Modelling Subsurface Geometry At Cordillera de Talamanca Using Gravity Anomalies & Seismic Constraints

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Aresty Research Center for Undergraduates

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Introduction

We aim to model the subsurface composition of the region south of San José, Costa Rica extending from Quepos to the Cartago Province by utilizing gravitational and seismological data. In order to do this, we develop 2D subsurface models that satisfy both seismic constraints and produce gravity anomalies consistent with those measured.

The Cordillera de Talamanca (CT) is a mountain range situated in central southern Costa Rica (CR) above a tectonic subduction zone, where the oceanic Cocos plate is being pushed beneath the CR-carrying Caribbean plate.

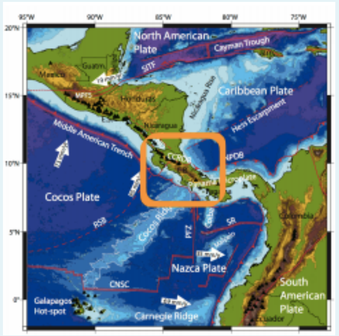

Figure 1: Costa Rica with the region of interest highlighted in orange and relevant tectonic plates labeled.
- Image from Reference 1

We expect this subduction zone to produce ample volcanic and seismic activity in the greater CT area; however, these elements are absent or reduced. Such anomalous features can be attributed to the unique structural geometry of the underlying crust and mantle.

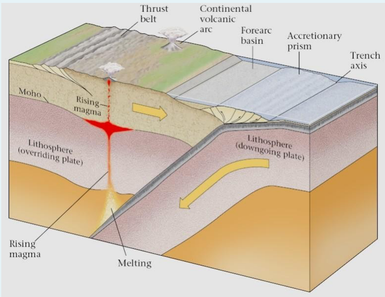

Figure 2: The subduction of the Cocos plate beneath the Caribbean plate is expected to produce volcanism all along the CT
- image from Earth: Portrait of a Planet by S. Marshak

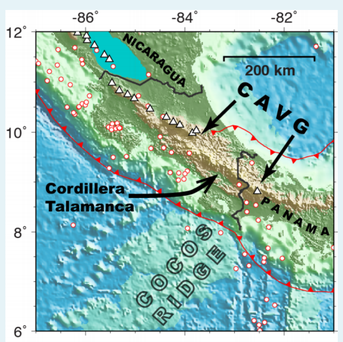

Figure 3: A closeup displaying CT''s distinct lack of volcanism despite its presence in flanking regions; volcanoes are represented by white triangles.
- Image Courtesy of Dr. Levin

Gravity anomalies and seismic wave characteristics depend on the density and geometry arrangements of underlying features. It was this consideration that drove us to produce a theoretical model of the underlying structure that might fit both recorded seismic and gravity anomaly data

Objectives

- Explore available gravitational and seismological data on CT
- Develop a viable two-dimensional density model of CT
    - Balance subjective and objective criteria in determination of model viability

Methods

1. Collecting Data With Gravimeters
- we use gravity anomaly data collected by previous groups.

2. Processing Data
- we plot and interpolate gravity anomalies using QGIS to create a continuous data field

3. Modeling
- observed anomalies are graphed as a function of distance along the route
- GravMag is used to model subsurface features that will produce anomalies matching the observed profile. Seismic constraints are also used.

GravMag enables analysis of "gravity data acquired along a profile". It estimates how subsurface bodies affect gravity measurements at sea-level.

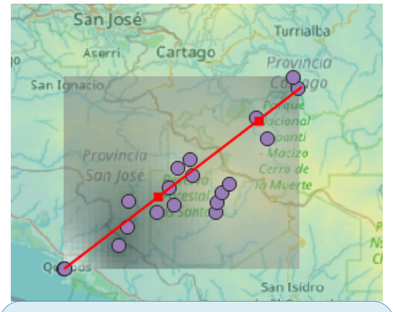

Figure 4 : Plotted anomaly points with interpolated field. Cross section (red line) is taken from Quepos to Cartago Province.

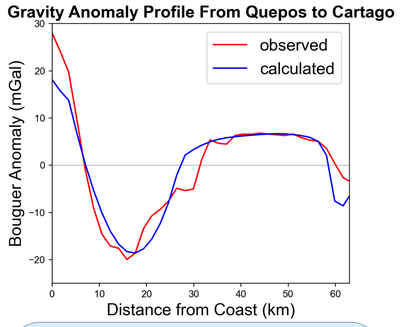

Figure 5 : Observed and calculated gravity anomalies as a function of position along the profile in figure 4. Pacific coast is at 0 km. Blue line is the anomaly profile produced by model in figure 6.

References
1. Density structure and geometry of the Costa Rican subduction zone from 3-D gravity modeling and local earthquake data, Lücke, O. H. & Arroyo, I. G. (2015)
2. A Recent Tear in Subducting Plate Explains Seismicity and Upper Mantle Structure of Southern Costa Rica, Bourke, J., et al (2020)

Results/Discussion

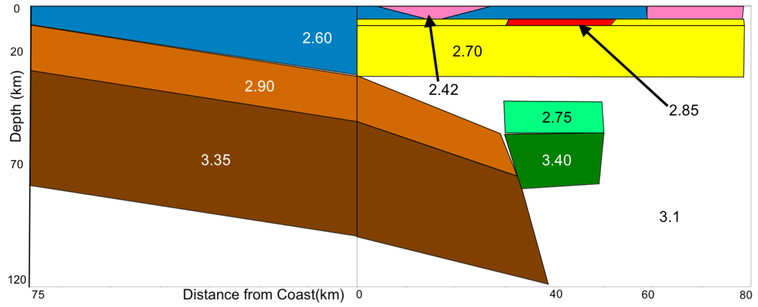

Figure 6 : Gravity density model corresponding to the calculated anomaly curve in figure 5. White space is ambient mantle with density 3.1 g/cm^3. Densities of other features are labelled.

We find that the model in figure 6 provides a good fit to the observed anomaly profile, as seen in figure 5. The model produced above is consistent with seismic results, as well as general geological patterns of the region. We also observe that shallow features (<30 km) primarily influence the 'shape' of the anomaly profile while the larger deeper features (>30 km) approximately shift anomaly values vertically.

Future Directions

Our team hopes to create a second model for a second region near Osa Peninsula further south. We hope that these two models will provide a strong basis for us to accept or exclude alternative models of the subsurface composition. Ultimately, we hope a theoretically and empirically consistent subsurface density model will lead to an explanation of the absence of volcanism in CT.

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