Seismic Refraction Study of Carbonate Platform Structure on the Island of Bonaire

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1. Introduction/Background

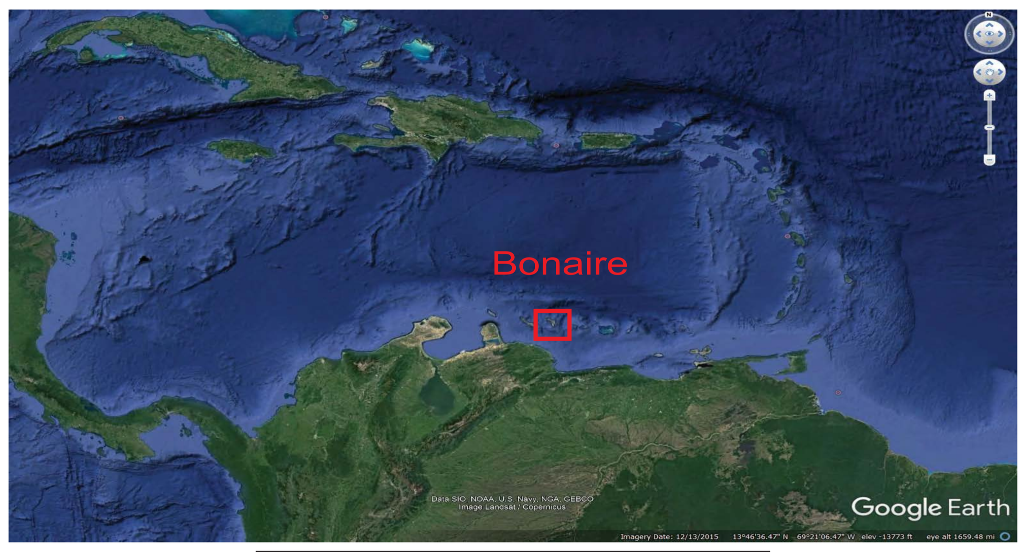

Figure 1. Regional Map of the Caribbean Plate

- Bonaire Island is a carbonate platform located on the southern Caribbean Plate. It is approximately 90 km off the coast of Venezuela.
- Bonaire is comprised of igneous basaltic basement rock with overlying carbonates.
- Originating in the Pacific Ocean during the Cretaceous on the foremost edge of the Caribbean Plate, it has since shifted back from the leading edge of the plate.
- Since the Pleistocene, Bonaire has undergone glacio-eustatic sea level changes and tectonic uplift leading to the formation of carbonate terraces (Bowling, 2017).

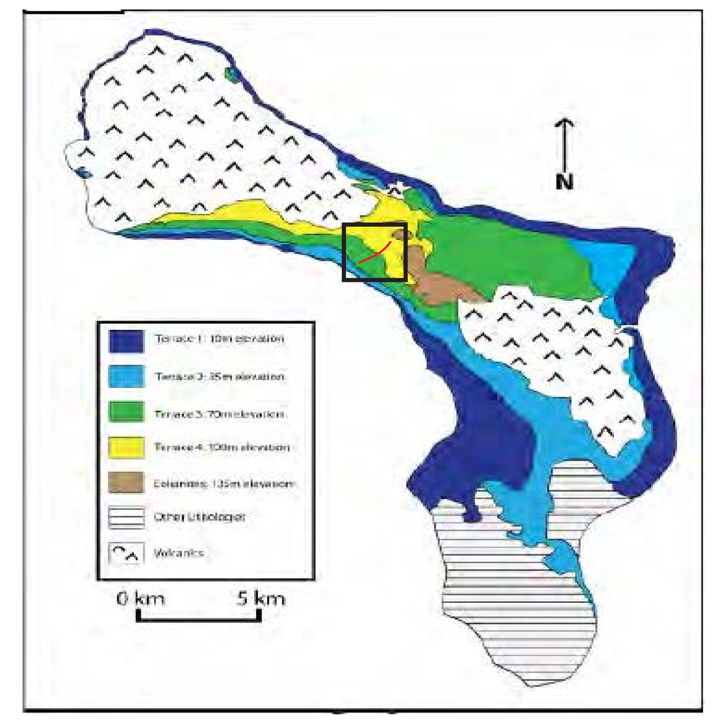

Figure 2. Geologic map of the island of Bonaire (Sulaica, 2015).

