Earthquake swarms and clusters in stable continental regions: a case study from Nordland, Northern Norway

Hasbi Ash Shiddiqi, Lars Ottemöller, Stéphane Rondenay, and Felix Halpaap

Department of Earth Science, University of Bergen, Norway

hasbi.shiddiqi@uib.no

UNIVERSITY OF BERGEN

"IPSIN - Intraplate Seismicity in India and Norway"

- IPSIN project is a collaborative research project between India and Norway and funded by the Norwegian Research Council.

- The main objective is to improve our seismotectonic understanding of intraplate earthquakes in India and Norway
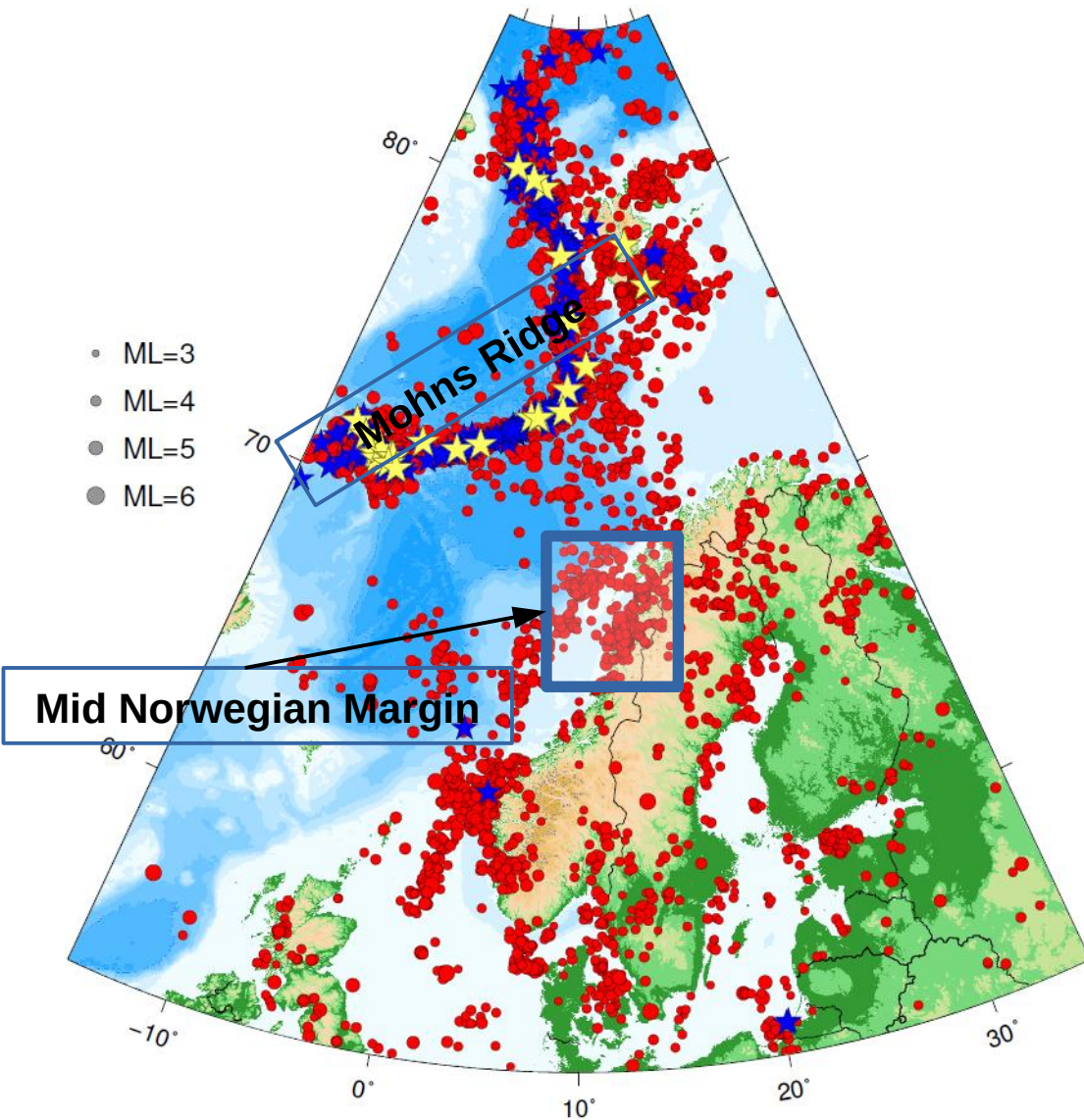
Backgrounds

