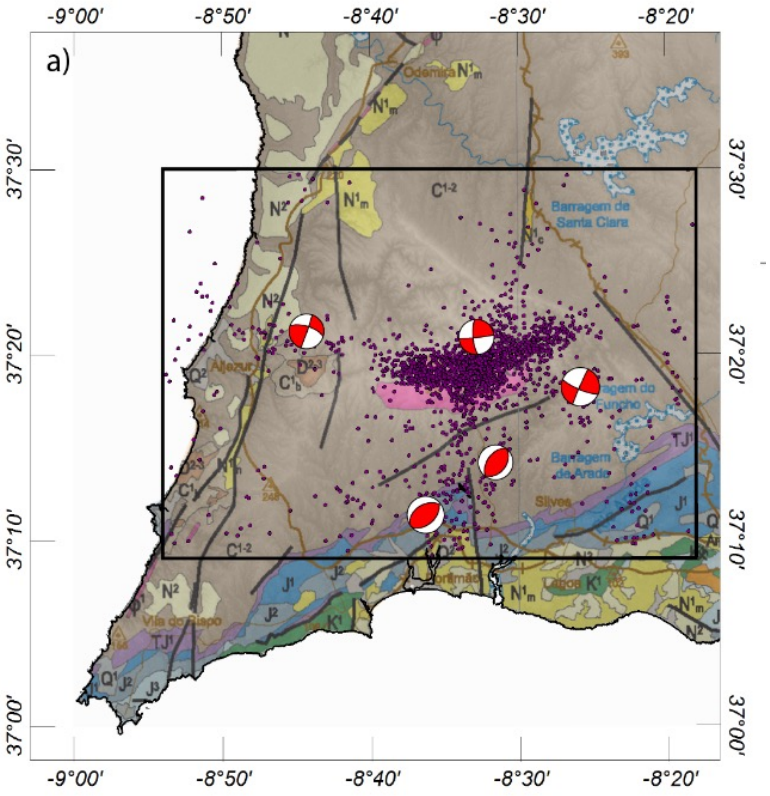
Depth = 12 km

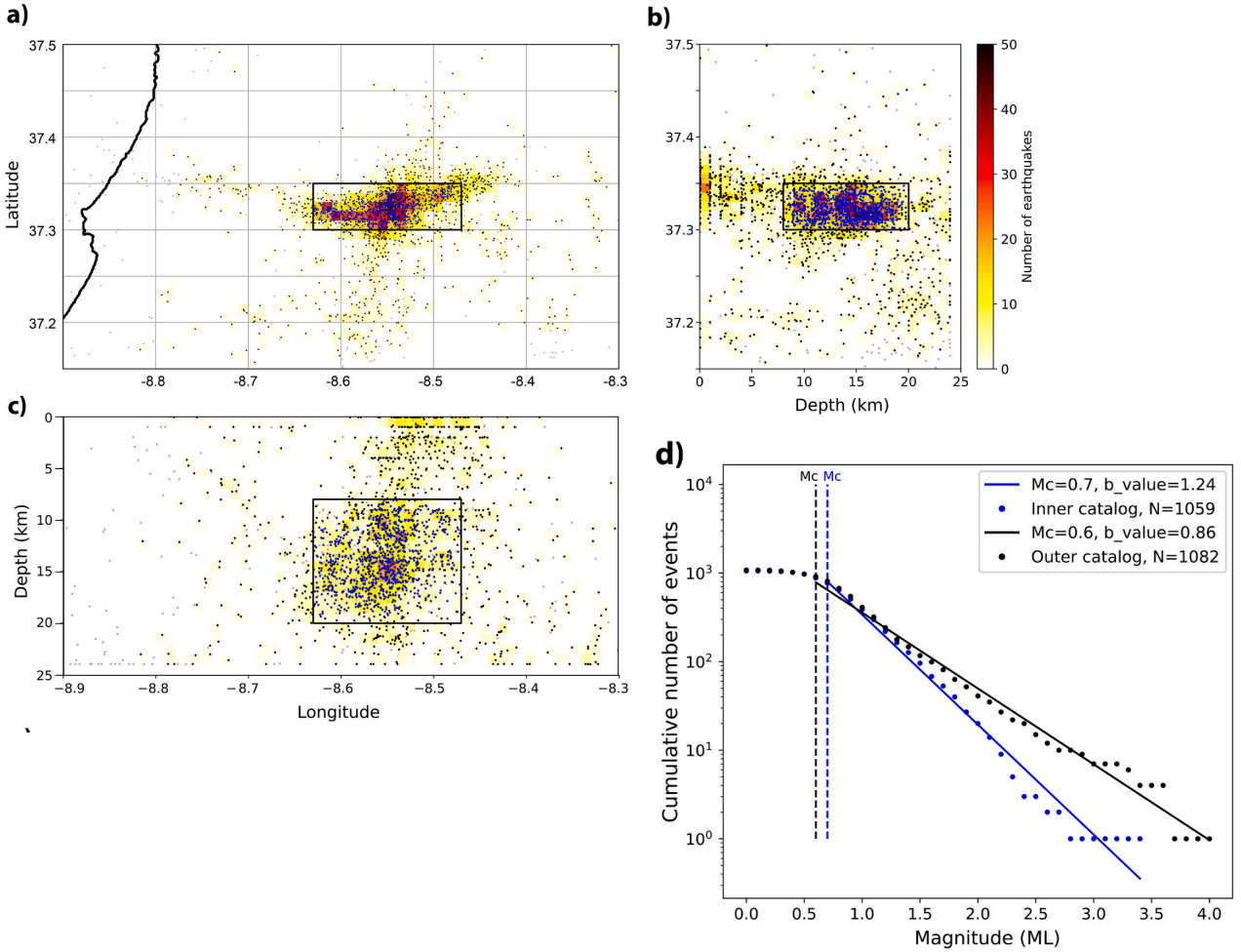


Relocations with NonLinLoc (Lomax et al, 2000)

