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Small-Aperture Seismic Array Monitors Vogtland Earthquake Swarm in 2008/09

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Seismic Activity

The most recent intense earthquake swarm in the Vogtland lasted from 6 October 2008 until January 2009. Greatest magnitudes exceeded M3.5 several times in October **(Fig. 1a)** making it the greatest swarm since 1985/86. In contrast to the swarms in 1985 and 2000, seismic moment release was concentrated near swarm onset. Focal area and temporal evolution are similar to the swarm in 2000 **(Fig. 1b)**.

Fig. 1a

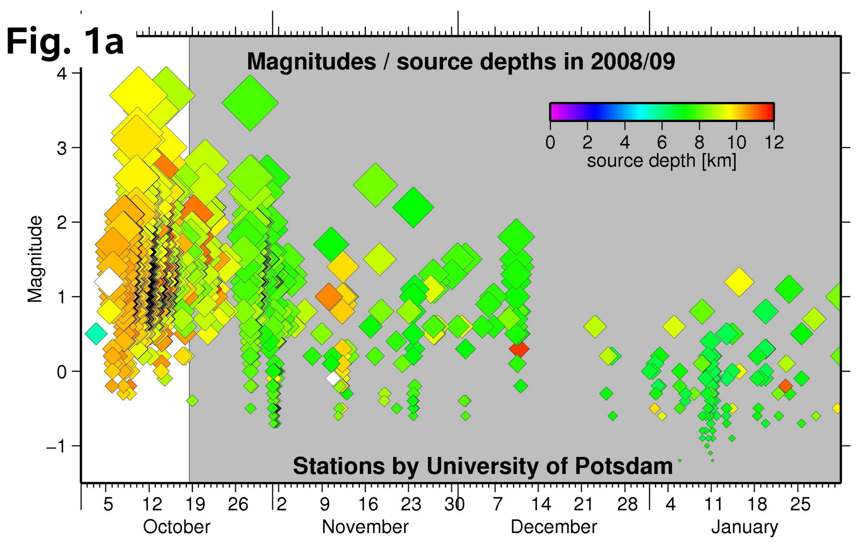
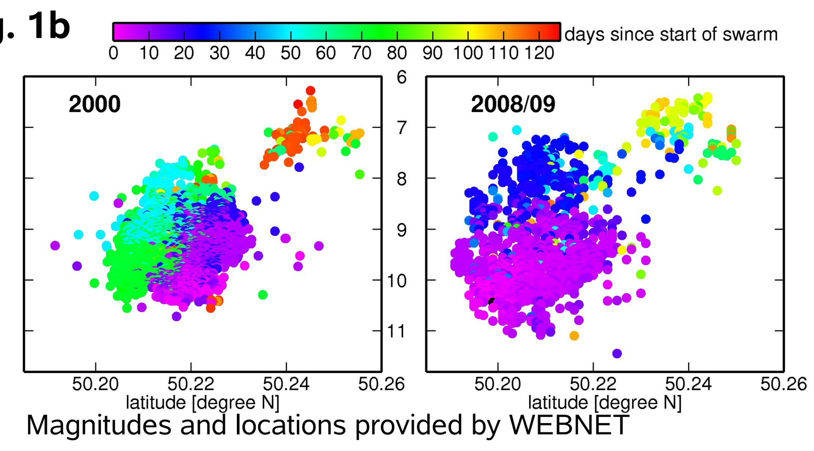


