The challenge of comprehensive monitoring of European geodynamics: integrating sea and land seismic datasets towards the EuroArray target

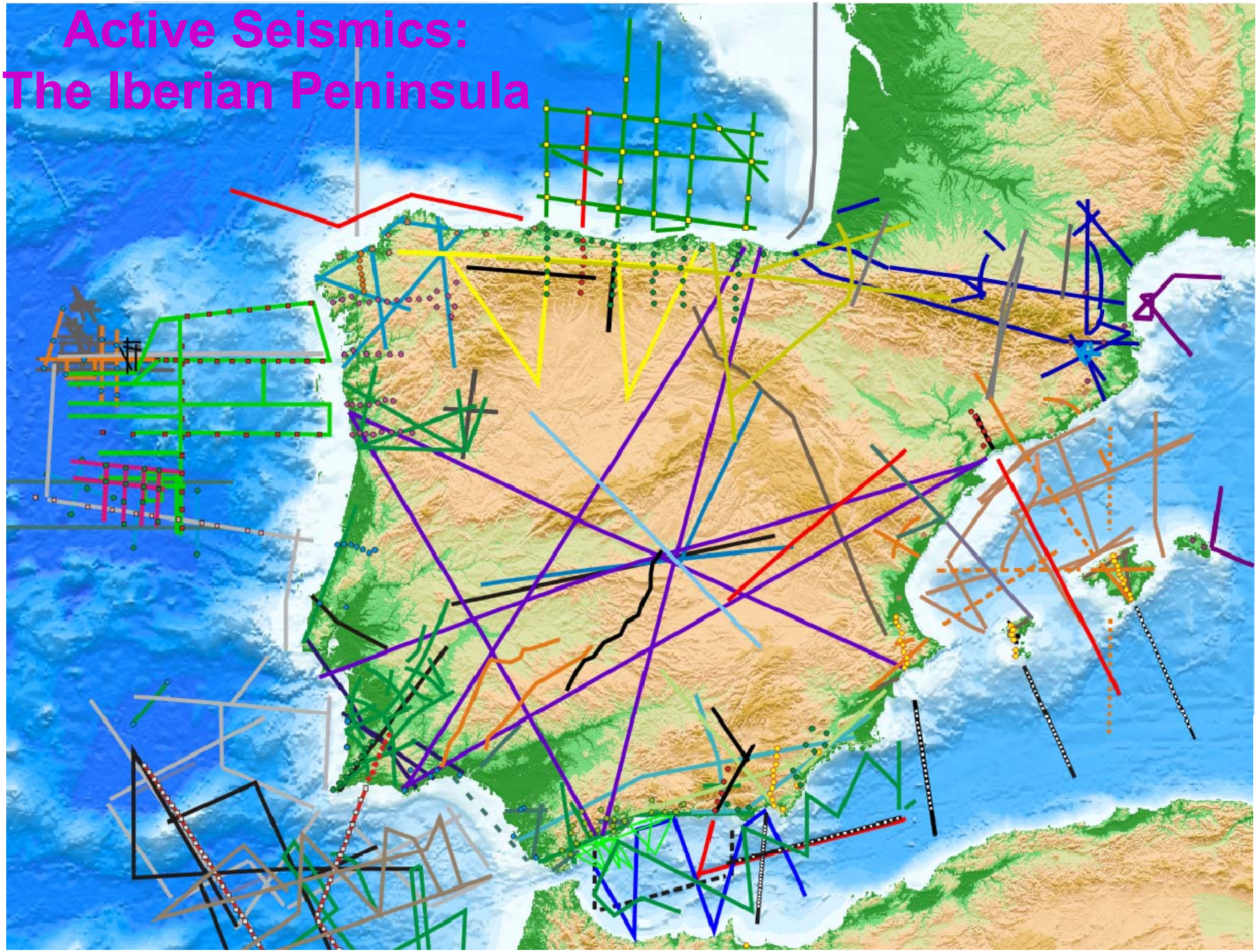
Josep Gallart, Institute of Earth Sciences (ICTJA)-CSIC, Barcelona, Spain

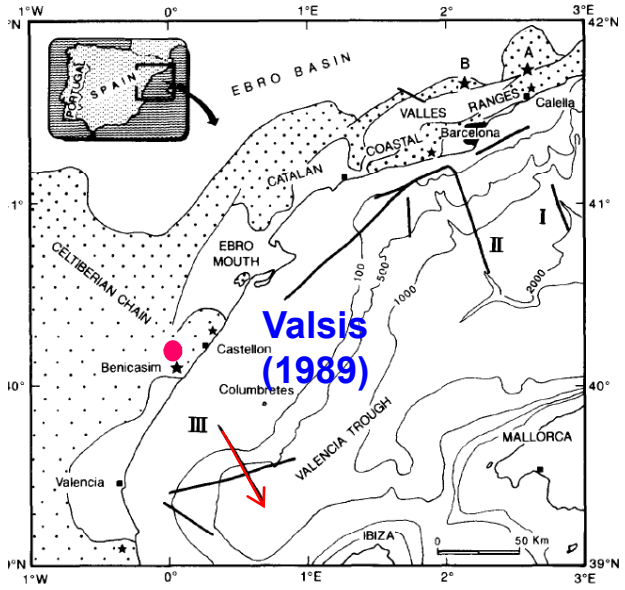
Sea-Land Seismic Research Interactions

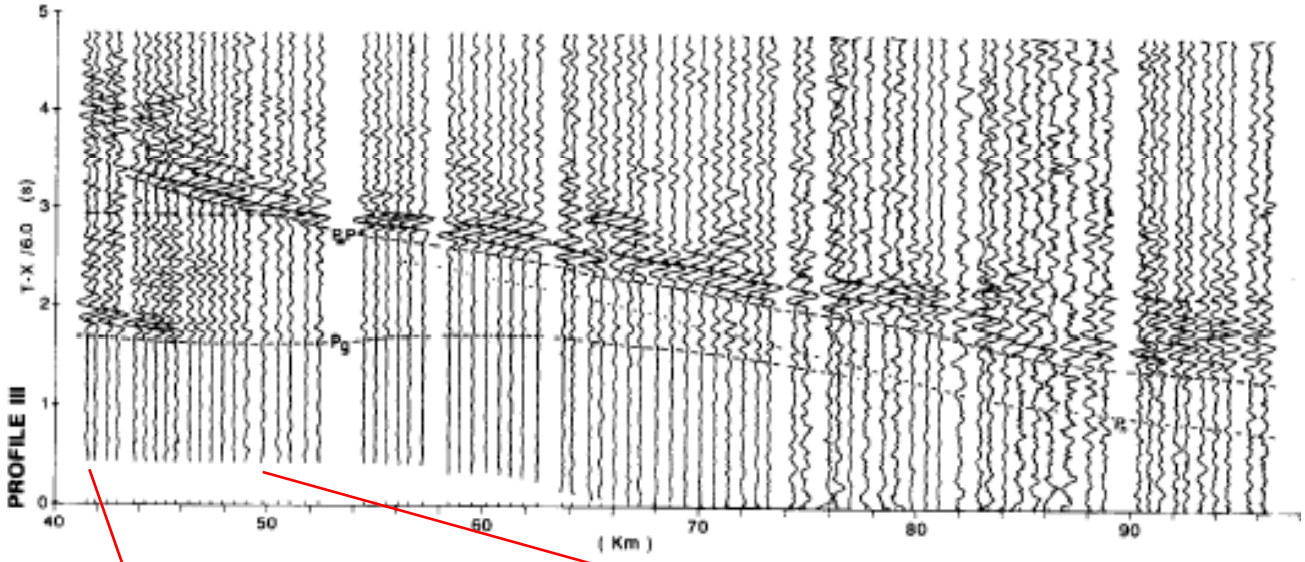
From Active Seismics (Onshore-Offshore Experiments) To Passive Seismics (Broad Band Networks)

