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Mapping the Mid-Atlantic Ridge at 14°N: Analysis of Small-Scale Tectonism Across Regions of Varying Magma Supply

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Abstract

Tectonism at mid-ocean ridges provides a primary control on ridge morphology, influences the physical properties of the oceanic crust, and records the relative contribution of magmatic injection to plate separation. This study examines the three-dimensional properties of small-scale faults within a segment (14N) of the slow-spreading Mid-Atlantic Ridge. Two research expeditions (AT33-03 and AT40-02) used the autonomous underwater vehicle *Sentry* to collect high-resolution (one meter) bathymetry data along the mid-ocean ridge. Bathymetry data were collected over four regions including the non-transform offset, the magmatic center, a magma-rich to magma-poor transitional zone, and a region adjacent to an extinct oceanic core complex. A GIS database of digitized faults from the *Sentry* data allow quantification of the tectonic setting and fault properties. The continuous wavelet transform, using the Haar wavelet, permits the extraction of spatial statistics. These data provide insight into the style and extent of fault growth in regions of varying magma supply along-axis.

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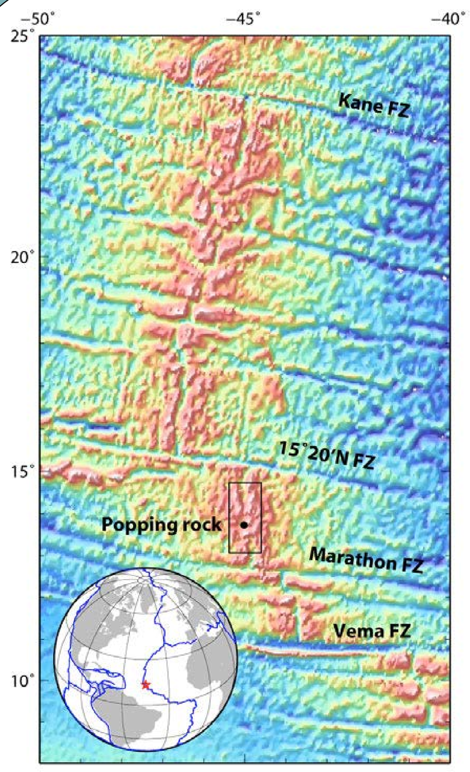
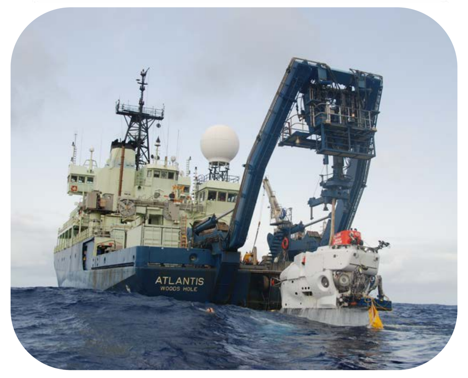
Introduction





R/V Atlantis

- Two research cruises aboard the RV Atlantis, in 2016 and 2018, (AT40-02, AT33-03) collected bathymetric data along a 240 km^2 region of the Mid-Atlantic Ridge.
- Rapid changes in bathymetry are caused by brittle deformation of the crust (faults and fissures). These brittle deformations provide insight into tectonism along this mid-ocean ridge segment.
- Tectonism acts as a primary control on ridge morphology and records the relative contribution of magmatic injection to plate separation.
- Magma supply can vary dramatically along slow-spreading mid-ocean ridges.

