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Istituto di Metodologie per l'Analisi Ambientale

Three-dimensional Magnetotelluric Crustal Model of High Agri Valley seismic area to identify and to quantify the resistivity variation in depth

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Anna Eliana Pastoressa

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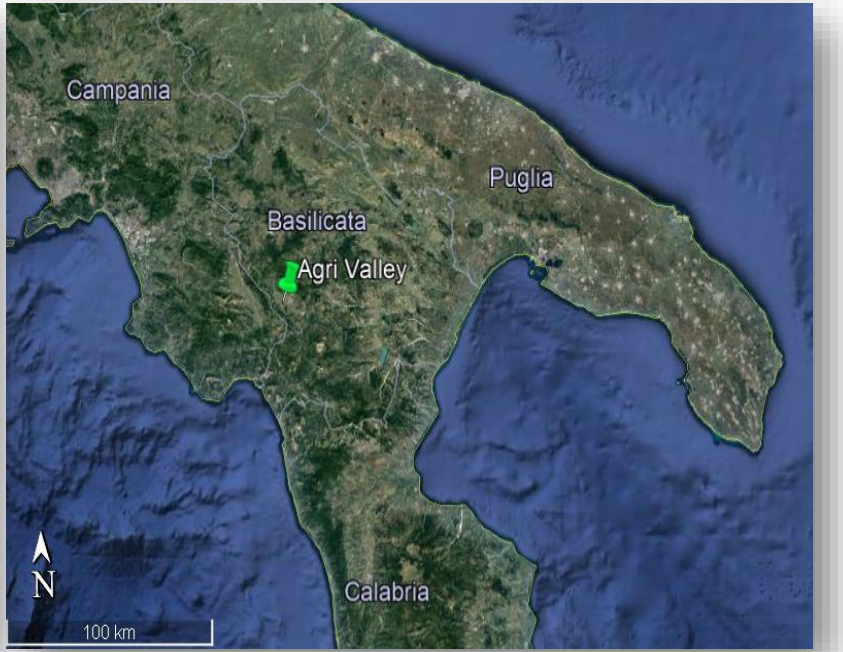
Project Aims

Define the relationship between **fluids dynamism**, **crust kinematics** and **earthquake's development** in High Agri Valley Study Area

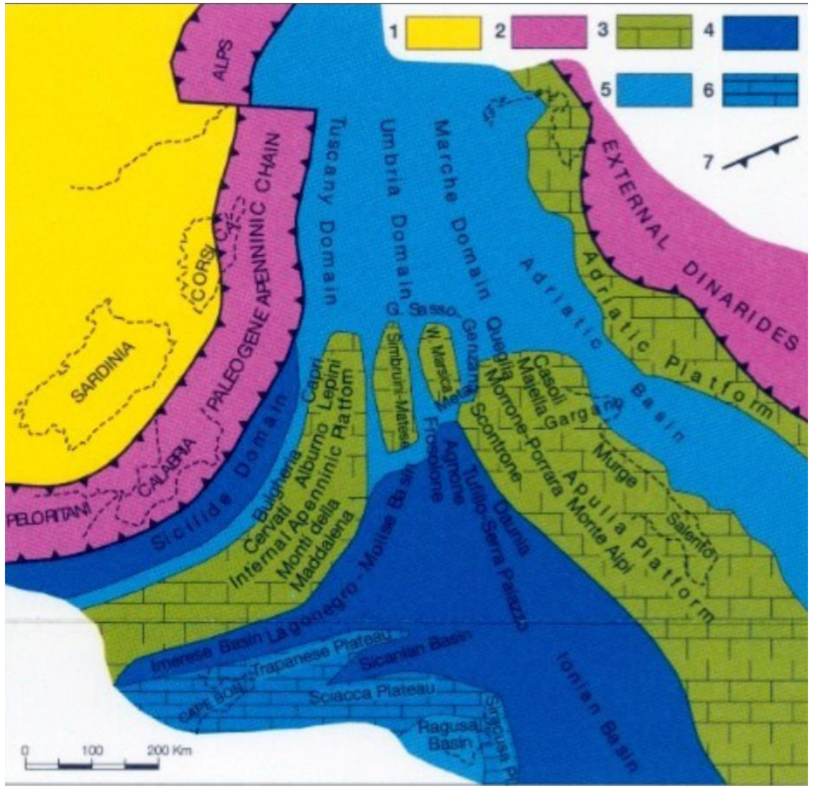
Contents

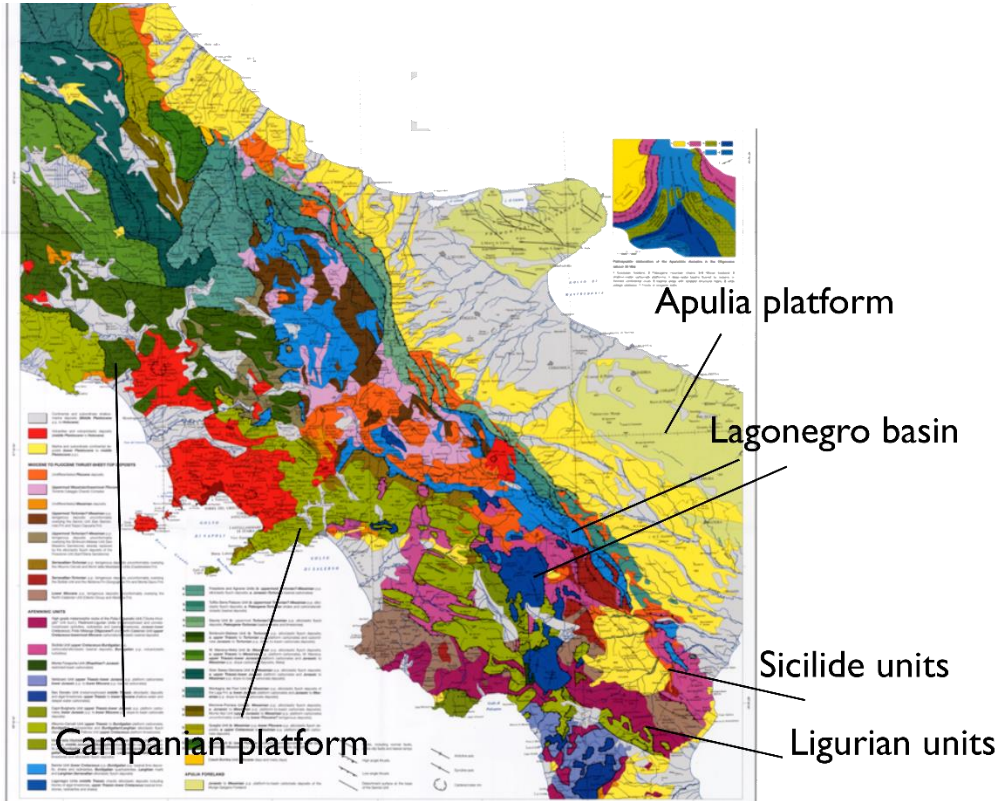
1. Background Information: Geological Framework

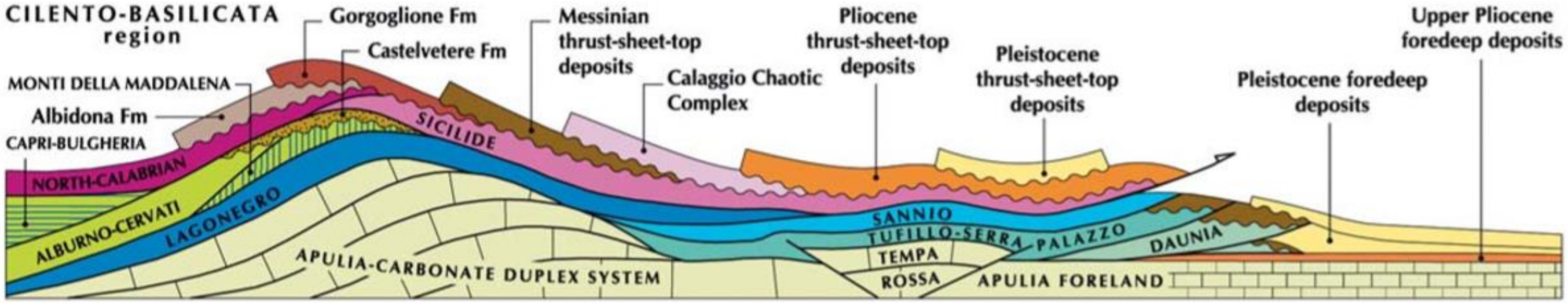
The High Agri Valley (HAV, Basilicata region, southern Italy) is a NW–SE trending intermontane basin of the Southern Apennine Chain