Neres et al, 2024

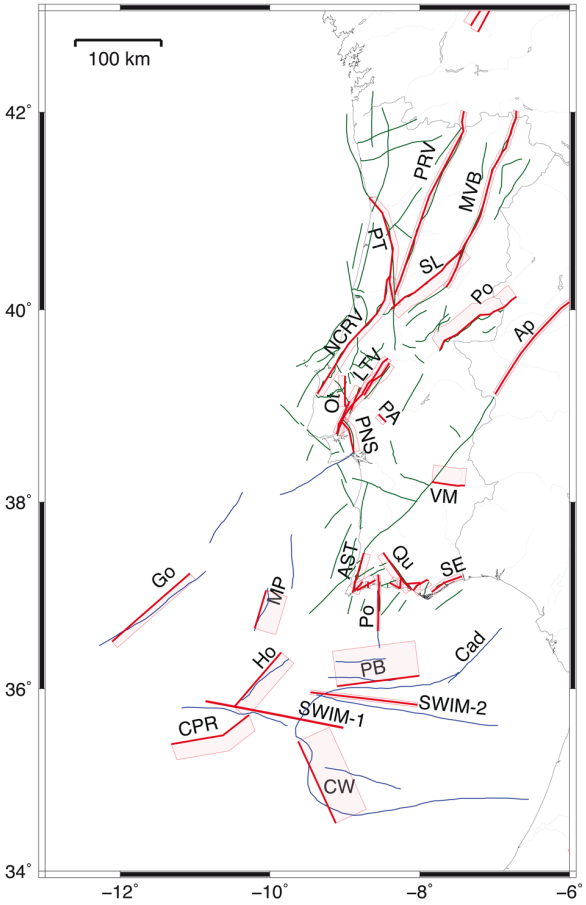
Seismicity





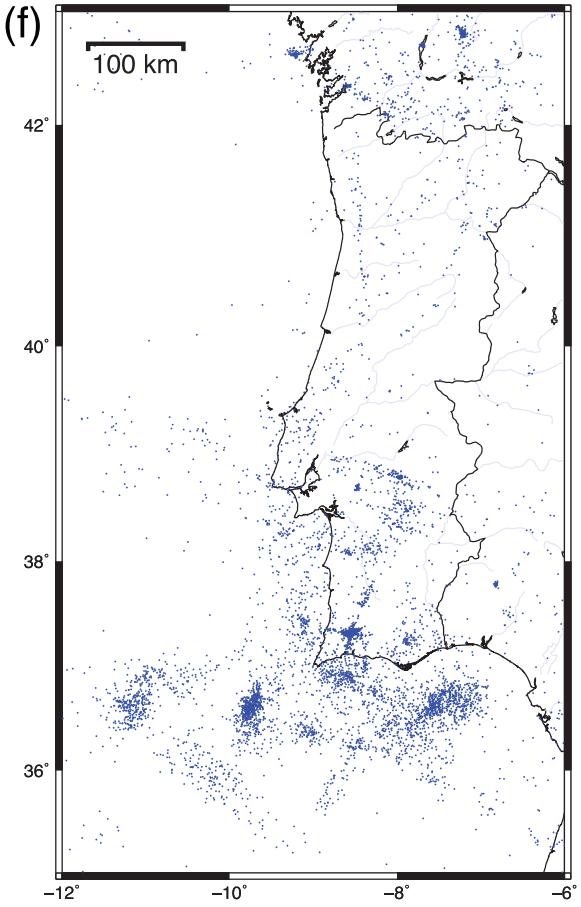
Neres et al, 2024

Fault networks



Custodio et al, 2015

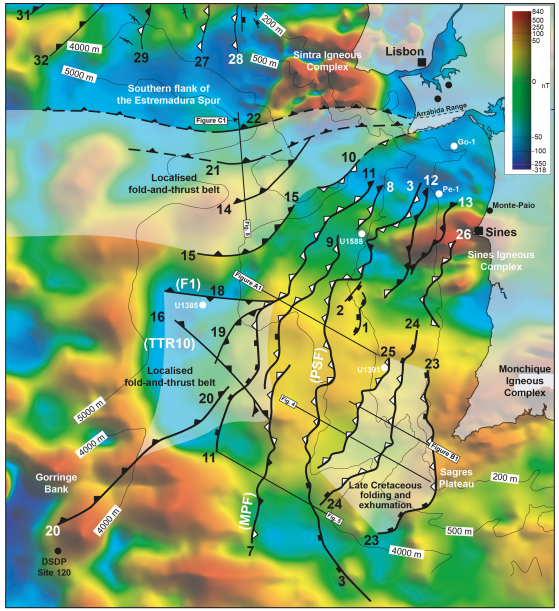
"Clustered Seismicity"
(+ GNSS)