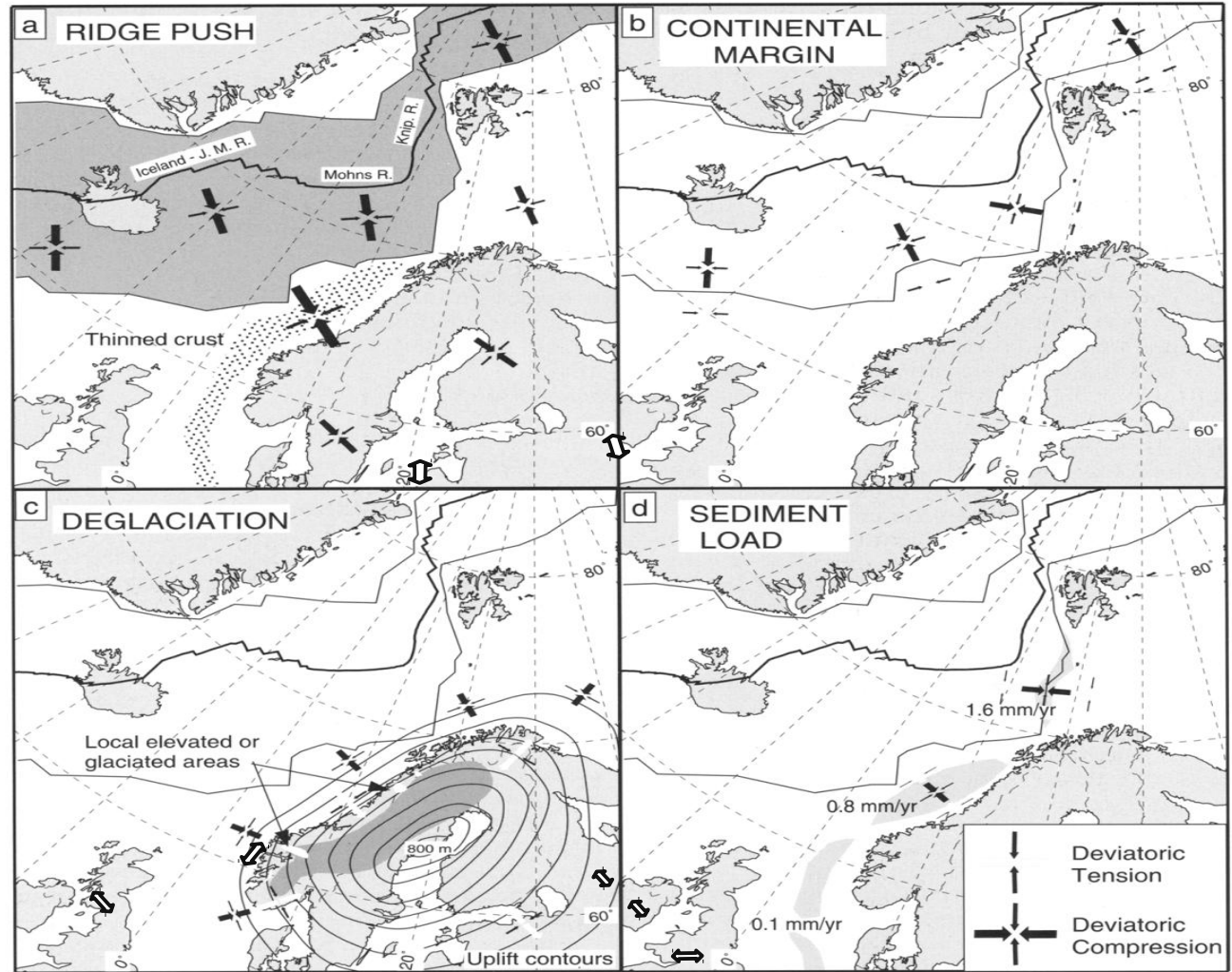# Seismicity in Northern Europe

Norwegian National Seismic Network (NNSN) catalog (Ottemöller et al. 2015)

Important stress-generating mechanisms in Norway

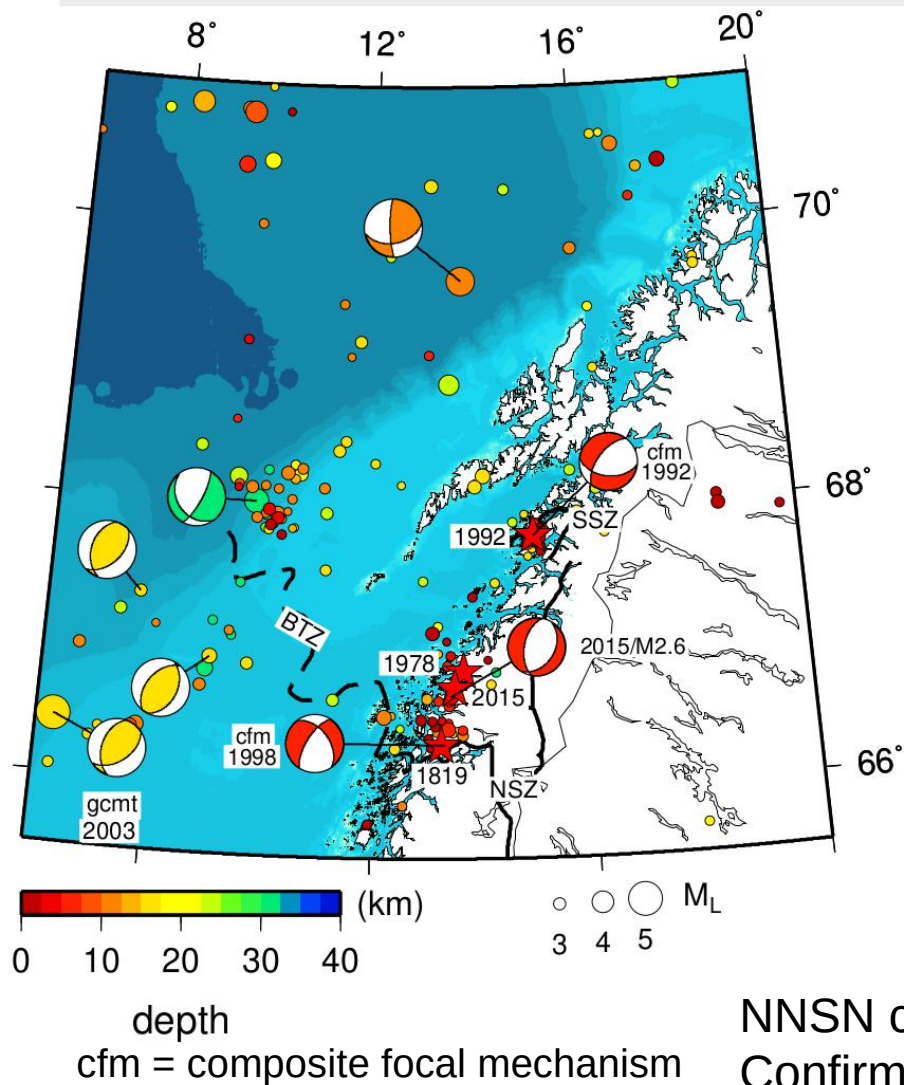
(Fejerskov and Lindholm, 2000)

Seismicity in Nordland
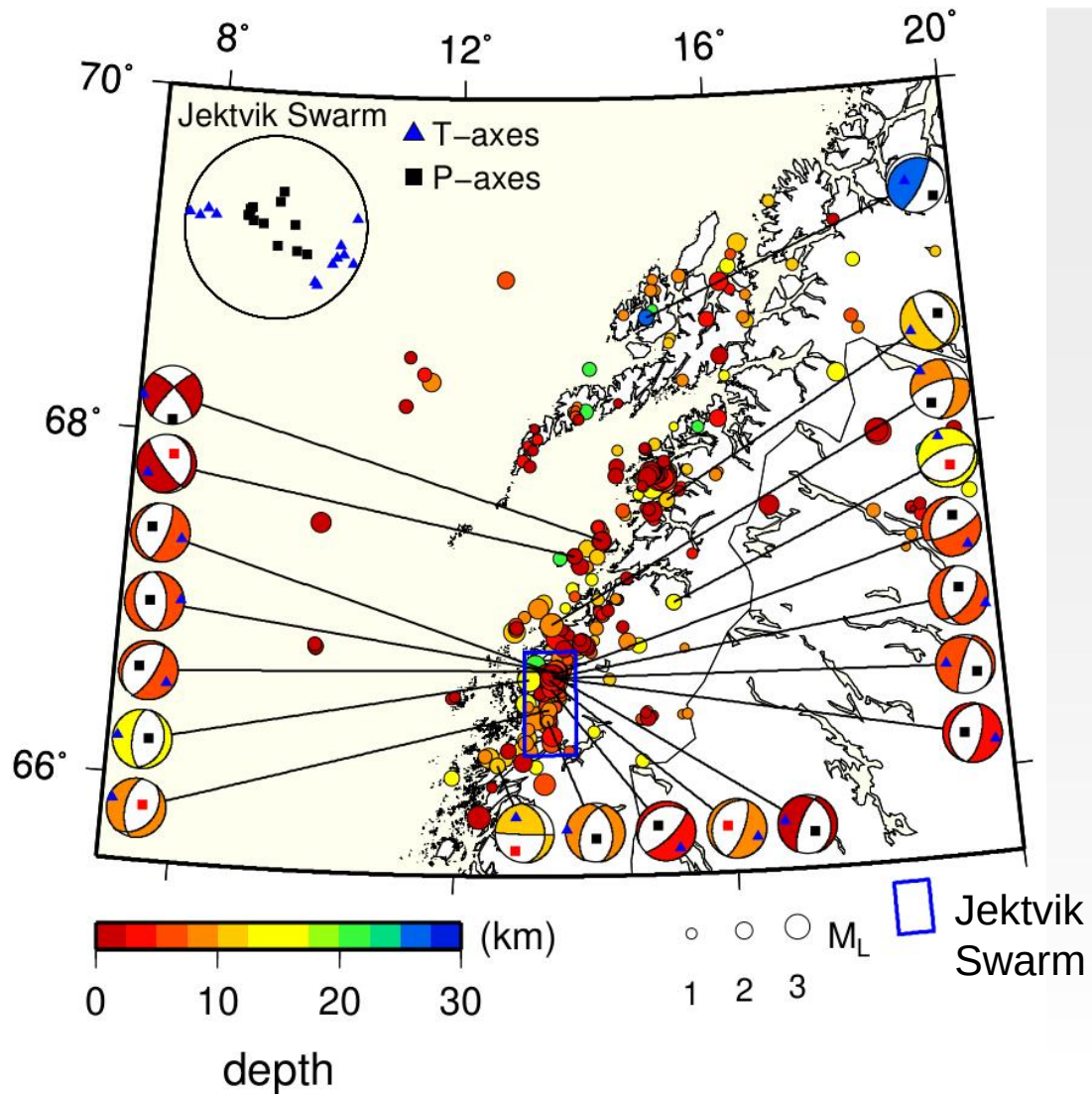
Largest documented earthquake:

- M 5.9, 1819 Lurøy.

Earthquake swarms:

- 1978 Meløy swarm
- 1992 Steigen swarm
- 2014-2016 Jektvik swarm

NNSN catalog since 1980 with ML ≥ 2.5.
Confirmed explosions are excluded

Focal mechanisms

Dominated by **normal** and **oblique-normal** solutions

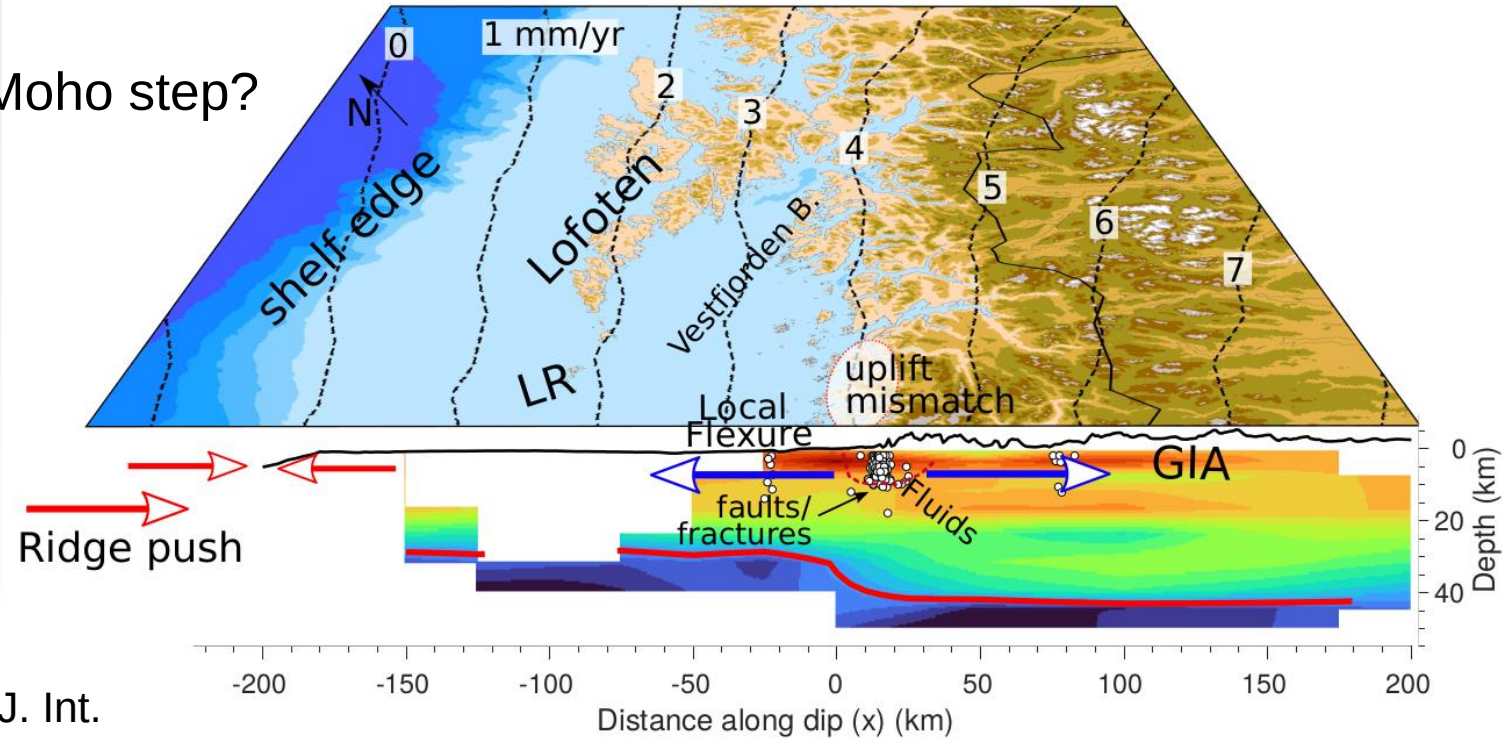Shiddiqi et al. 2022, Geophys. J. Int.

The cause of intraplate earthquakes in Nordland

Regional stress regime: compressive

Local stress regime: extension

Cause: GIA, erosion, Moho step?

Shiddiqi et al. 2022, Geophys. J. Int.

Seismic swarms and earthquake clusters

- Swarms in Nordland: occurred for a couple of years, and diffusive spatial patterns.