Location of Seismic Refraction Study

- A 1.7 km-long seismic refraction survey was conducted across the interior of Bonaire. The study was conducted along a bike trail that is ~3 km to the southeast of Rincon.
- A 24-channel land streamer with a sledgehammer source was used for this study.
- There is a paucity of geophysical data on Boanire, and therefore little is known about the subsurface. Our goal in the suvery was to map the igneous basement and overlying carbonates, and provide some constraint for the structural deformation observed in northern Bonaire.
- There are multiple carbonate terraces (fig.2) along with karstic features (fig. 8) on Bonaire.

2. Key Questions

- Where is the contact between the Igneous basement rock and the overlying Carbonates?
- Does this study help identify a constraint for structural deformation observed in northern Bonaire?
- Does the seismic study data correlate with the GPR study data?

3. Methods

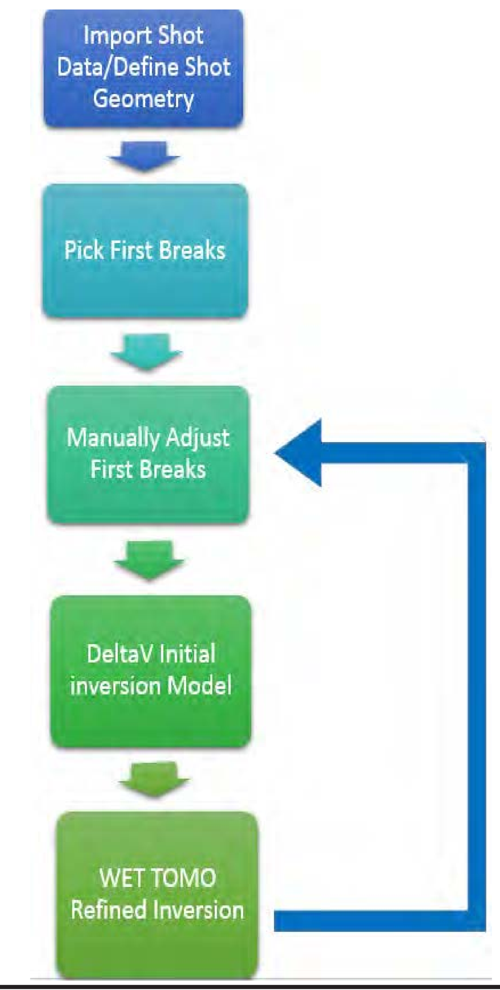

Figure 3. Processing flow chart of Bonaire seismic refraction survey

All data processing was done via Rayfract Software.

•1. Import shot data and define shot geometry. Data is imported via SGY seismic files. Using a parameter box to fill in the shot location and station spacing.

• 2. Pick first breaks using Polyline Picking. This is a semi-automatic way of picking arrivals, by drawing a straight line directly overtop arrivals. The software will then automatic pick the arrival.

• 3. Adjust first breaks. Although, the software automatically picks the first breaks they are not always accurate. It is essential to work through each shot adjusting the "modeled" first breaks to the "corrected" first breaks. This will increase the accuracy of your velocity model and reduce artifacts.

• 4. Run a DeltaV intial model (Figure 6). DeltaV is a turning ray inversion method that delivers a continuous depth vs. velocity profile for all profile stations.

• 5. Imput the DeltaV model into a Wavepath Eilonal Traveltime tomographghic processing inversion (WET Tomo). This refines the intial model by allowing the user to change parameters I.e. number of iterations, Wavepath frequency, Wavepath width, ext...

• 6. Analyze Tomogram for artifacts and reprocess first breaks to increase the accuracy.

