Coal-mining induced events in the Ruhr area, Germany

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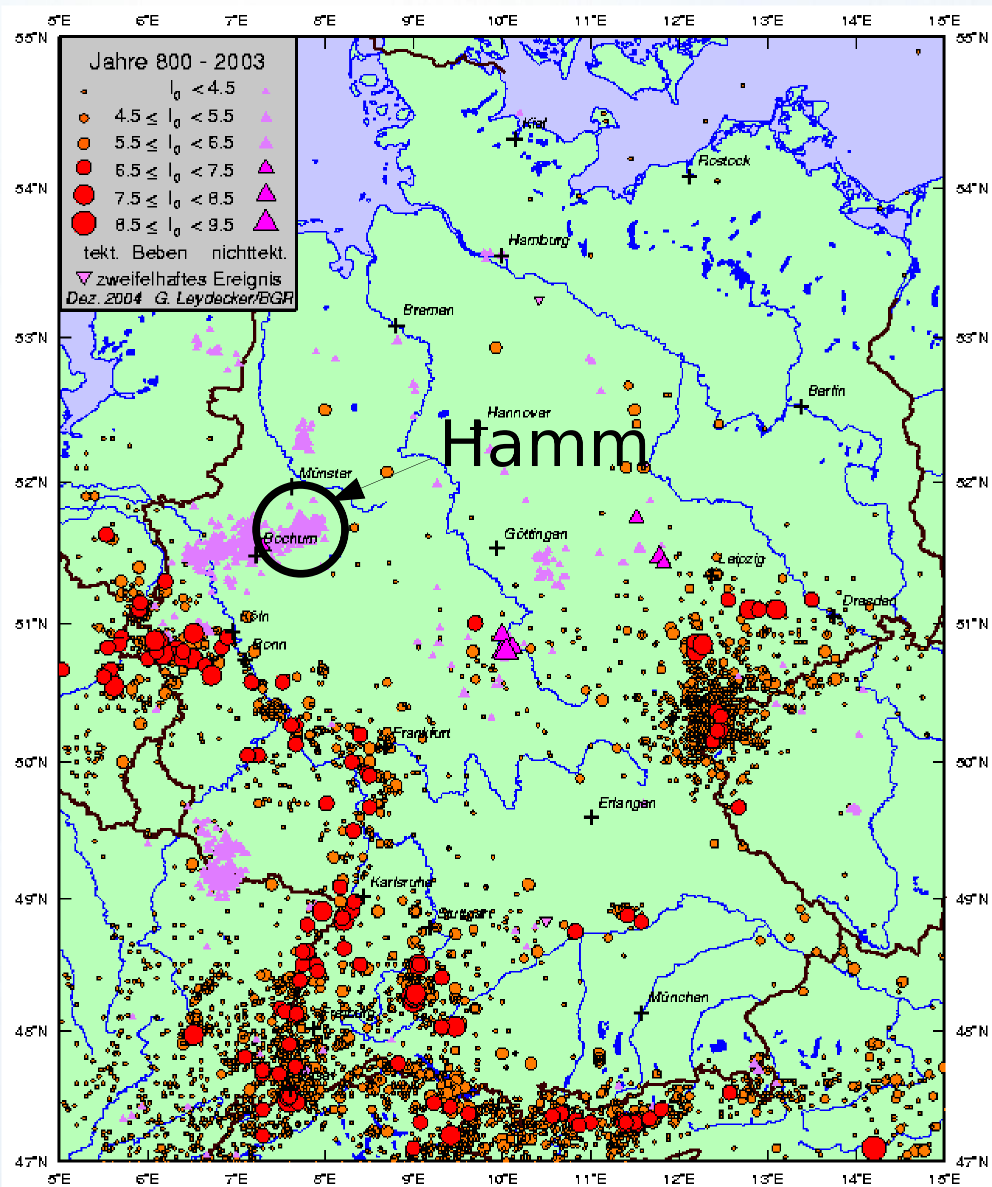
Distribution of seismicity

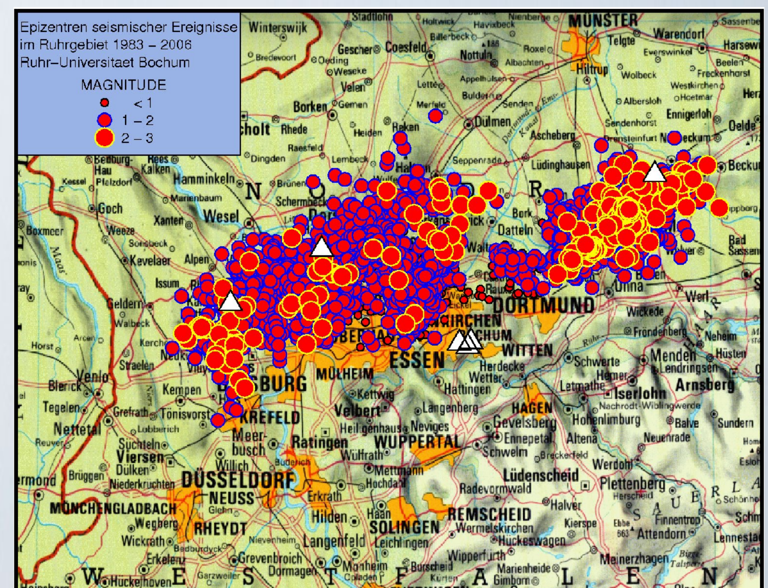


(Leydecker,2004)

<u>Seismological Observatory</u>

<u>Ruhr-University Bochum:</u>

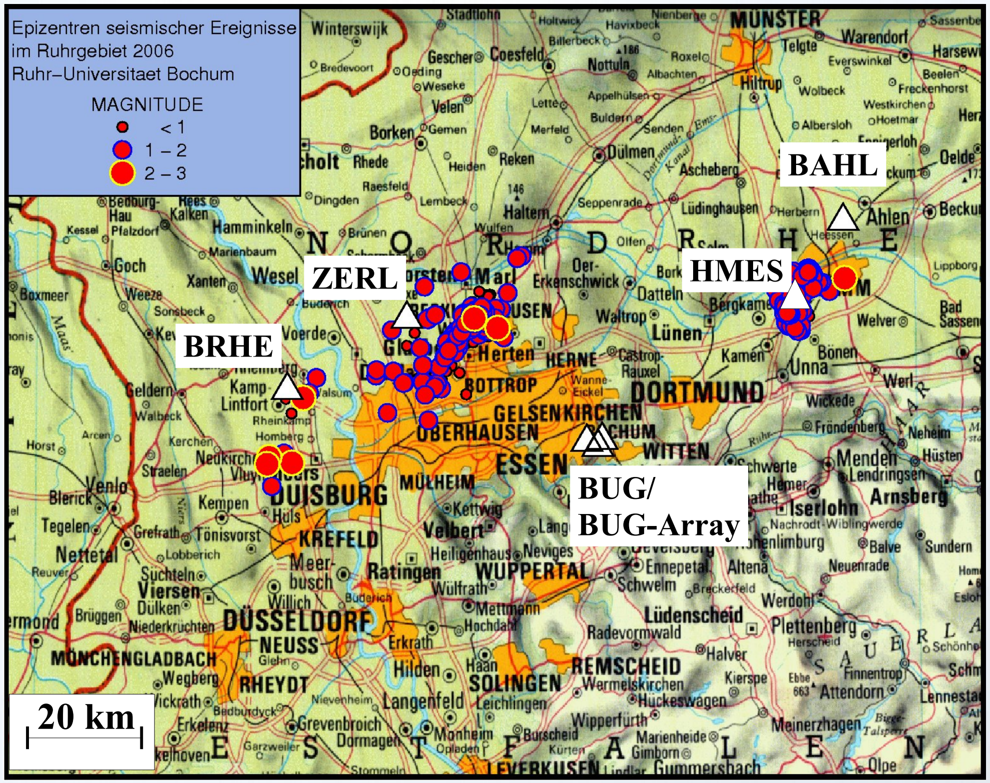
- continuously monitored since 1983
- 14000 induced events, $M_L \le 3.3$
- completeness of catalogue:
  whole catalogue: $M_L \ge 1.5$
  since 2005: $M_L \ge 0.7$

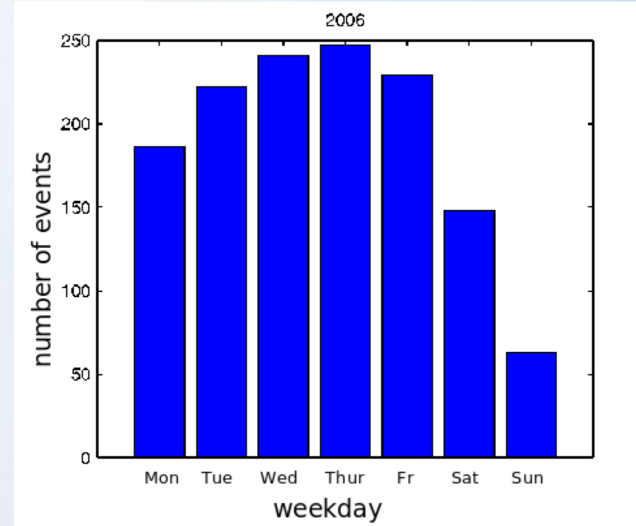


1983 - 2006

Distribution of seismicity

2006



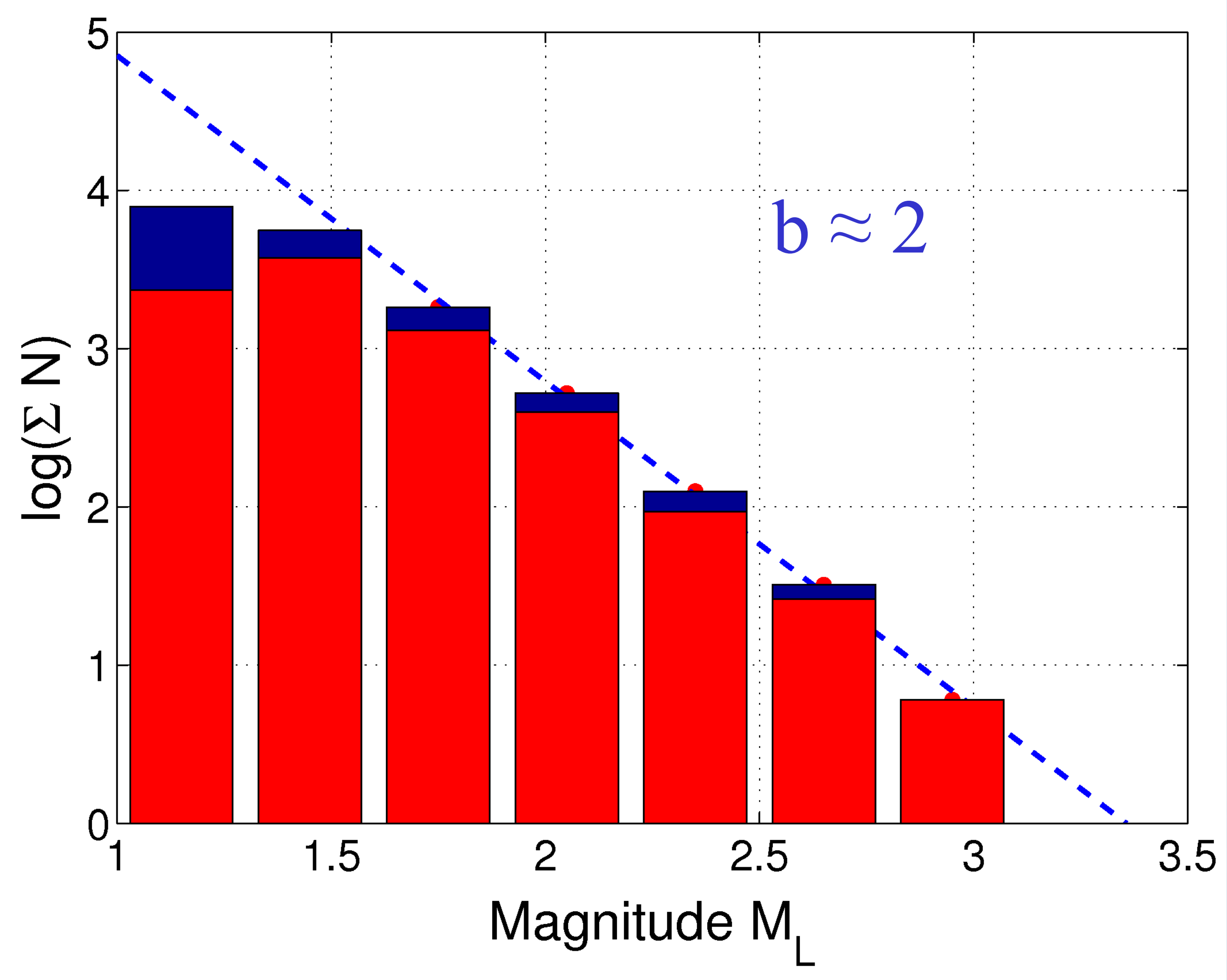


- 2006: ~ 1300 induced events
- $M_{L,\,max} = 2.4$
- ~20-40 events per month noticed by people ($M_L \geq 1.2$)