Onshore

Silva et al, 2006

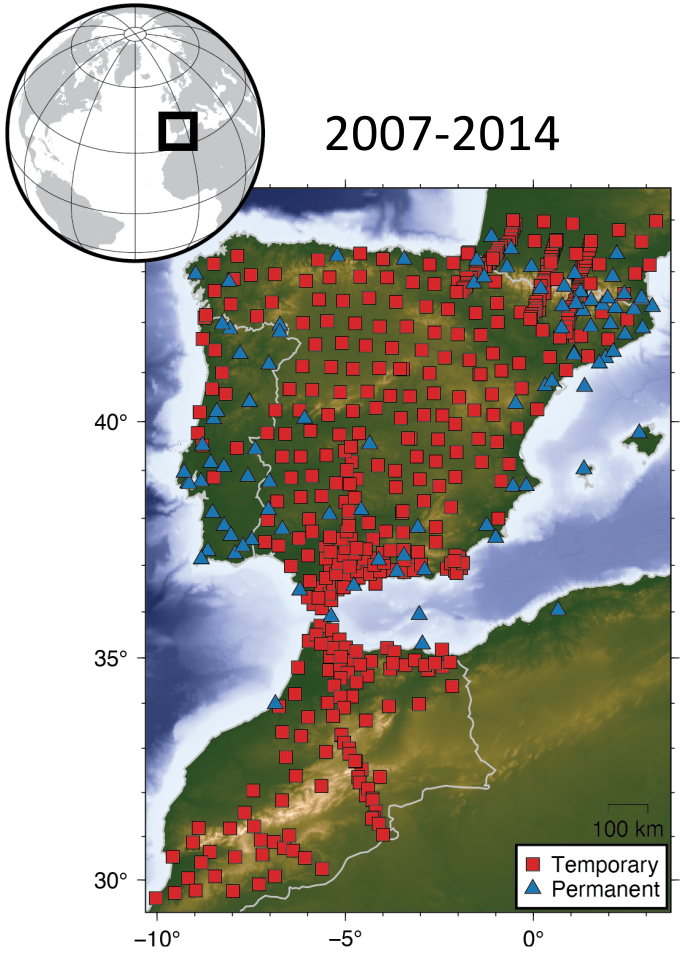
Offshore

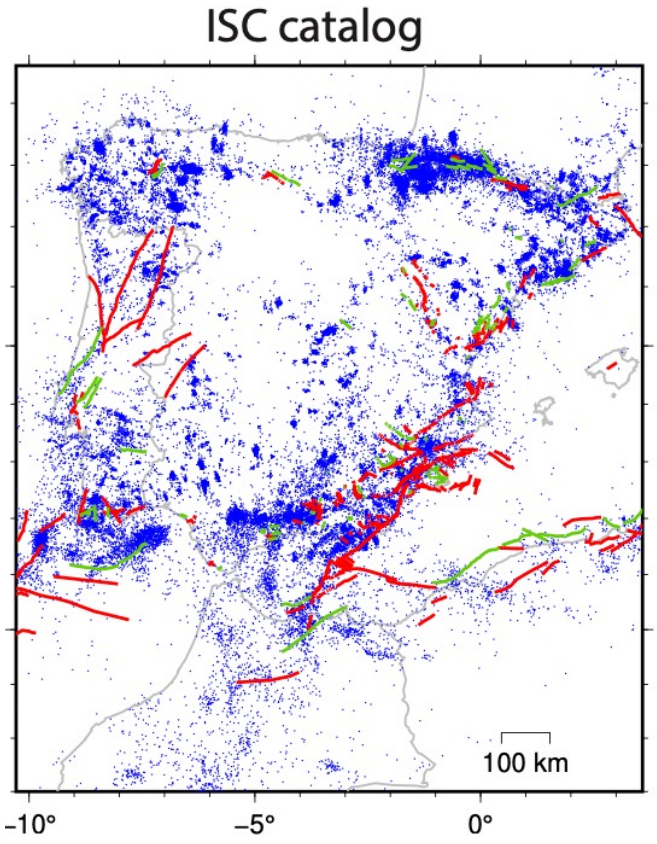


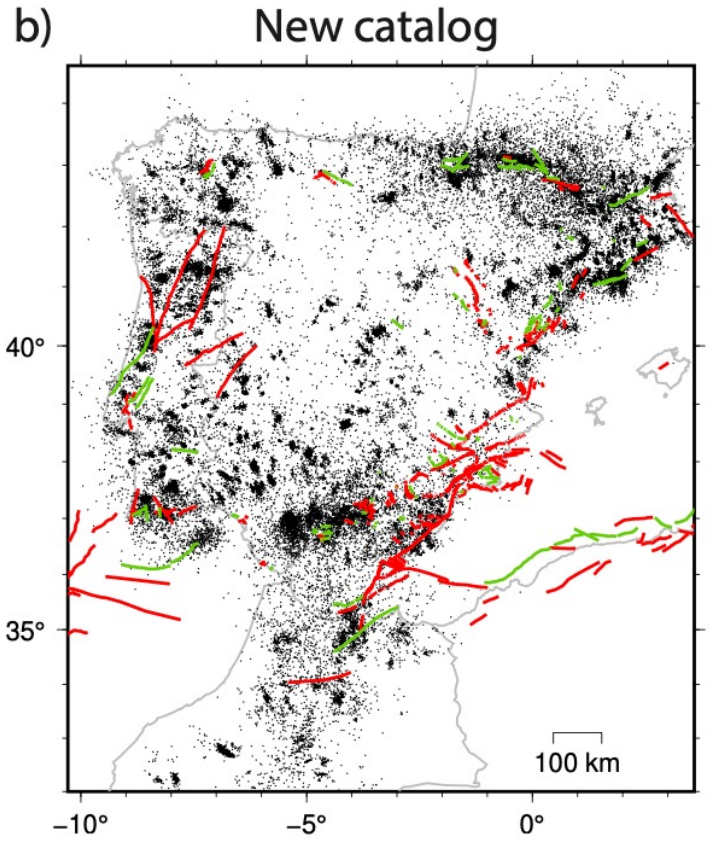
Alves, 2024

ML catalogs & New location algorithms

Opportunity!