1. Background Information: Geological Framework

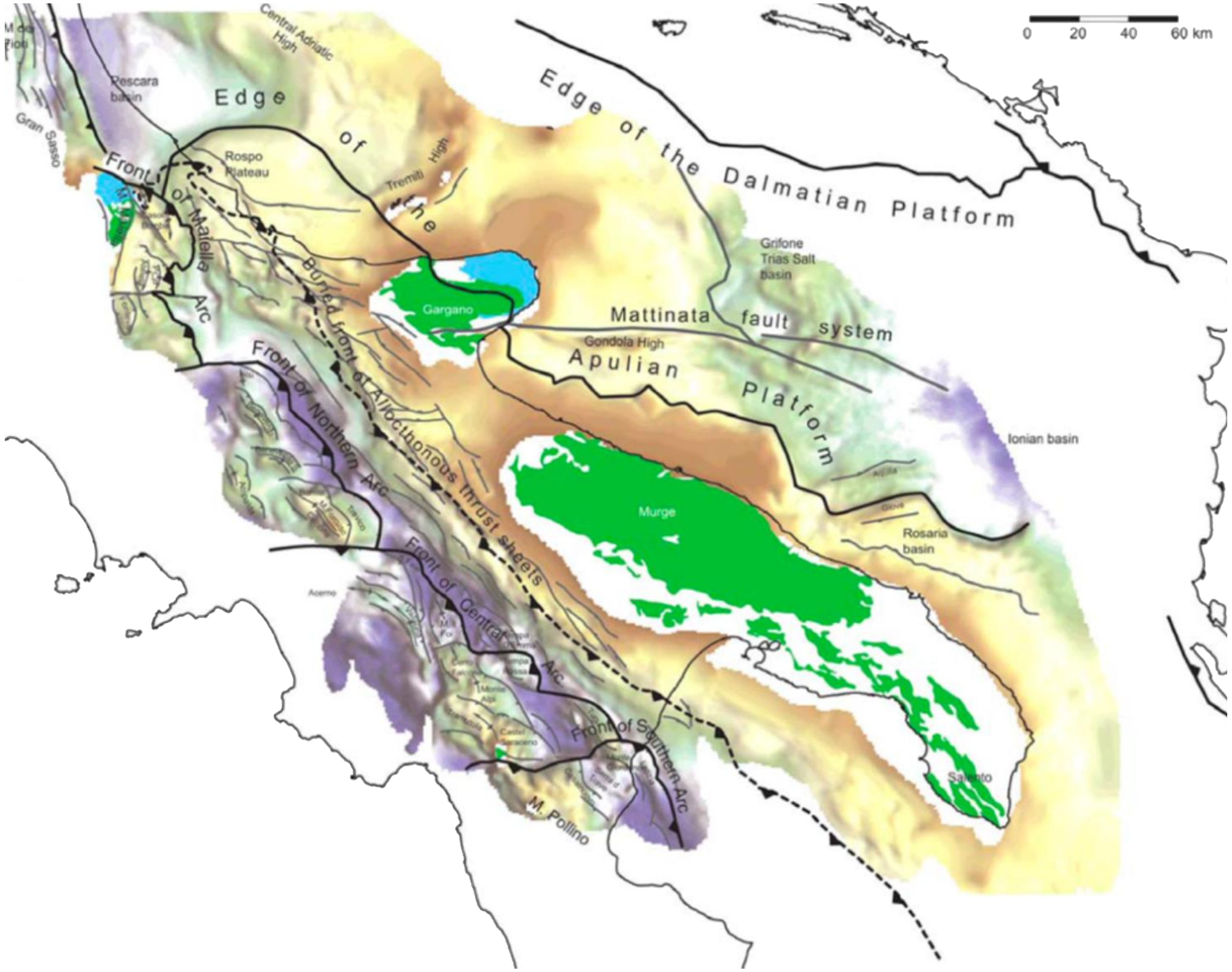




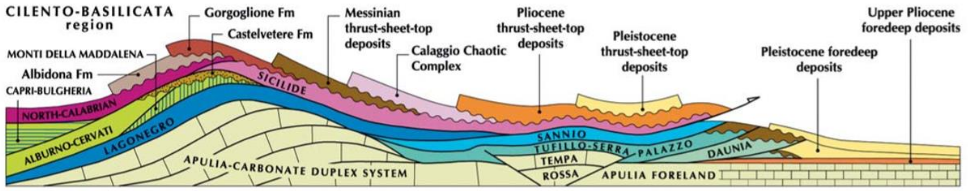


from Patacca et al., 2007

1. Background Information: Geological Framework



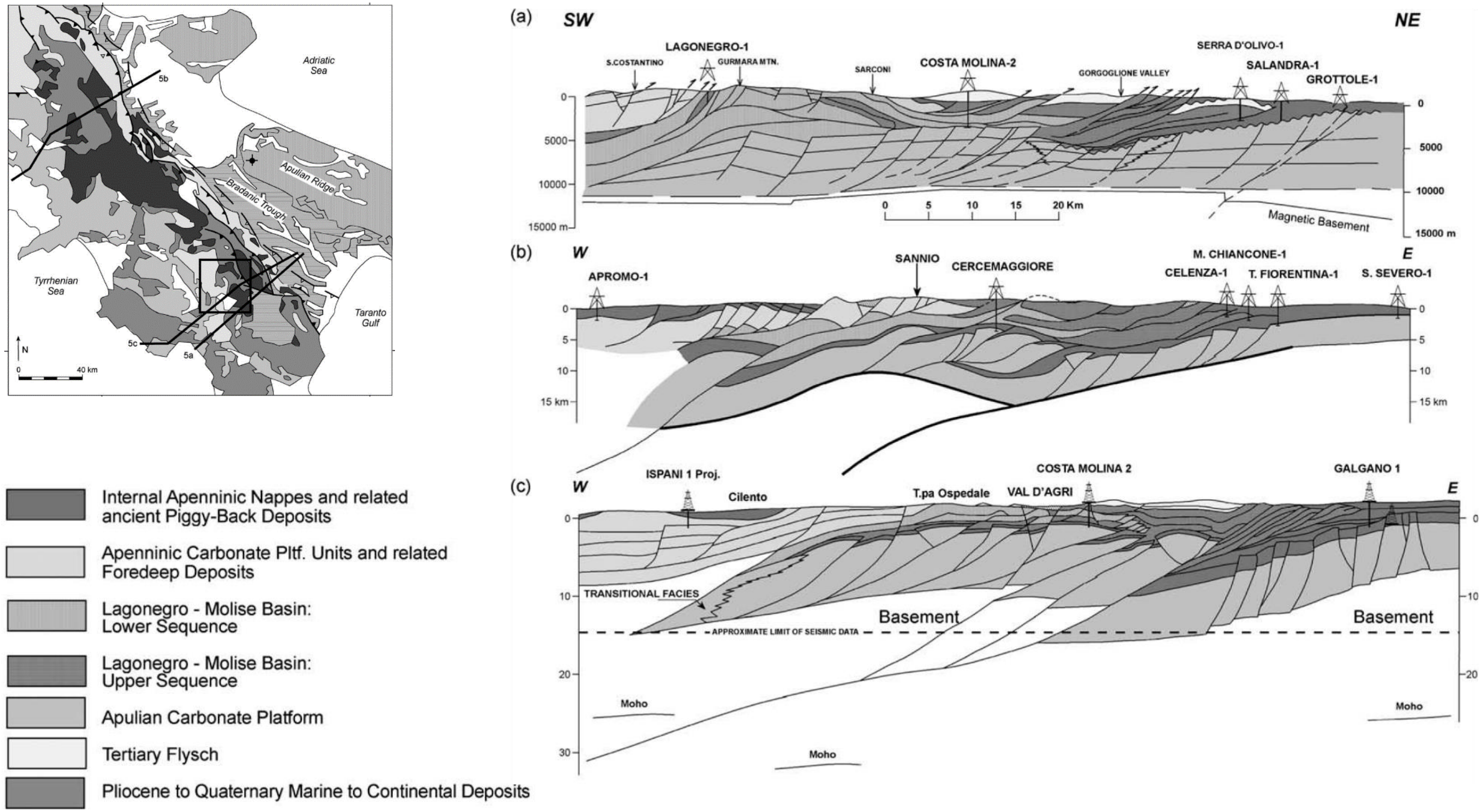
from Nicolai e Gambini., 2007



from Patacca et al., 2007

The level of detachment between the Inner Apulian Platform and the allochtonous units is defined by a melange level (one hundred meters thick) consisting mainly overpressurized and deformed siltstones (Mazzoli et al., 2001)

1. Background Information: Geological Framework

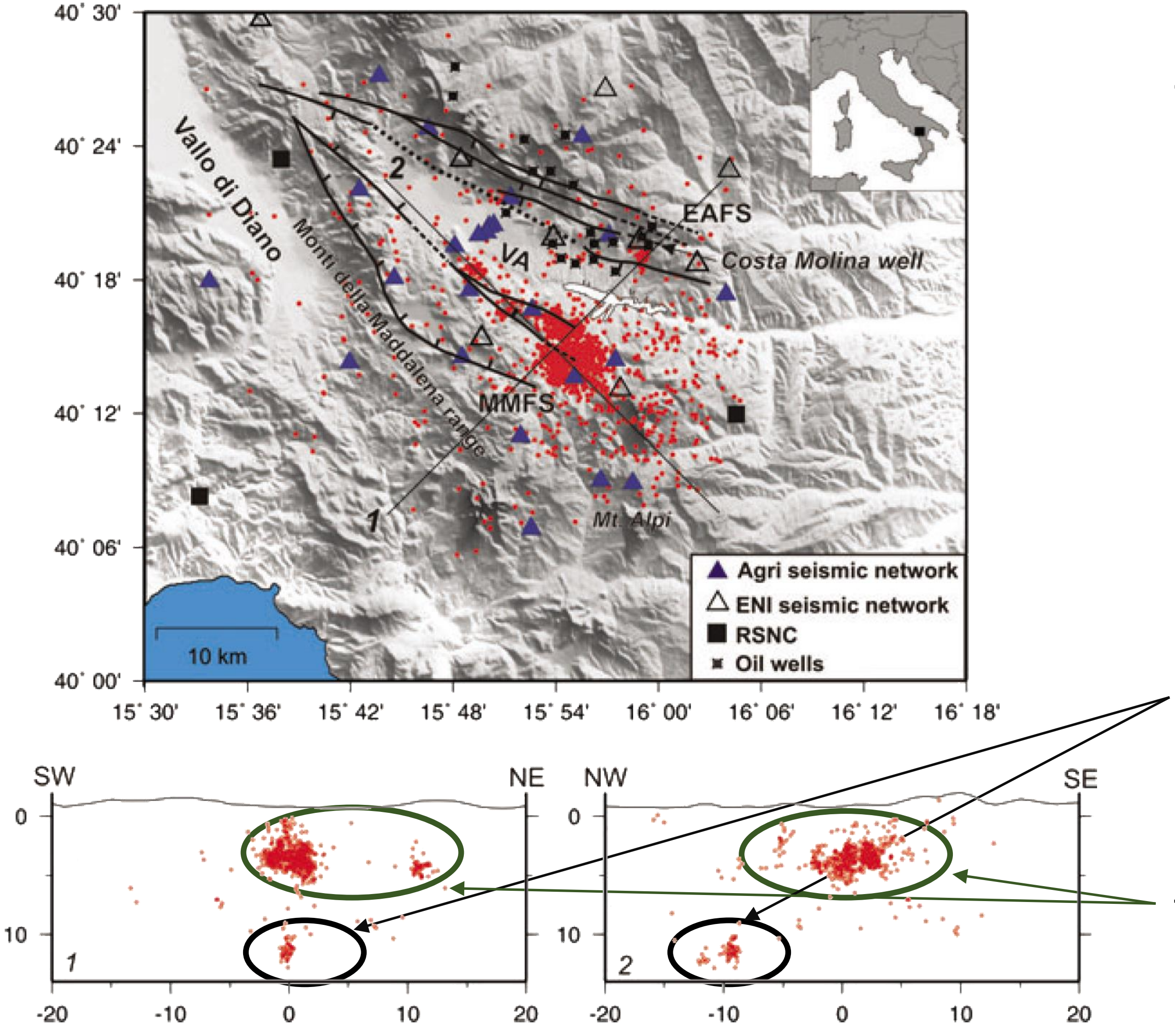


Reflection seismic data show **AP located at 1.5 km b.s.l**. in CM2 well (Menardi Noguera et al., 2000)

The AP constitutes the **reservoir unit** for major oil fields in southern Italy (Shiner et al. 2003)

Cross-sections across the southern Apennines showing contrasting structural styles for the interpretation of the deep Apulian structures. (a) The section of Mostardini and Merlini (1986), whilst (b) shows the section of Casero et al. (1988) and (1991), and (c) is from Menardi Noguera and Rea (2000) (from Shiner et al., 2003).