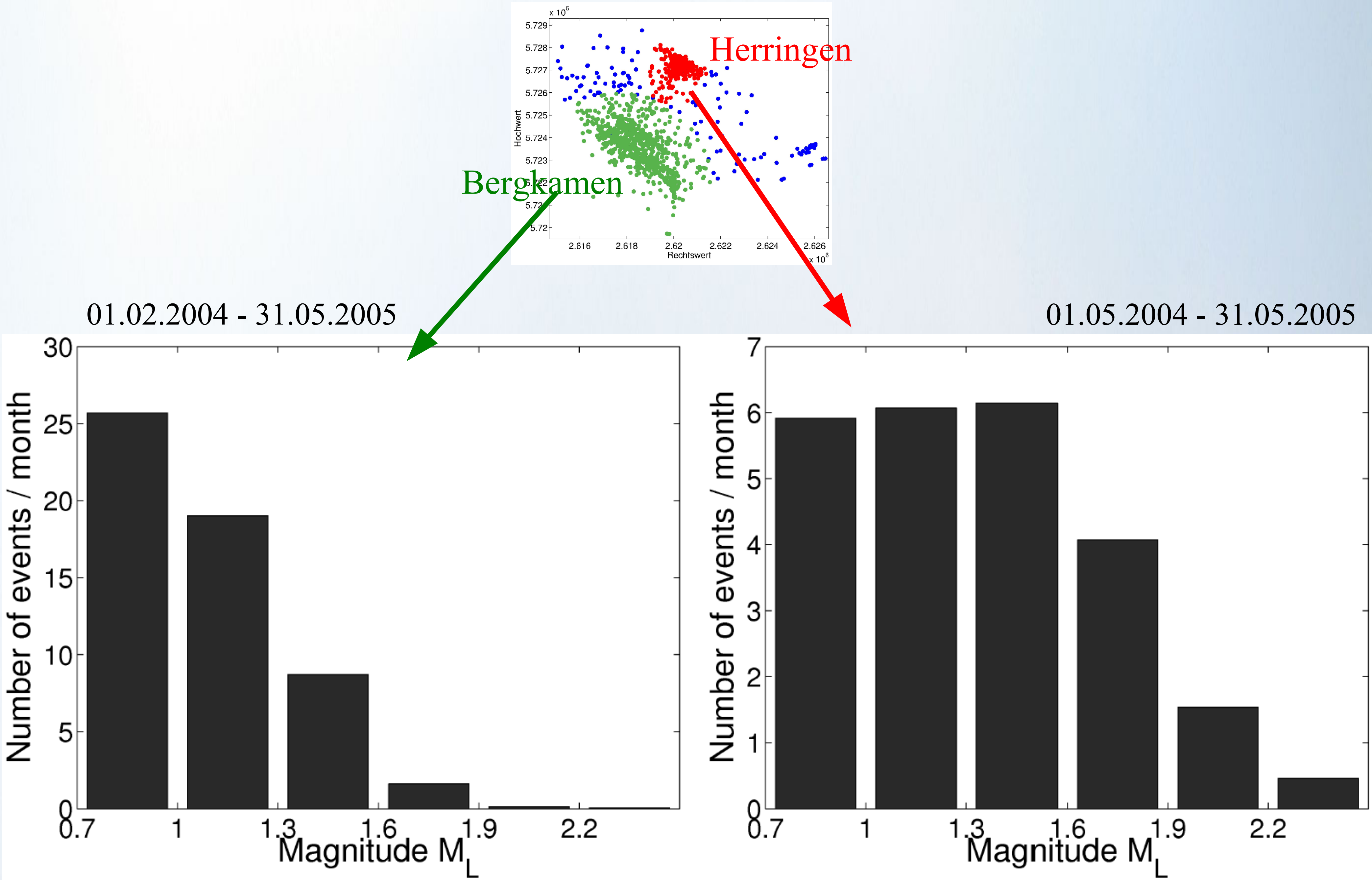
(DSK, 2006)