Fig. 1b



Magnitudes and locations provided by WEBNET

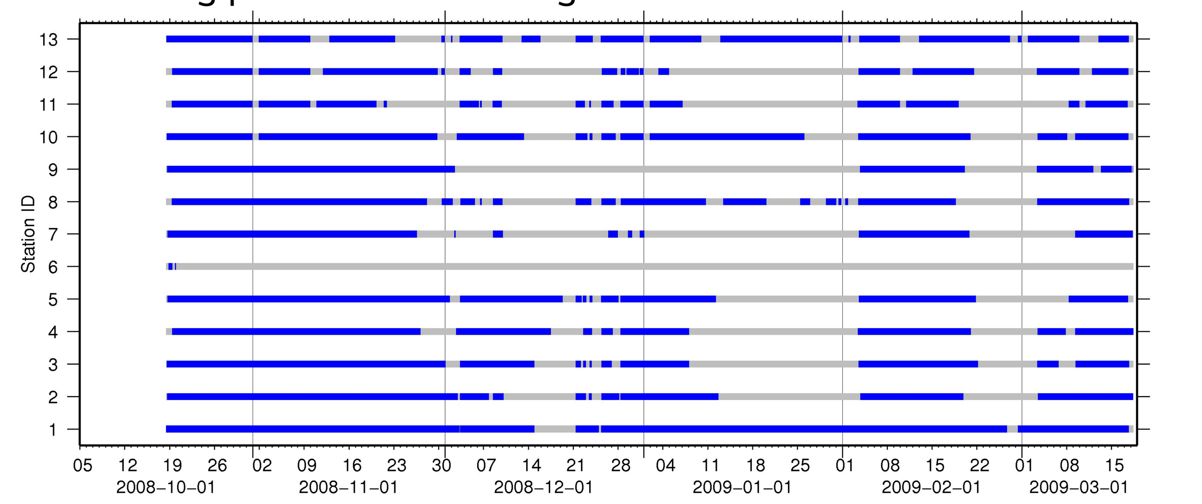
Motivation and Aims

Work hypothesis: uprising upper-mantle fluids trigger swarm earthquakes at low stress level. To monitor the seismicity, the University of Potsdam operated a small aperture seismic array at 10 km epicentral distance between 18 October 2008 and 18 March 2009 **(Fig. 2)**. Consisting of 12 seismic stations and 3 additional microphones (station 13, **Fig. 2**), the array is capable of detecting earthquakes from larger to very low magnitudes (**M<-1**) as well as associated air waves. We use array techniques to determine properties of the incoming wavefield: noise, direct P and S waves, and converted phases.

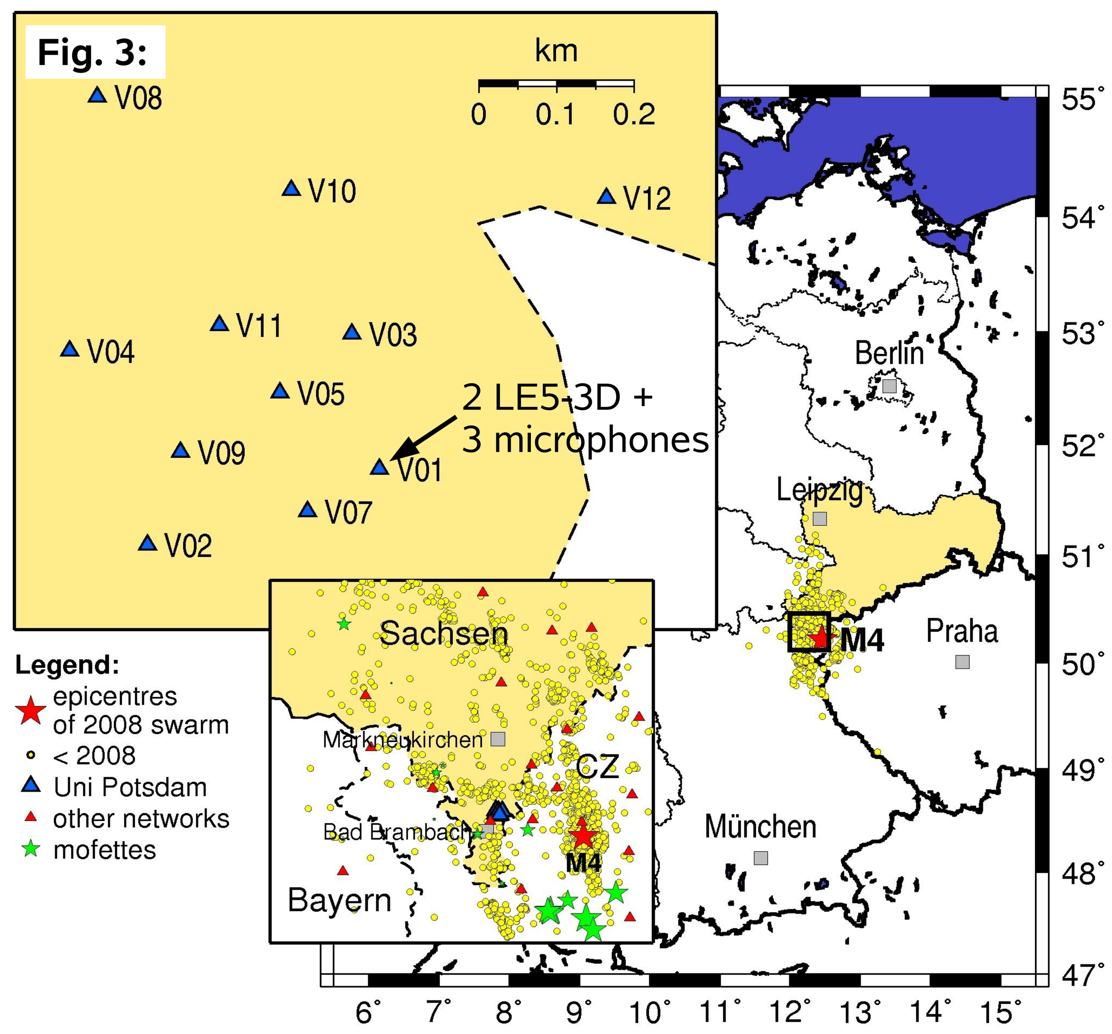
Our goals are:

- Registration of large to very weak earthquakes,
- Identification of local crustal structures to relate earthquakes to geological structures and to sites of gas emanations,
- Studies of source mechanisms and source details assuming finite source extent,
- Correlation of seismic and acoustic signals (often reported but never recorded).

Fig. 2: Stations **in operation** and **gaps** due to power failure during periods of bad sunlight conditions.



Array Setup: 12 LE5-3D Seismometers and 3 Microphones



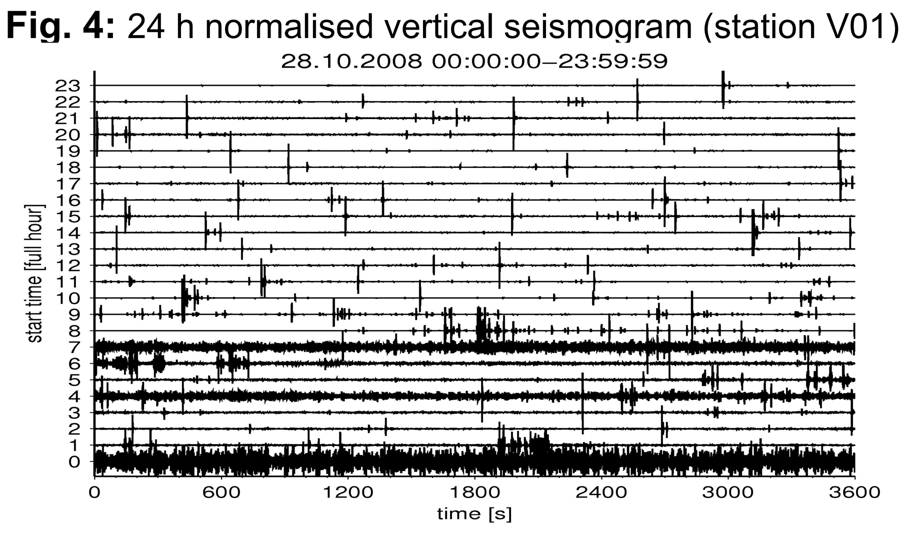
Array specifications:

- ≈ 700 m aperture at 10 km epicentral distance
- 12 LE5-3D sensors (5s corner frequency) buried into ground
- 3 microphones near station V01
- 250 Hz sampling rate
- power supply: solar / battery (buffers for about 1 week)

