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P- and S-wave Velocity Structure of the Near Surface from Seismograph Station Pair Analysis

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Abstract

The characterization of near-surface seismic velocities in Brazil remains challenging due to limited high-resolution data. This study develops an optimized station-pair apparent velocity method using data from the Brazilian Seismograph Network (RSBR), analyzing P- and S-wave arrivals across three key geological provinces: Sedimentary Basins, Cratons, and Fold-Thrust Belts.

Our approach combines trigonometric relationships between apparent velocities and incidence angles with strict event-station alignment criteria. Preliminary results demonstrate distinct provincial trends: Vp = 6.09-6.22 km/s and Vs = 3.56-3.64 km/s, consistent with global references but providing unprecedented regional resolution.

These findings establish the first comprehensive velocity constraints for Brazil's shallow crust. While sensitive to acquisition geometry, the method offers reliable approximations for seismic hazard assessment and resource exploration, creating a foundation for future high-resolution studies of Brazilian terrains.

Introduction

Since 2013, when the Brazilian Seismograph Network (RSBR) was implemented, the number of seismological studies has increased considerably (Bianchi et al., 2018). This is due to the densification of stations in Brazil, which facilitates the application of various methodologies, especially noise, body, and surface tomography. However, estimating velocities in the near-surface region is challenging due to the limitations of seismological studies in this frequency range. Therefore, this work aims to study the apparent velocity between pairs of stations and check their influences and values.

For this study, we used stations from the RSBR and events where the ray parameters can be considered approximately the same for pair stations. We used only the P and S wave arrival times between stations. Pairs of stations were separated into three distinct geological provinces (Basin, Craton and Fold-Thrust Belts).

Method and/or Theory

Our methodology for estimating P- and S-wave propagation velocities between station pairs utilizes trigonometric relationships between apparent velocity and incidence angle. Key requirements include an optimal alignment between the seismic event's epicenter and the station pair, and nearly identical wave incidence angles at both receiving stations. This approach was systematically applied to numerous station pairs, which were subsequently categorized according to their geological provinces (Basins, Cratons, and Fold-Thrust Belts) for comparative analysis. Station pairs were selected with a maximum interstation distance of 400 km, representing the feasible limit for estimating lithosphere-scale relative velocities.

Results

Figure 1 displays the seismographic stations used and the P-wave velocity distribution interpolated by kriging. The results reveal two distinct high-velocity zones: one extending from the northeastern portion of the Paraná Basin along the entire São Francisco Craton, and another in the northern sector of the Borborema Province. Low-velocity regions are observed along the southeastern coastal areas, as well as in the eastern and northwestern portions of the Borborema Province. In southern Brazil, a slight velocity increase is detected near the Luís Alves Craton, while the central sections of the Paraná Basin and Pantanal region maintained average velocity values.

