Northern Apennine buried structures observed from analyses of geophysical data to evaluate their geothermal potential

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InGEO Project Description

- The InGEO project (Innovation in GEOthermal resources and reserves potential assessment for the decarbonisation of power/thermal sectors) aims to develop an innovative exploration workflow integrating geophysical data and other direct and indirect information, organized to make available a sort of decision support system of geothermal projects. It consists of the reconstruction of the crustal and sub-crustal structures by joint analyses and interpretations of available and acquired geological and geophysical data (e.g., those provided by mechanical and thermal rock samples laboratory analyses, seismic and gravity anomalies), taking advantage of the different sensitivity that geophysical methods have on physical rock's parameters (temperature and composition). The results will be the input for the geothermal model that will quantify the deep geothermal resource potential of the area.
- The designed workflow will be tested in a case study area and partially calibrated with developed (hydrothermal) available data. The methodological approach proposed by InGEO is also expected to define the potential local use of geothermal systems by Deep Closed-loop Borehole Heat Exchangers (DBHE) for power generation, district heating and/or cooling.

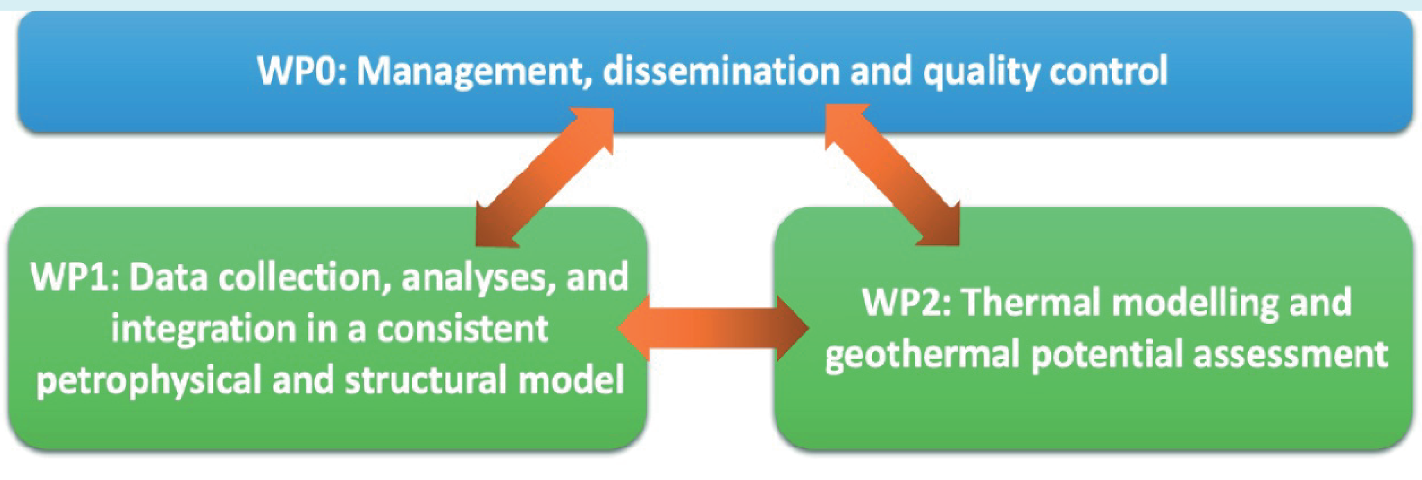

Fig. 1 :Thematic Work Package and workflow of the InGEO project

Study Area

The RFF area (Fig. 2) has been the target of previous geothermal studies highlighting relatively low geothermal gradients within the deep carbonate units of Mesozoic age, which constitutes the local geothermal reservoir depth is clear evidence for fluid thermal convection occurring in the deep-seated overlying impermeable formations [1-2]. This feature in temperature distribution with 14 °C/km) and more significant thermal gradients (on average 53 °C/km) in the overlying impermeable formations [1-2]. This feature in temperature distribution with depth is clear evidence for fluid thermal convection occurring in the deep-seated carbonate units of Mesozoic age, which constitutes the local geothermal reservoir.