Towards an EuroArray coverage

Active Seismics:
The Iberian Peninsula

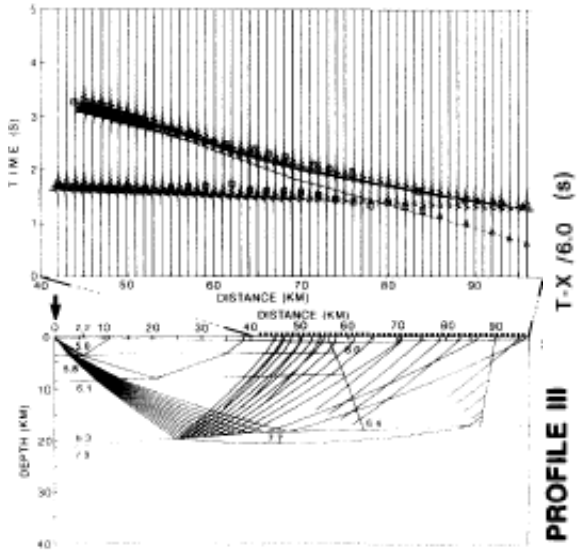


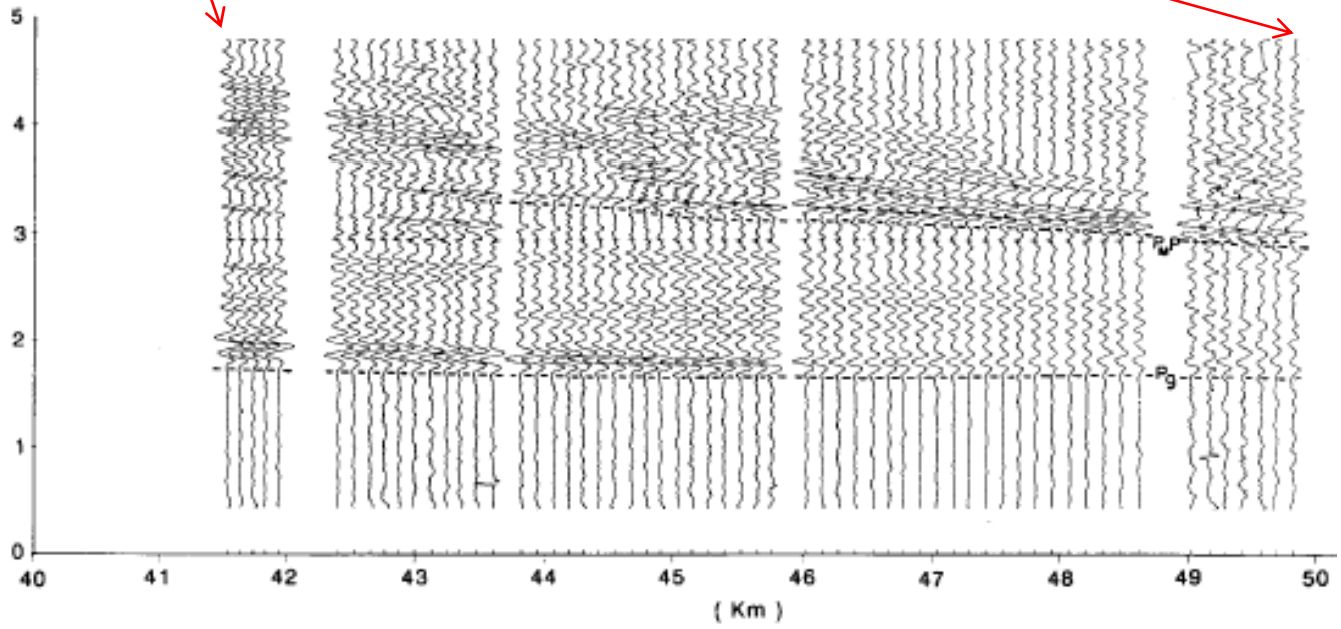


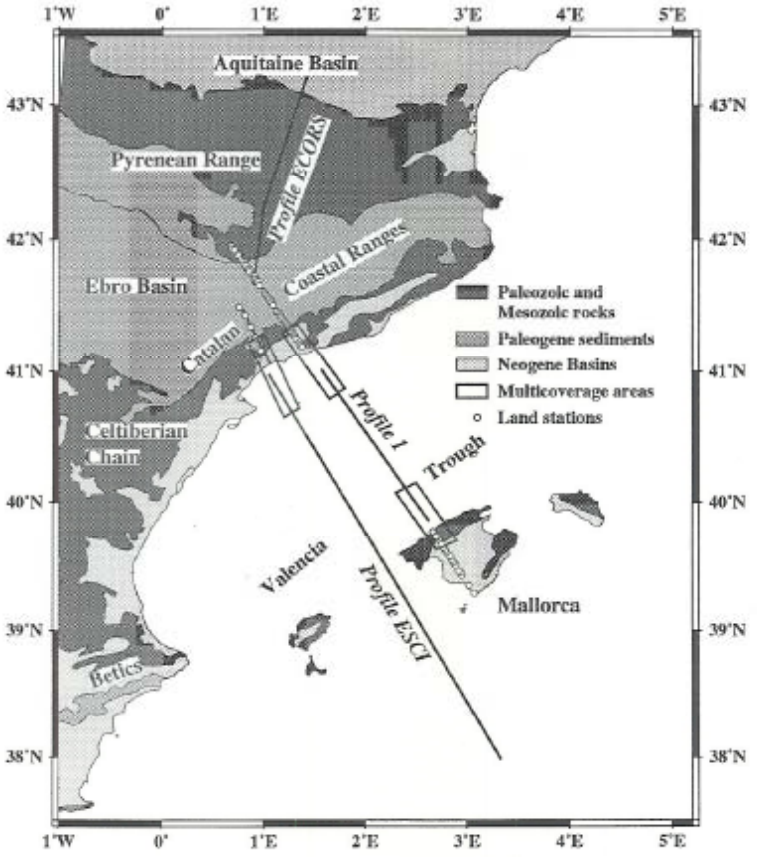


First example of marine air-gun profile recorded onshore

Gallart et al., J. Geodyn. 1990



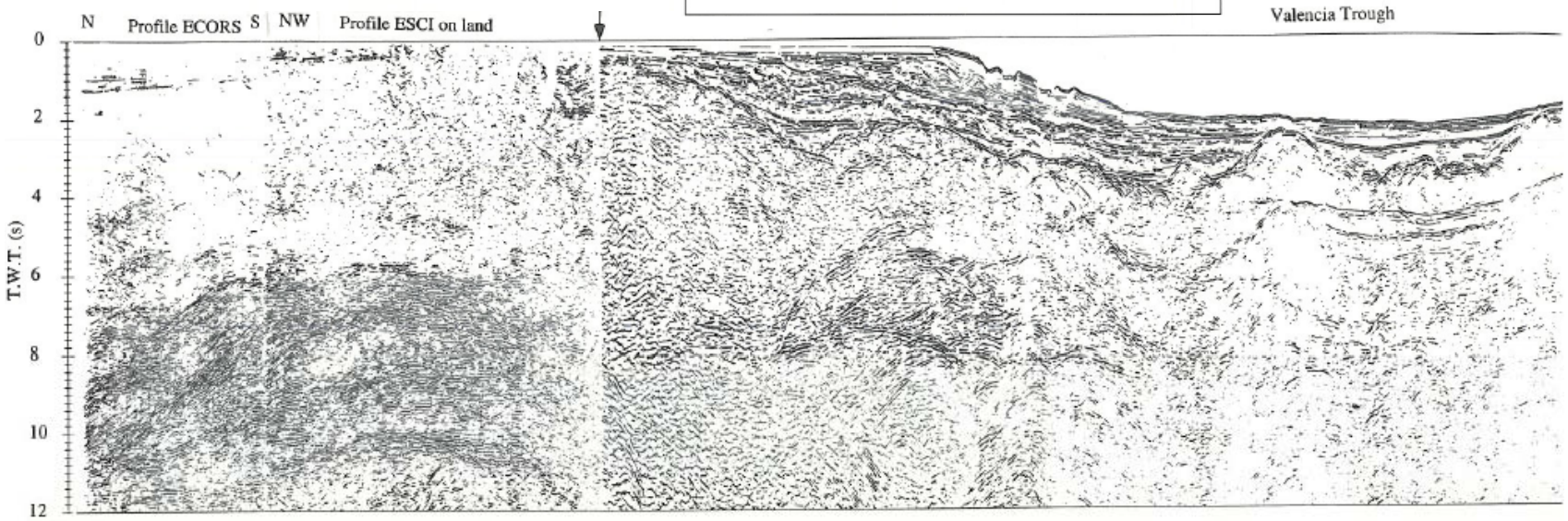


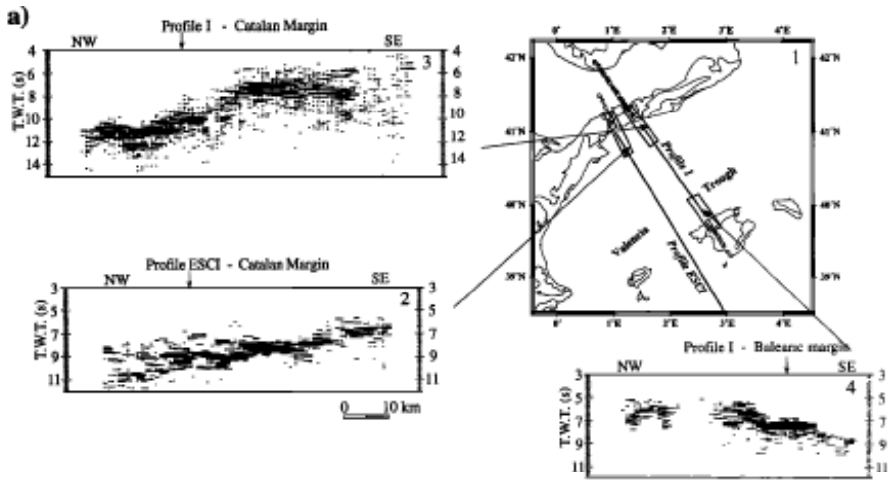


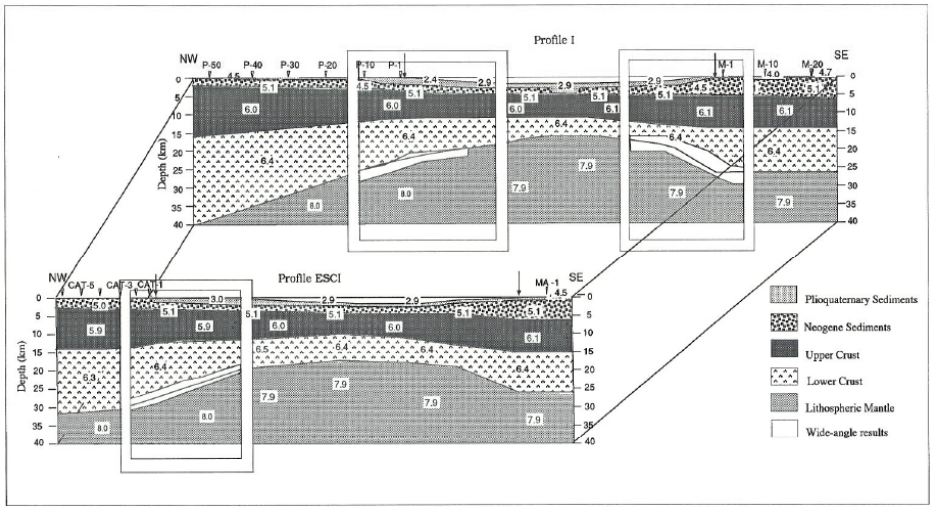
Near vertical processing		*Wide angle processing*
	Sampling rate	
-- 4 ms		-- 8 - 16 ms
Resampling		
	Geometry	
-- 30 m bin width		-- 1000 m bin width
	Data edition	
	Bandpass filtering	
-- 0-50 Hz		-- 3 - 20 Hz
	F-K filtering	
		-- Not useful for refracted phases
Amplitude compensation		**Mute of refracted phases**
-- Spherical divergence correction		-- Pg and Pn
	Energy balance	
Refraction statics		
Demultiple		
	CDP sorting	
-- 90 m - 3600 m	-- Distances	-- 10 km - 140 km
	Elevation statics	
	-- floating datum plane	
	Predictive deconvolution	
-- operator length 300 ms predictive gap 32 ms		-- operator length 1 s predictive gap 0.1 s
	NMO correction	
-- maximum correction 0.07 s		-- maximum correction 15 s
	-- mute application	
Residual statics		
	Stack	
-- fold 30		-- fold 10 - 30
	Elevation statics	
	-- final datum 400 m	
Time and space variant bandpass filter		
	Scaling	
	Time and depth migration	
-- Finite differences algorithm		-- Time shift algorithm
	Semblance coherency filter	
	-- all velocity ranges	
-- 20 traces		-- 3 traces

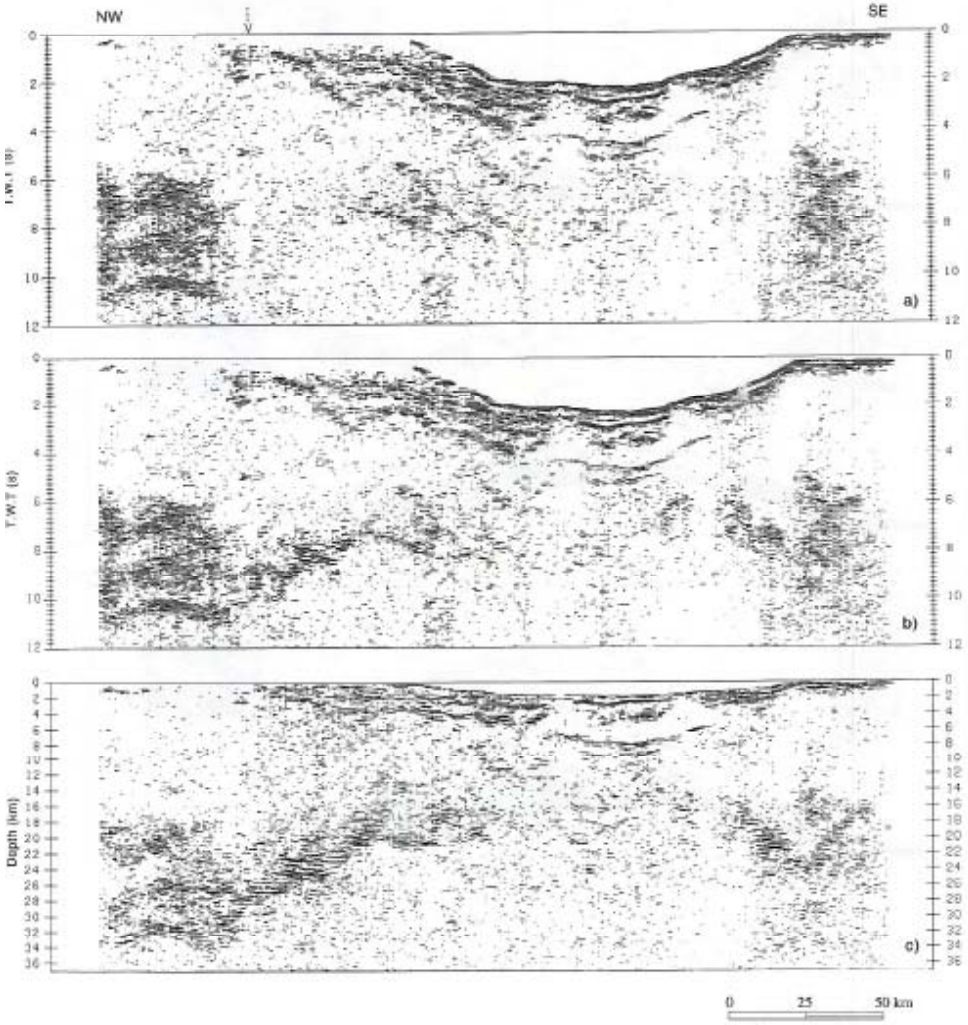
ESCI
Valencia Trough (1992):

