# *The seismotectonic significance of the 2008-2010 seismic swarm in the Brabant Massif (Belgium)*

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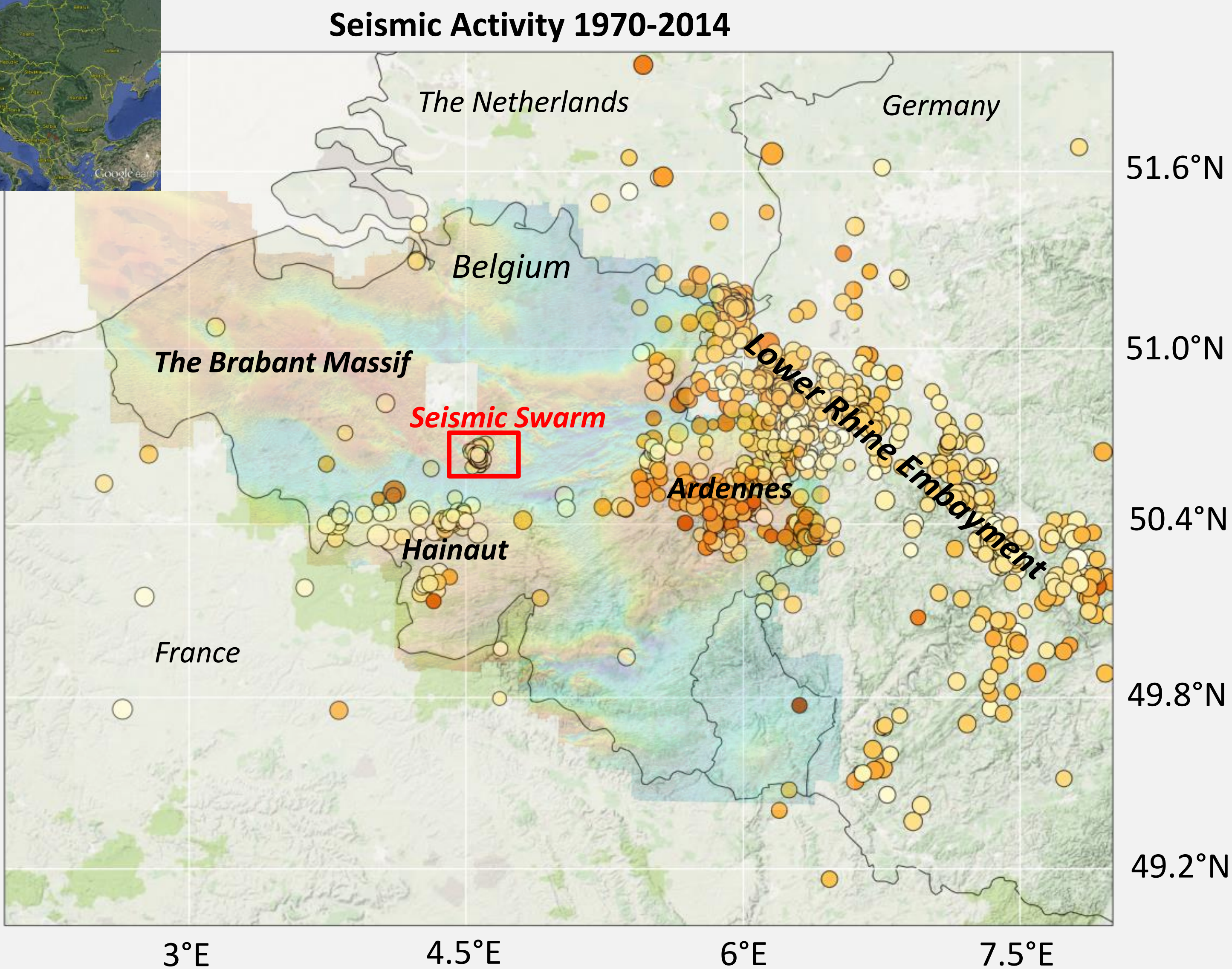
SEISMOLOGY - GRAVIMETRY

USGS

*Figures in this presentation are published in* ***Van Noten et al. 2015.*** *Seismotectonic significance of the 2008-2010 Walloon Brabant seismic swarm in the Brabant Massif. Tectonophysics*
doi:10.1016/j.tecto.2015.05.026

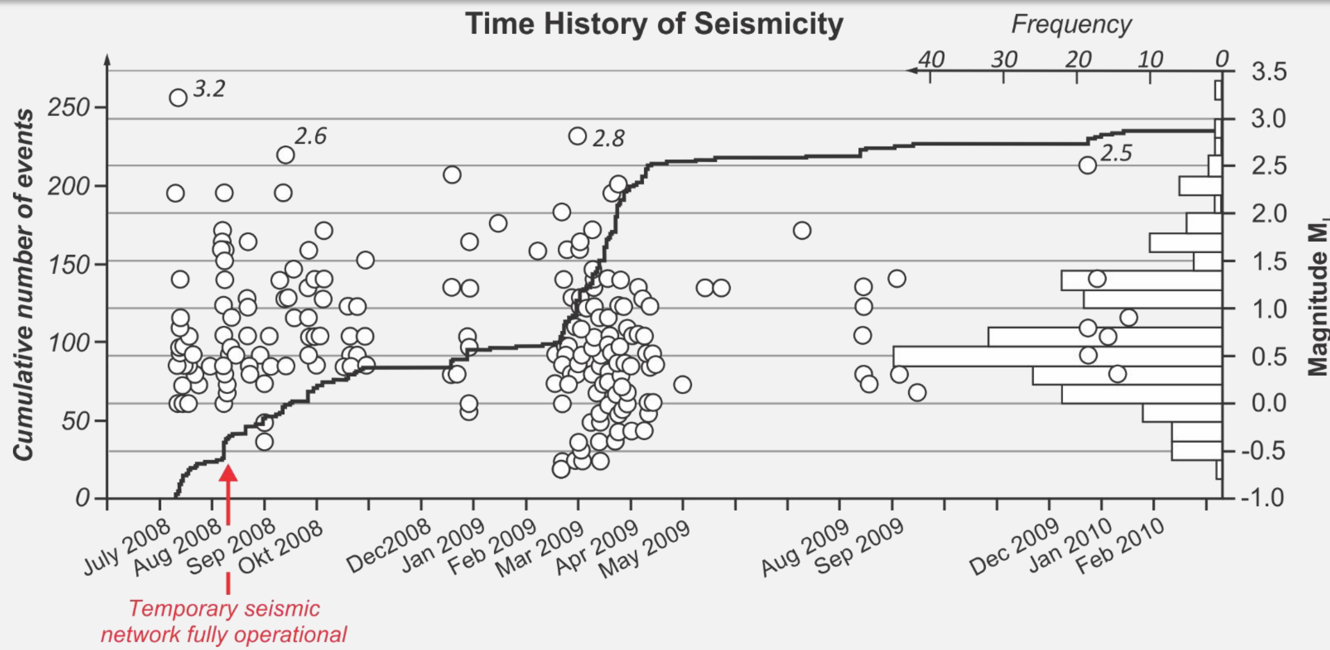


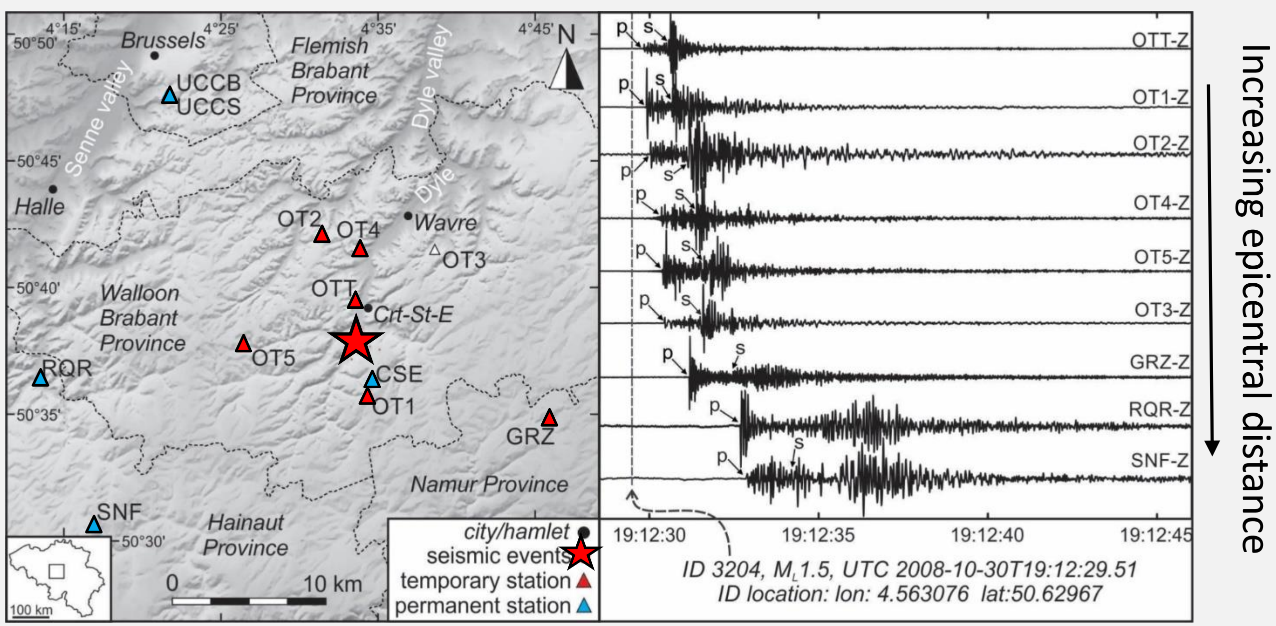

Aeromagnetic map of Belgium as background

Earthquake depth

- < 10 km
- 10-20 km
- >20 km

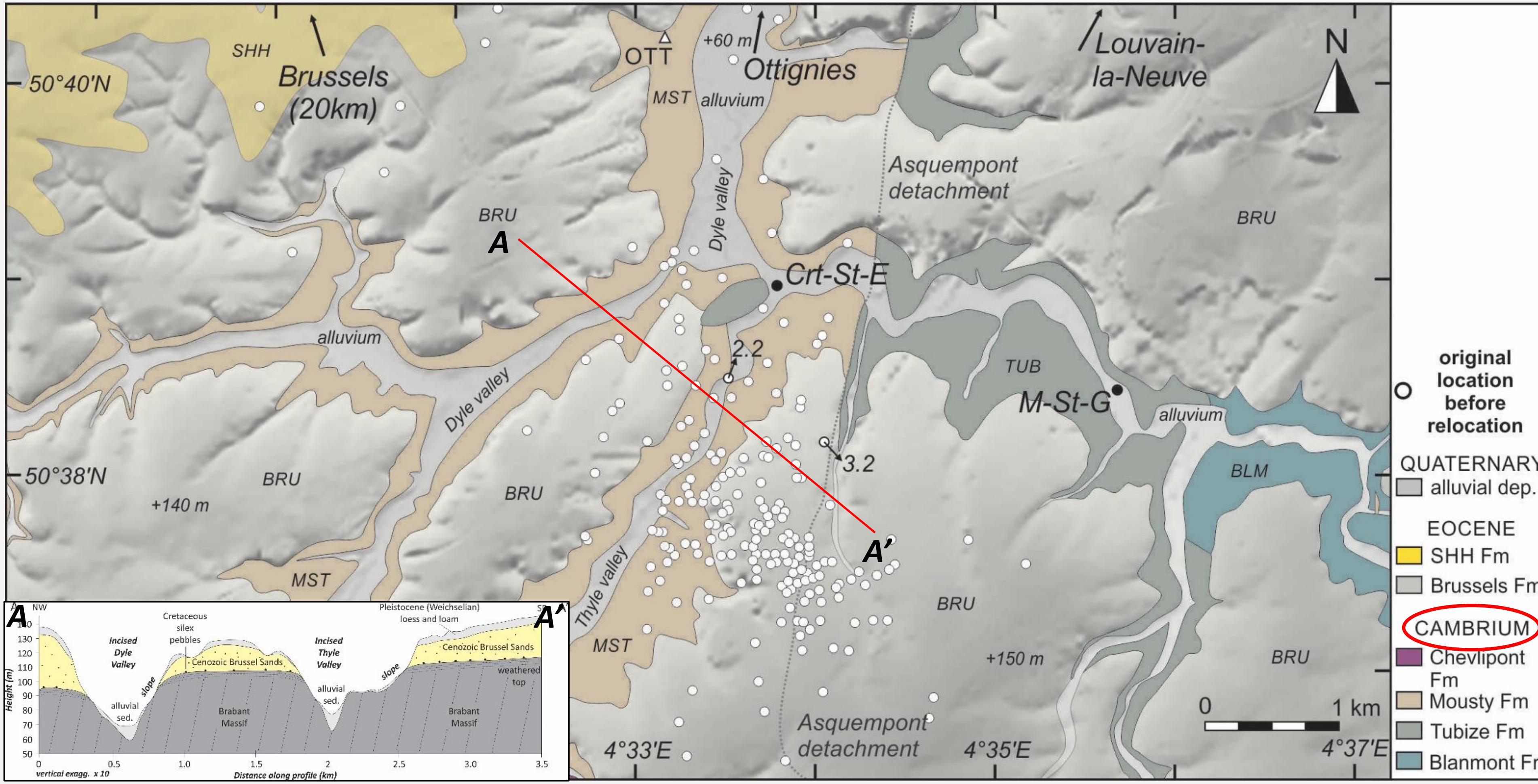
# The 2008-2010 Walloon Brabant Seismic Swarm