4. Results

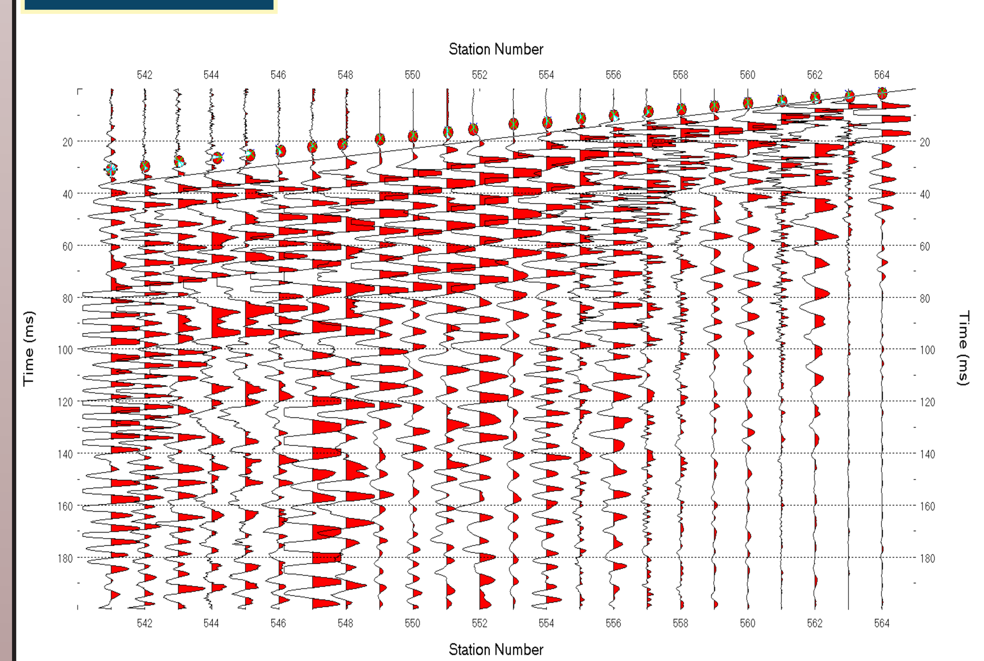

Figure 4. Seismogram showing picked first arrivals that are used to create the subsquent models below.

- This seismic study was conducted using 24 geophones at a station spacing of 3m.
- The red circles are the modeled picks that are used to create the models below.
- The "x"'s are corrected picks that indicate where the program estimated the correct first breaks to be.
- This line exhibits decent first breaks which are easily picked, but unfortunately not all lines were like this.

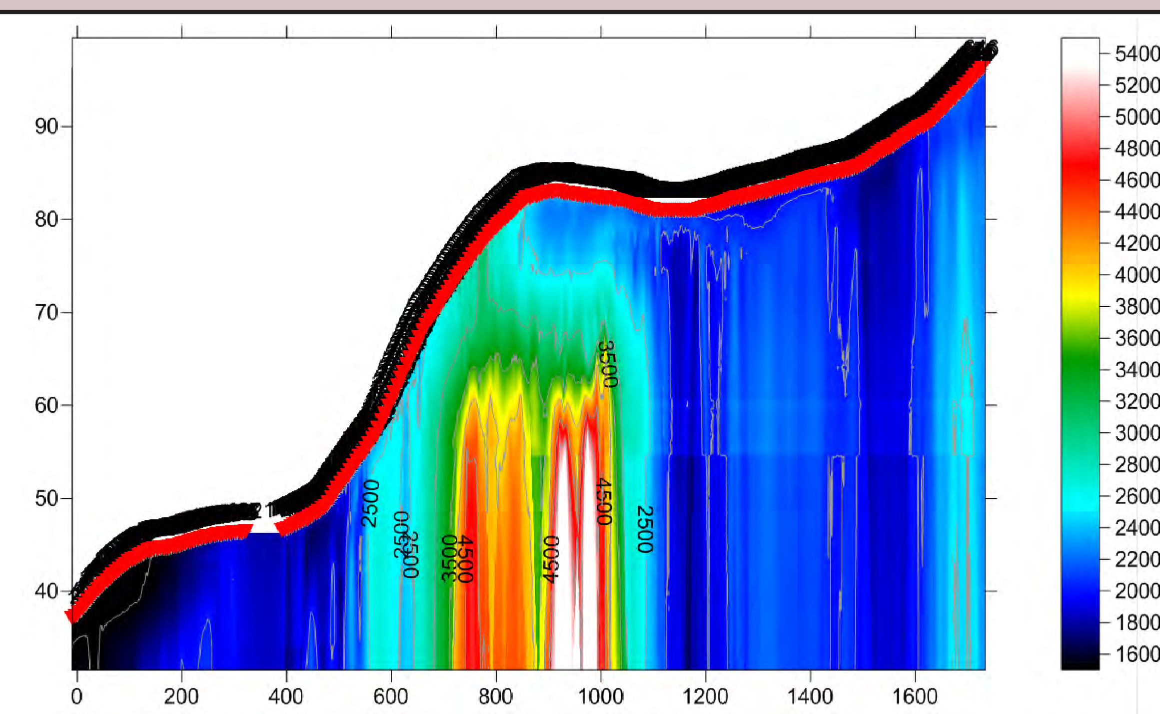

Figure 5. Above is a DeltaV 2-D psuedo initial inversion model, which is the starting model used to create the final tomography inversion.

