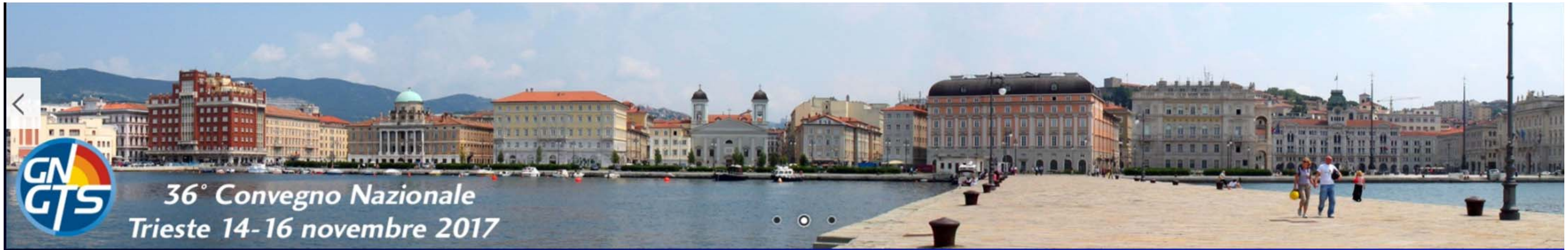

Insights on the seismotectonics of the Mercure Basin area (southern Italy) by integrated geological and geophysical data: coexistence of shallow extensional and deep strike-slip kinematics

Luigi Ferranti (1,*), Girolamo Milano (2), Marina Pierro (1)

(1) Dipartimento di Scienze della Terra, dell'Ambiente, e delle Risorse (DSTAR), Università Federico II, Napoli.
(*) CRUST, Centro inteRUniversitario per l'analisi Sismotettonica Tridimensionale con applicazioni territoriali.
(2) Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Vesuviano, Napoli.

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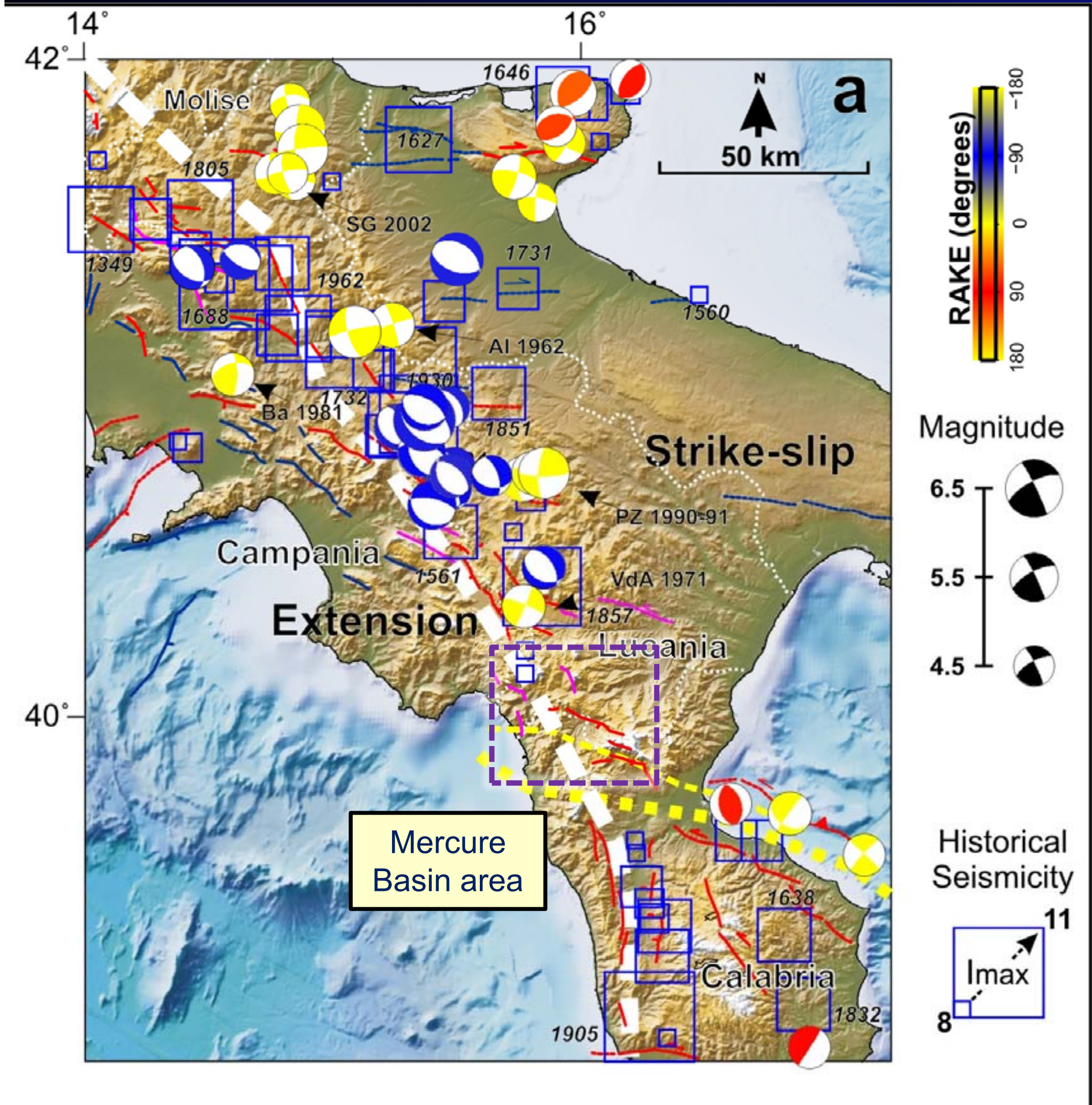
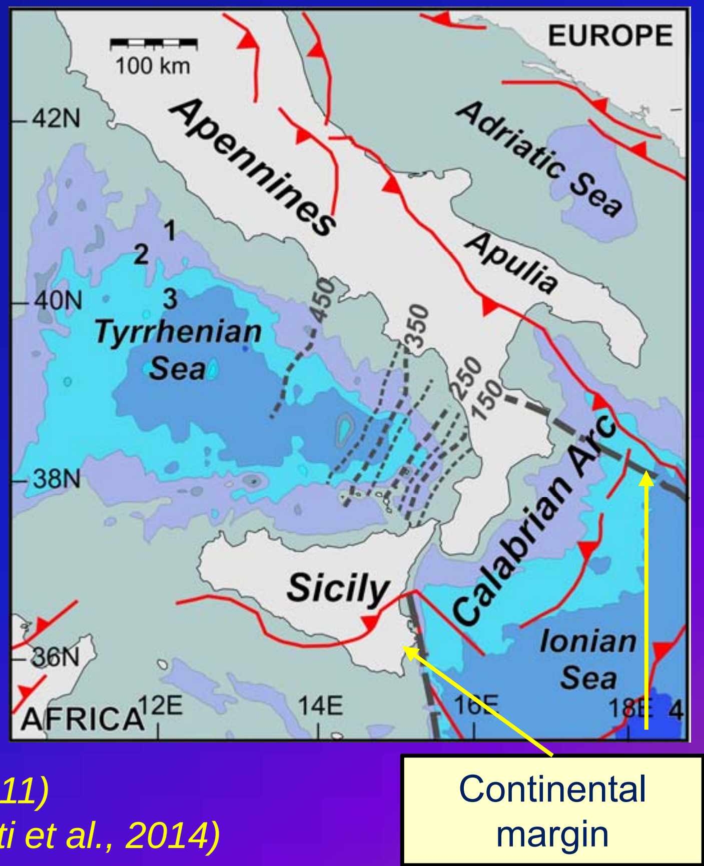
Insights on the seismotectonics of the western part of northern Calabria (southern Italy) by integrated geological and geophysical data: Coexistence of shallow extensional and deep strike-slip kinematics

L. Ferranti[a,*], G. Milano[b], M. Pierro[a]

Two seismotectonic regimes in southern Italy

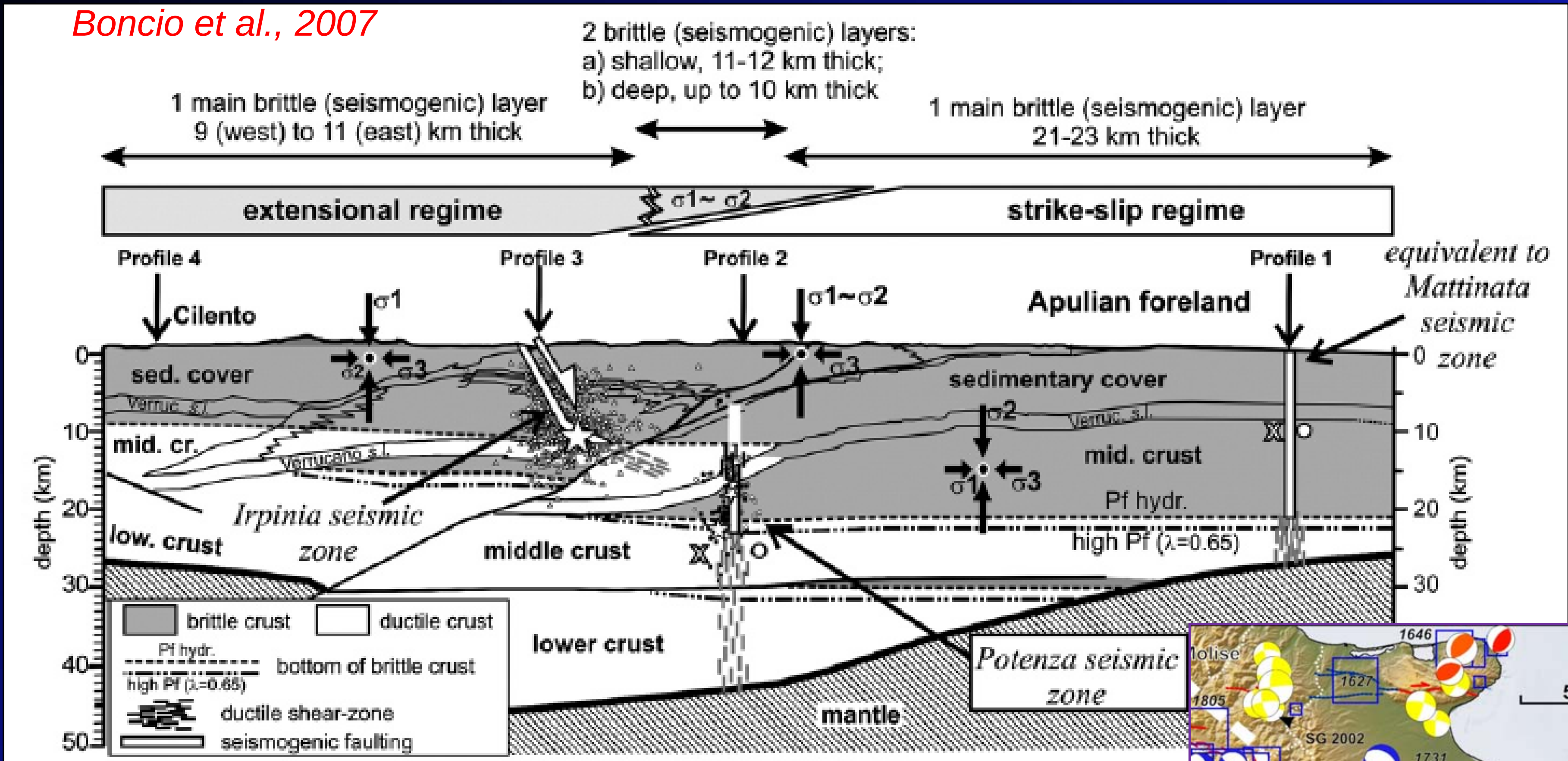


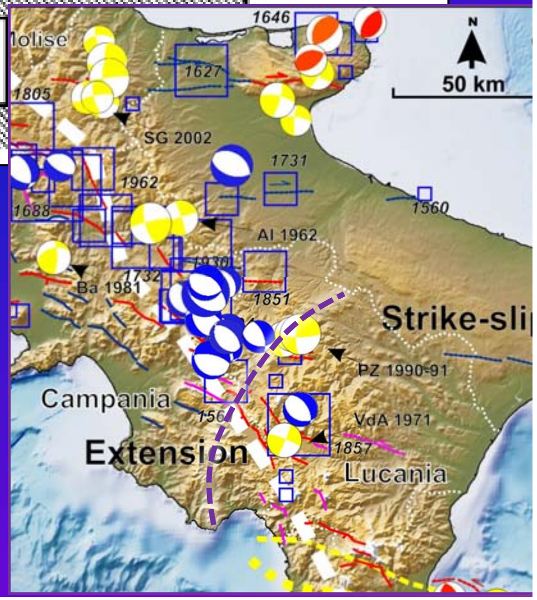
- ✓ Extension in axial belt and strike-slip in foreland belt;
- ✓ Boundary ill defined;
- ✓ Extension above Tyrrhenian Moho overthrust;
- ✓ Crustal-lithospheric boundaries (continental margins→slab tears→STEPs) in lower plate decouple Calabrian Arc and Southern Apennines (study area)



White dashed line: Tyrrhenian Moho overthrust (Di Stefano et al., 2011)
Yellow dot & dashed lines: continantal margin in upper plate (Ferranti et al., 2014)

