WEBNET network - a primary tool for understanding of the West Bohemia/Vogtland earthquake swarms.

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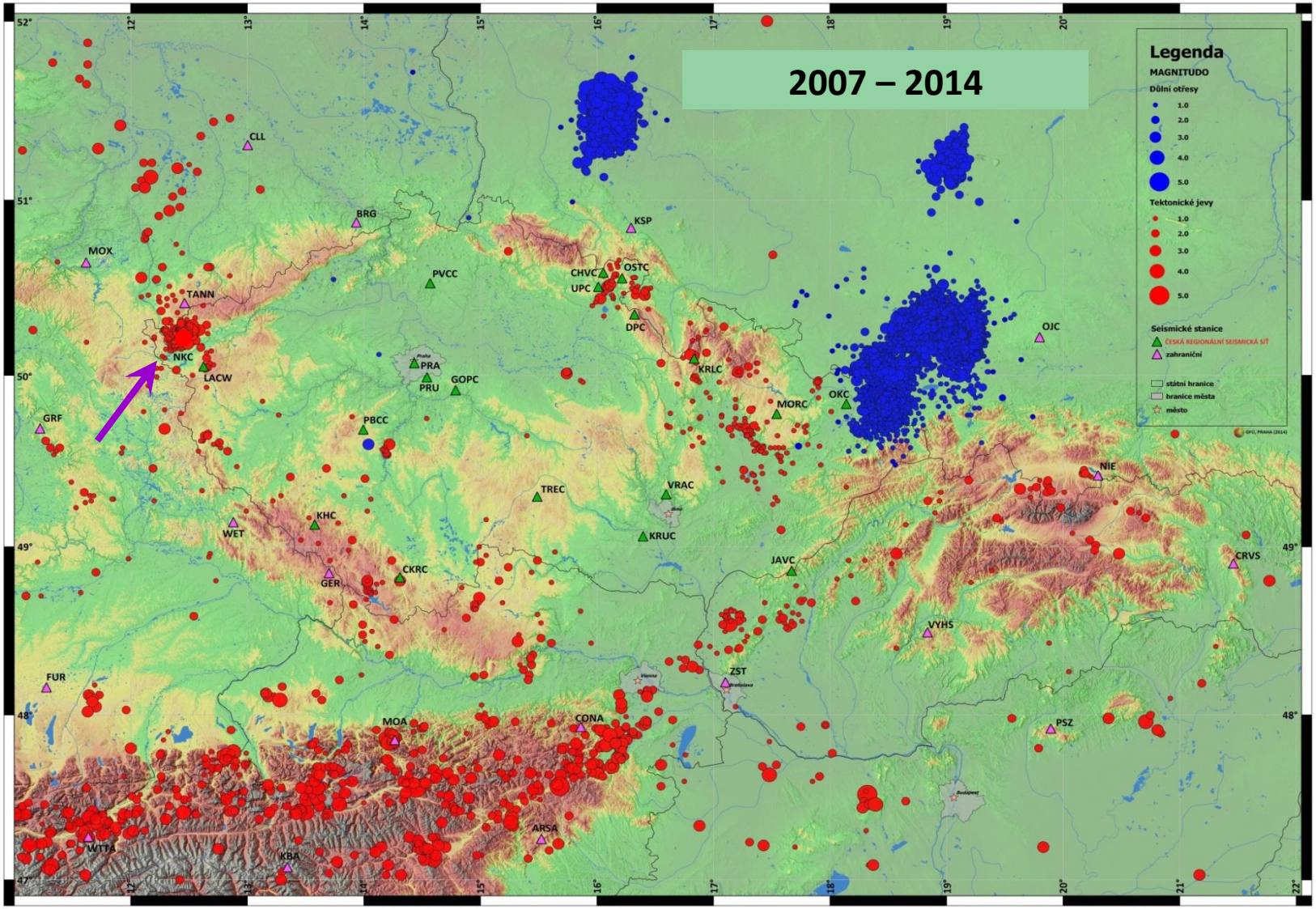
Tectonic and induce seismicity on the territory of the Czech Republic and the near vicinity



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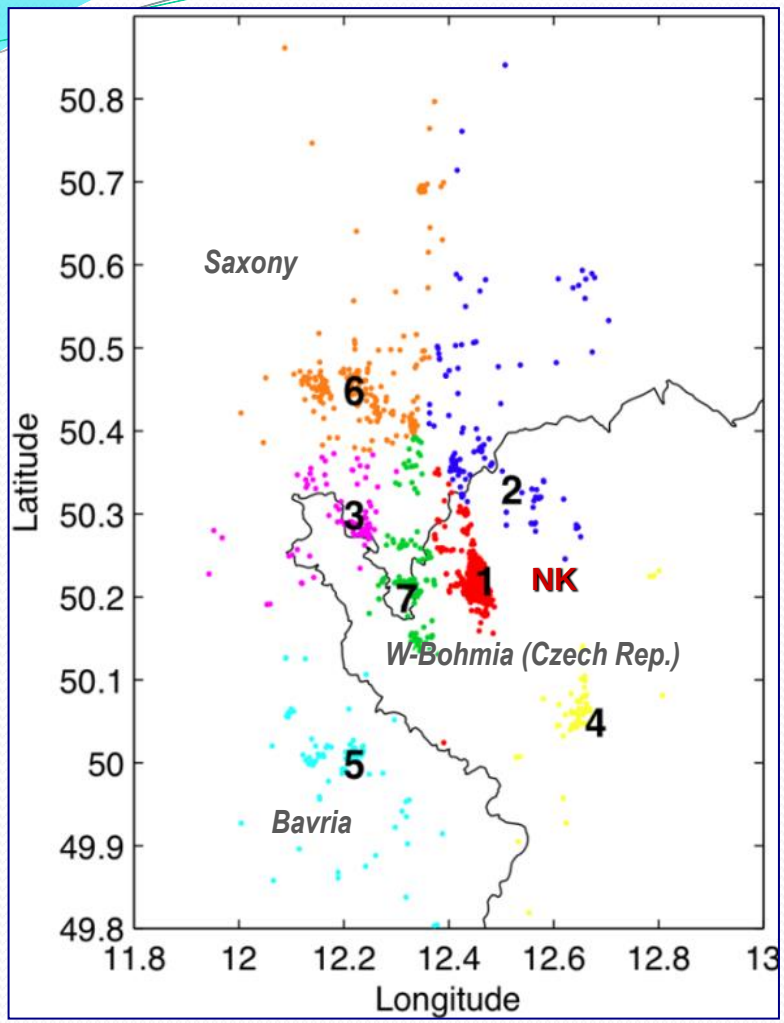
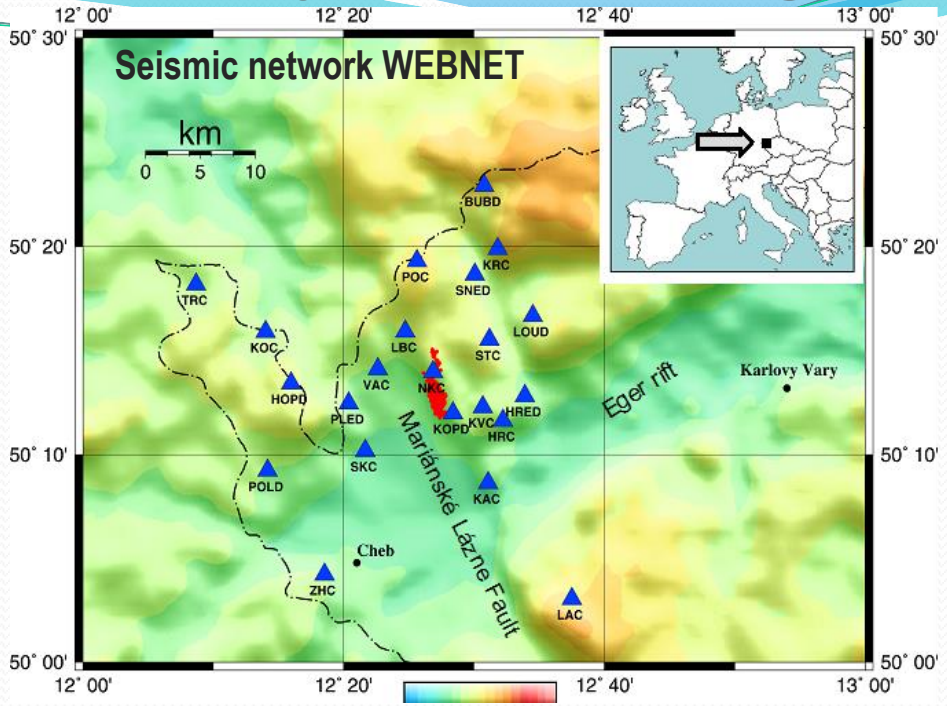
West Bohemia/Vogtland earthquake-swarm region





Basic characteristics:

- Intersection of Eger rift and Mariánské Lázně fault
- Quaternary volcanism
- Frequent occurrence of $M_L < 4.0$ intraplate earthquake swarms
- Seismicity concentrated in a few epicentral areas
- About 95 % of the total seismic-moment released in the **NK zone** ⇒ focal belt 10 x 7 km

- The region has been monitored by network WEBNET since 1991

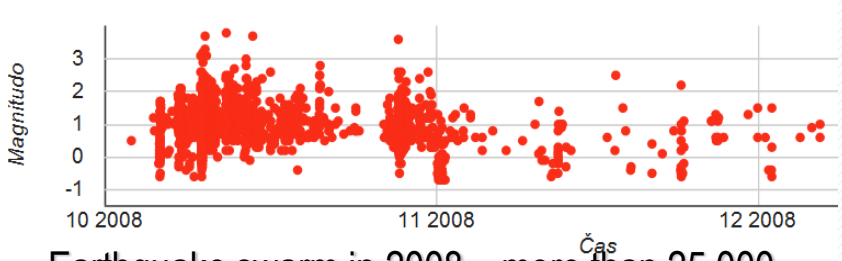
Area of about 3 500 km^2

What are earthquake swarms?