1. Background Information: Seismological Data

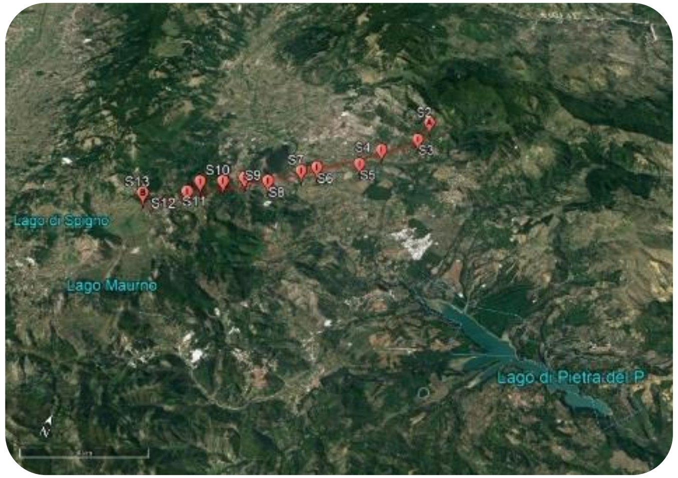


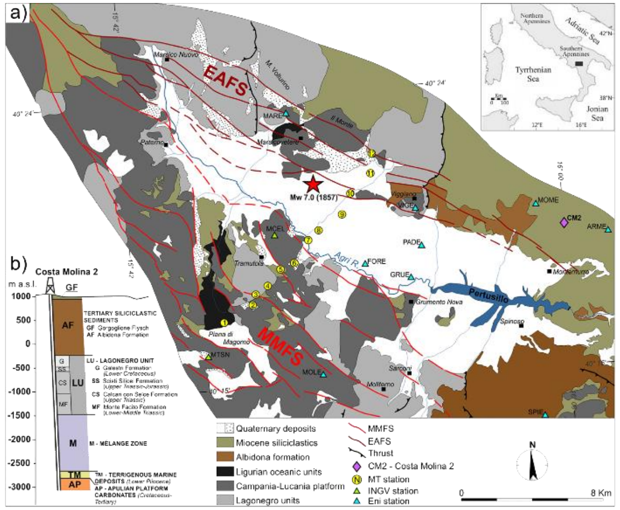
from Valoroso et al., 2009

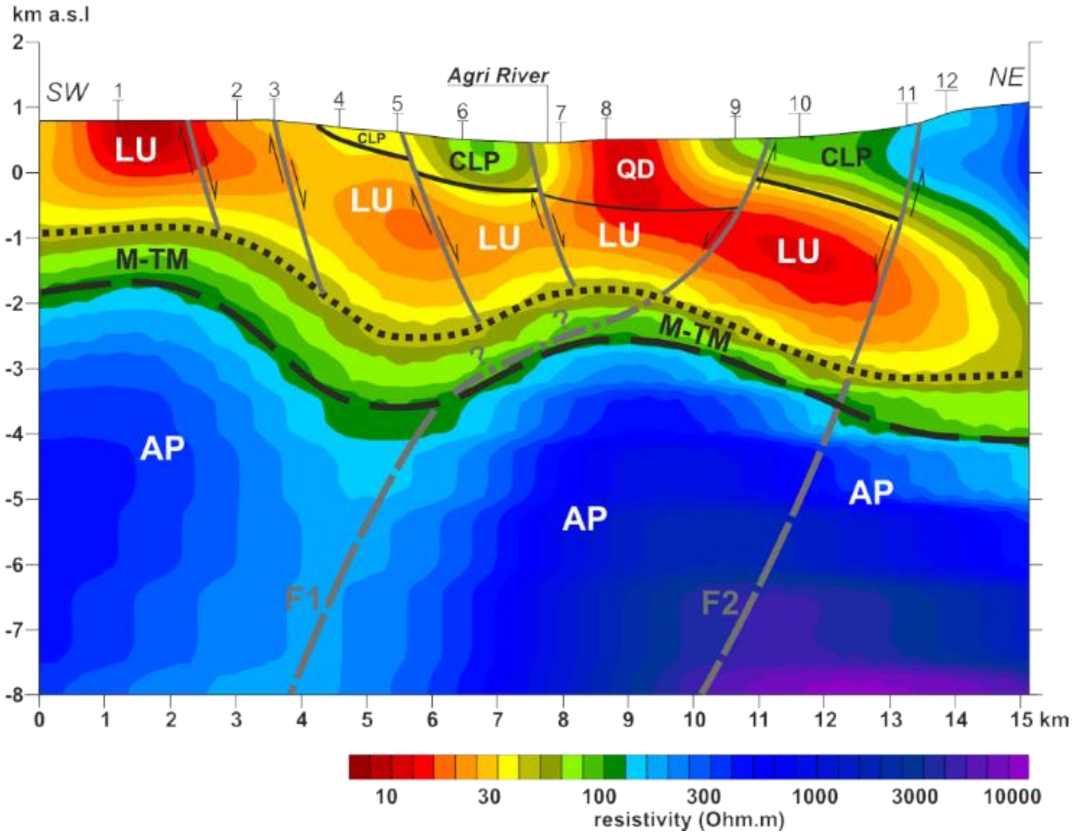
The seismogenic fault system capable of producing large events (such as the M 7.0, 1857 Basilicata Earthquake) is alternatively associated to the following Monti della Maddalena Fault System (**MMFS**) (Maschio et al., 2005) and Eastern Agri Fault System (**EAFS**)(Cello et al., 2003) and connected to **NE-SW extensional stress regime,** at a depth of about 9.5±0.5km below sea level .

micro seismic activity related to the water level fluctuations of Pertusillo lake and to fluid injection in CM2 well (Stabile et al., 2014).

1. Background Information: MT investigation in High Agri Valley (2015)





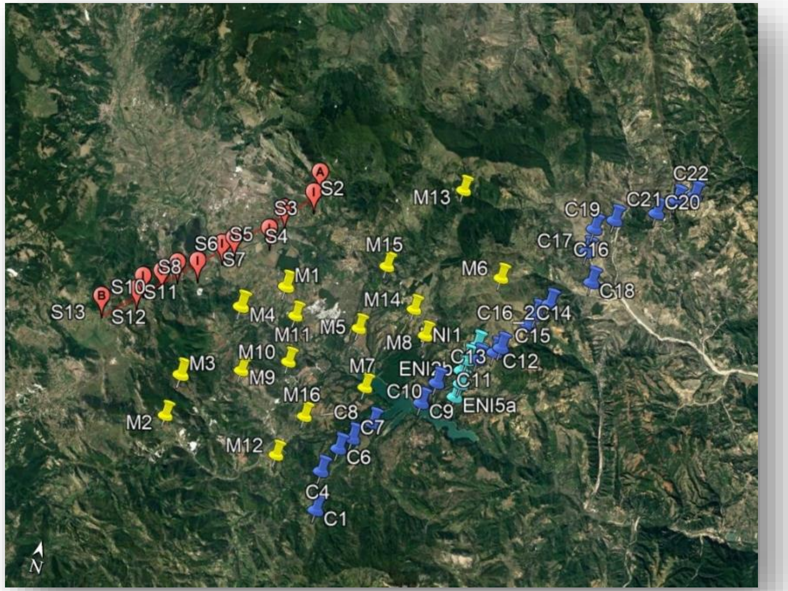


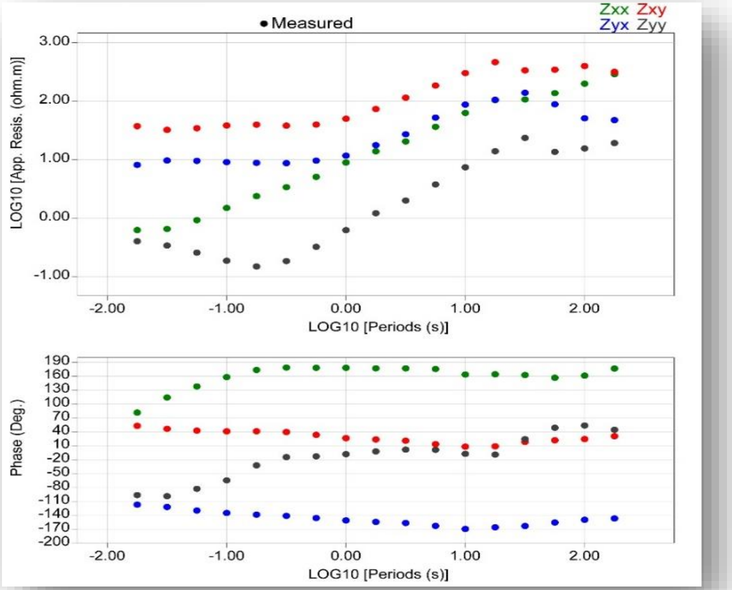
- **QD** = Quaternary Deposits
- **CLP** = Campania Lucania Platform
- **LU** = Lagonegro Unit
- **M-MT** = Mélange and Terrigenous Marine Deposits
- **AP** = Apulia Plataform Unit

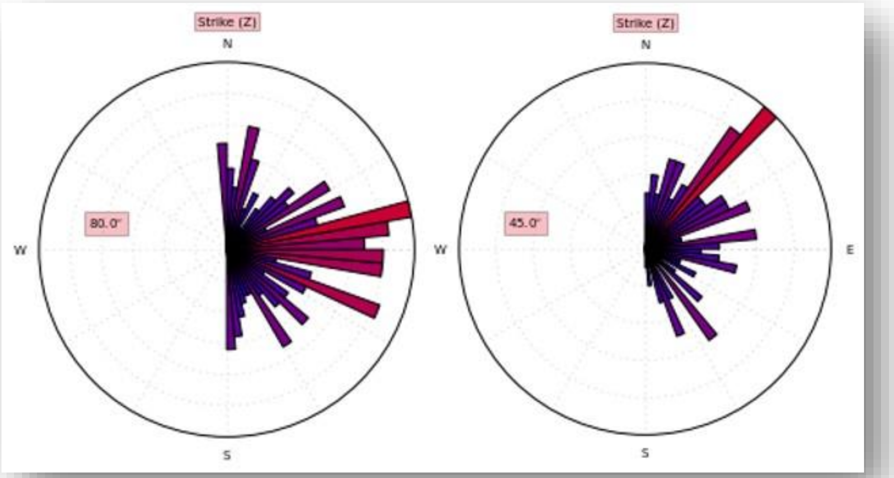
from Balasco et al., 2015

Balasco, M., A. Giocoli, S. Piscitelli, G. Romano, A. Siniscalchi, T. A. Stabile, and S. Tripaldi, 2015, «Magnetotelluric investigation in the High Agri Valley (southern Apennine, Italy)», Nat. Hazards Earth Syst. Sci.,n.15, pp.1–10.