Temporary network deployed during the seismic swarm

Permanent stations



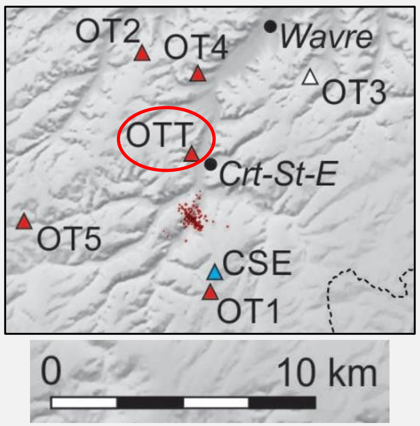

## *Aim of this study*

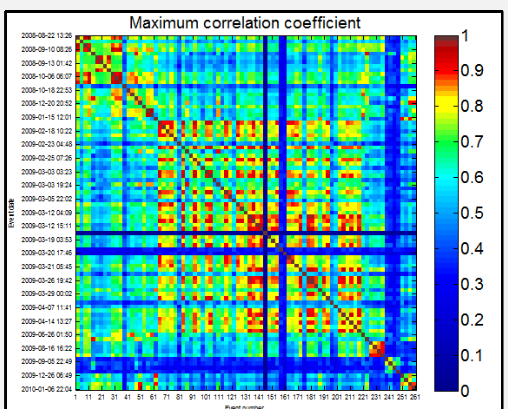
- Seismotectonic significance of the seismic swarm ?
- Link between local geology and the swarm?

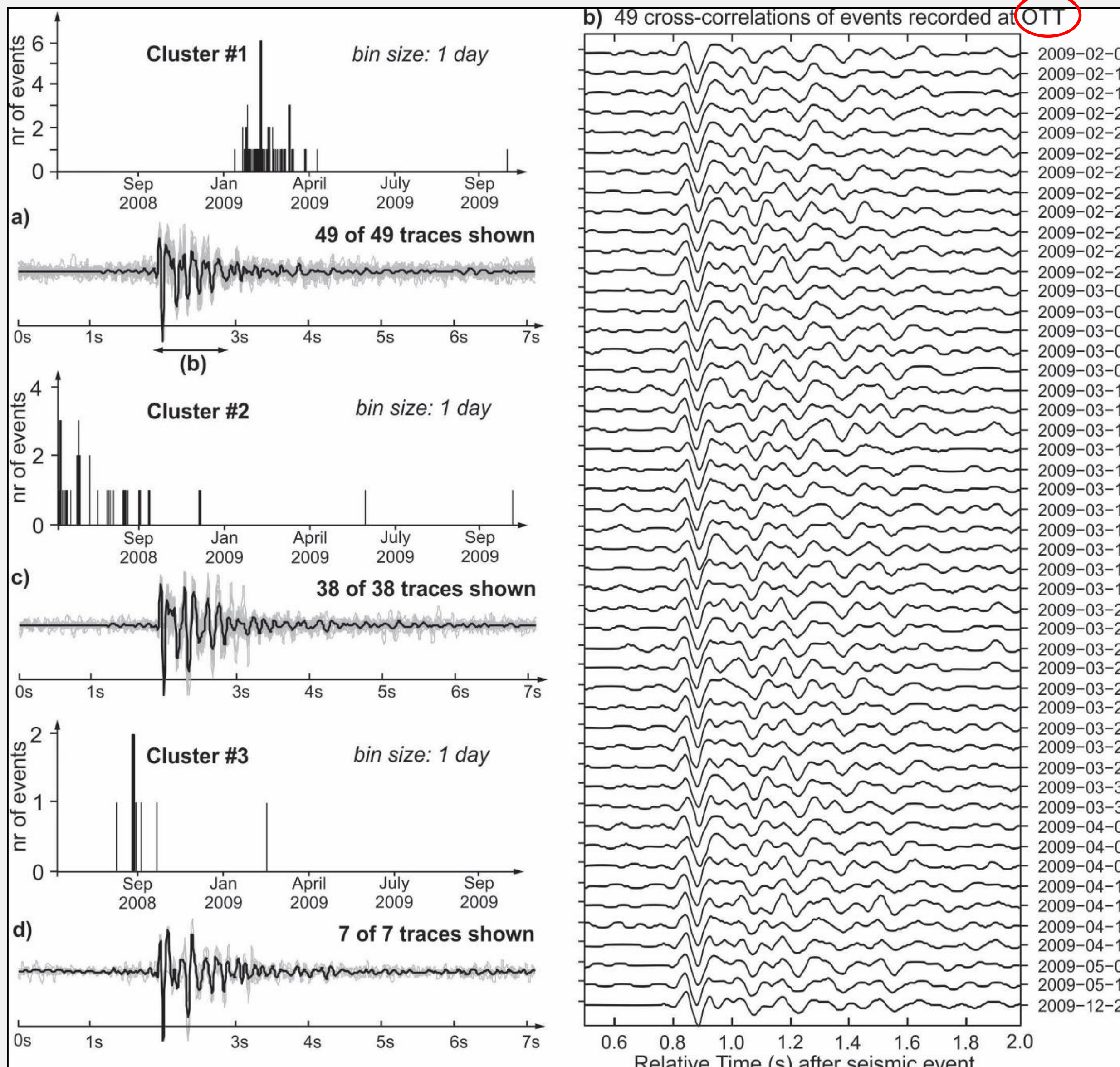
## *Methodology*

- Location improvement by cross-correlation
- Aeromagnetic filtering

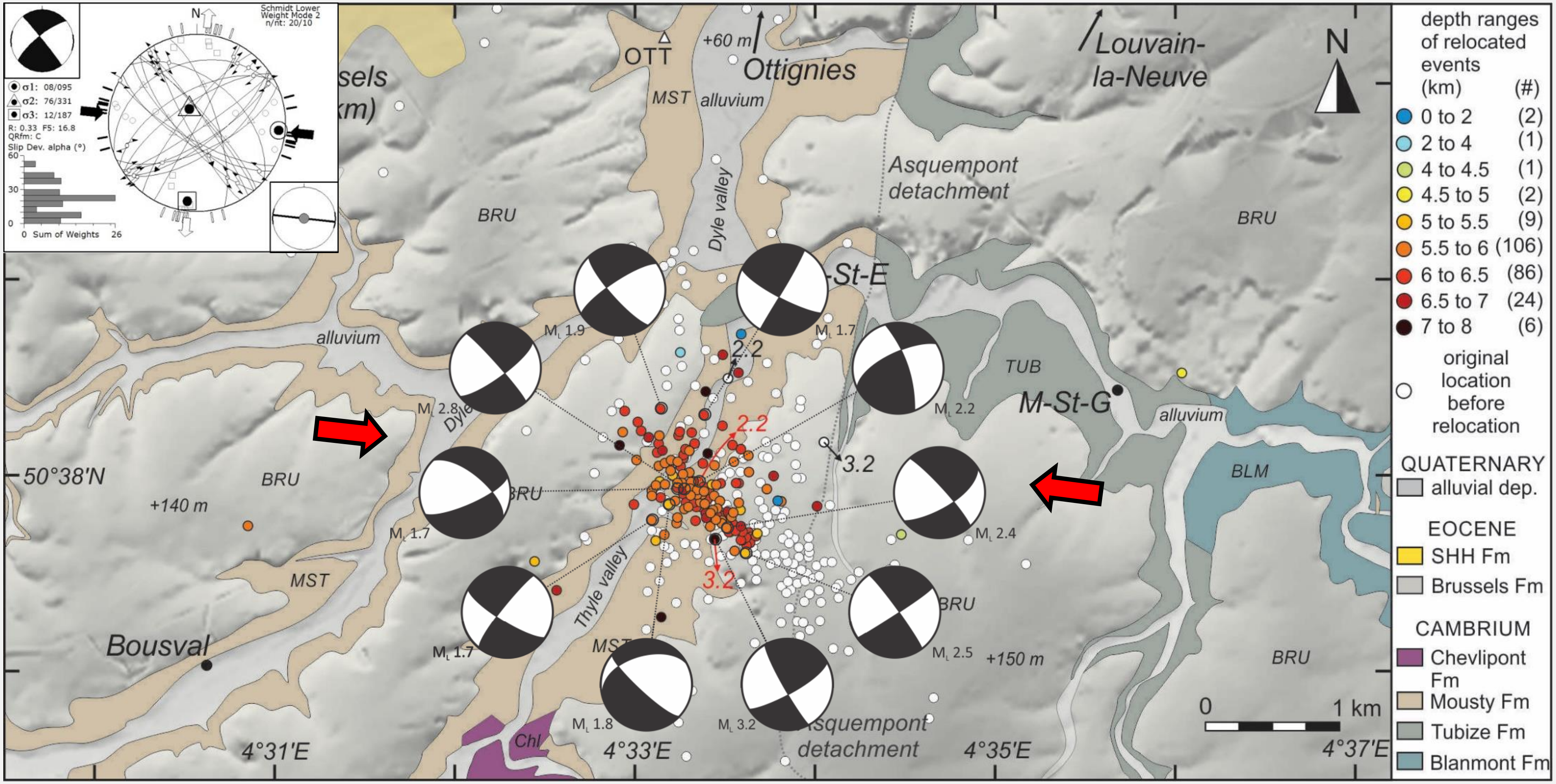
- Waveform similarity of co-located events at local station OTT
- Improvement of P- & S-wave arrivals allow event location improvement



# Relocation by cross-correlation




*Van Noten et al. 2015. Tectonophysics*

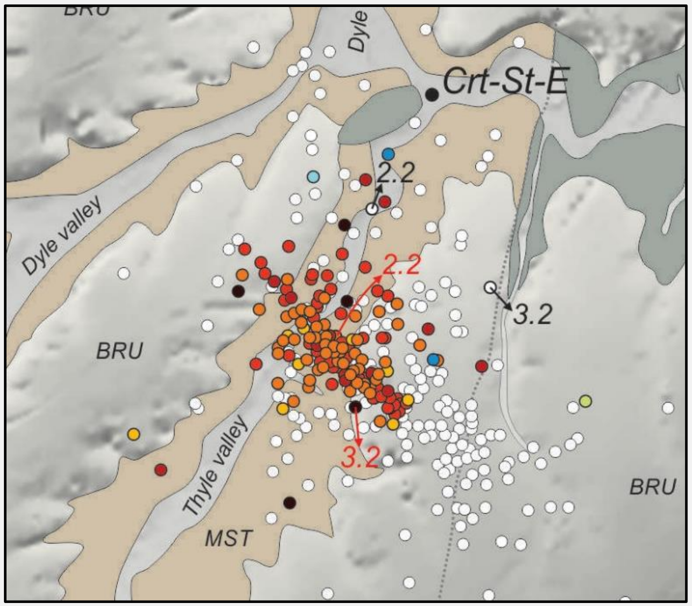
***After relocation:***

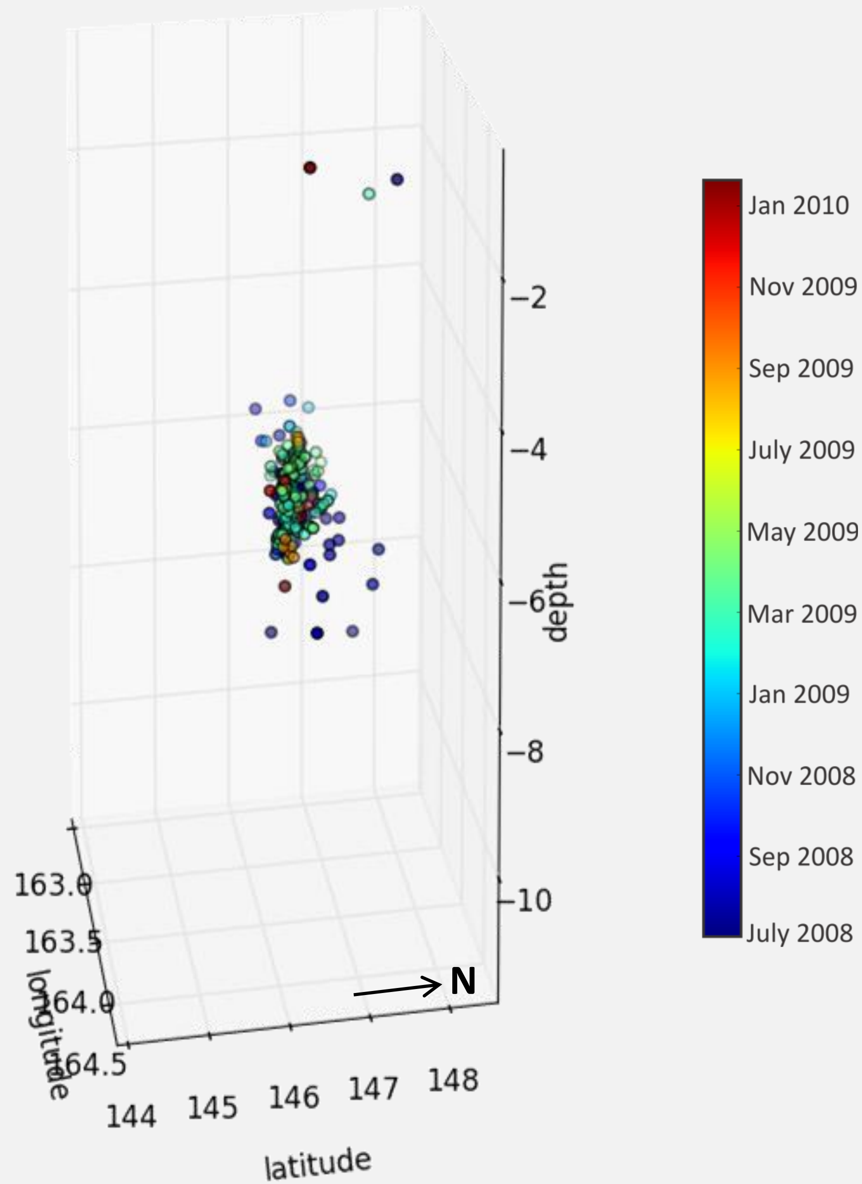
- *Improved epicentre and hypocentre distribution*
- *1.5 km long, 5-7 km deep, NW-SE fault structure*
- *Absolute error of swarm location +/- 200m*