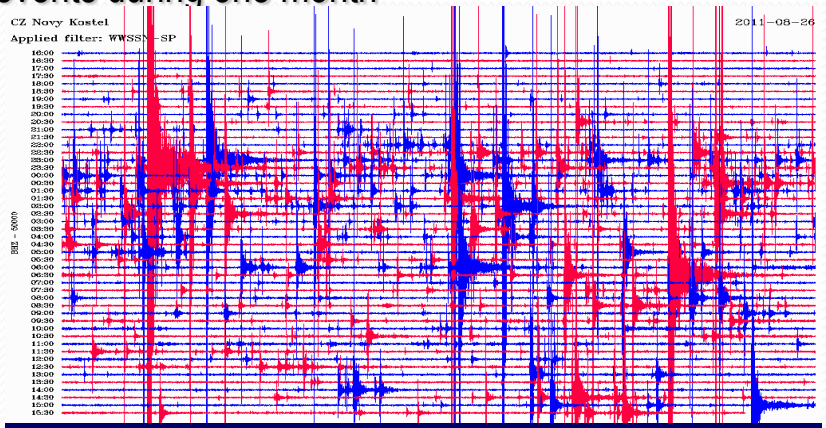
Specific type of seismicity - accumulated strength energy on the fault releases step by step in series of huge amount of weaker earthquakes, usually several dominant events have similar magnitude. Events closely clustered in space and time.

Ordinary earthquakes – one dominant event (mainshock) followed by a number of aftershocks with magnitudes usually of one or more magnitude units lower than the mainshock (called *mainshock-aftershock sequence*).

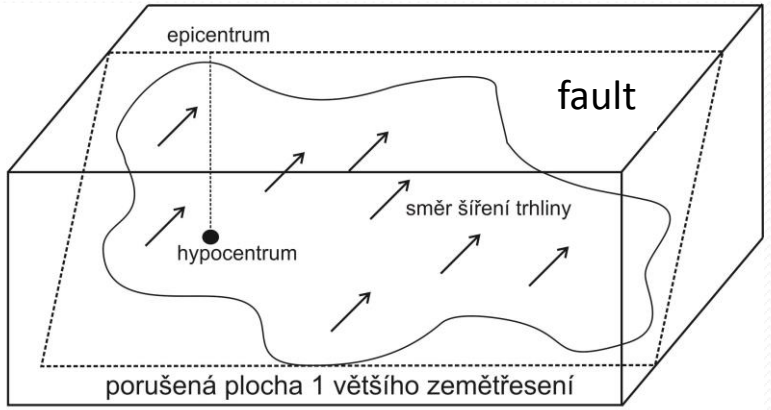
The origin of earthquake swarms still unclear

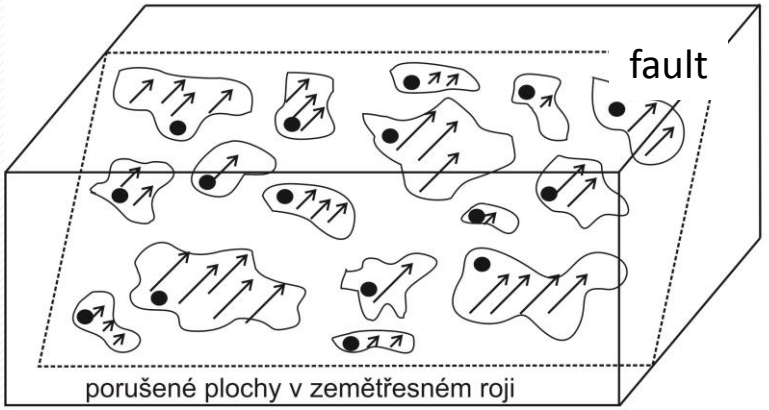


Earthquake swarm in 2008 – more than 25 000 events during one month



Earthquake swarms, example of August 26 2011





Where do earthquake swarms occur and what magnitudes do they reach?

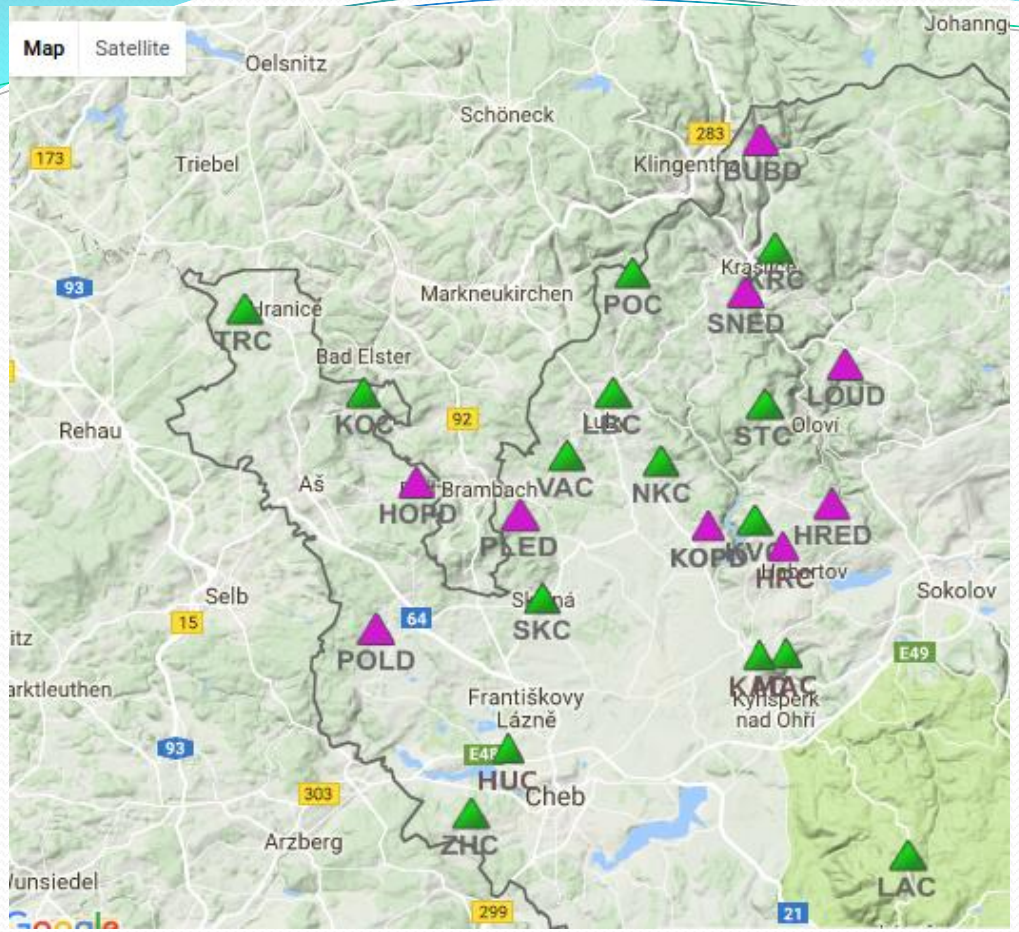
They occur worldwide at boundaries of the tectonic plates (interplate) as well as within the plates (intraplate) and are very often related to the volcanic areas, geothermal fields, and ocean ridges.

Examples: Japan, Yellowstone USA, New Zealand, Iceland, Hawaiian Island, Greece, Italy, ….. **West Bohemia/Vogtland**

On the global scale the strongest swarm earthquakes reach magnitudes up to M_L 6.0,

The West Bohema/Vogtland earthquakes **haven't exceeded magnitude M_L 5.0**

Seismic network WEBNET



▲ BB networked stations

▲ SP autonomous stations

Area covered by stations ≈ 900 km^2

Basic parameters of WEBNET:

- 14 BB networked stations (connected to Internet)
  upgraded in 2015, before that 13 SP networked stations

  9 SP autonomous stations (data recorded on the SD cards)

- records proportional to the ground velocity

- frequency band:
  0.03-80 Hz for the BB stations
  1.0-80 Hz for the SP stations

- sampling rate: 250 Hz.

