3D Anisotropic velocity model of the Los Humeros geothermal field, Mexico, using seismic ambient noise tomography

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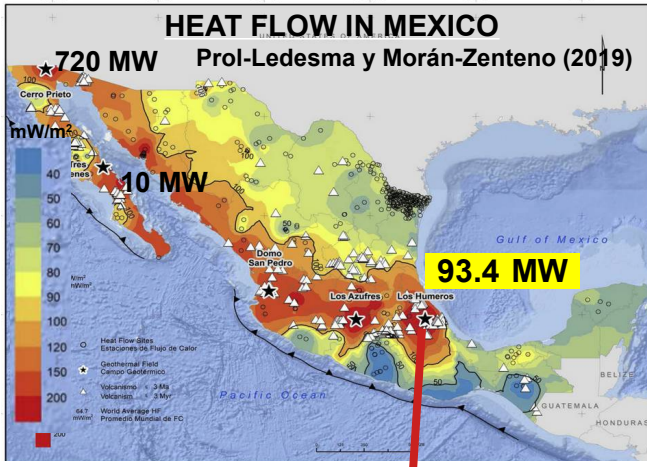
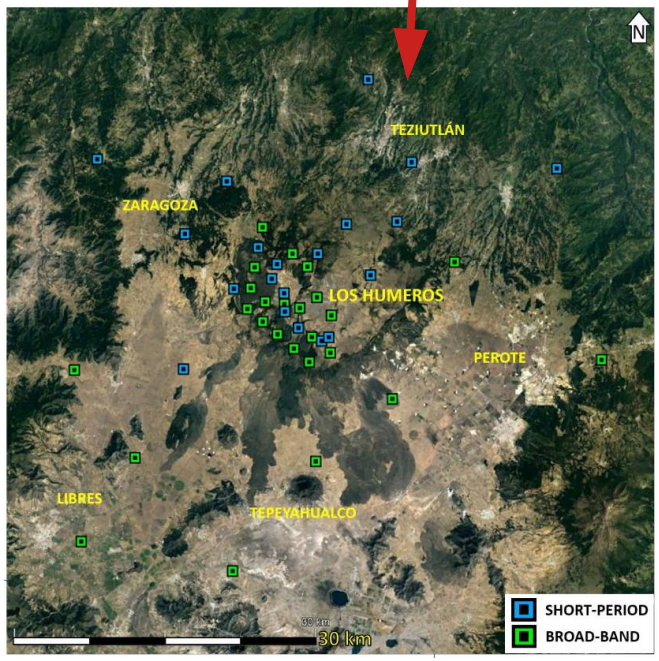
Seismic imaging of the deep structures for the Los Humeros caldera, a super-hot geothermal system in Mexico, as part of the framework of the consortium GeMex (Mexico – European Union).

- 3D anisotropic model for the geothermal system, using the seismic ambient noise tomography.

Los Humeros Seismic Network





SEISMOMETERS

BROAD-BAND

A)

B)

Trillium compact
120 s – 100 Hz

Digitizer: Data-Cube3

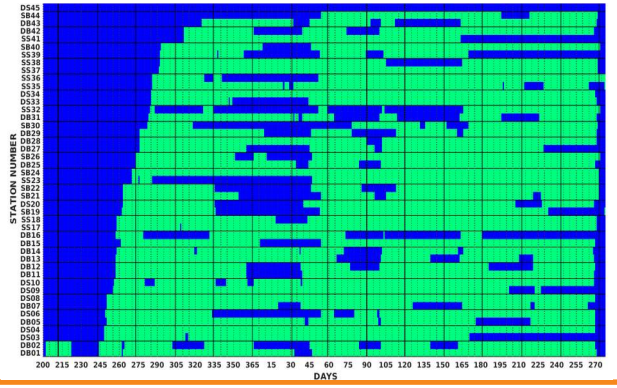
SHORT-PERIOD

Mark L-4V-3D
1 – 100 Hz

Digitizer: EarthData PR6-24

DATABASE AVAILABILITY

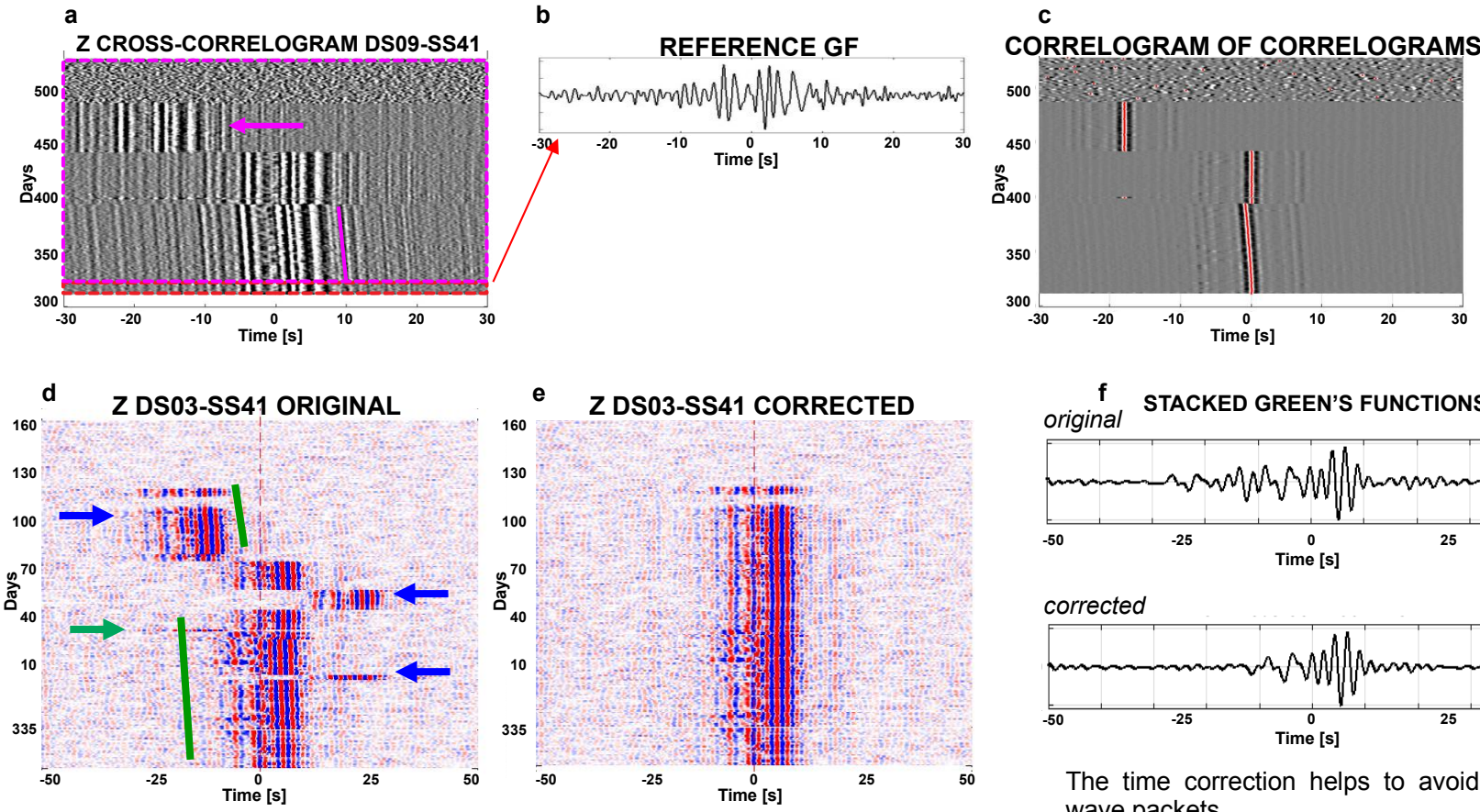
Since July 2017, until October 2018
(almost 440 days).