***Focal Mechanisms***

- *Of largest events only*
- *Consistent left-lateral strike-slip*
- *Regional stress tensor WNW-ESE*

# Improved hypocentre distribution

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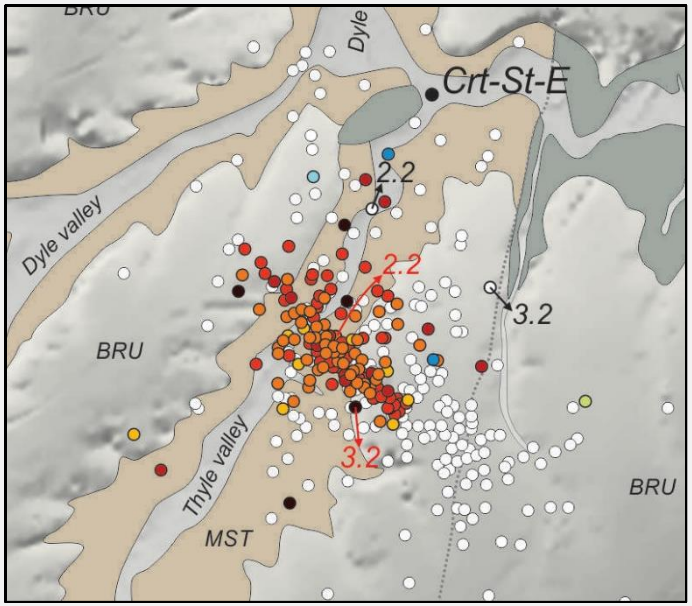


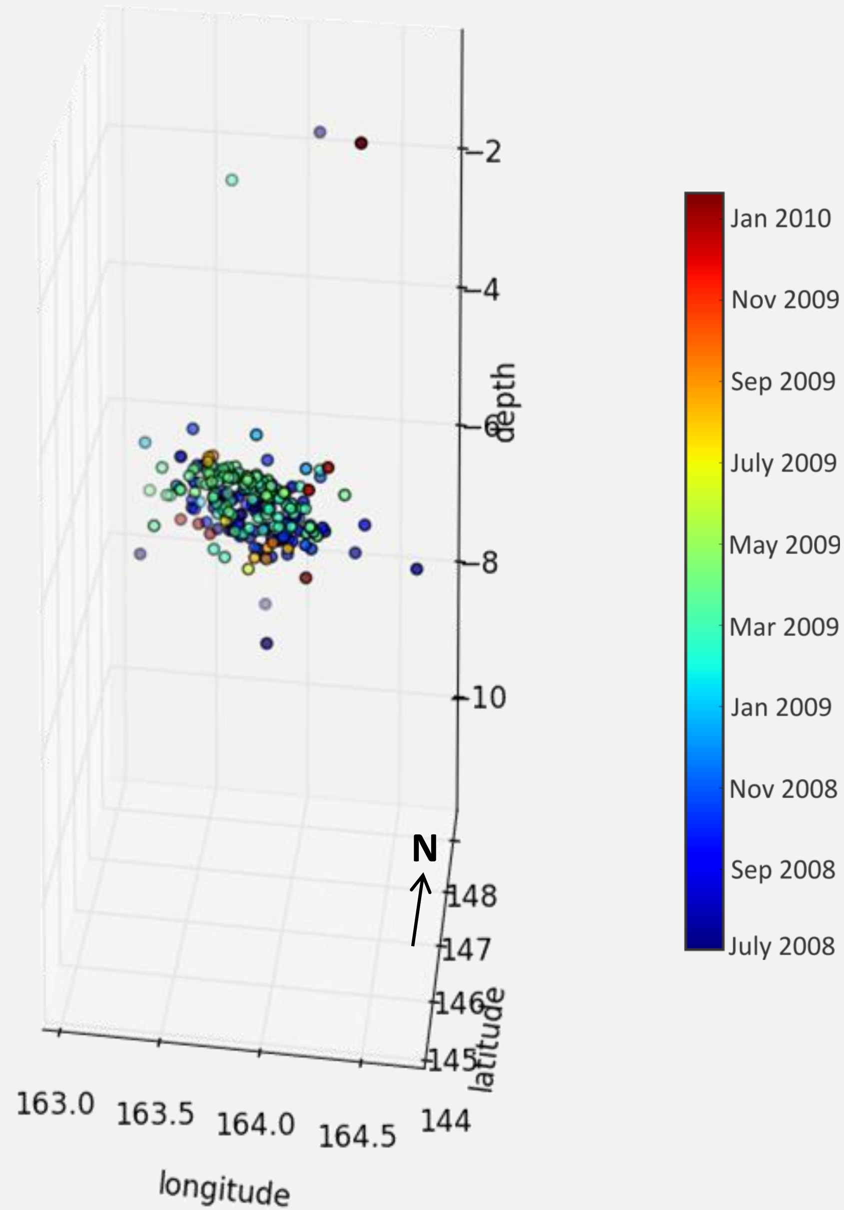


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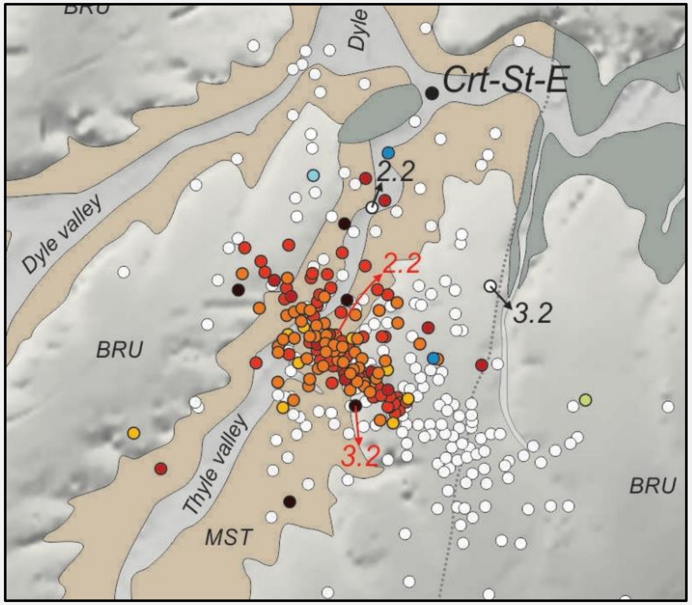


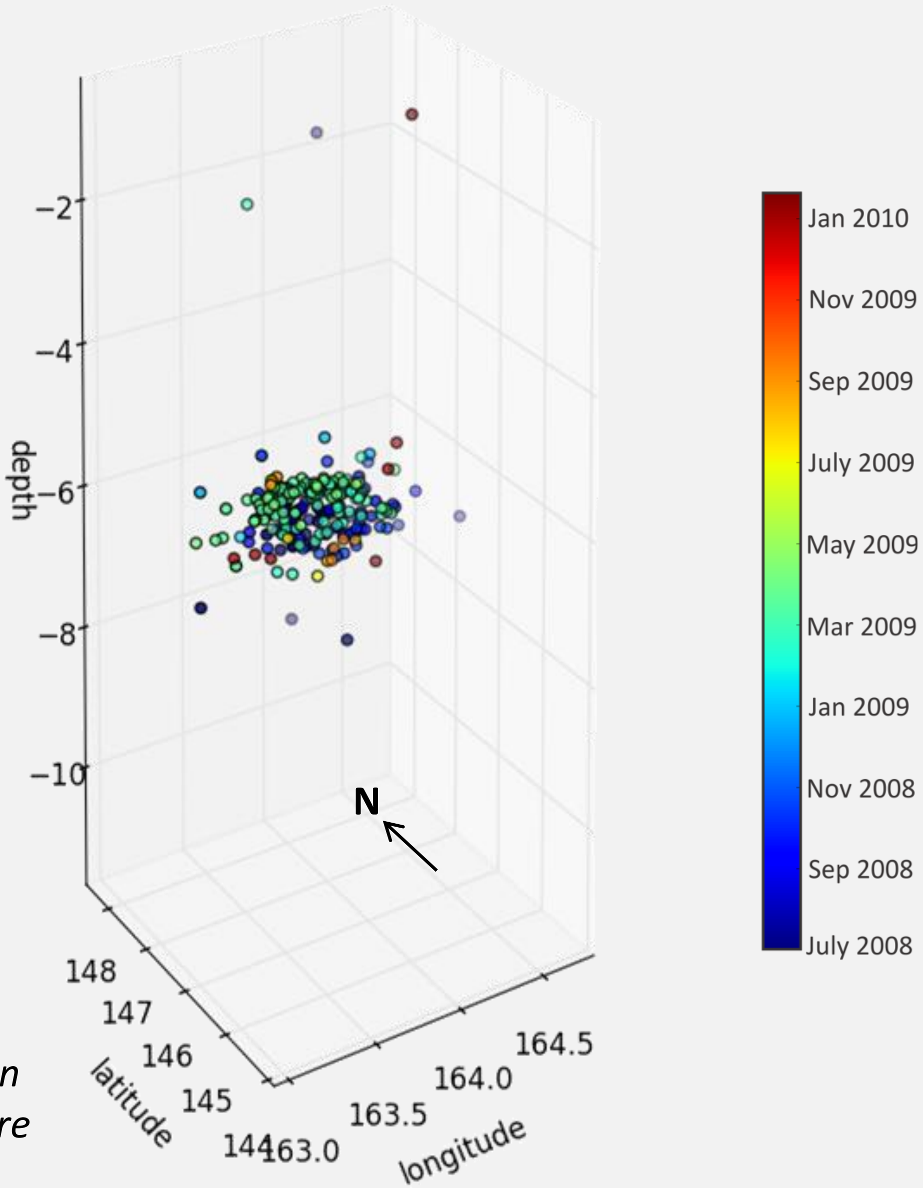


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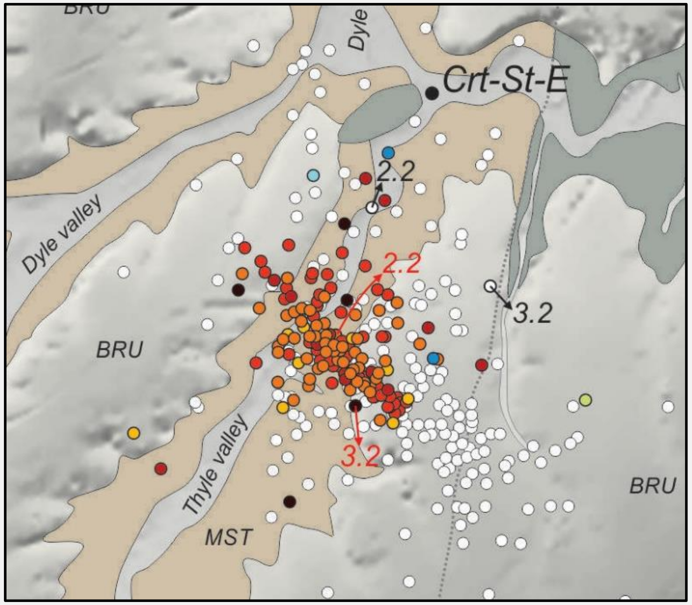


