RETRACE-3D

centRal italy EarThquakes integRAted Crustal modEl

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[3]*Dipartimento della Protezione Civile,* [4/5]*Consiglio Nazionale delle Ricerche (IGAG and IREA)*
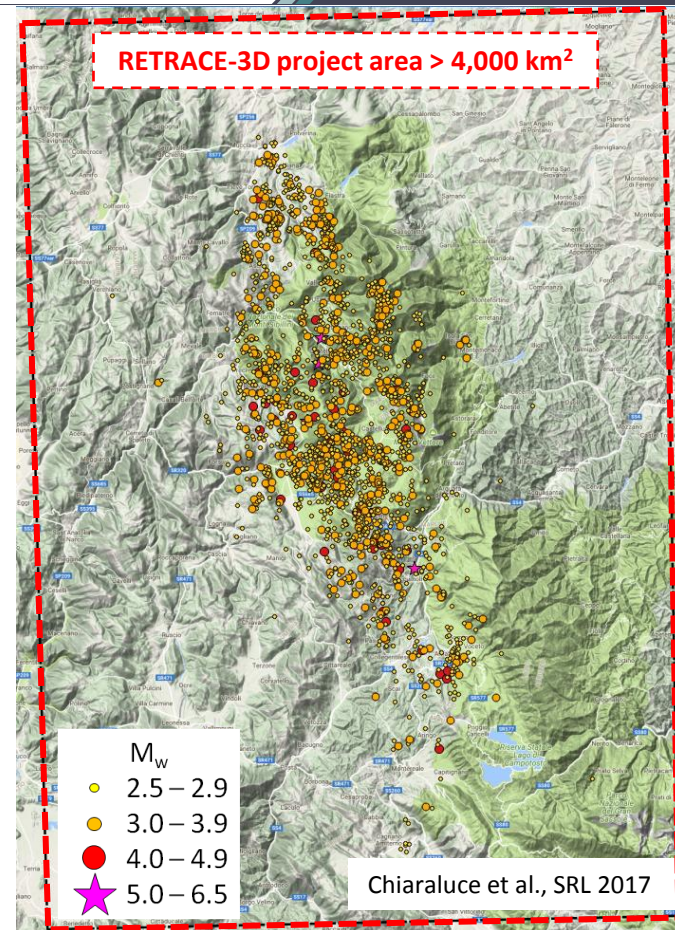
RETRACE-3D is a collaborative project

to develop a robust and broad consensus 3D crustal model of the area struck by the Central Italy seismic sequence (2016/2017)

blending in a synergic way the multi-disciplinary skills of CNR (IGAG and IREA), INGV and ISPRA (Servizio Geologico d'Italia) and associated researchers
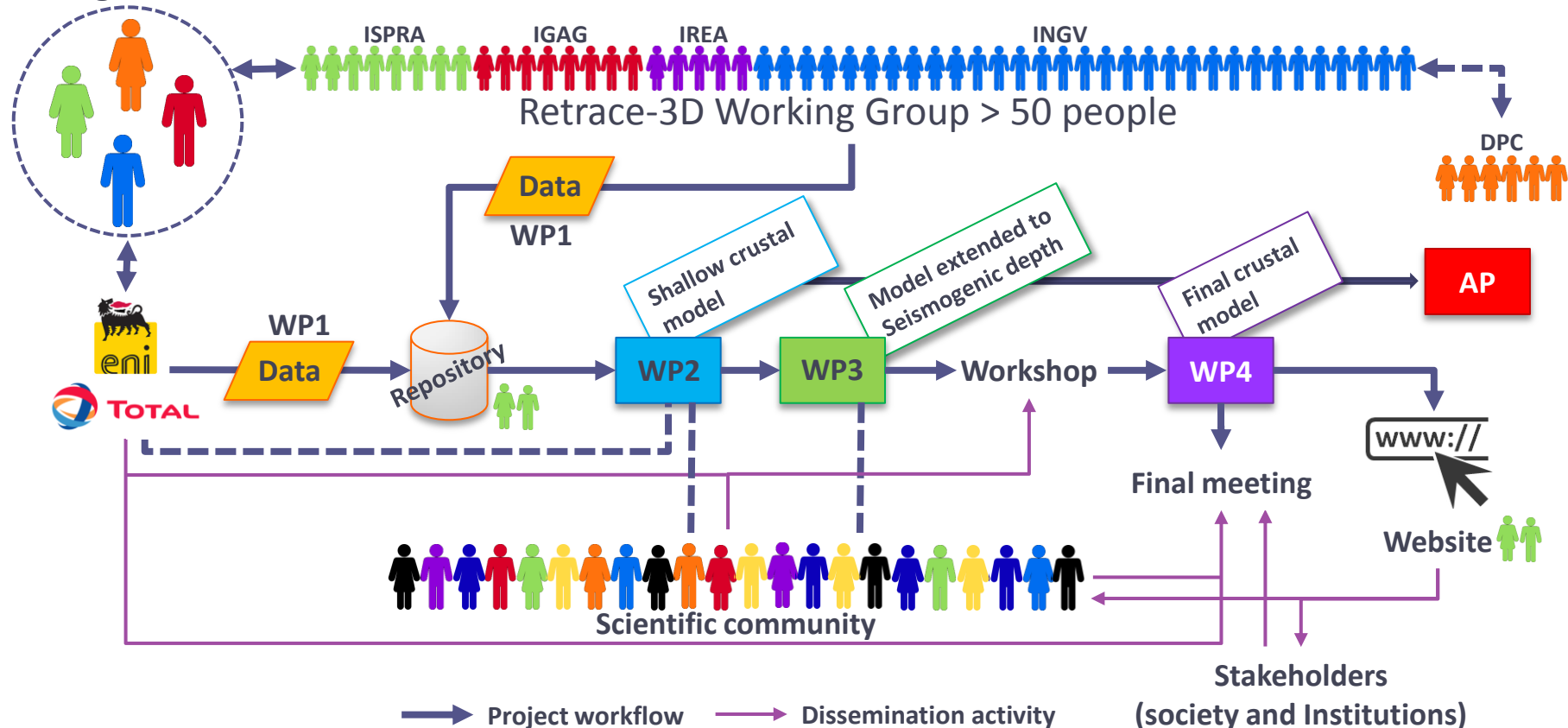
the coordination has been actively promoted by the National Department of Civil Protection