A first example of combining vertical and wide-angle sections





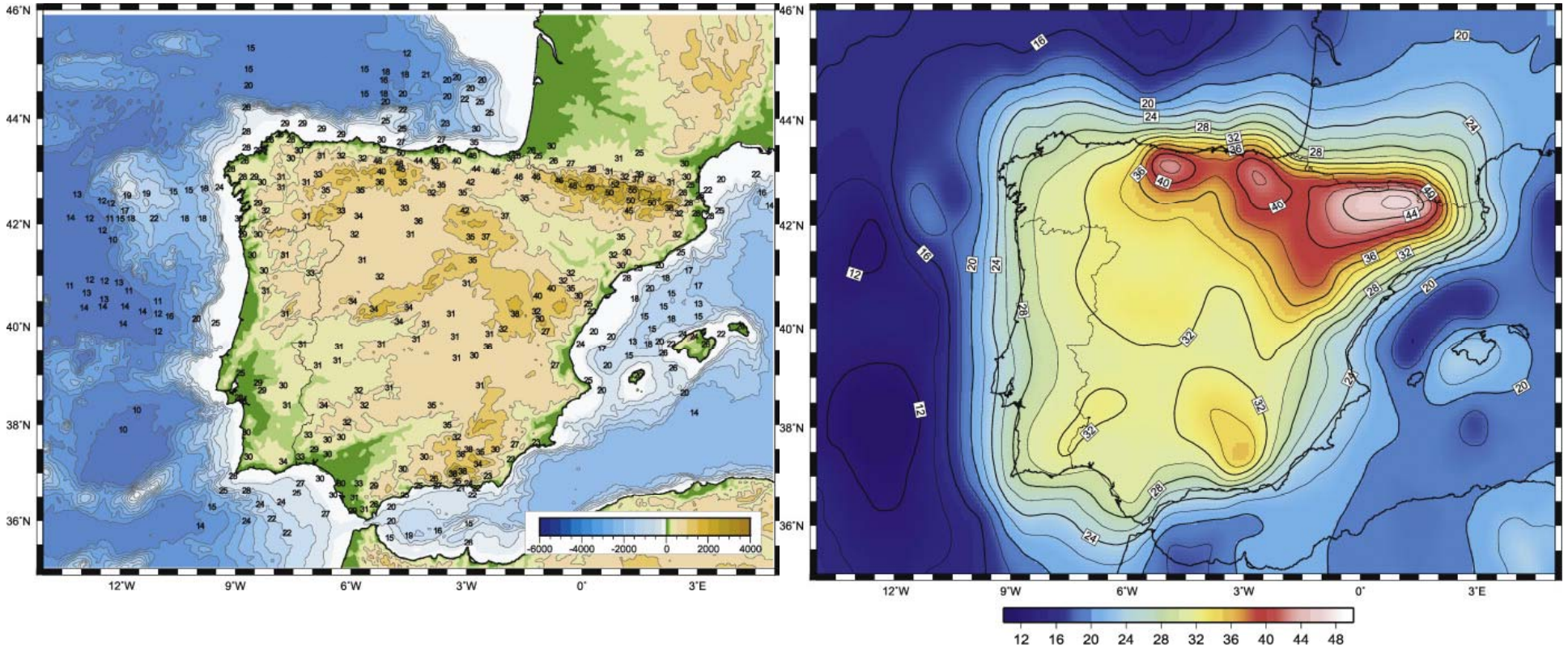




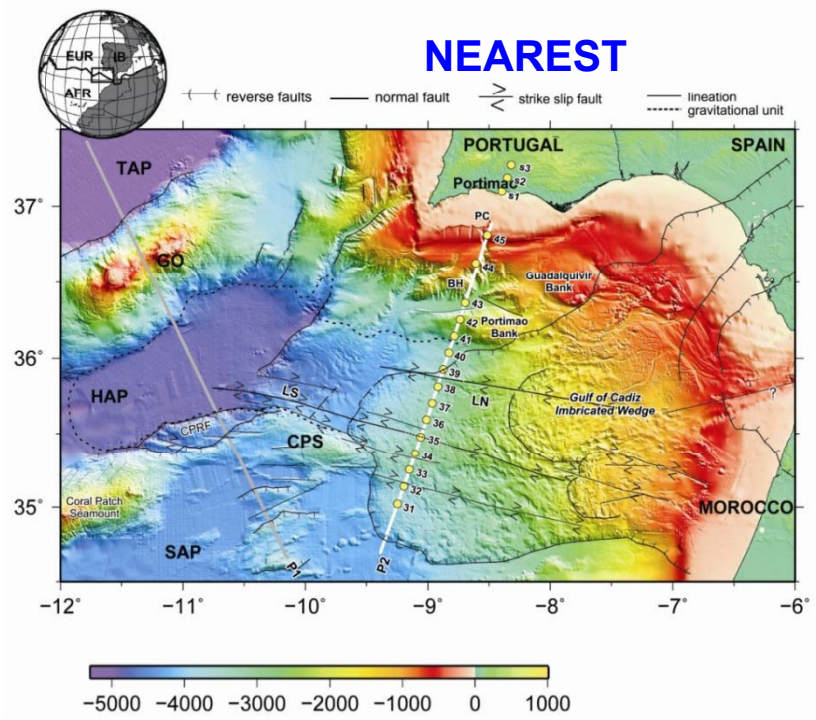
Vidal et al., JGR 1998

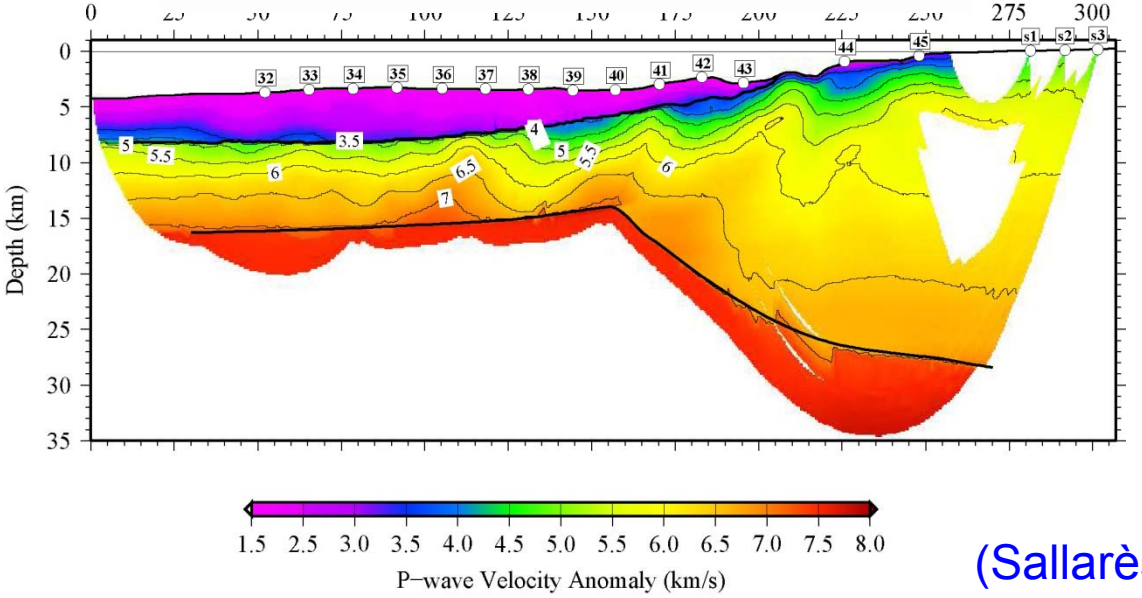
Moho depths from active seismics

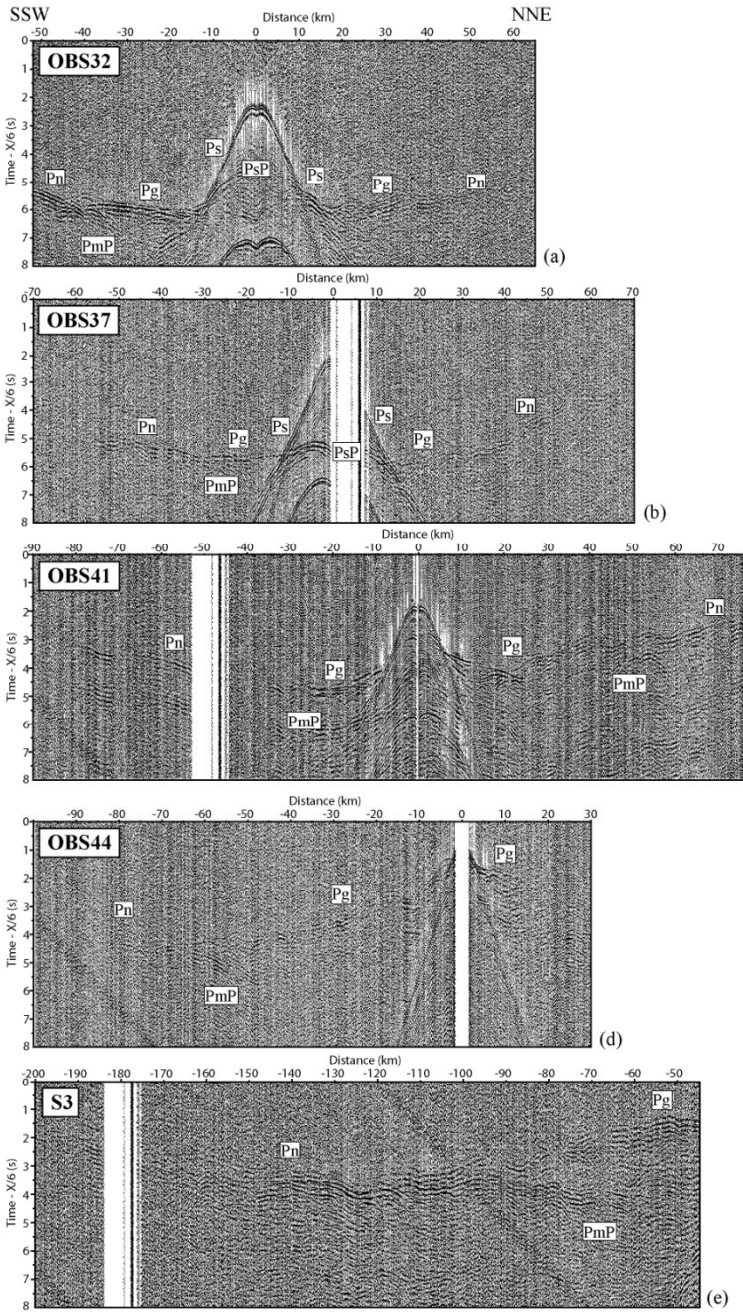
(Diaz and Gallart, PEPI 2009)



Example of recent onshore-offshore experiments





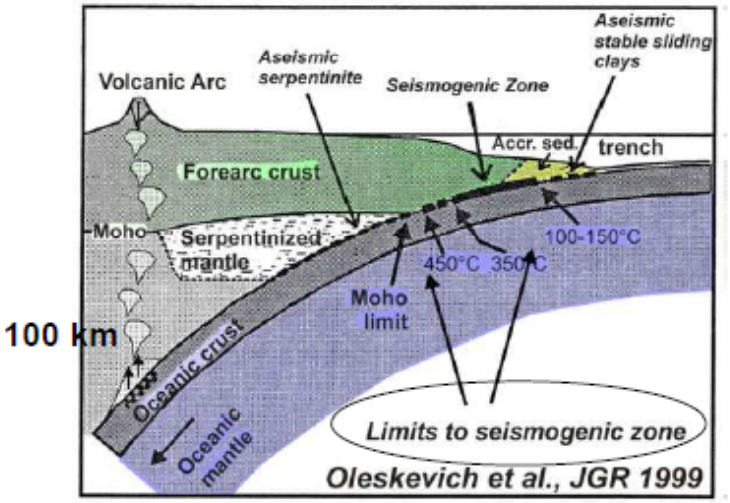


(Sallarès et al., submitted)

Combining Active and Passive Marine-Land Surveys:

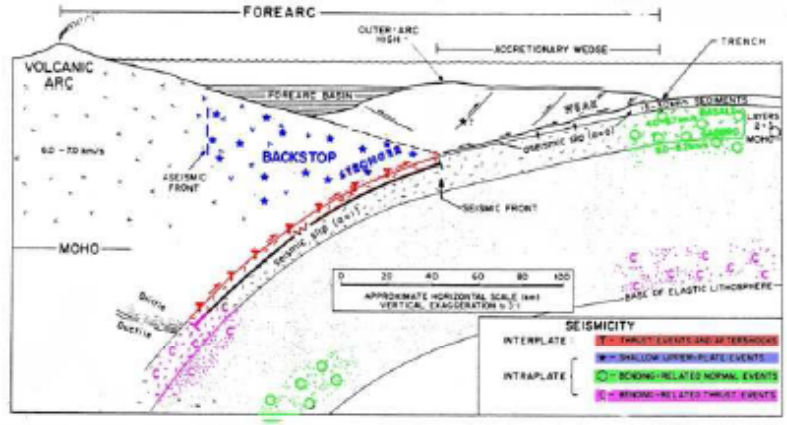
The example of **THALES-Was-Right** *(Strep-Nest EU-Project, 2006-2010)*

A. Major earthquakes in subduction zones: state of the art, possible breakthrough in understanding, and the perspective of "Thales was Right" and its objectives



Subduction and associated seismic activity

The seismogenic part of the interplate megathrust :
- where 90% of the Earth seismic energy release occurs
- where 9 of the 10 last major earthquakes occurred
- where the major earthquakes nucleate on an inclined plane several tens of km of downdip width, between 10 and 50 km depth
- where the convergence between the two plates occurs on t interplate in unstable, stick-slip mode



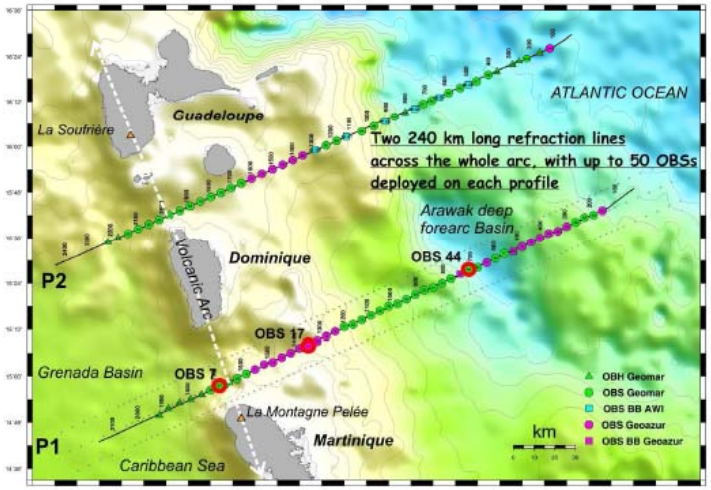
Byrne et al., Tectonics 1988

Subduction of oceanic lithosphere generates seismicity :
-in the incoming plate (mechanical flexure)
-in the upper part of the subducting plate (Wadati-Benioff earthquakes)
-in the upper plate, of the arc and forearc
-at the « mega-thrust » contact between the two plates, in its seismogenic part.

The meaning of current seismicity with respect to possible mega-thrust EQ can only be understood, with respect to these diverse types of earthquakes, if we can constrain
- the accurate absolute location of their hypocenters
- the accurate location of the interplate megathrust

THALES-Was-Right:
the Lesser Antilles subduction

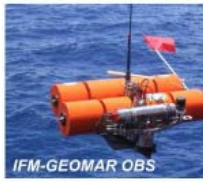
the German cruise **TRAIL** with the vessel **F/S Merian (Jan. 2007)**
(PI ***E. Flueh*** and ***H. Kopp***, IFM-GEOMAR)

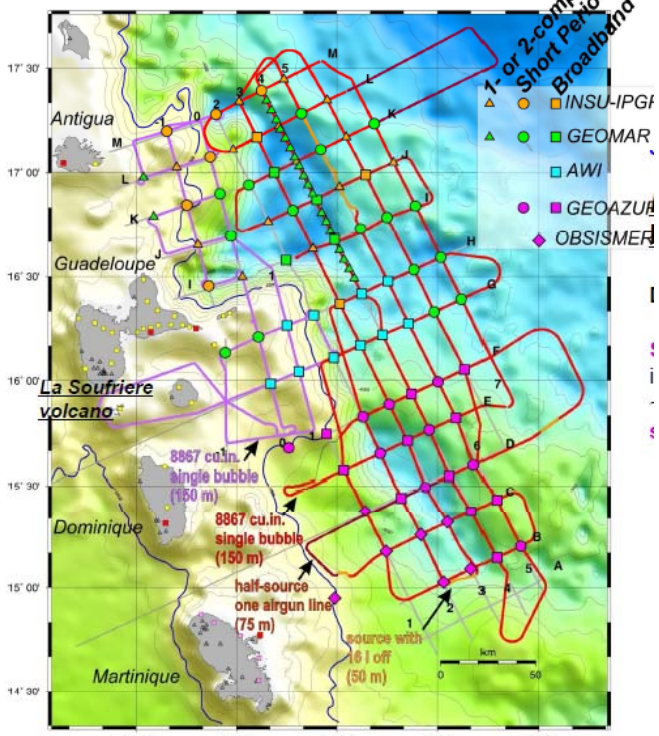


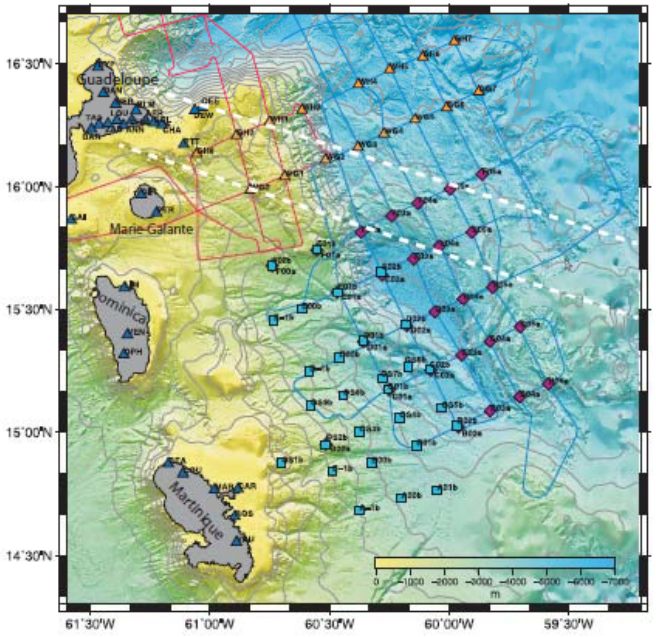
Airgun source :
3 x 16 litres
+ 2 x 32 litres
shot interval : 60 s ,
100m spacing

Multibeam bathymetry
acquisition along the profiles
and transits

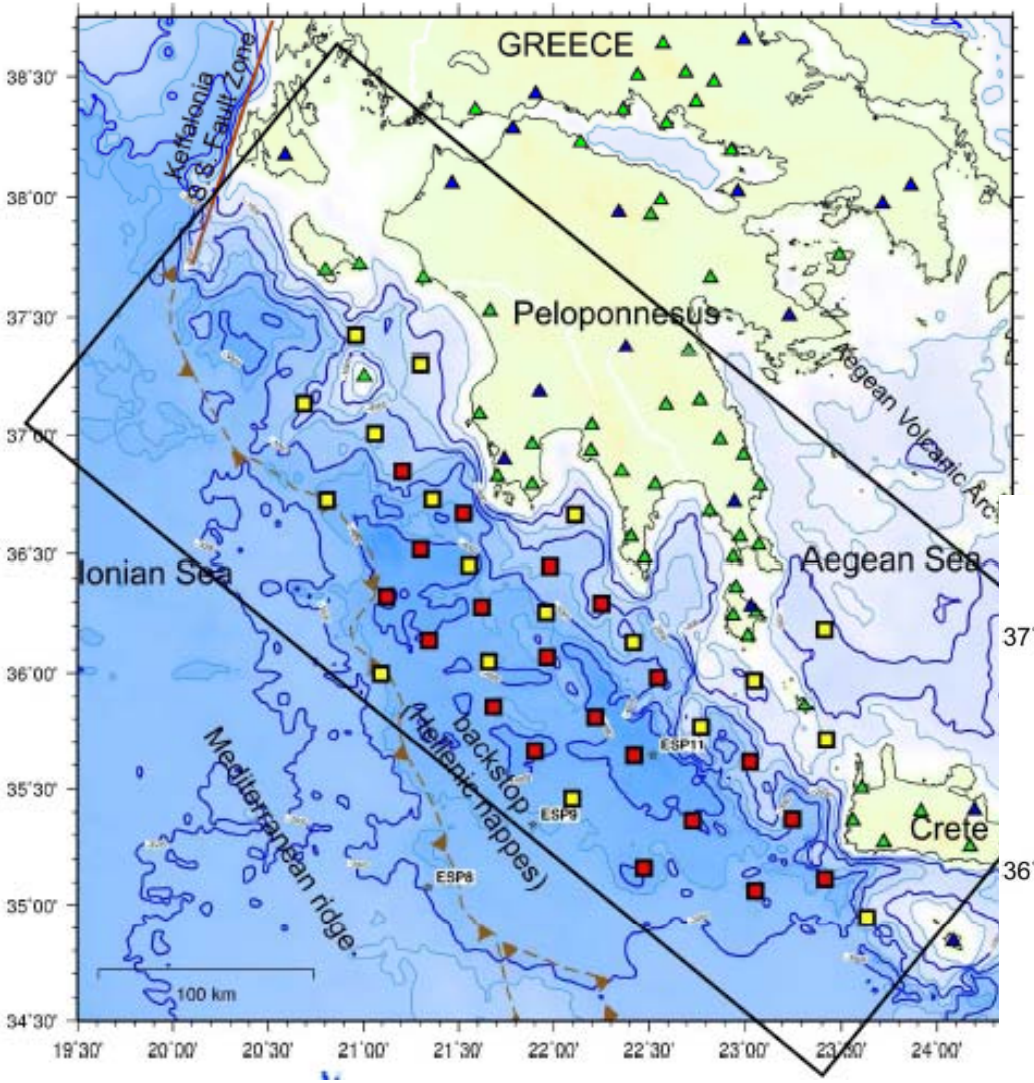
Re-deployment of 52 OBSs
on the nodes of the
SISMANTILLES 2 grid