- Clusters (repeating?): have been observed for almost 25 years, and tightly clustered.
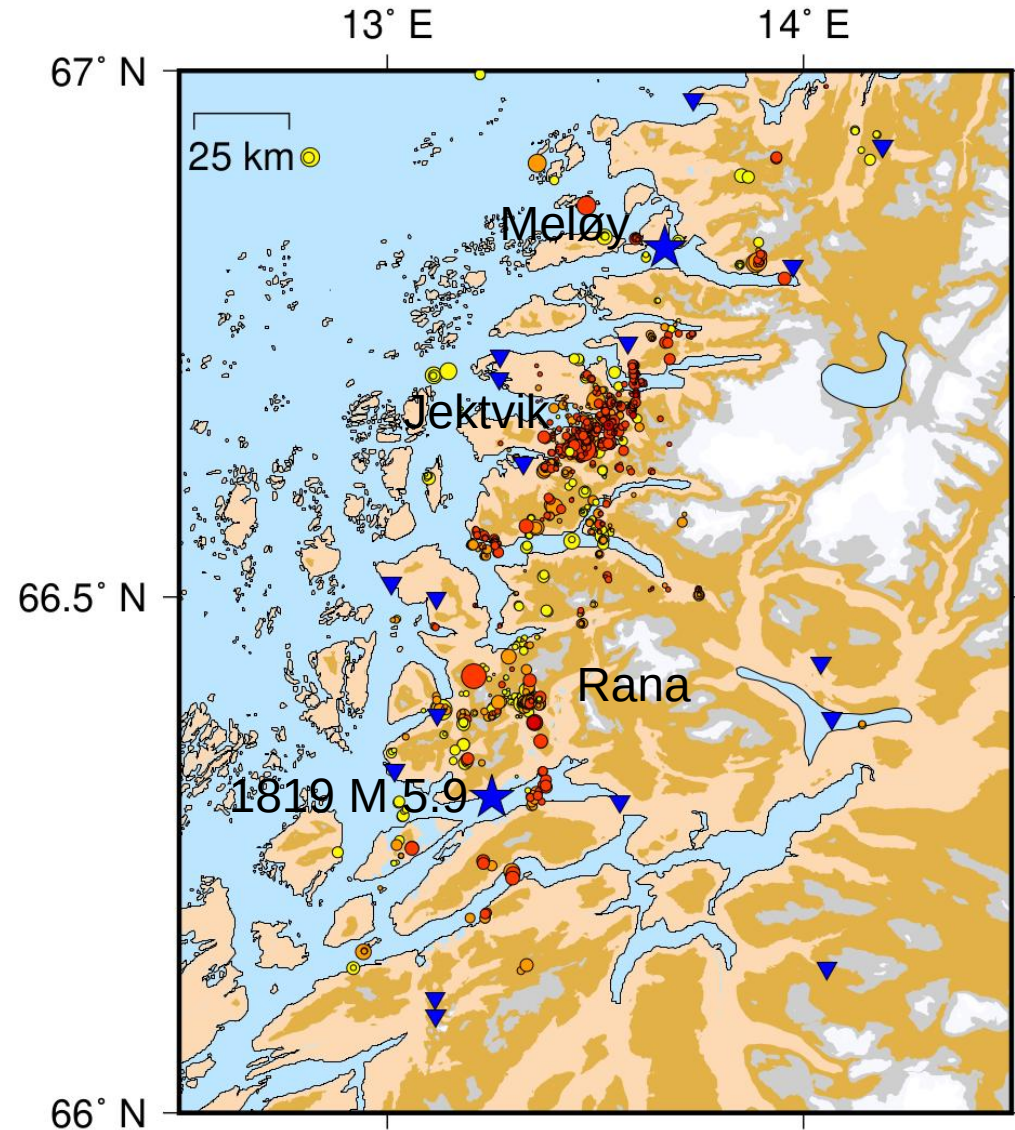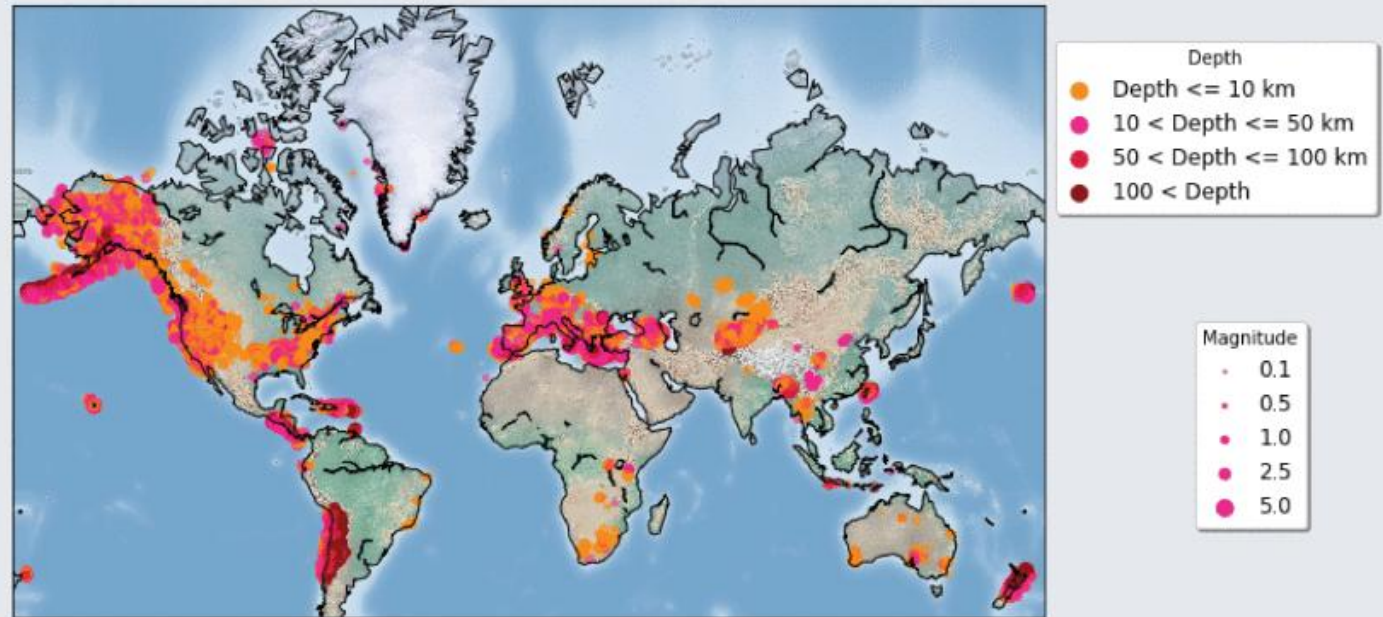
Data Processing

Deep-learning based picker

- Improving the existing catalog by improving the detection for low magnitude events.

- We used Eqtransformer code (Mousavi et al. 2020), trained using a global earthquake and noise dataset: 450k earthquakes and 1.2 M waveforms.

Stanford's STEAD database (Mousavi et al, 2019)

Eqtransformer:
Mousavi et al. 2020, Nat. Comm.

Data Processing

- Continuous detection: Eqtransformer

- Data: NNSN, Neonor2, Scanlips3D (2010 – 2021).

- Waveforms were filtered 1 – 20 Hz.

- Focus on new events (not in the NNSN catalog).

- Manual checking using SEISAN and adding picks manually, if necessary.