DATABASE QUALITY CONTROL

TIME SYNCHRONIZATION

We checked the time continuity of the database by analyzing the daily cross-correlation behavior, in order to identify if time deviations are present.

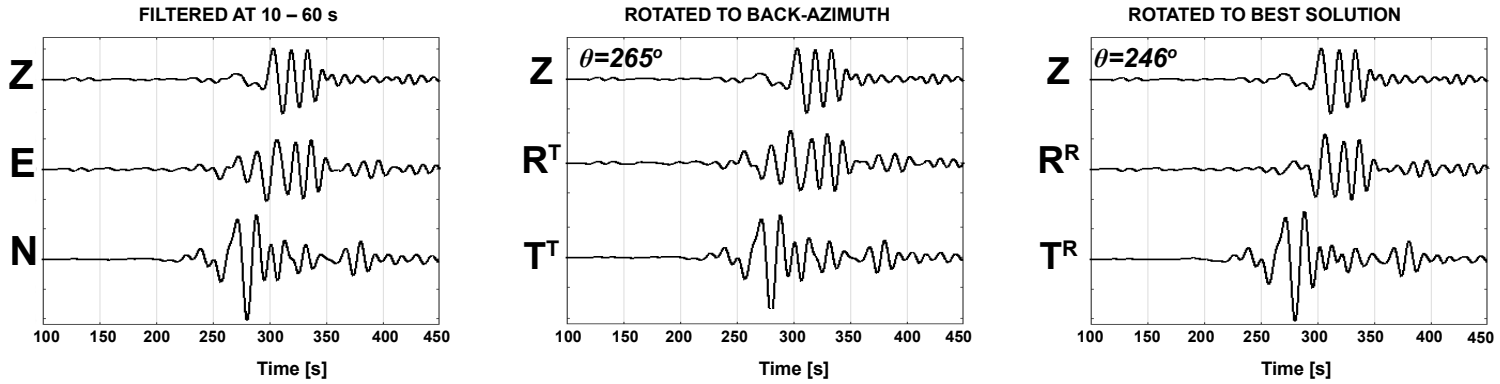


The time correction helps to avoid wrong wave packets.

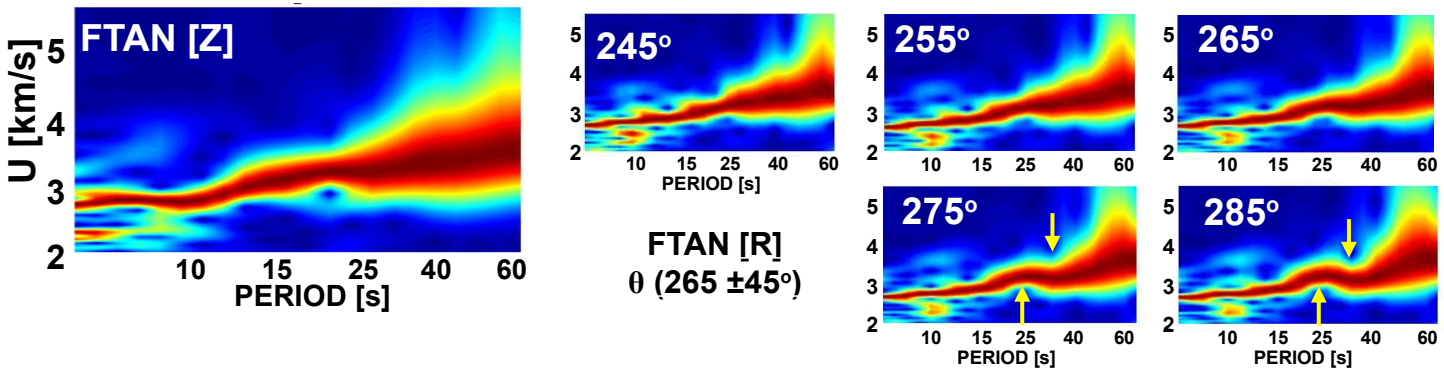
DATABASE QUALITY CONTROL

CORRECTION OF SENSOR'S ORIENTATION

We must assure the correct orientation if we want to analyze the anisotropy patterns. By taking several regional and tele-seismic earthquake records, we used the polarization of the surface waves in order to identify the correct orientation, based on the theoretical back-azimuth for each earthquake with respect the network position.