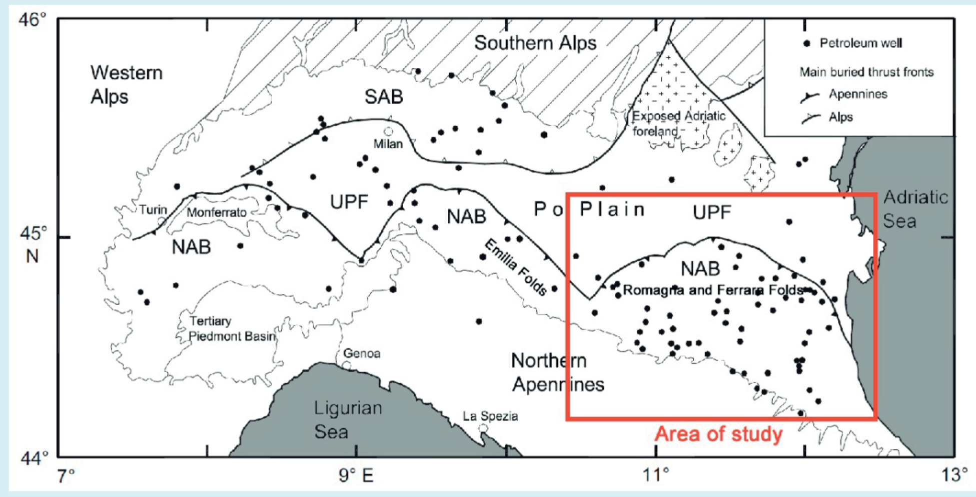

Fig. 2: Main tectonic units of the study area (delimited by a red rectangle) and surroundings. Abbreviations stand for: **NAB**: Northern Apennines buried structures; **UPF**: Undeformed Padan foredeepp; **SAB**: Southern Alps buried structures.

Crustal Velocity Model (Nouibat et al., 2023)

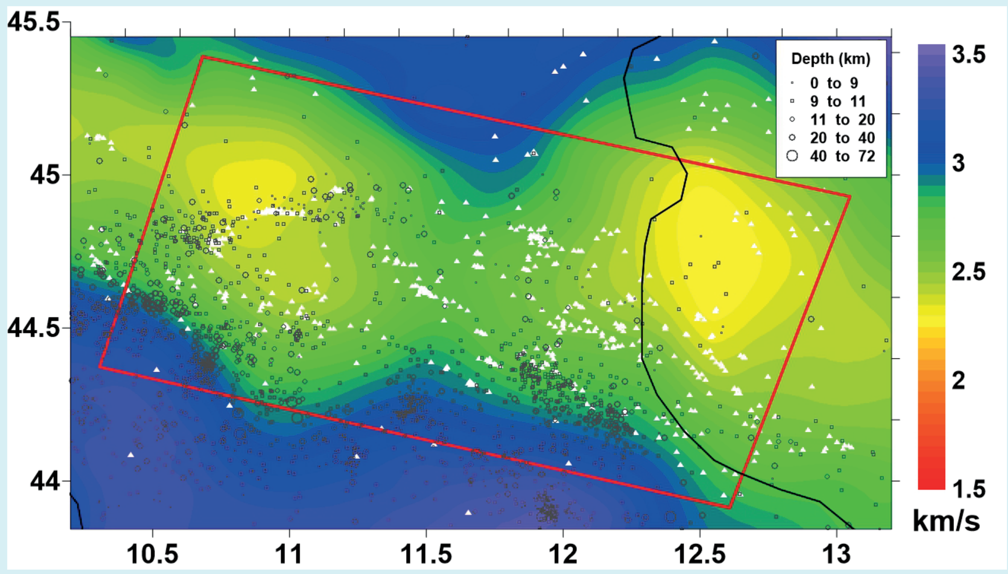

Fig. 3: S-waves velocities at a depth of 2 km [3]. Red rectangle delimits the study area. White triangles show the wells location from Videpi database. Grey circles show the earthquakes (1909-2024) location from the NEIC catalogue, with Mw> 2.5.

The S-wave velocities velocity model of the crust and upper mantle [3], was imlemented in the frame of AlpArray project, using ambient-noise wave-equation tomography.

We can observe that most of the study area is characterized by low seismic velocities in the very shallow crust (Fig. 3), probably reflecting the relative high sedimentary thickness in the RFF, which sharply reduces owards the Apennines.