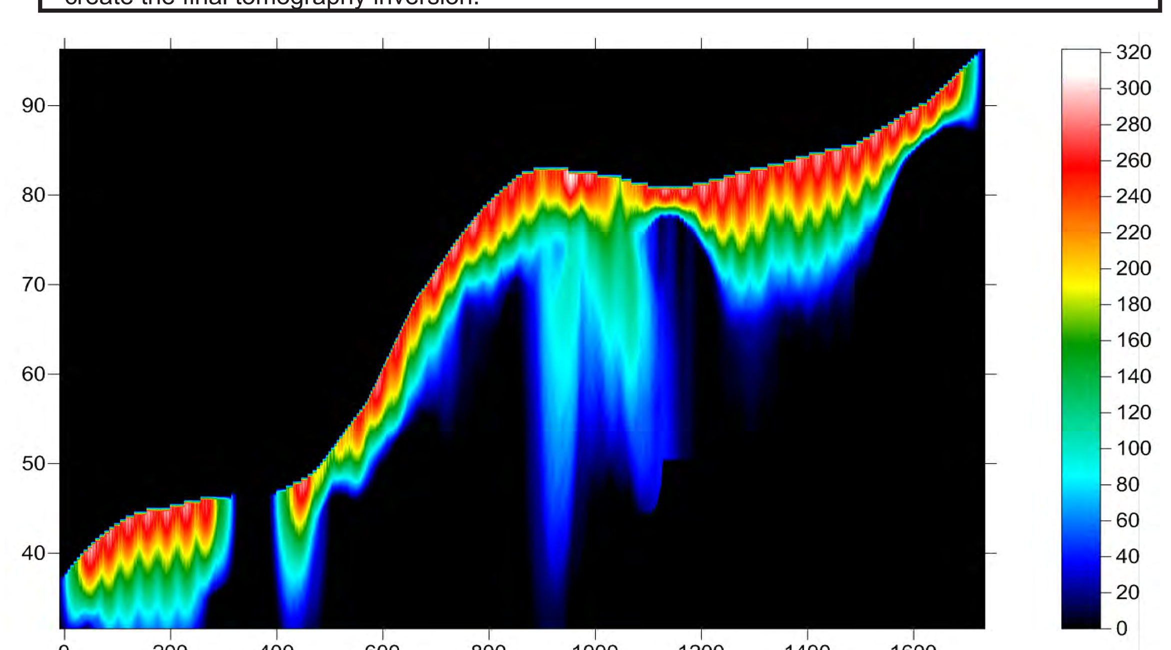

Figure 6. Above is the wavepath coverage from the velocity model below in fig. 7.