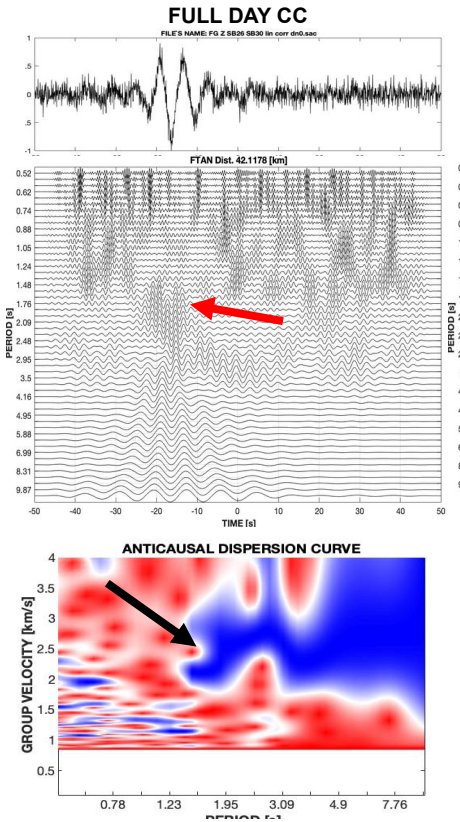
Comparing the dispersion pattern (FTAN diagram) for the horizontal components rotated at different angles, we were searching the angle where radial component are so much similar to the vertical component one, due the P-SV polarization of the Rayleigh waves.



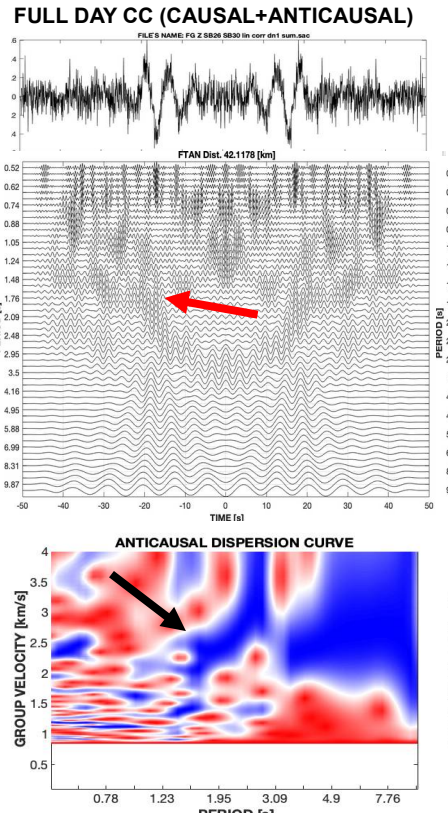
DATABASE QUALITY CONTROL

VARIATION OF THE GREEN'S FUNCTION RETRIEVAL

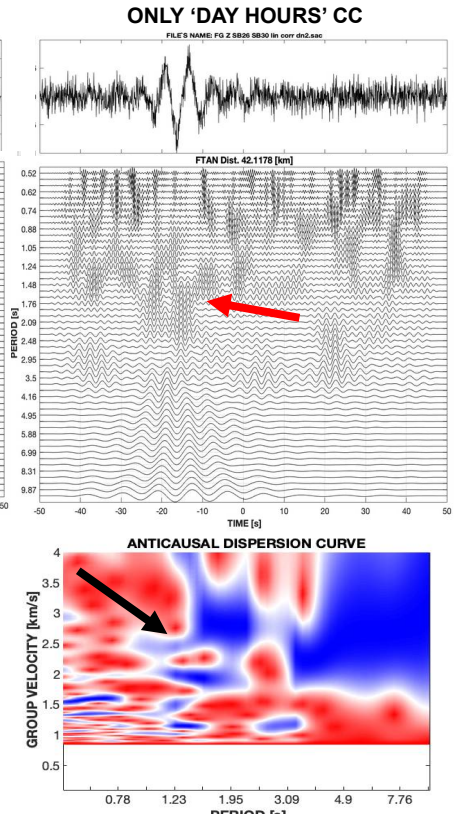
By using same processing scheme, variation of noise level during the day impacts on the retrieval of GF. Taking only "night hours" get a better recognition of the surface wave dispersion, even more than the sum of causal and anticausal part.



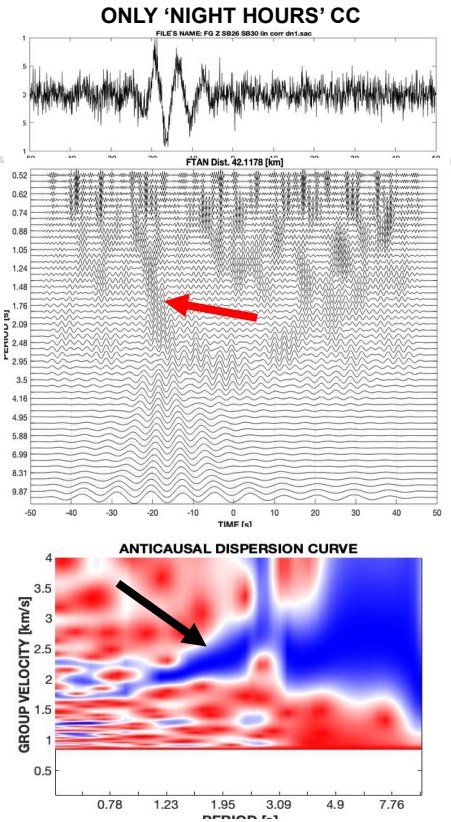
At short periods, dispersion pattern is not clear.



Dispersion pattern not focused.