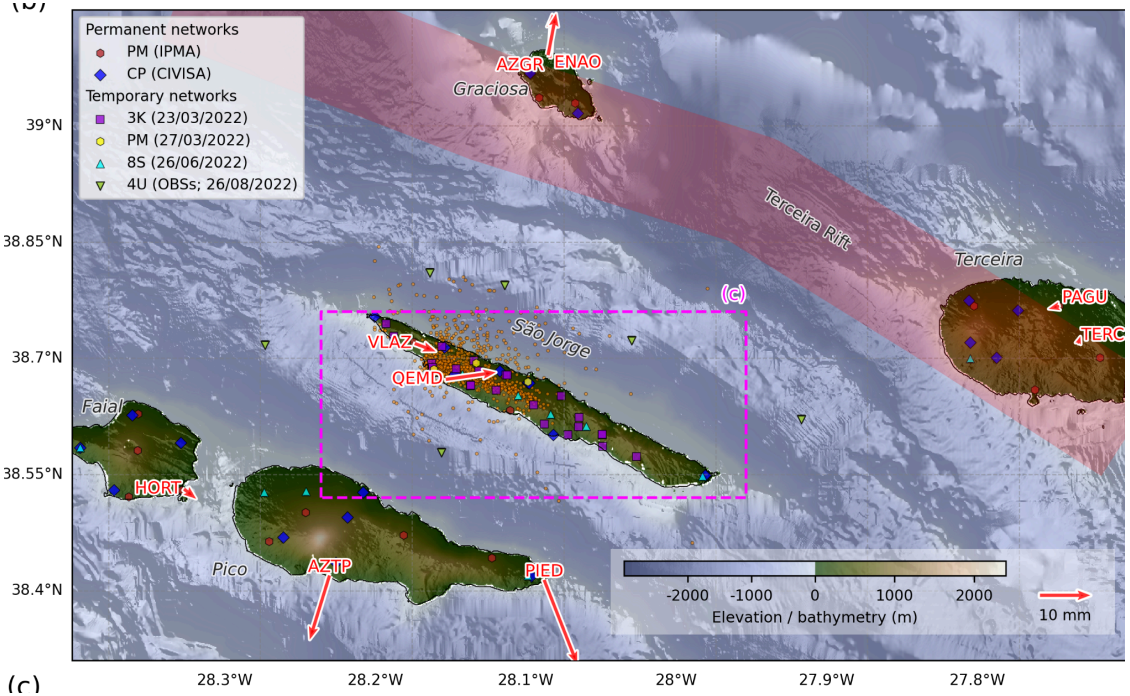


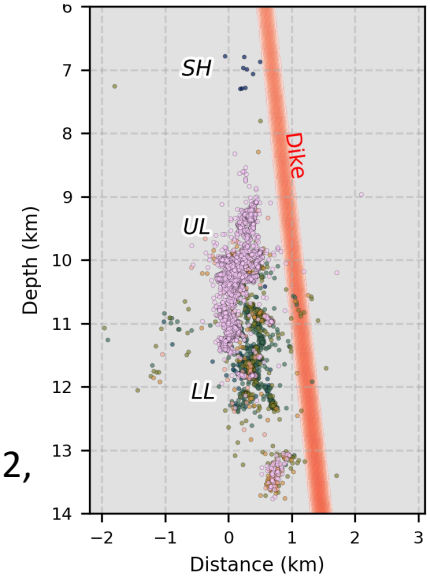




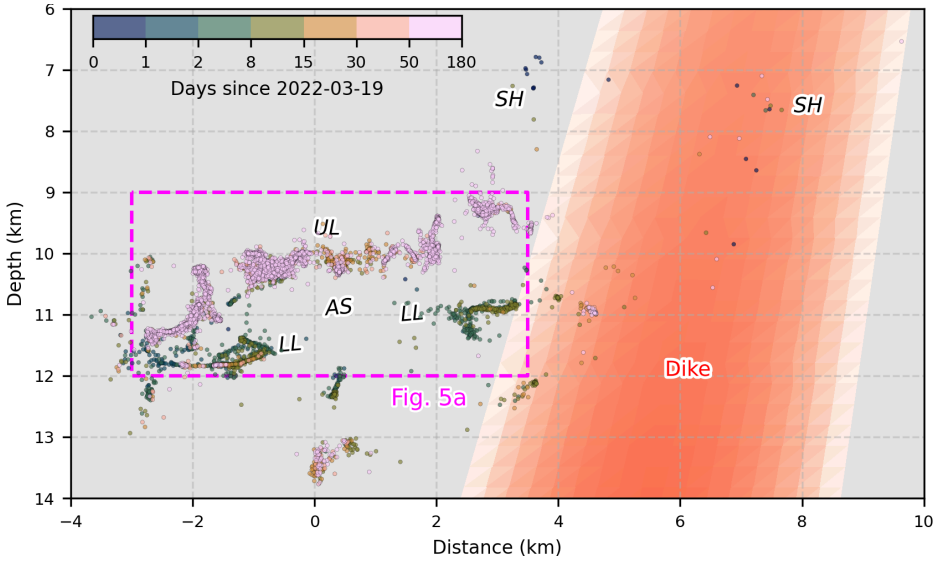
Neves et al, in prep (SSA 2023)