Magnitude-frequency distribution

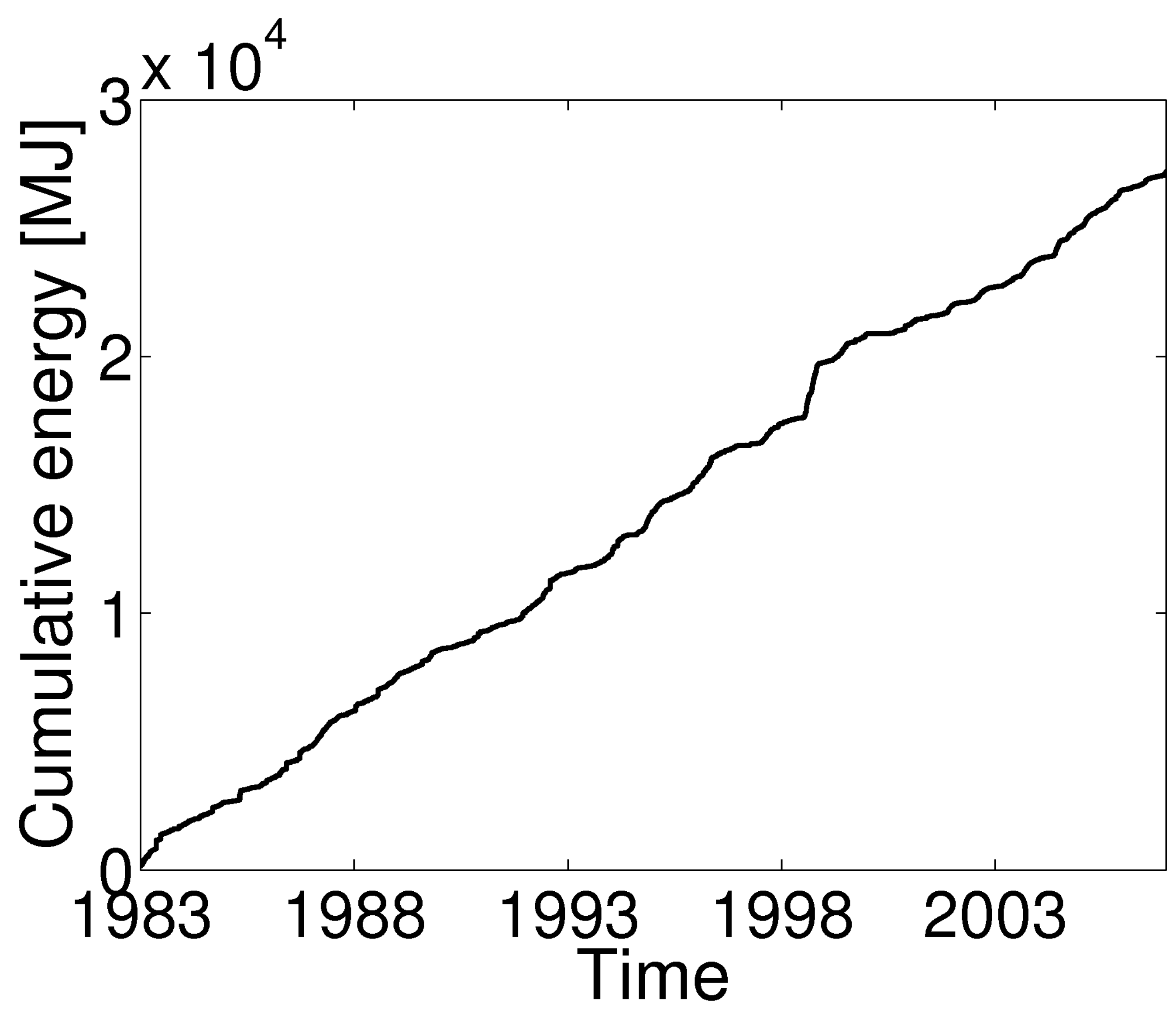
Ruhr area 1983 - 2006



Magnitude-frequency distribution

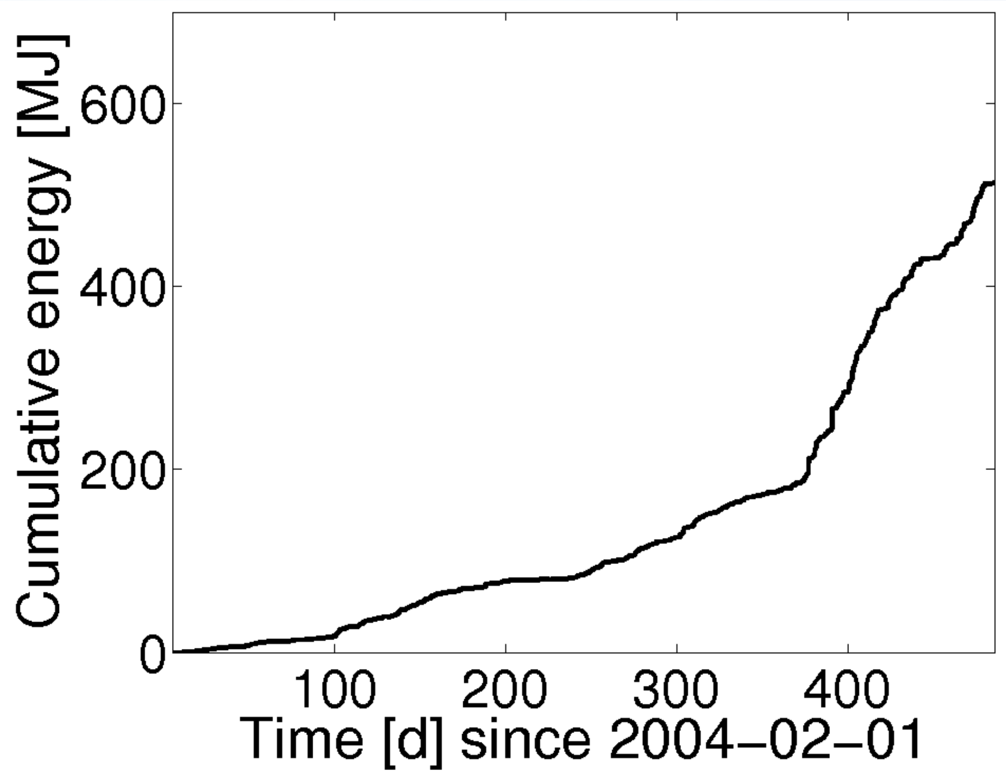


Energy release

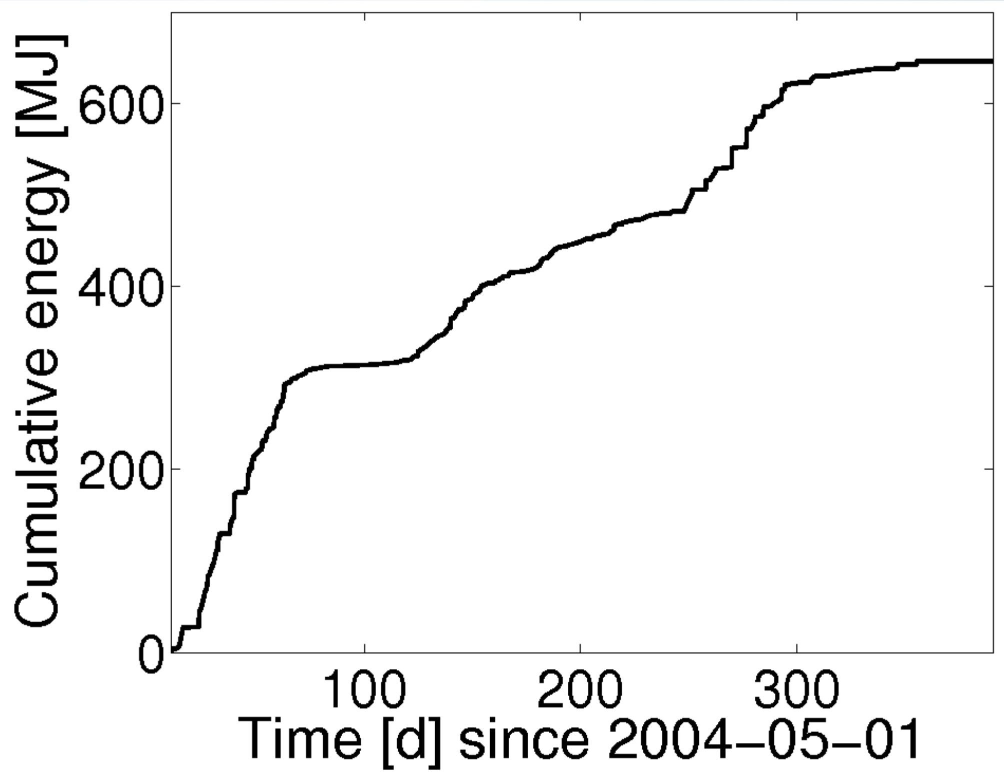


Energy release

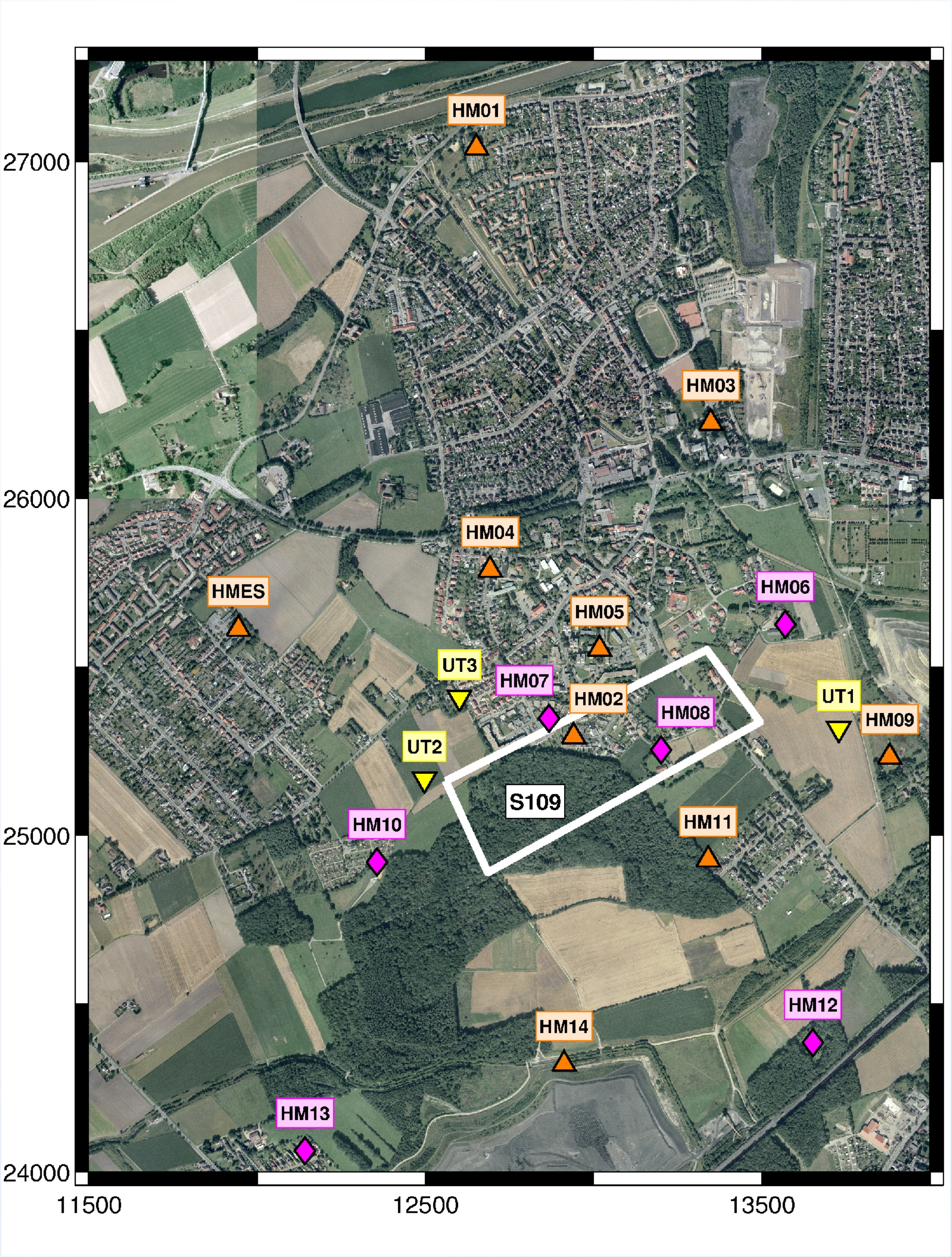
Bergkamen



Herringen



HAMNET – a local seismological network



- 15 stations (GFZ Potsdam):
  - 9 Mark L-4C-3D (1Hz)
  - 5 Güralp CMG (60s)
  - 1 Trillium 40 (40 s)

- Earth Data PR6-24 (GFZ)
  Digitizer, PC, local hard disc

- 6 subsurface stations (DMT):
  - 51 - 84 m above seam
  - 26 - 90 m below seam

- locations:
  private houses
  → garages, basements

- panel length: ~ 870 m
  depth: 1060 – 1100 m
  time period: 08/2006 - 04/2007

Localizations August – November 2006

Number of events:

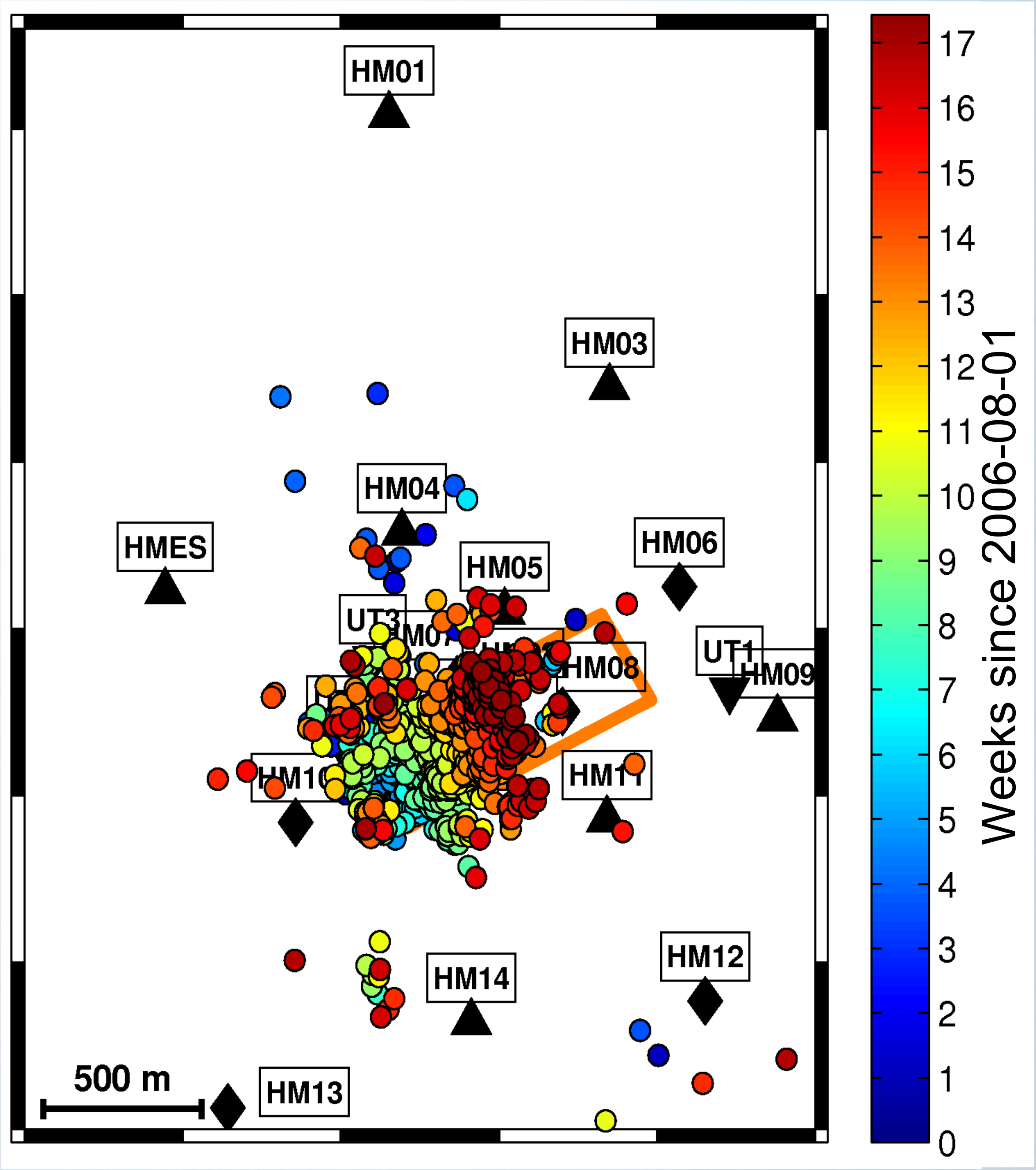
- 3437 Events
  → ~ 860 Events/ Month
- 2170 events localized (63%)

Selection criteria:

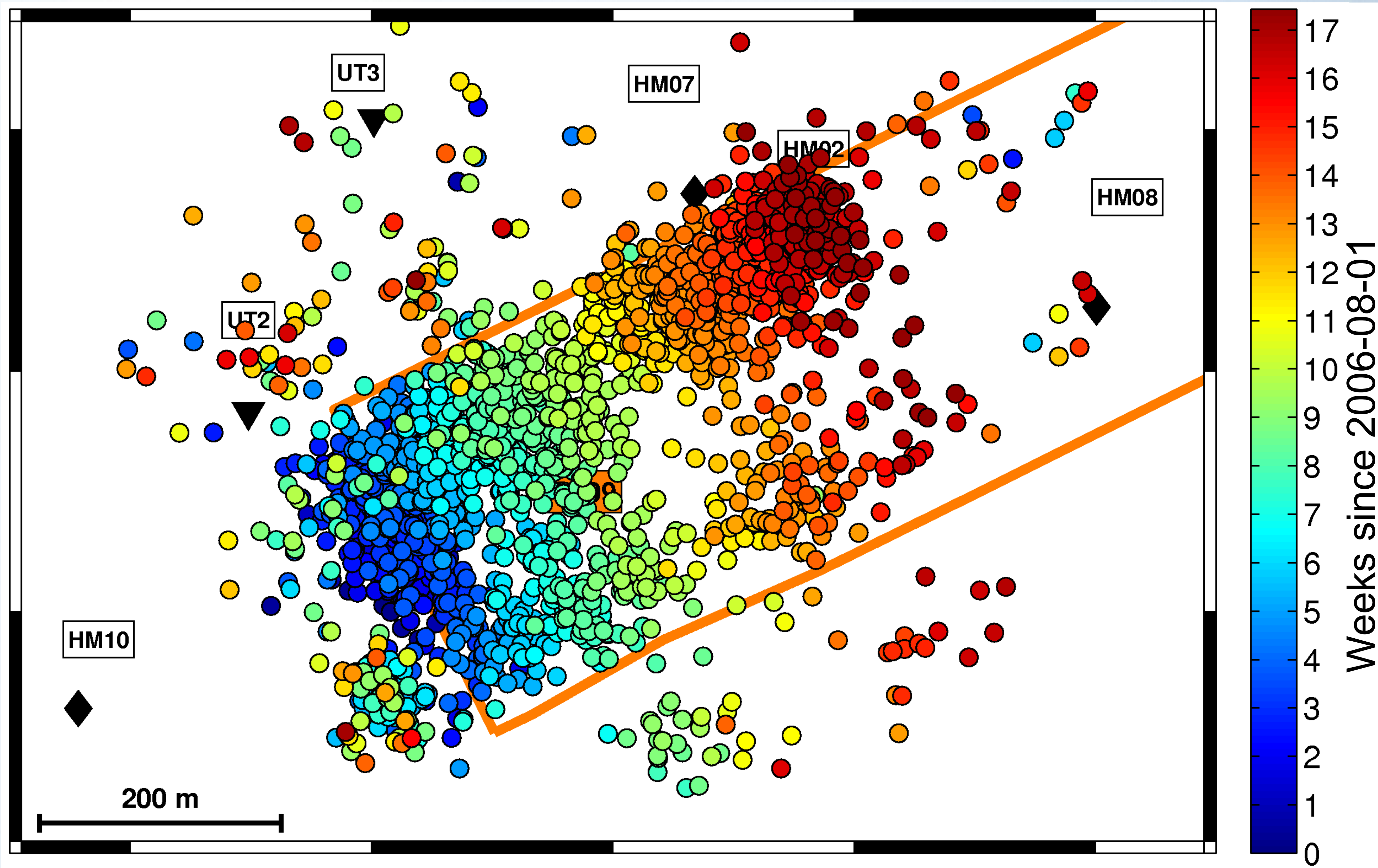
- at least 9 P-onsets
- rms ≤ 7 ms

Localization accuracy:

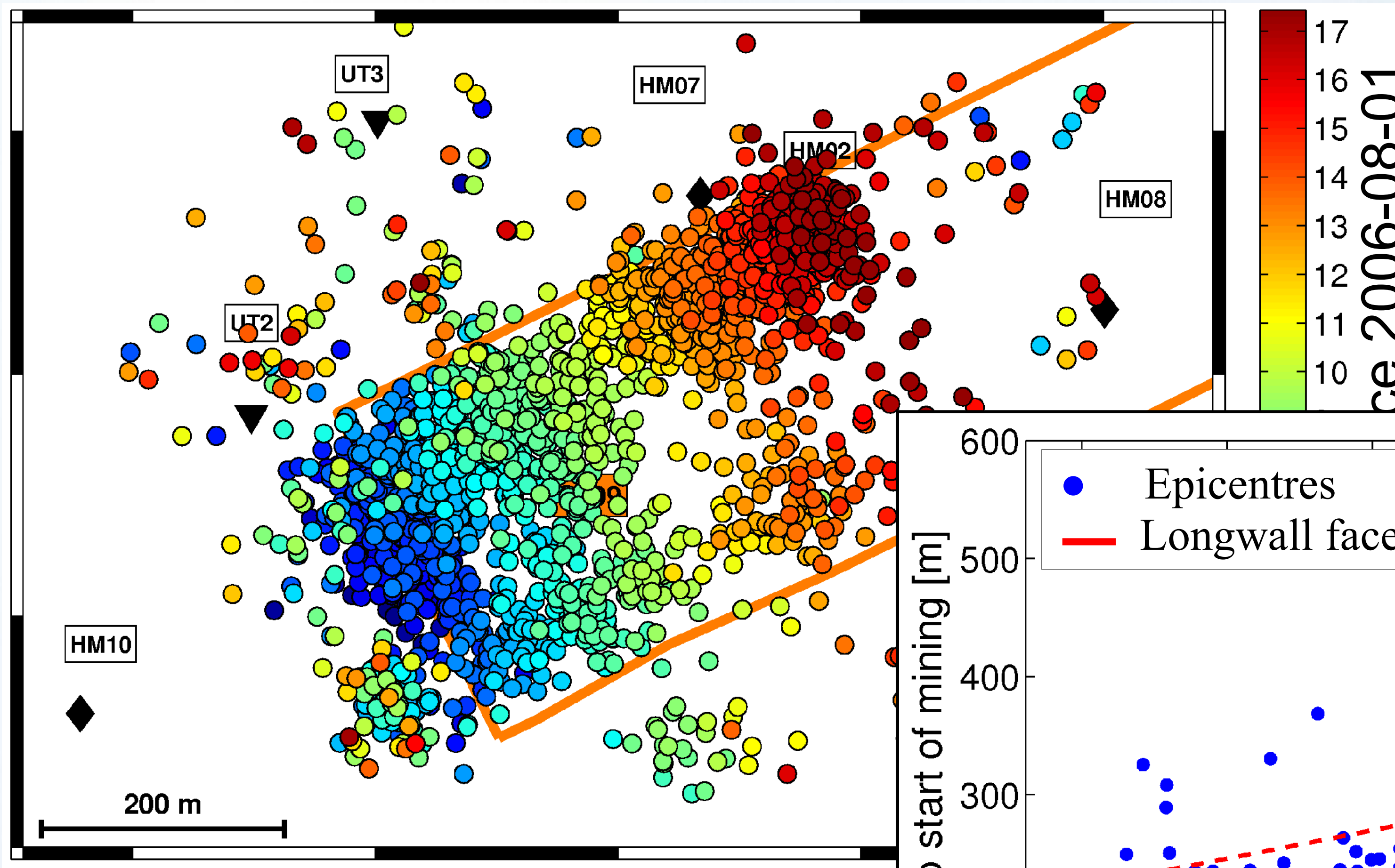
- +/- 30m

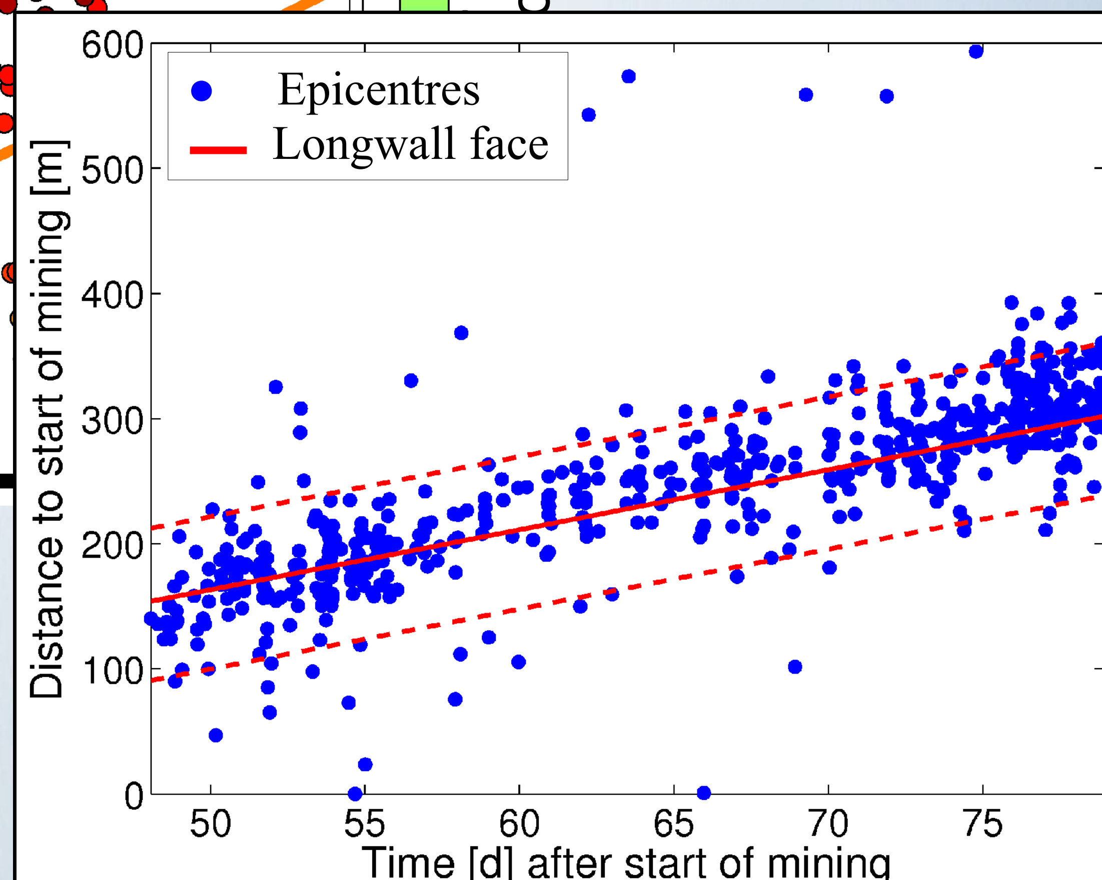


Localizations August – November 2006

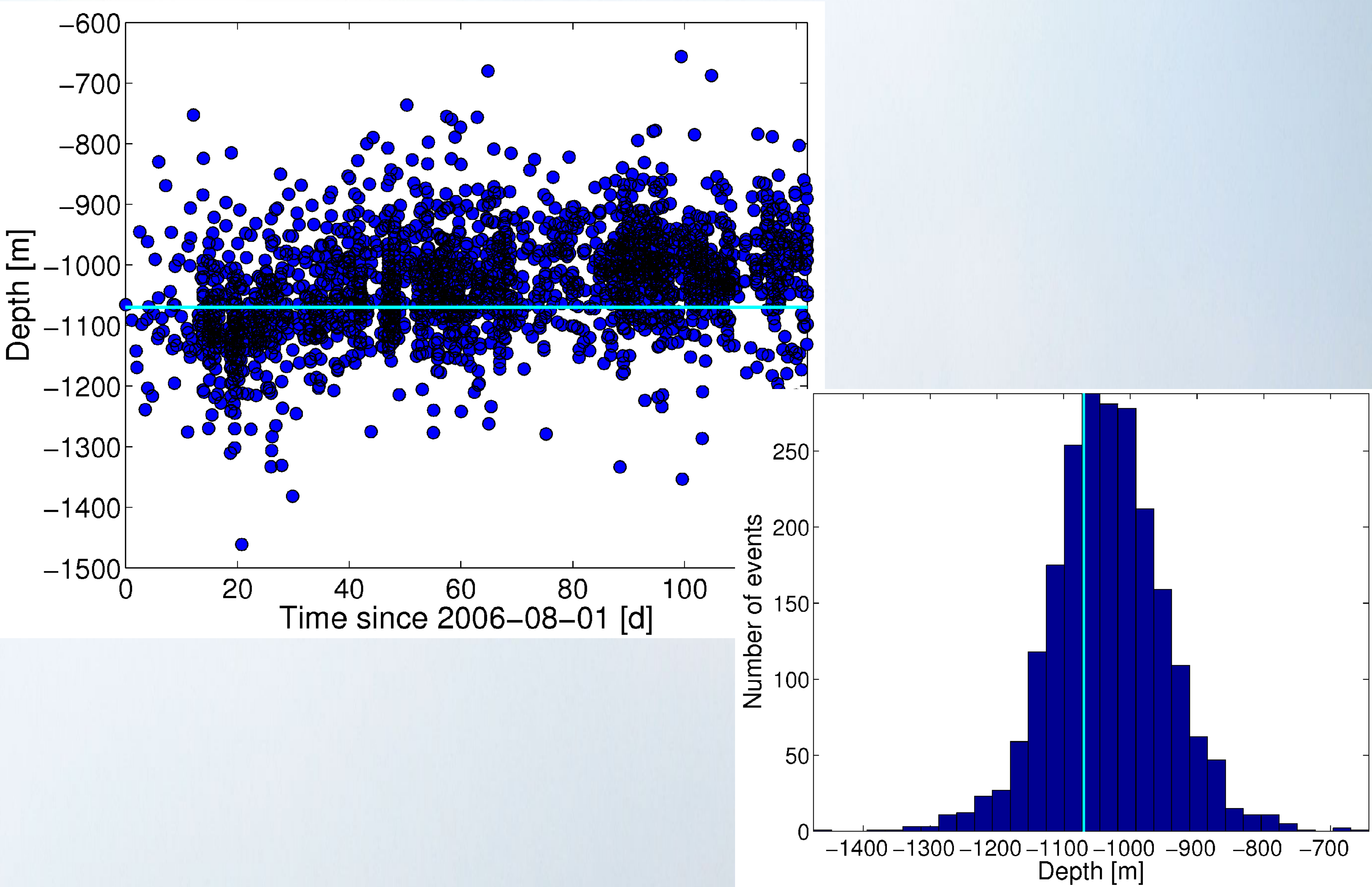


Localizations August – November 2006

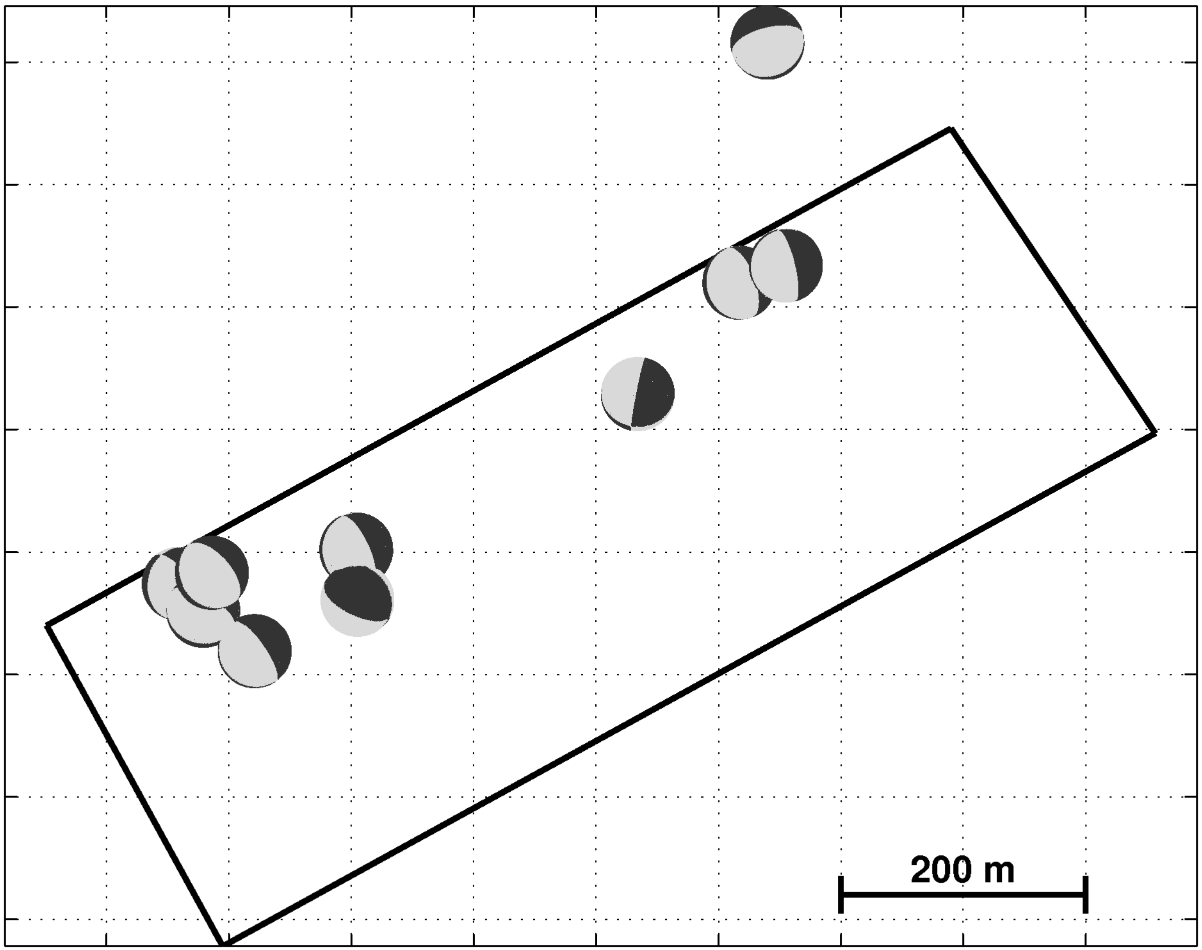




Localizations August – November 2006



Fault plane solutions



(Fritschen, pers. comm.)