WEBNET - instrumentation and data

BB stations:

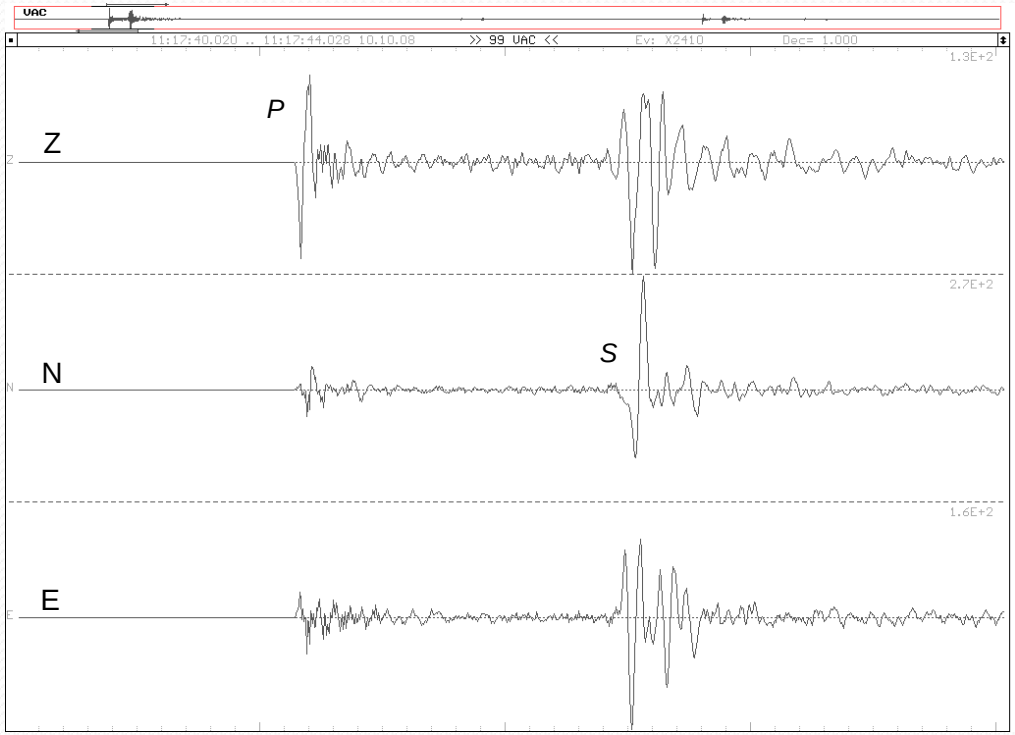
Sensors: Güralp CMG3-ESP, T_0 = 30s, f_{LP} =100 Hz
before upgrade: SM-3 (passive), T_0 = 2s, f_{LP} =100 Hz
Data acquisition systems: Centaur by Nanometrics
Connected to Internet by WaveLan and/or satellite telemetry

SP stations:

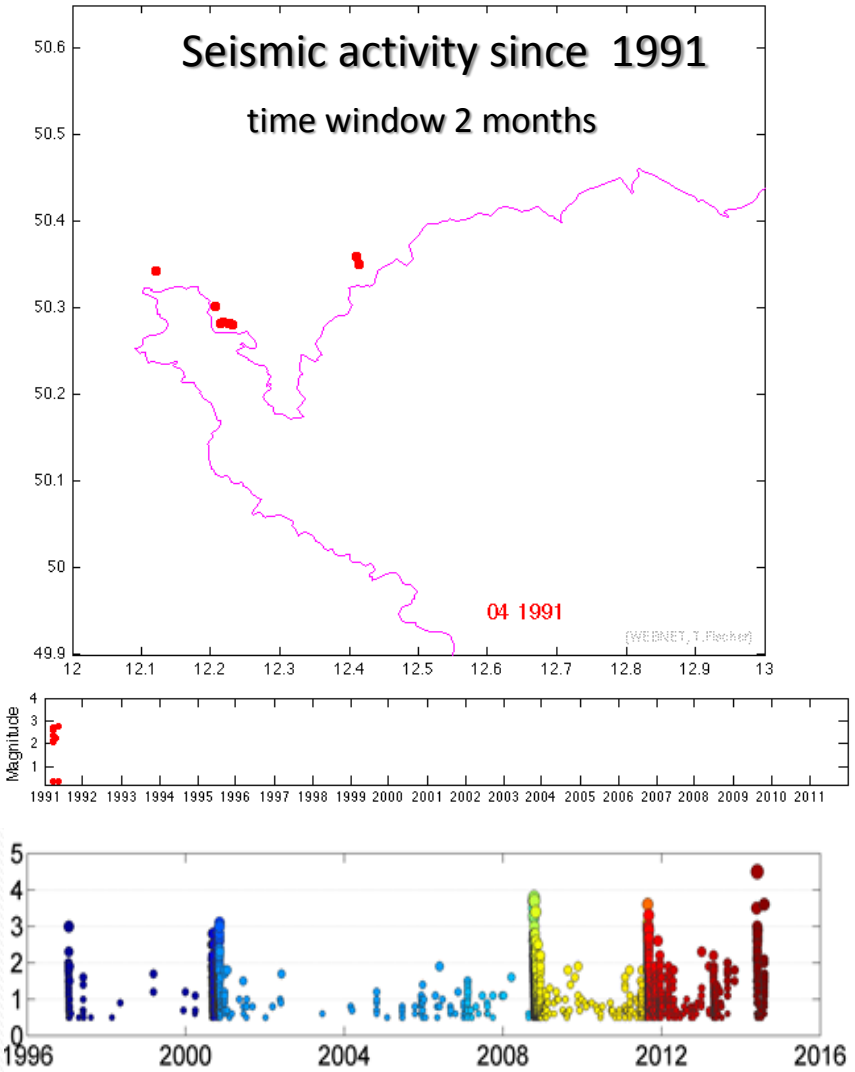
Sensors: Lennartz LE3-D, T_0 = 1s, f_{LP} = 80 Hz,
Data acquisition systems: Gaia II, by Vistec (domestic provenience)
Recording media: SD cards
data downloaded once in 2 months or if needed
All the stations operated in continuous mode

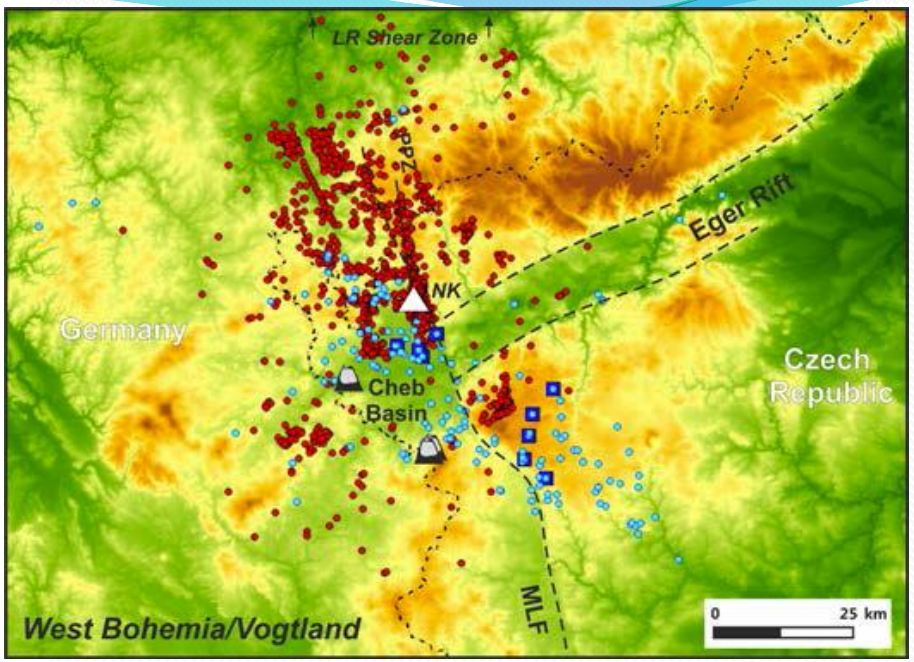
Data format: miniSEED
Data stored on data server SILO,
Date access: catalogs available on Internet
seismograms on request.

