Volcanism and hydrothermal venting on a hot-spot influenced slow-spreading mid-ocean ridge

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Introduction

- The Reykjanes Ridge (RR) is a slow spreading mid-ocean ridge (MOR) that extends ~1000 km south of Iceland (Fig. 1)
- 37 Mya, the Reykjanes separated into transform-fault connected segments which have been eliminating from north to south
- The evolution of the ridge has been influenced by basement depth gradients formed by the Iceland hotspot
- The southern extent of the ridge is still actively deforming making it a prime area for current ridge dynamics studies (Fig. 1)
- Near-continuous bathymetric data at grid resolutions from 50x50 m to 100x100 m has been collected over several research cruises
- Unlike most MORs, this bathymetric data extends far off-axis, providing insights into to the evolution of the crust over time
- The goal of this work is to investigate the tectonic and volcanic evolution of the RR through remote predictive geologic mapping
- The work will allow for a reconstruction of the ridge's spreading history and an understanding of the ridge's geodynamic controls
- This work will have implications for understanding the controls on the distribution of potential magmatic-hydrothermal systems along slow-spreading MORs

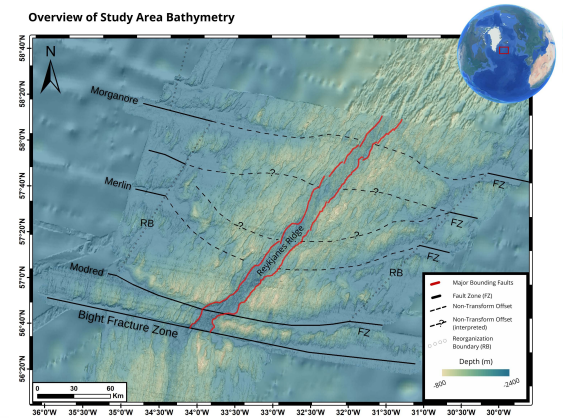


Figure 1 Multibeam bathymetry compilation of the Reykjanes Ridge between 56°50'N and 58°20'N. Dataset is from the Marcus G. Langseth cruise (MGL1309) gridded at 50x50m resolution overlain on regional bathymetry (GMRT). The names of remnant fault zones (FZ), now non-transform offsets (NTOs) are indicated beside the respective FZ.

Methods

- The remote predictive geologic mapping approximated the technique used in other sea-floor environments (Klischies et al., 2017, Anderson et al., 2017).
- Raw multibeam bathymetry data comes from the Marcus G. Langseth Cruise (MGL1309) at gridded resolution of 50x50 m
- Bathymetry was rendered into ArcGIS and enhanced with hill shade and slope shade
- Backscatter was used to determine relative ages of erupted crust
- Moderate to high backscatter intensities represent newly erupted hummocky lava and sheet flow (Fig. 2)
- Low backscatter intensities represent sedimented terrain
- Linear features mapped include: major and minor faults, eruptive fissures and lineaments
- Other features mapped include Axial Volcanic Ridges (AVRs), volcanic cones, flat-topped volcanoes, and cratered volcanoes

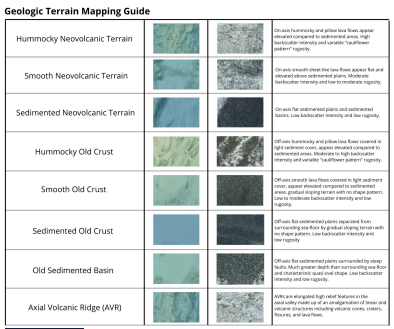


Figure 2 Mapping guide with criteria for classification based on multibeam bathymetry and backscatter data.

Results

- A total of 4337 major faults, 4470 minor faults, 3862 eruptive fissures and 4200 lineaments were mapped across the study area
- Features were binned according to their trend into 20-degree interval bins , and lineament density maps were calculated (Fig. 3)
- Darker colored areas represent the highest lineament density and lighter tones represent the lowest lineament density
- Almost 70% of all linear structures are oriented between 10 to 70 degrees azimuth (AVR long axis trends = 21°, axial valley trend = 40°)
- The region between two oppositely facing NTOs have few N/S trending structures compared to other zones corresponding to the same age (Fig 3a, 3b)
- Linear structures in or near the axial valley are more N/S trending (Fig. 3a, 3b) compared to those off-axis which trend towards the NE/SW (Fig. 3c, 3d)
- Structural trends typically dominating off-axis (30 – 70 degrees azimuth) are also found in the axial valley (Fig. 3c, 3d)
- Consistent high lineament density locus in the center of the two oppositely facing NTOs (Fig. 3a, 3b, 3c)

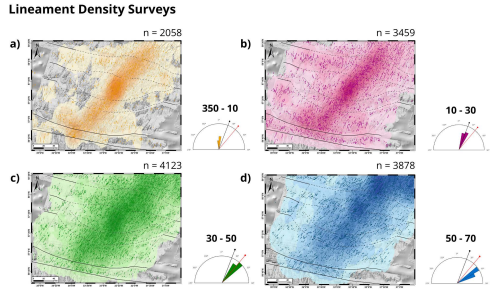


Figure 3 Lineament density maps using equally weighed mapped linear features: major/minor faults, eruptive fissures, and lineaments. Both maps and features themselves are shown for comparison.

