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A consistent geological/geophysical model of the Eastern Po Plain (Italy) for the evaluation of geothermal energy

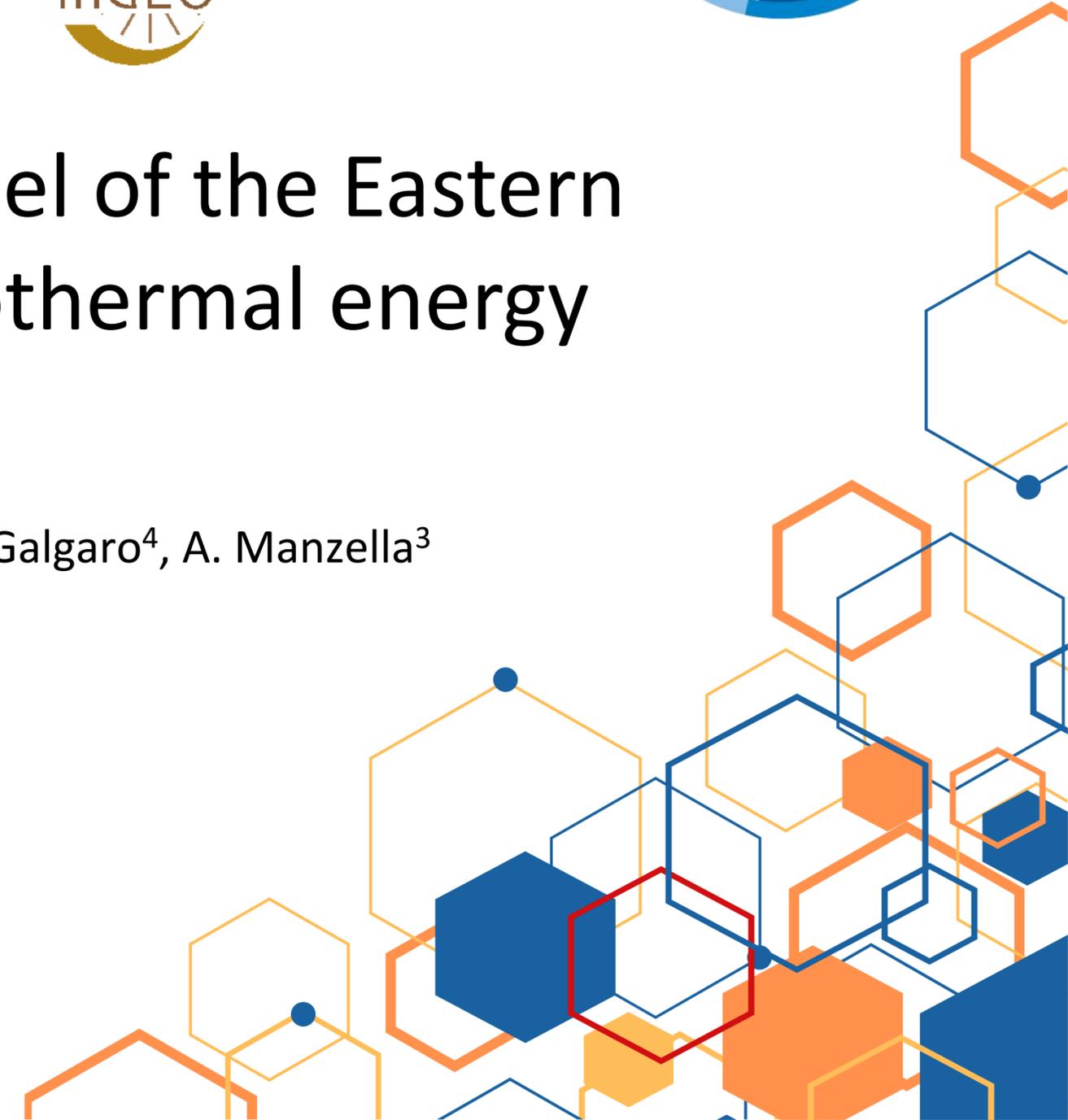
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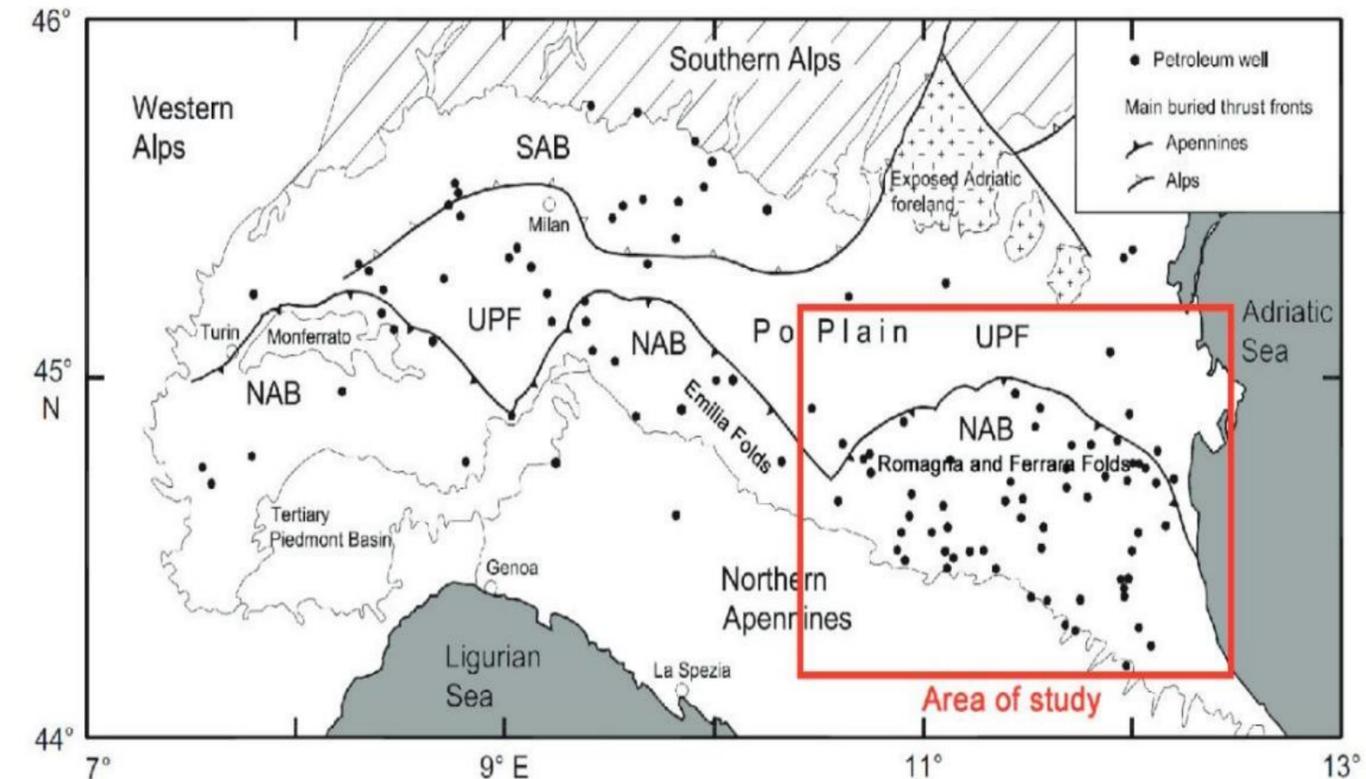
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InGEO: Innovation in geothermal resources and reserves potential assessment for the decarbonization of power/thermal sectors

The project focuses on developing a method to accurately measure the energy potential of deep geothermal sources (e.g., in Emilia Romagna).

- How much energy can be extracted from layers up to 10 km deep at a regional level to generate electricity or for district heating?
 1. We develop an innovative approach to deep-subsurface exploration, integrating different data to assess underlying conditions and evaluate geothermal potential of the target area.
 2. Reconstruct crustal and subcrustal structures through joint analysis and interpretation of available and acquired geological and geophysical data.



Modified after Pasquale et al. (2014)

