Tomografía sísmica del Batolito de Abitagua mediante sismos locales en la Reserva Colonso-Chalupas, Napo, Ecuador

Seismic tomography of the Abitagua Batholith using local earthquakes in the Colonso Chalupas Reserve, Napo, Ecuador

José Sebastián Araujo Soria[1]

1 Universidad Regional Amazónica Ikiam. https://orcid.org/0000-0002-9704-5779

Autor de correspondencia: jose.araujo@ikiam.edu.ec

DOI: https://doi.org/10.63804/CIBEN.25.cter.e5

Abstract

The Abitagua Batholith is a Jurassic intrusive and is considered the source of the alluvial gold deposits currently exploited in the Jatunyaku and Napo rivers. The northern part of this granite formation is located within the Colonso Chalupas Reserve, and our objective is to characterize the velocity of the seismic P and S waves. We obtain these velocities through seismic travel time tomography using local earthquakes recorded at five Raspberry Shake stations. We use the INSIGHT software to solve the tomographic inverse problem. We regularized the problem solution by generating L-curves, while the model's resolution level was calculated using the resolution operator. The resulting model is calculated on a 1 km grid. Both velocity values, Vp and Vs, show a gradual decrease from the highest granite elevation to its contact with the sedimentary Amazon formations. The P-wave velocity decreases from 3.9 km/s to 2.5 km/s, while the S-wave velocity decreases from 2.6 km/s to 1.6 km/s. These changes can be attributed to the transpressive tectonic interaction in the study area, as we are located on the edge of the North Andean Sliver.

Keywords: Abitagua Batholith; Seismic tomography; P-wave velocity; S-wave velocity.

Resumen

El Batolito de Abitagua es un cuerpo intrusivo jurásico y se considera la fuente de los depósitos aluviales de oro actualmente explotados en los ríos Jatunyaku y Napo. La porción norte de esta formación granítica se ubica dentro de la Reserva Colonso Chalupas, y nuestro objetivo es caracterizar la velocidad de las ondas sísmicas P y S. Estas velocidades se obtienen mediante tomografía de tiempos de viaje sísmicos, utilizando sismos locales registrados en cinco estaciones Raspberry Shake. Empleamos el software INSIGHT para resolver el problema inverso tomográfico. La solución se regularizó mediante la generación de curvas en L, mientras que el nivel de resolución del modelo se calculó utilizando el operador de resolución. El modelo resultante se calcula sobre una malla de 1 km. Tanto Vp como Vs muestran una disminución gradual desde las cotas más elevadas del granito hasta su contacto con las formaciones sedimentarias amazónicas. La velocidad de la onda P disminuye de 3,9 km/s a 2,5 km/s, mientras que la velocidad de la onda S desciende de 2,6 km/s a 1,6 km/s. Estos cambios pueden atribuirse a la interacción tectónica transpresiva en el área de estudio, dado que nos encontramos en el borde del Bloque Andino del Norte.

Palabras clave: Batolito de Abitagua; Tomografía sísmica; Velocidad de onda P; Velocidad de onda S.

Introduction

The Jurassic batholiths of the eastern flank of the Cordillera Real in Ecuador, which include the Rosa Florida, Abitagua, and Zamora intrusive bodies, are mainly composed of biotite quartz monzonites, monzogranites, granodiorites, and diorites (Spikings et al., 2015).

A seismic tomography study determined that the depth of the Abitagua Batholith averages 10 km in the section south of the Jatunyaku River, while decreasing to 2 km to the north. The tomography also shows that the southern zone is less compacted than the northern zone (Chalco et al., 2025).

The northern part of the batholith underlies the Colonso Chalupas Reserve in Napo Province (Figure 1). The objective of this study is to use records from five Raspberry Shake stations located east of the Reserve to perform seismic travel-time tomography. The results of this tomography allow for greater detail in the batholith's structure.