RETRACE-3D project area > 4,000 km²

M_w
- 2.5 – 2.9
- 3.0 – 3.9
- 4.0 – 4.9
- 5.0 – 6.5

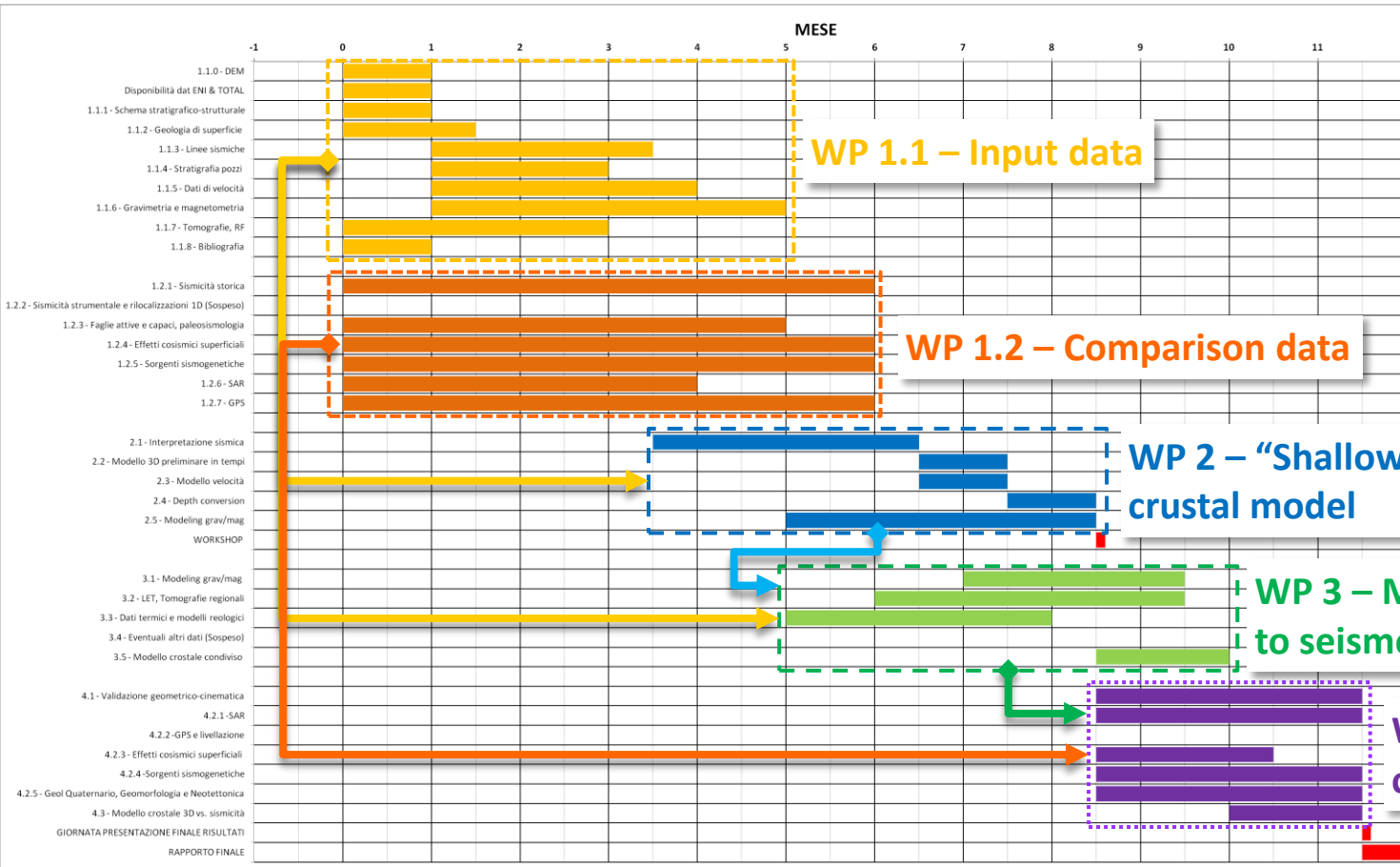Chiaraluce et al., SRL 2017

The main aims of the project are:

i)   to build up a **<u>high quality 3D model</u>** of the possible seismogenic sources in the crustal volume affected by the seismic sequence;

ii) to define the 3D subsurface tectonic setting and distribution of the geologic units, which will contribute in their turn to **<u>improve the velocity models</u>** currently used to locate the seismicity, and to better understand the potential role played by structural features inherited from previous tectonic regimes;

