New Constraints on the Upper Mantle Properties Beneath Cordillera Talamanca

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Introduction

The Cordillera Talamanca, a mountain range located in Southern Costa Rica, is marked by a unique absence of volcanoes and deep earthquakes observed in typical subduction zone configurations. This suggests that the tectonic environment beneath the Talamancas differs greatly from that of the rest of the country. One likely difference between the Talamancas and areas north of them is the structure of the crust, a chemically distinct upper layer of the Earth

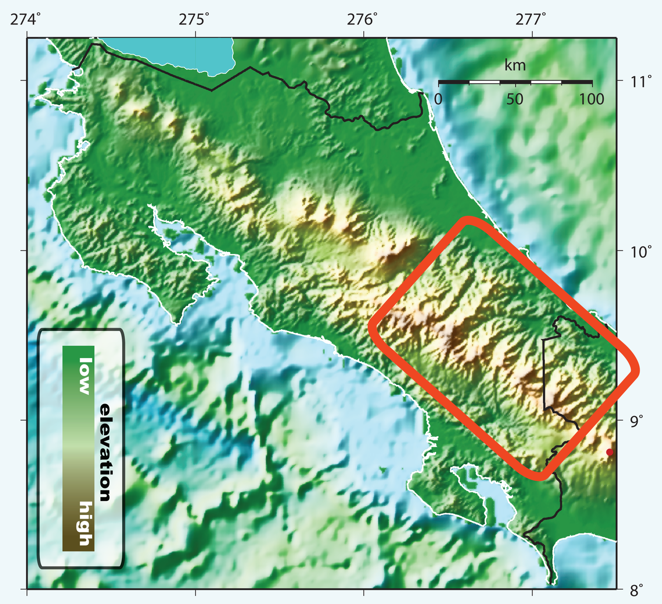


Figure 1: Topographic map of Costa Rica with Cordillera Talamanca outlined in red

However, few studies have been done in constraining the crustal structure and thickness beneath the Talamancas to determine what makes the region anomalous. Knowledge of the thickness of various layers of the crust and the speed at which earthquake waves travel through each layer helps constrain the probable composition of each layer and is necessary for creating accurate earthquake location models.

This project aims to:

1. Determine the crustal thickness and major internal boundaries within the crust
2. Create an improved earthquake location model for the Costa Rican National Seismologic Network (RSN)

Background

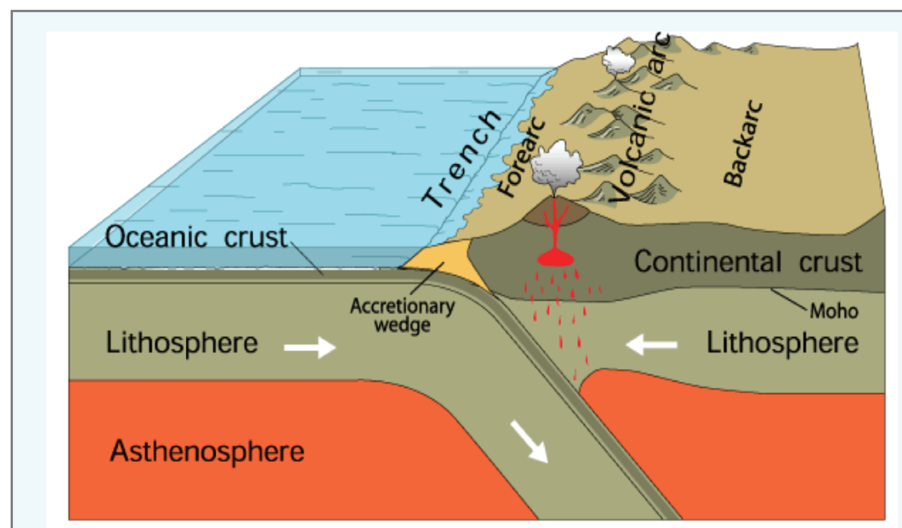


Figure 2: Typical subduction zone configuration.

Velocity (km/s)	Depth (km)
3.500	0.0
5.000	1.0
6.000	6.0
6.800	13.0
8.000	35.0
8.300	200.0
8.500	300.0

Figure 3: RSN's regional model for earthquake location.