Types of events:
(upper hemisphere)

- normal fault events parallel to longwall face
- normal fault events related to tectonic faults
- thrust fault events

Conclusions

- Mining induced events can be assigned to specific longwall panels.

- High b-value of about 2 is observed for the whole Ruhr area and is interpreted as average for different longwalls. For a specific longwall characteristic magnitudes were found.

- With the local network localizations relative to the face advance and hypocentral depths are determined.

- Most events are down to 50 m below and up to 100 m above the longwall...

- ... and between 60 m behind and 60 m ahead of the longwall face.

- Locations and source mechanisms hint at different causes: existing tectonic faults, new fault planes parallel to the longwall face, normal and thrust faulting events

Thank you!

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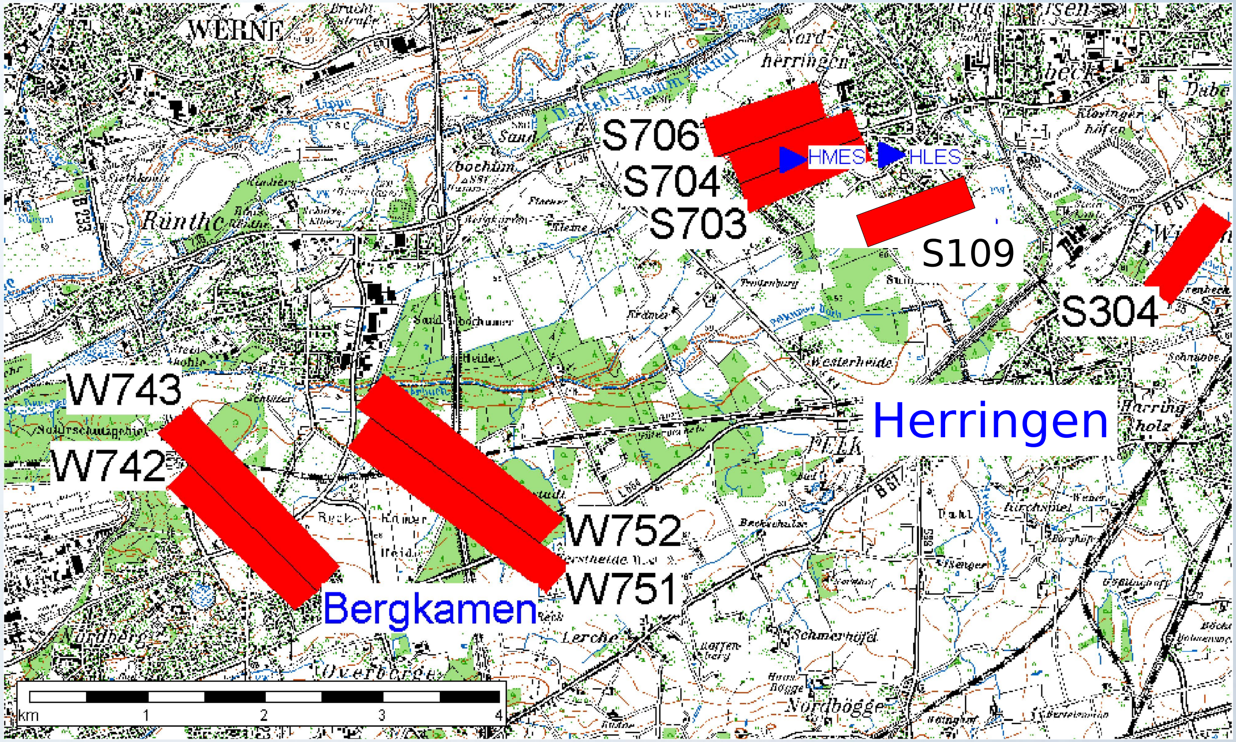
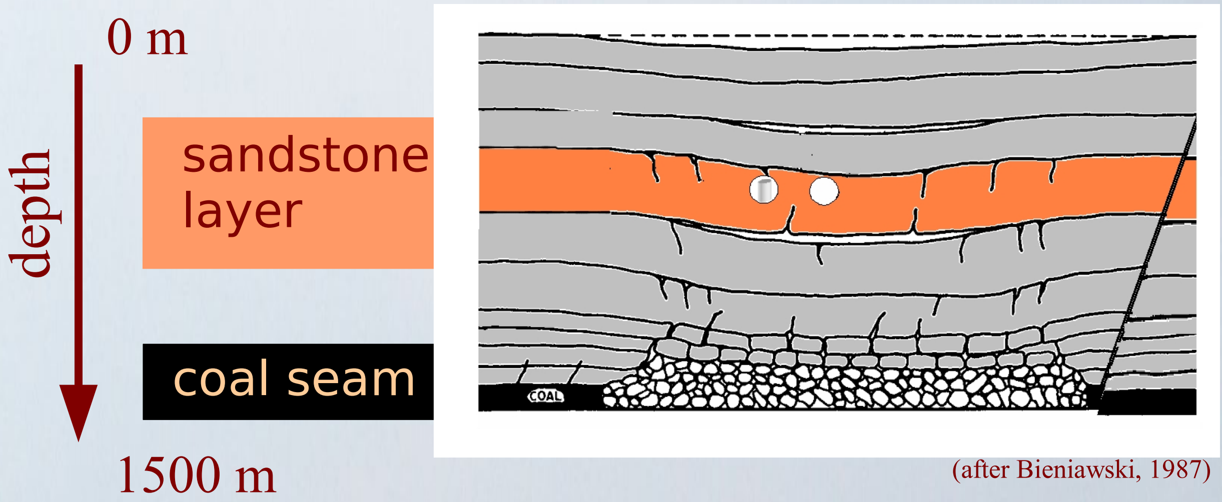
Mining geometry

Longwall mining:

- length: ~ 1 km
  width: ~ 300 m
- caving:
  excavations are not refilled
- face advance:
  100 m / month
  => ~ 8-12 month
- depth down to 1500 m



(after TK50, CD-Rom, Landesvermessungsamt NRW, 2003)



(after Bieniawski, 1987)


ACHTUNG

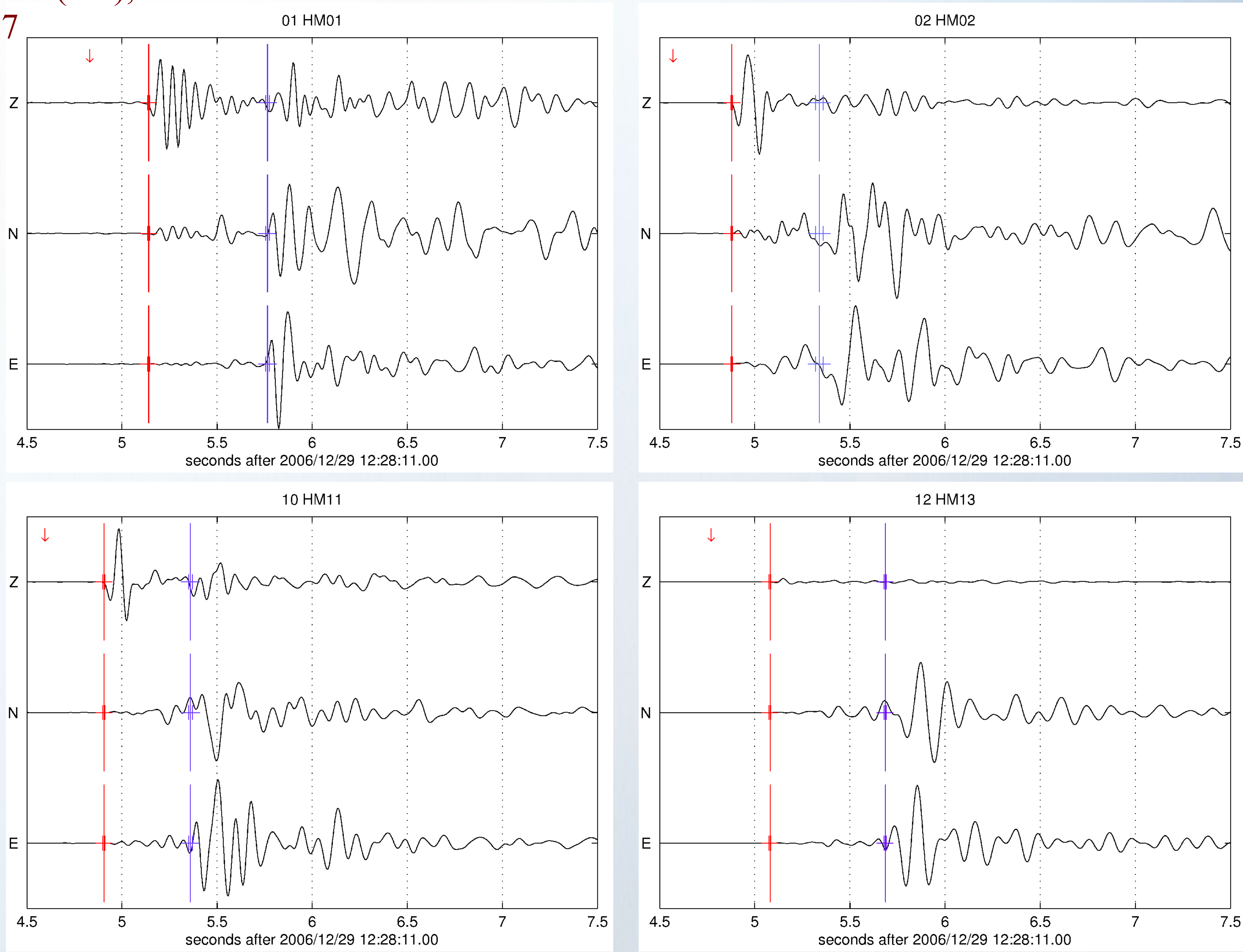
SEISMOLOGISCHE STATION

Bitte halten Sie Abstand
von Markierungen und Messgeräten!