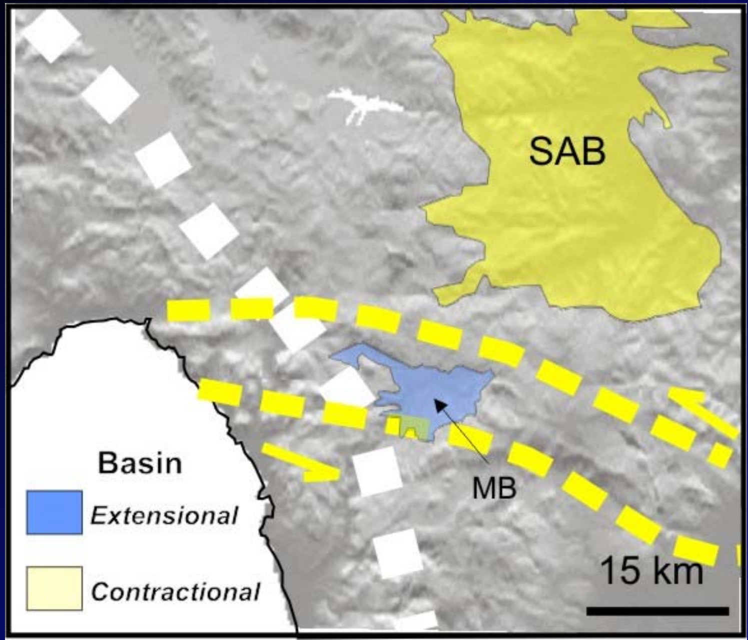
Current seismotectonic model



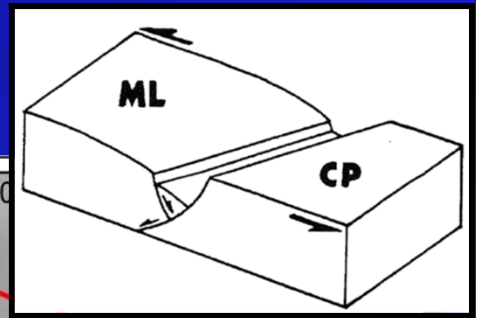


- ✓ Shallower (4-12) extensional earthquakes in overthrust Apulia foreland and Apennines FTB;
- ✓ Deeper (15-30) strike-slip earthquakes in underthrust Apulia foreland;
- ✓ Two distinct seismogenic layers only predicted in narrow transition zone

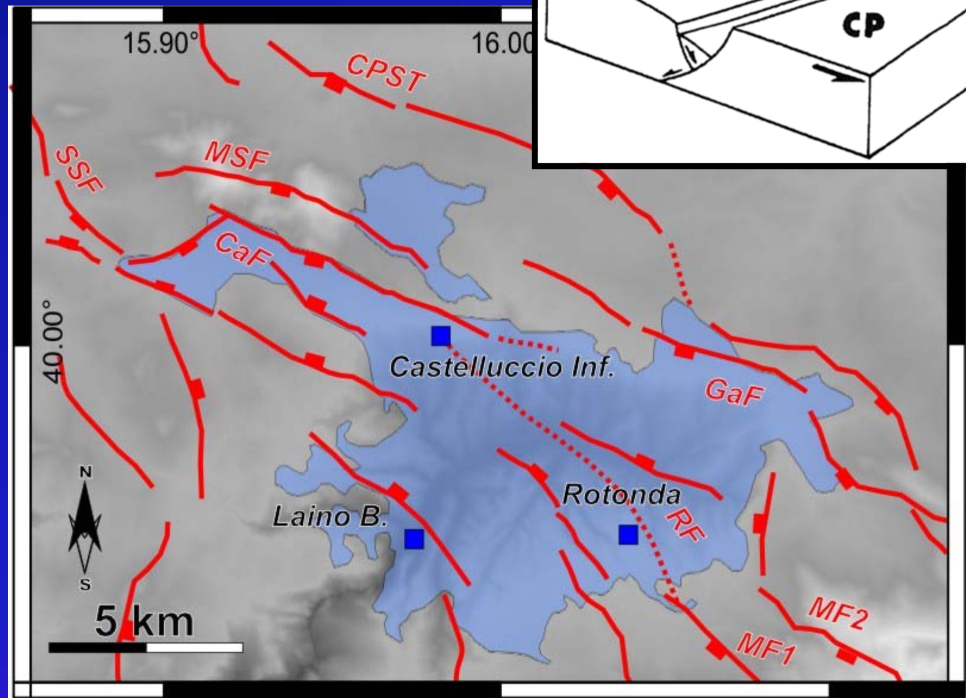
The Mercure Basin "greater" area



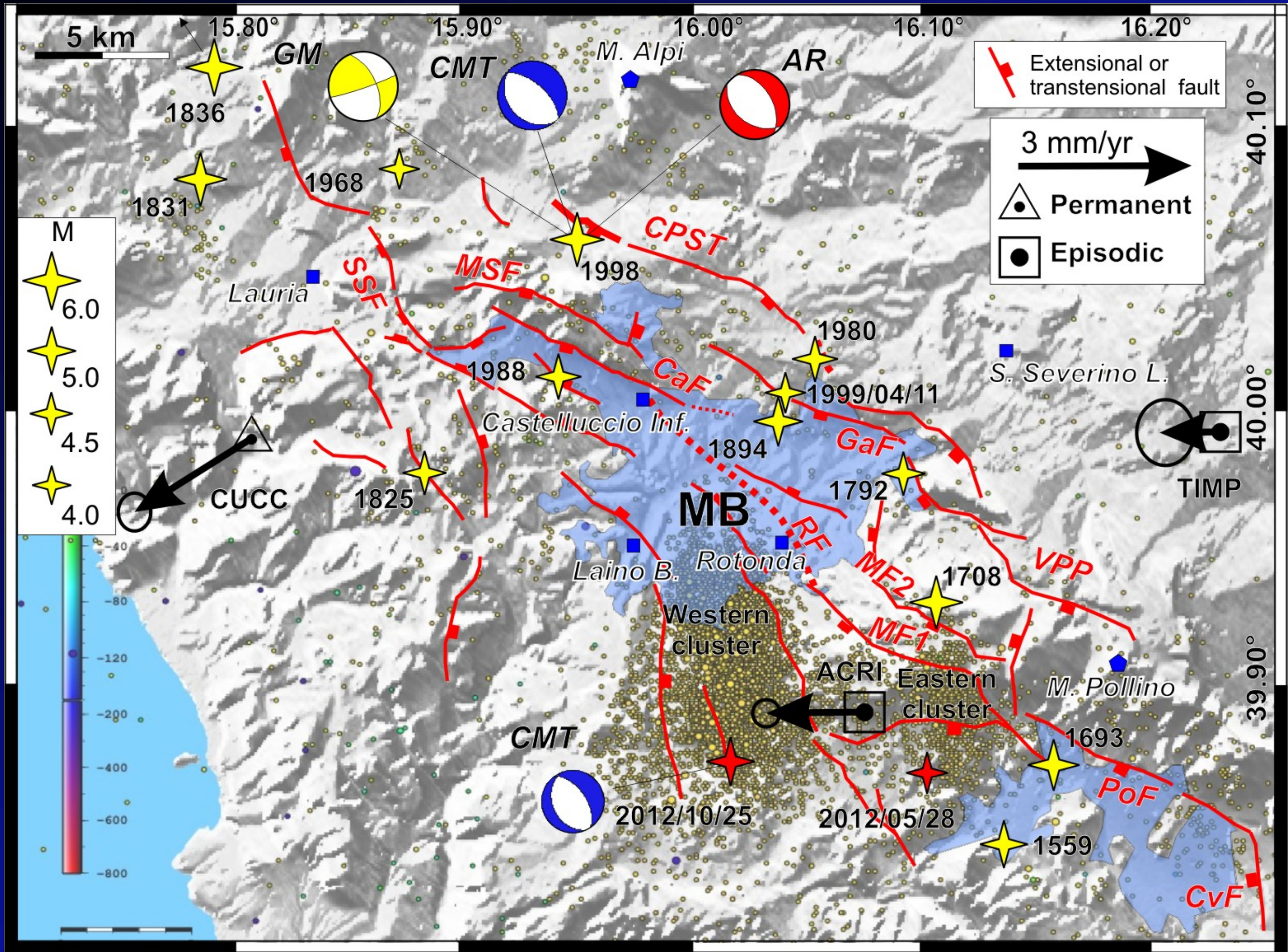
- ✓ Clear spatial separation between Quaternary extensional faults in the Mercure Basin (SW) and Late Pliocene-Early Pleistocene reverse-transpressional faults in the S. Arcangelo Basin (NE)
- ✓ Separation occurs across WNW-ESE trending left transtensional shear zone (Confine C-L, Pollino Line etc);
- ✓ Mercure Basin included within shear zone



- ✓ Upper crustal deformation of Mercure Basin dominated by WNW-ESE striking, SSW-dipping faults;
- ✓ Documented Early Pleistocene left transtension followed by Middle Pleistocene-current? extension (Schiattarella et al., 1994)



Seismotectonics of the Mercure Basin



✓ 1998 solutions:
AR=Arrigio et al, 2006
GM=Gervasi & Moretti,99
CMT=Harvard

✓ GPS velocities (S Apulia ref frame): Ferranti et al., 2014

✓ Instrumental seismicity: ISIDE (2009-2013)

✓ Faults: Brozzetti et al., 2009; 2017; Totaro et al., 2015; this work.

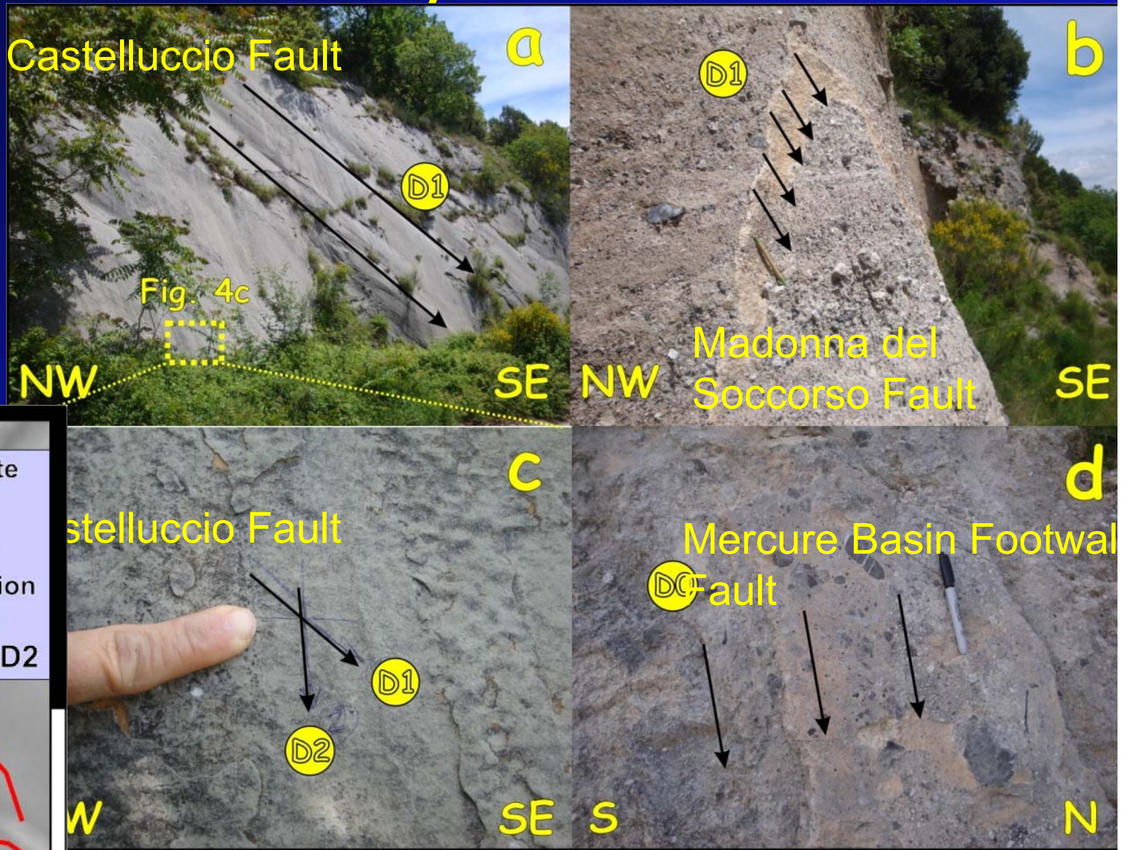
- ✓ Few moderate extensional earthquakes; Residual GPS velocities consistent with ~1.5±0.3 mm/yr NE-SW (N) to E-W (S) extension.
- ✓ **→ Seismotectonics is thought to be only characterized by extension**
- ✓ 2010-2014 Pollino seismic sequence

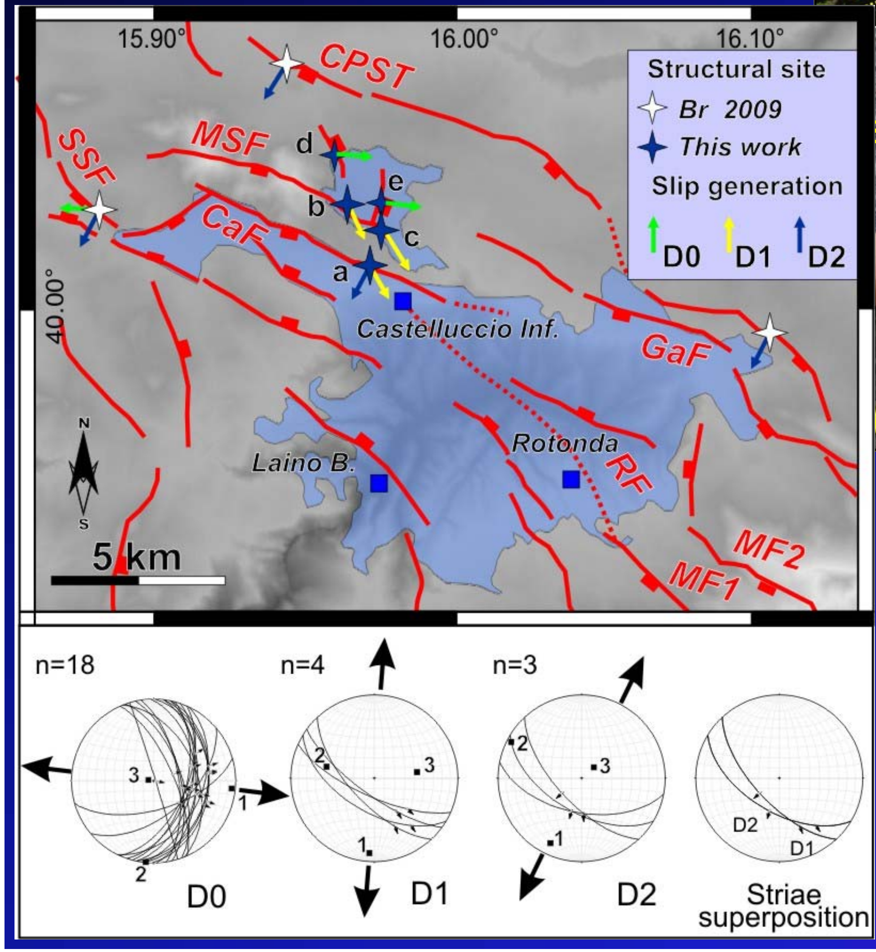
Methods & Objectives

- ✓ Integrate recent (2013-2017) low-magnitude background seismicity with field geological observations & geophysical subsurface information;
- ✓ Characterize the seismotectonics of the ‘’greater’’ Mercure region at demise or end of Pollino seismic sequence;
- ✓ Check if only extension is at work;
- ✓ Build a crustal model including different seismogenic layers;
- ✓ Investigate role of inherited deep discontinuity.