ML catalogs & New location algorithms



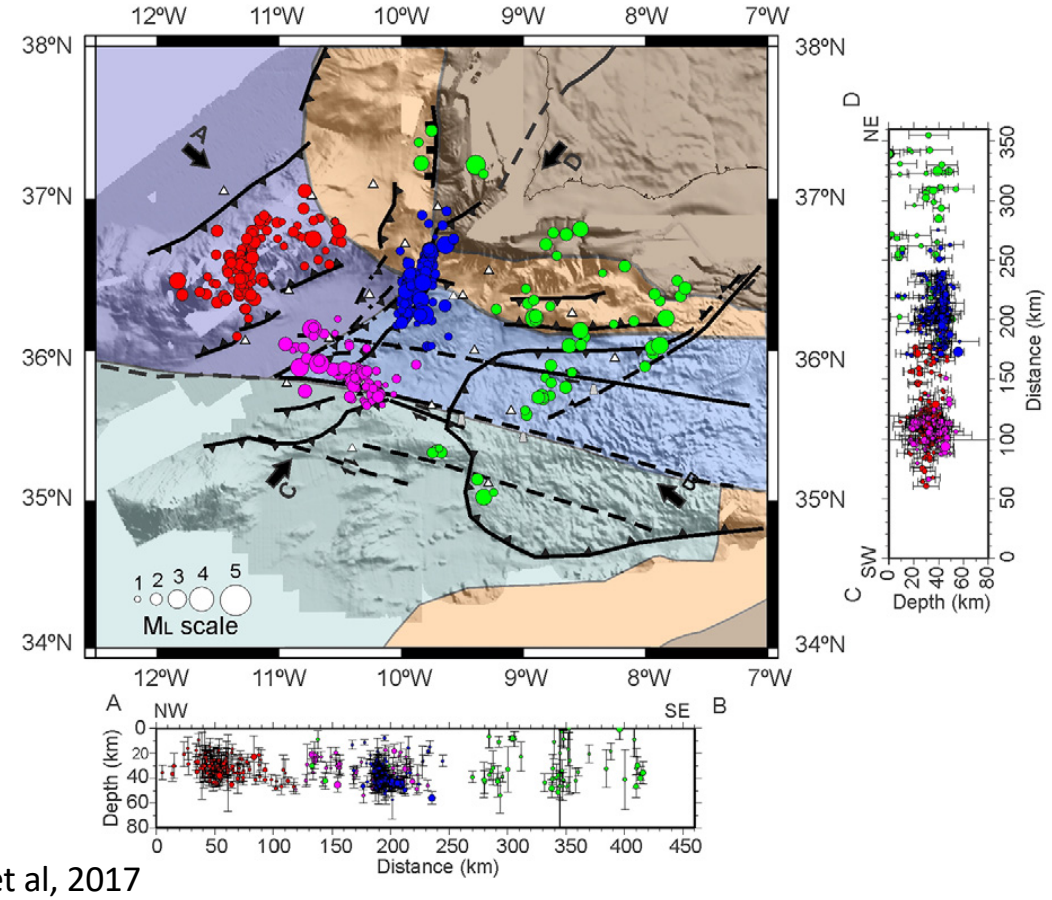


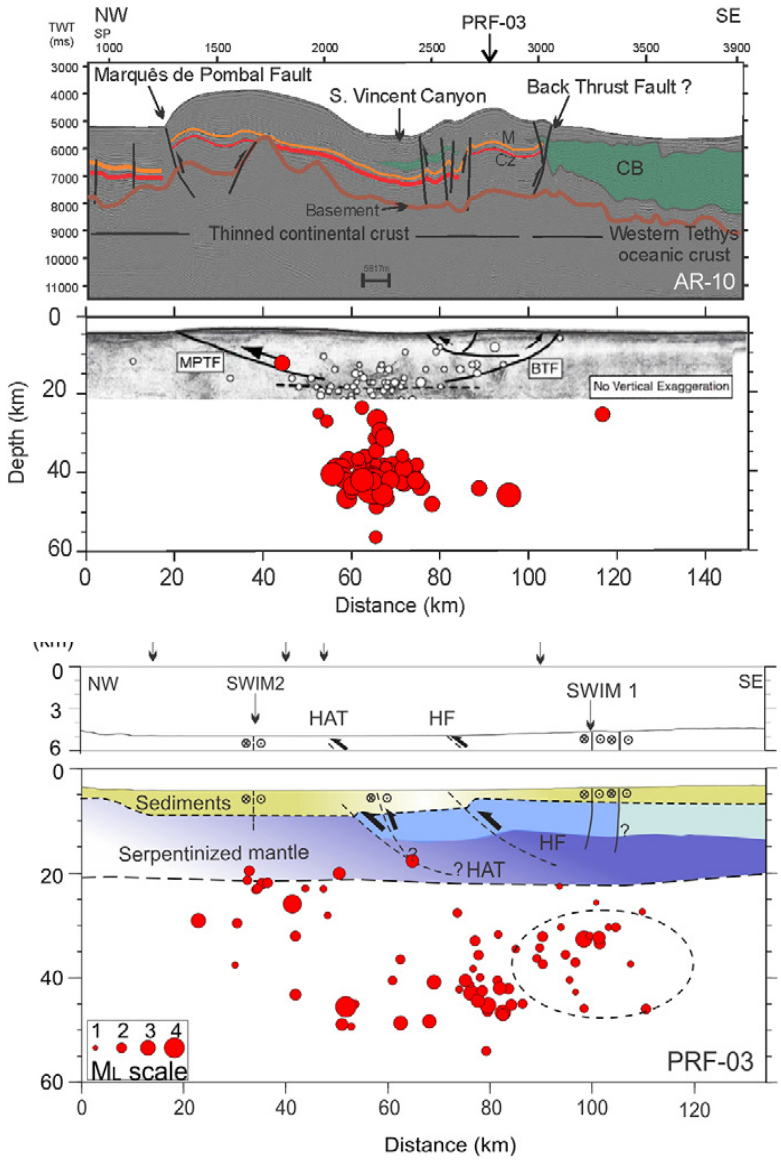
NLLoc-SSST-Coh
(Lomax & Savvaidis 2022,
Lomax & Henry 2023)