Observations and First Results

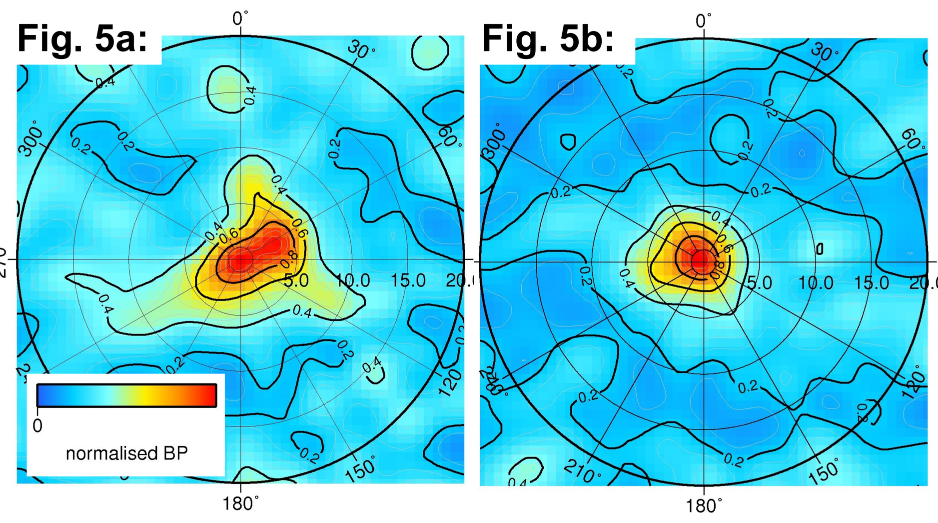
Station installation in the field with waterproof instrument casing, buried sensor, and solar panel.

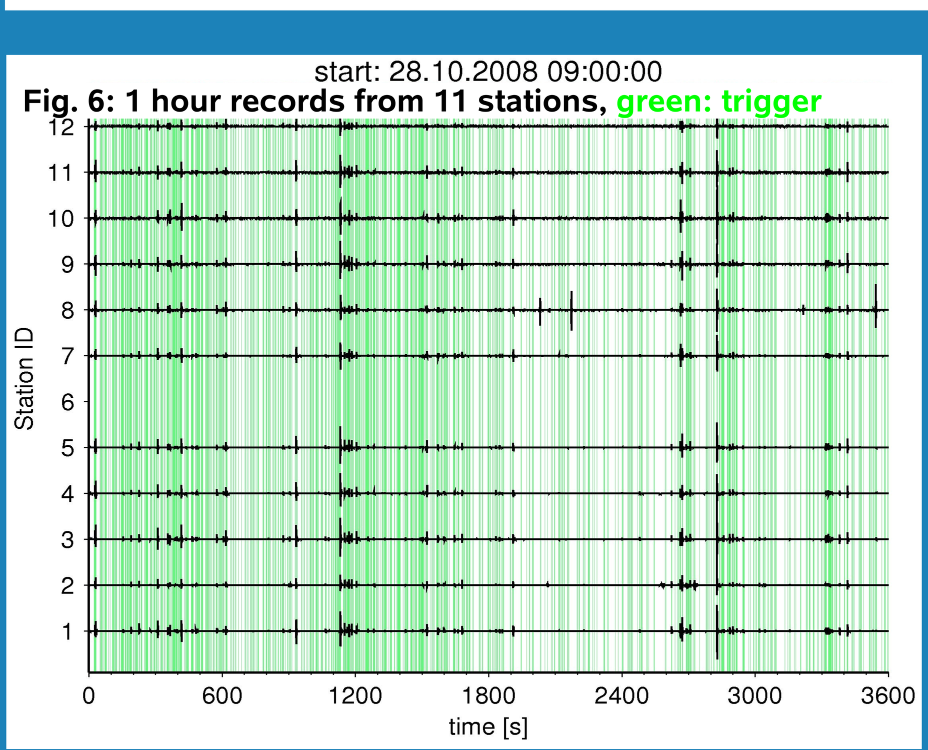
Fig. 4: 24 h normalised vertical seismogram (station V01)