Fault-kinematic analysis

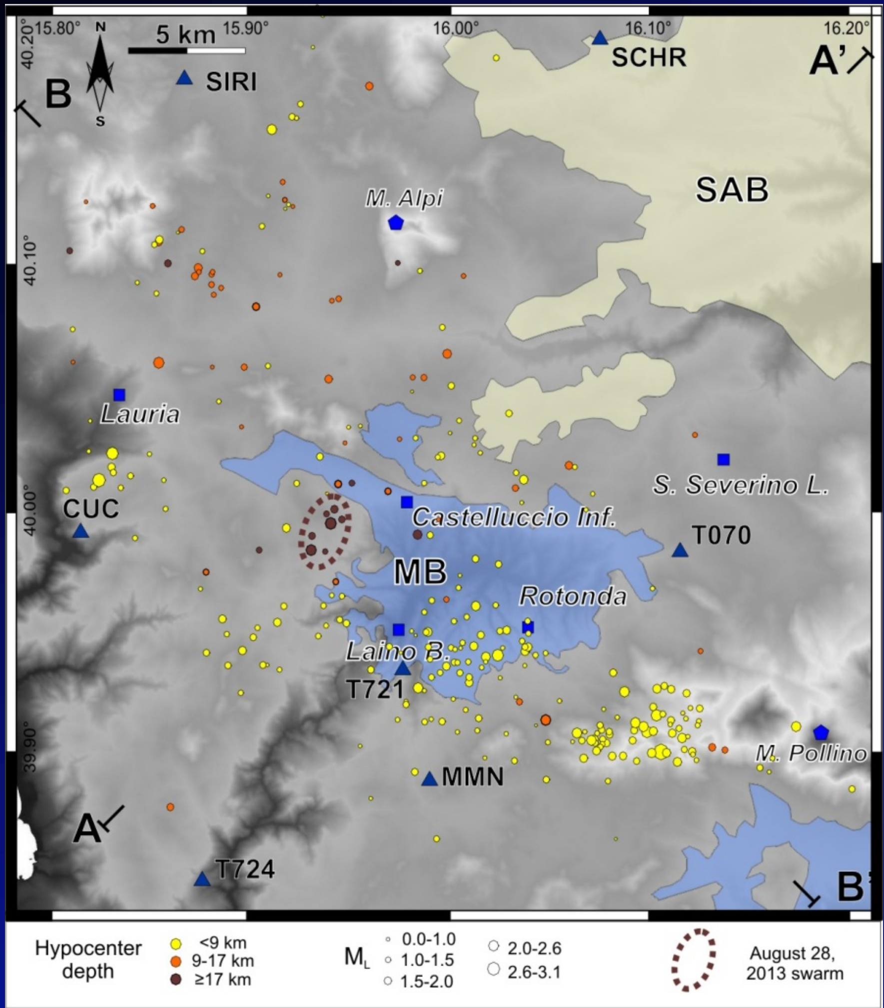
- ✓ Two superposed sets of slip lineations on major WNW-striking, SSW-dipping basin-bounding faults (CaF, MSF, etc);



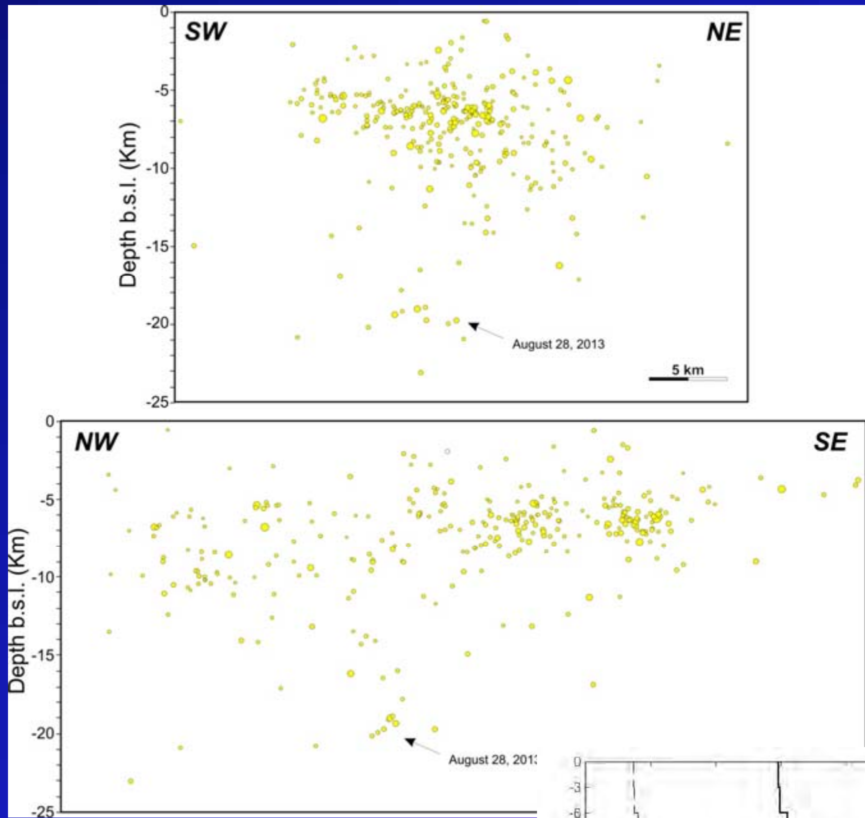


- ✓ D1 (left-transtensional) represents main slip; cuts Lower Pleistocene cgm;
- ✓ D2 (extensional) minor reactiv ation of master faults;
- ✓ D0 is an older slip lineation set only on faults in footwall of basin-bounding faults (Late Pliocene-Early Pleistocene).
- ✓ Mercure Basin forms during D1 transtension (main basin-forming event) with ~N-S tensile axis, Early Pleistocene;
- ✓ Basin widens during D2 extension (NE-SW tensile axis), Mid Pleistocene-present

Seismicity distribution



- ✓ Analysis of June 2013-March 2017 seismicity;
- ✓ Permanent + temporary UniCal & INGV stations;
- ✓ ~330 best-located events, with 1.0 ≤ ML≤ 3.0.



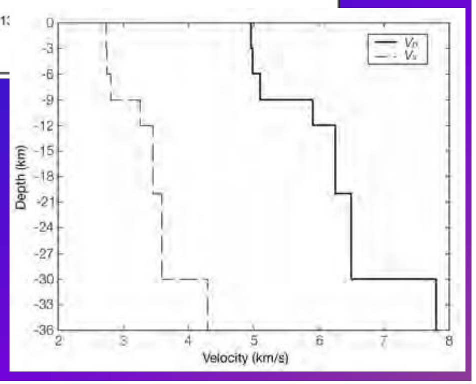
Three hypocentral distribution groups:

a) Shallow (<9 km) (~80%) → SE, S, W of basin;

b) Intermediate (9-17 km) →N of basin, WNW-ESE alignment;

c) Deep (17-23 km) → W of basin

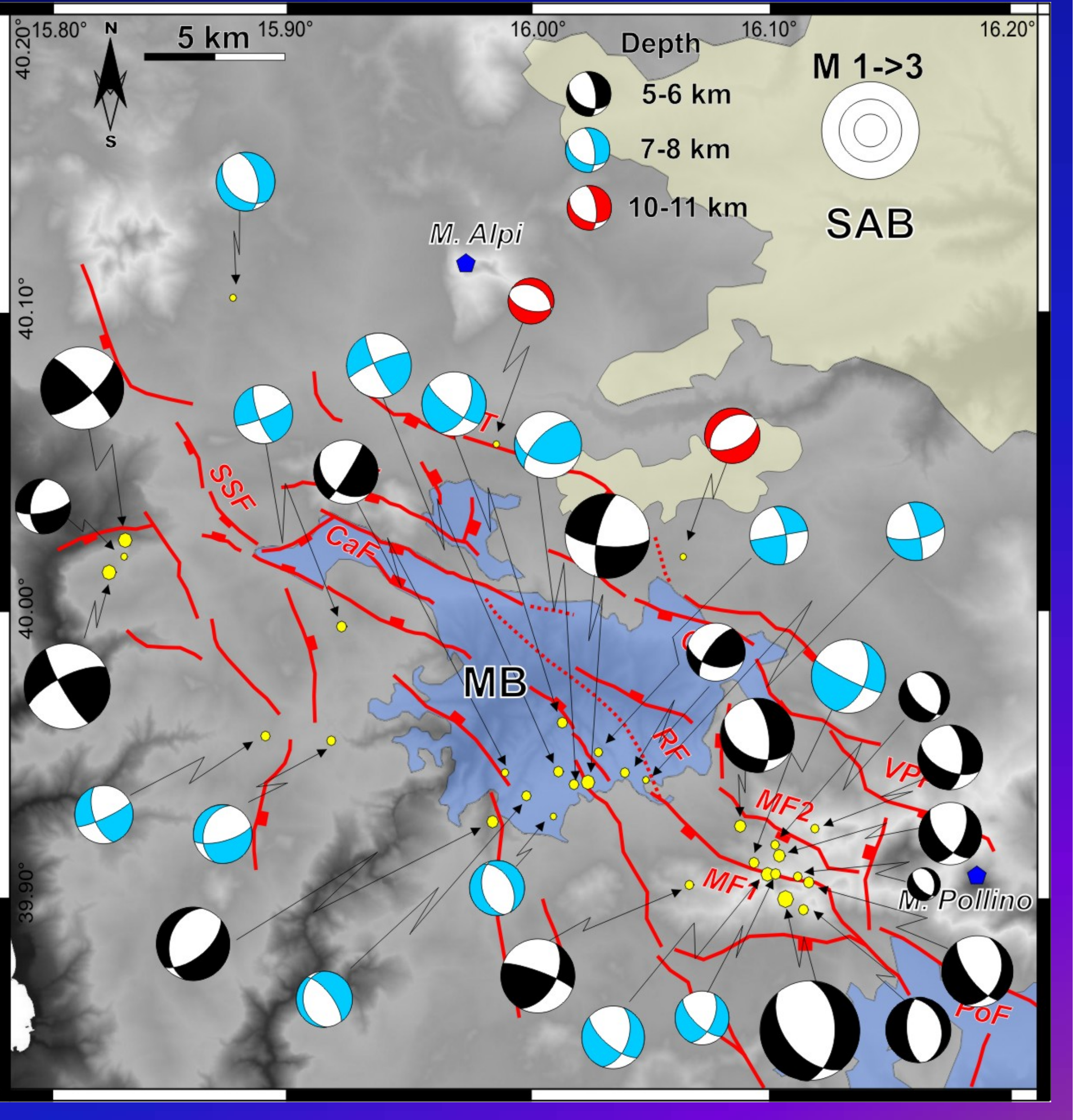
Almost all single events, except for a short (28 Aug 2013) swarm in Deep Group