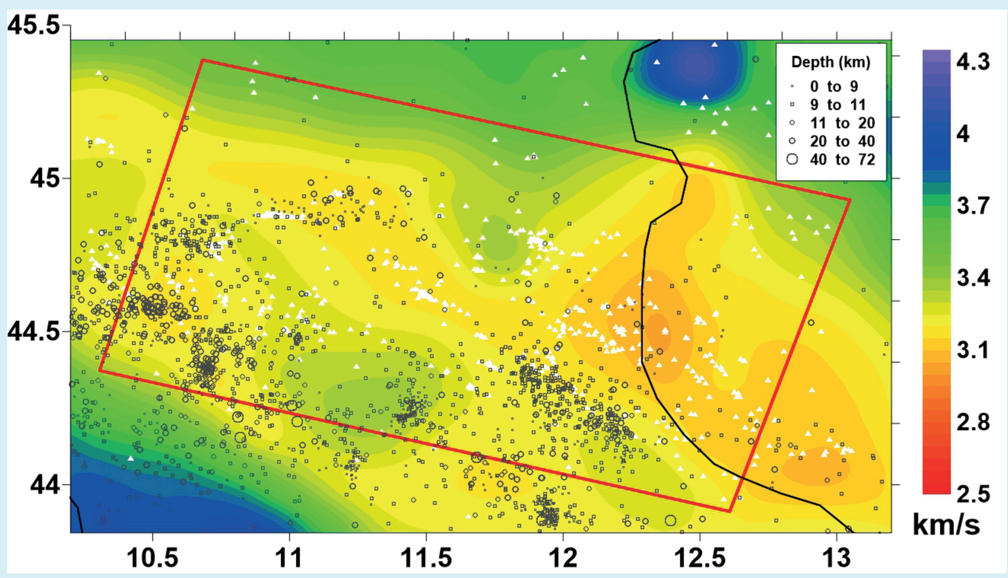

Fig. 4 : S-waves velocities at a depth of 20 km [3].

The S-waves velocities at the middle crustal depth in the RFF (Fig. 4) are relatively low, with respect the surrounding areas, indicating a weak crust, characterized by deep seismicity (20-40 km).

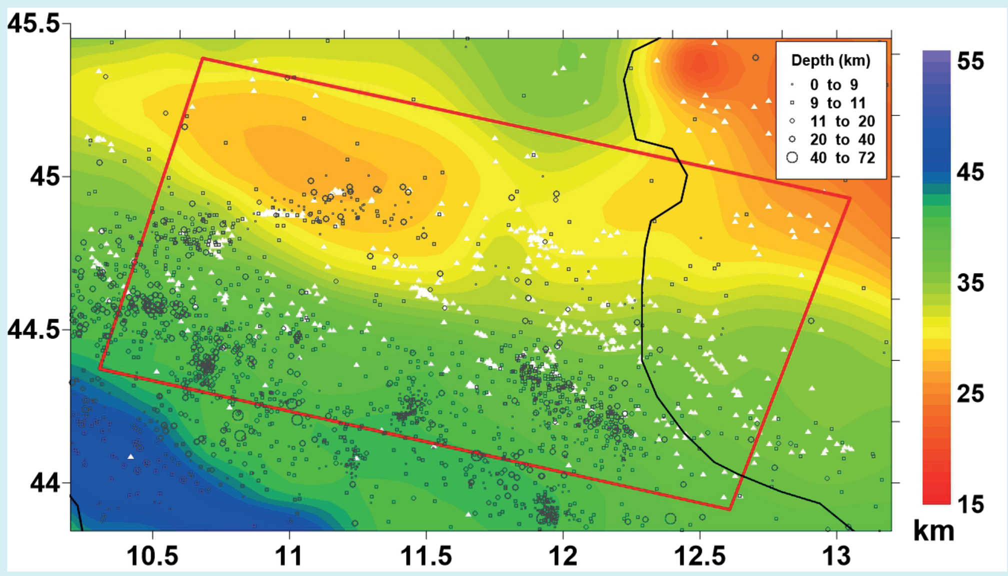

Fig. 5: Moho depth [3].

The Moho depth (Fig. 5), reconstructed by estimating the depth of the iso-velocity contour of 4.1 km/s, increases towards the Apennines, from ~27 km to ~48 km..