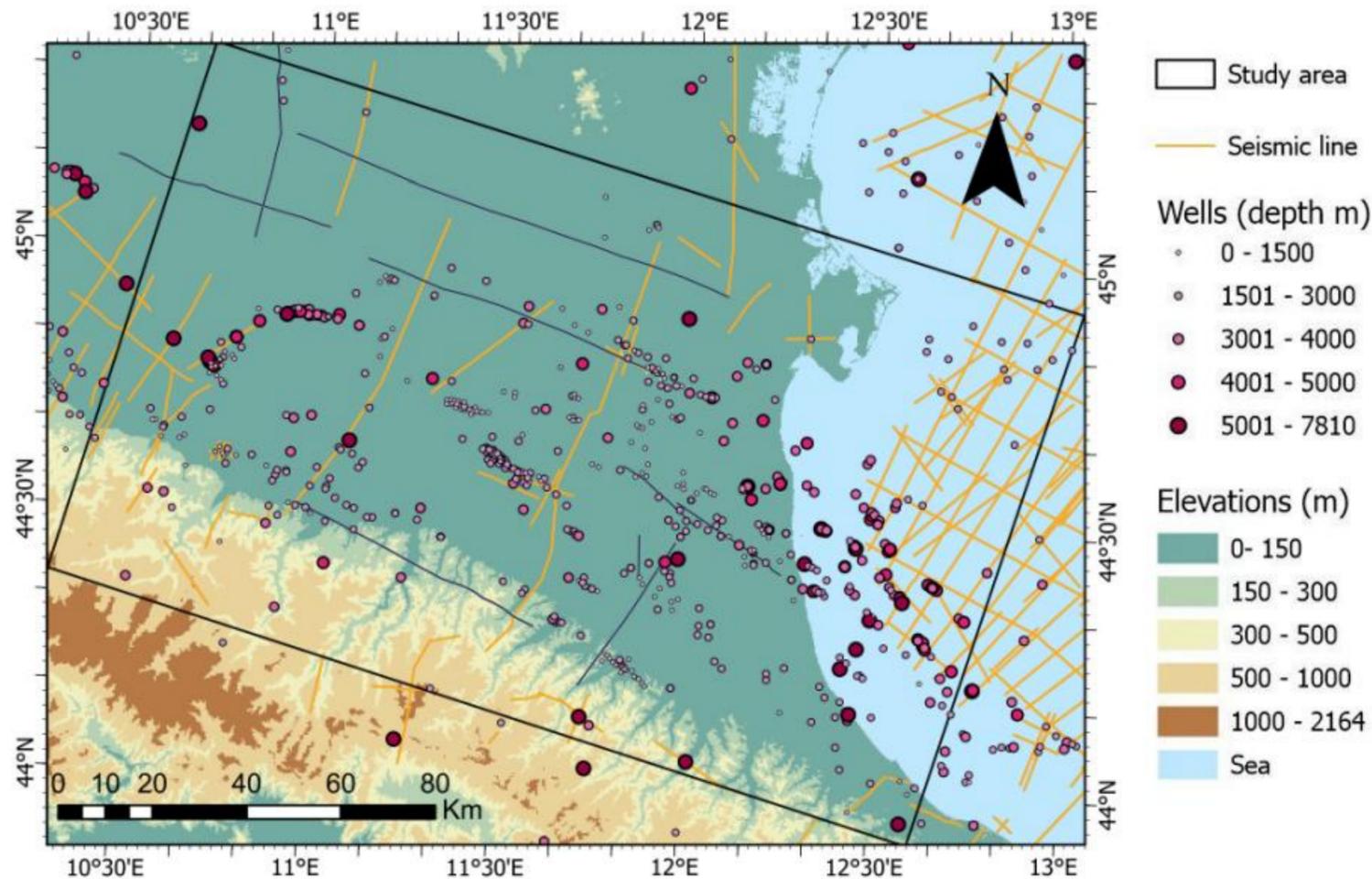
Multi-disciplinary dataset integration

1. Seismic Reflection and well log data

2. Seismic Tomography and Gravity

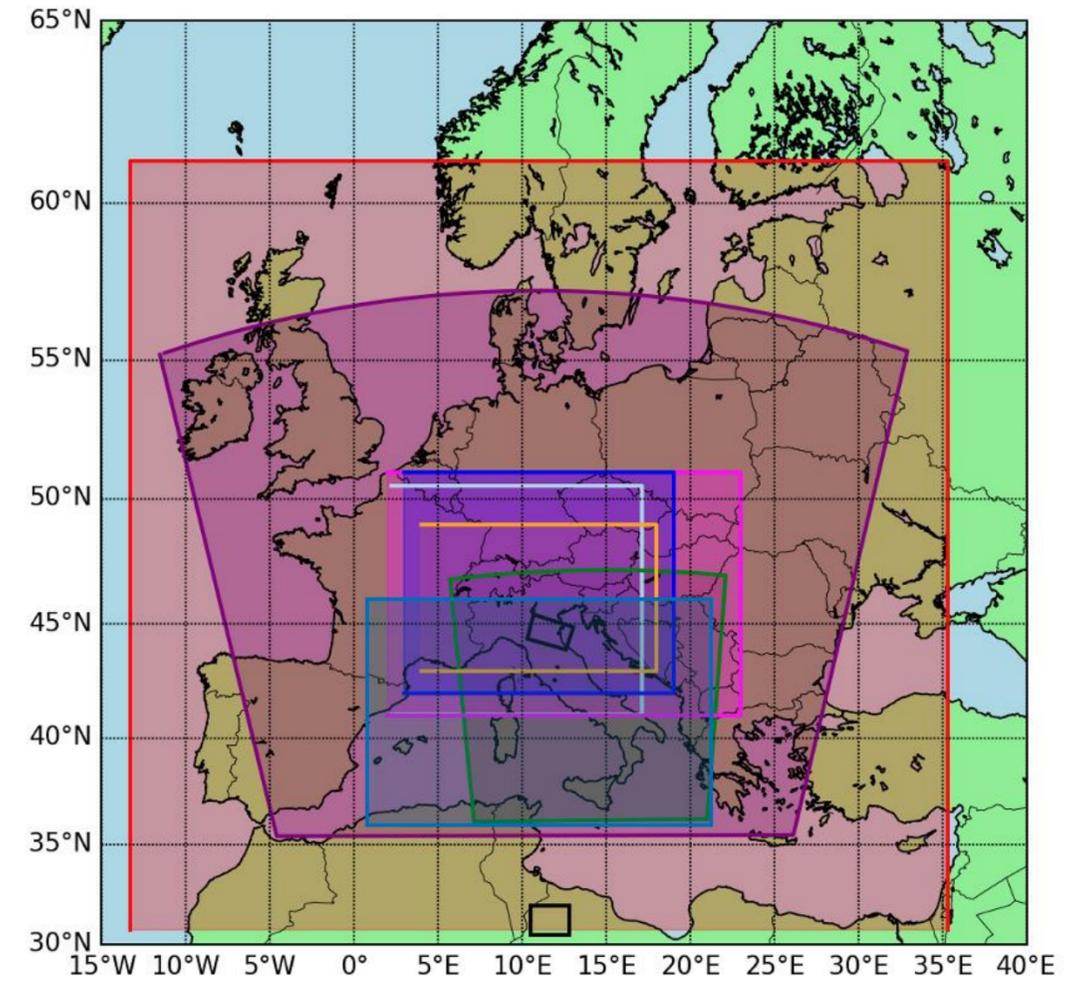
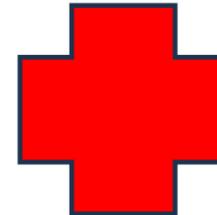
Main sources: 1. VIDEPI database (www.videpi.com) 2. CNR database www.geothopica.igg.cnr.it 3. ENI data

Other sources: 1. Livani et al. (2023), 2. Amadori et al. (2019)



The study area of the InGEO project on DEM. Location of available seismic lines and wells (colour and size are shown according to their depth).

Shallow

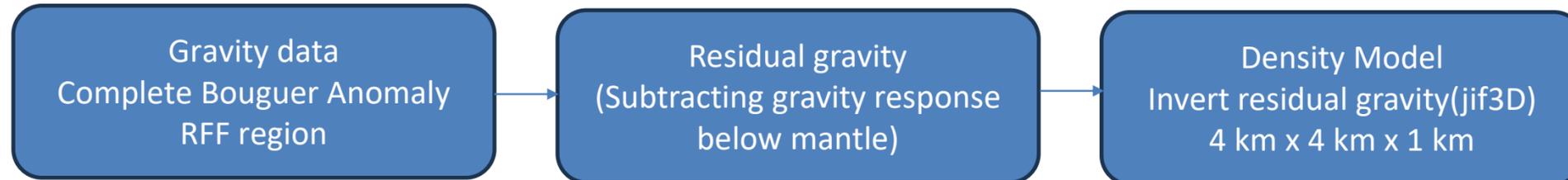
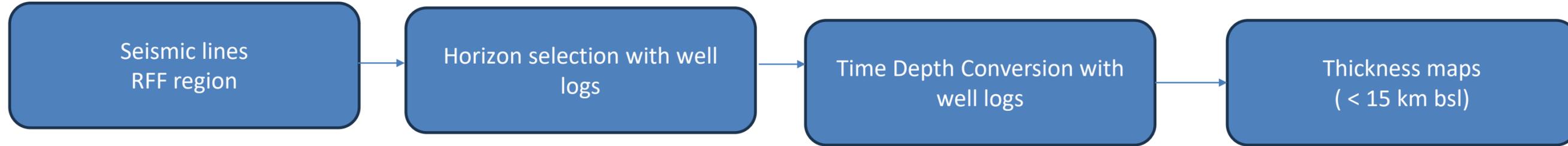


- Diehl et al (2009)
- Magnoni et al (2022)
- Paffrath et al (2021)
- Kastle et al (2025)
- Lu et al (2018)
- Zahorec et al (2020)
- Brazus et al (2025)
- Magrini et al (2022)