iii) to develop **<u>dynamic models of seismogenic structures through multi-parameter optimization of ground deformations from remote sensing data</u>**.
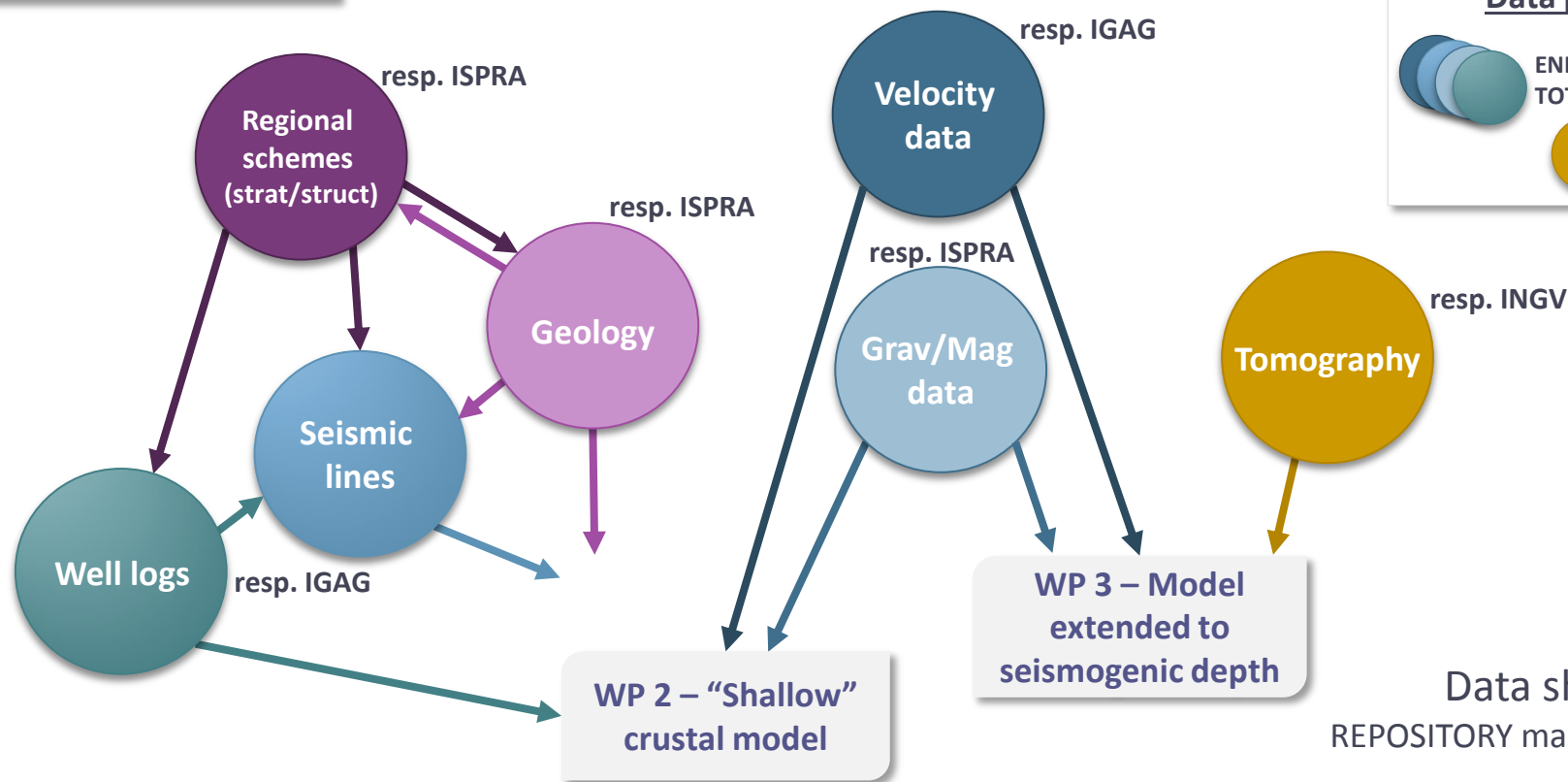
Input data preparation - Harmonizing the contents
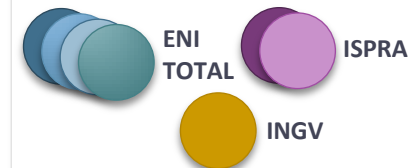
Literature, geological maps, deep boreholes

Unit code	formations	HORIZON code	Transizione Reatini	Transizione Gran Sasso	Pelagica Umbra	Pelagica Marchigiana
MIO-PL	Laga	UMH		500		max 3000-3500
EO-MIO	Marne a Pteropodi		800	300-800	250-700	250 (nord) – 1000 (sud)
	Marne con Cerrogna					
	Bisciaro					
	Scaglia Cinerea	VAS				
C-EO	Scaglia (B+R+V)		250-400	200-650	350-600	350-550 (750 Campotosto1)
	Marne a Fucoidi	FUC				
J-C	Maiolica		1150-1500	600-1500	500-1200	350 (550 Varoni 1)
	Diaspri/Filaments					
	Marne M.te Serrone	RSN				
	Corniola					
J	Calcare Massiccio	MAS / BUR	700-1000	700-1000	700-1000	700-800
TR	Dolomie/Evaporiti			600 (dolomie)	>1400-2000 (Perugia 1 - S.Donato)	>1700 (Burano 1)
	Basamento	BAS				

	Settore A	Settore B	Settore C
LAG3		500 lobes	600 lobes
LAG2	300 channels	700-1100 channels 300-1000 lobes	800 lobes
LAG1	200-400 channels	250-1000 channels 100-1500 lobes	600 lobes