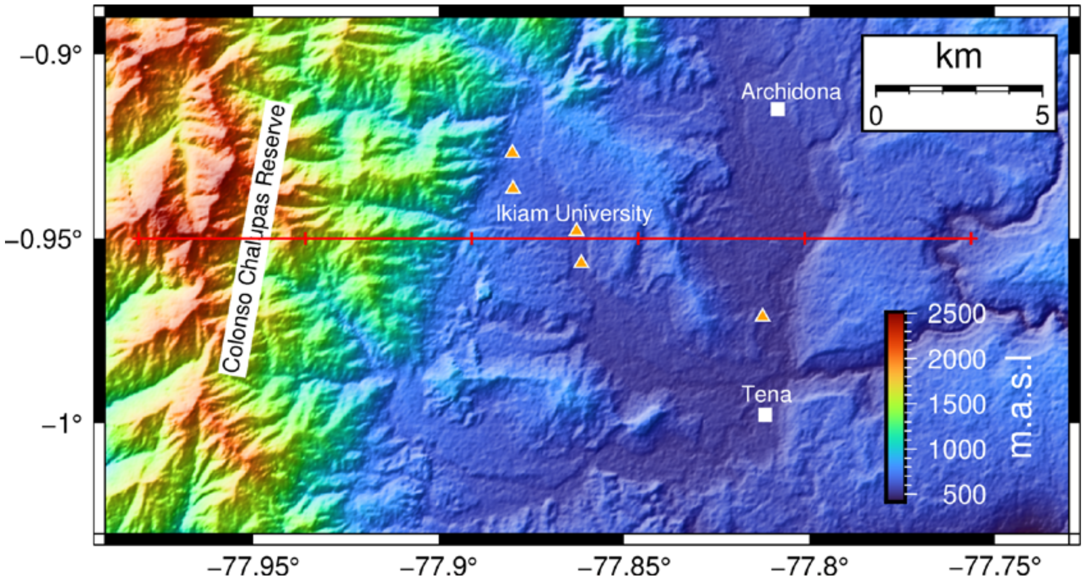

Figure 1. The map shows the regions where we obtain resolution in the tomography result. Yellow triangles are the Raspberry Shake stations. The red line represents the cross-section analyzed, with marks every 5 km as a reference.

Methodology

The software used for tomography was INSIGHT, following the scheme outlined in Araujo et al. (2021). The database consisted of 517 earthquakes recorded at the Raspberry Shake stations between 2023 and 2024. The data were complemented with four RENSIG stations available from the International Federation of Digital Seismograph Networks. These earthquakes were manually picked to determine their P and S waves, resulting in a total of 4,485 arrival times.

As an a priori model, we used the model obtained by Araujo et al. (2021), which was interpolated to a 1-km-per-side cubic grid. An initial localization was performed on this model using LOCIN software. With this data, we performed the tomography on 96 GRICARD cores, with an average computation time of 8 hours for each tomography solution.

We regularized the inverse problem using the L-curve, which led to the calculation of 35 tomography solutions. The resolution index was used to determine the areas where the model had resolution. In the tomography section, the resolution is indicated by a shaded area (Figure 2)

Results and discussions

A cross-section of the tomography result is shown in Figure 2. The cross-section is made in a west-east direction following the red line marked in Figure 1. The resulting velocity models for the P (P-wave) and S (S-wave) waves are expressed in kilometers per second. Both velocity models show a discontinuity in the 10 km vertical coordinate. This discontinuity suggests that the thickness of the Abitagua Batolith ranges from 3 to 4 km.

The portion of the solution corresponding to the Abitagua Batholith is visible due to the topography and extends from the abscissa 5 km to the left. The Vp velocity in the batholith decreases from values of 3.7 km/s in the upper part to 2.2 km/s on the flanks of the Amazonian foothills. The Vs velocity decreases from values of 2.5 km/s to 1.6 km/s in the same area.

The area where the model has resolution allows us to observe, using other tomography cross-sections, that this velocity decrease in both Vp and Vs is repeated from the Inchillaqui River in the north to the Jatunyaku River in the south. There is no information on lateral variations in the composition of the Abitagua Batholith, so this velocity decrease must be interpreted as changes in the structure of the granite that composes the batholith.

Structural variations can be attributed to two processes in the granite: erosion or fractures resulting from tectonic stresses. Since velocity variations are revealed down to significant depths of 5 km below the surface, it is doubtful that erosion could have reached these points. It is more plausible that the granite has degraded because it is located on the boundary of the North Andean Sliver, where shear and pressure stresses are significant.

We observe the transition from the Abitagua Batholith to the sedimentary formations in the study area at a Vp less than 2 km/s and a Vs less than 1.5 km/s. The contact could be with the Tena Formation, composed of clays, siltstones, and red sandstones, or with the Tiyuyacu Formation, which is mainly composed of conglomerates with a sandy to clayey matrix (Abarca et al., 2024).

