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ENERGIA DALLA TERRA

Shallow Geothermal Exploration by Means of SkyTEM Electrical Resistivity Data: An Application in Sicily (Italy)

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Programma Operativo Interregionale
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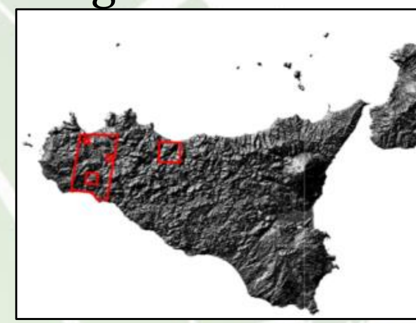
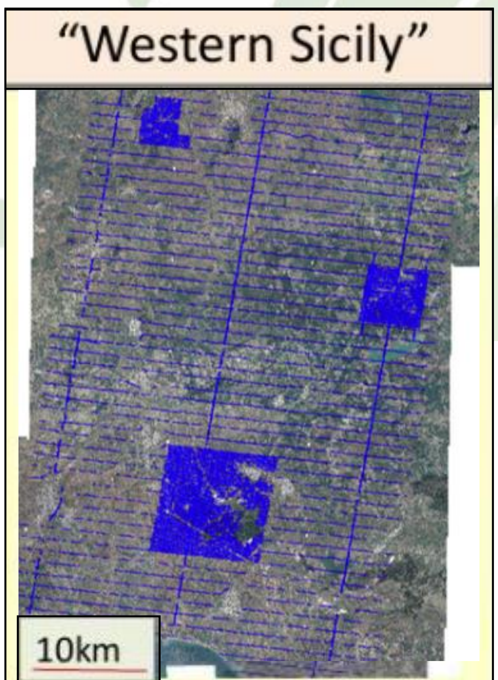
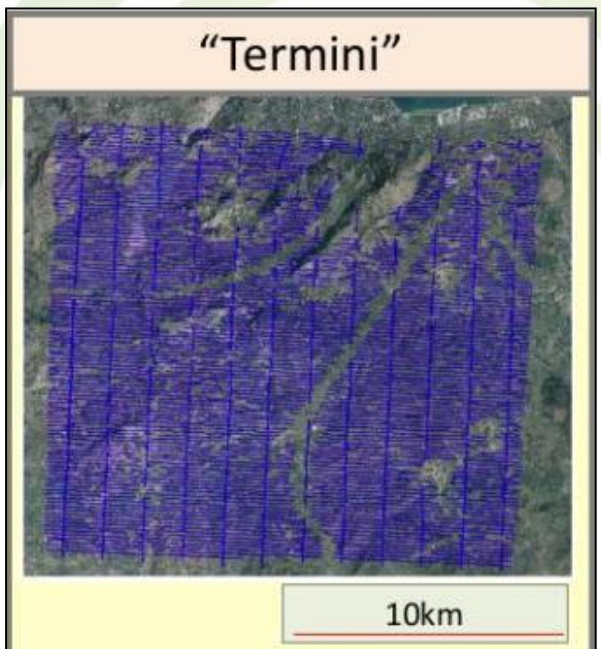
WHAT :
AEM METHOD FOR THE STUDY OF SHALLOW GEOTHERMAL RESOURCES

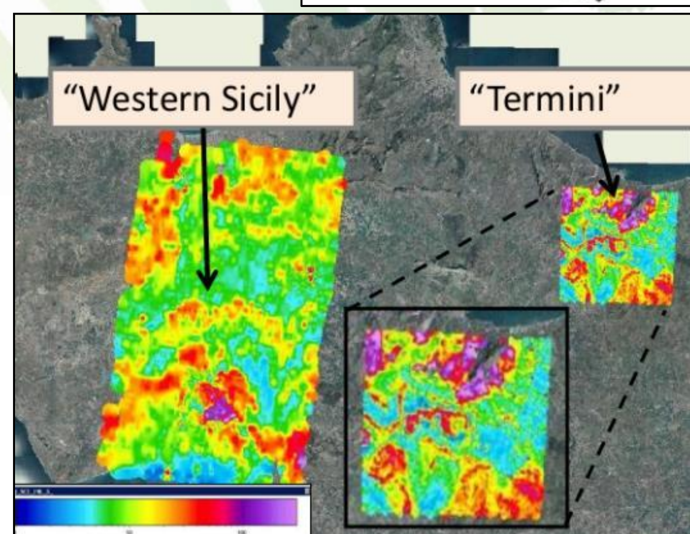
As part of planned geophysical activities in the VIGOR Project, **Airborne EM** survey has been carried out in Sicily, in late 2011, on two test sites:

- Investigated area ~1500 km² for Western Sicily and 300 km² for Termini site;
- 150 m flight line spacing for Termini Site;
- 1 km flight line spacing for regional scale in Western Sicily and 100 m flight line spacing for infill areas around main thermal springs (“Montevago”, “Calatrasi” and “Terme Segestane”).

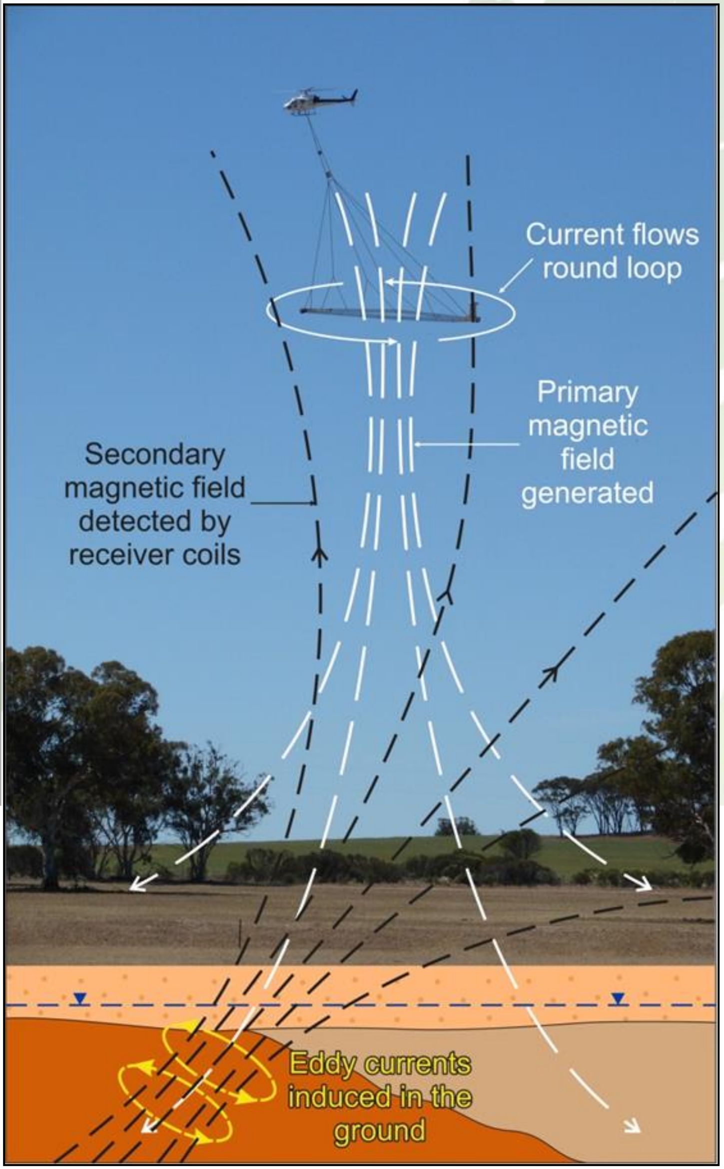








AEM METHOD FOR THE STUDY OF SHALLOW GEOTHERMAL RESOURCES

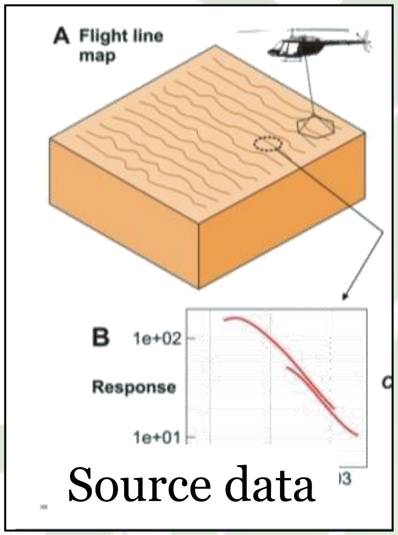


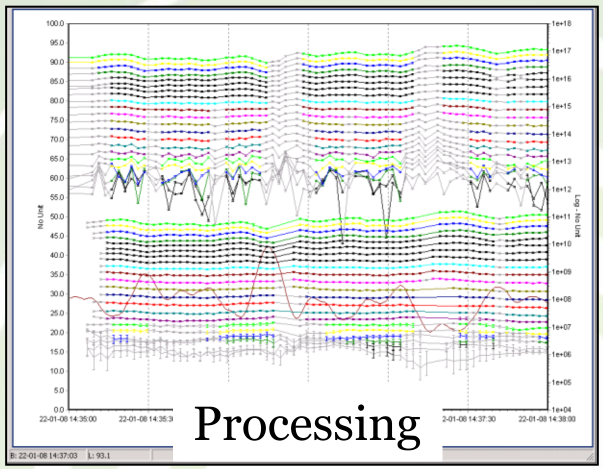
SkyTEM is a time-domain helicopter electromagnetic system:

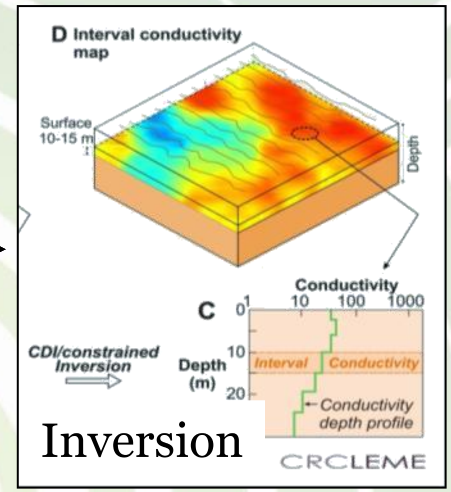
- $314\ m^2$ eight-sided loop transmitter:
  - ❖super low moment (SLM) is about 10 A
  - ❖high moment (HM) is approximately 112 A
- The z-component receiver loop is placed 2 m above the frame measuring continuously;
- 4580 line km of data and up to $1800\ km^2$ have been explored;
- Investigation depth up to few hundred meters.

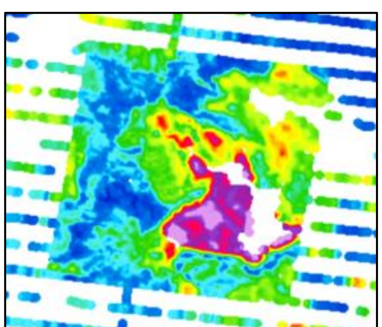
AEM DATA AND RESULTS FROM TERMINI AND MONTEVAGO SITES

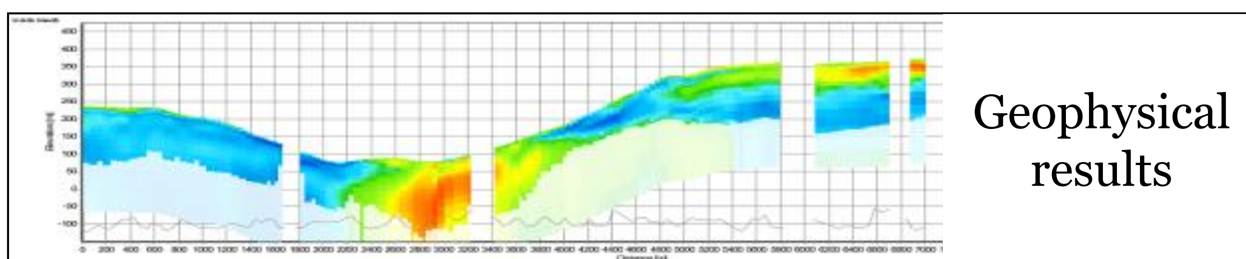
- The geophysical results are composed by 3D cell distribution of resistivity (X,Y,Z, ρ). Resistivity slice maps (both in depth and elevation a.s.l.) and resistivity cross-sections have been drawn from both smooth (multilayers) and blocky (few layers) models.





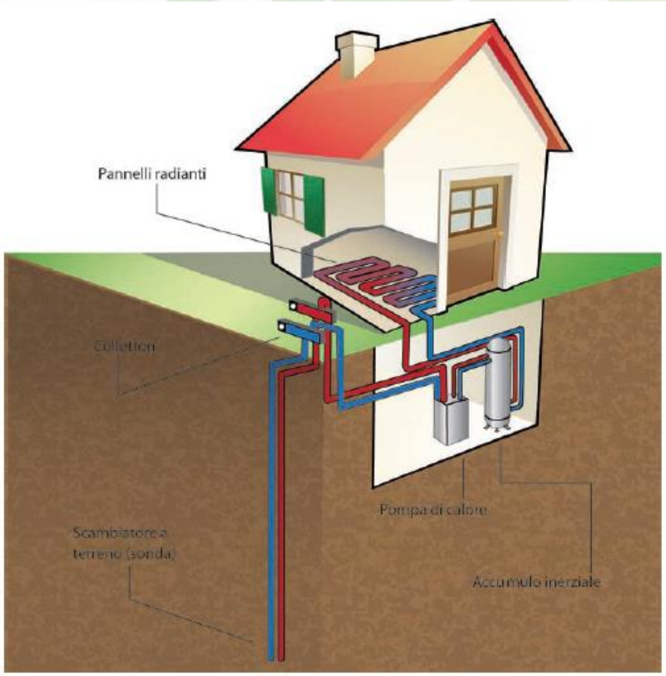






AIM OF THE STUDY

We attempted to provide information about one of the main parameters to design a closed loop GSHP system: the thermal conductivity of rocks.
A novel procedure for estimating the geothermal energy exchanged by a unit volume was tested in Sicily (Italy), where public well data were insufficient.
The results are the heat exchange potential maps for the studied areas.



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WORKFLOW FOR SHALLOW RESOURCE ASSESSMENT

Integrated analysis of resistivity and geological-lithological data (on surface)

Picking out the resistivity values and definition of Litho-Electrical (LE) Units

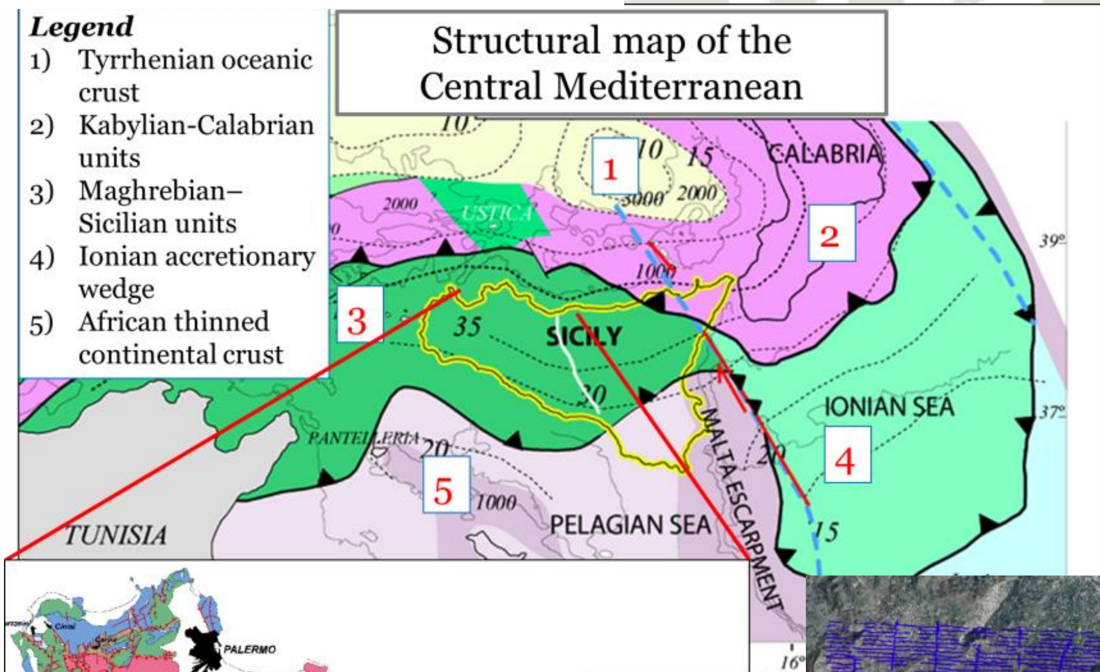
3D Geological modeling of LE Units based on resistivity volume distribution and geological data