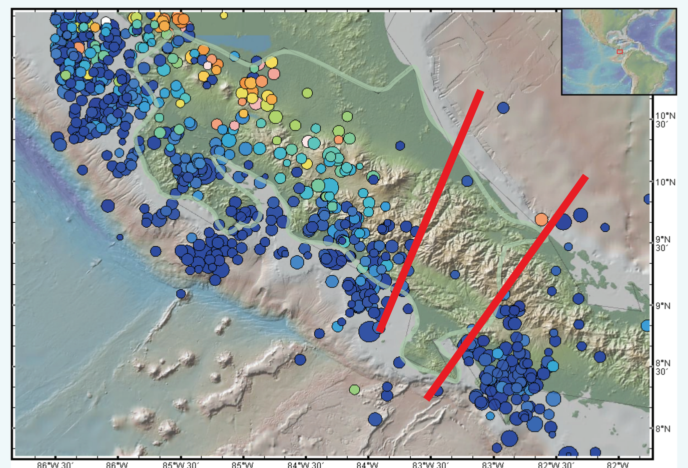


Figure 4: Locations of magnitude ≥4.0 earthquakes with a depth of ≥30 km from the last 20 years (blue=shallow, orange=deep).

Figure 5: Locations of volcanoes in Costa Rica.

Seismic Refraction

Principle:

- Seismic waves have different velocities in layers of different composition
- When a wave reaches the boundary between different types of rock, it is refracted

Assumptions:

- Earth is one-dimensional (flat layered with no lateral changes in composition)
- Seismic velocities increase with depth

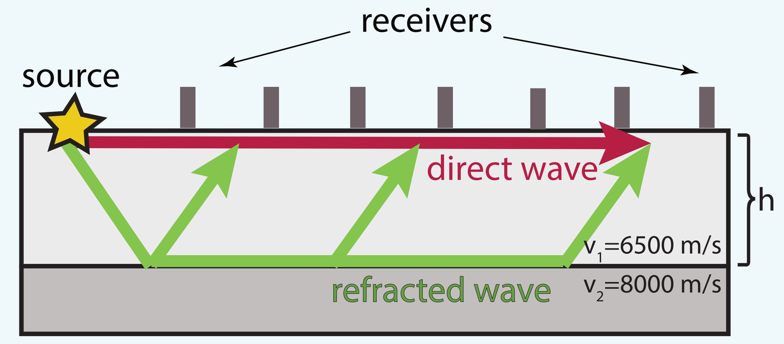


Figure 6: Typical refraction survey configuration.

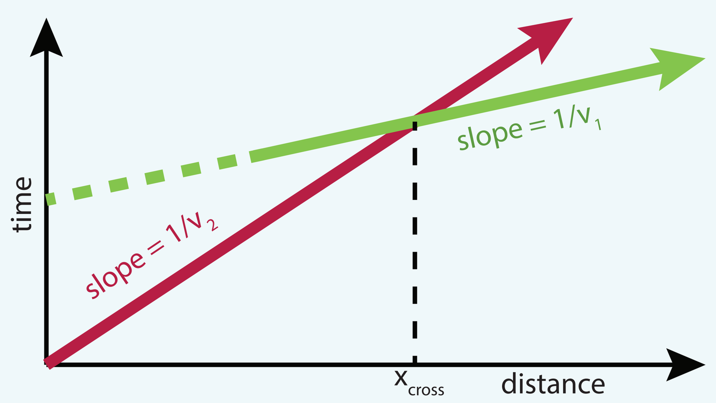


Figure 7: Plot of travel time versus distance.

For this study, earthquakes are the energy source and the seismometers (instruments that record ground motion) of the RSN's national network are the receivers.