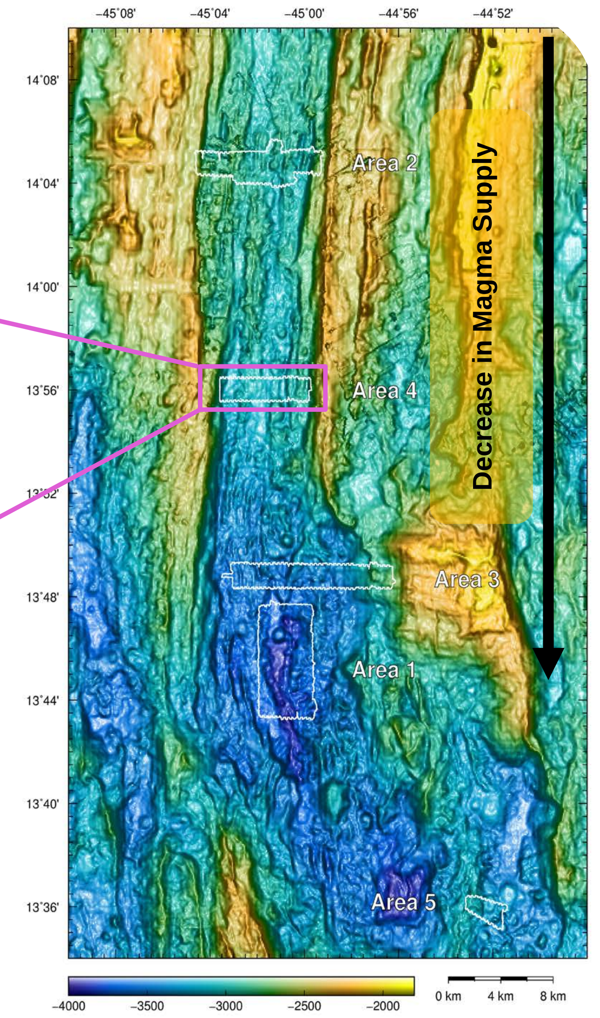
Research Question
Can we quantitatively analyze variations in tectonism versus magmatism along a ridge segment?

Data Acquisition

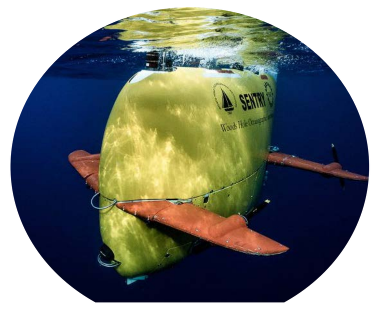
- High-resolution bathymetry (1m) collected using AUV *Sentry*
- Five regions mapped along axis

Fissures: Symmetrical Crack in the Lithosphere

Faults: Offset Crack in the Lithosphere



- Tectonism should negatively correlate with degree of magma supply.
- Modelling will allow further investigation of fault and fissure distribution.

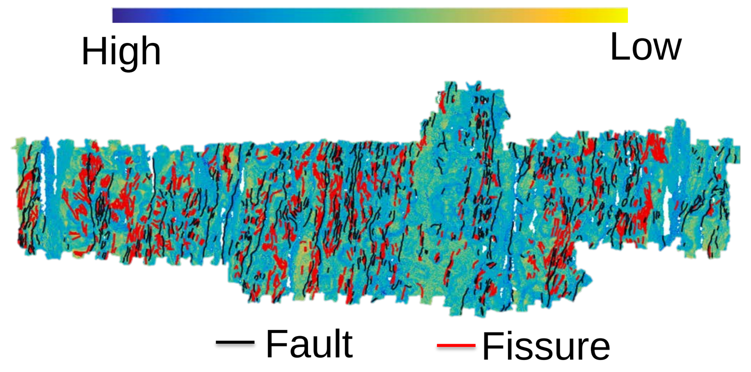


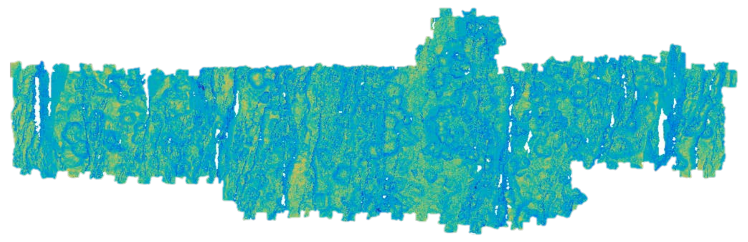
Autonomous Underwater Vehicle (AUV), Sentry

Modelling of Faults

1. Slope Map

Allows for easy visualization of rapid changes in bathymetry.