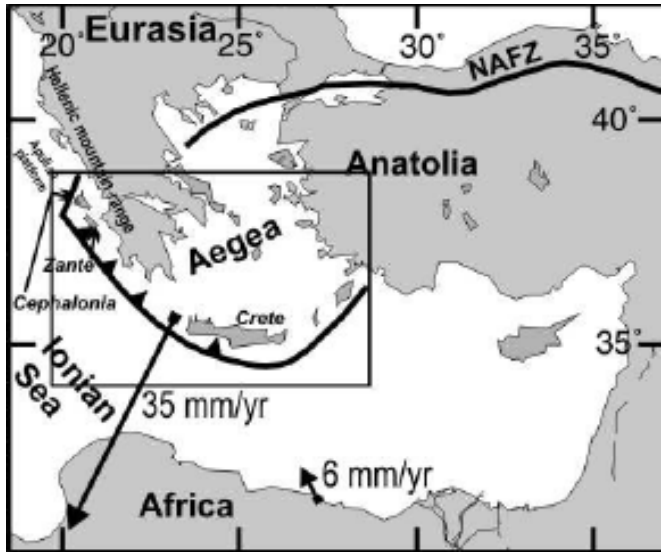


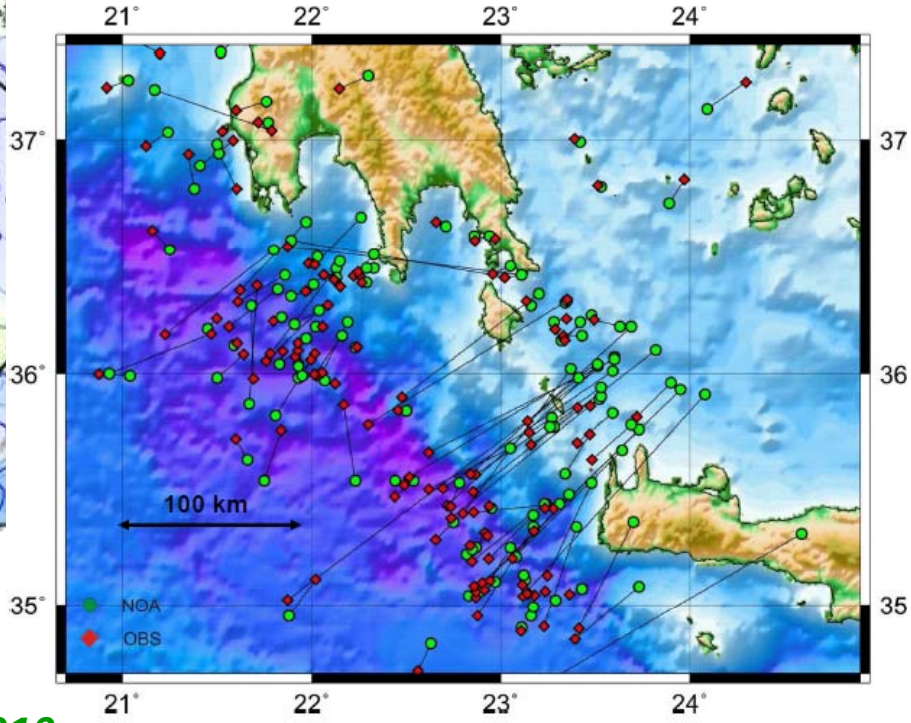




THALES-Was-Right: The Hellenic Subduction Zone

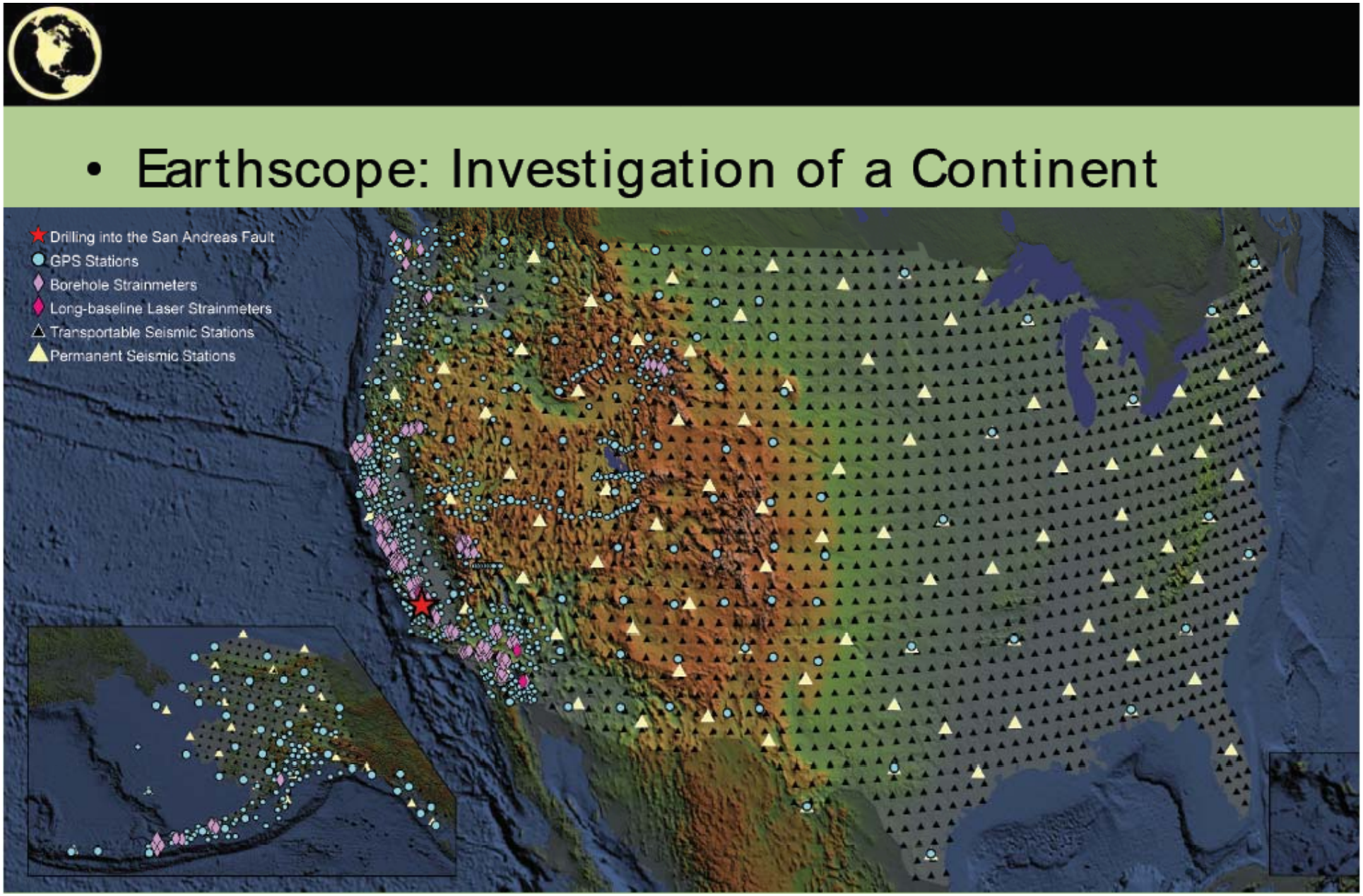




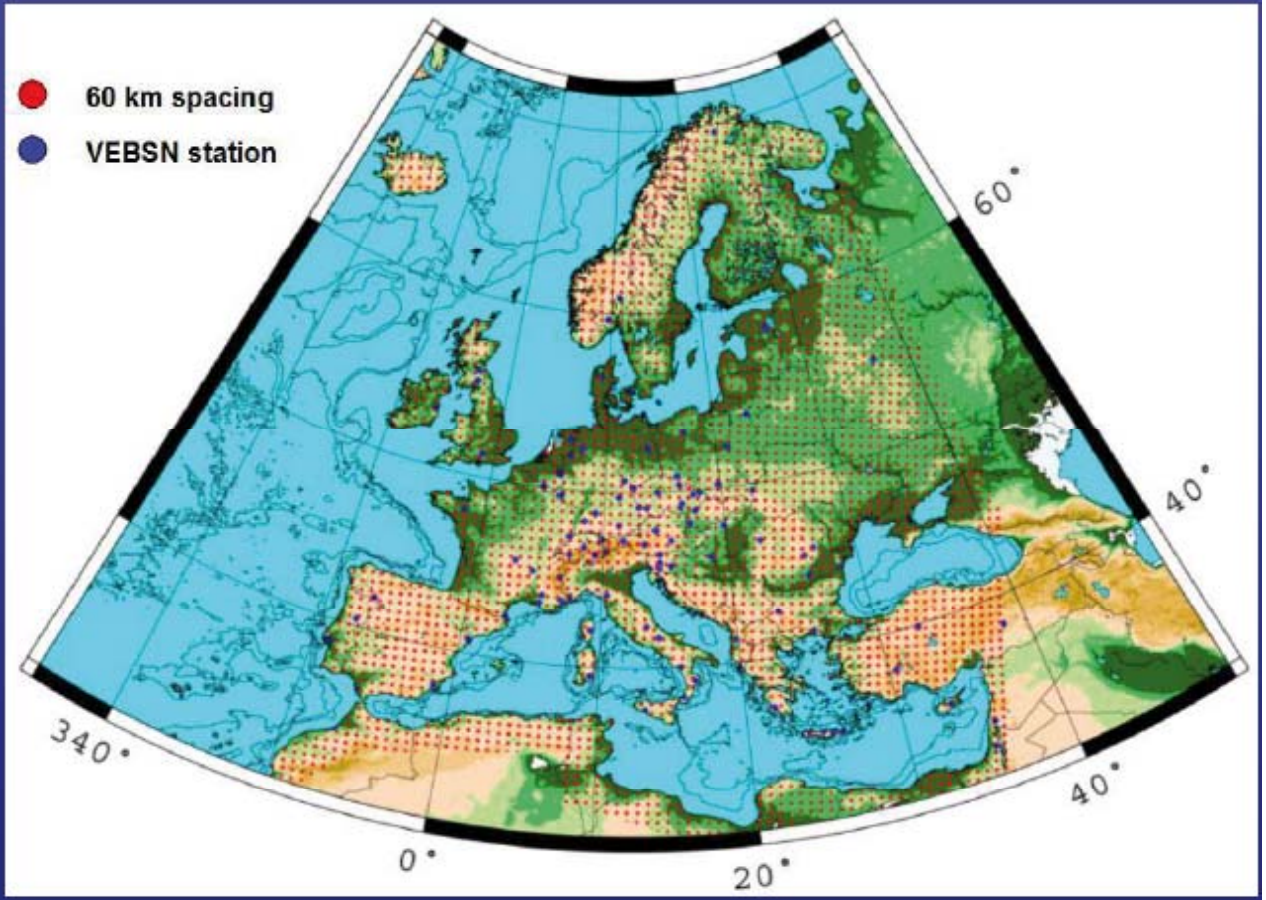


THALES-was-right . Final EU-report, 2010

Aim: to achieve a homogeneous, high density coverage of key geodynamic targets. *The EARTHSCOPE- USARRAY reference*



EuroArray: The European counterpart envisaged



Alan G. Jones, Dublin Institute for Advanced Studies
Peter Maquire, University of Leicester
Hans Thybo, University of Copenhagen

EUROARRAY

Hazards – Earthquakes and Volcanoes

Faults and Magmatic Processes

Continental Deformation

Formation and Evolution of Continental Lithosphere

Mountain Building

Convergent Margins

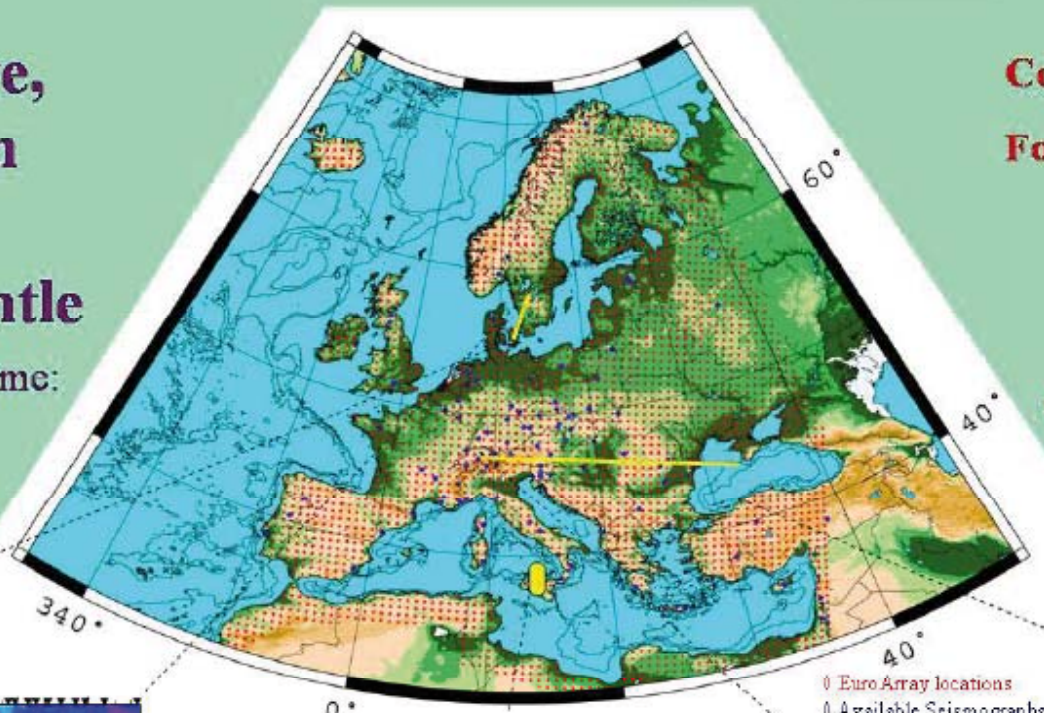
Passive Margins

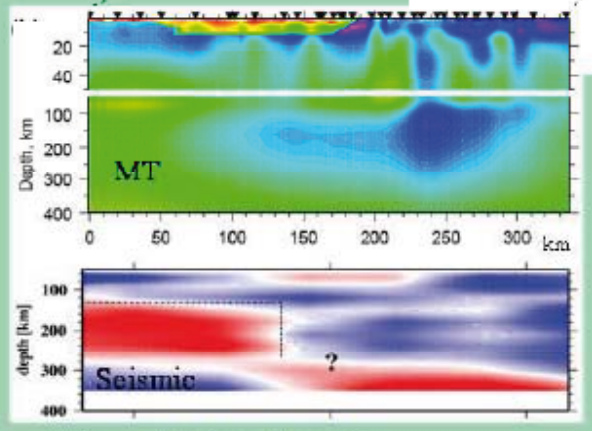
Rift systems

Mantle Plumes

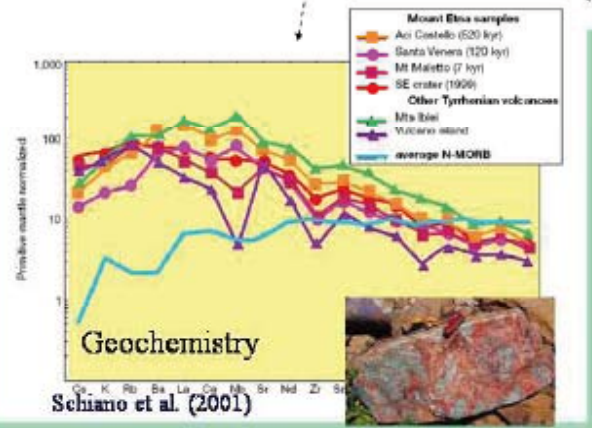
Comprehensive, high-resolution survey of the European Mantle

Pan-European Programme:
Backbone Array, and
Targeted Projects
10 years duration with
Real-time Data

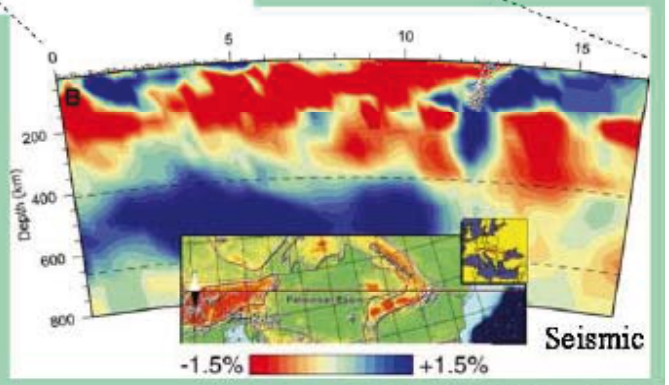




Smirnov and Pedersen (in prep.)