Array Transfer Function

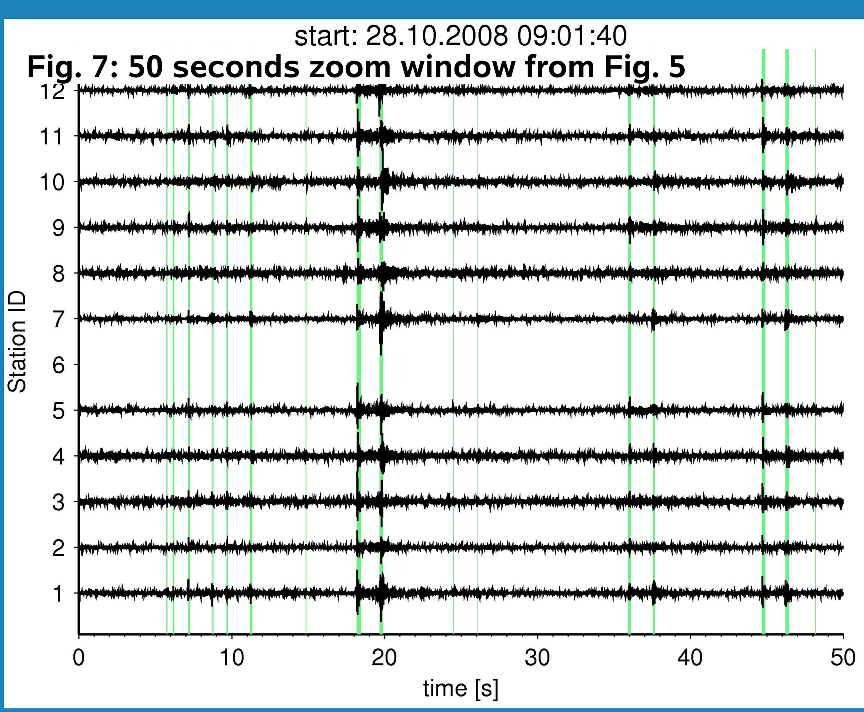
The array response at 5-40 Hz **(Fig. 5a)** shows a pronounced maximum but also smearing. Smearing is reduced by static corrections to account for structure and topography **(Fig. 5b)**.





Automatic Event Detection

We identify earthquakes using a FK detector (moving time windows) combined with a conventional sta/lta trigger. In our example **(Figs. 6-8)** on 28 October 2008, positive trigger (P or S phase) is indicated in **green**. More than **400** single earthquakes were detected **within 1 hour** (8:00-8:59) compared to only **18** events contained in the WEBNET catalogue. **Fig. 6:** Trigger density is overwhelming. Shorter time windows in **Figs. 7 and 8** proof that these detections indeed indicate earthquakes. Detection threshold is well below magnitude -1.



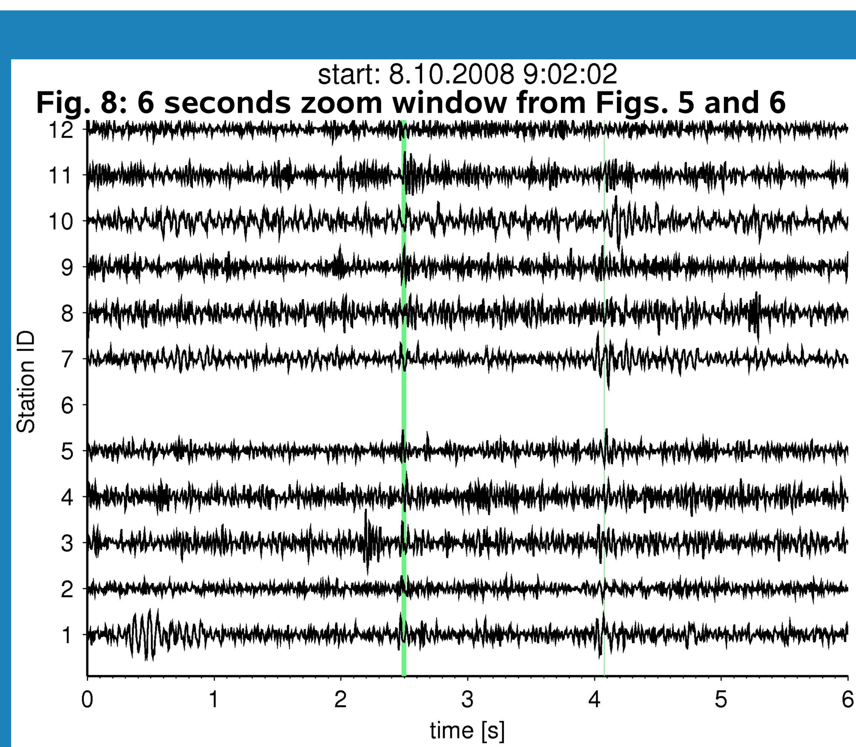


Fig. 9a: Almost daily at noon we record **blasts** from lignite pit in the Eger Graben.