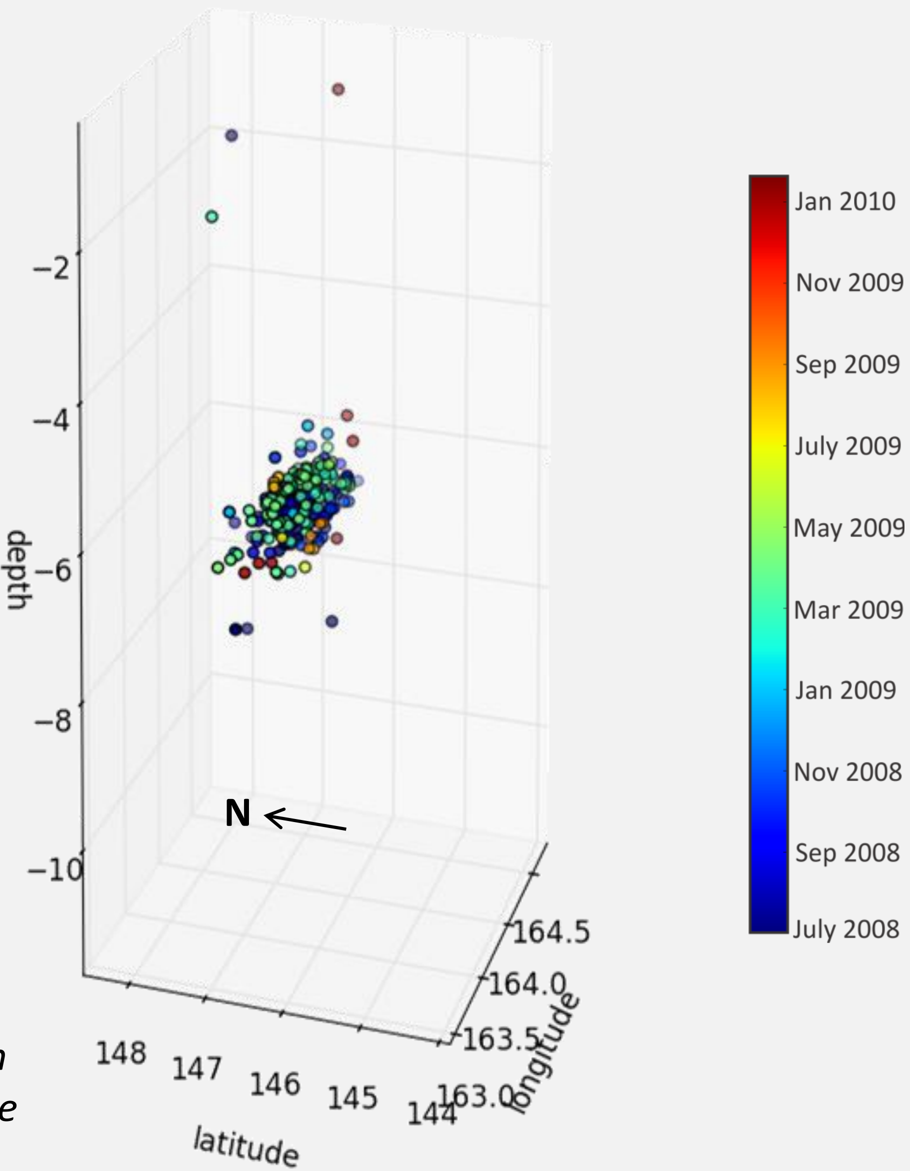


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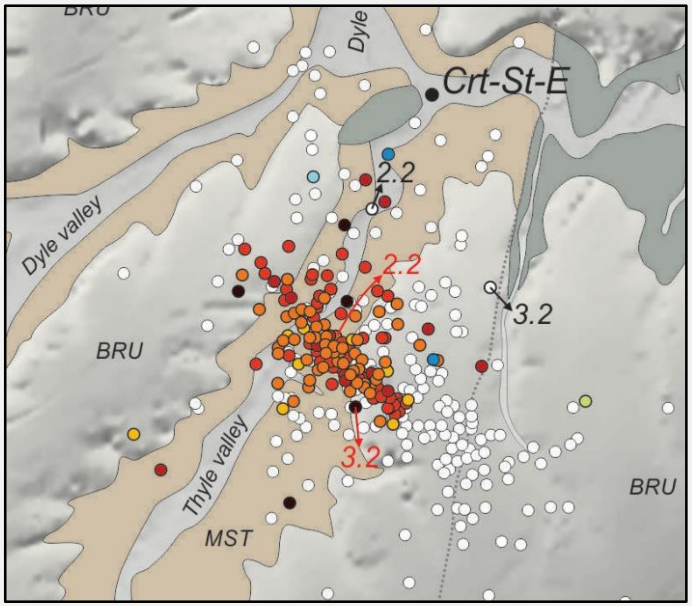


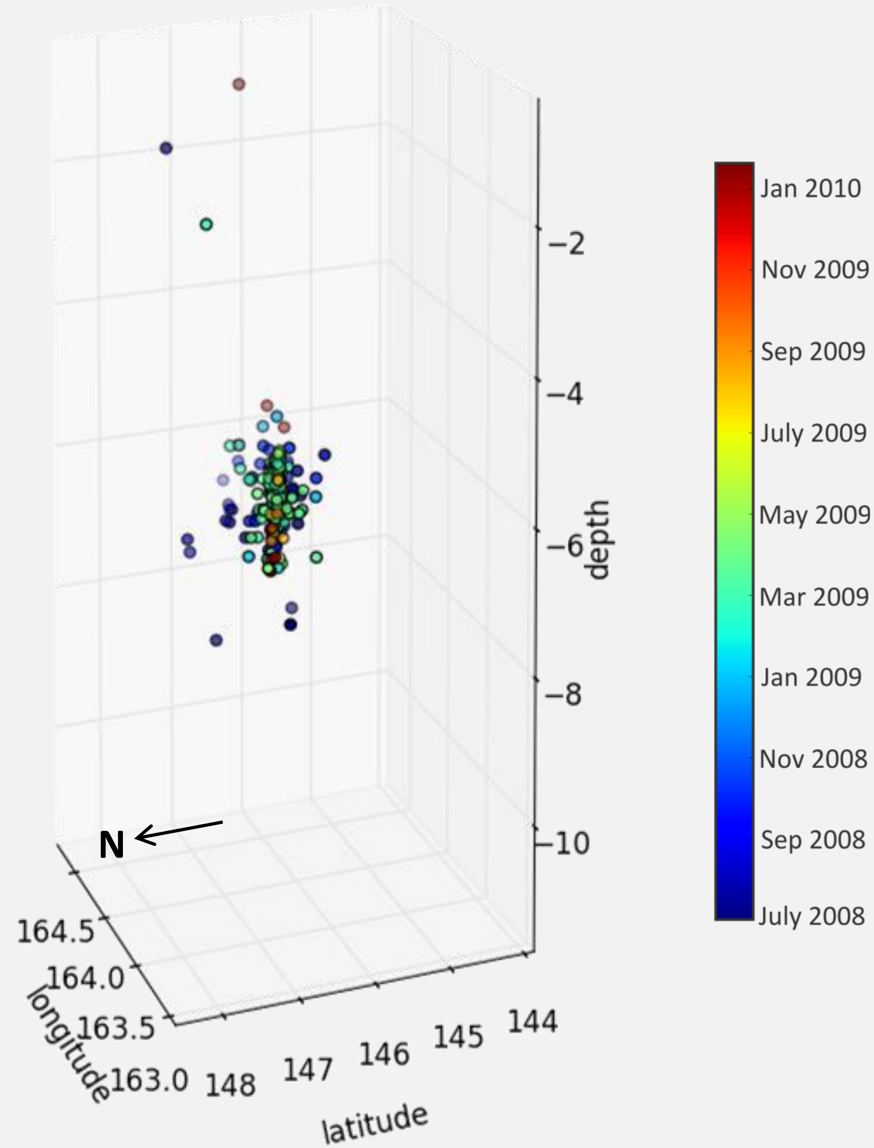


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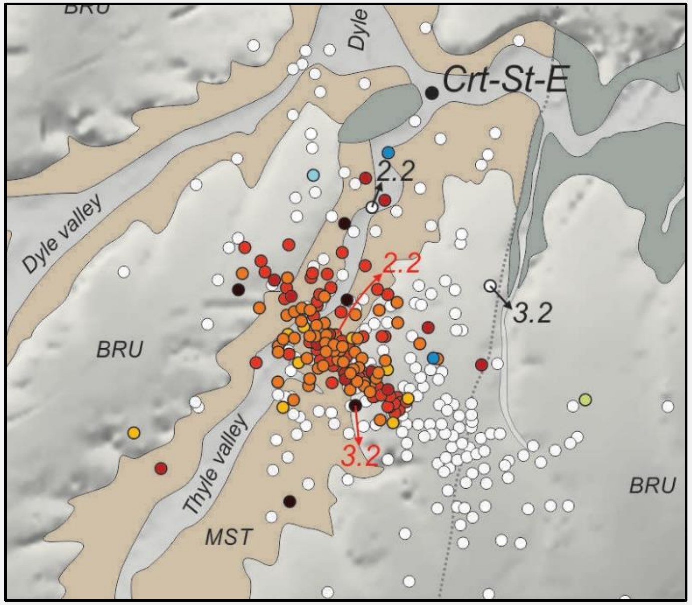


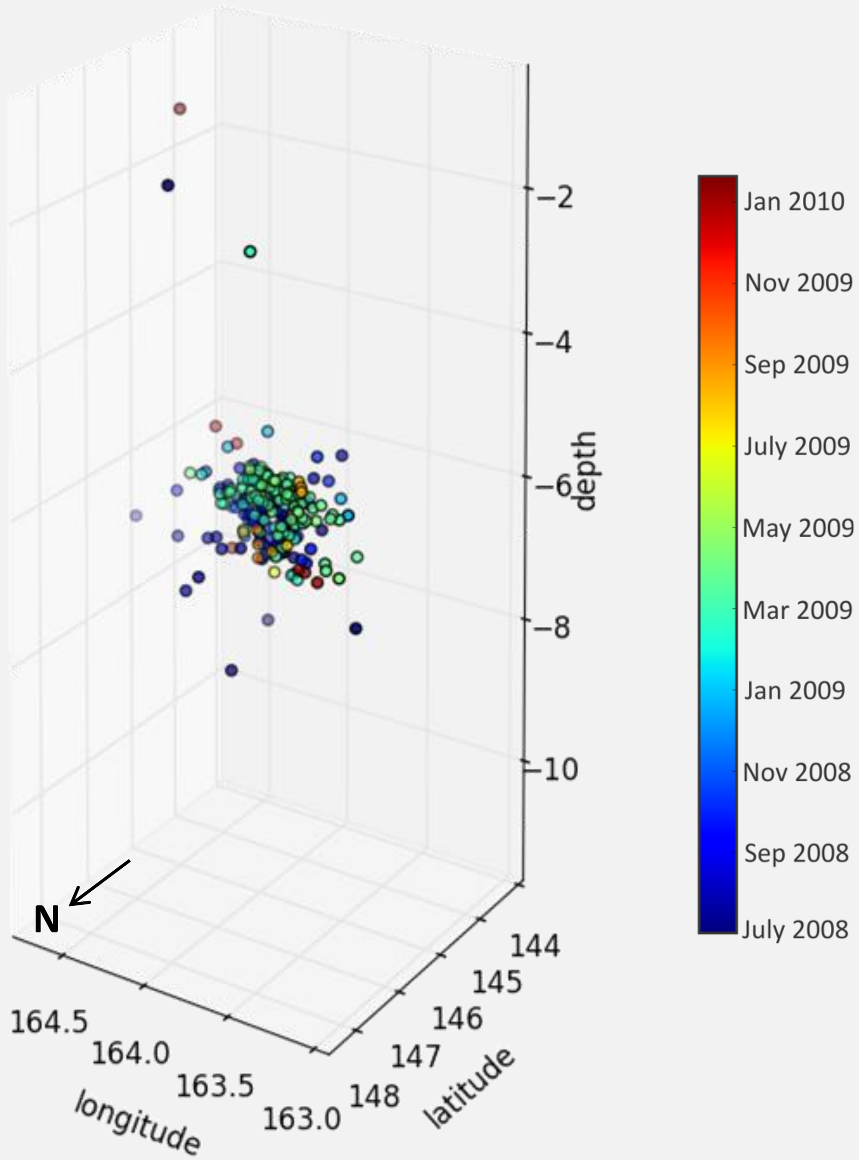


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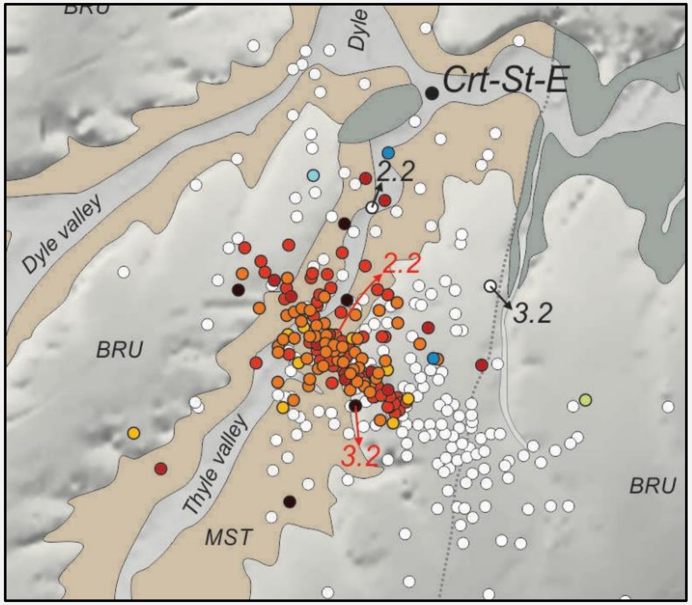