WEBNET stations and typical seismogram



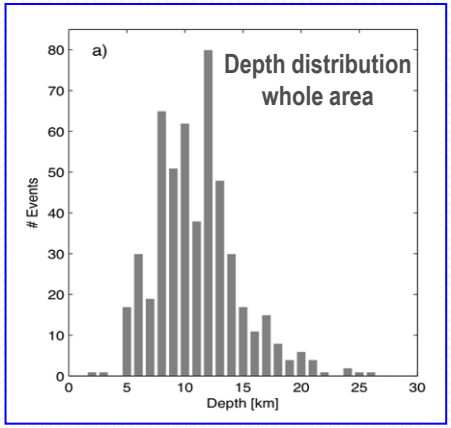
Swarm-like seismicity in West Bohemia/Vogtland

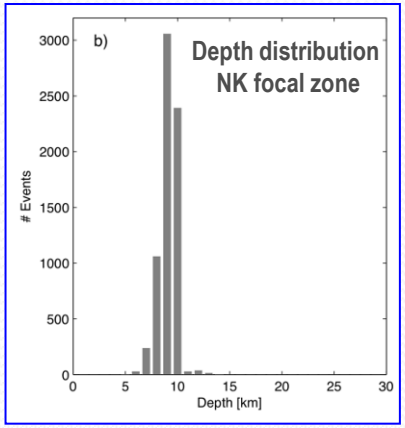




Development of the $M_L \geq 0.5$ earthquakes and their size (magnitude) in time.
Most of them occurred in the Novy Kostel focal zone (NK)

Depths of hypocentres





5 - 22 km in the whole area

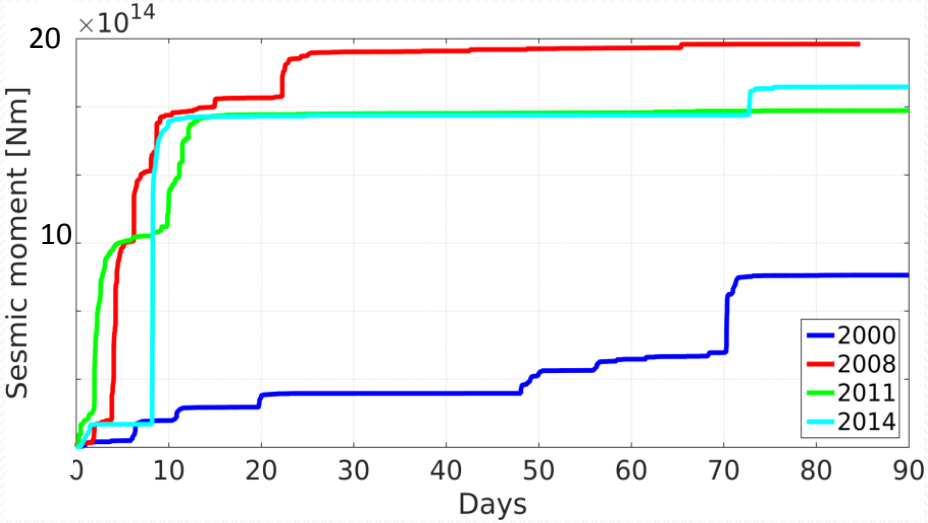
6 - 13 km in the NK zone

Characterization of significant West Bohemia seismicity

	Duration [days]	*Total number of ev.*	*Number of located ev. (NLLoc)*	*Characteristics*	ML_{max}
1985/86	70	8000 M_L>0.5	-	swarm	4.6
1997	20	1 800	1 150	swarm	3.0
2000	125	25 000	3 170	swarm	3.2
2008	70	25 000	3 880	swarm	3.8
2011	120	> 25 000	4 160	swarm	3.7
2013	20	1 500	250	mini-swarm	2.5
2014	14	4 000	1 250	3 mainshock-aftershocks sequences	3.5 4.4 3.6
2017	20	6 000	1500	swarm	3.1
background: 1997-2017	-	8 500	6 200		2.0

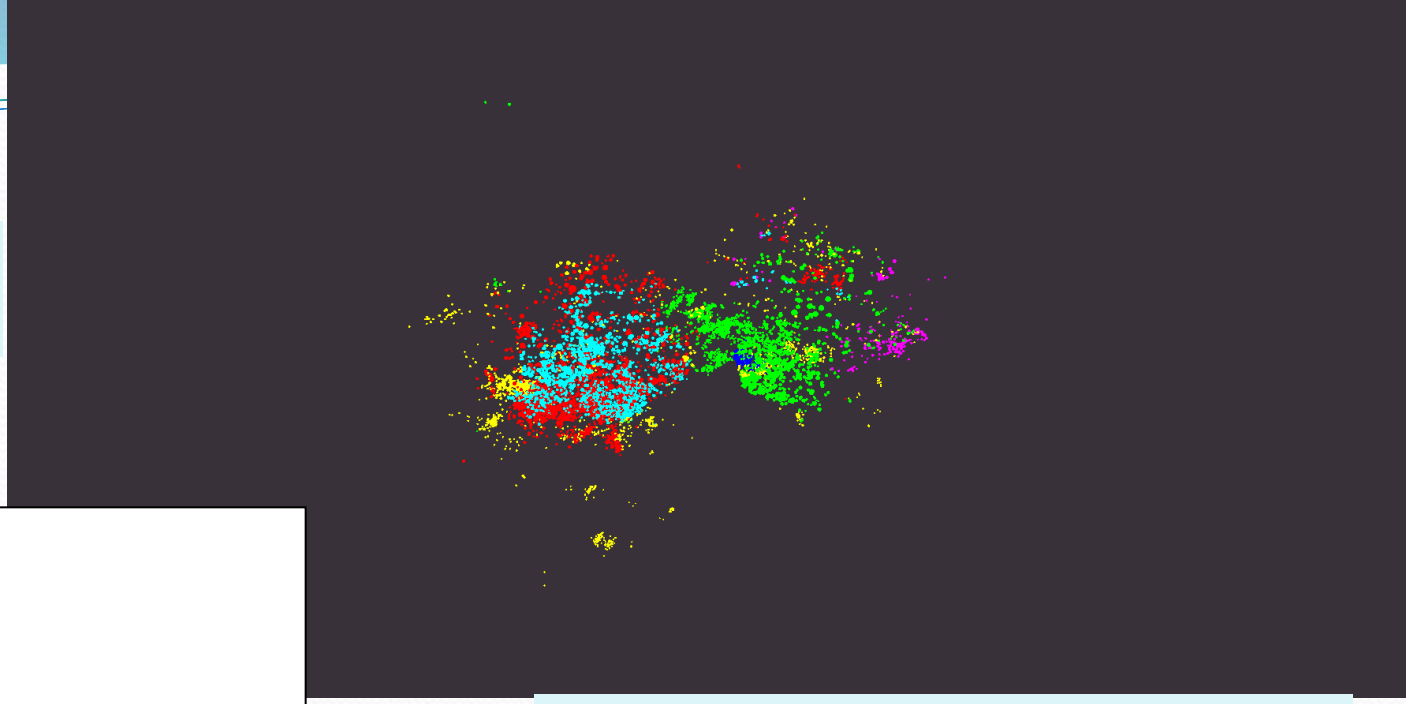
Seismic moment released

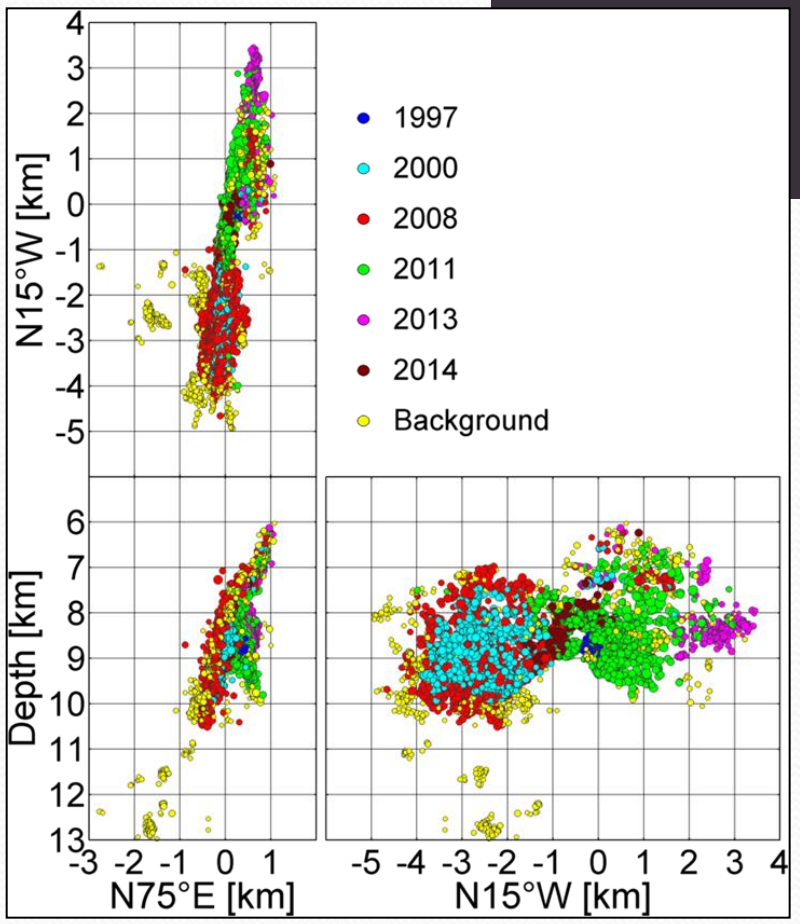
Seismic moment *Mo* - a measure of the earthquake size that combines the area of the rupture *A*, the average slip along the fault *D*, and the shear modulus *μ* (measure of the strength of the rock near the fault) : $M_o = \mu * A * D$ [Nm]