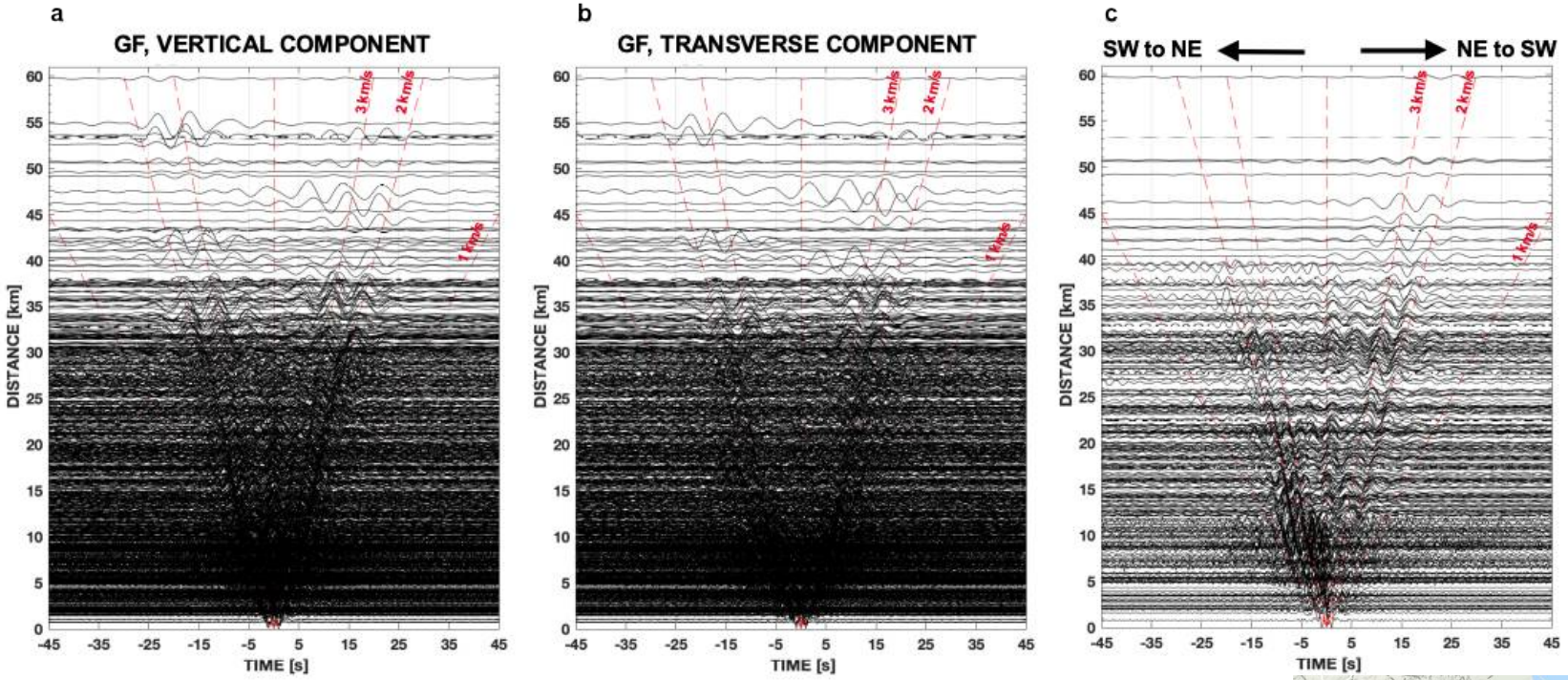
Dispersion pattern not focused.



The best dispersion pattern continuity.

GREEN'S FUNCTIONS

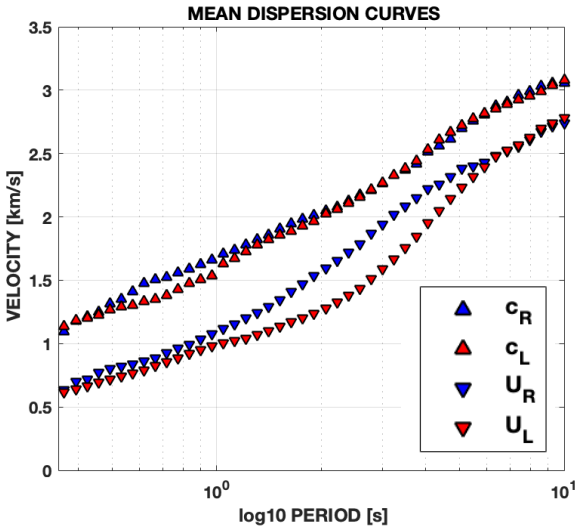
Retrieved GF for the Rayleigh (a) and Love waves (b). Velocities of the wave packets for the longer periods rounds 3 km/s.



The gather of the Rayleigh waves, aligned in the NE-SW direction (c) shown a high directivity of the noise sources coming from the NE to the SW (causal part), related to the swell of the Gulf of Mexico, located at 100 km NE of the LHVC.

Because of that, we used the NDCP code (Granados et al., 2019) for the picking of the dispersion curves in the causal and anticausal parts of the GF.