Characterization of rocks thermal properties by lab measurements on samples

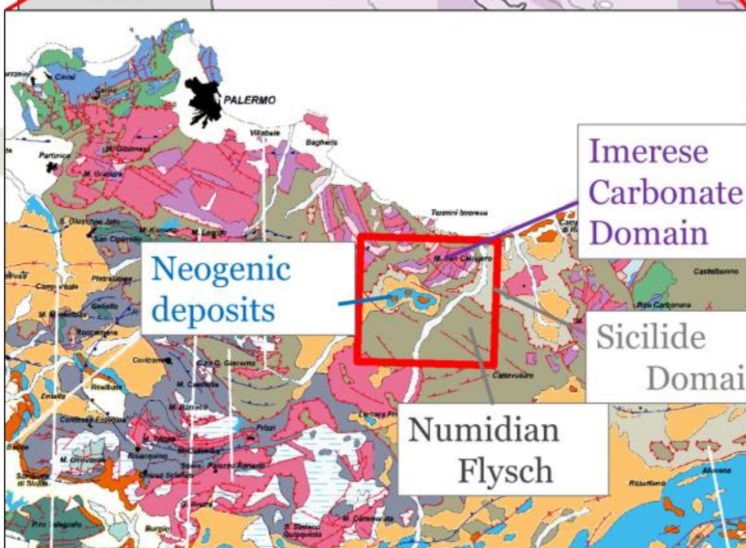
Assessment of the heat exchange potential for "direct uses" using an algorithm developed by CNR-IGG of Padova (Italy)

THE TERMINI IMERESE CASE STUDY- Geological framework

modified from Accaino et alii 2011

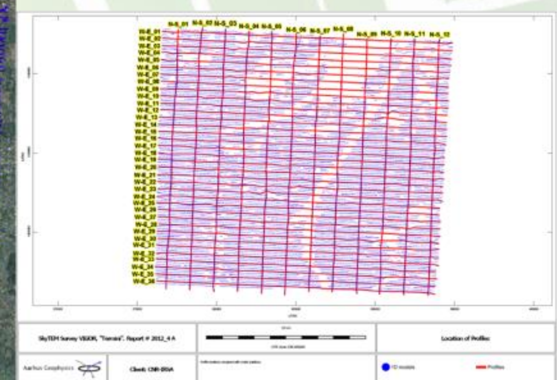


The area (300 km²) belongs to the Apenninic-Maghrebian Chain along the convergent plate boundary between Africa and Eurasia. This segment of Sicily FTB has a very complicated structural setting.