data from Milli et al., 2009

Seismic interpretation

The reference schemes
a common language for a heterogeneous community

Geol Map It 1:100k   Geol Map It 1:50k   Literature

successione pelagica marchigiana - C
successione pelagica umbra
successione pelagica marchigiana - B
successione pelagica marchigiana - A
successione transizione Mti Reatini
successione transizione Gran Sasso
successione piattaforma
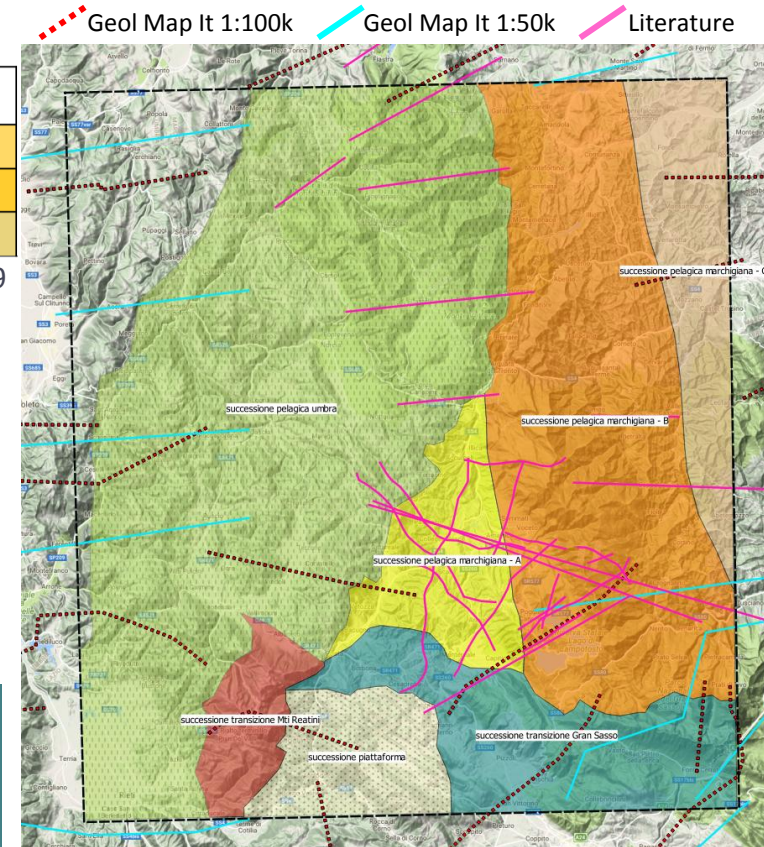
Input data preparation – surface geology
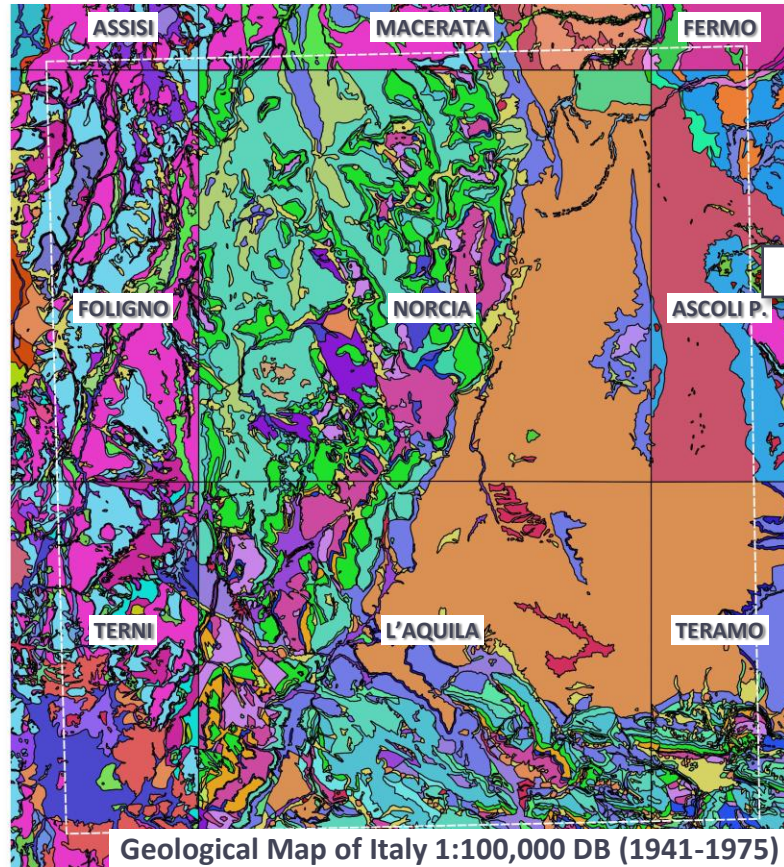
Harmonization according to Retrace-3D scheme

Unit code	formations
MIO-PL	Laga
EO-MIO	Marne a Pteropodi
	Marne con Cerrogna
	Bisciaro
	Scaglia Cinerea
C-EO	Scaglia (B+R+V)
J-C	Marne a Fucoidi
	Maiolica
	Diaspri/Filaments
	Marne M.te Serrone
	Corniola
J	Calcare Massiccio
TR	Dolomie/Evaporiti
	Basamento

Geological Map of Italy 1:100,000 DB (1941-1975)