2. Preliminary Results : MT Data Processing and Analysis







Dataset

- 12 soundings along 15 Km (NE-SW)
- 31 soundings along 33 Km (NE-SW)
- 16 scattered soundings

Data Processing

- Robust processing code of Egbert (1997)
- **0.01-800/1000 s** period range of apparent resistivity and phase
- **100 ohm·m** average apparent resistivity value

Data Analysis

(refer to 31 sounding along 33 Km profile and 16 scattered soundings)

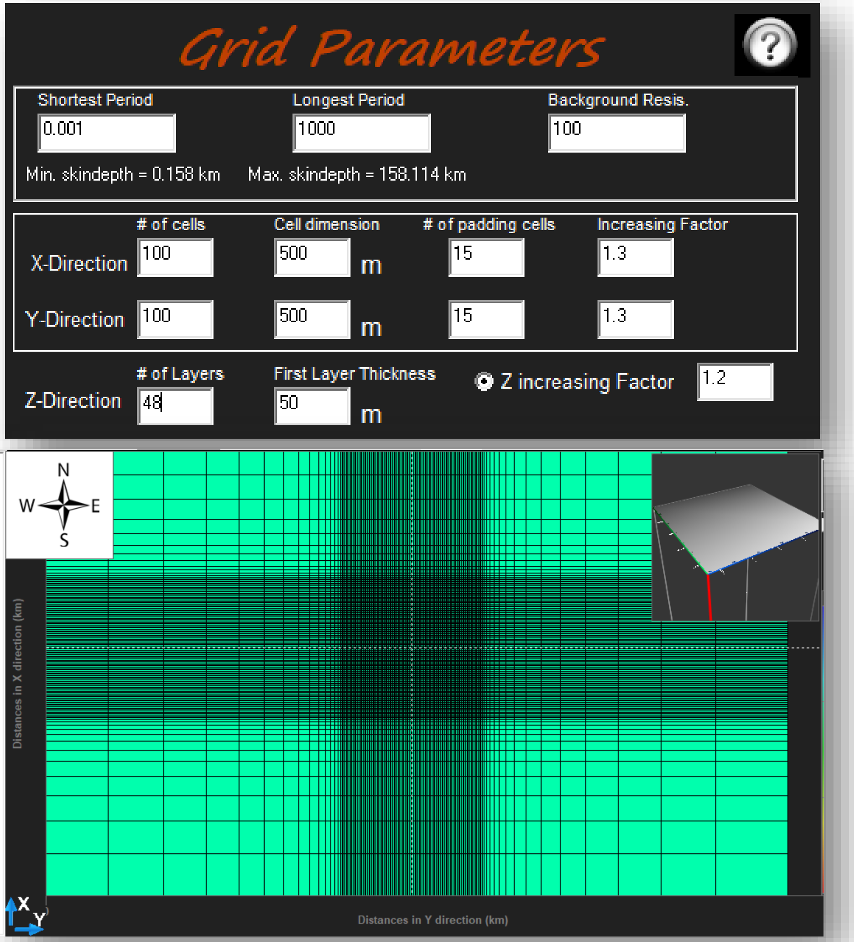
- **2D dimensionality** for 30s-1000s (β ~ 0)
- **Antiappenninc Directionality** for 30s-1000s (α ~ 45).

3. MT inversion tests using ModEM software in parallel version (Kelbert et al.,2014)

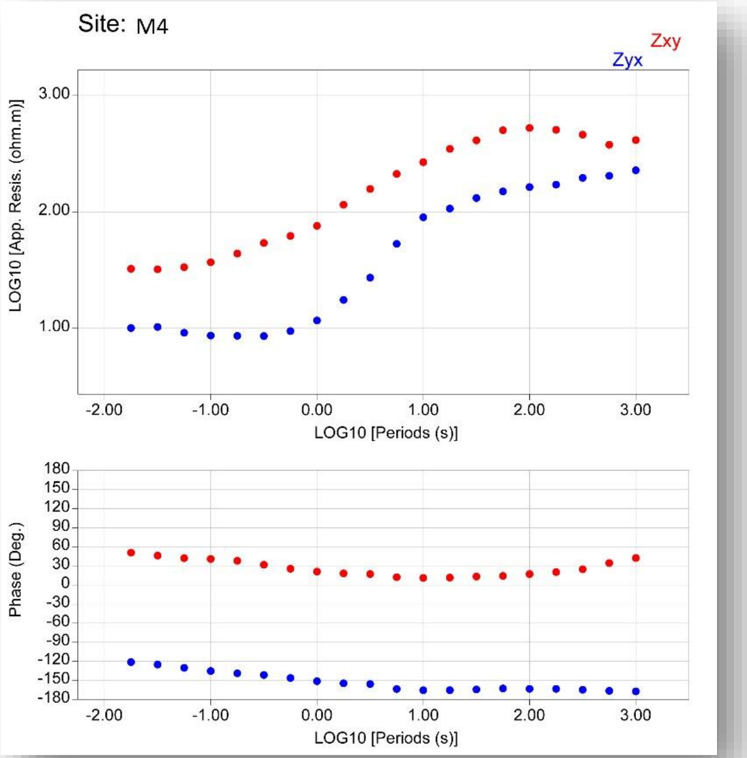
a. Best Model Grid and Mesh Choice
b. Topography and Sea Coast Effects Estimation
c. Comparison of full impedance tensor inversion result obtained from model and data NS oriented with the results of full-impedance tensor inversion obtained from model mesh and the data aligned with quasi-2-D geo-electrical strike
d. Comparison of full impedance tensor inversion result with the result obtained from inversion of only off-diagonal components of the magnetotelluric impedance tensor
e. Comparison of different impedance tensor inversion results obtained from different starting model
f. Comparison of different impedance tensor inversion results obtained through different values of covariance (smoothing)