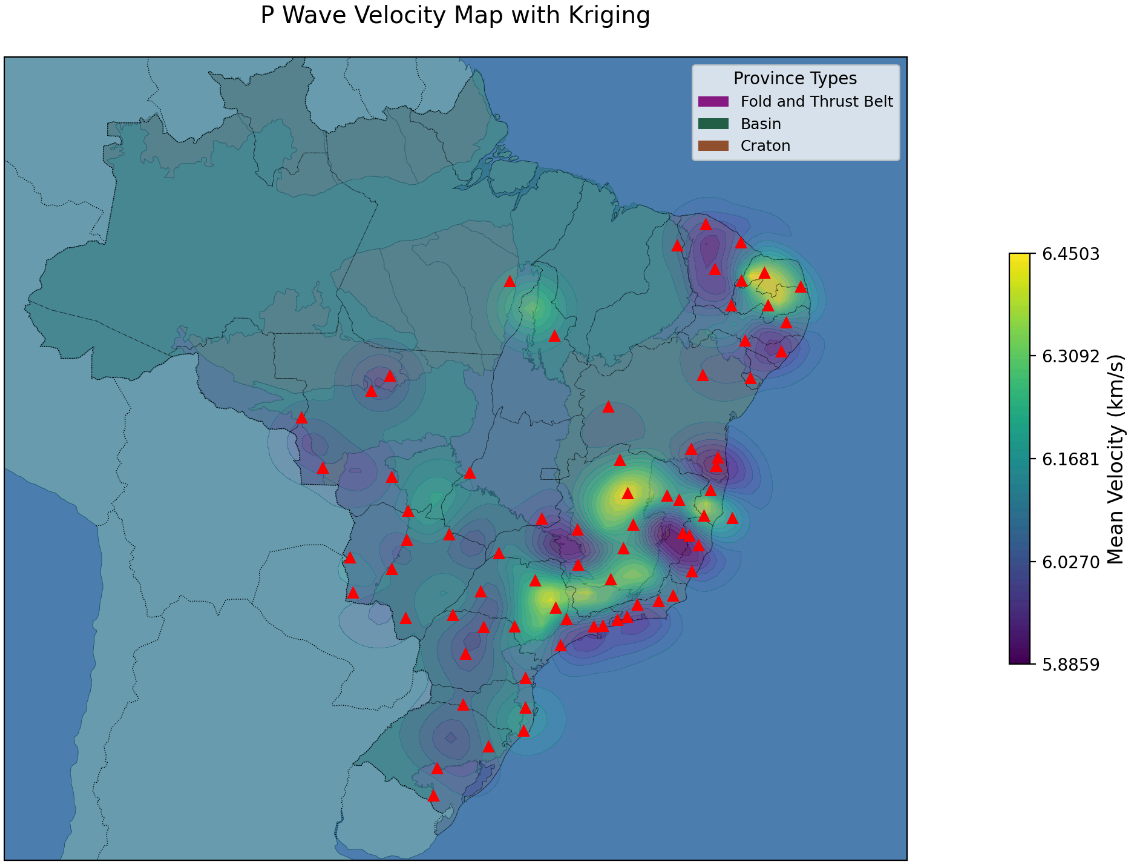

Figure 1: Map of P-wave velocity distribution interpolated by kriging and geological provinces (Cordani et al., 2016). Red triangles denote RSBR stations; velocity zones are color-coded. High-velocity zones (see text for details) correlate with the São Francisco Craton and northern Borborema Province, while low-velocity regions occur along the southeastern coast and parts of the Borborema Province.

The preliminary results (Figure 2) agree with the reference values from Mooney et al. (2002) for the studied provinces. The analysis included 17 station pairs for sedimentary basins (34 total events), 6 craton pairs (22 total events), and 54 fold-thrust belt pairs (114 total events). Additional cross-province pairs were excluded from these groupings. The cratons showed lower values, likely due to fewer ray path crossings resulting in reduced data coverage for this region, though the measured values remain higher than those observed in other provinces.

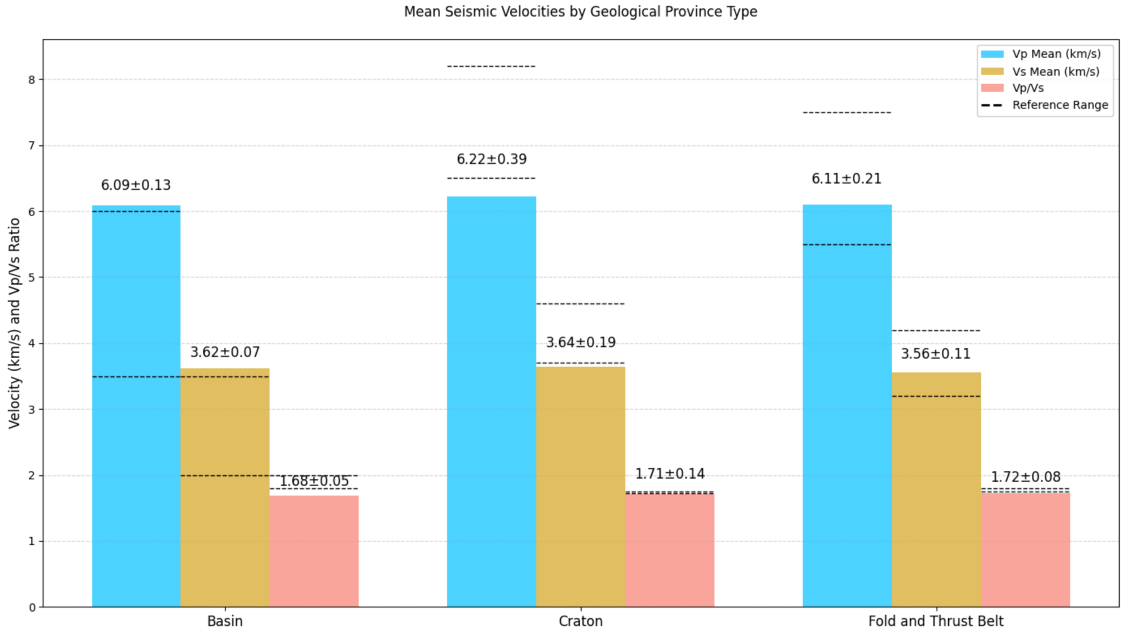

Figure 2: Averages for P-wave velocities (blue bars), S-wave velocities (yellow bars), and Vp/Vs ratios (red bars), with their respective values and uncertainties displayed above each bar, for the following geological provinces: sedimentary basin, craton, and fold belt. Dotted lines represent reference values from Mooney et al. (2002).

The apparent velocity method demonstrates potential as a viable tool for estimating body-wave velocities. With increased seismographic station density and greater event availability, this approach could prove particularly valuable for crustal-scale body-wave velocity determinations.

Conclusions

Our preliminary P- and S-wave velocity results demonstrate that the apparent velocity method shows promise for estimating near-surface wave propagation between station pairs. The findings clearly delineate the São Francisco Craton

The technique, however, has two major limitations: first, inadequate event-station pair alignment yields distorted velocities; second, proximal events creating high incidence angles similarly produce velocity artifacts. Nevertheless, when properly applied, the method yields velocity approximations that align well with established values from prior research in comparable geological settings.

Acknowledgments

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