Reclassified geological map 1:100,000
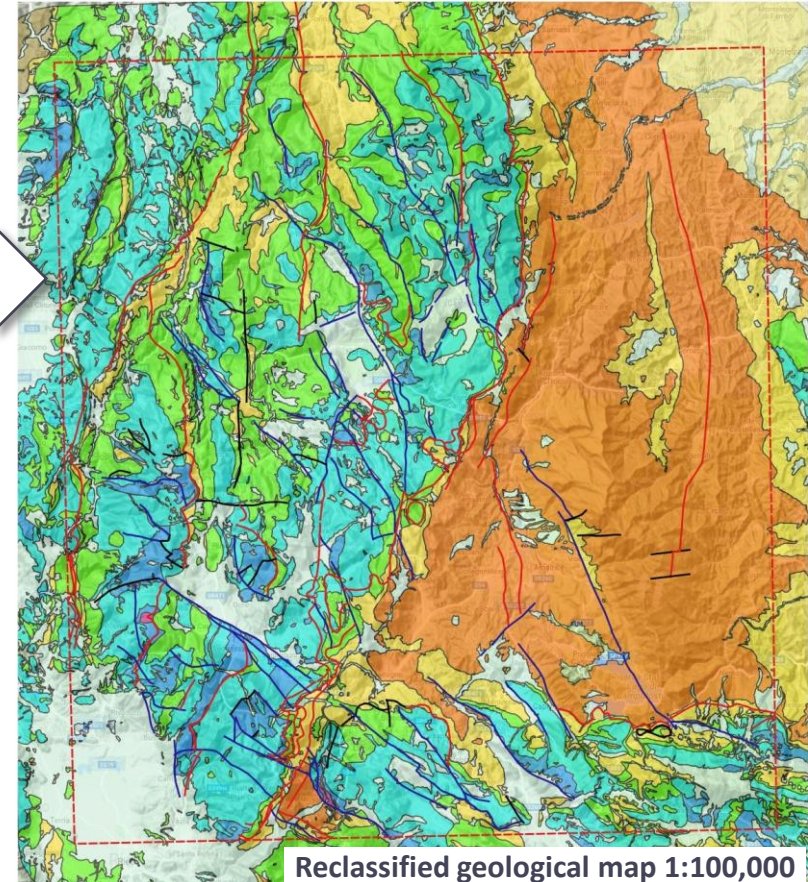
Input data preparation – Fault systems
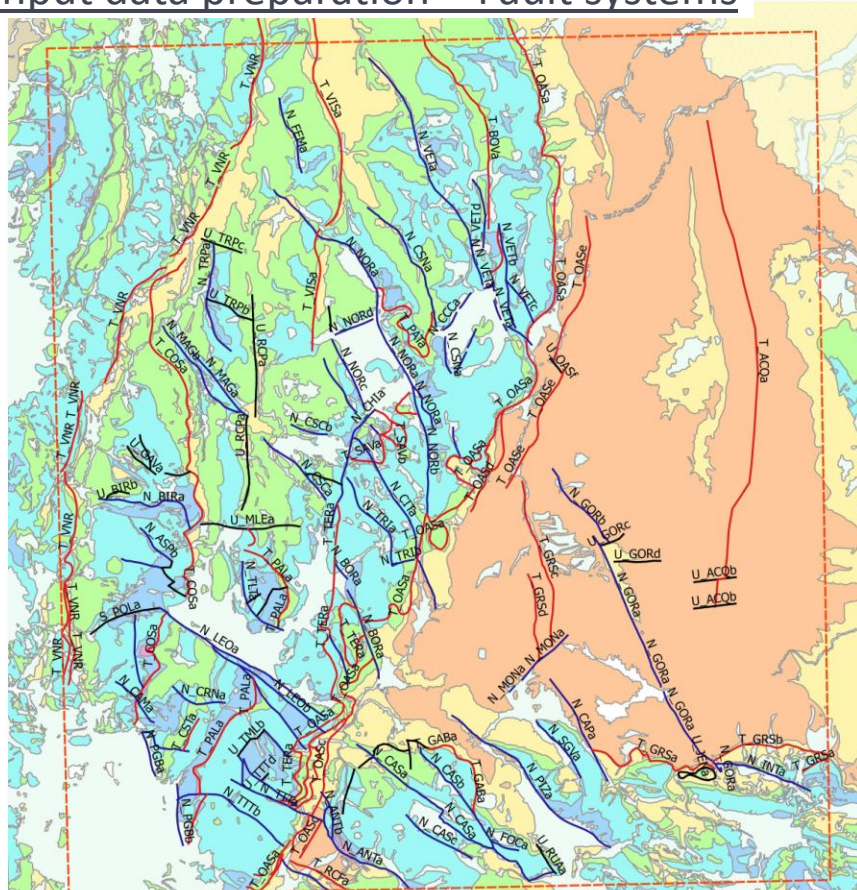
Main structural elements – Geological Map of Italy 1:500,000

Fault System Name	Code
Acquasanta	U_ACQb
Acquasanta	
Antrodoco	
Antrodoco	
Aspra	
Aspra	
Aspra	
Aspra	
Canetra	
Capitignano	
Casaline	
Casaline	
Casaline	
Cascia	
Cascia	
Cascia	
Castel Sant	
Castellucci	
Castellucci	
Castiglione	
Chiavano	
Cima d'Arm	
Cittareale	
Cittareale	
Forcella	

	Code
Monte Patino	T_PATa
Monte Rua	U_RUAa
Monte Tolentino	U_TLTc
Monte Tolentino	U_TLTb
Monte Tolentino	N_TLTa
Monteleone	U_MLEa
Montereale	N_MONa
Norcia	U_NORf
Norcia	N_NORe
Norcia	N_NORd
Norcia	N_NORc
Norcia	N_NORb
Norcia	N_NORa
Olevano-Antrodoco-Sibillini	U_OASf
Olevano-Antrodoco-Sibillini	T_OASe
Olevano-Antrodoco-Sibillini	T_OASd
Olevano-Antrodoco-Sibillini	T_OASc
Olevano-Antrodoco-Sibillini	T_OASb
Olevano-Antrodoco-Sibillini	T_OASa
Palloroso	T_PALa
Pizzoli	N_PIZa
Poggio Bustone	N_PGBb
Poggio Bustone	N_PGBa
Polino	S_POLa
Rocca di Fondi	T_RCFa

Gorzano	
Gorzano	
Gorzano	
Gorzano	
Gran Sasso	
Gran Sasso	
Gran Sasso	
Gran Sasso	
Intermesoli	
Leonessa	
Leonessa	
Maragone	
Monte Birbon	
Monte Birbon	
Monte Borag	
Monte Bove	
Monte Bove	
Roccapore	
San Giovan	
Savelli	
Savelli	
Savelli	
Terminillet	
Terminillet	
Terminillet	
Terminillet	

	Code
Triponzo	U_TRPc
Triponzo	U_TRPb
Triponzo	N_TRPa
Valnerina	T_VNR
Velino	U_VELa
Vettore	N_VETd
Vettore	N_VETc
Vettore	N_VETb
Vettore	N_VETa
Visso	T_VISa

Monte Carpe	
Monte Ciamb	
Monte Ciamb	
Monte Corno	
Monte Cosce	
Monte Fema	
Monte Gabbi	
Monte Gabbi	
Monte Gabbi	T_GABa