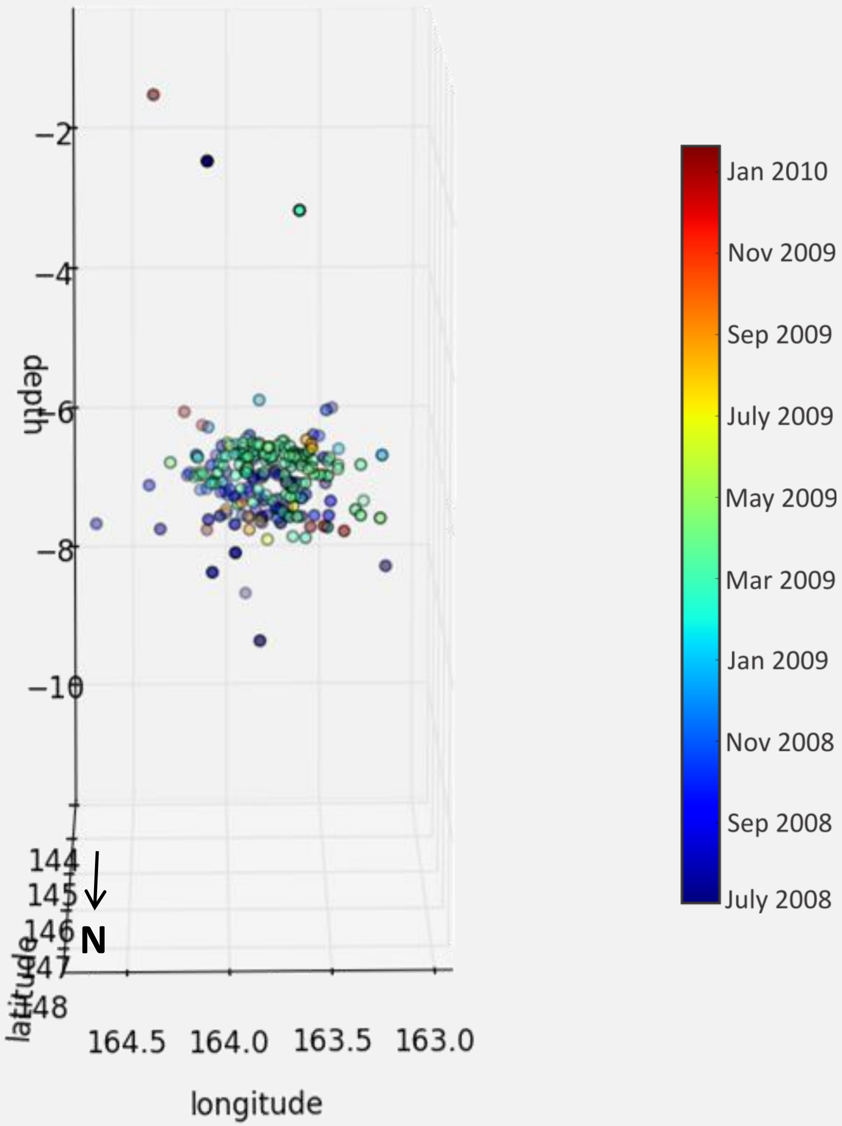


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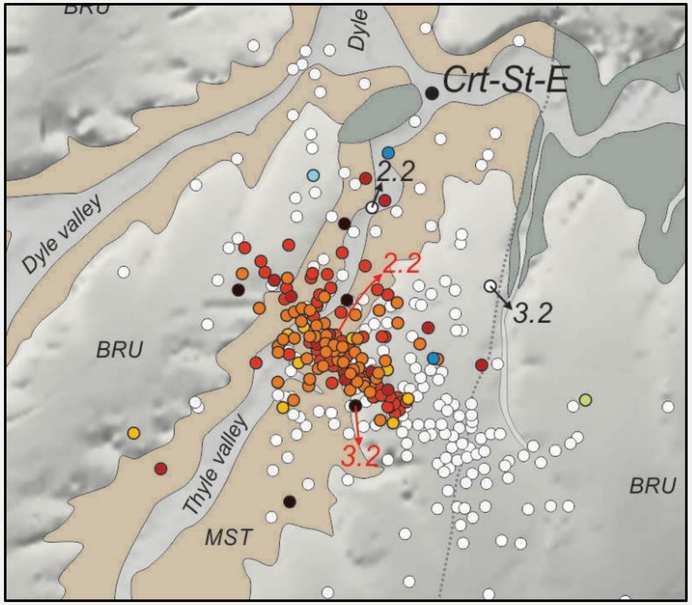


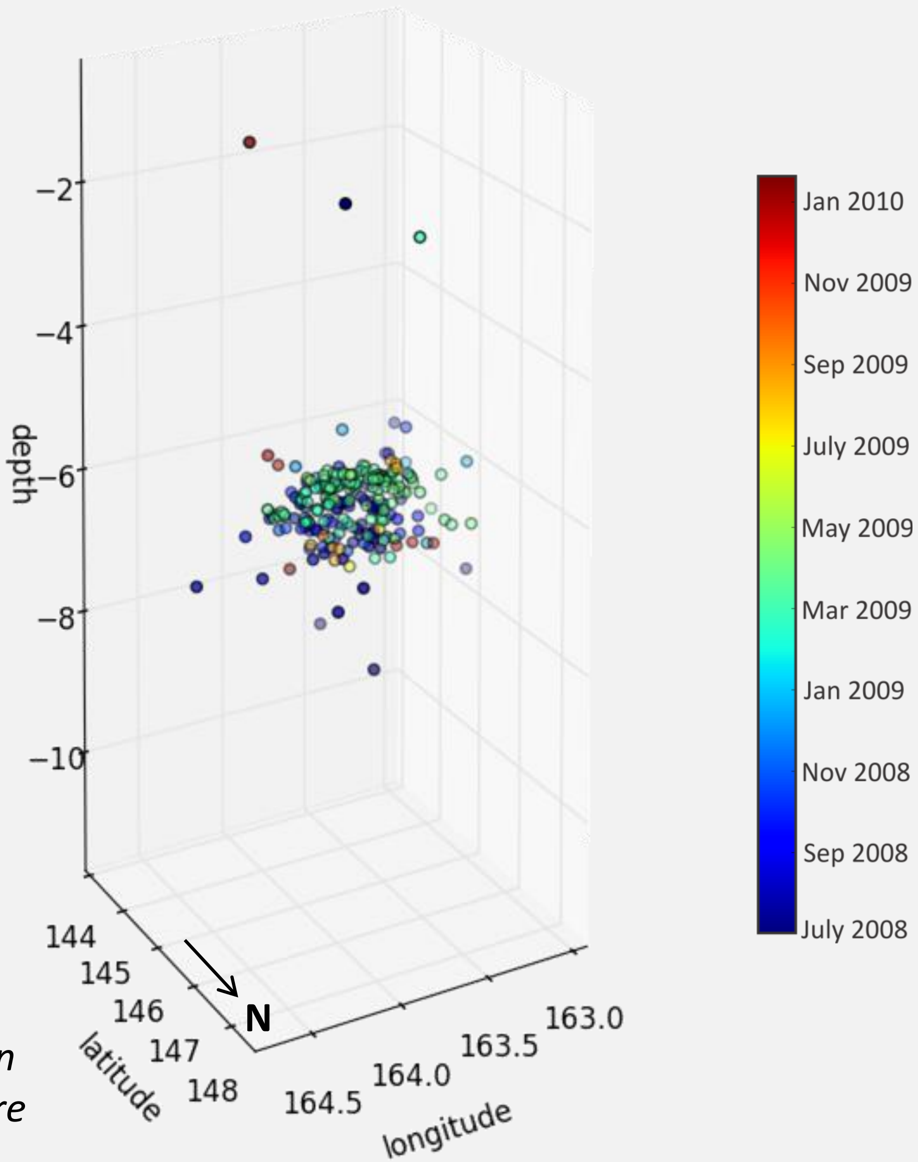


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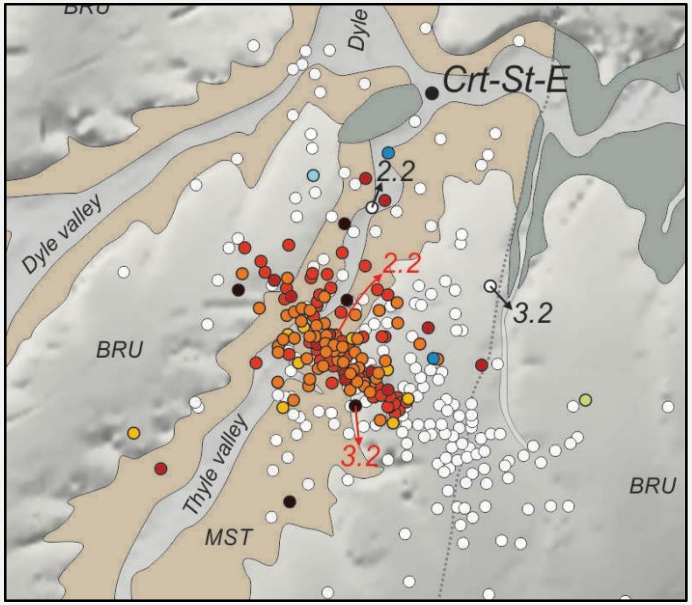