modified from Catalano et alii 2000

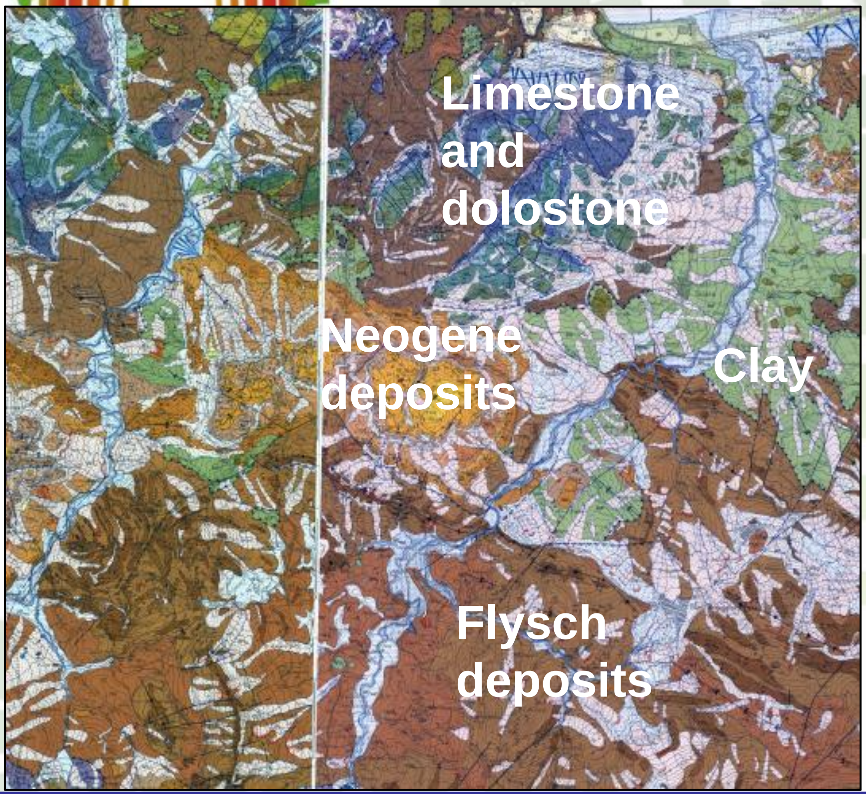
Flight lines

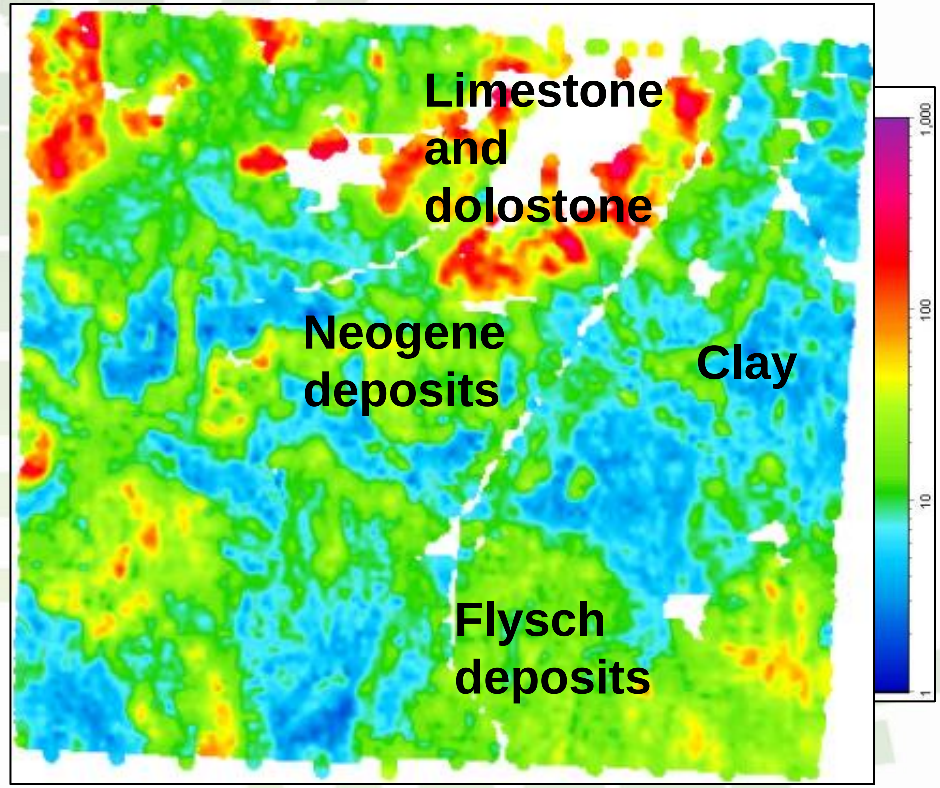


Resistivity cross-sections

THE TERMINI IMERESE CASE STUDY- LE Units

Geological map modified from Catalano et alii 2010-2011

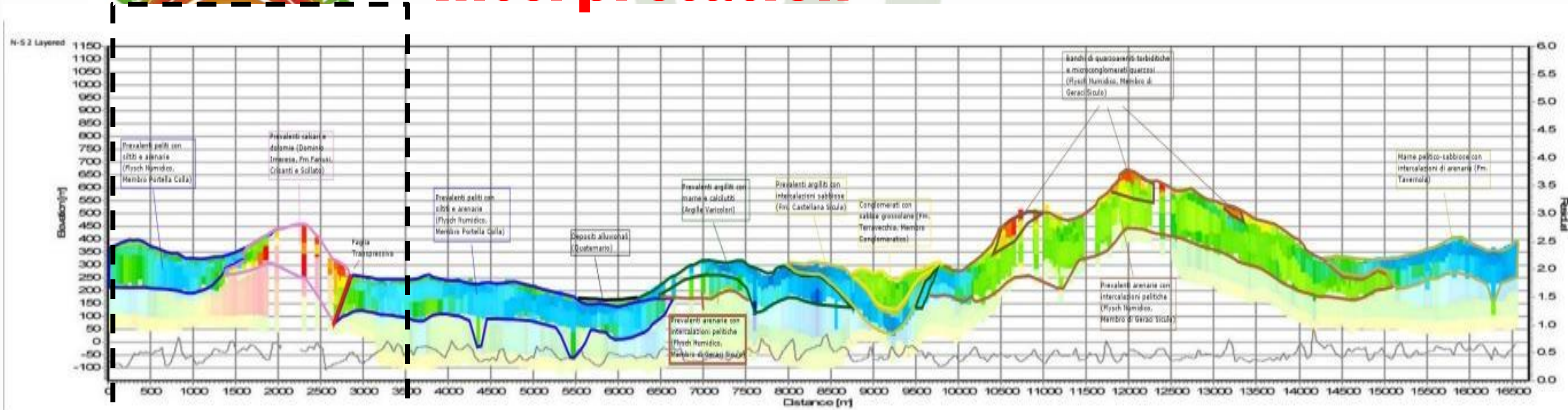


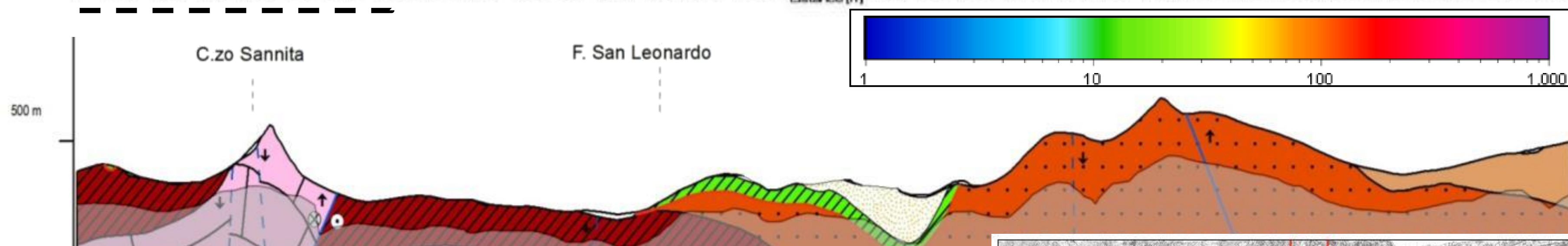


Seven LE units (after geology and resistivity surface maps comparing):

- **Quaternary deposits** (from < 10 ohm/m to > 50 ohm/m)
- **Neogene deposits** (from 10 ohm/m to > 100 ohm/m)
- **"Sicilide" Domain** (mainly <10 ohm/m)
- **Tavernola Fm** . (mainly <10 ohm/m)
- **Numidian Flysch GS member** (10 to 50 ohm/m)
- **Numidian Flysch PC member** (5-30 ohm/m)
- **"Imerese" Carbonate Domain** (80-1000 ohm/m)

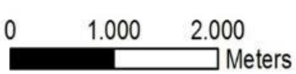
THE TERMINI IMERESE CASE STUDY- Interpretation



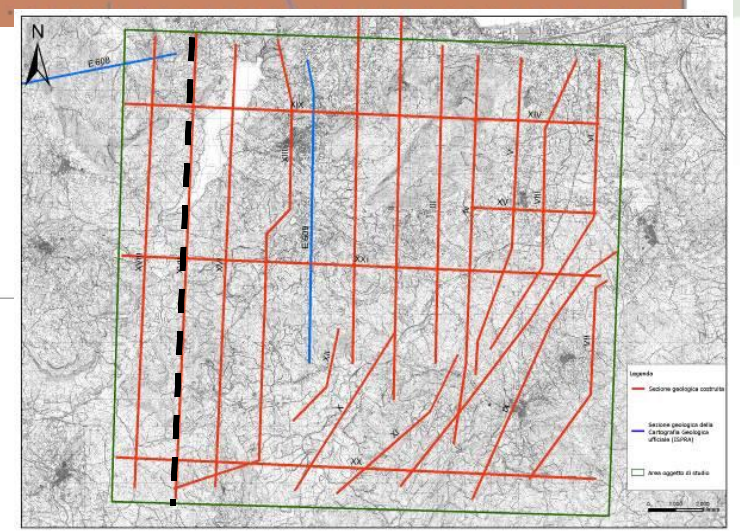


Legend

Quaternary deposits	Tavernola Fm. (Miocene)	Imerese domain (Triassic-Oligocene)
Neogenic deposits	Numidian Flysch, Geraci Siculo member (Miocene)	Depth of investigation of SkyTEM survey
Sicilide domain (Cretaceous-Eocene)	Numidian Flysch, Portella Colla member (Oligocene-Miocene)	



XVII cross-section

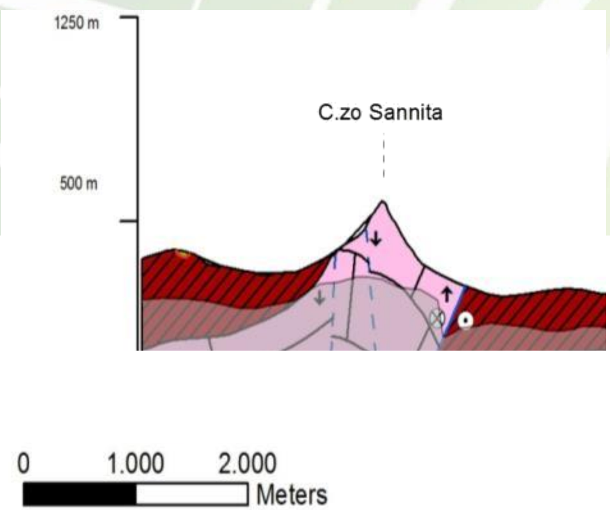


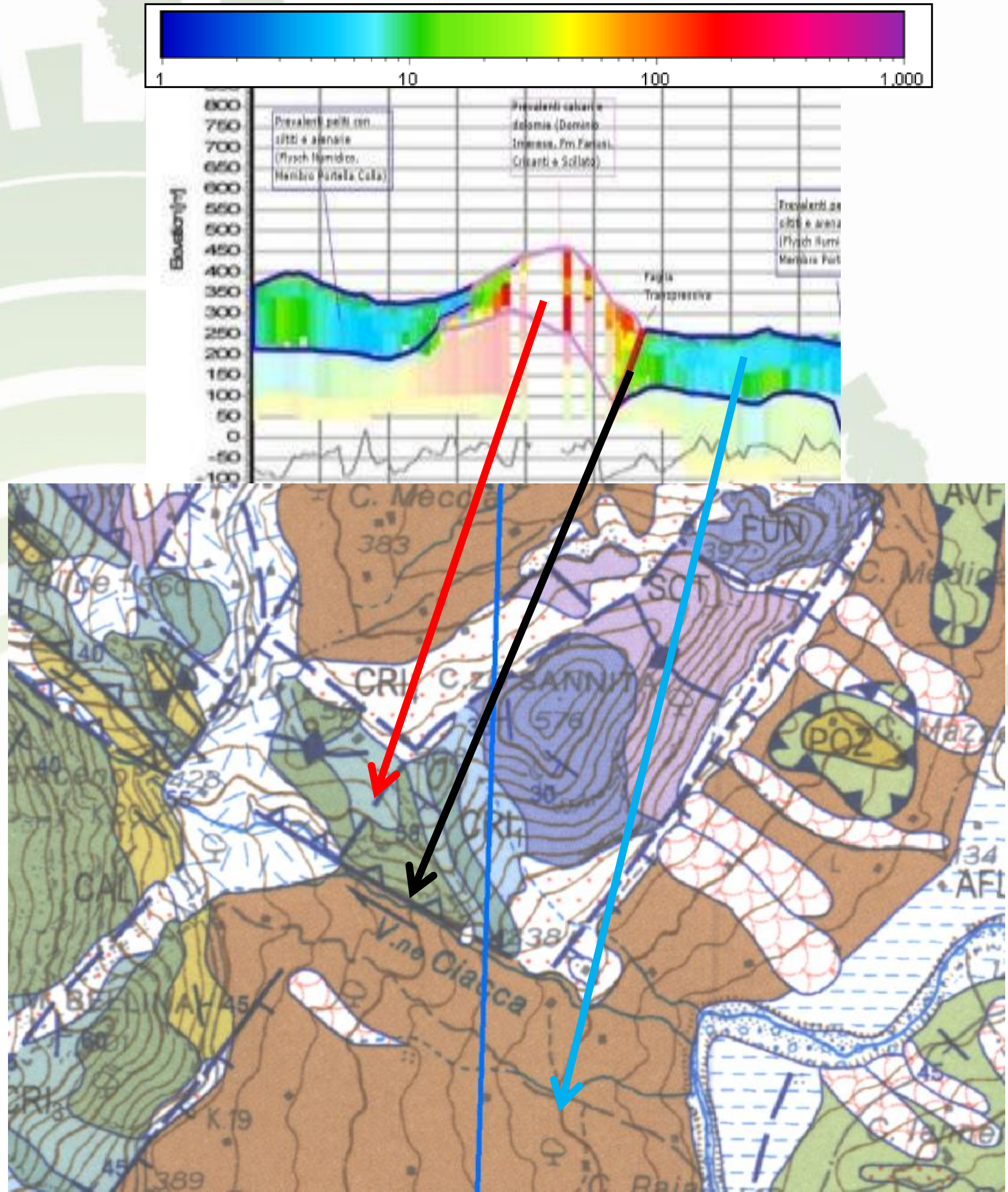
THE TERMINI IMERESE CASE STUDY- Interpretation

