Determination of prominent crustal discontinuities from waveforms of local earthquakes

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Motivation – structure from local seismicity

Waveforms bring information on source & structure

1. Method – depth & topography of discontinuities

- Passive investigation with local sources – advantage

  Large amount of data ideal for stacking

  Sources far from shallow structure – simpler waveforms

  Data acquisition inexpensive
- High-frequency conversions and reflections at interfaces
- Generated at shallow or deeper interfaces
- Local sources need special processing & interpretation
- Attention to focal mechanism & source-receiver geometry

2. Applications – natural swarm seismicity in West Bohemia

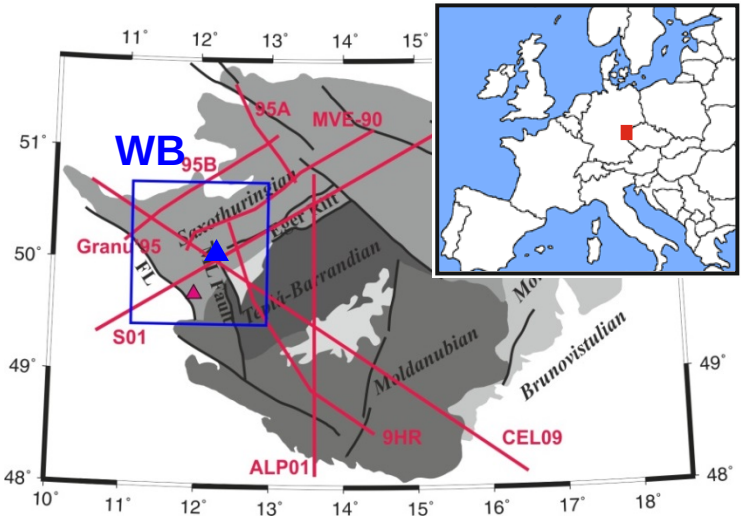
- Shallow structure
- Crust/mantle discontinuity – Moho