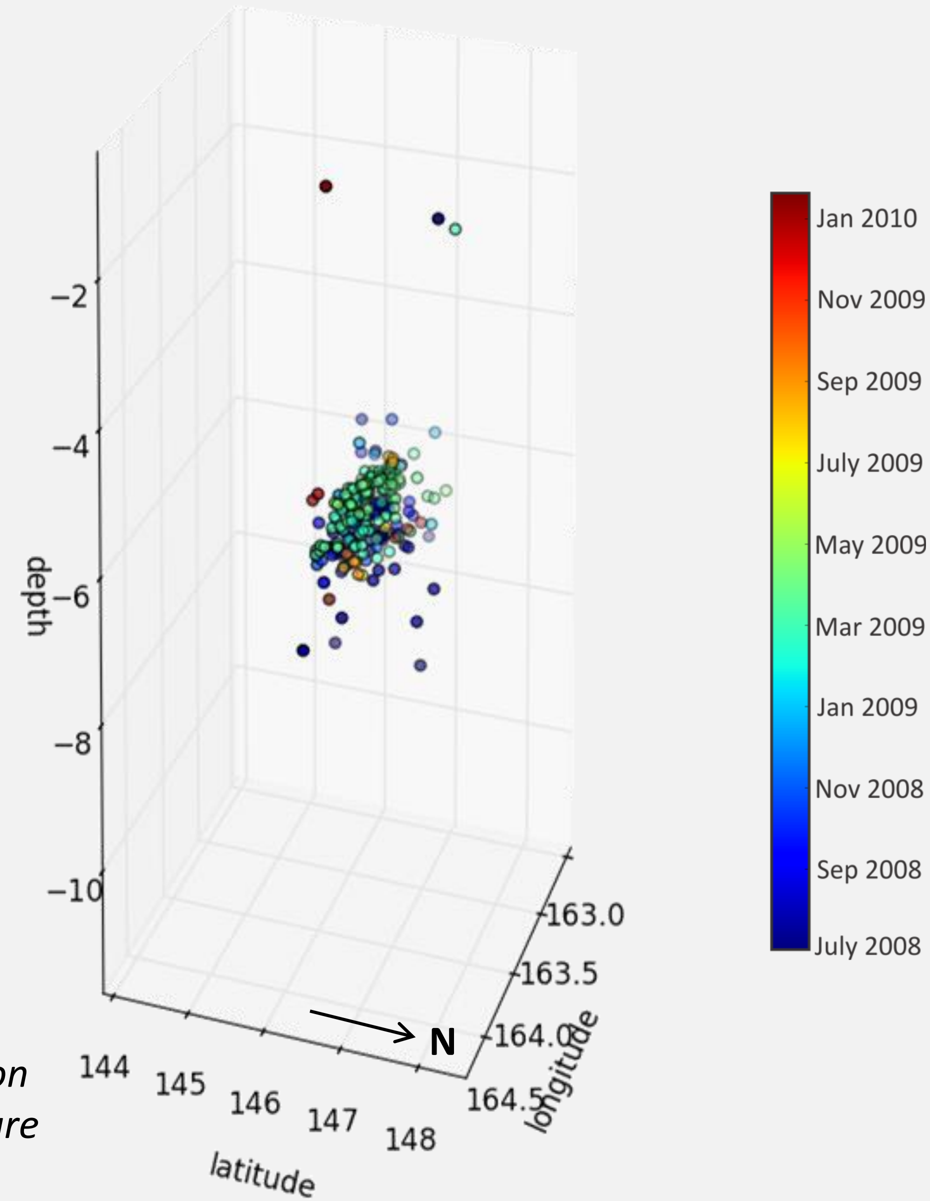


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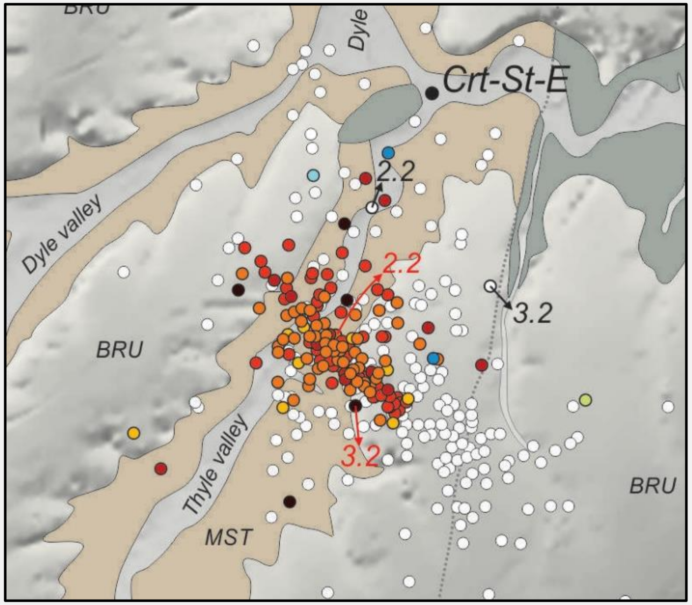
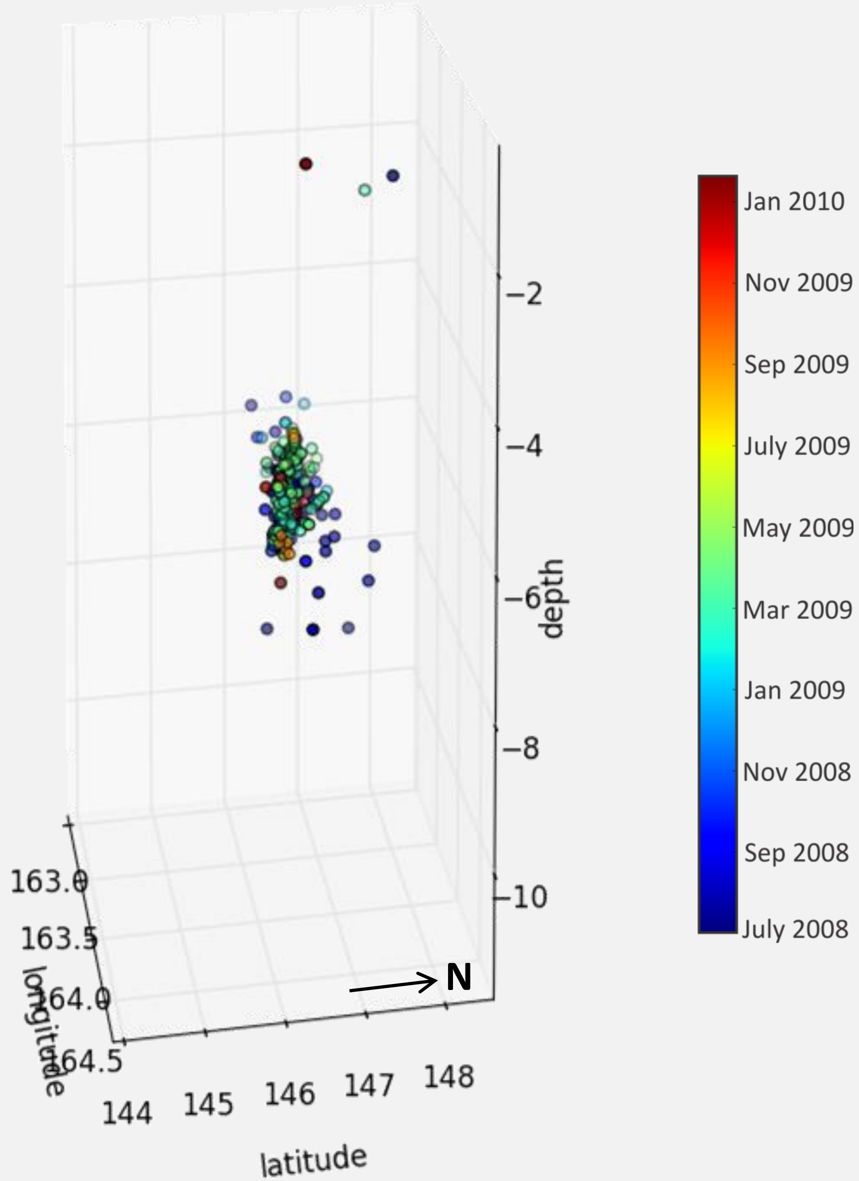
# Improved hypocentre distribution

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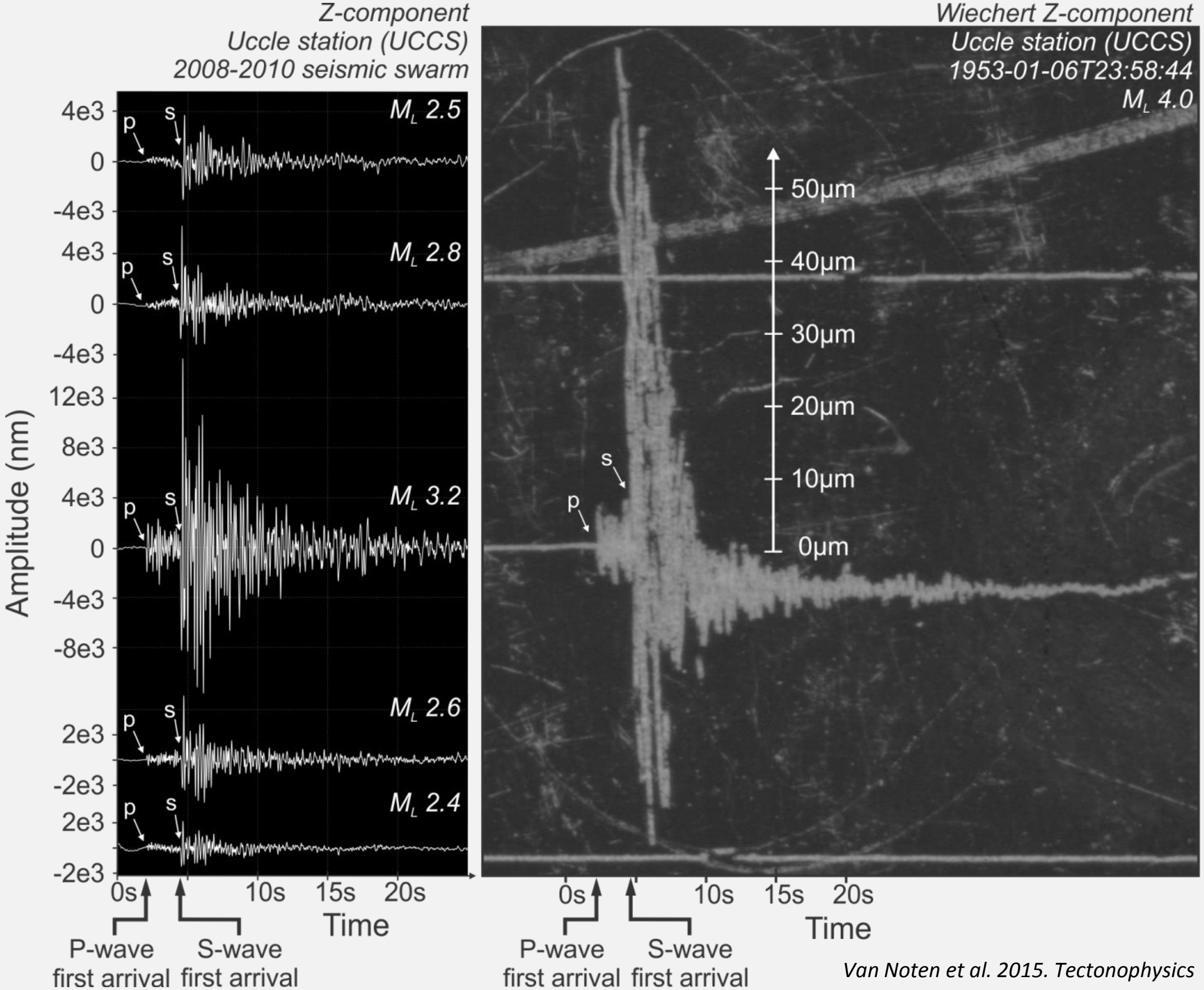
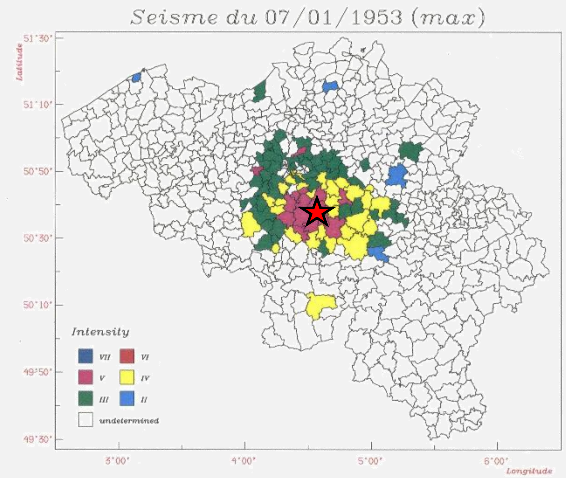
# Comparison of 1953 event with the 2008-2010 swarm

*Waveform comparison of the 2008-2010 swarm and a $M_L$ 4.0 event in epicenter area in 1953*

