A. OVERVIEW
Seismic tomography in volcanic-hydrothermal systems
1. It allows to infer the hydrodynamic state beneath the volcanic edifice and the surrounding area.

2. Locate spatially the magmatic reservoirs and related alterations.

3. Different petro-physical parameters of the host rock such as temperature, composition, and density, can be linked to the 3D velocity structure of P- and S-wave arrivals.

4. Locate the extension areas of geothermal energy.

B. GEOTHERMAL EXPLORATION IN NORTHERN CHILE
The southern segment of the Central Volcanic Zone, in northern Chile, has been the focus of increasing attention due to the large number of hydrothermal systems. In this zone, there are about 40 geothermal areas, of which only a few are under systematic exploration. Particularly, Tacora volcano (17º43'S – 69º46'W) had been studied during the last years by local and international teams, due to the presence of active thermal manifestations. Hot springs, fumarolic fields, and the large number of hydrothermal systems, for its magmatic-hydrothermal nature, suggested that it could correspond to a promissing geothermal field.

C. TACORA VOLCANO
Tacora volcano (Fig. 1 E) is a composite stratovolcano located at ~100 km northeast of Arica, northern Chile region. It has a summit elevation of 5980 m a.s.l. and 1700 m from its base.

The volcano is composed by andesitic lavas and pyroclastics of the Miocene age, with an intercalated felsic unit. The volcanic activity is related to the subduction of the Nazca plate under the South American plate. The last eruptions occurred ~650 ka ago, and it is considered that the current magmatic system is probably related with an explosion crater about 500 m in diameter, located on the NW side of the volcano. The present-day magmatic system is composed by dacite and andesite, with a maximum temperature of 900°C. The water-rock interaction in this system produces hot springs and fumarolic fields, with temperatures up to 94°C.

D. SEISMIC TOMOGRAPHY: VELOCITY MODELS

\[ \text{Vp/Vs} = \text{constant} \]

- High Vp/Vs values (1.6 - 1.8) are located in the western sector of the area identified as fluid-saturated rocks. The presence of fluids and the physical properties of the rocks (plasticity, La Tarata shallow aquifer) contribute to the presence of liquid water below the surface.

- Orientation and geometry of the low Vp/Vs anomalies (Fig. 3 & 4) suggest the presence of a high angle and locally blind structure below the volcanic cover. According to the observed geometry we infer that this structure corresponds to the Challaviento fault. It is not in relation with local seismicity and the Challaviento fault. Local seismic activity is likely related to fracturing generated by fluid mobility, or with the emplacement of a magmatic reservoir associated with Tacora volcano. Both, seismicity cluster and the proposed magmatic cavern are spatially correlated.

- The location and orientation of the low Vp/Vs anomaly (Vp/Vs < 1.68) and low ∆Vp/Vp (%) (Fig. 3 & 4) is attributed to the hydrothermal-magmatic reservoir (Fig. 3 & 4). For example, the area located between 270°C (Fig. 3) and the geothermal reservoir proposed by Capaccioni et al. (2011). According to our model, yellow zones (Fig. 3 & 4) could correspond to a network of active channels. These channels are responsible for the circulation of magmatic-hydrothermal fluids, which can be supported considering the low Vp/Vs values associated with the hypocaust zone and magnetic anomalies, i.e., the interpretation of fluid circulation and the interpreted fluid circulation model presented by Capaccioni et al. (2011).

- The presence of this magmatic-hydrothermal reservoir gives rise to clay deposits (5.5 km a.s.l.) and low Vp/Vs values (Fig. 4). These features are linked with intermediate Vp/Vs values and low ∆Vp/Vp (%) values. The presence of clay deposits is strongly linked to the surface of the Tacora volcano and indicated by the proposed model. This model enhance and support the results previously observed in the zone.

E. CLUSTER ANALYSIS

To better identify the phase segmentation that could be inferred from the Vp/Vs and ∆Vp/Vp (%) models (Fig. 3 & 4), a cluster analysis has been made. The clearly identifiable variations in ∆Vp/Vp (%) represent stronger variations of the bulk modulus, whereas Vp/Vs variations are related to changes in the fluid content. The cluster analysis is based on Vp/Vs, Vp, and Vs values.

- The first cluster is composed by low Vp/Vs values linked with the hydrothermal-magmatic reservoir, an intermediate Vp/Vs value, and intermediate ∆Vp/Vp (%). This cluster is related to the location of clay deposits and gas manifestations, which are coincident with the location of the Challaviento reverse fault.

- The second cluster is composed by intermediate Vp/Vs values (1.68-1.74) and low ∆Vp/Vp (%) values linked with the clay level. This cluster is related to the location of the Challaviento reverse fault, which is coincident with the location of the Challaviento reverse fault.

- The third cluster is composed by high Vp/Vs values (1.75-1.80), high ∆Vp/Vp (%) values, and high temperatures. This cluster is related to the location of the Challaviento reverse fault, which is coincident with the location of the Challaviento reverse fault.

F. MODEL OF FLUID CIRCULATION

This model consists of an overlap between topographic, fumarolic field locations, and the first and shallow layer of the Vp/Vs model between 3.0 and 4.5 km a.s.l. (Fig. 5). High Vp/Vs values are located at the location of the recharge zone of the magmatic-hydrothermal system, represented by the location of the Challaviento reverse fault. The second layer is represented by the location of the Challaviento reverse fault. The third layer is represented by the location of the Challaviento reverse fault.

The results of this model enhance and support the results previously observed in the zone. This model is based on the observed geometry of the magmatic-hydrothermal system and the presence of hydrothermal-magmatic reservoirs, which are coincident with the location of the Challaviento reverse fault. The model is consistent with the observed geometry of the magmatic-hydrothermal system and the presence of hydrothermal-magmatic reservoirs, which are coincident with the location of the Challaviento reverse fault. The model is consistent with the observed geometry of the magmatic-hydrothermal system and the presence of hydrothermal-magmatic reservoirs, which are coincident with the location of the Challaviento reverse fault. The model is consistent with the observed geometry of the magmatic-hydrothermal system and the presence of hydrothermal-magmatic reservoirs, which are coincident with the location of the Challaviento reverse fault.