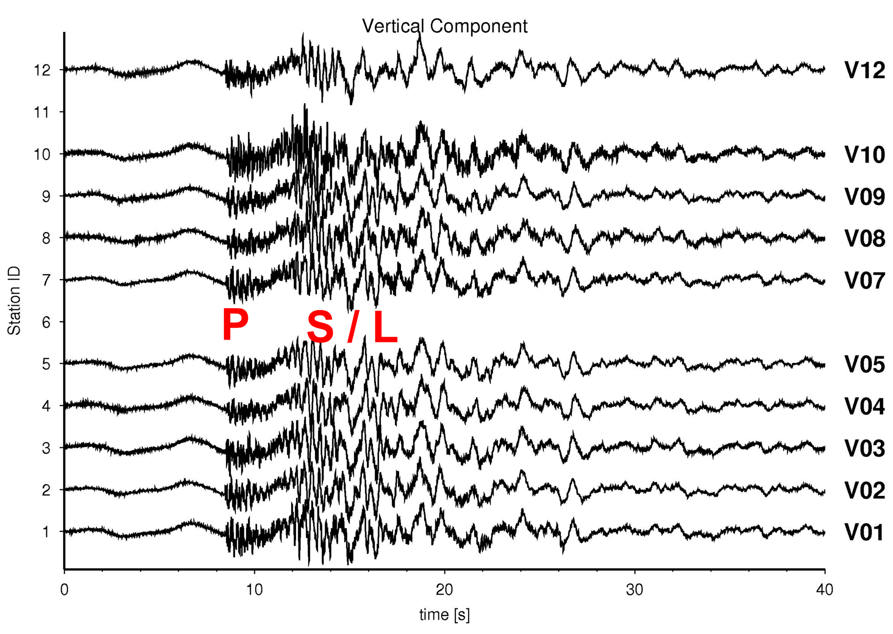
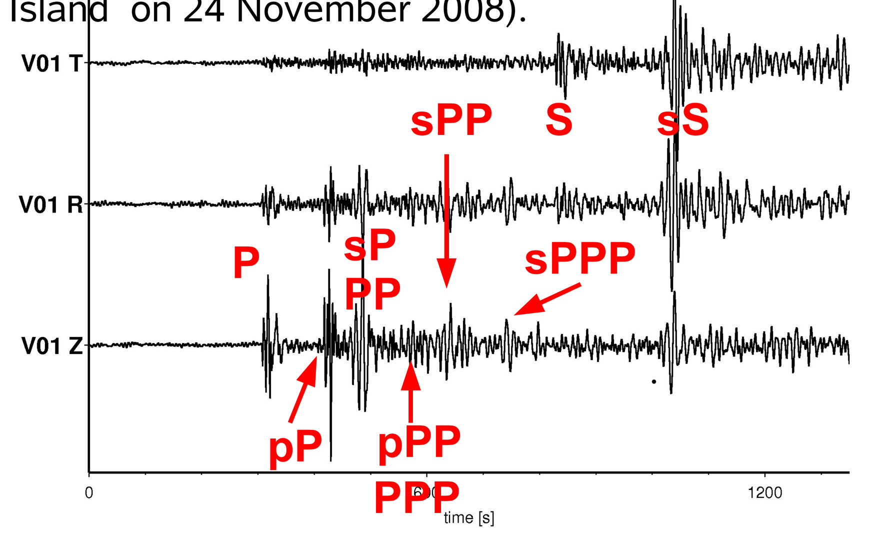