Schiano et al. (2001)

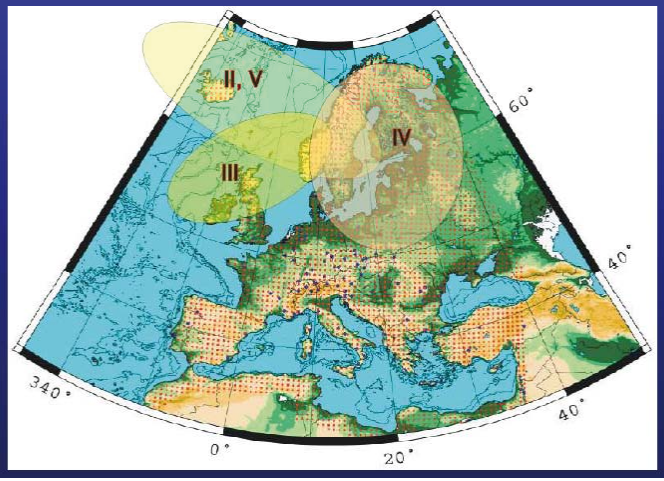


(Wortel & Spakman 2000)

Data Acquisition: 2600 Onshore Broadband Seismographs, Coincident GPS stations, 300 MT Stations, and 200 Combined Sea Floor Systems

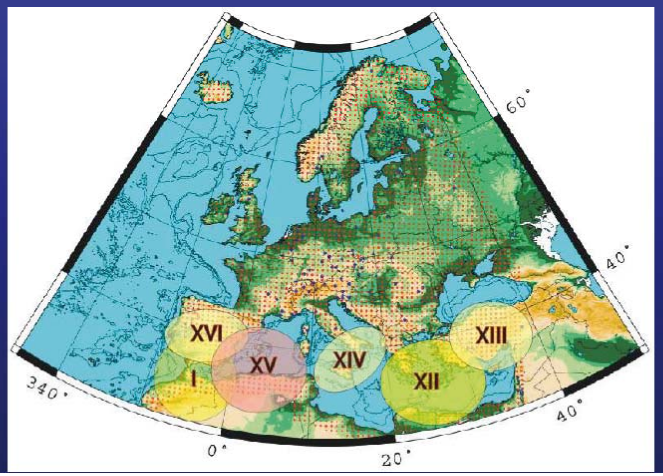
EuroArray themes: northern Europe

II North Atlantic Uplift
III Caledonides of Northern Europe
IV Formation & Evolution of Ancient Lithosphere
V Continent – Ocean Transition



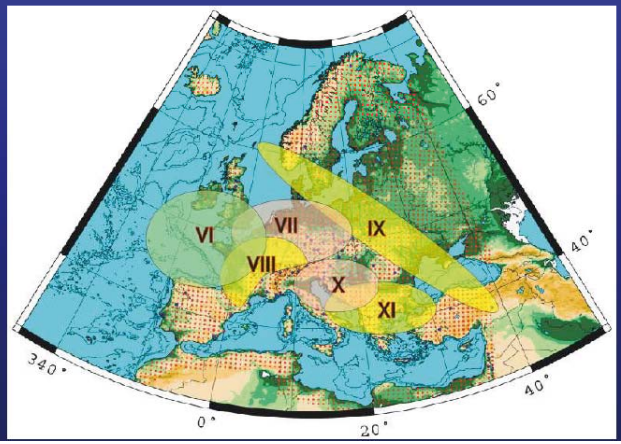
EuroArray themes: southern Europe

XII Eastern Mediterranean Subduction
XIII North Anatolian Fault
XIV Southern Italian Neotectonics
XV Western Mediterranean Processes
XVI Central Iberian Ascent
I PICASSO



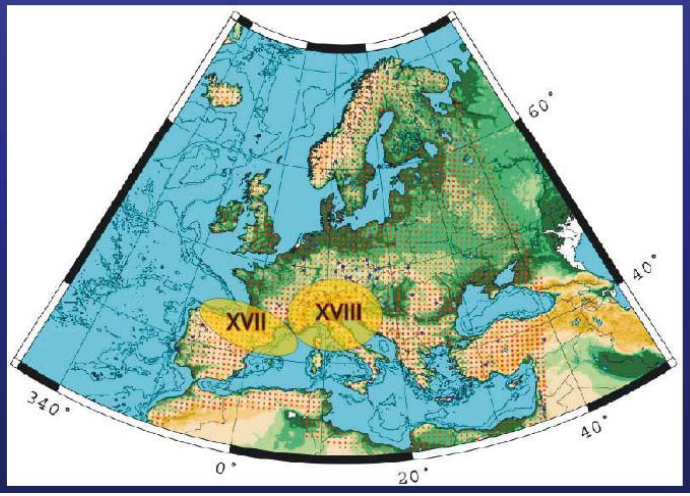
EuroArray themes: central Europe

VI Variscides of Northern Europe
VII North European Basins
VIII Plumes of Europe
IX Tornquist – Teissyre Zone
X Pannonian – Carpathian Basin
XI Carpathian And Danube System



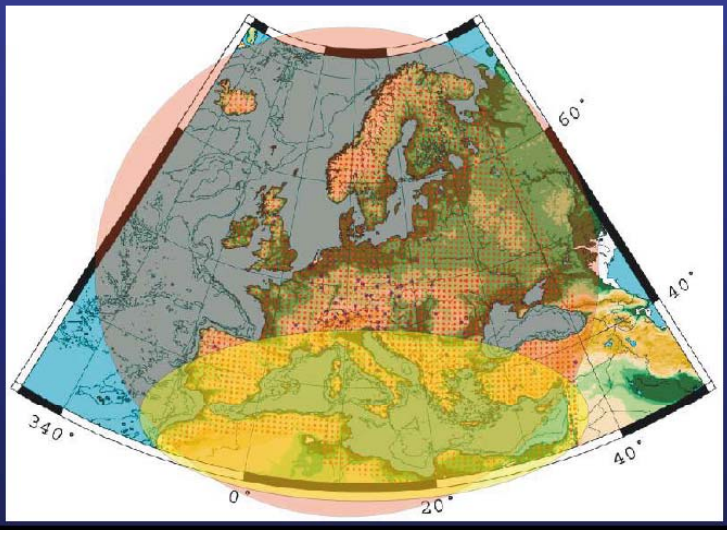
EuroArray themes: Orogens

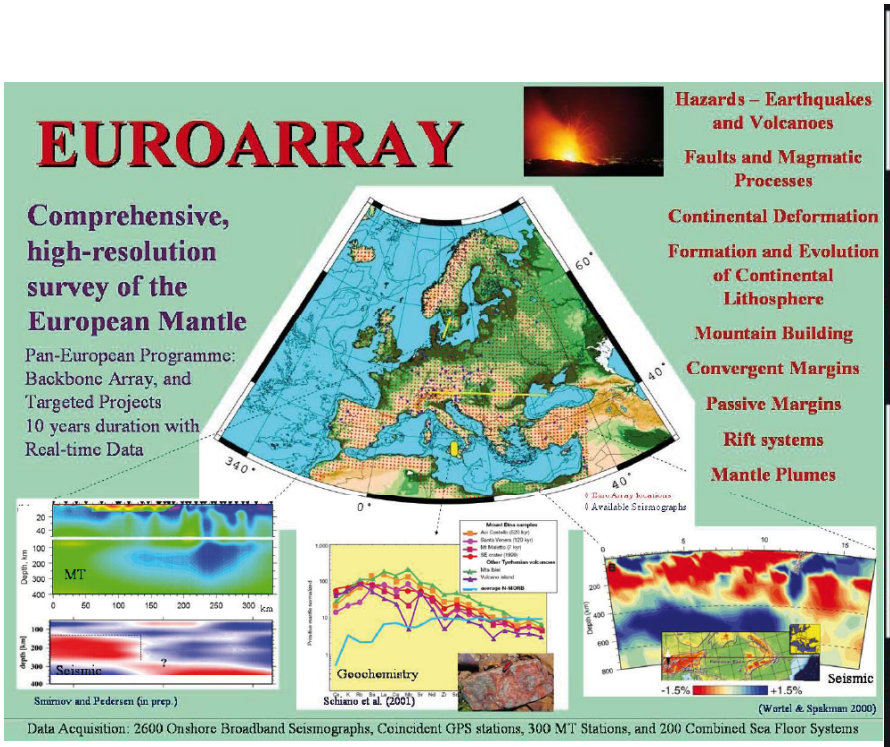
XVII Pyrenean Mountain System
XVIII Alpine Imaging

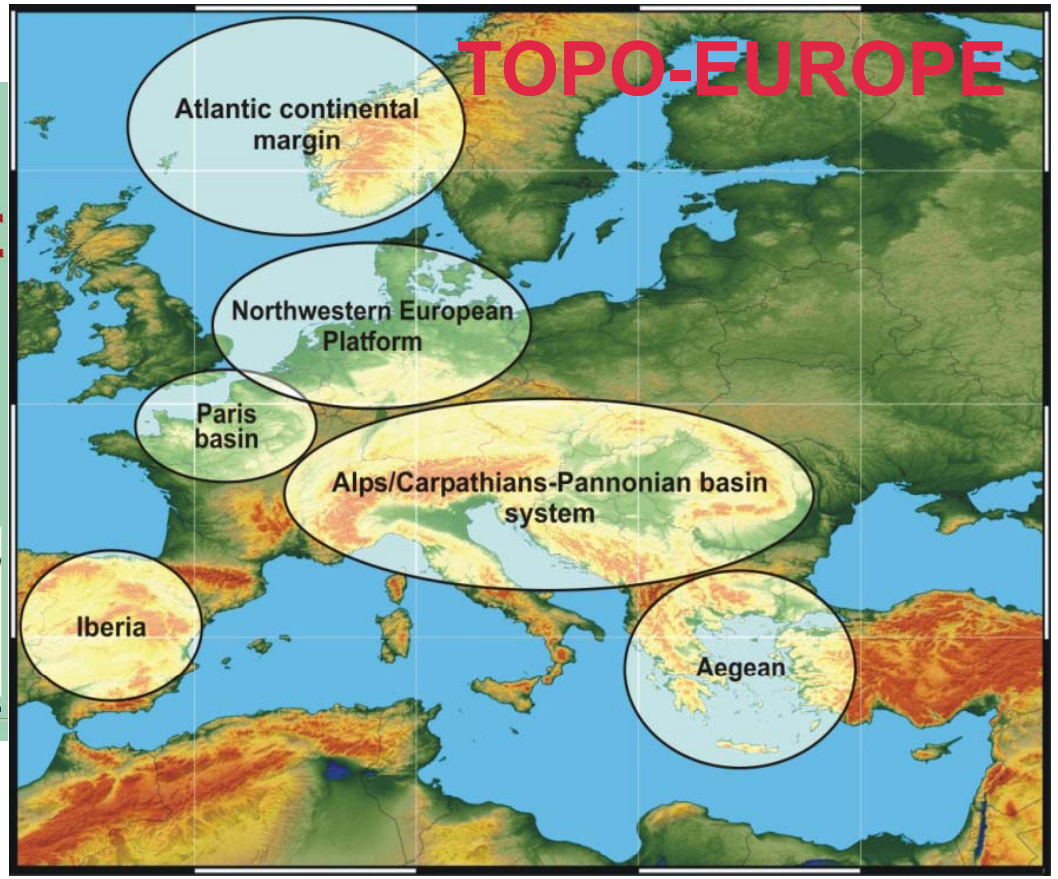


EuroArray themes: general

Deep Mantle Beneath Europe
Lithosphere – Asthenosphere Boundary beneath Europe
European Natural Resources
Southern European Tectonic Risk Assessment



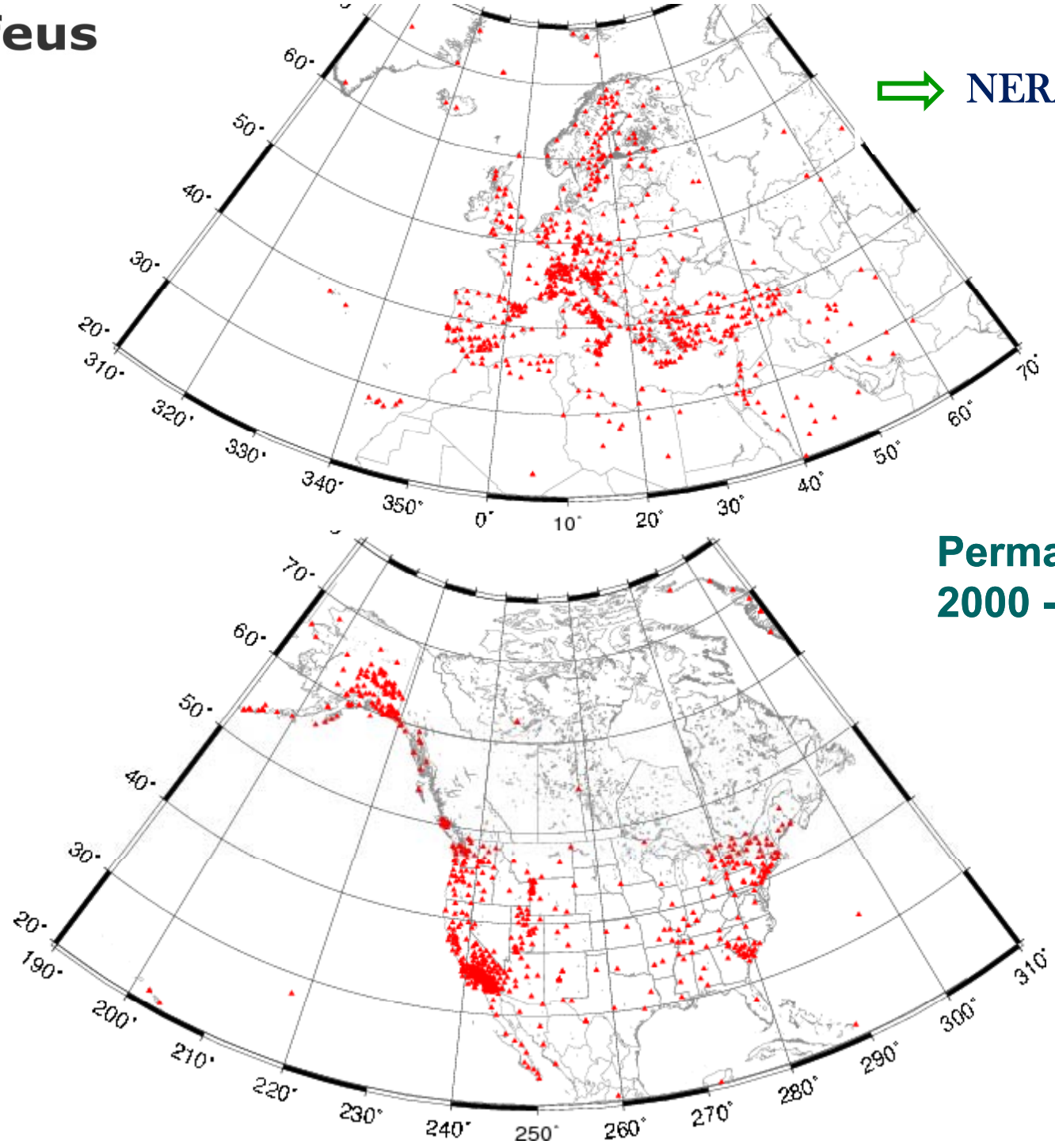




Finally, the EuroArray initiative was integrated in the TOPOEUROPE Eurocore proposal (2006), formally as the observational component of this programme