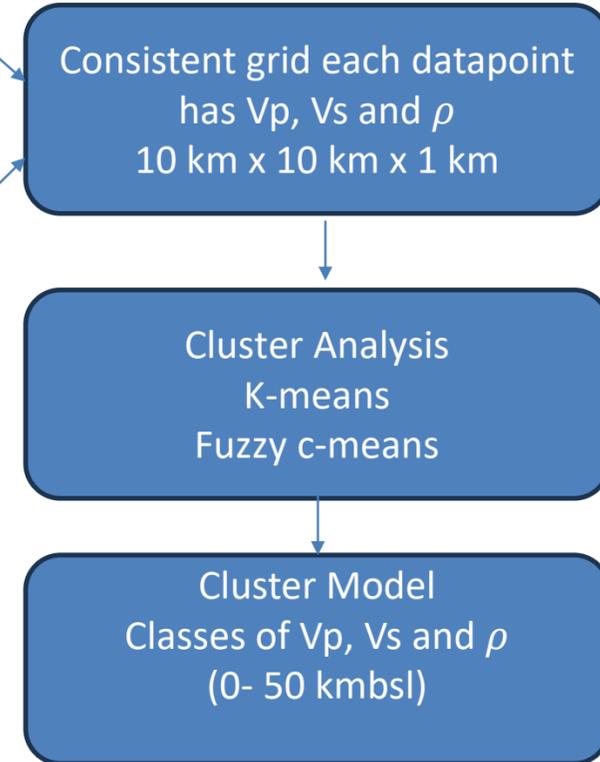
Deep

Multi-method classification workflow

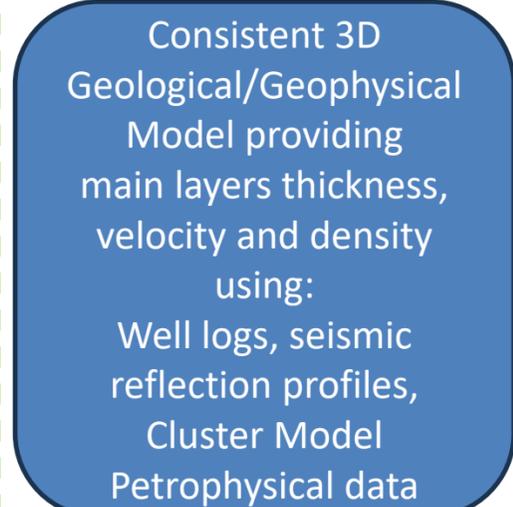
1: Seismic Reflection and Well log



2 : Seismic Tomography and Gravity



3 : Joint Analysis

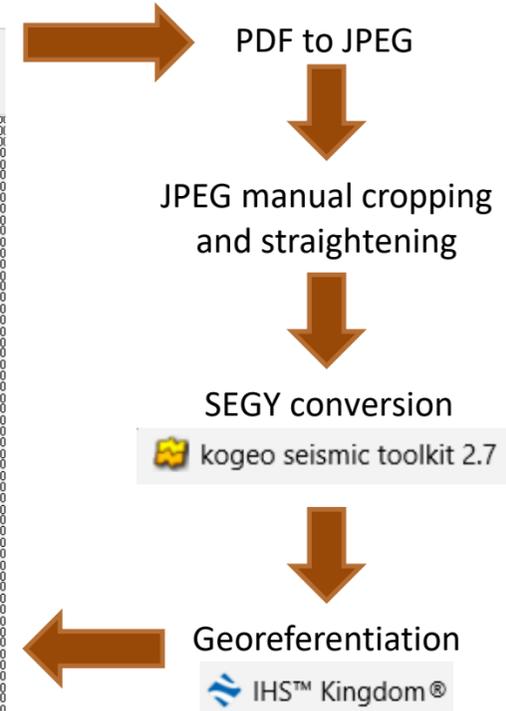
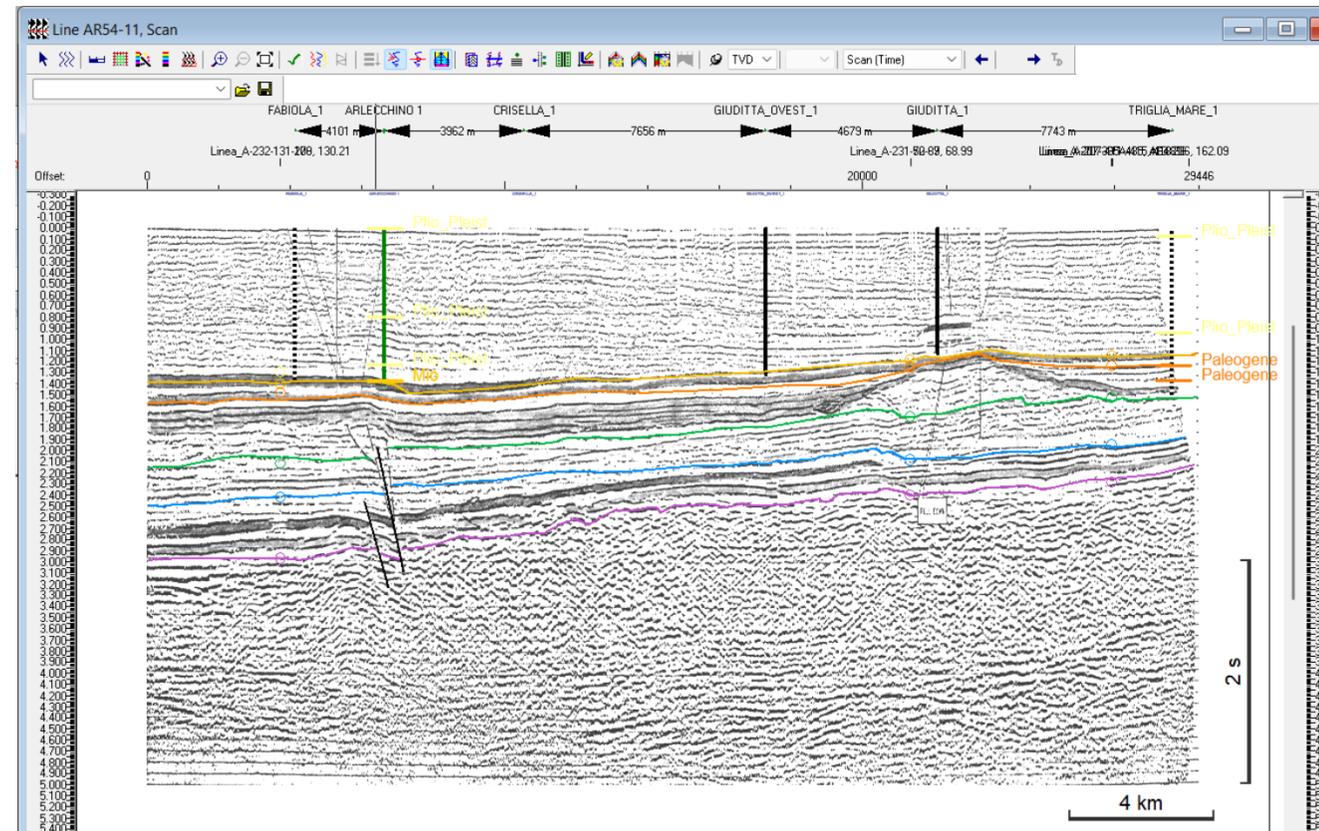


1. Seismic Reflection and well log data

Well log analysis and Seismic reflection interpretation

Età	Formazione
QUATERNARIO	DEPOSITI ALLUVIALI
PLEISTOCENE	SABBIE DI ASTI
PLEISTOCENE	CAROLA
PLEISTOCENE	RAVENNA
PLIOCENE INFERIORE	PORTO GARIBALDI
PLIOCENE INFERIORE	SANTERNO
PLIOCENE INFERIORE	PORTO CORSINI
PLIOCENE INFERIORE	SABBIE DI ERACLEA
MESSINIANO	COLOMBACCI
MESSINIANO	GESSOSO-SOLFIFERA
MESSINIANO	FUSIGNANO
SERRAVALLIANO	MARNOSO-ARENACEA
SERRAVALLIANO	MARNE DI SAN DONA'
MIOCENE MEDIO	SCHLIER
EOCENE	GALLARE
EOCENE	SCAGLIA
CRETACEO	MARNE DEL CERRO
CRETACEO	MAIOLICA
GIURASSICO MEDIO	ROSSO AMMONITICO
GIURASSICO MEDIO	LUMACHELLA A POSIDONIA ALPINA
GIURASSICO INFERIORE	CALCARI GRIGI DI NORIGLIO
CARNICO SUPERIORE	DOLOMIA PRINCIPALE
CARNICO SUPERIORE	FORMAZIONE DI RAIBL
CARNICO SUPERIORE	LEGNARO
CARNICO SUPERIORE	FORMAZIONE DEL CONTRIN
PERMIANO SUPERIORE	FORMAZIONE DI WERFEN
PERMIANO SUPERIORE	CALCARI A BELLEROPHON
PERMIANO SUPERIORE	ARENARIE VAL GARDENA
PERMIANO	VULCANITI ATEesine
DEVONIANO SUPERIORE	BASAMENTO VARISCANO

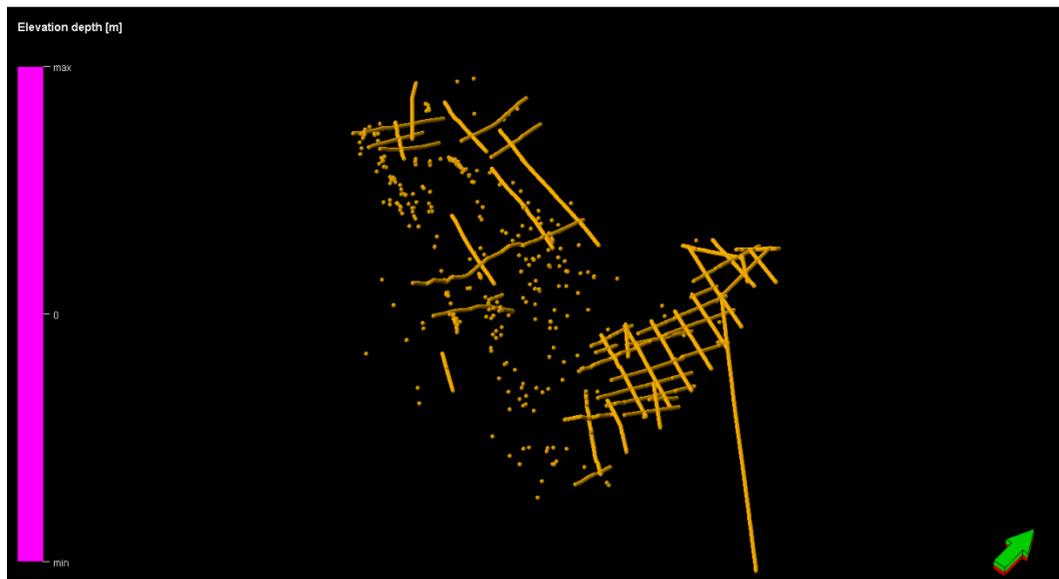
UNIT	Lithology
1-QUATERNARY	Alluvial deposits
2-PLIO-PLEISTOCENE	Sandstones and shales
3-MIOCENE	Sandstones, Sandy Marls, Marls, Evaporites
4-PALEOGENE	Limestones, Marls
5-CRETACEOUS	Marls, Limestones
6-JURASSIC	Limestones
7-TRIASSIC	Dolostones
8-PERMIAN	Sandstones
9-IGNEOUS/METAM. BASEMENT	Igneous and metamorphic rocks