3. MT inversion tests using ModEM software in parallel version (Kelbert et al.,2014)

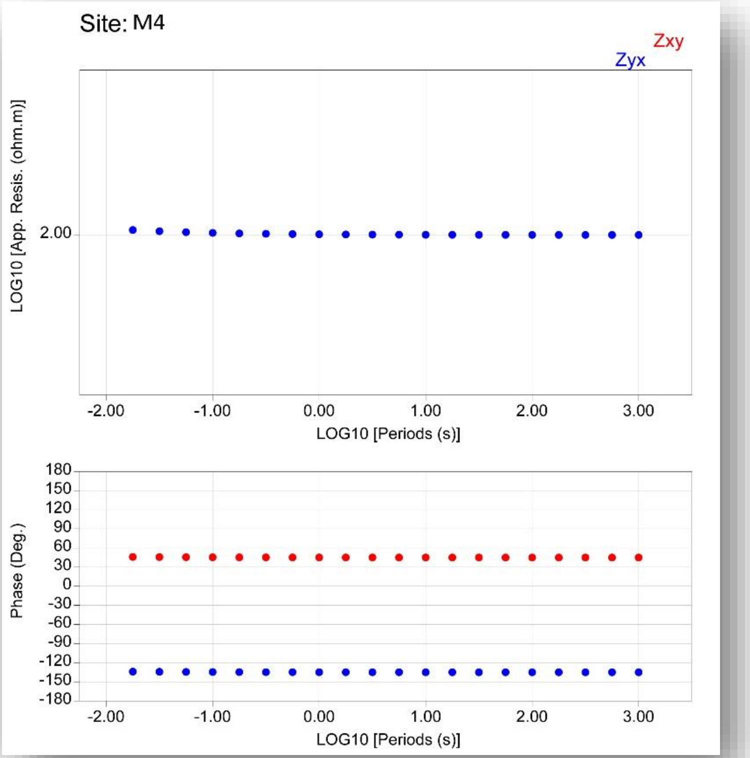
a. Model grid and mesh choice



267 km in x, 267 km in y and 1580 km in z



Data measured

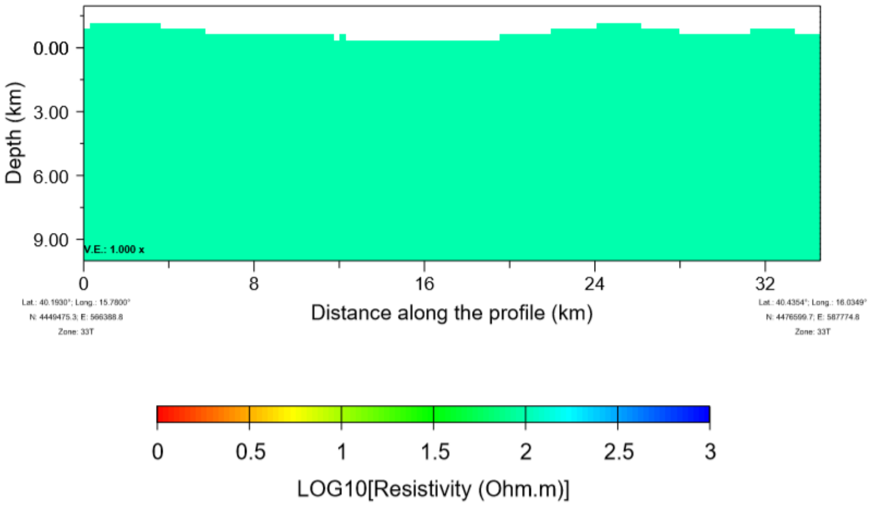


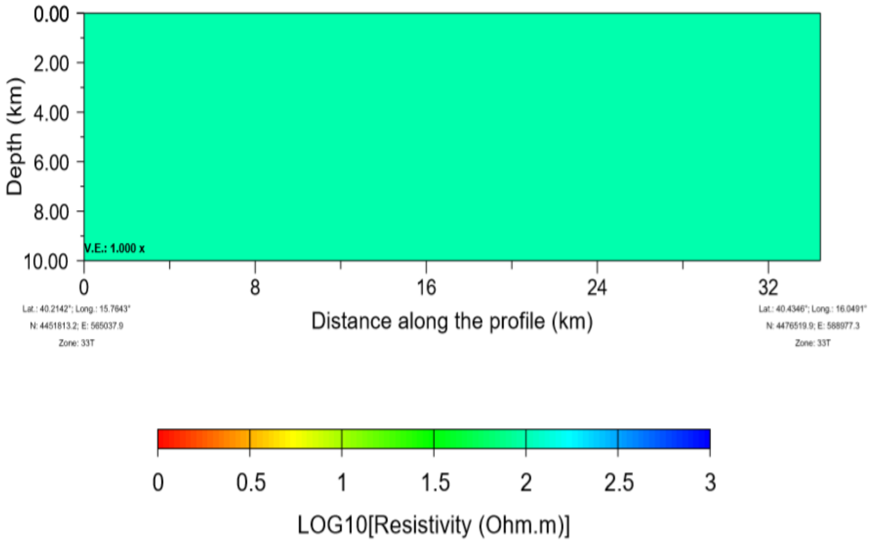
Data predicted
for homogeneous resistivity starting model

3. MT inversion tests using ModEM software in parallel version (Kelbert et al.,2014)

b. *Topography and Sea Coast Effects Tests*

Evaluation of topography effects: consists in the evaluation of synthetic forward modelling performed on **Land Model** and **Basic Model**





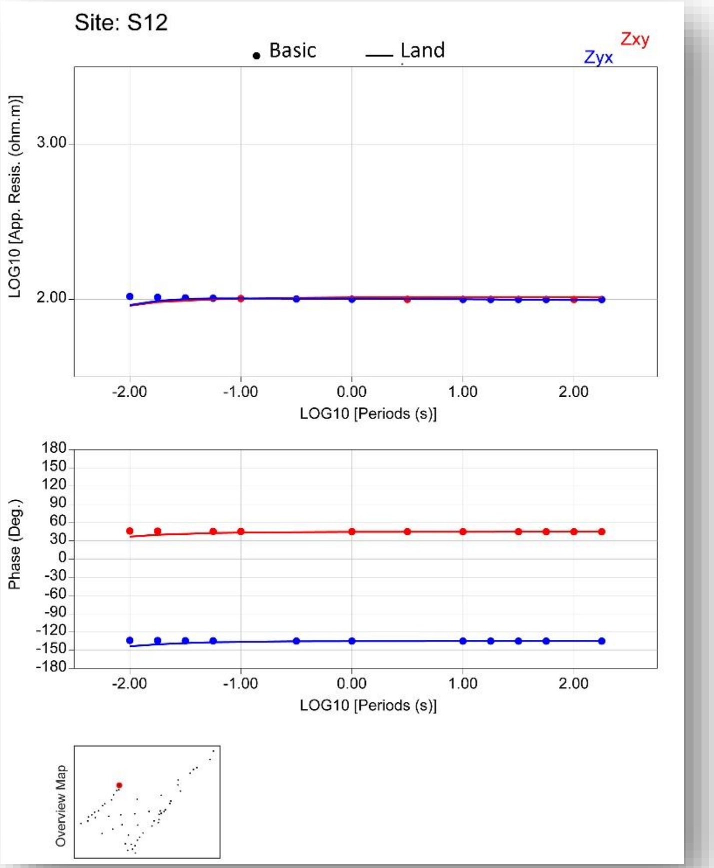
- **Land Model** is derived from replacing the ocean resistivity with a land resistivity of 100 ohm·m
- considering topography and bathymetry

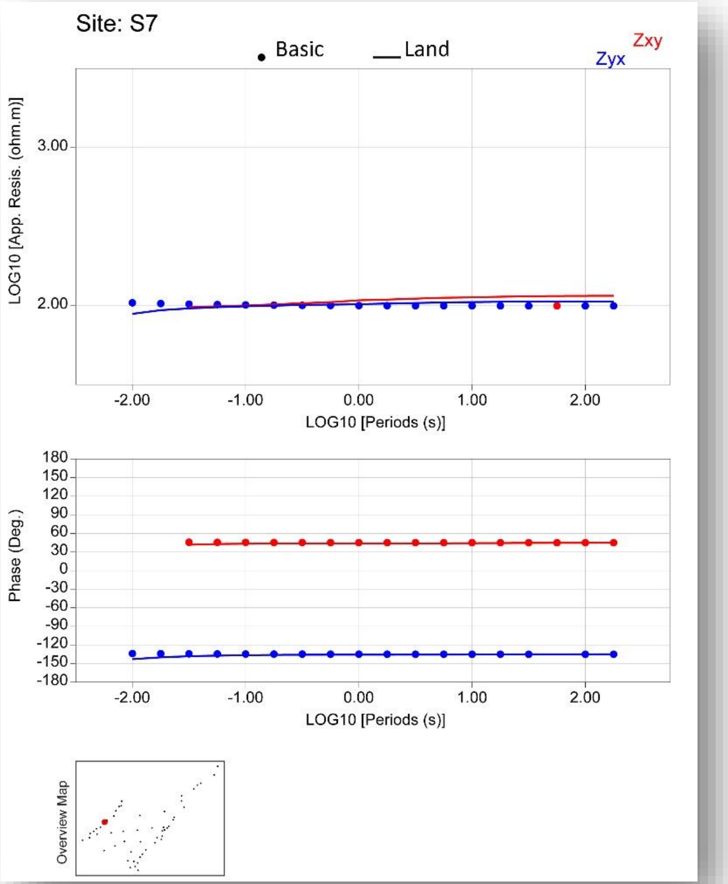
- **Basic Model** consists of the homogenous 3D starting model with a resistivity of 100 ohm·m
- without ocean and topography

3. MT inversion tests using ModEM software in parallel version (Kelbert et al.,2014)

b. *Topography and Sea Coast Effects Tests*

Evaluation of topography effects: consists in the evaluation of synthetic forward modelling performed on **Land Model** and **Basic Model**





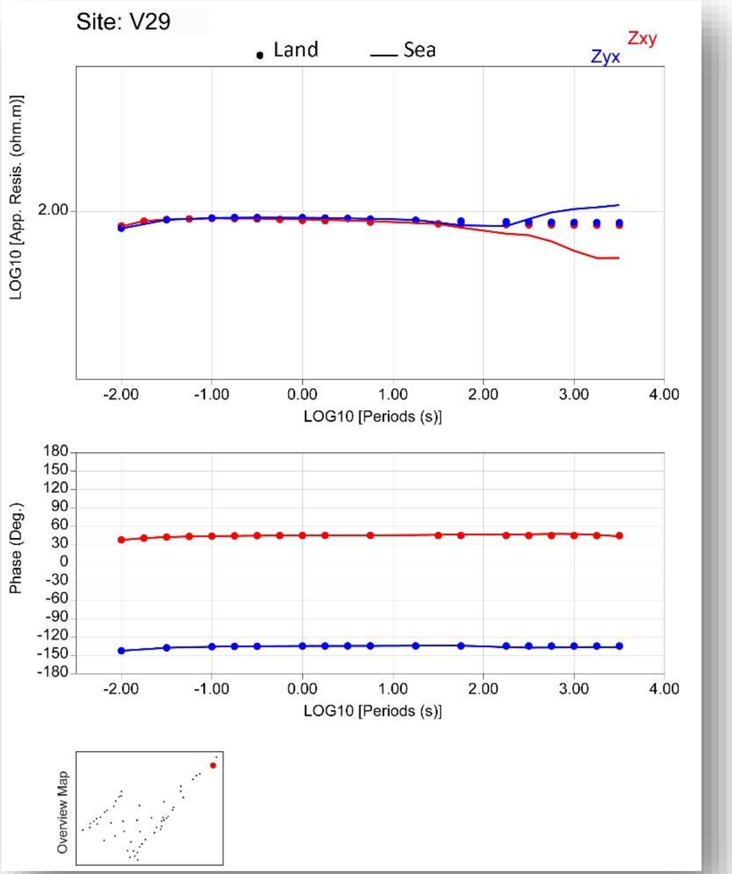
No particular differences between Land and Basic model

One MT sites close to an area with steeper topography (site S12) and one MT site in a flatter area (site S7)

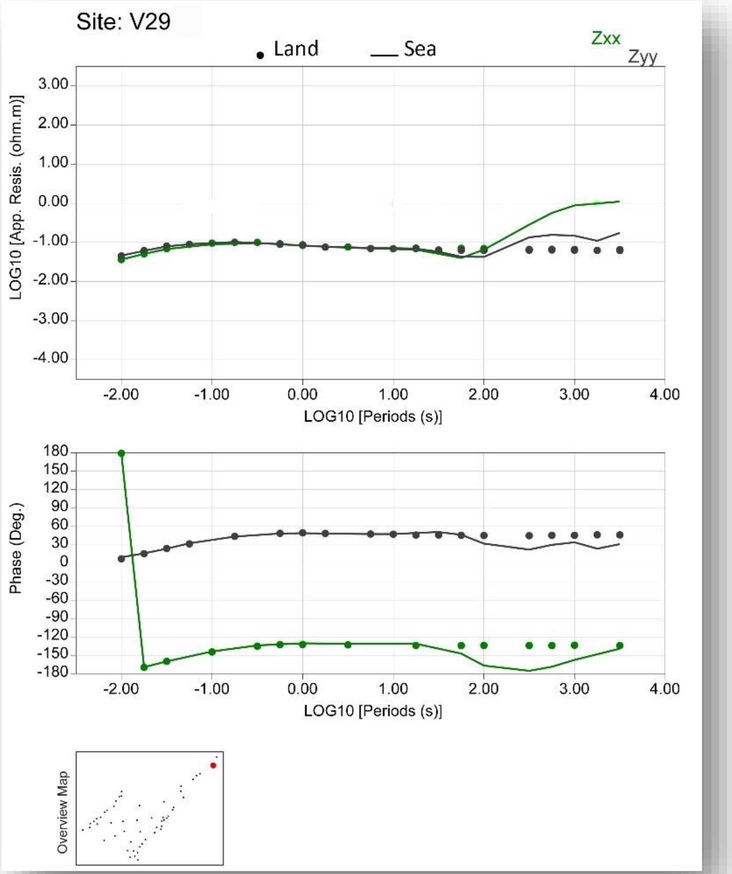
3. MT inversion tests using ModEM software in parallel version (Kelbert et al.,2014)

b. *Topography and Sea Coast Effects Tests*

Evaluation of ocean effects: consists in the evaluation of synthetic forward modelling performed on **Land Model** and **Sea Model**