Orfeus

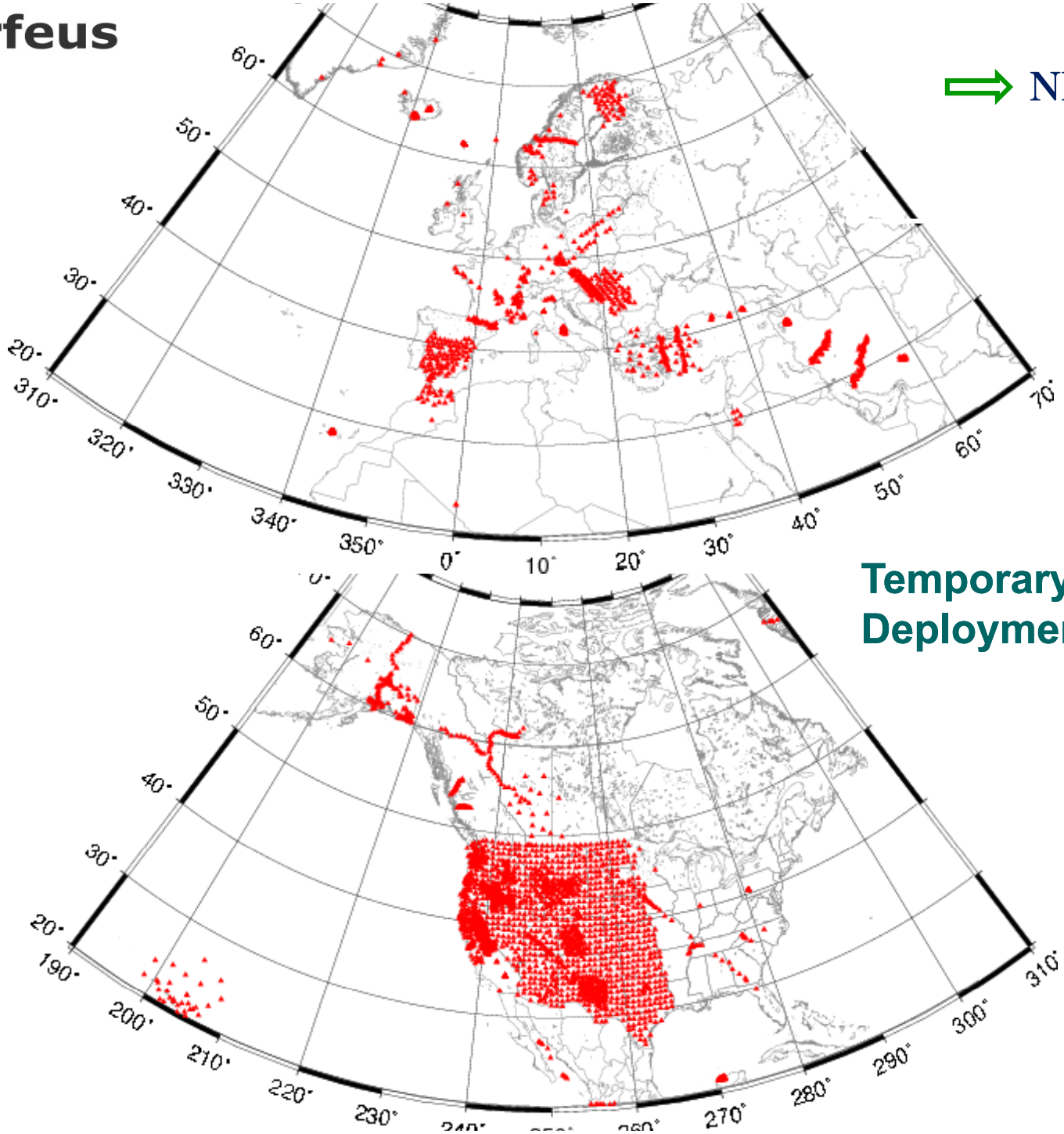
⇨ NERA ⇨ EPOS



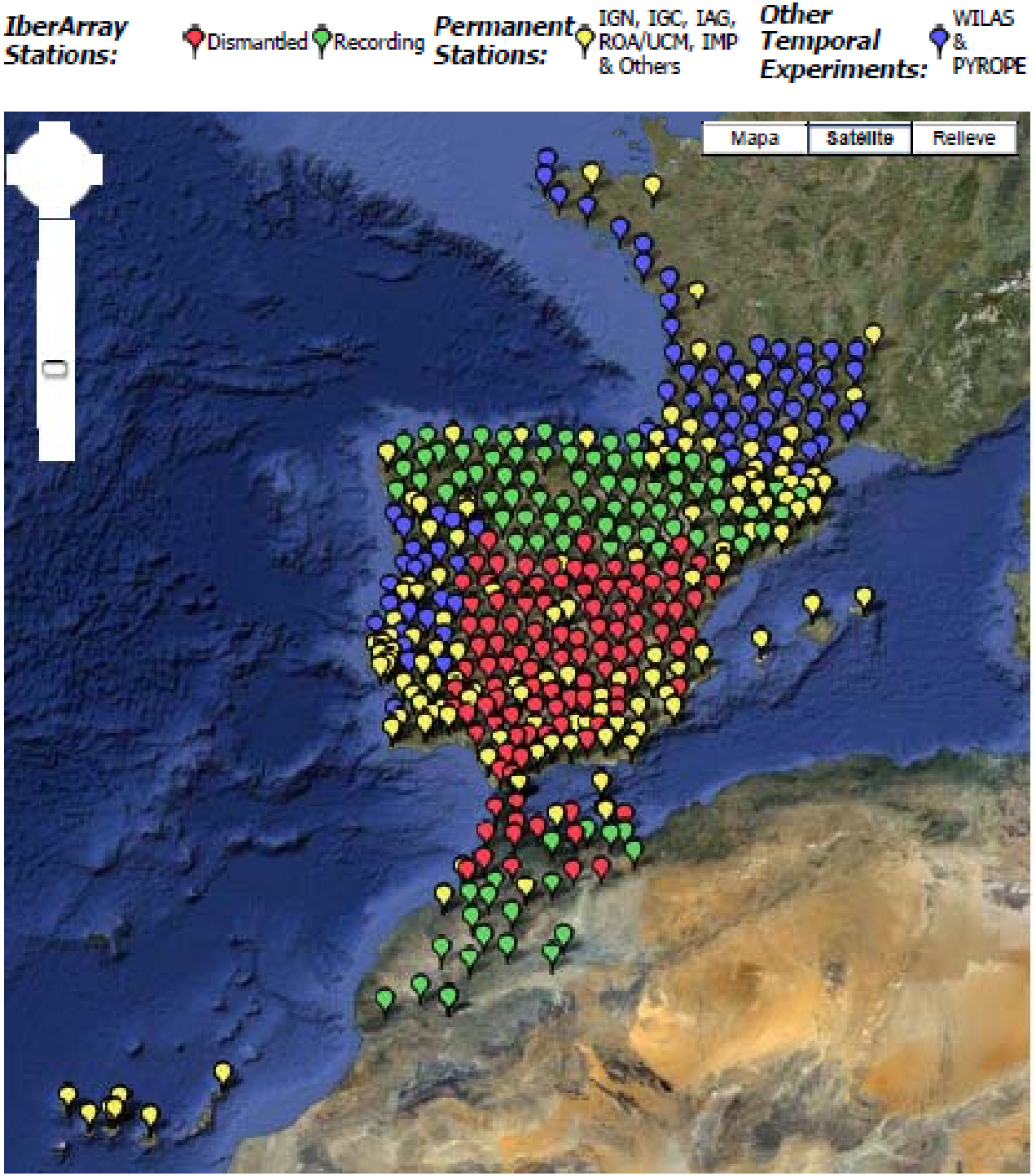
Permanent stations
2000 - 2010

Orfeus

⇨ NERA ⇨ EPOS



Temporary networks
Deployments 2000 - 2010


IberArray Stations:
Dismantled
Recording
Permanent Stations:
IGN, IGC, IAG, ROA/UCM, IMP & Others
Other Temporal Experiments:
WILAS & PYROPE
Mapa
Satélite
Relieve

Consolider
CSD2006-00041

TOPOIBERIA

Geosciences in Iberia: Integrated studies of topography and 4-D evolution

http://www.igme.es/internet/TopoIberia/

- *Topo-Iberia* is a 5-year project (*CSD2006-00041)* funded by the Spanish Ministry of Education and Science under the Consolider-Ingenio 2010 Programme of Excellence (4.5 M€), with 20% additional support by the CSIC.

- *Topo-Iberia* provides an integrated framework for multidisciplinary geoscientific studies in Spain
- It gathers 10 different Spanish institutions and > 125 senior researchers
- Coordinator: Prof. J. Gallart , Institute of Earth Sciences 'J. Almera' – CSIC, Barcelona

Participant Institutions

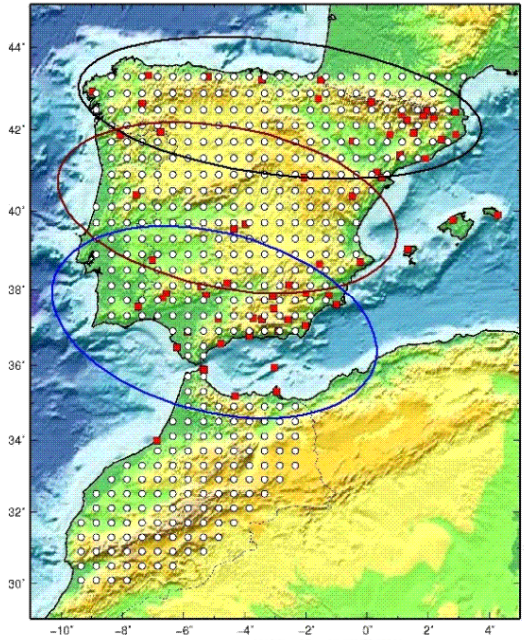
- ICTJA: Instituto de Ciencias de la Tierra Jaime Almera-CSIC
- UAB: Universidad Autónoma de Barcelona
- UG: Universidad de Granada
- UCA: Universidad de Cádiz
- UO: Universidad de Oviedo
- UJ: Universidad de Jaén
- UB: Universidad de Barcelona
- IGME: Instituto Geológico y Minero de España
- UCM: Universidad Complutense de Madrid
- ROA: Real Instituto y Observatorio de la Armada

The *IberArray* Platform

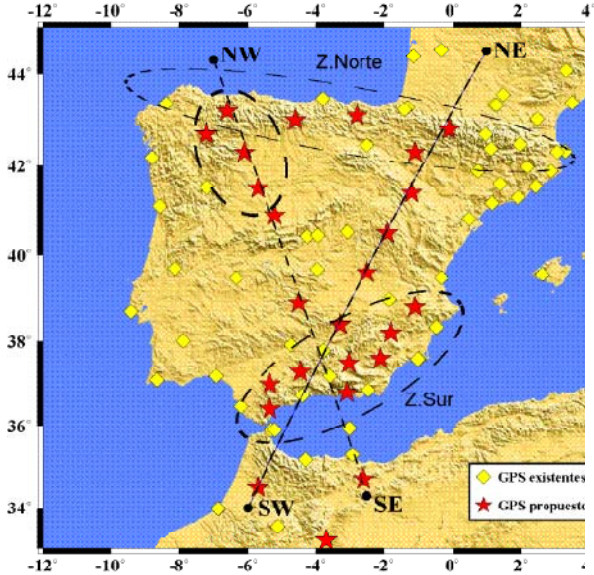
TOPOIBERIA

A major aim of **Topo-Iberia** is to increase the data resolution by acquiring and deploying a technological observatory platform, ***IberArray***, which includes:

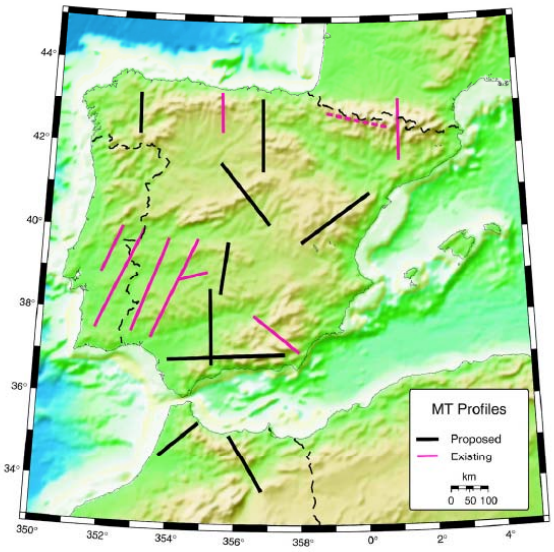
Seismic network



GPS network

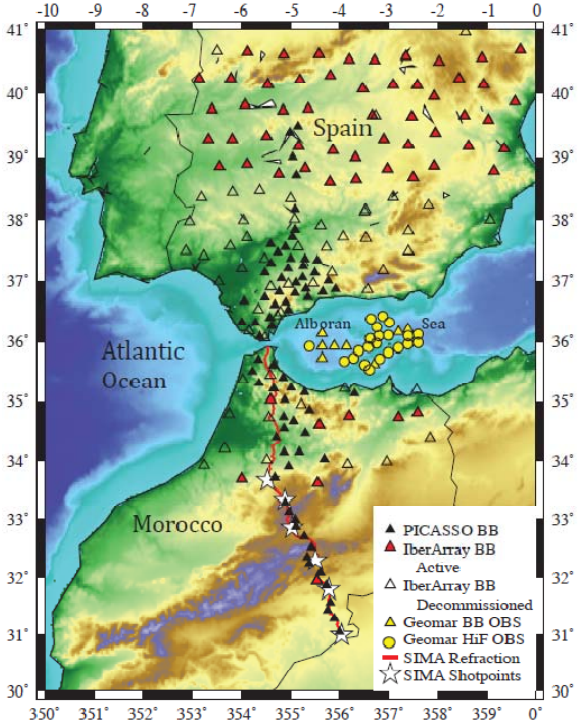


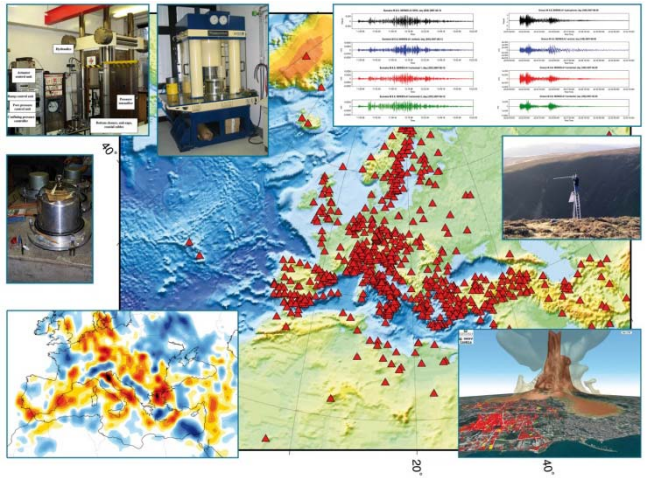
Magnetotelluric network



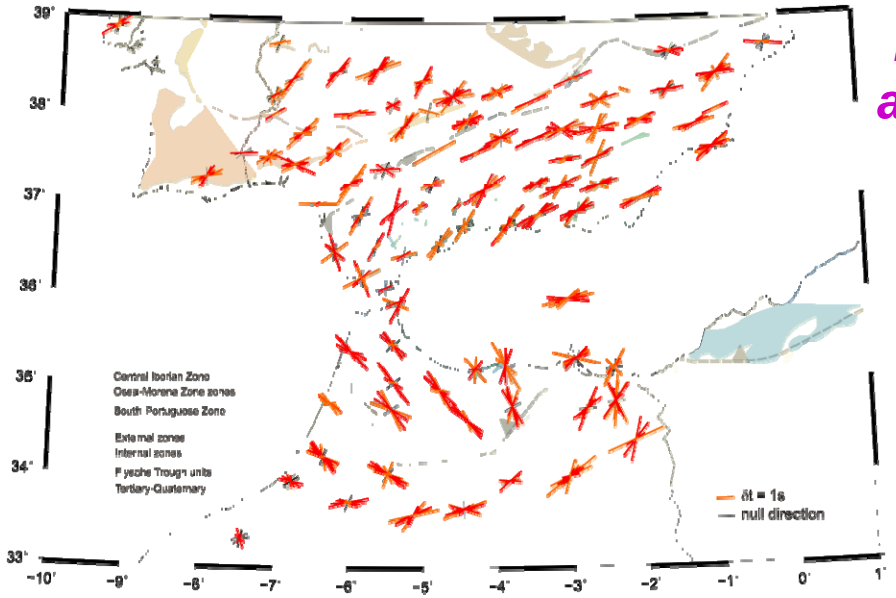
Perspectives of the Topo-Iberia Consortium:
Interactions/Synergies with coeval International projects