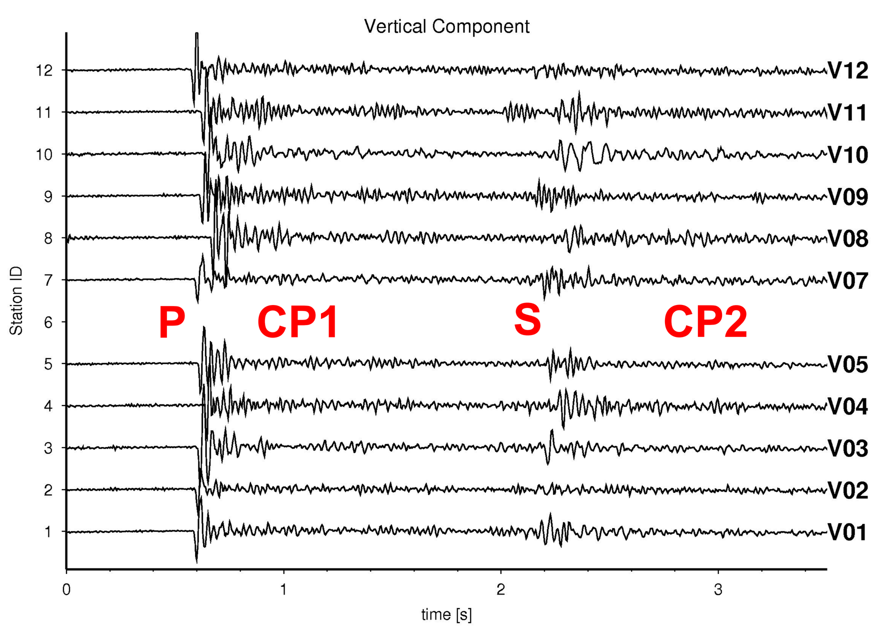
Fig. 9b: Restituted displacement seismograms at station V01 from a **teleseismic deep earthquake** at 71° distance and 480 km depth (Mw7.0, Kuril Island on 24 November 2008).



Acknowledgements: We thank the people of Rohrbach for their very kind provision of instrument sites and H. Kämpf and K. Bräuer for logistic support during station service.

Influence of Geological Structures

Fig. 10a: Vertical component seismograms with P and S waves. Event on 28 October 2008 5:43, Ml is unknown (<1.7).



We use array methods to identify and characterise converted phases indicative of seismic discontinuities. Vespagram and FK analysis are sensitive to earthquake location and geological structure.
Depending on source location, **seismograms** can be relatively simple **(Fig. 11a)** or more complex **(Fig. 10a)**.
Vespagrams (Figs. 10b, 11b) image arrivals of converted phases **(CP)** with varying slowness following the direct P and S waves. Such phases are difficult to detect in single seismograms.
FK diagrams (Figs. 10c, 11c) show converted phases arriving from N90°E whereas the direct P waves arrive from N120°E to N150°E. This indicates heterogeneity and inclined discontinuities along the raypath.

Fig. 11a: Vertical component seismograms with P and S waves. Event: Ml 1.7 on 28 October 2008 10:25.