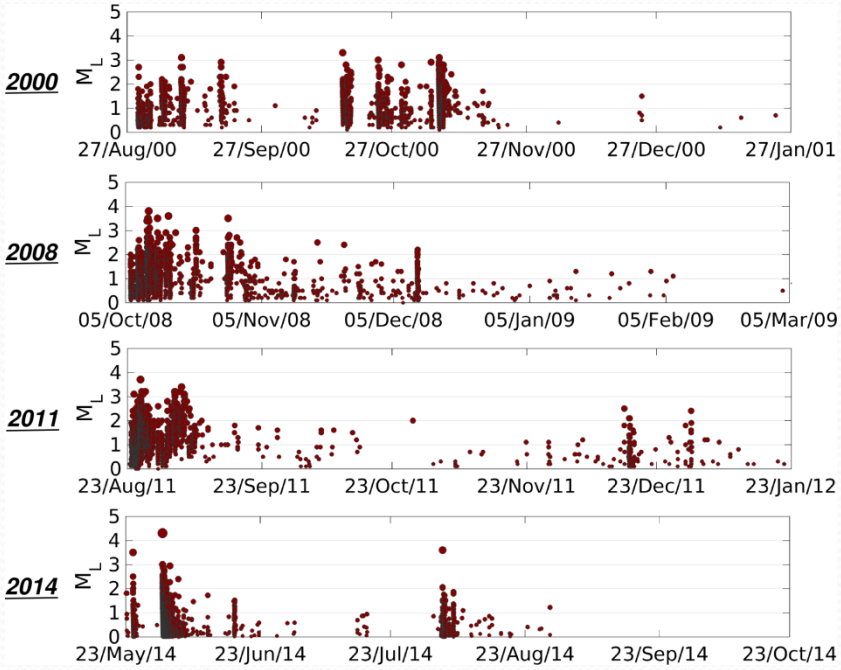
- similar total seismic moment *Mot ≈1.5 – 2.0 x 10^15* M·m (corresponding to a single *ML* ≈ 4.6+ event) in the 2008 and 2001 swarms, and in the 2014 mainshock-aftershock sequence
- but different style of the moment release ⇒ different maximum ground motions (a_{max} = *0.65* [*m/s²*] for the 2008 swarm and a_{max} = *2.25* [*m/s²*] for the 2014 mainshock-aftershock sequence).

Spatial distribution of the swarms

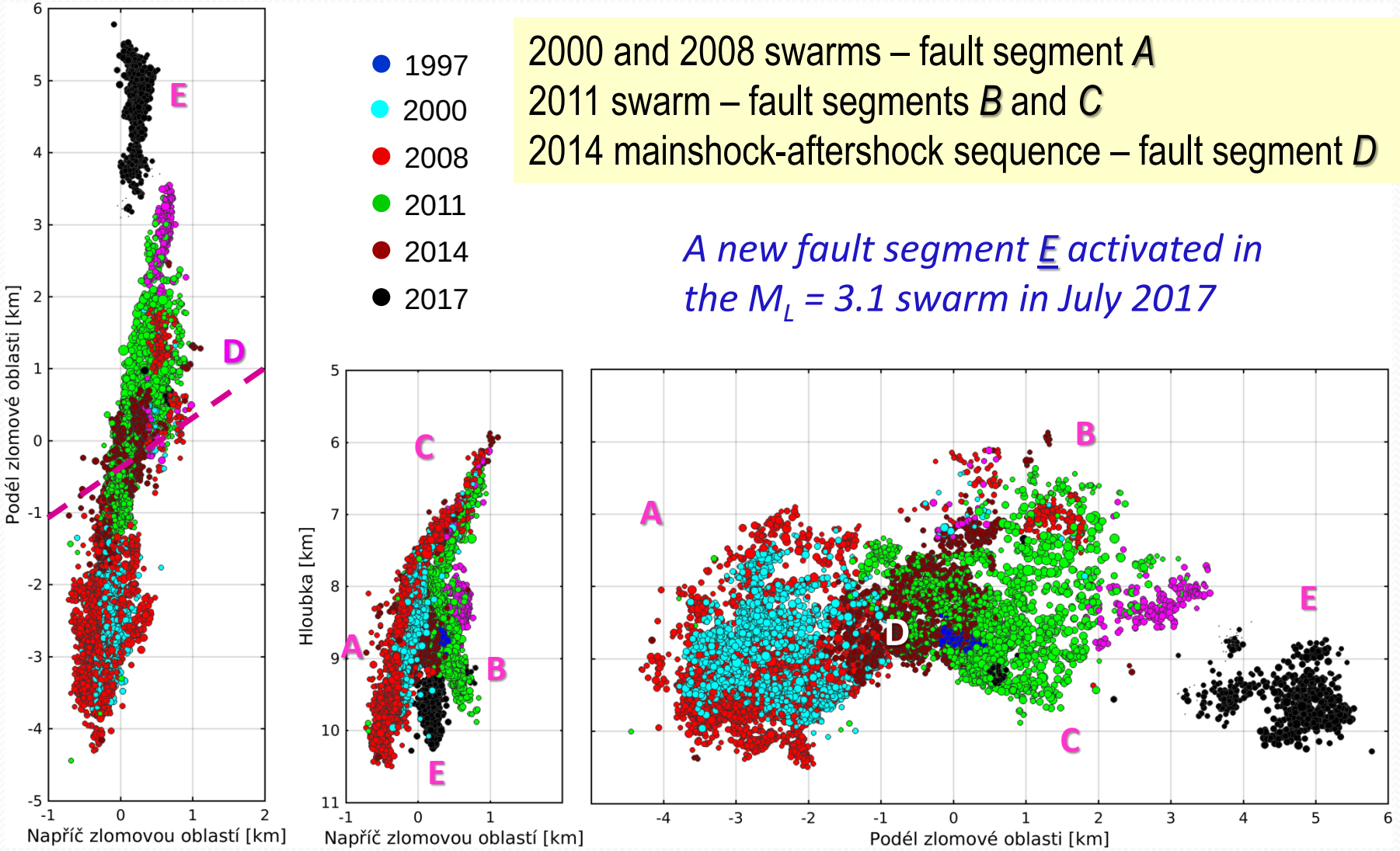




Temporal development of the swarms



Spatial distribution of earthquake swarms in the main focal zone NK

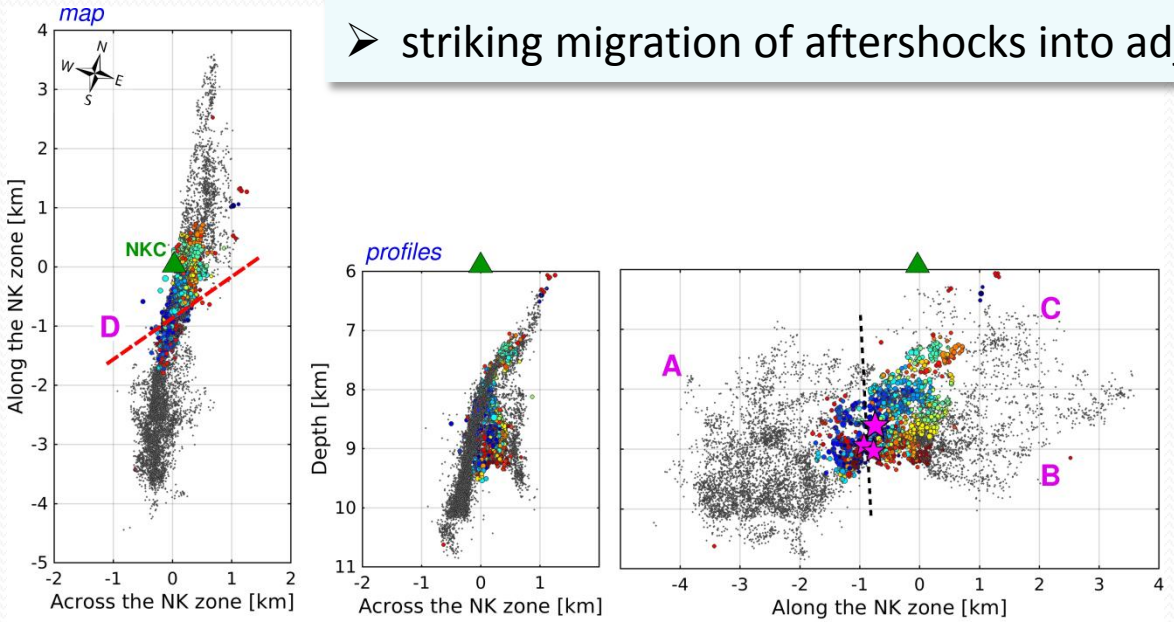


2000 and 2008 swarms – fault segment *A*
2011 swarm – fault segments *B* and *C*
2014 mainshock-aftershock sequence – fault segment *D*