Hicks et al, in prep

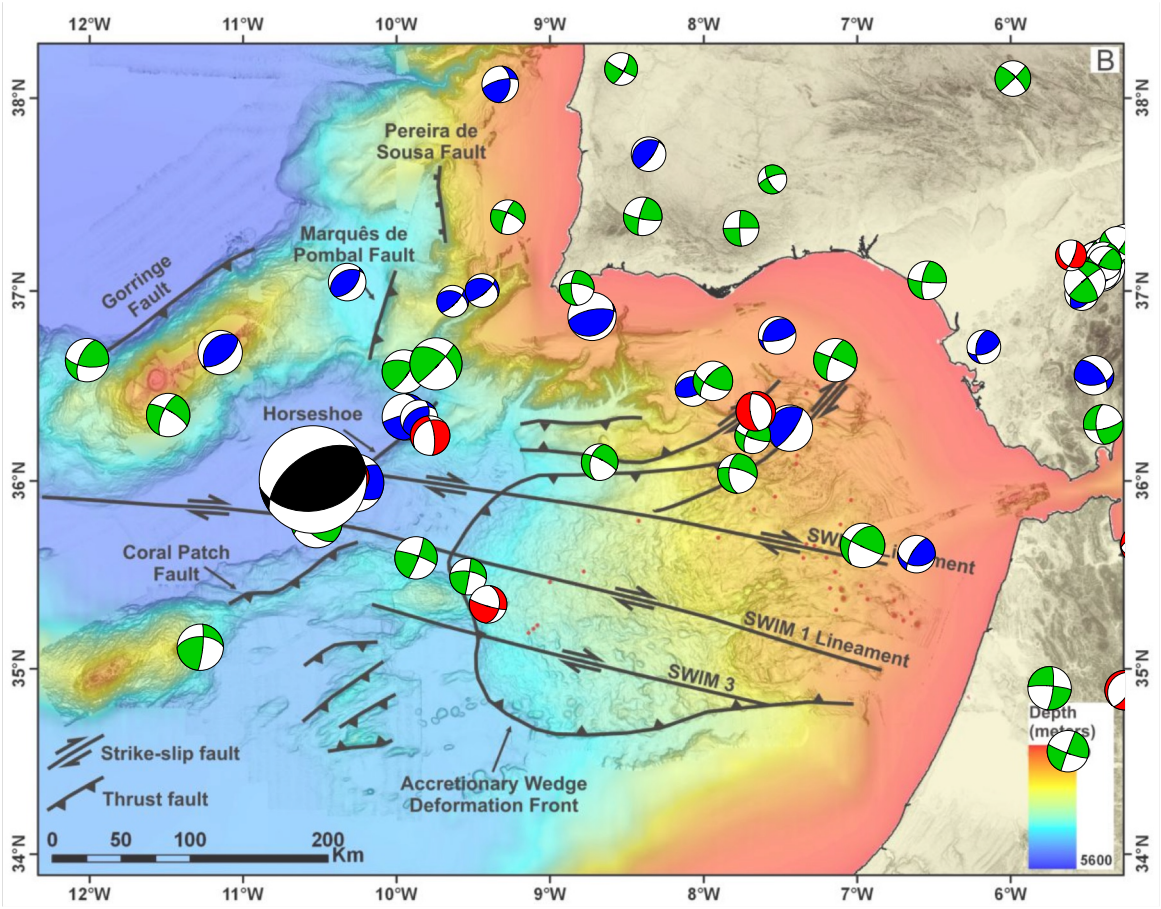
Offshore seismicity



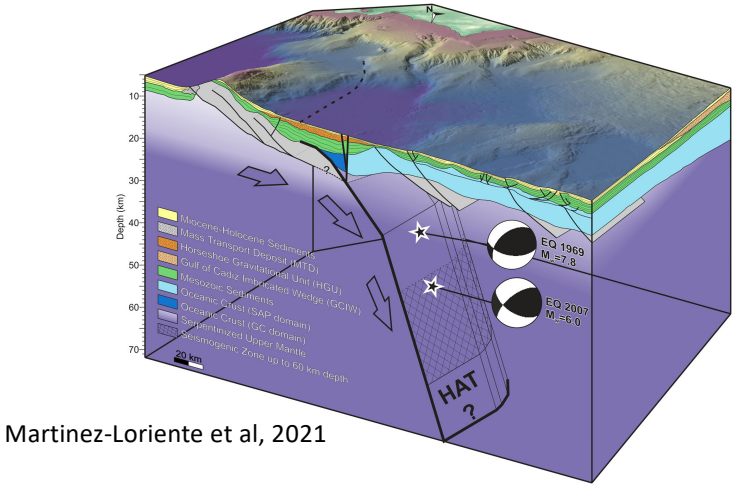


Silva et al, 2017

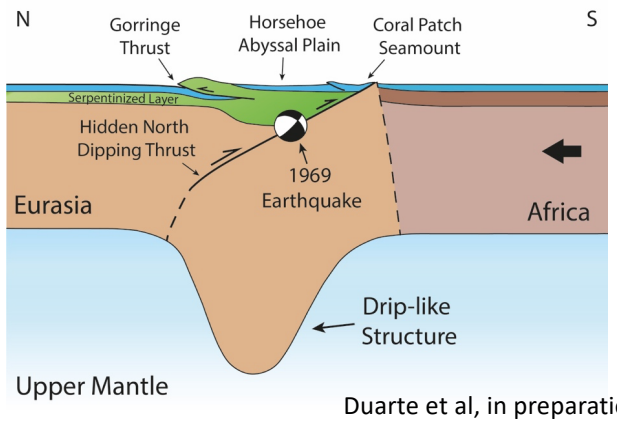
The 1969 M7.8 St Vincent earthquake (z=40 km)



