Significance of non-DC components of MTs for understanding tectonic processes to the Reykjanes seismic and volcanic activity, Iceland

Václav Vavryčuk, Pavla Hrubcová

INSTITUTE OF GEOPHYSICS
OF THE CZECH ACADEMY OF SCIENCES

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Abstract

The Reykjanes Peninsula in SW Iceland is a part of the Mid-Atlantic plate boundary. It forms its transtensional segment with several volcanic and faulting systems. We focus on seismicity that occurred in the central part of Reykjanes at the place of the Fagradalsfjall volcano prior to its eruption on March 19, 2021. We invert well-determined focal mechanisms and provide mapping of tectonic stress in space and time. Our results disclose heterogeneous stress field manifested by mix of shear, tensile and compressive fracturing. The prominent stress direction was in the azimuth of 120° ± 8°, which represents the overall extension related to rifting in the Reykjanes Peninsula.

The activity associated with the transform fault segment displayed predominantly shear strike-slip events. The non-shear fractures were associated with the opening of volcanic fissures trending in the azimuth of 30–35°, perpendicular to the extension. The dip-slips were mainly located close to the volcanic dike. Importantly, we detected local variation of stress when the stress axes abruptly interchanged their directions in the individual stress domains. These stress changes are interpreted in a consequence of plate spreading and upcoming fluid flow during a preparatory phase of a rifting episode.

Tectonic setting

Iceland

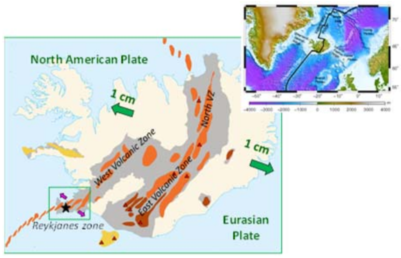
Mid-Atlantic Ridge – slow-spreading rift

Continuation of the rift onshore

Plate spreading : 105°

Rate 1.9 cm/y

Mantle plume (bending of rift)



Reykjanes Peninsula

SW Iceland

Highly oblique spreading segment

Transtensional plate boundary 70-80°

Spreading rotated to ~120°/300°

Volcanic fissures – NE-SW (30-35°)

Parallel to normal faults

Fagradalsfjall volcano-tectonic

Last eruption:

~6,000 yr ago

&

19 March 2021

Seismicity & Swarm 2021

Reykjanes Peninsula

High, episodic seismicity

every ~30 yrs (M < 6)

2016, 2017, 2019, 2020-2024

Strike-slip faulting & extension

Mainshock/aftershock sequences

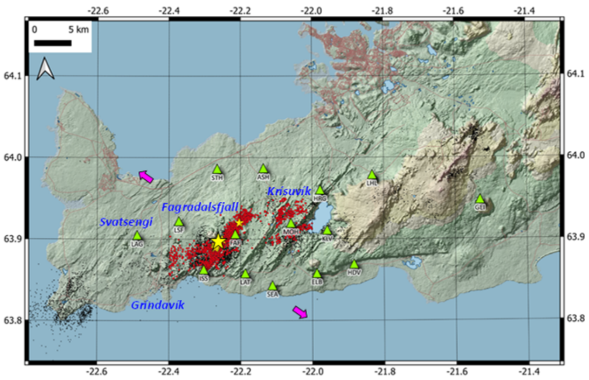
Seismic swarms

REYKJANET network (IG CAS)

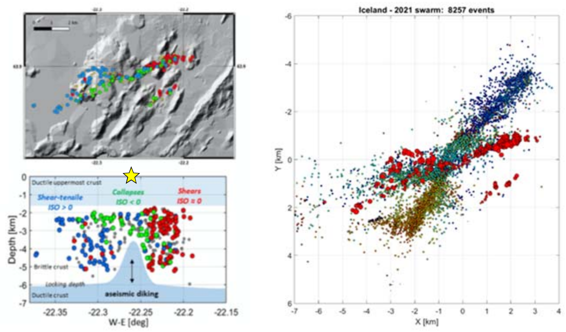
16 BB local seismic stations covering the **Fagradalsfjall volcano-tectonic segment**

Epicentral distance:

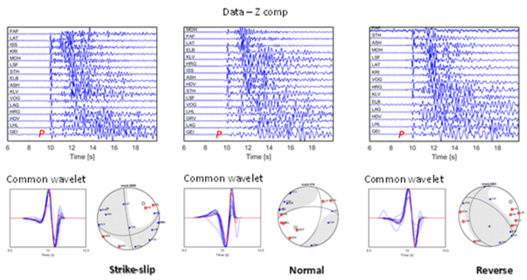
up to 20-25 km



Seismicity July 2017



Data processing and MT inversion



PCA MT inversion of direct P waves

P waveforms are windowed, filtered, cross-correlated, and aligned

(first principal component represents common wavelet from PCA analysis)

Principal component analysis (PCA) is applied to extract:

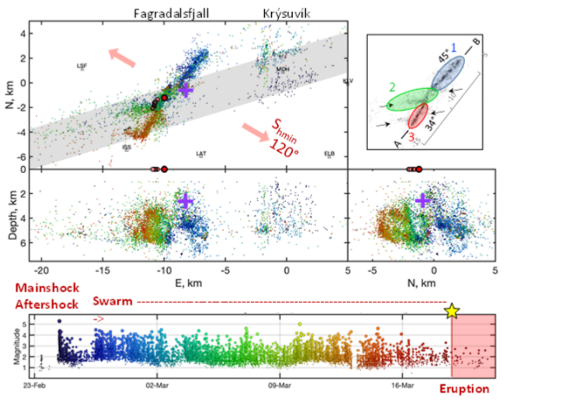
- common wavelet (= source-time function)
- effective P-wave amplitude

Fully automated MT inversion

- error estimate

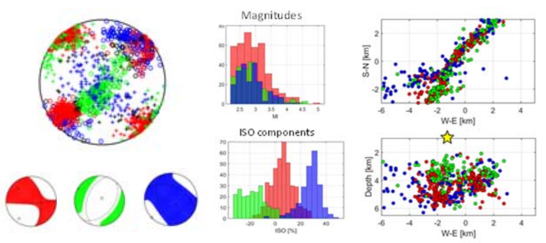
Vavryčuk et al. (SRL, **88**(5), 1303-1315, *2017)*

Seismicity February-March 2021



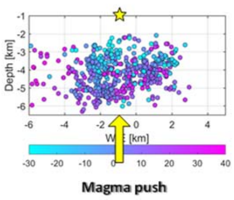
Fischer et al., 2022

Classification of moment tensors and focal mechanisms



Depth dependence of ISO

- positive values at greater depth
- negative values at shallow depth above the dike



Summary

Volcanic eruption 2021

- took place at the intersection of the dike (2021) and rift segments (2017, 2019, 2020)

MT and non-DC – 3 different regimes of faulting

- Strike slips ISO ~ 0, collapses ISO < 0 above the dike, reverse faulting ISO > 0 due to overpressurized fluids

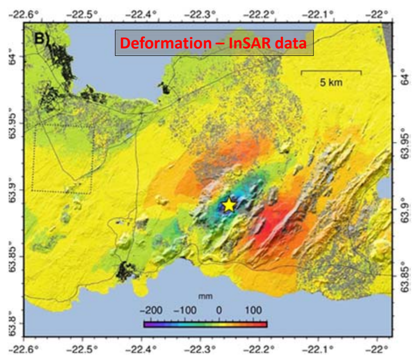
Complex stress conditions

- Maximum vertical compression – tensile faulting (volcanic fissures) perpendicular to the extension direction (ISO < 0)
- Maximum horizontal compression – strike-slip faulting (ISO ~ 0)
- Minimum vertical compression – reverse faulting (ISO > 0)

Principal stress directions are stable but the principal stress magnitudes vary

Complex surface deformation

- Strongly heterogeneous, areas with mix of subsidence and uplift



Drouin et al., IMO web page

Reference: Hrubcová, P., Vavryčuk, V., 2023. Tectonic stress changes related to plate spreading prior to the 2021 Fagradalsfjall eruption in SW Iceland, *Tectonophysics*, **851**, 229761

Fischer, T., Hrubcová, P., et al., 2022. Swarm seismicity illuminates stress transfer prior to the 2021 Fagradalsfjall eruption in Iceland. *EPSL*, 594, 117685.

Hrubcová, P., Doubravová, J., Vavryčuk, V., 2021. Non-double-couple earthquakes in 2017 swarm in Reykjanes Peninsula, SW Iceland. *EPSL*, 563, 116875.