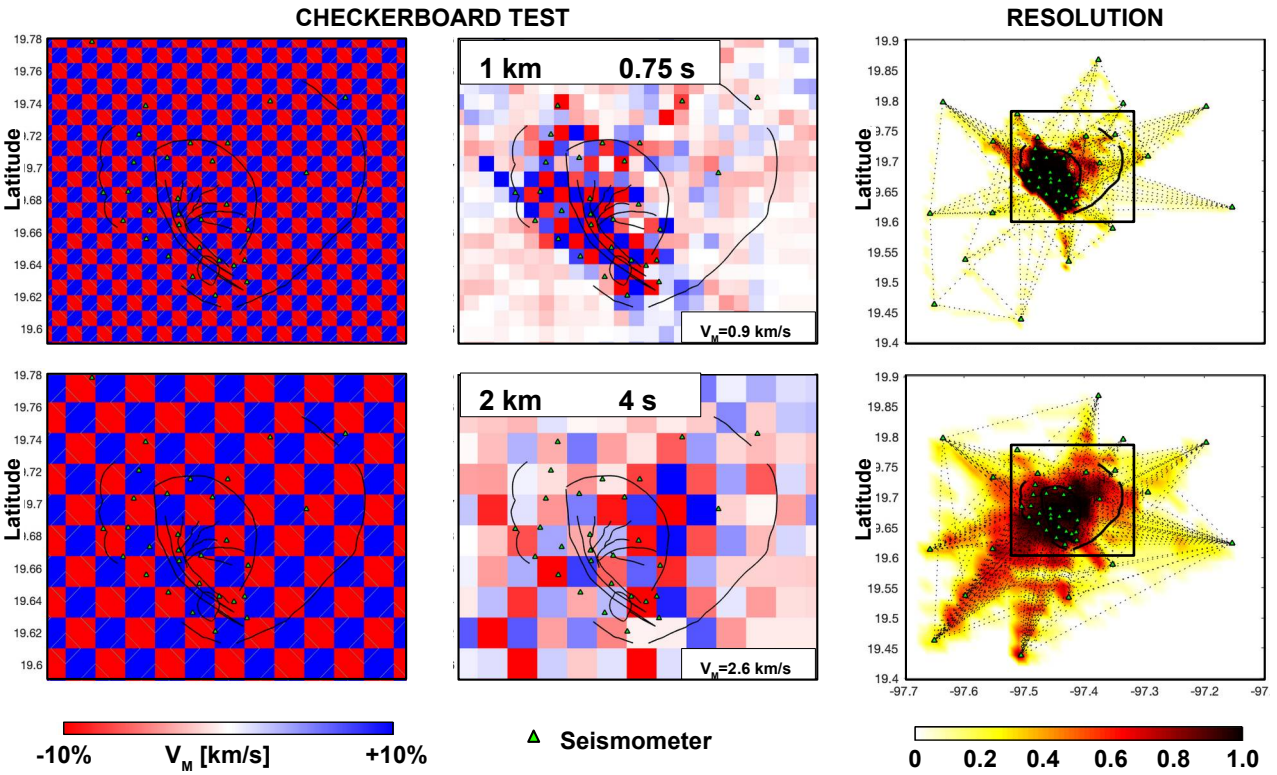
GREEN'S FUNCTIONS



Mean dispersion curves obtained for group and phase velocity, for Rayleigh and Love waves, from 0.3 to 10 s, and a velocity range from 0.5 to 3 km/s.

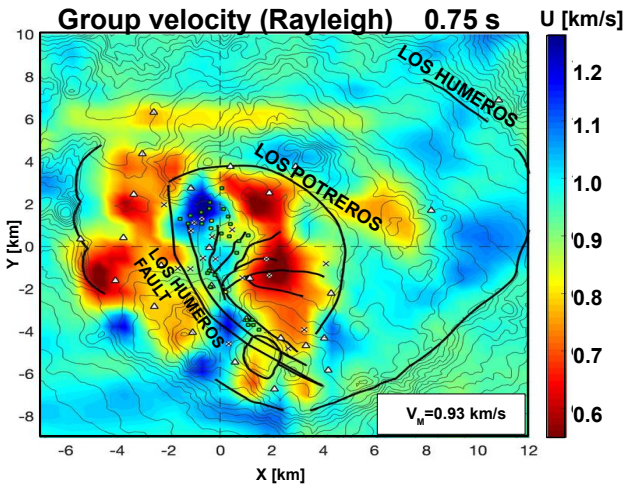
After the picking of the dispersion curves, we tested different cell-size grids, in order to obtain the better image at each period. We used cells from 1 km to 2.5 km, along the whole bandwidth.

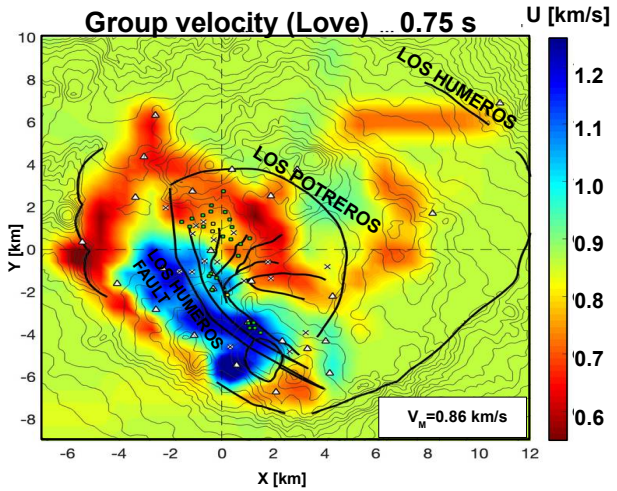
The best resolution is located inside the Los Potreros caldera, where the inner array of seismometers were placed.



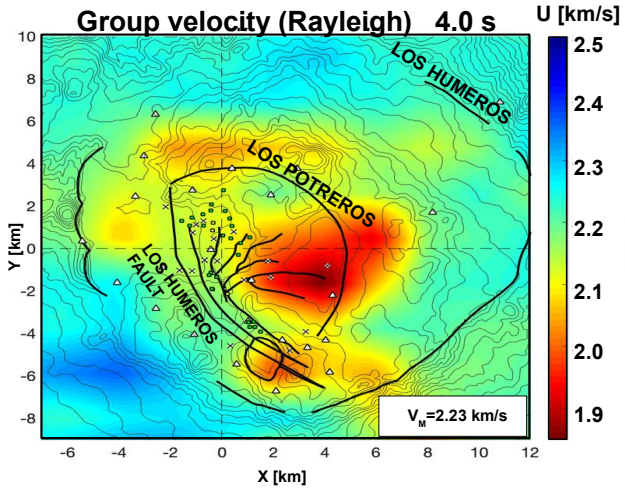
2D VELOCITY MAPS

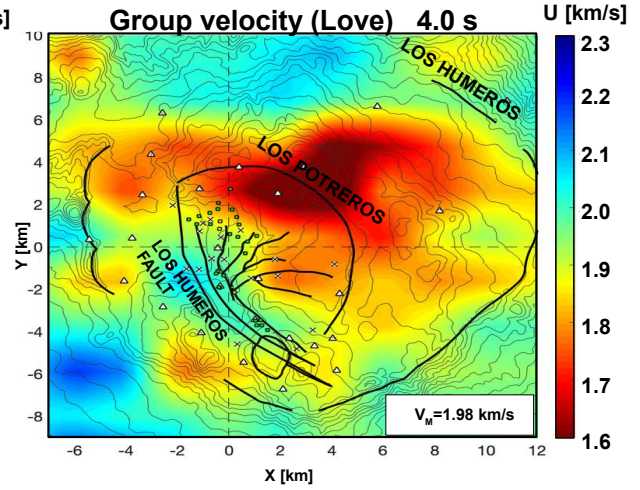
At short periods, we observe a low velocity ring-shape (0.55 – 0.7 km/s) pattern along the Los Potreros rim, surrounding a high velocity area (1.1 – 1.3 km/s) in its central part; along the Los Humeros fault for Rayleigh waves, and to the western part of the fault, for Love waves.