Mainly limestones and dolostones (Imerese domain)

Mainly pelites with sandstones (Numidian Flysch, PC member)

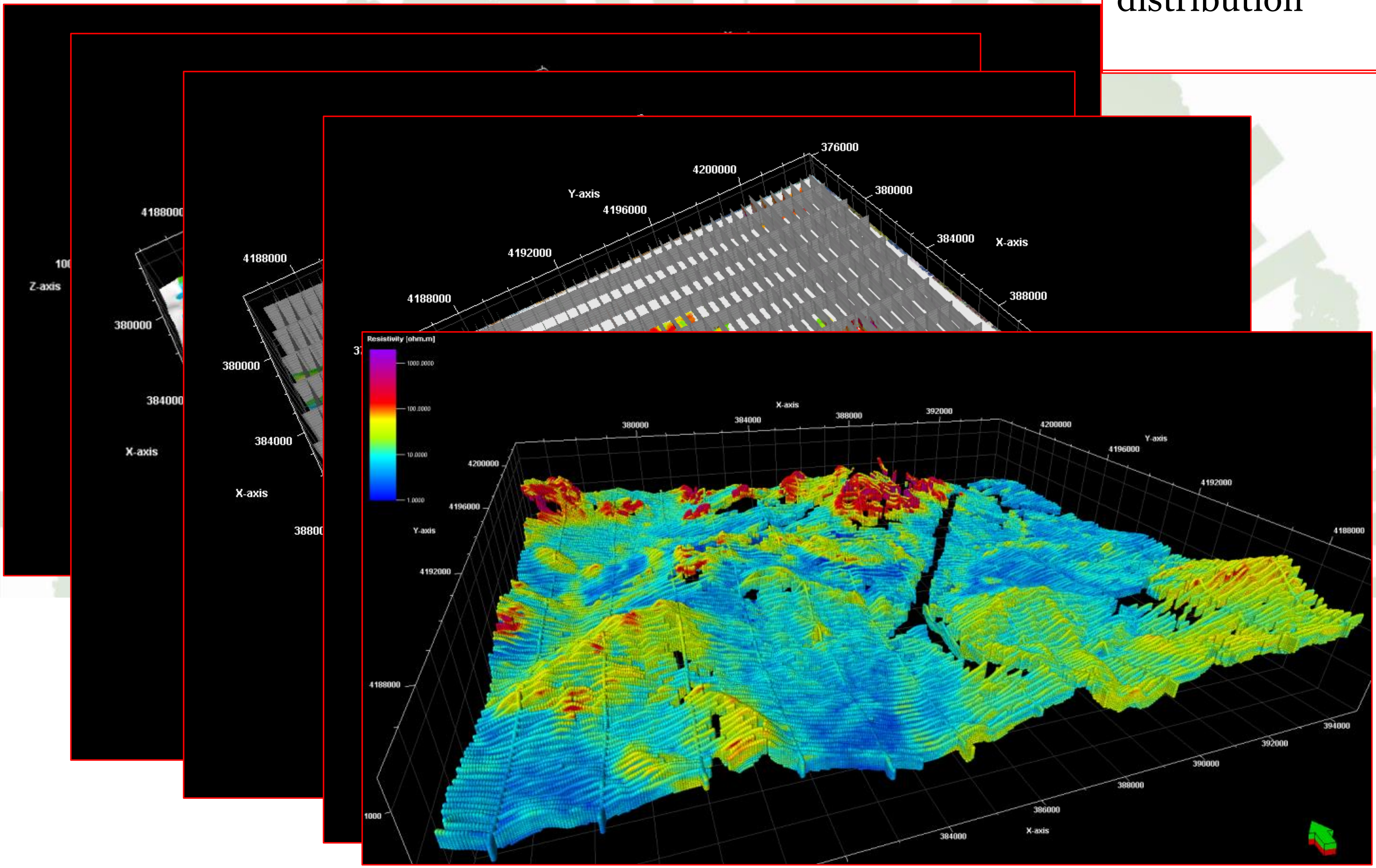
Tranpressive fault





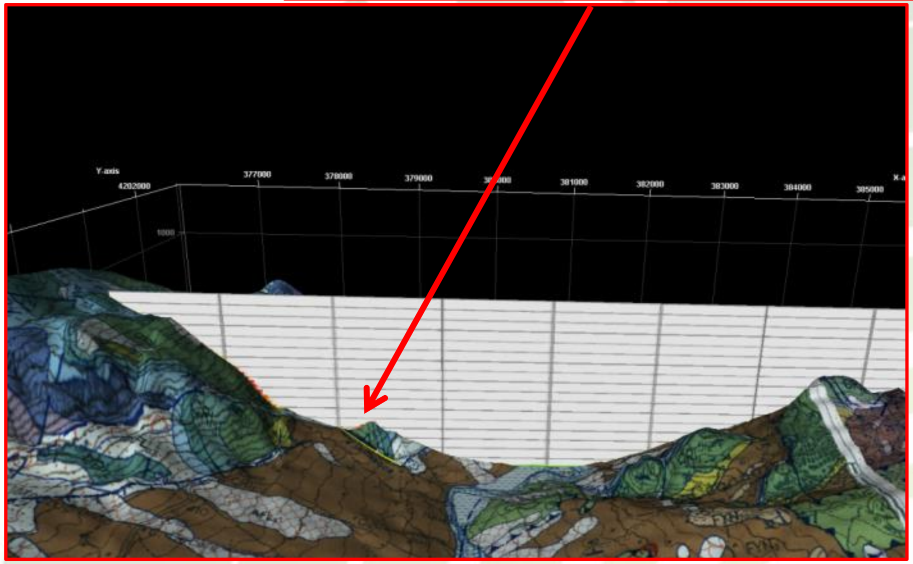
THE TERMINI IMERESE CASE STUDY- 3D Geological Modeling