West Bohemian Massif

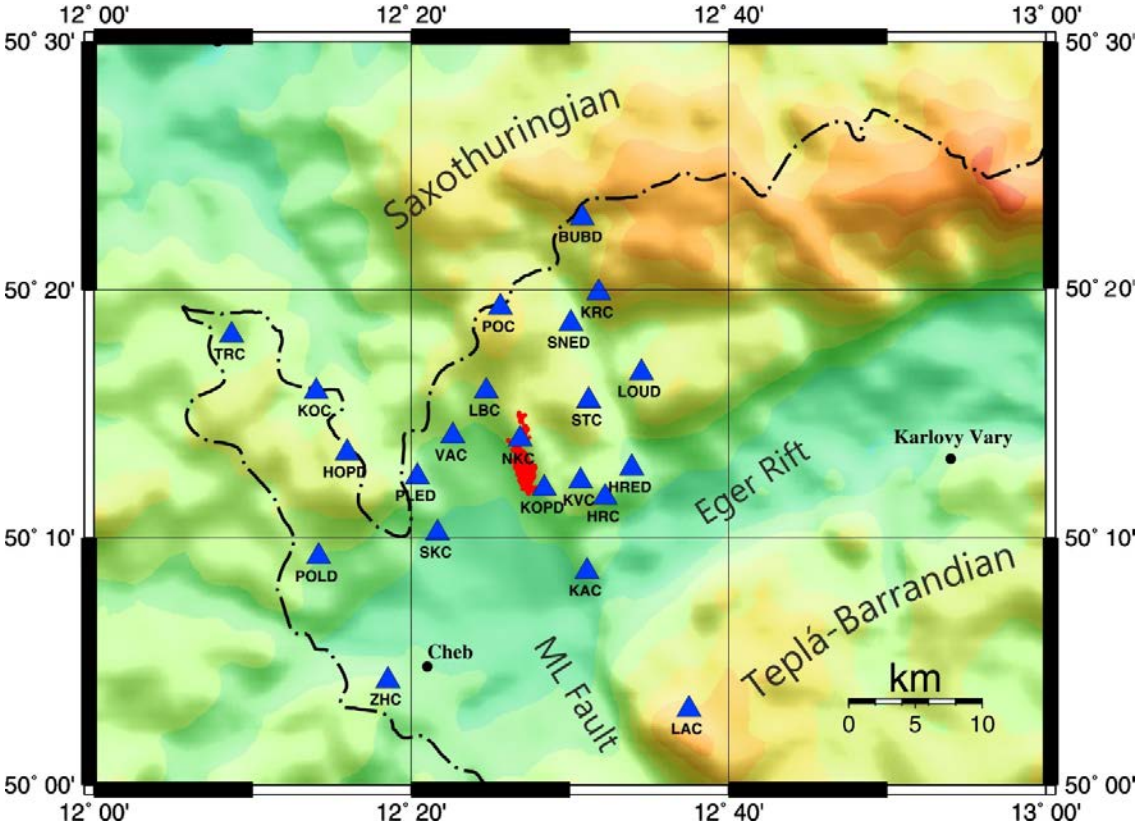
Central Europe

Increased geodynamic activity

Intersection of the Eger Rift & ML fault



Local microearthquakes



WEBNET network

Swarm 2008 $M_L < 3.6$

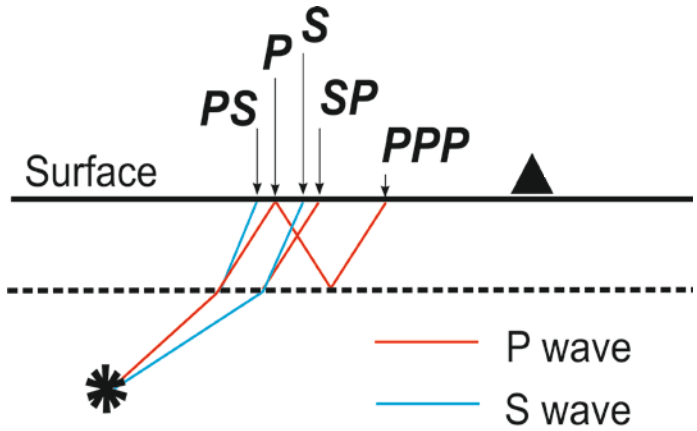
22 stations , filtered 2.5-30 Hz

azimuthal coverage

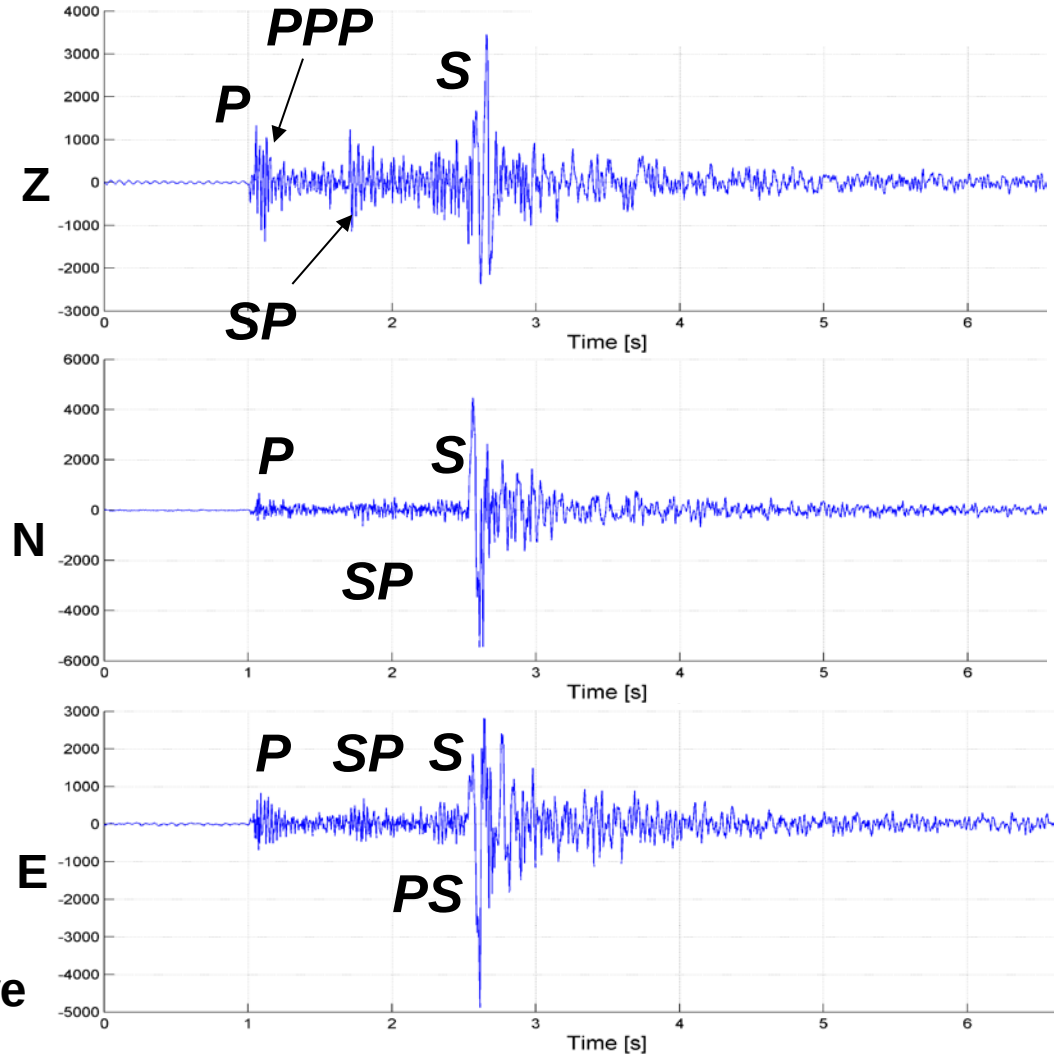
Focal depth 7.6-11 km

~ +/- 50 m (hypo DD)

1. Local microearthquake data



Single-trace view



Generated by weak local sources
Cluster in space & time
High-frequency data
Sensitive to discontinuities

Interpreted phases

Converted & reflected phases

PPP*, *SP* & *PS

Focus on *SP*, *PPP* phase => Z comp.

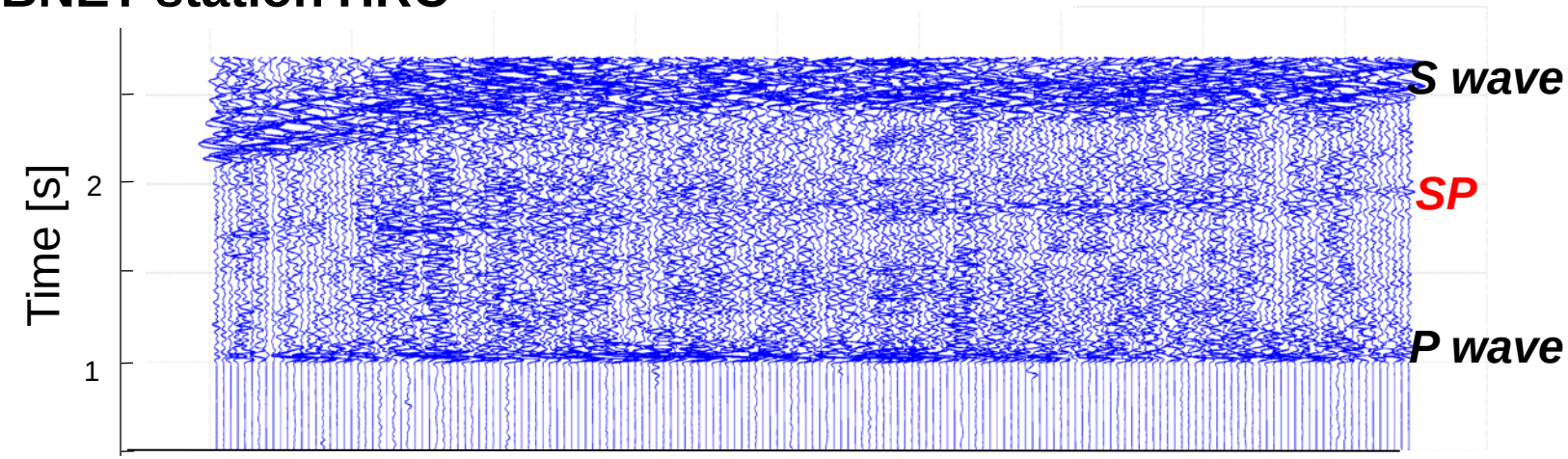
well visible & separated from P wave coda