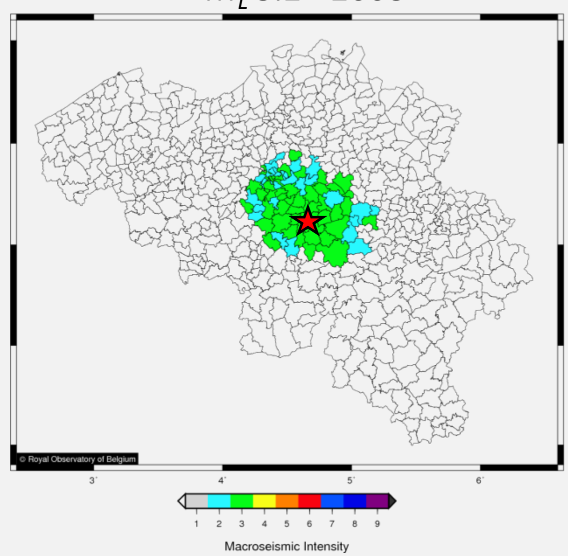



*Van Noten et al. 2015. Tectonophysics*

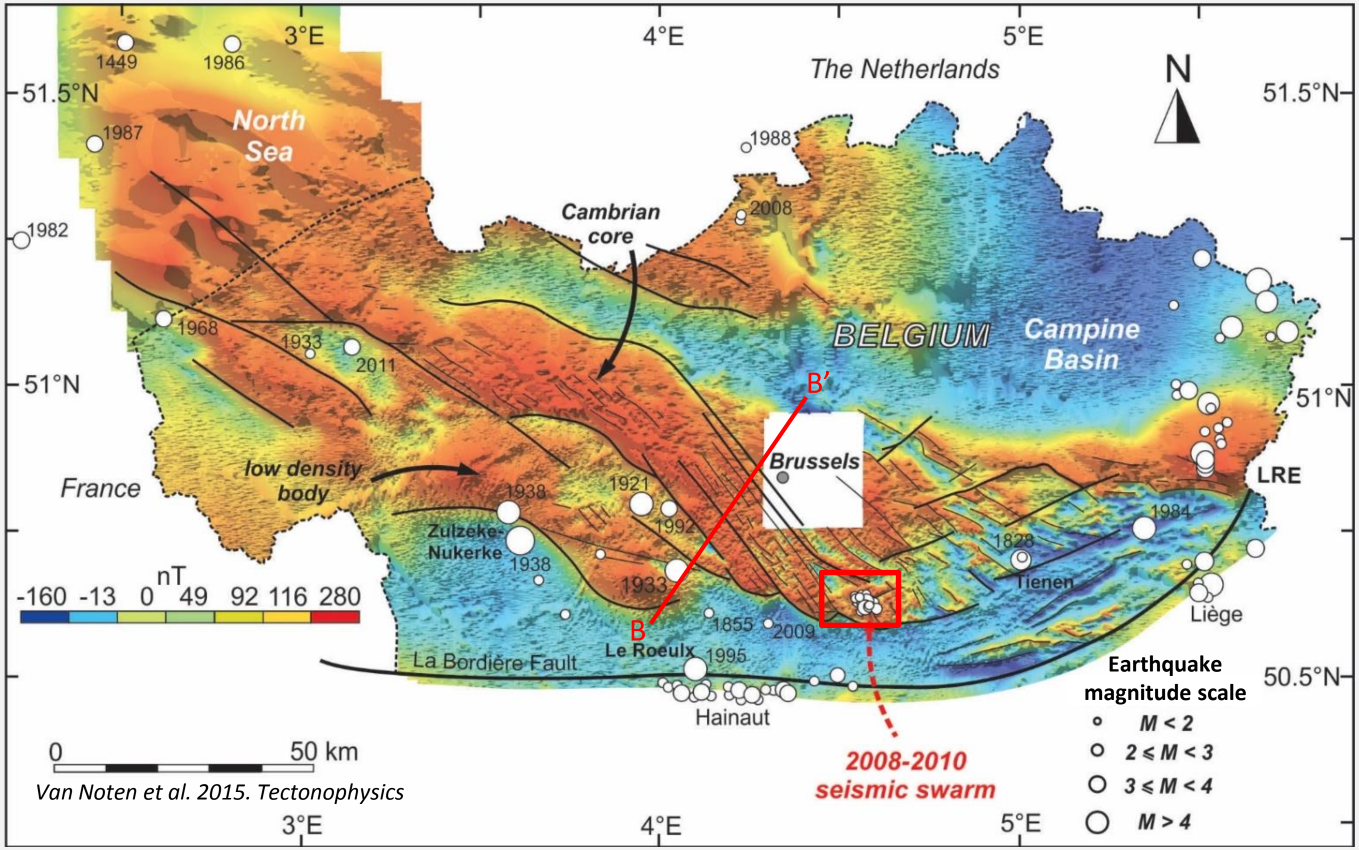
*$M_L$ 4.0 - 1953*



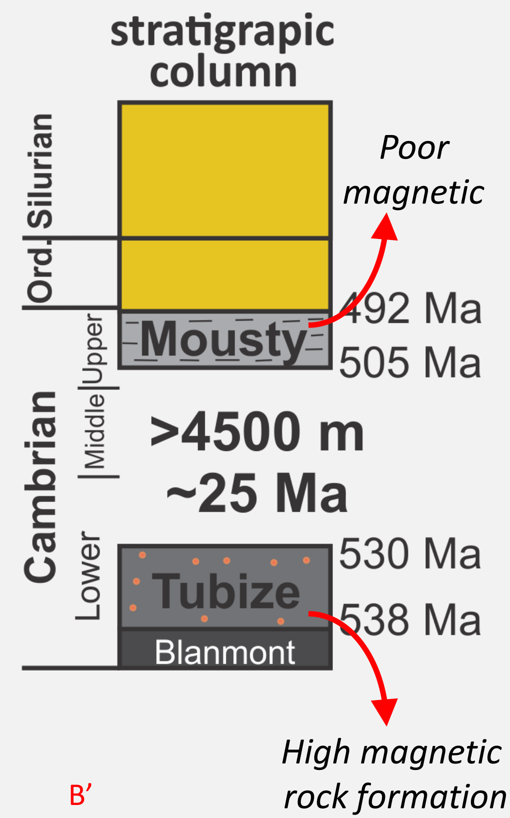

*$M_L$ 3.2 - 2008*



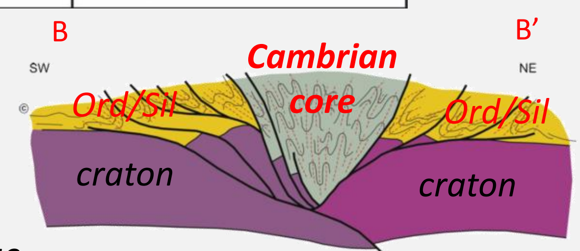
# Seismotectonic significance of the swarm ?




Aeromagnetic map of Belgium - Geological Survey 1994



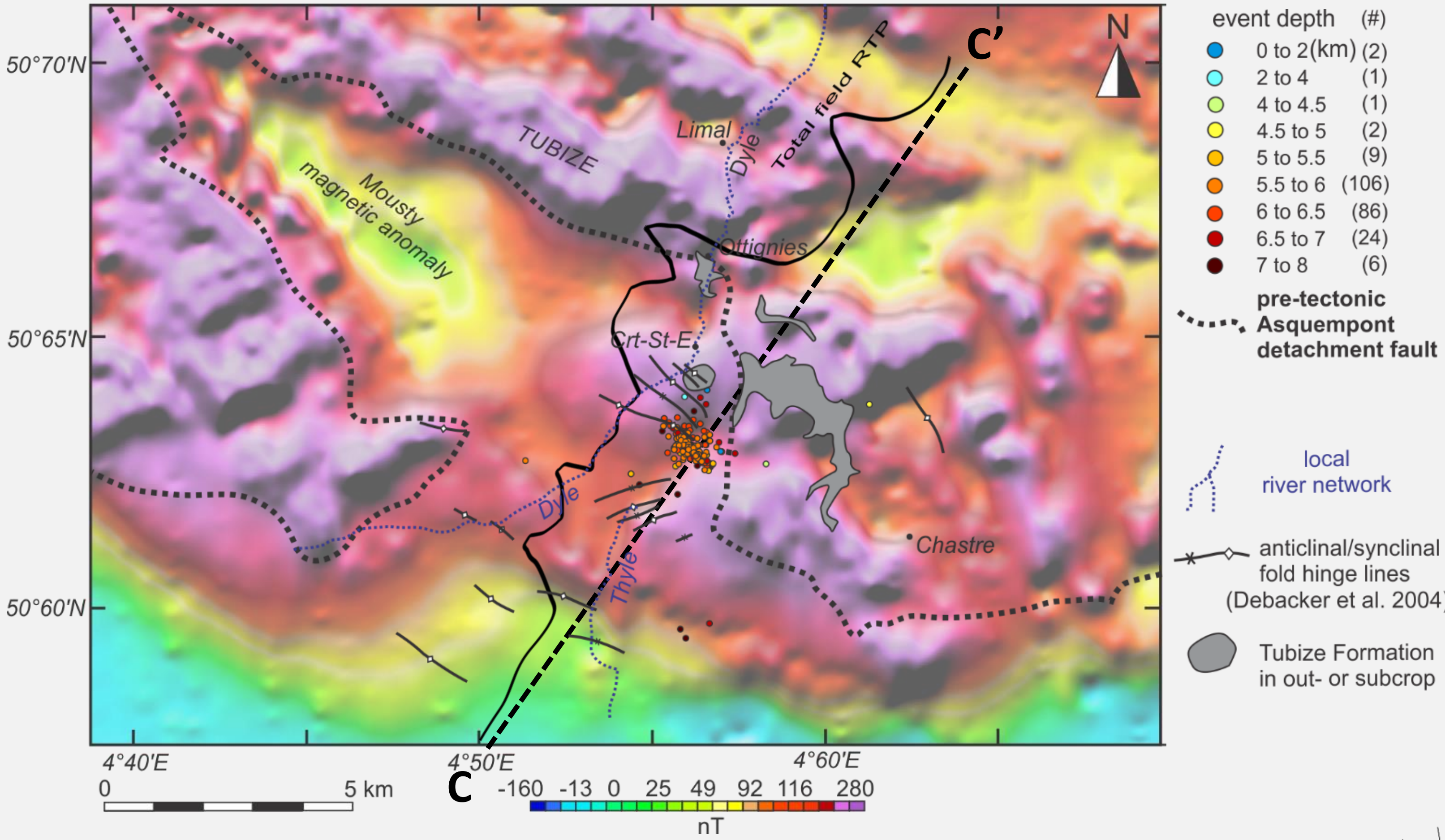

- *Arcuate shape of the Brabant Massif (BM)*
- *Pronounced NW-SE lineaments*
- *Low background seismicity in the BM, yet, few large $M_L > 4.5$ seismic events occurred in the BM*
- *2008-2010 seismic swarm at southern border*



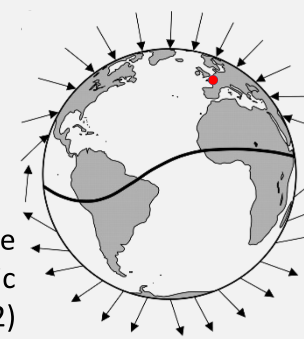

*Steep tectonic slate belt*

*Sintubin et al. 2009*
*Comptes Rendus Geoscience 341*

# Aeromagnetic analysis of epicenter area




- *Total magnetic field RTP = influence of shallow + deep sources (deep + shallow)*
- *Aeromagnetic highs due to magnetized Lower Cambrian Tubize Formation*
- *Magnetic lows = slaty Lower Cambrian Mousty Formation*

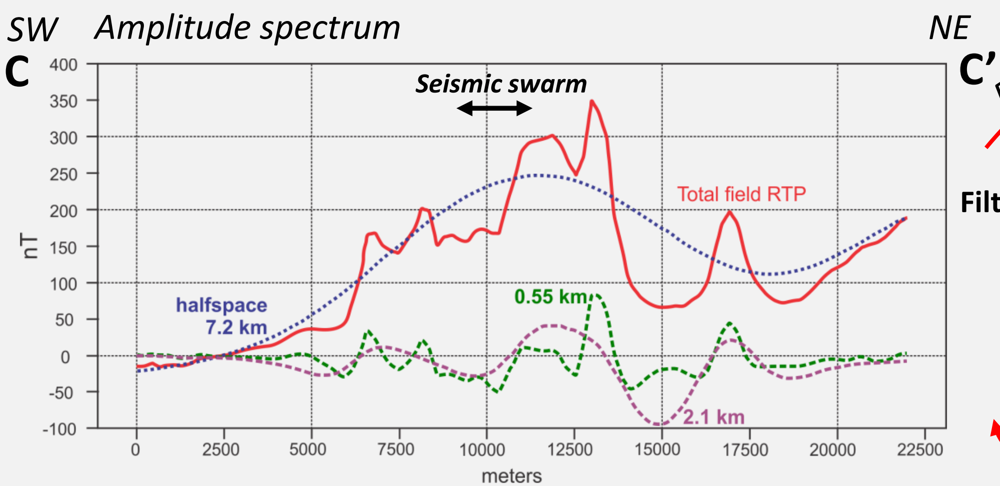


Total Field, reduced-to-pole
assuming Earth's local magnetic
field 1/1/1994 (I=65.8, D = -2)

# *Matched bandpass filtering: methodology*

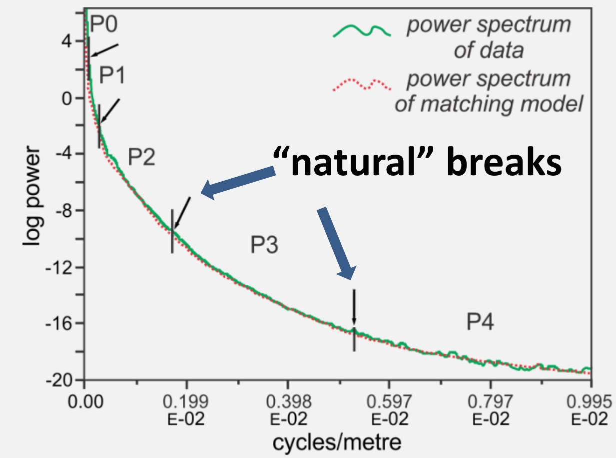
*Separating short-wavelength that originate from shallow depths from long-wavelength anomalies that generally originate at greater depths.*

*Jef Phillips 1997 (USGS)*

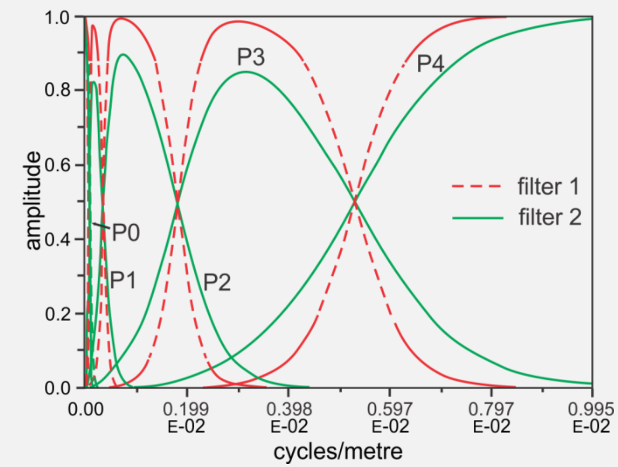



**Filter 1**

*Fourier analysis*




*Reverse Fourier analysis*




1. Amplitude spectra along a profile
2. Calculation of frequency-amplitude spectra
3. **Finding "natural" breaks that correspond to equivalent depths**
4. Calculation of anomaly map through the inverse transform