Methods

1. Select a subset of earthquakes from RSN's database using the following criteria
   - Magnitude of 5 or greater
   - Outside of Costa Rican borders
   - Large range of source-receiver distances
   - Shallow depth of hypocenter (<20 km)
   - Good waveforms
2. Pick first arrival of P (compressional) waves using Seisan (earthquake analysis software)

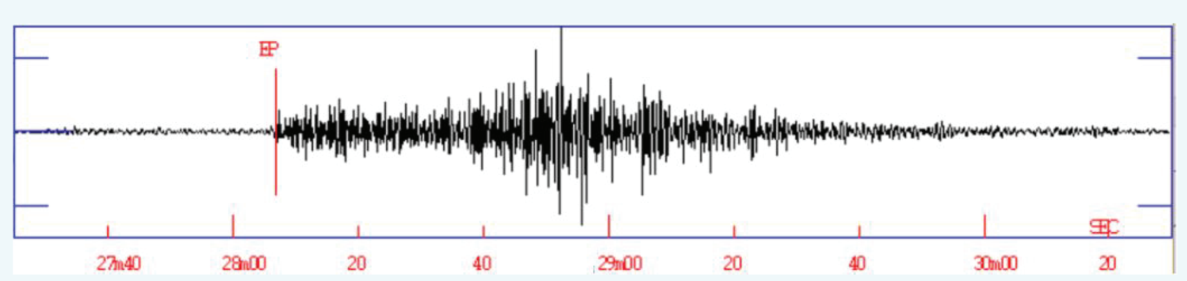


Figure 8: Example of an earthquake waveform in Seisan, with first arrival picked in red.

3. Filter data for azimuths that target the Cordillera Talamanca

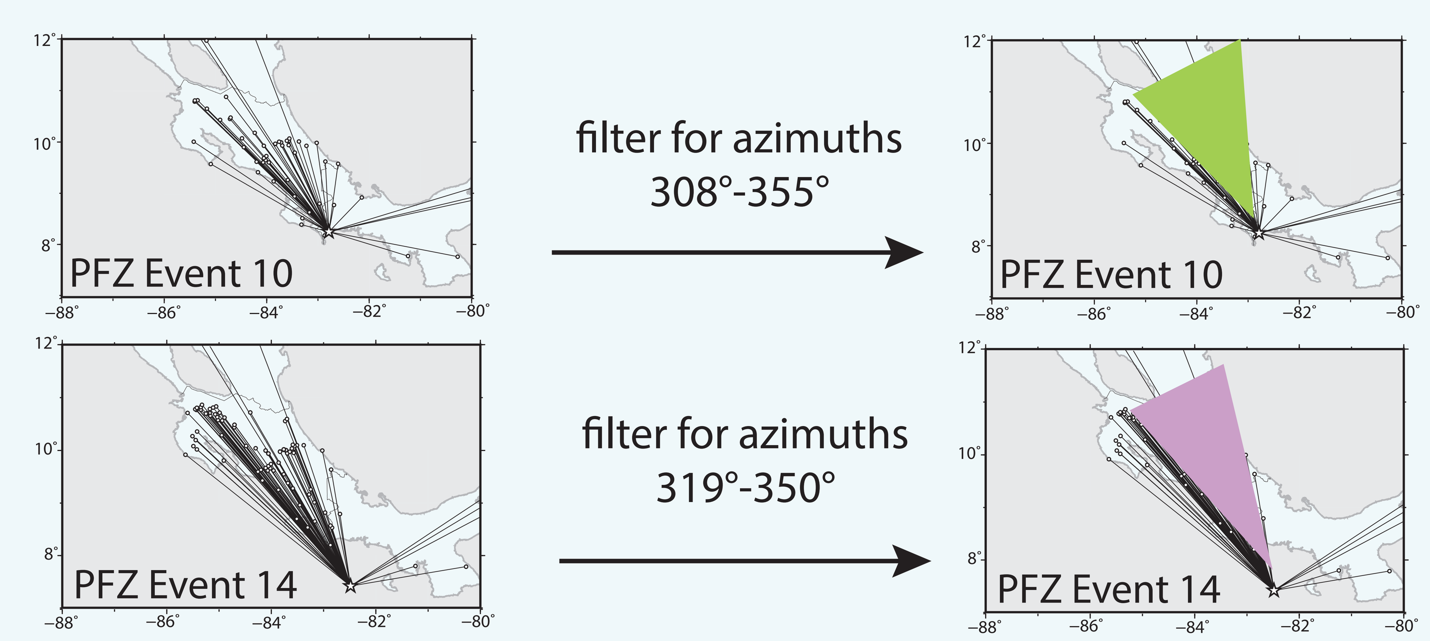


Figure 9: Ray path maps of Panama Fracture Zone events 10 and 14. Rays extend from source to seismometer.