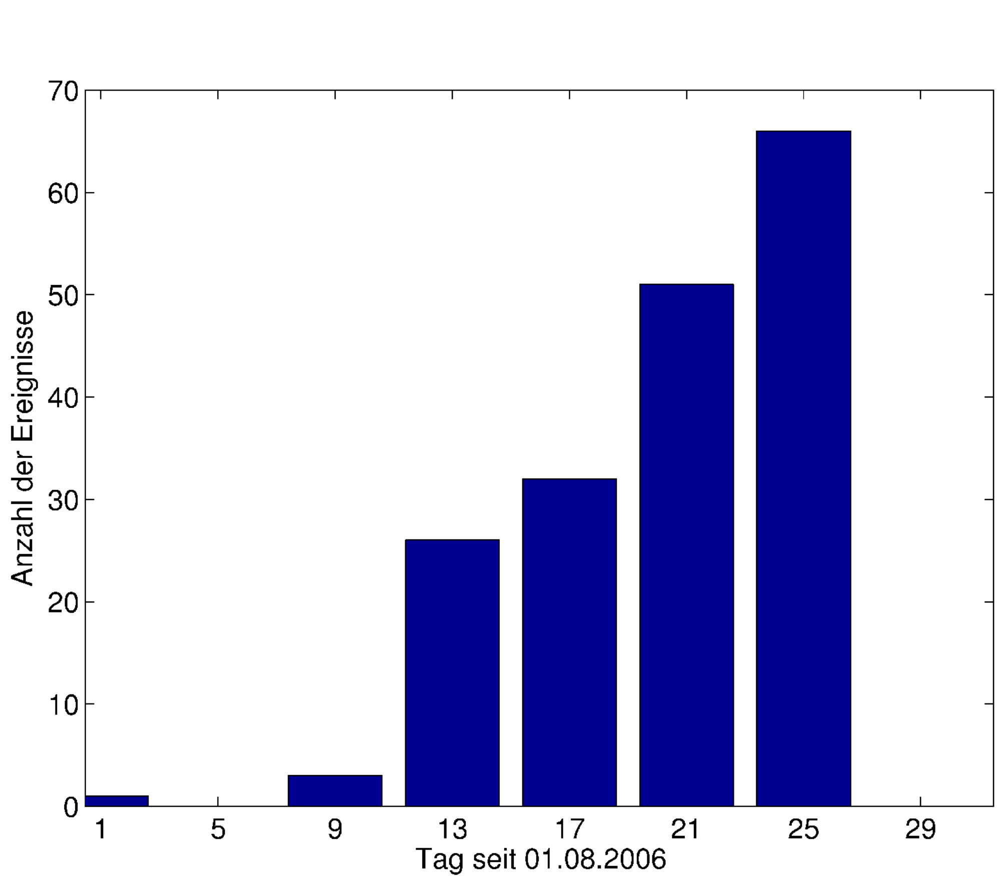
Bitte nicht berühren!

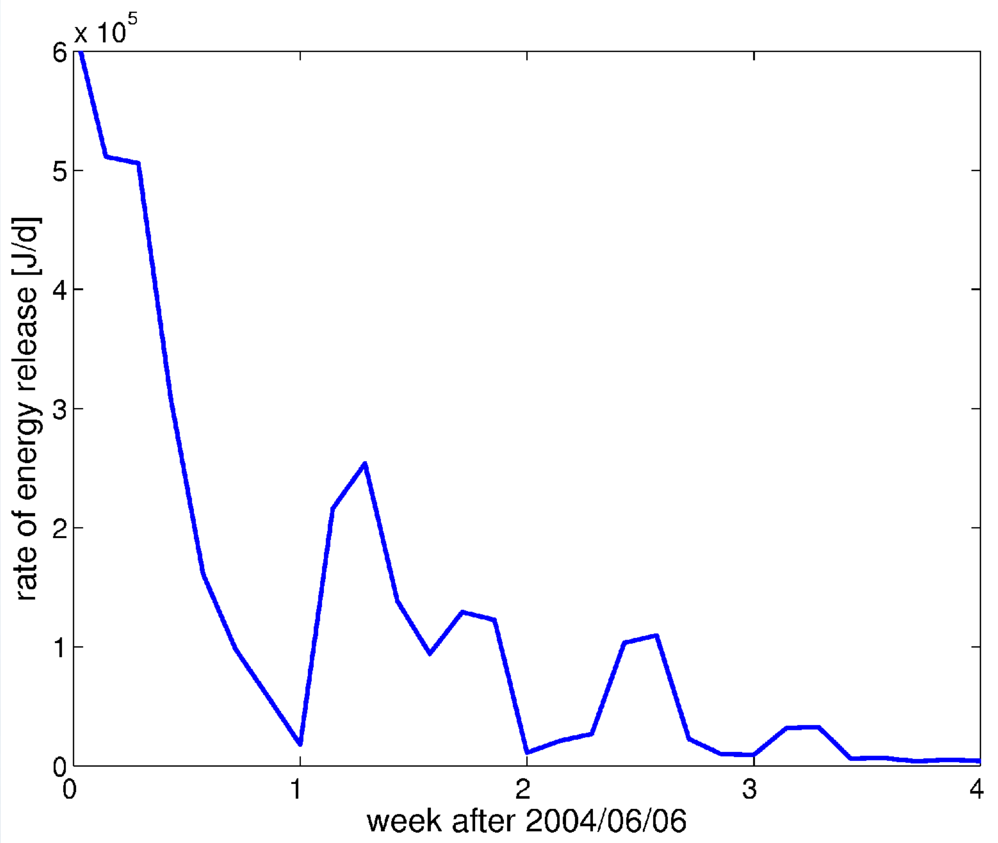
Bitte setzen Sie sich bei allen Problemen mit uns in Verbindung.
Verschieben der Geräte kann sehr leicht zu Defekten führen.