Local microearthquake data

Multi-trace / seismic section view – Z component

***P*-wave alignment – elimination of local site effects**

WEBNET station HRC



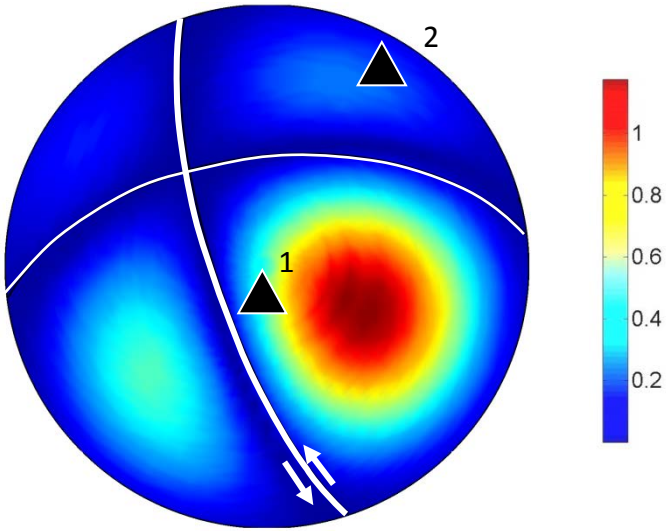
Individual events – *P* wave alignment

Goal – depths in different azimuths
– process each station individually

Radiation pattern analysis

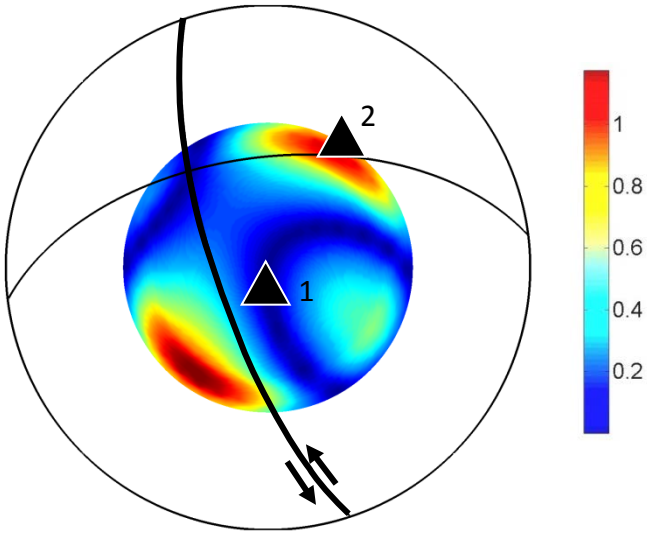
P focal sphere

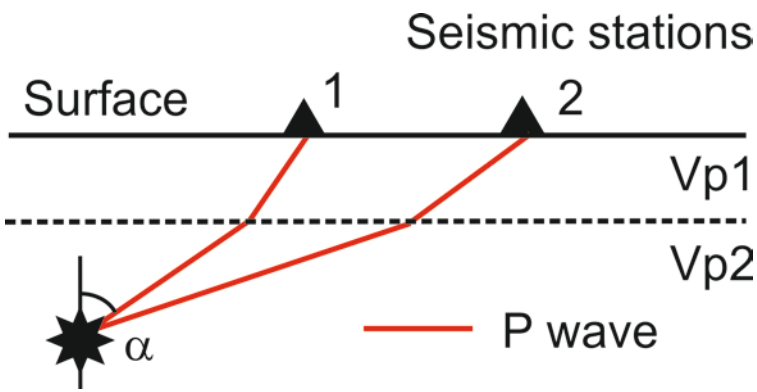
Focal sphere for direct *P* wave

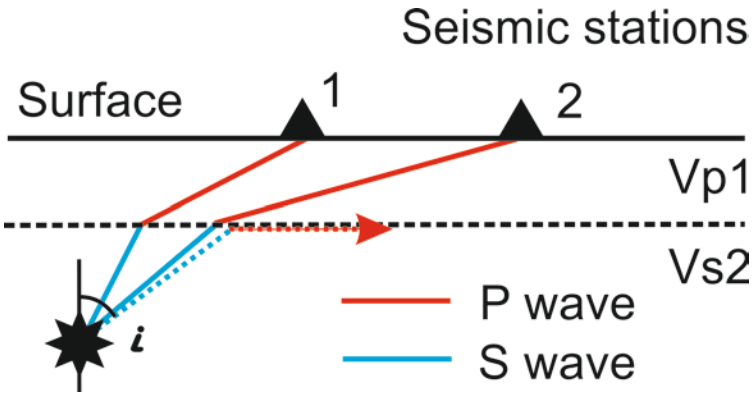


SP focal sphere

Focal sphere for *SP* conversions







limited ray inclinations **sin *i* = Vs2 / Vp1**

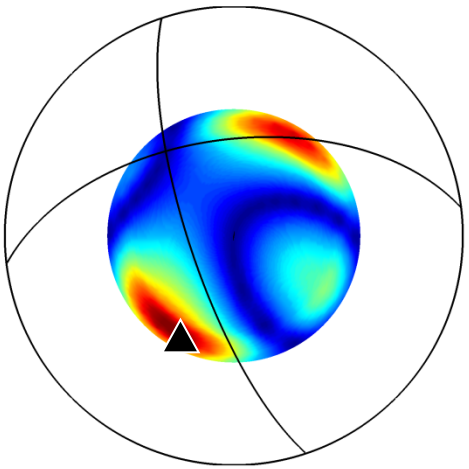
Radiation pattern & synthetic tests

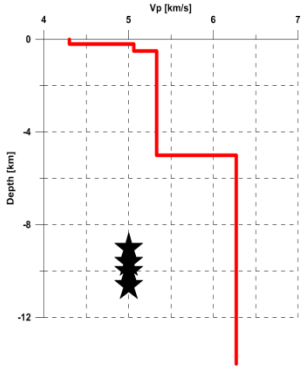
Mechanism 1

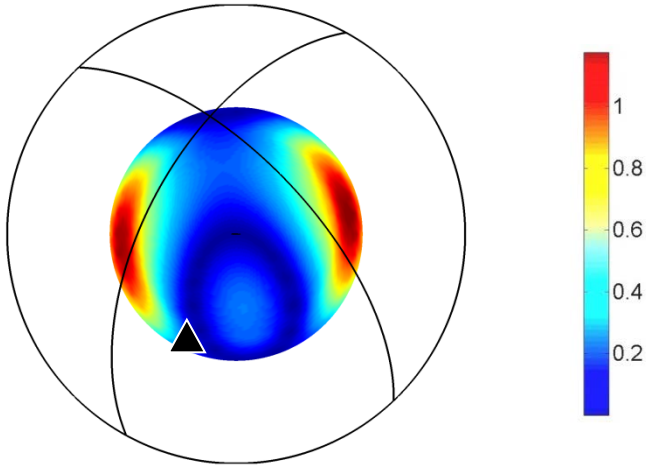