- The geologic map of the central study area covers the Reykjanes Ridge's axial valley between the Merlin and Morganore NTOs (Fig. 4)
- The left North American plate appears more faulted and tectonically dismembered than the right Eurasian plate off-axis
- Proximal off-axis faults on both plates shift orientation with the corresponding bend in the axial valley and resume a constant orientation off-axis
- The southern Reykjanes axial valley is dominated by hummocky and pillow lava flows with abundant point source volcanism
- A 16 km segment of the axial valley between the two oppositely facing NTOs is marked by an absence of significant point source volcanics

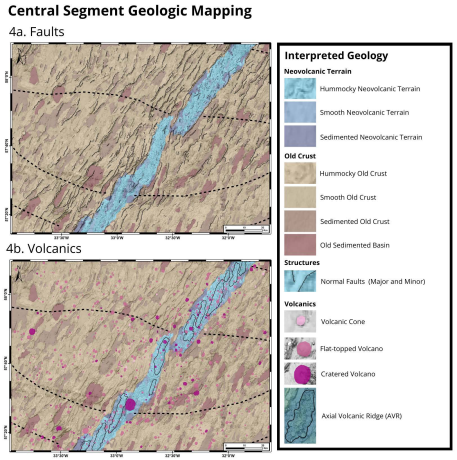


Figure 4 Interpreted geology of the central segment of the MGL1309 survey between NTOs. In addition to the interpreted geology, figure 4a also shows major and minor faults. Figure 4b highlights point source volcanic features: volcanic cones, flat-topped volcanoes and cratered volcanoes.

Discussion

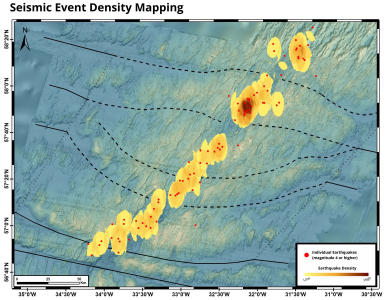
The Reykjanes Ridge is still actively deforming despite having mostly reorganized back to its original linear geometry. This is evidenced by the orientation changes in linear structures progressively off-axis and variability in geomorphology along the axis.

- Younger crust (on-axis terrain) is dominated by N/S trending structures and older crust (off-axis terrain) is dominated by NE/SW trending structures
- Significant number of structures exemplifying "older trends" in the on-axis terrain suggesting that older ridge dynamics may still influence modern spreading
- The central segment has two kinks near the connections between the interpreted NTOs (Fig .4a, 4b). These kinks are also traced by the normal faults which stand-in as major ridge bounding faults
- These faults regain their linearity off-axis means that the orientation of the axial valley has changed significantly
- Brittle structures form in response to stress fields; a changing tectonic stress field could have caused the shift in orientation
- There is preference for hummocky and pillow lava style volcanism with minimal point source volcanism in the central ridge segment between oppositely pointing NTOs
- This segment also corresponds to the location of greatest lineament density (Fig. 3)
- This region could be more magmatically robust and have higher crustal permeability
- The gradually diverging NTOs could thin the crust, explaining the more magmatically focused center
- This magmatically robust central segment offers the most potential for magmatic-hydrothermal systems

Future Work

The nature of the relationship between NTOs and the evolution of the recently reconstructed southern extent of the Reykjanes Ridge needs further study. To investigate the geodynamic control and interplay between NTO geometry, ridge deformation, and magmatically focused centers, the following work will be undertaken:

Figure 5 Seismic event density mapping shows localities with higher earthquake occurrences, possible zones of higher tectonic dismemberment and higher crustal permeability (Data from Global CMT Project).



1. Time correlated analysis of ridge segments and ridge bounding faults
2. Detailed mapping of Axial Volcanic Ridges and their morphological differences along the southern Reykjanes Ridge valley
3. Integrating multibeam bathymetry and backscatter data with other geophysical datasets, preliminary results (Fig. 5)

References

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