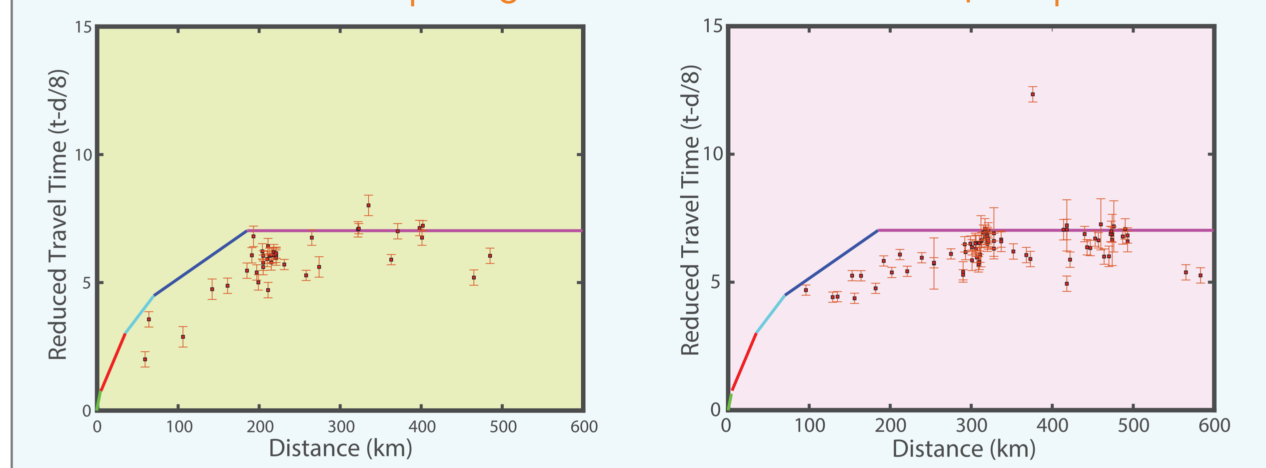
4. Write MATLAB scripts capable of:
   - Filtering data by azimuth and source-receiver distance from user input
   - Calculating predicted travel time and reduced travel time for the regional RSN model
   - Calculating influence of earthquake source depth on travel time
   - Presenting predicted and observed travel time on the same graph, with a possibilty of varying layer parameters (i.e. velocity and thickness)

Discussion

Plot reduced travel time of first arrivals from two earthquakes originating from by the Panama Fracture Zone against the reduced travel time predicted by RSN's model

- Assume that earthquakes originate at the earth's surface

PFZ Event 10 (depth: 9.2 km) PFZ Event 14 (depth: 6.0 km)