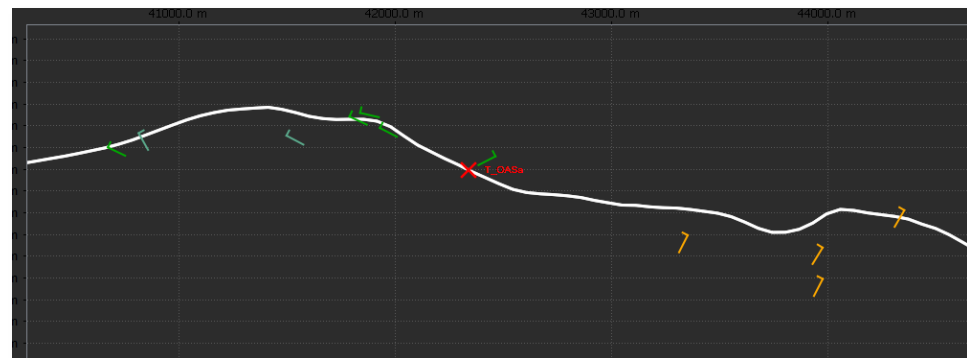| Code	Type
T_XXXx_00n	thrust
N_XXXx_00n	extensional
S_XXXx_00n	strike slip
U_XXXx_00n	undefined

Seismic interpretation

Input data preparation – Geometrical constraints

Attitude data (> 5,000) – dip domain reclassified
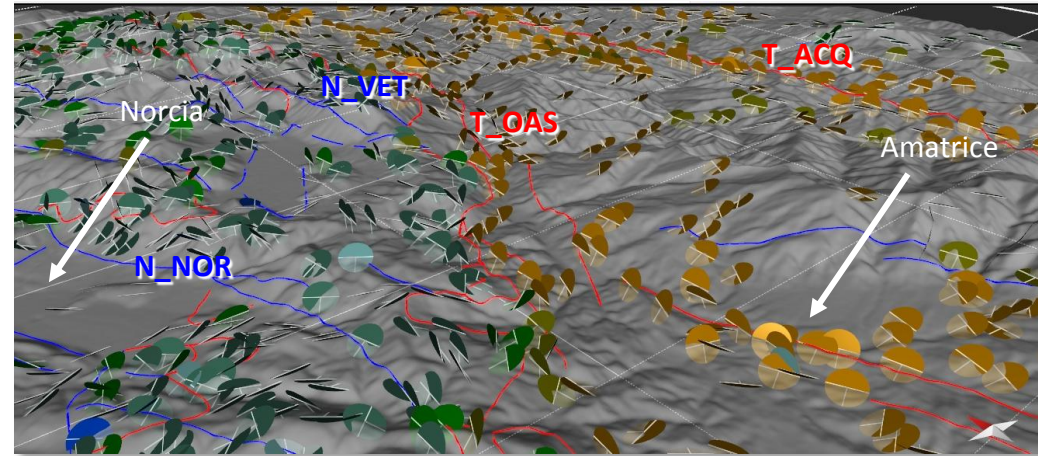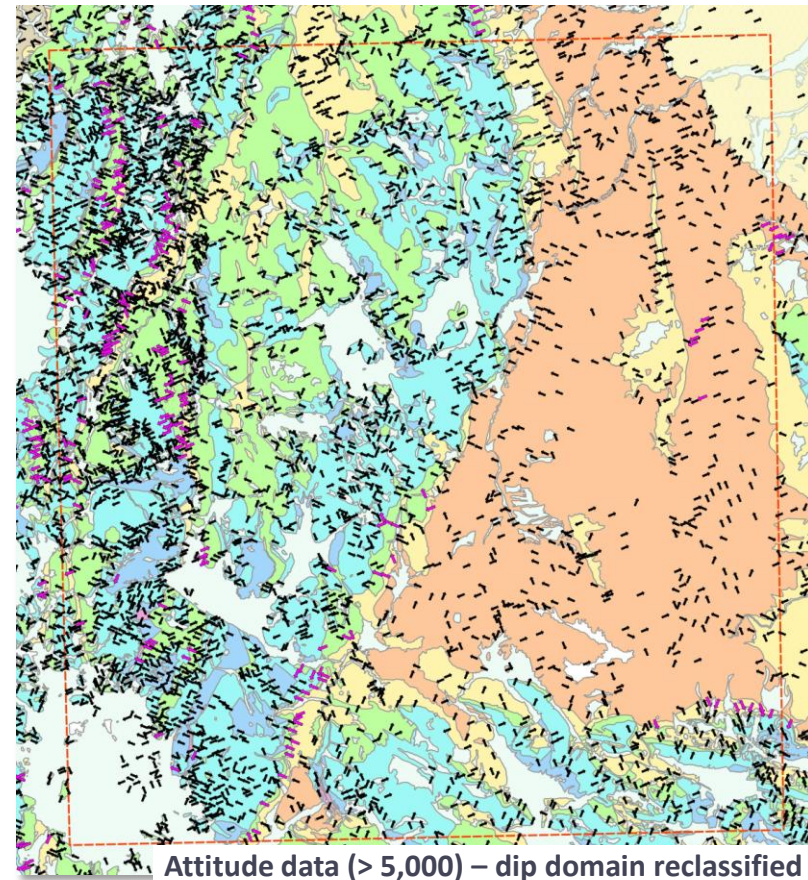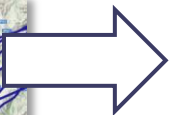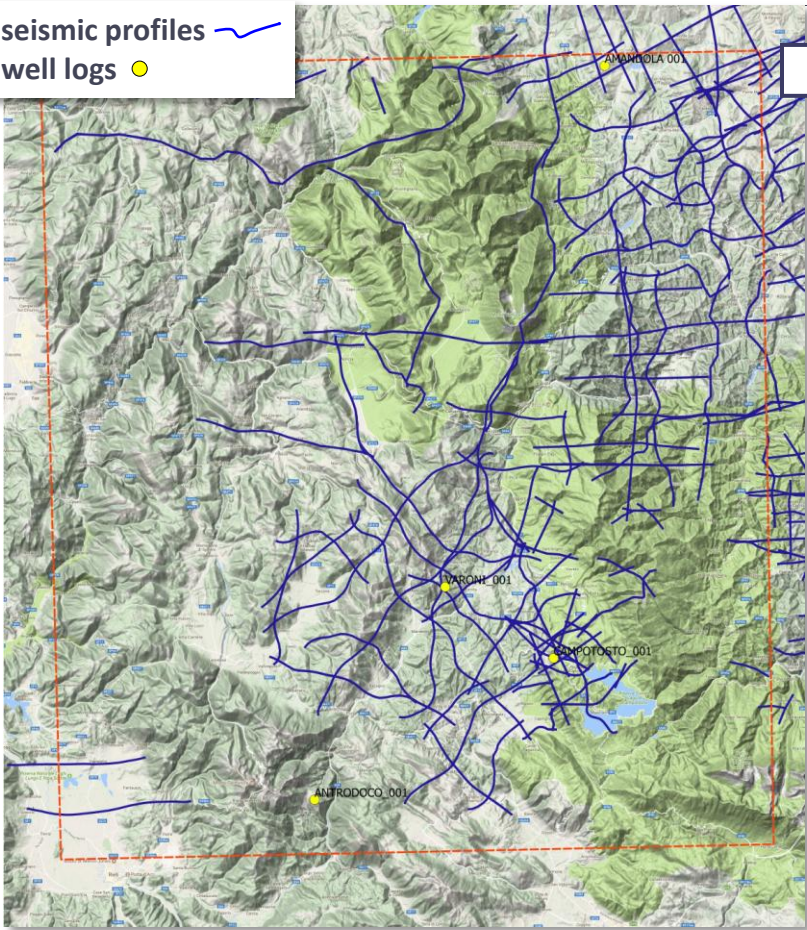