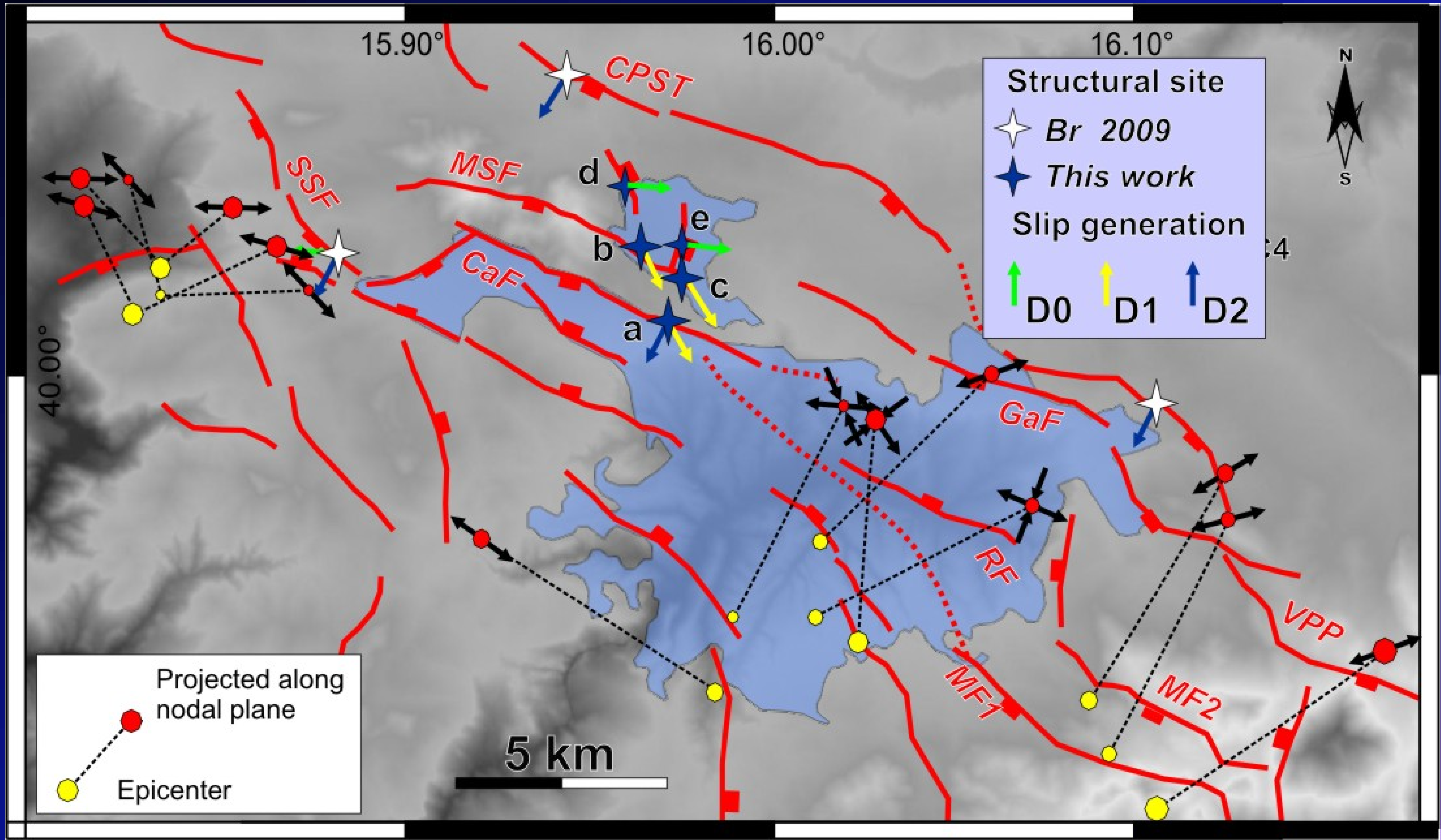
Velocity model: Guerra et al., 2005

Kinematic characterization of the shallow seismic events

- ✓ Extensional FMs with ENE-WSW T axes SE of the basin → ''tail'' of the Pollino seismic sequence (eastern cluster);
- ✓ Trastensional or transcurrent FMs in central part of basin (not consistent with W cluster of seismic sequence);
- ✓ Transtensional or transcurrent FMs in western part of basin (N-S alignment → tear fault)



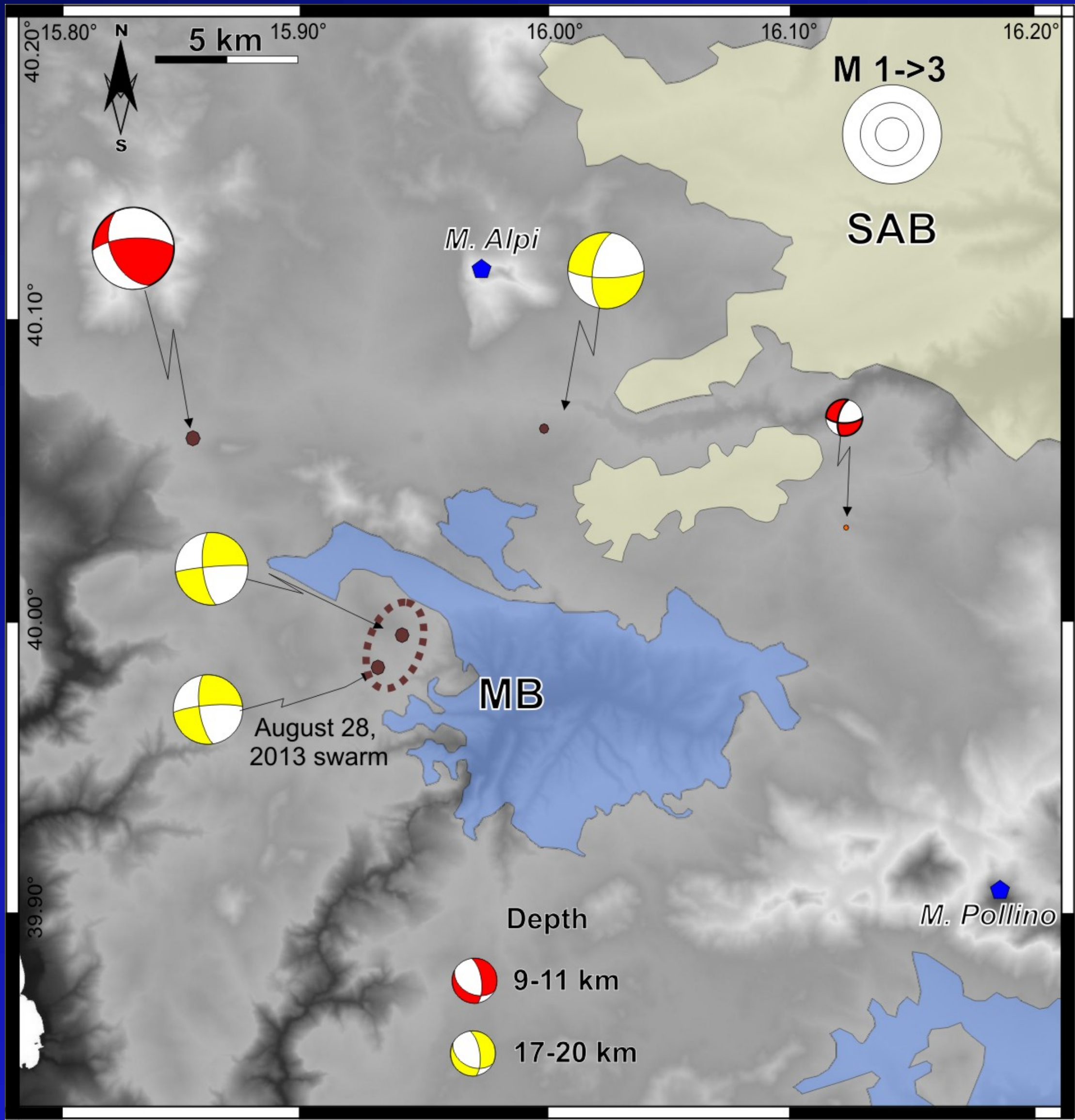
Correlation between geological and seismological data – shallow events



- ✓ Upward linear projection of the preferred nodal plane of the most energetic events;
- ✓ Events to the SE along or close to CPST, GaF, and VPP faults; geological and seismological T axes consistent;
- ✓ Events in central part of basin close to SE buried prrosecution of CaF, but T axis is fault parallel (consistent with D0 and D1, not with D2);
- ✓ Similarly T-axis rotated to parallel to SSF fault (1998 source according to Michetti et al. 2000) in the cluster W of basin
- ✓ Possible activity of N- to NE- striking minor tear faults (center & west of basin)

Kinematic characterization of the intermediate and deep seismic events

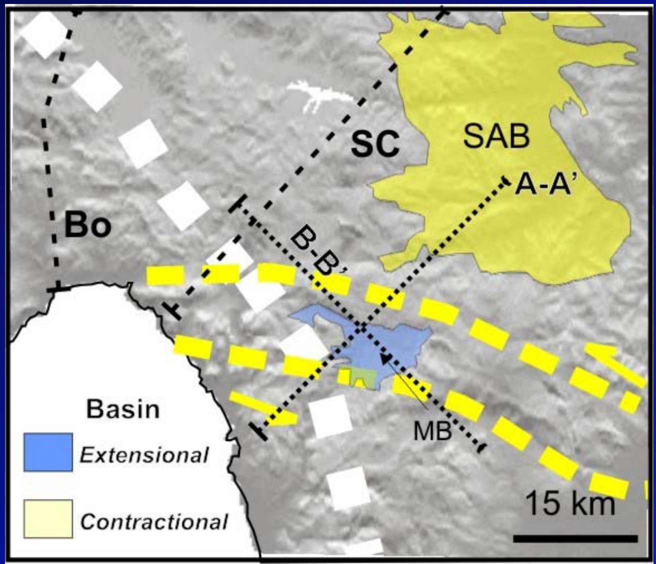
- ✓ Both groups are prevailing strike-slip with N-S and E-W nodal planes;
- ✓ Intermediate (9-17 km) events N of basin with strike-slip to transpressional FMs, and **NE-SW** trending P axes;
- ✓ Deep (17-23 km) events W of basin with strike-slip FMs, and **NW-SE** trending P axes;
- ✓ Deep FMs part of 28 Aug 2013 swarm, elongated NNW-SSE.

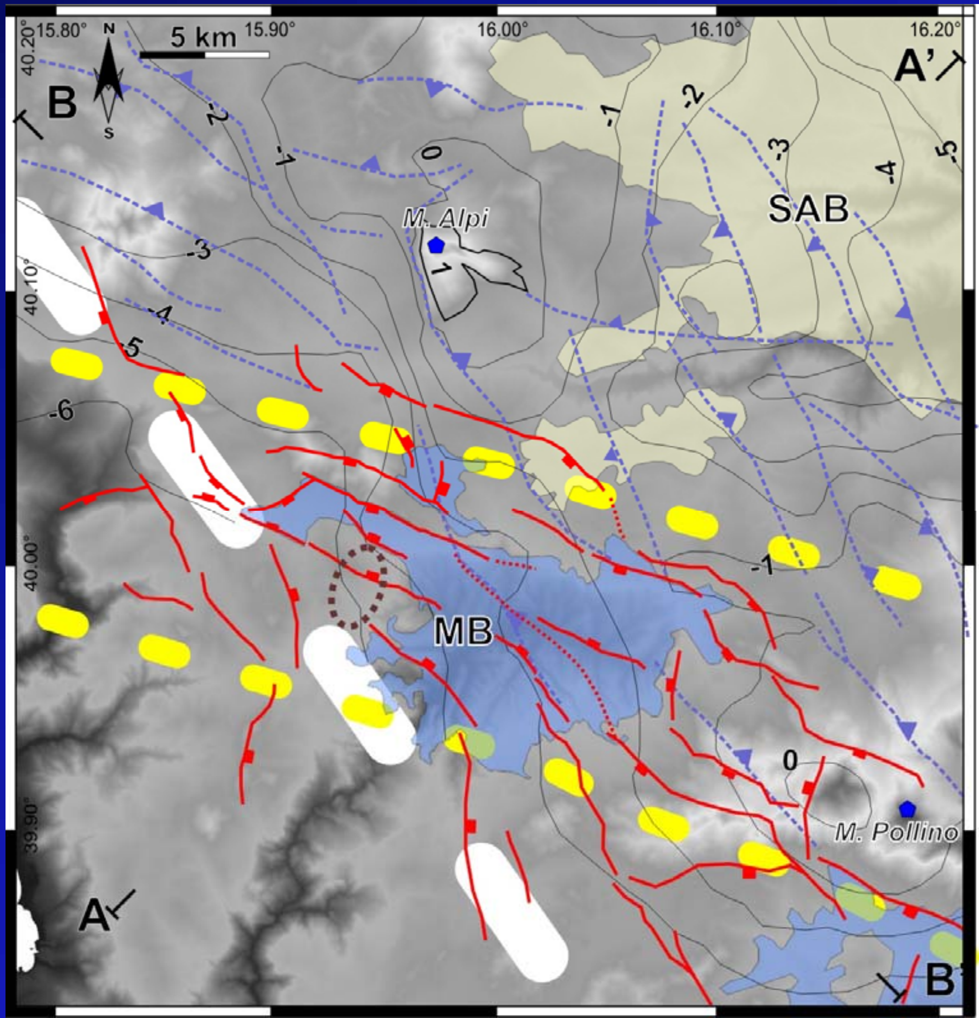


Crustal model build-up

Ingredients (top to bottom)