Off- diagonal components of V29

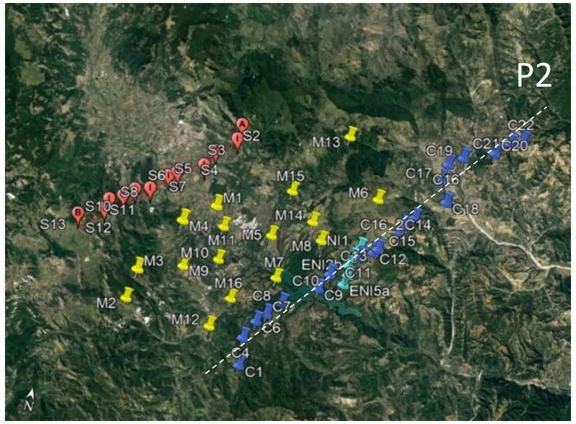


Diagonal components of V29

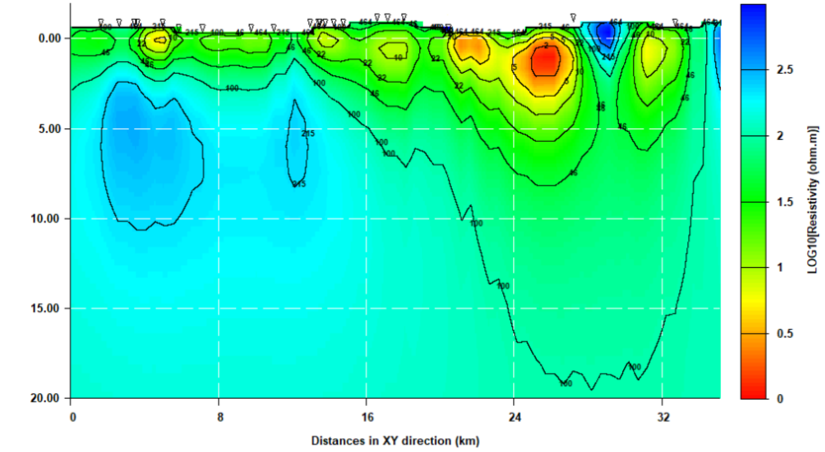
Different behaviour of two models and in particular for their diagonal components at lower frequency

3. MT inversion tests using ModEM software in parallel version (Kelbert et al.,2014)

c. *Model Mesh Orientation choice*

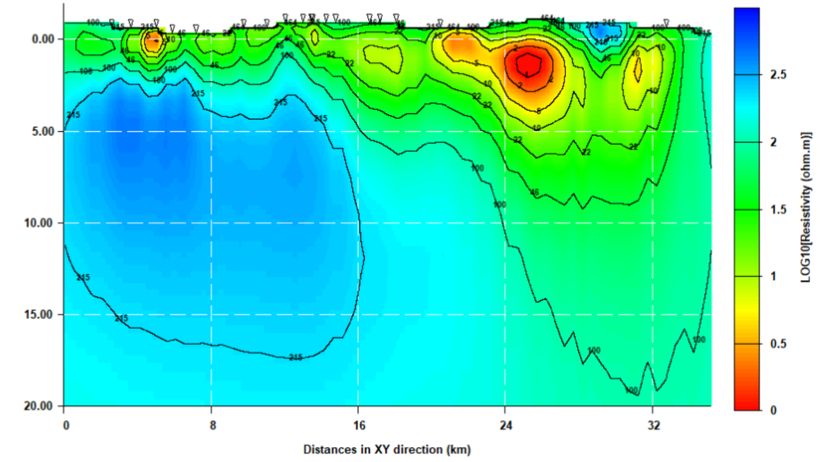


Model ad Data NS Oriented

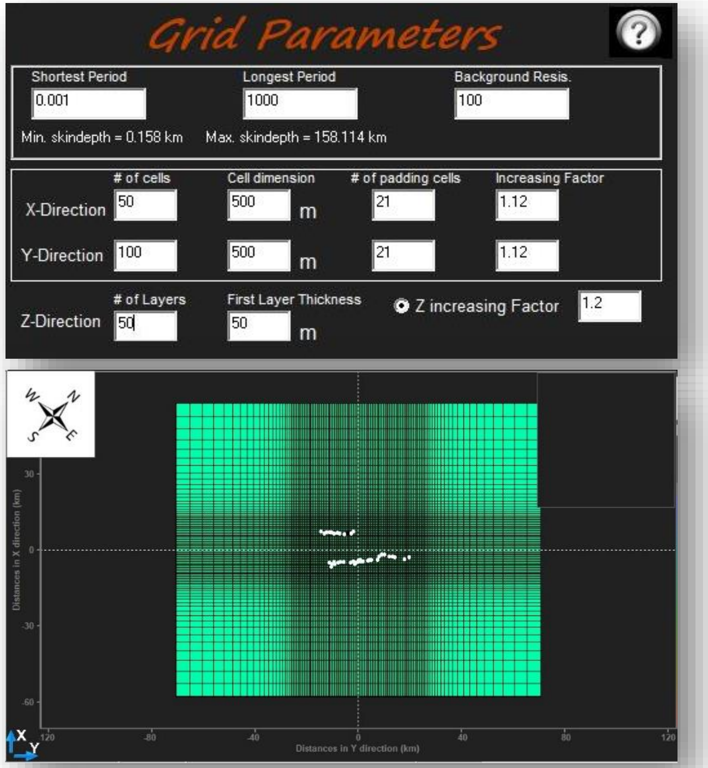


RMS 4.4

Model ad Data Strike Oriented



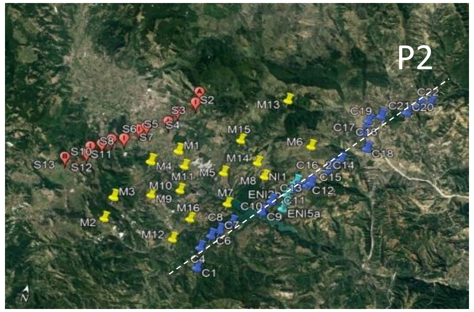
RMS 4.6

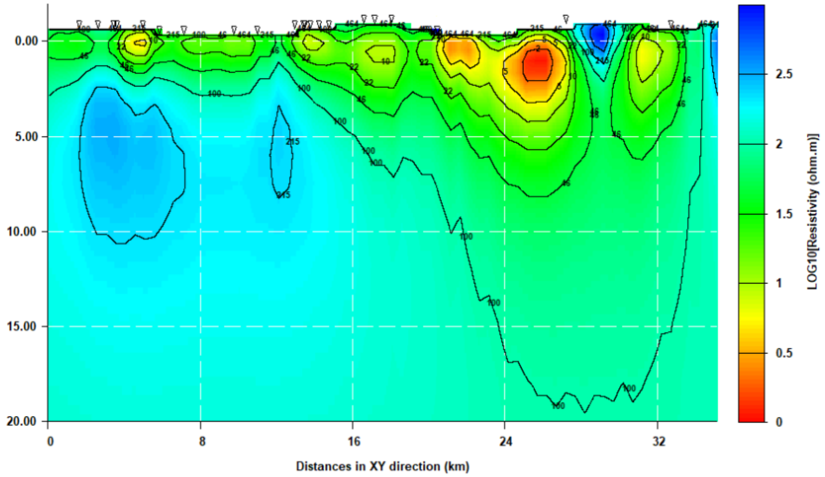


Model mesh and data aligned with quasi 2D geo electrical strike reduce the mathematical problem to the finite differences (Kiyan et al., 2013)

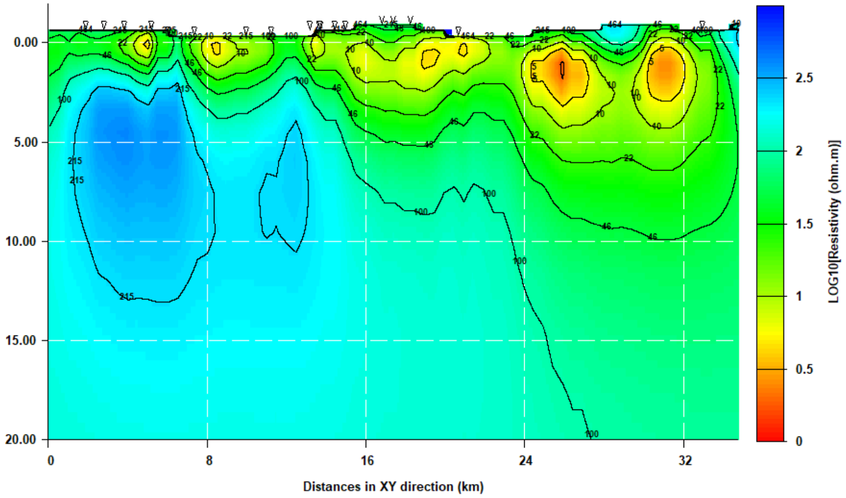
3. MT inversion tests using ModEM software in parallel version (Kelbert et al.,2014)

d. Off-diagonal impedance tensor inversion vs Full-diagonal impedance tensor tests