29.12.2006,
12:28:15.6 (UT),
$M_L = 1.7$

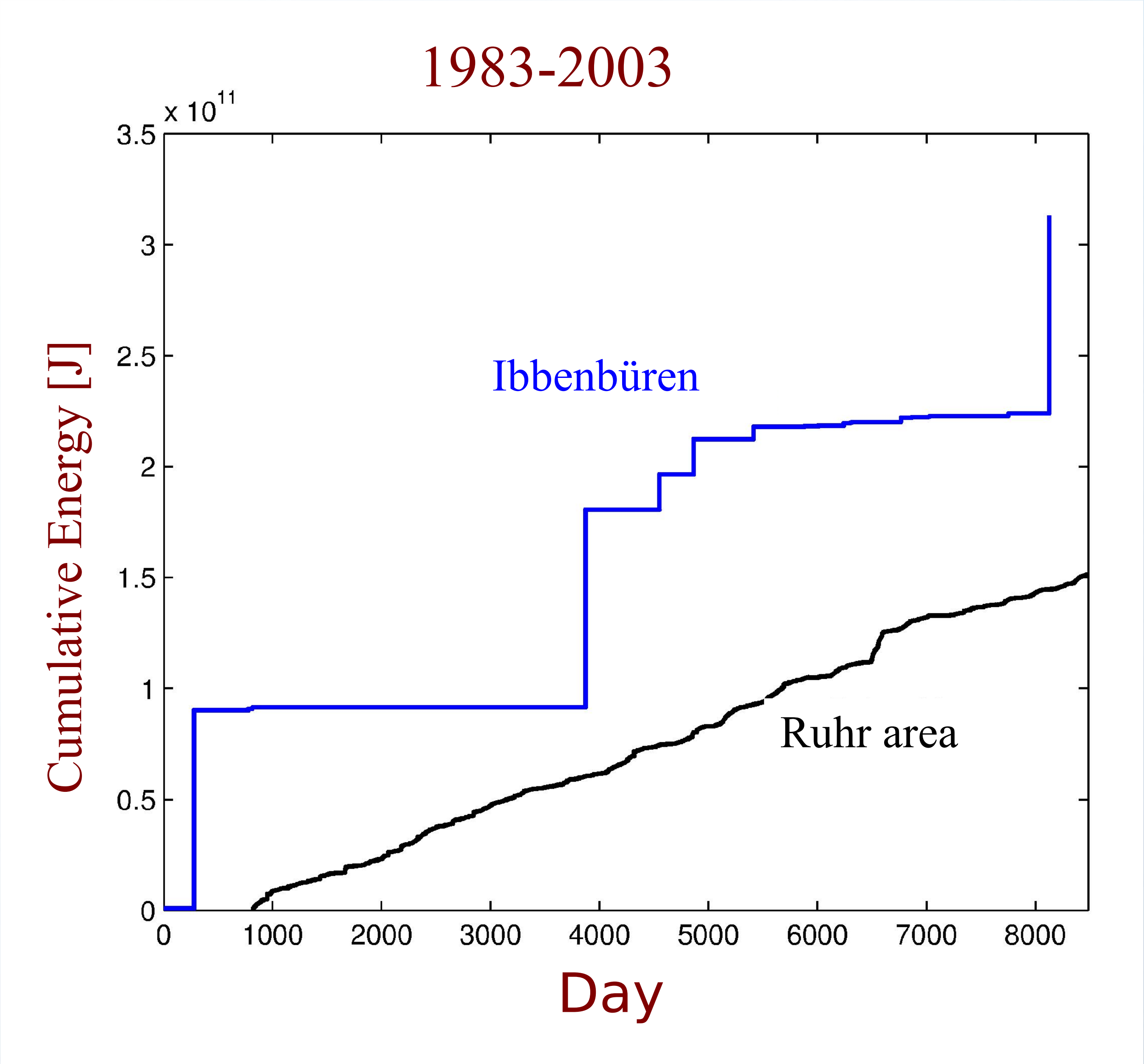


Increase and decay of seismicity

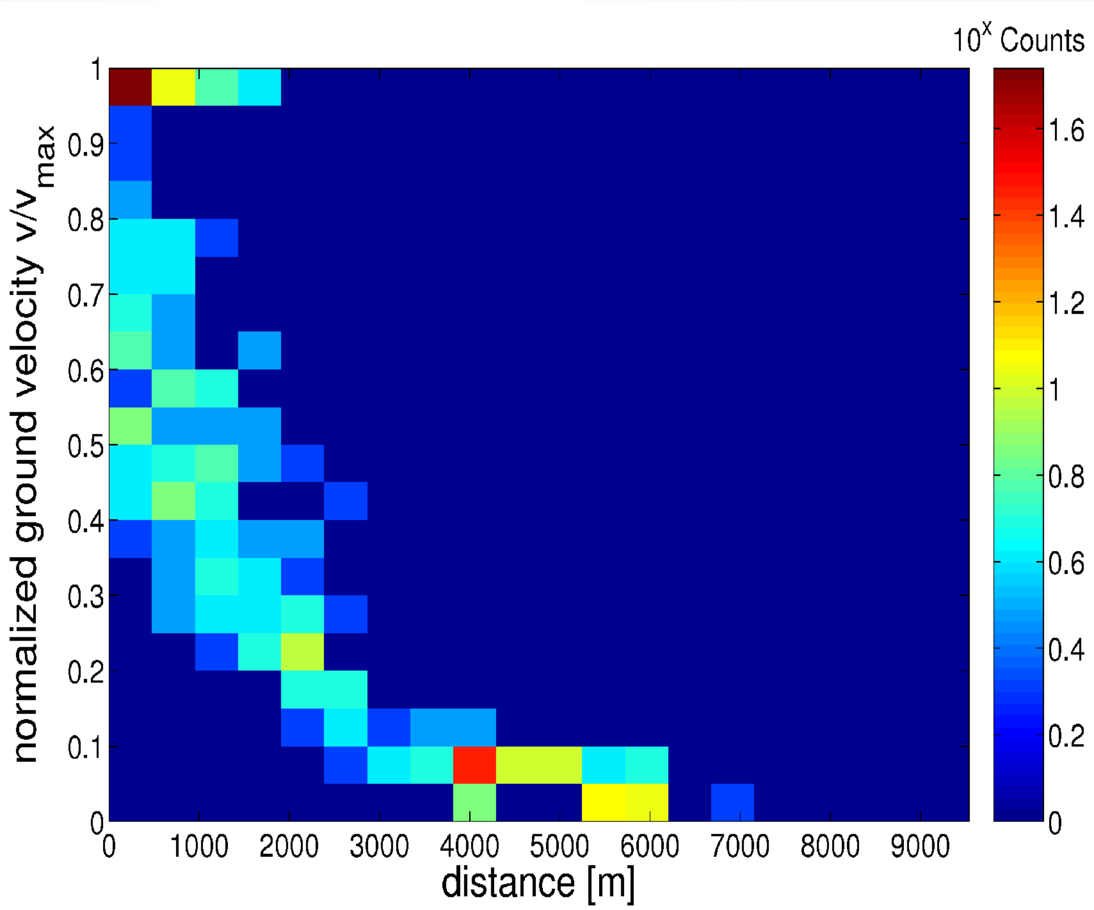


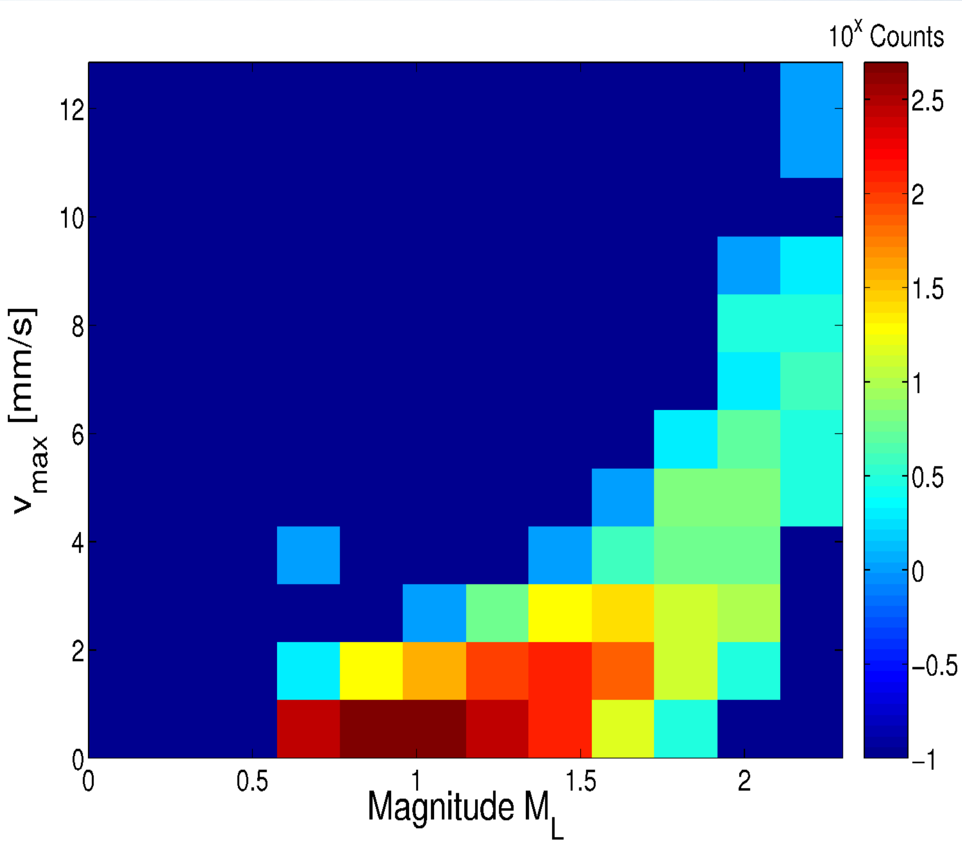


Energy release

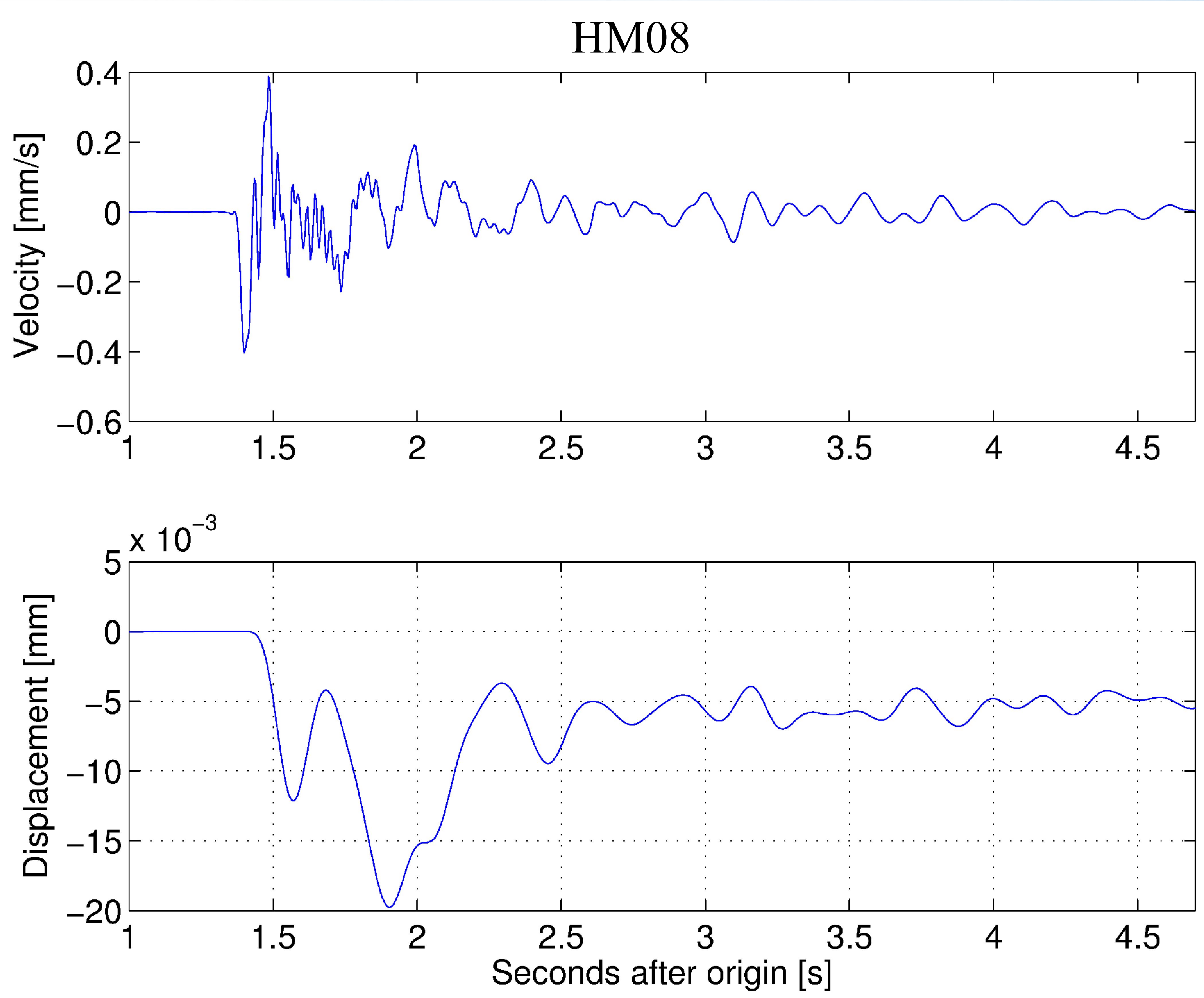


Ground motion - Hamm





Near-field effects

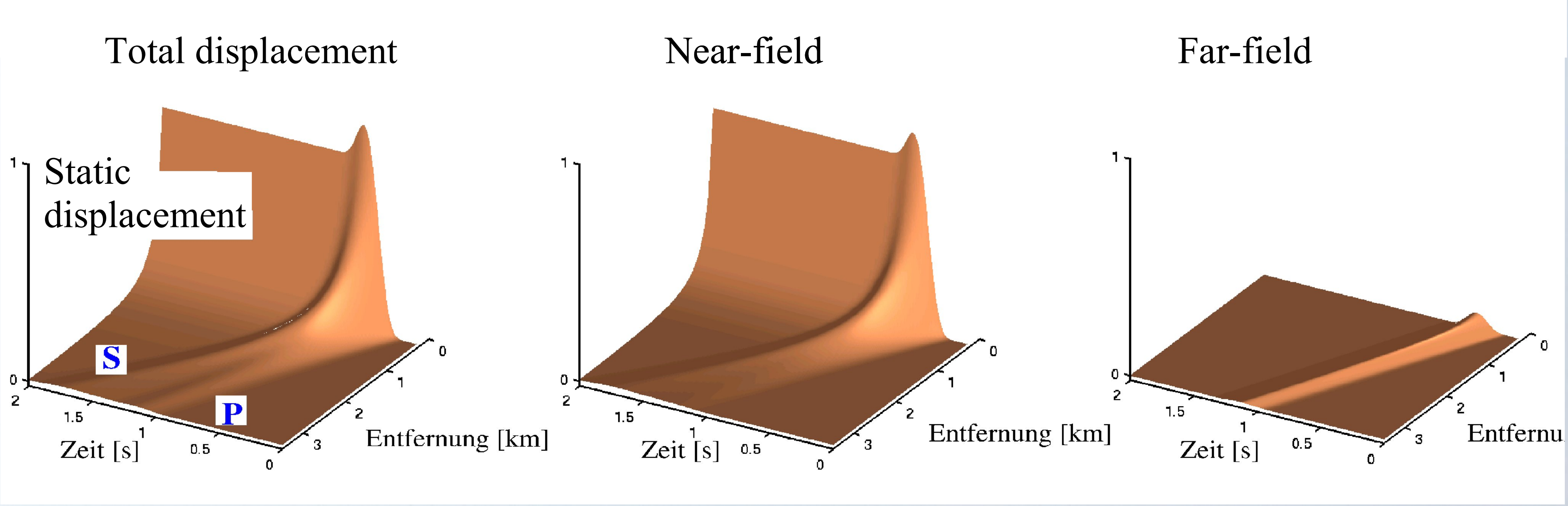


Near-field effects

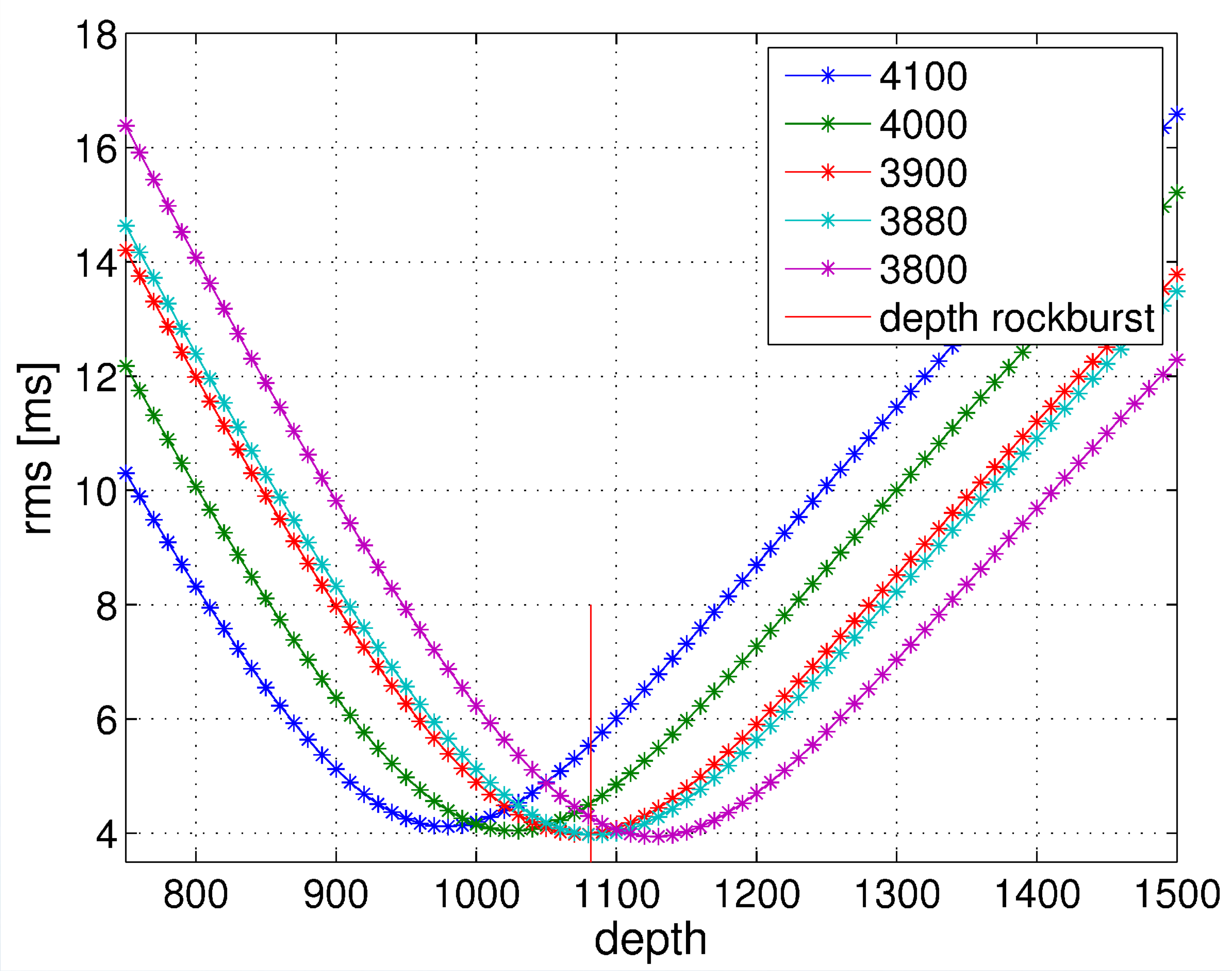
$$
\begin{aligned}
\mathbf{u}(\mathbf{x},\mathbf{t}) &= \frac{1}{4\pi\rho}\mathbf{A}^{N}\frac{1}{r^4}\int_{\frac{r}{\alpha}}^{\frac{r}{\beta}}\tau M_0(t-\tau)d\tau \\
&+ \frac{1}{4\pi\alpha^2}\mathbf{A}^{IP}\frac{1}{r^2}M_0(t-\frac{r}{\alpha}) + \frac{1}{4\pi\beta^2}\mathbf{A}^{IS}\frac{1}{r^2}M_0(t-\frac{r}{\beta}) \\
&+ \frac{1}{4\pi\alpha^3}\mathbf{A}^{FP}\frac{1}{r}\dot{M}_0(t-\frac{r}{\alpha}) + \frac{1}{4\pi\beta^3}\mathbf{A}^{FS}\frac{1}{r}\dot{M}_0(t-\frac{r}{\beta})
\end{aligned}
$$

(Aki & Richards, 1980)