- ►The USA-NSF **PICASSO** project *(>70 BB seismic stations complementary to the Topo-Iberia network)* +**SIMA** *project (Spanish-US active seismic transect across Atlas)*
- ►The German **PICASSO** project (*20 BB stations)*
- ►The IRISH **PICASSO** project (*Magnetotelluric transects*)
- ►The **TOPOEUROPE** ESF-EUROCORE Programme
  Projects: Topo-Med, PyrTec, Source-to-Sink,...)
- ►The **TOPO-MOD**-Marie Curie ITN project
- ►The **Nearest**-EU/FP6 project: *(tsunami research)*
  Included one year deploy of 24 OBS in the Gulf of Cadiz
- ►The **WILAS** project (*BB seismic coverage of Portugal*)
- ►The **Pyrope and Resif** projects (*BB seismic coverage of north Pyrenees domains and permanent French network*)
- ►The **NERA**-EU/FP7 project (*Infrastructures for earthquake risk assessment*)
- ►The **EPOS**:*European Plate Observing System*
  (*included in the* **ESFRI** *Road Map*):
  Spanish Consortium based on 'Topo-Iberia' Team





A strong Momentum generated !

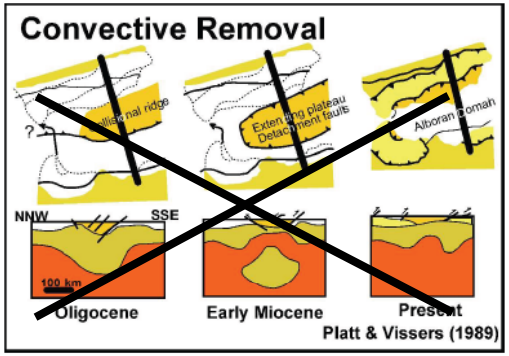


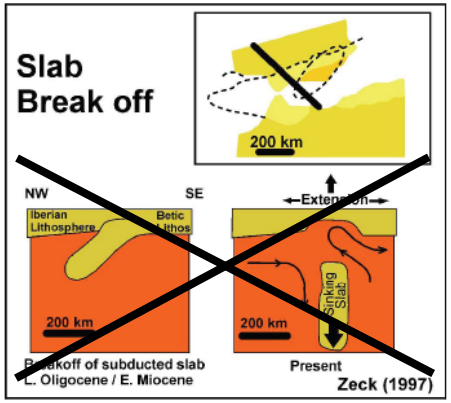
Many research topics need to be further addressed by collecting seismic datasets offshore

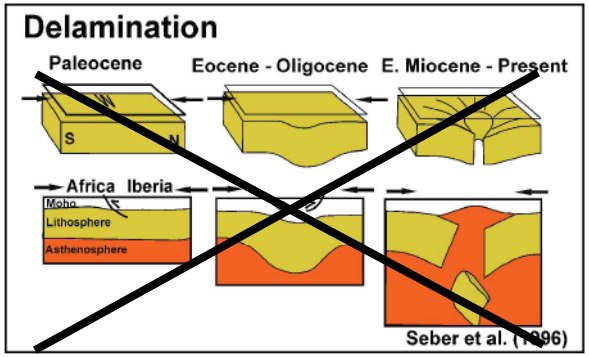
Example: SKS Anisotropy in the Gibraltar Arc System

FPD clearly follow a spectacular rotation along the Gibraltar arc following the curvature of the Rif-Betic chain

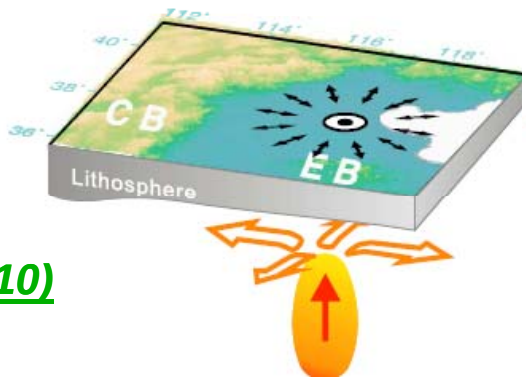
An abrupt change on the FPD appears to the S and SE of the Betic-Rif chain

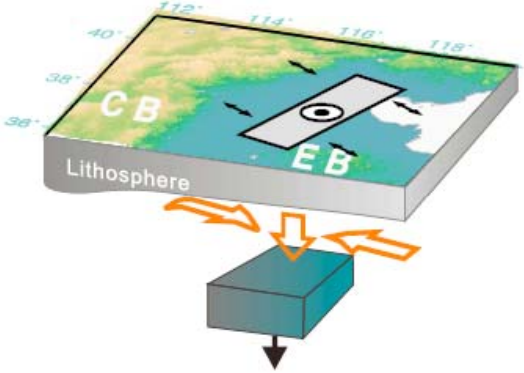






Geodynamical models implying asthenospheric upwelling do not see compatible with the results as the expected anisotropic pattern would radial rather than arc parallel

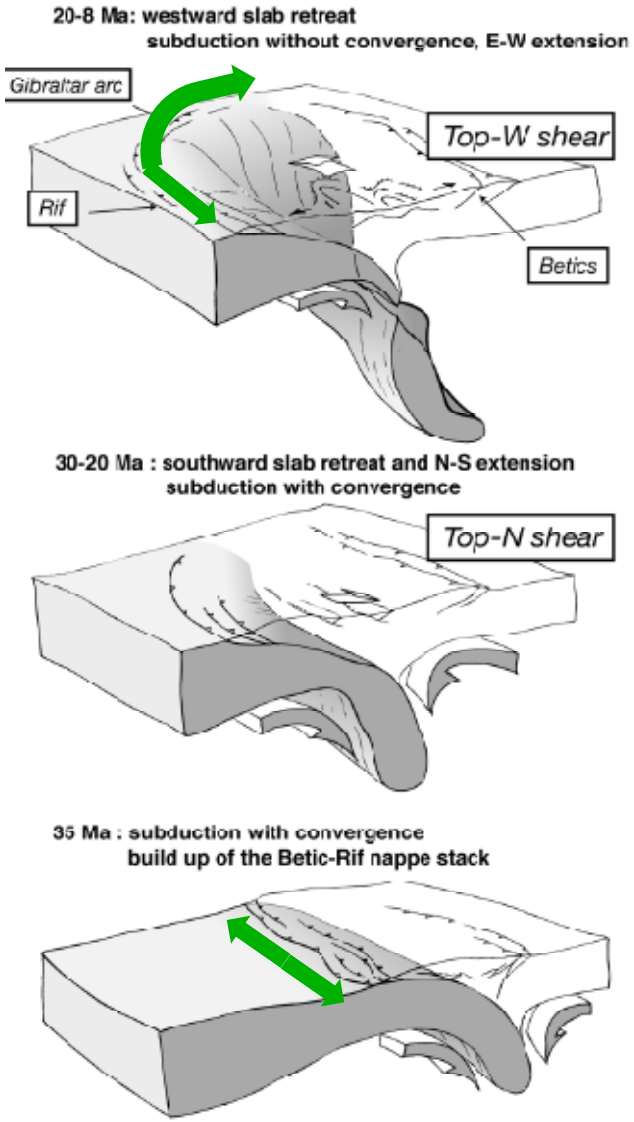




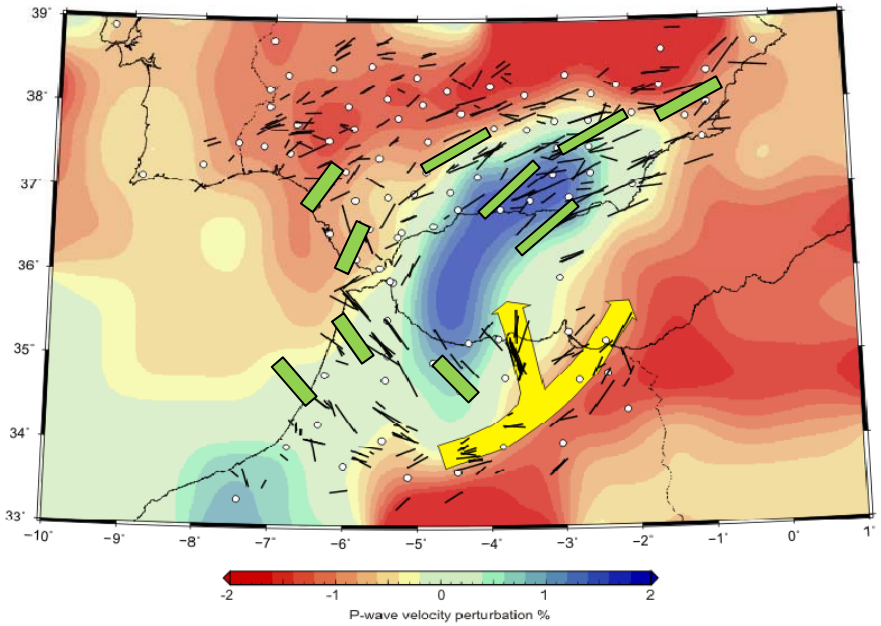
(Diaz et al, GRL 2010)

Retreating Slab Models **seem to explain the extensional features beneath the Gibraltar arc**

The arc parallel FPD may correspond to the trench parallel anisotropy acquired while the Western Mediterranen Subduction was active



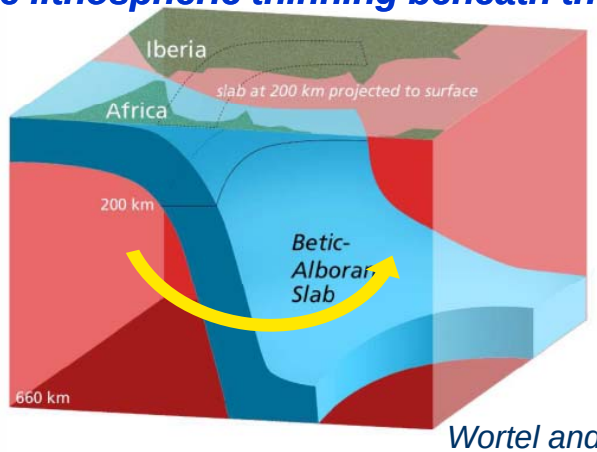
Adapted from Jolivet et al., 2008



The pattern variation beneath NE Morocco can be related to the imprint of a Miocene mantle flow episode during the roll-back emplacement of the Gibraltar arc, remained "frozen-in" in the lithospheric mantle since then…

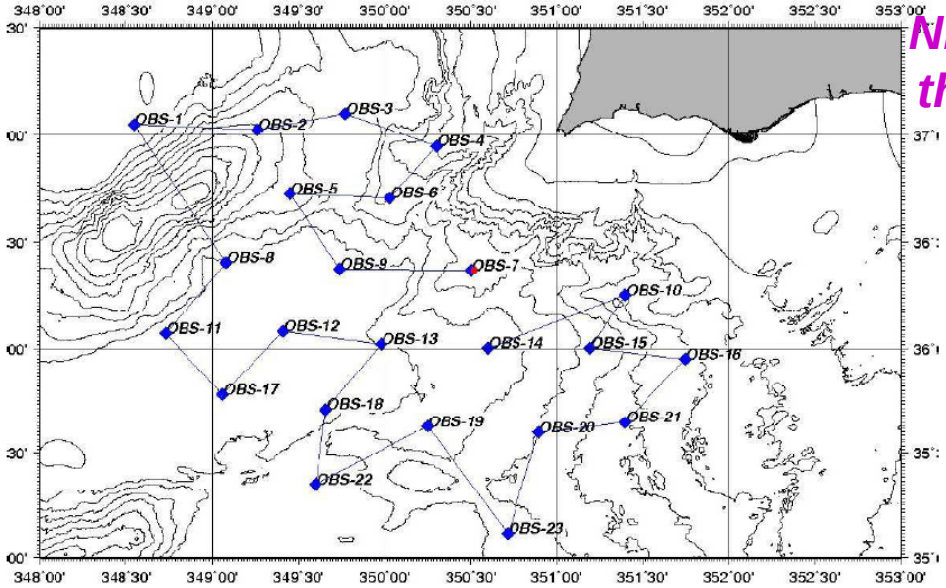
….or to a present-day process, related to the slab roll-back and perhaps facilitated by the lithospheric thinning beneath the Atlas belt

(Diaz et al, GRL 2010)

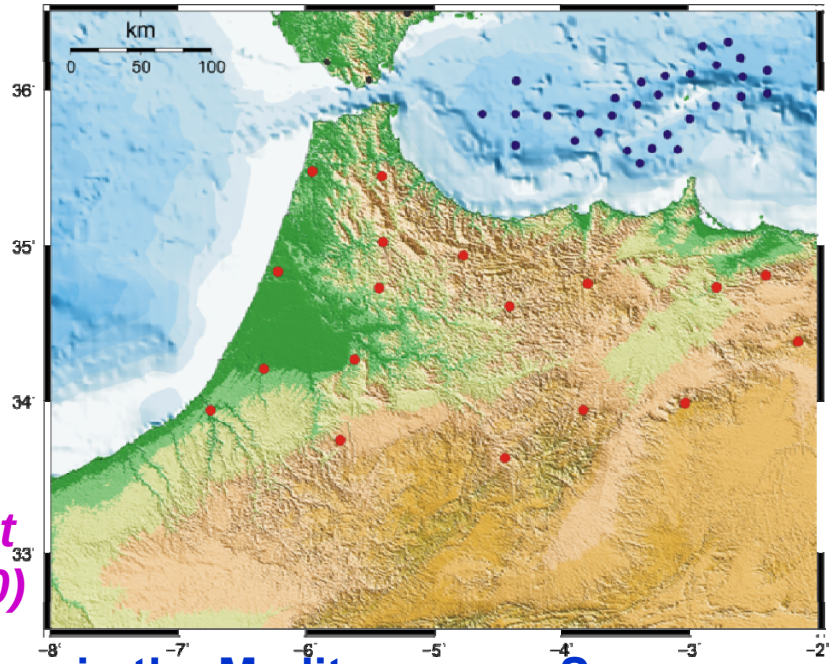


Wortel and Spakman, 2000

Examples of temporary OBS deployments for passive seismics in W-Mediterranean



NEAREST project: OBS deployment in the Gulf of Cadiz (~one year: 2007-08)