Mechanism 2

Station KRC

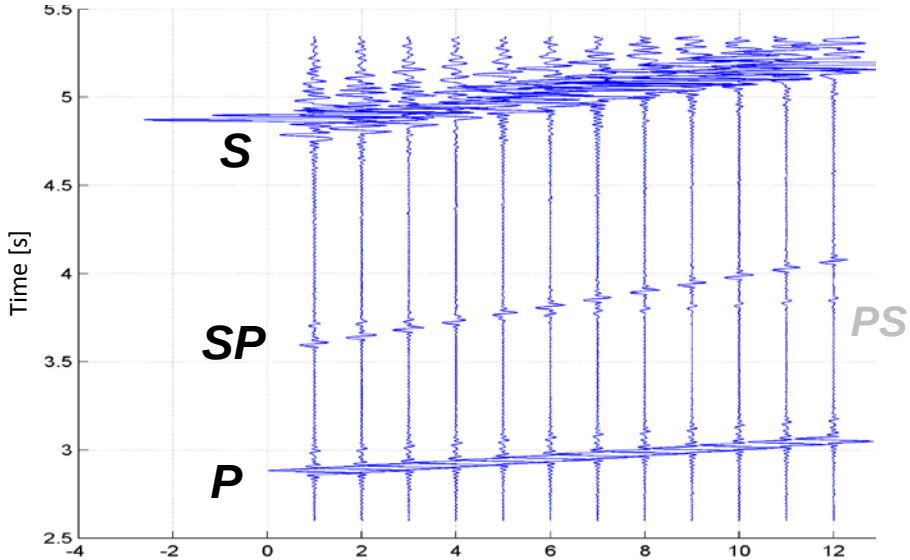
***SP* focal sphere**





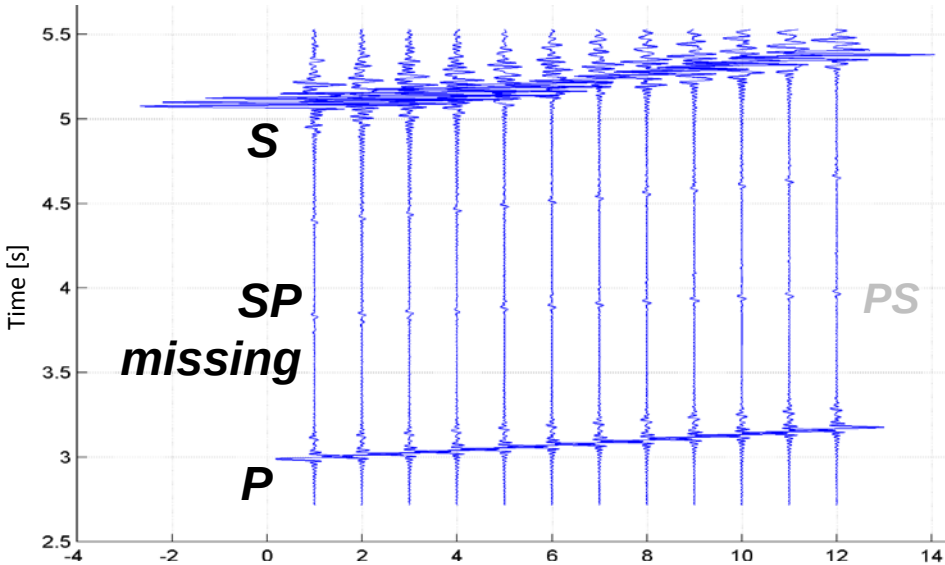


Pronounced-amplitude *SP* phase



Individual events – P wave alignment

Low-amplitude *SP* phase

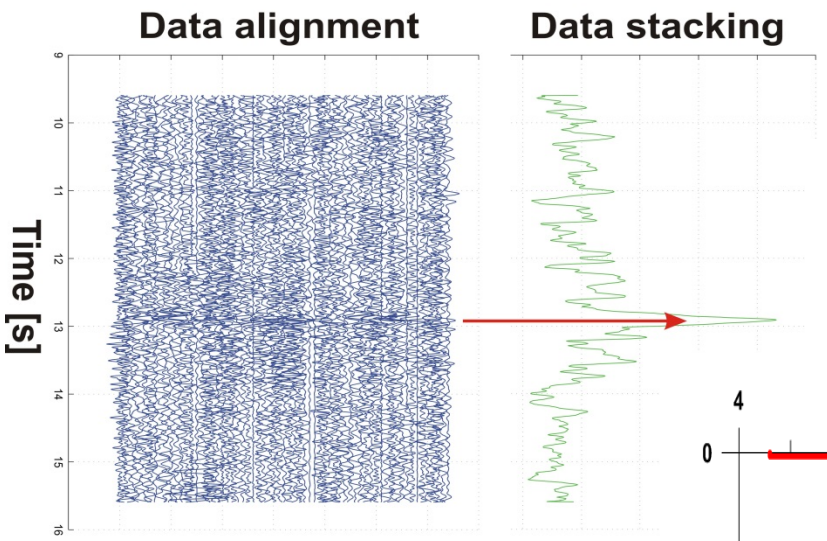


Individual events – P wave alignment

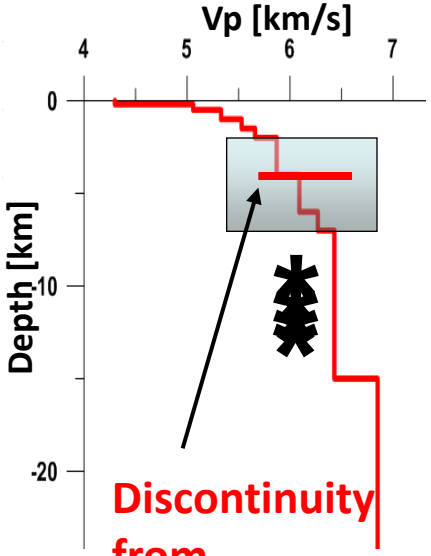
Data processing

for stations with prominent converted phase for given mechanism

Alignment and stacking

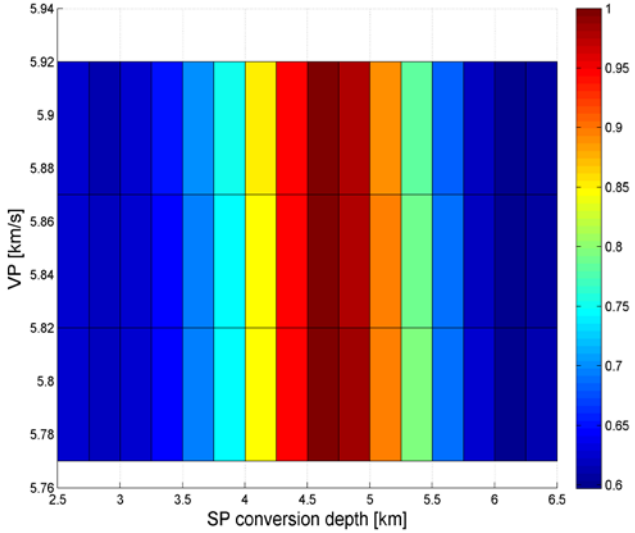


Alignment based on calculated ray-tracing



Discontinuity from conversions

Inversion of stacks with grid search



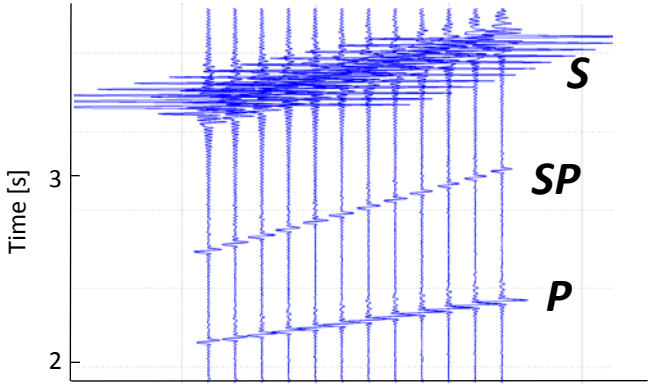
Upper crustal discontinuity in depths between 2-7 km

To remove local structure beneath each station - calculation of *SP* relative to *P* phase