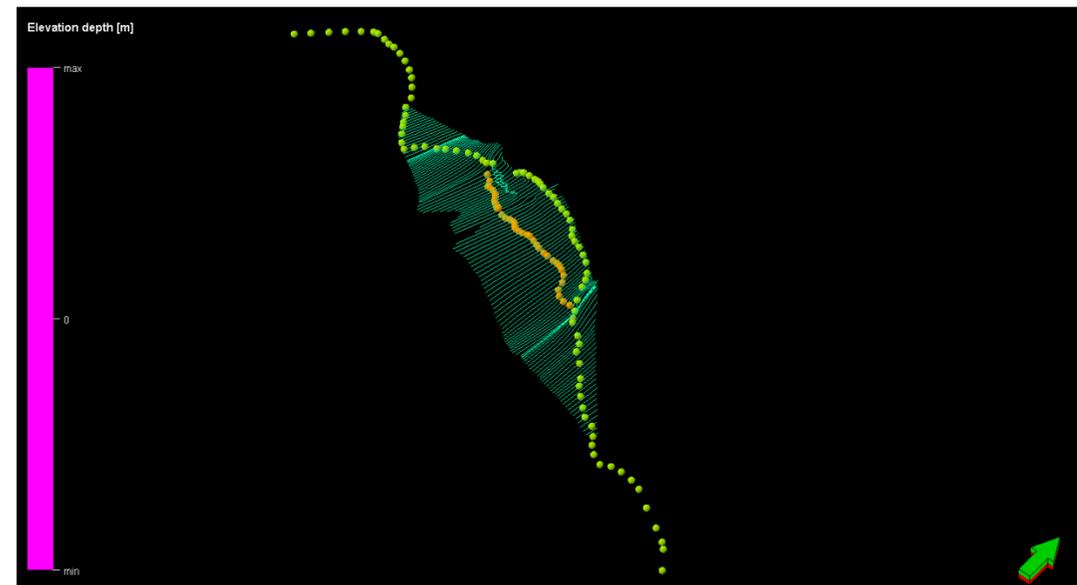
1. Seismic Reflection and well log data

Depths maps after time-depth conversion

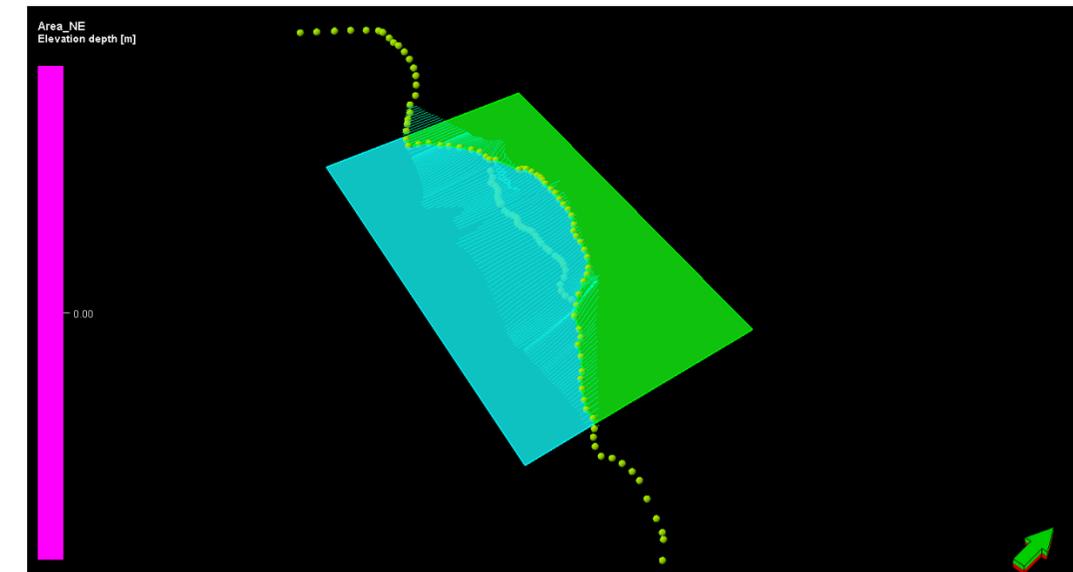
Data Available: seismic lines and well tops



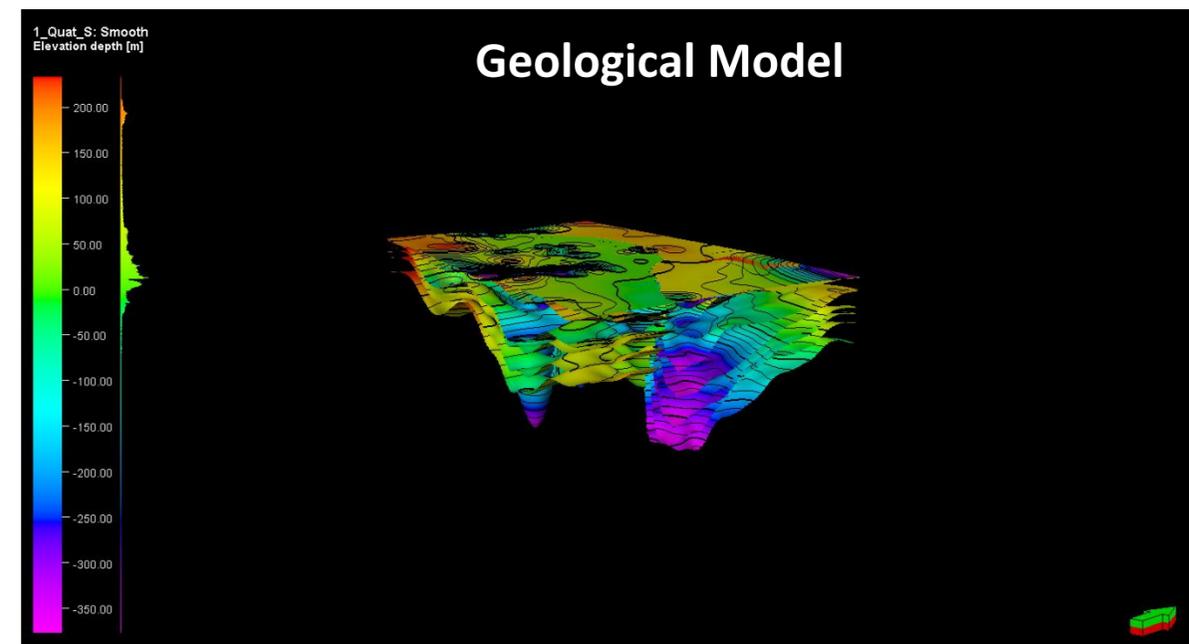
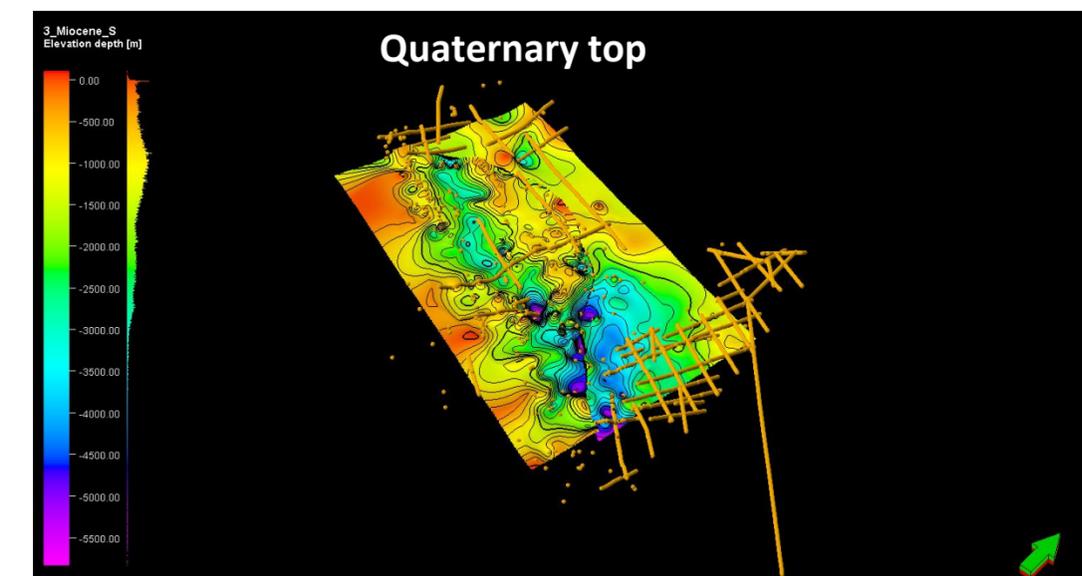
Inclusion of a major fault