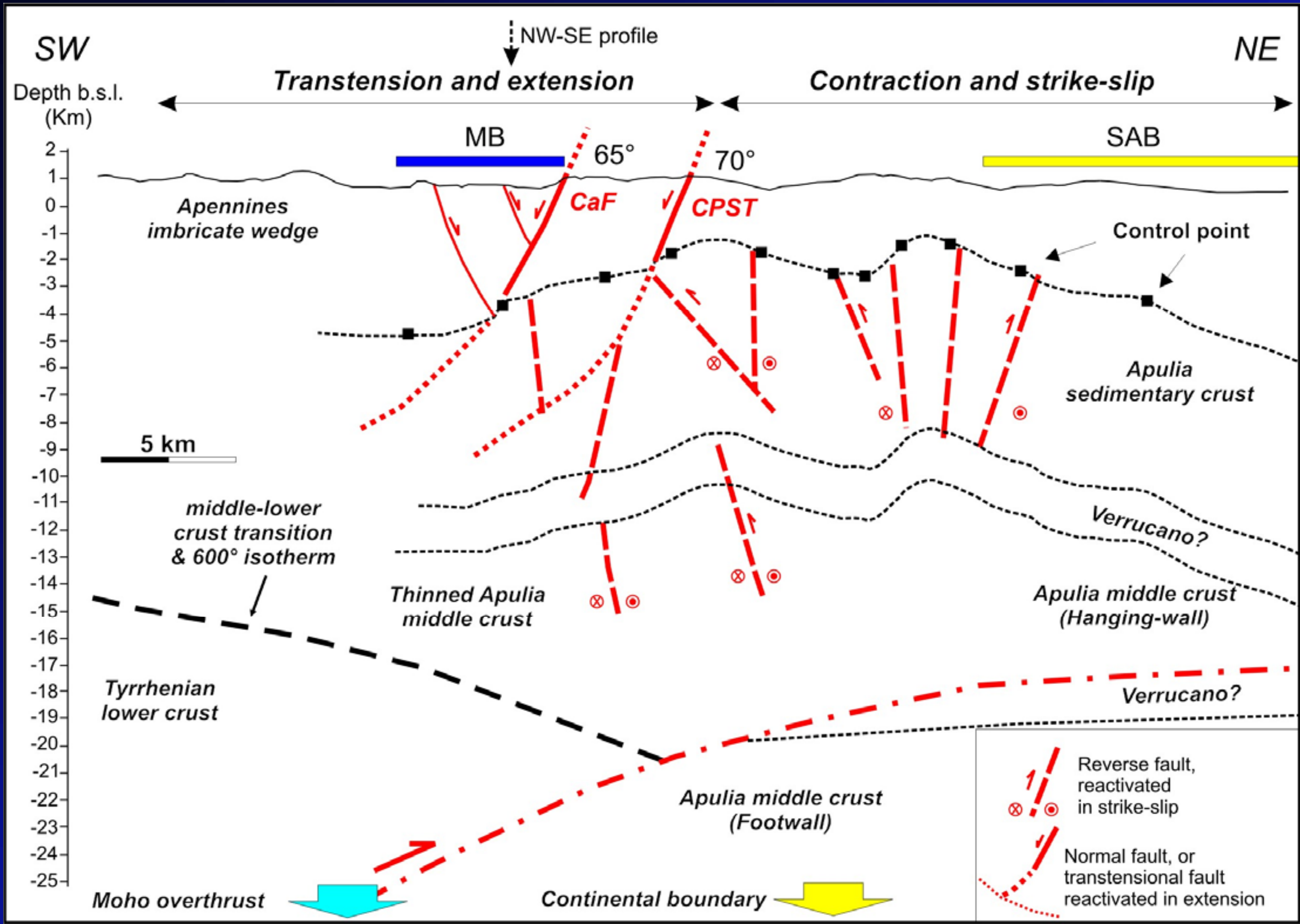
- ✓ Field observations (extensional faults);
- ✓ Oil-exploration data (isobaths of the Apulia platform top and buried reverse faults, Nicolai & Gambini, 2007);
- ✓ Regional stratigraphical-structural data calibrated against DSS data;
- ✓ Rheological model section (Bo=Boncio et al., 2007);
- ✓ Magnetic data (SC=Speranza & Chiappini, 2002)





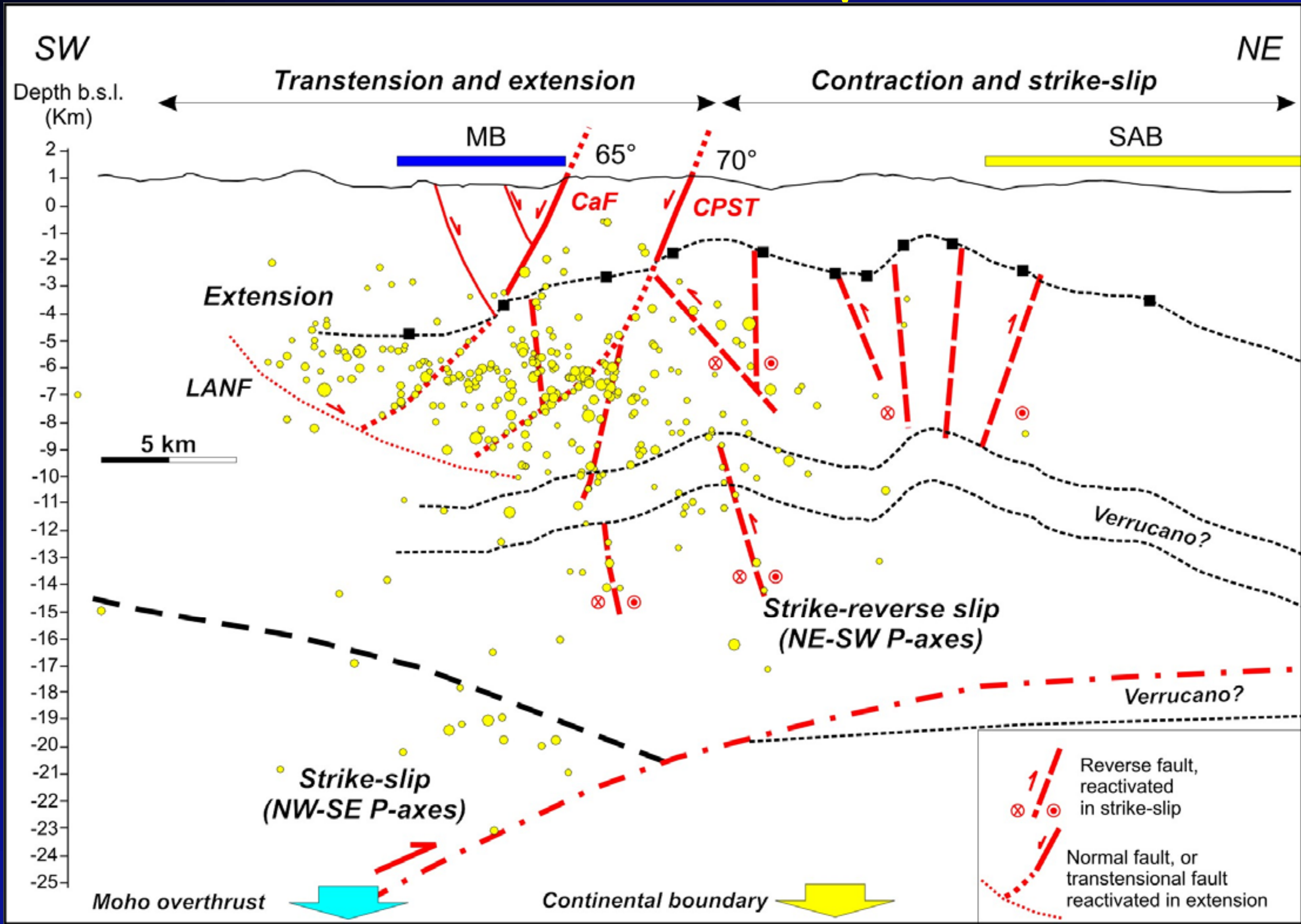
- ✓ Uplifted Apulian Ridge between M. Alpi and M. Pollino, fronted by the SAB contractional basin
- ✓ Mercure basin in saddle between the two Apulian culminations;
- ✓ Apulian highs bounded by and WNW- and NNW-striking high-angle reverse faults
- ✓ Deep WNW-trending N-Calabria shear zone coincides with shallower limit between extension (SW) and transpression (NE);
- ✓ Tyrrhenian Moho overthrust tip W of basin (detail location uncertain)

Crustal model profile



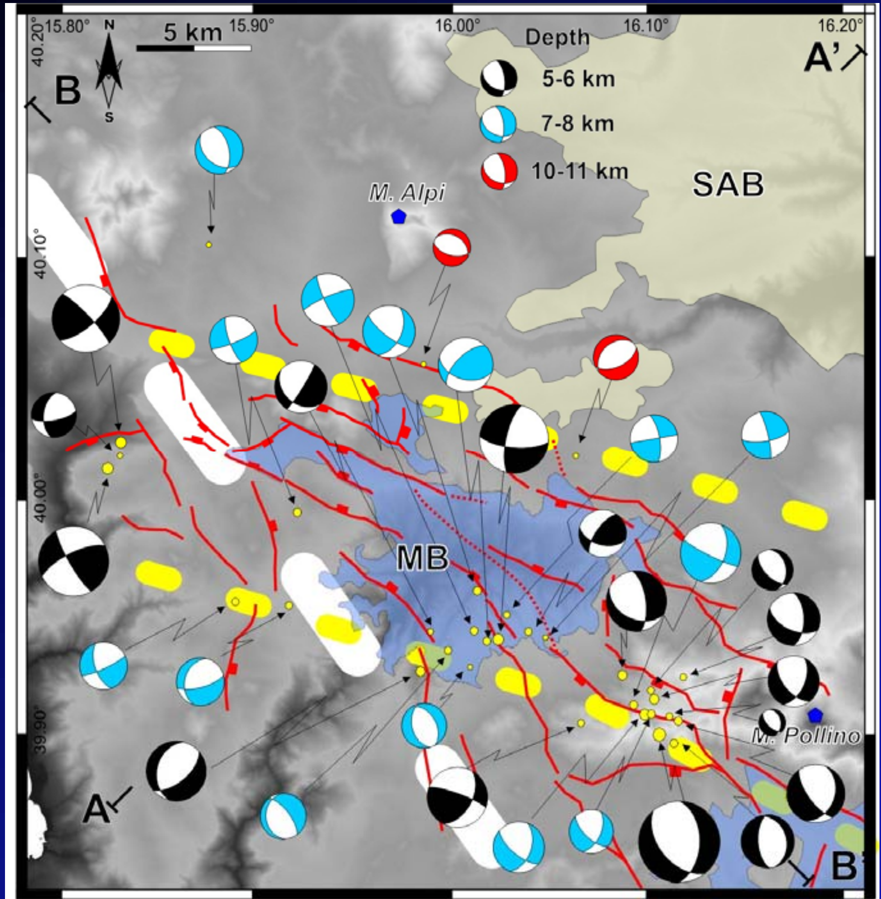
- ✓ 3-6 km thick allochthonous wedge overlyimg a 6 (Mz-Cz carbonate& anydhrite) + 2 (Verrucano) thick Apulia;
- ✓ Apulia sedimentary and crystalline crust forms broad wλ folds and is cut by high-angle reverse-transpressional faults; it is uplifted in the hanging-wall of regional overthrust emanating from deep Tyrrhenian Moho wedge;
- ✓ Underthrust Apulian foreland in footwall; detachment at ductile Verrucano;
- ✓ Extensional (MB) and conntractional (SAB) basins on either flanks of Apulian fold belt;
- ✓ Extensional faults detach at Verrucano or above and directly above Tyrrhenian wedge (thinned middle crust)

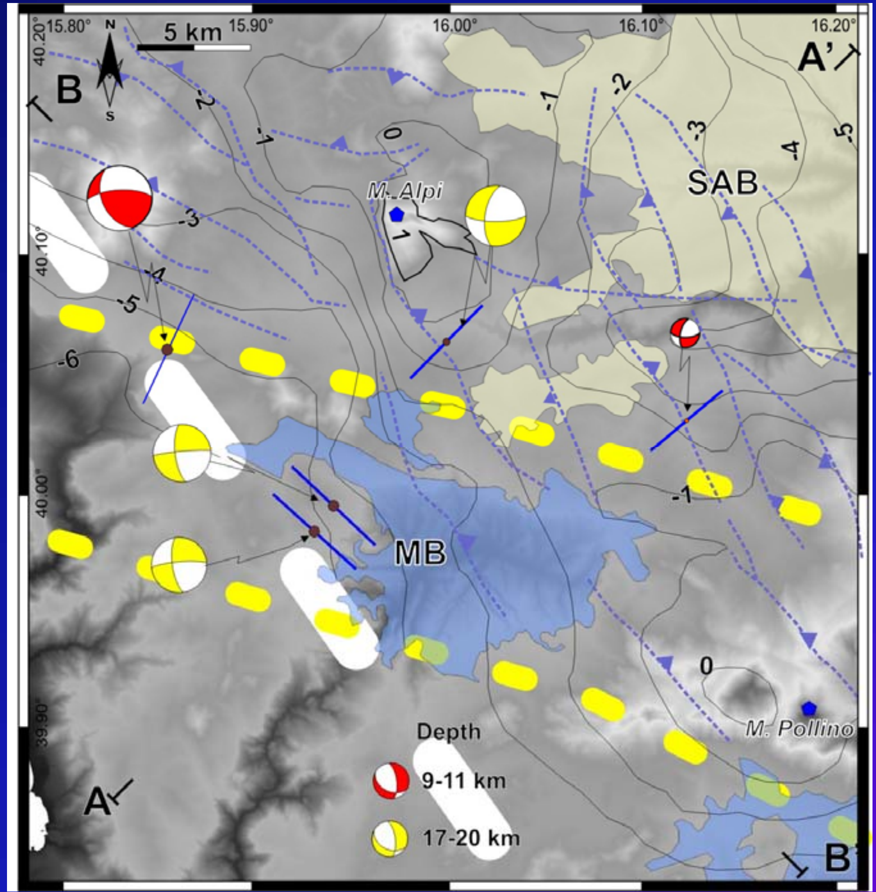
Seismotectonic interpretation



- ✓ Shallow (5-9 km) events in the extensional domain, focal volume in stiff Apulia carbonates, limited downward by ductile Verrucano, and to the west by E-dipping LANFs (Brozzetti et al 2017) or by diffuse geothermal rise related to Tyrrhenian wedge;
- ✓ Intermediate (9-17 km) strike-slip events with NE-SW P-axes in the uplifted Apulia middle crust and above continental lithospheric boundary-subduction tear in lower plate; strike-slip reactivation of reverse faults;
- ✓ Deep (17-23 km) strike-slip events with NW-SE P axes at the tip of the Tyrrhenian lower crust wedge.