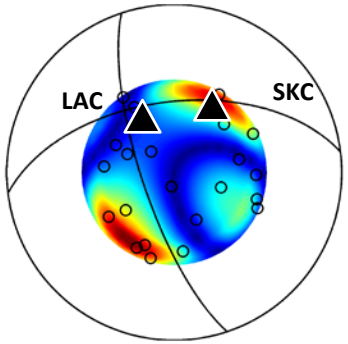
Data – swarm seismicity in WB

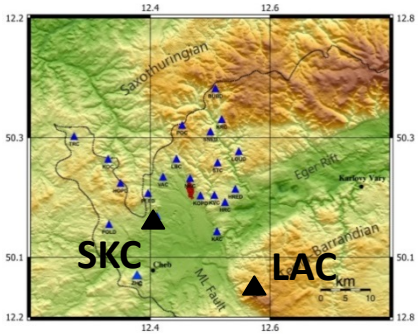
WEBNET – station SKC

Synthetics



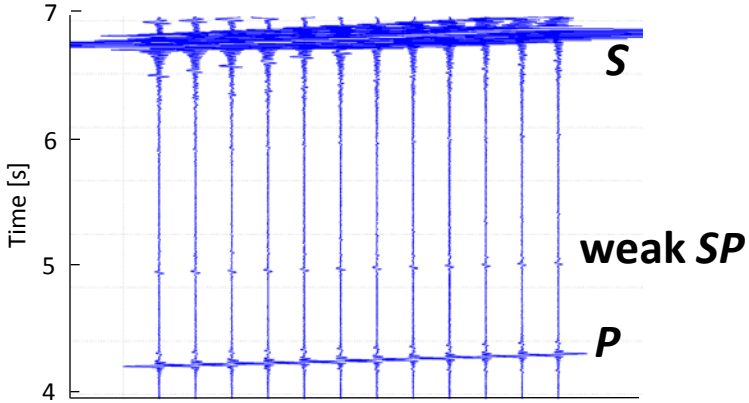
Individual events – P wave alignment





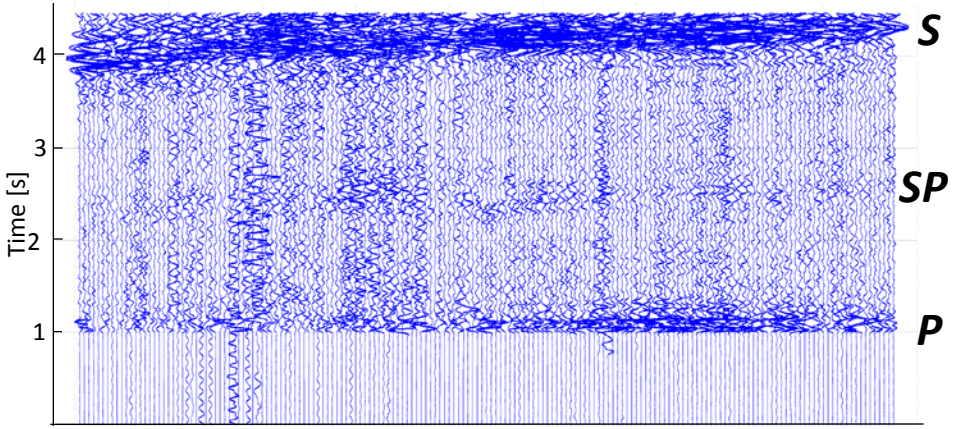
WEBNET – station LAC

Synthetics



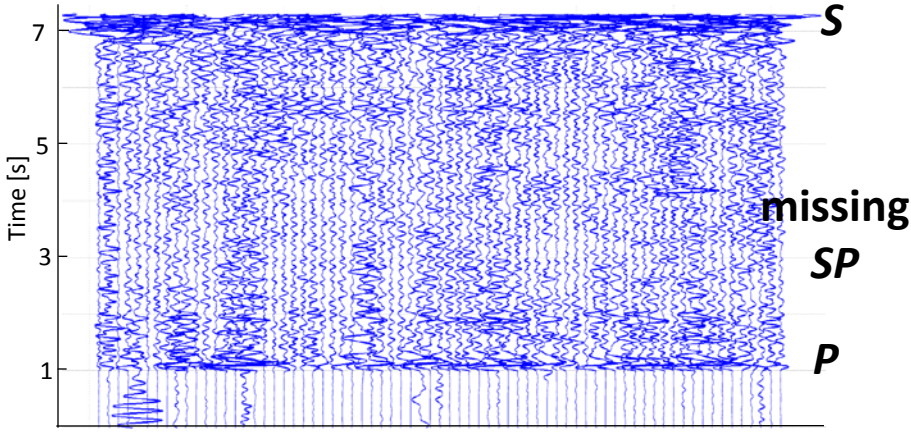
Individual events – P wave alignment

Data



Individual events – P wave alignment

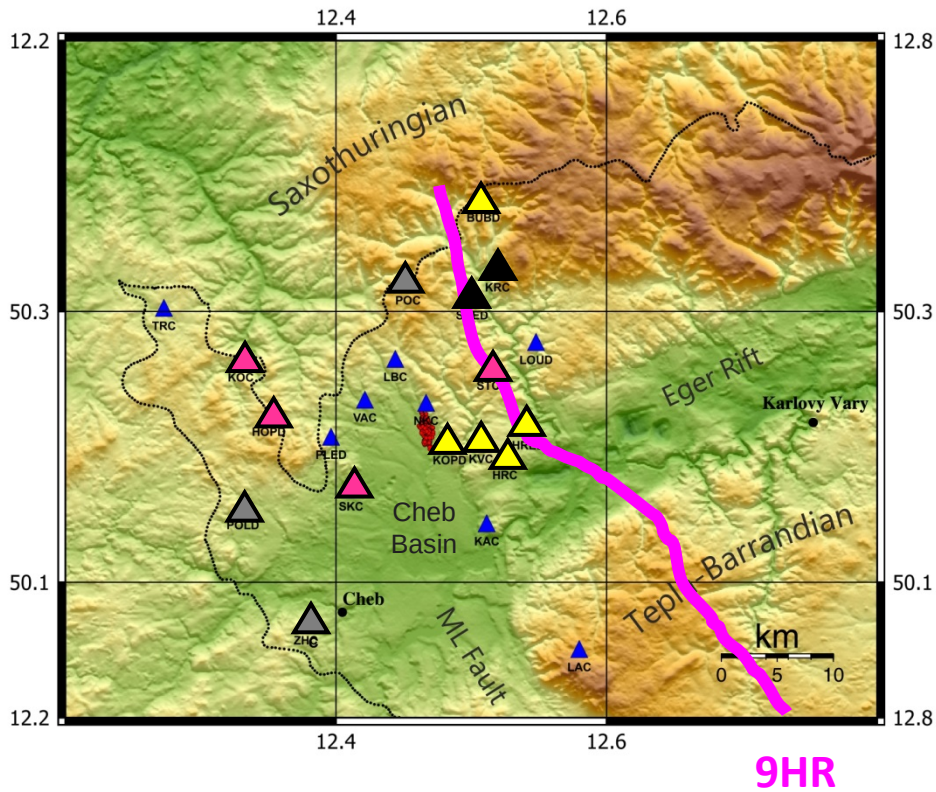
Data



Individual events – P wave alignment

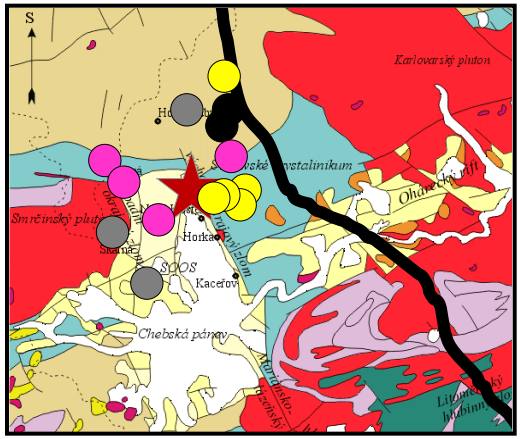
Results – shallow structure in WB

WEBNET network

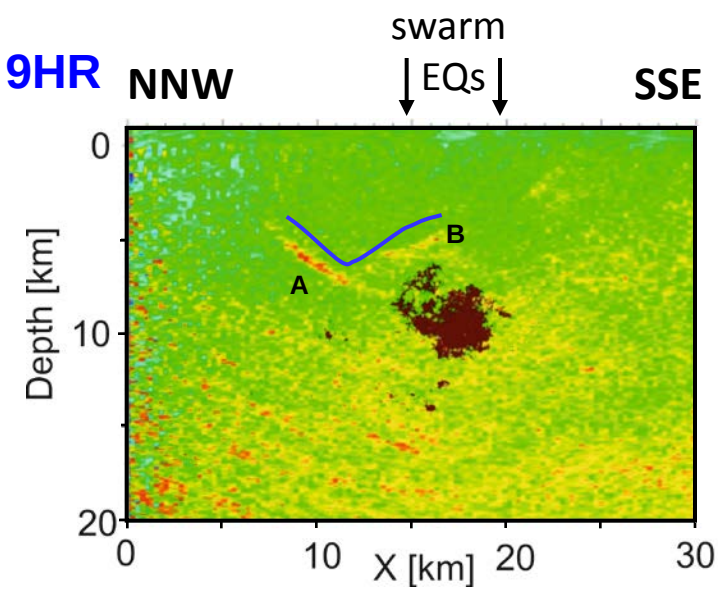


- Interface depth 3.5 km
- Interface depth 4.5 km
- Interface depth 5.5 km
- Interface depth 6.5 km

Geological map

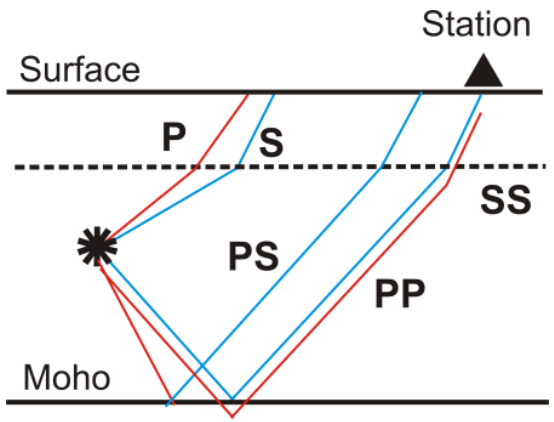


9HR



after Mullick et al., 2015

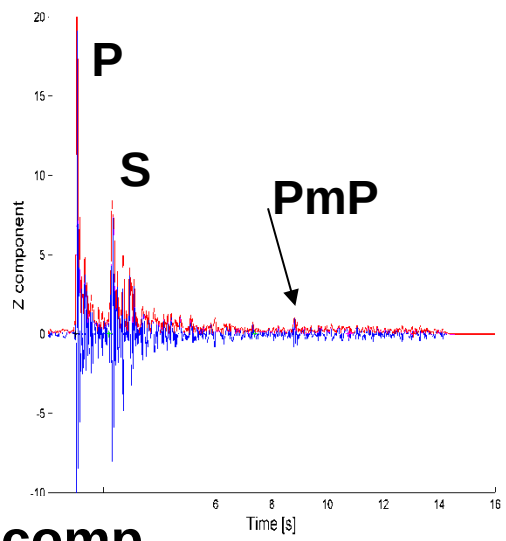
Moho topography from *SmS* reflections



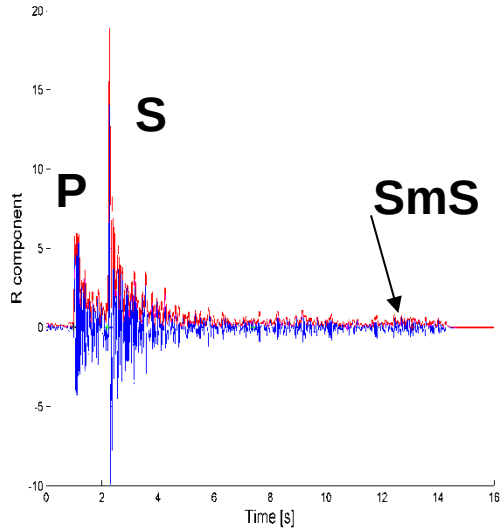
Swarm 2008
High quality data, 250 Hz
3 components
High frequency data