Two principal polygons: at Quaternary top

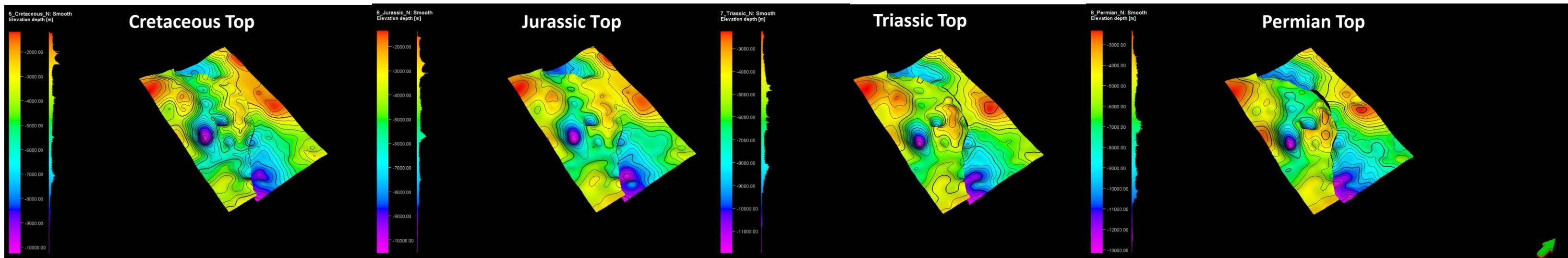
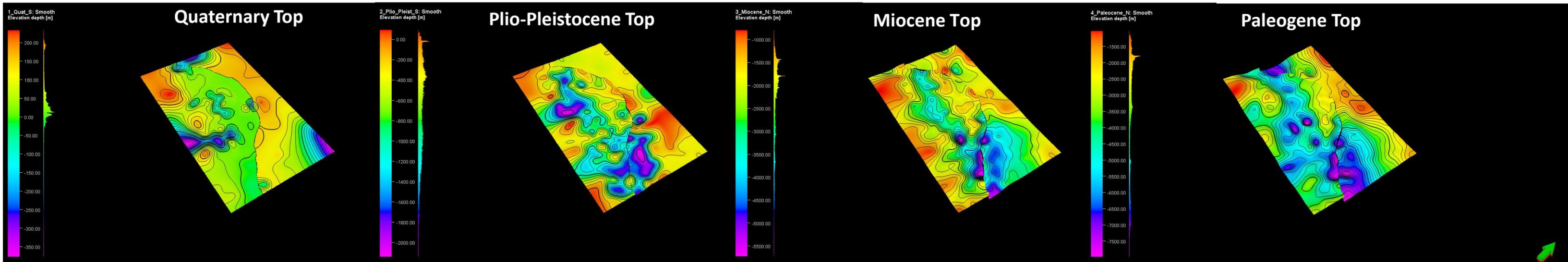


Interpolation final result



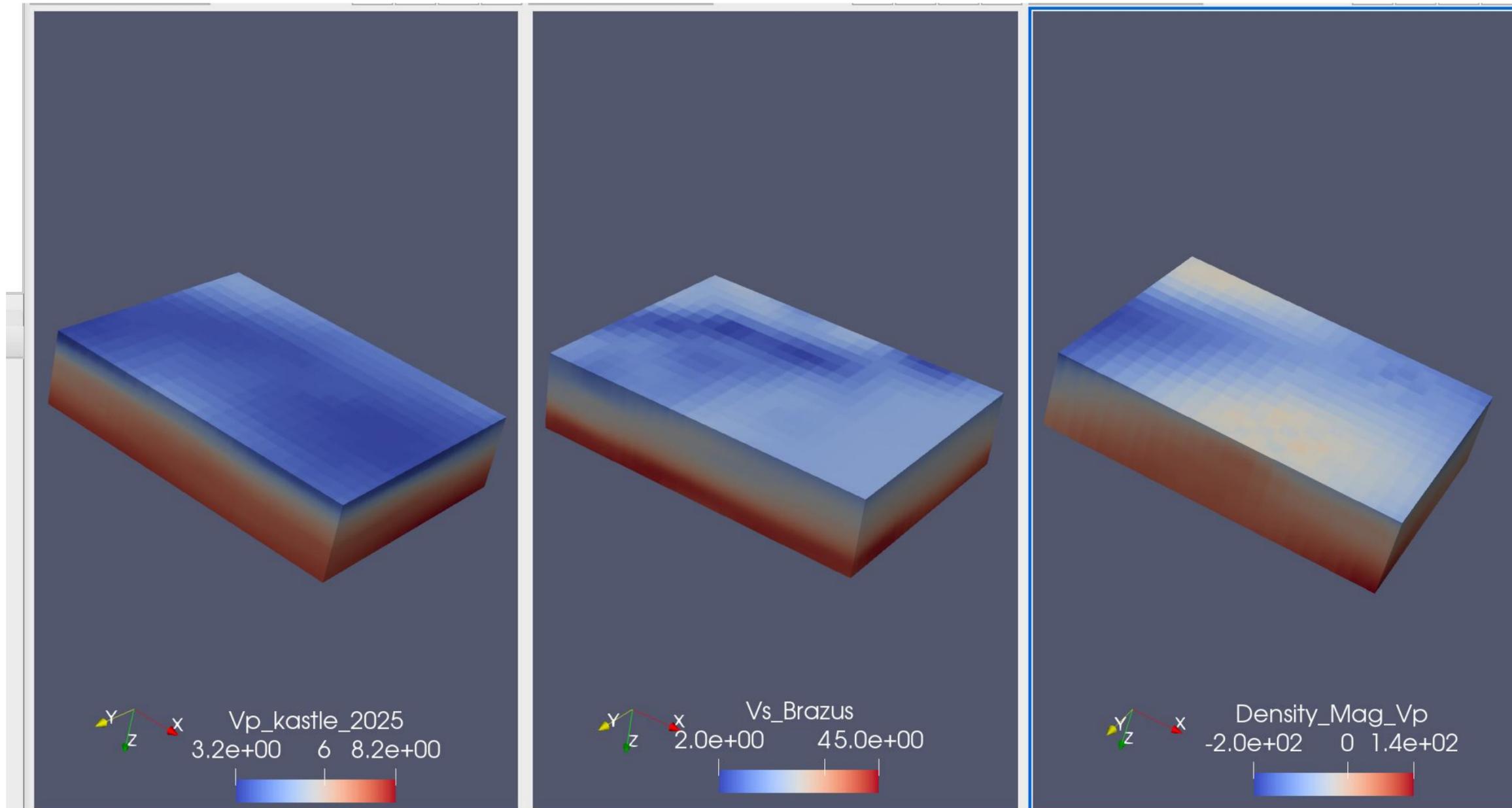
1. Seismic Reflection and well log data

Depths maps after time-depth conversion



2. Seismic Tomography and Gravity Data

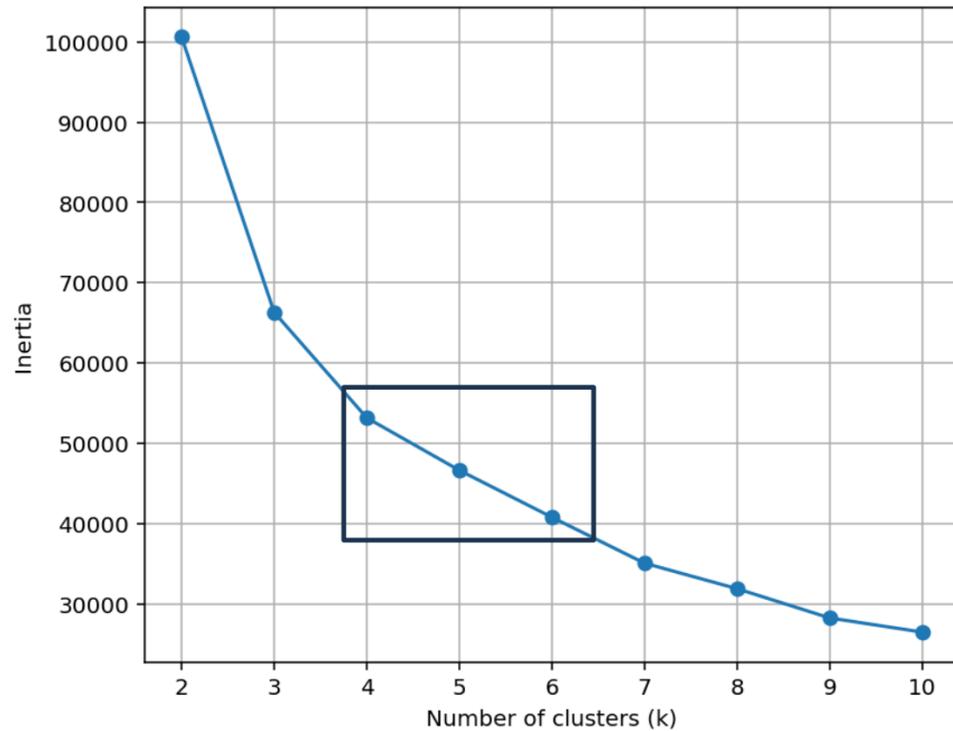
Consistent 3D models on 10 km x 10 km x 1 km