TOPO-MED project: OBS deployment in the Alboran Sea (6 months in 2010)

Examples of Permanent Ocean Bottom Systems in the Mediterranean Sea:

-GEOSTAR *(NEAREST-EMSO) in Gulf of Cadiz*

-FOMAR *(ROA) in Alboran Sea*

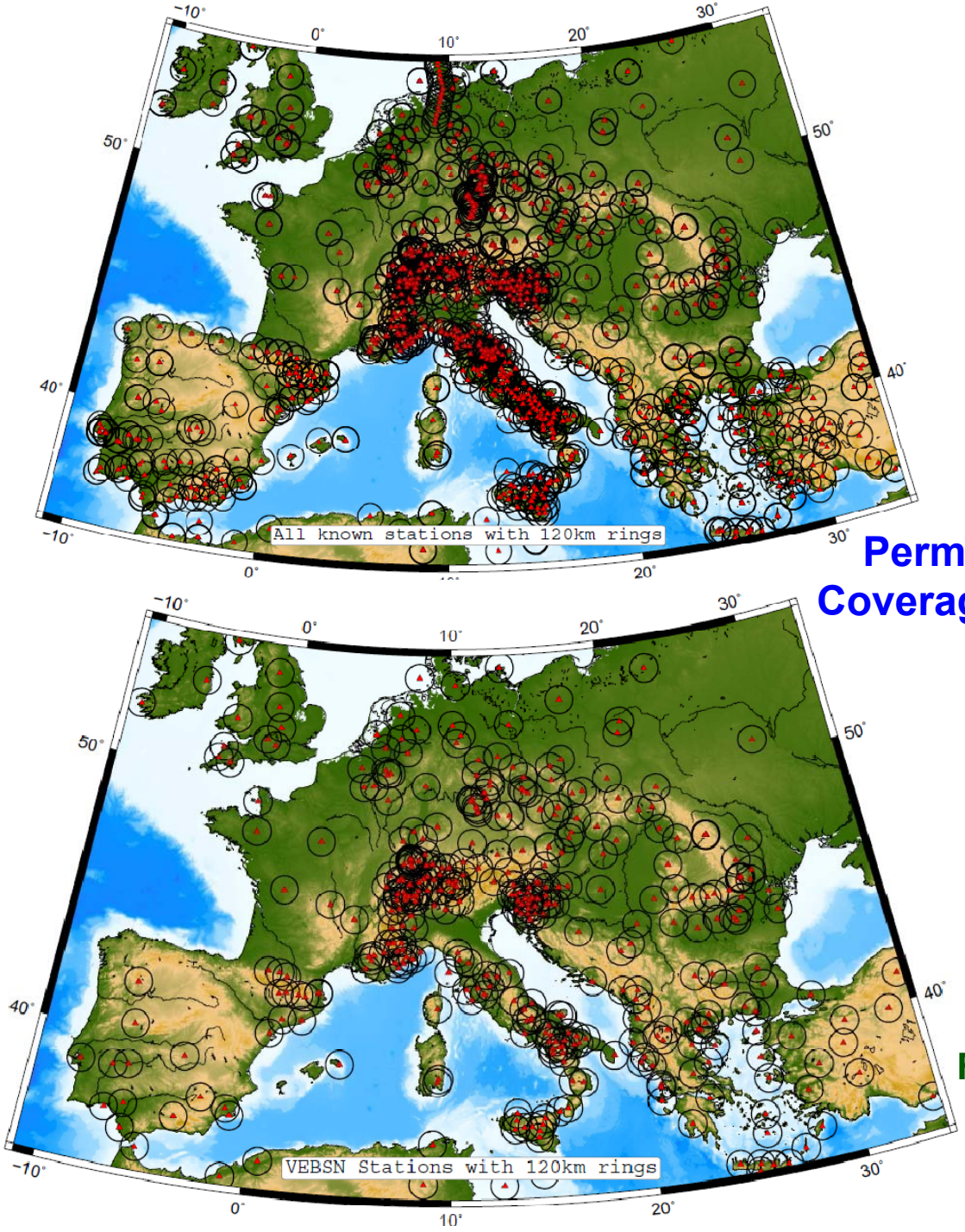
-COBS *(IGC) in Catalan margin*

-ANTARES *(U.Nice) in Liguro-Provencal Basin*

-CUMAS *(INGV) in Gulf of Puzzuoli*

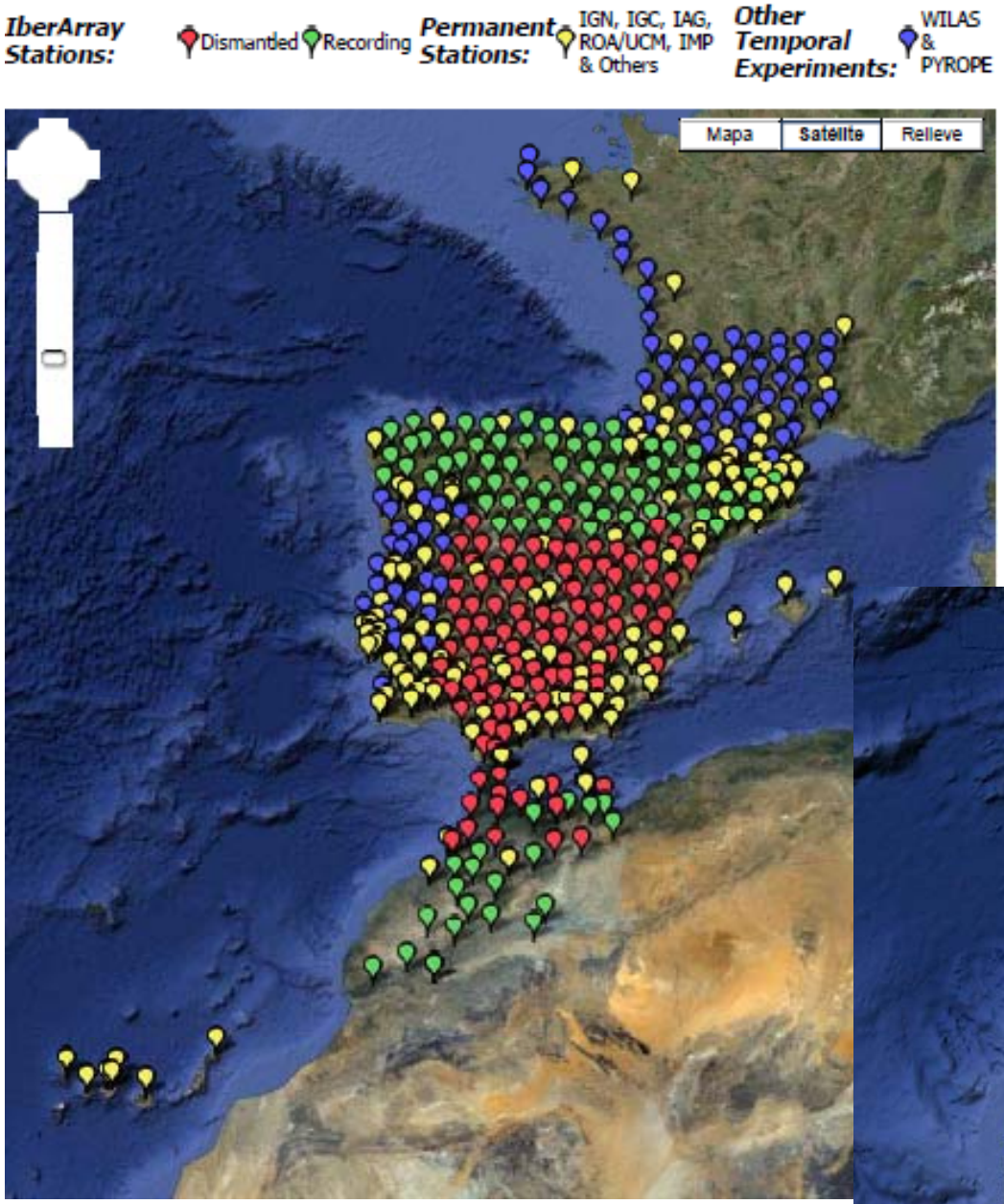
-MSBO *(KOERI) in Marmara Sea*

……



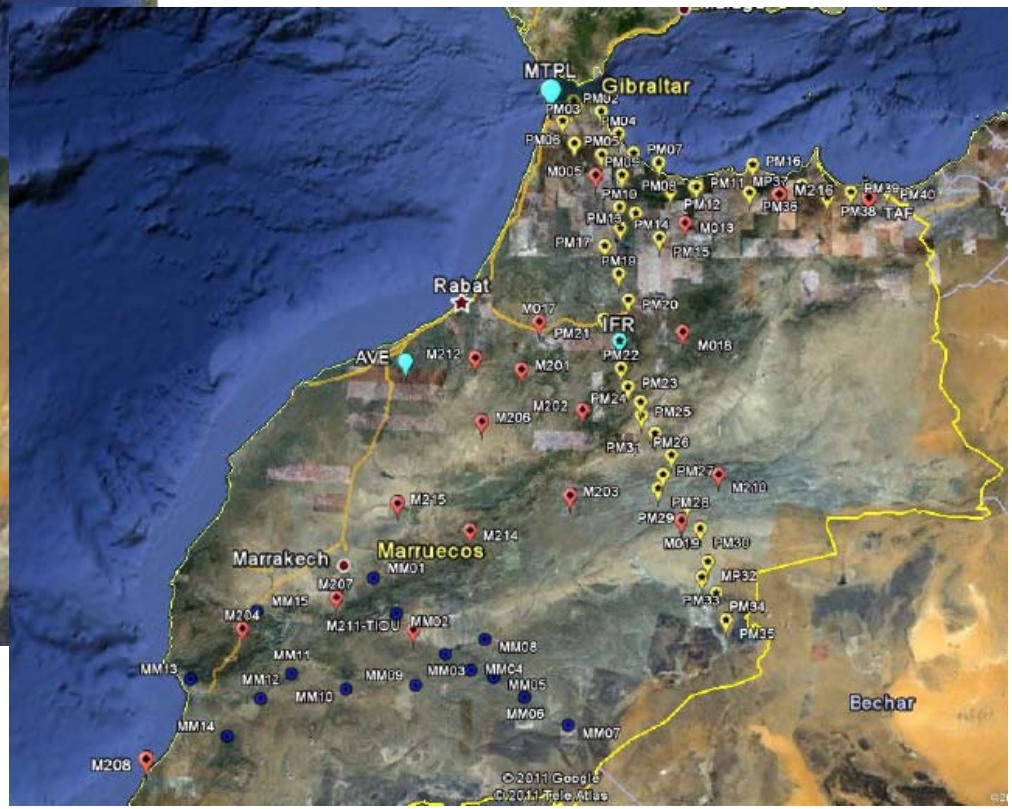
Permanent Stations Coverage (120 km rings)

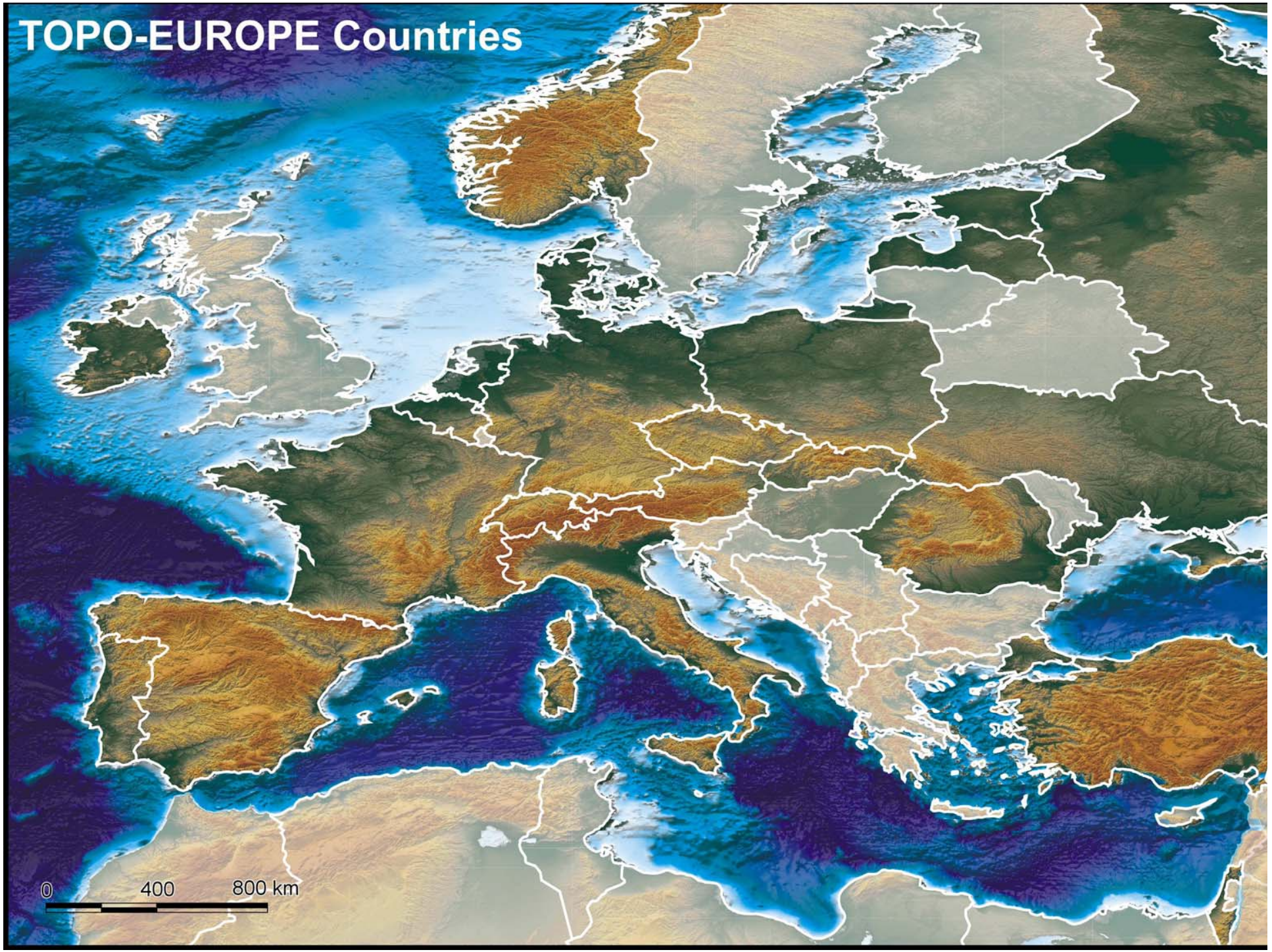
From A. Brisbourne, Orfeus-Nera



Topo-Iberia + Wilas + Pyrope + Permanent networks in W-Europe

Topo-Iberia + Picasso (USA + Germany) in N Morocco




TOPO-EUROPE Countries
0
400
800 km