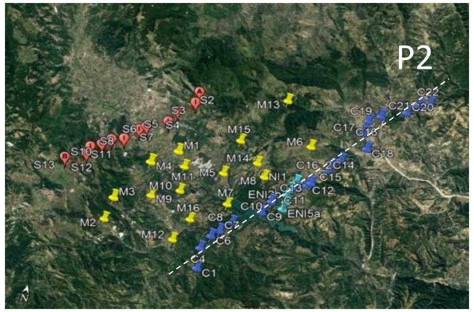
RMS 4.6
full impedance tensor inversion

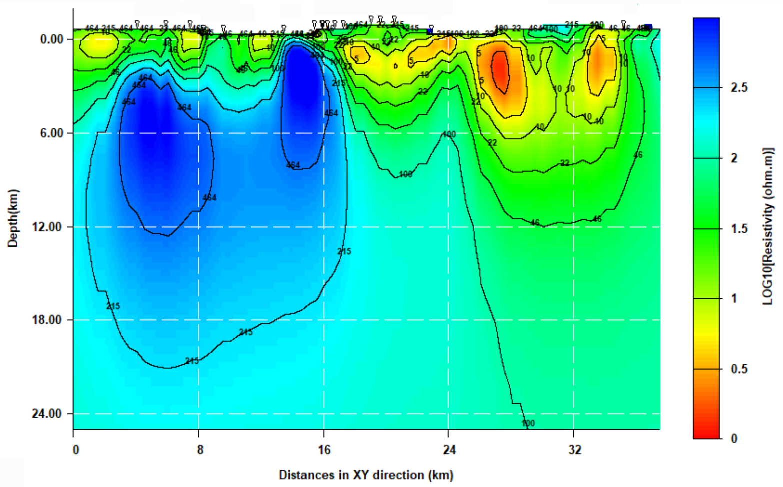


RMS 3.8
off-diagonal impedance tensor inversion

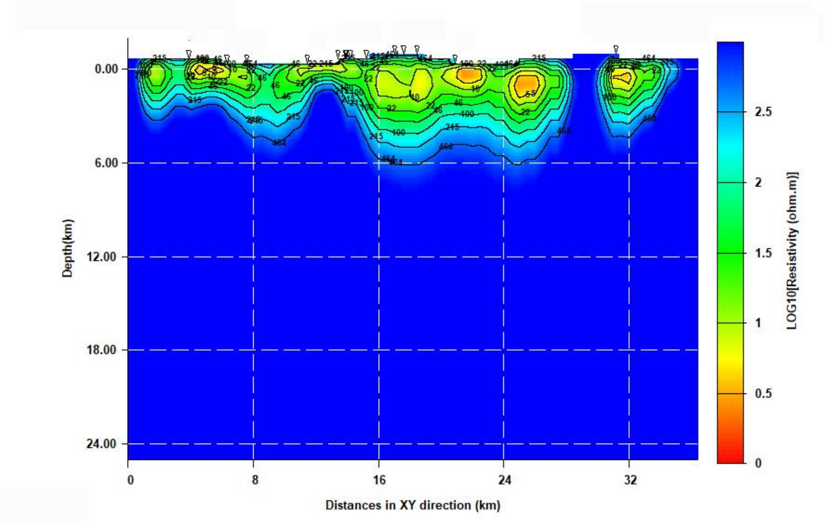
3. MT inversion tests using ModEM software in parallel version (Kelbert et al.,2014)

e. *Different Starting Model Tests*

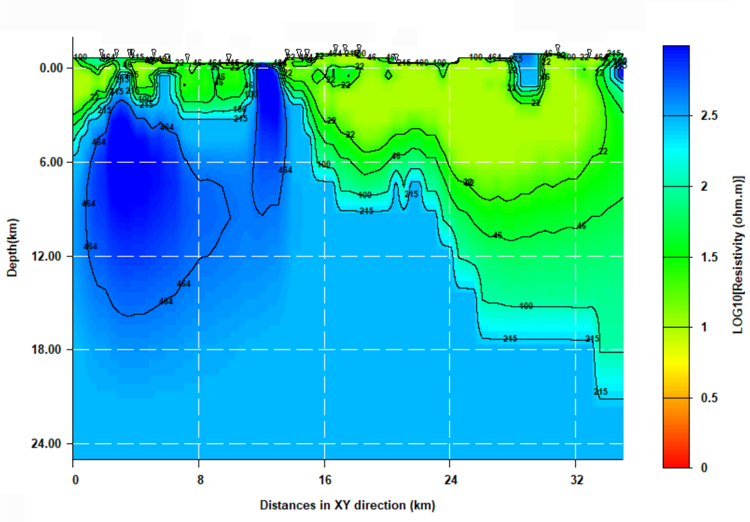




RMS 1.6
homogenous starting model of **100 ohm·m** (bathymetry and topography)



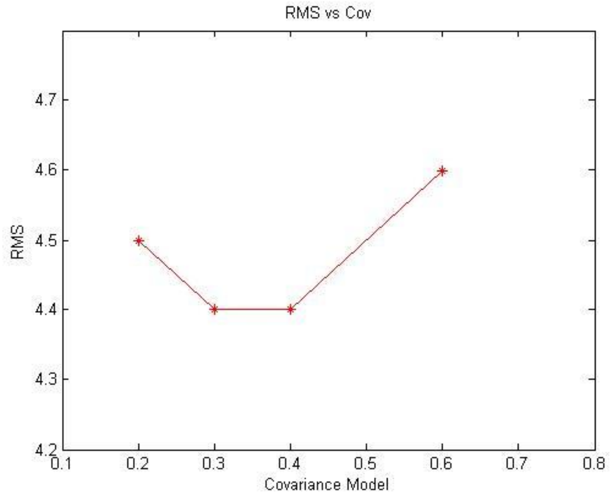
RMS 4.2
homogenous starting model of **5000 ohm·m** (bathymetry and topography)

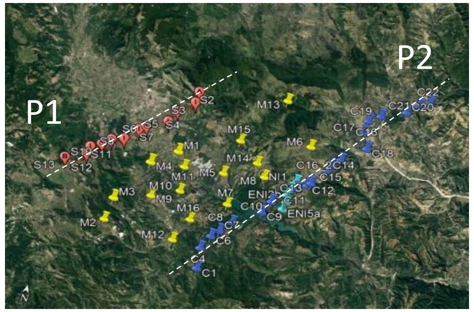


RMS 1.7
upper layer until 4 km in depth of **100 ohm·m**, half-space of **5000 ohm·m** (bathymetry and topography)

3. MT inversion tests using ModEM software in parallel version (Kelbert et al.,2014)

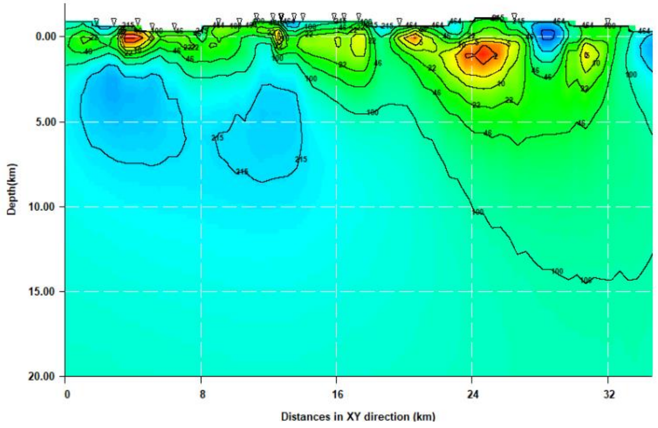
f. Covariance Model Tests



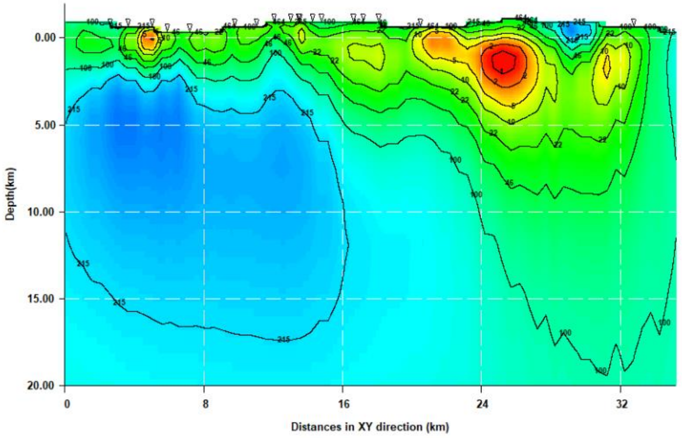


*For a same trade- off (equal to 10^{-7}) the model RMS lower values are associated to the smoothing values ranging from **0.3** and **0.4**.*

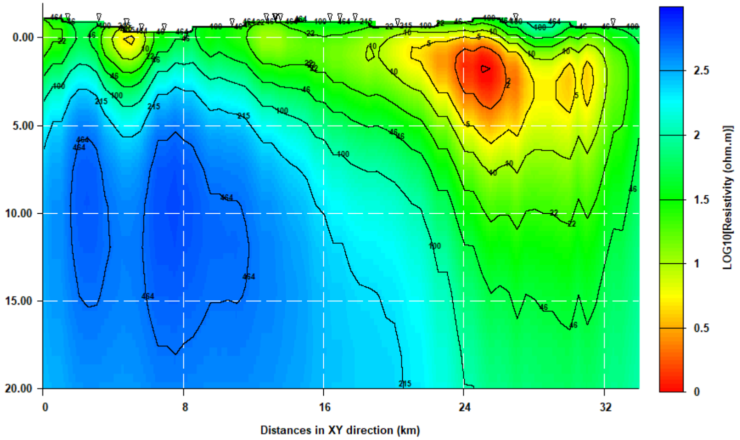
Covariance 0.3 (Kelbert et al.,2014)
RMS 4.4



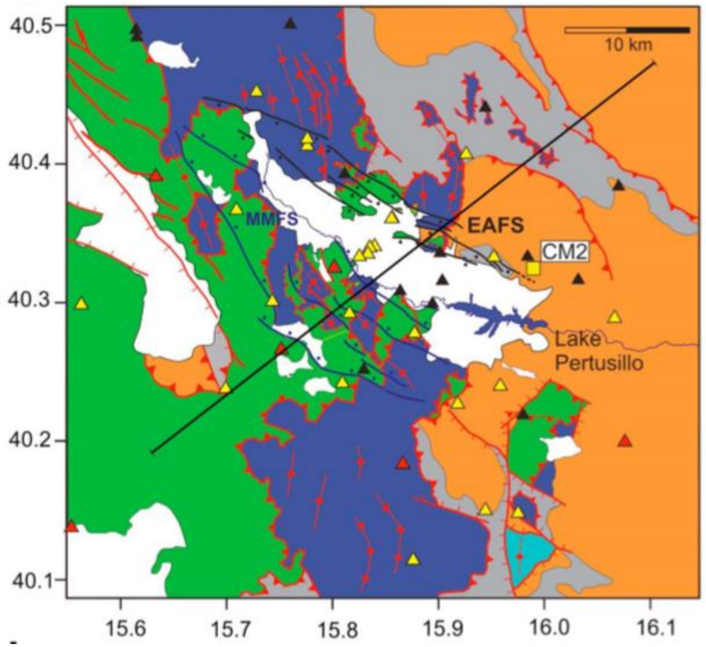
Covariance 0.4 (Kiyan et al.,2013)
RMS 4.4