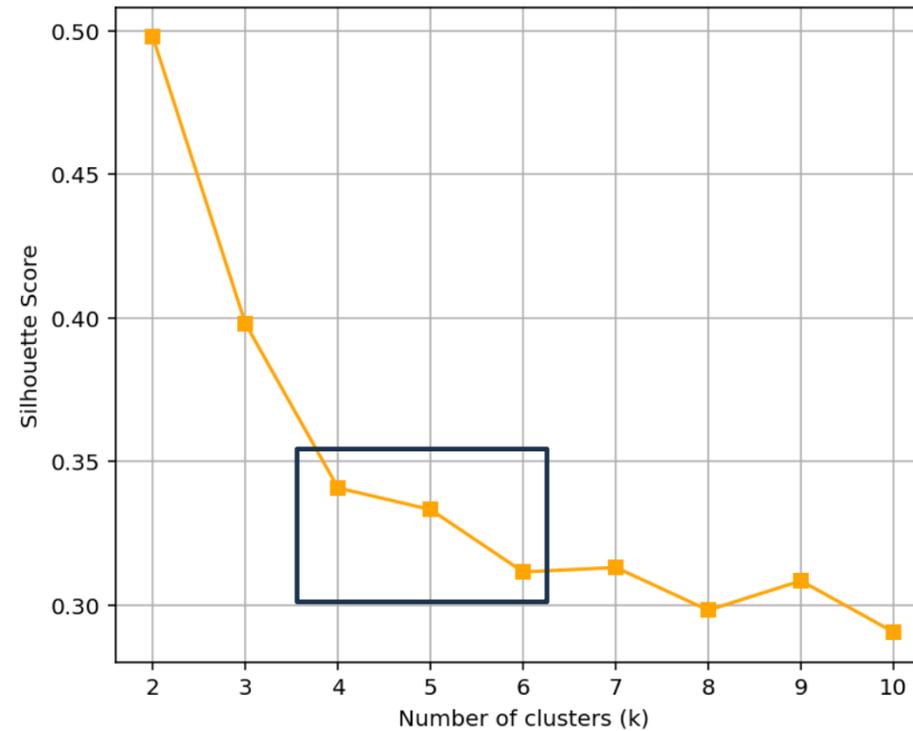
2. Seismic Tomography and Gravity Data

Selecting Optimal number of clusters

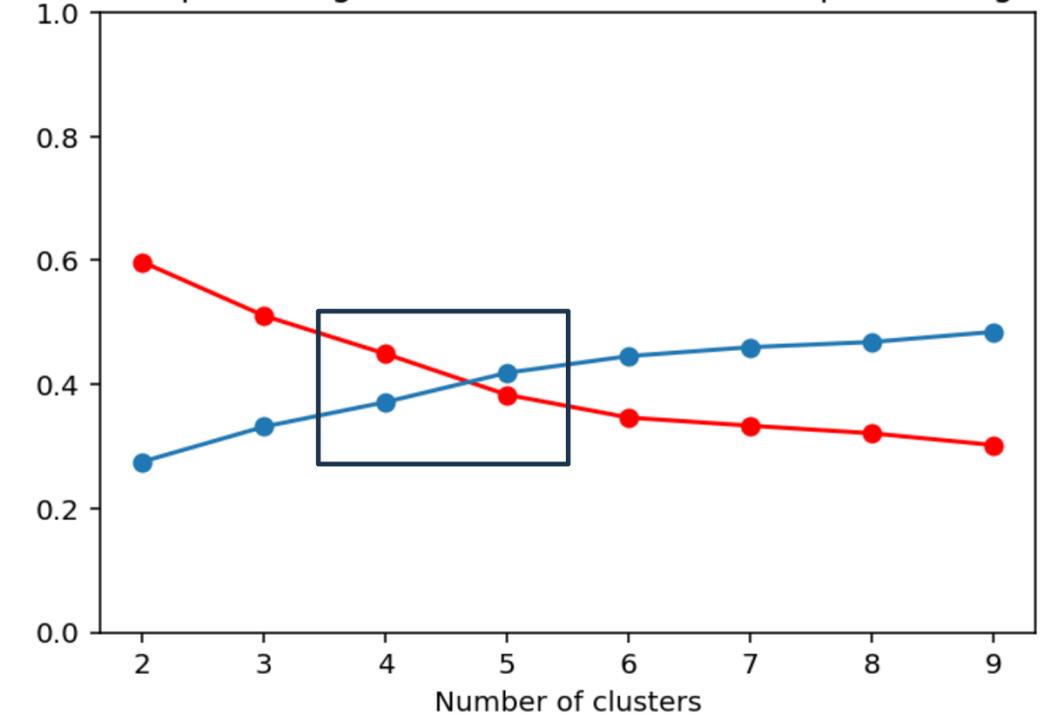
Elbow Method for Optimal k



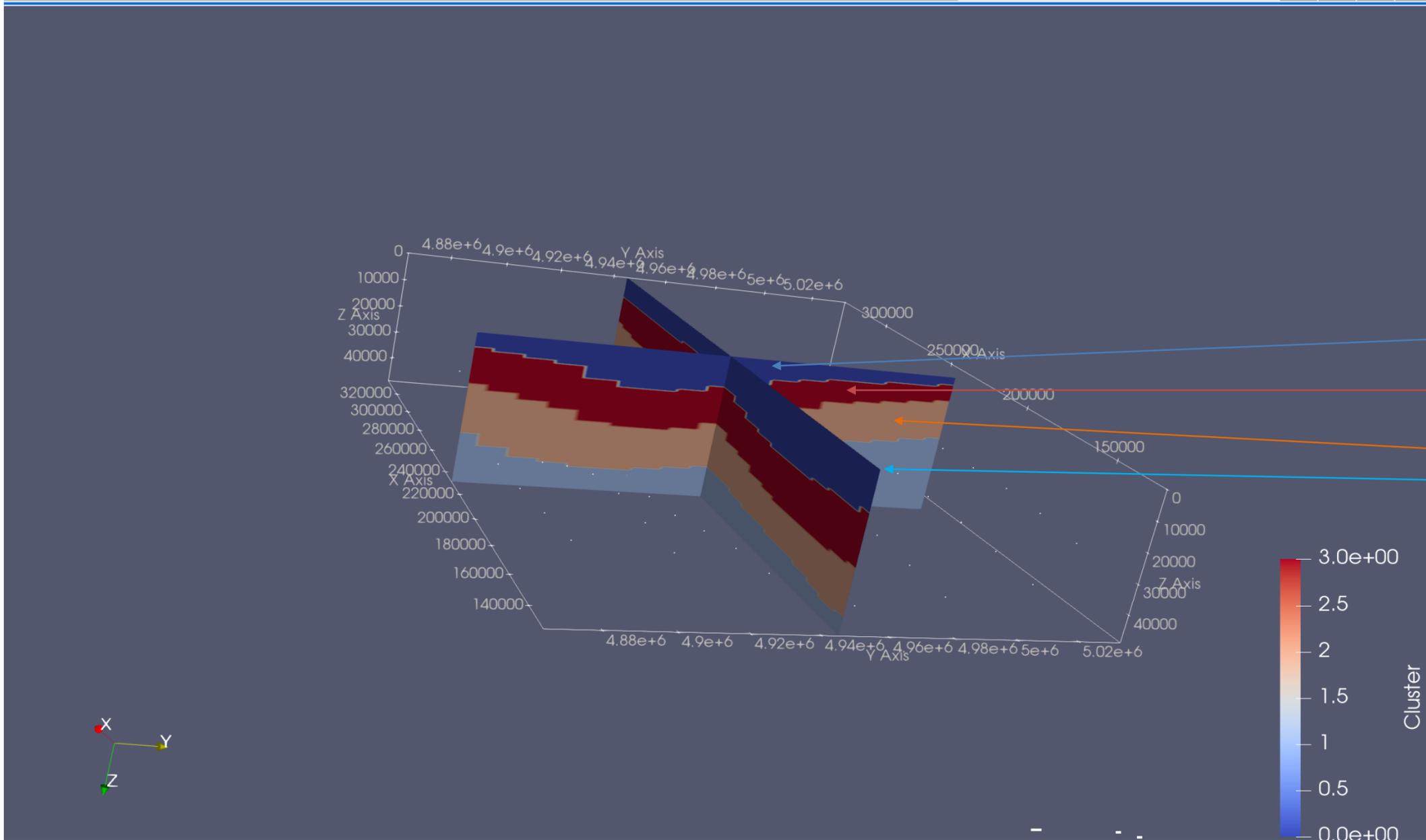
Silhouette Score by k



Normalized partitioning coefficient and normalized partitioning entropy



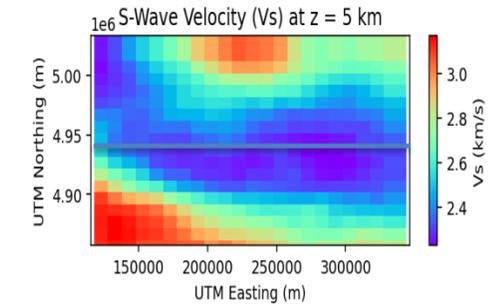
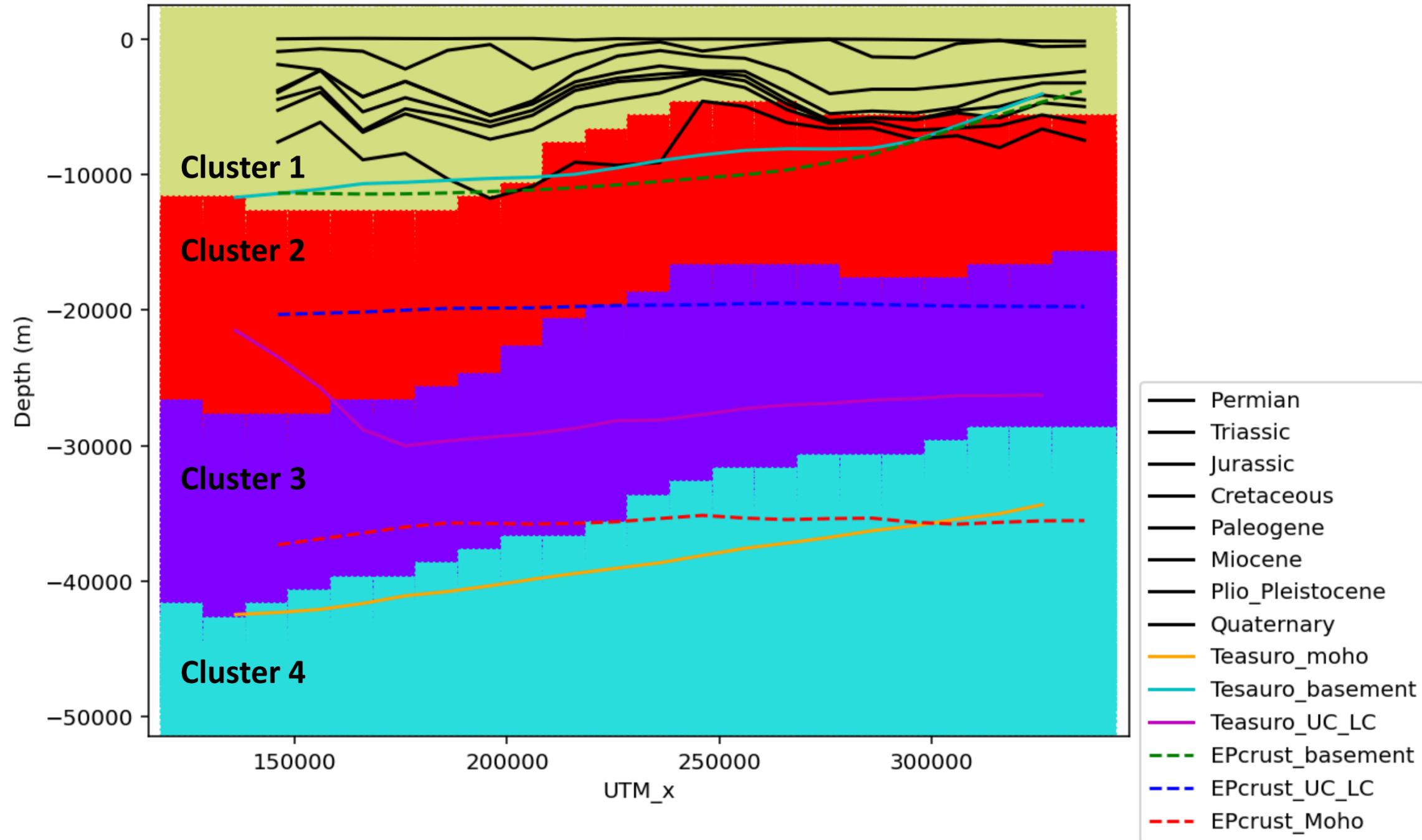
2. Seismic Tomography and Gravity Data Cluster Model: Classes Assigned



Cluster	Vp (km/s)	Vs (km/s)	Den_contr (kg/m ³)
1	3.99-4.73	2.48-2.72	-312 - -79
2	5.41-6.39	3.26-3.32	-216 - -43
3	6.43-7.17	3.54-3.86	-3 - 25
4	7.5-7.7	4.15-4.54	34 - 237