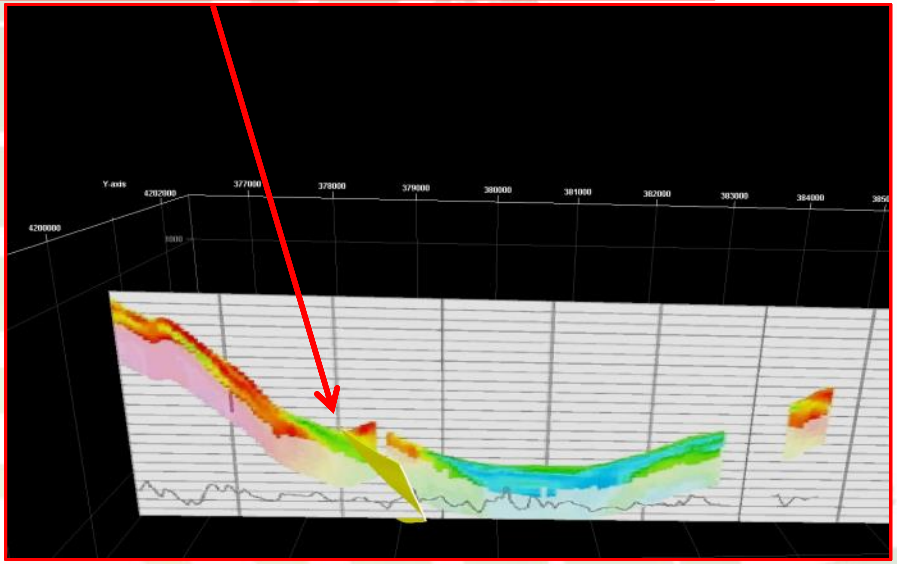
Resistivity 3D distribution

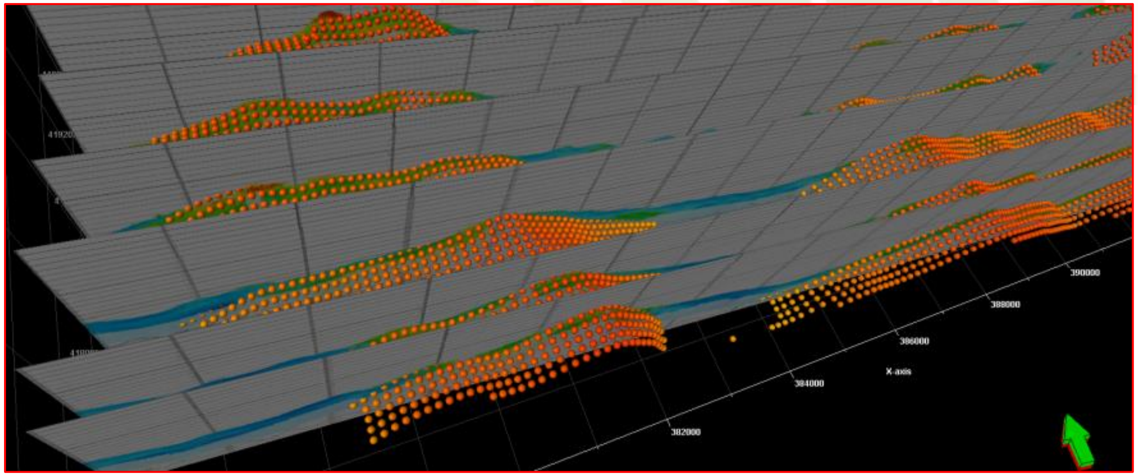


THE TERMINI IMERESE CASE STUDY- Structural Framework

1- Structual framework, an example:

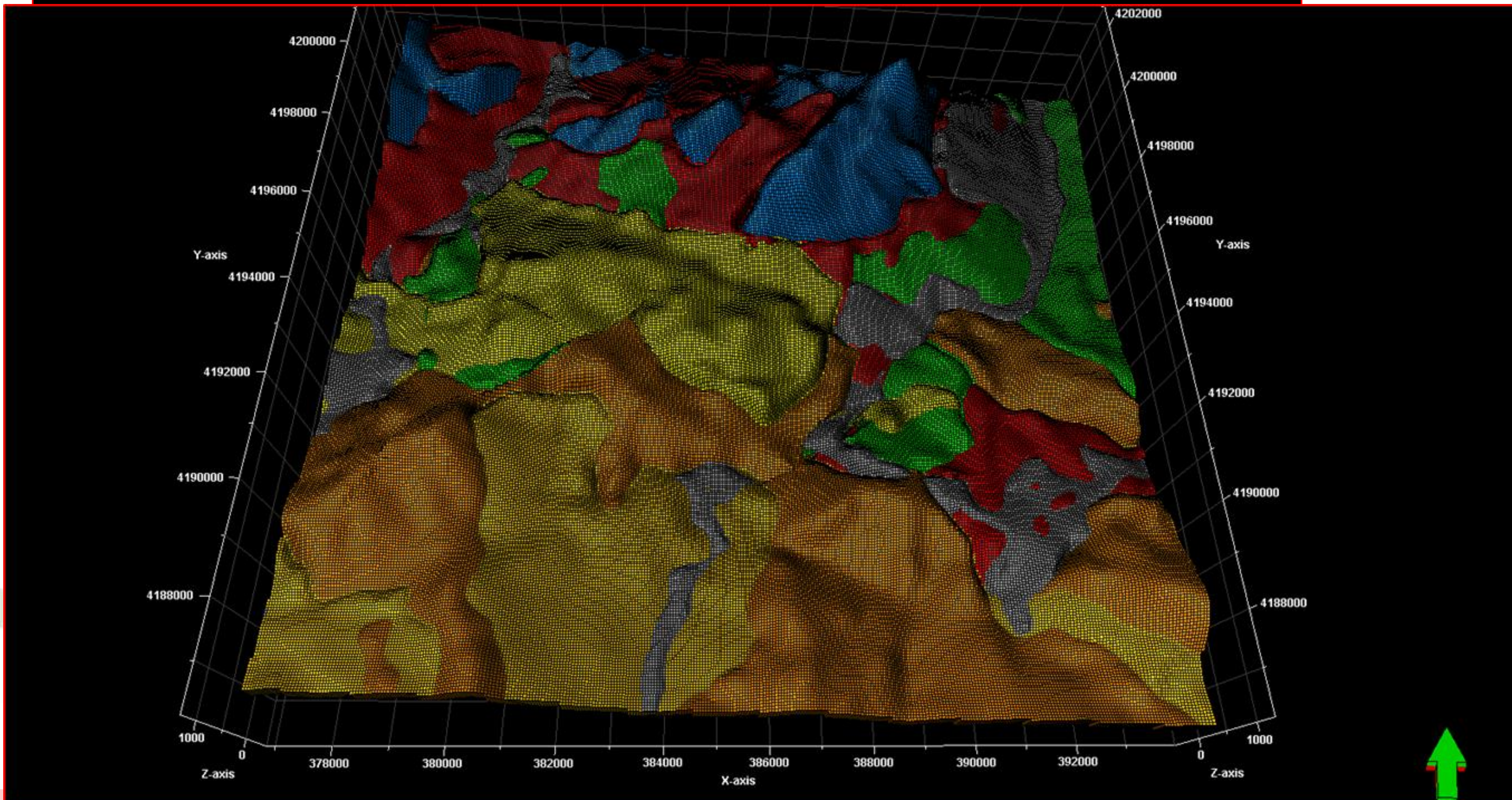






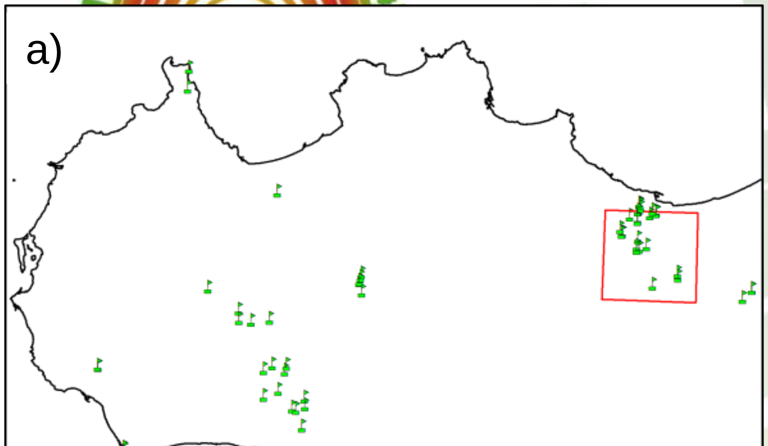
2- Horizon modeling (Top of LE)

THE TERMINI IMERESE CASE STUDY- Structural gridding

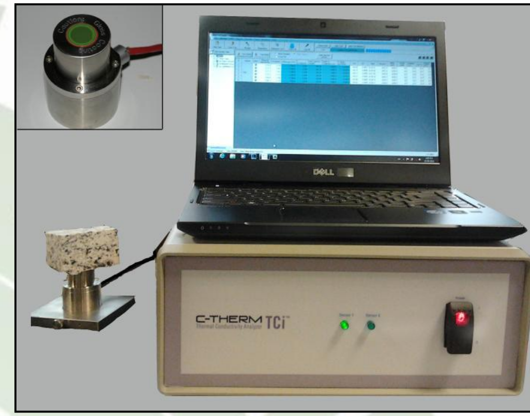


50 m horizontal resolution	Neogene Deposits (Miocene-Pliocene)	Tavernola Fm. (Miocene)	Numidian Flysch PC member (Oligocene-Miocene)
Quaternary Deposits	Sicilide Domain (Cretaceous-Eocene)	Numidian Flysch GS member (Oligocene-Miocene)	Carbonate Imerese Domain (Triassic-Oligocene)