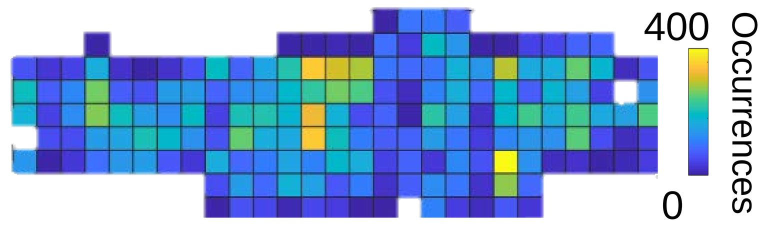


2. Digitized Tectonic Features

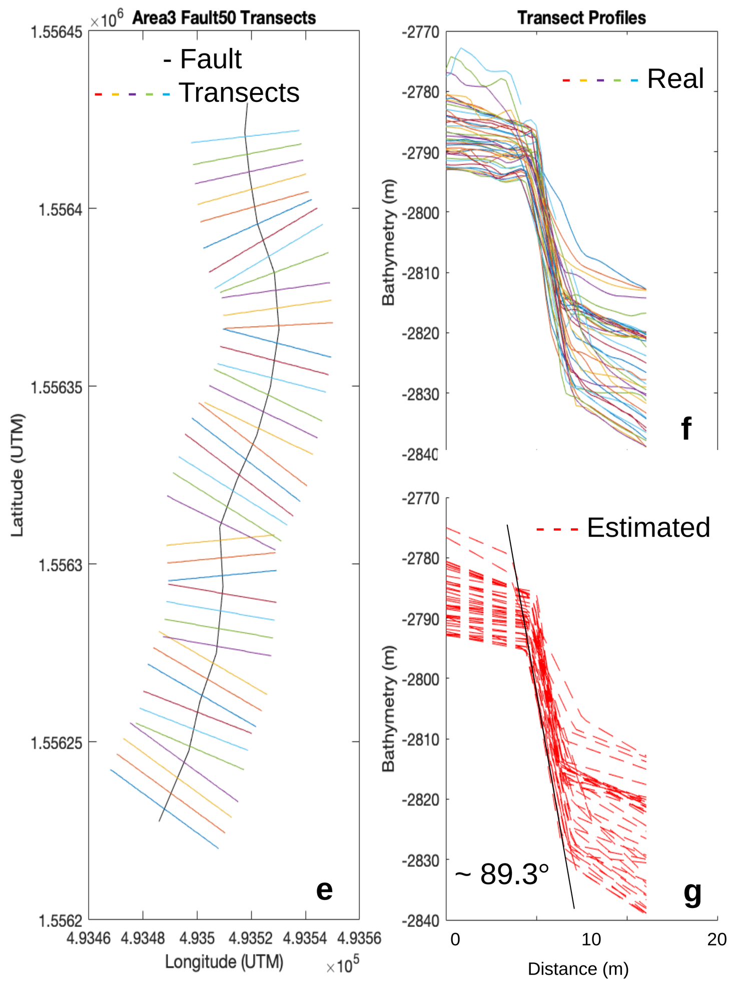
Quantum Geospatial Information System (QGIS) is used to trace tectonic features. Their profiles distinguish relative offset.

3. Density Map

Matrix Laboratory (MATLAB) uses a 2D histogram of the digitized data to highlight areas of high tectonic influence.



4. Determine height and width of faults



Rejected Model

(e) MATLAB generated plot of a fault (map view) and its associated transects. The transects are sampled every 5 m at a length of 20 m.

(f) Bathymetric data (cross sectional view) derived from (e)'s transects.