- Compute ML using automag in SEISAN, with higher frequency band (2 – 18 Hz).
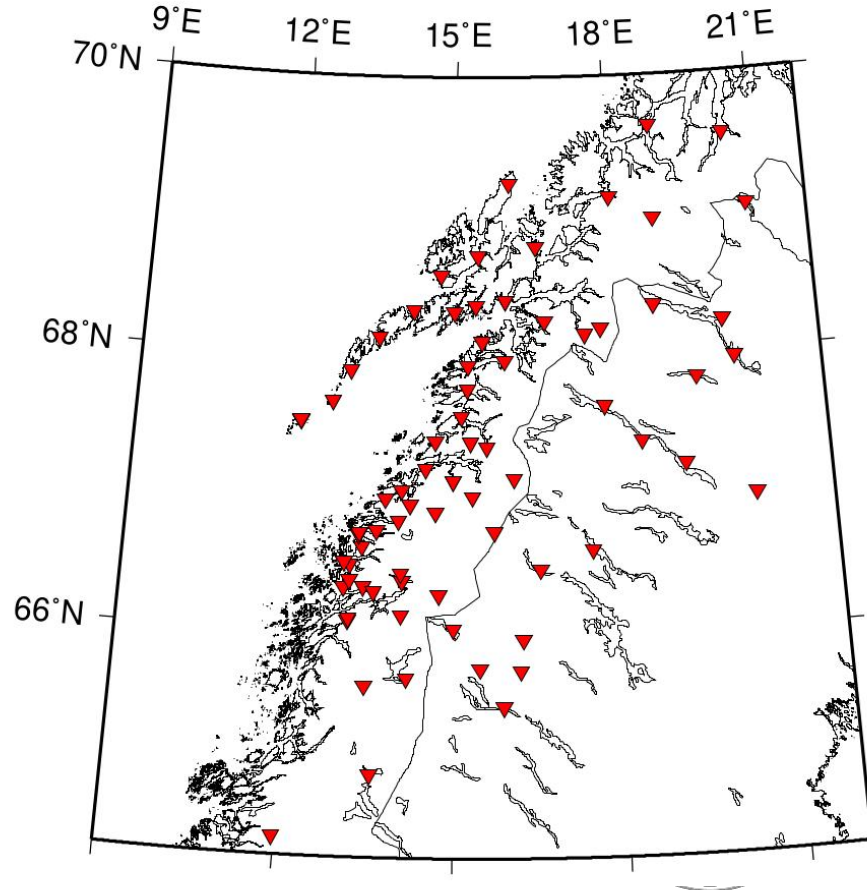
Combined earthquake catalog

- Norwegian National Seismic Network (NNSN) catalog 2005 – 2021 (~ 2000 events).

- Eqtransformer detections (additional ~ 2000 events).

- Hypocenter relocation using waveform cross-correlation and travel-time difference (GrowClust; Trugman and Shearer, 2017)