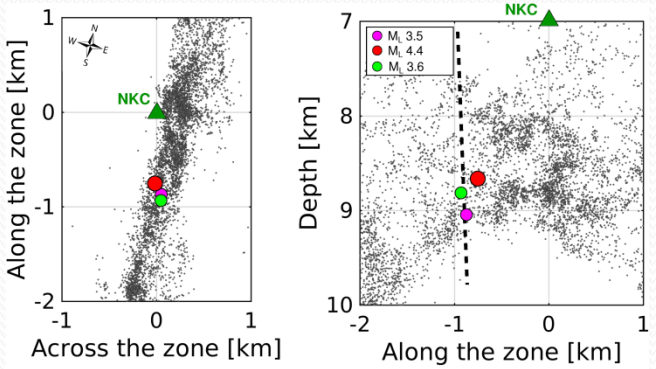
A new fault segment E activated in the M_L = 3.1 swarm in July 2017

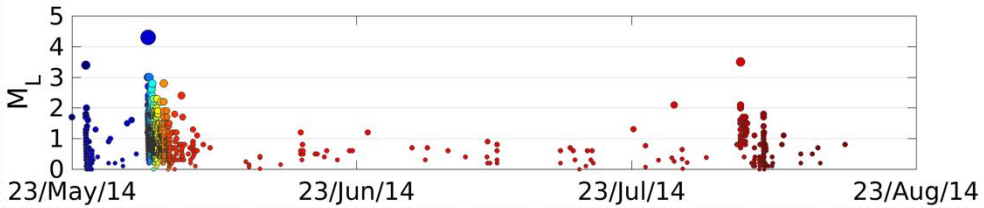
Mainshock-aftershock sequences of 2014

- mainshock-aftershock sequence exceptional in W-Bohemia/Vogtland
- mainshocks M_L= 3.5 (May 24), M_L= 4.4 (May 31) and M_L= 3.6 (August 04) located close to each another at the boundary of the 2008- and 2011-swarms
- striking migration of aftershocks into adjacent fault segments *A, B* and C

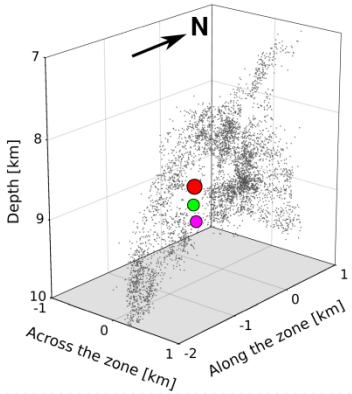


Locations of three mainshocks





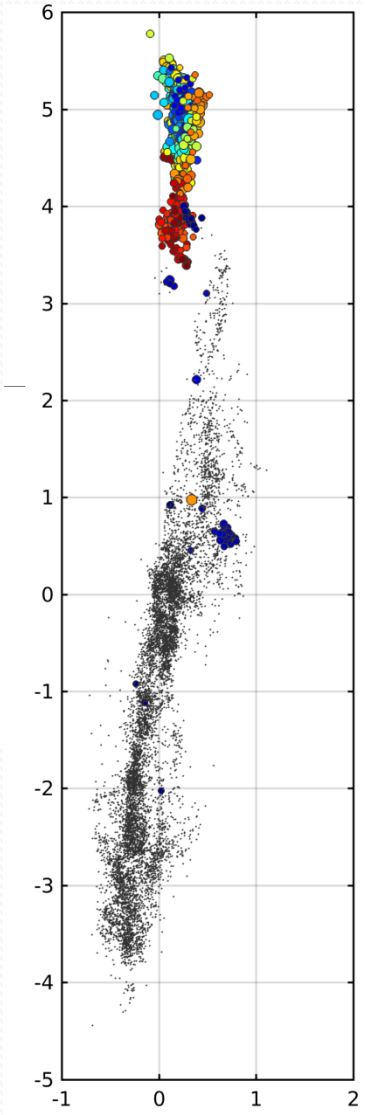
- M_L= 3.5, May 24
- M_L= 4.4, May 31
- M_L= 3.6, August 04

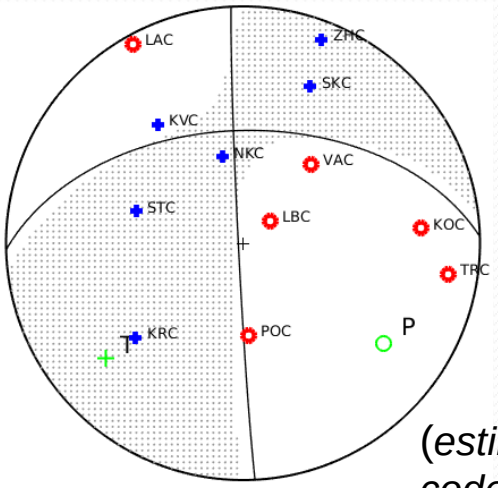


D *A new fault segment oriented across the focal belt*

Spatial distribution and characteristic focal mechanism of the 2017 swarm

Map of epicenters

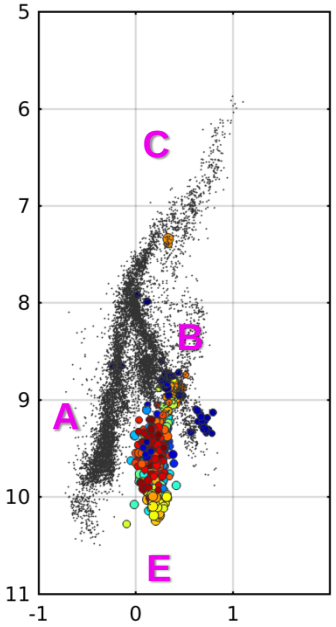




July 10, 2017
M_L = 3.1 event

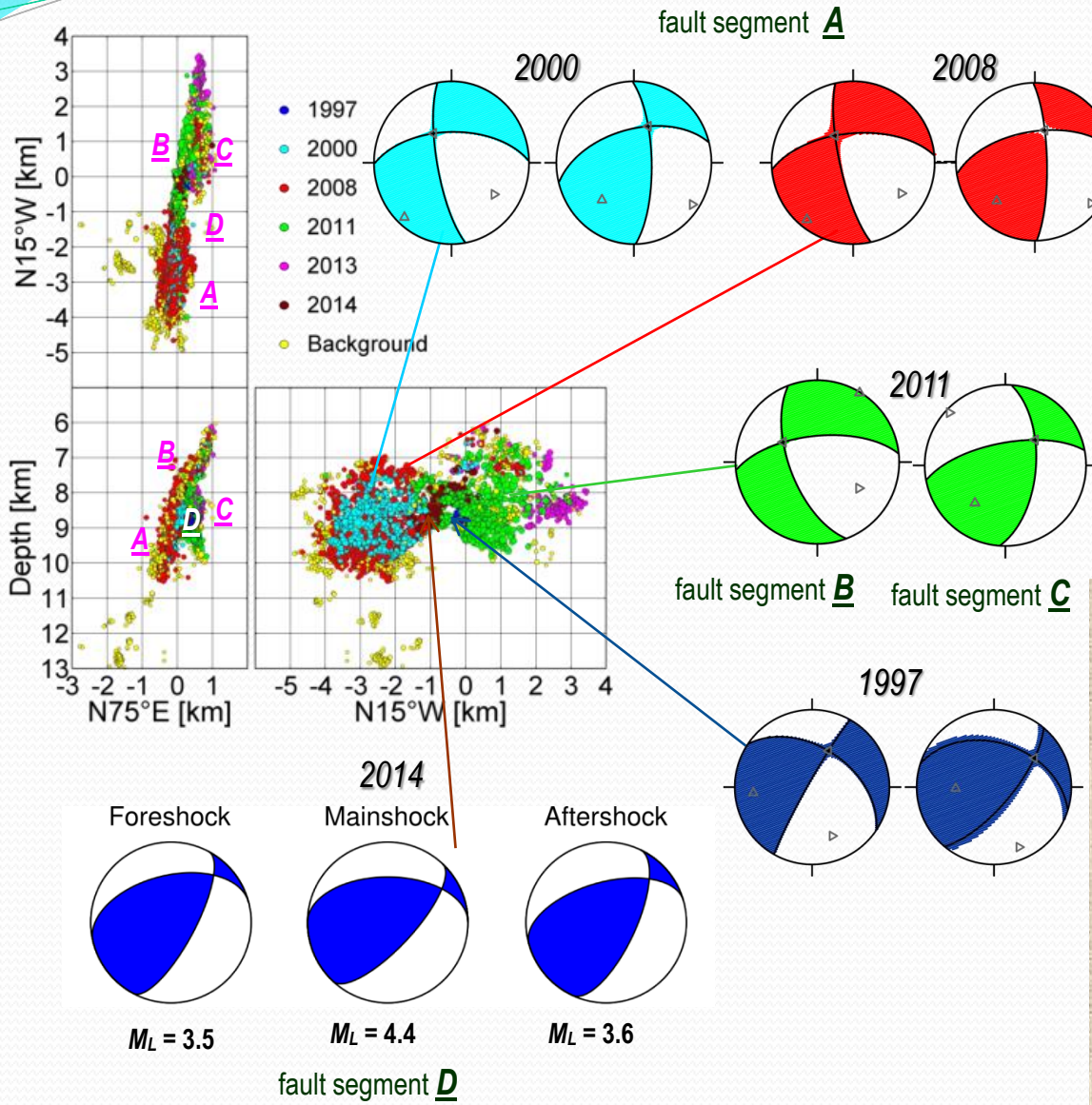
(*estimated using the AMT code by Vavryčuk, 2011*)