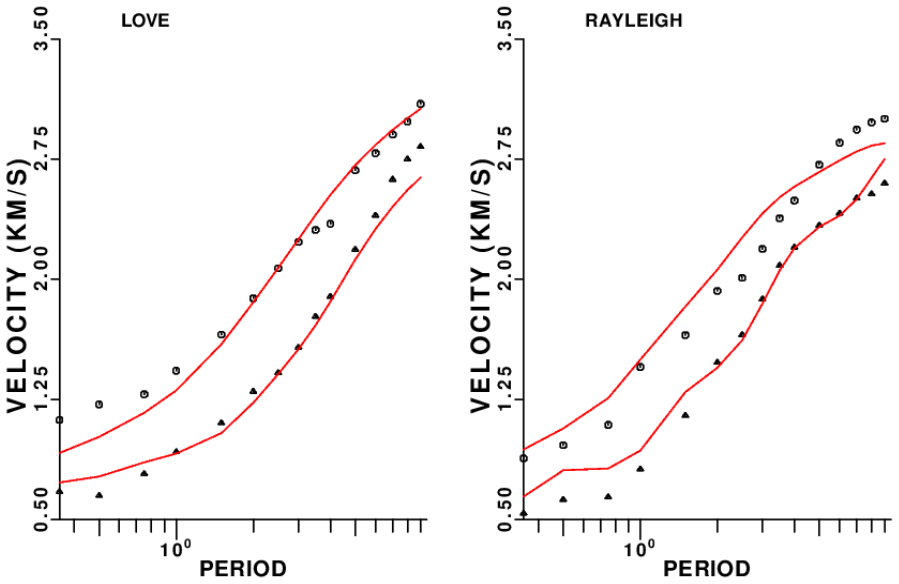
At 4 s, a large low velocity structure can be observed at the center of the Los Humeros caldera, but it differs in its extension and velocity magnitude from one component to the other, being higher for the Rayleigh waves (≈ 1.9 km/s) than the Love waves, (1.6 – 1.7 km/s).



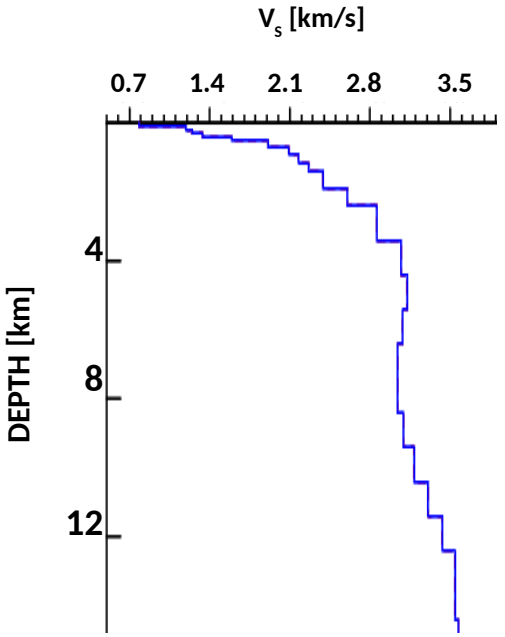


3D ANISOTROPIC MODEL

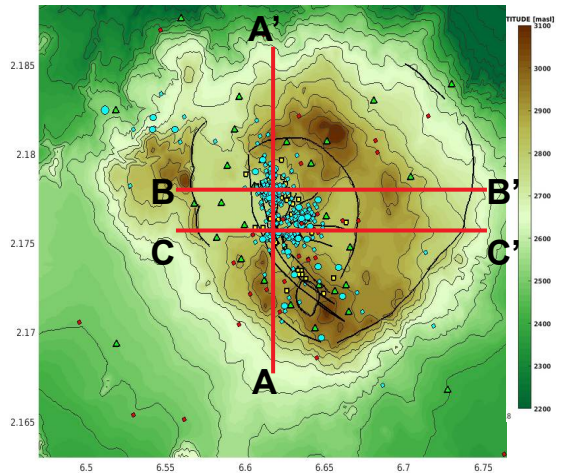
Joint inversion of group and phase velocities, for Rayleigh and Love waves (Herrmann, 2013).



Mean velocity model (V_s).



3D anisotropic V_s model

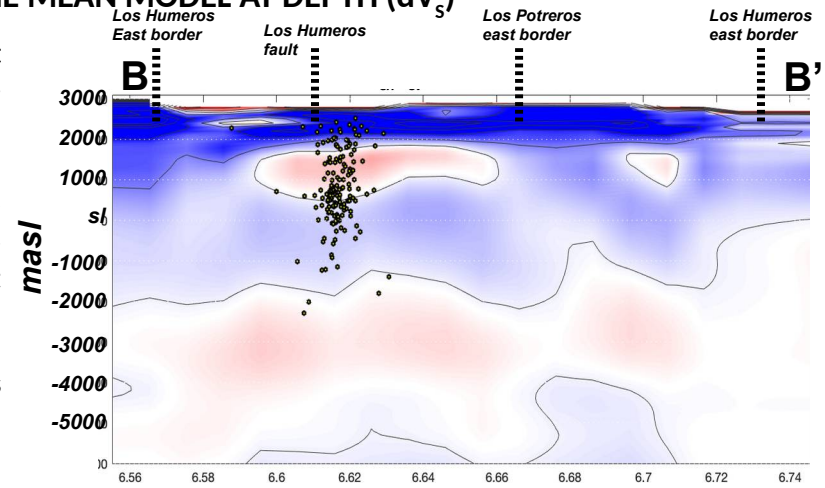


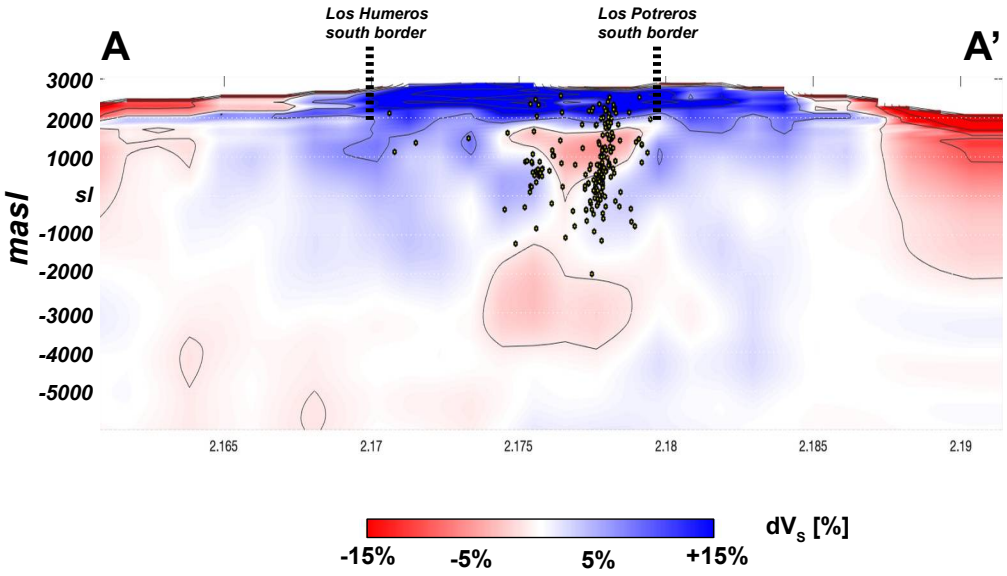
VARIATION WITH RESPECT THE MEAN MODEL AT DEPTH (dV_s)