Catalog comparison

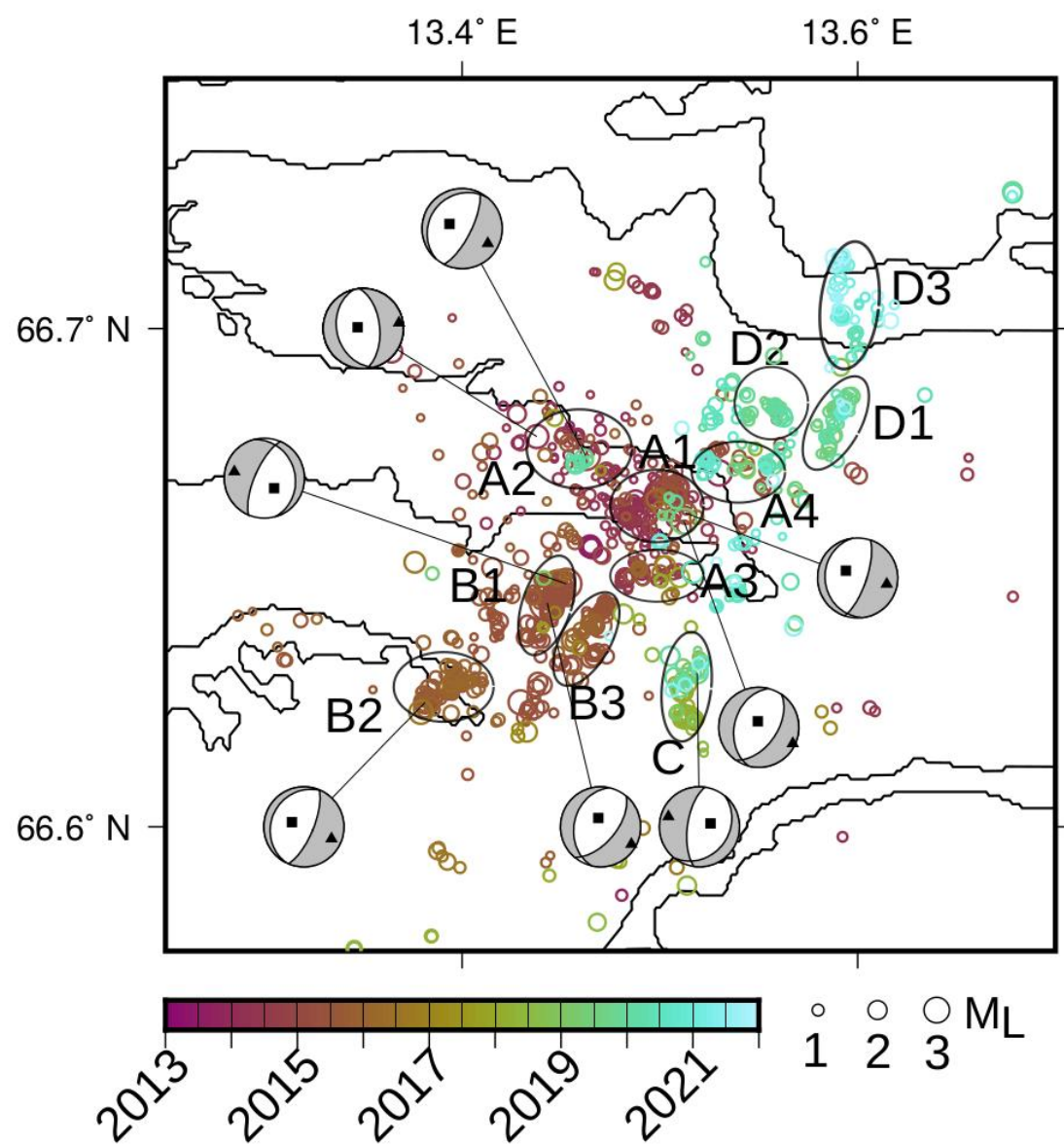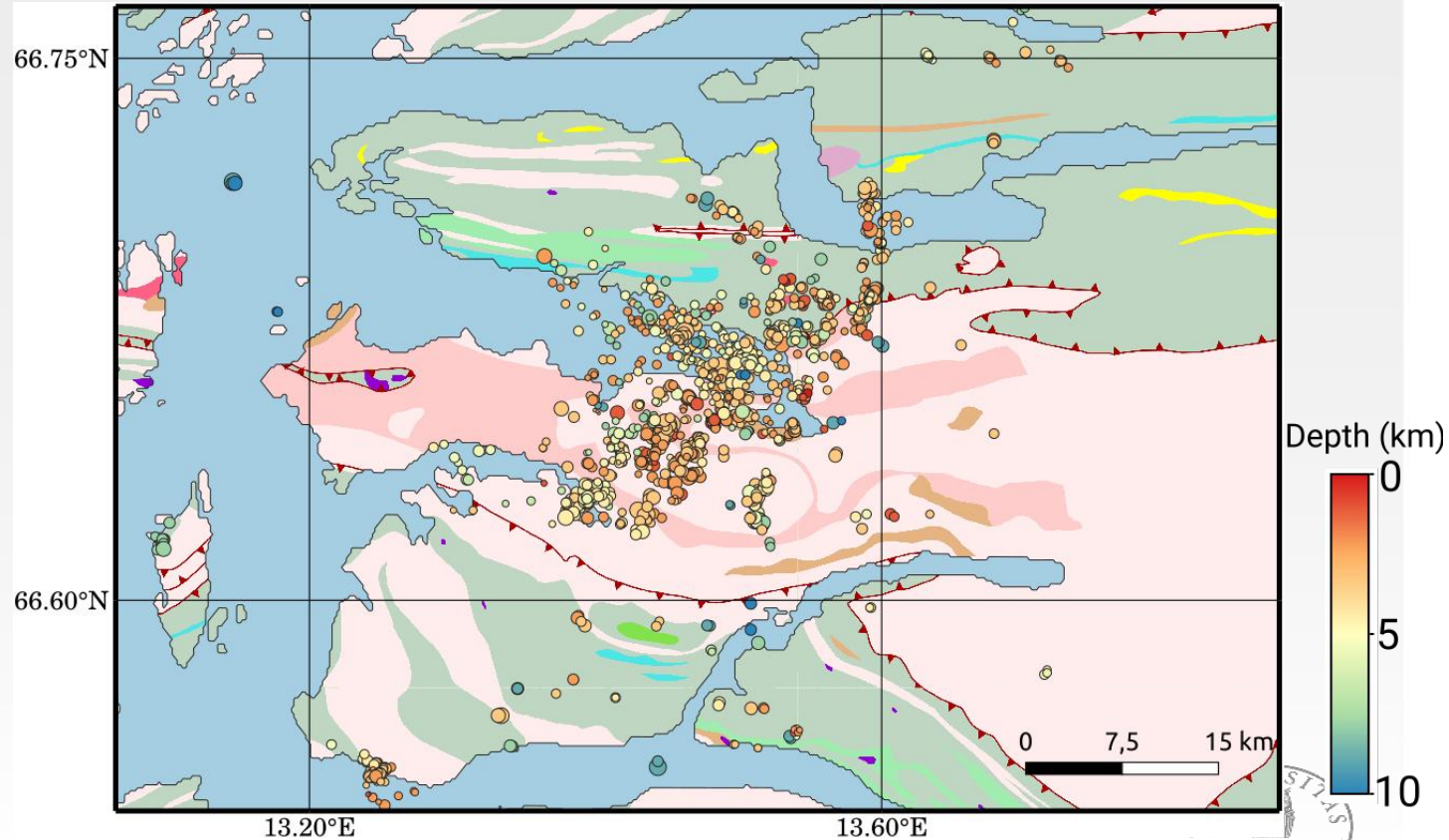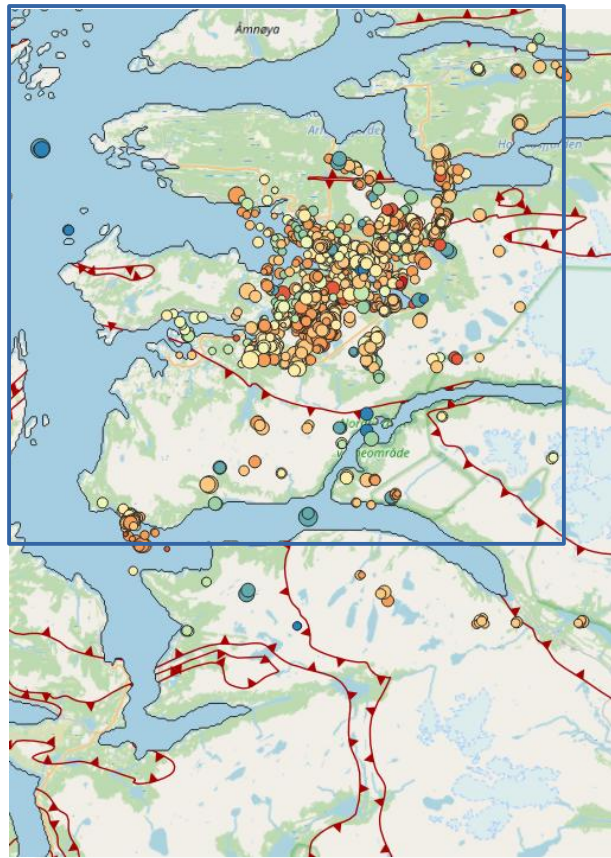- Combined catalog
- NNSN catalog
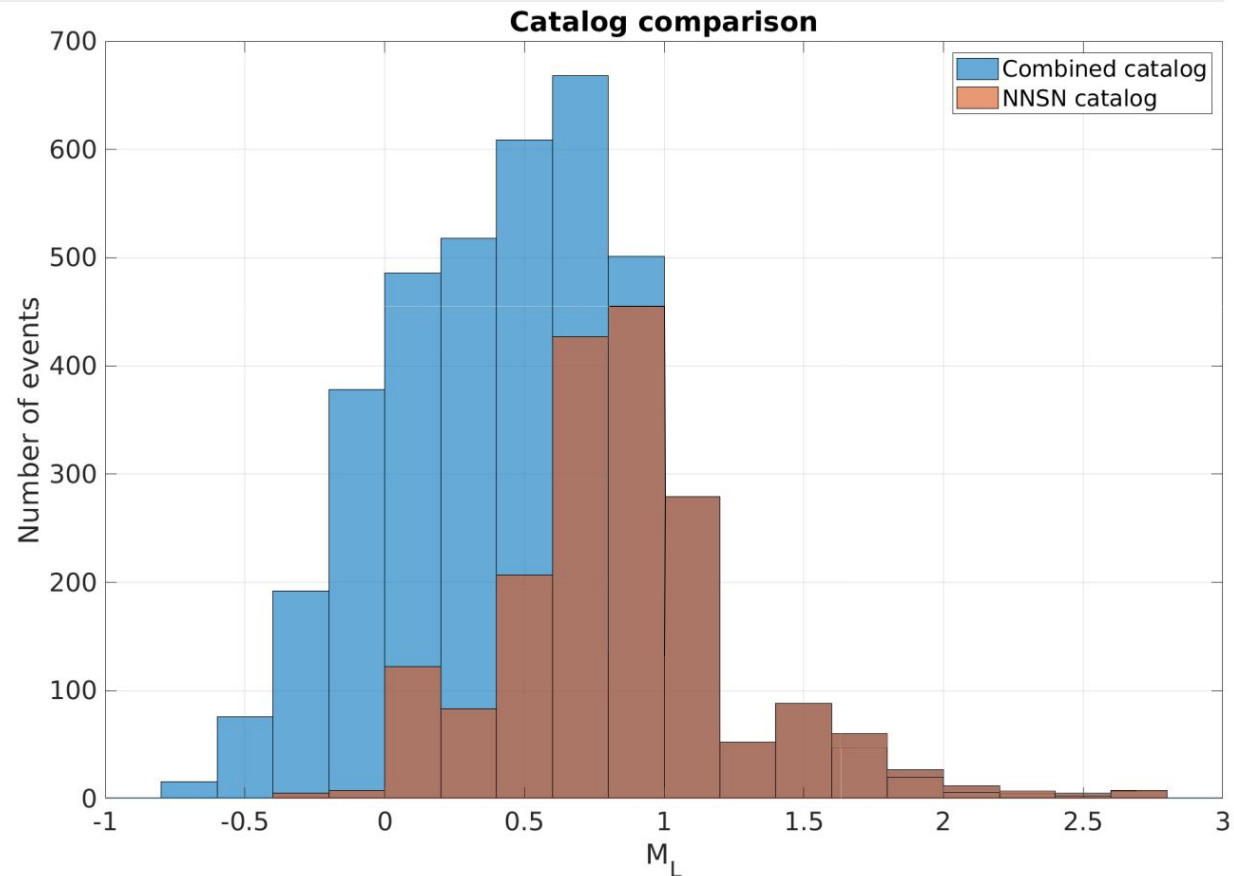
Seismicity analysis

Jektvik Swarm sequences

- Mechanisms are dominated by NNE-SSW normal faulting.