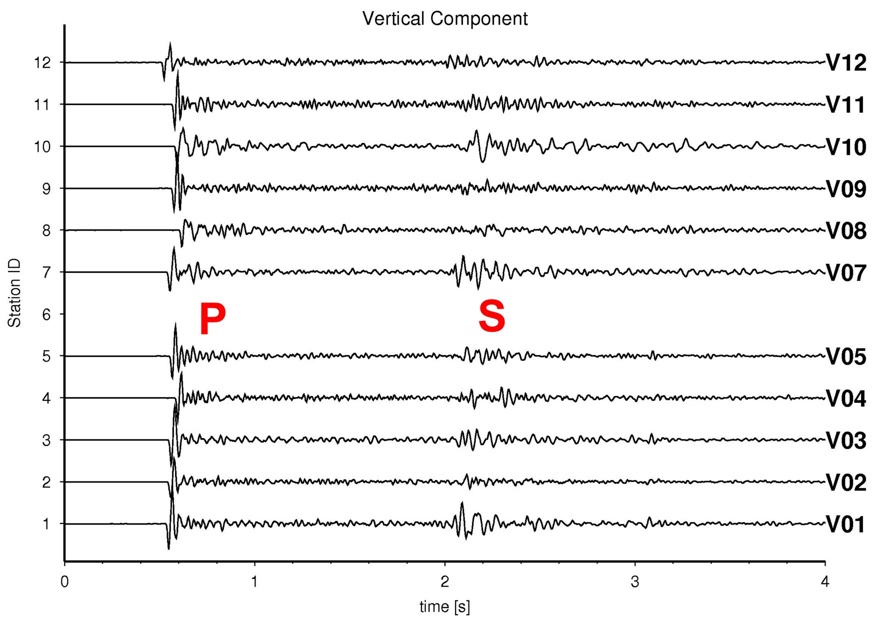


Fig. 10b: Vespagram of the direct and converted **(CP)** waves in **Fig. 10a**.

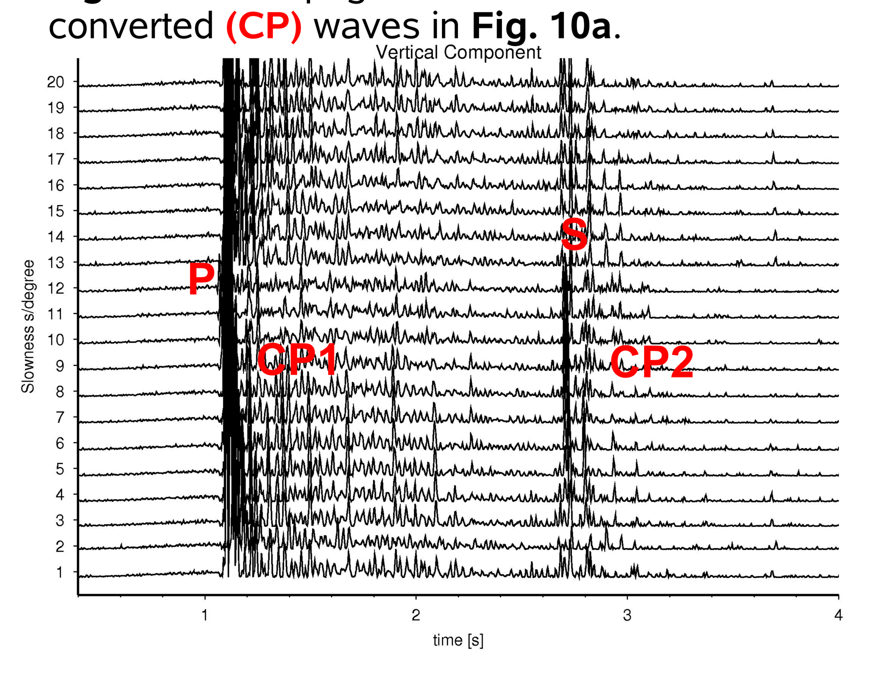


Fig. 10c: FK diagram of P waves in **Fig. 10a.**

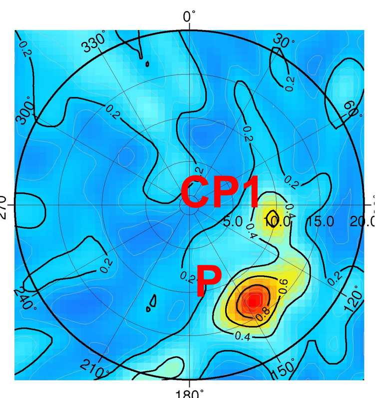


Fig. 11c: FK diagram of P waves in **Fig. 11a.**

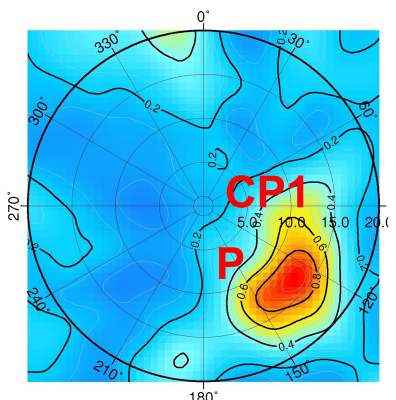


Fig. 11b: Vespagram of the direct and converted waves **(CP)** in **Fig. 11a**.