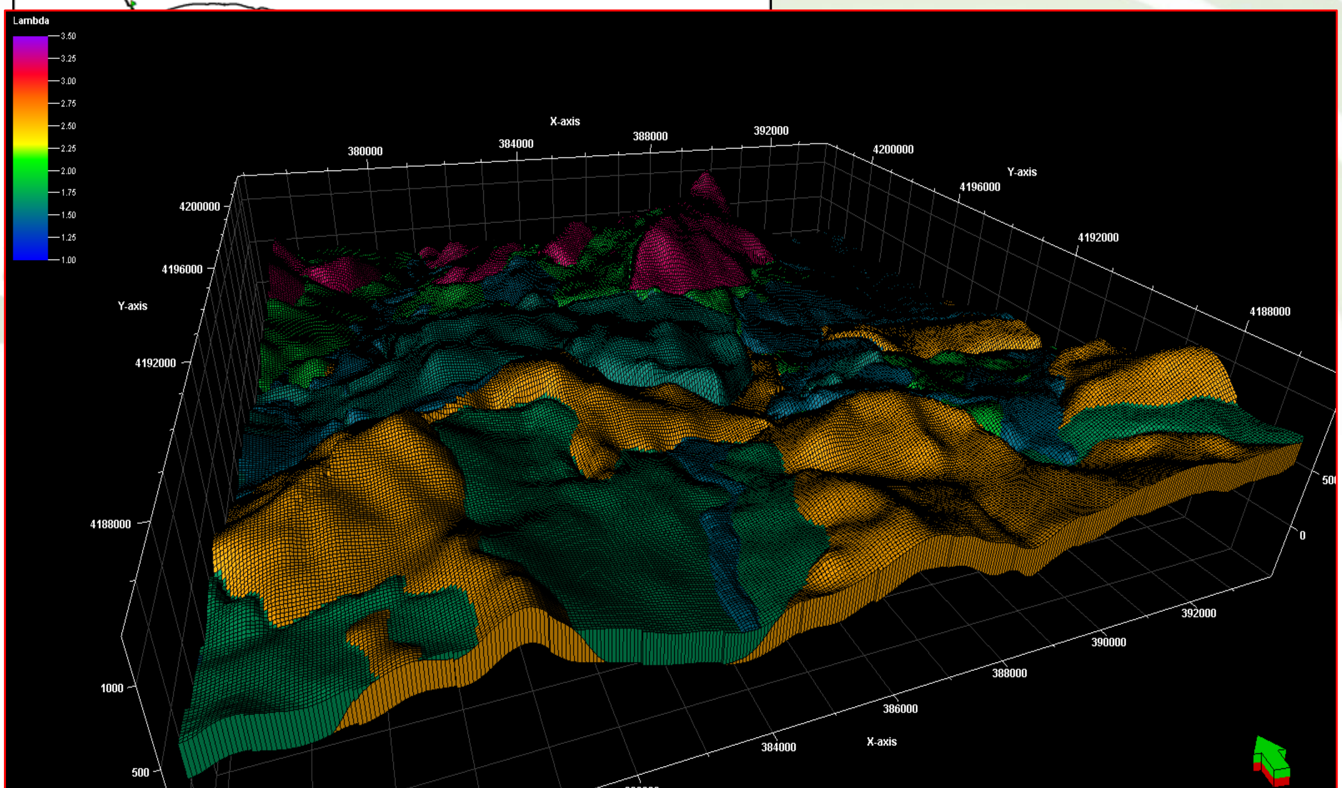
THE TERMINI IMERESE CASE STUDY- Thermophysical Parameters Modelling



a) Rock samples for thermal conductivity measurement. b) Thermal conductivity analyzer (C-Therm TCi) (from Di Sipio et al., 2013)

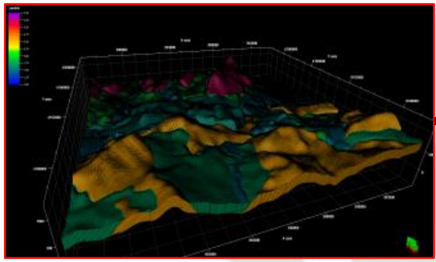


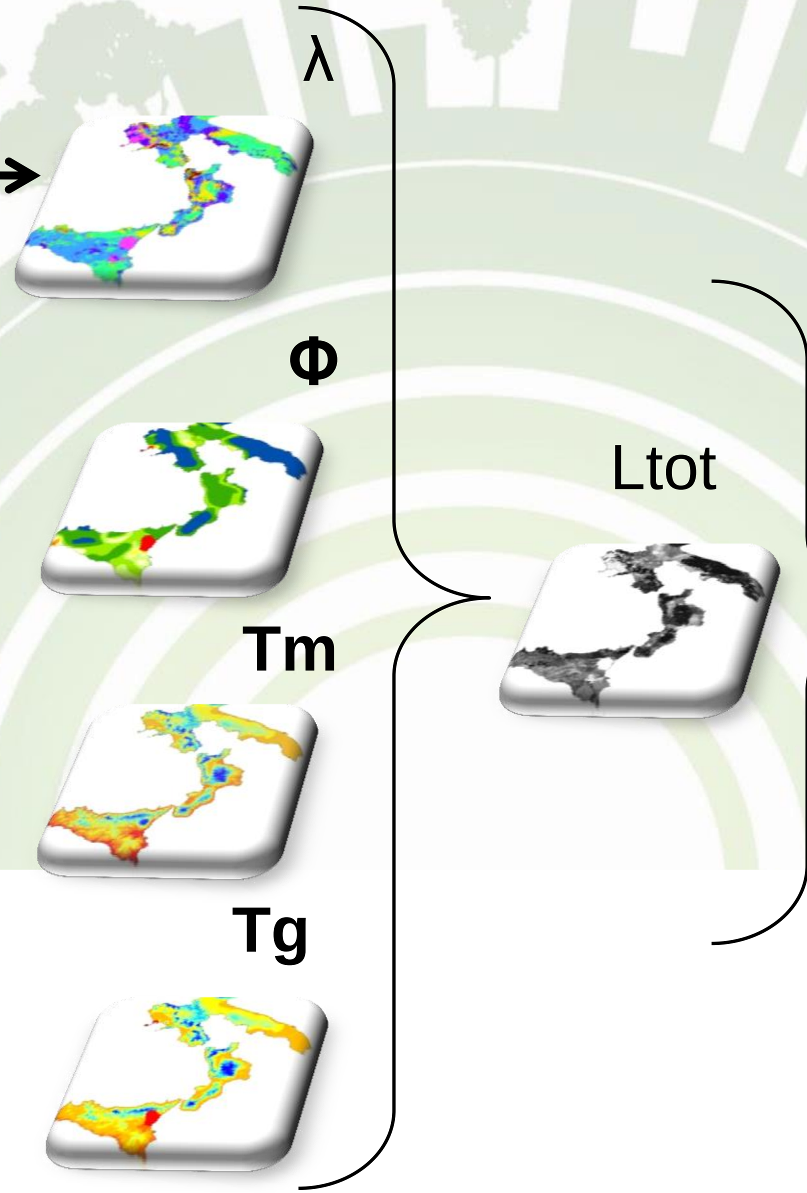
b)



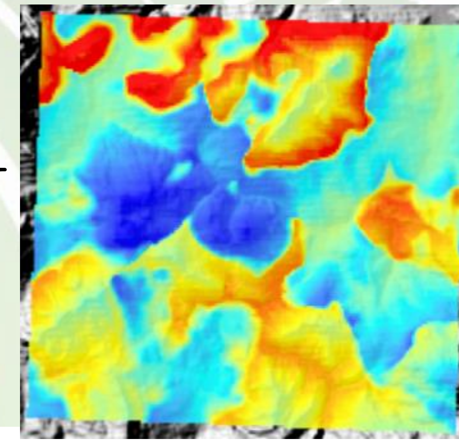
3D model of «λ» thermal conductivity (costant value for each LE unit)