- Majority of the events are between 4-8 km depth.

- B-value:
  - All: 0.98
  - Group A-C: 0.8 -1
  - Group D: 1.2 – 1.3
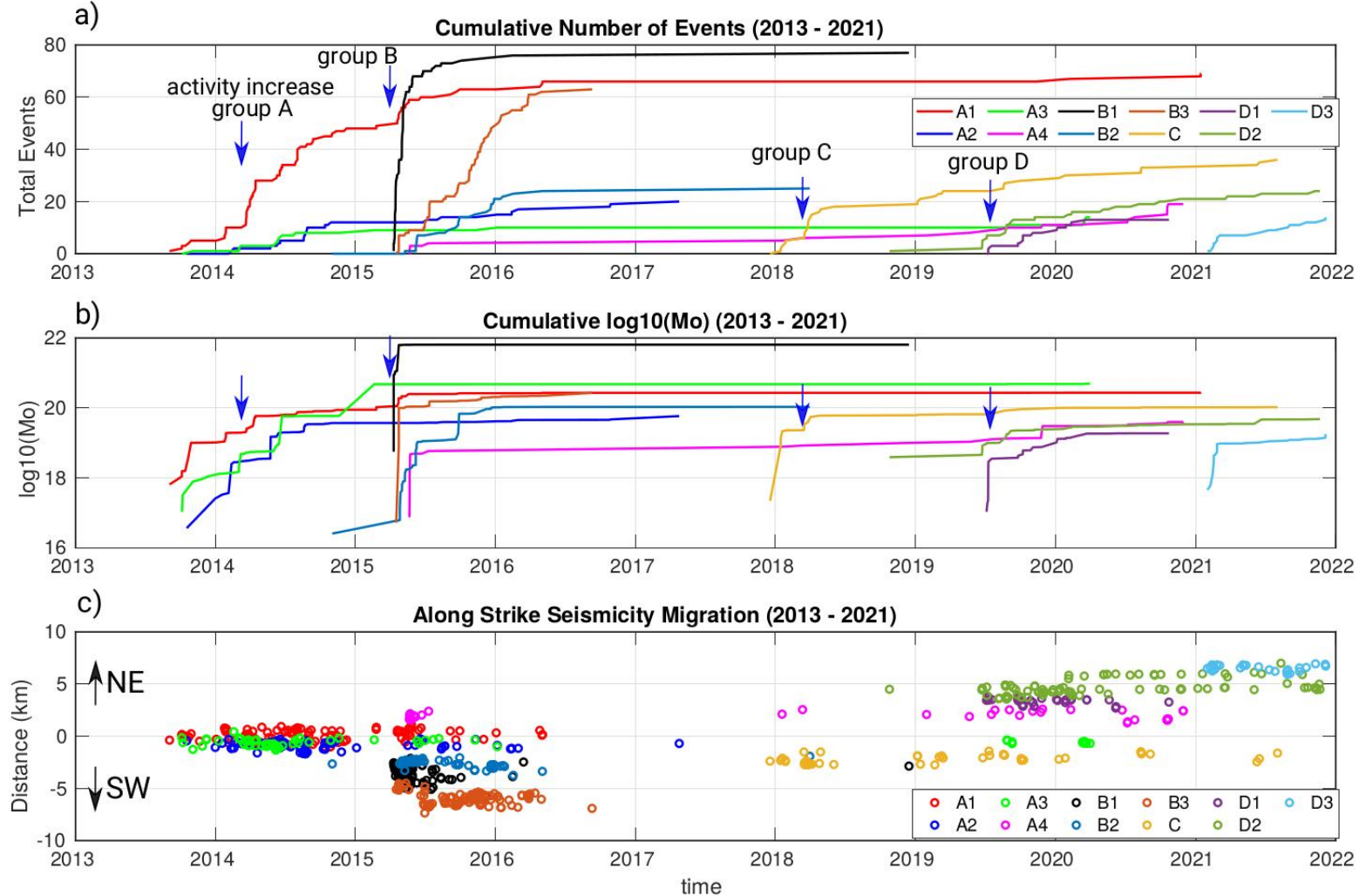
- Average WCC for each cluster: 0.82 – 0.88