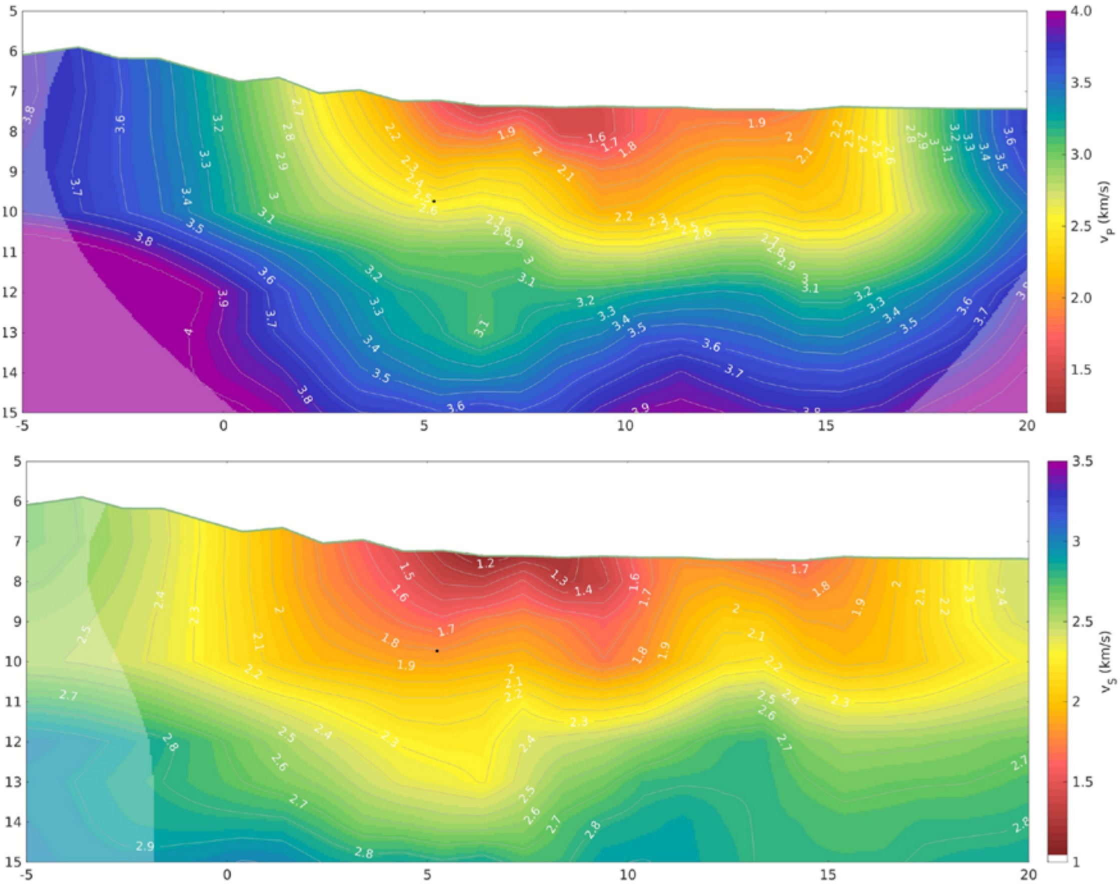

Figure 2. The tomography cross-section with velocity models for the Vp (up) and Vs (down). The values of velocities are displayed using a color scale and isovalue lines. The scale of the vertical and horizontal coordinates is in kilometers, and the velocities are in kilometers per second.

Conclusions

Travel-time seismic tomography using Raspberry Shake seismometers enables us to distinguish changes in the granite structure that comprise the Abitagua Batholith.

There is significant variation in both P-wave and S-wave velocities between the central part of the batholith and its flanks. These changes may be related to stresses generated by the movement of the North Andean Silver relative to the South American Plate.

The sedimentary formations in contact with the Abitagua Batholith exhibit P-wave velocities of less than 2 km/s and S-wave velocities of less than 1.5 km/s. This contact, as well as the rest of the formations present in the region, should be better detailed in a future analysis of our resulting model.

Acknowledgements

All tomography results in this study were performed using the GRICAD infrastructure (https://gricad.univ-grenoble-alpes.fr), supported by Grenoble research communities.

References

Abarca, K., Guzmán, O. y Campos, C. (2024). Características sedimentológicas y estratigráficas de rocas y sedimento alrededor del valle bajo del río Tena - Cuenca Oriente del Ecuador. En O. Guzmán y C. Campos (Eds.), Geociencias en la Amazonía Ecuatoriana (pp. 10-23). Editorial CEDIA.

Araujo, S., Valette, B., Potin, B., & Ruiz, M. (2021). A preliminary seismic travel time tomography beneath Ecuador from data of the national network. Journal of South American Earth Sciences, 111, 103486.

Chalco, D., Araujo, S., Loaiza, S. B., & Ruiz, M. (2025). Study of the Abitagua Batholith in the Sub-Andean Zone of Ecuador, using velocity models from seismic tomography. Andean Geology, 52(2), 254-267.

Spikings, R., Cochrane, R., Villagomez, D., Van der Lelij, R., Vallejo, C., Winkler, W., & Beate, B. (2015). The geological history of northwestern South America: from Pangaea to the early collision of the Caribbean Large Igneous Province (290–75 Ma). Gondwana Research, 27(1), 95-139.