Hints to different geodynamic processes

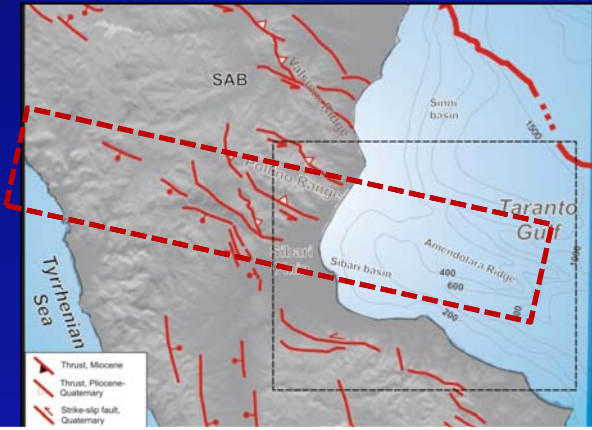


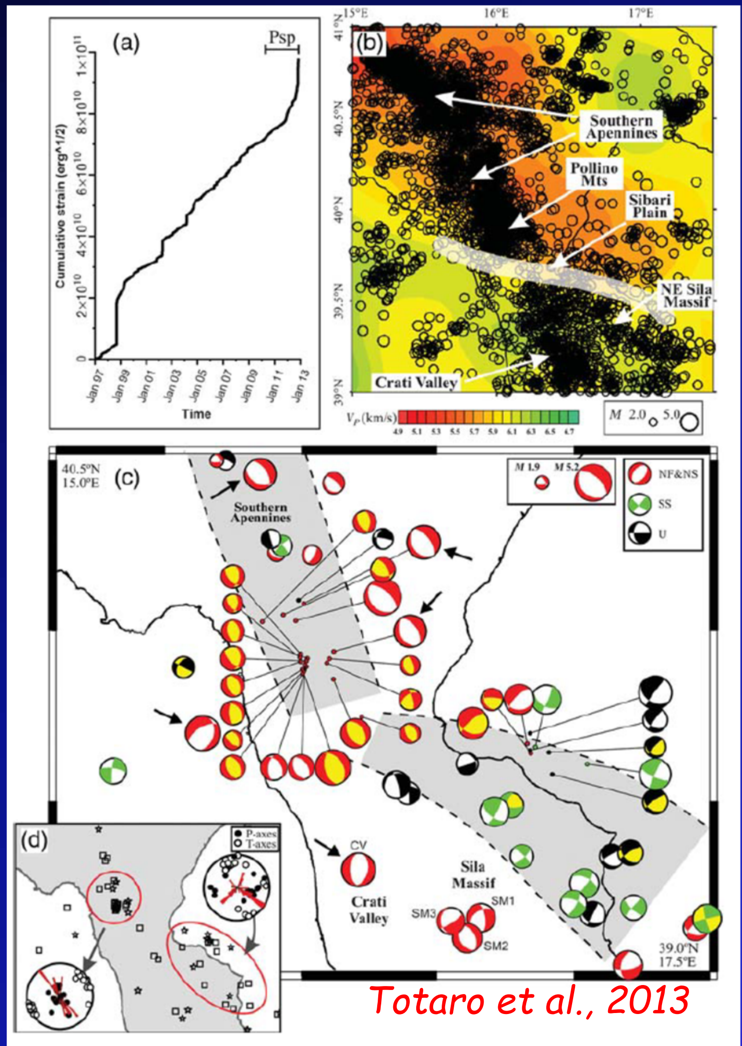


- ✓ Extensional and transtensional seismicity may represent collapse above Tyrrhenian lower crust and mantle wedge, superposed on trastension related to the regional WNW-ESE trending shear zone;
- ✓ Deep strike-slip events at tip of Tyrrhenian wedge, NW-SE axes CONSISTENT with regional displacement field driven by Adria-Europe collision
- ✓ Intermediate strike-slip events NOT CONSISTENT with regional displacement field, but aligned ESE-WNW with the trend of Adria-Ionian lithospheric boundary and slab tear

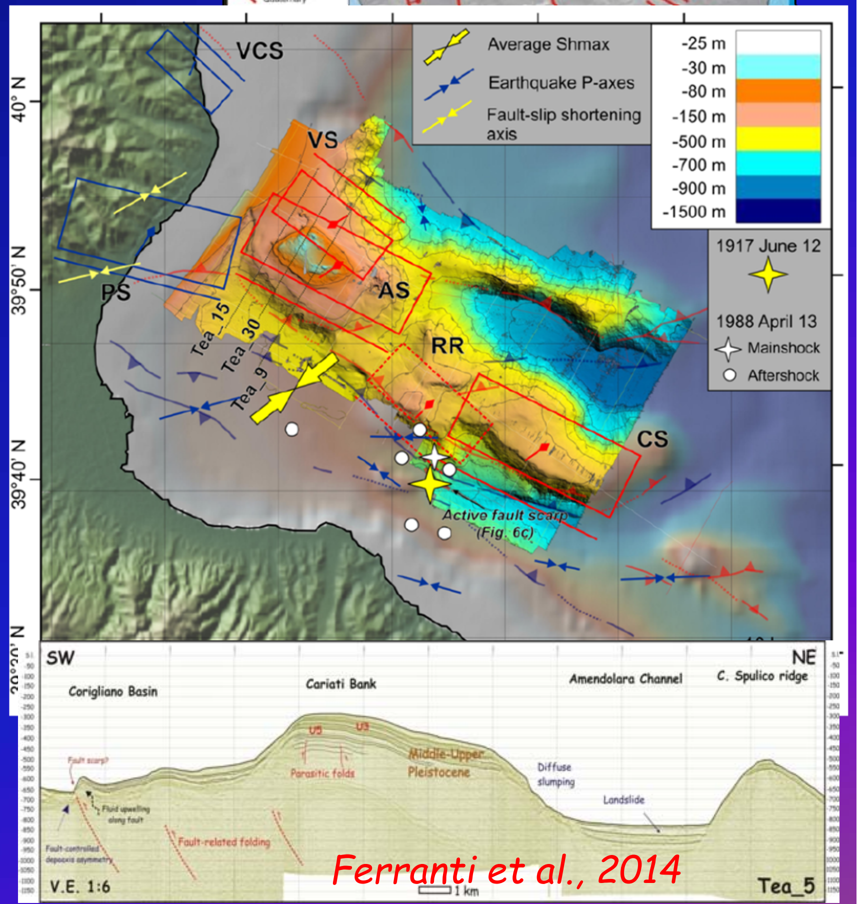
Calabrian Arc-Apennines boundary

- ✓ Seismological and geological data → decoupling between Apennines and Calabrian Arc as the upper plate expression of tearing in the lower plate at the old continental margin
- ✓ The boundary focuses local transpression with NE-SW shortening axes





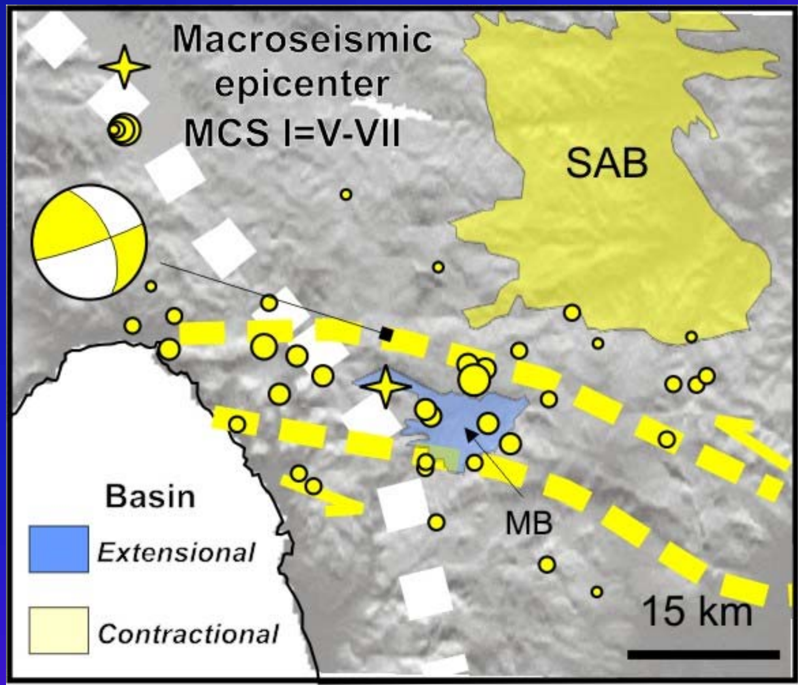
Totaro et al., 2013



Ferranti et al., 2014

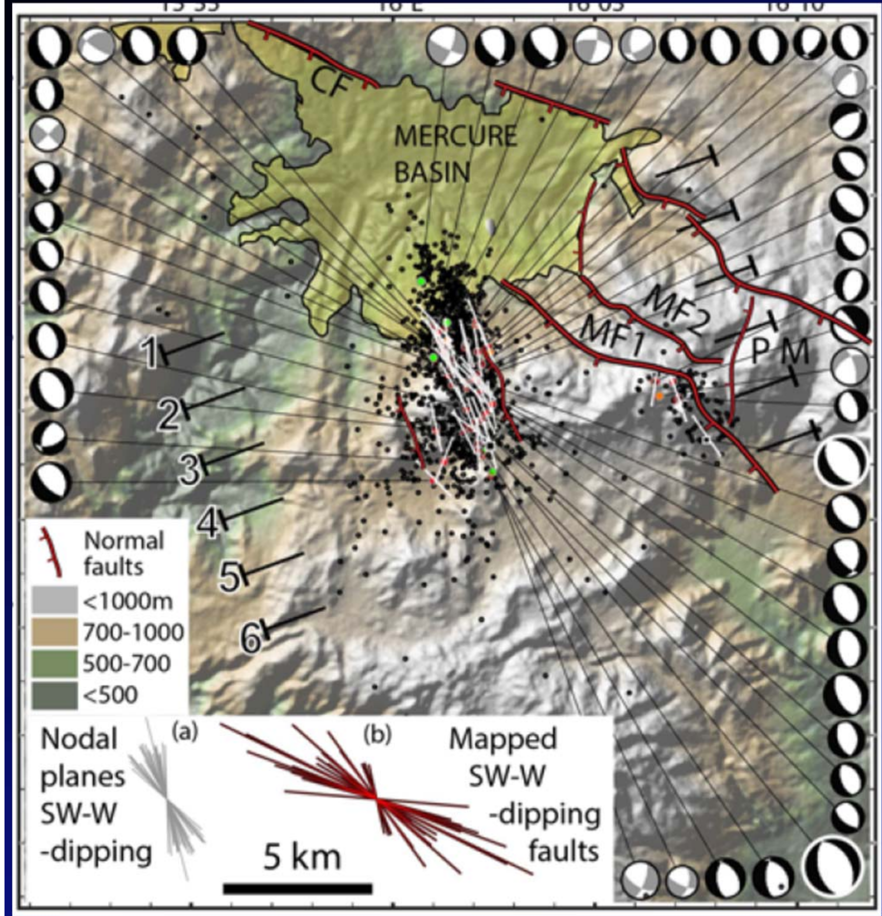
Conclusions

- ✓ Clear spatial segregation of seismotectonic compartments in a limited area
- ✓ Shallow extensional events & normal faulting → local processes above deep Tyrrhenian Sea overthrust, superimposed on regional shear;
- ✓ Intermediate strike-slip events & left strike-slip faulting → intermediate-scale processes related to a deep mechanical anysotropy in lower plate
- ✓ Deep strike-slip events → regional-scale processes driven by plate interaction and mantle wedging0808
- ✓ In this scenario, the 1998 event with a WNW-ESE elongated macroseismic field and possible strike-slip FM could be part of the Intermediate group of events triggered by deep shear zone. (re-analysis needed)

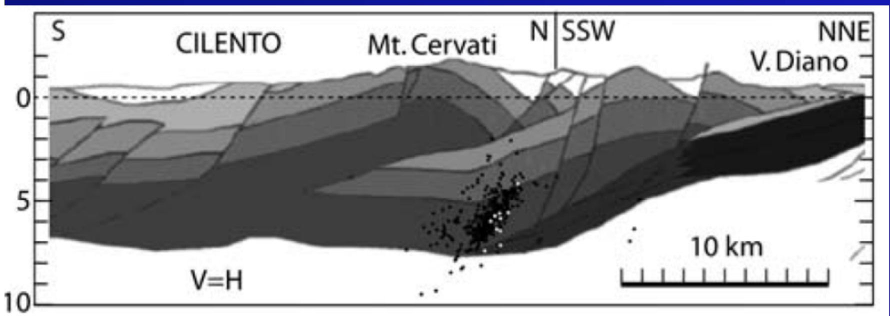


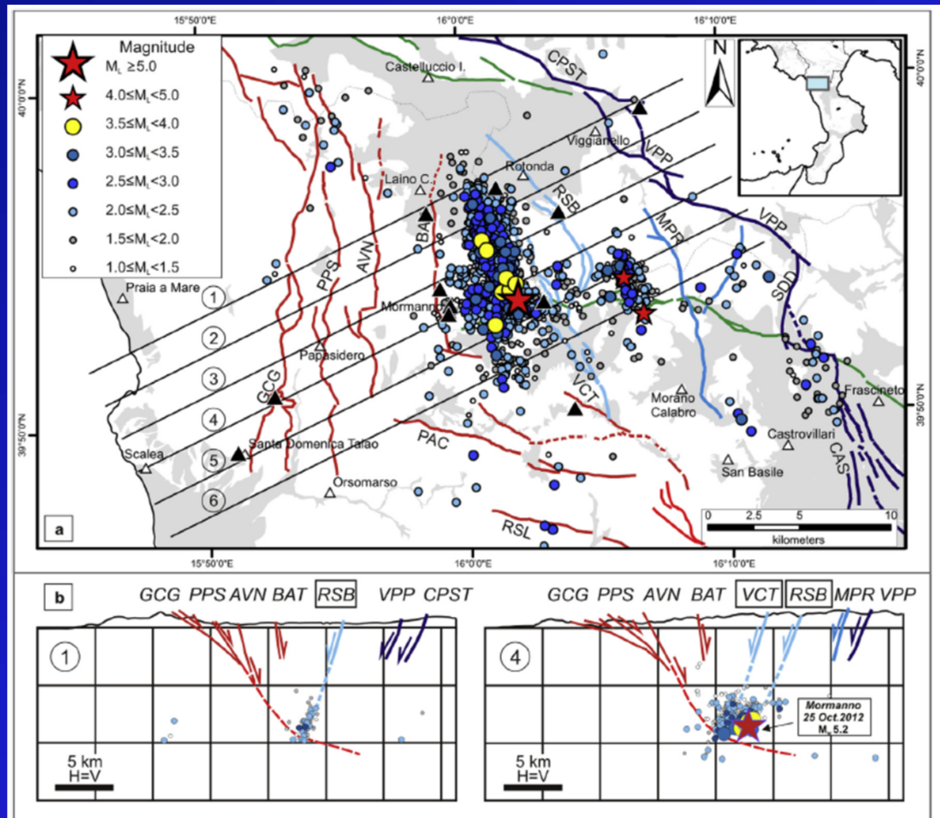
Galli et al., 2001

The 2010-2014 Pollino seismic sequence



- ✓ Extensional quakes; Ml Max=5.0; depth: 5-10 km (placed in Apennines thrust belt);
- ✓ Two E-migrating clusters at SE basin border → WSW-dipping faults;
- ✓ Seismogenic faults rooted in an E-dipping detachment?
- ✓ No activity of the WNW-ESE striking master faults