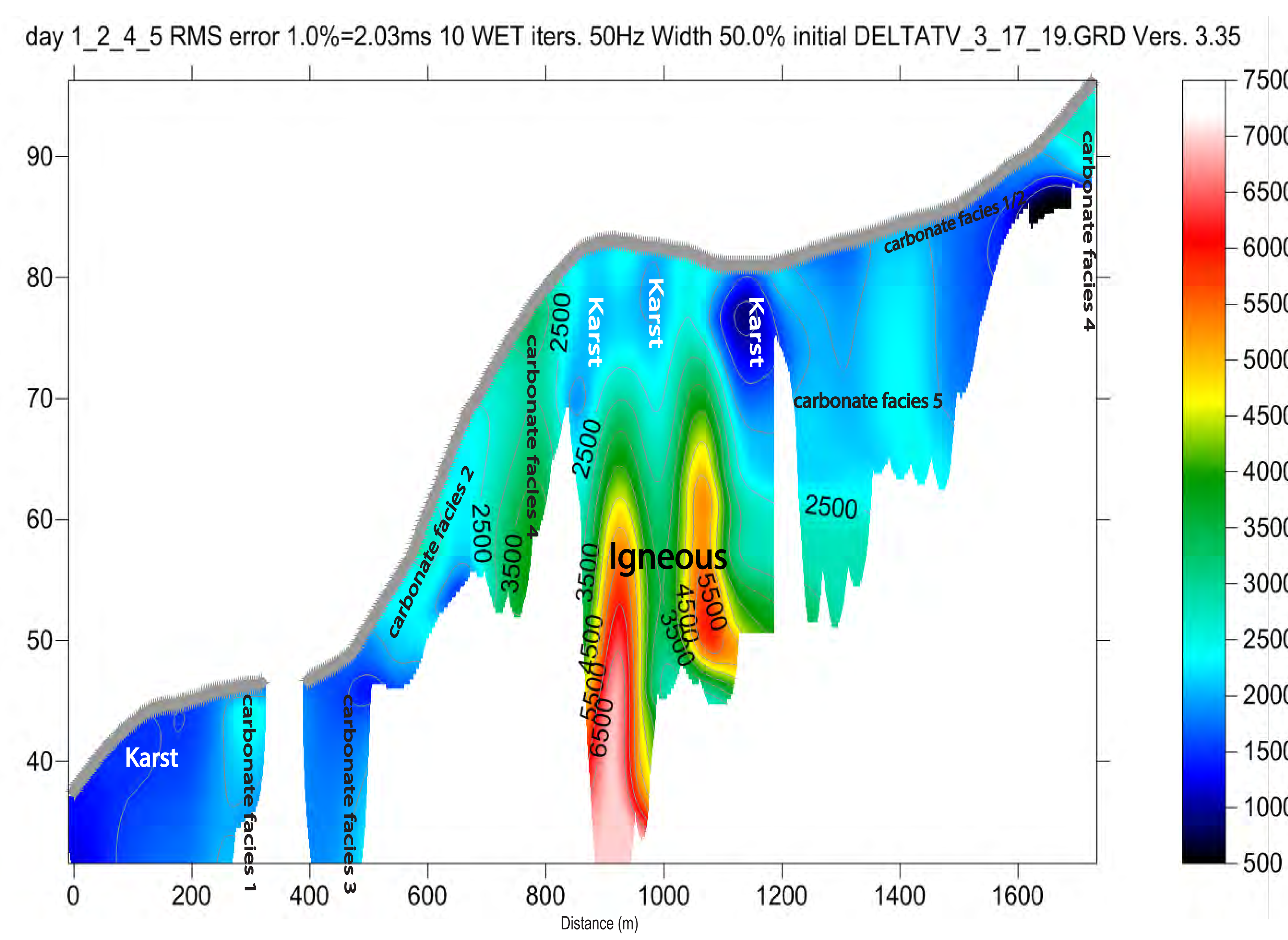

Figure 7. Above is a Wavepath Eilonal Timetravel Tomography model of the 1.7 km-long seismic study. 10 iterations with a 50 Hz wavepath frequency. A wavepath width of 50% of one period and a wavepath envelop width of 49%.

5. Discussion

Below I compare the carbonate facies of the Bowling, 2017 GPR study to my tomgraphy velocity model.

Although GPR does not penetrate as deep as seismic the two interpretations seem to correlate at the shallow depths that the GPR can reach.

• **Blue facies**
Correlates to the velocity zones of ~2300-2600 m/s. The areas on fig. 7 labeled "carbonate facies 1" correlate to the blue facies above.

• **Brown facies**
Correlates to an increase in velocity to ~2500-3200 m/s. The areas on fig. 7 labeled "carbonate facies 2" correlates to the brown facies.

• **Orange facies**
Correlates to a lower velocities of ~1800-1900 m/s. The area on fig. 7 labeled "carbonate facies 3" correlates to the orange facies.

• **Red facies**
Correlates to a higher velocity than previous zones at ~3000-3400 m/s. The areas on fig. 7 labeled "carbonate facies 4" correlates to the red facies

• **Yellow Facies**
Correlates to the velocites similar to the other carbonates at ~2300-3200 m/s. The area on fig. 7 labeled "carbonate facies 4" correlates to the yellow facies.