Attitude data reclassified according to the Retrace-3D scheme

WP 2 – Shallow crustal model

Seismic interpretation
COORDINATION GROUP

3/4 interpretation groups

Different softwares, same lexicon,
parallel interpretation sessions

INGV

3D model time domain
C. D'AMBROGI - ISPRA

Inconsistency check and refinement
(geometric, structural, stratigraphic)

ISPRA

3D velocity model
D. SCROCCA - IGAG

with ENI and TOTAL collaboration

Instantaneous velocity 3D grid
(check shot, sonic log and velocities from seismic data)

IGAG

Depth conversion
M. BUTTINELLI - INGV

Test different approaches and results comparison
(instantaneous velocity, interval velocities, different functions)

IREA

Grav/Mag modeling
F. FERRI - ISPRA

with ENI collaboration

Modeling (2.75/3D) pairing the seismic interpretation
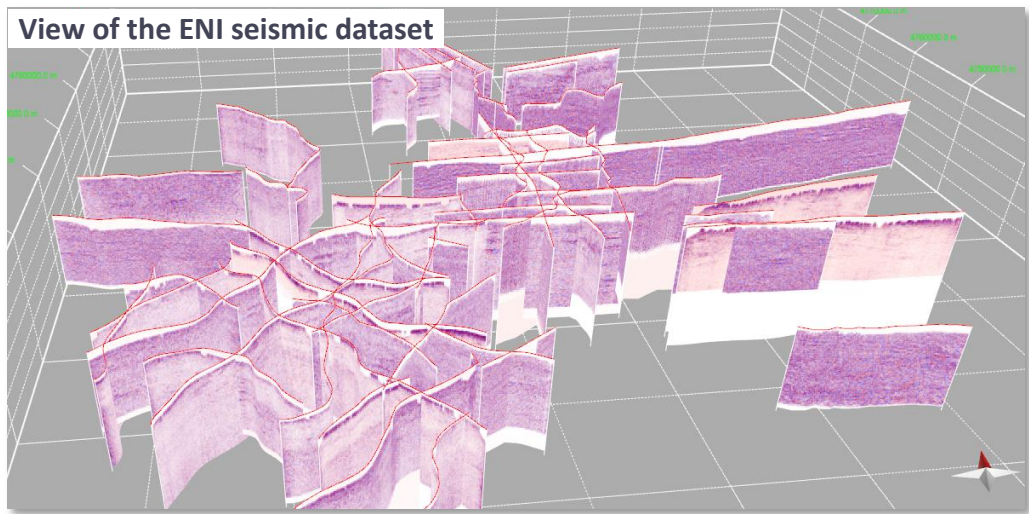
seismic profiles
well logs ⦿
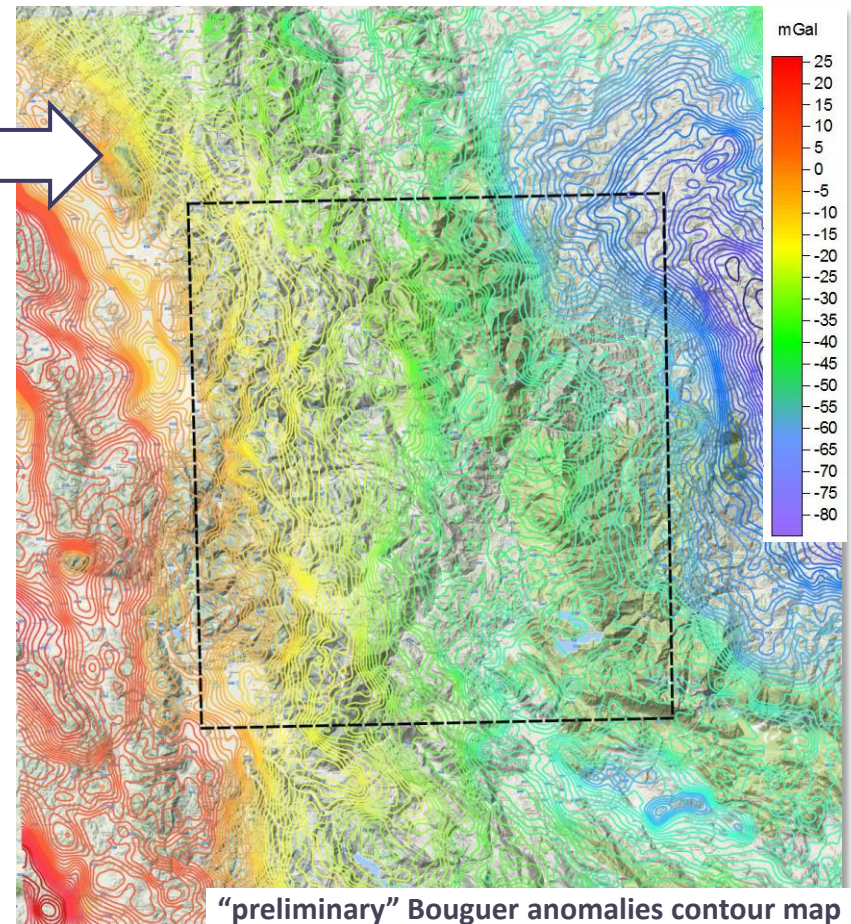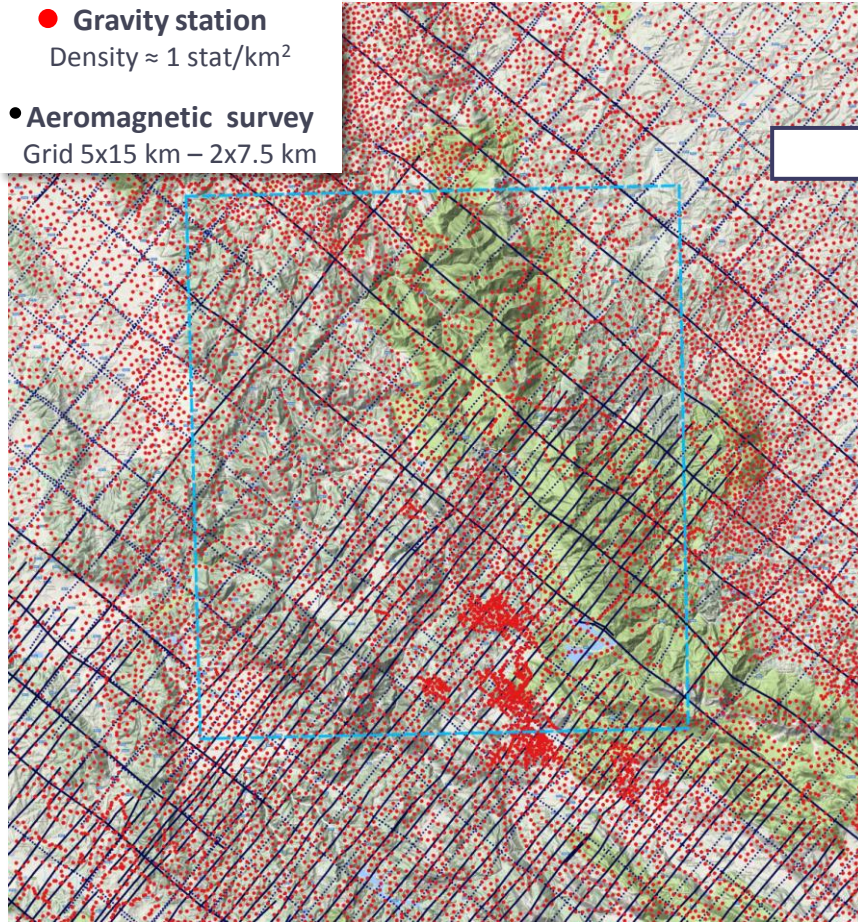

**Quality check
and datum shift**

Seismic interpretation

developed by different groups according to common criteria, with periodic comparison meetings

View of the ENI seismic dataset

- **Gravity station**
  Density ≈ 1 stat/km²

- **Aeromagnetic survey**
  Grid 5x15 km – 2x7.5 km

mGal

- 25
- 20
- 15
- 10
- 5
- 0
- -5
- -10
- -15
- -20
- -25
- -30
- -35
- -40
- -45
- -50
- -55
- -60
- -65
- -70
- -75
- -80

"preliminary" Bouguer anomalies contour map

WP 3 – Model extended to seismogenic depth

Grav/Mag modeling
F. FERRI - ISPRA

Definition of: density and magnetic susceptibility contrasts, magnetic basement and Moho