Crustal Velocity Model (Magnoni et al., 2022)

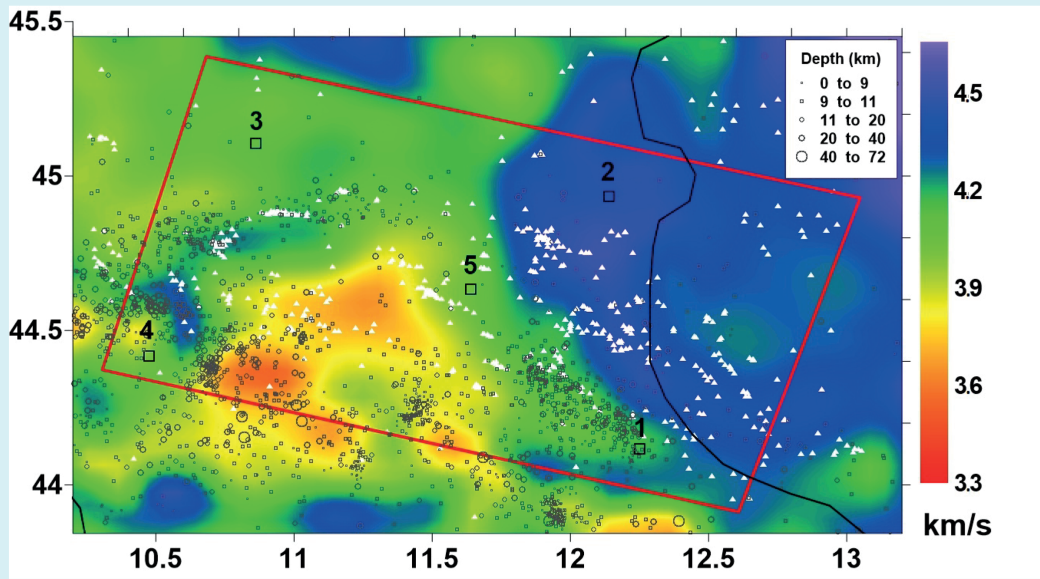

Fig. 6: P-waves velocities at a depth of 2 km [4]. Black squares with numbers show the location of the velcity distribution curves dislayed in Fig. 10. The other features are as in Fig. 3.

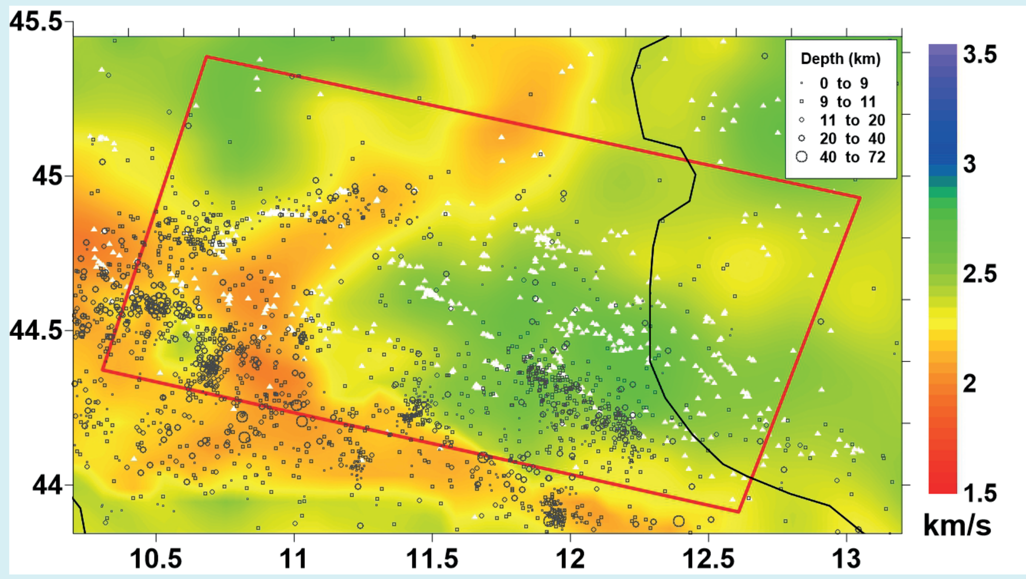

Fig. 7: S-waves velocities at a depth of 2 km [4].