Relation to geology

Depth (km): 0 — 5 — 10

Granitic gneiss Tonalite gneiss Quartzite Shear zones (compression)
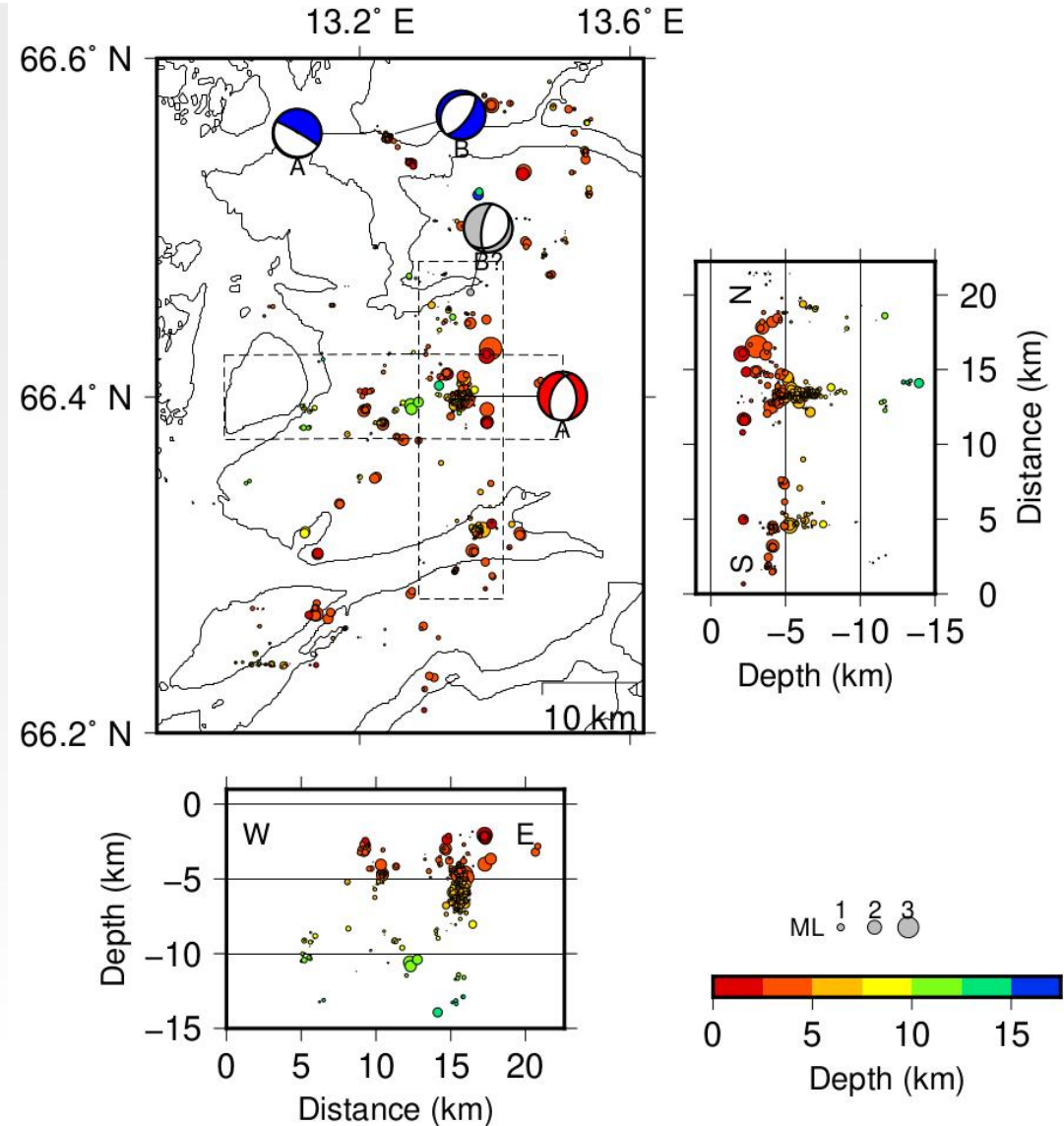Mica gneiss Mica schist

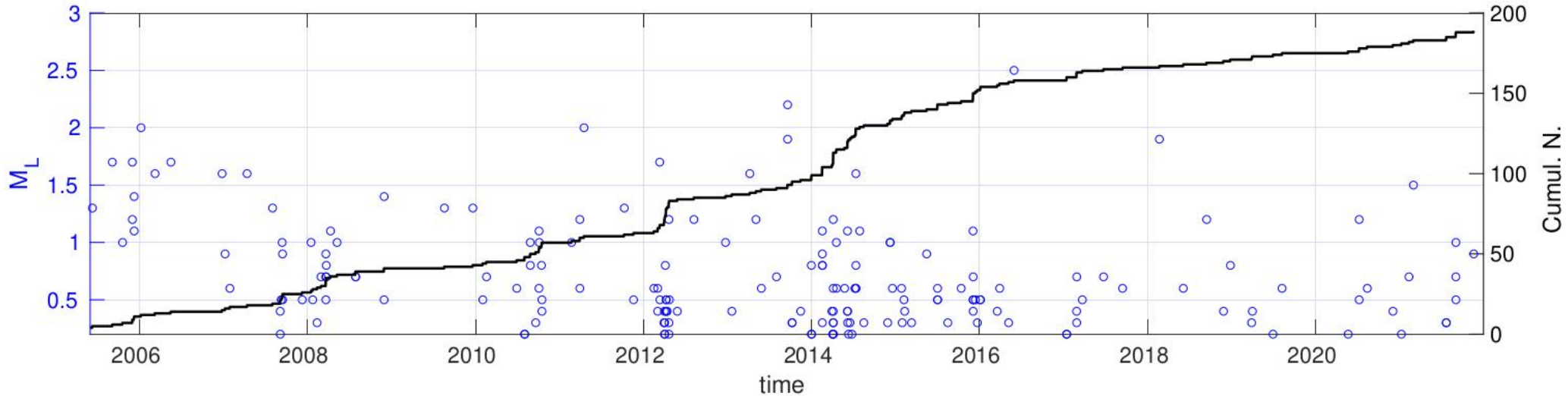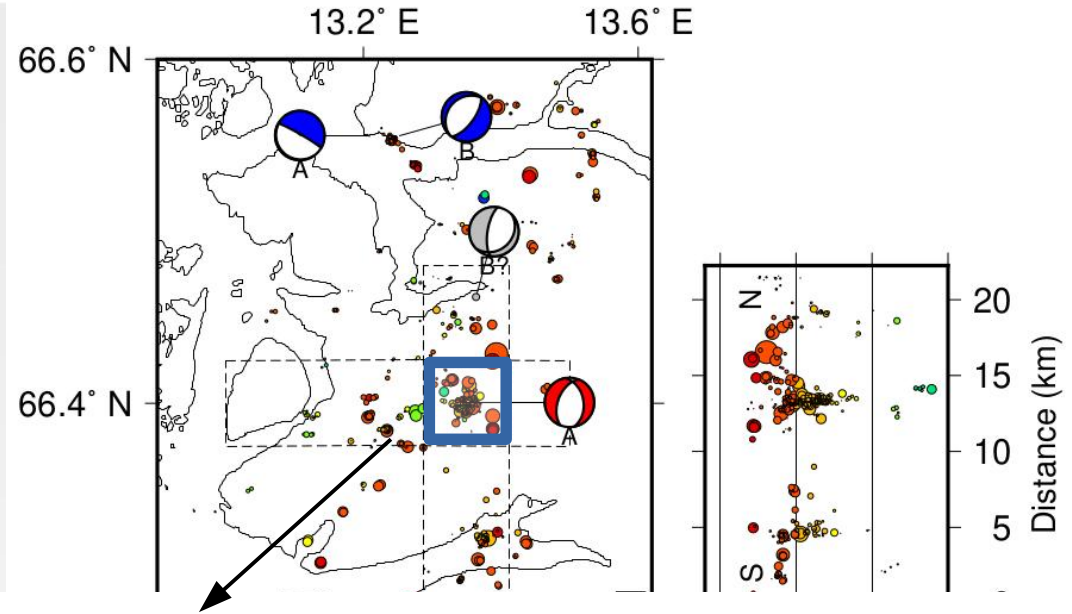Geological Survey of Norway, 2016

Seismicity Evolution and Migration

Clusters in Rana

- Highly correlated events, Average WCC in blue box > 0.9 → Repeating events?

- B-value: 0.75

- Differences with Jektvik swarm?

Clusters in Rana

- Highly correlated events, Average WCC in blue box > 0.9 → Repeating events?

- B-value: 0.75

- Differences with Jektvik swarm?

Summary

- The Jetkvik swarm exhibits a diffusive pattern, which together with a low VP anomaly found by a previous tomography study suggests that fluids may play a role in the source process.

- The highly-correlated events in Rana (possibly repeating events) are not as diffuse in space. This cluster may be attributed to fault intersection, and fluids may not be a major factor in its generation.

hasbi.shiddiqi@uib.no