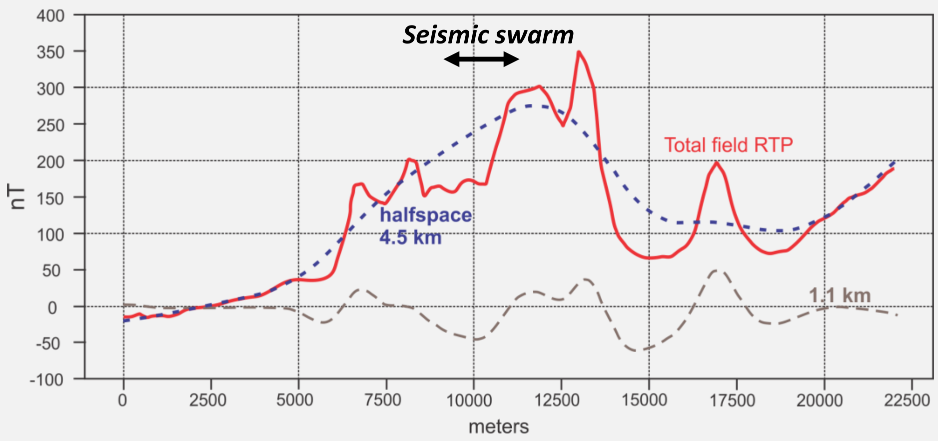
***= carefully chosen bandpass filter***

| | Filter 1 | Filter 2 |
|---|---|---|
| P4 | 0.05 km | 0.045 km |
| P3 | 0.20 km | 0.19 km |
| P2 | 0.55 km | 0.47 km |
| **P1** | **2.14 km** | **1.18 km** |
| **P0** | **7.27 km** | **4.55 km** |

*Separating short-wavelength that originate from shallow depths from long-wavelength anomalies that generally originate at greater depths.*

*Jef Phillips 1997 (USGS)*

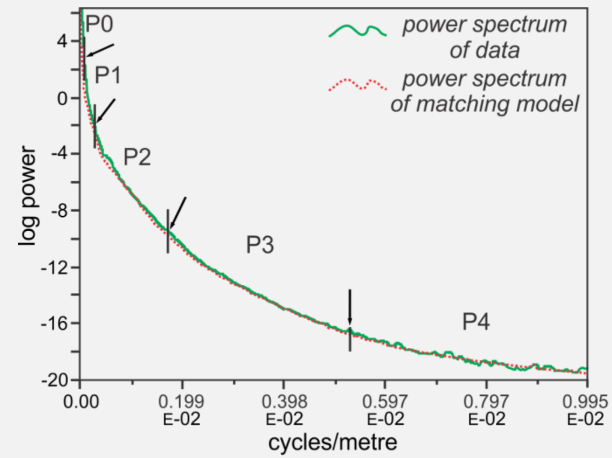
*SW* *Amplitude spectrum* *NE*

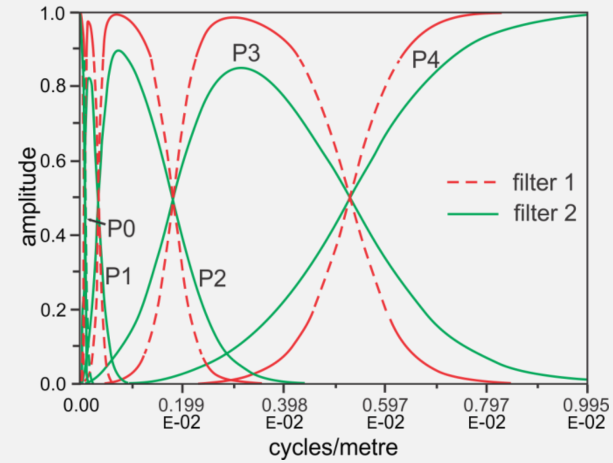



*Fourier analysis*

**Filter 2**

*Reverse Fourier analysis*

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**Useful for seismology?** Hell yeah!
Generate different aeromagnetic maps that represent sources near hypocenter depths.

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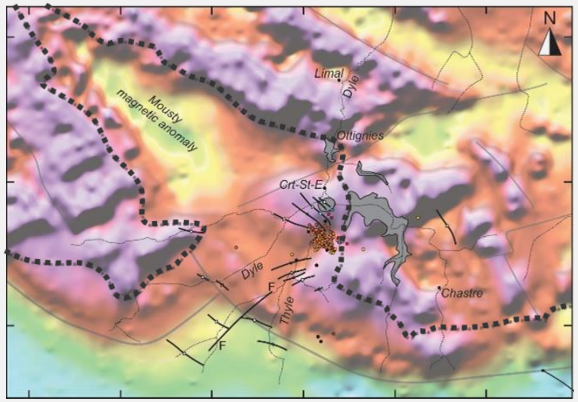
# *Aeromagnetic bandpass filtering applied to epicentre area*




*Total field – Reduced to the Pole*

LEGEND

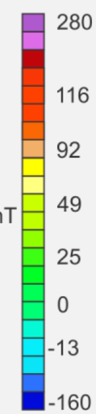
event depth (#)

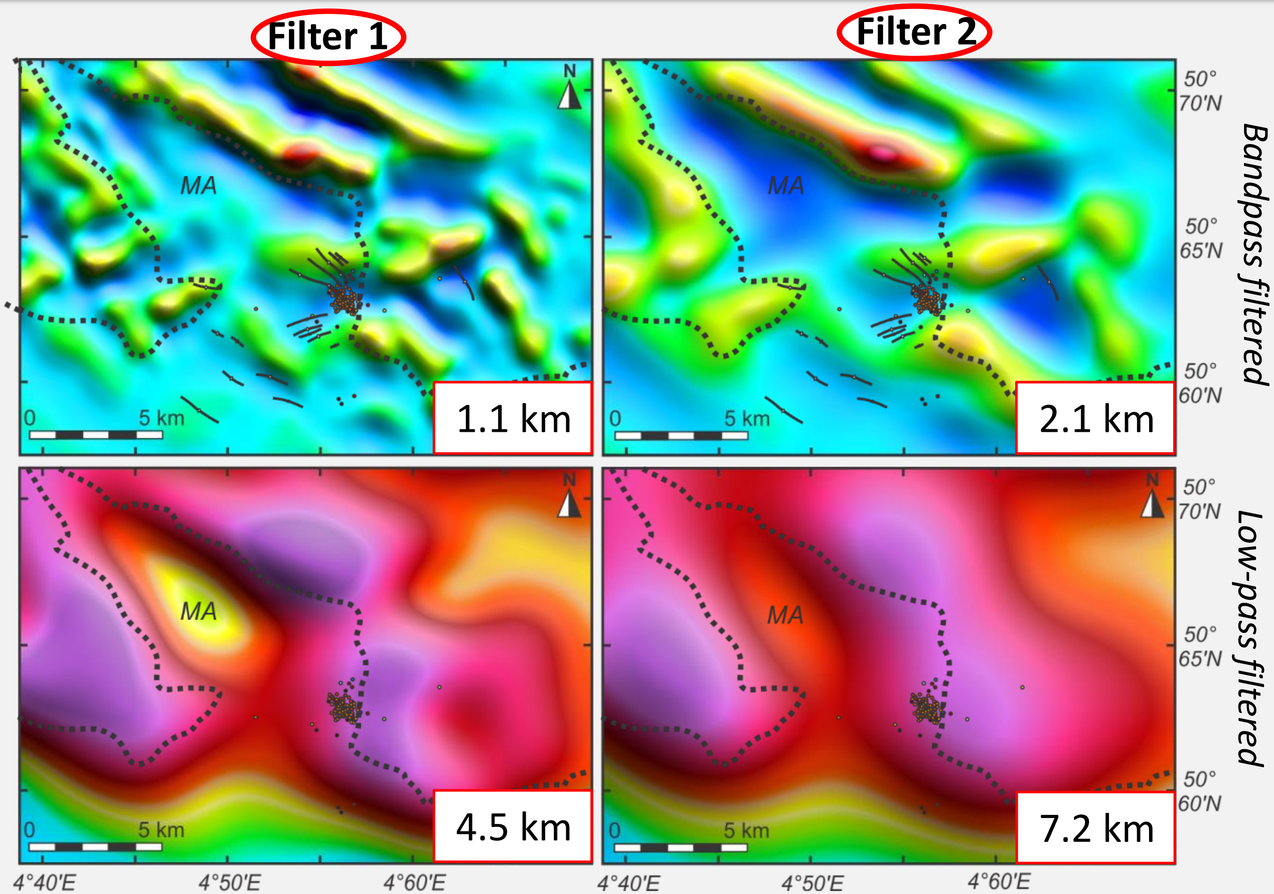
- 0 to 2(km) (2)
- 2 to 4 (1)
- 4 to 4.5 (1)
- 4.5 to 5 (2)
- 5 to 5.5 (9)
- 5.5 to 6 (106)
- 6 to 6.5 (86)
- 6.5 to 7 (24)
- 7 to 8 (6)

**Asquempont detachment fault**

anticlinal/synclinal superficial fold hinge lines

Tubize Formation in out- and subcrop




*Reduced to the Pole aeromagnetic filtered maps*

*By applying different filters, different "depth maps" can be made.*
*The seismic swarm is limited in size and located in the poorly magnetic shaly Mousty Formation.*

## Seismotectonic significance of the swarm ?

1. Magnetic filtering demonstrates that the fault is:
   - bordered by magnetic bodies with diff. orientations
   - bordered by rocks of different ‘stiffness’
   - limited in size

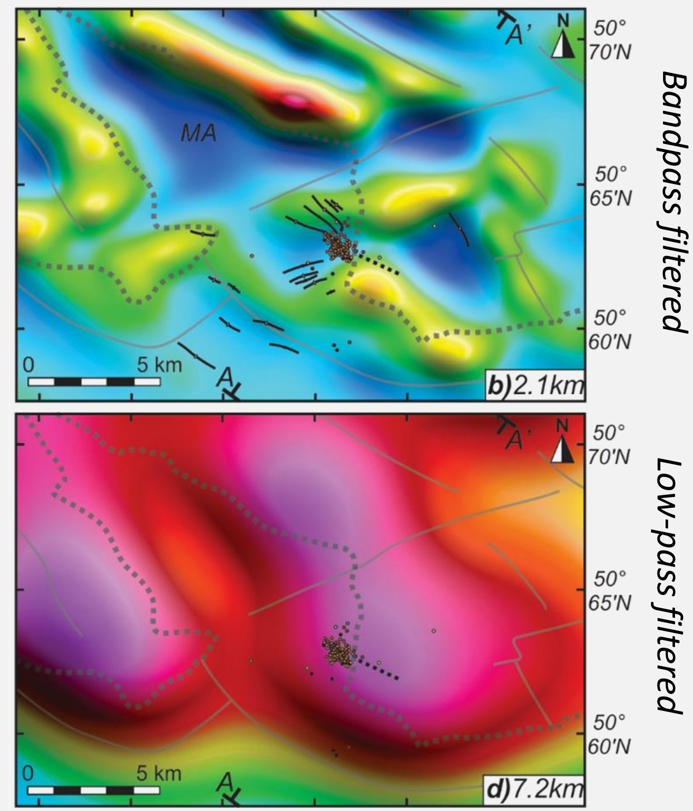
   = isolated structure in a shaly rock body

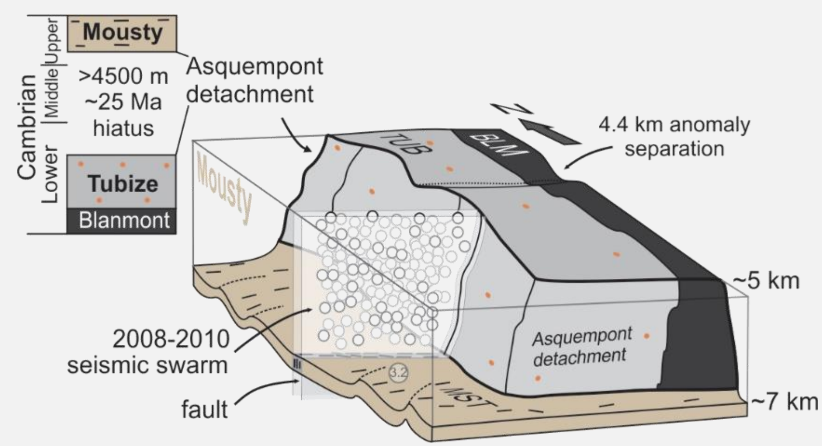
2. Limitation in size explains the restriction in seismicity

3. Orientation fits the NW-SE structural grain of the BM

4. This study shows the importance of inherited fault structures in an intraplate seismotectonic setting

5. Limited seismic hazard due to fault fragmentation





***References***

- ***Van Noten*** *et al.* ***2015.*** Seismotectonic significance of the 2008-2010 Walloon Brabant seismic swarm in the Brabant Massif. ***Tectonophysics***
- **Sintubin, M., 1999.** Arcuate fold and cleavage patterns in the southeastern part of the Anglo-Brabant fold Belt (Belgium): tectonic implications. *Tectonophysics* 309, 81-97.
- ***Debacker et al. 2004.*** The supposed thrust fault in the Dyle-Thyle outcrop area (southern Brabant Massif, Belgium) re-interpreted as a folded low-angle extensional detachment. *Geologica Belgica* 8, 53-69.