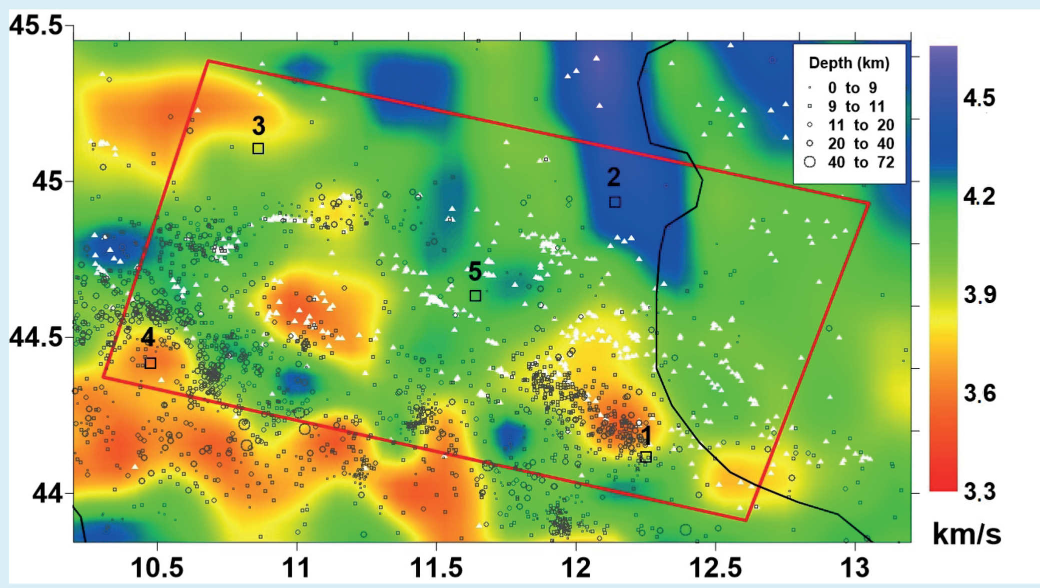

Fig. 8: P-waves velocities at a depth of 20 km [4].

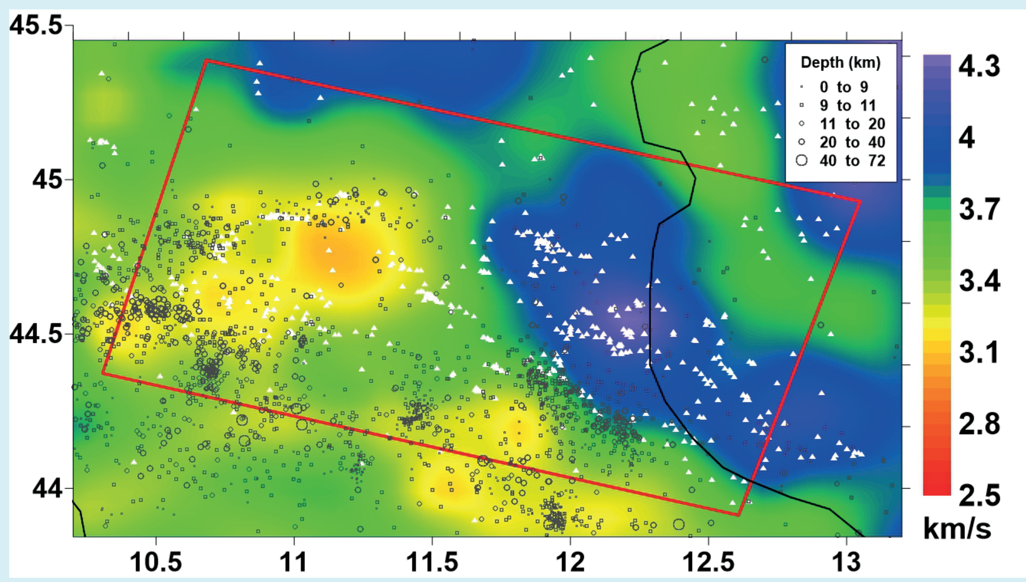

Fig. 9: S-waves velocities at a depth of 20 km [4].