Tomography
L. IMPROTA - INGV

Vp and Vs models based on Local Earthquake Tomography (local and regional) and Receiver Function analysis

Thermal data and rheological models
R. CASTALDO - IREA

Collection and processing of thermal data and geomechanical data to define ductile/brittle transition

Crustal model
Summarizing WP2/3 activities

INGV

ISPRA

IGAG

IREA

Public workshop

Scientific community

RETRACE-3D Applications
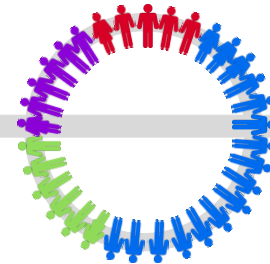
AP1 – Mechanical-structural model
P. TIZZANI - IREA

Integration of geological-structural and geophysical data in numerical calculation environment
R. CASTALDO/S. PEPE - IREA

Rheological crustal model
R. CASTALDO – IREA

3D Finite Element kinematic crustal model
R. CASTALDO/S. PEPE – IREA

Optimization of 3D Finite Element kinematic crustal model through multiparameter optimization of ground deformations
R. CASTALDO - IREA

AP2 – Earthquake relocation
INGV

Earthquake re-location of 2016-2017 seismic sequence in 3D a-priori velocity models based on exploration data (seismics, well logs).

AP? – Microzonation studies
Support for the definition of the seismic input in microzonation studies.

RETRACE-3D societal added value

multi-expertise coordinated Working Group, formally organized under the umbrella of the National Department of Civil Protection

The results of the WG activities will be more easily usable for civil protection purposes, representing not the idea of a single research group, but of a large and qualified community