Phases used for interpretation

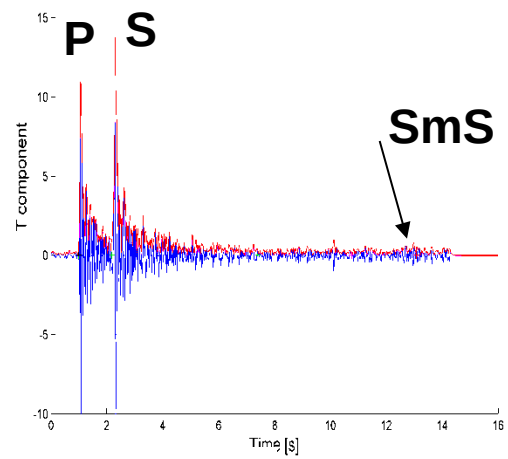
Moho reflected & converted phases
SmS, PmP, PmS



Z comp



R comp



T comp

Each station individually – lateral Moho variations

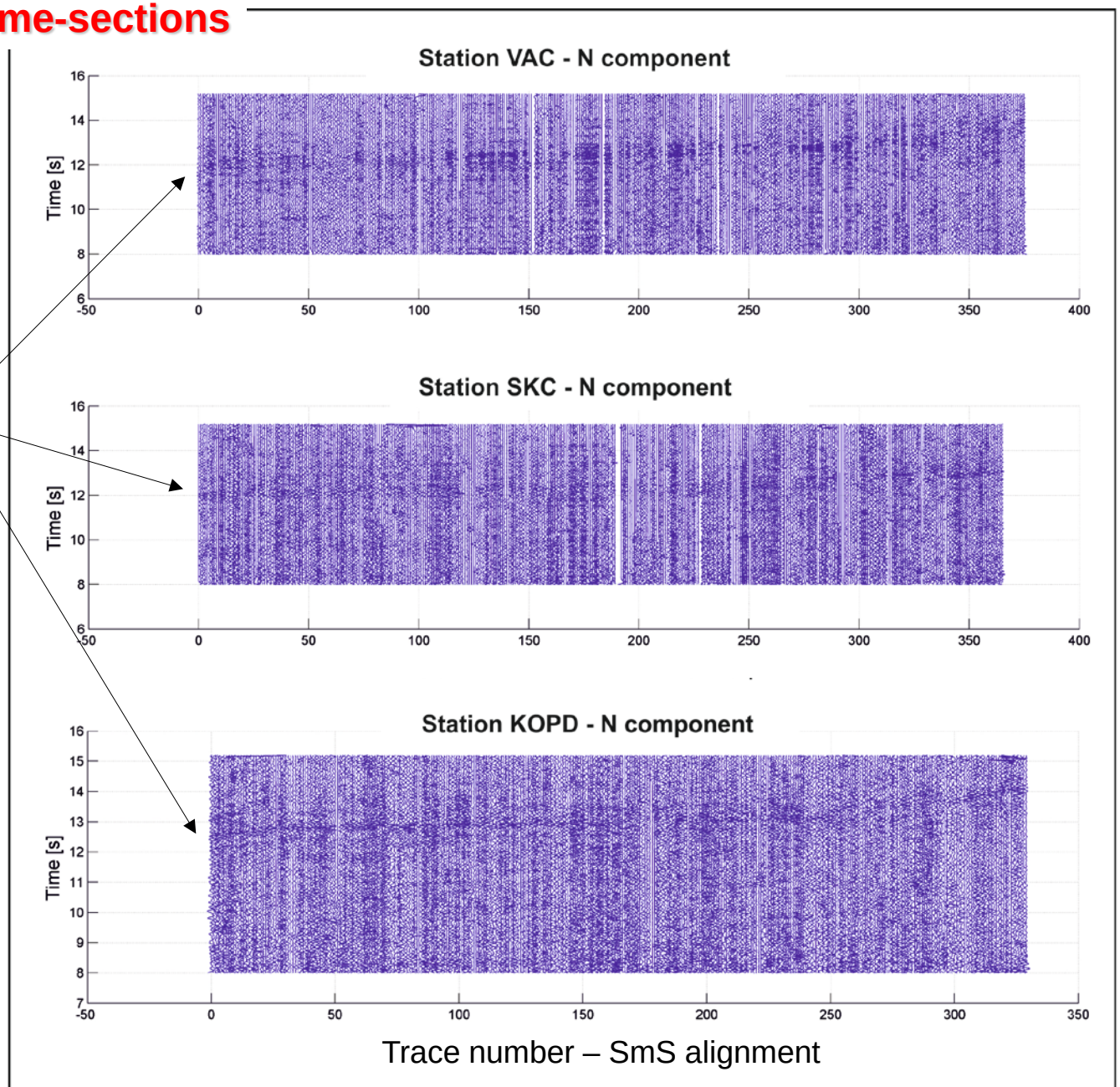
Data – *SmS* Moho reflections

When plotted as time-sections

***SmS* phases**

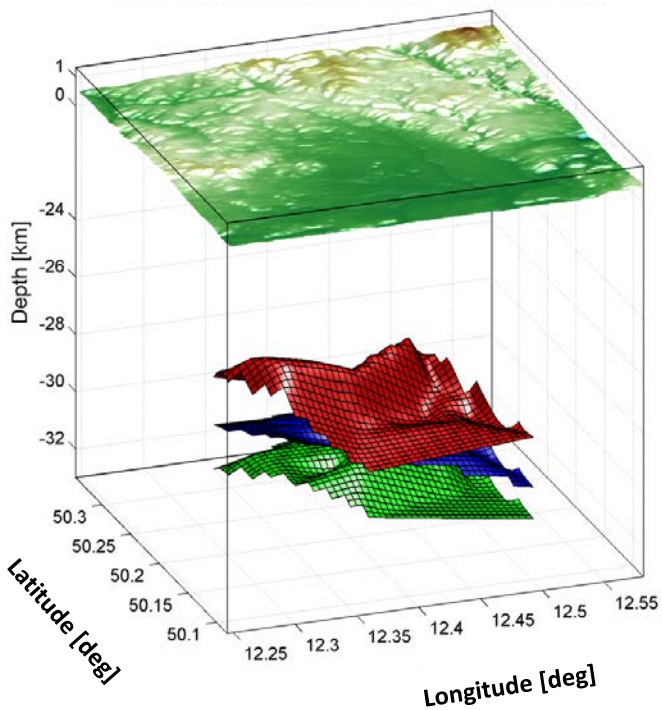
470 events
22 stations

9,000 waveforms
3 components

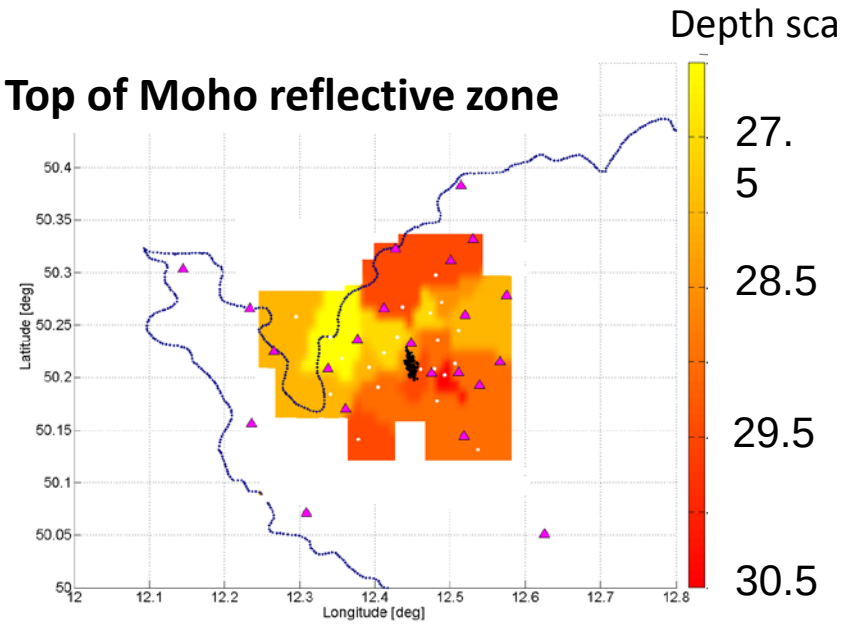


Moho topography from *SmS* reflections

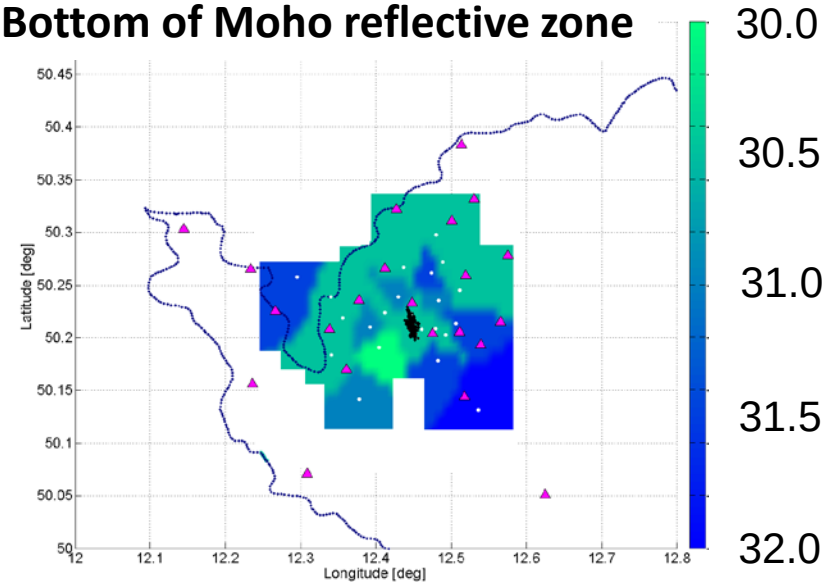
Moho reflective zone



Top of Moho reflective zone