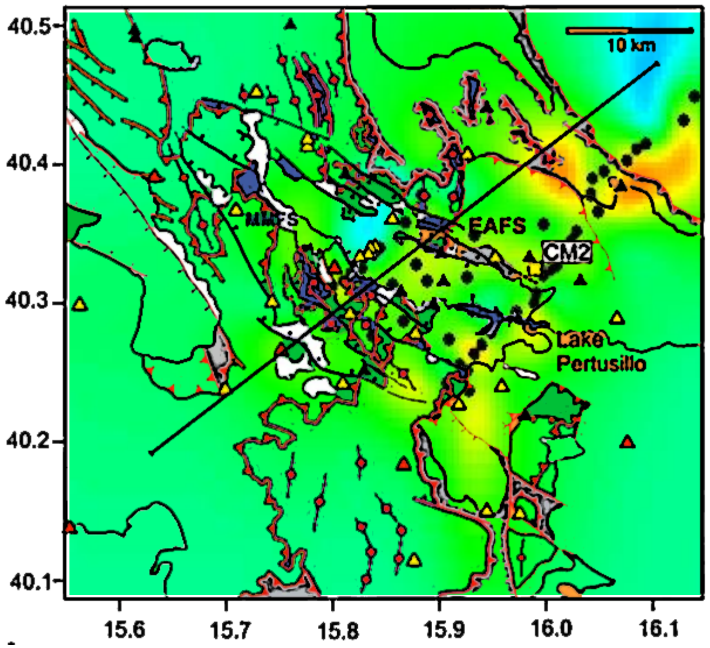


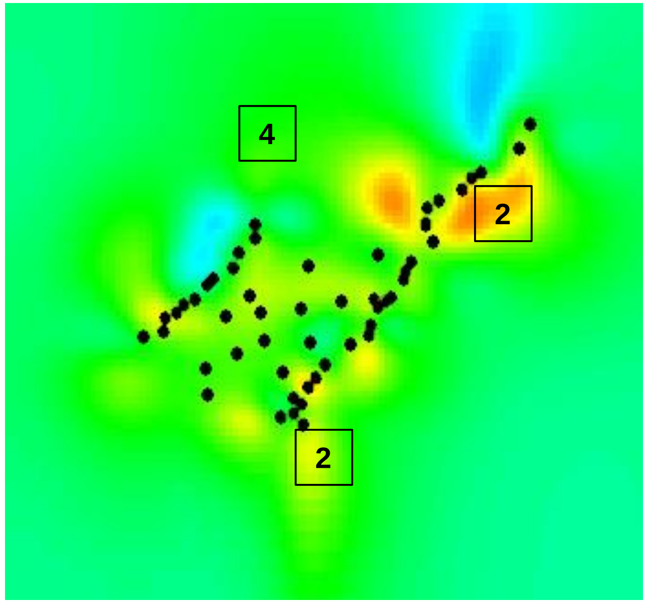
Covariance 0.6
RMS 4.6



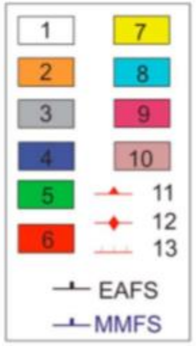
4. First interpretation of the conductivity model





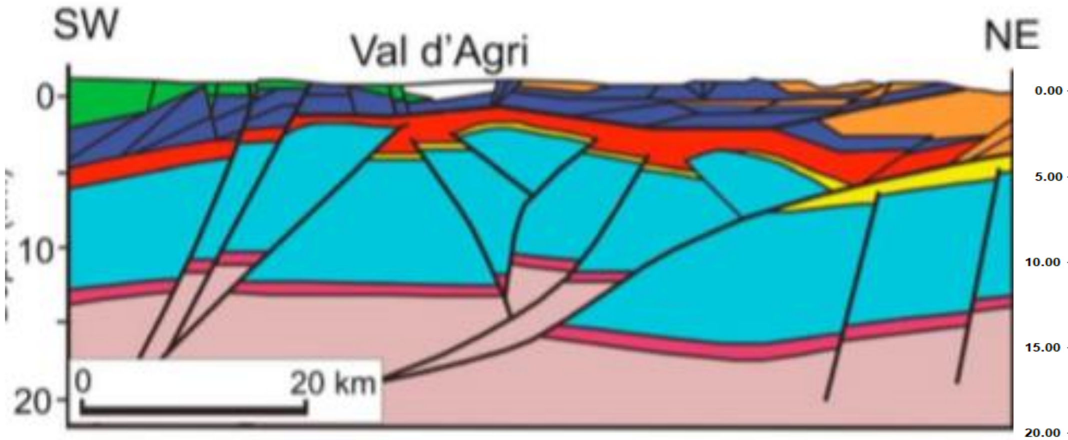


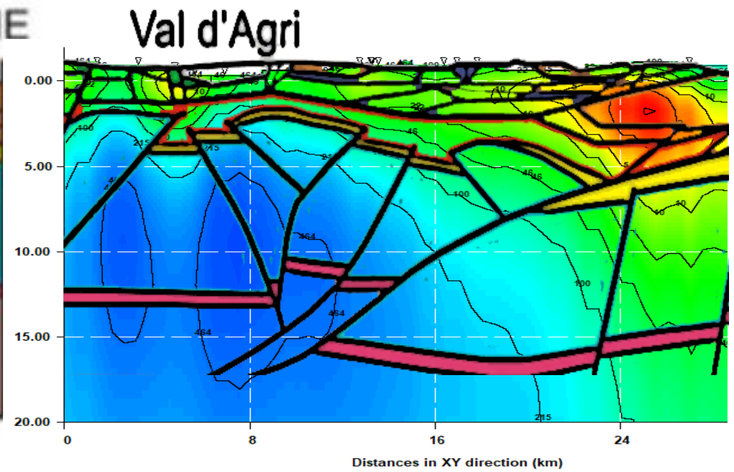
Improta et al., 2017

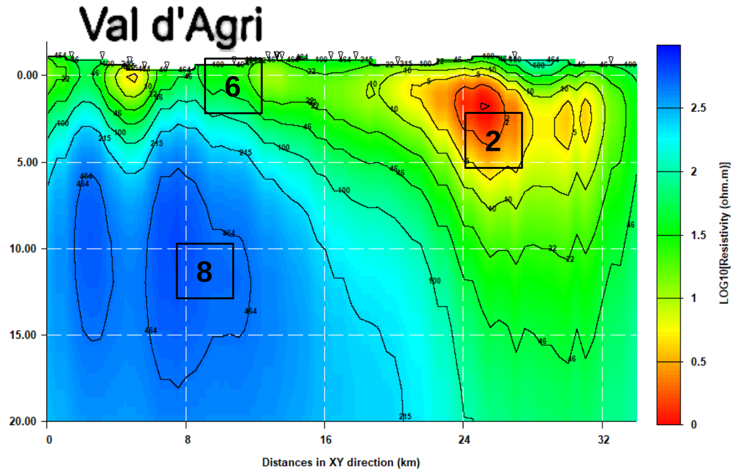


2. Flysch and terrigenous sediments of satellite basins (middle Miocene-Pliocene)
4. Mesozoic rocks of the Lagonegro Basin (mainly cherty limestones, cherts and slope carbonates; Cretaceous-lower Miocene)
5. Western Carbonate Platform (Mesozoic)

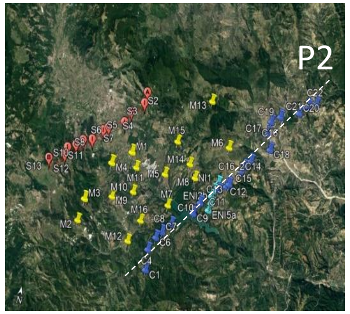
4. First interpretation of the conductivity model

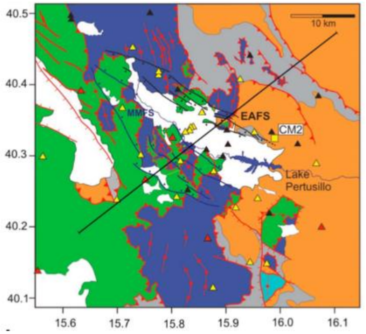


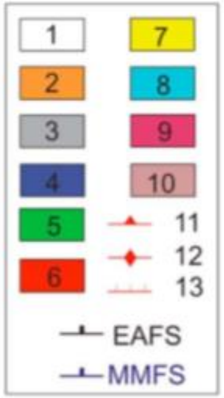




Improta et al., 2017







2. Flysch and terrigenous sediments of satellite basins (middle Miocene-Pliocene)
6. Tectonic melange zone (Miocene-lower Pliocene)
8. Inner Apulia Plataform (Mesozoic-Miocene)

5. Test Results

- *Model Mesh and Data geological-stike oriented allow to observe the resistivity bodies in depth;*
- *Full-impedance tensor inversion allow to individuate in more detail the bodies geometries in surface;*
- *Homogeneous starting model of 100 ohm·m allow to define clearly the resistivity variations in all three directions;*
- *The Covariance Model Parameter of 0.6 allow to remove the resistivity bodies in surface*
- *It is important to consider the sea effects on the deeper part of the 3D resistivity model*

6. Follow up

- *Reduce the number of MT soundings for MT data inversion, to obtain an homogenous MT array for High Agri Valley*
- *Construct a new model mesh and grid for the Homogeneous MT array*
- *Consider the MT inversion test results to obtain the High Agri Valley conductivity model*
- *Joint interpretation between MT impedance tensor inversion result and seismological data*

Acknowledgments

- *Impedance tensor inversion tests were made with ModEM parallel version, free provided by Prof. Gary Egbert, Prof. Anna Kelbert & Dr. Naser Meqbel;*
- *3D MT resistivity model visualization was possible thanks to 3D-Grid software, free provided by Dr. Naser Meqbel;*
- *MT impedance phase tensor analysis was execute with "mtphyton" code*
- *ModEM parallel version was execute on ReCas Datacenter cluster HPC of National Institute of Nuclear Physics, Bari University.*

Thank you for your attention