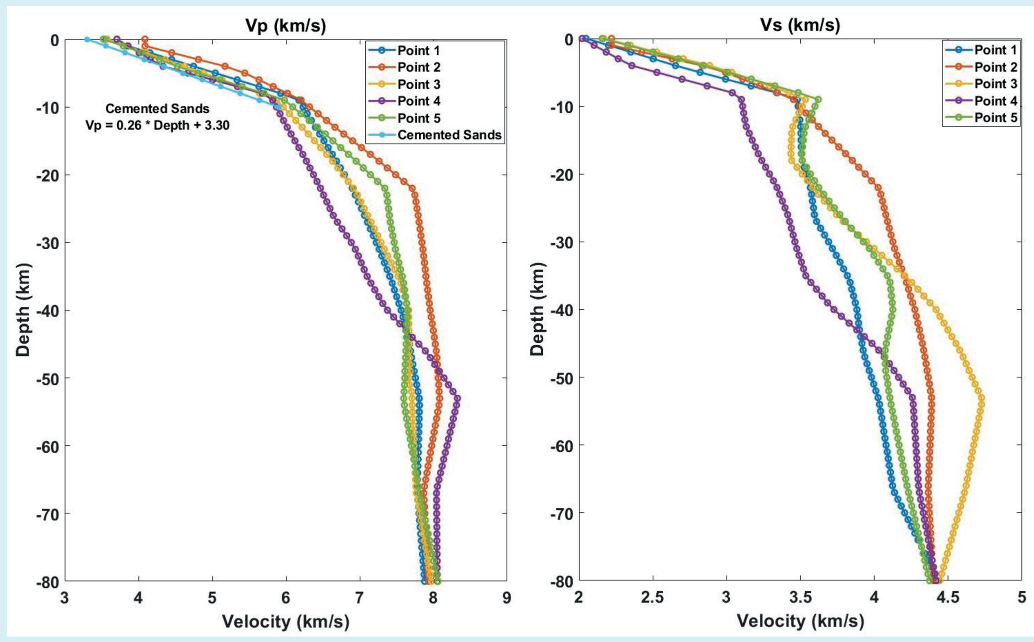

Fig. 10: P- (left panel) and S-waves (right panel) velocity depth distribution in the shallow lithosphere [4]. Calculated P-wave in cemented sand is from [5].

A very recent seismic tomography model of the Italian lithosphere based on ground motion recordingshas been implemented [4].

The comparison between the Vp and Vs-depth distribution in our study area help identify both the main crustal layers and areas of crustal thickening. (Figs. 6-9). We notice a general velocity trend decrase from the northeastern to the southwestern part of the study area (Figs. 8-9), supposing an increase of the crustal thickness in the same direction.

We also observe that the P-wave velocity in the shallow crust (< 10 km) is consistent with that obtained from the linear regression between the sonic velocity and depth for the cemented sand (Fig.10). The last one was obtained using the empirical linear relationship proposed in [5].

Bouguer anomalies model (Zahorec et al., 2021)

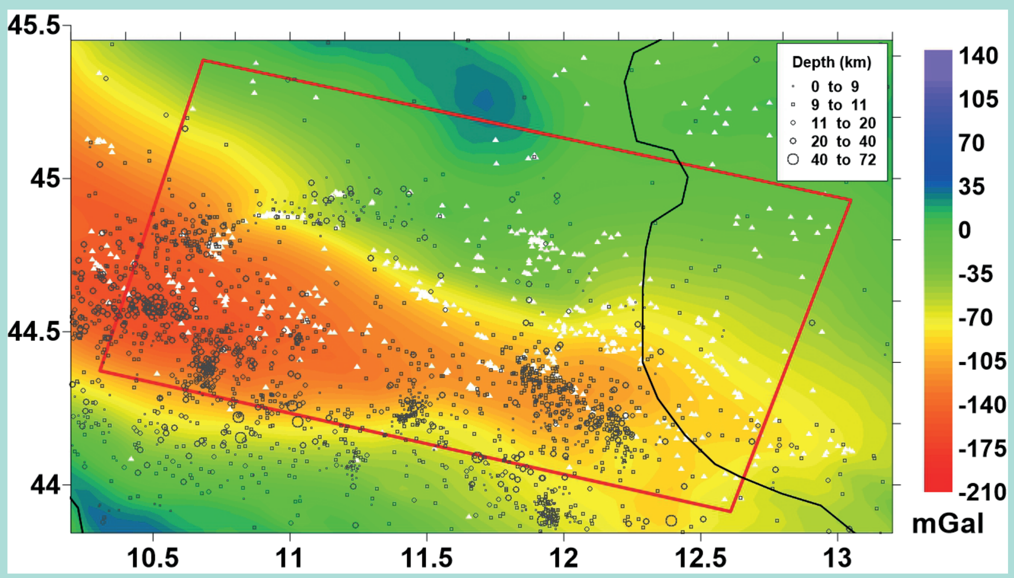

Fig. 11: Bouguer anomalies [6].