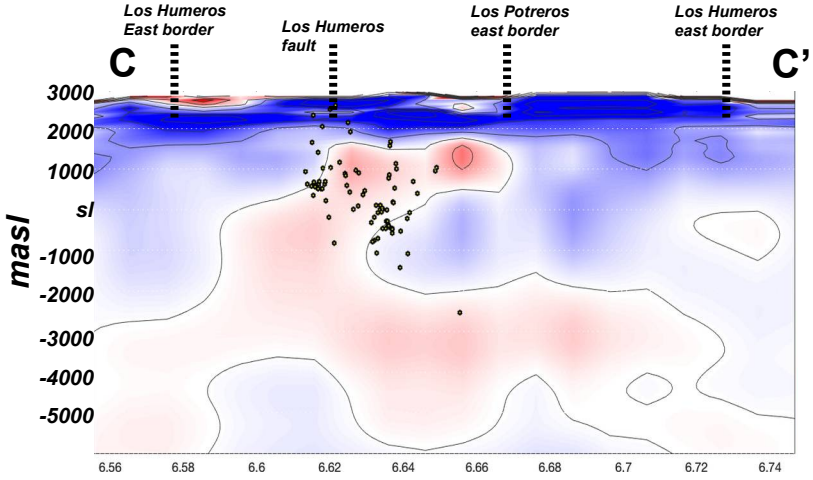
In A-A', we observed a low V_s body at from 1500 – 3500 mbsl, just below the seismicity stops.

In B-B', a thick layer of low velocity is observed at 2000 masl (-10% V_s), where the seismicity pass through it at the north.

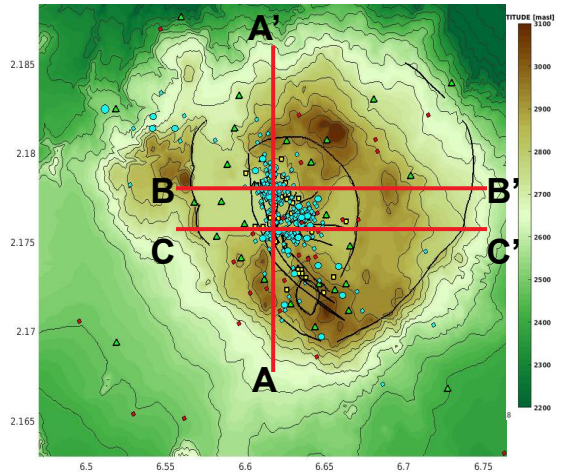
In C-C', this low VS body becomes thicker and deeper to the south.







3D anisotropic V_S model

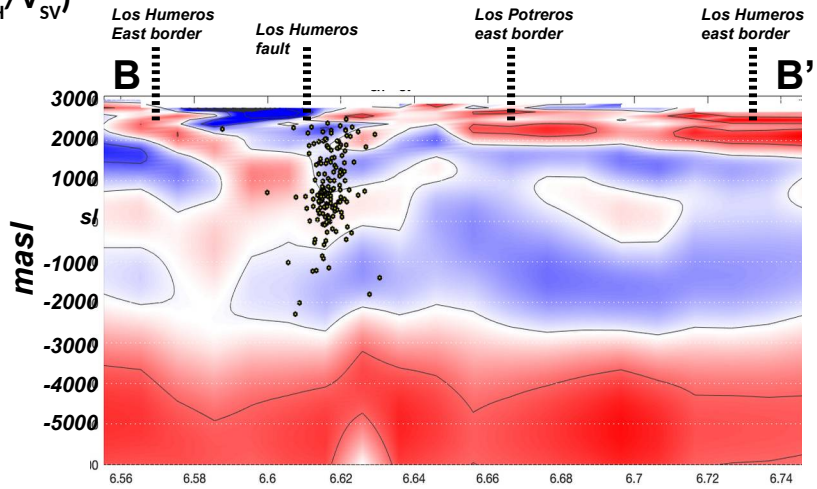


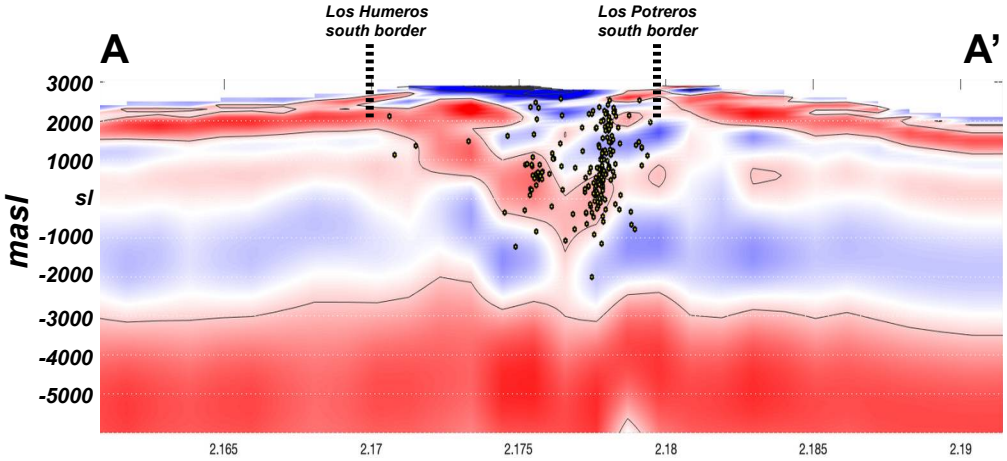
RADIAL ANISOTROPY $\xi = (V_{SH}/V_{SV})^2$