Bottom of Moho reflective zone



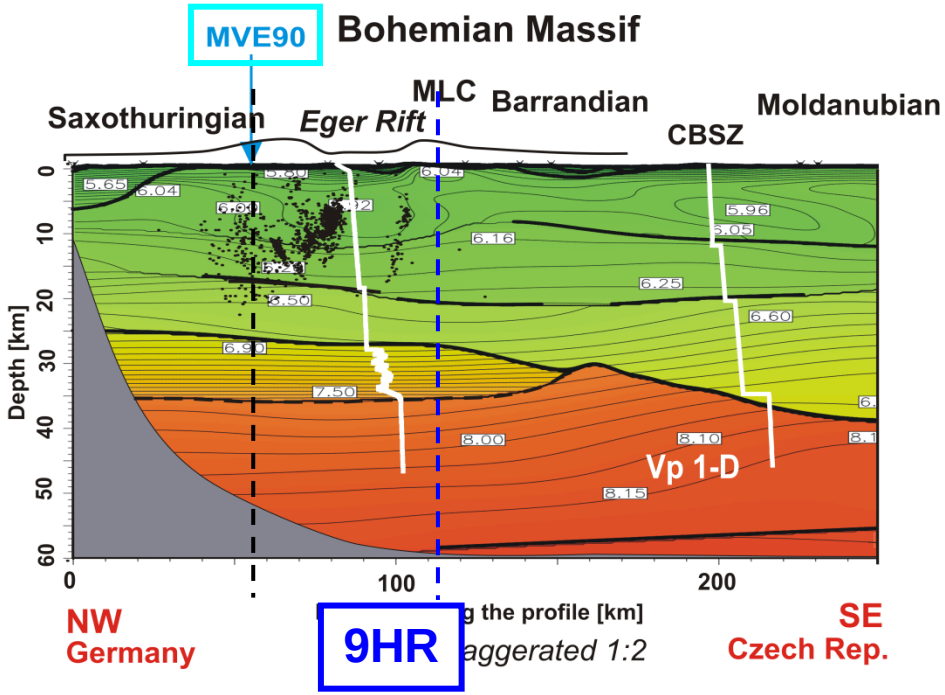
West Bohemia – previous investigation

Active & passive seismic investigation

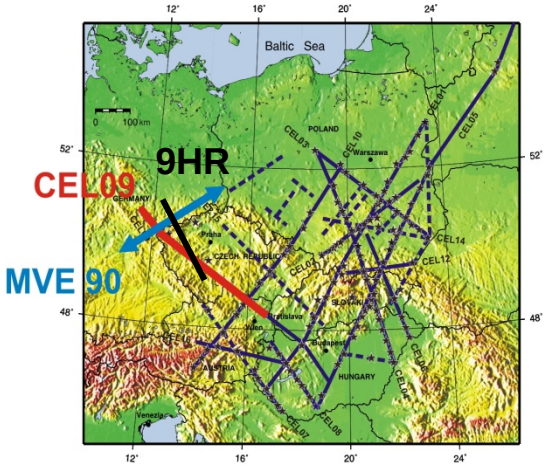
Receiver function

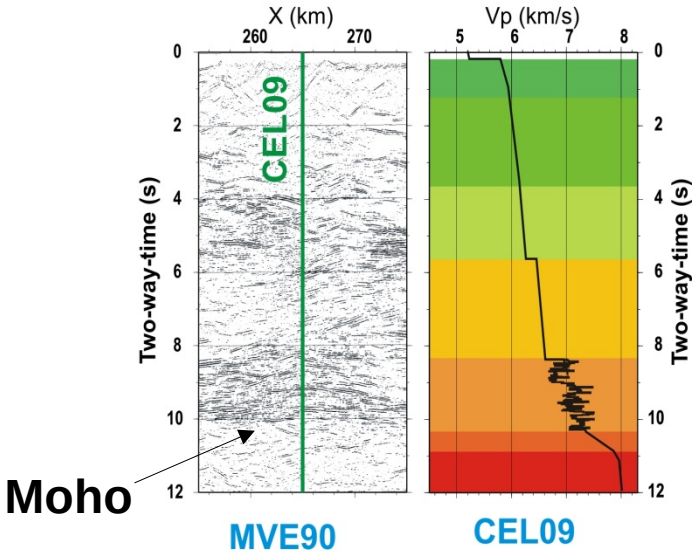
Reflective lower crust

Refraction profile CEL09



Reflection profile MVE90 & CEL09





After DEKORP (1994)

Hrubcová et al., 2005
Hrubcová & Geissler, 2009
Behr et al., 1994

Conclusions

New method to detect prominent discontinuities from high-frequency local earthquake data

- Processing of converted/reflected phases for depth of interfaces
- Natural seismicity