The Bouguer anomalies are provided with a resolution of 4 km x 4km by the AlpArray Gravity Research Group.

The negative Bouguer anomalies characterize most of he RFF and are consistent with the low velocities of the shallow crust (Figs. 3, 6-7).

Upper mantle velocity model (Rappisi et al., 2022)

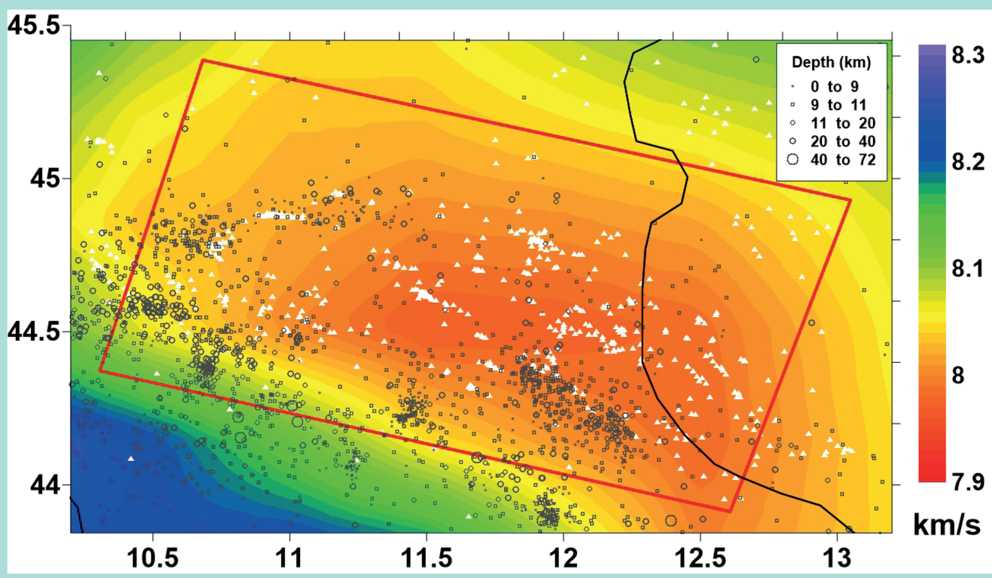

Fig. 12: P-waves velocities at a depth of 100 km [7].

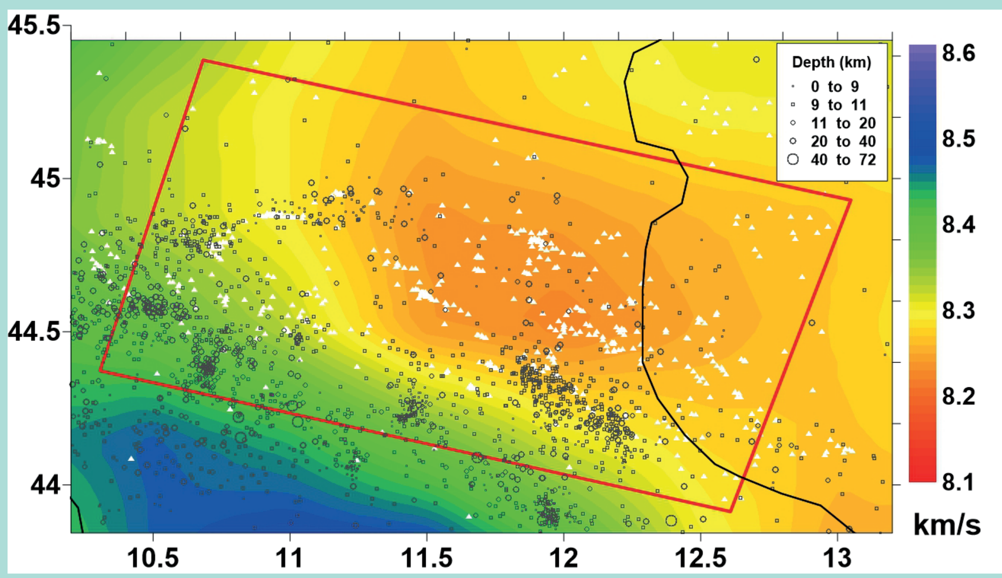

Fig. 13: P-waves velocities at a depth of 200 km [7].

The three-dimensional anisotropic teleseismic P-wave tomography model show that the upper mantle velocity is low in the central part of the study area, likely due to a local asthenospheric

References

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