THE TERMINI IMERESE CASE STUDY- GEOTHERMAL APPLICATION





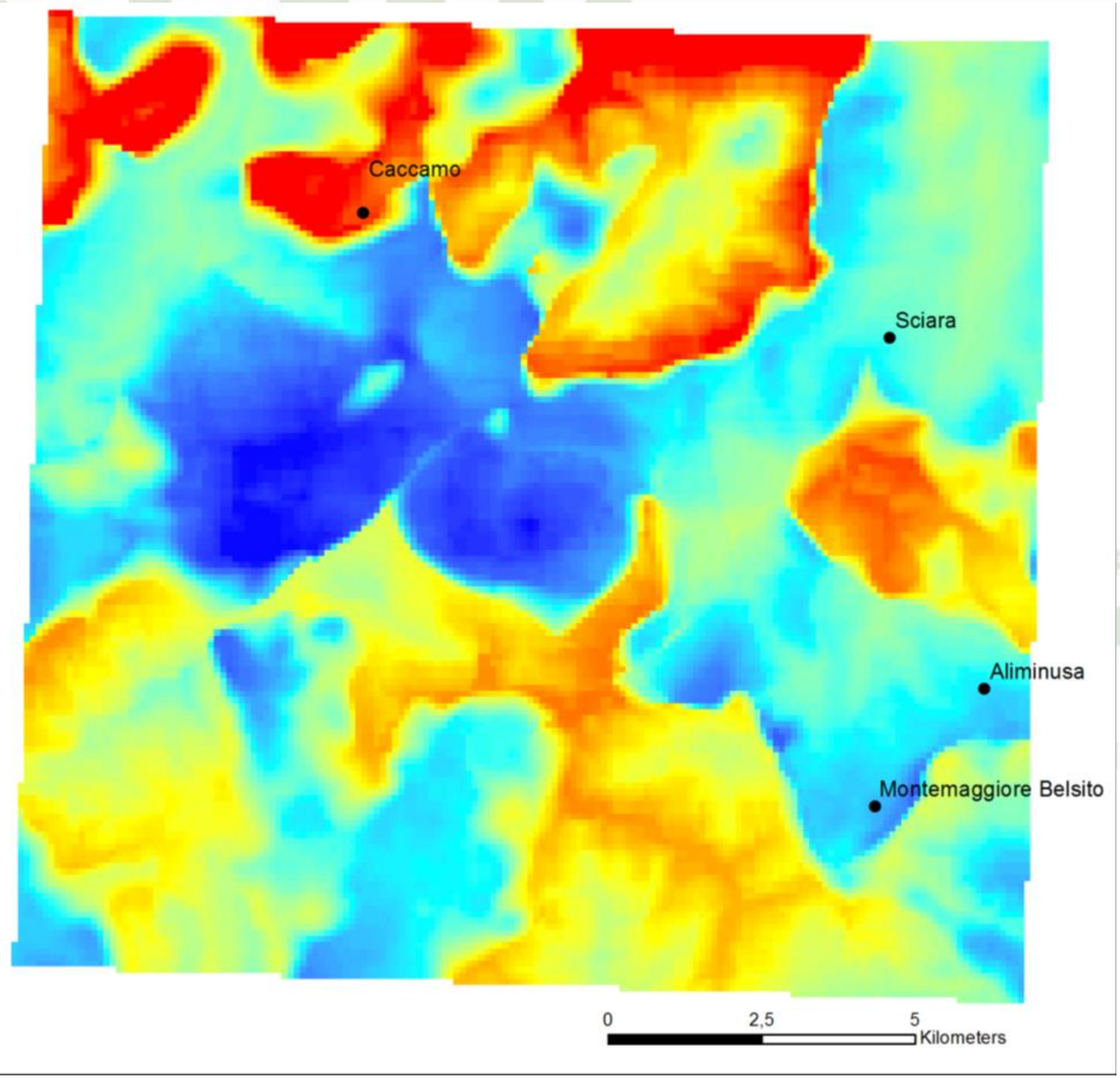
Thermal energy that can be exchanged by a unit volume of ground for a reference GSHP plant



The final activity of the proposed workflow is the evaluation of the heat exchange potential based on the 3D thermal conductivity distribution using a algorithm developed by CNR-IGG of Padova (Italy)

HEAT EXCHANGE POTENTIAL

Termini Test Site



Value kWh/m²

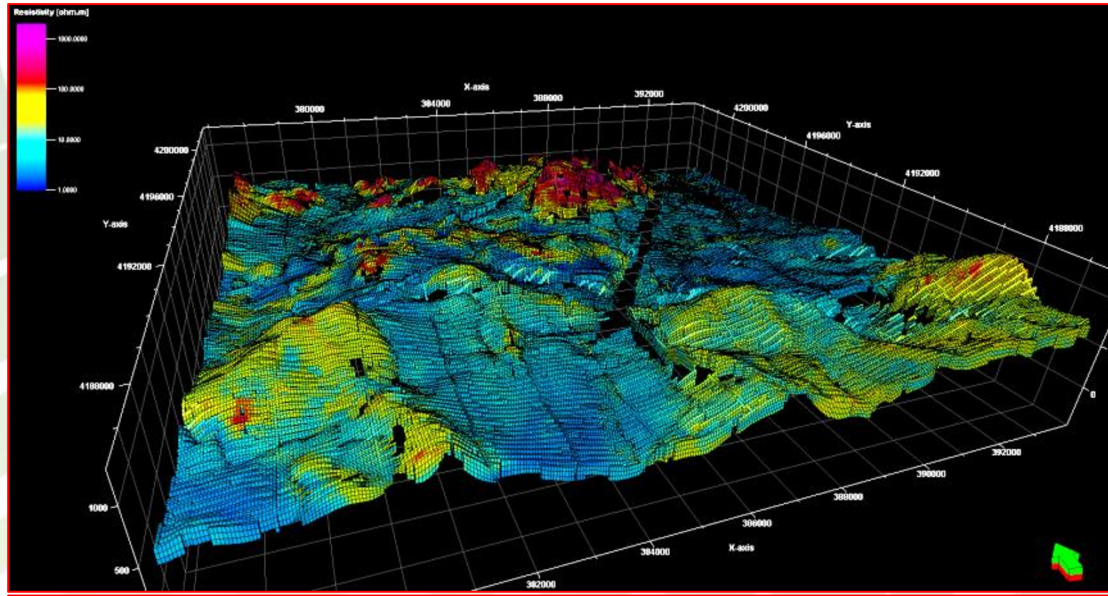
High : 127,659

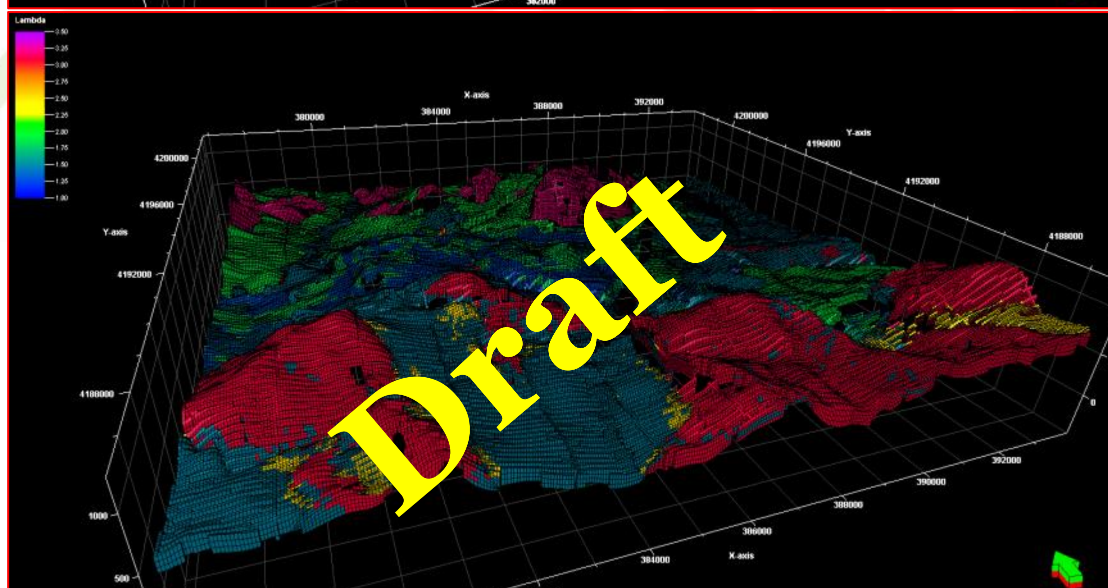
Low : 73,4862

WORK IN PROGRESS- Petrophysical Modeling

Relation between thermal conductivity and electrical resistivity

- Without the geological information, it is very hard to define this relation (e.g. in Termini model a very high resistive value could be related to limestone, quartz-arenite, gypsum etc...).
- Once the 3D geological model is built we are able to assign for each cell a geological information (LE Unit) and a resistive value allowing us to perform a simple algorithm to obtain a thermal conductivity values for each cell.





CONCLUSIONS

- Good match between resistivity and geological properties on a wide area characterized by a very complex geological setting (Sicilian FTB);
- The geo-exchange map provides a clear picture of the areas where heat exchange is favoured by geological conditions;
- Unlike the other sites, in Termini area we have not identified conductive anomalies in the carbonate geothermal reservoir ;
- We will improve the heat exchange potential maps using a detailed thermal conductivity distribution obtained by the petrophysical modeling;
  - **The 3D geological models and the maps of heat exchange potential (for Termini, Montevago, Calatrasi and Terme Segestane areas) will be freely available on the VIGOR WebGIS at http://www.vigor-geotermia.it/geo-portal/**

Thanks

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