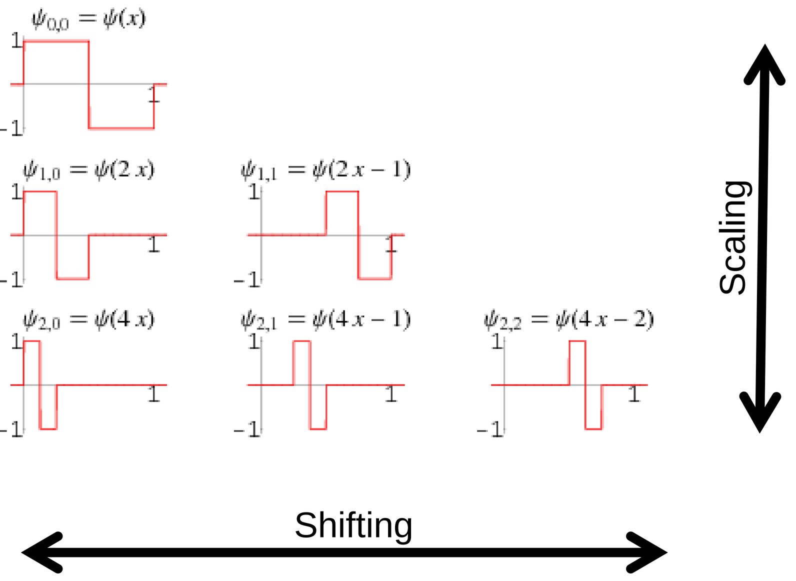
(g) Model of the fault's transects using a 3 line fit. This model generates information such as: slope, top, and bottom.

Although (g) demonstrates an ideal estimation , faults of lower delineation cannot be resolved.

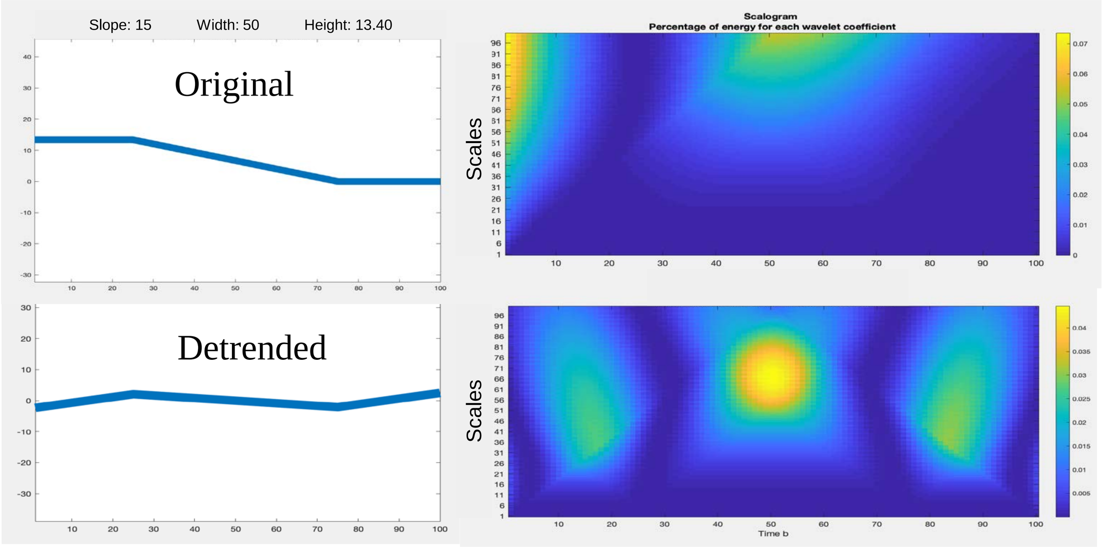
New Model Basis

The continuous wavelet transform digitally processes discretized data through pattern isolation. It preserves onset times and energy.

A Haar Wavelet is a biorthogonal wavelet that resembles a perfectly vertical fault.