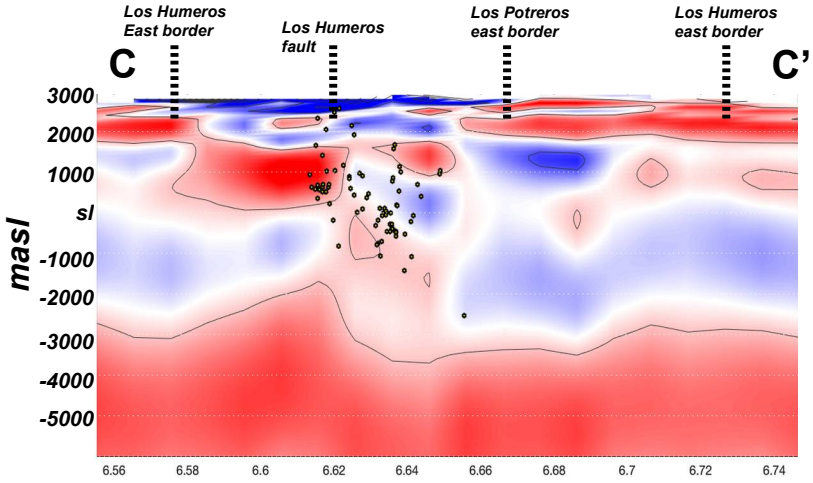
In A-A', a dominant VSV (ξ<1) upward pattern connect the low V_S with the base of the seismicity clusters.

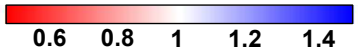
In B-B', the seismicity pass through two ξ>1 areas, as a lateral discontinuity at 2000 masl, where the seismicity is located.

In C-C', this ξ>1 pattern where located above several ξ<1 bodies, surrounding a ξ>1 body at 0 masl.



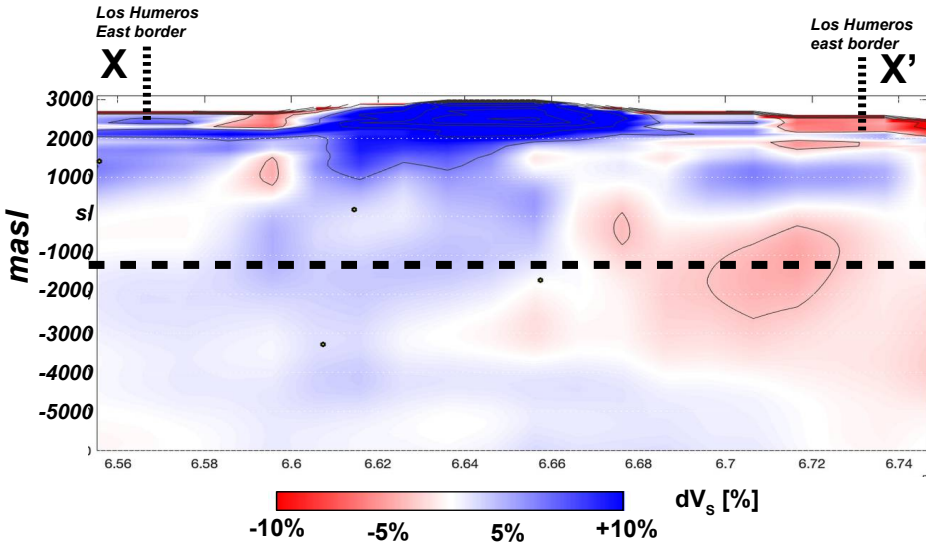






$\xi = (V_{SH}/V_{SV})^2$

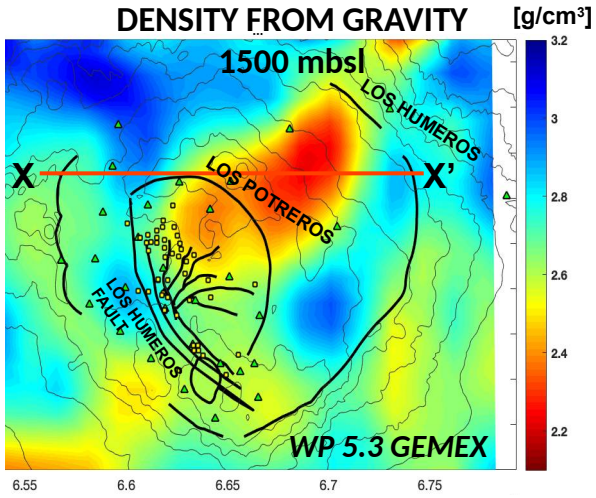
3D anisotropic V_s model

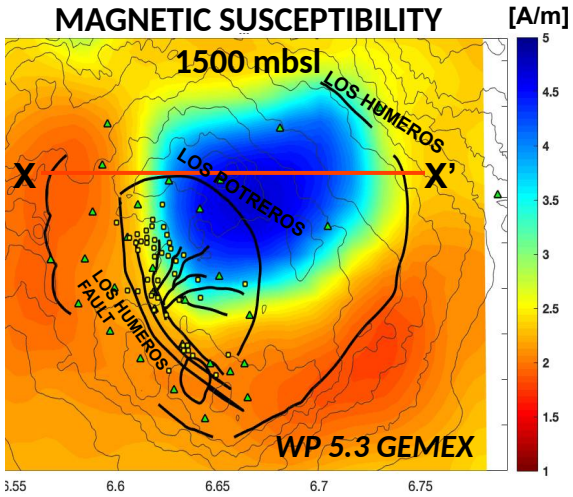


A deep anomaly…

We were able to identify a **low V_s** big area located in the NE part of the Los Humeros caldera, where other geophysical methodologies have been observed a body of **low density** and **high magnetization**.

A electrical resistivity image obtained with magnetotelluric soundigns, revealed a low resistivity body (≈3Ωm) in this same area.





Conclusions

- Good agreement with shallower geology of the caldera (i. e. Los Potreros rim, Los Humeros fault, etc).

- A low V_S layer at 1 km depth (its top), with variable radial anisotropy pattern, is located at the center of the Los Potreros caldera.

- A low VS body at 1500 mbsl, with an upward $\xi<1$ pattern ($V_{SV}>V_{SH}$), could be related with the up-flowing paths of the geothermal reservoir.

- At the NE part of the Los Humeros caldera, we observed a big low V_S body, from sea level down to 4000 mbsl, that is located where a low density and a high magnetization anomaly was identified for other work package of the GeMex project.

Acknowledgements

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