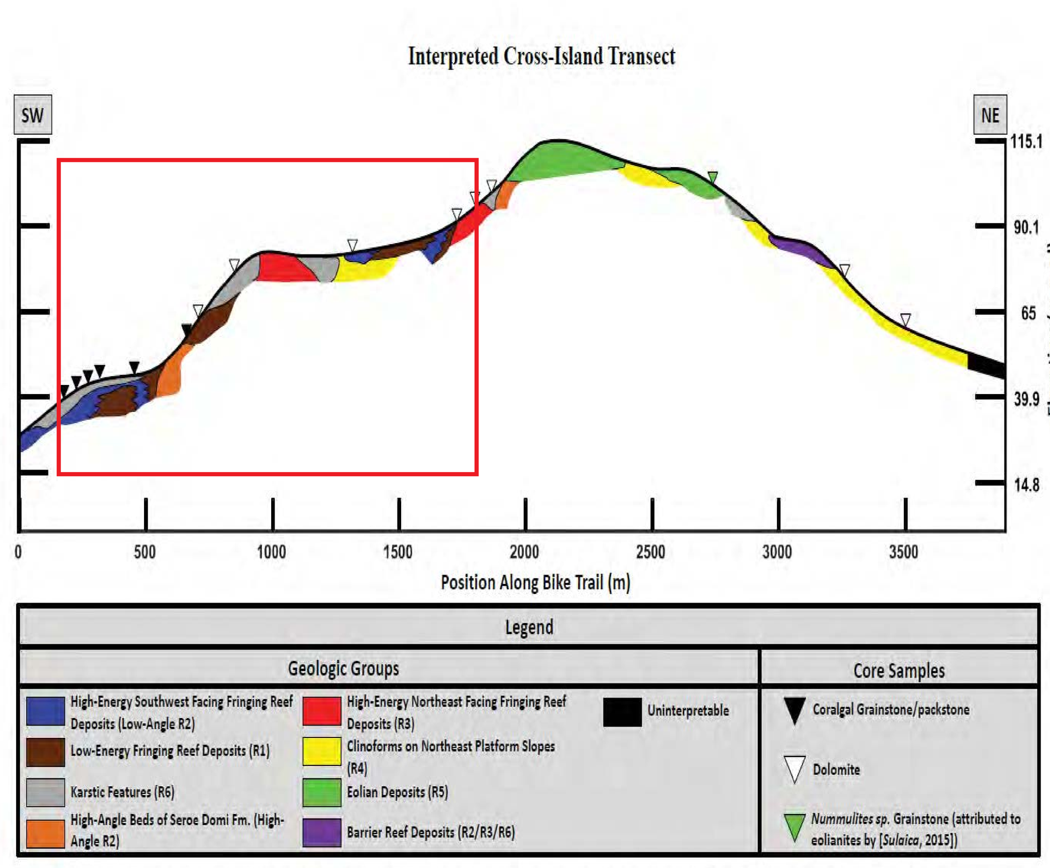

Figure 8. Above is a GPR interpretation (Bowling, 2017) along the same transect as our seismic study. There is a 160m offset from the start of our seismic survey and the GPR survey.

Variability of Velocities in Carbonates

Intrinsic properties in carbonates, such as porosity vary causing the velocities of seismic waves passing through them to vary as well. We observe a range of velocities in what is interpreted as carbonate lithologies. This can explain why at certain locations the velocities are not consistant. Velocities in carbonate samples from other locations in the Caribbean range from ~1800-6000 m/s (Anselmetti and Eberli, 1993). As porosity increases the velocity decreases. Although, the average was ~3200 m/s. As noted in fig. 8 there were core samples taken at the locations marked with the lithologies labeled. Only grainstone/packstone and dolomite pertain to this study. Grainstone/packstone on average have more porosity than dolomites. This correlates well with the velocity increase observed from 575m to 600m and subsequent locations showing dolomites having slightly higher velocities.

Karst Features Interpretation

Karstified features form by dissolution of rocks such as carbonates. This process forms caves and drainage systems underground which cause disruptions in our seismic waves. One affect karstified features has on P-wave velocity models is it can cause scattering of the surface waves and result in low velocities. On fig. 9 the grey facies in the GPR model is karstic features, and in the first ~200m of the velocity model there is a consistant low velocity which is due to the karstified feature. ~600-850m there is a karstified feature on the GPR model, but that does not correlate well to the velocity model. Although, the karstified feature at ~1100m seems to correlate well with the extremely low velocities at that location.

Igneous Basement Interpretaton

• First in the velocity model the HVZ is interpreted as the igneous basement rock, and this is due to the high velocity contrast between the overlying carbonates. Igneous basaltic rocks depending on depth and pressure can have velocities from 4600-6400 m/s (Gebhard and Carlson, 1982). The HVZ in fig. 7 exhibits velocities that point towards igneous basement. The shape of the HVZ also helps deteremine that it is most likely igneous due to it upwelling into the carbonates, and the GPR shows a change in elevation (hump) at this location. Although, the two areas with velocities of ~3500 m/s inbetween the two red 4500+ m/s areas seem rather low for igneous basalts, but I believe this is due to the karstified features directly above not allowing for accurate modeling of those areas.