Depth cross-section

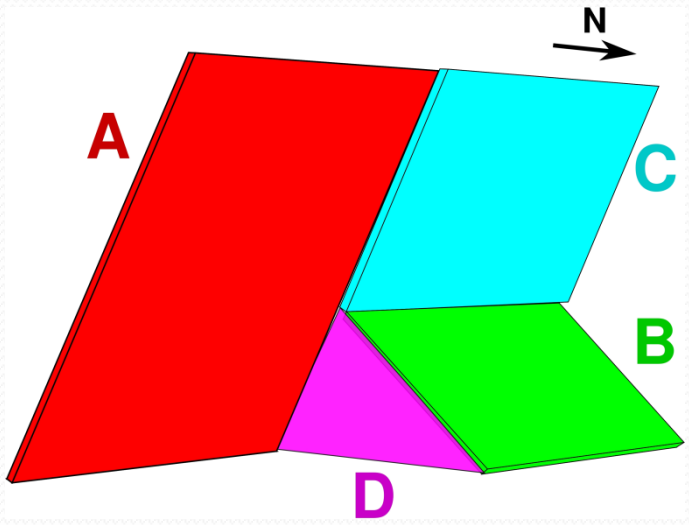


Strike and dip of the focal mechanism fit well geometry of a new fault segment E

Typical focal mechanisms



Basic scheme of the main focal zone NK

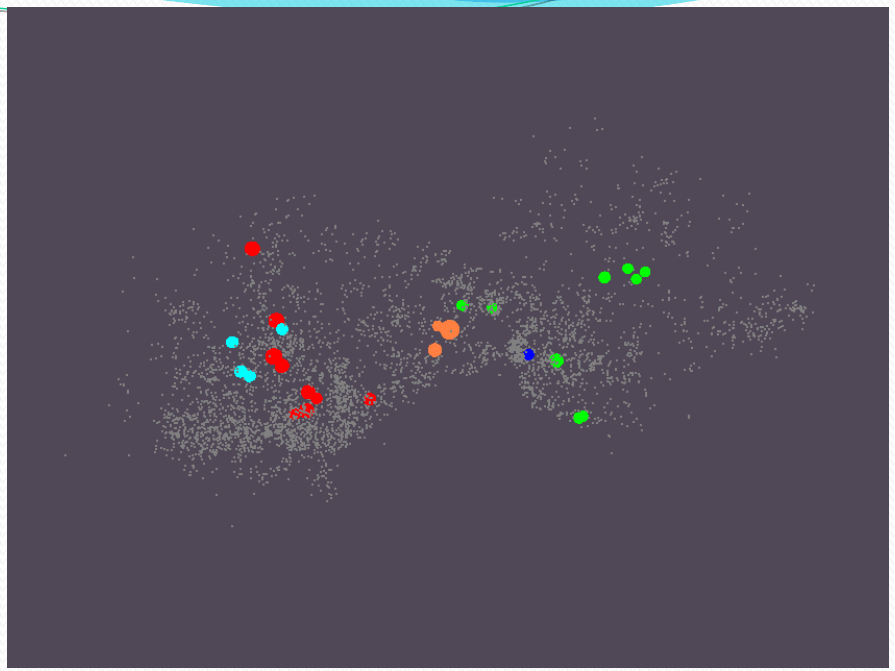


- Several families of the mechanisms, which fit well geometry of the corresponding fault segments.
- The 2000 and 2008 swarms on the same fault segment ⇒ similar mechanisms;
the 1997 and 2011 swarms took place on two differently oriented segments ⇒ two different mechanisms .
- MTs of most events signify pure shears except for the 1997- events which indicate combine sources - both shear and tensile components .

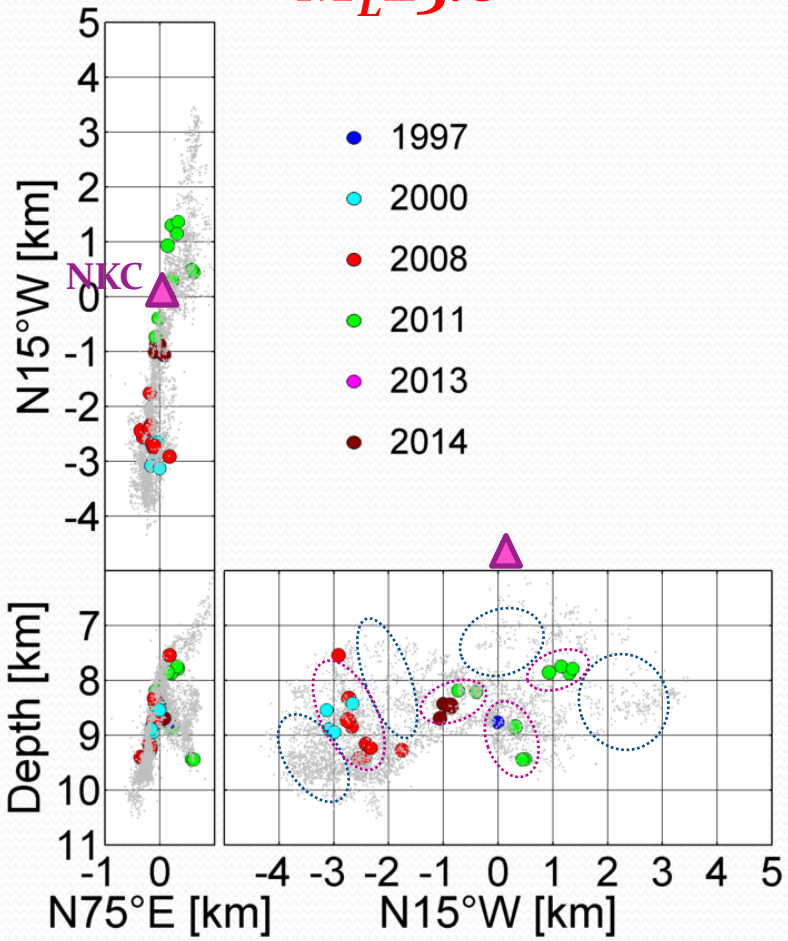
Key issue:

What are W-Bohemia/Vogtland earthquake swarms in fact ?