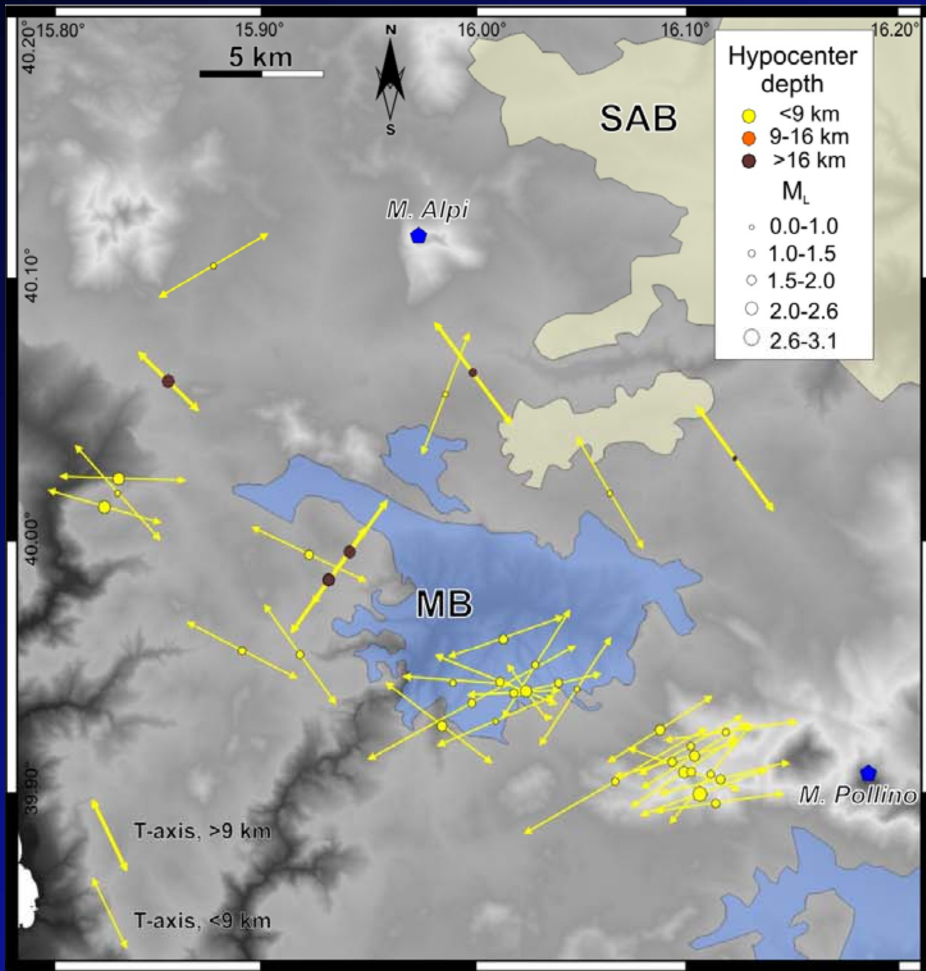




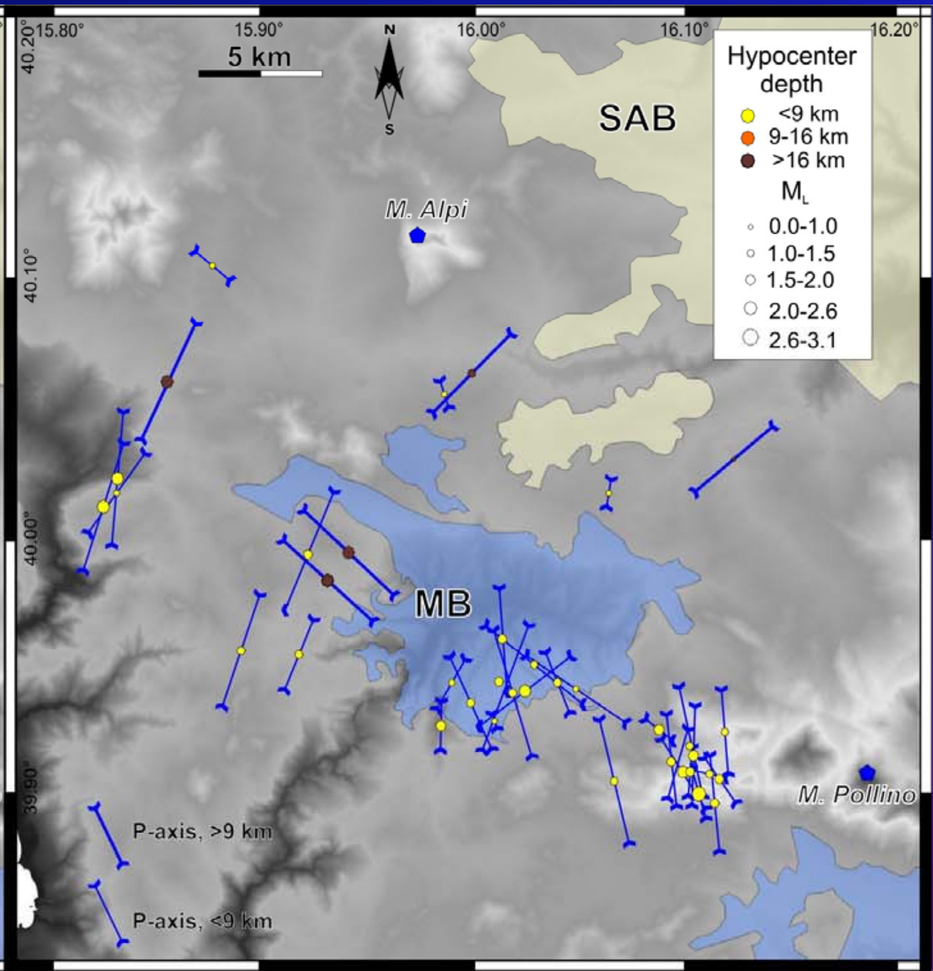
Totaro et al., 2015

Brozzetti et al., 2017

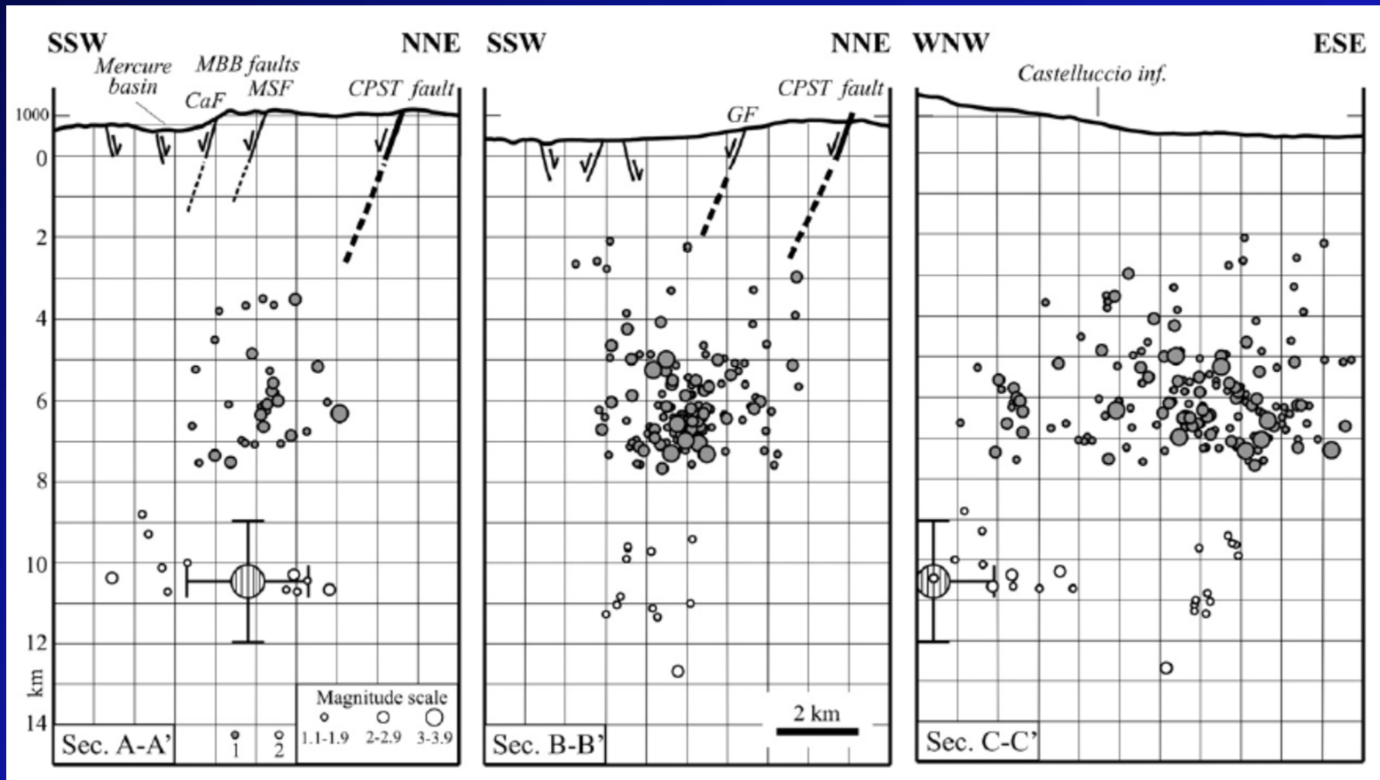
Seismic axes distribution



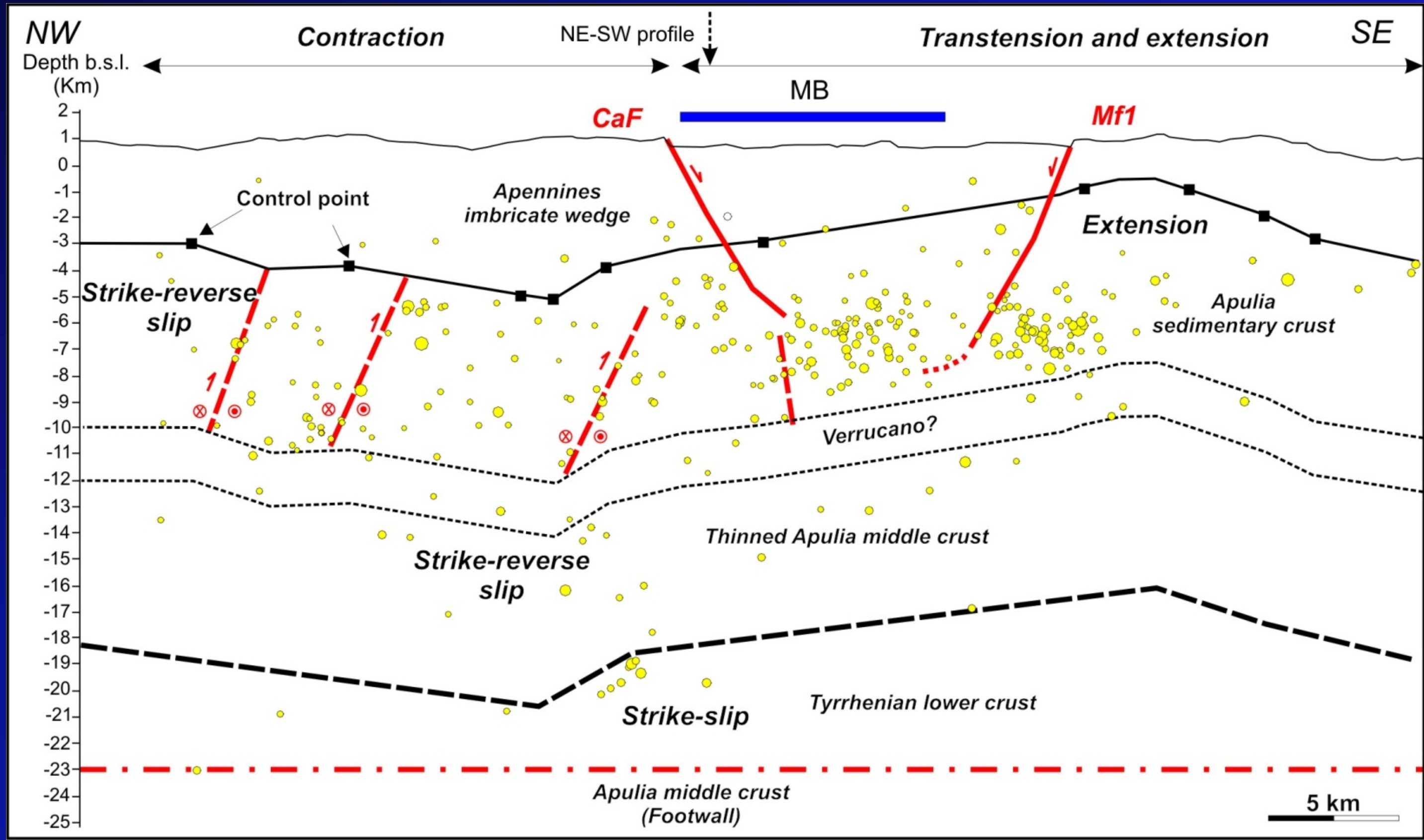
T axes

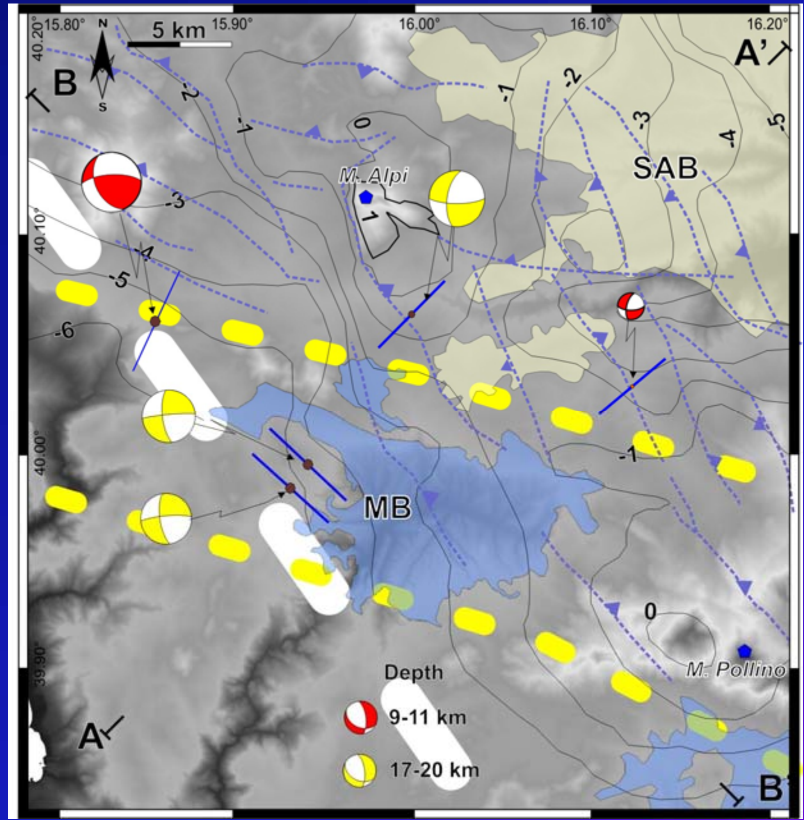


P axes



Brozzetti et al., 2009

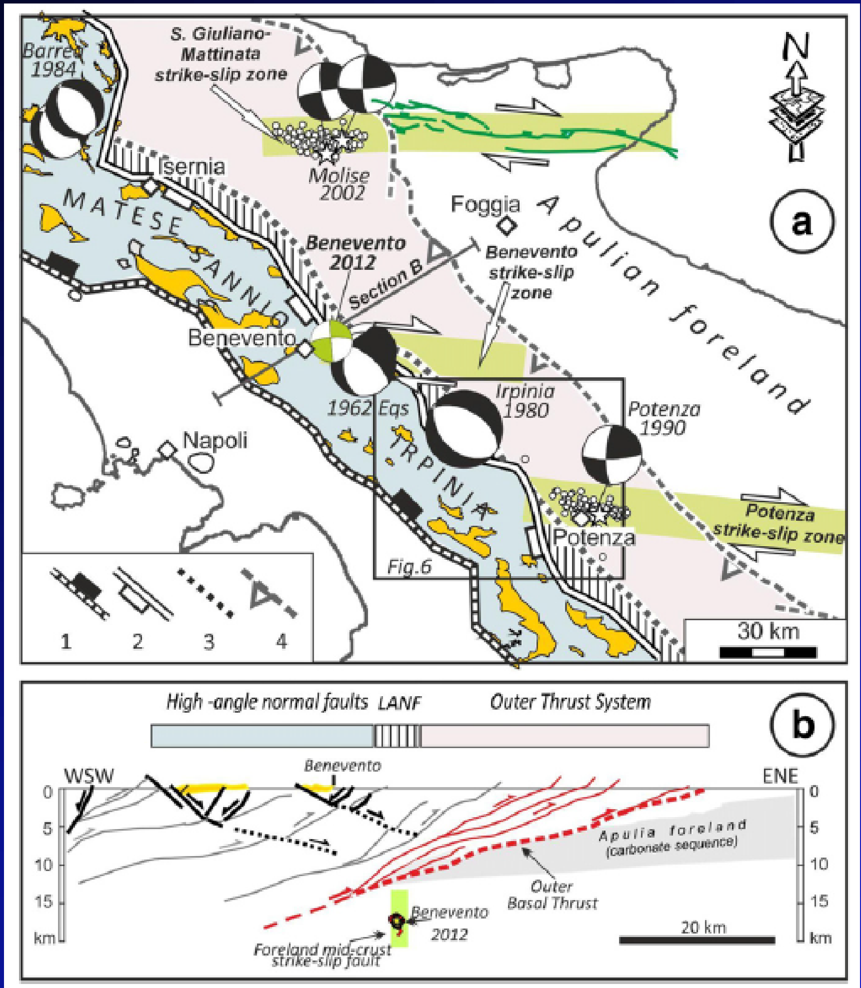

NW
Contraction
NE-SW profile
Transtension and extension
SE
Depth b.s.l. (Km)
MB
CaF
Mf1
Control point
Apennines imbricate wedge
Extension
Strike-reverse slip
Apulia sedimentary crust
Verrucano?
Thinned Apulia middle crust
Strike-reverse slip
Strike-slip
Tyrrhenian lower crust
Apulia middle crust (Footwall)
5 km



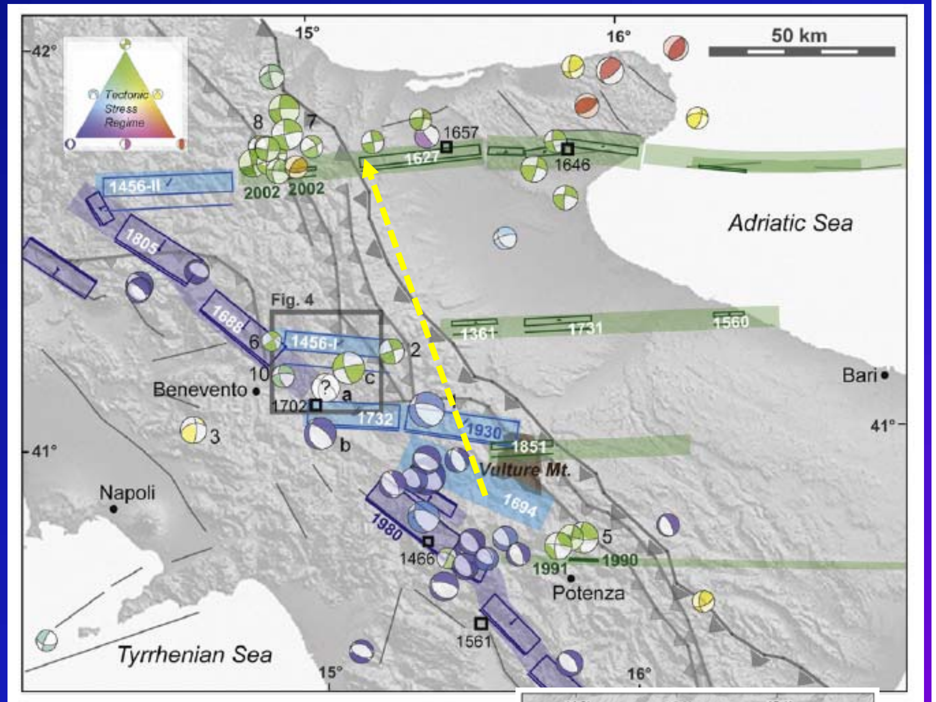
- ✓ Extensional and transtensional FMS