Tools applied

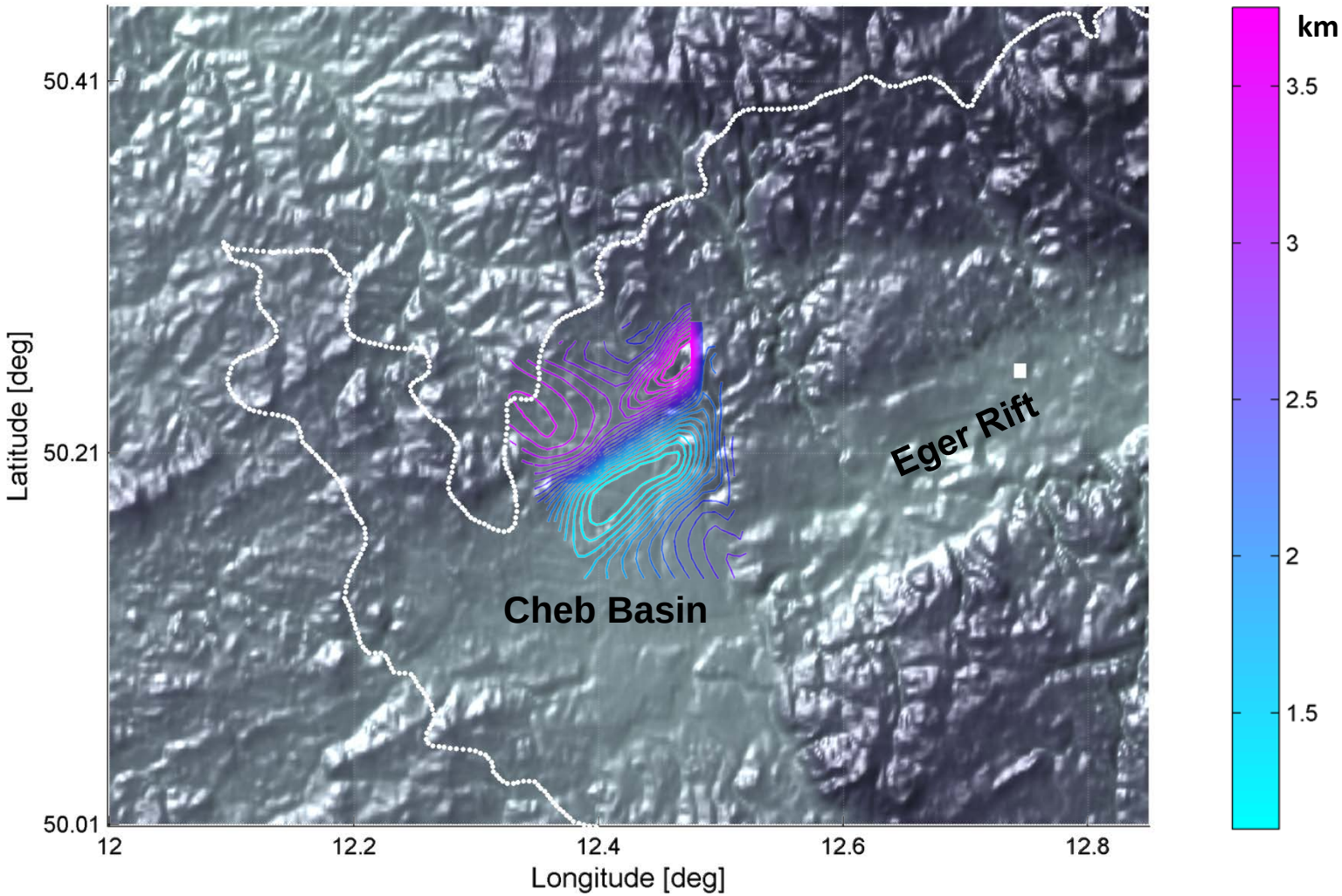
- Reflection seismics – data alignment and stacking RT
- Focal mechanisms & radiation pattern analysis
- Synthetic tests with full waveform modelling with DWN
- Phase amplitude analysis
- Selection of stations & mechanisms for phase detection in data
- Inversion for depth

Prominent interfaces in West Bohemia region

- Depth and topography
- In agreement with previous investigations

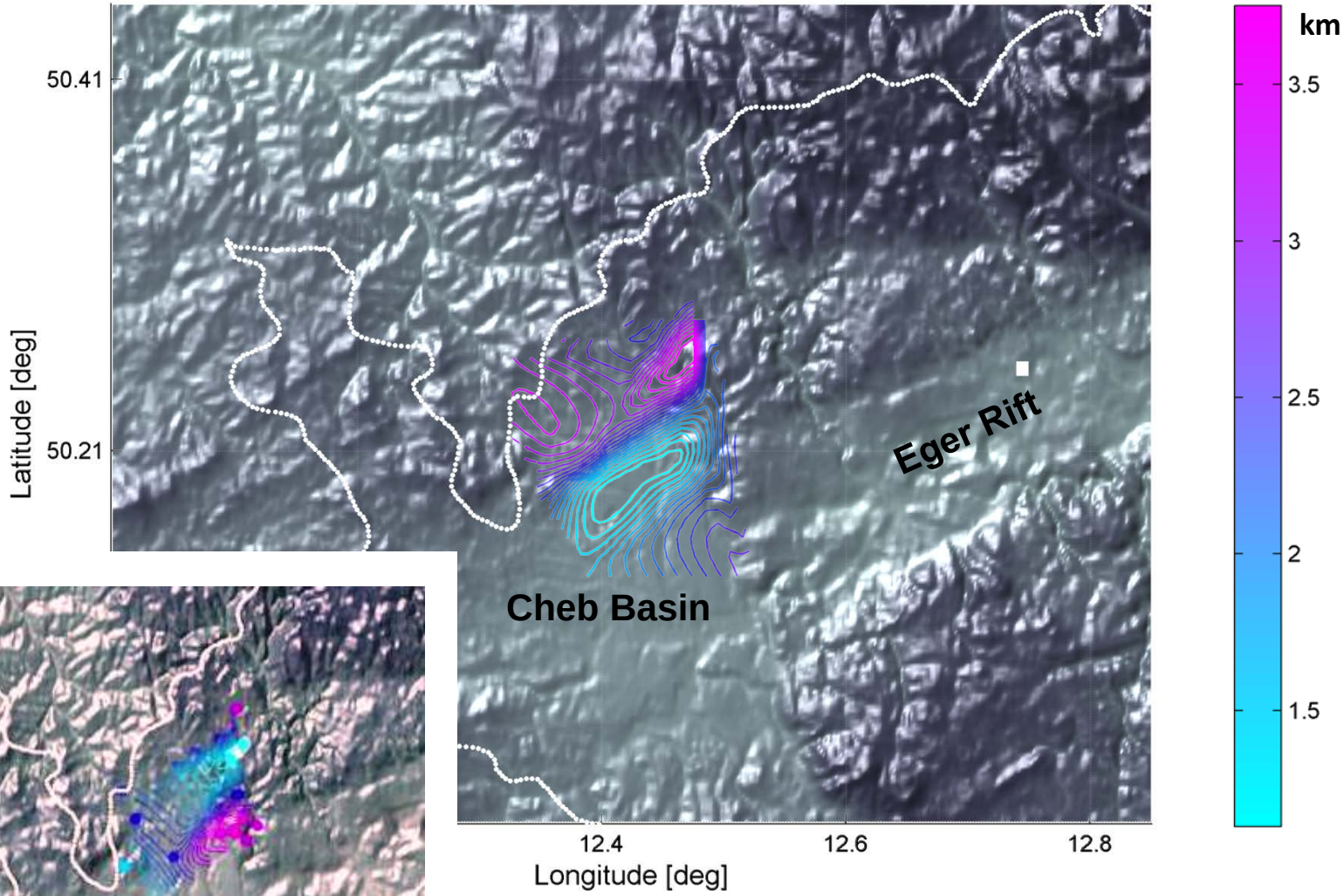

Thank you for your attention !
Moho in Gros Morne National Park, Newfoundland, Kanada

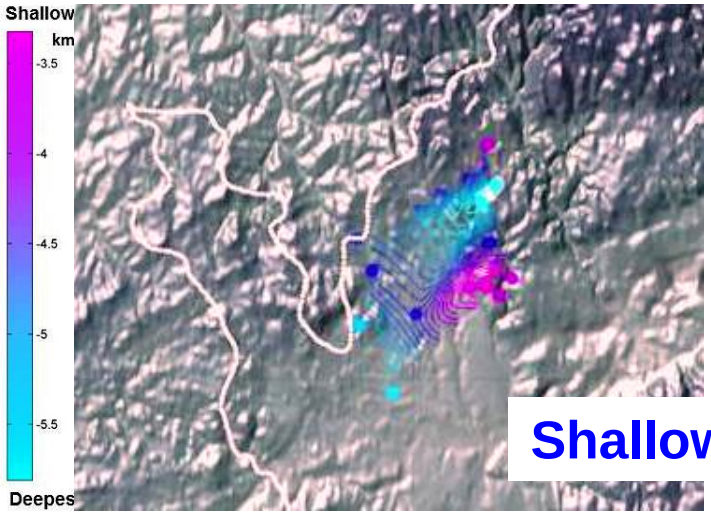
Thickness of the Moho zone from *SmS* reflections



after Hrubcová et al., 2013

Thickness of the Moho zone from *SmS* reflections





Shallow interface – depth

after Hrubcová et al., 2013