Distribution of stronger events



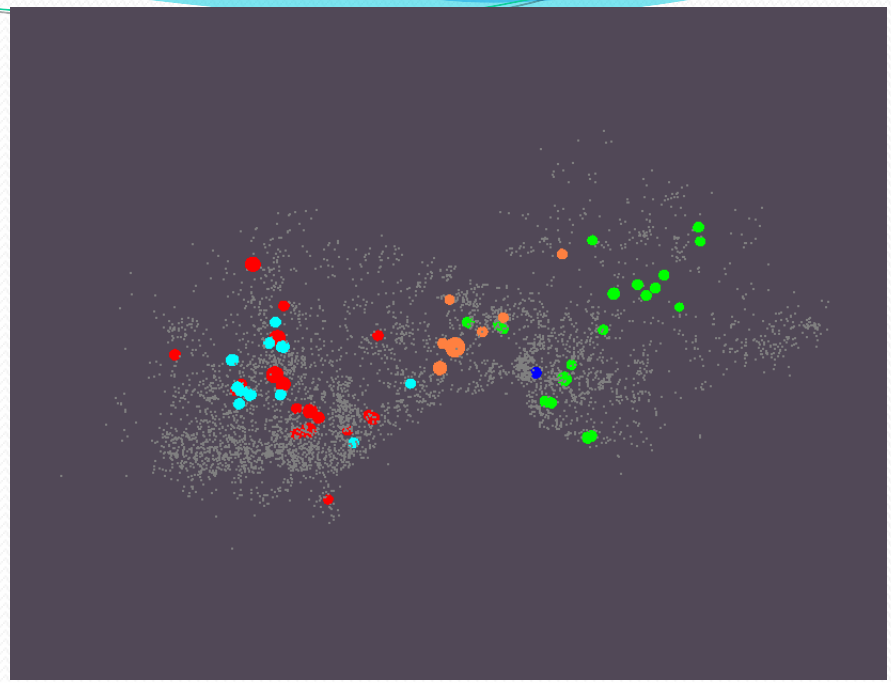
$M_L \geq 3.0$



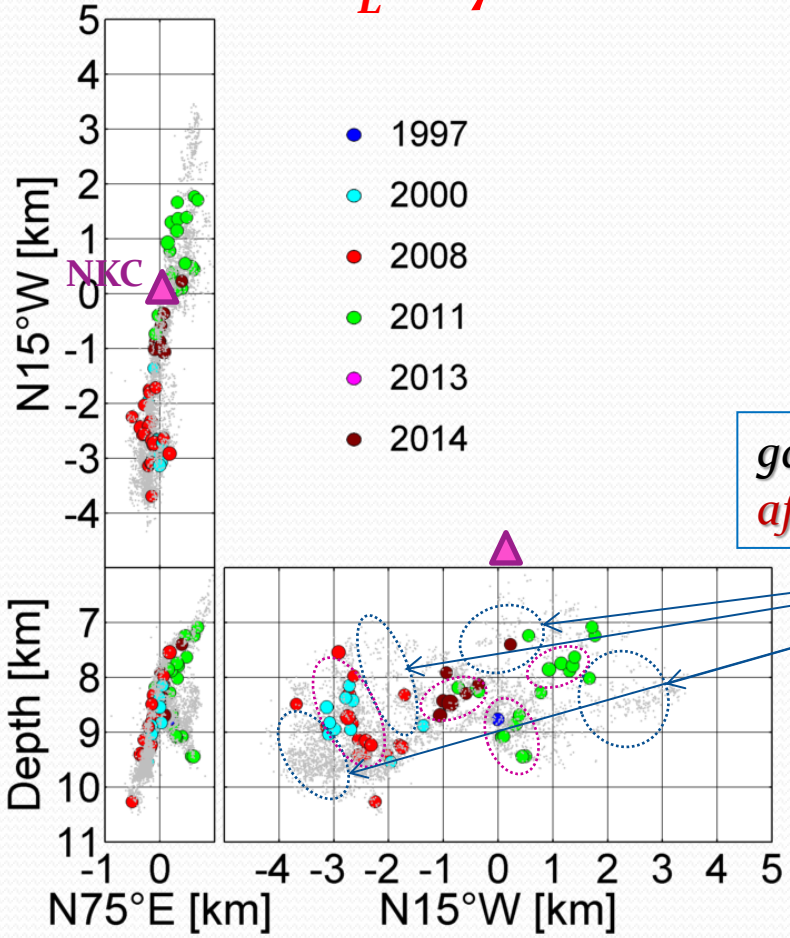
asperities

gaps of larger events

Distribution of stronger events



$M_L \geq 2.7$

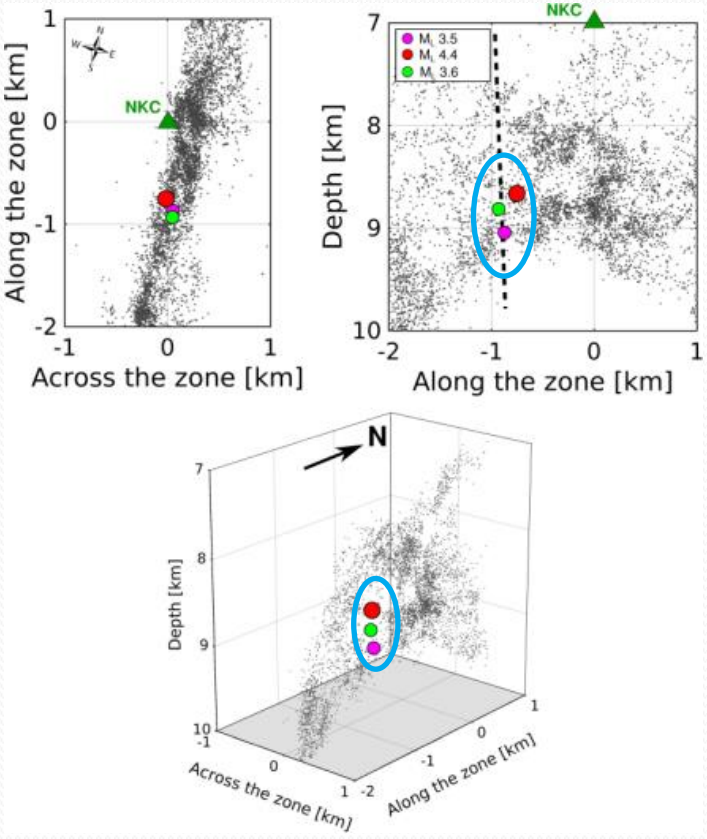


gaps filled only by small events - aftershocks ?

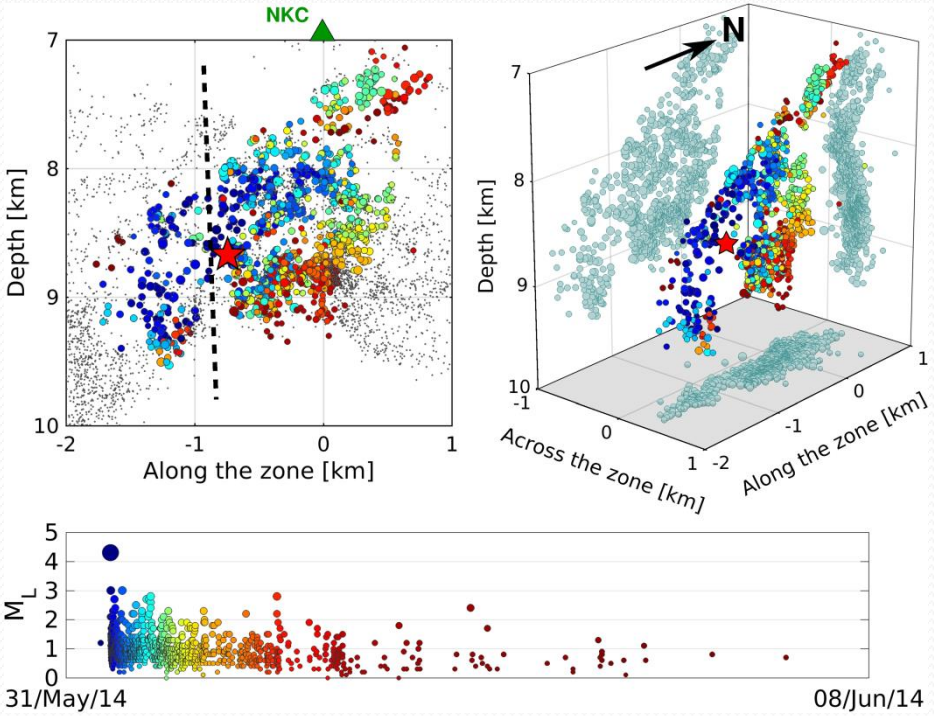
asperities

gaps of larger events

Distribution of mainshocks and aftershocks in the 2014 sequence



An asperity (fault segment D) corresponding to the rupture areas of the 2014 mainshocks (M_L = 3.5, 4.4 and 3.6)



Large extent of the 2014 aftershocks, stretching into fault segments A, B and C

Conclusions & Inferences

The main focal zone NK is characterized by:

- complex system of short, differently oriented faults / fault segments
- heterogeneous local stress (indicated by various of source mechanisms)
- strain-energy release mostly in the form of earthquake swarms, exceptionally in distinct mainshock-aftershock sequences

The individual swarms show:

- most of the seismic moment released in a few asperities which implies step by step propagating rupture
- mostly shear faulting of differently oriented faults/fault segments, fully controlled by the local tectonic stress.

Our inferences:

- West Bohemia eq. swarms are series of overlapped mainskock-aftershock sequences: stronger events (mainshocks) are due to step by step propagating rupture, weak events are aftershocks.

- What are the causes leading to a different strain-energy relea earthquake swarm vs. mainshock-aftershock sequence?
- What are the processes loading the faults and mechanisms governing step by step propagation of the rupture in the W-Bohemia/ Vogtland?

These questions remain to be answerred

Thank you for your attention!

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