Adapted from Duarte et al, 2011; Custodio et al, 2016

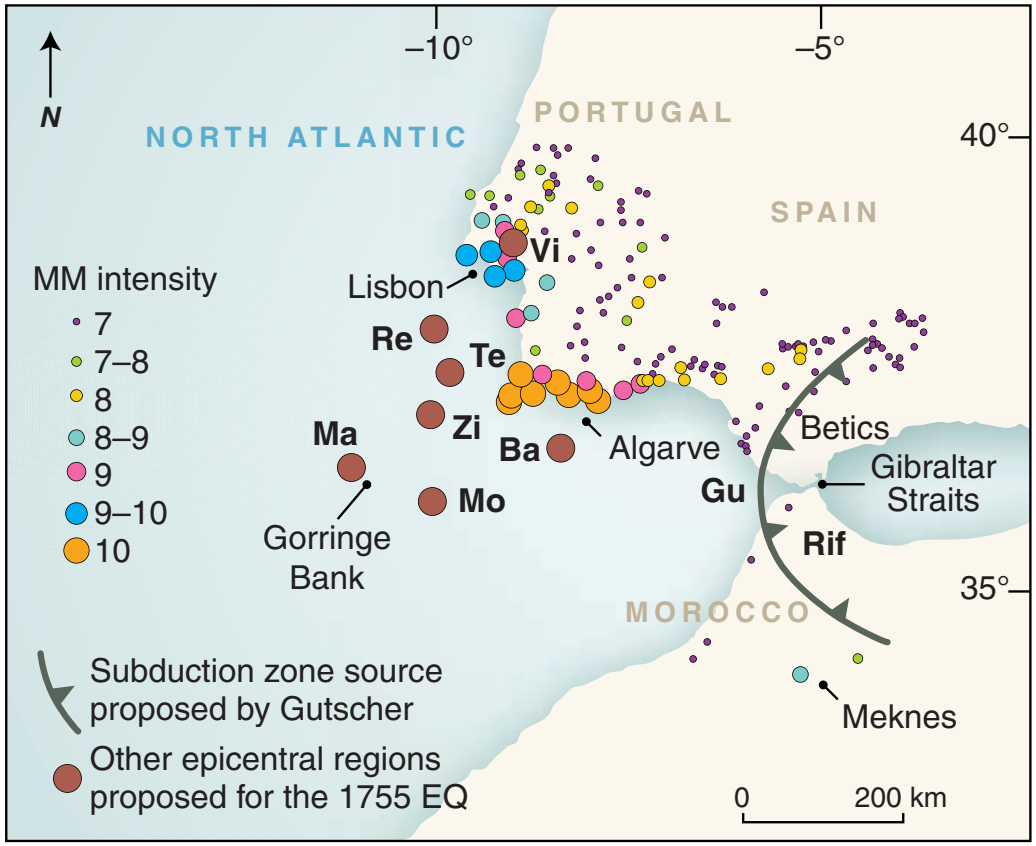


Martinez-Loriente et al, 2021



Duarte et al, in preparation

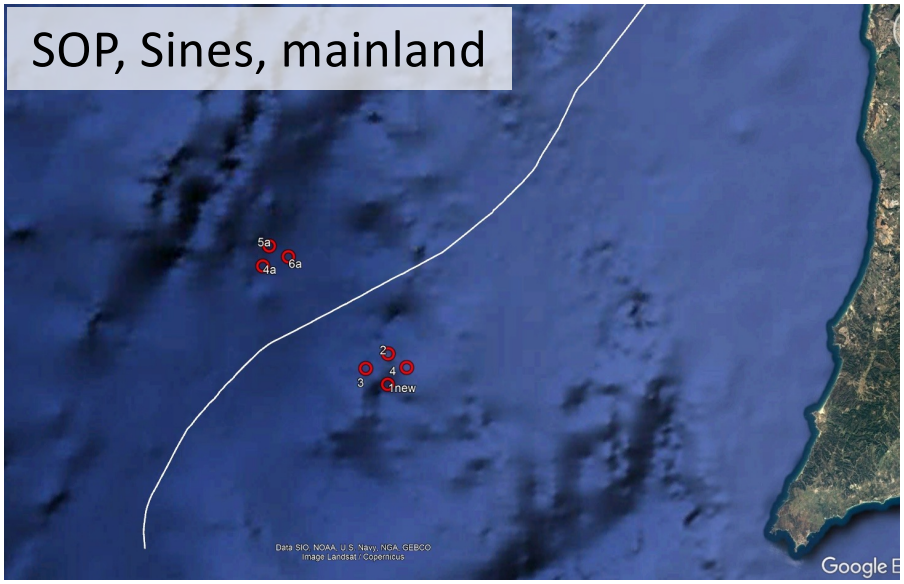
The 1755 M8.5(?) Lisbon earthquake

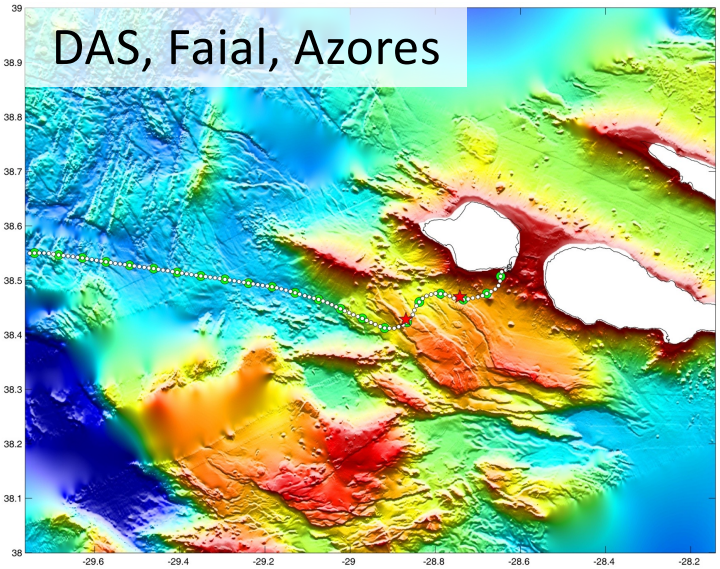


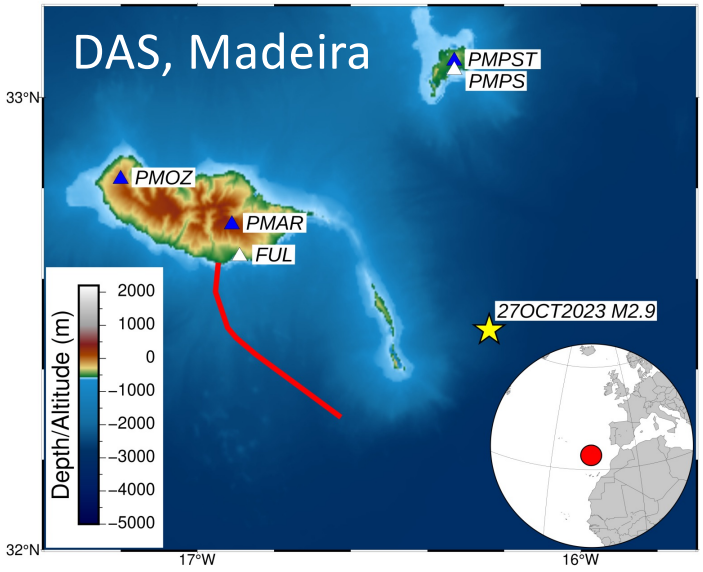
Fonseca, 2005

Areal

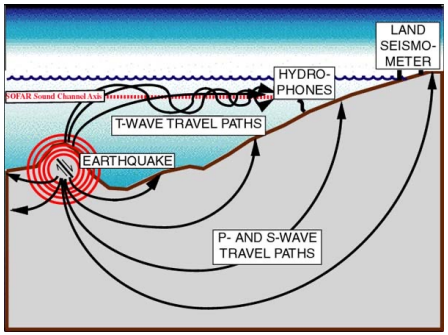
Submarine Cables

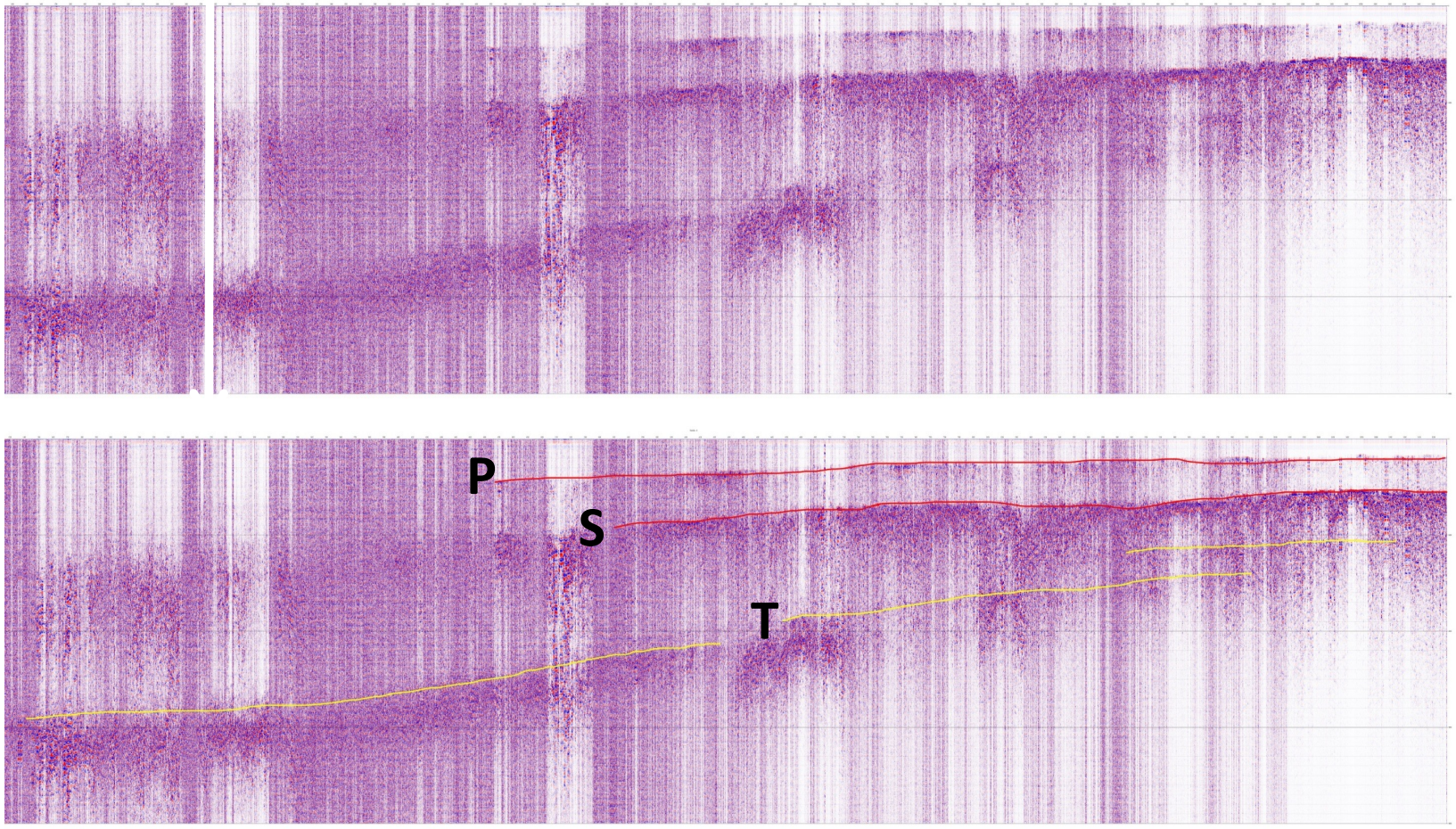




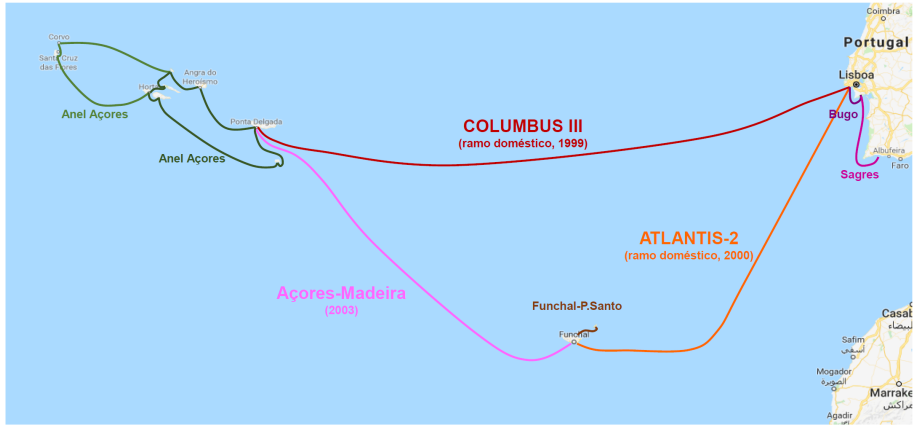


DAS, Madeira, M2.9



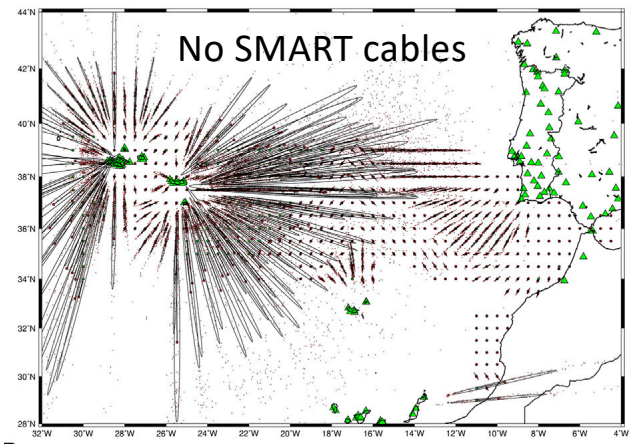


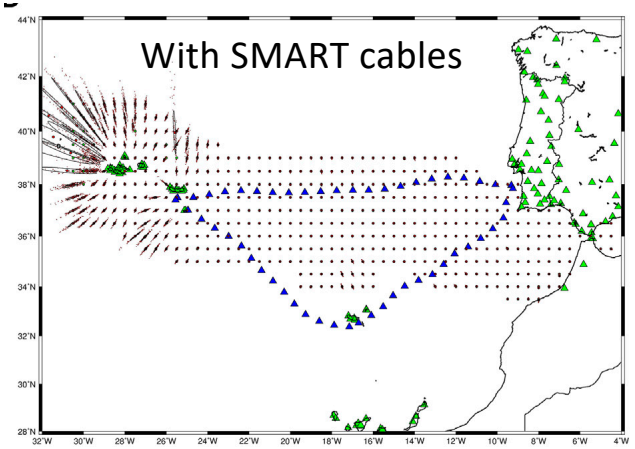
Upcoming (operations due 2027): SMART cables



P, T, BB+SM

Improvement in earthquake location (error ellipses)





Matias et al (2021)

Concluding Remarks

- There are still some very basic gaps in our knowledge of seismic sources…
- Seismology is at a turning point in observational capability. It's an exciting time for Seismology! 😀
  - How do we integrate information from small earthquakes in hazard?
- Integration of datasets is key; better if physis based.
  - GNSS and seismic data are very complementary (more on GNSS in the next talk); also in the context of RT and EEW.
  - Need to develop algorithms for data integration.

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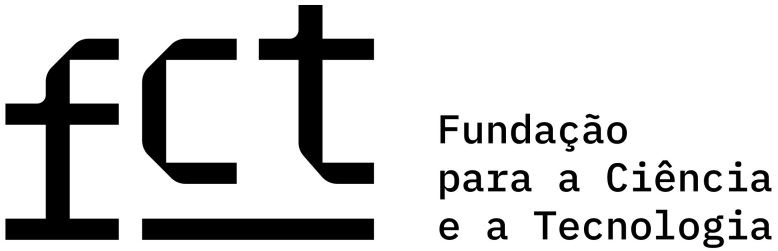
Abstract submission:
12/Mar/25

S05 Frontiers in Fiber-Optics S

S11 Disaster risk reduction fo

S12 Toward the next generati

S15 Earthquakes in low strain



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