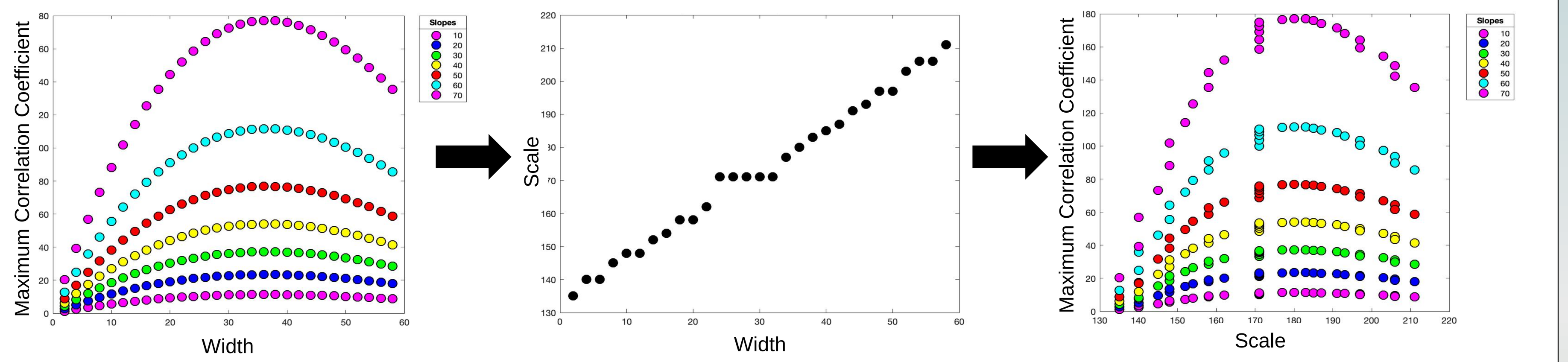
Haar Wavelet Analysis



Scalogram

The distribution of energy should be highest at the center of the synthetic fault. However, without detrending, the energy is dispersed around the peripheries. Therefore, detrended data should be used.

Relationship Between Scales, Slope, and Width using Synthetic Fault Data



Correlation Coefficients (CC)

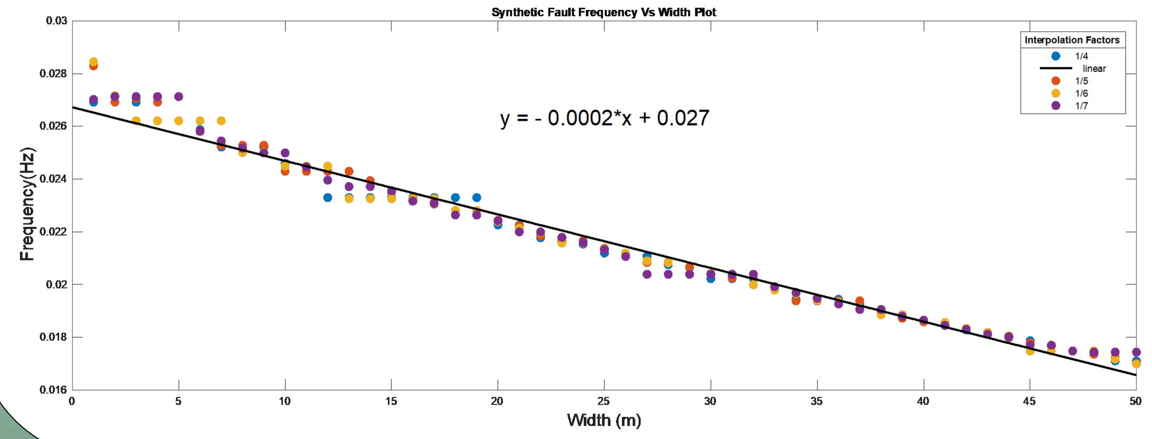
Values indicate how well the data matches the wavelet's pattern

Scales Associated with CC

Linear relationship with width regardless of slope. Areas of discontinuity differ with sampling rate

Scale as a Proxy for Width

If scale and width are interchangeable, this plot should mimic the first slope plot.



Frequency of Scales

Scales increase with an increased sampling rate. The conversion to frequencies allows for the combination of differing interpolations which should help mitigate the above discontinuity

Conclusion/Future Work

Frequencies associated with CWT scalings can act as a proxy for fault widths.

The model has not been tested on real/noisy data, but if it is successful, it will be run on 1,982 faults that contain at least 39,000 cross sectional profiles. The data collection will permit statistical analysis of fault characteristics and distribution. Optimally, the same concept will be extended to fissures.

Acknowledgements

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