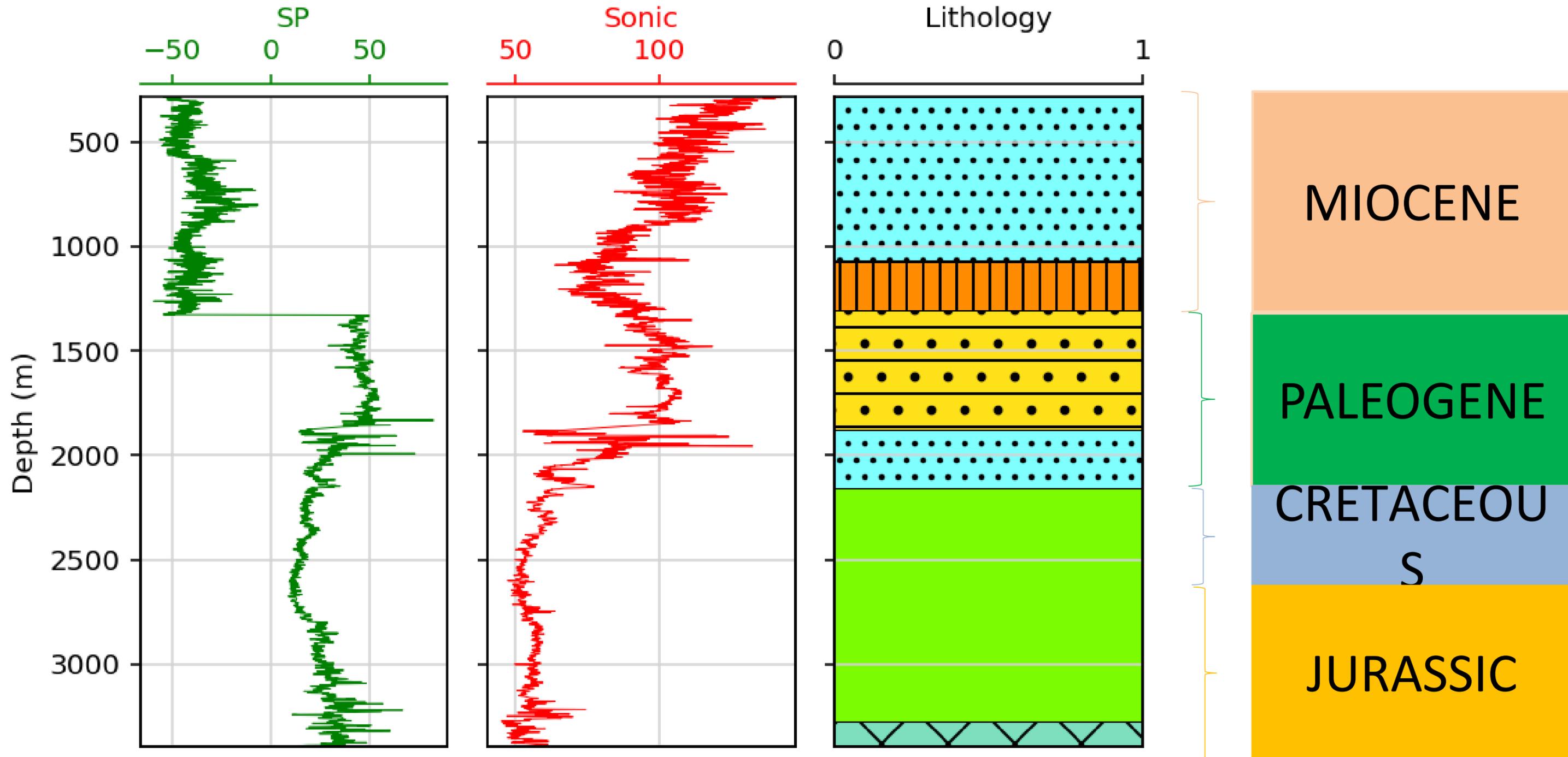
3: Joint Analysis

Comparison with Crustal Models



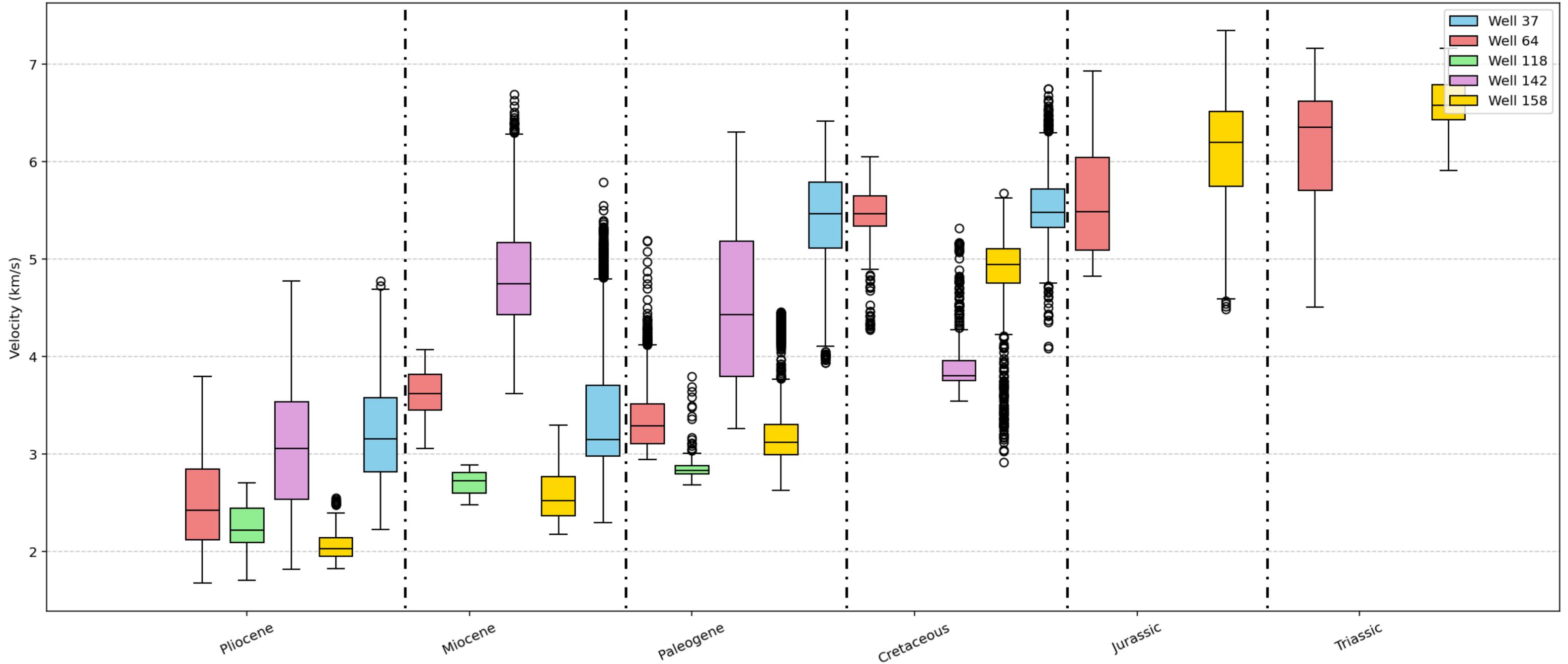
3: Joint Analysis

Validating data with with Sonic log



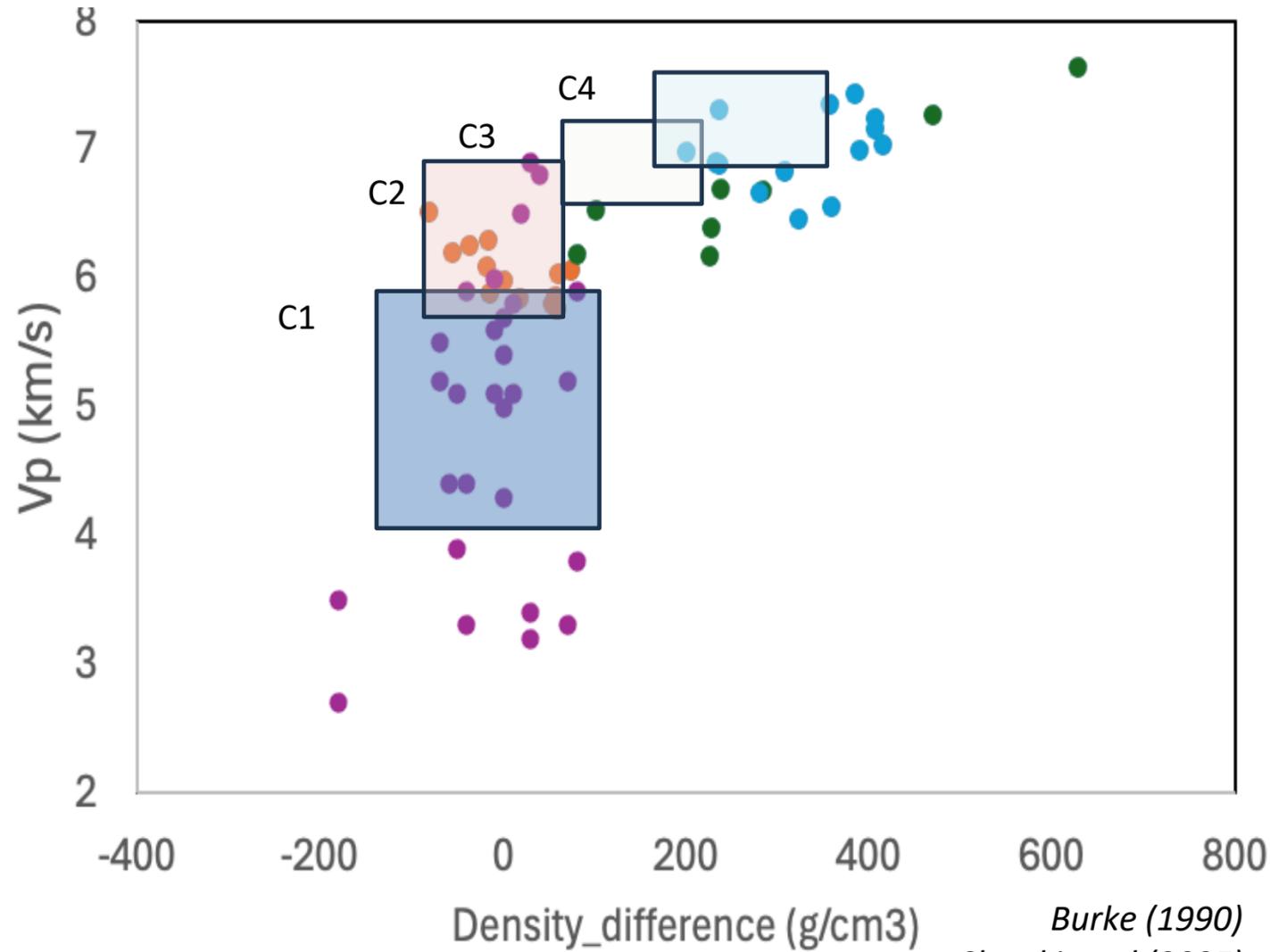
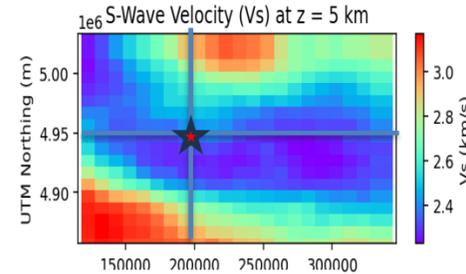
3: Joint Analysis

Comparison with Sonic log

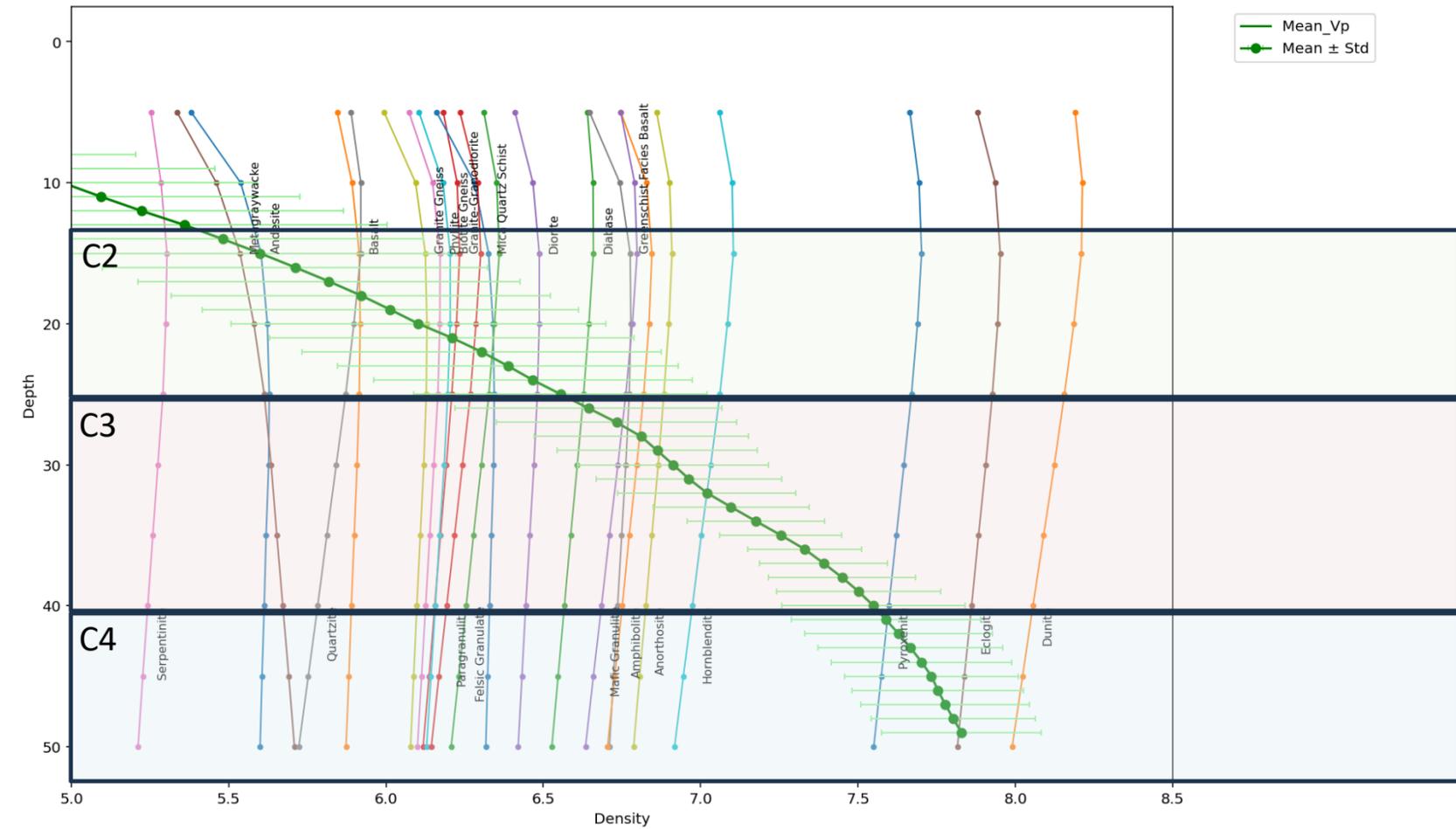


3: Joint Analysis

Validating data with field and experimental data



- Felsic
- Intermediate
- Mafic
- InGEO



Christensen and Mooney (2005)

Conclusions and Outlook

- 3D geological model including eight horizons ranging from the Quaternary to the Permian age.
 - Unsupervised classification resulted in the 3D characterization of four classes
 - 1) sediments to basement
 - 2) upper crust
 - 3) lower crust
 - 4) the mantle.
 - Joint Analysis
 - Geological/Geophysical data
 - Well log data
 - Petrophysical data
-
- Input for a thermal model of the region and the implementation of an open-source and web-based GIS tool that will assess the deep geothermal resource potential for both hydrothermal resources and deep heat exchangers.
 - Our general approach is transferable and can be taken as guideline for investigations of other geothermal systems worldwide.



Thank you for your attention

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Acknowledgements

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Ministero
dell'Università
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