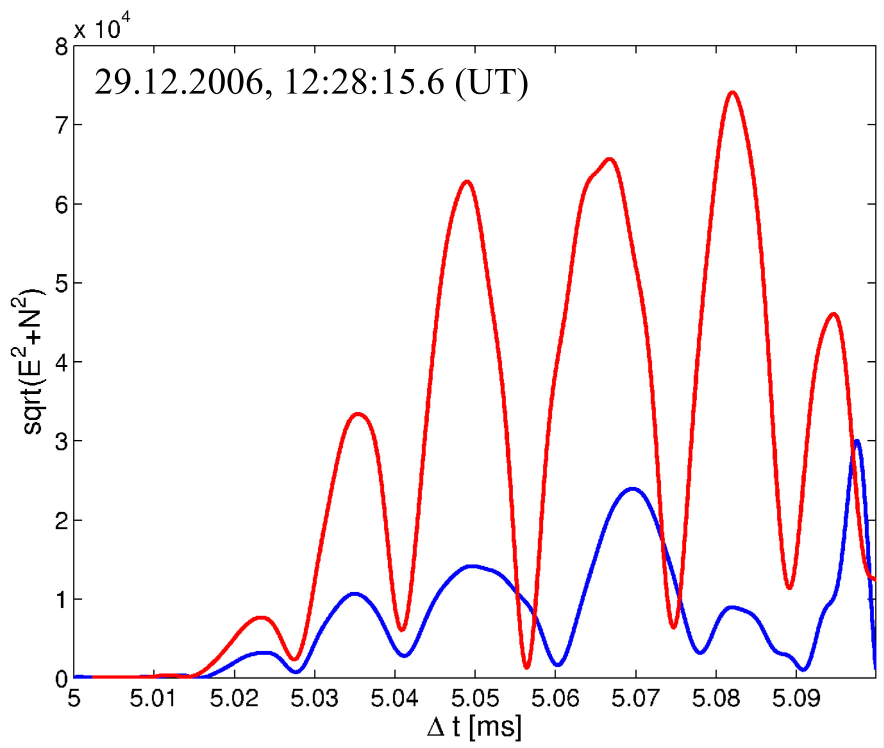
Radial component



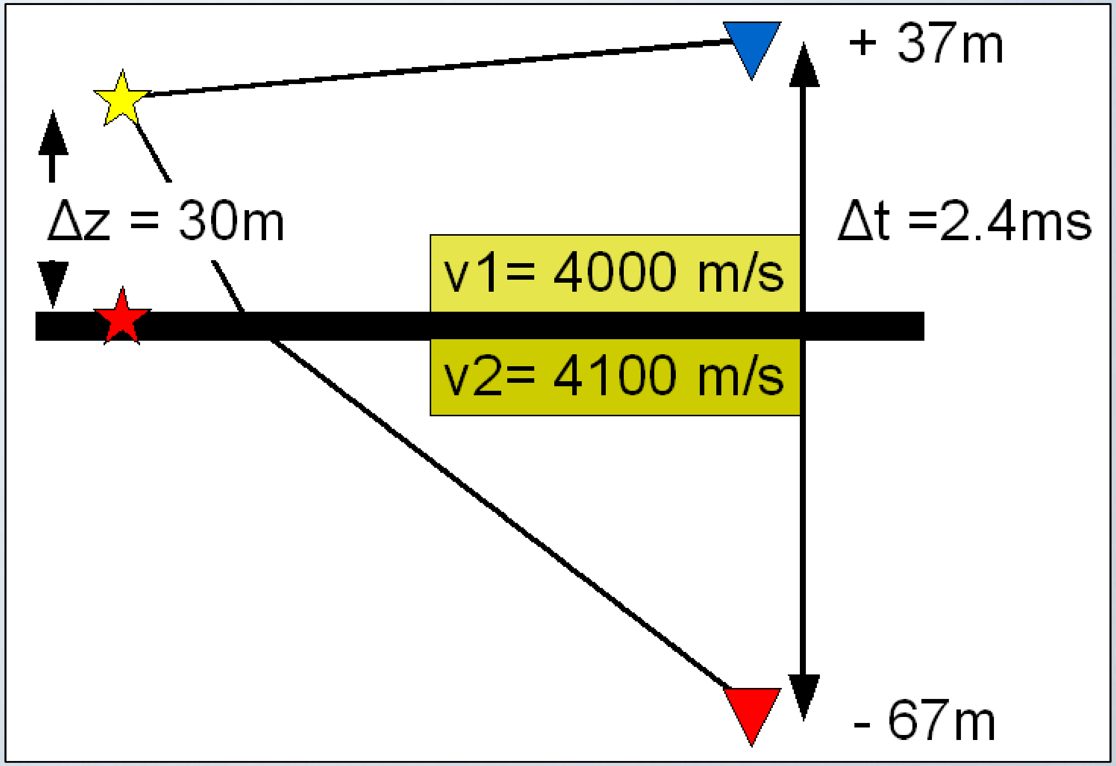
Localization



Determination of depths with subsurface stations

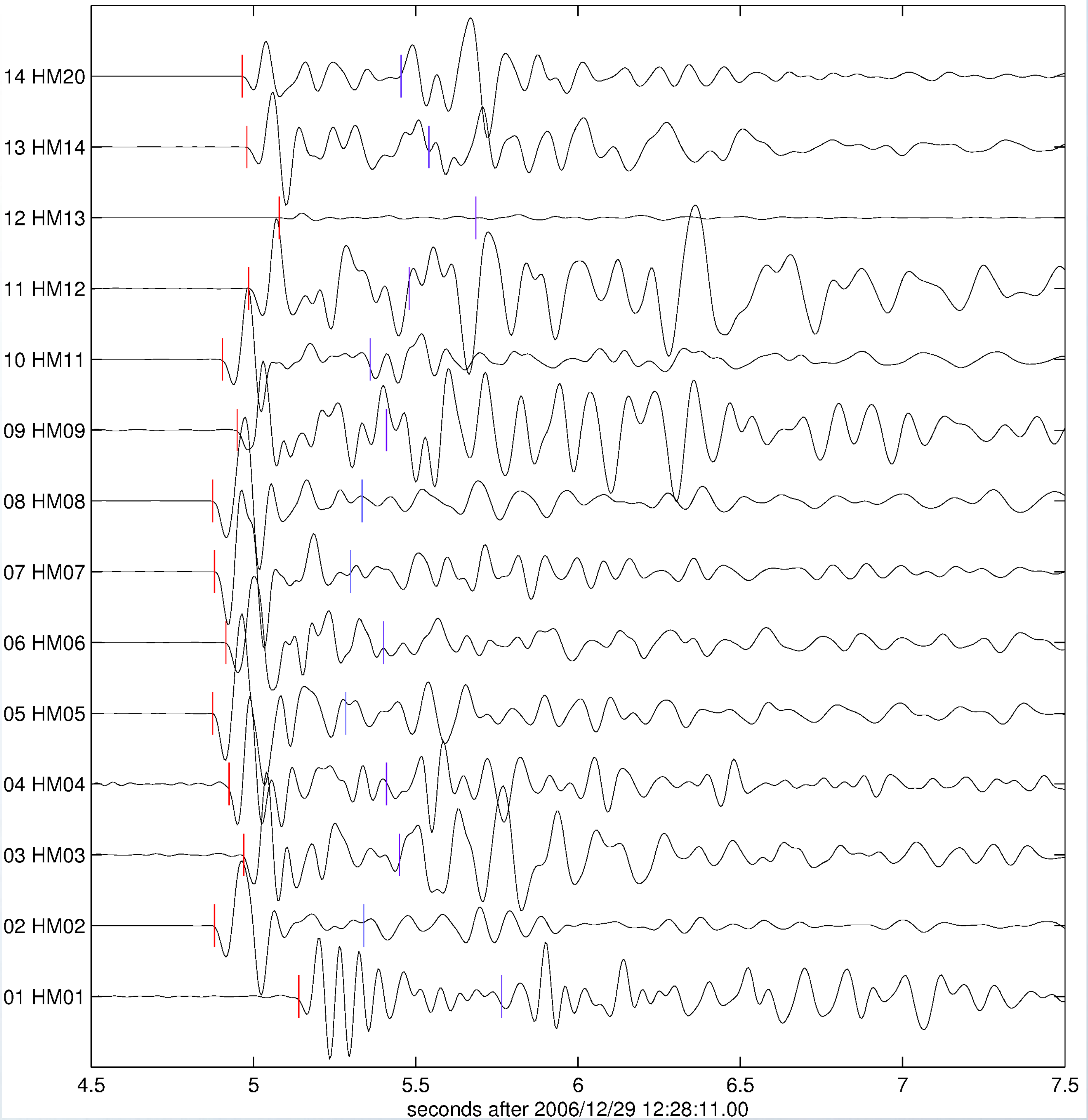


=> synthetics:
v1 = 4000 m/s above longwall
v2 = 4100 m/s below longwall

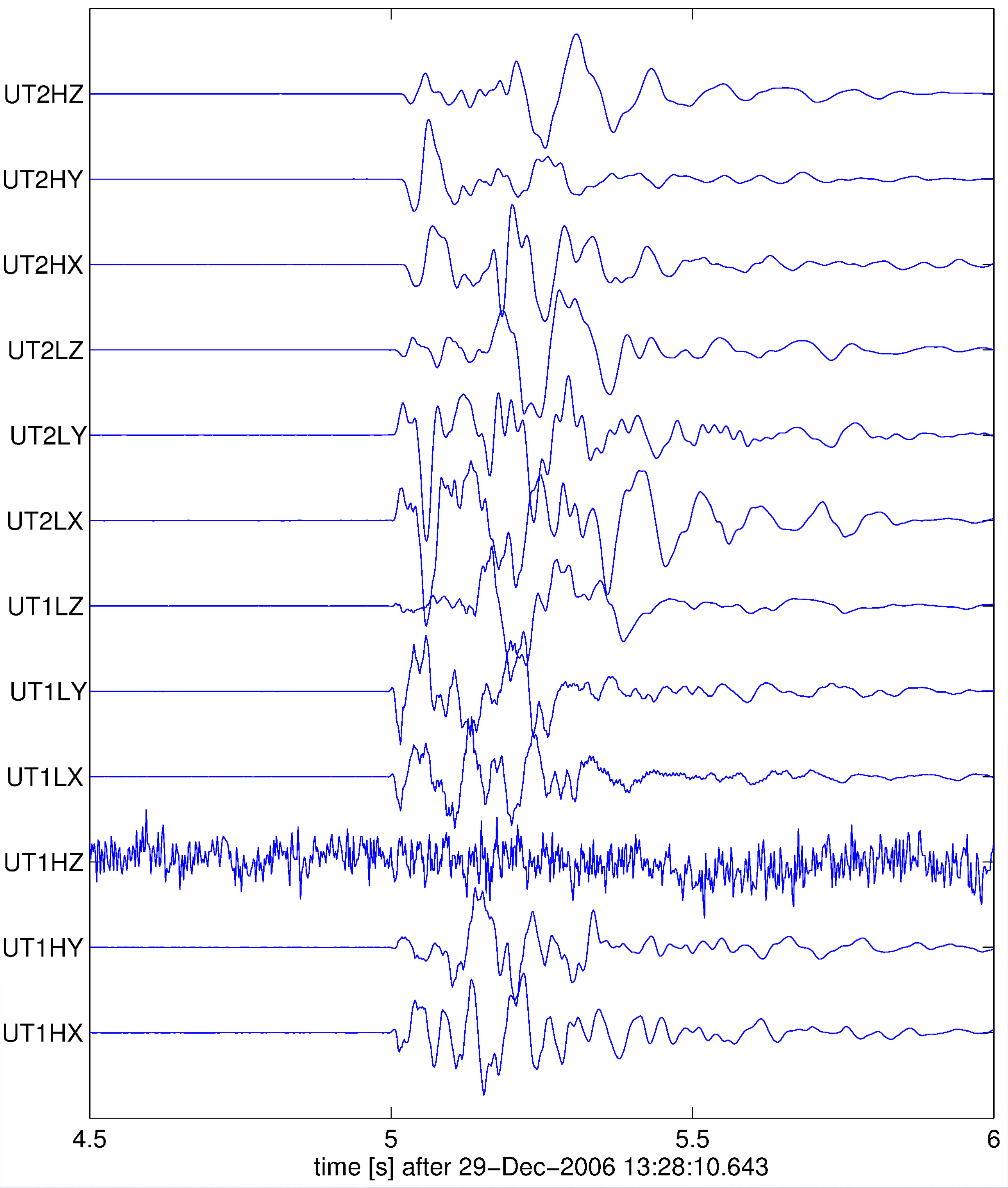


- Travel time difference is in the order of sampling rate
- Maximum amplitude of horizontal ground velocity
- First onset earlier at UT1L: $\Delta t = 2.4$ ms

29.12.2006, 12:28:15.6 (UT), $M_L = 1.7$



Subsurface Stations



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Fault plane solution