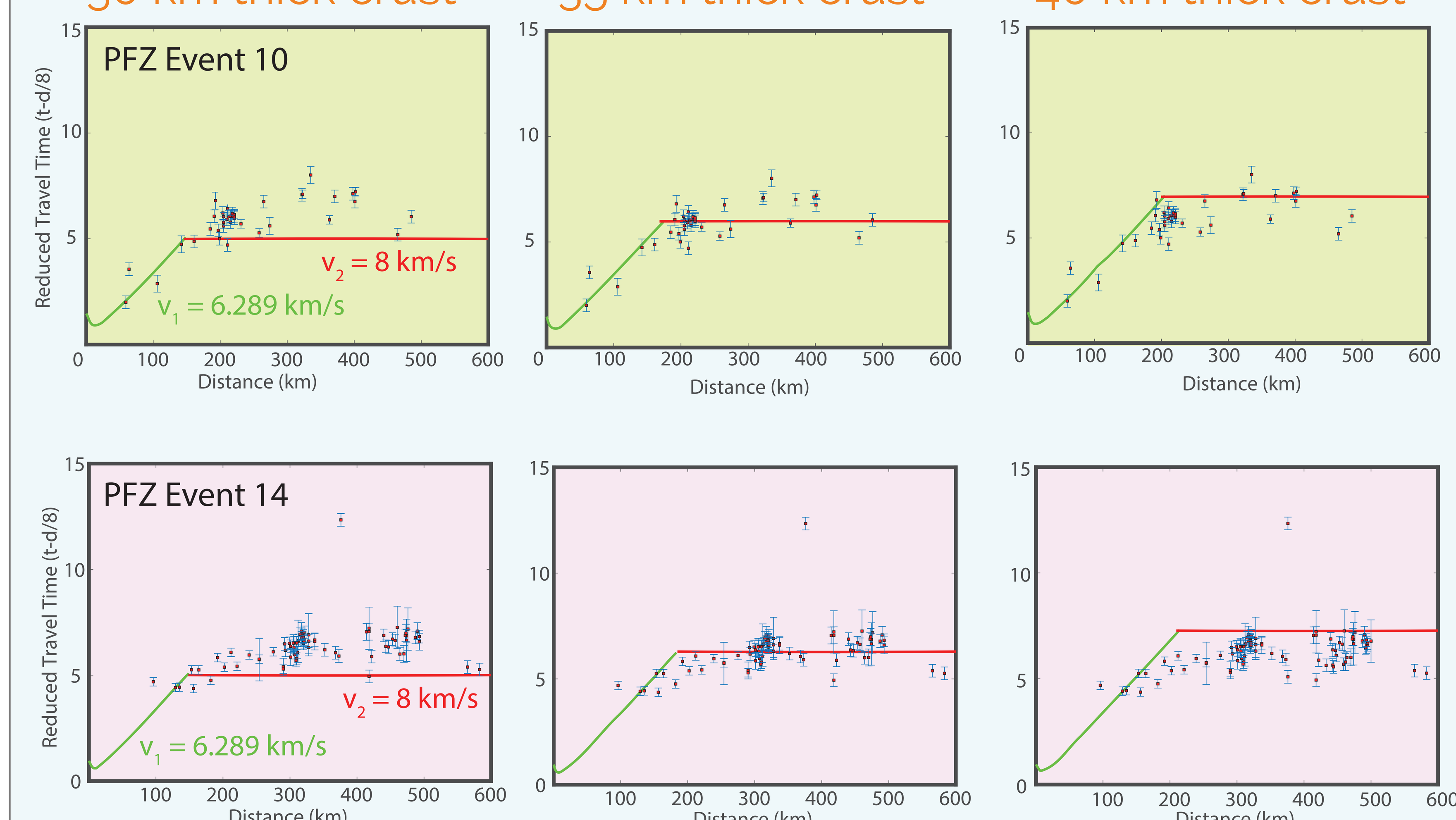
V_n	Velocity (km/s)
v_1	3.500
v_2	5.000
v_3	6.000
v_4	6.800
v_5	8.000

Figure 10: Layers and their corresponding velocities (RSN model)

Plot reduced travel time of first arrivals against those predicted by RSN's model, accounting for earthquake sources at depth

- Vary crustal thickness of the model
- Assume existence of only 2 layers: (1) a uniform crust with seismic velocity 6.289 km/s (weighted average of crustal layers in RSN's model) and (2) the upper mantle

30 km thick crust 35 km thick crust 40 km thick crust



Conclusions

Comparing reduced travel time curves of multiple events from the Panama Fracture Zone shows that accounting for depth of source aids in fitting the data to RSN's regional model. For each of the PFZ events I looked at, a crustal thickness of 35 km fitted the data the best, implying that the crust beneath southern Costa Rica/the Cordillera Talamanca is likely around 35 km thick.

Future Work

- Determine if there is any difference in the crustal thickness value if data from seismic events located in the northwestern (Pacific) side of Costa Rica and eastern (Caribbean) side are used
- Constrain the seismic velocity of the upper mantle (here we assume it is 8 km/s)
- Calculate "measure of fit" to determine how well our prediction actually fits the data
- Create an improved regional earthquake location model for the RSN