The transition between extension and strike-slip regimes

- ✓ Recent work documents strike-slip earthquakes also beneath extensional belt;
- ✓ Re-analysis of the 1962 Irpinia earthquake places the mainshock at 9 km depth → overthrust Apulia belt

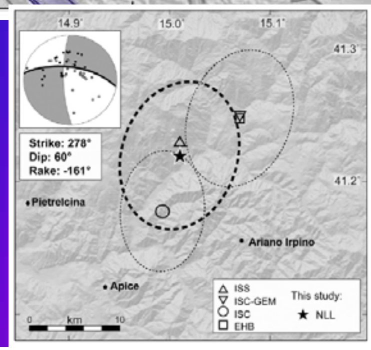


2012 Benevento - Ml 4.1 (*Adinolfi et al., 2015*)
18 km depth – **underthrust Apulia foreland**

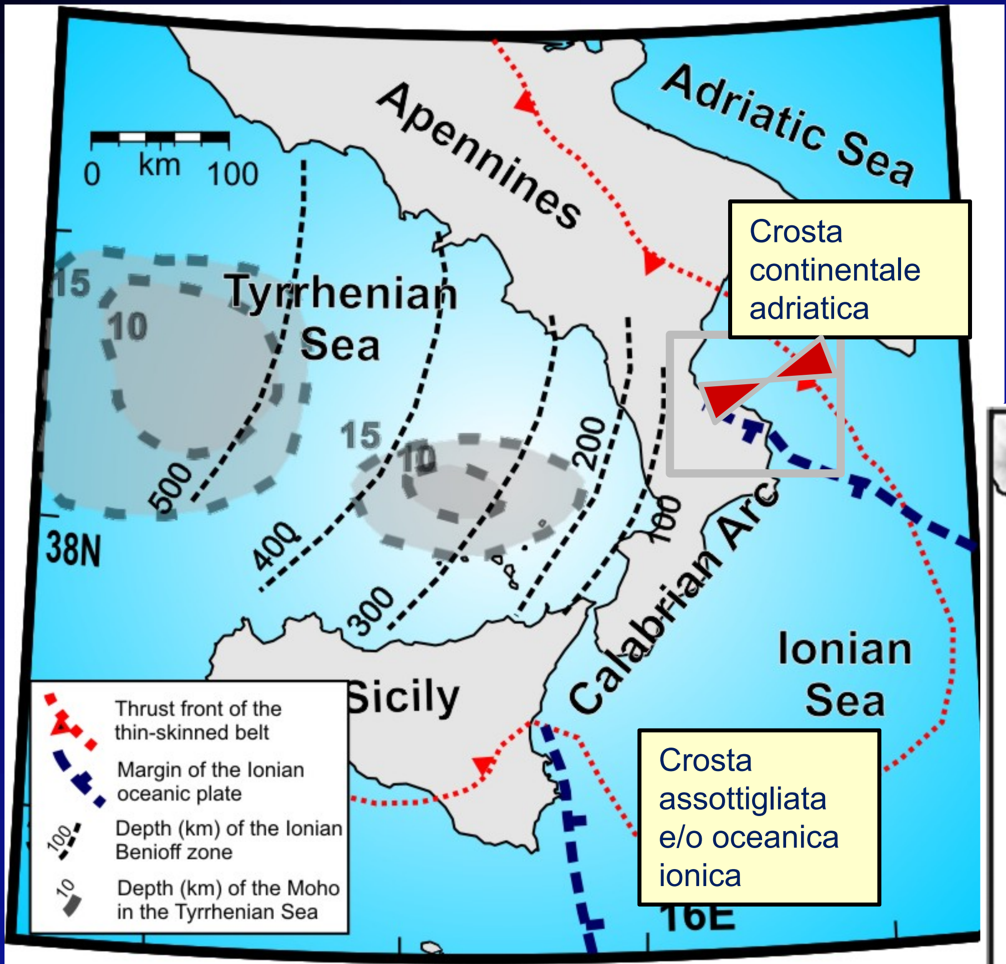


1962 Ariano Irpino sequence - Mw 6.1 (*Vannoli et al., 2016*)

9 km depth – **Apulia thrust belt**



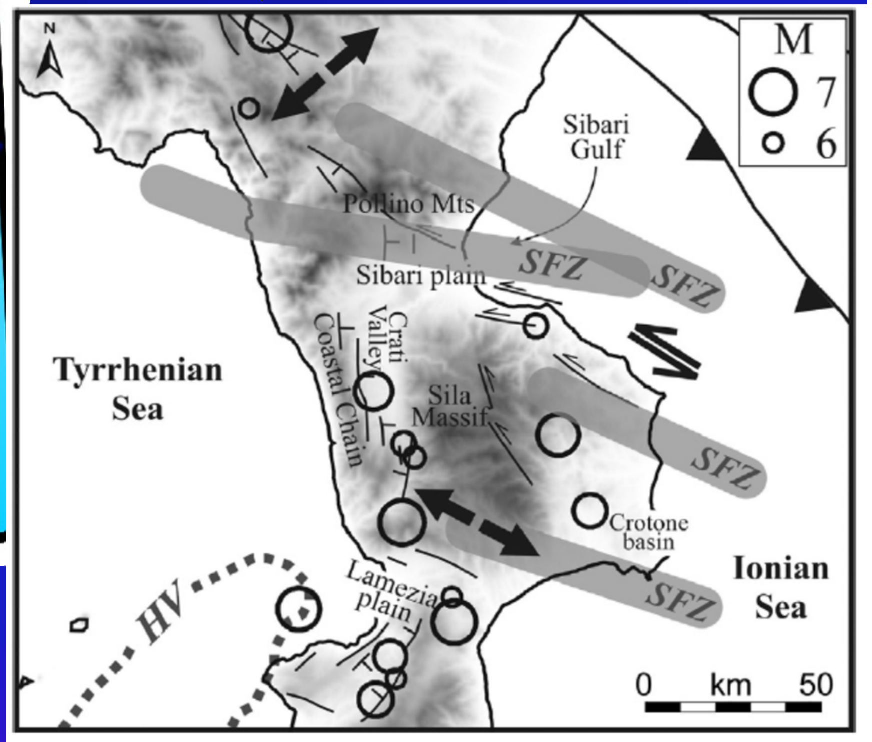
Transpressione al margine continentale ionico



Ferranti et al., 2009

La localizzazione della fascia transpressiva può essere relazionata a un limite crostale ereditato

La transpressione si focalizza



Orecchio et al., 2015