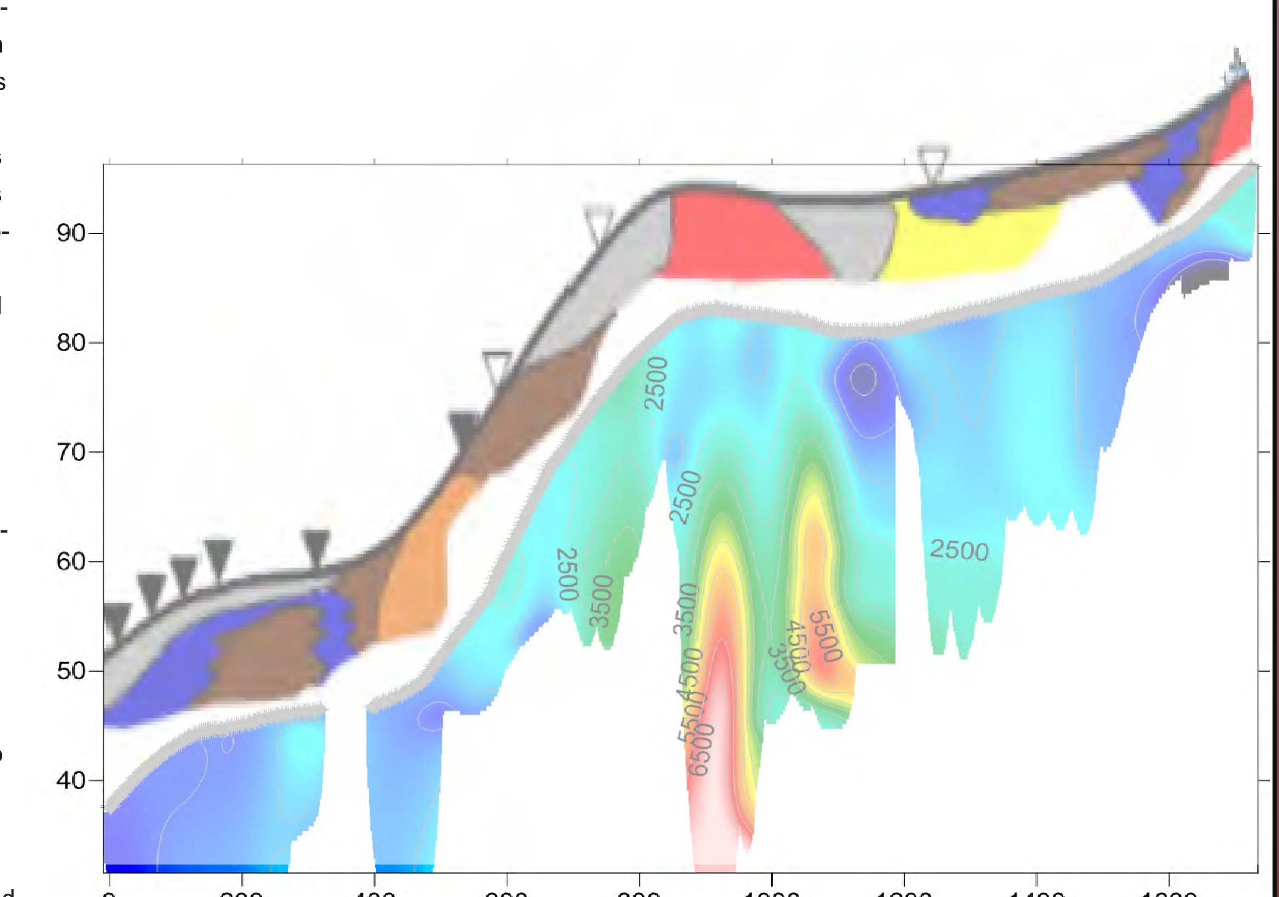

Figure 9. Correlation of facies from GPR interpretation to velocity in tomographic velocity model

6. Future Work

- I'm graduating this May, so there is a possibilty I can continue this project if I am accepted into graduate school.
- If so, the next step is to write a paper for publication.

References/Acknowledgments

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• Gebhard and Carlson, 1982, Compressional-wave velocities in basalts from the Rio Grande Rise

Anselmetti and Eberli, 1993